VOL. 1

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS, } ss.
EASTERN DIVISION.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* **vs.** **THE SANITARY DISTRICT OF CHICAGO,** *Defendant,*	**C. C. No. 29,019, and Equity No. 114.**

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

MR. JAMES H. WILKERSON,
United States Attorney, and
MR. ALBERT L. HOPKINS,
Assistant United States Attorney,
For Complainant.

MR. EDMUND D. ADCOCK and
MR. ALFRED S. AUSTRIAN,
For Respondent.

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Note 2.—Pages 3661 to 3765, inclusive, of Volume VI, contain the following: Extracts from a public hearing on February 23, 1912, in connection with the application of the Sanitary District of Chicago, dated February 5, 1912, for permission to divert 10,000 cu. ft. per second of water through the Chicago and Calumet Rivers; extracts from a public hearing in connection with the same application on March 27, 1912, at which representatives of the Canadian Government and various Canadian cities and interests were heard; extracts from briefs and memoranda submitted; and also certain letters, telegrams, resolutions of protest from various states, cities, chambers of commerce, associations, and individuals located on the Great Lakes and in the Illinois River valley.

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RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

New York, February 15, 1909.

Deposition of Alfred Noble of New York City, taken before John A. Shields, Esq., United States Commissioner, pursuant to stipulation hereto attached.

Appearances:

James H. Wilkerson, Esq., Frank R. Reid, Esq., for the United States of America.

John C. Williams, Esq., for Sanitary District of Chicago.

ALFRED NOBLE, being duly sworn, testified as follows:

Examined by Mr. Wilkerson.

Q. What is your full name?
A. Alfred Noble.
Q. Where do you live?
A. New York.

Q. What is your address, residence address?
A. Residence, 501 West 120th.
Q. And your office address?
A. 315 Fifth avenue.
Q. What is your business?
A. Civil engineer.
Q. What position do you now hold, if any?
A. Chief engineer of the East River Division of the Pennsylvania Tunnel & Terminal R. R. Co.
Q. How long have you held that position?
A. About seven years.
Q. What has been the scope of your work in that position?
A. Well, it comprises in the first place the excavation of the Pennsylvania station between 9th and 7th avenues, and the construction of a retaining wall around the site and the building of tunnels from a short distance east of 7th avenue to Long Island City and the approaches and the terminal yard connected therewith.
Q. That has occupied the principal part of your time during the period mentioned?
A. Yes.
Q. Have you been engaged in any other work?
A. I was a member of the consulting board for the Panama Canal.
Q. What was the scope of your duties in that position?
A. To make a recommendation as to whether the sea level or summit level canal should be adopted.
Q. During what period were you occupied with that work?
A. For four or five months into the fall and early winter—fall of 1905 and early winter following.
Q. Prior to your taking your present position in what work as engineer were you engaged—what position did you fill in a general way?
A. I was in charge, local charge of the St. Mary's Falls Canal and River.
Q. During what year?
A. 1870 to '82. I was then on various bridge works as resident and assistant chief engineer for about 10 years—for about 12 years. I was a member of the Nicaragua Canal Board in 1905 and of the United States board of engineers and deep waterways from '97 to 1901, and with the Isthmian Canal Commission from '89 to 1902 or '03.
Q. With reference to the positions in which your duties brought you in contact with the Great Lakes, I wish you would

state a little more in detail just *what* the scope of your work was and what—in a general way what line of work you did?

A. The St. Mary's Falls Canal had been built by the State of Michigan and paid for by land-grant made by the United States and opened for navigation in '55, and the general government took in hand in 1870 the enlargement of the canal and the building of a new lock and sundry improvements in the river channels to obtain a greater depth for navigation.

Q. Well, you had some other positions, had you not, which brought you in contact with work in connection with the lakes?

A. I was a member of the board of engineers on deep waterways, charged with the duty of surveying a ship canal route from the lakes to tidewater.

Q. During what period?

A. That was from '97 to about '01.

Q. I would like to have you state a little in detail the general nature of your work in that connection.

A. The principal part of the work was in surveying routes from Lake Erie, one from Lake Erie to Lake Ontario and from Lake Ontario there were two routes, one ascending to the Oswego River and crossing over the summit to the Mohawk at Rome and on the Mohawk to Schenectady, and thence across country to a point on the Hudson River a little below Albany, together with an alternative route from the Mohawk all the way down to the Hudson River and continuing far enough down the river to obtain a depth of 30 feet to the sea.

Q. (By Mr. Williams.) What was that depth?

A. To obtain a depth of 30 feet. The other route followed the St. Lawrence to Lake St. Francis, and then across country to the lower end of Lake Champlain, thence via Whitehall and Ft. Edward; thence down the Hudson to the junction of the route first described.

Q. (By Mr. Wilkerson.) I direct your attention particularly to the subject of hydraulic measurements on the Great Lakes and on the inter-lake outflow of rivers, and I ask you what connection, if any, you have had with that matter?

A. The board of engineers had measurements taken of the outflow of Lake Erie and Lake Ontario, and through the United States engineer's office in Detroit the outflow from Lake Huron. This constitutes about all the work of that kind that I have been connected with.

Q. Now, over how long a period has your study and your

work in connection with the matters about which you have been testifying extended?

A. Well, I first became interested, particularly interested in lake and navigation matters in 1870 and my work at St. Mary's Falls Canal was directly connected with that until 1882.

Q. Would you say your study and work in connection with those matters has been fairly continuous since that time—that is, kept you in touch with the subject since the time that your connection first commenced?

A. Yes, sir; that is the case.

Q. You say that is the case?

A. Yes, sir.

Q. In connection with your profession are you a member of any association or society?

A. I am a member of the American Society of Civil Engineers.

Q. And have you held any position?

A. I have been president.

Q. During what period?

A. During the year 1903.

Q. Did you have any occasion in connection with that association to make any study of any question connected with the Great Lakes?

A. The president of that society has to present an address to the society about the middle of his term of office, and my subject was the Commercial Development of the Great Lakes—in the main historical.

Q. Of what college are you a graduate?

A. University of Michigan.

Q. And you hold your degrees from the institution, I suppose?

A. Yes, I obtained the degree of Civil Engineer when I was graduated and had the honorary degree of LL. D. since that time.

Q. Basing your answer on your experience and on your knowledge of matters connected with the Great Lakes and navigation, and assuming that a certain definite quantity of water as, for example, 4,000 cubic feet per second is diverted from Lake Michigan at Chicago, I ask you to state what, in your opinion, would be the effect of that as to the lowering of Lake Michigan?

A. I think it would lower Lake Michigan.

Q. Assuming that there was a definite lowering at a point

in Lake Michigan as, for example, 10 miles from Chicago, I ask you to state what, in your opinion, would be the relation of that lowering to the lowering which would take place in other bays and harbors of Lake Michigan and Huron for the whole area of each lake and at the head of St. Clair River?

A. I think there would be the same amount of lowering that occurred at the point 10 miles distant from Chicago.

Q. I ask you to state why you make that answer?

A. The stage of the lake—other things being equal, the stage of the lake is determined by its outflow and by the area of its outlet channels, and if a certain amount of water is diverted in a new channel the lake would fall until a normal discharge through the former channel is reduced by the amount diverted.

Q. What do you mean by the word lower used in that connection?

A. Lower than it would have been without the new diversion.

Q. Do I understand you to mean that as you use the term lowering would take place even though the lake may be actually higher than it was before the diversion of the water took place?

A. Yes.

Q. That is to say, you speak of lowering not with reference to a fixed mark, but with respect to the level that the lake would have in the absence of the diversion?

A. Yes, sir, precisely.

Q. I ask you to state whether or not, in your opinion, it is possible to divert a given amount of water from Lake Michigan at Chicago as, for example, 4,000 cubic feet per second, if the outflow of the St. Clair River goes on permanently undiminished precisely the same as before the diversion was begun?

A. The surface would be lower until the outflow from Lake Huron was less by 4,000 feet than the outflow would have been if the diversion had not been made.

Q. That is to say, I understand you mean that when the lowering effect of the diversion is accomplished the outflow in the St. Clair River would be 4,000 cubic feet per second less for exactly the same conditions of net supply than it was before?

A. Yes.

Q. What do you mean by the term net supply as used in this connection?

A. The amount of water to be disposed of by outflow; the inflow, less the evaporation and absorption—that would be the same.

Q. Can you make that explanation of the term net supply any fuller by the use of an example or illustration?

A. Well, the gross supply is the amount of water coming into the lake, that is the amount flowing in from the surrounding country plus the amount falling on its surface. Those are the main features at least, and a portion of that escapes from the lake by evaporation, and the remainder would pass through the lake by discharging at its outlet, and the remaining portion which is ultimately discharged from its outlet would be equivalent, I should say, to its net supply.

Q. What effect, if any, would the diversion of the water—

A. May I extend that answer, I don't know that this—that the amount discharged is equivalent to the net supply during any given period, though it ultimately becomes that.

Q. What effect, if any, would the diversion of the water from Lake Michigan at Chicago have upon the rainfall, evaporation, absorption, running off from the drainage basin of the lakes or inflow of St. Mary's River?

A. They are all independent of that. Temporarily with the outlet so formed the outflow would be more than under normal conditions.

Q. Treating the diversion of water at Chicago as another outlet like the St. Clair River, and assuming that the net supply is unchanged by the diversion of the water at Chicago, what do you say as to the effect of the diversion at Chicago upon the outflow of the St. Clair River?

A. The outflow of the St. Clair River would be reduced by the amount of the diversion.

Q. What is the effect of the reduction of that outflow upon the level of the lake?

A. I think the situation is reversed. The lowering of the lake reduces the outflow. A diversion of water through an additional outlet would cause a lowering of the lake until the total amount discharged through both outlets becomes the same as would have been discharged from a higher or normal level through the original outlet, and the amount of discharge through the St. Clair River, other things remaining unchanged, dependent upon the stage of the lake, the outflow to the St. Clair would be reduced in the case supposed.

Q. And how long will the lowering go on?

A. Until—it will go on until that condition is reached in

which the discharge of the St. Clair River is less than normal discharge—less than the discharge would have been without the diversion by the amount diverted.

Q. I show you, Mr. Noble, a chart or plat of the river, which I ask now to have the commissioner mark Exhibit 1 of this date, for identification, and I ask you to assume for the purpose of your answer that the observations which are there platted are correct. The discharge measurements therein referred to being platted with Lake height as ordinates and the volume as discharged as Abscissa. This chart shows a diagonal line threading the circles representing these observations drawn to represent or express the law of relation between lake height and volume of discharge. I ask you to examine the plate and state whether or not, in your opinion, that diagonal line drawn to express that law is accurately drawn or correctly drawn (showing)?

A. It seems to me to be accurately drawn.

Mr. Williams: Do I understand now that the answer is for the purpose of indicating the correctness of the plate as an abstract proposition to show the law?

Mr. Wilkerson: I think my question is plain. We are assuming—I am asking the witness to assume the correctness of the observations.

Mr. Reid: That is, lake measurements.

Mr. Wilkerson: On the plate are platted the lake height and the volume of discharge. The line which is drawn through these observations is a line to represent the law of relation between lake height and volume of discharge, and I am asking him for his best opinion as to whether or not that line is correctly drawn.

Witness: It appears to me to be correctly drawn.

Q. Now, assuming, always for the purpose of your answer, the correctness of these observations, I ask you to state whether or not, in your opinion, the line as there drawn expresses correctly the law of relation between lake height and the volume of discharge?

A. I think it does.

Q. I direct your attention to the fact that some of those observations are represented as squares while others are represented as circles. Would you say substantially the same if you were to exclude the observations put down as squares, those being the observations for 1908?

A. That would make very little difference in the position of the true line.

Q. I put to you the same question, the difference being that in the answer the observations which are platted as triangles as included would that make any substantial difference?

A. It would make no substantial difference.

Q. It appears, I think, from the plate that the parts platted as triangles are for 1901?

A. Yes.

Q. I will ask you to take the line embracing the law of relation between lake level and outflow, and assuming the correctness of the observations upon which that law was based, I ask you whether you can give to us a formula or equation which expresses the relation between outflow through the St. Clair River and lake level; that is to say, I want you to explain how you would determine the change in the lake height for a given change in outflow?

A. I would determine from the diagram the change in outflow to the change of height in the lake of one foot, which could be done intimately on the chart, divide by it the suggested change in the outflow and it would give the corresponding change in elevation of lake surface.

Q. Can you state a formula which could be used as the basis for that determination? If so, how would you express it, explaining the terms which you use in the formula?

A. If by Q we designate the outflow of the lake with the surface of the lake at elevation H, and by Δ Q the increase or decrease of outflow, for an increase or decrease in height of lake surface of Δ H, and by I the increase or decrease of outflow for an increase or decrease of one foot in lake elevation, then Δ H equals Δ Q divided by I.

Q. Can you make a statement of that formula or law, Mr. Noble, in less technical language assuming that you were explaining the ultimate effect on the lake level in terms of volume of diversion and the increment: by increment I mean the change corresponding to the foot's change in lake level?

A. The diagram or chart shows or states that the change of outflow corresponding to a change of elevation of lake of one foot as 23,820 cubic feet per second, and by measuring this on the chart—I assume that that is substantially correct—the change of height of lake corresponding to any assumed change in discharge is given by dividing the amount of the assumed change by 23,820.

Q. Will the result be expressed in fractions of an inch?

A. That would be expressed in fractions of a foot. It would be expressed in feet rather than in inches.

Q. Directing your attention again to the plate, Exhibit No. 1 of this date for identification, calling your attention particularly to the portion thereof headed "Scale showing loss of level in Lake Huron corresponding to the loss of outflow on St. Clair River by reason of the diversion at Chicago," assuming for the purpose of your answer, the correctness substantially of these observations and basing your answer upon this law expressed by the diagonal lines as they are drawn, what do you say as to the correctness of that scale; the scale that I refer to is the one at the left hand of the plate?

A. That scale shows the resulting changes in height correctly.

Q. Still having in mind this law or formula of expressing the ultimate effect on lake level of the diversion, what is the lowering of Lakes Michigan and Huron in inches for 10,000 cubic feet diversion?

A. About five inches.

Q. Now, you have given the answer with reference to the diversion of 10,000 cubic feet per second in Chicago, is that true proportionately for the diversion of smaller quantities than 10,000 cubic feet?

A. It is.

Q. That is to say, what would be the lowering for the diversion of 5,000 cubic feet?

A. Five thousand would be one-half of five inches or two and one-half inches.

Q. And 4,000?

A. Two inches.

Q. Can you explain that a little further, Mr. Noble?

A. The lowering of lake level due to the diversion of 10,000 cubic feet per second would be about 10/25 of a foot.

Q. (By Mr. Williams.) That is assuming that a diversion of 23,000 and some odd figures there causes a fall of a foot?

A. Yes.

Q. That is, you always assume that to start with?

A. Yes. Assuming the correctness of this chart the fall for the diversion of 4,000 cubic feet per second would be about 4/24 of a foot.

Q. Between 4/23 and 4/24?

A. Yes.

Q. (By Mr. Wilkerson.) If a certain quantity of water is

diverted at Chicago through the drainage canal what will be the effect ultimately upon the outflow of the Niagara and St. Lawrence Rivers?

A. It would be the same reduction in outflow.

Q. What would be the effect on the Erie?

A. Lake Erie would fall until its discharge was less by the Chicago diversion than the discharge that would have occurred without that diversion.

Q. What would the effect be on Lake Ontario?

A. The same.

Q. What, in your opinion, would be the effect upon the St. Clair River, Lake St. Clair, Detroit River, Niagara River, St. Lawrence River and St. Mary's River?

A. They would all be lowered; the St. Mary's River below the falls.

Q. I show you, Mr. Noble, plates which I ask to have marked Exhibits Nos. 2, 3 and 4, respectively, for identification of this date—assuming for the purpose of your answer the substantial correctness of the observations platted, I ask you to explain to us as an engineer what those plates represent and to give us a statement as to the correctness of the law or formula as represented by the diagonal lines on each one of the plates, and, if you will in explanation of the plates, I will ask you to make your answer rather complete so that we will have translated in a less technical way the meaning of those plates?

A. I have examined the three charts referred to and in my judgment the lines representing the relation between the height of the water surface and discharge is substantially correct.

Q. Directing your attention to the scales at the left hand side of each of those plates, I will ask you to make the same examination that you made with reference to the scale on Government Exhibit No. 1 for identification and to state what is the fact with reference to their correctness?

A. They are substantially correct.

Q. That answer applies to each one of the plates, does it, Mr. Noble?

A. Yes.

Q. Giving to the letter Q and H and Δ Q and Δ H, the same significance that was given to them in the plate Government Exhibit No. 1 for identification, I ask you to examine the formulæ which appear on each one of those plates and state the fact as to the correctness or incorrectness of that formu-

læ as expressed in the changed relations represented by each of the plates.

A. The formulæ express the relation between the change of height and the change of discharge correctly, assuming the correctness of the lines—the diagonal lines—on the several charts.

A. And I understand you to say that assuming in each case the correctness of the law representing these changed relations as indicated by this diagonal line you find the scales on the left hand side of each of the plates correct as representing those changes in inches?

A. They are.

Q. I also understand you to give it as your view that the lines are substantially correct, assuming the correctness of the observations?

A. Yes; the correctness of the observations and the platting thereof.

Q. So that if the observations were correctly made and are correctly platted on each one of these Exhibits Nos. 1 to 4, respectively, the scales at the left hand side of each of those plates are correct?

A. Substantially correct.

Hearing adjourned until Tuesday, February 16, 1909, at 10 o'clock a. m., at 315 Fifth avenue.

New York, February 16, 1909.

Present:

The Commissioner and counsel as before.

Hearing resumed at No. 315 Fifth avenue, New York, pursuant to adjournment.

ALFRED NOBLE, recalled:

Direct Examination Continued by Mr. Wilkerson.

Q. Directing your attention again, Mr. Noble, to the relation between discharge and height of lake, I want to ask you this question: Assuming that running over a number of years you have a series of measurements representing the discharge and height of lake, could you give a method of reaching a formula which would express the relation between those two?

A. The first part of the method would be to plat the observations on paper ruled at right angles so that horizontal lines,

for example, would represent stages of the lake, and the vertical lines represent discharges; and a line can be drawn by the eye, which is probably the way in which I would do it with my limited knowledge of the art, which would represent as fairly as I could make it an average of these observations. That is sometimes done by more accurate methods, with which I am not thoroughly familiar.

Q. Having drawn that line, then what would be the next step?

A. Then you could read from that diagonal line the relation between the stage of the lake and the discharge.

Q. Just what would that line represent?

A. Represents the relation between those two factors.

Q. Directing your attention again to Government Exhibits Nos. 1, 2, 3 and 4, I ask you what you have to say of those with reference to the method of determining this relation between lake height and discharge; in other words, what have you to say as to those charts as representing a method of reaching a conclusion on that subject?

A. The diagonal lines on those charts seem to me to represent fairly that relation between height of lake and discharge.

Q. And are those lines drawn in accordance with the methods which you have indicated as you would do if you had the series of observations?

A. I don't know that. They are substantially the lines I would draw if I were to draw lines representing that relation. They would not differ substantially.

Q. I am, of course, assuming the correctness of the observations and assuming that they are correctly platted as we did yesterday.

A. Yes; I am also assuming that.

Q. Assuming that the observations are substantially correct and that they are correctly platted, in order to get an expression of that relation the method you would follow is the one that has been followed in the preparation of those charts?

A. I don't know as to that.

Q. I mean drawing the lines.

A. Drawing a diagonal line on some basis or other is what I should do. But I should probably draw the line by eye and I should draw it with the limited range of observations and the limited range of lake levels represented by these observations and draw it as a straight line, and its position would not differ materially from the position shown on the charts or chart.

Q. What experience have you had in connection with the measurements of Lake Erie on this matter of height of the lake and discharge?

A. Gaugings were made of the outflow of Lake Erie and the upper end of the Niagara River under the general direction of the United States Board of Engineers on deep waterways, of which I was a member. The work was carried out by Mr. E. E. Haskell, who was engineer in charge, with Mr. Shenehon and Mr. Stewart as assistants in the various parts of the work.

Q. What was the result of that work? Tell us all about it as far as you know.

A. Measurements were made under the direction of that board—were taken from the International Bridge at Buffalo, and measurements were made by the Haskell current meter.

Q. What was the increment as the result of that work?

A. The curve drawn to represent the result of those gaugings—the line drawn to represent the relation between stage of lake and discharge was drawn as a curve, having a slight curvature, and from different portions of the curve the relation between height of lake and discharge varies slightly—increment I should say varies slightly; the varyings in the two portions of the curve which I measured were from 22,000 cubic feet per second for a change of elevation of one foot to 24,800 feet a second.

Q. What period did the observations on which that computation is based cover?

A. I could not answer that without referring to the records. It might have continued some months as I recall it.

Q. Do you know anything about lake observations having been made there and if so what would be the effect of those lake observations on the precision of drawing the degree of accuracy which you could make a statement as to?

A. In the reports of the chief engineers are given statements in regard to the subsequent gaugings, the important ones being taken 2,000 and 3,000 feet below the International Bridge, and the relation between height of lake and discharge is substantially the same as in the first series of observations.

Q. Referring again to the diversion of water from Lake Michigan at Chicago, what would be the effect of that diversion upon the available power of the Niagara River?

Mr. Williams: We have reserved in the stipulation objections as to that.

Mr. Wilkerson: As to the competency, materiality and relevancy of the testimony.

A. The effect would be to reduce the amount of water power available.

Q. And with reference to the St. Lawrence River?

A. The same result in kind.

Q. Have you given consideration, Mr. Noble, to the matter of data regarding the evaporation and the use of data of that kind in any attempt to detect presence or absence of the effect produced at the lakes by the diversion of the water made at Chicago?

A. It doesn't seem to me useful and it seems to me to be entirely unnecessary.

Q. Will you state the grounds upon which you base that answer?

A. The withdrawal of water through a new channel is the only new condition introduced in the case. Suppose we have only to deal with the results of the new condition, the evaporation, the inflow are not in any wise changed.

Q. What is your general information on the subject of the accuracy of data with reference to rainfall and evaporation—the degree of accuracy?

A. I do not understand that rainfall observations have been made, or evaporation observations in detail over the whole Great Lakes territory, and I should think a large percentage of doubt would exist in any figures that might be used in that connection.

Q. In your opinion are the figures relating to rainfall and evaporation sufficiently accurate so that they may be used as an element in reaching any correct conclusion on the subject whatever?

A. I should think they are not definite enough or accurate enough for use, and if they were definite and accurate they would be absolutely unnecessary I think for the purpose of determining the changes of elevation of the lake due to the diversion of water through new channels.

Q. You are familiar, I think you said yesterday, with the hydraulic measurements which have been made in the St. Clair River. I wish you would give us your judgment as to the scale on which these measurements were made and as to the competency of the persons who directed the making of those measurements.

A. I think those measurements were very carefully done by people who are exceedingly competent to make them.

Q. Do you know who made them?

A. I think the first St. Clair measurements, if I remember rightly, were made by Mr. Sabin, either by Mr. Sabin or Mr. Shenehon. My recollection is that they were made by Mr. Sabin.

Q. What do you say with reference to the skill with which the measurements of the Niagara River were made and the competency of the person under whose direction those measurements were made?

A. I think they were made with skill and by competent persons.

Q. By men qualified to do the work and giving as accurate results as could be obtained under the circumstances?

A. I believe so.

Q. What do you say about the measurements of the St. Lawrence River?

A. The same.

Q. And the St. Mary's River?

A. The same.

Q. Have you any opinion as to the degree of precision with which this line representing relation between stage of the lake and discharge has been drawn—I refer to the percentage of accuracy?

A. I should think that the lines drawn would represent the results of the observations as platted within about 1 or 2 per cent. and within the range of the observations themselves.

Q. What is your judgment as to whether or not the lowering of the lake level, as you have used that term, about from two to three inches is a material or substantial modification of the navigable condition of the lake?

A. I should expect the reduction of that amount to really effect the loads that ships could carry.

Q. In a substantial way?

A. I think in a substantial way, yes.

Q. Explain that if you will?

A. Well, in a rough way and as an approximation, the loads one of the largest class of lake freighters would carry would be reduced about 60 tons by the inch reduction in draught.

Q. You determine tons by what pounds?

A. Twenty-two hundred and forty pounds to the ton.

Q. Have you any knowledge on the subject of the expense of operating vessels of different draughts, whether if you in-

crease the draught of the vessels two or three inches it would cost very much more to operate it or not?

A. I don't see how it could effect the cost of moving a ship a mile, for example, but I have never figured it out with any degree of precision.

Recess until 2 o'clock p. m.

After recess:

ALFRED NOBLE, recalled:

Cross-Examination by Mr. Williams.

Q. Mr. Noble, assume a diversion of water at Chicago sufficient to lower the level of Lake Michigan one foot, what in your opinion would be the effect, if any, on the depth of water in the Gulf of St. Lawrence?

A. I couldn't say; it would be a very small allowance.

Q. In your opinion would there be any proportionate effect.

A. No; I should think not. Not appreciable by any ordinary methods.

Q. Assuming the same state of facts in a diversion sufficient to lower the level of Lake Michigan one foot at Chicago, what would be the effect, if any, on the depth of water in Lake Superior?

A. I don't think that it would be appreciable. I don't see how that could affect Lake Superior.

Q. What would be the effect on the depth of water in Lake Huron?

A. I think it would be a foot.

Q. Practically the same effect as on Lake Michigan itself?

A. The same effect as on Lake Michigan itself.

Q. What would be the effect in your opinion on the depth of water in Lake St. Clair?

A. I don't know. I haven't studied that matter and I don't know.

Q. Would it be more or less in your opinion?

A. I have no opinion on that point.

Q. You have no opinion then as to whether or not the effect on Lake St. Clair would be greater or less than on Lake Huron?

A. No; I couldn't say from my own studies and reading.

Q. Have you an opinion, and if so what is it, as to the effect on the depth of water in Lake Erie under such conditions as I have mentioned as compared with the effect on Lake Michigan?

Mr. Reid: You are now talking about a foot diversion?

Mr. Williams: Yes.

A. I should have to think that over; I couldn't answer it offhand.

Q. Would you be able to state without very much figuring whether the effect would be more or less in Lake Erie, for instance, than it would be in Lake St. Clair—the effect of the diversion at Chicago I am speaking of?

A. I think that question ought to be readily answered if one had time to look over the data and do the necessary figuring, but I couldn't tell it now.

Q. Would you be able to state whether or not the effect of such a diversion at Chicago would be more noticeable, more or less noticeable in Lake Ontario than in Lake Erie—by the word noticeable I mean would it affect the depth of Lake Ontario more or less than it would Lake Erie?

A. I think I shall have to make the same answer as before. That answer does not seem to be a difficult one to give if one could look over the figures with a view of ascertaining that, but I have not.

Q. I am not asking for figures.

A. I know, but still it involves the same sort of consideration.

Q. In your opinion would a diversion of water from Lake Michigan at Chicago sufficient in extent to cause the lowering of the levels of Lakes Michigan and Huron to the extent of one foot be likely to lower the level of any of the Great Lakes, or the rivers connecting the lakes to an extent greater than one foot?

A. I would not want to answer that offhand.

Q. I will ask you whether or not you have an opinion, and if so, what it is, as to the effect of the diversion of water at Chicago sufficient to lower the level of Lake Michigan one foot on the depth of water in the St. Clair River?

A. That involves the same sort of consideration as the other questions.

Q. And you would give the same answer?

A. The same answer, yes.

Q. And would you answer in a similar manner the same

question with reference to the Detroit, Niagara and St. Lawrence Rivers?

A. Yes.

Q. Suppose there were a diversion of water from Lake Superior sufficient to lower that lake one foot, what in your opinion would be the relative effect on the level of Lake Huron?

A. If applied instantaneously, the effect would be the raising of Lakes Huron and Michigan, which I assume to take place simultaneously, being proportioned to the sum of the areas of those two lakes to Lake Superior.

Q. The diversion assumed is not a diversion of Lake Superior into Lake Huron, but a diversion of water from Lake Superior; suppose it were of a nature similar to the diversion which has been spoken of here at Chicago?

A. I should think the effect of reducing the inflow into Lakes Huron and Michigan would be, so far as I see, equivalent to like a withdrawal through another channel from Lakes Michigan and Huron.

Q. If the diversion was sufficient to lower the level of Lake Superior one foot, can you give us an opinion as to how much that would lower the level of Huron?

A. That involves so much more data than I have that I couldn't answer that.

Q. Would that effect be contingent upon the discharge of the two lakes in any way; that is, if you knew the distance of Lake Superior and the discharge of Lake Huron, would that assist any in forming an opinion as to the relative effect of the diversion of this water from Lake Superior?

A. That would be pertinent to a study of the subject certainly, but I hesitate to say; I don't want to give an answer offhand. The effect of those changes takes a little time.

Q. I assume that this is a permanent diversion and I am speaking of the effect after the equilibrium has been established.

A. That would have a variable effect upon the Lake Huron. It would reduce the amount of water flowing into the lake by an amount of the diversion, and it would not be a constant and invariable reduction of the level of Lake Huron in amount; there would always be something and the variations would be constantly equalized by the lake storage feature.

Q. In your opinion would the level of Lake Huron be lowered more or less than a foot?

A. I think that matter is pretty closely determinable with a little study. While I have an impression on the subject I can hardly say it is an opinion. It is an impression which might be absolutely changed by an examination of the matter, that the effect on Lake Huron would be less than on Lake Superior. I am not very sure of that.

Q. And would the discharge of Lake Superior in proportion to the discharge through the St. Clair River bear any relation to the proportion between the lowering of the level of the two lakes—whether there is any relation at all between them?

A. A change in elevation of a foot in Lake Superior would correspond to some condition variable, depending upon the stage of the lake and still some positive difference in discharge from Lake Superior, no matter how that lowering of the surface was obtained. If that were a permanent one, or practically a permanent one, its effect on Lake Huron would be determined by the corresponding increment and discharge from Lake Huron, that is the effect such an increment or change in inflow would have upon the outflow, the increment of outflow being the same, I should say, as the increment of inflow, the amount of the change in the outflow being the same with the change in inflow that the effect upon the stage of Lake Huron would be quite determinable from the discharge curve.

Q. Suppose, Mr. Noble, that there were a permanent diversion of 20,000 cubic feet per second from Lake Superior, what would be the relative effect upon the levels of Lake Superior and Lake Huron in the case of such a diversion?

A. I don't know. I couldn't tell without referring to the data what the effect on the level of Lake Superior would be. It would fall until its outflow was 20,000 feet less than the normal outflow.

Q. Without reference to how much it would affect the level of the lake—

A. That is not a necessary feature—

Q. Can you indicate what the effect would be as compared with the effect on Lake Huron?

A. What effect the reduction of 20,000 feet in the inflow would have on the outflow?

Q. On the elevation?

A. I think that could be read so far as I see from the discharge curve. I think that would be the only disturbing element brought into the situation.

Q. Now, assume, Mr. Noble, that the discharge from St. Mary's River is 77,000 cubic feet per second and that the discharge from the St. Clair River is 197,000 cubic feet per second, would the withdrawal and diversion of 20,000 cubic feet per second have a greater or less effect upon the level of Lake Superior than it would have upon the level of Lake Huron?

A. That question ought to be easily answered with the data, but I haven't them before me.

Q. Have you given some attention, Mr. Noble, to the effect of the regulation of Lake Erie in connection with the developments of navigation?

A. That matter was taken up by the United States Board of Engineers on Deep Waterways.

Q. Of which you were a member?

A. Of which I was a member, yes.

Q. Do you recall from the investigation that you made at that time what the effect of such regulating works would be on Lake St. Clair as compared with Lake Erie?

A. My recollection—although I did not make those figures in detail—my recollection of the conclusions of the board are that about—that a change of three feet in Lake Erie would produce a change of two feet in Lake St. Clair and about one foot in Lake Huron. That is a matter of recollection.

Q. I think your recollection is very good. That was your opinion and is still your opinion as to the effect of those works?

A. Well, that is, I haven't gone into the matter since. I haven't used any of the new data which I believe exists in that connection. That was rather a rough approximation that we considered at the time.

Q. You have not, however—

A. I haven't gone into the matter since and have used none of the data collected since.

Q. So that you have not changed your opinion?

A. I should think there were better data existing.

Q. Yes; but you have not availed yourself of that data so as to change your opinion yet?

A. So far as the opinion went I think that is right.

Q. The contemplated plan suggested by your board at that time involved the raising of the level of Lake Erie 2.14 feet, did it not?

A. I don't remember that.

Q. Do you recall what the cost of the regulation was as estimated by your board, approximately?

A. I would like to have that understood that it is merely a rough estimate; I think it was eight or nine hundred thousand dollars.

Q. I will ask you in this way—

A. I can verify that very readily.

Q. I can ask you whether it was not $796,923?

A. I think that is it. It is not very far from that amount according to my recollections and I assume that it is correct.

Q. Suppose, Mr. Noble, that the outlet of any lake were restricted by an obstruction, that would result in the surface of the lake rising, would it not?

A. I think so.

Q. And then after the equilibrium had been established, the obstruction having remained there a sufficient length of time for that purpose, if the obstruction were removed the surface of the lake would then return to its original elevation, or level, would it not?

A. In time, yes; return to the elevation it would have had if the obstruction had never been introduced.

Q. Now, you testified this morning with reference to the effect of the lowering of Lake Michigan by a diversion of 4,000 cubic feet per second at Chicago.

A. Yes.

Q. Is that the basis of your testimony this morning, or was it an assumed condition of the lowering of two inches, do you recall?

A. That was yesterday. The question was in relation to the effect on Lakes Michigan and Huron of withdrawing 4,000 feet from Lake Michigan.

Q. And you testified that the effect would be about two inches?

A. About two inches.

Q. And then following that up you testified as to the effect on navigation in Lake Michigan?

A. I think some question was asked me about that subject this morning.

Q. Now, then, on what parts of Lake Michigan would navigation be affected by a diversion of 4,000 cubic feet per second?

A. It would be only in those harbors where the depth of water was near—it would apply only to those harbors where

the limit in depth corresponded closely with those on the route traversed by any given ship.

Q. Are you able to testify as to what harbors come within the purview of your last answer?

A. No, I couldn't. I don't know what the conditions are.

Q. Do you know of any harbor on Lake Michigan where navigation would be interfered with by the diversion of 4,000 cubic feet per second?

A. I am not informed as to the depth of water in any harbor on Lake Michigan.

Q. I will ask you the same question with reference to Lake Huron. Do you know of any harbor on Lake Huron that would be so affected by the diversion of 4,000 cubic feet per second at Chicago as to substantially interfere with navigation?

A. I don't recall any. I don't know the depth of harbors in Lake Huron.

Q. Without repeating the question I will ask you whether or not you can enumerate what portion, if any, of the St. Clair River would be affected and to what extent, and to a sufficient extent to substantially interfere with navigation?

A. I don't know that. I don't know of any critical point in the St. Clair River.

Q. How about the Detroit River?

A. I should suppose that at some points in the neighborhood of the Lime Kiln Crossing and Ballard's Reef might be the case in point as affecting the large commerce.

Q. Now assuming this withdrawal of 4,000 cubic feet per second in Chicago from Lake Michigan, have you an opinion as to the extent of the lowering of the level of the Detroit River by such a diversion?

A. I don't know the exact amount. That involves the same consideration as the series of questions you asked a short time ago. It is determinable, but I haven't the data before me now.

Q. Is it necessary to determine that in determining whether or not navigation will be substantially interfered with in the Detroit River?

A. That would be easily determinable relation, I should say, between the depth of water in Lake Michigan, or between the elevation of the surface of Lake Michigan and the reduction of depth at the critical point. There would always be, so far as I can see, the reduction in elevation due to the 4,000 feet less supply to the river.

Q. But until you have had the data submitted to you and you have calculated the extent of the lowering of the Detroit River you would not be able to express an opinion on the extent of the interference with navigation by that division?

A. I think it would go a little farther than I had in mind when I answered your question before. The effect on the only portion of the Detroit River that would be important in this case would follow very closely the effect upon Lake Erie, which is determinable and readily so.

Q. You have spoken of a point on the Detroit River in the vicinity of the Lime Kiln Crossing?

A. Yes.

Q. Can you state the extent of the river in miles that would be so affected?

A. I haven't that in mind.

Q. Approximately; I don't mean accurately?

A. No, I don't know that. I don't know what length of river would be affected; that would involve the question as in what part of the present channel the water is least I should say; but the effect on lowering the level, I think, could be readily determinable throughout this entire stretch mentioned within a small margin, and within that small margin I think it would be the same as that in Lake Erie.

Q. Now the, coming to Lake Erie, you may, if you will, state what harbors in Lake Erie will be so affected by a withdrawal of 4,000 cubic feet per second of water from Lake Michigan at Chicago so as to substantially interfere with navigation?

A. If that question is as to the entrance of vessels into the harbors in question I would say at once I don't know; but I think that the withdrawal or lowering of water in Lake Erie will affect all of the important navigation on Lake Erie by reason of affecting the water in connecting channels; the Detroit River, possibly the St. Clair River and pretty certainly the St. Mary's River.

Q. I understood you to say that you were not able to give any opinion with reference to any portion of the St. Clair River.

A. I am not certain about the St. Clair River. I do not recall any place there that limits the draught of vessels.

Q. The navigation on the Niagara River; would that in your opinion be substantially interfered with by the diversion of the 4,000 cubic feet per second at Chicago?

A. I can't say as to that, because I am not familiar with the depths of water in the Niagara River, but if my recollection is correct, that there is shoal water that limits them there, I should say the surface of the river would certainly be depressed by such a withdrawal from Chicago. It would be at the head of the river substantially that given by the discharge curve in question in Lake Erie, and as to whether it would be more or less coming down the river I wouldn't undertake to say.

Q. Are you familiar with the kind and size of the craft that navigate the Niagara River?

A. Not particularly.

Q. Is it not true as a general statement that it is only navigated by small craft at present, that is, that large lake vessels do not use the Niagara River for navigation purposes?

A. I am not positive as to the facts in this case.

Q. Now I assume that with reference to Lakes Michigan, Huron, Erie and Ontario, your answer would be the same, that the only portions of those lakes in which navigation would be substantially interfered with by a diversion of 4,000 cubic feet per second in Chicago would be the harbors?

A. And the connecting channels.

Q. We took this up separately. We have mentioned each one of the connecting channels.

A. Address that question again.

Q. Is there any portion of Lake Michigan, Lake Huron, Lake Erie or Lake Ontario, except the harbors and the connecting channels where navigation would be seriously or substantially interfered with by the diversion of 4,000 cubic feet per second at Chicago?

A. I think there is ample depth for navigation.

Q. Are you able from your own knowledge to state or give the name of any harbor on Lake Ontario where navigation would be substantially interfered with by the diversion mentioned at Chicago?

A. I don't know; I am not familiar with the harbors in Lake Ontario.

Q. In your opinion would navigation on the St. Lawrence River be substantially interfered with by the diversion of 4,000 cubic feet per second at Chicago?

A. The interference, by which I mean the reduction of depth for navigation over the shoal places would be affected by the withdrawal of water from Lake Michigan at Chicago.

Q. What I wish to know is if you are personally familiar

with the shoal places so that you can tell us where, if at all, on the St. Lawrence River channels would be affected?

A. I don't think I am familiar enough with the navigation of the St. Lawrence River to answer that question.

Q. This morning I understood you to say that there would be a loss by decrease of loading in vessels amounting to about 60 tons to an inch?

A. Yes.

Q. What depth or draught boat did you have in mind in making that estimate?

A. The type of boat I had in mind was one about 550 feet long and 56 foot beam, which is not the largest but one of the larger class of boats now engaged on the lakes, and the amount of the loss would not vary much; there would be quite a little change in draught.

Q. What would be the total tonnage of such a vessel?

A. The total loading, as near as I remember, would be in the neighborhood of 10,000 tons.

Q. How many feet of water would such a boat draw; what is the depth of the draught?

A. I think in the neighborhood of twenty.

Q. Twenty feet?

A. I think so.

Q. Twenty feet is 240 inches?

A. Yes.

Q. Sixty tons to the inch?

A. No; not for 240 inches.

Q. How many inches?

A. Because the boat doesn't sail along through the air when it has no load; it still draws water.

Q. How many inches?

A. I don't know that precisely. That is a very obvious consideration; I did not determine this in that way and I don't recall now what the average draught of those larger boats is like.

Q. Do you know about how many vessels there are now navigating the Great Lakes of the capacity and tonnage that you had in mind?

A. No, I don't recall; not a great many.

Q. Not a great many?

A. Not a great many, no.

Q. Suppose the water was lowered a foot instead of two inches, would that reduce the loading by the same amount?

A. Practically so. By the same relative amount, you mean?

Q. Yes.

A. Yes.

Q. You mean by relatively that it would be six times as much as two inches?

A. That is it exactly.

Q. Without reference to the loss of tonnage, 60 tons to an inch, would the loss of a foot of water, or reduction of the depth of water by one foot reduce the depth of the loading by the same amount, that is, a foot?

A. I think so. My immediate connection with those matters is, of course, pretty old, but during the time that I was directly connected with the work the skippers watched the stage very closely and took the load for every inch of water there was over the shoal places, and my information is that that is still the case.

Q. Is it or is it not true that the difference in elevation between Lakes Huron and Erie has been 9/10 of a foot less since 1886 than it was before that time?

A. It is my recollection of the situation at the time the report was written that for substantially the period mentioned the records of the stages of the lake seem to show that difference.

Q. Now then, do you know or are you able to give an opinion as to what causes contributed to that difference?

A. It is my recollection of the situation at the time speaking under the reservation of trying to recall a matter that is several years old, I believe that we—I think that we were led to believe by a comparison of the survey made before 1870 with the one made I think after the deep waterways board began its work, there is indicated an enlargement of the outlet to Lake Huron from which it was believed and I think Mr. Wisner made some calculations to show that, such enlargement would result in about the difference of level stated. I think the inference that the enlargement occurred about 1886 was based entirely upon the records of the stages of the lakes.

Q. Have we got in the record now an opinion by you as to whether or not there was such a condition to start with?

A. I don't know. My recollection is that another survey was found prior to 1886 which did not agree with the one which we used, and I have never gone into the matter since

to revise my opinion, and the effect of the new data has been to leave me in some doubt as to the old.

Q. You testified this morning, Mr. Noble, with reference to the accuracy of the discharge measurements. I will ask you to state whether or not in your opinion the discharge measurements which are taken by the government engineers and concerning which you were asked this morning are the most accurate that it is possible to procure at this time?

A. I don't know of any better way.

Q. Do you know of any other information which you would compare favorably with these in accuracy on the subject of discharge measurements?

A. That calls for a little more expert knowledge upon the subject than I have. I have read of some difference of opinion by engineers as to the precision and accuracy of meter measurements and float or rod measurements. In an ideal channel I think the rod measurement would give—I don't see why it shouldn't give at least as good results.

Q. Do you know of any other measurements being in existence on the particular channels involved here than these?

A. I think in the St. Clair River there was an old—I think the double float measurements made in the '60s.

Q. The information prior to 1898 is rather incomplete, is it not; prior to 1898 the information at hand with reference to these gaugings is rather indefinite and unsatisfactory, is it not?

A. I don't think the measurements made in the earlier days were made—of course they were not made with the whole knowledge the subject afterward acquired, but my impression is, without having the comparison before me, that the former measurements of the Niagara and St. Clair Rivers were fairly good. I don't remember now how the St. Lawrence River measurements compare, and in arriving at such an opinion my opinion would be the result of the later measurements.

Q. I just want your opinion as to the relative accuracy of the discharge measurements that are referred to in the plats exhibited to you and concerning which you have testified.

A. I would not be able to discriminate between those with the limited expert knowledge I have on the subject; they are all taken by competent engineers and during much the same period.

Q. I did not ask you to compare one sheet with another. Was that the best information so far as you know?

A. In my opinion they are the best information available without knowing exhaustively the rest of the data.

Q. Your estimates of the specific effect of the diversion of water at Chicago are based entirely upon the results of these discharge measurements, this platting produced and presented here by the government and shown as Government Exhibits 1, 2, 3 and 4?

A. Those are all that I used, I think, in estimating.

Q. And your estimates are based upon them?

A. Yes, sir.

Re-direct Examination by Mr. Reid.

Q. In regard to the last question, you have independent knowledge in regard to Lake Erie? You made measurements there independent of any charts or anything else in this case in regard to Lake Erie, did you not?

A. I don't know that I am clear as to whether you include all the discharge measurements in Lake Erie or not.

Q. The Board of Engineers of Deep Waterways made them?

A. Yes.

Q. In regard to Lake Erie?

A. In regard to Lake Erie.

Q. And you stated this morning some figures in regard to Lake Erie?

A. Yes.

Q. Now they had nothing whatever to do with these charts here?

A. I would like to examine those charts with reference to that.

Q. I say in answering the question this morning, the Board of Deep Waterways, they didn't have these charts here?

A. No.

Q. You did not have these charts Government Exhibits 2, 1, 3 and 4 in mind when you gave those figures in regard to Lake Erie?

A. No. Those figures in regard to Lake Erie —

Q. They were independent of any charts in this case?

A. Yes; they were taken from old measurements of the Board of Engineers on Deep Waterways.

Q. In regard to the effect that this diversion at Chicago would have on navigation at certain points on the Great

Lakes, you call them critical points, do you not, of navigation?

A. They can be called so.

Q. I will ask you Sturgeon Bay Canal and Green Bay Entrance and Manitou Passage as well as the mouth of the Detroit River and one end of Lake Erie as it approaches Toledo might be included as critical points and would be affected by a lessening of the height two inches or more?

Mr. Williams: I object to the question on the ground that it is leading and suggestive, and on the ground that the witness has already testified fully as to his personal knowledge of the points at which navigation would be affected.

Question withdrawn.

Q. I wish to refresh your memory in regard to some of these critical points of navigation. Can you think of any more than you stated to Mr. Williams?

A. Points in the St. Mary's River I have in mind.

Q. Any others?

A. I don't know the circumstances in regard to any others. I do not recall at this moment any other points than those in the first two streams; the depths of the harbors I am not familiar with.

Q. In your first answer to Mr. Williams you said the entrances to the harbors would be affected by this two-inch diversion and the shoals of the lake would be affected and that would affect navigation?

A. Where the depth of the water was near the critical depth.

Q. And that would be in regard to the shoals as well as in entrance to the harbors?

A. Yes.

Q. And you gave the figures to Mr. Williams as $796,923 as the amount of the cost to have the regulating works as made by your report of the Board of Engineers of Deep Waterways; now has that been revised to date?

A. Not that I know of; that is the figure given.

Q. Can you give us an estimate of how much more it would cost to complete them now than the estimate at that time?

Mr. Williams: I object to the question on the ground that it assumes that there is an increased cost since that estimate was made.

Q. Is there an increased cost now than there was at the time this estimate was made?

A. In the cost of works in general?

Q. Yes.
A. In my opinion, yes.
Q. Can you give us any amount?
A. No, I wouldn't want to do that without going over the matter in some detail.
Q. You haven't anything in mind now?
A. No, I haven't anything in mind.

Signed and sworn to before me this 8th day of March, 1909.

Hearing adjourned to February 17, 1909. at Ithaca, N. Y.

Ithaca, N. Y., February 17, 1909.

Appearances:
Frank R. Reid, Esq., Assistant United States Attorney, for plaintiff.
John C. Williams, Esq., for defendant.

Prof. EUGENE E. HASKELL, called as a witness on behalf of the plaintiff, being duly sworn, testified as follows:

Direct Examination by Mr. Reid.

Q. What is your name?
A. Eugene E. Haskell.
Q. Where do you live, Mr. Haskell?
A. Here in Ithaca, New York.
Q. What is your profession?
A. Civil engineer.
Q. How long have you been engaged in that profession?
A. Nearly 30 years.
Q. Of what schools are you a graduate?
A. I am a graduate of this college—this college of Civil Engineering—Cornell University.
Q. Do you occupy any official position in the university?
A. I am the director of the college.
Q. And what is the scope of your duties in connection with the college at this time?
A. Largely executive.
Q. How many years have you been connected with this college?
A. Since the fall of 1906.
Q. Where were you before that?
A. Engaged in practical engineering work.

Q. Where? Just generally, now.

A. I was five years on the Mississippi River; eight years with the Coast and Geodetic Survey in Washington, and thirteen years with the Lake Survey.

Q. Now, just give us an idea of what your duties consisted of with those surveys?

A. On the Mississippi River I was engaged in surveys—hydraulic surveys of the river. With the Coast and Geodetic Survey, I spent almost all my time upon the tides and currents of the coast, and the hydraulics of New York harbor, also on Long Island Sound.

Q. Have you held any position with the government—a member of any boards, rather?

A. I am at present an International Waterways Commissioner.

Q. What is that?

A. It is a commission that has to deal with matter pertaining to the Great Lakes, that is of common interest to the United States and Canada.

Q. And what in regard to the Great Lakes?

A. That is, the diversion of water and the preservation of their stages.

Q. What other experience have you had in regard to the Great Lakes?

A. I have been connected with the surveys and with the investigation of lake levels; in fact, I planned the investigation of lake levels that has been going on since 1898.

Q. Just give us, in a general way, with whom you were connected in that work?

A. With the United States Lake Survey, located at Detroit. The work really started before the Lake Survey was organized, in the United States Engineer's office at Detroit.

A. Can you name any of the individuals that assisted in this work?

A. General Leydecker was in charge of the engineer's office at the time the investigation started; he was also later in charge of the Lake Survey. In 1901, the Lake Survey was transferred to—now—Colonel Fisk of the Engineer Corps.

Q. Now, what range did your investigations cover—just a general idea?

A. A general idea?

Q. Yes. What the actual work consisted of.

A. The work consisted of—in the collection of gauge rec-

ords; that is, of the stages of water of the several lakes and of their connecting rivers, and of the measuring of the discharge of the lake outlets.

Q. Now, can you give us a general idea of where those investigations were—

A. On all the lakes and their outlets.

Q. Now, can you give us some of the outlets there?

A. The St. Mary's River is the outlet of Lake Superior; the St. Clair River is the outlet of Lake Huron; the Detroit River is the outlet of Lake St. Clair; the Niagara River is the outlet of Lake Erie and the St. Lawrence River is the outlet of Lake Ontario.

Q. What systems or devices did you use in doing this work; any particular ones?

A. Why, we designed a special self-regulating gauge for the registering of the stages of water.

Q. What is the common name of that? What is that known by; what is the name?

A. The gauge is officially known as the "United States Lake Survey self-registering gauge."

Q. That was used in all your work, was it; in this connection?

A. Well, not all of it. We had to resort in many instances to the use of staff gauges or float gauges.

Q. Now, what other instruments or devices were used in this work?

A. We had sounding machines for making soundings and current meters for measuring velocities.

Q. What were the current meters?

A. We used the meter which I designed, known as the "Haskell Current Meter."

Q. Now, these instruments and devices that you used were the best devices that could be obtained for this work, and these investigations?

A. We considered them so.

Q. Now, from your experience in dealing with the Great Lakes and the levels and the outflow and other work that you have described, have you an opinion as to whether or not the diversion of water at Chicago to the amount of four thousand, five thousand, ten thousand and fourteen thousand cubic feet per second, would in any way affect the navigable capacity of Lake Michigan, or the Great Lakes? First, have you an opinion?

A. Yes.

Q. Now, would it affect the navigable capacity of Lake Michigan or any of the Great Lakes?

Mr. Williams: I object to that.

A. Yes.

Q. Have you, or do you know of any system of measuring the amount of the decrease or effect on the lake level of a certain outflow or diversion of water through a channel, or any other means of diversion?

Mr. Williams: Objected to on the ground that it calls for a conclusion of the witness on a question which is to be determined by the court from the facts, and not from conclusions alone.

A. Yes.

Q. Now, in regard to the word "lowering" as used in connection with the Great Lakes, what do you understand that to mean?

A. A decrease in the stage of water, an actual lowering of the water surface.

Q. Just give us a further definition of what you mean. I am talking now in relation to a diversion of a body of water from a body of water, what would you mean by the lowering?

A. That is a diminishing of the stage. That is, the mean level of the lake for a certain year may be up here (indicating on blue print) and due to the diversion for the next year it might be a certain quantity lower.

Q. Now, might the lake be actually higher and still have a lowering, in the sense that you mean?

A. Yes, sir.

Q. That is what I meant.

A. Yes.

Q. If 4,000 cubic feet per second should be diverted at Chicago would that lower Lake Michigan at a point ten miles off from Chicago, and would that have an effect on all the lakes if it did affect it ten miles off?

A. Certainly.

Q. Is it possible to divert a given amount at Chicago, say 4,000 cubic feet per second, and have the outflow in the St. Clair River go on forever undiminished?

A. No, sir.

Q. And it is your opinion that it must be absolutely certain, that the lowering effect of the diversion must affect the outflow in the St. Clair River?

Mr. Williams: I object to that question as leading.

A. Certainly.

Q. Now, what do you understand by the term "net supply" used in regard to the Great Lakes and the diversion of water?

A. By the term "net supply" I should understand it to mean the supply in any particular lake that its outlet had to take care of.

Q. And even though the amount through the outlet might vary, still the net supply would always remain the same? You understand that?

A. Yes.

Q. The net supply in any way would not be altered by the diversion itself, as you understand it?

Mr. Williams: Objected to as leading.

A. It would not.

Q. Are the rainfall, evaporation and absorption of the run-off in the drainage basin of the lakes, or the inflow from St. Mary's River, increased or decreased by the diversion at Chicago?

A. Neither.

Q. Now, can you give us an example or illustration of the effect that the outflow, say, through the St. Clair River would be affected by a diversion at Chicago, in any way?

A. I don't know that I caught the first part of that question.

(Question read.)

Q. As to its less, or greater—the relative relation between the outflow and the increase?

A. The St. Clair River is the natural outlet of Lake Huron,-Michigan, and any water diverted at Chicago would mean that it must come from the discharge of the St. Clair River; must be taken from that.

Q. In your experience have you made any measurements or have you any data in which, say, was given a certain amount of outflow through the drainage canal at Chicago, that you could figure out the effect it would have on the outflow of the lake?

A. Yes.

Q. Now, just give us, in a general way, what that system is that you would use?

A. First of all, would be the determination of the discharge curve of the St. Clair River.

Q. What would that be for?

A. For the purpose of finding out the discharge of the river corresponding to any particular lake stage.

Q. You mean by that, you get a formula to use and apply it?

A. A formula or curve which would give the discharge of the river for all stage of the lake.

Q. Now, can you tell us what the lowering of Lake Michigan and Huron would be, in inches, for a 10,000 cubic feet of diversion?

A. Very close to six inches.

Q. Could you tell us what percentage of the lowering in Lake Michigan the water in St. Mary's River at the foot of the locks will be lowered?

A. The lowering of the locks would be slightly less, about 20 per cent.

Q. Would the discharge of 4,000 cubic feet per second at Chicago effect the navigability of Lake Michigan or the Great Lakes?

Mr. Williams: Objected to on the ground it is leading and calls for a conclusion. I have no objection to the witness stating, if he has an opinion, what the effect of the diversion would be in so far as the lake level is concerned, but what that effect would be on navigation—I don't understand that the witness is qualified on navigation.

A. It would lower the water on all shoal places, which, of course, would be a detriment to the interests of navigation.

Mr. Williams: I move to strike out that part of the witness' answer referring to navigation in the last sentence thereof.

Q. What places would be effected on the Great Lakes? What do you term those places where a difference of a few inches of water may make a difference

A. The lower Detroit River is one of the critical places, and all of the west end of Lake Erie. Lake St. Clair; the northern end of Lake Michigan. Certain areas in Green Bay; the head of the Niagara River, and, in fact, the Niagara River to Port Day, and the lower St. Lawrence River below the Galops Rapids.

Q. You answered a short time ago, in regard to 10,000 cubic feet per second, the diversion would be a lowering of six inches?

A. A trifle over six inches.

Q. Now, the same proportion would hold good in 5,000 cubic feet, or any amount?

Mr. Williams: I object to the question as leading.

A. Yes.

Q. If Lakes Huron-Michgan were lowered a known amount and Lake Erie a known amount, what would be the lowering in the Detroit River, Lake St. Clair and the St. Clair River?

A. It would be substantially the same.

Mr. Williams: I object to the answer on the ground that it is not responsive to the question as put, and ask to have it stricken out.

A. (Continued.) The Detroit River and Lake St. Clair would be changed by very closely the amount that Lake Erie was changed; the St. Clair River would be changed by the amount that Lake Huron was changed—or very close to it.

Q. If a certain quantity of water is diverted in the drainage canal at Chicago, how much will the outflow of the Niagara and St. Lawrence Rivers be lessened?

A. They will be lessened by the amount of the diversion.

Q. Will Lake Erie be lowered?

A. It will.

Q. And the Niagara River?

A. And the Niagara River.

Q. Lake Ontario?

A. Lake Ontario and the St. Lawrence River.

Q. Do you know anything about the hydraulic measurements that have been taken in the St. Clair River since 1897, as to how much time has been spent, and the instruments, equipment and methods used? Just in a general way.

A. That is about three years—that is previous to my departure from the Lake Survey—previous to 1906. I am not quite sure of what has been done there since that time.

Q. Now, do you know as to the equipment they had for doing that work, and as to the instruments and methods they used at that time?

A. I do. The outfit was a very complete one, and the most of the velocity measurements on the cross-section were made with two meters.

Q. What were they?

A. They were Haskell Current Meters, used in such a way as to check each other.

Q. Who was in charge of the work there?

A. Mr. L. C. Sabin for the first two seasons.

Q. And who else?

A. And Mr. Murray Blanchard for the third season.

Q. Were they competent men for that work?

A. They were.

Q. Now do you know anything about the work done in the Niagara River?

A. I do.

Q. Just give us a general description of that?

A. The discharge measurements in the Niagara River were started by myself for the Board of Engineers on Deep Waterways in 1897. These observations were made—that is, the current observations were made—by Haskell Current Meters from the International Bridge. The following season beginning about midyear of 1898, that work was taken up by the United States Lake Survey with Mr. Shenehon in charge of the work, and was continued during 1898 and 1899, and into 1900, if I remember correctly. And as a check upon the observations made from the International Bridge, a second section known as the "Open Section" was selected at a point about 1,800 feet below the bridge and the discharge measurements of the river were made on that section and the two sections compared; that is, the discharge curves as determined from the observations at the two places were compared and they agreed within about a half of one per cent., as to the volume of discharge for any particular stage of Lake Erie.

Q. You consider that as accurate as it is possible to get it?

A. It is.

Q. And the St. Lawrence River, too?

A. The discharge of the St. Lawrence River was made at what is known as the "Three-point Section," by Mr. Shenehon, covering parts of two years.

Q. The same methods and systems applied?

A. Substantially the same methods, same instruments and same outfit employed in the work.

Q. And as far as your judgment is concerned the results are as accurate and trustworthy as may be obtained, are they?

A. They are.

Q. Now, with regard to the results of the volumes of flow for the various stages of Lakes Michigan, Erie, Huron and St. Lawrence, and other things that you have testified in regard to the results, within what scale of accuracy were they—the per cent.?

A. Within 5 per cent.

Q. Five per cent., is that the result in inches, or just what do you mean by that?

A. That the results were accurate within 5 per cent. That is, that the volume of discharge, for instance, is known within 5 per cent. of the absolute truth.

Q. You testified that a diversion at Chicago would lower the St. Lawrence River a certain amount?

A. Yes.

Q. Now, what would the corresponding lowering of Lake Ontario be for one foot, suppose, between Lake Ontario and Ogdensburg—be less than one per cent.?

Mr. Wiliams: Where would the one foot be?

A. You mean for a lowering of Lake Ontario for one foot?

Q. Yes.

A. It would be about .92 of a foot at Ogdensburg.

Q. It would be less than one foot?

A. Less than one foot.

Q. I want to ask your opinion regarding the propriety of using any existing data in regard to evaporation in the attempt to detect the presence or absence of the effect already produced on the lakes by the diversion made at Chicago since 1900?

A. It is hardly permissible to use that data at the present time.

Q. Have you any knowledge as to how large the error of those figures would be?

Mr. Williams: I object to the question on the ground that it is manifestly beyond the range of human knowledge to know, if they are not reliable, how unreliable they are.

A. Do you wish me to answer it?

Q. Certainly.

A. I should think that one might easily get into an error of 20 to 25 per cent.

Q. Now, the same question in regard to the precipitation, on the drainage of the Great Lakes?

A. Precipitation is a great deal better known. I think it is safe to say that the observations of the Weather Bureau give within 12 to 15 per cent.; that is, particularly the observations made during later years.

Q. Do you know particularly the extent of the observations made by that Bureau?

A. By the Weather Bureau?

Q. Yes.

A. They now have a large number of stations in the drainage basin of the Great Lakes, of course, they began with a few when the Weather Bureau started, and these have been increased, and for the last ten years they have had a pretty good number of permanent and volunteer observing stations.

Q. It might differ—the extent on the Great Lakes themselves—there are no stations on the lakes?

A. No stations on the water surface, no.

Q. Assuming a diversion of 10,000 cubic feet per second at Chicago, how long would it take 9/10 of the ultimate lowering in Lakes Michigan-Huron, due to this diversion, to take place?

A. About four and a half years.

Q. The same question in regard to Lake Erie, and the St. Clair River and Detroit and Niagara River?

A. Take nearly six years for Lake Erie.

Q. St. Clair River?

A. You asked Ontario, did you not?

Q. Yes.

A. And about six and a half years for Lake Ontario.

Q. Have you any figures on the St. Clair River?

A. The lowering of the St. Clair River?

Q. Yes. How long will it take?

A. The time?

Q. Yes.

A. The St. Clair River is controlled by Lakes Michigan and Huron, and the time required there would be substantially the time of those lakes.

Q. Do you know the fall of the Niagara River at Niagara Falls, as to the horse-power? Can you tell us what 4,000 cubic feet would be worth in horse-power at Niagara Falls?

Mr. Williams: I object to that question.

A. That is, as to the Falls?

Q. Yes, as to its use there as horse-power?

Mr. Williams: I want to state my objections. Not on the ground of immateriality, because that can be reached later, but on the ground that nothing has appeared to show that the witness is qualified to answer the question.

A. I should have to figure that out, if you want it for the Falls. That is, if you want it for the total fall in the Niagara River.

Q. Well, could you tell us what a thousand cubic feet per second at Niagara would be in horse-power?

Mr. Williams: I object to the question on the ground it is not complete.

A. The total fall there would amount to about 3,500 horse-power.

Q. You do not know anything about the fall available at Lockport and Joliet?

A. No, I do not.

Q. What would be the lowering of Lake Erie in inches of a diversion of 4,000 cubic feet per second at Chicago?

A. Two inches.

Q. And Lake Ontario?

A. An inch and two-thirds.

Q. This is reckoned on 4,000 cubic feet?

A. Four thousand, yes.

Q. The same proportion would apply on 5,000, 6,000 or 10,000?

A. The same proportion, yes.

Q. You testified as to Lake Michigan as 10,000?

A. As 10,000, yes.

Q. The change in the elevation that you testified to in regard to the level of the lakes, that would reach into every harbor and bay connected with the Great Lakes, would it not?

A. Certainly.

Cross-Examination by Mr. Williams.

Q. Mr. Haskell, what would be the effect on the level of Lake Michigan and Lake Huron by the diversion of 4,000 cubic feet per second at Chicago?

A. Can you give me time to figure it?

Mr. Reid: I think we took it for 10,000 instead of 4,000.

A. Two and a half inches

Q. Would the same proportion prevail with a discharge of any definite amount from nothing, say, to 20,000 cubic feet per second at Chicago, from Lake Michigan? That is, what I mean is, suppose there was a diversion of any definite amount at Chicago, that amount varying anywhere from nothing to 20,000 cubic feet per second, would the same proportion of lowering of level occur in Lake Michigan as is shown by the testimony you have given based on 4,000 cubic feet per second?

A. The figures that I have stated would be for mean level, substantially the mean level of those lakes.

Q. Yes?

A. It would be slightly less for lower stages and greater for higher stages.

Q. But would the same proportion exist as between the lowering of the level of Lake Michigan and Lake Erie, no matter what the diversion was up to say 20,000 cubic feet per second?

A. I don't think I get your question clear in my mind.

Q. We have a diversion of 4,000 cubic feet at Chicago which gives a lowering of Lake Michigan as you say of 2½ inches, and a lowering of Lake Erie of 2 inches, which is practically 4/5 of the lowering which occurs in Lake Michigan. Now, suppose the diversion was in amount from nothing to 20,000, would the same diversion take place in Lake Michigan as in Lake Erie?

A. Substantially so.

Q. How far from Chicago would you say that the effect of the diversion of 4,000 cubic feet per second would be noticeable and appreciable, following the chain of the lakes and the connecting rivers toward the Atlantic?

A. It must be appreciable throughout the entire lake system, in Lakes Michigan and Huron and the entire lake system below.

Q. To the Gulf of St. Lawrence?

A. Yes.

Q. Would it be appreciable in the Gulf of St. Lawrence?

A. It would be so infinitesimal that we would say no.

Q. Would it be noticeable, the lowering of Lake Michigan caused by the diversion at Chicago of 4,000 cubic feet per second, would that have any effect upon the level of Lake Superior?

A. No.

Q. Lake Huron, you would say, was effected the same extent as Lake Michigan?

A. To the same extent; Lakes Huron and Michigan are practically one lake.

Q. Now, taking the level of the water in St. Clair River would the diversion of 4,000 cubic feet of water in Chicago have any effect upon the level or the depth of the water in the St. Clair River?

A. It would.

Q. How much as compared with Lakes Huron and Michigan?

A. Well, nearly the same amount as Huron and Michigan.

Q. Would you care to express an opinion as to the percentage?

A. I have not worked it out in that form; it would be slightly less.

Q. Then I take it from the answers that you have already given that, in your opinion, the lowering of the level of Lake Erie would be substantially four-fifths of the lowering of Lake Michigan?

A. Yes, for mean stages.
Q. Yes.
A. Yes.
Q. Now, what would you say as to the level of Lake St. Clair, as compared to the level of Lake Huron—the effect of the level with a diversion of 4,000 cubic feet per second?
A. The effect on Lake St. Clair?
Q. Yes, sir. In your opinion would it be somewhere between the effect on Lake Huron and Lake Erie?
A. Yes.
Q. It would be slightly less effect—more effect on the depth, than the effect shown in Lake Erie, and less than shown by Lake Huron?
A. Would you mind repeating that?
Q. I mean, that the effect of the depth of the water in St. Clair River would be slightly less than the depth in Lake Michigan and Lake Huron?
Q. And slightly more than the effect of the depth of Lake Erie?
A. No; slightly less.
Q. The effect would be less than the effect upon the water in Lake Erie?
A. Yes. Because Erie, to a large extent, controls the Detroit River and Lake St. Clair.
Q. Well, suppose there is a diversion of 4,000 cubic feet of water per second at Chicago, which you say effects the depth of Lake Michigan to the extent of two and a half inches, to what extent would it effect the depth of Lake St. Clair?
A. Really it would be so close to the two inches, that you wouldn't need to bother about the difference.
Q. To the two inches?
A. Yes; of Lake Erie—perhaps I misunderstand you.
Q. Well, can you give your opinion as to the precentage of the 2½ inches lowering of the lake level of Michigan appreciable in Lake St. Clair?
A. I don't know that I see—
Q. Two and a half inches is 100 per cent.?
A. Is 100 per cent.
Q. Yes, sir. Now, what percentage of that effect would be shown in Lake St. Clair?
A. Practically 80 per cent. of it.
Q. And Lake Erie substantially the same?
A. And Lake Erie substantially the same, yes.
Q. What, percentage of that variation in depth would be

found in Lake Ontario as the result of the diversion of say 4,000 cubic feet per second?

A. I don't know that I see your point clear there. That is, what percentage?

Q. Yes.

A. Of the depth at Lake Michigan?

Q. Lowering of Lake Michigan, would be noticeable in Lake Ontario?

A. Would be noticeable in Lake Ontario?

Q. By the diversion of any quantity of water at Chicago?

A. About 70 per cent.

Q. Now, take the Detroit River. Assume a lowering of Lake Michigan by reason of diversion of water to the extent of one foot, or any definite lowering, to what extent would the depth of the Detroit River be affected as compared with the effect upon Lake St. Clair, or in connection with Lake Michigan, say, in comparison with Lake Michigan? What percentage of the lowering would be noticeable in the Detroit River?

A. About 80 per cent.

Q. What percentage of the lowering noticeable in Lake Michigan by reason of the diversion of a definite quantity of water would be noticeable in the Niagara River?

A. Well, that would depend upon the point in the Niagara River.

Q. Well, what part of the Niagara River is used for navigation purposes?

A. Clear down to Port Day, which is a short distance above the Rapids that approach the Falls.

Q. And how many miles?

A. About sixteen.

Q. Well, take it at Port Day?

A. Take it at Port Day?

Q Yes, sir.

A. Are you referring to Lake Michigan?

Q. Yes, sir.

A. Forty-one per cent.

Q. After you have passed through Lake Ontario and into the St. Lawrence River, what percentage of the lowering manifested in Lake Michigan would be noticeable in the St. Lawrence River due to a diversion at Chicago of any definite quantity?

A. That is, the percentage in the St. Lawrence of that in—

Q. In Lake Michigan?

A. —in Lake Michigan. Sixty-six per cent.; that is, in the St. Lawrence River down to the Galope Rapids.

Q. And from there on?

A. From there on I don't believe I have the data that I could express an opinion on that.

Q. Would it be less than the amount above the Rapids—66 per cent.?

A. Yes. For mean stages, yes.

Q. And would that—whatever the amount you determine to be the proper percentage—would that continue without variation to the Gulf, or would the effect decrease gradually as it neared the Gulf?

A. It would decrease.

Q. Until it reached zero, practically at the entrance of the Gulf?

A. Yes.

Q. Now, Mr. Haskell, let's go back to the St. Clair River and Lake St. Clair again, and having now clearly in your mind the purport of my questions, you stated substantially that there would be no difference between the effect observable in Lake Michigan and between that in Lake St. Clair, but you showed practically 20 per cent. between Lake Michigan and Lake St. Clair; where does that occur?

A. It occurs in this way: The St. Clair River is controlled by Lake St. Clair and Lakes Michigan-Huron.

Q. Yes.

A. —while the Detroit River and Lake St. Clair are controlled substantially by the stage of the water in Lake Erie.

Q. Well, could you have a drop of any amount in the St. Clair River and not have any in Lake St. Clair?

A. No. Still it might be masked by the stage of Lake Erie.

Q. Well, assume then, that at the connection of Lake Huron and the St. Clair River the effect of a diversion at Chicago is equally noticeable in Lake Huron and in the St. Clair River, would that continue to be true through the entire length of the River St. Clair down to Lake St. Clair, where the effect is only 80 per cent. of that noticeable in Lake Michigan?

A. Yes.

Q. And the drop then from the hundred per cent. lowering to the 80 per cent. lowering is at the outlet of the St. Clair River into Lake St. Clair?

A. It is distributed along the St. Clair River.

Q. Along the entire length of the river?

A. Substantially along the entire length of the river.

Q. All right. Now, this testimony that you have given with reference to these relative lowerings in these bodies of water, applies generally without reference to any specific gauge readings or discharge measurements or anything of that kind; you give that testimony based upon your knowledge of the lay of the lakes?

A. Yes.

Q. And you do not use, in arriving at these conclusions any specific discharge data?

A. No; only what is given by the United States Lake Survey.

Q. Well, what discharge data do you take into consideration in giving this testimony that we have just been going over now?

A. The date that has been obtained by the survey and that is in their published reports.

Q. But you use the specific data that you obtain from the United States Lake Survey reports in arriving at these percentages?

A. Yes.

Q. But you would be able to testify without any specific discharge data on the general proposition of the effect of the lowering being less appreciable as you approach the Gulf of St. Lawrence, and as you left Lake Michigan?

A. Yes, sir.

Q. And without going into the question of percentages?

A. Yes.

Q. You have testified, Mr. Haskell, with reference to the substantial accuracy of these discharge measurements and gaugings of the United States Government, and as exhibited to you, and have you had your attention called to these plates shown as Comp. Exhibits 1, 2, 3 and 4 lying on the table (indicating)?

A. Yes, I think those are the same ones. (Examining plates referred to). Yes.

Q. In giving your opinion as to the effect upon the level of Lakes Michigan and Huron of the diversion of 10,000 cubic feet per second, and 4,000 at or near Chicago, you have used the data contained in these gaugings and discharge measurements of the Government?

A. Not as they are given there; that is with one exception.

Q. Now, did you prepare yourself any plates or plats from which you arrived at the conclusions that you have testified to?

A. Yes. That is, this plate here (indicating), upon which I base my testimony, is one that is used by the International Waterways Commission.

Q. By whom was it prepared?

A. By Mr. Wilson.

Q. And the data from which it was prepared was obtained where?

A. The Lake Survey.

Q. The same source of information as used for a basis for the plates that I have called your attention to, as Government Exhibits 1, 2, 3 and 4?

A. Yes. That is, we may have used less than is given there. I won't be positive as to that, but the information comes from that source.

Q. And your testimony is based upon the computations made by you from the plate which you hold in your hand?

A. Yes.

Q. And used by the International Waterways Commission?

A. Yes.

Mr. Williams: Now, I would like to have that plate marked as "Haskell's Ex. 1, for identification," and attached to the deposition, so we will have it.

Plate marked "Haskell's Ex. 1, for Identification, 2/17/09 H. J. R. on X Ex."

Q. Now, is there, Mr. Haskell, to your knowledge, any information that is complete and reliable enough so that any estimate could be made of the effects of diversion of water from one of the Great Lakes, aside from the information which you, as a member of the International Waterways Commission and the Government have used, being the gauge readings and discharge measurements of the United States Government used as a basis for these plats or plates?

A. No; I think the only information available, from which the question can be worked out, are these data.

Q. Now, are you acquainted with the fact—if it is a fact—that the difference in the elevation between Lakes Huron and Erie has been nine-tenths of a foot less since 1886 than prior to that time?

Mr. Reid: That is objected to as not being proper cross-examination.

Q. What is the difference of elevation between the two lakes?

A. I don't think it is a fact.

Q. All right; it is not a fact. Then there is no explanation necessary?

A. No.

Q. Do you know that it has been so claimed?

A. Yes.

Q. But do you not think that that is true?

A. That is, that there has been a permanent change?

Q. That since 1886 it has been—there has been 9/10 of a foot less in difference of elevation than there was preceding 1886?

A. Yes. That is, I am aware that that does exist, but it is by no manner of means permanent.

Q. Well, now then, if it does exist, how do you account for that?

A. Due to the low stages of Lakes Huron and Michigan for a considerable period of time.

Q. And do you know why—have you any opinion as to why Lakes Huron and Michigan have had that low stage?

A. Lack of precipitation.

Q. Does that condition still prevail?

A. Partially so.

Q. You testified that in your opinion the data of the United States Government obtained from the Weather Bureau and the observation points under the jurisdiction of the Weather Bureau, were inaccurate to perhaps 12 to 15 per cent.

A. 12 to 15 per cent.

Q. For how many years back would you consider that to be true?

A. I should say for the last fifteen years.

Q. In your opinion that system of observation is increasing in efficiency from year to year?

A. From year to year.

Q. And would you say that 12 to 15 per cent. applied to the whole period, or to the latter portion of the period?

A. Well, I should say for the whole period of that fifteen years.

Mr. Williams: I think that is the extent of our questions, Mr. Haskell.

Re-direct Examination by Mr. Reid.

Q. Do you know what the water movement is—that is, if Lake Erie goes down a foot, how much does the water go down at Suspension Bridge,—at Whirlpool?

A. It goes down a foot at Lake Erie, you mean?

Q. Yes. Have you figured that out? Do you know?

A. Yes, I figured it out. I could not do any more than give a guess at it, without referring to the computations. (To Mr. Wilson.) Have you got one of those diagrams here, Mr. Wilson?

Mr. Wilson: I have not; it is in the report of the Commission on the Whirlpool Rapids.

Q. Then you have not it here?

A. I have not it here.

Q. It is greater or less than one foot?

A. It is greater than one foot.

Q. Now, does the position of any one of the lakes, or a pool, prescribed its lowering—its position in the chain?

A. Prescribe its lowering?

Q. Yes.

A. Yes.

Q. Well, do the lakes lower gradually to Montreal, is that what you mean by these figures you have been giving us here?

A. Yes. The actual lowering of the level would depend upon the discharge curve, as you go east, the increment of the discharge, would be greater.

Q. What I meant is, it gradually tapers off as far as Montreal, but beyond there the volume is so large—

A. Yes, below Montreal the volume is so large, compared to the amount of diversion that the effect is less.

Q. How does the increment in the Whirlpool compare with that at the head of the Niagara River?

A. The increment?

Q. Yes.

A. That is, per foot? It would be less.

Q. You answered the question before, it went greater as it went down. Now, is that as you understand? In your answer before you said it got greater as it went down?

A. Well, this question relates particularly to the Niagara River?

Q. Yes.

A. You see it does not apply to another lake, or another outlet. The increment of discharge for any particular section—when you mention the head of the Whirlpool Rapids that is a particular section in that river.

Q. That is protected by the motion, isn't it, of the water. Would not there be some difference?

A. The section is narower; that section is very much nar-

rower; very much narrower than the river where the discharge was measured.

Q. Yes. Wouldn't the area of the section control more from the fact that it was nearer the sea?

A. No, that would not make any difference.

Q. Now, the curves upon which you base your statements as to the lowering of the lakes, does not take into consideration the measurements made in 1908?

A. No.

Mr. Williams: There is one thing I would like to have, Mr. Haskell, go into the record, the definition of the word "increment." I don't think the court will know what we are talking about when we are talking about the "increment," and somebody ought to explain it?

A. We mean by the increment of discharge the additional quantity of water that is discharged per foot rise of the particular lake with which you are dealing.

Q. You mean the per foot rise or unit rise?

A. We usually term it the "per foot," and then if we want it in small quantities, we take the tenth of it, or in inches—to satisfy the lawyers—why we take the twelfth of it.

W. EDWARD WILSON, called as a witness on behalf of the plaintiff, being duly sworn, testified as follows:

Direct Examination by Mr. Reid.

Q. What is your name?

A. W. Edward Wilson.

Q. Where do you live, Mr. Wilson?

A. Buffalo, New York.

Q. What is your business?

A. I am secretary of the International Waterways Commission.

Q. How long have you been occupied in that position?

A. About two and a half years.

Q. Have you any profession?

A. Civil engineer by profession.

Q. What school are you a graduate of?

A. Graduate of Cornell University.

Q. What other positions or experience have you had in this line?

A. Why, since 1901-02 I was in charge of hydraulic meas-

urements on the St. Marys River; in 1903 I was in charge of the hydraulic measurements on the Niagara River, and for a period of three years I was in the Rocky Mountains at that time doing hydraulic work in addition to holding a position of assistant professor of Civil Engineering in the University of Utah.

Q. Did you finish giving your experience and positions?

A. Yes.

Q. Now what connection have you had with the hydraulic measurements on the Great Lakes and on the rivers?

A. That has partially been explained in the previous answer. Do you wish it stated again?

Q. Well, just on what rivers.

A. On the St. Mary's River and some work on the Niagara River.

Q. Well, just give us a short statement of the methods and results?

A. In 1901-2 I was in charge of the work on the St. Marys River in which we took up the measurements of the discharge of this river and in 1903, I think, the work on the Niagara River consisted of slope observation. In 1908 I made an investigation at Niagara Falls as to the effect of the diversion of water as caused by the Power Companies.

Q. Do you know anything about the local conditions at Chicago?

A. Very little.

Q. Now, is it possible to divert 4,000 cubic feet per second at Chicago without lowering Lake Michigan?

A. It is my opinion that you could not divert water through the Chicago Drainage Canal without lowering Lake Michigan.

Q. What effect would that have in the bays and harbors in Lake Huron?

A. Well, eventually it would lower every bay and harbor in the lake.

Q. Now, will you give us your idea and definition of "lowering" as used in this connection?

A. "Lowering," in this case means, with me, the change in level of Lake Michigan and Huron due to diversion at Chicago compared with the level of the lake without the diversion for the same period.

Q. The level of the lake may be, in fact, higher than it was before and still there be a lowering according to this definition?

A. According to this definition, yes sir.

Q. It is possible to divert 4,000 cubic feet per second at Chicago and have the outflow in the St. Clair River go on the same, undiminished?

A. It is not.

Q. What do you understand by the term "net supply"?

A. The net supply to any lake?

Q. Yes, or as it applies to Lake Michigan or Huron. Just give us a general definition and afterwards apply it.

A. Applied to any lake, it is the total quantity of water supplied to this lake, or in other words, it is the water yield to any lake. In the case of Lake Michigan and Huron it is equal to the discharge of the St. Clair River plus or minus the storage on the lake surface, or, it is equal to the precipitation on the lake surface plus the run-off from the streams of the water-shed minus the evaporation on the lake surface.

Q. Is that a constant quantity?

A. It is not; it varies from month to month and year to year.

Q. Notwithstanding that, is it still a concrete and tangible thing?

A. Yes, sir.

Q. Are the rainfall, evaporation, absorption, run-off, in the Drainage Basin of the Great Lakes, or the inflow of the St. Marys River increased or decreased by this diversion at Chicago? It does not alter these factors.

Q. Have you any method or can you compute the effect of diversion of water from a lake as to the amount it would lower in inches?

A. Yes, sir, I can compute it.

Q. Could you tell me what the lowering of Lake Michigan and Huron would be in inches for a 10,000 cubic foot diversion?

A. At mean stage, Lake Michigan and Huron would ultimately be lowered by a diversion of 10,000 cubic feet per second, about six and one quarter inches.

Q. Now, can you give us the same for Lake Erie and Lake Ontario?

A. For 10,000?

Q. Yes.

Mr. Williams: You are speaking now of a diversion at Chicago from Lake Michigan?

Mr. Reid: Yes.

Mr. Williams: And the effect of diversion?

A. The effect of diverting 10,000 cubic feet at Chicago would eventually lower Lake Erie about five inches.

Q. And for Lake Ontario?

A. The effect on Lake Ontario would be about four and one-quarter inches.

Q. Those would hold good for the same proportions for say 4,000 cubic feet per second and 6,000?

A. Yes, sir.

Q. What percentage of the lowering in Lake Michigan will the water in St. Marys River at the foot of the locks be lowered?

A. Well, the water will be lowered at the foot of the locks an amount slightly less than that on Michigan and Huron.

Q. What percentage at the critical points, and what do you consider the critical points?

A. In the St. Marys River?

Q. Yes.

A. I should say the locks at Ste. Marie and the improved channels along the St. Marys River.

Q. You gave these figures in regard to the mean stage. Now, what would be the effect on the high stages and the low stages?

A. The effect on these lakes?

Q. Yes; as to the larger or smaller; would it be greater when they are high or low?

A. For any particular lake?

Q. Well, any of these?

A. On Lake Michigan and Huron the effect would be greater as the stage becomes less, and vice versa.

Q. If a certain quantity of water is diverted in the Drainage Canal at Chicago, how much will the outflow in the St. Lawrence and Niagara Rivers eventually be lessened?

A. The same amount.

Q. Will Lake Erie be lowered?

A. Yes, sir.

Q. And Niagara River and the St. Lawrence River, as far as Ogdensburg?

A. Yes, sir.

Q. Did you do any of the work on the measuring of the outflow of the St. Lawrence River and the Niagara River?

A. No, sir. Other than my work in 1903, which did not take into consideration the discharge measurements specifically.

Q. Where was the work at that time?

A. At that time it was carried on between Buffalo and Niagara Falls.

Q. Have you any information as to the money spent in hydraulic measurements in the St. Clair River since 1897?

A. In a general way.

Q. Did you do any specific work in that line?

A. I did not do any on the St. Clair River. I did a little on the Detroit. My work has been principally on the St. Marys River.

Q. You consider the diversion of 4,000 cubic feet per second to 10,000 cubic feet per second through the Drainage Canal of Chicago would have any effect upon the navigable capacity of the harbors or lakes or bays of that section?

A. I do.

Mr. Williams: Objected to on the ground that it calls for a conclusion of the witness, and not facts, and, on the ground also, that the witness has not shown himself qualified to testify on questions affecting navigation.

A. Continued. It would lower the water in the entire system below Superior, and naturally cause a decreased draft for vessels.

Q. Now, where in the area you speak of would this likely effect the navigable capacities of these places?

Mr. Williams: I object to that question on the ground that it assumes a conclusion which has not been shown and on the further ground that it calls for another conclusion of the witness.

A. Lake St. Clair, at the foot of the Detroit River; on the shoals of the western part of Lake Erie. It would effect the Niagara River and the St. Lawrence canals and the St. Lawrence River.

Q. I want your opinion regarding the propriety of using any existing data regarding evaporation and an attempt to detect the presence or absence of the effect already produced by the diversion made at Chicago on the lakes since 1900?

A. It is my opinion that any deduction made from observations for evaporation would not be very reliable considering the fact that evaporation varies from month to month and from year to year. ——— In some months, the evaporation on, for instance, Lake Michigan and Huron is greater than the amount of precipitation in the lake surface and run-off of the streams. That also applies to Lake Erie and Lake Ontario.

Q. Take a diversion of 10,000 cubic feet per second at Chi-

cago, how long will it take 9/10 of the ultimate lowering in Lakes Michigan and Huron, due to this diversion, to take place?

A. Michigan and Huron—a little over four years.

Q. As to Lake Erie, St. Clair River and Lake Ontario?

A. Lake Erie, 9/10 of the effect would be noticeable in five or six years.

Q. Lake St. Clair?

A. Lake St. Clair would be somewhere between the time required for the lowering of Lake Huron and Lake Erie.

Q. Lake Ontario?

A. Lake Ontario, 9/10 of the effect would occur from five and a half to six and a half years.

Cross-Examination by Mr. Williams.

Q. In making your computation Mr. Wilson, as to the effect of a discharge or a diversion of 10,000 cubic feet from Lake Michigan at Chicago, that effect being as I understand --in making the computation, whatever the result—you must compute from some basis of discharge from Lake Michigan and Huron outflow?

A. I compute that quantity from a difference in discharge per unit rise.

Q. As shown by what?

A. As shown by this plate here, (indicating).

Q. That is the plate identified as "Haskell's Ex. 1."

A. Yes, sir.

Q. And which is to be attached to the deposition?

A. Yes, sir.

Q. Well, now, you use as a basis for your computation Haskell's Exhibit 1.

A. Yes, sir.

Q. And where did you get the data that is on that chart?

A. That data came from the United States Lake Survey.

Q. And is that the same data that is used, if you know, in the preparation of the plats or plates which have been heretofore identified as Complainant's Exhibits 1, 2, 3 and 4, being the plates on the table before us?

A. The results as shown on that plate are derived from a part of these observations.

Q. Did you have any information in the preparation of Haskell's Exhibit No. 1 not used in the preparation of the

Government Exhibits 1, 2, 3 and 4; you say you have used a part of the information shown on those plates?

A. Yes.

Q. Now, did you use anything that is not shown on those plates?

A. No, sir.

Q. So that the sole source of your information from which Haskell's Exhibit No. 1 has been prepared, is from the information derived from the Lake Survey?

A. Yes, sir.

Q. And the information shown on these charts?

A. Yes, sir.

Q. Is there any other definite and accurate information upon which to base conclusions upon the subject matter which you have testified about?

A. Not to my knowledge.

By Mr. Reid: Re-direct Examination.

Q. The Complainant's Exhibits 1, 2, 3 and 4 contain some more information than you have on Haskell's Exhibit No. 1, do they not?

A. They contain more data.

Q. Yes.

A. Yes, sir.

Q. Can you give us the statement in regard to the tapering off of the lowering or the effect of a certain diversion

Q. Now Mr. Wilson, you spoke of certain gorge sections in which the general rule which you stated might be reversed?

A. Yes, sir.

that you forgot to ask it on direct, I will not object to it, but if not, I will object to it as not re-direct examination.

Mr. Reid: Yes.

A. In a series of reservoirs, such as the Great Lakes are, the effect of diversions generally decrease as they go down to the source. There are occasions, however, in which—there are sections in which—the increment, or rate of change, in discharge per unit, is greater than at some definite point located above.

Q. Now, just explain why, and any instances you think of?

A. The best example that I know of is at Suspension bridge. That section the river is very narrow so that a unit rise of the river produces as less rate of change in discharge than say, at the head of the Niagara River where the width

of the controlling section is several times greater than at the Whirlpool.

Q. In regard to Haskell's Exhibit No. 1, you told Mr. Wil-
Mr. Williams: If you are asking this question on the basis liams that you based your calculations on that. That does not take in the measurements made for 1908 does it?

A. No sir.

Re-cross-Examination by Mr. Williams.

in Chicago, and its effect as it goes toward the East?

Q. Have you in mind any other gorge section than the one mentioned by you at the Suspension Bridge in the chain of lakes?

A. There is one at the Whirlpool, that is in the Niagara River. There is another at the Rapids Plat in the St. Lawrence River.

Q. Now, take the gorge at the Suspension Bridge and the Whirlpool Rapids; is there any navigation carried on there?

A. There is a boat called the "Maid of the Mist" that navigates below the falls, but at these two sections—

Q. There is no navigation there?

A. No.

Q. And the Maid of the Mist would not be affected by the rise or fall of a foot?

A. Well, I understand that occasionally boats have gone down in that section, but not intentionally. That does not apply to the Rapids Plat; boats do navigate there.

Q. Yes, and do you know the depth of the St. Lawrence River there?

A. Well, I don't know that exactly. I know that boats draving 5 or 6 feet navigate there.

Q. Pleasure boats?

A. Almost entirely pleasure boats.

Testimony of O. H. Ernst, taken before Anson S. Taylor, Commissioner, on February 18, 1909, at Washington, D. C.

Present for the complainant: Mr. Frank R. Reid.

Present for the respondent: Mr. John C. Williams.

O. H. ERNST, being first duly sworn to testify to the truth, the whole truth and nothing but the truth, testified as follows:

Direct Examination by Mr. Frank R. Reid.

Q. What is your name?
A. O. H. Ernst.
Q. Where is your residence?
A. Washington.
Q. What is your profession?
A. I am an army officer, retired.
Q. What is your title now?
A. Brigadier General, retired.
Q. I wish you would state what experience you have had, or what investigation or study you have made in matters regarding hydraulic measurements, and the same in regard to your knowledge of the conditions of the Great Lakes, and the waters connecting, and other waters in the United States; in a general way, the scope of your experience in these lines.
Witness: As an engineer?
Mr. Reid: Yes.
A. I graduated from West Point in 1864, and served in the corps of engineers of the army until I retired under operation of law in 1906. After a short service in the Civil War, I was engaged on the Pacific Coast on fortifications, and surveys until 1868. From 1868 to 1871 I was stationed at the Engineer's School of Application at Willetts Point, where, among other things, were more or less studies of hydraulics and topography. From 1871 to 1878 I was instructor of Practical Military Engineering at West Point Military Academy, where I performed the duties of architect of the more important structures there and in charge of water works. From 1878 to 1886 I was stationed at St. Louis in charge of the River and Harbor District, with headquarters at that place, including the Mississippi River. From 1884 to 1894 I was a member of the Missouri River Commission, and from 1888 to 1894 I was a

member of the Mississippi River Commission, and later on I was President of that Commission, from 1902 to 1905, I think, or perhaps from 1903 to 1906, yes, that was it. From 1886 to 1889 I was stationed at Galveston, Texas, having charge of the rivers and harbors of the Texas Coast. From 1889 to 1893, I was here in Washington as Aide-de-Camp to President Harrison, and had charge of the public buildings and grounds here, and was a member of the Lighthouse Board. From 1893 to 1898 I was in command of the Military Academy at West Point. I served in Porto Rico and Cuba during the Spanish War of 1898. In 1899 I was a member of the Isthmian Canal Commission, appointed to investigate all routes for the Canal across the Isthmus. I served on that Commission until 1901. From 1901 to 1905 I was stationed at Chicago, having charge of the rivers and harbors in that district, of the local works there, and was also division engineer of the Northwest division, which included the Great Lakes system as far east as Erie, Pennsylvania. During that time I was Chairman of a Board of Engineers appointed to make surveys and estimates for a waterway 14 feet deep from Chicago to St. Louis. From 1905 to 1906, I was again a member of the Isthmian Canal Commission, and in 1905 I was appointed on the International Waterways Commission. I am still Chairman of the American Section of that Commission. That Commission has made a report on the Chicago Drainage Canal. I believe that covers my record.

Q. State what the scope of your duties was in regard to the Great Lakes and bodies of water connecting, or the connecting waters; what you had to do, your observations, studies and just what came under your direction and observation.

A. I had general supervision of all the districts in the region I speak of, the construction districts, and in connection therewith it was necessary for me to know more or less about the needs of navigation in order to fix on the dimensions of channels and the propriety or necessity of their construction.

Q. In that matter, it would come under part of your duties to know about the diversion of water from other bodies of water, the decrease or increase of water levels, hydraulic measurements and things of that nature?

A. Yes. I had to examine into these questions.

Q. State in a general way what you had to do or what came within your knowledge in these capacities in regard to navigation and commerce on the Great Lakes.

A. Well, I had to become familiar with the size of vessels employed, the amount of commerce that existed; in other words, the requirements of navigation, and I made some original studies in connection with the Illinois River, ascertaining what could be done in that river with the volume of water such as was being diverted down that river, what use could be made of it for navigation purposes.

Q. State what came under your observation with regard to vessels and the loads they were to carry and the different methods of handling these loads and vessels.

A. I visited the ports where the great freight carriers loaded and unloaded and had conversations with the managers of that business, and ascertained from them their needs and their prospects. I have overhauled the official list of vessels published by the United States Government to ascertain how many vessels of deep draft were navigating the Great Lakes, and what their freight tonnage was.

Q. Did you become acquainted with the drafts that the different vessels draw, and the loads, and things of that nature?

A. Yes, sir.

Q. Leaving that for a moment, I want to ask you if you know of the local conditions in the vicinity of Chicago, as in the Chicago and Calumet Rivers, and in and about where the Chicago Drainage Canal is located? Do you know what effect the diversion of say 4,000, 5,000, 10,000, or 14,000 cubic feet of water per second would have on Lake Michigan, if diverted into the Drainage Canal?

A. I think I do, yes.

Q. What would it be on Lake Michigan?

A. I have in mind—

Mr. Reid: As to whether it would lower it, or what effect it would have.

A. It would be lowered.

Q. State the effect it would have on Lake Michigan or the other Great Lakes.

Witness: For a given amount?

Mr. Reid: No, just generally.

A. It would lower the whole system of Great Lakes below the St. Marys River.

Q. That would include all the bays, inlets and harbors connected with the Great Lakes?

A. Yes, everything.

Q. Could you state what effect the diversion of 4,000 cubic

feet per second out of Lake Michigan into the Drainage Canal would have on Lake Michigan?

Mr. Williams: The question is objected to. I have no objection to your asking for his opinion, but object to your asking for absolute fact, unless the proofs or data from which he speaks are submitted.

A. The figures which I have in mind are the amount that would be lowered by 10,000 cubic feet per second. That is about 52/100 of a foot, say 6¼ inches.

Q. Would the same proportion hold good as to 4,000, 5,000, 6,000, or any other number of feet?

A. Yes.

Q. Could 4,000 cubic feet per second be diverted at Chicago without lowering Lake Michigan?

A. No.

Q. What do you understand is the meaning of the term "lowered"?

A. I mean relative lowering. Of course, the level of that lake is oscillating, due to winds, varying barometric pressure, varying rain fall and evaporation. When I say lowering, I mean that it is lower than it would be without that diversion.

Q. It is possible that the lake may really be higher in feet and inches, and still be lower in your definition?

A. Yes.

Q. Is it possible to divert 4,000 cubic feet per second, and have the outflow in the St. Clair River go on forever undiminished?

A. No, sir.

Q. What is the net supply, as you understand it, in regard to bodies of water?

Witness: What is meant by that expression?

Mr. Reid: Yes.

A. To my mind it means the quantity of rain fall diminished by the amount of evaporation.

Q. Is that a certain or tangible thing?

A. Yes.

Q. Are the rain fall, evaporation, absorption, run-off in the St. Marys River increased or decreased by the diversions at Chicago?

A. Not at all.

Q. If Lakes Huron and Michigan are lowered in a known amount and Lake Erie in a known amount, what will be the lowering in the Detroit River, Lake St. Clair, and the St. Clair River?

A. I am not prepared to answer that question.

Q. Could you give us the lowering of Lake Erie and Lake Ontario, with a diversion of 10,000 cubic feet per second in Chicago?

A. If you will allow me to refer to memorandum. I do not carry these numbers very well in mind. (No objection being interposed, witness was permitted to refer to the memorandum.) For Lake Erie about 45/100 of a foot; for Lake Ontario, about 35/100.

Q. If a certain quantity of water is diverted in the Drainage Canal, how much will the flow of the Niagara and St. Lawrence Rivers be diminished by that diversion?

A. By that exact amount.

Q. In your experience you have had occasion to reckon upon and take into consideration evaporation in regard to the effect it might have on bodies of water, have you not?

A. Yes, sir.

Q. I will ask you if in your judgment the evaporation should be considered in an attempt to detect the presence or absence of the effect already produced in the lakes by the diversions made at Chicago since 1900?

Mr. Williams: Question objected to on the ground that it is leading.

Mr. Reid (continuing): And can you give us your opinion as to how exact any data of this kind is?

Mr. Williams: The objection stands to the whole question as completed.

A. Why, of course, evaporation is an exceedingly important consideration, but you mean, I suppose, whether I think that the result of direct observation on evaporation, the amount of evaporation, is of use?

Mr. Reid: Whether that is certain or accurate enough to take into consideration.

Witness: No, nobody knows what the volume or amount of water evaporated is.

Q. Have you any information as to how much the error might be in regard to this data?

A. No; it might be very great; it might be 20 per cent., more or less. Nobody knows even approximately what that evaporation would be.

Q. In regard to precipitation and its effect in the same way, that is not well determined, is it?

A. The rain fall observations are made at isolated points over this large area. They can not be made on the areas occu-

pied by the lakes themselves. The average taken over that entire basin may be a fair average or may not.

Q. I want to ask you with regard to the boats. Can you give us the figures as to how many boats plying between Lake Superior and the lower lakes or the lakes below Superior are capable of loading to 19 feet?

A. I can give you these figures with close approximation, and I can tell you how I obtain it. I went over the official list of merchant vessels published by the government for 1906, took out all the vessels that had a depth sufficient to enable them to load to that draft. I then went to the Lake Carriers' Association and obtained from them the list of vessels that had been added during the season of 1906, and which would not appear in that list. That gives me the vessels for 1907, which is what I have here.

Mr. Williams: Before the witness answers further, in view of what he has already said as to his source of information, I object on the ground that it is not the best evidence on the subject matter upon which the witness is being interrogated, as the reports referred to by him and the persons communicating to him the information should be produced.

Witness (continuing): Four hundred and eighty-three.

Q. With regard to 20 feet?

Mr. Williams: Please note the same objection.

A. Four hundred and thirty-six.

Q. Twenty-one feet?

Mr. Williams: Same objection.

A. Three hundred and ninety-four.

Q. Can you give us the figures on how many tons of freight are carried by all boats capable of loading to 19 feet, traversing the routes as I have before indicated?

Mr. Williams: Same objection.

A. The percentage of freight in such vessels is about 70 per cent. of the total freight carried. In 1907 the total freight which passed through Detroit River was 71,226,895 tons, from which it is computed that about 50,000,000 tons were carried in boats drawing 19 feet or more in that year.

Q. What proportion of this freight is carried under conditions of maximum loads as limited by draft in the lower levels of the lakes, of the Sault or St. Marys River, and in the lower lakes and rivers to Chicago or Buffalo, or other lake or river ports?

Mr. Williams: Same objection.

A. 36,000,000 tons.

Q. Can you give us the proportion of what is known as up-bound freight and the other way?

Mr. Williams: Same objection.

A. The freight bound East is about 80 per cent. of the total. Up-bound 20 per cent.

Q. Which is up-bound?

A. The west-bound. The percentages are:

1904, 76 per cent.

1905, 83 per cent.

1906, 80 per cent.

1907, 78 per cent., about 80 per cent.

Q. You gave us some figures in regard to the tons of freight carried by boats capable of loading to 19 feet, I want to ask you the figures regarding boats capable of loading to 20 feet.

Mr. Williams: I make the same objection.

A. About 29,000,000 tons.

Q. Can you give us the way this freight is carried by boats loading to 20 feet, the proportion, through the routes indicated for the 19 foot boats?

Mr. Williams: Same objection.

A. When I say the total freight, I speak of all the freight.

Q. For all the boats?

A. Yes.

Q. When a large freighter is loaded in Lake Superior for Lake Erie ports or Lake Michigan ports, what determines the depth to which she is loaded?

A. The depth of water in the locks and the Sault and channels below. The depth of water on the mitre sill on the Poe lock is 19 feet usually. Nineteen feet is the depth at low water. They keep in telegraphic communication at the Sault and when a boat is loading at the west end of Lake Superior, they will load her down deeper than 19 feet if they find they can do so with safety.

Q. You mean by that the limiting depth?

A. You may say it does not go below 19 feet; it sometimes goes above 19.

Q. You mean that is the limiting depth?

A. That is what fixes the draft to which they can load these ships, the freight carriers.

Q. By mitre sill, do you mean the highest point?

A. The highest point of the lock, yes.

Q. What about the lower level? How do you consider that in saying that the mitre sill is the one that controls?

A. I mean by 19 feet over the mitre sill, the least depth to be found in the lock.

Q. The lock or any body of water changes and fluctuates, does it not, on account of storms and other causes?

A. Yes.

Q. Do you consider that the loss of depth of two, four or six inches affects the navigation any way?

Mr. Williams: I object to the question as leading, incompetent and also on the ground that it calls for a conclusion and not for a fact.

A. I think it does.

Q. Is the loss more serious under these conditions than it would be otherwise?

Mr. Williams: Objected to on the ground that it is leading and calling for comparison.

A. I do not think it is a very important consideration. If it affects it in any way at all, I think it would make it a little more serious.

Q. Do you know the dimensions of the present largest freight carriers of the lakes, traversing the water below Lake Superior?

A. There are three new boats.

Q. How much freight in tons is carried on these vessels on each inch of draft between 19 and 21 feet?

Mr. Williams: Objected to on the ground that it calls for information which witness does not purport to give as from his own personal knowledge.

A. There are three new boats, the William M. Mills, William B. Kerr and the Le Grande De Graff. They are all the same size, and are the largest freight carriers now on the Great Lakes. They are each 607 feet long over all, beam 60 feet; depth 32 feet. Each has a gross tonnage of 7,970 and a carrying capacity of 13,000 tons. About 85 tons is carried in one of these vessels on each inch of draft between 19 and 21 feet.

Q. For a boat of less than 19 feet, would the same proportion hold good?

A. Yes.

Cross-Examination by Mr. Williams.

Q. All the information that you have given with reference to the vessels navigating the Great Lakes, their tonnage, and their dimensions, has been based on information obtained by

you from other sources, partly from official records and partly from records of private concerns, associations, etc.?

A. Yes, sir.

Q. And no part of this evidence that you have given with reference to these matters is based on your own personal knowledge?

A. No, sir.

Q. You spoke of the fact that Lake Michigan was subject to oscillations on the surface of the lake, do you know the extent of these oscillations?

A. Yes, I can give you that by reading a couple of paragraphs in this report by the International Waterways Commission, of which I am a member, or I can refer you to them. Shall I read them?

Mr. Williams: So much as is in answer to my question. I asked to what extent is the surface of Lake Michigan subject to oscillations.

Gen. Ernst: It will oscillate two or three feet in 15 minutes sometimes.

Q. And these oscillations are caused by weather conditions largely and barometric pressure?

A. The oscillation that I just spoke of is the barometric pressure. That is what is called a seiche.

Q. You stated, General, that in case of a diversion of 10,000 cubic feet of water per second from Lake Michigan, the level of the lake would be lowered to the extent of 52/100 of a foot, and I also understood you to say that the withdrawal of any larger or smaller amount would cause a corresponding variation in the level of the lake?

A. Yes.

Q. Is that true precisely or only approximately?

A. I think you may say it is true absolutely. The curve of relation between the discharge and the level is a straight line, plotted as carefully as it can be plotted.

Q. Would you say, for instance, if 100,000 cubic feet of water was diverted from Lake Michigan, the variation in the lake level would be just ten times as great as the variation caused by a diversion of 10,000 cubic feet per second?

A. I think approximately that is true.

Mr. Williams: That is the reason I asked you before whether it is exactly true or approximately true.

Witness: It is approximately true. It is within the limits of our observations.

Q. Does it make any difference what the stage of the water

in Lake Michigan is as to what effect a diversion of 10,000 cubic feet or any definite quantity of water from the lake at Chicago would have on the lake level?

A. Yes.

Q. In your opinion, the effect testified to by you of 52/100 of a foot by the diversion of 10,000 cubic feet is assuming a certain definite stage of the water?

A. The average stage.

Q. Averaged for what periods?

A. The periods covered by the records, what is known as the mean stage of the lake.

Q. And these records include what year last?

A. From 1860 down to date.

Q. Including the year 1908?

A. We will say 1907, or perhaps 1906. They were made a couple of years ago. The mean average stage from 1860 to 1906.

Q. That is 47 years?

A. Yes.

Q. Your estimates are based on what data, General?

A. Upon the reports of the Lake Survey.

Q. Are they the same reports as those used as a basis for the preparation of the plates that have been referred to in the testimony heretofore given by Mr. Noble?

A. I think there has been some revision since those reports that have been used in the preparation of those plates, but I am not positive.

Q. In the making of the estimates and the forming of the conclusions of which you testify, did you obtain any information which was not available and used in the preparation of these plates?

A. No.

Q. Do you know of any other record of discharges and gauging that afford sufficient accuracy to enable you to make any computation that would be reliable, and to which you would want to testify as to the effect of diversions?

A. I rely entirely upon the observations on the lakes in the opinions that I have given, absolutely.

Q. And you consider them the best in existence?

A. Yes, sir.

Q. What percentage of accuracy would you ascribe to the records of precipitation in the area covered by the water shed of the Great Lakes?

A. I do not know. That may be about 20 per cent. I do not know anything about that and nobody else does.

Q. Do you consider the records of discharges which you have used as a basis for your computation as absolutely correct?

A. Well, when you say "absolutely," no. It is impossible to measure water with absolute precision. There are very close approximations.

Q. What percentage of accuracy would you ascribe to those computations?

A. I suppose within 5 per cent.

Q. Assuming that Lake Michigan and Lake Huron were lowered in a definite amount, say one foot, by reason of the diversion occurring at or near Chicago, what effect would such a lowering have upon the depth of the St. Clair River as compared with the lowering in Lakes Michigan and Huron?

A. Approximately, I think, it would lower a foot at its head, and a somewhat less amount at its foot.

Q. Have you memorandum or data or could you make a computation to indicate the difference in the effect at the foot of the St. Clair River as compared with its head, assuming a loss of a foot in the Lakes Michigan and Huron?

A. It has been worked out. I think I could find it for you. I haven't it in my mind just now.

Q. Could you give the percentage?

A. Not now.

Q. How much work would it involve?

A. I could not tell you. I would have to look that up.

Q. Have you an opinion and can you state approximately what percentage of the effect perceptible in Lakes Michigan and Huron due to diversion at or near Chicago would be observable in Lake St. Clair?

A. That is the same question. I am not prepared to give you the exact relations.

Q. Would Lake St. Clair be approximately the same level as the foot of St. Clair River?

A. Yes.

Q. The entire lake?

A. Yes.

Q. And what would you say as to the Detroit River?

A. The head of the Detroit River is the same level of Lake St. Clair.

Q. And the foot of it?

A. There would be a slight depreciation of the effect.

Q. For Lake Erie you gave us figures on the basis of 10,000 cubic feet, now for Lake Michigan would the same proportion apply there?

A. Yes.

Q. What would you say as to the effect observable in Niagara River?

A. There would be a diminution there again.

Q. As you approach Lake Ontario there would be a diminution of the effect observable?

A. Yes.

Q. And Lake Ontario would bear the same relation upon the hypothesis of 10,000 cubic foot diversion?

A. Yes.

Q. And the St. Lawrence River, I take it that at the head of the river the effect would be practically the same as Lake Ontario?

A. In the lowering of the level, yes.

Q. And that effect depreciates down to the Gulf?

A. No, that does not follow. Then comes the difficulty of cross-sections and slopes.

Q. Except as to the narrowing effect of the river in some cases, the general tendency would be to depreciate in effect until it dropped down to the Gulf, if you did not take into consideration those parts of the river that had a great variation of slope?

A. If you can omit those, but you can not do that.

Q. I take it that by the time you have reached the Gulf of St. Lawrence, the effect of the diversion is scarcely perceptible?

A. When you get down into tidal water, I do not know that it is.

Q. In order to make an accurate determination at any given time of the effect of any definite diversion from a lake, say Lake Michigan at Chicago, I mean the effect on the lake level, would it not be necessary at that particular time to take into consideration the evaporation and rain fall?

A. No.

Q. You could not take them into consideration?

A. No; not directly. Of course the whole question is dependent on them absolutely, but their relative value is what we want. We can get that by discharge measures.

Q. Suppose you wanted to know the effect today on the level of Lake Michigan of the diversion of a definite amount of water, not the ultimate effect or general effect, or the aver-

age effect, but what is the effect today on the lake level, would it not be necessary to take into consideration the rain fall and evaporation?

A. No, except as to their relative values. If you should take absolute values of these, you might get results which would be preposterous.

Q. Is it a fact or is it not that the reason you will not take them into consideration in arriving at a conclusion as to the actual effect at a given time, is that the information concerning them is so indefinite and unreliable that you could not with safety testify?

A. That is a reason which is certainly conclusive, but if you ask me whether any man can go out and ascertain the change of level in Lake Michigan today without any observations before or after, I would say he can not do it. Let me explain that subject a little more fully. I would like to read a couple of paragraphs from this report.

Mr. Williams: Would you like to read them in as a part of your testimony?

Witness: Yes.

Mr. Williams: This is not in response to a special question, but is an additional statement by witness in explanation of the difficulty of ascertaining the effect of diversions upon the level of the lake by any brief or limited observations.

General Ernst requests the privilege of reading the two paragraphs Nos. 22 and 23 of the Report of the International Waterways Commission of the Chicago Drainage Canal. Counsel for the respondent signifies his willingness to have the paragraphs read. Counsel for the petitioner requests the witness to abstain from reading the paragraphs, unless counsel for the respondent makes the special request therefore and adopts it as part of his cross-examination.

Q. I will ask you whether or not you have heretofore made any statement bearing upon the subject of this inquiry which you would like to incorporate in this record as an additional explanation of the subject matter about which you have testified?

A. I would like to explain what I mean by the oscillations of the Great Lakes.

Mr. Williams: I will ask you to make that explanation.

Witness, reading from the report of the Chicago Drainage Canal by the International Waterways Commission, paragraphs 22 and 23, as follows:—

"22. Variations in the level of the lakes' surface, due to

winds and to change of barometric pressure, are frequent and irregular and at times violent. Variations of more than six inches are very common, often occurring hourly for many hours in succession, while variations of two or 3 feet within an hour are not uncommon. Besides these irregular variations there is a regular annual variation due to difference in rain fall, evaporation, and run-off, the water level being highest in mid-summer and lowest in mid-winter. The levels are affected also by the greater or less severity of the winter and the consequent greater or less decrease in the discharging capacity of the outlets by ice. In order to study the annual oscillations it is necessary to eliminate the irregular oscillations, and that is accomplished by using the average levels for a month. Using the monthly mean levels it is found that the regular fluctuation in Lake Huron-Michigan usually does not exceed two feet in any one year, but in a long series of years there is a great difference in the height to which high water will rise. The highest high water (monthly mean) recorded for that lake was in June, 1886, and the lowest high water in June, 1896, the difference between the two being over 3½ feet. The first is what navigators of the Great Lakes call a high-water year and the second a low-water year.

23. It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they can not see it they will not know it and will not feel it. The argument is fallacious. It is true that they can not see it immediately, but they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works."

Q. These paragraphs were written by you?

A. Yes.

Q. Is there an expression of opinion there contrary to the opinion expressed by you at a previous time?

A. No.

Q. Were you a member of the Board of Engineers which reported on the proposed waterway from Lockport to St. Louis?

A. Yes.
Q. You were Chairman of that Board, were you not?
A. Yes.
Q. Did not the Board, of which you were Chairman, state in its report that navigators were not likely to find out that a lowering of six inches had occurred in Lakes Michigan and Huron?
A. No; here is what I said, or the Board said. I may say that I wrote both these reports:
"A permanent average lowering of six inches in the lake's level therefore is not easily observable, and will probably not be noticed by navigators. Nevertheless, the effect is real and important." Now a great deal of weight has been put on that language "probably not be noticed by navigators." You may undermine the foundations of a man's house and he will not notice it, and in that sense the navigators do not notice that their foundations are being undermined. There is nothing inconsistent between this statement and that statement, not a bit.

CURTIS McDONALD TOWNSEND, a witness called on behalf of the complainant, having been first duly cautioned and sworn, testified as follows:

Direct Examination by Mr. Reid.

Q. What is your name?
A. Curtis McDonald Townsend.
Q. Where do you live?
A. Detroit, Michigan.
Q. What is your profession?
A. I am army engineer; Lieutenant Colonel of engineers.
Q. How long have you been employed in that capacity?
A. Since 1879.
Q. What has your experience been?
A. Well, I have been very generally employed in the improvement of rivers and harbors of the United States.
Q. State in a general way the geographical locations that you have been in.
A. At the present time?
Q. No, in your experience.
A. Oh, my experience; well, as assistant I had work on the rivers in the vicinity of Baltimore, of Petersburg, Vir-

ginia, and of Charleston, West Virginia. I then was an assistant to the engineer commissioner in the District of Columbia. Afterwards was Quarter Master at Willets Point in charge there of constructing some houses. I afterwards was assistant in charge of the construction of the tunnel for supplying the City of Washington with water. I then was in charge of the third district on the Mississippi River. Then I had charge of the Grand Rapids district, and the rivers and harbors on the east shore of Lake Michigan. Then the Rock Island District, in charge of the upper Mississippi River from St. Paul to St. Louis, or to the mouth of the Missouri. Then was in charge of the harbor of Manila in the Philippines. Then returned to this country and had charge of the rivers and harbors in the Cleveland district; the harbors on Lake Erie from Toledo to Conneaut, and from there was placed in charge of the Detroit district, which has charge of the waters connecting the Great Lakes and certain harbors in Michigan, on Lake Huron and Lake Erie.

Q. How many years have you been on the Great Lakes altogether in this line of work?

A. About five years.

Q. Now state of what your work consisted.

A. The improvement of harbors, which would consist at certain times of dredging those harbors to certain depths; at other places including building breakwaters, which would protect the entrance to certain streams.

Q. Particularize a little more.

A. Well, for instance when improving the harbor at Toledo, there the work consisted simply of dredging a channel in the Maumee River from Toledo to Lake Erie. In improving the harbor of Conneaut, the work there consisted of dredging into the river at that place and also constructing breakwaters that would protect this dredged channel. At Cleveland the work consisted of building a breakwater and of dredging a harbor behind it. The work I am now employed upon consists in deepening the channels which are connecting the Great Lakes and building a lock at the Sault Ste. Marie. That is the principal work.

Q. What do you do in accomplishing this result in regard to measuring and obtaining knowledge of the water, and things of that kind?

A. The first thing that is necessary to do is to make a survey and determine the depth of water that you have in your channel; then to determine the material of which the

bottom is composed. Then you have to make a contract for either excavating the sand or rock.

Q. Now in regard to the level of the water there, does this work which you do necessarily take into consideration the levels?

A. That is the first necessary thing in a survey is to know the level of the water, so that you can determine what your depths are.

Q. In doing this, you not only know the level of the water in the particular places, but in connecting bodies of water?

A. We have to know the levels of water at the point where we are doing our work, and its relation to the levels of the connecting lake.

Q. You actually had those things under consideration when you were doing this work?

A. Yes.

Q. And that is part of the work?

A. We have to arrange our work on a certain datum plane.

Q. I show you Complainant's Exhibit No. 5 of date April 19, 1909, and ask you to mark the limits of the district in which you are now in charge; and when you mark it state where the marks are being placed.
of the district.

A. The head of St. Mary's River marks the northern limit

Q. Mark that No. 1.

A. That is Number 1. The next limit of the division are the Straights of Mackinaw between Lake Michigan and Lake Huron.

Q. Mark that No. 2.

A. Marked No. 2. The district then includes Lake Huron and St. Clair River, Lake St. Clair, the Detroit River and the harbor of Monroe, which is the southern limit of the district.

Q. Mark that No. 3.

A. That is No. 3.

Q. Have you named all the geographical names of the bodies of water within that district?

A. No. There have been improved in this district in the upper St. Mary's River, three localities. Then there have been constructed some locks, the Whitsall and Poe locks at the Sault Ste. Marie. The channel from the Sault Ste. Marie to Mud Lake has been improved and is now under improvement. There have been certain spots between Mud Lake and Detour dredged. Then there has been improved along the shore of Lake Huron the harbor of Cheboygan, Alpena, Saginaw

River; a breakwater at Harbor Beach, Sebewaing. Then the St. Clair River has been improved in sections; the Black River, the Pine River, Bell River. Then Lake St. Clair has been dredged practically across the lake. Clinton River emptying into Lake St. Clair has been improved, and the Detroit River has been improved particularly in the vicinity of the Limekiln Crossing. Then the furtherest southern work of the district is the harbor of Monroe.

Q. Now in regard to Lake Huron, was there work done at the foot of Lake Huron?

A. Yes, a channel has been excavated at the entrance to St. Clair River at the foot of Lake Huron.

Q. You stated in a general way the improvements and the places that have been improved in your district. Now state the fact as to whether or not there is practical navigation going on in your district?

A. Yes, sir, there is a very considerable navigation going on in the district.

Q. Could you give us in a general way of what that navigation consists?

A. Well, during the year 1907, which is the maximum, there was in the vicinity of fifty eight million tons of freight passed through St. Mary's River; and over sixty million tons of freight passed through the Detroit River; also through the St. Clair River.

Q. Have you observed the vessels that carry the freight through your district, as to their method of loading?

A. Yes, I observed the depths to which they have loaded.

Q. State to what depths they load.

A. They load to as great depth as we will allow them to load.

Q. What has that been?

A. Well, the last year it ran from 19 to 20 feet.

Q. What limits the nineteen or twenty feet?

A. The depth that we have on the floor of the Poe Lock is now our limiting depth. And we have a second limiting depth at Bar Point, which is at the end of the Detroit River; is the entrance to Lake Erie. The third limiting depth would be at Ballard's Reef, a crossing which is just a little further up in the Detroit River.

Mr. Williams: Q. Where is that Ballard's Reef?

A. That is several miles up the Detroit River, from the mouth.

Q. Bar Harbor is at the mouth?

A. Bar Point is at the mouth. That is in Lake Erie.

Mr. Randolph: Q. Is Bar Point the second limiting point?

A. Bar Point is the second limiting depth. Of course I will say the second limiting, it will be the same as the first limiting point.

Mr. Reid: Q. What information do you give the lake carriers?

A. There is published at the Sault Ste. Marie the depth that we allow in the Poe Lock; that is published, given to the public.

Q. Assuming that 10,000 cubic feet of water is drawn from Lake Michigan at Chicago, and the drawing of that 10,000 cubic feet per second lowered the lake, the level, say five inches. Would that have any effect on the level in your district?

Mr. Williams: Just a moment, before that question is answered: I want the record to show that I object to the question, first on the ground that it is not intelligible and second on the ground that the witness has not shown himself to be qualified to testify on the point of the effect of diversions at different points?

A. Yes, it would.

Q. Will you give us to what amount?

Mr. Williams: I object to the question on the ground that it is not intelligible; and second, on the ground that the witness has not shown himself to be qualified to testify on the point of the effect of diversions at different points.

A. I could not tell the exact amount except by hearsay.

Q. Assuming that there would be a loss in the level of five inches in your district, state what effect it would have in your district at the particular points.

Mr. Williams: Objected to first on the ground it assumes a condition not shown; and in the second place that it is incompetent, irrelevant and immaterial, because this suit has nothing to do with the diversion of 10,000 cubic feet of water per second.

Mr. Reid: Q. Assume that 4,000 instead of 10,000 cubic feet, as in the other question, would lower the level of Lake Michigan two and a half inches, would that affect the level of the water in your district?

A. It would.

Mr. Williams: I object to the question on the ground it is improper; on the ground it contains an assumption; on the ground it has no meaning whatever.

Mr. Reid: Q. Assuming that the water in your district were lowered two and a half inches, would it affect the practical navigation therein?

Mr. Williams: I object to that question on the ground the witness has not shown himself to be qualified to testify upon questions of navigation.

A. It would.

Q. What effect would the loss of two and a half inches of water in your district have on the different places in your district?

A. It would have a lowering effect; while not necessarily of two and a half inches at these localities, it still would have an appreciable lowering effect at each of the localities that I have alluded to.

Q. Where would the loss of two and a half inches make any difference in your district?

A. It would make a difference in the district to all harbors on Lake Huron; not exactly to two and a half inches.

Q. What do you consider the critical points in your district for navigation?

A. The critical points for large vessels are Poe Lock and the foot of Detroit River.

Q. What effect would the loss of two and a half inches of water in the level have on these particular places?

Mr. Williams: I object to that question on the ground that it assumes the lowering of a definite amount at these particular points, and there is no testimony yet in the record—the witness testifies he can only testify as to hearsay as to the effect of a lowering of two and a half inches at Chicago on these different points; therefore I object to the question as an assumption.

A. That would require a mathematical computation to determine, as the level of Lake Erie does not fall exactly in co-ordinance with the level of Lake Huron, nor does the level below the lock at the Sault exactly co-incide with the level of Lake Huron.

Mr. Reid: Q. What effect would it have on the amount of water that would be in these particular places that you name, considering the vessels that go through them, having in mind the fact that you people give to the carriers on the lakes the depths to which they can load?

Question objected to by counsel for the defendant, on the ground it is incompetent, irrelevant, immaterial, and calls for a conclusion and not a fact; and on the ground

that it is based upon an assumption that has not been shown to exist.

A. Well, it would lower those depths.

Q. At these critical points state the fact in regard to the vessels, if it is a fact, loading right down to the very limit that you people allow them.

A. These vessels load to the limit and sometimes even beyond the limit. I have to give instructions to allow no vessel to enter the Poe Lock that draws more than the orders admit for that date.

Q. Now, if you had an inch or two inches or two inches and a half less water in those particular places, they would have to load that much lighter would they not?

A. They would load just that much lighter. If they had two inches less, that would be the—

Q. Would one inch make any difference whatever?

A. Every inch, then, they would make use of.

Q. Do you know the number of tons those big vessels load to the inch beyond a certain amount?

A. They load from 75 tons to 100 tons to the inch; that is when they are loaded; that is when you are between 18 and 19 feet, or 19 and 20.

Q. The lowering of an inch at Bar Point would have the same results?

A. The lowering at Bar Point would have practically the same results. They utilize that to the utmost limits.

Mr. Reid: That is all.

Witness: Let me state in reference to that that one time it will be the Poe Lock and another time Bar Point where we have conditions—Bar Point is lower than Poe Lock, and other conditions when Poe Lock is lower than Bar Point; but the limiting depth that we have, they will utilize to that extent.

Cross-Examination by Mr. Williams.

Q. Colonel, you speak of a vessel being loaded between 19 and 20 feet to the extent of about from 75 to 100 tons to the inch?

A. Seventy-five to 100 tons to the inch would be about what it was.

Q. Assume that a vessel is loaded to a depth of five feet, and then loaded an additional inch, would that be a different

amount that would be required to lower it an inch, after it had been loaded to 19 feet?

A. Yes, there the effect of the bottom would enter in more.

Q. Sir?

A. Yes, sir, I should say the effect would be—there is a slight curvature at the bottom. These boats are pretty nearly rectangles so that when you get down a little ways they lower about the same; but there is a slight curve to the bottom, and I think in the earlier loading, I should say that there would be a tendency to be a little less amount for—

Q. For each inch?

A. For each inch.

Q. Does that amount of loading necessary to lower the boat one inch increase proportionately all the way down from say 6 feet to 20 feet?

A. No, after you get the boat started, it is pretty nearly a rectangular section, but in the earlier starting of loading, I would not be able to say; in the first place your boat is tilted instead of being a rectangle she is a triangle; I should not know just what would take place, but after she gets well loaded then she is pretty nearly rectangular.

Q. Will you give me the name of any vessel that loads 100 tons to the inch?

A. Well, I should take one of these 605 footers, that would come very close to it. They would be the maximum.

Q. Do you know the name of any of those boats that you refer to?

A. No, I cannot at the present time recall the names of the—

Q. How many of those 605 foot boats are there navigating the Great Lakes in your district now?

A. At the present time there are none; but there are five or six.

Q. What is the depth of the water at the Poe Lock?

A. Poe Lock, the last I heard it was 18 feet 5 inches was the depth allowed in the Poe Lock.

Q. And that was the limit of depth at that time?

A. At this particular time.

Q. What is the average depth at Bar Point?

A. Well, that depends on the stage of Lake Erie, and at the average stage of Lake Erie it would be about a little over 20 feet.

Q. Now what is the average depth, taking the mean level

of the water in Lake Huron and Lake Erie, of Ballard's Reef?

A. Ballard's Reef, that is a little over—about 21 feet at mean levels.

Q. Now you state that there are improvements now in progress on the Detroit River?

A. Yes, sir.

Q. And at Bar Point?

A. There is not in progress at Bar Point, but we contemplate improving Bar Point.

Q. Plans are made for improving Bar Point?

A. For improving Bar Point.

Q. When those plans have been executed and the work contemplated is completed, will the depth of water at Bar Point be increased?

A. We intend to have that 21 feet at extreme low water.

Q. Twenty-one feet at extreme low water. What work is now being done at the Poe Lock?

A. Poe Lock, we are at the present time enlarging the channel entrance to the lock and we are proposing to build a second lock, to increase the depth there.

Q. To what extent will the depth there be increased?

A. To 24½ feet.

Q. When will that improvement be completed?

A. We expect in about five years.

Q. In five years?

A. About five years, hope to complete it.

Q. When do you contemplate, would you say, that the work on the Detroit River at Bar Point will be completed?

A. We will improve the Bar Point reach within the next year.

Q. What effect will the improvement of the Detroit River have upon the level of the Detroit River?

A. I do not know.

Q. What is the natural result of the improvement, does it increase or decrease the slope in the river?

A. It should theoretically increase the slope—decrease the slope.

Q. Decrease the slope?

A. No, let me see a minute: No, it increases the slope over the section of the river not improved.

Q. Over the section not improved?

A. Not improved; decreases it over the section improved.

Q. Will this deepening, in your opinion, provide for an

outlet of a greater amount of water than now flows through the Detroit River?

A. Yes, I think it will provide for a slight increase.

Q. And the supply of water which flows through the Detroit River comes primarily from Lakes Huron and Michigan does it not?

A. Comes from Lakes Huron and Michigan.

Q. And the effect of that improvement will be of itself theoretically at least, to lower the level of Lake Huron?

A. Theoretically, yes.

Q. What do you say practically?

A. Practically I say I don't know, as I am at the present time engaged in trying to determine just that very question.

Q. You can conceive of a situation then where theoretically the withdrawal of water and increase of flow through a channel leading from Lake Huron ought to lower the level, but actually would not?

A. No, I didn't say that. I say that theoretically I think it does but it may not be a practical question of sufficient—

Q. You would want further investigation before you would say actually it did?

A. Actually it did; that is it was of any practical amount.

Q. And the level of Lake Huron is substantially the same as the level of Lake Michigan?

A. Yes.

Q. In other words what affects the level of the water in Lake Huron, to the same degree affects the level of the water in Lake Michigan?

A. Yes.

Q. In making your reports to the commercial interests that navigate the Great Lakes, you report the navigable depths at the critical points?

A. I report particularly the navigable depths at the Sault.

Q. At the Poe Lock?

A. At the Poe Lock.

Q. And that is considered really the critical point?

A. That is at the present time the critical point.

Q. How nearly do you report, and how closely do you report that navigable depth, in inches or fractions?

A. What I report is the safe—what is considered the safe limit of loading for the boat so that she will not get aground in the lock.

Q. Do you report that in inches or in feet?

A. I don't remember whether it is reported in feet and inches, or feet and tenths.

Q. But either in feet and inches or feet and tenths?

A. Either in feet and inches or feet and tenths.

Q. How closely to the actual navigable depth do you report it safe for a vessel to load?

A. I don't know what the exact relation is there.

Q. You prepare the reports yourself?

A. I do not; I instruct my assistant at the Sault to submit these daily reports of what he considers safe for a vessel.

Q. Then the reports you have mentioned that are given to the owners of the vessels are not made or submitted by you?

A. They are submitted at the Sault.

Q. They are not submitted as the result of any specific direction of your own?

A. Except that I specifically direct them to report the safe depths.

Q. But you don't know the proportion of the depth to the safety of loading?

A. No, I do not.

Q. How do you arrive at the displacement per inch of depth in deep vessels?

A. By the area, cross section of your vessel, multiplied by the cubic feet, multiplied by a cubic foot of water.

Q. Multiplied by what?

A. By the weight of a cubic foot of water.

Q. What is the width of these 605 foot vessels?

A. A little over 60 feet.

Q. About 60 isn't it?

A. It is a little over 60.

Q. It is an easy matter to compute in a vessel 605 feet long and 60 feet wide what the displacement is?

A. I think probably 61 feet wide would be nearer the larger ones.

Q. Very well. I suppose you can do it in just a minute, figure the displacement per inch?

Mr. Reid: I object to this; this is no time for calculation, and things of this kind. The Colonel does not have to do it if he does not want to; encumber the record here with a lot of calculations.

The Witness: I should make that about 94 tons.

Mr. Williams: You figure it as a perfect rectangle.

A. I just took it as a perfect rectangle.

Q. Isn't it customary in making those figures to take 90 per cent., by reason of the slopes at the bottom?

A. It may be. I say, my expression is 75 to 100 tons.

Q. You take the net tons of 2,000 pounds instead of the gross tons, 2,240?

A. Yes.

Mr. Wilkerson: Q. How much would it be allowing 2,240 to the ton?

A. Seventy-five tons. I made the statement 75 to 100 tons.

Mr. Wilkerson: Seventy-five is good for our purpose.

Mr. Williams: Q. Are these improvements that you have testified to as being now in progress going on constantly under the direction of the government?

A. They are at the present time.

Mr. Wilkerson: And with the permission of the Secretary of War, I assume.

Mr. Williams: It is a part of the general policy of the government to adjust the condition of the harbors at the critical points to the needs of navigation along the Great Lakes, and this is in pursuance of that general policy?

A. The general policy has been to increase the depths, according to the demands of navigation.

Q. You were asked with reference to a lowering of the lake level at Chicago to the extent of two and a half inches. You do not, of your own knowledge, pretend to give an opinion as to what effect that would have upon these critical points?

A. I do not.

Q. And your answers are all based upon the presumption of two and a half inches at those points?

A. No, they are based on that there will be a reduction at those points, but the amount of that reduction, whether it will be two and a half inches or not, I do not pretend to say.

Q. The improvement of any of the connecting channels lying below Lake Huron will have a tendency, at least theoretically, to lower the levels in the lakes lying to the north?

A. Yes, I think theoretically it would.

Q. The level of Lake Superior would not be influenced by any improvement made below the locks?

A. Not by any improvement made below the falls.

Q. St. Mary's falls. These improvements of the connecting waters lying below Lake Huron have been going on a number of years?

A. Yes, sir.

Q. Have you made any observations or have you familiarized yourself with the result of those improvements?

A. Yes.

Q. Have those improvements tended to lower the level of Lakes Huron and Michigan?

A. I can't find any evidence that they have.

Q. In your opinion as an engineer would you say, without looking into the concrete evidence, whether the tendency would be in that direction?

A. Well, the tendency would be in that direction, but in a very small amount, so small an amount that it is going to be very difficult to determine it. The enlargement of the section is about 5,000 square feet through Lime Kiln Crossing.

Q. And what will be the increasing flow through an enlarged section of that extent?

A. Well, the increased flow immediately in that section will probably be in the vicinity of 14,000 cubic feet, in that particular section; that is if it was just merely that section alone that was being considered.

Q. By the improvement that you have referred to, what would be the increased flow through the St. Clair River?

A. Well, that is just what is very difficult to determine. It will have very much less effect on the St. Clair River than it would on the Detroit River; and it is going to have a comparatively small effect on the Detroit River, because this section is a very short section in a long length of river, and the small change in slope at this one point has got to be spread over the entire river; to make a very serious change.

Re-direct Examination by Mr. Reid.

Q. These measurements at the Poe Lock are made in your department, under your direction are they not?

A. There are no measurments at the Poe—what do you mean, of the depth at the Poe Lock?

Q. Yes.

A. Yes, they are made by my assistants at the Lock.

Mr. Reid: I think that is all.

Mr. Wilkerson: Q. I want to ask you a further question about this Livingston cut: Do I understand that it is proposed to compensate the increased cut at one place, by filling in at another? What is the fact about that?

A. I don't remember having testified anything about the Livingston cut.

Mr. Williams: We have not heard about the Livingston cut before.

Mr. Wilkerson: We understood you were referring to the Livingston cut.

Mr. Reid: What section was that you were referring to?

A. I was referring to the existing section that has been increased; the existing Lime Kiln Crossing extending about 5,000 square feet, but I can find no evidence of its having lowered either Lake St. Clair or Lake Michigan.

Mr. Wilkerson: Q. Has there been any filling in there?

A. We recently built a coffer dam that has filled in very much more than we have excavated.

Q. So that in a sense it would compensate what is taken out in the other way?

A. That will more than compensate for all we have taken out.

Q. In the course of cross-examination, in response to some questions as to the effect of these improvements upon the level of the lakes, you said that theoretically it would have some effect. By that do you mean that if you go ahead and do what you propose to do and the loss would remain constant, that will be the result?

Mr. Williams: I object to the question as a statement by counsel of what the witness means; and I prefer to have the witness state what he means.

Mr. Wilkerson: Q. That is what you mean?

A. I said theoretically it might lower, but that practically I had not seen any effect of its lowering.

Q. Well, what do you mean by theoretically?

A. Well, there are certain results of theory that are obscured by the general things we see in nature. You can say theoretically a thing will be done, and you will find practically that the differences are so slight that they are obscured, and that practically you do not see any effect from it, that is what I mean.

Q. What is it that limits the size of vessels that can be used on the lakes?

A. The draft.

Q. And what is there in connection with either these channels about which you have been testifying, or with reference to harbors about which you have been testifying, which make

it impossible, if that is the fact, to use on Lake Michigan and Lake Huron an Ocean steamer?

Mr. Williams: I object to the question on the ground it is immaterial, and on the ground that it assumes a condition.

Mr. Wilkerson: I do not make myself clear. I want to find out what relation the depth of these channels and the harbors has to the size of the vessels that can be used?

A. Why, they are simply building vessels just as large as we have channels for them.

Q. And are these vessels much larger or much smaller than the vessels which are used, for instance, on the ocean?

A. They are very much smaller. A great many vessels on the ocean are very much larger. A great many other vessels on the ocean are smaller.

Q. I mean as compared with the largest vessels that are used?

A. The largest vessels on the ocean are very much larger than the largest vessels on the lake.

Q. What would be necessary to do to use large ocean vessels on Lake Huron?

A. If you were going to build as deep steamers on the lakes as you have on the ocean, we would have to have channels 35 feet deep.

Q. You would have to deepen these channels and deepen the harbors?

A. Deepen the harbors.

Q. To follow that up, along the line of cross-examination, what practical relation does the size of vessels it is possible to use on the lakes bear to the lowering of these channels and these harbors, even by so small an amount as an inch?

A. If you lower your channel an inch—

Mr. Williams: I want to interpose an objection to the question as calling for a conclusion instead of for facts, on which the court can form its own conclusions.

Mr. Wilkerson: Answer the question.

A. If you lower your channel one inch, you diminish by just that amount the draft which you can utilize in your channel.

Q. And would you say that that same observation would apply to harbors?

A. It would apply to any channel.

Re-cross Examination by Mr. Williams.

Q. That would not hold true however, where the depth of the channel was considerably greater than the draft of the vessel?

A. No, sir. That would only apply to the limiting points of the channel.

Q. The lowering of Lakes Huron and Michigan, you have already testified, would not have any effect upon the amount of water, the depth of the water in the Poe Lock?

A. No, I have not made any such statement as that; I never intended to. The lowering of the water of Lake Michigan will have a very decided effect on the Poe Lock.

Q. What will be the effect on the Poe Lock in the amount of water—

A. It will be in proportion to the lowering of Lake Michigan, but as to the exact amount I could not tell you without a mathematical computation.

Q. Would it be as much as in Lake Michigan?

A. Not quite as much, but it will bear relation to Lake Michigan. That would be a mathematical computation that I have not made.

Q. You have testified that at the Lime Kiln Crossing, when the improvement was being made there, there was a coffer dam built?

A. No, not in the Lime Kiln Crossing, but there is a coffer dam being built on the work we are now constructing.

Q. Did you testify that when the cross section was increased 5,000 square feet that the filling was deposited against it?

A. No—well, that filling was deposited in a sort of a way to compensate in the channel which we are now improving, under the name of the Livingston channel.

Q. And that filling is in the shallow water?

A. That was placed in the shallow water.

Q. Would that have as great an effect on the amount of water flowing through the channel as though it were deposited in the channel proper?

A. No, it would be not as much.

Q. Would you say, Colonel, that the average of the size of vessels navigating the Great Lakes was less than the average size of the vessels navigating the ocean?

A. No, it is very much larger, the average; but the great

vessel that navigates the ocean is very much larger than the greatest vessel that navigates the Great Lakes.

Mr. Wilkerson: That is for the reason you stated.

Witness: The average vessel is a very different thing from the largest vessel.

April 19, 1909; 2:00 p. m.

Court convened pursuant to recess.

Present: As before.

EBEN S. WHEELER, a witness called on behalf of the complainant, was first duly cautioned and sworn, and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name, please?
A. Eben S. Wheeler.
Q. Where do you live?
A. In Detroit, Michigan.
Q. What is your present occupation or profession?
A. Civil engineer; United States Assistant Civil Engineer.
Q. In what line of service?
A. I am in the river and harbor improvement office.
Q. At Detroit?
A. At Detroit.
Q. How long have you been connected with that office?
A. That particular office about ten years.
Q. I want to bring out, Mr. Wheeler, your experience as an engineer. Where were you educated?
A. At the University of Michigan. I received the degree of Civil Engineer in '67, and an honorary degree in '97.
Q. Commencing at the time you received your degree of civil engineer, in a general way, and yet being specific as to particular large pieces of work with which you have been connected, I will ask you to state your experience.
A. Well, I was employed by the United States Government on the United States Lake Survey for a number of years, during which time I was engaged in many of the surveys.
Q. What were some of the more important ones?
A. The triangulation of the Great Lakes. I planned most of that and measured its base lines and determined its standards of measurement, and I was also connected with the sur-

veys of various harbors and parts of the shores of Lake Superior. I assisted in some of the earlier stream measurements in the Detroit and St. Clair Rivers, and in the reduction of the same. After I was transferred from the lake survey to the river and harbor office I first went to the Sault, and had charge of the works at Sault Ste. Marie and the superintending of the building of the whole lock under General Poe, I was in local charge. Later I was chief engineer of the Nicaraguan Canal Commission of 1898-9, and since then have been engaged in various works in the river and harbor improvement. While at the Sault I had charge of the stream measurements of the St. Marys River.

Q. In addition to what you have stated is there anything that you can add with reference to your connection with hydraulic measurements of the Great Lakes, tending to give you experience in matters of that kind?

A. I do not know that there is anything further.

Q. You have stated the principal facts—

A. Yes.

Q. —upon which your experience is based. Well, can you state a little more definitely with reference to studies which you may have made of water measurements and determining lake levels, computations with which you have had to do?

A. I discussed the river system of Nicaragua and published the results in the report of the Commission. I have discussed the physics of the Great Lakes, which has appeared from time to time in the chief engineer's reports. I made rather an extensive report of that kind in the report of 1893, and I have made some study in regard to the relative elevations of the different lakes.

Q. You say you made a study of the physics of the Great Lakes; a little more concretely, just what do you mean by that?

A. That includes a study of climatic effects on the lakes, and the relation of the lakes to each other, the characteristics of the drainage basins of the various lakes and it involves a study and analysis of any of the peculiar fluctuations which take place in the levels of the lakes in regard to each other, involves something of the study of the winds and precipitation, humidity, evaporation and allied studies.

Q. You used the term, relation of the lakes to each other. Just what particular relations had you in mind in using that term?

A. One of the most important is the elevation of their surfaces.

Q. And just how much of a study did you make of that, over how long a period of time did your observations extend, and how completely did you discuss that study with the different boards with which you conferred?

A. I occupied several month, perhaps more than half a year, in that special subject. I cannot say that it is very completely discussed yet.

Q. With respect now to the navigation of the Great Lakes, during how long a period have you been making a study of the subject, and having connection with that?

A. Why, since about 1882, when I went to Sault Ste. Marie that became necessary in the building of the lock, and I have a knowledge of the navigation of the lakes, its needs and necessities.

Q. And since the time you commenced that line of work, how continuous has been your observation and study of matters connected with that subject as carried on?

A. I cannot say that it is complete, but I have had the subject generally in mind and have treated it in a general way, hardly exhausted it yet, though—it is a pretty large subject.

Q. Well, compared with others in your line of work who have been studying this subject, what do you say as to the amount of time you have spent, speaking in a comparative way?

A. Well, I should say I have spent more time than most people have on the subject. I do not know that I have got better results, though.

Q. Now, you referred, in enumerating the subjects of which you had made a study, to the term "relative elevation of the lakes" and the "relative elevations of the lake," for the benefit of those of us whom may not be so familiar with the phraseology of this subject, will you define a little more exactly what you mean by that term?

A. Beginning with Lake Superior we find it in general is about 20 feet higher than Lakes Huron and Michigan, but this is not a constant, this varies. The same is true between Lake Huron and Lake Erie. In general that is about eight and one-half feet, the difference between the two lakes. There have been times when it has been more than 10 and sometimes when it has been less than six. We come to Lake Erie and Ontario, and the same variation in elevation is discovered there, and the

causes which lead to these changes in elevation are complex and require some analysis and study to determine them. Perhaps they are not all well determined yet.

Q. What do you mean by the word "elevation" as used in speaking of the lake, the elevation of the lake?

A. Its elevation above sea level, which has been carefully determined at the several lakes.

Q. That means the surface of the lake is so many feet—

A. Above the surface of the sea.

Q. Above the surface of the sea?

A. There would be two planes, that is imaginary plane, the plane of the lake as extended over the ocean, and the two places would be separated by a certain distance.

Q. And that distance you speak of as the elevation of the lake?

A. That is the elevation of the lakes.

Q. Speaking of the elevation of the lake, what is the relation between Lake Michigan and Lake Huron?

A. They are the same. As far as elevation is concerned, they are one, the two make one body of water, one lake. The separation is only for geographical convenience, the separation in name. This would also include Georgian Bay, and those regions on the North of Lake Huron.

Q. In the light of your observations and study, Mr. Wheeler, what do you say would be the effect of the diversion of a given quantity of water, as for example, 4,000 cubic feet per second at Chicago, upon Lake Michigan, upon the elevation of Lake Michigan?

A. One of the results of such a diversion would be ultimately to diminish the flow in the St. Clair River an equal amount. A second result would be to lower the level of Lakes Huron and Michigan, and also of Erie and Ontario, and the connecting rivers.

Q. With reference to the effect of the diversion of this quantity of water, with reference to the determination of the amount of this lowering, have you had occasion recently to make any special inquiry into the subject, any special study of the subject?

A. I have made an examination of some of the points bearing on this question.

Q. With a view to testifying in this case as to the effect of that diversion?

A. Yes, with the purpose of giving more accurate answers than I could from memory.

Q. Supposing that something is done, as for example a diversion of this water at Chicago, the effect of which is to reduce the elevation of the lake at a given point off the shore, say, ten miles, what do you say as to the lowering at that particular point, in its relation to the lowering which would take place at other points in Lake Michigan and Lake Huron and in the harbors and channels?

A. It would lower both lakes an equal amount, both at the upper and lower extremities eventually, of both lakes.

Q. Just what do you mean by the word "lowering" as you used it in this connection?

A. Perhaps I had better refer to my notes.

Q. You may do that.

Mr. Williams: Let the record show that the witness is referring to his notes.

Mr. Wilkerson: I will ask the witness to refer to the notes to refresh his recollection, and to enable him to make a more definite answer.

A. I have said in my notes that lowering means that a definite amount of diversion at Chicago will make the surfaces of Lakes Huron and Michigan a definite amount lower at all times and places than it would have been if the diversion had not taken place. Perhaps I have given too long an answer, the actual elevation of the surfaces of the lakes at any time is the algebraic sum of all the causes which tend to change the elevations. Some of the most important of these causes are rain fall, outflow, evaporation, et cetera. If two causes, producing opposite effects, are operating at the same time then the actual effect produced will be of the same kind as the larger one, and the amount will be the difference between the two causes. For example, a merchant deposits a thousand dollars each week, and checks out fifty dollars each day, his balance is lowered by the amount he takes out, and raised by the amount he deposits, and in this case the deposits are larger than the withdrawals, therefore his balance will be raised by the difference between the two. At the end of the week it will be raised $650, notwithstanding it was lowered $350 by his withdrawals. Similarly, if for the period, we will say, from 1900 to 1908, the rain fall was greater than the outflow, and evaporation, the lake would rise. This appears to have been the case, notwithstanding the outflow for the period was increased by the diversion at Chicago. A cause which tends to lower the lake itself actually does make the lake lower than it

would have been without the cause. I do not know but my answers are a little too long.

Q. That is the sense in which you speak of the lowering of the lake level, you use the word "lower"—

A. Yes.

Q. You mean that it is lower than it would have been if that particular cause had not been present?

A. Yes, I should emphasize that, *it is lower than it would have been without the cause.*

Q. But as you have stated there through the operation of other causes the ultimate effect may be that the elevation is actually higher?

A. Yes.

Q. But through the operation of one cause the real effect of that particular cause has been to lower the level?

A. Yes.

Q. That is to say, to repeat, when you speak of "lower," you do not mean with respect to a fixed mark, but you mean with respect to the level the lake would have been in the absence of the cause?

A. Yes.

Q. Now, directing your attention again to the outflow in the St. Clair River, what is the effect of this diversion, the proposed diversion at Chicago, upon the quantity of water which would flow out through the St. Clair River?

A. It will diminish the flow ultimately in the St. Clair River an equal amount.

Q. If I may put the question in this leading way: by that you mean that ultimately there will be, if there are 4,000 cubic feet per second diverted at Chicago, that number of cubic feet per second less flowing through the St. Clair River than there would have been if the diversion had not taken place at Chicago—am I correct in that?

A. That is correct.

Q. Do you use the term "net supply" in connection with the quantity of water in the lakes?

A. Yes.

Q. What do you mean by that?

A. I am almost afraid to say, because I shall differ with Mr. Noble, and the man who differs with him is usually wrong. I have said here, net supply is all the water that flows into the lake from streams, springs, seepage, et cetera, plus all rain and snow which falls on the surface of the lake, and

minus evaporation from the lake surface and it is a concrete quantity.

Q. You say it is a concrete quantity?

A. It is a concrete quantity.

Q. Will you explain a little more fully what you mean by that?

A. Why, I don't hardly know; the lexicon would do it a great deal better.

Q. I mean by way of illustration or example.

A. Well, it is a quantity that can be measured, it is a real, an actual quantity, with suitable observation we could measure all these effects and get the net supply, and then we would know that that supply had actually been received by the lakes.

Q. What do you mean by suitable observations?

A. It would be necessary to measure the rain fall, all kinds of precipitation and evaporation, measure all of these quantities which I have mentioned here, accurately, and we would eventually get the net supply, if our observations were correct, if they were properly made.

Q. Do you happen to have any knowledge on the subject of the observations which may have been made along those lines?

A. Why, concerning precipitation continuous observations have been made by the weather bureau for about, less than thirty years. They have measured also various other quantities such as the wind, temperature, humidity and rain fall. From these observations the total amount of precipitation has been determined approximately, of course, the determination is no better than the observation, and the amount of discharge from the lake has been measured at the same time, and the difference between these two has been assumed to be the evaporation. It has been determined in that way and to that extent. That would be the total evaporation for a basin.

Q. Now, referring to items of rain fall, evaporation, absorption, the run-off in the drainage basin of the lakes, and the inflow from the St. Marys River, would the diversion of this quantity of water at Chicago have any effect upon any one of those items?

A. None at all.

Q. In other words, if I gather the result of what you have said, this diversion of water at Chicago is a fixed factor, which will tend, to the extent to which it is operated, to modify whatever condition with reference to elevation that the lake would be in, if that factor had not been produced?

A. Yes. In my answer to the previous question I said that it had no effect whatever on evaporation, precipitation and run-off. I should qualify that by stating that it has an effect on the run-off, not on its total amount, but on its locality; it changes a portion of the run-off from the St. Mary's River to Chicago. It does not change the amount; simply a change in locality. The other items are not affected at all by it, and the run-off is not affected in amount by it either.

Q. I understood you to say that would be eventually the effect that the amount of run-off through the St. Clair River would be decreased by the amount which was diverted at Chicago?

A. Yes.

Q. When you said "St. Marys River" you meant St. Clair?

A. I meant the St. Clair River; it would be ultimately decreased by that amount.

Q. Now, if the net supply were to remain absolutely the same then what would be the effect with reference to the actual elevation of the lake, as a result of this diversion at Chicago?

A. The actual elevation would begin to diminish the moment the diversion at Chicago began, and the elevation of the lake would slowly be lowered, but on account of the large area it takes some time to accomplish the thing, and it takes an infinite time to completely accomplish it.

Q. Well, how long, to substantially accomplish it?

A. In about four years a little more than 90 per cent., a little more than nine-tenths would occur.

Q. How long before half of the effect?

A. A year and a half or something like that, less than two years.

Q. How long would it be before you could say there would be an appreciable lowering?

A. Well, I haven't worked that out; I would have to express that approximately.

Q. Well, approximately?

A. If in four years it reduces the elevation four inches, that would be an average rate of an inch per year. For the first year that would be considerably more than the average rate, so I should expect there would be an inch and a half the first year—something like that—so in the first six months there would probably be three-quarters of an inch.

Q. That is, expressed by one of these formulas of a curve always approaching its limit, and never quite gets there, is that it?

A. Yes, the curve would be an asymptote to it.

Q. I am showing you, Mr. Wheeler, a chart or plat in which certain observations have been platted, of lake heights, platted as ordinates and the discharge as abscissa—that is to say, the lake heights have been so platted that they are represented by vertical lines, and the volume of discharge so they are represented by the horizontal lines, and that chart has been marked Complainant's Exhibit 1, under date, February 15, 1909. On that plat there has been a certain line drawn, expressive of the relation between the lake height and the volume of discharge, the result of which has been the determination of the loss of outflow in the St. Clair River, by reason of the diversion of water at some other point along the lakes. Have you had a copy of that plat presented to you for your consideration? (Handing plat to witness.)

A. Yes, I have had a blue print of this drawing.

Q. Now, Mr. Wheeler, this is a law suit, and one of the questions that is here for determination is, what will be the effect upon the lake elevations of Lakes Huron and Michigan as a result of this diversion of water and the corresponding loss of outflow in the St. Clair River, to which you have testified. Here are the observations and here is a line which has been drawn so as to present a basis for that computation. I wish you would take that up and, as an expert, explain first what you have to say with reference to the drawing of that line and next, what that line shows on the plat with reference to the lowering of the lake level, why you show that, take it up and explain it in your own way.

A. Well, I have examined the data and I find it to correspond with the published data from the Lake Survey Office. I have made a special study of the position of this line which is really the mean line.

Q. If I may interrupt you there just a moment, so that we may get it in the record here, are you able now to give us the references to these reports to which you have just referred, which show that those observations, as platted, are correct?

A. I think I can, I think they are before you on that paper, which you have.

Q. The one that I have?

A. Yes, the first pages.

Q. Now, let me hand this to you, and in your testimony, Mr. Wheeler, where you refer to reports, official records of any kind, it will be helpful if you will indicate so we will have

them here in the record, just to what books you have made reference, so we may be able to find the references easily.

A. I will, wherever I recollect it, and can make the reference.

Q. Yes. We will be obliged to you if you will.

A. I don't remember—shall I read this to you, or just submit—

Q. No, just read them so the Commissioner will get them in the record.

A. Well, concerning the water level tables I find those in the full reports of the Chief of Engineers for 1900, on page 5362, and for 1902, on page 2819, for 1903, page 2837. 1903 again, page 2855—1904, page 4069.

Q. You have given all the references that relate to the data on the plat which you have before you?

A. Yes.

Q. Now, go ahead with your answer with reference to that plat.

A. I have made special computation of this mean line, and I find the position of it practically the same as given here, in some of the sheets almost exactly the same. Let's see, this is the St. Clair River.

Q. Well, referring to your own computation and refreshing your recollection with reference to the plat, what have you to say as to the substantial accuracy of the line that is there drawn?

A. It is almost exactly as I find it, the differences on the plat are hardly perceptible to the eye. I will submit them here. I have drawn in red on this blue print the position of the mean line as I determined it.

Q. Did you make any attempt to determine the degree of precision of the computation?

A. Why, yes, I determined the probable error, I think I have it in my notes, that is one of the things that one don't remember. The diagonal lines on these plates show the exact mean of the observations. This is exact, it is not an estimate, it is susceptible of computation. The agreement of the observations among themselves show the probable error of the increment which really means the position of the line, as determined for the several rivers, as follows: For this one, the St. Clair, it is 227 seconds feet.

Mr. Williams: That means cubic feet per second?

A. Yes, cubic feet per second. It is the probable error of this determination of the increment.

Mr. Wilkerson: How nearly accurate would that be when expressed in simpler and easier words, if you can express it, would you call that a very high degree of precision?

A. Yes, I do.

Q. About what percentage would it be?

A. I have said in my answer that the agreement of the observations among themselves show the probable error, and I consider the small size of this probable error in evidence of the high degree of accuracy in the observations.

Q. Have you, in your own mind, figured out just the percentage of error?

A. Yes, sir; it is——

Q. Its relation?

A. The increment as determined is 25,200 s-f., and the probable error is 227, which would be a little less than 1 per cent.

Q. One-tenth of one——

A. One per cent—it is a little less than 1 per cent.

Q. Now, let us come back to this plat, Mr. Wheeler, and having gone over the questions that relate to its accuracy——

A. Well, perhaps I have not stated all that I might say——

Q. Please state what you have to say then.

A. ——on the matter of accuracy. These observations have been made for determining, what in this trial has been called the increment, we commonly use that term, which simply means the discharge due to one foot of elevation. These results show a close agreement among themselves and great care and accuracy in the observations; but the observations were made mostly in the summer season, entirely in the summer season. They may be different in the winter, they may be different on other occasions, so that the absolute value of that increment cannot be as closely known as indicated. Do I make it plain? The probable error which I give is the probable error of these observations. These observations are not sufficiently prolonged to say that the determination which is sought from them is known with entire accuracy the increment yet may be different at different times, but at the times these observations were made I know——

Q. You know that the basis of the observations, as made and platted on the plat——

A. At that time, when they were made, we know the value of the increment within this limit that I have given.

Q. Now, is there anything further that you would add in

connection with the accuracy of the computation, or have you covered that?

A. I think I have covered it. I have had this line determined, and I have checked the computation myself, and I feel perfectly safe in saying that this red line is the mean line of these observations. It is not an estimate, it is the mean line.

Q. Now, having said that with reference to the accuracy of the computation, I wish you would pick up that plat and explain to us just what it shows as the results of the determination of that line, translate it, so to speak, now, from the phraseology of the plat, to language that the layman can understand.

A. In making an observation to determine the "increment" of discharge, two things are observed, first, the elevation of the Lake surface as shown on the gage. Second, the amount in cubic feet per second of the discharge. Suppose at the time of the first observation the elevation of the lake surface to be 580 feet and the discharge to be 174,200 s-f. Suppose that at the time of the second observation the elevation of the water surface is found to be 581 feet and the discharge 199,400 seconds feet. These two observations together show that the elevation of the lake surface increased one foot and that the discharge increased 25,200 seconds feet. This is the "increment" or the change in discharge corresponding to one foot change in elevation. To show this result graphically the observations are plotted on the sheet as follows,—For the first one a circle is made around the point where the horizontal line representing 580 feet of elevation crosses the vertical line representing 174,200 seconds feet of discharge, and similarly for the second observation, a circle is drawn around the point where the horizontal line representing 581 feet of elevation crosses the vertical line representing 199,400 seconds feet of discharge. If now a diagonal line should be drawn through the two points one could tell by inspection what elevation of surface would correspond to any discharge. The diagonal on the plat is such a line, but instead of being made from two observations only, it is the mean of many observations, made in different years at different elevations. Since a change of discharge of 25,200 seconds feet, causes a change in surface elevation of one foot or 12 inches, it follows that a change in discharge of 1 second foot would cause a change in surface elevation of 0.000476 inch. For the purposes of this case this is a more convenient form for expressing the "increment" of discharge, because the change in surface elevation caused by

any change in discharge or "diversion" can be found by simply multiplying the diversion, when expressed in seconds feet by 0.000476, which gives, in inches, the resulting change in elevation.

Q. Well, now, having drawn the line, what is the result of that plat as to determining the effect upon the level of Lake Huron resulting from this loss of outflow through the St. Clair River?

A. We find that the value of the change for one foot is 25,200 seconds feet, that is, we find that if the discharge is diminished 25,200 seconds feet, that the elevation will be diminished one foot.

Q. Now, then, referring to the scale that is at the side of this plat here, at the head "Reduction in outflow, cubic feet seconds" and the other "Loss in stage, inches," what do you get there as to the—well, on the basis of your computation 10,000 cubic feet diversion, with the corresponding loss of outflow in the St. Clair River, would result in how much of a loss in stage of the lake?

A. It would come from there (indicating) down to there (indicating as shown graphically).

Q. That would be five inches?

A. If 14,000 it would come down to here, seven inches.

Q. Seven inches?

A. Yes, sir; on the natural scale.

Q. In your computation in which you went over these figures yourself, I notice there is a slight difference in the figure which you use in the formula that is down here on the original plat as denominator, a slight difference in figures in the computation. Does that make any substantial difference?

A. It does not make any substantial difference.

Q. In the result?

A. None at all, or hardly any. Hardly any appreciable result.

Q. That is, they are so nearly together that when you come to express the result in lake elevation in inches there is no appreciable——

A. No appreciable difference. I of course stand by my own computations.

Q. Yes.

A. I had them made with great care by an assistant, and I checked them myself, and I have great confidence in their correctness.

Q. Now, then, having explained to us the method through

which this result is obtained, and putting to you as an expert the question as to your conclusion, what, Mr. Wheeler, would be the effect upon the level of Lakes Huron and Michigan of the diversion of 10,000 cubic feet with the corresponding loss of outflow through the St. Clair River in inches?

A. I think I have computed that. You ask for that in inches, and I had the result in feet. I will have to figure it in inches.

Q. Give it to us in feet the way you have it. You may give the result in inches if you will—you say you have the computation in feet—our computations are all——

A. I can make it in inches in a moment.

Q. Very well, then, that would probably be more convenient, because we have been using that result.

A. Four inches and seventy-six thousandths for 10,000 seconds feet.

Q. Have you made the result for a diversion of 4,000 cubic feet at Chicago, with the corresponding loss of outflow from the St. Clair River?

A. It would be one and nine-tenths inches.

Q. That would be at the same rate for——

A. This is the same rate, yes.

Q. It would be at the same rate for any different quantity of water diversion?

A. Yes, sir.

Q. That is to say, it would be in the same proportion for one or two or five or eight thousand cubic feet?

A. True, with this limitation: This is true for any range of level that we know anything about, that we have ever had a chance to observe. It would not be true in an infinite range of level; there would come a time when your range would be distributed, but for anything we have, any range of level we have had this is true.

Q. In giving your result for the diversion of 4,000 feet, have you given that in tenths or in inches—will you look at it again?

A. It is 16/100 of a foot; and for 1,000 feet it would be one-fourth that much; I make it 48/100 inch.

Q. What is it for 4,000?

A. Oh, I made an error in this computation.

Q. I think it is a little over two inches when you come to figure it out. It would be one and nine-tenths inches.

Q. A fraction under two inches?

A. Yes.

Q. A small fraction under two inches. Now then the result of that is that speaking with substantial accuracy the effect of the division of each 1,000 cubic feet per second is, within the limits that there have been any opportunity to observe, a reduction of about half an inch in lake elevation.

A. Half an inch.

Q. Half an inch for each 1,000 feet?

A. Half an inch for each 1,000 feet.

Q. What will be the effect of this lowering on the water in the St. Mary's River at the foot of the locks?

A. That requires rather a long answer.

Mr. Williams: What condition do you mean now, a diversion of 4,000 or 10,000 or 5,000?

Mr. Wilkerson: For any diversion.

A. You mean the percentage.

Q. I mean the percentage of diversion.

A. During the 17 years between 1891 and 1907 there were no large changes in the channel of the St. Mary's River, I mean by that there were no dredgings of any considerable extent done there to affect the current. The slope between the locks and Mud Lake remained nearly uniform, the mean being 2.12 of a foot, that is the water at the foot of the locks was 2.12 higher than in Mud Lake. The observations for those 17 years show that any change in the surface elevation of Lake Huron caused a change in the surface elevation at the foot of the Locks amounting to 58 per cent. of the Huron change. In 1907, the West Neebish Channel was opened. This reduced the slope in the river, the amount is not yet very accurately known. The mean slope for 1908 was one foot and twenty-two hundredths. This decrease of slope would tend to increase the percentage of change, probably proportionally. If so, it would now be about 75 per cent of the Huron change. That is the answer that you wanted, I believe.

Q. Now, with reference to the percentage at the critical points of the St. Mary's River, what are those critical points and what would be the effect of the lowering of the level of the lakes at those points?

A. The critical points in the river are Sailors Encampment, Middle and West Neebish and Little Rapids, and the locks. The percentage of change for Mud Lake being 100 and for the locks as just determined, 75 per cent., the intermediate point would be between 100 and 75. I estimate Sailors Encampment at 98 per cent.; Middle and West Neebish, 90 per cent., and Little Rapids, 80 per cent. This is an estimate that

is made from the geographical position of the points. We have no observation at those points, it is only an estimate.

Q. What would be the effect of the diversion of a certain quantity of water from Lake Michigan at Chicago ultimately upon the outflow of the Niagara and St. Lawrence Rivers?

A. I have not made those computations and could not give them with any great accuracy.

Q. Can you give any——

A. As far as amount is concerned it would be the same, as far as the lowering is concerned——

Q. I was speaking—I think perhaps I did not speak distinctly. I was asking simply as to the amount of loss.

A. Oh, it is the same for those, too.

Q. That is to say, if there is a loss of outflow through the St. Clair River there will ultimately be the same loss in outflow through the Niagara and St. Lawrence Rivers?

A. Yes.

Q. Is that correct?

A. That is correct.

Q. I direct your attention, Mr. Wheeler, to two plats or charts which have been marked in this case Complainant's Exhibits Numbers 3 and 4, respectively, under date of February 15, 1909. Those plats or charts purport to show computations with reference to the loss of level in Lake Erie corresponding to the loss of outflow in the Niagara River by reason of the diversion of a certain quantity of water from Lake Michigan at Chicago. Have you seen those charts before?

A. I have.

Q. Well, what did you do in connection with those?

A. I computed the mean line drawn on the plat.

Q. Did you verify the accuracy of the observations by referring to any——

A. I referred to the published reports and verified them in that way.

Q. Can you tell us to what you referred?

A. It is the same references as before.

Q. The same references as before?

A. Yes.

Q. Now, take up those two plats and follow in the same method of explanation which you followed in connection with the plat concerning the loss of outflow through the St. Clair River, and explain to us what the result of those computations is.

A. The observations as platted, were platted in precisely, a

similar manner, to the one for the St. Clair River. Perhaps it would not be necessary to repeat that, would it?

Q. You can condense that—that is to say, if you followed the same general method, you can say it was the same general method you followed in the other computation.

A. The mean line was computed in the same manner as for the St. Clair River. The determinations are almost exactly coincident with those which were given me on the plat.

Q. If you will pardon me, I want to see, I think the record shows it, but I want to be sure—you verified by the published reports the accuracy of the points as platted?

A. Yes.

Q. And those you have recomputed yourself?

A. Yes.

Q. The diagonal lines?

A. Yes, that is the mean line, the mean of those observations.

Q. Now, then, go ahead with your answer.

A. I find that they correspond almost exactly with those which I found on the sheet. The discharge is for two different sections of the Niagara River; one section gives the increment 21,867 seconds feet; the other section gives it 21,744 seconds feet. The probable error of these, of the first of these, is 157 seconds feet, and of the other it is 143 seconds feet, and as before, the very small probable error is to me an indication of the excellence of the observations and the agreement of the two sections of the river is a still further indication of the excellence and accuracy of the observations.

Q. Now what is the result of that computation in the showing of the relation between the reduction in the outflow, and the loss in the stage of the Lake in inches, as shown by the scale that appears on the plat, have you that computed in feet as you had in the case of——

A. No, I haven't.

Q. ——of Huron. I mean of the——

A. Of the St. Clair discharge?

Q. The St. Clair discharge, yes.

A. I can give that in inches in a short time. For the Niagara River the diversion of 1,000 seconds feet would lower the lake 55/100 of an inch and any other amount in proportion.

Q. Ten thousand would be about 5½ inches, and 4,000 would be about two and two-tenths of an inch?

A. Four thousand would be four times as much as that—well, 2.2 of an inch 4,000 would be.

Recess to April 20, 1909, at 10:30 a. m.

April 20, 1909, 10:30 o'clock, a. m.

Parties met pursuant to adjournment.

EBEN S. WHEELER resumed the stand for further examination by Mr. Wilkerson, on behalf of the Government, and testified as follows:

Q. Directing your attention again, Mr. Wheeler, to the lowering of Lake Huron and Michigan, if they be lowered a certain known amount, and Lake Erie a certain known amount, what would be the lowering in the Detroit River and Lake St. Clair and the St. Clair River, speaking particularly with reference to the critical places in that chain?

A. Well, reading from my notes, observations from 1884 to 1909, of the U. S. Lake Survey—do you wish a reference to that?

Q. Yes, if you can give it to us.

A. They will be found in the reports of the Chief of Engineers from 1900 to 1904. These observations show that a lowering of Lake Huron lowers St. Clair 22 per cent. of the Huron change; a lowering of Lake Erie lowers Lake St. Clair 63 per cent. of the Erie change. If Erie and Huron are lowered an equal amount simultaneously, St. Clair will be lowered 85 per cent.

Q. How did you get that result?

A. That comes from direct observations. The Deep Water Commission—I have forgotten what date—placed observers all along the river from Port Huron to Gibraltar, reading the elevations of many places. They waited until there was a change of about seven-tenths of a foot in both lakes, and read it again. These curves show that while there was a change of seven-tenths at the extremities, there was only about eighty-five one-hundredths in Lake St. Clair, and perhaps fifty-three one-hundredths in the narrowest and rapidest place, which was opposite Algonac. This result is derived from a range of four and a half feet in Huron and three and a half feet in Erie. A similar result is shown by the observations made by the Board of Engineers on Deep Waterways in 1898 and 1899. That is what I have just alluded to.

Q. What have you to say about the probable error in those results, based upon the observations?

A. The agreement of the observations among themselves indicates that the probable error of these results is 8 per cent.; that is, if the lowering of Huron and Erie be given, the lowering of the St. Clair can be found by means of these percentages within 8 per cent.

Q. What do you say about the observations given by the Board on Deep Waterways, as the result of their observations?

A. The observations made by the Board on Deep Waterways in 1898 and 1899 show that if Huron and Erie are lowered an equal amount, St. Clair and Detroit Rivers will be lowered respectively 75 and 91 per cent. of this amount.

Q. What are the critical places between Erie and Huron?

A. The critical places, beginning at the lower end, is first Amherstberg.

Q. What about the percentage there?

A. About 95 per cent.

Q. Of what?

A. Of the lowering in Lake Erie.

Q. What is the next one?

A. Lake St. Clair.

Q. And the per cent. there?

A. That would be about 85 per cent.

Q. The next one?

A. Squirrel Island.

Q. And the per cent. there?

A. About 66 per cent.

Q. And the next?

A. Opposite the village of St. Clair.

Q. And the per cent?

A. 83 per cent.

Q. The next one?

A. Stag Island.

Q. And the per cent.?

A. The same, 83 per cent.

Q. The next one?

A. Opposite Black River, 88 per cent.

Q. The next one?

A. And last in the lower end of Lake Huron, for a distance of four miles, it would be 100 per cent. Now these percentages are determined from the geographical position of these

critical points. We have not observations made at all these points; and they are therefore approximate.

Q. I show you another one of these charts, Mr. Wheeler, that have been marked Complainant's Exhibit No. 2, date February 16, 1909, and ask you to state whether you have seen that before, and what you have done with reference to it?

A. This has been given to me and I have examined the observations, so as to note that they correspond with the published observations of the Lake Survey; and I have computed the diagonal line, or the mean line, recomputed; find it to agree almost exactly with the given one here. On the blue print which I submitted, the line which I computed is shown in red, which corresponds almost exactly with this one. This line shows graphically the discharge which corresponds to a change in stage. It is found that the discharge for one foot of level is equal to 28,870 cubic feet per second. That is the St. Lawrence River.

Q. What would be the lowering effect, therefore, of the diversion at Chicago of 4,000 cubic feet of water per second upon the level of the St. Lawrence River?

A. Since this shows that a diversion of 28,870 cubic feet would lower it one foot, 4,000 feet would be its proportional part. I have not worked that out.

Q. Is the scale that is on the left hand side of the chart substantially correct as expressing the lowering effect of the diversion of this water?

A. Yes, it is correct, and it is marked on the scale here. Ten thousand cubic feet per second would——

Q. A little over four inches?

A. About four and a third inches.

Q. What is the season of navigation in the St. Clair River, Mr. Wheeler?

A. The records of the last six years show that vessels use the Detroit and St. Clair Rivers during every month in the year. The broadest definition of season of navigation would include the entire year.

Q. Taking out now the months where the navigation is comparatively small.

A. During January, February and March the number of vessels is very small, averaging less than 50 per month. In April, the number of vessels is from one to 2,000. In December it varies between 700 and a thousand. I should think a better definition of "season of navigation" would be from April to December, inclusive.

Q. What do you mean by ice effects, as they are used in connection with the St. Clair River?

A. I understand ice effects to be the effects which ice has on the discharge and elevation of the rivers and lakes. Ice, when actually present in St. Clair River, tends to retard the flow, and to raise the level of Huron. These are one kind of ice effects. After the ice disappears, the increased elevation of Huron caused by the ice tends to accelerate the flow in the river, and diminishes the elevation in the lake.

Q. Is there any other kind of ice effects?

A. I think that would include them all. These are also ice effects, but of another kind; one or the other kind is always present. In the aggregate the two kinds are equal to each other. There are times when both are operative, and the final result is the difference between the two. Ice effects are sometimes cumulative; that is, the cold months of winter may raise the level of Huron more than can run down in the warm months of summer. Ice effects are very erratic in their intensity. They may be large for several consecutive years, as they probably were from 1880 to 1886, when the level of Huron was raised one foot. Or they may be small, so as to be almost negligible, as they probably have been in the last few years. The retarding effects of the ice must be small during the season of navigation, generally so small as to be negligible, but this may not always be the case. For example, during the period from 1880 to 1886, it is probable that there were large retarding effects during the months of April, May and December. The retarding effects of ice are present, whenever there is any ice.

There is often ice in the river before the first of December, and therefore the retarding effects generally begin before the first of December. But the December ice is often so thin and broken that its retarding effects may be negligible; and I should say that as a rule it is not large enough to be measurable before the middle of December.

Q. How about the effects in April and May?

A. There is much ice in the river in April; generally broken by passing boats. The retarding effects last as long as there is any ice, but it is usually small by the middle of April. Sometimes ice effects last through May. I should say that the retarding effects of ice would generally be unimportant after the first of May.

Mr. Lindley: What river are you talking about now?

A. St. Clair.

Mr. Wilkerson: How about May?

A. There have been, though rarely, large ice jams in May, and retardation during the whole month. There have also been, though rarely, years when there was no ice in May, and therefore no retardation. I should say that more than half the time the ice effects in May are unimportant.

Q. What information can you give us about ice effects in the St. Mary's River?

A. In St. Mary's River the ice raises the water at the foot of the locks during the winter months, sometimes as much as two feet; an average of 20 years shows about six-tenths of a foot. Above the locks no ice effects are observed.

Q. The observations which appear on the charts which you have examined, and from which has been deduced the lowering effect upon the lake level of the diversion of water at Chicago, the observations, as I understand it, most of them were made out of what you call this ice period, were they, Mr. Wheeler?

A. Made in the summer season.

Q. Made in the summer season. By that you mean the open season?

A. Yes.

Q. What they call the season of real navigation, as distinguished from the season when navigation is practically closed, although during the closed season there are a few boats that pass. Is that right?

A. Yes, that is right.

Q. Now I wish you would take up this subject, Mr. Wheeler, and in your own way give us your conclusions with reference to it. The subject is this: The bearing, if any, which the presence of ice during these winter months has upon this lowering effect of the diversion of water in Chicago; I mean not the actual level of the lake, but upon the lowering effect, the tendency of the diversion, whether it would be to lower the level more than what it otherwise would be?

A. I understand that the ice effects do not in any way increase or diminish or change such quantities as the precipitation, evaporation and final outflow, but it has a disturbing effect which might be compared in one sense to storms. It raises the elevation of the lakes at times. It diminishes the outflow of the river at times. It increases the outflow of the river at times, but as it makes no change in the outflow, it makes no change in the effect of a diversion.

Q. That is to say, if I may interrupt you, in order to get

your idea clearly before us, the presence of more ice for instance in the St. Clair in a given winter is a circumstance that is analagous to more rain, for example, is that right?

A. Would you repeat that question.

Q. I say the presence of more ice in the river in a given winter is a circumstance which would be analagous to there being more rain at a given time.

A. Well, in a limited sense that would be true.

Q. I am speaking now in its relation to the lowering effect, so far as it would modify the lowering effect.

A. Well, I should say that it would change the rate of the lowering, but not its final amount.

Q. Well, suppose you compared it with the wind blowing up stream, on the St. Clair river?

A. That would be analagous in a certain respect. It would diminish the current in the river for a time and later the current would be accelerated because of the water that was held up. But the final result would be that just as much water ran down with the wind as would have done without it, and that is true of the ice effects. The total discharge is not affected by it, although the rate at different times is made variable.

Q. What can you say, Mr. Wheeler, with reference to the relation of this ice retardation to the increment of the outflow in the river?

A. I should say that I know of no reason why it should change it. It is a physical possibility that it might so alter the form of the outlet that it would change the value of the increment, but I can see no reason why it should do so.

Q. Now take these two things: The diversion of the quantity of water from Lake Michigan at Chicago, and the fact that some time in the year there is ice in the St. Clair river. What is the relation of the presence of this ice to the ultimate lowering tendency, if any, of the diversion of the water at Chicago?

A. I think it does not change it in any respect.

Q. That is to say, if a diversion of 4,000 cubic feet of water per second at Chicago had certain definite lowering tendency upon the water in Lake Michigan, upon the level of the water in Michigan and Huron that ultimate lowering effect would remain, even though there were ice in the St. Clair river. Is that the result of your answer?

A. It would, I think. The rate at which that lowering would proceed would, I think, vary somewhat on account of

ice. It would be increased in the winter season and diminished in the summer season, but the ultimate effect, which I believe was your question—

Q. I am speaking about the ultimate result about which you testified yesterday. You said, as I understood you, that the diversion of this water at Chicago had a lowering tendency that while the lowering tendency was never absolutely realized because of the law which you expressed yesterday, yet within a few years substantially all of it would be accomplished?

A. Yes.

Q. Now I am asking whether the presence of this ice in the St. Clair River in any way modifies or affects what you have already stated as to the lowering tendency of the diversion of this water?

A. I don't think that it does. The ultimate effect would be just the same. It is similar to that of a great storm on the lake which might change the rate of the discharge temporarily, but it would not change the ultimate lowering effect of the diversion.

Q. And in your judgment would it have any appreciable effect upon the time which would elapse before this lowering effect would be substantially accomplished?

A. I don't think that the effect would be appreciable. I can conceive that there might be some possible slight effect.

Q. Would it substantially modify the time?

A. It would not.

Q. Have you any information Mr. Wheeler, as to whether the St. Clair river is changing its regimen by scouring out its bottom or banks, so as to make a greater outflow from Lake Huron. If so, to what extent is the scouring taking place, and what is its effect on the level of lakes Huron and Michigan?

A. The Board of Engineers on Deep Waterways in 1900 say: "The mean level of Lake Huron is apparently one foot lower than it was fifteen years ago, which change has resulted from enlargement and deepening of the channels for waterway improvement and from the natural erosion of the bed of the river at the outlet of the lake."

This opinion of the Board caused some alarm. The United States lake survey directed a new survey and an examination of all old ones. Assistant Engineer Haskell reported that: "Surveys of the outlet made between 1867 and 1900 do not indicate any enlargement or lowering of the outlet." It

was further pointed out that while an enlargement of the outlet might explain the fall in Huron from 1886 to 1892, it would not explain the rise from 1880 to 1886. The most convincing proof that there has been no enlargement of the outlet comes from the relations between the levels of Lake Huron and Erie since 1886. Thus if Lake Huron had been permanently lowered one foot about the year 1886, the slope between Lake Huron and Erie would be one foot less after 1886. An examination of the records shows that during the twenty years between 1860 and 1880 (before the supposed subsidence of Lake Huron) the mean difference in level between the two lakes was 8.52 feet. For the twenty years between 1887 and 1897 (after the supposed subsidence) the mean difference was 8.47 feet. This close agreement shows that there has been no measurable subsidence of Lake Huron. The continual degradation of all stream beds is recognized, and it is probable that there is some small wearing in the outlet of Lake Huron, but not enough in the last fifty years to be measurable.

Q. What is the diversion from Lake Erie into the Welland Canal and the Erie Canal?

A. Through the Welland Canal, it is given as eleven hundred seconds feet.

Q. You say it is given as that. Where is it given?

A. This is given by the officer in charge of the canal, and I think that his title is Custodian of the Canal. It was obtained from him by correspondence. I gave it in my report in 1903. That can be found in the Chief of Engineers' report for 1903.

Q. Now about the Erie canal?

A. That is 1200 feet per second.

Q. Any changes since then?

A. I know of no changes since then. Both of these quantities were given in that report of mine, 1903.

Q. Is there any other outflow from Lakes Michigan and Huron, except through the St. Clair River and the Drainage Canal?

A. I don't know of any and I don't think that there is any. I don't think that it is possible that there is any.

Q. Suppose there was such an outlet, and it had a discharge, what bearing would that have upon the conclusions you have stated as to the lowering effect of the diversion of the water at Chicago?

A. It would make no change whatever, for our conclusions

and determinations are made from what is actually flowing above ground and in sight; and it would be of no importance if there was a subterraneau outlet, it would make no change in our results.

Q. Do you know of any inconsistencies in the outflow volumes of the St. Clair, Niagara and St. Lawrence Rivers, which are not accounted for by the ice retardations about which you have testified?

A. In a report dated 1893 I say: Formerly there was an inconsistency between the derived discharges of St. Clair, Niagara and St. Lawrence Rivers; but the investigations of ice effects have corrected the derived discharges, so that their relations are entirely reasonable, and there is no longer cause for the theory that a part of the discharge from Lake Erie passed by underground percolation into Lake Ontario.

I have the same opinion now. It is easy to see how these discrepancies, supposed discrepancies, occurred. The discharge through the St. Clair River is always measured in the summer time, in the open season when, as has been before stated, the outflow was accelerated and increased by ice effects. Therefore, the measurd values were always larger than the mean; and when we come to compare it with the Niagara River the two were found to be nearly of the same size. Considering the drainage basin of Erie this was impossible, was absurd, but since the effects of ice on the measurement in the St. Clair River have been recognized, there is no disagreement now in the relative sizes of the two rivers.

Q. Are you familiar with the hydraulic measurements which have been made in the St. Clair River and in the Niagara and St. Lawrence River, and with the management in charge of that work?

A. Mr. L. C. Sabin was in local charge of the St. Clair work, and Mr. E. E. Haskell and F. C. Shenehon in charge of the Niagara and St. Lawrence work.

Q. Having in mind your experience as an engineer, and having in mind the study which you have given to the results of their work, what have you to say as to the degree of accuracy with which it was done?

A. They were all competent engineers, and their work has been reckoned of the highest order, as is indicated by the fact that all are now in positions of responsibility. I consider their work of the highest order.

Q. And what you have said in that answer applies to the

observations which have been platted on the charts which have been exhibited to you here and about which you testified?

A. It does.

Q. When you were on the stand yesterday, we went briefly into the subject of the probable error of the increment of outflow as determined from these observations. You have made, I understand, a careful and particular examination on that subject, and I would like to have you testify now more in detail about it, if you will, Mr. Wheeler.

A. The increment is determined—I determine it by computation. It is given graphically for better illustration on these sheets. The probable error means that quantity which the truth is as likely to exceed as to fall short. It does not mean that the error cannot be greater, but it means that it is as likely to be less as it is to be greater. That applies to the observations that were used. It does not apply to all determinations that might be made. For example if these same quantities were redetermined several years hence, they might differ from the present determinations by quantities greater than the probable error. The several increments with their probable errors are: St. Clair River 25,200 seconds feet± 227 seconds feet. Niagara, first section, 21,867 seconds feet±157 seconds feet. St. Lawrence 28,338 seconds feet±264 ± 143 seconds feet. St. Lawrence 28,338 seconds feet± 264 seconds feet. That is as badly determined as any, but all are believed to be well determined.

Whereupon a recess was taken to two o'clock, p. m.

April 20, 1909, two o'clock, p. m.

Direct Examination of Eben S. Wheeler, resumed.

Mr. Wilkerson: Q. When we adjourned this morning, there had been a question put to you with reference to the meaning of the term "increment" as it has been used in this connection, and its relation to the diversion of a given quantity of water from the lake at Chicago, for instance. I would like to have you go ahead now with that explanation?

A. "Increment" means the number of cubic feet per second that the discharge of a stream is increased by a rise in its surface of one foot. The increment of St. Clair River is 25,200 seconds feet; therefore the fall caused by any diver-

sion has the same ratio. For example a diversion of one-half of 25,200 seconds feet would cause a fall of a half a foot and proportionately for any other amount of diversion.

Q. The fall of Niagara River I think is 308 feet approximately, isn't it?

A. It is, the total fall.

Q. The total fall of Niagara River?

A. Yes, sir.

Q. What then would be the loss in power to that river of the diversion of 14,000 cubic feet per second at Chicago?

A. 14,000 seconds feet of water falling 308 feet has a theoretical potential of 490,000 horse power. If 14,000 seconds feet are diverted at Chicago, it will diminish the theoretical potential at Niagara 490,000 horse power.

Q. That would be true proportionately would it for the diversion of a smaller quantity of water?

A. It would.

Q. What knowledge have you, Mr. Wheeler, on the subject of data regarding evaporation from the basin of Lakes Michigan and Huron?

A. In a report dated 1902, I found the evaporation from the Michigan and Huron basin to be 208,000 seconds feet. This is from a mean of sixteen years. Evaporation is largely controlled by temperature, the wind, humidity, rainfall, etc. These elements are variable and erratic, making the determination of evaporation difficult and uncertain. I do not think that the evaporation in the basin of Michigan and Huron could be determined for one year with a probable error less than 20,000 seconds feet.

Q. Well, in view of the consideration which you have given to data relating to evaporation, precipitation and so on, what have you to say with reference to any attempted deduction which was based upon these alleged data as to evaporation, precipitation?

A. Well, as I think my own determinations had a probable error of ten per cent., I should not expect any results derived from that determination to have any less error than that.

Q. Is there anything else that you can say with reference to the source of those data, that would be further explanatory of your statement that there is a large probable error?

A. Well, the data concerning all of these elements—

Q. I will refer for instance to the extent of territory

covered and the distance apart of the stations where observations were made, things of that kind?

A. I was going to say that it was taken from the Weather Bureau's records, and their records are made at a large number of stations, but with the area so large, the distance between stations is great, and the determination at a single point only gives the correct result for that point, and the mean result of a large area cannot, necessarily, be as close to the truth. The elements, wind for example, is measured at their stations, and very varying results are obtained. I remember that one year at Chicago, the wind records, or the anemometer was changed from a building here in the city out to the crib, with the result that the wind velocity at Chicago was reported after that about twice as much as before. This illustrates the uncertainty of that kind of observations.

Q. In the very nature of things is it possible that with reference to observations concerning evaporation, precipitation, and matters of that kind, there should be anything like that accuracy of observation which is possible in measuring the outflow through the St. Clair River, for instance?

A. No, the outflow through the St. Clair River is measured with much greater accuracy than the rainfall and evaporation can be measured.

Q. Is the difference so great that it can be said that the only class of data, those relating to the outflow through the St. Clair River, can be used as a basis for obtaining accurate results, while the other class of data cannot be used as the basis for determining anything like accurate results?

A. Why I should say for example that the discharge of the St. Clair River has been determined and can be determined with ten times the accuracy of the evaporation of the Huron and Michigan basin and lakes; I should say that there was at least that ratio between them.

Q. In the course of your examination on yesterday, I think in a general way you went over the subject of the length of time which it would take for the ultimate effect of the diversion of the water at Chicago to be accomplished. I direct your attention to that subject again, and ask you if you are prepared to make a more definite statement with reference to it?

A. It will take about four years for a diversion of 10,000 seconds feet to produce nine-tenths of its ultimate effect on Huron and Michigan. A discharge of 25,200 seconds feet from Huron is equal to one foot of elevation. 10,000 seconds

feet will equal 10,000 divided by 25,200, which is .397 feet. Therefore the lake surface will eventually fall .397 feet. The areas of Lake Huron and Michigan is 45,500 square miles. 10,000 seconds feet would cause a fall in one month of .02 feet. This rate will diminish as the lake runs down. At the end of the first year, the lake will be lowered .184 feet. At the end of the fourth year, it will be lowered .360 feet, which is a little more than nine-tenths of the total lowering. But, as stated yesterday, it will take an infinite time to complete the remainder, that is theoretically.

Q. Having in mind, Mr. Wheeler, that the lakes vary in stage from year to year, and that the surface is affected by the influence of wind; it grows rough in storms, and having in mind the other forces which determine the condition of the surface of the lake, what have you to say as to the effect, injurious or otherwise, upon navigation, of the lowering of the level of the lake by say two or three or four inches?

A. I should say that a loss of draft in a fluctuating and disturbed channel is as injurious to navigation as a similar loss would be in a perfectly calm channel.

Q. Why do you say that; that is to say if there is any reason in your mind other than it seems to be perfectly obvious?

A. Why, a loss of draft in a disturbed or fluctuating channel, for example, would tend to cause the boat to strike the bottom. A loss of draft in a perfectly calm channel would also tend to cause the boat to strike the bottom; and the effect in the two cases appears to me to be entirely similar.

Q. How many boats are there on the great lakes that ply between Lake Superior and the lower lakes, or on the lakes below Superior, that are capable of loading to 19 feet?

A. There are three hundred and twenty-three boats that can load to nineteen feet, and of these there are forty-eight that could not safely load deeper.

Q. How many are there to load twenty feet?

A. There are 275 that could load to 20 feet, and of these 87 could not load deeper.

Q. How many could load to 21 feet draft?

A. There are 188 boats that could load to 21 feet draft, or perhaps deeper; some as deep as 26.

Q. Do you know how many tons of freight are carried on all boats capable of loading to 19 feet, traversing the routes which were referred to just a moment ago, during the season of navigation for 1907?

A. Well, in 1907 there were 47 million tons of freight carried through the Sault locks in boats capable of drawing 19 feet of water. Two million tons of this were carried in boats that could not safely load deeper than 19 feet. There were 45 million tons were carried in boats that could have carried more if the channels had been deeper, which is about 85 per cent. of the freight carried on a 19 foot draft.

Q. Now as to boats that could safely load to 20 feet draft, if the chanels had been deep enough, how much was that?

A. Well, 44 millions of tons were carried in boats that could safely load to 20 feet draft, if the channels were deep enough. Of this, 11 million tons were carried in boats that could not safely load deeper than 20 feet.

Q. How much was carried in boats that could safely load to a draft of more than 21 feet, if the channels were deep enough?

A. Thirty-three million tons were carried in boats that could safely load to a draft of more than 21 feet, if the channels were deep enough.

Q. What determines the amount of the load that can be put on these large freighters; that is to say those boats which have a possible draft of more than 19 feet?

A. Well, those points which we have referred to as the critical points, of which the most important is the Sault locks, at the present time. Boats in the Lake Superior trade that can pass the Sault locks can generally pass all other points en route to Buffalo. The vicinity of Amherstberg is the second critical point in importance; and boats in the Lake Superior trade load with the purpose or the object of going through the Sault locks.

Q. In this connection, we have been speaking here of the depth of the water in this Poe lock; it is probably covered by what I have asked you already, but I will ask you again to explain to us just what relation the elevation of Lake Michigan and Huron has to the depth of that lock, and how the lowering of the level of Lakes Michigan and Huron affects the depth of that lock?

A. The lowering of Lake Huron causes a lowering at the foot of the locks of about 75 per cent. My conclusions were that lowering in Huron caused a lowering of 75 per cent. at the foot of the locks.

Q. In the floor of the lock; also of the Poe lock?

A. That is the Poe lock; yes, it affects all those locks.

Q. Having in mind the number of boats now engaged in

commerce on the lakes, that load to the limit, and have to carry a smaller load if the level of the lake is lowered, and that can carry a larger load if the level of the lake is higher, have you made any computation as to the loss to commerce for each loss of one inch of draft?

A. In 1907 there were 323 boats that were carrying up to the load limit. It is estimated that these boats carried fifteen loads each, making 4,841 loads. It is further estimated that one inch of draft in this class of boats is equal to seventy tons of 2,000 pounds each, which would make a total of 239,150 tons. The cost of transportation of iron ore in 1907 was 67 cents per ton. I mention iron ore; that is the lowest priced freight, lowest priced item that there is. This makes the total cost $227,230 for one inch of draft; or the loss of six inches, a half a foot, in 1907 would have caused a loss to vessel men of $1,336,000.

Mr. Williams: It is understood that the testimony taken before the Commissioner is taken with the same understanding as the testimony taken pursuant to stipulation which is attached to the testimony of witnesses Noble, Haskell, Wilson and Ernst.

Mr. Wilkerson: That stipulation I understand is that all substantial objections to the testimony may be urged when it is offered.

Mr. Williams: That is right.

Mr. Wilkerson: But that any objections to the form of the question should be noted at the hearing.

Mr. Williams: That is right.

Mr. Wilkerson: Q. You have been giving us here some conclusions, Mr. Wheeler, which have been based upon statistics. What had you to do in connection with the Poe lock? When were you familiar with the data upon which these conclusions are based?

A. Why, at the present time I am not in local charge of the Poe lock. For a number of years I was, and I looked after the collecting of the data and also designed and arranged the form of reducing it, and publishing it. I am, and was at that time, very familiar with those details; and at the present time they are conducted in substantially the same way as they were then.

Q. With respect to the size of the vessels which are engaged in commerce on the lakes, are those vessels becoming larger or smaller?

A. They are increasing yearly in size, capacity.

Q. Take the next five years for instance: What do you say about the size and draft of vessels that will be engaged in commerce?

A. I have conferred with some of the vessel men, owners and shippers, and some of the large building firms, and they are expecting an increase in the next five years, a small increase. They expect they will have a length of five to six hundred feet; that is nearly everything that is built. A few now have a length even exceeding six hundred. They expect a draft of 21 to 25 feet.

Q. Do you know anything about the dimensions of the large freight carriers of the lakes, that traverse the waters below Lake Superior?

A. The J. P. Morgan has carried a load of 13,800 tons on a draft of 20.2 feet. Her length over all is a little over 600 feet and her beam is 58 feet. The W. B. Kerr has carried a load of 13,300 tons. Her length is 605 feet; beam 60.2 feet. In these boats one inch of draft is equal to 85 tons of freight. This determination was made by getting the difference between the draft of the boat when she was loaded, and light, the amount that her draft was increased by putting a given load on board her. It was easy to determine how much her draft was increased for a single inch.

Q. Do you know how much water is used in the locks at the Sault Ste Marie?

A. It is roughly estimated that 500 seconds feet are used in all of the locks at Sault Ste. Marie.

Cross-Examination by Mr. Lindley.

Q. I understood you yesterday to say in your direct examination that elevation was or is the resultant of a number of elements or forces. Did you use some such expression as that?

A. Yes, I think I did.

Q. I wish you would now enumerate all of the elements or forces which go to make up that resultant, starting in the order of the most important ones, as you consider them?

A. I could not give you all of them.

Q. Just name them?

A. One of the most important is: (a) precipitation, which includes snow fall and rainfall; (b) evaporation, which tends to diminsh the elevation; (c) outflow. These are the prin-

cipal ones. I think it would be hardly worth while to mention or attempt to mention the infinite variety of other things.

Q. That is exactly what I wanted to get at Mr. Wheeler, was the infinite variety; but of course being infinite you cannot name them all, but name as many as you can.

A. That is rather a hard thing to undertake.

Q. I want to get all we can, that is all. I would be very much obliged if you would enumerate all you can name?

A. I could not undertake anything of that kind. You might ask me to classify all the rain drops I should find. I could not do it.

Q. What I do want you to do Mr. Wheeler if you will, is to name all that you can?

A. Well, I have named all that I can.

Q. That is the three, precipitation, evaporation and outflow?

A. Yes.

Q. Didn't I understand you to say yesterday that it also was affected by humidity?

A. The evaporation is affected by humidity, and indirectly that would affect the supply, I suppose. I said that evaporation was affected by humidity.

Q. And seepage?

A. Well, I don't know that I would classify seepage; that is a part of the inflow. I would not discriminate it from the—

Q. From precipitation generally?

A. Precipitation generally, which would include snow fall and rain fall and hail and everything of that kind that is precipitated into the lake.

Q. Well, then, where will you classify wind? I understood you to give that yesterday?

A. That affects evaporation, and it disturbs the elevation of the lake. I don't know that it makes any permanent effect.

Q. That is exactly what I want to get. You used that expression, it is the resultant of various things. I wanted to get what that resultant was made up of, and if you say there are just the principal ones, precipitation, evaporation and outflow, well and good. Then we will try and see what goes to make up those three things.

A. Well, I said that evaporation was caused largely by four things; rain fall, temperature, wind and humidity.

Q. Yes.

A. And as evaporation affects the elevation of the lake's surface, those four things indirectly do it.

Q. As to precipitation, you include in that simply snow fall and rain fall?

A. Yes.

Q. Nothing else?

A. Nothing else.

Q. And in outflow, you include exactly what?

A. The discharge at the outlet.

Q. The discharge at surface outlets?

A. Yes.

Q. Now are you prepared to say that it has been thoroughly demonstrated that there are no subterranean outlets?

A. I am well convinced that there are none.

Q. Do you think that that is an accepted proposition?

A. I think so. Dr. Gilbert of the Geological Survey in speaking of that said that the land between the lakes was known to hold gas, and he believed that if it would hold gas that it would water, and that there would not be any percolation through it, could not be. But it has not been—you ask if it has been thoroughly demonstrated. I can't say that it has, but I am very well convinced that it is true that there is no percolation of water from one lake to another.

Q. As a subject of investigation, however, it is still an open question, open to investigation?

A. Yes.

Q. Referring to the quotation which you just made a moment ago as to the gas, at what depth generally do we obtain gas?

A. The gas that is being found nearest here, over in Canada, is at the depth of between four and five hundred feet, but in other places it is often more than a thousand feet.

Q. Most generally below the level of the lakes is it not, below the level of the bottom of the lakes?

A. Yes, below the level of Lake Erie; not below the level of Lake Superior, however. Still it is often found in deeper localities than the bottoms of any of the lakes.

Q. While you are speaking of the level of the bottom of these lakes, can you give us the average depth of these lakes?

A. Well, I don't think I can give you the average depth. I can give you the deepest sounding that has ever been made in Lake Superior, very closely; I believe it was 1007 feet, something like that. I happen to remember that because I

assisted in making it. As for the average, I don't remember those things.

Mr. Lindley: I take it some of the exhibits that will be offered will show all the soundings which have been made.

Mr. Wilkerson: We will agree on what that shows.

Mr. Lindley: So I do not care to ask any further questions on that.

Mr. Wilkerson: We will make up a table.

Mr. Lindley: Q. You speak of evaporation. What do you include in the term evaporation?

A. All of the moisture or water that rises in the form of vapor into the atmosphere, after having been on the surface of the earth once; goes back into the atmosphere in the form of vapor, vapor of water.

Q. As you use the term, does it also include what the earth absorbs?

A. No, I don't understand it to include that.

Q. How do you arrive at the amount of evaporation, which you give at something like 208,000 seconds feet?

A. I obtained from the records the precipitation in the basin.

Q. On the surface of the lake, and in the run-off area?

A. In the entire basin, which includes of course the lake. Without saying this for reference, I might say I give an elaborate description of how I did this in a report that will be found in the Report of Chief of Engineers for 1903. It perhaps will be sufficient for your purpose if I say that I sum up the rain fall at all the stations and made such corrections as appeared necessary from their location, and determined the area of the basin carefully and in this way I arrived at the total precipitation into the lake; into the basin and lake together.

Q. Let me ask you right there: You are speaking of the basin of both Huron and Michigan?

A. Yes.

Q. They were considered as one lake?

A. In the discussion we considered that as one lake; that made one quantity. I took from the records the discharge from the outlet, the measured discharge from the outlet at that time, and the remainder I assumed to be evaporation.

Q. Well, then, by that process, is it not true that you considered that which the earth consumed as evaporation, because all that fell upon this basin or upon the run-off area did not reach the surface of the lake, nor was it evaporated

as we use the term, or go off in vapor. Didn't some of it seep into the earth and remain there?

A. No, not as I understand it. The earth is not constantly receiving water and retaining it forever. There is no more goes into it than comes out. And I assume that during the time that I was dealing with it, there was not any more going into the earth than was coming out.

Q. So that in evaporation you accounted for all the rain fall upon the surface of the earth within the basin?

A. Yes.

Q. And considered it as either having run off into the surface of the lake and been evaporated or being evaporated directly from the face of the earth?

A. That is it exactly. I assumed there was only those two ways to account for it. If one has two of those three quantities, he can determine the third one.

Q. Did you determine the evaporation from the basin of any of the other of the great lakes?

A. Yes, from all of them.

Q. From all of them?

A. Yes.

Q. Did your computation cover more than one season?

A. Yes, it was the mean of sixteen years.

Q. The mean of sixteen years?

A. Yes.

Q. Beginning with what year?

A. I don't remember. It must have been about 1884, something like that.

Q. To 1900, sixteen years coming down from 1884?

A. Yes. It might have been a little earlier. The time was governed by the character of the records which the Weather Bureau had. They improved their records very much a certain year, and I went back and included that and didn't go any further back. It made this sixteen years that I say.

Q. Your computation was based upon the weather reports from the various stations?

A. Yes.

Q. And those reports were kept by the government officials in the ordinary course of their official duties, is that right?

A. Yes.

Q. And in your judgment are the most reliable extant?

A. Yes.

Q. And the computation can be made with accuracy from

the data given, but the data is not as full as might be, is that it?

A. That is the point exactly.

Q. In your judgment were the number of stations where records were kept by the government sufficiently great and sufficiently well distributed over the area as to give approximately a correct result of the precipitation?

A. Why I estimated within ten per cent.

Q. Within ten per cent?

A. That is not a very close approximation.

Q. Do you recall what the variation was in the way of precipitation during the sixteen years?

A. That is one year with another?

Q. Yes.

A. I do not, further than it was very great. There were certain dry years and certain wet years, and the range of observation of precipitation was very great.

Q. Speaking of dry seasons and wet seasons, do you mean by that taking a calendar year as a whole, or was it that one calendar year for instance with another would be about the same, but different portions thereof would differ greatly?

A. One calendar year with another would vary very much, vary 50 per cent. perhaps in extreme cases, and portions of years would vary still greater. This is as I remember it. It has been a long time since I have been looking at it, and I am not expected to give very accurate answers to these questions.

Q. No, sir. That will all appear, however, from this report which you have referred us to?

A. Yes, I have given it fully there.

Q. If as a matter of fact there should be found to be subterranean outlets or inflows, would there be any possible way of telling how much if any variation there was in the discharge therefrom or the flow thereto?

A. That is a hypothetical question, I think, where you would have to define what the condition of this subterranean outlet was, whether it was in a measureable condition or not. I don't know of any outlet likely to be found, except the ordinary percolation through strata that permits percolation, and that is very difficult to measure.

Q. There is, is there not, around the whole bank of the great lakes more or less percolation from the soil into the basin of the lake?

A. Yes.

Q. So that whatever you may call it, it is in a manner a subterranean inflow?

A. Yes, it is under the surface.

Q. Now that inflow takes place at all distances below the surface, down as far as the bottom of the lakes?

A. Possibly.

Q. Through different strata?

A. Yes, possibly.

Q. And it is not affected, is it, by the rainfall on the surface of the earth, after you have gone down any distance at all, any substantial distance?

A. Why, it is caused entirely by the rain fall. If there was not any rainfall on the surface of the earth, there would be no percolation through it.

Q. Rainfall in the basin?

A. In the basin, yes.

Q. Might it not be that, say going down a distance of fifty feet, that the percolation below a fifty-foot depth would remain constant, no matter what the rainfall in the basin would be?

A. No, not as I understand it; that would be impossible. Its supply must come from some source, and it would soon exhaust it, if there was no longer any supply.

Q. Isn't it possible when you get down a considerable distance that the supply would come from further away than within the basin?

A. Outside of the basin?

Q. Yes.

A. Yes, it is possible that there might some come into the basin from the outside. It is also probable that an equal amount would go from the basin out.

Q. In other words the percolation there would act just like the inflow into the deep wells, would it not? If you get wells sufficiently deep down into the rock strata and different kinds of strata, slate strata, the inflow into that well is not affected by the lack of rainfall on the surface?

A. I don't understand it that way.

Q. In the immediate vicinity, I mean, of the well?

A. Well, it is not affected instantly by a shower in its neighborhood, but its original source is the rainfall, and if there was no rainfall there would be no percolation.

Q. Exactly, somewhere, but not in the immediate vicinity?

A. It comes from somewhere.

Q. It is true, in what they call the arid region east of

the Rocky Mountains, that they are now getting wells at a sufficient depth that have water in abundance, where they never have any water scarcely upon the immediate surface, or for some hundred miles around there?

A. Yes, that is possible.

Q. And if the percolation into the great lakes were of the same character, it would act accordingly?

A. Yes.

Q. Is it possible, Mr. Wheeler, assuming that this inflow into the great lakes around its banks, in the form of what we speak of as percolation, if instead of being what we commonly think of as percolation, that it comes in there in heavy veins as we might say, so much so that it would almost be a stream, is that so?

A. I don't know of any such thing as that; I don't think it is so.

Q. You have seen them dig wells into the slate, and all at once they strike almost a river of water; at least the water comes up in the wells so abundantly so that they do not even have an opportunity to wall the well?

A. Yes.

Q. Is it not probable, not only probable but likely that there are such subterranean streams or veins of water flowing into the basins around the great lakes?

A. I think it is not probable at all; I think it is very unlikely that there is anything of that kind. I am not prepared to say that there is not.

Q. Where you get this water by the boring of wells and the digging of wells, where does the water come from and where does it go to?

A. Why it comes from the surface of the earth in that vicinity somewhere, more or less remote from the well, and where it goes to is usually—it is taken out of the well; there is no stream there, no flowing stream. The well can easily be exhausted; it don't usually amount to much. You cannot pump much water from the well.

Q. You have seen them where they afford considerable water though?

A. Some wells furnish a good deal of water, but nothing like a stream. You can't get enough for a water power out of it.

Q. Have you ever been through the copper mines of northern Michigan, Mr. Wheeler?

A. I have been in some of them, not very thoroughly though.

Q. Are you aware of the depth of those mines?

A. I know the depth of some of them; some are deeper than others.

Q. Some are 2,000 feet, are they not?

A. There are some 5,000 feet; some more than a mile deep.

Q. Are you cognizant of the inflow of water into those mines, at depths far below the level of these lakes?

A. Why, the wet area, the wet depth is less than 400 feet. Usually the miner will say they don't get any water below that. If they get below that they get into the dry dock, I have understood.

Q. Are you personally cognizant of the inflow—

A. No, I never—

Q —into those mines, of water?

A. I never had charge of the sinking of any pits as deep as that. But I know that the first 400 feet is what they call the water bearing depth, and if they get below that they do not expect to have any more trouble with water.

Q. Assuming that there was a stream, subterranean stream flowing into the basin of the lakes, at a considerable distance below the surface, or near the bottom, and that it was a stream of considerable size, would the depth of water above it have any effect upon its flow into the basin?

A. Yes.

Q. What would be that effect?

A. Why, its source would be somewhere higher than the surface of the lake, and if the surface of the lake was increased, then the slope of this stream, this imaginary stream, this supposed stream would be less. If the surface of the lake was lowered, the slope of the stream would be greater and probably its flow would be greater, if its supply remained undiminished.

Q. That is the flow into the basin would be in the reverse proportion to the depth of the water above it?

A. In case the supply remained constant.

Q. That is the pressure of that water above would have an effect on that flow in, would it not?

A. Yes.

Q. And the greater the pressure the less the flow?

A. Yes.

Q. And that would be the effect on any number of these streams of water flowing into the basin of the lake?

A. Yes. It is equally true with a stream flowing on the surface.

Q. Yes, sir.

A. The surface streams just the same.

Q. Exactly; the higher you raise the water in the main body, into which the smaller stream discharges, it has a tendency to block the water in the smaller stream, doesn't it?

A. Yes. It all goes into the lake, just the same.

Q. Eventually?

A. It gets in just the same. That is another question though.

Q. From the surface.

A. Yes, from the surface.

Q. Because there is only so much of it on the surface, and eventually it all gets in?

A. Yes, sir.

Q. Coming back to the question of evaporation just a moment, Mr. Wheeler: The impression which I get from your answer would be that all the water which falls upon the run-off area gets into the lakes, except that which is simply evaporated from the surface?

A. Yes.

Q. Now, as a matter of fact, the relative proportion of the amount of the precipitation upon the run-off area, which actually does get into the lake itself varies greatly, does it not, from season to season?

A. The proportion of the—

Q. Of the precipitation upon the land area in the basin?

A. Do you mean that the evaporation varies, so that the part that gets into the lake varies?

Q. In proportion to the total amount that falls?

A. Why, yes—

Q. Did you use the term, the run-off varies?

A. The run-off, that is a suitable term; why, yes, the evaporation varies from year to year, and if there is a year when there is great evaporation, then there is a smaller proportion of precipitation that gets into the lake, for that year.

Q. Now in other words the proportion in the run-off varies greatly from season to season?

A. Yes.

Q. Well, the level of the lake would be greatly affected would it not, by the proportion of the run-off to the whole precipitation?

A. Yes, sir.

Q. So that as a matter of fact, the same amount of precipitation in one year might affect the level of the lakes a great deal more than the same amount of precipitation in another year, because of the condition of the earth's surface upon which it fell?

A. Yes, on account of evaporation; more evaporation one year than another.

Q. Now the evaporation from the surface of the lake itself depends largely upon what one thing?

A. Why, it depends upon those four elements that I spoke of, but the most important one is the temperature and the second in importance is the rainfall; the third is the wind and the fourth is humidity; and the other elements that affect evaporation are numberless. But the Weather Bureau say that these four make at least nine-tenths of the changes; are caused by these four elements.

Q. What the layman usually speaks of as evaporation, he thinks of that which goes away in the form of vapor; that depends largely upon temperature, does it not?

A. Temperature is the largest of these. It depends very largely on rainfall; the evaporation is very much accelerated by the rainfall. That has been explained to me in various ways, why a rainfall should make increased evaportion, but it does increase it very much.

Q. Around this city, Mr. Wheeler, and in cities surrounding the lakes, south of here and elsewhere, there are a number of artesian wells?

A. Yes.

Q. A number of hundred feet deep. I think some of them in Chicago are in the neighborhood of 1700 feet in depth, comparatively with an inexhaustible supply of water?

A. Are they flowing?

Q. Flowing wells. What would you say was the source from which the water came. Let us assume that they only come within 50 or 60 feet of the surface, then what would you say?

A. Your question is, where does the water come from?

Q. Yes.

A. Why, it is some area that is 50 or 60 feet higher than Chicago at least; may be much more than that. I do not understand geology very well, but the geologists say that artesian wells are caused by an inclined permeable strata of rock, one edge of which is exposed on the surface, and it goes down at an angle, so that it gets lower and lower; and water

percolates in and fills up this strata and it remains there, would remain there infinitely, would be as permanent as the rock itself, until from some cause or other—we will say an artesian well—it is tapped at its lower extremity or somewhere near its lower extremity. Now, water will rise in the artesian well to the same height as the source that filled this permeable strata, this inclined permeable strata.

Q. It will rise voluntarialy without pumping?

A. Yes, without pumping. And when the surface of the earth is lower, where the well is bored, than the source of supply is, then it spouts up and rises above the surface of the earth. And these are not streams of any considerable size; they are soon exhausted. The supply in this permeable strata is generally soon exhausted; but in some of them it is carried on so rapidly from its upper source that the artesian well has a continuous flow; always discharging from it. So I should say that for any of these wells there is some such a phenomena as that. There is an inclined permeable strata that carries the water down to the bottom of it, and its source is higher than the surface around Chicago, and they have been tapped or pierced by an auger and the water comes up and will rise to the same height as the source, whatever that may be.

Q. If the strata, the slant at the angle which causes this artesian effect, as you say, ran into the lake, there would be that discharge into the lake, would there not?

A. Yes, it would be there in the nature of a spring, only it would be under water.

Q. And if a strata started from the bank of the lake, so that the waters seeped above it in a slanting direction, it might be the cause of an artesian well hundreds of miles away?

A. Yes. And I think that I see the point you are making, which is correct. I should say that there may be such things as that coming from outside of what we recognize as the drainage basin. Some water might come into the basin from what we call the limits of it; we haven't got the limits quite right.

Q. Yes.

A. There is not likely to be much of it, and there is as much of it would be likely to go out as come in, and no very great error in taking the limits as we have taken them, as they show on the surface.

Q. But it is not only likely, but more than probable that

there is more or less of that going on, both coming into the lake and going out from the lake?

A. Yes, I should say so.

Q. And that it necessarily follows that these things are some of the elements which enter into that resultant, namely, the elevation of the great lakes?

A. That may enter into it. The flow of water through permeable strata is very slow, very insignificant. I obtained from Mr. Davis of the Geological Survey, only a year or so ago, data in regard to that; and a flow of 12 feet a day is a rapid one, and a flow of only about three feet a day is an ordinary flow.

Q. Would you say, Mr. Wheeler, that if there were a series of wells dug or drilled around Lake Michigan, at say a very short distance, a quarter of a mile therefrom; and that all these wells were what we term ordinary strong wells with a good supply of water, would you say that that water came from Lake Michigan, or was on its way into the basin of Lake Michigan?

A. I should have to examine the case. It would be as likely to be one way as the other.

Q. But there is no doubt is there that all around the great lakes, and within the whole basin of the great lakes, there are innumerable wells all of which are supplied by subterranean supplies, either going into or coming from the great lakes?

A. Yes.

Q. So that it follows that there is an outlet or outflow, with an inflow through the entire water shed area of the great lakes, underneath the surface of the earth?

A. Yes.

Q. And the amount of that out-flow—

A. Is insignificant.

Q. —is unmeasured?

A. Oh, excuse me; I thought you were looking for the word.

Q. Is unmeasured, is that right?

A. No, it is insignificant.

Q. No, isn't it unmeasured?

A. Yes, insignificant things can be unmeasured.

Q. And being unmeasured, the amount of it is unknown?

A. Yes.

Q. Your table that you referred to will give the discharge through the St. Mary's River for the sixteen years of which you spoke?

A. Yes, through all the connecting rivers.

Q. Are there available equally reliable statistics showing the discharge through the St. Clair River since 1900?

A. Yes.

Q. Do you know, Mr. Wheeler, whether the discharge through the St. Clair River in, say the last five years, has been greater on an average or less than for five years preceding 1900?

A. I don't know.

Q. Would these tables show?

A. Yes; it is exceedingly easy to determine that.

Q. Assuming that the discharge has been equally as great in the last five years as in the five years preceding the opening of the main channel of the sanitary district, would you say that additional precipitating upon the basin accounted for that fact?

A. I should most likely say that.

Q. If the additional precipitation would not account for it then what would you say?

A. Well, then, I would say that it did not occur.

Q. Well, then, you say that the data are wrong if they gave that result?

A. Something wrong somewhere.

Q. Something wrong somewhere?

A. Yes.

Q. And could not be accounted for, is that it?

A. Yes.

Q. I understood you to say on your direct examination that notwithstanding improvement and enlargements in the Detroit river and the St. Clair river for fifty years, that there had been no appreciable change in the discharge through there, is that right?

A. Yes.

Q. Have you in mind substantially the change which has been effected within that period of time in the cross-section of those streams?

A. No, not completely in mind.

Q. Could you give us your best offhand guess?

A. Well, it is certain that docks, many docks and piers have been built out from the shore, opposite Detroit and Windsor and all the cities along the shore. That has a tendency to contract the width of the stream, at least; and I can't give you any estimate of the amount.

Q. Where is the governing section of the discharge between Lake Huron and Lake Erie?

A. I always want that term "governing section" defined before I begin to talk about it, because I make a good many mistakes when I treat it differently from the way my questioner means. What do you mean by the term "governing section"?

Q. I will be the Yankee and ask, what do you mean by the governing section?

A. I can't tell you very well. I have had a good many long discussions with Mr. Haskell on that very question. I know I did not think as he did, but I will say that there is a section at Port Huron where it has the greatest velocity; that is it is the smallest section in the river and has the greatest velocity.

Q. Well, the layman's idea of the governing section would be the smallest section I would say?

A. I would say then at Port Huron.

Q. A section through the stuff had to go, and for which more room to fill up the rest of the channel—

A. I would say that was at Port Huron.

Q. At Port Huron?

A. Yes, in the rapids at Port Huron.

Q. Have you now in mind, Mr. Wheeler, what change, if any, there has been in the area of the cross-section at that point, since the improvement of the great lakes began, by the federal government?

A. Why, none at all. I think I stated that, that Mr. Haskell looked that up and made a report in—I gave the date of it; I have forgotten it now—on which he testified that there had not been any change in that cross-section; and I have not done the work myself, but I presume that is the case.

Q. I understood you to say, however, that the fall from Lake Huron to Lake Erie had remained substantially the same?

A. Yes, it was substantially the same; it is within a very few hundredths of a foot the same within the last ten years; the difference in the level between the two lakes, the mean difference in the last ten years, is within a very few hundredths of a foot the same as it was before 1880, the ten years before 1880.

Q. I understood you to say a few moments ago, changing

the subject for a minute, that there had been a gradual increase in the capacity of the vessels of the great lakes?

A. Yes, there is quite a uniform increase in them.

Q. In your study of that question, is there any particular period of time in which you would say that there had been a greater increase proportionately than at any other period of time?

A. Why, yes, I should say that the years that followed the opening of the Poe lock, and certain other improvements in the river, gave suddenly an increased draft; a possible draft of three or four feet, three feet about, and the increase in the size of the vessls was very rapid at that time. They built them rapidly, so as to utilize this increased draft. Otherwise I do not know that I could mention any particular era when the increase began.

Q. When was the Poe lock opened?

A. 1896.

Q. So that just at that period there was a spurt in the efficiency of the freight carrying vessels?

A. Yes, if I remember right.

Q. It would be 1896, they say?

A. 1896, I should say.

Q. But aside from that period, accounted for as you say, there has been a gradual development, and increase in the capacity of vessels?

A. That is as I understand it. I am not very conversant with it, but I think that is the case.

Q. What was the capacity of the Poe lock, so far as permitting the passage of vessels, when it was first opened; what draft vessels?

A. Twenty-one feet.

Q. When it was first opened?

A. Yes.

Q. Is it the same now?

A. No, it has diminished; the capacity now is considerably less.

Q. Why is that?

A. The improvements in the St. Mary's River have diminished the slope. The water used to be about two to three feet higher at the foot of the locks than it is now, so the lock has lost that capacity, a couple of feet perhaps.

Q. That was occasioned by a change in the slope in the St. Mary's River?

A. Yes.

Q. By increasing the cross-section of it, is that right?
A. Yes.
Q. What was that done for?
A. For the deepening of the channel, and the improvement of the channel; making the new one at West Neebish.
Mr. Wilkerson: Was that a government improvement?
A. Oh, yes, that was a government improvement.
Mr. Lindley: The improvement was supposed to more than offset the detriment occasioned by the lowering of the water at the miter-sills?
A. Yes.
Q. What was the nature of this improvement?
A. Dredging out channels to a greater depth than they had had before; dredging out channels, the West Neebish is one of the largest ones.
Q. The west what?
A. The West Neebish, we call it; that is the new channel that Mr. Sabin opened two years ago.
Q. Was the capacity of those channels before the improvements made therein less than the capacity over the miter-sill?
A. You mean the draft for boats?
Q. Yes.
A. Oh, it was about the same. The improvements were kept along somewhat together. Sometimes the dredging was not completed, or before it was completed there might be a shallow place in the river which was lower than the miter-sill of the lock; but at the present time there is not any such place; the St. Mary's River itself is everywhere deeper than the lock.
Q. You were stationed at the Sault, you say, for a number of years?
A. Yes.
Q. I wanted to ask you a little more particularly on that, more for my own information than anything else, what you know about the current between Lake Huron and Lake Michigan at Mackinac?
A. Through the river?
Q. Through the Straits of Mackinaw?
A. Oh, through the Straits of Mackinaw?
Q. Yes.
A. Why, I don't know anything from direct observation. I have seen some discussions in regard to it, and I have heard from captains, vessel captains; and have no doubt but that the current is sometimes one way and sometimes another;

but a majority of the time it runs from Lake Michigan into Lake Huron, and it is affected by the wind; certain winds will cause the current to run the other way for a short time, but most of the time it runs from Michigan to Lake Huron; that the drainage basin of Lake Michigan is such that we may compute a considerable discharge through there, and consequently there is—must be some current flowing through, because the waters of Lake Michigan do get into Lake Huron, and they must move through the Straits to get there.

Q. Is there an official record kept by the Federal Government of the movement of the water at that point, showing the current?

A. No, there is not, that I know of.

Q. What is it?

A. There is not. I think some sort of record of that kind was kept by the railroads, when they were establishing ferries a number of years ago, but the government never did that I know of.

Q. Mr. Wheeler, you testified yesterday, if I recollect right, that the computation which you made from the data obtained from the survey of the Great Lakes, something of that kind, from which these tables that have been referred to were produced, was in your judgment within 1 per cent. of accuracy. Is that right?

A. Why, not fully right. I did not say that I thought that the result itself was within 1 per cent.

Q. No, the computation within 1 per cent.?

A. The computation——

Q. That you made?

A. ——that I made, indicated that the result which those observations showed was within 1 per cent. of being right.

Q. Yes, sir.

A. Some of them were that way; some were 20, but there were some that was 1 per cent., I know.

Q. You don't know what degree of accuracy the data themselves represent?

A. In the sense that I made them myself I do not; but in the sense that I know that they were made by competent men, and they have been handled by competent men, I do know that they are trustworthy and reliable.

Mr. Williams: Mr. Wheeler, you just testified a moment ago that the result of the observations made tended to the belief that the waters of Lake Michigan run into Lake Huron?

A. Yes.

Q. And I believe you have testified that generally speaking Lakes Huron and Michigan form one body of water?

A. Yes.

Q. Are you familiar with the fact that in the government reports of elevations of these two lakes, they are given as varying to the extent of five one-hundredths of a foot?

A. No, I am not familiar with that.

Q. Are you familiar with the fact that in the report in Bulletin No. 16 of the Survey of the Northern and Northwestern Lakes, page 97, issued in April, 1906, it appears that the elevation of Lake Michigan is—the mean elevation of Lake Michigan is 581.34 feet, and that the mean elevation of Lake Huron is 581.39 feet, showing the elevation of Lake Huron to be higher than that of Lake Michigan?

A. No, I was not familiar with that.

Q. And you have no explanation to offer?

A. No.

Q. As to why those figures are so given out?

A. No, I didn't make them, and I don't know whether they were so given.

Q. On page 249 of the same document, the discharge through the St. Clair River is given as 206,200 cubic feet per second and the variation or the increase of discharge per foot rise of the lake is given as 19,238 cubic feet per second. Do you know, or have you any information as to the data from which that figure of 19,238 cubic feet per second was obtained?

A. No, I am not familiar with that.

Q. Do you know who made the computations that are contained in this report?

A. No, I do not. May I see what report it is (examining same)? I am not familiar with that at all. That is the Bulletin issued for the benefit of navigators, and I have not had anything to do with it.

Q. What is the relation, if any, between your office and the duties that you perform, and the duties of the Lake Survey?

A. The Lake Survey is engaged in surveying and mapping the harbors and the channels; and the office in which I am employed is engaged in the improvement, the deepening of the channels and dredging them; improvement of harbors.

Q. Are there any surveys made in your office, in your department?

A. Not extensive and general ones. In doing our work it is always necessary to make small surveys in the vicinity

of our work; such as we make for estimates and so on; but none that are incorporated in the published map.

Q. Do you know the method or manner of making the observations of the discharge through the St. Clair River, to form the basis of the plates that have been introduced in evidence?

Q. Yes, I know the general method.

Q, At what point in the St. Clair River was the discharge measured?

A. There have been a number of cross-sections where the discharge has been measured. The principal one is below the rapids and opposite the City of Port Huron, from one to two miles below the rapids.

Q. Now will you state in a general way the method of making these observations. I believe you stated yesterday that first you have a gauge reading indicating the elevation of the lake?

A. Yes.

Q. Now how frequently is that gauge read, or is it read constantly?

A. Why, at Port Huron they have a self-registering gauge, read continuously there, but usually when they are making these observations, it would be read every quarter of an hour. An observer is stationed at a gauge to read it and record it.

Q. What instruments would be used in the measuring of the discharge?

A. The principal instrument is a meter, which determines the velocity. The discharge is obtained by getting the area of the cross-section, and the velocity in that area, and those two factors multiplied together give the amount of the discharge.

Q. Are you familiar with the meters that were in use at the time of the observations that are platted upon these plates?

A. Yes, somewhat familiar with them.

Q. What meters were used there?

A. At that point the Ritchie-Haskell meter, as it is called.

Q. That is the meter invented by Professor Haskell?

A. Yes.

Q. How many of those meters would be used at one point, I mean in the making of one observation there?

A. Twelve or thirteen I think were often used. I don't know how many.

Q. Do you know whether the measurements would be taken of all these meters at the same time?

A. Yes, of a large number of them at least at the same time.

Q. And how far apart would they be located?

A. Well, often they were on one vertical line. Perhaps there would be six on a vertical line, so as to get the velocity simultaneously at six different depths, and the sections in which they were read were 100 feet perhaps, so that transversely across the river they would be perhaps 100 feet apart.

Q. How wide is the river at the point you have mentioned, where most of these observations were probably made?

A. Oh, 1,600 to 2,000 feet, somewhere I should imagine.

Q. And in a vertical line from one shore to the other these meters would be used at varying depths?

A. On each vertical line. When they were observing at a certain point in the cross-section, they did at times have these meters suspended vertically, one of them at the bottom, or as near the bottom as it was safe to use it, and the others at uniform distances perhaps above it, and then in the neighboring section, say, 100 feet further, this operation would be repeated in this place, until the whole section of the river had been so occupied.

Q. What is the greatest depth of the river at that point?

A. I think something like between 40 and 60 feet; I don't know what the depth is.

Q. And that is approximately the center of the stream?

A. Yes.

Q. These observations were taken at stated points, each one at a different distance from the shore, to reach the other shore?

A. Yes.

Q. And how near together, if you know?

A. I don't remember that. I did not take these observations myself. You will have before you a man who knows all about it, who did do it, and whose information would be much more accurate than mine.

Q. Have you an opinion as to the degree of accuracy obtained from the observations made of the discharge, by the use of these meters?

A. Yes.

Q. What degree of accuracy would you say was attained?

A. I should say that they could determine the total discharge at a certain date, a certain time, within 3 per cent. I don't remember what they have assigned—the probable error that is given in their work; that can be easily found.

Q. You have a higher opinion of the Haskell meter than Professor Haskell himself, then?

A. Perhaps I am giving it better than it should be. It is not at all surprising that I do have a higher opinion of Mr. Haskell than he has himself. He is a very modest man.

Q. Have you an opinion as to the degree of accuracy of the discharge measurements in the St. Clair River?

A. Yes, but I would not be able—it would not be at all valuable to give an estimate of the percentage of error, by me, when these matters are accessible and can be known correctly.

Q. Do you think it is possible to know correctly and absolutely the degree of accuracy of this discharge measurement?

A. Well, I will have to explain that to you. I think it is possible to know the probable error; that is, to know a quantity which the truth is as likely to exceed as it is to fall short of; that is all that computers claim for it. An absolute truth is not reached anywhere by any one.

Q. According to your computations, using these plates that are introduced in evidence as a basis, the effect of the diversion of 10,000 cubic feet per second at Chicago upon the level of Lakes Michigan and Huron would be about four and seventy-six one-hundredths of an inch?

A. I think that is what I made it.

Q. At what elevation do you compute that?

A. I think that is true for all the elevations within the range that we have been able to observe it; I do not observe any change.

Q. Is there any difference in the effect of that diversion when the lake is, say, a foot higher than the average elevation?

A. No observable difference.

Q. And the same would be true if it were a foot below the mean elevation?

A. Yes, I think so. These results are only expected to be used within the range in elevation that we have observations. We cannot extrapolate and get it correctly outside of that range.

Q. What is the range of elevation of Lake Michigan, that is within the experience of your office or yourself?

A. I think the records show something like five feet but that should be—the ordinary range is less than three feet.

Q. What would you say as to the natural oscillations in

Lake Michigan and the extent of a change of level, oscillations in the level of Lake Michigan?

A. I don't know that I get the question quite right.

Q. Is it true that the level of the lake frequently changes within a very short time.

A. Oh, yes, there are changes, wind changes, barometric changes; that is in parts of the lake. I do not think that the mean level of the entire lake changes very much in a short time. It takes considerable time for that to be effected; but it is only in parts of the lake.

Q. Do you know the extent of that variation?

A. You mean in parts of the lake?

Q. Yes.

A. Oh, there are known cases of two or three feet.

Q. And continuing for what length of time?

A. Oh, several hours. In Lake Erie, I think wind storms have produced still greater effects than that. They have made one end of the lake five feet lower than the normal and the other end five feet higher, making a slope of 10 feet in the lake.

Q. Are there any causes that occur to you for these oscillations, other than wind?

A. Well, there is the well known seiches.

Q. From the plates that are before you and from which you have testified, is the effect of a diversion at Chicago more or less appreciable in Lake Erie than in Lake Michigan?

A. The difference is so slight that I won't say which is the larger.

Q. I think you testified that the effect of each 1,000 cubic feet diversion would be about five-tenths of an inch in Lake Michigan, and fifty-five one-hundredths in Lake Erie, per each 1,000 cubic feet diversion?

A. There is a slight difference between the two lakes; the effect would be a little greater on Lake Erie.

Q. Taking a diversion of 4,000 cubic feet per second, the effect on Lake Michigan would be approximately two inches, and on Lake Erie two and a half inches?

A. A little more on Lake Erie than Lake Michigan.

Q. Two and two-tenths inches. Now, the lowering of the level of Lake Erie two-tenths of an inch more than the lowering of the level of Lake Michigan would, in itself, have a tendency to lower Lake Michigan further, would it not?

A. Yes, they interact on each other infinitely.

Q. What is the level, or the elevation of Lake Erie as compared with Lake Michigan?

A. Lake Erie is about 8½ feet lower than Lake Michigan.

Q. Have you read the testimony given in this case by Professor Haskell?

A. No, I have not.

Q. Professor Haskell in his testimony states that the effect of a diversion at Chicago would be about 80 per cent. in Lake Erie of what it would be in Lake Michigan. He had before him the same plates that you have. I will ask you whether or not you can account for the difference of opinion that is apparent between your opinion and that of Professor Haskell.

A. No, I have no means of accounting for that.

Q. What would you say as to the accuracy of this general statement, Mr. Wheeler, a statement made by Mr. Wilson, a witness called on behalf of the Government: "In a series of reservoirs such as the Great Lakes are, the effect of diversions generally decrease, as they go down to the source." What would you say as to the accuracy of that statement?

Mr. Wilkerson: Whose statement is that?

Mr. Williams: Mr. Wilson's, Secretary of the International Waterways Commission.

A. If the increment increased as it went towards the outlet, that would be true; but whether it does or not must be determined by the actual conditions as they exist, by measurement. In going from St. Clair to Niagara the increment diminishes; it increases again in the St. Lawrence. Therefore his statement would be incorrect for the Erie section, and true for the St. Lawrence section. But that it is generally true in all systems, I should not agree with that at all. I should want to have it measured, and it might or might not be true.

Q. Would you say that the effect of a diversion at Chicago would be more or less noticeable in the Detroit River than in the St. Clair River?

A. No, I should say that there was no difference.

Q. They would be both the same?

A. They would both probably be the same.

Q. And would it be any more or less noticeable in either the Detroit or St. Clair Rivers than in Lake Michigan itself?

A. Oh, it might or it might not. That is a question that involves the channel conditions to such an infinite extent that no one can give any answer on that at all. If you would

care to look at a curve that was made by the deep waterway people from actual observations, showing the change in level at all points in the St. Clair and the Detroit River for a change in level in Lake Huron and Lake Michigan, you would see that it is different at every point between Port Huron and Gibraltar, and that can only be explained from the character, nature of the channel, its cross-section and the slope and so on.

Q. Would you say then that it was practically impossible to determine the relative effect upon the level of those rivers?

A. Yes. If you like I will get that illustration that I speak of, and I think perhaps you will understand my position better if you will look at it (producing same). It is impossible to determine it accurately, with any very great degree of accuracy, because you can see they do not obey any law between them; that we have discussed and demonstrated to an extent, so that we cannot divide it up into sections and give the functions of each section.

Mr. Wilkerson: You do not mean to say it is impossible to determine whether there is any effect?

A. Let me hear the question once more.

(Question read to the witness as follows: "Would you say then that it was practically impossible to determine the relative effect upon the level of those rivers?")

Mr. Williams: In its relation to the effect upon Lake Michigan; that is what proportion of the effect that is seen in Lake Michigan would be observable on those rivers?

A. On the rivers?

Q. Yes.

A. Well, I would not say it was impossible to determine it approximately.

Q. Accurately.

A. Accurately, it is impossible to determine it accurately; that is for me to do it, because I have not the data.

Q. That is what I mean.

A. I can determine it approximately.

Q. Would it be possible to determine accurately the effect, relative effect upon the level at any one of the critical points mentioned by you?

A. It would be possible, if the proper observations were made at that point.

Q. Do you know whether the proper observations have been made at those points?

A. At many of those points, no observations have been made, and the estimates that I have given, I have given from

the geographical location of the point. They are not expected to have the accuracy that those points which were determined by careful observations have.

Q. What is the low water period in Lakes Michigan and Huron?

A. The recent low water period was in 1895 if that is——

Q. During what seasons of the year would you say that the water is at its lowest stage?

A. I don't remember what month it is; February, I guess.

Q. And generally speaking during the winter months?

A. Yes.

Q. Now have you an opinion, and if so what is it, as to why the water in Lake Huron and Lake Michigan is, generally speaking, at a lower stage during the winter months, when the ice effect would be most noticeable in diminishing the outflow through the St. Clair River?

A. The elevation, as I have had occasion to say, is the algebraic sum of all the causes, and I suppose the reason is the algebraic sum of all the causes producing it.

Q. The tendency of the ice gathering in the St. Clair River is to diminish the outflow through the St. Clair River, isn't it?

A. Yes.

Q. And the diminishing of the outflow would naturally result in raising the level of the lakes, Huron and Michigan?

A. Yes, and then if you ask me the still further question, why don't it make them higher, I say it is because the total height depends on other causes as well, upon the algebraic sum of all of them; that one is not sufficient to do it.

Q. Do you know what the aggregate amount of the storage in Lakes Huron and Michigan was for a period of three years, as shown in the report of the Chief of Engineers for 1903; the storage for the months of December, January, February, March, April and May, caused by the diminished flow, in consequence of the ice in the outlet of Lake Huron?

A. I don't remember what that was.

Q. Suppose that the total stored water for those months aggregated more than the entire year's supply for the Sanitary District's main channel, what would you say as to the effect of that diversion through the main channel upon the level of the entire system of great lakes?

A. How many cubic feet was the diversion that you speak of?

Q. Assume that the diversion was 10,000 cubic feet.

A. I think that I have stated that several times, what it would be. It would be something like five inches.

Q. Would it make any difference that there was more than enough water stored in those lakes during those months——

A. On the effect the diversion had?

Q. Yes.

A. Not a particle. The effect went into the algebraic sum and helped to make it smaller.

Q. What percentage of the effect of the diversion at Chicago of a given amount of water from Lake Michigan would be noticeable in the St. Lawrence River?

A. The amount, do you mean, or the effect on Lake Ontario?

Q. I think you testified with reference to the St. Lawrence River?

A. I don't think I testified anything definite because I have not looked that river up; but the discharge through the St. Lawrence River would be diminished by the same amount as the diversion. Its effect on Lake Ontario would not be as great as it would be on Lake Erie.

Q. You gave the increment of discharge in the St. Lawrence River?

A. Yes.

Q. And how much is that?

A. Twenty-eight thousand and something; I don't remember.

Q. And if you diverted 10,000 cubic feet at Chicago, in your judgment there would be ten twenty-eighths of a foot lowering in Lake Ontario?

A. Yes.

Q. And have you any information from which you can give an opinion as to what the extent of the lowering would be in the St. Lawrence River itself?

A. No, I have not; perhaps such information is available but I don't happen to have it.

Whereupon an adjournment was taken to April 21, 1909, at the hour of 10 o'clock a. m.

April 21, 1909, 10 o'clock a. m.

Parties met pursuant to adjournment.

EBEN S. WHEELER resumed the stand and was further cross-examined by Mr. Williams as follows:

Q. Mr. Wheeler, on your direct examination, I believe that you referred to a report made by you in June, 1903, and shown in Appendix FFF of the report of the Chief of Engineers for that year?

A. Yes, I made such a report.

Q. And that was the report that is contained from pages 2855 to 2862, inclusive, of that volume, which I have indicated?

A. Yes.

Q. What have you to say as to the reliability and accuracy of the computations made and shown and the facts set forth in that report, at this time?

A. The computations were very carefully made and were checked; and contain, so far as I know, no errors.

Q. As to the data contained in the report, what do you say as to the reliability of that data, that is used in the making of the computations?

A. I will say, first, that I believed it to be at that time, and I still believe it to be, the best extant. I will say, second that some of the observations had greater accuracy than other portions; that probably some part of the data, there was an error of 20 per cent.; some part of the data would lead to errors of 3 per cent.

Q. Will you indicate as to the different subject-matters, which data have a probable error of 20 per cent. and which 3 per cent.?

A. I should say that data relating to meteorology.

Q. What percentage of error would you say there was in the data from which you make your computations respecting evaporation?

A. I should not be surprised if there should prove to be 20 per cent. error in that; there may be much less.

Q. And what percentage of error would you say there was in the data respecting rainfall?

A. That is a part of your first question, as I understood it. That includes rainfall.

Q. Evaporation includes rainfall?

A. Yes, it is a function of rainfall. At any rate the answer applies to it.

Q. About 20 per cent.; that is it is possibly 20 per cent. What percentage of error would you say there was in your data from which you made your computations respecting the discharges through the St. Clair, Niagara and the St. Lawrence Rivers?

A. Probably less than 10 per cent.

Q. What percentage of error in your data is there as to the areas of the lakes, Lake Erie?

A. I didn't understand that.

Q. What percentage of error would you say there may be in your data respecting lake areas?

A. That is given in the report. I do not remember it.

Q. I think you gave the areas, but not the probable error?

A. I think I did, page 2856.

Q. You say in order to make an approximate estimate of the error in the determined area of the drainage basin, it may reasonably be assumed that the best located part of the boundary is never more than six miles in error, and this not oftener than once in 100 miles. And you said then that it is probable that the areas are correctly determined within less than 2 per cent.?

A. That is of the drainage basin.

Q. That is the drainage basin. Now as to the surfaces of lake areas, does the surface of the lakes——

A. I think you will find the same thing, the method of determining them is given there. You will find it is stated they were divided into rectangles that were bounded by parallels and meridians.

Q. Can you by referring to your report answer definitely the question as to, in your opinion, a probable percentage of error in the determination of lake areas?

A. Well, I say this much about it at that time, and I could not say any more or better at the present time: "Quadrilaterals, of one degree or less in extent, bounded by meridians and parallels were selected, so as to completely cover the basin. This gave a polygon, the sides of which were meridians and parallels. The total area of this polygon was determined accurately from geodetic tables of areas. Those small parts of the polygon which extended outside of the boundaries of the basin were measured with a plainimeter and subtracted; the remainder being the area of the basin. This work was done with care and checked, and it is believed that the areas of the

lakes and basins as above given on Plate 1 are as accurate as extant maps will permit." I could not say any more than that. A long time has elapsed since doing the work, and I knew better then than now.

Q. You say that the computations made as to lake areas were as accurate as those made relating to the drainage basins?

A. Yes, they are more accurate.

Q. And the determinations would be more accurate?

A. Yes.

Q. What would you say as to the percentage of error in the determinations arrived at with reference to the elevations of the several lakes mentioned in your report?

A. Well, I don't know that I would say anything about it. If one knew what his errors were, he could give an accurate result. It is an unknown quantity.

Q. You have an opinion with reference to it, the same as with reference to the other matters concerning which you have testified, where there was a probable percentage of error?

A. Well, I should say that it was less than 10 per cent.

Q. That is the percentage of error. Does that refer to the computations or to the data from which the computations were made?

A. It refers to the data.

Q. The computations you consider absolutely accurate?

A. So far as I know no errors were left in it.

Q. Is 10 per cent. as near as you would want to testify as to the probable error in the data respecting lake elevations?

A. Yes.

Q. Are we to understand then that these figures shown on page 2867, showing the mean monthly elevation of Lake Superior above the locks at St. Mary's Falls canal, might possibly be an error to the extent of 10 per cent.?

A. You asked what my opinion was, and I said my opinion was it would be less than 10 per cent.; so you are at liberty to understand that.

Q. From the data before you, at the time of making that report, would you now therefore be unwilling to say that, taking, for instance, the elevation of Lake Superior for December that figure, 602.14, might be 662.14 or 552.14?

A. I should be quite willing to say that it would be less than 10 per cent., but I am very unwilling to say what it would be or that it would be more——

Q. I said that it might be either more or less to the extent I mentioned?

A. I am unwilling to testify to that. I think it is less; that is my opinion.

Q. Are you willing to express an opinion that there is a percentage of error in that data of less than 10 per cent.?

A. No.

Q. Do you believe, Mr. Wheeler, that the actual elevation of Lake Superior was either 10 per cent. more or 10 per cent. less than the amount shown by the data to which your attention is called?

A. I haven't any fixed belief on that question.

Q. Are you familiar with the methods by which these elevations were determined?

A. Yes, somewhat familiar with the methods.

Q. Now, taking the Table 4 shown on page 2870 of this report, relating to the mean monthly elevation of Lake Erie at Cleveland, would you answer the questions as to the probable error in the data as to those elevations in the same manner that you did with reference to the data respecting the elevations of Lake Superior?

A. Yes. I have no means of determining it.

Q. And the same would be true as to the elevations in Lake Huron?

A. Yes.

Q. And Lake Ontario?

A. Yes.

Q. Now suppose that as a matter of fact the elevation of Lake Huron was actually 10 per cent. greater, higher than that shown by the data here submitted, and that the elevations of Lake Erie were actually 10 per cent. less than those shown by these tables, would you say then—what would you say then as to the accuracy of the computations, the determinations, made by you on the basis of that data?

A. Why, I should say that the computations were entirely accurate.

Q. As to the results obtained?

A. I should say that the results had had the errors of the observations in them.

Q. Do you think that it would be possible, Mr. Wheeler, that there would be a difference of over 100 feet in the elevations of Lake Huron and Lake Erie?

A. Lake Huron and Lake Erie, a difference in the elevations of over a hundred feet?

Q. Yes.

A. No, I don't think there would likely be any such difference as that.

Q. And yet if there was an error of 10 per cent. in the data respecting the elevation of Lake Huron, and an error in the other direction of 10 per cent. in the elevation of Lake Erie, as shown by this data, it would show a greater difference than 100 feet?

A. I said that I thought it would be less, but I am not inclined to tell you what the error of those observations was, for I know nothing about it; it is an uncertain question.

Q. How much less would you say than 10 per cent.

A. I would not like to say. I can only give you an opinion within limits. This accurate knowledge of the error is impossible.

Q. But 10 per cent. is as near an accurate answer to the question as you would care to go?

A. I don't care to make the limits any nearer.

Re-direct Examination by Mr. Wilkerson.

Q. In your cross-examination yesterday, Mr. Wheeler, you were asked some questions and made some replies with reference to alleged or possible seepage into the lake. What have you to say further on that subject with reference to the effect of that upon the diversion of this water at Chicago?

A. I should say that there is a possible seepage into the lake; that a part of the precipitation may be returned, or get into the lake in that way; that it is entirely immaterial whether it gets in under ground or in surface streams. It has no effect whatever on the Chicago diversion, or in other words the Chicago diversion influences the level of the lake just the same, whether there is much or little seepage.

Q. That is to say if the effect of a diversion of a quantity of water from the lake at Chicago was to lower the elevation of the lake by two inches, that effect would be the same whether all the water came into the lake either by rainfall on the surface, by flowing in on the surface of the land, or whether it seeped in. Is that what you mean?

A. That is what I mean.

Mr. Williams: I object to counsel framing an answer for the witness, and testifying himself. I object to the form of the question.

Mr. Wilkerson: Q. Now, Mr. Wheeler, on yesterday you

were also asked some questions with reference to the elevation of Lakes Huron and Michigan during the ice period, as compared with the elevation during the open period. And you made some explanation of the factors which caused the holding back of the water by the ice during the ice period, not to have the effect of actually raising the elevation of the lake. Now what in your opinion is the cause of that condition?

A. I don't know that I clearly understand the question.

Q. You said that the fact was that during the ice period, the elevation was lower than it was during the other period, as a matter of fact, although the ice did hold the water back?

A. I don't remember that I said that; it may on occasions be that; it is not necessarily that way.

Q. It is that way sometimes?

A. It is that way sometimes.

Q. When that is the case, to what is that due?

A. It is due to the other elements that enter into the elevation of the lake surface; the ice disturbance is only one, and the final effect on the lake surface is the difference between all those that raise it, and all those that lower it.

Q. And the fact that the snow does not melt in the winter would be one of them, I assume?

A. That would be one. That is when it is stored on the shore it permits the lake to run down; when it melts and runs off, it has a tendency to raise the lake.

Q. I would like to ask you a few questions in reference to the elevation, with reference to the probable error in these figures found in this report of 1903, so far as they relate to the elevation of the lakes. Now I understood you to say that you were unwilling to express an opinion that the figures as set down were more nearly accurate than say within ten per cent. of the truth?

A. I don't think I said that. I said I was willing to express an opinion that I expected that they were.

Q. They were within—much below the ten per cent.?

Question objected to by counsel for the defendant.

A. That they were below 10 per cent.

Q. Now the figures that are set down here show the elevation of these lakes in the first place above the sea level, is that right?

A. Yes.

Q. Then there is also a statement of the elevation of the lakes in relation to the locks at St. Mary's Falls, and at Sand

Beach; that is with reference to zero on the gauges at those points?

A. I would have to look at it to see. (Referring to same.)

Q. There is a statement at the head of those columns there, one relating to—

A. These figures have reference to sea level. That means that it is 602.60 of a foot above sea level.

Q. Now, if you take as a standard and assume the accuracy of that figure, the elevation of the locks above the sea level, the wall of the lock above the sea level, then the difference between that figure and the figure which is put down as above the sea level would be the elevation of Lake Superior above that lock wall?

A. Yes.

Q. Did you have charge of these gauge measurements at any time?

A. Yes, for some time.

Q. I wish you would tell us just how those are made, just how you go about determining the elevation of Lake Superior below the lock wall?

Mr. Williams: I object to the question on the ground that it is not re-direct examination.

Q. Answer the question?

A. There is a staff gauge installed at the head of the canal, with a scale with a zero, and the elevation of the zero above the level of the sea has been determined by precise levels. The observer takes a scale resembling a yard stick somewhat, and he measures the distance between the surface of the water and the zero of the gauge which he records in a note book. This he does three times a day. That is one form in which the measurements are made; and that was all the form for many years. But during a part of the time there has been a self registering gauge established which records the elevation in a continuous line, so that the elevation can be found at any instant of time. But the former method enters into these tables much more than the latter one does.

Q. When you have three readings a day, you make a mean of them do you, monthly mean?

A. Yes, that is reduced to a monthly mean and those monthly means appear in those tables.

Q. Now, if we were to assume the accuracy of the figure which is put down as representing the level of the wall of the lock, the elevation of the wall of the lock above sea-level, and the figure which it was desired to obtain was one which ex-

pressed the difference between that and the level, we will say of Lakes Huron and Michigan, and of Lake Superior, what would you say as to the accuracy with which the figure representing that difference could be stated in, we will say, hundredths of a foot?

A. I could say that the work is done by competent observers and the record is accurately made and is properly reduced, and as to what the error which might come in from all other sources in the observations is, I don't know,—I don't like to state. You are asking me something I would like to know about, but I don't.

Q. Do you think that figure has been determined with respect to the elevation of the wall of the lock within one-tenth of a foot?

Mr. Williams: I object; wait a minute.

A. I don't remember—

Mr. Williams: I object to the question as leading, and not proper re-direct examination.

Mr. Wilkerson: Answer the question.

A. I don't remember what the derived probable error is—it has been obtained and can be found in the reports. I should imagine it would be less than a foot, certainly less than two feet. That is an opinion only.

Q. The thing that I want to have clear in the record, Mr. Wheeler, on this question of probable error is to have you explain, if there is any further explanation—if there is anything further that may be added to what you have stated already, the difference between the term "probable error" as you used it in referring to these figures, which represent the elevation of the surface of any one of the lakes above sea level and the term "probable error" as you used it with reference to a figure which will express the difference between the elevations, we will say, of Lakes Michigan and Huron and Lake Superior, or Lakes Huron and Michigan and Lake Erie, without regard to the absolute accuracy of the figure with respect to the sea level.

A. The probable error of the observation is the probable error of that part that was observed. For example, if the difference between the zero of the gauge and the water surface is one foot, and the observer measures one foot and records it, and you ask me the probable error of that observation, and I say that it is less than ten per cent., I mean that I think he has measured it within one-tenth of a foot. It is

measuring the quantity of the thing and observed to which the probable error refers.

Q. And that is what you had in mind when you used the term ten per cent.?

A. Yes.

Q. Now having three observations a day, that would run up to ninety observations in a month, what would you say as to whether or not the probable error in that number of observations would fall much or little within the ten per cent. limit which you named?

A. I should expect, as the observers are competent and careful, that it would be less than ten per cent.

Q. Well, then, when you were speaking with reference to the probable error in these tables, showing the mean elevation of the lake, do I understand that you used the term "probable error" in the sense which you have last defined it, taking its relation to the thing which was observed—

A. Yes, sir.

Q. —and not to a probable error of ten per cent. of 602 feet for instance, when the subject under consideration was the difference in the level between Lake Michigan and Lake Superior—

Mr. Williams: Just a moment; I object to the question as improper in form—

Mr. Wilkerson: I wish you would just explain fully, I want to get here a precise statement of what you mean by that term "probable error."

Mr. Williams: I want the record to show that I protest against counsel putting words in the mouth of the witness and telling him what he wants him to testify to. It has been done repeatedly, and it is becoming worse and worse as we go along.

Mr. Wilkerson: I think counsel, both counsel and the witness, are amply able to take care of themselves, and will be, when the record is submitted to the court. Proceed with your explanation, Mr. Wheeler.

A. Is the question to be answered?

Q. Yes, sir.

A. The probable error of an observation is the probable error of the thing observed. It is not the error of a quantity that may be made up of the observation and many other things added to it; it is the thing observed. That is what I mean by probable error. As I said before, if we measure the distance between the surface of the water and zero, and

that distance is one foot, and the probable error is less than ten per cent., I should say that it was less than one-tenth of a foot. Now it would be easy to determine the distance of the zero of the gauge from the center of the earth, and insert that in the table, and then my statement that it is less than ten per cent. does not mean one-tenth of the distance to the center of the earth.

Q. Certainly; but it means ten per cent. of the thing which has been observed?

A. Ten per cent. of the thing observed. In order to make this clearer, I think I ought to add there is a probable error in the distance above sea level. The quantities in the table there seem to be made up of two things. One is the elevation of the zero of the gauge above the sea level, and another is the elevation of the water surface above the zero of the gauge, or below it as the case may be. Both of those quantities have probable errors and when I am speaking of errors of observation, water level observations, I mean the water level observations. I don't mean the precise level work from there to the sea.

Mr. Wilkerson: That is all.

Mr. Williams: That is all.

Mr. Wilkerson: These pages of the report of 1903 that the witness has referred to in the course of his testimony may be treated as identified by the witness as figures in a report, by you, wasn't it, Mr. Wheeler?

The Witness: By me.

Mr. Wilkerson: Figures in a report prepared by him.

Mr. Williams: Well, the report itself, together with the tables attached thereto, he testified from those observations, showing the elevations.

Mr. Wilkerson: This report may be treated as having been identified by the witness.

Mr. Williams: Yes, sir.

Mr. Wilkerson: Of course, when it comes to offering it on either side the question of the materiality and relevancy may be raised.

Mr. Williams: Of course those are reserved anyway.

Mr. Wilkerson: But the report may be treated as identified by the witness, at the request of counsel for the defense.

LOUIS C. SABIN, a witness called on behalf of the complainant, was first duly cautioned and sworn, and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name, please, Mr. Sabin?
A. Louis C. Sabin.
Q. Where do you live?
A. Sault Ste. Marie, Michigan.
Q. What is your occupation?
A. Civil engineer.
Q. In the government service?
A. Yes, sir.
Q. What branch of it?
A. The corps of engineers, under the Corps of Engineers.
Q. Just what is the scope of your duty now?
A. I am in local charge of the improvements being made by the War Department on the St. Mary's River and the general superintendent of St. Mary's Falls Canal.
Q. How long have you held that position?
A. Three years, about.
Q. Are you a graduate of any college?
A. Yes, sir.
Q. What college?
A. The University of Michigan.
Q. What degree?
A. Bachelor of Science and Civil Engineer.
Q. What year?
A. 1890 and 1894.
Q. I wish you would state briefly what experience you have had since you left college?
A. As assistant on the improvements of St. Mary's River from 1890 to 1897, inclusive; precise measurements in Texas, 1898; surveys and discharge observations for the Lake Survey, 1898 to 1903; assistant on the St. Mary's River improvement, 1903 to 1905; secretary of the American Section International Waterways Commission, 1905 and 1906; assistant St. Mary's River improvements, 1906 to date.
Q. Now, just what connection have you had with hydraulic measurements of the Great Lakes, a little more in detail?
A. I was in local charge of the measurements of the discharge of the St. Clair River.
Q. When?

A. From 1898 to 1902.

Q. And prior to that?

A. In 1896 I assisted in measurements of the St. Mary's River, and in some hydraulic studies in connection with those measurements.

Q. And after that time have you given—

A. I think that covers it.

Q. That covers it, your hydraulic work.

A. That is the hydraulic work, yes.

Q. What work did you have to do on the International Waterways Commission?

A. The ordinary executive work of the secretary of the American Section, and such hydraulic studies as were made during the time of my holding that position were under my local supervision. Those studies included the effect of regulation works on Lake Erie. I think that is as far as I need to—

Q. Now, speaking of these hydraulic measurements, particularly those relating to the discharge, the quantity of water that is discharged through the St. Clair River, I think you said you had to do at one time with those measurements?

A. Yes, sir.

Q. I wish you would tell us how those are made.

A. The instruments used to measure the actual velocity of the water passing a given section were current meters of the Haskell type. By measuring the velocity in each of several points in a cross-section, and in multiplying the resultnig velocity by the cross-section of the water in that section, gave the amount of water flowing past that partial section of the river, and the summation of these partial discharges gave the total discharge for the conditions under which the observations were made.

Q. Now, in determining the relation which the elevation of the lake has to the quantity of water which is discharged through the river, is there any set of observations made, any other?

A. Yes, sir.

Q. That you have to make observations—

A. On the St. Clair River?

Q. Yes.

A. Yes, sir; there have been some observations made since those of which I had local charge.

Q. I mean, suppose the thing which we wish to determine is the relation which the quantity of water which is dis-

charged through the river bears to the elevation of Lake Huron—

A. Yes.

Q. —what other observations are made to be used in connection with those observations, so you can—

A. I do not know that I can give the dates correctly; I know the work has been carried on since I left. That is a matter of record.

Q. Well, I mean, you take the—you determine the elevation of the lake at a certain fixed time—did you—or how did you determine that?

A. By precise levels run from the tidal waters to the various points on the great lakes, the elevation of these several points, with respect to mean sea level is determined. These points of which the elevation has been determined are called bench marks. By the use of a leveling instrument the difference of elevation between this bench mark and a point to be used in measuring the height of the water surface is determined. This gives, then, the elevation of the point used in making the water level observations. The distance of the water surface at any instant above or below this mark so set, and the elevation of which has been so determined, gives the deduced elevation of the water surface at that moment.

Q. Now, knowing the elevation of the lake at different times, and knowing the quantity of water which is discharged at different times, how do you proceed to determine the relation which the one bears to the other, the method of that?

A. It is found that in general the discharge is greater as the elevation of the lake from which the discharge is coming is increased, and the relation—

Q. If you will pardon me for interrupting, if you had no measurements at all, made no measurements at all, is there any principle which would be applicable in determining the relation the quantity of water which went through the river would bear to the height of the lake, the elevation of the lake?

A. You mean by "no measurements at all," do you mean the measurements of the current velocity?

Q. Measurements of current velocity, yes.

A. An approximate idea could be obtained from measurements of the characteristics of the river, that is, the cross-sectional areas at various points, and then by analogy the probable effect for that particular stream obtained.

Q. Well, go ahead with your description of your method.

A. Where did I leave off?

(Answer read, as follows:

"It is found that in general the discharge is greater as the elevation of the lake from which the discharge is coming is increased.")

A. That is, a relation exists between the elevation of the water surface in the lake above and the discharge of the river. This relation of the discharge to the elevation is expressed as an equation in which the discharge is given as a certain amount at a given elevation of the lake, and increasing a certain amount for each foot of rise in the lake.

Q. Through how many outlets does the water flow out of Lakes Michigan and Huron, so far as you know, Mr. Sabin, or so far as is known?

A. One.

Q. What is that?

A. The St. Clair River.

Q. And in addition to that, of course, there is the quantity that is diverted here in Chicago?

A. Yes, sir.

Q. Through the Drainage Canal?

A. I was speaking of it, naturally.

Q. You are speaking of the natural outlets. What is the effect of the diversion of a given quantity of water from Lake Michigan at Chicago upon the quantity of water which is discharged through the St. Clair River?

A. If a new outlet, an artificial outlet, is made in the lake, and no change is made in the natural outlet, the amount of water leaving the lake is greater at first than it would have been without the artificial outlet. The effect of this diversion through the artificial outlet will be to lower the water surface of Lake Michigan, until it is at such a level that the amount of water flowing in the natural outlet, plus the flow in the artificial outlet, is equal to what it would have been through the natural outlet alone, had no artificial outlet been made.

Q. So that, all other conditions remaining the same, is it or is it not impossible to divert a certain given quantity of water from Lake Michigan at Chicago, without affecting the level of the lake?

A. No, sir, it is not possible, if all other conditions remain the same.

Q. Are there any of the other factors which enter into the determination of the level of the lake, which would be modified by the diversion of the water at Chicago? I am speaking of precipitation, evaporation and those things?

A. No, it would have no effect on such natural phenomena.

Q. What are the elements, Mr. Sabin, that enter into the determination of the lake elevation?

A. Referring to some particular lake?

Q. Well, take Lakes Michigan and Huron.

A. The inflow from the lake above—the outflow through the outlet—and the rainfall on the lake surface, the evaporation from the lake surface and the run-off of the land area.

Q. I assume that you limit your answer to the natural state of the lake without any artificial modifications?

A. Yes.

Q. By the creation of any artificial outflow?

A. Yes, sir.

Q. If there was such an artificial outflow, that would be an additional factor which would have its effect?

A. Yes, I said the outflow through the outlet, and if another outlet were made that would make that plural.

Q. Certainly. Now, assume that the water is taken out from the lake at Chicago, and the result of the taking out of that water is, as you have said, to lower the level of the lake, so that the level of the lake is lower at a point 10 or 15 miles off the shore, what would be the fact with reference to the lowering of the level of the lake at other points and in the harbors and channels of the entire lake?

A. The mean level would be lowered the same amount throughout Lakes Michigan and Huron.

Q. That would be true with the level at the head of the St. Clair River, would it?

A. Yes, sir.

Q. Now, we are using the term "lowering," and you speak of lowering the level of the lakes. When you say that the diversion of the water through an artificial outlet at Chicago would be to lower the level, do you mean that that would be the absolute result; that is, that the level of the lake would as a matter of fact of necessity be lower than it was before the water was diverted, or do you use the term as if you meant lowering effect?

A. If other natural conditions remained the same after the opening of an artificial outlet as before, it would mean an actual lowering. The other factors, however, regulating the level of the lake might be such as to cause for a limited period an actual rise of the surface after the diversion was made.

Q. Well, for example, what?

A. For example, if through the artificial outlet a discharge of 10,000 cubic feet a second were taken, beginning at

some particular instant, and at that time the natural conditions changed so that the inflow from the drainage basin, we will say, is more than 10,000 cubic feet a second greater than it was before, under those conditions the water level would actually rise after the diversion was made, temporarily.

Q. Well, supposing we take this case, to fix what we mean by the definition of lowering: suppose it was possible for us, instead of having one set of Great Lakes, to have two sets; suppose we had two globes like this, identical in every respect, with the exception that for a given year on one of the globes no water was diverted at Chicago, and on the other of the globes a certain definite quantity was diverted at Chicago, what would be the effect of the level of the lake on the one globe as compared with the other?

A. The level of Lake Michigan on the one globe having the diversion would be lower than that on Lake Michigan on the other globe.

Q. In accordance with the amount that was diverted?

A. Yes, sir.

Q. Does that represent fairly what we mean by the term "lowering" as we speak of it in this connection?

A. I think that is a good illustration of it.

Q. I want to get it clearly here in the record because it is a term we use right along in the testimony. Can you give another illustration that would show it any more clearly?

A. Only perhaps by bringing it down to smaller areas, it may be perhaps more easily grasped. If we have a small pond with a certain outlet and a certain inlet, the outflow and inflow being so regulated that that pond remains at a constant level. If you now enlarge the outlet or make a new one, so that the amount of water flowing out is temporarily greater than it was before, while the amount flowing in remains the same, the level of the pond will fall. And to complete the illustration, when it has fallen enough so that the amount of water flowing out by the first outlet is decreased by the amount flowing out by the second or new outlet, the equilibrium will again have been established and the pond will be found at a lower level.

Q. Take now the case of Lakes Michigan and Huron, and the proposed diversion of the water here at Chicago. What is the fact with reference to the amount of water which will ultimately go out through the St. Clair River as compared with what would have gone out at that time if there had not been the diversion of the water at Chicago?

A. After the equilibrium disturbed by this new outlet has

again been assumed, the amount flowing out of the St. Clair River would be less than under the first supposition by the amount of the diversion.

Q. That is the ultimate effect?

A. Yes, sir.

Q. You use, I assume, in connection with your testimony in this matter, a term "net supply," and so that we may understand what is meant by that as it is used, I will ask you what you mean by net supply?

A. The net supply to a given lake I consider to mean the inflow to the lake from all sources less the abstraction of water from the lake from all sources, except the flow discharged out of its outlets or inlets.

Q. You say the quantity of water which is in Lakes Michigan and Huron—and in this examination when we speak of Lake Michigan I assume that Lakes Michigan and Huron are, so far as elevation is concerned, one about the same as the other, is that correct?

A. They are, yes, sir.

Q. So that it is proper when we speak of Lake Michigan to assume that it naturally applies to the whole?

A. We call it Lakes Michigan-Huron.

Q. Now, you say the quantity of water in Lakes Michigan and Huron is determined by rainfall, evaporation, absorption, the discharge through the St. Clair River and the inflow from the St. Mary's River: is there any one of those factors that enter into the determination of how much water there is in the lake which in itself is modified or affected by any diversion of the water at Chicago?

A. You mentioned the outflow of the St. Clair River; that is affected.

Q. Any except that?

A. No, none other to an appreciable extent.

Q. Is there any factor which determines the amount of water which comes into a lake which to any appreciable amount is itself affected by the diversion of the water at Chicago?

A. No, except for the amount of water which may be intercepted by the channel carrying this diversion. I mean the flow, for instance, of the Chicago River, which would have reached the lake, may under the new conditions be intercepted and go through the river channel.

Q. That is, it would make it that much less?

A. Yes, sir.

Q. It would diminish the quantity that came in?

A. Yes, sir.

Q. Is there any other factor which goes into the determination of that which you can conceive would be affected in any way at all?

A. No, sir, no appreciable effect.

Q. Is there any conceivable source of water coming into the lake which would be appreciably affected?

A. Not to my mind.

Q. Which in itself would be appreciably affected by the taking of water out at Chicago?

A. Not to my mind.

Q. Now, there have been presented already in the taking of the testimony in this case, certain charts or plats which have been marked Government's Exhibits 1, 2, 3 and 4; now, on those maps or charts certain observations have been platted. Did you have anything to do with the making of any of the observations that are platted on any one of those charts?

A. I had something to do with the observations taken on the St. Clair River in 1899, 1900, 1901 and 1902.

Q. Now, I wish you would tell us just how those observations are made, with particular reference to the manner in which the record of them is kept; who makes the record and how is it kept? Take a given observation, for instance, what is the system about making a record of that?

A. That is rather a long story. Those instruments are read in the field by an observer. Some of that work was done by myself personally, and sometimes it was done by an assistant, and the observation of the number of revolutions of the meter wheel in a certain length of time, as 100 seconds, is recorded in the book—in the note book.

Q. Is that note book kept?

A. That note book is preserved as a part of the records. By what are called rating observations, the meaning of a certain number of revolutions per second of the meter wheel for a given meter is determined, by methods familiar to all engineers. I suppose it is not necessary to go into it in reply to this question.

Q. Well, this is a law suit, with lawyers and judges; I guess you will have to go into it, Mr. Sabin. What I want, and you can be brief so we can get that point, is, we platted here certain observations and these observations are taken from records, of course, and they are official records, I assume?

A. Yes, sir.

Q. Made by government employes in the discharge of their duties as such employes, is that right?

A. Of the Lake Survey, yes, sir.

Q. And the record of those observations is kept at the office there at Detroit?

A. At the office of the United States Lake Survey.

Q. As a part of the records of the office?

A. As a part of the records of the office.

Q. And those records show the quantity of water which passes a given point at a given time, is that correct? What I want to find out is just what is platted there.

A. This plat is composed of points, each one of which is the mean of several observations of the discharge of the St. Clair River. The discharge is platted on this plat with respect to the elevation of Lake Huron. A line has been drawn on it which shows approximately the apparent change in discharge for a given change in level. That is what we call a discharge curve or a discharge line, and having the increment of discharge from such a plat, or from the equation of the line, the effect of any change in level of the lake upon the discharge may be determined.

Q. What does that diagonal line drawn across there show?

A. It purports to be a line which is the straight line most nearly according with the observations as platted.

Thereupon a recess was taken to 2 o'clock p. m. of the same day, Wednesday, April 21, 1909.

Wednesday, April 21, 1909, 2 o'clock p. m.

Parties met pursuant to adjournment.

LOUIS C. SABIN resumed the stand and testified further as follows:

Mr. Wilkerson: Q. Referring now to these plats which you had before you this morning, Mr. Sabin, I wish you would take the one that is marked Exhibit No. 1, which relates to the discharge through the St. Clair River, I think, does it not?

A. Yes, sir.

Q. I wish you would tell us whether you have seen that plat before and what you have done in connection with it?

A. I have seen a copy of it before and have examined it; I did not prepare it.

Q. What do you say as to whether that line that expresses the relation between the lake level and the volume of discharge is correctly drawn?

A. I have not checked over the platting of these points; with those points as platted, I should say that the line drawn through them fairly represents them.

Q. Assuming that that line is correctly drawn, what have you to say with reference to what is there denominated the "increment"?

A. The increment is the change of outflow for a foot change in stage; as given here is 23,800 cubic feet per second.

Q. On the basis of that chart, what would be the lowering of Lakes Michigan and Huron in inches for a diversion of 10,000 cubic feet at Chicago?

A. It would be 10,000 cubic feet divided by the increment, 23,800 cubic feet, multiplied by 12, which gives about five inches.

Q. You mean divided by 12. Is that what you said?

A. No, multiplied by 12.

Q. Multiplied by 12?

A. Yes, sir.

Q. In your opinion, how exact is that statement?

A. From my general knowledge of the discharge increment of the St. Clair River, is that what you mean?

Q. Yes.

A. I think that five inches would be a minimum amount; but I should expect it to be not less than five inches, and perhaps considerably more.

Q. Explain why do you say that?

A. Because in the work that I have done with a portion of these data, I have been led to the conclusion that the increment, when referred to Lake Huron alone, was somewhat smaller than the one that is given here.

Q. The smaller the increment, the greater the change in lake elevation, corresponding to the loss in outflow. Is that correct?

A. Yes.

Q. Why is that true?

A. A loss in depth of one foot makes a given change in outflow, which is called the increment. Now, if that increment is small, then a given diversion is a larger proportion of that increment, and therefore a larger proportion of the foot which the increment represents.

Q. Now I direct your attention to this fact, Mr. Sabin: you speak of the increment which is used as a basis of those

calculations as being probably larger than the true increment; and I direct your attention also to the fact that Mr. Wheeler, in his computation on the chart, had to recompute it, the points as there platted, and had a figure for increment which differed slightly from the increment which is there used. Can you explain to us why it is in different calculations with reference to these, there is this slight variation in the increment which is used?

A. Yes, because on the St. Clair River, the discharge at any time is a function of two quantities; the elevation of Lake Huron and the elevation of Lake Erie; and it therefore requires a larger number of observations to obtain it with the same accuracy than in the case of those streams where they have but one variable affecting the result. And the nature of the effect of Erie and Huron is such that a change, an assumed change given in deriving the equation, an assumed change in one will have an effect upon the resulting change in the other, in the effect of the other, so that, to illustrate: under certain conditions of levels in Lakes Huron and Erie, we have a certain discharge. Now, suppose that Lake Huron goes up an inch, Lake Erie remaining the same; the discharge will be increased by a certain amount.

Q. Do you mean Lake Erie or Lake St. Clair?

A. Yell, I am speaking of Lake Erie rather than Lake St. Clair, for the reason that Lake St. Clair's level is practically controlled by the levels of Lake Erie and Lake Huron. And I thought it better, therefore, in this illustration, to go to the lake that had this regulating effect.

Q. Excuse my interruption; go on with the answer.

A. As I was saying, this raise of an inch in Lake Huron would have a certain effect. Now, at another time, with Lake Huron at the same elevation, if Lake Erie went down an inch, that would also have the effect of increasing the discharge. When you have a series of observations, you have various variations in the surface of both Lake Huron and Lake Erie, but as a lowering of Lake Erie has a smaller effect than a raising of Lake Huron, in the discharge on any given day, you may mistake for the effect of a raise in Lake Erie a lowering in Lake Huron; and the variation in increment of Lake Huron, as gotten by different computers, has this variation due to this cause. And this is one of the highest ones; that is this increment shown on this plate of 23,820, is one of the highest increments. During practically the first year or two of my observations on the St. Clair River, I de-

duced an equation which showed that the increment was about 19,000, instead of 23,820.

Q. That is from a different series of observations?

A. No, that series of observation is also included in here.

Q. But other observations are added?

A. Are also added to those. I should think that the truth lay between probably 19,000 and 23,820.

Q. Without regard to the precise quantity which is to be put down as representing this increment, what do you say as to the absolute fact as to the effect of diminishing the quantity of water which flows out through the St. Clair River upon the level of Lakes Michigan and Huron; I say, without regard to the precise accuracy of the increment?

A. What effect has the flow?

Q. What do you say as to the absolute fact as to the diminishing of the quantity of water which goes out through the St. Clair River upon the level of Lakes Michigan and Huron, the relation between those two?

A. Well, certainly an increase in discharge of the St. Clair River would have a tendency to lower the level of Lake Michigan. Is that your question?

Q. My question is as to the absolute fact as to the relation between the level of Lakes Michigan and Huron and the discharge from the St. Clair River, as to there being such a relation.

A. Yes, there is no doubt at all about that.

Q. I mean as to the absolute fact?

A. No, sir, no doubt at all about that.

Q. And as to the amount of the change, do you think the truth is some place between the low increment, to which you have referred here, and the higher increment which is used on the charts that have been produced by the government?

A. Yes.

Q. And if the lower increment be used, would the effect be greater or less; that is, would the lowering of the level be greater or less?

A. The effect of a given diversion would be greater with a small increment.

Q. Having in mind your own deductions and your own experience, what would you say as to the limits between which the effect of a diversion of 10,000 cubic feet at Chicago would fall, in inches?

A. Between five inches and seven and one-half inches.

Q. Can you give us any information as to the percentage, as to what percentage of the lowering in Lake Michigan the

water in St. Mary's River at the foot of the locks would be lowered?

A. I can't give a definite answer to that question for the conditions prevailing at present, because last August the conditions of outflow of the St. Mary's River were quite seriously disturbed by the opening of a new channel. Previous to about 1890 the work that had been done in the improvement of the lower St. Mary's River was quite small. And I have had occasion to go into that question for that period, and the effect for that period, up to 1890, would be about 47 per cent. That is, that a change in the elevation of Lake Huron would change the elevation of the St. Mary's River at the foot of the locks 47 per cent. as much; that is, one foot of Lake Huron would change the St. Mary's River .47 of a foot. Since that time, due to the improvements in the St. Mary's River, the slope, which previous to that time had had a mean value of about 2.1 feet, has been reduced by from a foot to a foot and two-tenths, I should say, by the new channels opened and the improvements in the channels, and the slope being less for a given elevation of Lake Huron, and a given discharge from Lake Superior, the effect would be greater; how much greater it is difficult to say, bearing in mind that 47 per cent. was the figure before 1890, and that the slope has been changed over a foot; I should say that perhaps 60 to 75 per cent. of the loss would be felt.

Q. Within what limits, then, if you are going to get the effect, could you put the fact as to that, so as to be absolutely sure that you were within the truth?

A. There would be no question in my mind about the lower limit being above 47, and the upper limit would be below 100; and I would not care to go any further.

Q. The point I wanted to bring out was, would there be any doubt, is there any doubt that there is some substantial effect, first?

A. No. Those limits give substantially the effect; 47 per cent. is the lower and 100 the higher; that is not absurd.

Q. And as to the lower limit, you would say that was not open to doubt?

A. No, not open to doubt, any more than any other engineering data are.

Q. I suppose this is true, if I may put the question in this form, isn't it, Mr. Sabin, that without regard to the precise amount of the effect, there are elementary laws or

principles which control, in a situation of that kind, which make it absolutely certain that there would be some effect?

A. Yes, with a knowledge of the natural conditions existing; there is no doubt of it.

Q. What is the mean fall at the present time between the water at the foot of the lock and Lake Huron?

A. The recent improvements have not been completed long enough to determine that. The mean fall for the seven months of navigation from 1871 to 1890 was 2.1 feet. That fall is affected by the elevation of Lake Superior, or rather by the discharge of the St. Mary's River and by the elevation of Lake Huron; and it varies considerably. Taking the mean for seven months, considering only the mean for each year for the seven months of navigation from May to November, it has varied from a foot and a half to 2.9 feet, roughly.

Q. You have given us your answer now with reference to the lowering of the water at the foot of the locks. Are you prepared to make any statement as to the effect at the critical points in the river?

A. Only within rather wide limits.

Q. Well, first, as to there being some substantial effect?

A. There would be substantial effects, and the character of the river is such that the percentage of a given change on Lake Huron, the percentage of that effect, starting out, whatever it may be at the locks, would increase from the locks down until it became 100 per cent. at the mouth of the river.

Q. So if 47 per cent. were taken as the lowest limit at the locks, the effect at those different critical points would be expressed by percentages larger than that?

A. Yes.

Q. Increasing as you went down the river?

A. Yes.

Q. Which would in the case of most of them be in excess of 50 per cent.?

A. Yes.

Q. And as to those that were further down the river, very considerably in excess of that?

Question objected to by counsel for the defendant, on the ground the counsel is leading the witness and testifying.

A. A very considerable extent.

Q. If Lakes Huron and Michigan are lowered a known

amount, and Lake Erie a known amount, what would be the effect in the Detroit River, Lake St. Clair and the St. Clair River?

A. They will also be lowered.

Q. Can you make any statement as to the amount, or have you given consideration to that?

A. I should expect that the level of St. Clair would be affected by practically the mean of the two lowerings; that is, the mean of the lowering for Lakes Michigan and Huron, and the lowering of Lake Erie.

Q. What would be the effect of the diversion of water from the lake at Chicago upon the outflow of the Niagara and St. Lawrence Rivers, and why?

A. It will decrease the outflow of those rivers by the amount diverted at the Chicago Drainage Canal, practically undiminished.

Q. Now, with reference to these three other charts that I showed you this morning, Mr. Sabin, I wish you would take each one of those charts and tell us what examination you have made of them; what each one represents, and whether in your opinion the result as stated in the form of that scale at the left hand side is correct?

Mr. Williams: He is not testifying now to the correctness of the observations or the correctness of the platting of them.

Mr. Wilkerson: Q. I understand, with the exception of the observations on Lake St. Clair, you did not make any of the observations that are represented on the plat?

A. No, sir.

Q. You have testified about the only one of the plats as to which you made observations?

A. Yes, sir.

Q. As to the others you did not make the observations yourself?

A. No, sir.

Q. Nor did you plat the observations?

A. Not on this, no, sir.

Q. What you have done is as an engineer to make an examination of the methods of reaching the result. Is that what you have done?

A. Yes, sir, I have gone over that, not with respect to these plats, because I have not gone over that matter since that time, further than to see that this agreed approximately with the data which I had checked over and satisfied myself about before.

Q. Have you gone over the method which has been there used of reaching this result?

A. Yes, sir.

Q. As based upon observations of lake level and outflow?

A. Yes. That is a proper method.

Q. I wish as an engineer you would give us for the record here a brief explanation of the method that has been used on these charts.

A. Exhibit No. 2 has a number of points plotted, purporting to give the discharge measured a certain heights of water surface in the St. Lawrence River at Ogdensburg. Through these observations a line has been drawn which fairly represents the observations as plotted. This line may be used to indicate the change in discharge of the St. Lawrence River for a given change in level at Ogdensburg, or to show for a given change in discharge at Ogdensburg what the resulting change in level would be. This line shows a change of outflow for one foot change in stage, 28,870 cubic feet per second.

Q. Now, does the same general explanation which you have made with reference to that apply to the others?

A. It does.

Q. Assuming the accuracy of the observations which have been platted, and assuming the accuracy of the platting of those observations, what have you to say as to the correctness of the result which has been reached, based upon the observations as platted?

A. I think that line fairly represents the observations plotted. That is all that can be said, I think.

Q. Would you say, if the observations were correctly made, and if they are correctly platted, that the result is substanitally correct?

A. Yes, sir.

Q. And by that I refer to the result in the lowering of the lake level, as expressed there on the scale at the left of the chart?

A. That would refer to the St. Lawrence River, and the lowering of the river at Ogdensburg.

Q. That is as to that chart?

A. Yes. You said "lake." It would show the lowering of the river at Ogdensburg.

Q. I was correct in using the word "lake," with the exception of the one chart where it is in the river?

A. Yes, sir.

Q. So that, if water is diverted at Chicago, will Lake Erie be lowered?

A. Yes, sir.

Q. And what will be the effect upon the Niagara River?

A. That will also be lowered.

Q. And what about the effect on Lake Ontario?

A. That will also be lowered.

Q. Now, how much in each case?

Mr. Williams: Do you mean in percentages, or given a certain amout of diversion?

Mr. Wilkerson: I am speaking on the basis of 10,000 cubic feet per second, and I am assuming—and I ask you to correct me if I am wrong in it—that if we have the amount of the lowering for 10,000 cubic feet, for a smaller amount or a larger amount, it is proportionately smaller or greater. Is that correct?

A. It is.

Q. So we will take a diversion of 10,000 cubic feet for the purpose of shortening the record, and limit the answers to that, with the understanding that the lowering for a different diversion can be reached by taking a proportion thereof?

A. The effect on Lake Erie will be five and one-half inches, forty-six hundredths of a foot. The lowering at Ogdensburg four and one-quarter inches. That answers the question, does it not?

Q. Have you given them all?

A. Lake Erie and St. Lawrence River.

Mr. Williams: Lake Ontario you did not give.

Mr. Wilkerson: Did you give Lake Ontario?

A. Lake Ontario would be very slightly greater than the St. Lawrence River at Ogdensburg; practically the same, but very slightly greater.

Q. With regard to the accuracy of those figures, as to their being larger or smaller than what is probably the fact, what do you say about that?

A. I think that the figures for Lake Erie and Lake Ontario are very good; roughly, I should say not over half an inch in error, as given.

Q. That is for a diversion of 10,000 cubic feet?

A. That is for a diversion of 10,000 cubic feet a second.

Q. How do the recent measurements of the Niagara River agree with the measurements made by the Deep Waterways Commission in 1897 and 1898?

A. They agree quite well; when I speak of agreement, the

same conditions are not always renewed—do not always occur again.

Q. With regard to the increment of discharge?

A. I have never worked out the increment from the measurements of the Deep Waterways Board alone.

Q. How about the comparison of the recent measurements with those by Quintus in 1891 and 1892?

A. I could not testify to that.

Q. Coming back now to the St. Clair River, what is the season of navigation in the St. Clair River? I don't mean whether there may be a few boats a month, but using that word in the generally accepted meaning that is given to it?

A. Usually during January, February and March, there is very litle navigation on the St. Clair River.

Q. Now, in connection with the St. Clair River, there is what is known as ice retardation, is there?

A. Yes, sir.

Q. What do you mean by that?

A. The presence of ice in any channel cuts down the cross-section of flow and reduces the amount flowing as compared with the same conditions without ice, I should say.

Q. When does this ice effect begin?

A. It varies from—in different years. There are no accurate records that are available except for the last few years, with this exception, that a disturbance in the relative fall in St. Clair River and Detroit River indicates the presence of ice is one or the other. But I should say retardation might be of such an effect in both at the same time that no disturbance of the relative falls would be noticed, and aside from that data I say there are none that I know of, that I recall at least at the present, previous to about 1899, when the gauges were established at the head of the St. Clair River. Since that time one can infer with considerable certainty whether there were ice retardations in the St. Clair River. Have I answered the question?

(Last question read.)

A. In those last few years, there are only three which show a marked effect in December. And there is but one or two that show any marked effect in May.

Q. How long does that ice effect continue?

A. Different lengths of time in different years.

Q. How about April?

A. April, there is quite frequently an ice effect, a retarding effect from ice in April.

Q. How about May?

A. Seldom, as I said.

Q. And is some time in May as late as it is ever noticeable?

A. Yes, and I think it is never noticeable in November; usually not in December.

Q. Now, what is the effect of this ice retardation upon the level of Lakes Michigan and Huron?

A. As it holds the discharge to a lower value than it would have without the ice, it has the effect, the immediate effect, of raising the level of the lake.

Q. Is there anything in this ice effect about which you have been testifying that in any way neutralizes or overcomes the lowering tendency from the diversion of water at Chicago?

A. No, I can see that it would have no effect on that.

Q. Would it have any relation on that whatever, that is, so far as the lowering tendency of the diversion of the water at Chicago is concerned, is there any conceivable relation?

A. No, I think not.

Q. By that you mean you can see none?

A. I can see none.

Q. By that answer you mean this lowering tendency here would go on even though—

A. Yes, sir; that, I think, was in your question.

Q. —even though there was the other tendency, on account of ice in the St. Clair River? I wanted to make it clear, that is all. What information are you able to give us, Mr. Sabin, as to whether the St. Clair River is changing its regimen?

A. I don't know what it has been doing in recent years other than the reports of others. I made an investigation of it about 1900, 1902, and concluded that there was no reason to suspect that there had been any appreciable change in regimen as far back as the records went, of the depth of the channel.

Q. Well, suppose there was some small scouring, what would be the effect?

A. It would change the value of the increment of discharge for a given change in stage. The most likely effect would be that it would increase that increment; making the change in discharge for a given change in stage greater.

Q. I assume that there is some change in the regimen of the St. Clair River from time to time, at a given time, at a

given fixed time. Is there anything in that which neutralizes or overcomes in any way the lowering tendency of the diversion of water at Chicago?

A. No, it does not neutralize or overcome that lowering tendency, but may change its amount.

Q. Is or is not that a factor that is analogous to the ice effect, about which you have testified?

A. Yes, with this exception, that if such a change in regimen were made as to change the value of the increment, then the ultimate effect of a given diversion at Chicago would be different with that new increment than it is under the present conditions, with the present increment.

Q. But there would be?

A. The same tendency would be there to lower.

Q. There would be the same original diversion, which would be translated into effect on the basis of the new increment?

A. Yes, sir.

Q. Well, has there been any such change or do you think any such change possible, that would result in such a change in the increment as to materially affect the lowering tendency of the diversion at Chicago?

A. I should dislike to testify about what is going to happen, but judging from what has happened in the last 50 years, I should not expect—

Q. Assuming that the laws of nature remain constant, for the purpose of your answer, and that there is no such thing as an earthquake or other dire disturbance?

A. In the last 50 years there has been no practical change in the regimen of the upper St. Clair, so far as I know.

Q. So that, so far as that factor is concerned, could you say that increment would remain substantially unaffected from time to time?

A. I think I have practically said that.

Q. I wanted to be clear on that.

A. Yes, sir.

Q. You have given your time for a number of years pretty continuously to the study of the lakes, have you, Mr. Sabin?

A. For certain periods during the last few years, yes, not continuously.

Q. Do you know, or did you ever hear of any outflow from Lakes Michigan and Huron, except through the St. Clair River and what water is diverted at Chicago, substantial diversion?

A. No, sir.

Q. Well, what other diversions do you know of? Is there any other?

A. Nothing, I think, that could be called a diversion, nothing that could be called an outflow.

Q. Anything that would have an appreciable effect upon the quantity of water in the lake?

A. Well, the effects of rainfall and evaporation, but nothing in the nature of outflow.

Q. Outflow?

A. Yes.

Q. I was speaking of the outflow, that is, of the ways in which water gets out of the lake. There is some water, it is said, seeps into the lake, and it has been assumed, or I suppose it may be assumed, that some water comes in in the shape of subterranean streams or springs. Now, what would be the relation of that condition to the level of the lake?

A. I do not think, in the first place, that such an assumption is warranted.

Q. Well, give us your view of that. I would like to have your opinion, based upon your experience and your study of lake conditions, with reference to that.

A. I can see no reason for anticipating that there is any large flow into the lake or out of the lake by underground streams. If there were such streams its effect upon the ultimate effect of the diversion would be practically nil.

Q. From the very nature of things where does most of the water that gets into the lake come from?

A. It comes from streams flowing in along on the surface, streams flowing into the lake and on the surface of the ground, the rainfall, representing the rainfall on the drainage basin, and there should be added to that, perhaps, the rainfall on the lake surface, if that is not included.

Q. Well, if there was some water coming into the lake through subterranean streams, is there anything in that which there is not in the water which comes in on the surface which would counteract or neutralize the lowering tendency of the diversion of water at Chicago?

A. No, sir; nothing.

Q. There has been some reference, Mr. Sabin—I don't know whether it has been in your testimony or not, but in connection with this matter—to inconsistencies in the outflow value of the St. Clair, Niagara and St. Lawrence Rivers;

what do you know about that, and as to there being any that cannot be accounted for by ice retardation?

A. There are no inconsistencies so far as I am aware of that cannot be accounted for.

Q. Is that the result of your observation and study of this matter?

A. Yes, sir.

Q. Have you had occasion in your investigation of these questions to give consideration to data regarding evaporation and precipitation?

A. I have done a little work along that line, not very much.

Q. Have you any information as to the manner in which these statistics are collected, as to the number of observations, and as to their frequency, as to the amount of territory which is covered?

A. Yes, sir; I think that is all a matter of record, as those observations are made by the weather bureau, the observations for precipitation.

Q. It being a matter of record, it is a matter which has been brought to your attention?

A. Yes, sir.

Q. And which you have considered?

A. Yes, sir.

Q. Have you given consideration to them with a view to forming an opinion as to the degree of accuracy with which they indicate the given result?

A. In a general way, yes.

Q. Now, having that in mind, what would be your view of the propriety of using those particular data in a computation, the attempt of which was to detect the presence of absence of the effect which was produced on the lakes by the diversion of water at Chicago since 1900?

A. To my mind the character of the data which we have as to rainfall, and particularly as to evaporation, is such that it does not compare with the accuracy with which we know the outflow of the lakes, and the effect of a diversion of water can be obtained from our knowledge of the law of outflow. I should think it would be very poor engineering to attempt to combat information obtained from outflow observations with a computation which rested upon the observations for evaporation and rainfall. Is that what you wanted?

Q. Yes. Now go along that line a little further, and compare for us, if you will, the accuracy with which the outflow

observations are made and the accuracy with which these statistics about evaporation and precipitation are obtained. Let me add to that question: is there anything in the very nature of things which makes it possible to get a high degree of accuracy in one case which you cannot, from the nature of things, get in the other?

A. I can only answer that in a general way; that the information regarding the rainfall is—that the observations at any given place are subject to a considerable error, and the stations are not sufficiently distributed to give an accurate result, accurate knowledge of the amount of water falling on the lake basins, and the information regarding evaporation is in still worse shape.

Q. Now, as to those observations with regards to outflow, how about the frequency of the observations and the amount of space that is covered and their limits that make possible or impossible the obtaining of a high degree of accuracy?

A. I think that the outflow at any given time, at any given lake stage, can be determined with a reasonable number of observations within something like 5 per cent., I should say. The determination of the law of discharge, as related to the lake level, cannot be determined with that accuracy, but the errors in these determinations are much smaller, in my opinion, than those which attach to the data concerning rainfall and evaporation.

Q. I think you said a little farther back in your testimony, Mr. Sabin, that at the outside you regarded these scales expressing the loss in level, loss in lake level, at a diversion of 10,000 cubic feet at Chicago, as within half an inch?

A. For Lake Erie and Lake Ontario?

Q. Yes.

A. Yes, sir.

Q. As to Lakes Huron and Michigan, you may state the figures, from your knowledge and information, so formed.

A. I should think the upper limit was perhaps seven and one-half inches.

Q. Why do you say that maximum figure is seven and one-half, Mr. Sabin?

A. That is merely a matter of judgment, from my investigation of the data.

Q. Have you had occasion to give consideration to the subject of navigation of the lakes, the use of boats and vessels on the lakes?

A. Yes, sir.

Q. To what extent have you had occasion to study and observe that?

A. I have been in charge, local charge, of the locks at Sault Ste. Marie, and I have been more or less familiar with the operations of the shipping interests.

Q. Very well. Now, bearing in mind the fact that the lakes change in their stage from year to year, and that at times the lake surface is disturbed on account of wind and storm, I will put to you the question whether or not the lowering of the level of Lakes Michigan and Huron to the extent of two or three or four inches has any appreciable or material effect upon navigation in the harbors and channels of the lakes?

Mr. Williams: I object to that, to the form, as calling for a conclusion and not for the facts—

Mr. Wilkerson: I will accept the amendment of counsel, and have you give us the fact as to the effect of the lowering of the lake by two or three or four inches, upon nagivation.

A. It requires the vessels to load accordingly. There are certain places in the lake system where certain vessels are loading as heavily as the water level will permit.

Q. As to the number of vessels which could carry heavier loads than they do, if these channels or critical points in the lake were deeper, what have you to say about that?

A. In 1907 there were 360 boats passing St. Mary's Falls Canal that were capable of loading to 19 feet or over. The amount of freight carried through the canal by these boats in 1907 was about 49,000,000 tons.

Q. Now, what determines the depth to which those large boats can be loaded?

A. Those boats which come from or go to Lake Superior are governed by the amount of water at the lower end of the Poe Lock.

Q. Have the levels of Lakes Michigan and Huron anything to do with that?

A. Yes, sir; as already testified to under another question, the effect of Lakes Michigan and Huron lowering is felt at that point.

Q. Have you any figures which show the number of boats that are capable of loading to 20 and 21 feet, based upon your observations and study?

A. Of the boats passing the St. Mary's Falls Canal in 1907, there were 227 that were capable of loading to 20 feet and 133 capable of loading to 21 feet or over.

Q. How deep could they load at that time?

A. The available draft varied from about—it was about 19 feet 9 inches, and from that—I think from memory it was 19 feet 6 to 20 feet, and about 43,000,000 tons of freight were carried in boats which were limited by the draft in the lower levels of the locks.

Q. You send out instructions or information as to the depth to which boats can load?

A. Yes, sir; and we post that information for the information of vessel masters and shippers.

Q. How much do you allow between the bottom of the boat, do you allow any space in there?

A. No, not ordinarily. The water levels vary from day to day, and we try to give in those notices the mean drafts that they will find on the Poe Lock floor.

Q. Well, suppose the level of the lock there, the level of the water there at the canal is lowered, what effect has that on the load which the boat can carry?

A. That depends upon the size of the boat.

Q. Have you any figures there that would indicate the effect of this lowering on commerce as it is now carried on?

A. Yes.

Q. If you have that I will ask you to refer to your notes and give us the exact figures on that. Are those figures on the basis of the lowering of an inch?

A. Yes.

Q. All right. Assume, now, the level of the lake is lowered an inch, so that you can draw that much water in the locks.

A. For the larger class of boats an inch of draft means from 80 to 85 tons of freight, so that from an inch change in the draft the load of the boat would be changed by 80 or 85 tons.

Q. Have you figured out what the loss of an inch would be to commerce on the basis as it is now carried on, and taking into consideration the boats that are now engaged in this trade?

A. No, I don't remember that I have; I think not.

Q. I think, though, you have given us the data from which we could make the computation ourselves, haven't you? You have given the number of boats and you have given the loss in tonnage?

A. I think the question of the loss of tonnage, I have given that for each inch of change in draft.

Q. So all we need to know, then, would be the number of trips?

A. The number of trips?

Q. About how many trips would one of those big boats make in a season?

A. I think about 20 trips.

Mr. Williams: You are testifying now from your own knowledge, and not from something that somebody has told you or reported.

Mr. Wilkerson: Well, he is up at the Sault.

A. Yes, from information as collected at the lock.

Mr. Williams: Q. It is your personal information and not information given to you by bulletins?

A. No, it is not given to me by bulletins, but it is not what I have personally collected.

Mr. Wilkerson: Q. Is it information which is collected from a record which is made under your supervision?

A. Yes, sir.

Mr. Williams: I object to his testifying from it.

Mr. Wilkerson: Q. Answer the question.

Mr. Williams: On the ground that it does not purport to be information which is the result of his own personal information, but as a result of work done by others.

Mr. Wilkerson: Q. How are those records compiled, Mr. Sabin?

A. Each vessel that passes the locks is reported by the captain as to her tonnage, freight carried, ports of hail and destination, and this information is kept and tabulated in the office.

Q. Can a boat go through the lock without giving that report?

A. No, sir; not ordinarily. I think we may lose two or three in a season until they come on the second trip.

Q. What is done with those reports?

A. The information is tabulated and published in the form of statistical reports of lake commerce, covering in considerable detail the amount of freight carried, the number of boats of different sizes and so forth.

Q. Have you that report with you?

A. That is a copy of it. (Handing document to counsel.)

Mr. Williams: Instead of asking the witness the questions you have, I haven't any objection to your introducing that report that he is testifying from.

Mr. Wilkerson: Very well.

Q. What you have stated with reference to the number of vessels going through is based on this report, is it, Mr. Sabin?

A. No, it could not be obtained from that report, but it was obtained from the data from which that report was obtained.

Q. I see.

A. The information which I gave was based upon the records for the entire season of 1907.

Q. Yes.

A. And they are voluminous records.

Q. Could you get from this report which you have produced the facts with reference to the number of times any given vessel made a trip?

A. No, sir.

Q. You would have to go to the—

A. Yes, sir.

Q. —reports from which this book is compiled?

A. Yes.

Mr. Wilkerson: This book which Mr. Sabin has produced may be marked for identification as an exhibit of this date, so that we will have this book identified in case that either side wants to refer to it or offer it hereafter. It may be, when we get through, we will not want to encumber the record with it, so I will not offer it in evidence, thinking perhaps maybe we may be able to make some agreement as to what it shows.

Mr. Williams: Is that the 1908 report or the 1907?

A. 1907.

Mr. Wilkerson: Mark it as Statistical Report of Lake Commerce Exhibit of this date.

Whereupon said book was marked as Statistical Report of Lake Commerce of 4/21/09.

Mr. Williams: Does that report show the tonnage of the vessels, or the number of tons carried on their different trips?

A. Both, in a collective way.

Q. In that report?

A. Yes, sir; not the individual instances.

Mr Wilkerson: What do you know, Mr. Sabin, as to the dimensions of the largest freight carriers now engaged in commerce traversing the waters below Lake Superior?

A. The L. S. De Graff has a length of 605½ feet over all, and 60 feet beam. She has carried a cargo of 13,638 tons.

Q. Any considerable number of those large boats engaged in commerce now?

A. Yes, a great many.

Q. What is the tendency in the construction of those boats?

A. Most of the boats that are being built now are what may be called the larger class, although not all of them by any means of that size. The tendency is to increase the average size of the boats. That is a part of the data in that report that you have just made an exhibit.

Q. What about the tendency to build boats so large that they cannot be loaded to the limit now, and which would be affected in the load which they would carry by the lowering of the water in these channels?

A. We have just now an available draft of 18 feet 3 inches over the Poe Lock, through the Poe Lock, and in 1907 there were 360 boats that could draw 19 feet or more. Those 360 boats carried 49,000,000 tons of freight.

Mr. Williams: You testified to that before, Mr. Sabin.

Mr. Wilkerson: Yes.

A. The question was practically repeated.

Mr. Williams: He asked you about the tendency now.

Mr. Wilkerson: Q. I say, is it the tendency to build boats of that class now, so that they are becoming more and more numerous all the time?

A. Yes.

Q. And they cannot be loaded to the limit because of the condition of the lakes at these critical points?

A. Yes, sir.

Q. And the boats which would be affected by a lowering of from an inch, the lowering of the lake?

A. Yes, sir.

Mr. Wilkerson: You may cross-examine Mr. Sabin. It may be that I have overlooked a question. If so, I will put it in re-direct as though it was direct examination.

Mr. Williams: That is all right.

Cross-Examination by Mr. Williams.

Q. Mr. Sabin, are you familiar with this bulletin No. 18 of the War Department Corps of Engineers? (Handing book to witness.)

A. No, I am not familiar with it; I have seen it.

Q. On page 259 of that bulletin, referring to the Detroit River, occurs this statement: "During the lowest water of the season of 1907, except for temporary storms, a draft of 19 feet could be carried through the river, the place of lowest depth being at Lime Kiln Crossing, near the mouth of the river." Do you know how long that condition has existed?

A. No, sir.

Q. That is a greater depth by how much than that provided for during the year 1907 at the Poe lock?

A. The depth of water in the Poe lock in 1907 varied from 19.5 to 20.8.

Q. During the entire year?

A. During the season of navigation, April to December.

Q. What was the situation there during the year 1908, what was the depths?

A. I haven't those figures with me.

Q. What is the present available depth?

A. Eighteen feet three inches.

Q. How long has that depth been the available depth?

A. About ten days or two weeks.

Q. Taking up the chart or plate—

Mr. Wilkerson: Will you pardon me?

Q. Do you have what is known as low water days?

A. Oh, yes.

Q. What do you mean by that?

A. The water fluctuates, not only daily, but hourly and monthly. The water level at the lower end of the lock changes from month to month as is shown on the exhibit just put in evidence or identified. The water level is usually low in April and May and high in July, August and September, at the foot of the locks, so that this 18 feet three inches probably will not hold very long.

Q. You are giving the monthly means, are you?

A. Yes, sir; I was giving the monthly means when I read them off as to the variation, those are the means of the month. Of course, that is not the maximum variation by any means.

Mr. Williams: Q. Right on this very question propounded by Mr. Wilkerson, and in answer to it, you say that the height of the water there varies sometimes hourly and sometimes daily?

A. Yes, sir.

Q. What are those variations caused by?

A. The short time variations, those rapid variations, are caused principally by barometer and wind.

Q. And how great a variation would you consider as not being unusual, resulting from such causes?

A. In how long a time?

Q. Well, say in 24 hours?

A. During the summer season about two or three inches.

Q. Have you known of variations exceeding two or three inches, occurring within a period of say 24 hours, resulting from barometric and wind causes?

A. Yes.

Q. How great a variation have you seen within that time?

A. Well, certainly six inches; I would not say how much more.

Q. Would you say that you had ever seen a greater variation than six inches?

A. No, I would not say that I had.

Q. And within how short a time have you seen a variation of six inches?

A. My recollection of the times that I have seen those fluctuations on the lower St. Marys River are not sufficiently exact for me to go into them.

Q. How near the bottom of the channel does the ship's bottom pass at the locks, ordinarily?

A. I think that that question is a little indefinite. Not ordinarily. Some of the boats drag on the bottom as they go out; some of them may have an inch under them and some may have two or three feet.

Q. Do you give any instructions to the vessel owners as to the amount of draught they may carry through the locks?

A. We give them the amount of available draught as near as we can,—the amount of water there is in the lock. We give them that information.

Q. And you supplement that information by a statement of the draught they will be permitted to load to?

A. They draw all the water there is in the lock.

Q. And there are no instructions given, then, only information as to the amount of water in the lock?

A. No, sir.

Q. Now, passing through the St. Clair River, or the Detroit River, do you know to what depth the vessels load, how near the bottom, at the critical points?

A. It is my understanding that they touch the bottom in going through. They certainly did in the St. Marys River before it was improved.

Q. You made or had charge of the observations in the St.

Clair River, which in part form the foundation for the Exhibit No. 1?

A. Yes, sir.

Q. When were those observations made?

A. In 1899, 1900, 1901 and 1902.

Q. Were those observations and the results thereof published?

A. Yes, sir.

Q. With a report by yourself in the report of the chief of engineers?

A. Yes, sir.

Q. The gauge heights and elevations of water surfaces shown in your reports published in Appendix EEE, are they subject to correction? This is 1902?

A. The water levels that are found in that report are based on the determination of elevations of bench marks made a good many years ago. In 1903 the lake survey completed a new determination of the difference in levels between these bench marks and the sea level.

Q. Well, now, then, assuming that the several gauges, heights and elevations of water surfaces mentioned in these reports are subject to correction due to a more accurate determination of bench marks by the levels known as the levels of 1903, I will ask you whether the data presented on pages 2830, 31, 32, 33, 34, 35, 36 and 37 of Appendix EEE of the annual report of the Chief of Engineers for 1902 are correct representations of your observations of the discharge on the St. Clair River as shown by these reports during the years 1899, 1900 and 1901?

A. Yes, so far as they purport to be.

Q. Will you explain what you mean by that last sentence?

A. Why, that there are some things in those tables which are not a matter of observation.

Q. For instance?

A. For instance, table No. 7, on page 2837, is one that I notice.

Q. Yes?

A. The effects of ice there are not measured effects. They are from the application of a formula.

Q. Then we will exclude table No. 7 and refer only to the first six tables, and limit the question to page 2836; that is, I think, the last page,—from 2830 to 2836, inclusive.

A. They, I believe, are a correct representation of the

data as obtained by me, and the deductions which I made from them.

Q. Now, then, would you say the same as to pages 2811 and 2812 of Appendix FFF of the annual report of the Chief of Engineers for 1903, referring to observations for the year 1902?

A. No, I don't think that I prepared that table.

Q. Were the results of your observations for the year 1902 published?

A. I think all I made were in this previous report.

Q. Now, Mr. Sabin, the data concerning which you have testified as being the results of your own observation, and shown in Appendix EEE, are those observations and the data contained in that report subject to any other corrections than those that I suggested in the former question, than the corrections due to the more accurate determinations of the bench marks?

A. No, except as appears in the report.

Q. Now, will you look at the map and the cross-section on plate 1, opposite page 5400 of Appendix III and KKK of the annual report of the Chief of Engineers for 1900, and state whether or not that plate was prepared under your direction and supervision?

A. Yes, sir, it was.

Q. And is it correct, and does it correctly represent the matters purporting to be shown thereon?

A. It was compiled from the best data available at the time.

Q. And to the best of your knowledge and belief it is as correct as could have been made from that data?

A. Yes, sir.

Q. Have you any reason to believe that the conditions existing at the time that that plate,—cross-section,—was prepared, were any different from what they are now?

A. There have probably been some slight changes along the banks.

Q. Well, confine it, then, to the time that it was prepared. Have you reason to believe that any of the facts purporting to be shown on that plate were different from the actual facts?

A. No, sir.

Mr. Williams: Now, Mr. Wilkerson, I would like to have marked for identification, or else have it understood, that

those pages from the report of the Chief Engineer for the year 1902 may be offered in evidence later on.

Mr. Wilkerson: You can give the numbers of the pages to the reporter, and the numbers of the plates that have been previously identified by the witness, and those pages to which you have referred may be used for the purpose of impeachment or parol testimony, so far as he has identified them.

Mr. Williams: Q. Mr. Sabin, at how many points in the measured cross-section of the St. Clair River did you use the current meter in making your observations?

A. The section was divided into, I think, 21 partial areas.

Q. At what width of the river was it divided into that many areas?

A. The section is a little over 2100 feet in width, and then observations for discharge were taken 100 feet apart. The section was divided into 21 partial areas with a discharge station in the center of each, with the exception of the two end areas, the width of which varied with the water stage. Then within each of those partial areas the meters were placed at different points,—that is, not simply at one point in that 100 feet.

Q. You mean different points horizontally?

A. Both the vertical and transverse curves were observed for, but more particularly the vertical curve, that is, the change in velocity from the surface to the bottom.

Q. How many meters did you use?

A. I think 11 at one time was the most that we used, but ordinarily in taking the discharge, only two meters at a time.

Q. Well, now, in making the measurement at a given point, how did you arrange your meters? Were they suspended in the water one above the other?

A. They were, for getting what I have referred to as the vertical curve, that is, showing the changes in velocity from the surface to the bottom.

Q. And in such case how many meters would be used?

A. We used from 6 to 11 meters for that purpose.

Q. How many of these meters, or were they all, rated?

A. Yes, sir, they were all rated.

Q. How many of those meters that were used there were direction meters?

A. That information is given in the report; I can only get it from that.

Q. Is that in that same report that you have just referred to?

A. Yes.

Q. Will you give the page?

A. It is about 5369, for 1900; there is a description of the method of getting the vertical curves.

Q. How long a time was consumed in getting the vertical curve at any given point?

A. Station 1 was occupied three days in making observations, and there were six sets, that is, six settings of the meter for that, and 11 curves were observed, and in the stations further out usually more than that, but from three to four days' occupation; that was not continuous. I don't mean eight hours a day continuously, but they were occupied on that many different days, so that the vertical curve was obtained, that is, this relation of change of velocity was obtained under several different conditions.

Q. And what was the total length of time required to make a single measurement of the discharge of the whole river?

A. I think we took from two to four discharge measurements, running across the river two to four times in one working day. That is my recollection of it. That shows in the table which I have identified, the number of discharges that were measured on any given day.

Q. Ten hours or eight or sixteen?

A. Well, about ten, probably.

Q. Will you give us your opinion as to the degree of accuracy that is secured by the use of these meters, the percentage?

A. In order to make my answer to that intelligible I think I should know a little more definitely just what you have in mind, whether you mean under the conditions existing on one day, how close did we know the discharge when we measured it on that day,—is that what you have in mind?

Q. Yes.

A. I should say somewhere in the neighborhood of 5 per cent.

Q. You mean by that that the actual amount of water flowing might be either 5 per cent. less or 5 per cent. more than there shown?

A. For that one observation.

Q. For that one observation?

A. Yes, sir.

Q. Within a range, then, of practically 10 per cent.?

A. Yes, that is a rough approximation of my idea of the accuracy of it.

Q. What method did you use to determine the exact point on the line which was the water surface or the vertical plane of the cross section?

A. Horizontally?

Q. Where you had an upper line of a vertical plane?

A. The intersection of the cross section with the water surface of the river?

Q. Yes.

A. And how we located ourselves across the river, transverse to the river, along the line?

Q. Along the upper line, yes.

A. By the use of ranges on shore.

Q. How nearly accurate would you say that those determinations of positions were?

A. Within probably five feet.

Q. What precautions did you take, or what means did you employ to make sure that none of your determinations were vitiated by the shifting currents, and the changes of lake elevation due to the wind and eddies?

A. We measured the velocity of the current as it actually existed at the time we were there. There was no way of stopping the wind or the eddies.

Q. But those measurements you were making were later to be used in connection with the level of the lake in order to ascertain the relation one to the other?

A. Yes, sir.

Q. Now, then, did you have any means of making sure that that relation could not be ascertained because of temporary fluctuations in the lake level during the time of your observations?

A. The lake level was taken continuously during the time of the observations. We knew the lake level at each observation.

Q. But if the lake level rose suddenly by reason of some temporary cause, such as a wind, and remained in that position for a few hours, did you take that as an ordinary stage of the lake, as unaffected by that temporary condition, in ascertaining the relation between the two, the discharge and the level?

A. That observation was used with all of the information which we had about it, in the reduction of the entire series of observations.

Q. I don't know whether we understood each other when

I asked you the possible error in locating the upper line of your gauging section?

A. Those were located from the shore.

Q. The vertical location of the water surface at your gauging station, I mean?

A. That was considered to be the same as the elevation at the end of the section. That is what you are getting at is it not?

Q. At both ends or one end?

A. A part of the time it was read at both ends; usually at one end.

Q. Did you ever observe any difference in the elevation at the two ends?

A. Oh, yes, slight variations; nothing that was at all surprising?

Q. How great a variation did you observe?

A. I don't recall.

Q. Would it have been more accurate if you had located your line from both ends rather than from one end?

A. It would have been a refinement that was hardly warranted.

Q. Can you give us any estimate of the difference in elevation which you did observe between the two ends?

A. No, I have no recollection of that.

Q. Could you within any reasonable limits? Could you say an inch, or half an inch, or a foot?

A. I should think at times it might have been as much as an inch.

Q. Suppose that the level of Lake Huron was lower, would the increment become greater or less per foot of drop as the level of the lake was lower?

A. It would be very slight, if any change; the tendency would be to decrease the increment.

Q. Suppose the level of Lake Huron should drop, say, five feet, would there be a substantial decrease in the increment?

A. I should not expect a very serious change from a five-foot drop.

Q. Suppose it should drop ten feet?

A. I don't care to go into that.

Q. Would you have any opinion on it at all?

A. No, sir.

Q. You say you have no opinion as to whether the increment would decrease substantially?

A. No, there has never been known to have been as low as a ten foot fall.

Q. Suppose that Lake St. Clair is at the same elevation during a series of observations, and different elevations in Lake Huron, would you say then that the difference of the discharge in St. Clair River was due to the changes in Lake Huron alone?

A. If that was the only factor named, I would expect that the effect would be due to that change.

Q. What other factor would you expect to enter into that situation?

A. What part of Lake Huron are you considering?

Q. At the north of the St. Clair River?

A. At the head of the St. Clair River?

Q. The part that you observed during the time you made your observations, and upon which these plates are based?

A. A given level at a given point on the St. Clair River would not necessarily mean that the level at another point was always the same at the time that the level at the first point became the same. It would depend upon what made the changes in level at the time. That is, I can conceive of temporary effects, such as wind, which would pile the water up at one part of the river, and make a different form of water surface than when the same level existed at one of those points under natural conditions without wind.

Q. Assuming just natural conditions, without wind?

A. Then I should expect that the change in discharge, the observed change in discharge, was due to the change in Lake Huron, that being the only factor there.

Q. Did I understand you to say, in answer to a question asked you by Mr. Wilkerson, that a decreased flow through the St. Clair River indicated a lowering of Lake Huron?

A. Other things being equal, yes.

Q. There might be a decreased flow, owing to an increase in the elevation of Lake Erie?

A. Yes, sir.

Q. And that would not indicate that Lake Huron was any lower?

A. Not necessarily.

Q. You testified in reference to the ice effects. What is the relative importance of the ice effect in the outlet of Lake Huron, as compared with the ice effect in the outlet to Lake Erie, the Niagara River?

A. I don't know what the relative importance is, for a

term of years. I think that the effect on Lake Michigan and Huron,—or the effect on the discharge of the St. Clair River,—might be greater at times—I will change that just a little—

Q. What we are trying to get at is, would the ice effect tend to raise the elevation of Lake Huron more than the ice effect would tend to raise the elevation of Lake Erie, or less?

A. For the same retardation of flow in the outlet, the effect on Lake Erie would be greater.

Q. I mean the conditions as they exist, and as they are customarily to be observed?

A. I am inclined to think that the effects on Lake Michigan and Huron are greater than they are on Lake Erie.

Q. Would a change in the channel of the Detroit River affect the level of Lake St. Clair?

A. Yes.

Q. An increased cross-section there, having greater flow, would tend to lower the level of Lake St. Clair?

A. Yes, sir.

Q. State whether or not, in your opinion, the levels of Lakes Huron and Michigan are controlled by the hydraulic conditions at any single section in the outlet of those lakes?

A. No, I think not.

Q. In your opinion would changes in the channel of the St. Clair River at points other than at the Rapids affect the discharges of Lakes Huron and Michigan, for a given stage?

A. Slightly.

Q. Would a change in the level of Lake St. Clair affect the discharge from Lake Huron?

A. Yes.

Q. Did you make any computations from the result of your observations as to the discharge through the St. Clair River, and the elevation of Lake Huron, with a view to determining the increment?

A. That was one of the main purposes of those discharge observations.

Q. Well, you made the computation?

A. Yes, sir.

Q. And the result of your computation was that the increment of Lake Huron, based upon those observations, was 19,238 cubic feet per second?

A. Approximately that.

Q. What percentage of accuracy, in your opinion, does that figure represent?

A. I think that that may vary, as I said in my direct testimony, from about 16,000 to 23,000 or 24,000,—24,000.

Q. There is a range there of about 50 per cent.?

A. Yes, sir.

Q. And have you any explanation to offer, other than the lack of precise and accurate methods of determination of the difference in results obtained by you as the result of your observations and the results shown by these plats, as to the increment from Lake Huron?

A. It is not a question of accuracy of methods of observation; there is no such error as that in the observations.

Q. Did you use a different method of computation from those employed in this chart?

A. The difference is due to the amount of the change in discharge which is charged to the level of Lake Erie, and the amount of the change in discharge charged to the level of Lake Huron and Michigan. That is where that large possible error of increment comes in.

Q. Do you think it possible that there might have been a change in the regimen of the St. Clair River, and that that might account for some of the difference?

A. It is possible but not probable.

Re-direct Examination by Mr. Wilkerson.

Q. Counsel in cross-examination asked you something about changing bench marks. I think you testified on that.

A. In connection with those tables?

Q. Yes.

A. Yes, sir.

Q. Did that change have any relation to or bearing upon the determination of the increment or the lowering—

Mr. Williams: We do not claim it does have.

Mr. Wilkerson: You do not claim it does have?

Mr. Williams: No.

Mr. Wilkerson: Q. Now, counsel put to you some questions that were predicated upon the assumption that in measuring the levels of the lake at a given time, the measurement would be taken under conditions where by reason of a storm or some other local condition, the level of the lake would be temporarily affected by that. Assuming that you did at any one time take some measurements when there was that temporary condition, I wish you would explain a little more fully just how that particular observation would be treated so far as

correcting it with reference to other observations, and taken in combination with others, taking into consideration the fluctuation that the lake made?

A. That is the reason or at least one of the main reasons why these points which we get in making observations do not fall on the straight line, showing the relation between the height of the lake and the amount of discharge.

Q. Now, looking at one of those lines that are drawn there, treating it as a question of eyesight, as well as of mathematics, what is the fact with reference to any error that might be injected, by reason of temporary conditions at one time being counterbalanced or overcome by temporary conditions the other way at another time? How does that work out in practice, when you come to group all these observations together?

A. In a line drawn as this one is on Exhibit No. 1, there are about as many points on one side of the line as there are on the other. That is what we mean by saying that the line fairly represents the observations and the variation of any given point from the line shows the error there may be in that observation. If every measurement were exactly correct, we would only need to take two to get this increment.

Q. So that even though there may be a large chance for error in one observation by reason of temporary conditions when we have simply the single observation in mind, what is the fact with reference to the comparative error when we speak of the general result which is reached from the combination of a large number of these observations, and of many series of them?

A. A great many of the errors of observation are what we call compensating; that is they may at one time make the result too large and at another time too small. There are certain other errors which are constant errors. The compensating errors tend to compensate each other; and the effects of wind and storms and things of that kind are of that nature. And if they are so serious as to warrant it, they sometimes cause the rejection of an observation; although that is rather seldom done.

Q. Isn't this principle that you have just pointed out here something that enters into—is it or is it not something that enters into the determination of any rule which is derived from a long series of observations? Take for instance tables of mortality, derived from actual observation.

Mr. Williams: I do not assume that the witness is an expert on mortality tables, too.

Mr. Wilkerson: Q. You know in a general way how those tables are derived, do you not?

A. I think that that might be put as an illustration of any engineering data that rests upon observation; no observation is absolute.

Q. Now, I have used here, for the purpose of comparison, mortality tables, which are things that are used as the basis of computation in all the affairs of life and are recognized in courts as stating the results with substantial accuracy. For one time, for instance, there will be temporary conditions that intervene, as for instance the prevalence of an epidemic at the particular place where the observation is made; while there may be another period, at another place when there is something that tends to compensate that. That is, is that a fair analogy to—

A. I should hardly think so. If our engineering data were not any better than that—

Q. I mean not with respect to the degree of accuracy, but with respect to the method?

A. Qualitatively, yes, but not quantitatively.

Q. Mr. Sabin, if the water surface on the cross section may not be quite level across and the two gauges show slightly different heights, does the same condition obtain when the soundings are made, so as to eliminate any error which may come in by the arching of the river?

A. What I understood the counsel to have in mind when he inquired about that was a temporary effect due to wind, which may pile the water up on one side of the section slightly; and if that is what you are referring to, of course the soundings might not have been made under that same condition. But if the wind piled the water up on one side of a section by an inch at one time, it would be as likely to pile it up on the other side at another time, and it would be one of our—go in as one of our errors of observation.

Q. In the case in which you assume, in response to the question of the counsel on cross-examination, that the one gauge was an inch higher than the other, what would be the error that would come from that, would it be a substantial one; error in the discharge?

A. Very small.

Q. Can you state that more definitely than that, what do you mean by very small?

A. Perhaps one-tenth of one per cent.

Q. In speaking of this increment of 19,000 cubic feet per second, that is the one deduced from your observations, what do you say, Mr. Sabin, as to the range of those observations, compared with the range of the observations on the charts which have been used in this case?

A. I have not in mind just how much the range was increased by the later observations, but it was increased, appreciably increased; so that taking the new observations with mine, a larger range of height was covered, and therefore the deductions from it would be, on that account, better.

Q. Then there was some difference you said that grew out of the manner in which Lake Erie was treated?

A. Yes.

Q. That is the allowance that has been made on account of that in these later computations would make the increment larger than the one as you had it?

A. It did make it larger.

Q. And I think you have already said that so far as the size of the increment as a maximum is concerned, the figures that appear on these charts are at the limit on that?

A. Yes, I think that that would be—for St. Clair I think that is the largest determination that I would expect to be the truth.

Q. In other words in dealing with those, whose interest it is to have the increment as large as possible, would you say that the substantial considerations have all been resolved in favor of the large increment?

A. I gave that as the upper limit of my determination.

Re-cross Examination by Mr. Williams.

Q. Mr. Wheeler in his testimony yesterday—you heard him testify?

A. I heard most of Mr. Wheelers' testimony.

Q. He testified that he had compared the observations that were platted here with the published observations, did he not?

A. I don't recall whether he said that he had compared the observations on these plates with the published observations or not.

Q. Assume that he did say that, what observations have been published other than those to which your attention has been called this afternoon?

A. The observations of 1902, in the report of 1902.
Q. His attention was called to that?
A. Yes, sir.

Further Re-direct Examination by Mr. Wilkerson.

Q. I do not recall, Mr. Sabin, whether you covered this ground or not, but to make sure I want to ask you a question with reference to the degree of the precision of these gauge readings in hundredths of a foot. What is your idea about that?

A. The gauge readings which were published in the 1903 report, and have been mentioned in this case, are monthly mean levels. Those are obtained by taking one or more observations per day on a given gauge. It is possible to have in one reading a considerable error; probably they are easily read within one-tenth of a foot; but occasionally mistakes may be made larger than this. I would expect that the result given for any month as the monthly mean would not have an error in it due to such errors of observation of the gauge of more than three-quarters of an inch.

Q. Have you anything to add in the way of a reason for that?

A. Principally from my experience in looking over gauge readings and reducing them, that it is so seldom that a mistake is made that I should think the final result, being a mean of a large number of observations, would be quite accurate.

Q. Then there is the check of the two gauges, is there not, on the same lake?

A. In many places there are two gauges.

Further Re-cross Examination by Mr. Williams.

Q. The testimony you have just given in response to counsel's questions, applies, does it, to the elevations recorded on pages 2867, 2868, 2869, 2870 and 2871 of Appendix FFF of the Annual Report of the Chief of Engineers of 1903?

A. It applies so far as that class of errors is concerned.

Q. And you would consider that the elevations recorded on those pages to which your attention was called correctly represent those elevations, subject to only the very slight errors which you have indicated might have crept in?

A. No, sir, I do not; I do not agree with that; I said so far as the errors of the kind which I mentioned were concerned.

Q. What other errors do you take into consideration in the compiling of these tables showing the elevations of these lakes?

A. Those tables give the difference in elevation between the lake surface and sea level.

Q. In addition to the error that you have pointed out as possible in the gauge readings, what would be the probable error or possible error relating to the elevation between sea level and zero on the gauge? You mean that there may be an error in addition to the error of the reading of the measurement between the sea level and the zero?

A. Yes, that is one error.

Q. To what extent would you say that error prevailed if at all, within what limits?

A. I don't know anything about the size of that, possible size of that error, but I will say this, which will answer your question, I think: that the difference between the error for one lake and the error for another lake is not very great.

Q. When you say not very great what do you mean?

A. Well, not greater than three-tenths.

Q. Of a foot?

A. Yes.

Q. And that is a constant, a continuous error?

A. For that given lake, yes, as published in those tables, yes. Then there is one other kind of error, or one or two other kinds of errors that may be in that table.

Q. Just enumerate them if you will; we want to get them?

A. The leveling from the bench mark to the water gauge may be an error depending upon the length, the distance; that will usually be less than one-half of a tenth.

Q. Are there any others?

A. No, I don't recall any others, so far as giving the elevation at the place where the gauge is located is concerned.

Further Re-direct Examination by Mr. Wilkerson.

Q. Just one question: with reference to this possible error in the elevation of zero on the gauge above the sea level, is that an error which would in any way affect substantially the result attained for increment of flow?

A. No, it would have practically no effect on that quantity.

Adjourned sine die.

Detroit, Michigan, May 24, 1909.

Ten o'clock a. m.

WILLIAM LIVINGSTON, a witness called on behalf of the government, was first duly sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. State your name please.
A. William Livingston.
Q. Where do you live?
A. Detroit.
Q. What is your present business or occupation?
A. I am at present with the Lake Carriers Association.
Q. What is the nature of your work in connection with that position?
A. I am supposed in a general way to look after the interests of the association. We have an executive committee that I work in conjunction with. I am supposed to look after, to a certain extent, everything that pertains to or affects the interests of navigation, in the way of improvements, etc., for instance deepening of harbors and rivers.
Q. How long have you had to do with matters relating to the navigation of the lakes?
A. Thirty-five years, certain.
Q. In a general way, what experience have you had in connection with such matters?
A. Well, as owner of vessels, handling of them, managing of them.
Q. Have you had any practical experience?
A. Well, a little.
Q. In connection with the management of vessels?
A. What do you mean by practical experience?
Q. Owning and handling them.
A. Some.
Q. I mean for you to cover in outline just what your experience has been, in matters relating to navigation on the lakes?
A. Well, my first vessel experience, so far as my memory goes now, dates back to 1867; I used to handle a good deal a small boat at that time; and I have been continuously connected with the lake transportation business. I think, on re-

flection, that makes 40 years instead of 35, and I have been continuously in the business all that time.

Q. What is it that determines the size of vessels which may be used in commerce on the lakes?

A. You mean at the present time?

Q. Yes. For instance, what determines how large a boat may be used in carrying on commerce between Buffalo and points up in Lake Superior?

A. There was a boat launched the other day that is 607 feet over all. I didn't measure it, but that is the statement made to me. That is the Chenango. I think the boat on that measurement would be a lot the largest boat on the lakes. She was launched either three or four weeks ago Saturday.

Q. What determines the depth to which boats engaged in lake commerce can be loaded?

A. The lowest point going through the rivers and, of course, the harbor or port she is consigned to. For instance, if a boat were loaded in Chicago or South Chicago, she would have to load to the depth of water there at the present time. She would be confined to two things: First, in rivers to the depth of water on Ballard's Reef, down here in the lower Detroit River, the reason for that being that the water crossing Ballard's Reef is a little shoaler than the Lime Kiln Crossing and at Bar Point. I should add, of course, if the harbor wherever she was consigned to and went to load, if that harbor was shoaler than Ballard's Reef, she would have to take that into consideration. But I do not know of any just now where she would have to take that into consideration. I think Ballard's Reef would be about the governing point.

Q. What about boats that are carrying to points on Lake Superior, Duluth, for example?

A. We take the depth of water there from the Poe lock. In other words, the engineer at the Poe lock, the assistant engineer, Mr. Sabin, keeps a constant gauge of the water there; and whatever depth he gives that we can load safely to going through the lock is what we use. It started in this season at 18.3; it is now 18.8. You can go through the Canadian lock with a little more water; I don't know just how much, because we do not have an official report on that, the same as we do on the Poe Lock; so that the Poe lock has to govern on that. Going there, it makes no difference if you load to a hundred feet outside, you have to take the shoalest spot and be governed by that. The water is lower this year in the Lake Superior district.

Q. Having in mind your experience with reference to matters connected with the navigation of the lakes, and speaking from that experience and from your knowledge, I wish you would state what would be the effect upon the load that a boat can carry of the lowering of the water at any one of these critical points in the channels of the lakes? For example, suppose that in some way the water in one of those channels was lowered an inch or two inches. What is the relation between that and the size of a load that a boat could carry going through the channel?

A. Speaking of the average?

Q. Well, take any boat that you have in mind. I would like to have you give us an explanation of that relation; state what the effect would be, based upon your experience.

A. Well, approximately speaking, taking the smaller class of boats, they are rapidly becoming obsolete.

Q. Go ahead and make you explanation in your own way.

A. As fast as they get into trouble or become disabled or anything of that kind, or lost, they are not replaced. Of course, now everything is steel. You take the last ten years, the last eight years particularly, has worked a sort of revolution here on the lakes. For instance, seven years ago—I am approximating; I can't give you to the month perhaps, but about seven years ago, for instance, the steamer A. B. Wolvin was built; and when she was built she was the largest vessel on the lakes. She exceeded in tonnage by 3,500 tons the next largest vessel. All the boats that have been built from that time on, with the exception of boats that were built for some specific traffic, say for instance the package freight traffic, something of that kind, have all been built of her type, all through; some a little smaller. But the smallest boat that is built now for business purposes, I know of none that will run under say 7,500 to 8,000 tons; and they run from that up. We have boats now that will carry 12,000 gross tons. I figure that the average per inch when a boat is loaded, say 18 feet or more, would be from 80 to 100 tons per inch. You take the lowest average, 80 tons, or cut it a little more if you choose to 75 tons, on the present rate of freight.

Q. Let me put a question to you there, Mr. Livingston: Having in mind this average boat with reference to which you have been testifying, and assuming that there was a permanent lowering of the water at one of these critical points of navigation of one inch, and basing your answer upon

freight rates as they exist now, what would be the loss to that boat?

A. Of one inch?

Q. Of one inch on the navigation of a season, we will say.

A. Assuming the average boat, and putting it on the basis of 80 tons—you could cut that to 75, but call it 80 tons just for illustration purposes, assuming as a fair average, in other words a very conservative average, the boat made twenty trips during a season, one inch would make a loss to each boat of over a thousand dollars in a season. Each inch would add just so much more to it. In other words, a boat going down and crossing Ballard's Reef drawing 18 feet or 19 feet, each inch you cut from that would be just that difference in the course of a season. The loss would vary as the freight rates vary.

Q. Now, you have knowledge on the subject of the number of boats that are engaged in commerce on the lakes in a general way, have you, Mr. Livingston?

A. Yes, sir.

Q. Have you given any consideration to the question of the total loss to commerce on the lakes, which would result from this lowering we will say, of one inch, basing that upon the number of boats that are engaged in lake commerce. Have you given any consideration to that subject?

A. Well, I could do this: We have, roughly speaking, in our association—of course you understand I confine my attention practically to our own association—we have about 600 boats.

Q. I wish you would give us anything that would be helpful in determining the loss to the commerce of the lakes occasioned by that lowering, based upon your experience and your knowledge; any facts that you think bear on that within your knowledge, I wish you would give it to us.

A. I would be glad to hand you in a computation; I would have to make it. It would not take me long to make it. I can also in that connection give you, as we are just getting one out now, a printed list of all the boats in the association, and the tonnage, both gross and net, the tonnage of each.

Q. You started out by giving us the effect of that lowering upon the carrying capacity of one boat?

A. Yes, sir.

Q. You have knowledge, of course, with reference to the total number of boats that are engaged in commerce on the

lakes. I want you in a general way to give us the facts with reference to the aggregate effect of this lowering upon commerce, so far as you have knowledge on the subject.

A. Well, do you mean all the vessels engaged in commerce on the lakes?

Q. Excluding, of course, those that are engaged exclusively in traffic on Lake Superior.

A. Yes, but what I am trying to get at, Mr. Wilkerson, is this: I have got a fairly thorough knowledge, I think, of everything pertaining to the boats that belong to the Lake Carriers Association. I am not quite so familiar, of course, naturally, with the boats outside of it. I could give you pretty accurate statements regarding, say, the six hundred boats that belong to the association. That would take the cream of the carrying capacity on the lakes.

Q. Answer the question on that basis.

A. It would give you a great big average. I want you to understand when I speak about registered tonnage, for instance, when you have a boat that will carry say in the neighborhood of 6,000 tons, a 600 footer, in the neighborhood of say 6,000 tons gross tonnage, custom house measurement, that boat will carry 12,000 tons of freight.

Q. Have you given the number of vessels that belong to the owners who are members of your association, approximately?

A. I will give it to you approximately.

Q. About 600 I think you said?

A. Yes.

Q. What percentage of that number of vessels is engaged in through traffic?

A. By through traffic you mean that pass the Detroit River, loading above?

Q. Yes. Practically all of them?

A. All of them, yes.

Q. Would all of the 600 be affected by the lowering of the lake levels to the extent of an inch?

A. No, sir.

Q. Which would not?

A. You take the boat for instance, as you can readily see, the boat that was so small that it didn't draw depth of water enough to be affected by the water, for instance, at the lowest point, of course an inch would not affect that boat.

Q. About what proportion would be affected by lowering?

A. I would prefer before stating it under oath to figure it out, but if I were to give it to you approximately, I would say 70 per cent.

Q. Seventy per cent. would be affected?

A. Yes.

Q. Would you say at least 70 per cent.?

A. I think so. I can figure it out. I can give you one fleet, if you care to have it, approximately.

Q. All right.

A. We have one fleet on the lakes that has 73 ships.

Q. What fleet is that?

A. Pittsburg Steamship Company.

Q. Give us the facts with reference to the Pittsburg Steamship Company.

A. Seventy-three ships have been loaded to 19 feet, but 18 of those 73 could load to 21. These boats in a normal season carry 10,000,000 tons, so that if you take these boats, they will make more trips than I gave you, more than 20, perhaps, in a season, but I did not think it was fair to take them, for the reason that they are peculiarly situated. In other words, they can make more trips per season than any other fleet on the lakes, owing to the advantages which they have in their loading and unloading facilities. No other fleet on the lakes has the advantages they have for loading and unloading, facilities for dispatch. But if you take that fleet alone for instance, if you cut them down to 20 trips, was that two inches you figured on?

Q. Figure it on the basis of an inch.

A. The loss for that fleet alone would be, roughly speaking, over $85,000 on one inch; that is on the present freights.

Q. I think you said that of the vessels that were connected with your association about 70 per cent. would be affected by this lowering?

A. Yes, sir. I don't give that as positive.

Q. Taking it on the basis of 70 per cent., what would be the total loss to the commerce of the vessels that are connected with your association? I wish tc get a general idea on that.

A. Roughly speaking, about $650,000.

Q. That is for one inch?

A. That is for one inch.

Q. What proportion of the vessels that are engaged in commerce on the lakes and that would be affected by this low-

ering, would you say are connected with your association? I put that with a view of getting some idea of the total effect. You know approximately, do you not, about what percentage of vessels that are engaged in commerce on the lakes, that is of the largest, the ones that would be affected, belong to your association?

A. The lumber fleet would be out entirely, because none of the lumber fleet draw enough water to be affected. But outside of that, if you take the boats in the ore and the grain trade and that class of boats, I should think seven-eighths of them would be a fair estimate.

Q. That is seven-eighths are in your association?

A. Yes, sir.

Q. You think you are within safe limits when you say more than 80 per cent.?

A. I think so, sir.

Q. More than 80 per cent. belong to the Association?

A. I really do not know of any—yes, I think that is a fair estimate.

Q. So that the total loss to the commerce of the lakes would be about one-eighth more?

A. Yes. I am speaking now of the depth of water. I mean to be understood this way: that seven-eighths of the loss would be borne by the members of our association, from the fact that more than seven-eighths of the boats that draw that draft of water are in the Lake Carriers Association.

Q. When you have given us this information with reference to the loss to the commerce on the lakes from that permanent lowering, in order to get the total loss, you would have to increase the figures you have given by the amount lost by the vessels outside of your association?

A. Yes; the figures I have given, $650,000, are what 70 per cent.—I am not sure but I have made a mistake, because I was figuring the whole, and I have made a mistake on that. I was figuring the whole, and there is a certain percentage that would not load to that depth. I took the whole 600 vessels and I made a mistake. There is a portion of our fleet would not be affected, because when they are loaded to their utmost capacity, on account of their size, they would not be affected.

Q. The correct answer would be 70 per cent. of this $650,000?

A. Yes.

Q. Which would be between four and five hundred thousand dollars?

A. Yes, I have added 30 per cent. that I should not add. I think that is a very low estimate, but I had to give it approximately.

Q. That would be between four and five hundred thousand dollars?

A. Yes, it would go half a million, easy.

Q. You think that is a low estimate?

A. I think that is a low estimate, yes, sir.

Q. Now, coming back for a moment, Mr. Livingston, to the question of limitation upon the size of the vessels which engage in commerce on the lakes; what would be the effect with reference to the size of those vessels, if it were not for the limitations that are imposed by the depth of water in these critical points of navigation?

A. Why, it would very largely increase their carrying capacity, of course. You know the question of the 25-foot channel has been brought up a number of times. In fact, a survey has been made in some places regarding it, but the cost was so very great—

Mr. Williams: Just a moment. I object to the answer to this question as not being responsive to the question.

The witness: Well, sir, if you put the question so I understand it, I will be glad to answer it.

Q. (The question was read to the witness.) The fact I am trying to bring out, Mr. Livingston, a little more definitely is this: it relates to the extent of the effect of this lowering of the lake levels upon the future commerce of the lakes, and that in relation to the size of the vessels which can engage in that commerce.

A. Naturally the size of the vessels has to be limited to its present capacity, or, that is not putting it fairly, because we are building vessels right along with reference to getting a greater depth of water; consequently, all the vessels that are built now are built with reference to that in the future. That is, that we will eventually get the 25-foot channel. I can put that another way: all our modern vessels could load considerably deeper if the water would admit of it; in other words, if the shallow spots would admit of it.

Q. That is the fact I wanted to bring out.

A. Just wait one moment; I think I have something in my hand here; I did not know just what you wanted. (Referring to memorandum.) There is one fleet of some 18

boats that can load to 21 or 21½ feet; quite a number of fleets, I have not got them all here. There are none of the modern boats but what could load to a greater depth than that, load now, provided they had the water to do it.

Q. Is there any relation, Mr. Livingston, between the draft of a boat and the length of a boat?

A. They are all built in proportion.

Q. I will put a leading question to you: is the length of the boat in any way limited to the draft of the boat, as a matter of practical construction?

A. Well, it is supposed to be, but you see here on the lakes we have been compelled—we could not get any deeper under the present condition of affairs, and so the result was they have gone to length. They are limited, of course, in breadth. No, I will qualify that, because the Poe lock has 100 foot gates. The Canadian lock, the Canadian Sault, that lock is 60 foot wide, so, of course, going through that lock they are limited to the width.

Q. The question is, when you impose a limitation upon the draft of a boat, do you or do you not as a result of that impose a limitation upon the length of a boat that may be constructed with that particular draft?

A. It is generally figured that every marine architect in figuring out the cost of the boat, that he makes her depth—just as they do with the vessels on the ocean—he makes her breadth and her depth of beam proportionate to her length. We will say 1 to 10 the scale may be; that varies. But here on the lakes, on account of the shallowness of the water, we have been compelled to go outside of this variation, as evidenced by the fact that we have got quite a lot of 600 footers on the lakes and if they had been built strictly according to the scale they would have had greater depth on account of their length. But the theory was they would put in compensation straight against that.

Q. These boats that are constructed that way out of proportion you say—

A. I do not say they are out of proportion.

Q. Out of the orthodox rule?

A. Out of the standard rule.

Q. Out of the standard rule, do they hog in the middle?

A. No; the way that they have—as a matter of fact, most of these large boats have been made up in this way, so as to comply with the standard rule; they have given them a greater depth of water in anticipation of getting three or four more

feet of water within a reasonable time, so that although they do not actually draw it, they have still got the depth of hold. It would be pretty difficult, a man would be a bold man to say just what limits we will reach here on the lakes, any more than they would on the ocean.

Cross-Examination by Mr. Williams.

Q. What is the depth of water at Ballard's Reef?

A. It is 20 feet today. I think the water has been coming up a little.

Q. What is the depth of water at the Poe lock?

A. The depth of water at the Poe lock is 18 feet 8 inches, the latest report I have.

Q. The real critical point, then, is the Poe lock, is it not?

A. Coming from Lake Superior.

Q. Outside of Ballard's Reef that is the real critical point?

A. Yes; the Lime Kiln Crossing has always been the "Hell Gate," you know.

Q. At the present time what is the depth of water at the Lime Kiln Crossing as compared with Ballard's Reef?

A. Well, it is the same thing, 20 feet. Ballard's Reef is the gauge for Lime Kiln Crossing; it is just at the entrance, you know, of Lime Kiln Crossing.

Q. In your experience, is it your observation that those who are building vessels for lake traffic are building with a draft to meet the present or the future probable depths at these critical points?

A. I think the majority of the boats that are built now are built with a view to future depths. There is a strong, definite feeling in the minds of many of our vessel men and owners that we will get 25 feet. The question of cost is what comes up, getting the appropriation from Congress.

Q. Suppose there were an unlimited depth of water, that is, I mean a depth sufficient so that it could not in any way interfere with the draft of vessels on the great lakes, and at these critical points, to what depth would you consider it practicable to construct a lake vessel, what depth of draft, assuming there was no limitation whatever, so far as the critical points are concerned?

A. You mean that to apply to harbors, too?

Q. Yes.

A. Because it would not make any difference if you had a hundred feet outside, if you only had 20 foot depth in harbors.

Q. Assuming harbors having sufficient depth to meet any requirement that you might have?

A. I could not place a limit on that. Perhaps I can answer you in another way. You remember when the Great Eastern was built on the ocean, she was 640 feet, and was considered a failure. The result is now we have big boats in commission on the ocean that are 800 feet in length, 789, the Lusitania and Mauretania. There are two boats under construction so I am told—I do not vouch for it, but I think the contract has been let, although I am not positive about that, to build two trans-Atlantic liners of 1,000 feet.

Q. What is that thousand feet?

A. Thousand feet over all.

Q. That is in length?

A. That is in length.

Q. But I am speaking of the depth of draft?

A. Well, they will have boats, the deepest channel they can come in, the Ambrose channel at New York, when that is completed is to be 40 feet in depth.

Q. What I was trying to get at was this: Assume you are not limited in the depth of water either at the critical points on the Great Lakes or in the harbors, and that you are to do business, what amount of draft would you consider it practical to have in lake carrying boats?

A. Oh, I could not limit that. If you have your unlimited water, could draw any amount of water you wanted, I could not limit that. I could not give you—would not want to pass an opinion on that, because you see here ten years ago if a man had—

Q. Never mind about ten years ago. Answer the question.

A. I beg your pardon, I want you to mind about that, because ten years ago—you are asking me questions and I want to be straight about it—ten years ago if I or any other man in the business had stood up and predicted boats of the size of the Wolvin and the present line of boats we are building would ever be built on these lakes, that man would have been considered a fit candidate for a medical asylum.

Q. Is that the reason you say you do not want to make any prediction now?

A. Yes, because commerce on the lakes has gone forward with leaps and bounds, and I would not attempt to predict what the future might be.

Q. Now, assuming that there was 25 feet of water at the critical points and in the harbors in which your proposed

lake carrying vessels are to do business, what would be according to your information and experience the normal length over all of a boat drawing say 22 feet?

A. It would depend a little on her beam. You take such boats, for instance, as the Chenango launched the other day—

Q. I am not asking you for illustrations. If you can answer the question I wish you would; if you can't answer I would be very glad to have you say you do not care to express an opinion?

A. Then I will say no, I cannot.

Q. Is it true, according to your information and experience that vessels are now constructed longer than they would be constructed if it were not for these shallow points, for the purpose of carrying the same load?

A. Yes.

Q. And that increased length is for the purpose of compensating for the decreased draft, is it?

A. Yes, sir, but it is made up in beam, you understand, in breadth, to some extent.

Q. But the object of that is compensation for the decreased draft?

A. Yes, sir.

Q. The tendency, during the past ten years or so since 1900, has been to increase the size and draft of lake vessels, has it not?

A. Yes, sir.

Q. Can you state approximately the increase in average carrying capacity of lake vessels since 1900?

A. Approximately, yes.

Q. About what increase would you say?

A. Well, let me think a moment. Did you say since 1890?

Q. 1900?

A. Oh, 1900. Since 1890, about the largest boat on the lakes was 3,000 tons, and when I speak of tonnage—

Q. You say 1890, you mean 1900?

A. I will get to that in a moment. When I talk about the carrying capacity that has nothing to do with the Custom House measurement. In 1890, about the largest boat on the lakes carried about 3,100 tons of ore. It gradually increased from that up to 1900, until we may have had a boat that reached a carrying capacity of 5,000 tons; I am not positive about that. But there has been an increase from 1900 up to the present time of the difference say between a boat that could carry 5,000 tons up to the present carrying capacity.

We have had some boats that I think have gone into South Chicago that carried over 12,000 tons.

Q. Would you be safe in saying that the average carrying capacity of the lake vessels has increased a hundred per cent. since 1900?

A. I should say so, yes, sir, all the new vessels built.

Q. And that refers to the new vessels built?

A. Yes, sir.

Q. You have stated in answer to Mr. Wilkerson's questions, but I do not understand it and perhaps you can explain it so that even I can understand, that the gross tonnage would be 6,000 tons, but the boat would have a carrying capacity of perhaps twelve thousand?

A. Yes. I have some data I could give to you on that.

Q. Just explain how that is. I do not care anything about the details of it.

A. It is the government system of measurement. That is all I can tell you. It has been used ever since I have had any experience. For instance, take boats like the Gary and the Corey and this larger class of boats, 600 footers, their tonnage will run 5,900 tons, that is Custom House.

Q. That is gross tonnage?

A. Yes.

Q. That is according to government measurement?

A. Yes.

Q. What you would actually carry is what you will weigh and collect freight on?

A. Yes. It goes all the way through. For instance, I happen unfortunately to own a boat; she has a Custom House measurement of 1,700 tons. She carries for the present draft of water about 3,150 tons of ore.

Q. Mr. Livingstone, what would you say as to the comparison, if any, that you may be willing to make between the facilities for lake commerce at present and the demand for shipping facilities on lake carrying boats? Is there a sufficient number of boats to take care of the traffic?

A. To-day there is.

Q. And if there were a greater demand for transportation facilities on the lakes, there would be an increased number of boats to take care of that demand very probably?

A. We generally build a little ahead, always.

Q. What would you say as to the present situation, that you would be able to take care of more commerce than is actually taken care of on the Great Lakes, with the present facilities?

A. If the business of the country was normal, we would have but little if any tonnage to spare. Last year, being the panic year, or 1907 rather, you know how badly that affected the iron and ore trade, and what a large percentage of tonnage that is on the lakes, and the fact that Congress is chewing away just now on the tariff bill—

Q. Take last year, for instance, you had an excess tonnage?

A. Oh, we had excess tonnage, last year was the panic year, 1908.

Q. Did you have any excess tonnage in 1907?

A. No, not in 1907. Every available ton in 1907, so far as my knowledge goes, was in use; the largest year in the history of the shipping business on the lakes occurred in that fiscal year. I could give you the exact figures from my report in the office, but I haven't it with me. It was the largest in the history of the United States.

Q. What is the expense connected with the operation of one of these large lake freighters for a season, approximately?

A. Well, you know managements differ a little; approximately say $160 a day.

Q. That would be for how many days?

A. We generally figure about, being in commission, generally figure 240 days; that is for an average. Some seasons are a little longer; some are a trifle shorter.

Q. Two hundred and forty days at $160 a day?

A. $160, I am giving it to you approximately. You know some men will run their boats a little more economically than the others; some will carry more cargo, more passengers than others, and these things vary. Some will live better than others.

Q. In your opinion then about $40,000 would cover the expense?

A. Roughly speaking.

Q. The figures you have given would approximate $38,400?

A. The insurance on one of these boats amounts to between $16,000 and $17,000 dollars a year.

Q. Do the figures you give include insurance?

A. Yes, sir, I figured that. You understand that was an approximate figure because you see the insurance foots up so on a modern vessel. To-day, the insurance runs between $16,000 and $17,000.

Q. In giving your estimate, approximate estimate, do you

include anything in that for interest charges, or is this just operating expense?

A. Those are operating expenses. Include what did you say?

Q. Interest charges or depreciation on the vessel?

A. No, sir.

Q. What is the cost of one of those large vessels approximately?

A. Ten thousand tons, they run about $400,000. In some cases they will be built for a little less; sometimes a little more. It depends on the state of the iron and steel market, but about $400,000. If you take a 600-footer, built right up to date, and she is fitted up with perhaps a private cabin and separate dining room, private dining room, some of them run up perhaps to $440,000, or say $400,000. They will carry 10,000 tons of ore on an average draft of water; some even with a little less, you know.

Q. What in your judgment is the average life of one of those vessels?

A. These steel vessels?

Q. Yes.

A. I can't tell you that, because you understand that steel ships are comparatively new on the lakes as compared with the ocean. Then comes up the question as to how far rust is going to affect it, whether fresh water is going to affect that. That is a matter I would not like to pass on.

Q. What is the longest that any one boat has been in service?

A. I should say fifty years.

Q. How long has the longest one you have known been in service?

A. That is the steamer Michigan. She has an iron hull. She has been in service nearly sixty years now. They cut a piece of iron out of her hull, that must have been nearly twenty years ago, she was then forty years old, and the government had their engineers cut a piece out of her hull to look at the iron, etc., and they pronounced the fibre in connection with the piece they cut out as sound as the day it was built.

Q. If you were going to make an estimate, do you think fifty years would be conservative?

A. Yes, sir, I would. At that, I am only guessing. I think this: a good deal would depend on the care a man took of his vessel, having it scraped and the rust taken off; keeping it

painted inside and all that. It is like a man taking care of his health.

Q. What would you consider a fair interest charge, if you were going to figure on a valuation of $400,000 on a boat, and if you were going to ascertain whether you were making a profit or not?

A. You mean depreciation per year?

Q. No, I say interest charge?

A. Oh, interest on the investment; that is the return a man ought to have?

Q. Yes, if you were to figure whether or not you had a profitable year, you would figure first interest on your investment of $400,000?

A. I would.

Q. Your depreciation, and your operating expenses and your receipts. What interest charge would you consider a fair charge?

A. Well, I would figure something this way: I would take first, of course, all the actual expenses of the boat, all the money paid out and I would add to that 5 per cent. for depreciation. And then I would figure the return I should have on the face of that, above all.

Q. Would you consider it necessary to figure 5 per cent. depreciation on a boat that was likely to last fifty years?

A. Well, yes I would.

Q. Or would you include in that 5 per cent. the maintenance of the boat, repairs, and keeping it in condition?

A. Well, perhaps partially, but if you will let me explain when I say partially, you understand I would expect the hull of the boat to outlast for instance several series of boilers. Boilers subject to pressure, etc., wear out and have to be taken out. I would not class that in; so that I would take that out of depreciation. You take the life of an engine; take our triple expansion or quadruple, whatever they might be, they would have to be probably replaced after a certain length of time. I would in that 5 per cent. include the up-keep of the boat, keeping the boat in good condition, and any minor expense I would include in the 5 per cent. Then there is another thing you have to figure on, the changes in boats. You build a boat to-day, you think she is modern and up to date, you think you have everything up to date, but five years later something else may come along, and you will find you are behind the light house; and that 5 per cent. is little enough depreciation.

Q. Would you consider 5 per cent. also a fair interest on the investment?

A. No, sir, I would not.

Q. I am not speaking of profits on your season's work. I am figuring on the value of the money invested in the boat?

A. I think that ought to be 6 per cent. for this business.

Q. About 6 per cent.?

A. Yes, sir, I think so.

Q. Do you know of any bond issues being floated on boats of that character?

A. Well, yes.

Q. At what rate of interest?

A. Six per cent. But I will say this, so that you will clearly understand me, that the usual way of issuing these bonds is on a 5 per cent. basis, and they are issued for ten years and 10 per cent. are retired each year, but some bonds particularly —and that perhaps is not a fair criterion. Last year, you know, was the panic year, a good many bonds, a large number of bonds in fact—I speak from absolute personal knowledge on this—were sold below par sufficient to make them 6 per cent.; in fact went down to 6¼.

Q. A 6 per cent. estimate on the investment would be liberal to cover even panic years, wouldn't it?

A. Why, you clearly understand that I do not think 6 per cent. investment for a man's profits in the business—

Q. No, I am not talking about profits.

A. Yes, I think 6 per cent.

Q. That is something you ought to get before you figure profits?

A. Yes, sir. Then I understand you this is 6 per cent.

Q. Is there anything else you would figure on in the way of charges against your investment in a boat of this character, besides what you have mentioned; 6 per cent. interest on the investment, 5 per cent. for depreciation and up-keep, $160 a day approximately for operating expenses?

A. Yes, and insurance.

Q. And insurance. Is there anything else that will be proper to be charged?

A. I don't think of anything else now. I might just add one thing: you understand your expense account is dependent on conditions; is liable to vary some for this reason: sometimes provisions advance and sometimes labor costs more.

Q. That is included in your estimate of $160?

A. No, I am talking about the present situation.

Q. The normal situation?
A. The present situation.
Q. And is it normal?
A. Yes, it is normal. You never can surely tell just what labor is going to do.
Q. It might be a little more or a little less?
A. Yes.
Q. It is as likely to be one as the other?
A. Our experience on the lakes is it has never been less; it has been a constant increase. The experience of the last twenty years shows it has been in increase; wages increased, materials increased, living has increased. Help demands a great deal more than it used to.
Q. Have you any data from which you could give us accurate information as to the amount of money expended in any one season for repairs and maintenance of one of these large boats?
A. I could get it for you; but that is outside of extraordinary expense. You understand if a boat had a collision or broke down or for instance if she broke her cylinder, something of that kind, that would be extra. You mean a boat that runs through with just the ordinary—
Q. The average expense?
A. Yes, I could give you that; I could get it for you. I can't give it to you right now.
Mr. Wilkerson: To get the average, you would have to take the extraordinary with the ordinary?
Mr. Williams: The average conditions.
The Witness: I understand you mean a boat that runs through the whole season with the ordinary risk she takes, with nothing unusual happening during the season.
Q. That is right.
A. Because these accidents vary so much.
Q. Those accidents are usually covered by insurance, aren't they?
A. Yes.
Q. So that that would not be a proper element of charge in this?
A. As a rule they are covered by insurance.
Q. You will bring us those figures I have just asked for, this afternoon?
A. Yes. I do not know whether I can give it this afternoon. I will agree to turn it in the next day or two.
Q. Just as soon as you conveniently can, and before we conclude the hearing?

A. I have got a few things to do just now. I may want to increase that expense account per day before I get through.

Q. Now you have given us an estimate of the value to the vessel owner of a carrying capacity of 80 tons?

A. Yes, sir.

Q. For a season. And you estimate that value to be about a thousand dollars?

A. Yes.

Q. Basing that on present freight rates?

A. Yes, sir, based on 65 cent rate, from the head of the lake. This reduction of rate was made from 75 cents to 65.

Q. Was that thousand dollars a season gross or net?

A. That thousand dollars is gross.

Q. Nothing taken out for the expense of loading and unloading?

A. Yes, sir. I made a low estimate, just jumping at that, but I made the basis, my hasty conclusions, I made it on the basis of 65 cents, and it costs 20 cents a ton to unload.

Q. Did you make that estimate on the basis of 65 cents?

A. That was a rough estimate. I am trying to explain it was based on the present rate on freight, 65 cents a ton from the head of the lake. Out of that freight rate is paid about 20 cents a ton for unloading.

Q. What I am trying to get at is, does the thousand dollars include anything else; is that gross, without taking into consideration any of the expenses?

A. That is gross. That would be the only expense that would attach to the boat, because there would be the same expense for fuel.

Q. That applies to your half million dollars that you mentioned as being the loss to the entire fleet?

A. What I mean to be understood is this: that the actual loss to the boat would be this, supposing the rate was 65 cents a ton, that the actual loss to the boat would be 45 cents a ton.

Q. Is there any other expense connected with the carrying of this extra 80 tons besides the cost of unloading it?

A. None that I know of. The crew would be the same, the actual coal you would burn would be the same. I do not know of any other expense I could figure.

Q. Would a large load take any more coal than a small load?

A. I think it would be almost imperceptible, that.

Q. Would it take any more coal, if the vessel was capable of being loaded two feet deeper?

A. Oh, yes, if that is what you are getting at; I did not misunderstand you a bit. You are talking about 80 tons. I do say this: you take the percentage of coal, take it your way, take the percentage of coal used for six inches; you take the percentage of coal used for a boat drawing 19½ feet, and a boat built exactly like it, of the same power and the same boilers; one drawing 19½ feet and the other drawing 20 feet, the boat that draws 20 feet would burn some more coal; there isn't any question about that at all, but the proportion would be small. I think it is fair to say that there should be a little allowance made for it.

Q. Would it make any difference in the speed with which the boat moves?

A. Yes, it would make a little difference in the speed; still, by the same terms that would be very small. I would not go much on that for this reason: that your displacement in the water would be greater, and you would burn extra coal to make up for that displacement in the water, so that you could not count it both ways, you know.

Q. What is the widest beam of any of the lake carriers with which you are familiar?

A. Sixty feet is the greatest beam that we have at the present time. I have heard of one or two being projected wider, but not built yet. They have only been built within the last three years.

Q. Taking the 600 boats that you mentioned as being owned by members of your Association, 70 per cent. of which, you say, would be affected by the lowering of the water at the critical points—

A. (Interrupting.) At Ballard's Reef.

Q. At Ballard's Reef, do all of the boats included in that 70 per cent. navigate through the Detroit River?

A. Do they go through the Detroit River?

Q. Yes, on all their trips?

A. Well, perhaps, not; the largest portion do, but there is some that would not for this reason: you take a boat, for instance, going from Lake Superior to South Chicago, she does not come down the river at all.

Q. And she would not be affected by any change in the level at Ballard's Reef?

A. She would not be affected, no.

Q. What percentage of the 70 per cent. would you say ply between South Chicago, or any port—

A. I can't answer that question without looking it up; I would not like to answer it. I will look it up.

Q. Have you data from which you could determine that question?

A. Well, I could, so far as our own boats are concerned, I think.

Q. I mean so far as your own boats are concerned?

A. Yes, I think I can.

Q. Will you be kind enough to do so before the hearing closes. I am not particular as to the time but let us know what percentage of the boats do not pass through the Detroit River?

A. It is small as compared to the whole number; but then there is a percentage and I have an impression, but it is only an impression—I do not give it as a fact—I have an impression that in making my estimate of 70 per cent., it would allow for any that might go in the Lake Michigan trade; but that is my impression, not positive about it.

Mr. Wilkerson: Those would be affected by the Poe lock. The boats that come down from Lake Superior to South Chicago would be affected by the level of the water in the Poe lock?

A. Oh, yes, of course.

Q. As I understood you a moment ago, now the water is lower there than it is at these other critical points that you testified to?

A. Yes, sir.

Q. Eighteen and eight-tenths at the Poe Lock?

A. Yes.

Q. And 20 at Ballard's Reef?

A. Yes; just a shade less than that. We call it 20 feet.

Mr. Williams: Mr. Livingston is going to give us some figures and my suggestion is that we stop here. I do not think of anything more I wish to cross-examine him about except on those points, but I would like to reserve the right to ask him some further questions when he brings in that information.

Mr. Wilkerson: Certainly. You may reserve your right to question him further.

Re-direct Examination by Mr. Wilkerson.

Q. Coming back to this question of freight rates and the elements that enter into the determination of those rates, is there anything that enters into that with the exception of these items of cost and interest, cost of operation and allow-

ance to be made for depreciation. I refer, for example, to the fact of railroad rates and competition of that kind. Is that an element that enters into determining what the rate is?

A. No, that would affect the tonnage; it does not affect the general—

Q. I mean, would it affect any trade at all?

A. I must confess I do not think I clearly understand that. So far as the bulk of the carrying trade on the lakes is concerned, the railroad rates practically cut no figure, because we carry freight on the lakes at the lowest rate of freight known in the world. You take railroad freight, for instance, roughly speaking about the lowest estimate that I know of that has been made anywhere, and that is when the Lake Shore was publishing rates, these rates, I think they were about—the lowest freight rate that I know of now on any railroad is about four-tenths of a cent per ton per mile, about that. I do not give it exactly. And you see we carry freight on the lakes now for about seven-tenths of a mill per ton; so that there is no place in the world where freight is carried so cheaply as it is on the Great Lakes. The package freight lines, they would carry in competition to some extent with the railroads; but as a rule the package freight lines are owned by the railroads, and so they take their mileage *pro rata* out of whatever the rate would be. I would have to qualify that to a little extent; it would affect a little the grain rates, but we always carry it so much cheaper that it does not affect us seriously. It would, of course, if the railroads would go in, as they have done sometimes in Chicago, when they wanted tonnage they would go in just before the opening of navigation; they used to make a practice of that but they have not gone into that so much lately; they would slaughter a rate and make a low rate for the sake of moving a lot of the grain before navigation. But Chicago has ceased to be the great grain port that it used to be.

Q. Directing your attention to the line of questions relating to the lengthening and widening of the vessels that are engaged in commerce on the lakes, is it a fact that a vessel might be made longer and wider and yet not be understood as affecting in any way what you have stated with reference to the loss to commerce, by reason of diminishing the depth of the water in the channels and harbors?

A. I do not know that I get that quite clearly.

Q. (The question was read to the witness.)

A. Every inch you lowered the water would be a loss to

commerce, of course, because you would reduce the tonnage you carry. For instance, everything that is done now is done with a view to the future. Here is the new lock at the Sault that the government is building now.

Q. That is to say, without regard to how long or how wide you may construct vessels—

A. Not at all.

Q. The loss by reason of being unable to make the draft more than so much is always there?

A. Well, that is evidenced by the fact we are going to get more water; that is beyond a doubt, because here is the new lock at the Sault that is to be 1,350 feet long, 85 feet wide and 24½ feet on the mitre sill, based on a depth of water of 601.5 at New York, ocean level.

Q. You spoke about accidents to vessels being covered by insurance, that is to say about the loss resulting from accidents being covered by insurance?

A. Yes, sir.

Q. I assume it is not the practice, is it, to have an insurance which covers the lost time?

A. Oh, no, no.

Q. That always remains?

A. No insurance covers lost time; there might be a case arise, which Golden explains better than I can, a vessel might do this: in case she had a collision and the other vessel was found to be at fault, she would be able to charge demurrage for the time she was out of commission.

Q. But that has nothing to do with insurance?

A. Oh, no, nothing covers delay of that kind, nothing at all.

Q. So that in addition to the loss to the vessel because of the accident, there is always the lost time?

A. If a boat goes aground and she loses a week getting off, that is gone; she loses that utterly, or if by any other accident she loses time, no matter what the accident may be.

Q. Coming back to the question of construction again, what do you say about the strength of a vessel which is 600 feet long, which draws 20 feet, as compared with one of the same length which draws 30 feet?

A. I do not see any difference in them; the boat that is built to draw 30 feet, she is built under specifications required to give her a rating of Lloyd's 100, as they call it. That is a standard classification that is used on the other side of the water, that we have adopted over here largely. And so, allow-

ing for the difference in depths, etc., the longer you build the vessel as a rule, the greater depth you make her hold.

Q. Precisely, and it is a fact recognized in connection with the construction of vessels, is it not, that the long, shallow vessel is not so strong as the one of greater depth?

A. No, sir, she is not.

Q. The vessel which has the greater draft is the stronger vessel?

A. That is assuming, that is true—

Q. It is stiffer, isn't it?

A. A stiffer vessel, oh, yes. You take the shoaler vessel, if they build her right, they should put in some compensation, but the deep draft boat has the advantage. That is the reason that many of our boats now could draw several feet more water than they do; on account of that it gives extra strength, depth of hold.

Q. Counsel on the other side asked you some questions with reference to the effect of increasing the cargo on the amount of coal that it would be necessary to consume. Suppose you increased the cargo 1 per cent., would you have to increase the amount of coal which you burned 1 per cent.?

A. Oh, no.

Q. That same thing would apply to what you said about speed?

A. That would be about at the proportion.

Q. Does the same thing apply to the effect, if any, on the speed of a vessel; if you increased the cargo 1 per cent., would it have that effect on the speed?

A. In other words, supposing you carried a given number of pounds pressure; let us take a unit. If you had a boat that was carrying we will say 200 pounds of steam and she was drawing 19½ feet and then you load her to 20 feet and carried the same steam, same revolutions, it would not make as good time; you would have to accelerate your turns and burn a little more coal to get it, but the proportion would be very small as compared with the increased cargo.

Mr. Wilkerson: I think that is all until after you bring in the data in response to the request of counsel for the defendant.

Recess to 1:30 p. m.

May 24, 1909, 1:30 p. m.

CHARLES KELLER, a witness called on behalf of the Government, was first duly cautioned and sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name, please?
A. Charles Keller.
Q. Where do you live?
A. I live here in Detroit.
Q. What is your present occupation?
A. I am Major of the Corps of Engineers U. S. Army; and I at present have charge of the office of the United States Lake Survey; that of the Engineer of the Eleventh Light House district, and of the United States Engineer office at Grand Rapids.
Q. What have been your preparation and what has been your experience in work as an engineer?
A. I am a graduate of the Military Academy, and of the Engineering School of Application. Since 1893 I have been engaged in the work of river and harbor improvement. In more recent years, I have been in charge for two years of the harbors upon the east shore of Lake Michigan. I have had for four years charge of the office of the Engineer of the Eleventh Light House District. I have been in charge of the office of the United States Lake Survey for two years; and I was for two years in charge of the rivers and harbors upon Lake Huron.
Q. Have you had anything to do with hydraulic measurements on the Great Lakes, if so what?
A. Since May, 1907, I have been in charge of the office of the United States Lake Survey which, since that time, has made hydraulic measurements upon the Niagara, St. Clair and St. Lawrence Rivers.
Q. Having in mind your experience as an engineer, what have you to say as to the effect of diverting a given quantity of water, as for instance 4,000 cubic feet per second, from Lake Michigan at some point, for instance Chicago, the effect, I mean, as to the lowering of the level of the Lakes?
A. In my opinion it would unquestionably lower the levels of Lakes Michigan and Huron; and all the connecting rivers and lakes below there.

Q. Would that effect be general and uniform?

A. It would be uniform over the entire chain of lakes with the exception of Lake Superior, which would probably not be affected.

Q. That is to say if there is a certain definite lowering at any one point, that lowering would be general?

A. It would be general, although not precisely the same amount on all the other lakes and on the rivers.

Q. When you speak of the term, lowering the level of the lakes, are you speaking of that in an absolute sense? By that do you mean as a matter of fact the level of the lake would be lower, or do you mean it would be lower than it would have been if there had not been the diversion at Chicago?

A. It would be lower than it would have been had there been no diversion at Chicago. As a matter of fact, natural conditions might be such as to obscure the natural effect of any diversion at Chicago.

Q. Where are the outlets of Lakes Michigan and Huron, Major?

A. In the St. Clair River, whose head is at Port Huron, and it discharges into Lake St. Clair.

Q. If you take water out of the lake at Chicago, what is the effect of that upon the quantity of water which goes out through the St. Clair River?

A. You eventually diminish by precisely that amount the outflow of the St. Clair River.

Q. What do you mean by the term "net supply" as it is used in connection with the water in the lakes?

A. The net supply which is in effect the discharge of the outflow rivers, is the difference between the precipitation upon the Great Lakes and upon the drainage basin tributary to the Great Lakes, and evaporation and other losses, such as percolation. In other words net supply is precipitation minus evaporation and minus other losses.

Q. Having in mind the elements which go to determine the level of the lakes at any given time, what is the relation or connection between rainfall, evaporation, absorption and runoff, and the water which would be diverted at a given point, say Chicago?

A. There is no connection whatever between them.

Q. That is to say, would the diversion of the water at Chicago have any effect upon any one of these other elements?

A. Oh, yes, it would. I misunderstood you. It would af-

fect the runoff eventually. It would not affect rainfall, nor could it affect evaporation.

Q. The only thing it would affect would be the quality of water that went out through the St. Clair River?

A. Yes, the net supply as we have called it.

Q. By that you mean this: the quantity of water which is in the lakes and the resulting level is the product of a number of different elements. If you divert a certain quantity of water from the lakes at Chicago, is that an element which would affect the level of the lake, that is have an effect upon the level of the lake, independent of these other elements?

A. It certainly would.

Q. Would that always be present as a controlling factor?

A. It will always be present as one of the factors which control the ultimate level of the lakes.

Q. I am about to show you some charts which indicate the relation between the quantity of water which flows out through the St. Clair River and the level of Lakes Michigan and Huron; also charts which have to do with the outflow from other lakes and the level of the water in those lakes. As preliminary to that, I would like to have you explain in a general way, Major, how you would proceed to determine the relation which exists between the level of the lakes and the outflow from the lake, and how you would proceed to determine the effect upon the level of the lakes of diverting this water at Chicago. State first whether it is possible to determine what that effect would be, and if it is how you would go about determining it.

A. The effect is determined by the process of making what are termed discharge measurements. The object of the measurements of a discharge at any given time is to determine what the flow of the river, whose discharge is being measured is, at the time that the discharge is being taken. When the discharge is measured, close observation is also made of the level of the lake from which the river flows.

Q. If I may interrupt you, how do you make those measurements which determine the quantity of water that flows out through the river?

A. The general process in use by the Lake Survey, and in general use everything for the determination of the discharge of a large stream is that of measuring the flow by means of current meters at a section, cross-section of the river, at a point on the river that has been selected because

of its fitness for this purpose. A section is fit for discharge measurements when the conditions of flow are uniform, steady; when the cross-section itself is deep and fairly uniform in depth; when the flow approaches at a good velocity say in the neighborhood of 4 feet or more per second and leaves it with a fairly good velocity; and when the conditions above and below the section are such as to indicate that the flow itself is steady and appropriate.

Q. Just what is a current meter, how is it operated in practice?

A. A current meter is an instrument of precision, in our opinion, which consists roughly of a wheel or propeller which is set in motion by the movement of the water in which it is immersed. The revolution of this wheel is indicated at the surface of the water through an electric current, which is alternately made and broken by means of contacts upon the shaft of this propeller. It is indicated at the surface of the water upon a register which is part of the machine. This register is merely a counter and discloses the number of times the propeller of the meter revolves in a given length of time, given number of seconds, to be accurate. As the meter is intended to measure velocity, it becomes necessary to express in a definite formula the connection between speed or velocity of the water and the number of revolutions of the meter wheel. This is done by means of rating operations in which the meter itself, in place of remaining stationary in the water, as it does when a discharge measure is being made, is drawn through the water at known velocities. That is, known velocities are recorded and are varied sufficiently to obtain what is known as the rating equation of the meter. From this rating equation and the curve which results from the rating equation, it is therefore possible, having the number of revolutions which the meter makes in a given period of time, to derive directly the velocity of the water which has caused these revolutions. Having used the meter in this fashion, in accordance with a program which has been definitely fixed as being sufficient to obtain the information which is necessary with respect to all portions of the cross section, from the meter registrations and the record that is made of them, and from the record of the levels of the controlling lake, we are enabled to plot diagrams which show the relation between lake stage and lake discharge, river discharge, and from this, in general terms, we are enabled to derive a law which is probably the law of discharge of the river whose measure-

ments we have been taking. I can go into further detail if you want, but I do not think it is material.

Q. I wish only the statement of the general process leading up to the plotting of these measurements and these charts, and the drawing of the line expressing that relation. I direct your attention to a map or chart which has been already marked in this case "Complainant's Exhibit No. 1, 2/15/09." Have you seen that before?

A. Yes, I have seen it before.

Q. What have you done in connection with determining the formula that are expressed on that chart, with reference to determining the accuracy of the line which is drawn there, expressing this relation between the stage of the lake and the outflow through the St. Clair River?

A. From a personal investigation of the method in which the discharge measurements of 1899 and 1902 were conducted, and from a personal knowledge of the methods which were pursued in 1908, I know that the measurements as platted upon this diagram represent with the highest attainable degree of precision the actual outflow of Lake Huron, at the time when the discharge measurements were made. And I believe that the straight line which is drawn through the platted points represents as nearly as any line may represent, the law which governs the outflow of Lake Huron, or the flow of the St. Clair River.

Q. To go a litle more in detail into what is shown on this chairt, I direct your attention particularly to the formula at the bottom of the chart and to the scale which is out at the side of the chart?

A. Yes.

Q. I will ask you first to explain the formula and then to state the fact with reference to the correctness of what is indicated on the scale there at the side?

A. An examination of the drawing itself shows that for a change of one foot in the level of Lake Huron, the discharge or outflow changes by 23,820 cubic feet. This same law is expressed in algebraic or mathematical language in the legend in which is the equation: delta H=delta Q divided by 23,820. That states in mathematical language what I have just described in ordinary terms. This equation means that for any given change in discharge in the St. Clair River expressed in cubic feet, the change in height of Lake Huron expressed in feet will be that change in discharge divided by 23,820.

Q. What name do you give to that figure, 23,820?

A. We have called it the increment, increment of discharge.

Q. Increment of discharge means what, to state it in simple language?

A. It is the change in discharge for one foot change of a stage in the controlling lake.

Q. How is that increment obtained?

A. By direct measurement from the line which is drawn on the diagram, by measuring the horizontal distance on the scale, which corresponds to a vertical distance of one foot, we get what is called the increment of discharge; and this has actually been done on the diagram which appears here.

Q. Now carrying out the conclusion from the line as there drawn and from the formula as you have explained it and from this increment of discharge as you have explained it, what is the fact shown with reference to the lowering of the level of Lakes Michigan and Huron for the diversion of 5, 10, 15, 20 thousand cubic feet?

A. The scale at the side which appears to be correctly drawn shows that for a reduction in outflow of 5,000 cubic feet per second there will be a reduction or lowering of level in Lake Huron of a trifle over 2¼ inches.

Q. And the effect of the diversion of 4,000 cubic feet at Chicago would be what?

A. Practically two inches, as shown by the scale.

Q. And for 10,000 cubic feet?

A. For 10,000 it would be a shade over 5 inches; for 15,000, it would be a trifle more than 7½ inches, and for 20,000 it would be slightly more than 10 inches.

Q. Now keeping in mind your experience in connection with these measurements and observations, what have you to say with reference to the accuracy of the conclusions based upon the platting of these observations, and upon the formula which you have just explained?

A. I think that in all probability the results that I have just given are accurate within approximately 5 per cent.

Q. Can you, without going through any long mathematical process, state why you put that at 5 per cent? What is the reasoning in your mind that leads you to say 5 per cent?

A. Well, as a general rule, we have found out in our discharge measurements that the line which most nearly expresses the law of discharge will be so drawn upon a diagram that the extreme measurements, those which diverge furthest from the line, will contain an error not to exceed

about 2 per cent. That in itself is probably an error that does not altogether measure the total error which appears in the measurement. It shows the internal or relative consistency of the measurements, but it does not exhibit the fact that it is possible that in addition to small errors due to the use of the meter itself, there may appear small errors due to the impossibility of measuring the cross section with absolute accuracy. And the final result will also show a very small error due to the slight errors of gauge readings, that may appear in the result. And while I have said 5 per cent., it is merely my opinion that the final result may show an error as large as 5 per cent. I do not believe it will show anything larger. I think all causes combined would probably aggregate at the very utmost 5 per cent.

Q. You have, in your study and investigation of this subject, had occasion to read what engineers, men in your profession, have had to say about the relation between the level of a lake and the quantity of water which flows out from it?

A. Yes.

Q. What is the fact as to its being generally accepted as something that is practically axiomatic, if you can use that term, that there is some relation between the level of the lake and the quantity of water which flows out through the river?

Mr. Williams: Let the record show that I object to the question first on the ground that it is leading; in the second place that it is calling for the opinions of others than the witness himself?

A. I have never known of any engineer who has disputed the general axiomatic proposition that the discharge of the outflow rivers varies directly with the height of the lakes themselves; increasing as the lakes rise and diminishing as the lakes fall.

Q. The only question then remaining for determination is as to the——

A. The quantity of change of discharge with a given amount of change in level.

Q. I understand you to say you have never known an engineer to question the general fact that such a relation does exist?

A. I never have.

Mr. Williams: I wish to note an objection to that question as a statement of counsel and not a question.

Mr. Wilkerson: Q. And further, that there may be no question about it: how generally have you given considera-

tion to what has been said on this subject; have you covered a good deal of ground?

A. I answer your question as generally as you ask it; I think I have read everything that has been written on the subject of the levels of the lakes as connected with the discharge of the connecting rivers. So far as I know there is nothing that has ever been written that I have not read, with greater or less care.

Q. Have you read everything you have heard of on the subject?

A. Yes, I have read everything that I have heard of.

Q. And what you have just said, the statement you have just made, is based upon that study?

A. It is a summary of that study.

Q. Now, what is the effect of the lowering of the waters of lakes Michigan and Huron upon the water in the St. Marys River, at the foot of the locks?

A. There is a lowering at the foot of the locks, but it is less in amount than the lowering of the lakes themselves.

Q. As a result of your study and investigation, are you prepared to make a statement with reference to the percentage of lowering there would be in the St. Marys River at the foot of the locks?

A. No, I am not prepared to make a precise statement.

Q. Suppose that Lakes Huron and Michigan were lowered a certain definite amount, and Lake Erie a certain known amount, what would be the lowering in the Detroit River and Lake St. Clair and the St. Clair River?

A. The lowering of the St. Clair River, of Lake St. Clair and of the Detroit River at various points would depend directly upon the amount of lowering on Lakes Huron and Erie. Lake St. Clair, or the level of Lake St. Clair, is directly connected with the level of Lake Erie by means of an equation, which if you desire I am prepared to give, as derived from the investigation of the Lake Survey.

Q. I would like to have you give that.

A. The height of Lake St. Clair at the Flats is h—.602 H+.373h′ times plus h′ times .373. Small h will give the change in elevation of Lake St. Clair due to change of H in Lake Huron and h′ in Lake Erie. If there is a change of a foot in each lake, the change in Lake St. Clair would be .975 in feet. The change in the St. Clair River between the head of the river and Lake St. Clair would vary from the full amount of the change on Lake Huron down gradually to a

limit which is set by the amount of change of the St. Clair Flats gauge. In the formula or equation above, h equals St. Clair Flats gauge, minus 575.12; H equals Harbor Beach gauge, minus 580.70; h′ equals Cleveland gauge, minus 571.96.

Q. That is to say at any one of the critical places of that change, the Detroit River or Lake St. Clair, the lowering would be some place between the total lowering of Lake Huron and the minimum?

A. And the corresponding change on the other lake.

Q. Which you have given?

A. Yes.

Q. How exact, in your opinion, is that statement that you have just made?

A. For any given change in Lake Huron and Lake Erie it is probably at least 10 per cent. wide of the truth; but for a long period of years it will come pretty close to expressing the average elevation of the St. Clair Flats gauge.

Q. I direct your attention now to a chart which has been marked "Complainant's Exhibit No. 2" under date of February 15, 1909, the same purporting to show the loss of level in the St. Lawrence River at Ogdensburg, corresponding to loss of outflow by reason of the diversion at Chicago. I will ask you to state whether or not you have examined that before; if so what examination you have made of it?

A. I am familiar in a general way with the processes by which this diagram has been derived, and I know it to be based upon actual discharge measurements made in the St. Lawrence River. And I further believe from examination that the line which represents the law of discharge of the St. Lawrence River is the probable law as based upon discharge measurements actually made.

Q. If water is diverted from Lake Michigan at Chicago, what effect does that have upon the outflow of the Niagara and St. Lawrence Rivers?

A. Reduces by precisely the same amount eventually the outflow of the Niagara and St. Lawrence Rivers.

Q. Why do you say that?

A. Because the outflow of these two rivers consists only of the surplus waters of the lakes. If anything is taken away from those surplus waters of the lakes up above, it is necessarily taken away from the outflow of these rivers.

Q. The formula and the increment is derived from the same process as the one that you have already explained?

A. As in the case of the St. Clair River, except that the

increment in the case of the St. Lawrence River is 28,870 cubic feet per second for a change of one foot in the elevation of Lake Ontario.

Q. And what result does that give as to the effect of the diversion of say 4,000 cubic feet at Chicago from Lake Michigan?

A. The resulting changes are somewhat smaller than they are on Lake Michigan and Lake Huron. For 4,000 feet, the lowering of Lake Ontario and the upper St. Lawrence River is about 1.6 inches.

Q. I show you two other charts which have been marked Exhibits 3 and 4 respectively of the same date as that given in connection with the charts already in evidence. No. 3 relates to the loss of level in Lake Erie corresponding to the loss of outflow in the Niagara River, and No. 4 relates to Lake Erie also; one being the International Bridge section and the other the Open Section. Will you take those two charts and state what investigation you have made of the matters to which they relate, and explain to us the result as shown by the charts?

A. I am familiar with the diagram concerning the discharge measurements at the International Bridge section, and I know personally concerning the discharges which were measured in 1907 and 1908, as these were taken during the time of my being in charge of this office.

Q. That is to say those measurements were measurements made under your direction?

A. Made under my direction in 1907 and 1908.

Q. And with your knowledge?

A. And with my knowledge.

Q. Go ahead?

A. The line which appears upon the diagram is in my opinion correctly drawn from the platted discharges, and represents the probable law of discharge of the Niagara River at the International Bridge Section. The diagram shows an increment of 21,900 cubic feet per second for a change of stage of one foot in Lake Erie. The second diagram relating to the Open Section of the Niagara River is based upon discharges which were measured before I assumed charge of the Lake Survey office; but I am familiar with the manner in which the discharge was measured, and I believe that the discharges themselves are correctly platted, and the line which represents the law of discharge correctly drawn: For the Open Section, the diagram shows an increemnt of 21,640 cubic

feet per second for a change of stage of one foot in Lake Erie.

Q. In order to get it in the record, what do those charts show as to the effect of a diversion of 4,000 cubic feet per second at Chicago?

A. They show about the same thing, a lowering of about 2.2 inches, corresponding to a diversion of 4,000 cubic feet at Chicago.

Q. In connection with Lake Erie there are two sections taken, one is the Open Section and the other is the International Bridge section?

A. Yes.

Q. Why were those two sections taken, Major?

A. The measurements at the Open Section were taken in order to verify the measurements previously taken at the International Bridge Section; and as a result they show a very close agreement between the two sets of discharge measurements.

Q. Now coming back to the question which I put to you with reference to the observations of the St. Clair River, as to the accuracy of the result which is based upon those observations, what have you to say as to the accuracy of this result with reference to Lake Erie?

A. I believe that the measurements at the International Bridge Section are considerably more accurate than those of the St. Clair River because of the fact that the cross-section itself gave opportunity for measurements superior to the opportunities which existed in the St. Clair River. The bridge offered an absolutely fixed platform from which measurements could be made, and absolutely fixed the points at which velocity was measured by discharge meters. At the same time, the cross-section itself was an absolutely fixed one. The nature of the bottom material was permanent, so that there could be no great uncertainty as to the area of cross-sections and absolutely no uncertainty as to the points where soundings were made.

Q. With reference to the substantial agreement between the result as shown from the observations at the Open Section and the one at the International Bridge Section, is there anything in that which to the engineer furnishes a basis for reaching a conclusion as to the accuracy of the statement you have made with reference to the general result?

A. It is very strong corroborative evidence of the results obtained at the International Bridge Section. The close agree-

ment must be due to very painstaking and trustworthy methods of measurement. The agreement in the very nature of things cannot be accidental.

Q. In your own mind, and in connection with your own opinion on this subject, has the fact that there is that agreement with reference to these Lake Erie measurements had anything to do with the statement which you have made as to the accuracy of the result showing the relation between the stage of the lake and the outflow through the rivers?

A. Yes, that is one of the principal grounds for my statement.

Q. The measurements on one of these sections was made from the bridge?

A. Yes.

Q. The measurements on the Open Section were made where?

A. Made about 1,800 feet below the bridge.

Q. And without the assistance which would come from making the observations from the bridge?

A. Yes.

Q. Referring again to that substantial agreement between the observations, does that indicate anything with reference to the accuracy of the observations which were made at the Open Section?

A. They indicate that the observations at the Open Section were themselves very accurate.

Mr. Williams: We will agree if the observations on the Bridge Section showed that the observations on the Open Section were accurate, the observation on the Open Section shows that the others were accurate too.

Mr. Wilkerson: Q. In the very nature of things, from which set of observations would you expect the highest degree of accuracy?

A. From those at the Bridge.

Q. Why?

A. For the reason I have already given, that the bridge itself was a more favorable cross-section for measurement than an ordinary open section can be.

Q. Coming back again to the thought just suggested by the counsel on the other side, having the observations on the bridge, with this element of greater accuracy present for the reason which you have stated, does the agreement that results from those observations and the ones at the Open Section furnish a foundation for making a statement and

forming an opinion with reference to the accuracy of the observations at the Open Section?

Mr. Williams: I object to the question on the ground it is leading; on the ground it is furnishing the witness with additional reasons for the testimony he has given already; and on the further ground that he has already answered the question several times.

A. I understand you to ask whether the agreement between the results at the International Bridge and those at the Open Section gives additional reason for believing in the high degree of accuracy in the methods used at the Open Section?

Mr. Wilkerson: Yes.

A. Yes, it does. It is the only independent evidence we have.

Q. On this same general subject of the correctness of results which are reached through the method which you have described, are you familiar with the measurements on the Niagara River, which were made by the Deep Waterways Commission in 1897 and '8?

A. Yes, I am.

Q. Those were the measurements made by the United States Board of Engineers on deep waterways. You are also familiar with the recent measurements which have been made on the river?

A. Yes.

Q. How do the recent measurements agree with the measurements of United States engineers on deep waterways?

A. For any given stage of discharge as published in the report of the United States Board on deep waterways, the figures are from ten to twelve thousand cubic feet per second in excess of the figures which we now give as being correct. And the reason for that discrepancy appears to have been that while the measurement of velocity made by the Deep Waterways Board was as accurate as anything that we do nowadays; that the soundings taken in ascertaining the area of cross-section were by no means as accurate as the later soundings, those of 1898 and 1899 being made with far higher degree of precision.

Q. Are you familiar with the measuremnets that were made by one Quintus in 1891 and '2?

A. I have read his published reports.

Q. Who was he?

A. He was assistant engineer; he is an assistant engineer in the employ of the United States Engineer Office at Buffalo.

Q. With reference to his measurements on the Niagara River, how do they agree with the more recent measurements?

Q. The agreement is only fairly good so far as concerns discharges pertaining to definite stages, but both his discharge measurements and those of the Deep Waterways Board show a substantial agreement with the Lake Survey discharges. In the derivation of the increment of discharge, the increment of discharge corresponding to a change of one foot in the level of the lake, they all give an increment between 20,000 and 30,000 cubic feet per second for a change of one foot in the level of Lake Erie.

Q. The larger the increment, the smaller would be the lowering for any given diversion, is that right?

A. Yes.

Q. What is the largest increment that has ever been derived from any set of observations that you know of?

A. I think the one of Quintus. That shows an increment of about 35,000, but I think that is an isolated case, and I think the largest increment that has any standing is the increment for the St. Lawrence River which is 28,800, or thereabouts.

Q. That is as high as anybody has ever called it?

A. As high as anybody has ever called it that I know of.

Q. And on these different observations, how low does it go?

A. Well some of the St. Clair increments go as low as sixteen or seventeen thousand cubic feet to the second; that is the lowest any of them have gone.

Q. That is the lowest increment that has ever been derived from any series of observations?

A. From a series of observations, yes.

Q. Going back to the Quintus observations, Major, can you make, after referring to the report, a more definite statement as to his increment?

A. I have here in my hand a copy of Mr. Quintus' results sworn to by him, in which he states the discharge increment per foot at or near mean lake level at 21,000 cubic feet per second.

Q. Now those are measurements on the Niagara River?

A. Yes, sir, made in 1891. And while that statement is

an answer to your question, in explanation of my previous answer I desire to call attention to page 4371.

Q. Make your explanation as clear as you desire.

A. I said in my previous answer his increment varied between 21,000 and 35,000 cubic feet per second. The flow which I have just read you from his report is for mean lake level. For a different stage of the lake, in the printed and published report upon page 4371 of Part 6 of the Annual Report of the Chief of Engineers U. S. Army for 1893 there is a table which shows in the last column a single increment of 35,000 cubic feet. That explains my previous answer.

Mr. Williams: Q. What was the lake level there?

A. He gives the lake level as probably between four and five feet; that would be four or five feet above mean lake level; and I imagine that is a deduction from his curve rather than an actual measurement.

Mr. Wilkerson: Q. So that we will not have to come back to it again, that 35,000 increment I understood you to say it is obvious from the report that it was not based upon actual observations but was a computation based upon the formula for a higher stage?

A. Yes, that is what I believe to be the fact; and I think the curve shows it.

Q. Just find what he says on that subject and read it.

A. I think the answer to your question is given from the table here, the table on page 4367 of the same report, which shows all the discharges which were actually measured, contains no discharge which was measured at a stage corresponding to that for which the increment was previously stated as 35,000 cubic feet per second.

Q. In the light of investigations which have been made subsequent to that time, was there any warrant in attempting to extend a computation with reference to the increment on the formula, to those higher stages which were not covered by actual observations?

A. That is what he has done in this table where he gives this theoretical increment of 35,000 cubic feet. The increment of 21,000 cubic feet is actually derived from the measurements themselves.

Q. Should he have done that?

A. It is not good practice.

Q. In the light of practical experience?

A. It is not good practice, and it is not ordinarily done.

Q. You are familiar with the conditions on the St. Clair River, are you, Major?

A. Yes, sir.

Q. What is the season of navigation on the St. Clair River?

A. I will answer your question as Engineer of the Eleventh Lighthouse District. As Engineer of the Eleventh Lighthouse District, it is my duty as early as possible to send from Detroit completely loaded and equipped the lighthouse tender belonging to that office. During the last four years, the date of despatch of the tender (and that represents practically the opening of the season of navigation) has been as follows: 1906, April 17; 1907, April 16; 1908, April 24; 1909, April 24. During three of those four years, the closing of the season of navigation was coincident with the final date of the last trip of the same vessel, and in those three cases, to the best of my recollection,—I have not verified the exact dates—the season of navigation may be said to have closed in the St. Clair River on or about December 15.

Q. During the winter months there is ice in the St. Clair River?

A. Yes, sir.

Q. What is the effect of that ice in the river upon the outflow of the water from Lake Huron?

A. The effect is to diminish or retard the outflow.

Q. As to this ice retardation, approximately when does it begin and when does it end?

A. In general terms it may be said to begin about the middle of December, and to end about the middle of April, although there have been exceptional years when it has begun earlier and lasted later.

Q. How about May?

A. The year 1901 is a typical year in which there was ice effects shown after the first of May, but as a general rule May is not an ice month.

Q. I wish you would take up this subject of the presence of ice in the St. Clair River and in the Niagara and St. Lawrence Rivers also, and state what information if any you have upon the subject of the effect of this ice retardation.

A. The only information that I have on the subject is derived from my reading of reports of investigations made by the United States Lake Survey into ice effects. The first investigations of that sort were the investigations into the ice effect in the St. Clair River. These investigations

were made late in 1900 and early in 1901, and they showed that the discharge of the St. Clair River measured at a time when the river was in its lower portion sealed by ice was considerably less than the discharge which corresponded to the existing level of Lake Huron. The discharge curve or formula derived from—

Q. I wish you would take up that subject, as the result of your experience and your study, and state just what your conclusion is with reference to that ice retardation; and what is the determination of the government?

A. My conclusion, independently of that of this office, my personal conclusion is that the ice effect is a large but unknown factor in the determination of the levels of the Great Lakes; and that up to the present time the Lake Survey has not made sufficient measurements to enable any one to form a justifiable conclusion as to the measure of the ice effect, either in the St. Clair River, or in any of the other rivers; the Niagara or the St. Lawrence.

Q. Are you familiar with the formulae which have been derived, bearing upon the subject of ice effect?

A. No, I am not familiar with any formulae that have been derived bearing directly upon ice effect.

Q. You have spoken in connection with the determination of the effect of diminishing the outflow through the St. Clair River upon the level of the lake, of the increment; what could you say on the subject of the relation between this ice retardation during the winter months and this increment, with reference to which you have testified?

A. The effect is to diminish the increment.

Q. Why do you say that?

A. Because the increment is the result of the increased head due to a rise in the level of the lake surface. The effect of that head is lessened by the increased friction due to the presence of the ice, or to put it in other words, the efficiency of the cross section when sealed by ice is less than it is when open.

Q. Taking the diversion of the water from the lake, at Chicago, as one element, and the presence of this ice in the St. Clair River as another element, when it comes to the determination of the effect of the diversion of the water at Chicago, is there anything in the presence of this ice in the river during the winter months, which in any way overcomes or counteracts the ultimate effect of that diversion?

A. No. It aggragates the effect of the diversion by in-

creasing the relation which the amount of the diversion bears to the value of the average increment; the increment during the ice months being less, the average increment for the entire year is less than if the river were open for twelve months; and as a consequence the effect upon the lake level is larger than it would be in the absence of ice effect.

Q. That is to say, if I may put the question in this leading way: it has the same effect as if the St. Clair River were smaller?

A. Smaller or narrower or shallower.

Q. Referring to the St. Clair River again, what information have you on the subject of the scouring of the river, as to whether it is changing its regimen or not?

A. During November and December, 1908, I directed that four cross sections in the St. Clair River, which had been permanently monumented or marked at a previous time so that they could be again identified for purposes of measurement, should be remeasured, with a view of finding out what change had taken place in these cross sections, since the previous measurements. The remeasurement was done, as directed by me, and I have here a table, of which Mr. Shenehon will exhibit the original, which shows that at the cross sections which are described in the Annual Report of the Chief of Engineers for 1900 as cross sections Culvert, Fish, Arthur and Stauber, there has been practically no change since the measurements of 1899. That is in a period of over nine years, there has been no measureable change in these cross sections. In cross section Culvert, the measurement showed a scour of about 1.3 feet on the section since 1901. In cross section Fish, there was an apparent shoaling indicated since the previous measurements. In cross section Arthur, a fill of about 2½ feet is indicated since the previous measurement, and in cross section Stauber no change is shown in the area of cross section. These cross sections were in the gorge of the river at its narrowest place, and where scour would be most likely to take place. They are also in what we regard as a critical or controlling portion of the St. Clair River.

Q. Based upon these recent observations then, which have been made under your direction, what is your conclusion as to whether there is any change in the regimen of the St. Clair River?

A. There is no evidence whatever to show any change in the regimen of the St. Clair River. At the same time that these cross section measurements were taken, we made dis-

charge measurements at a new cross section, and we made discharge measurements at a cross section formerly occupied for this purpose; and these discharge measurements were in absolute accord with the measurements that had previously been taken. There exists no evidence upon which to base any assertion of a change in the regimen of the St. Clair River at its head.

Q. About that time, were there any observations made for the purpose of determining the relation between lake level and discharge; that is were these observations used as the basis of any new computation on that subject?

A. The discharge measurements closely accord so far as they go. They were few in number, only thirty-seven in all, but they accord with the previous discharge measurements and are platted in the line of discharge that is exhibited on one of these plates, for the St. Clair River, to show that the law which was formerly deduced for the St. Clair River applies also at these sections.

Q. Is there anything in that that throws light upon the subject of the correctness of the statement that you have made with reference to the increment?

A. It shows that the increment as derived from previous measurements is probably correct and that the law of discharge has been correctly determined.

Q. Since you have been in charge of this work here, have you caused a new section to be measured, for the purpose of corroboration?

A. I have already mentioned that. We established a new cross section at the head of the St. Clair River, above the cross section previously used for discharge measurements. We called it cross section gorge. We had this carefully sounded, and thereafter we took discharge measurements at this new section and these discharge measurements showed discharges which accorded with the discharges deduced from the law here; that is for a given stage of Lake Huron as shown on the gauge, the discharge as derived from Cross Section Gorge corresponds to the discharge which would be taken from the line indicated on the plate.

Q. That is to say, I understand that the practical result of these later observations is in accordance with the law of discharge as it had been already derived from the previous observations?

A. Yes.

Q. What light if any does that throw on the accuracy of the formula which you have given here?

A. Which formula?

Q. On the chart?

Mr. Williams: I object to that. The witness, I assume, in answering the previous questions with reference to the degree of accuracy obtained in making these discharge measurements, took into consideration all the facts that he knew of, and he is testifying to some of those facts now. I object to counsel asking whether each specific item of information confirms the opinion which he has expressed as being the result of all his information.

Mr. Wilkerson: I think it entirely proper for the witness to state any fact or any element which he acted upon in making his statement with reference to the accuracy of the observations.

Mr. Williams: It would be entirely proper for the witness to do that, and for counsel to ask him to state all the facts he took into consideration.

Mr. Wilkerson: I am directing his attention to one specific fact.

Mr. Williams: I object to his attention being directed to every specific item of information.

Mr. Wilkerson: Answer the question.

(The question was here read to the witness.)

A. It affirms the accuracy of the diagram or formula.

Q. What knowledge have you on the subject of the outflow of the Niagara River, as to whether it has been increased or diminished?

A. Alterations in the Niagara River in the vicinity of Niagara Falls, and some slight changes at the head, have tended to increase the discharge capacity of the Niagara River; while on the other hand contraction of the stream above the Canadian Fall has tended to neutralize this effect so that the net result is practically no change in the discharge of the Niagara River, and practically no effect upon the level of Lake Erie.

Q. What is the diversion from Lake Erie into the Welland Canal?

A. I think about 1,200 cubic feet per second.

Q. And into the Erie Canal?

A. That was measured by the Lake Survey under my direction, and was ascertained to be 768 cubic feet per second; the measurement being made in the fall of 1907.

Q. How are those diversions, as compared with what they were before 1890?

A. I believe the Erie Canal diversion is practically unchanged. I am not informed concerning the Welland Canal diversion.

Q. You are pretty familiar with the conditions on Lake Michigan and Huron, I assume, Major?

A. Yes.

Q. That is you have been over them a good deal?

A. Yes.

Q. Now do you know of any outflow from Lakes Michigan and Huron except through the St. Clair River, and what water is diverted at Chicago?

A. I know of none.

Q. What is the generally accepted scientific fact as to that, is there any other?

A. There is no evidence to show the existence of any other outflow.

Q. Suppose there were some subterranean outlet—I put this to you as a hypothetical question—would the fact that the water flowed in or out at a point under the ground make any change in what you have said as to the effect of the diversion of the water at Chicago through the drainage canal?

A. No, it would not.

Q. In other words, would the diversion of that water—

Mr. Williams: I object to the "other words." Let the witness give the other words if there are any.

Mr. Wilkerson: Q. Would that diversion of the water at Chicago remain a fixed factor, which would have the effect that you have indicated upon the level of the lakes?

A. Yes, it would. It has been deduced in view of all facts.

Q. Do you know about the expenditures which have been made in the hydraulic measurements of the St. Clair River?

A. In a general way, I know what time has been spent there and approximately what it has cost.

Q. Let us have a general statement. What I want to get is the extent of the work which has been done, whether there has been much or little, much time or little time spent.

A. Counting the cost of the office reductions as part of the cost of doing the work, I should say we have spent between ten and fifteen thousand dollars in the actual field work of making the discharge measurements. That counts nothing as the cost of the equipment, which is permanently the property of this office, and is used everywhere.

Q. You are familiar with scientific measurements that are made in different departments of research. What do you say as to the maner in which these observations were made, as to the kind of men who made them and the degree of skill and care with which they were made?

A. They were made by men who possessed a high order of engineering skill.

Q. Did they have scientific training?

A. They were men of the highest possible character; men of scientific training, and with a known wish to ascertain nothing but the truth. The measurements were made with no preconceived notions as to what the results should be; and I believe that they are entitled to the very highest credit.

Q. With reference to the measurements on the St. Clair River, take the ones from which these formulae with reference to which you testified are based. Do you know who had charge of that work?

A. Mr. L. C. Sabin, now in charge of the St. Marys Falls canal, had charge of the bulk of the work at the St. Clair River. He is an engineer of the very highest possible standing.

Q. You have had occasion have you to know with reference to his skill as an engineer, and with reference to the kind of work which he does?

A. I know him both personally and professionally.

Q. What would you say on that subject?

A. I regard him as an engineer of the highest possible qualifications.

Q. What do you know with reference to the measurements that were made on the Niagara and St. Lawrence Rivers?

A. Those were made by Mr. Shenehon, who is present. I believe they were honestly and skillfully made, and deserve the utmost credit.

Q. The point that I wanted to have covered, and I think you have covered it already is as to whether it is a fact that all of these measurements and observations were made by men who are men of education in their profession, and men who were trained for this particular work.

Mr. Williams: I object to that question on the ground it is improper for counsel to tell the witness what he desires to have covered in the answer which is about to be made.

Mr. Wilkerson: Answer the question.

A. All the discharge measurements were made by men

who had had a unique training in this kind of work, and who were especially qualified for its performance.

Q. You have come in contact with matters relating to the navigation of the lakes, have you?

A. A great deal, yes.

Q. What have you to say as to whether or not a lowering of the water in Lakes Michigan and Huron, particularly at these points which are characterized as critical points of navigation, to the extent of two inches, would have any real effect upon the navigation of the lakes?

A. I believe it would.

Q. Just what would be the effect? I wish you would explain that somewhat in detail if you can.

A. The draft to which the larger class of vessels may load is directly limited by the depth at what you have called the critical points; that is by the depth at the shallowest places upon the route which they must pursue from their point of departure to their port of destination. In the case of vessels which must pass through the Detroit River, the critical point is at and above the Lime Kiln Crossing. As a matter of fact I know, from my contact with vessel men, that ordinarily they load to the last inch which may safely be carried over these critical points, and that is natural, with a view to earning as much as possible upon each cargo carrying trip. Any reduction in depth at these critical points, therefore, results in a corresponding reduction in the amuont of cargo which may be carried; and the effect is doubly bad because the reduction in the depth of the cargo itself, the depth to which the vessel is loaded, is made at a point where the vessel has the greatest capacity; that is in the upper part of the vessel where it is ordinarily built square, practically like a box. So that a loss of depth has a maximum effect upon earning power. From my frequent conversations with vessel owners and vessel navigators, and personal investigation as to the capacity of cargo carrying vessels, I have ascertained that an inch of draft for the larger class of vessels corresponds roughly to a capacity of 75 tons. So that a loss of two inches in depth of loading is the equivalent of a loss of 150 tons of profitable cargo.

Q. In making the statement that you have made as to the substantial effect upon navigation of this reduction in the quantity of water at these critical points, have you had in mind and given consideration to the fluctuations in the lakes which take place from time to time?

A. I have had those in mind and I know, as a matter of fact, that vessel men are very observant in watching the change in lake levels; the seasonal change is one that they take very close account of, and one which they allow for in their loading. The uncertain changes, those which may be due to barometric effects, they take no account of. Vessels are frequently hung up, as they say, waiting for water at the mouth of the Detroit River, due to what are purely temporary barometric effects. But any reduction due to diversion would be a permanent loss of depth, and would be added to the disadvantages which now arise from the natural fluctuations on the lakes. Such a loss they would have to allow for constantly in the transaction of their business.

Q. In outlining the scope of your present duties, what district was it you said you had charge of?

A. The Grand Rapids Engineer District.

Q. That brings you in contact with navigation on Lake Michigan?

A. On Lake Michigan. It includes all the harbors on the east shore of Lake Michigan proper, with the exception of the harbor of Michigan City.

Q. You spoke of the effect of this permanent lowering at these critical points of navigation of two inches. Are you able, as the result of your observation, to give any specific cases in which vessels have been damaged or where they have grounded, where the injury would not have occurred, if there had been two, four or six inches more of water than there was?

A. There was recently a case of exactly that sort at the harbor of Ludington.

Q. Explain that to us, so that we can see the effect of that, will you, Major?

A. The harbor of Ludington has an authorized depth, that is the depth which we are permitted to create under the law is 18 feet; and ordinarily there is a channel from Lake Michigan into the inner lake at Ludington, which is the harbor of Ludington proper, which affords a depth of fully 18 feet. During the month of April, however, we had a great many southwesterly storms, and as a result of shifting sand, which prevails in the neighborhood of Ludington, and in fact all along the east shore of Lake Michigan, as far north as Charlevoix, at about the middle point between the piers, there was created a very small shoal upon which the minimum depth was found to be 17.2 feet. Now this shoal occurred

between storms, and before the fact of its existence was officially known a vessel loaded with coal, which had come from Buffalo and carried a cargo for the salt works at Ludington went aground in the channel between the piers. Her draft was less than 17 feet forward and a trifle less than 18 feet aft. She remained aground at that spot between the piers, that I have described, for between two and three days. In order to release her, it was necessary to bring the government dredge Gillespie from Frankfort, which is a little over 50 miles north of Ludington, down to Ludington, and pump away a little of this sand, dredge away that sand; and as a result of less than two hours' dredging the steamer was released, entered the harbor, unloaded her cargo and returned to her port of hail to be reloaded. Had there been two or three inches more of depth upon that slight shoal, unquestionably the vessel would have been able to pass over, because the sand was not very compact, and there was not very much of it as was shown by the fact that the dredge by removing less than a thousand yards was able to release the vessel. I think as a matter of fact the dredge moved something like 600 yards before the vessel came off and proceeded into the inner lake.

Q. Would the effect of this proposed diversion at Chicago be felt at Ludington harbor?

A. Yes; not only Ludington, but every harbor on the east side of Lake Michigan, because all of them are in very much the same condition; they have no more depth than they need. Muskegon is a parallel case, where vessels are constantly running aground, due to the lack of merely a few inches.

Q. As a result of your experience in charge of the district with reference to which you have just testified, have you had occasion to give any consideration to the effect upon vessels of introducing a current into a river?

A. Not in that district, I have had no direct contact with the matter of current there.

Q. Where have you ever come in contact with that?

A. Never practically except in the St. Marys River, where in my official journeys as light house engineer I frequently observed that in the large class of vessels the existence of a current of any extent makes the handling of the vessel a great deal more difficult and leads to a great many accidents.

Q. What is the effect upon the tendency to accidents?

A. Oh, it increases largely the tendency to casualties. The worst place upon the St. Marys is known as the Dyke; it is

in what is known as the Middle Neebish Channel, and the trouble there has always been produced by the existence of a very swift current.

Q. You have not had occasion from observation then to know about the effect of the current in the Chicago River with reference to damage to vessels there?

A. Not from direct observation. I am familiar with the facts as generally reported in the annual reports of the Chief of Engineers and as stated by mariners, vessel owners and engineer officers who are familiar with the facts.

Q. Are those facts substantially the same as you stated?

A. Substantially the same; that the presence of a current is a great disadvantage to the navigation of large vessels.

Q. I show you a chart here, which I will ask to have marked Exhibit No. 5 of this date. Tell us what that is, Major, and what you had to do with its preparation, and what it indicates?

A. The chart is a series of diagrams which exhibits the monthly mean water levels of the Great Lakes, as taken from the records of the office of the United States Lake Survey, since January the 1st, 1860. The curves are directly drawn from the measured ascertained levels of the Great Lakes, as derived from gauges upon those lakes. Personally I have had to do with the preparation of these diagrams since early in 1907. It has been republished twice since I have had charge of the Lake Survey office, and in each new edition there has been an addition of the results of the preceding calendar year. We add annually the results of the preceding year to complete it.

Q. You made a like addition each year?

A. Yes. This diagram shows results to January the 1st, 1909. The next edition of this hydrograph will be published early in 1910, and will incorporate the results derived from our gauges for the year 1909.

Q. With reference to the effect of this diversion of the water at Chicago, I omitted to ask you with reference to the effect at different points on the Niagara River. What have you to say on that?

A. The investigations of the Lake Survey made under my direction in 1907 and '8 show that for a foot of fall on Lake Erie the corresponding fall at Black Rock is about .89 of a foot; at Chippewa, it is about a half a foot, and at the Crest of the American Fall it is about $\frac{1}{8}$ of a foot. At intermediate points, it varies in proportion to the values that I have al-

ready stated. I can give more definite values if you wish them, from actual measurements.

Q. I wish you would give that value.

A. The lowering at Austin Street, Buffalo, is .821; at Chippewa .557; Grass Island .556; Willow Island .422; Prospect Point .126; Terrapin Point .238; West end of the Horse Shoe fall .600; at Suspension Bridge it is 2.29 feet, and at the Whirlpool 2.47.

Q. Going back to the measurements which were made by what you have called a current meter, do you know whether or not any tests have been made for the purpose of determining how accurately those meters measured?

A. Yes.

Q. Were they made in connection with your work here?

A. No, the tests were made by this office but before I assumed charge of it. They were made in 1906; I assumed charge of the office in 1907.

Q. Without going into the details as to the results which are shown, I wish you would tell us in a general way how those tests were made?

A. The tests were made in the Detroit River, a short distance below here upon a measured base of 200 feet. At the upper end of the base, about a foot below the surface, a water meter was suspended, and at the lower end of this base another meter was suspended, and the records of both meters were taken. At the same time there was released above the upper meter and suitably timed upon this base, a series of globules, or globes of colored water. These were injected into the stream with a syringe, and it was found that they preserved their form in well defined fashion for the entire length of the base, so that the exact moment of their crossing the upper end and the lower end of the base line could be timed. As a result, the actual velocity of the water could be derived from the velocity of these colored balls of water, and compared with the velocity as derived from the current meters themselves, suitably rated. The tests were, I believe, about seventy-two in number.

Q. Who had charge of the details of the tests?

A. Mr. Shenehon who is present.

Q. And who will be able to give the facts in detail with reference to that?

A. Yes.

Q. Generally what was the result?

A. A practically exact correspondence in velocity, as meas-

ured in the water itself and as measured by the current meter; the only difference existing in the third place of decimals for the average. I mean that the velocity was less than three feet, it was about 2.9 feet, and the difference as measured was in the third place of decimals.

Q. For what purpose were those tests made; that is to say, what connection did they have with the Lake Survey work?

A. There had frequently been made in published articles here and elsewhere an assertion that the operation of rating the meters did not give a true statement of the velocity which the meter was supposed to measure, because the meter when measuring velocity in the stream was stationary and the water moved with respect to it; whereas in rating the meter, the meter was drawn through the water and the water was stationary. That is to say the effect of the water on the propeller wheel of the meter must necessarily be different because of the difference in the two sets of conditions. And these tests were made to ascertain what merit there was in this statement. The result showed there was no merit whatever in the contention.

Q. What did I understand you to say the test showed?

A. The test showed that the velocity derived from meter measurement upon discharge work actually determined the velocity of the water.

Q. That was from a series of how many observations?

A. I think it was seventy-two. It was over seventy.

No cross-examination.

Recess to May 25th, 1909, at the hour of 9:30 o'clock a. m.

May 25, 1909, 9:30 o'clock a. m.

SHERMAN MOORE, called as a witness on behalf of the Government having been first duly cautioned and sworn, testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name?
A. Sherman Moore.
Q. Where do you live?
A. 316 Lincoln Avenue, Detroit.
Q. What is your occupation or profession?
A. I am a civil engineer.
Q. Where were you educated?
A. At the University of Wisconsin.
Q. When did you graduate?
A. I graduated in 1902.
Q. Do you hold any degrees?
A. I have the degree of Civil Engineer given in 1907 by the University of Wisconsin, in addition to degree of Bachelor of Science given at graduation.
Q. Any other?
A. No, sir.
Q. What has been your experience as an engineer, what work have you done?
A. I have been employed by the Lake Survey since June, 1902, on survey work, on triangulation; and during the past three years almost exclusively on hydraulic measurements.
Q. Have you had anything to do with hydraulic measurements on the Niagara River?
A. Yes, sir.
Q. When did you make those measurements?
A. 1907 and '8.
Q. What kind of measurements did you make?
A. They were measurements of the discharge of the river made from the International Bridge.
Q. Go ahead now and tell us just how you made those measurements and for what purpose they were made?
A. The measurements were made for the purpose of determining the effect on Lake Erie of water diversions at Niagara Falls for power purposes.
Q. How did you make them?
A. The measurements were made with the Haskell cur-

rent meter, observing at the index points established in 1899, 1900.

Q. You say they were made by the Haskell current meter. Describe to us briefly and concisely how you make the measurements with that meter?

A. On the Niagara River we did no coefficient work at all. We observed index velocities, velocities at two or three points in each span, and the reduction was made with the coefficients determined in 1899.

Q. How do you measure this velocity with the meter?

A. In the measurements of the discharge of a river, the procedure is first to divide the river into sections of such a size that the current velocities may be considered as proportional to each other. Ordinarily in an open river of large size, we use about a hundred feet. In that space the transverse curve of velocities, that is the distribution of velocities across the river, is not great; and the velocity at any point in that section may be considered as a percentage of the velocity at any other given point which may be taken as the index for that section. At the International Bridge, there were two and three sections in each span. The water passing in a given time through a section, if it was solidified may be conceived as a solid of which four sides would be planes; that is the surface, the back and the two sides limiting the section under consideration. The front would be curved, depending on the distribution of the velocities in the vertical. That is, the velocity at the surface is not the same as it is at the bottom, and the front would be a warped surface. There is a transverse coefficient coming in to a slight extent. In ordinary work on a river, that curve is so slight that ordinarily it would be neglected. Determining the volume of this solid, if we may speak of it as such, is very similar to determining the volume of any solid of irregular size. We measure the ordinates in a vertical plane through the center of the section, ordinarily. The method employed is the two meter method. One meter is placed at the index point, to which the velocities are later referrd, and the other meter traverses the vertical curve, measuring the velocity at the surface at each tenth depth, and also at the bottom. The two meters are run simultaneously and the results are reduced by considering the velocity given by the traveling meter as a percentage of the simultaneous velocity given by the meter at the index point. In that way the vertical velocity curve may be drawn, platting the percentage velocities with respect to the

percentage depths. The mean ordinate to this curve is the mean velocity; the transverse curve, if it is considered, is obtained by platting the index and sub-index velocities for a large number of measurements, with respect to the distance from either side, and drawing through these points a smooth curve. Then the transverse velocity coefficient for any section, or sub-section, will be the mean ordinate to the transverse curve divided by the ordinate at the index point. The product of the vertical velocity coefficient and the transverse velocity coefficient is the velocity coefficient for the panel. The velocity as measured at the index multiplied by this velocity coefficient gives the mean velocity in that panel. The produce of the area of the panel in square feet as determined by soundings, and the index velocity in feet per second multiplied by the velocity coefficient is the discharge through the panel. The summation of all the panel discharges makes up the discharge of the river.

Q. What was the result of these measurements of the Niagara River that you made at the bridge? I refer now to the determination of what we call the increment, in connection with this matter?

A. The measurements in 1907 and '8 checked almost exactly with the measurements made in 1899.

Q. Do you know who made the measurements in 1899, so that we will have them identified here?

A. They were made by Mr. F. C. Shenehon.

Q. You say they checked almost exactly with those?

A. Yes, sir.

Q. How many measurements did you make?

A. I made 126 measurements.

Q. And when did you commence to make them?

A. The first measurements were made in October, 1907. Measurements were made during October and November of that year, and in 1908, in June, July and August.

Q. You say they checked almost exactly with Mr. Shenehon's measurements. What was the increment as you derived it?

A. The increment at mean stage is 22,000 cubic feet for one foot on Lake Erie.

Q. Did you make any soundings of the Niagara River in connection with these measurements?

A. The section at the bridge was sounded in the first four spans on the American side.

Q. What was the result of those observations?

A. The soundings showed absolutely no change in spans 1, 3 and 4, and a scouring out in span 2 amounting to between 15 and 20 per cent increase in area.

Q. What were the conditions in that span which caused this scour?

A. The bottom, in spans 1 and 2, is a deposit of silt. A short distance above the bridge, prior to 1907, there had been quite extensive dredging close to the shore, and this probably resulted in a slight increase of velocity, which scoured out the span. The bottom in the other spans is bed rock, and showed no change.

Q. A little more in detail about these soundings in spans 3 and 4. Have you the result of your work there?

A. You mean in regard to the results or the method of measurement?

Q. Just what were your soundings on spans 3 and 4? You say they showed no change?

A. They showed no change.

Q. About how deep was it in those places?

A. In span 3 the depth is, mean depth, about 28 to 30 feet; maximum depth of about 36 feet. In span 4 the mean depth is 42 to 43 feet and the maximum depth is 48 feet.

Q. What was the velocity of the water at this place?

A. The velocity was high, ran in the neighborhood of six to seven feet per second.

Q. How did you make those soundings, will you give us the method, Mr. Moore?

A. The soundings were made by means of a cast iron weight, which was of the projectile type, a sphere drawn out into cones on each end, with a wooden tail to hold the nose of the weight in the line of the current. The weight used there was 135 pounds. It was suspended with steel piano wire, a little less than one-tenth of an inch in diameter. This wire was carried on the drum of a reel which rested on the chord of the bridge. The circumference of the drum was exactly three feet, and the depth was determined by the revolutions and partial revolutions of the drum. In spans 3 and 4, the velocity of the current was so great that in order to bring the weight to the bottom in the plane of the section, it was necessary to cause the wire to enter the water about four feet above the line of the section. This was done by a heavy weight, which carried a hook which engaged the sounding wire. The auxiliary weight was suspended from the down stream chord of the bridge, and a guy line was run to the

up stream chord of the bridge, so that the weight and the sounding wire could be pulled back up stream any desired distance. The angle of inclination of the wire did not exceed 18 degrees; it was usually much less. The weight was lowered to the water surface, and the reading of the circumference of the drum was taken with the weight just touching the water surface. Then it was lowered to the bottom, and a second reading on the drum was taken. The weight was then raised just clear of the bottom, and the angle which the wire made with the vertical was measured. The difference between the two readings corrected for the inclination of the wire, was the sounding; gave the depth of the water. It was referred to a fixed plane by the readings of a gauge on the shore.

Q. Did you make any measurements on the St. Lawrence River?

A. Yes, sir.

Q. When?

A. In September and October, 1908.

Q. For what purpose?

A. For the purpose of determining the effect of changes which had been made in the river since the former measurements were made.

Q. Were those soundings?

A. The hydraulic section was sounded, and twenty-six measurements of the flow were made.

Q. What was the result of those observations?

A. The observations showed that the flow of the river had been decreased about 5 per cent for a given stage of Lake Ontario.

Q. What change had been made in the river, the effect of which it was your object to determine?

A. The greatest change was due to the construction of what is known as the Gut Dam. That is a dam between two islands at the head of the first rapids in the river, the Galops Rapids, which was built in 1903, I think, for the purpose of facilitating vessel navigation.

Q. Do you know whether there had been any estimate or computation made with reference to the effect of that dam?

A. Yes, sir, there has been.

Q. Was there any before you made the measurements?

A. Yes, sir.

Q. Based upon this method of determining the relation

that you have described. What was the estimate and who made it?

A. It was made by Mr. Shenehon.

Q. And what was it?

A. It was 5½ per cent.

Q. That would be the effect of the construction of the dam?

A. Yes, sir.

Q. How closely did your observations tally with that computation, if you know?

A. They checked exactly as near as could be determined.

Q. That is they showed the change up to 5 per cent?

A. Yes.

Q. That had been estimated on this method of computation?

A. Yes.

Q. What effect did that change, about which you have just testified, at this dam have upon the increment?

A. The change in the increment from the discharges made last year, cannot be determined. The discharges cover a range of stage of only one-half foot at Ogdensburg.

Q. Having in mind now these observations which you made and your experience, what do you say with reference to the increment of the St. Lawrence River? I am referring to this point at which you made your measurements?

A. It is between twenty-eight and twenty-nine thousand cubic feet for a foot on Lake Ontario.

Q. Does that take into consideration this 5 per cent change about which you have just testified?

A. Yes.

Q. That is to say would the effect of that be to make the increment greater or less?

A. The effect would be to make the increment less.

Q. And you have taken that into consideration in your statement of twenty-eight or twenty-nine thousand?

A. That is my impression of it. I do not remember the exact figures.

Q. That is within how close, do you think, as you have stated it? Is there anything to which you can refer to give an accurate statement?

A. For a stage at Ogdensburg of 245 feet above mean tide, the increment is about 28,000; it is that within one or two per cent.

Q. What measurements if any have you made on the St. Clair River?

A. In November and December of 1908, I made fifteen measurements of the flow of the river on Section Dry Dock, and twenty-two measurements of the flow on a new section, at the head of the river.

Q. What was the purpose of those observations?

A. To determine whether or not there had been any change in the conditions governing the outflow from Lake Huron.

Q. What did you find?

A. The observations on section Dry Dock, which is the old section, showed practically no change.

Q. You measured a new section?

A. Yes, sir.

Q. What was the purpose of that?

A. To furnish a check on the measurements on the old section.

Q. That is to say for the purpose of verifying the computation which had been made with reference to the relation between lake stage and outflow?

A. Yes, sir.

Q. And as a check on the increment as it had been determined by former observations?

A. Yes, sir.

Q. Will you describe a little more in detail the measurements on this new section which you made; tell us a little more in detail just what you did there?

A. The new section which is known as section Gorge, is located about a quarter of a mile from Fort Gratiot Light House, just above the narrowest point in the river. The section is a thousand feet wide.

Q. Is that a comparatively wide or narrow part of the river?

A. It is a comparatively narrow section. The narrowest point is about 800 feet wide. This section is just above it.

Q. Was that a section which was favorable or unfavorable for the purpose of making discharge measurements?

A. I consider the section exceedingly favorable.

Q. Why?

A. The velocity averages between five and six feet per second. The current threads are steady and slightly converging and the velocity is accelerated. Under those conditions, there exists very little boiling or broken current threads; the current threads run very smoothly.

Q. In that connection did you make any measurements with water gauges?

A. During the measurement of the discharge, gauges were maintained at a point about a mile and a half above Fort Gratiot light, and at various points in the river below the section, and a gauge on the section.

Q. How did you make the readings? Describe that. And I assume that what you say as to the readings of the gauge on the St. Clair applies also to the measurements of the Niagara and St. Lawrence?

A. Yes.

Q. How did you make those measurements?

A. The gauge used on the river work is what is known as the small type automatic gauge, designed by the Lake Survey office. It consists of a drum about four inches in diameter driven by a clock. On this drum are needle points every two inches, which engage a roll of paper three inches wide, which passes from a spool on one side over the drum on to a receiving spool on the other side, at the rate of two inches each hour. The elevation of the water surface is recorded as a continuous line on the paper, by means of a float in a box which is attached to a wheel about four inches in diameter, geared to a pencil which moves across the paper. The elevation of a fixed line on the paper is determined by readings of a staff gauge, taken usually once a day. This staff gauge is ordinarily a small box about four inches in square set into the water, in which floats a bottle carrying a graduated staff. The elevation of the top of the box is determined by levels from known bench marks, and the gauge reads distances below the top of the box. These elevations by the staff gauge fix the elevation of a fixed line on the paper, and elevations at any other time are scaled from this line to the stage line.

Q. Where did you say you had these gauges?

A. There was an automatic gauge at Muronia Beach, about a mile and a half above Fort Gratiot Lighthouse; a gauge at the old Ferry slip of the Grand Trunk Railroad, about three-quarters of a mile I think below the section; another gauge at the old Dry Dock of Dunford and Alverson, about three miles below the city; a gauge at Roberts Landing and a gauge at St. Clair Flats ship canal. In addition, during all measurements of the flow, there was a staff gauge read at five minute intervals at Fort Gratiot Lighthouse. There was also an automatic gauge on the section which gave the elevation of the water at that point.

Q. What was the result of these observations which you made at this new section, as to the increment which you determined, as to comparison with the former observations?

A. There are in existence a great many formulae for the flow of the St. Clair River. Comparing the observations on section Gorge with what are probably the best of these formula, the results there in 1908 showed between one and a half and two per cent smaller than indicated by the formulae. Considering the results by themselves, the increment of flow for normal stage of Lake St. Clair is between 20,000 and 21,000 cubic feet per second.

Q. Have you, as a result of this work which you have been doing for the last two, or three years, had occasion to reach a conclusion with reference to the precision of the observations which are made from current meters?

A. Yes, sir.

Q. What do you say on that subject?

A. The velocities as given by the Haskell meter, which we have used in all of our work, are unquestionably true velocities.

Q. Why do you say that?

A. In 1906 on the Detroit River tests were made of the velocity as given by the meters compared with the velocity of the river as given by floats.

Q. Did you have anything to do with those tests?

A. I did.

Q. What did you have to do with them?

A. I recorded all the observations.

Q. So you were on the ground, or the water, all the time?

A. Yes, I recorded the observations.

Q. Describe in detail how you made those tests and what the result of the tests was?

A. Two steel catamarans such as were used in the pontoon sweep, used at one time by the Lake Survey, were suspended in the current of the Detroit River; the upper one fastened to an anchor in the bed of the river and the lower one suspended 200 feet below it by means of two galvanized iron wires. These wires were very carefully measured and were marked at the exact distance of 200 feet. On each catamaran, suspended by an overhang so that the meter ran at least six or seven feet to one side of the hulls, so as to be beyond the influence of the hull, there was suspended a current meter. The floats used consisted of balls of bluing, which were injected into the water by means of a bicycle pump.

Floats of this character, forming part of the water itself, unquestionably give the true velocity of the water. A float was started several feet above the first meter, and as it passed the first meter, both meters were started by one movement. As the float passed the second meter, both meters were stopped. The relation was determined between the velocity of the current as given by the colored balls of water and the mean of the velocities given by the two current meters which had been rated in still water, both before and after the tests. There were seventy-six tests made, and the result showed that the indications of the meters agreed with the velocity of the water by about one-fifth of one per cent.

Q. Have you any other reasons for reaching the conclusion which you have stated with reference to the accuracy of the measurements made by this Haskell current meter?

A. The precision of the measurements themselves has been tested in several cases by the measurement of two sections on the same stream.

Q. Have you had in your own personal experience occasion to do that?

A. Yes, sir.

Q. Where?

A. On the intake canals of the power companies at Niagara Falls.

Q. Tell us what you did there and what the result of that work had to do with your statement as to the accuracy of these current meter measurements?

A. The intake of the Niagara Falls Power Company is between 175 and 190 feet wide, 180 feet at the point of measurement; with a depth of about 12 feet and a velocity of about four feet per second. Two sections were measured on this canal in 1907, one about a hundred feet below the other with slightly decreased width and increased velocities. The two sections showed the same discharge by one-half of one per cent. The intake canal of the Niagara Falls Hydraulic Power & Manufacturing Company is about 120 feet wide and from 16 to 20 feet deep with velocities ranging from one and a half to three feet per second. Two sections were measured in that canal, one from a bridge spanning the canal near the lower end, and one from a cable-way near its upper end. The two sections were separated by over a quarter of a mile. The flow as measured by the two sections agreed by 1.7 per cent. This canal did not offer the best facilities for current meter work on account of dredging work which was going on in the

canal at the time, and the continual passing of a tug back and forth, which broke up the threads to some extent.

Q. How did you compare these two sections, were the measurements taken simultaneously?

A. On the canal of the Niagara Falls Hydraulic Power & Manufacturing Company, simultaneous measurements were made for eight hours. On the canal of the Niagara Falls Power Company, as both sections were determined from cableways, simultaneous measurements could not be made. The check between the sections there is obtained by the indications of a meter run at a point in the head of the canal from a conveyor which carries pulp wood to the paper mill, crossing the canal at its head. This meter was run continuously during all the measurements, and suitable coefficients were derived to give the discharge through the canal in terms of the velocity by this meter. The check between the two sections is the check between these coefficients at a given time. With a given velocity at the meter of the conveyor, the product of the coefficient for Section 1 by the area of the section must equal the product of the coefficient for Section 2, by the area of that section.

Q. Have you done any other work that bears upon the question of the accuracy of these current meter measurements?

A. The measurement of the new section in the St. Clair River indicates the accuracy of the work.

Q. Why?

A. The two sections there are exceedingly different. The lower section is about two thousand feet wide, the upper one only a thousand. The velocity in the lower section is about three feet per second, and in the upper section nearly six. The depth in the lower section lies between twenty and thirty feet; the depth in the upper section reaches sixty-five feet. The sections were measured by different observers at different times, and yet the results agree within less than two per cent.

Q. Do you recall anything else in addition to that about which you have testified, which bears on this matter of the accuracy of those measurements?

A. On the Niagara River, in 1898 to 1900 two sections were also measured. These sections were very different; one was a section from the International Bridge, broken up by the bridge piers, with eddying around the piers to a large extent. The other was an open section half a mile further down, where

the water was running smoothly. The measurements on the two sections agreed by about 1.3 per cent.

Q. What does that indicate to you as an engineer?

A. The tests made in the Detroit River indicate that the Haskell meter gives true velocities, and the agreement of two sections on various streams indicates that the method of measurement, the use of the instruments, gives accurate results.

Q. What do you say as to the accuracy of the soundings? Have you any way of checking soundings on cross sectional areas?

A. The accuracy of the soundings is as great as the accuracy of the measurements of velocity.

Q. Why do you say that?

A. The soundings made by different observers at different times at the International bridge, in spans 3 and 4, under extremely difficult conditions showed absolutely no change in the cross sections. Soundings made on the St. Lawrence River in 1908, at the same points at which soundings were made in 1901, showed absolutely no change in the cross section. Soundings made on Section Dry Dock in the St. Clair River in 1908 checked exactly with the result of earlier work.

Q. What do those facts indicate to you as an engineer?

A. The facts show that the soundings as made are correct to at least within one per cent.

Q. You have given evidence here with reference to the measurement of these velocities and the determination of these increments. What have you to say as to the problem there presented as compared with the problem of measuring earth works for instance, as to whether as a matter of engineering it can be done so as to get any accurate result?

A. I consider the measurement of stream flow, so far as the process is concerned, just as simple and sure as the measurement of earth work. It requires a little more observation, but the process is exceedingly simple.

Q. Did you make any observations with reference to the scour in the St. Clair River?

A. Yes, sir.

Q. When?

A. In the fall of 1908.

Q. And how were those observations made, what was your method?

A. In 1897 and '8, four cross sections were laid out in the rapids at the head of the St. Clair River and established by

monuments at the ends. These sections were sounded in 1898, 1899, 1901, 1904 and 1908. The measurements in 1908 were made by me. The results of those measurements showed that there has been no scouring out of the bottom in that portion of the river to any appreciable extent. There have been minor changes on the four sections, but considering the four sections together, there is no scour shown. On the upper section, the soundings of 1908 show an increase in the depth.

Q. Which section is that?

A. That is the upper of the four sections, established in 1898.

Q. Does that have a name?

A. Section Culvert; it shows an increased depth of about 1.3 feet since 1901. On the second section, section Fish, there is no change in the area shown by the soundings of 1908. On Section Arthur, the third section, since 1901 there appears to be a filling in of about two and a half feet. This is probably due to a wreck which lies just above the section and reduces velocities near the bottom. On section Stauber, which is the fourth section, there is no change shown since 1901; the two areas are identical.

Q. Did you measure the flow in the Erie canal?

A. Yes, sir.

Q. When?

A. 1907.

Q. What was the result of those observations?

A. The flow through the Erie canal at the time of the measurements was about 800 cubic feet per second, between seven hundred and eight hundred cubic feet per second.

Q. As the result of your observations and the study which you have given to this subject, are you able to make any statement with reference to the relation which exists between the level of Lakes Michigan and Huron and the outflow of the water through the St. Clair River?

A. The relation between the flow through the St. Clair River and the elevation of Lakes Michigan and Huron has not changed since the measurements made in 1898.

Q. What do you state the increment to be?

A. For normal conditions of the lakes, the increment is between twenty-three and twenty-four thousand cubic feet per second, for a foot change on Lake Huron.

Q. What do you say with reference to the relation which exists between the elevation of Lake Erie and the outflow through the Niagara River?

A. The flow through the Niagara River with respect to the elevation of Lake Erie is exactly the same as it was in 1899.

Q. And what is the increment?

A. The increment for mean stage is 22,000 cubic feet per second.

Q. That is in round numbers?

A. In round numbers.

Q. If water is diverted from Lakes Michigan and Huron at some other point, what will be the ultimate effect upon the quantity of water which flows out through the St. Clair River?

A. The quantity will be decreased.

Q. Why do you say that?

A. The opening of a second outlet to any body of water is certain to lower the level of that body of water, and the lowering of the level of the lake—

Q. Do you state that as an established, recognized, scientific fact?

A. Yes, sir.

Q. Unquestioned?

A. Unquestioned.

Q. Go ahead?

A. The lowering of the level of the lake means a decrease in the outflow of the river.

Q. From the observations you have made and computations which are based on those observations, what do you say as to the effect of diverting 4,000 cubic feet of water per second from Lake Michigan at Chicago, upon the elevation of Lakes Michigan and Huron?

A. The elevation of Lakes Michigan and Huron would be lowered about two inches.

Q. At one point or all the points?

A. At all the points.

Q. At all the channels and harbors?

A. Yes, sir.

Q. What would be the effect of that diversion upon the level of Lake Erie?

A. Of 4,000 cubic feet diversion?

Q. Yes.

A. The effect would be slightly over two inches.

Q. What would be the effect on Lake Ontario and the St. Lawrence River?

A. The effect would be a little less than two inches on Lake Ontario.

Q. And would the effect of diverting other quantities be in proportion to the figure which you have given for the diversion of 4,000 cubic feet?

A. Yes, sir.

Q. That is if ten thousand were diverted instead of four thousand the lowering would be in the ratio of ten to four?

A. Yes, sir.

Q. And so on for other quantities?

A. Yes, sir.

Q. Did you make any observations, with reference to the water power at Niagara?

A. I measured the amount of water which was being used for power by the Niagara Falls Power Company, and by the Hydraulic Power & Manufacturing Company.

Q. How did you do that?

A. The measurements were made in the intake canals of both companies, in the same manner in which the flow through any stream is measured, as I have explained earlier.

Q. What is the head at Niagara, head of the water?

A. The Niagara Falls Power Company uses about 143 foot head; the head of the Hydraulic Power & Manufacturing Company is about 200 feet.

Q. Translating that into horse power in a cubic foot per second, what is the figure?

Mr. Williams: I object to that. I do not understand the diversion of 4,000 cubic feet a second at Chicago, or any other amount, is going to change the head, or interfere with the operations of these power companies, and if it did, this suit is not brought for the protection of the power companies.

Mr. Wilkerson: Q. Do you understand my question?

A. You want the—

Q. How many horse power in water of that head is there in a cubic foot?

A. The Niagara Falls Power Company generates about 65,000 horse power from about 8,000 cubic feet. That would be about 37,000 horse power for 4,000 cubic feet. The Niagara Falls Hydraulic Power & Manufacturing Company develop a greater amount than that.

Q. Will you check your figures on that, Mr. Moore?

A. About 32,500 for about 4,000 cubic feet.

Recess to 1:30 p. m.

1:30 o'clock, p. m., May 25, 1909.

SHERMAN MOORE, resumed the stand and testified further as follows:

Cross-Examination by Mr. Williams.

Q. Mr. Moore, what would you say as to the possibility of error in the reading of these Haskell Meters, or in the meters themselves?

A. The error of observations with a meter is less than one per cent.

Q. That is the error of observation?

A. That includes the error of rating the meters.

Q. Would there be a possibility of the meter indicating a greater velocity than actually existed?

A. By very small amounts.

Q. What circumstance or situation might cause a meter to indicate a higher velocity than actually existed?

A. The rating of the meter is not absolutely constant but is dependent upon a great many things inherent in the meter itself. Wear on the pivots has some effect; but it has been found that unless some accident accurred to the meter, the difference between two consecutive ratings was ordinarily very small. A single observation might be an error by as much as two per cent; but by the combination of more than one meter, and none of our results are based on one meter only, such errors are largely eliminated.

Q. By taking one meter alone, what situation might cause that one individual meter to indicate a greater velocity than actually existed? Are there any situations that come to your mind readily?

A. The substitution of a new contact pin in the meter will ordinarily for a short time cause the wheel to turn slightly harder, if this occurred at the time of rating the meter it will indicate a greater velocity than actually existed, but the change is very slight.

Q. Does the direction of the current, and the way the current happens to strike the meter have anything to do with it?

A. The meter is so built that the current always strikes the meter square.

Q. So that you would say that the possibility of a meter

recording a greater velocity than actually existed would be very slight?

A. Yes.

Q. What would you say as to the possibility of a meter indicating a less velocity than actually existed?

A. A meter would be just as likely to indicate a less velocity as a greater velocity.

Q. Not any more likely?

A. No more likely.

Q. Are there any situations that you can think of that would cause such a result?

A. The pivot on which the wheel spins is occasionally sharpened, and after the pivot is sharpened, it takes a few days for the pivot to wear smooth. During that period there would be a very slight variation.

Q. If there should be a temporary interference by a small amount of weeds or string or anything of that kind that would wrap around the pivot, would that have any effect temporarily?

A. If such a thing occurred, it would. The meters, however, are inspected so frequently that any condition of that kind could not exist for more than an observation at a single point.

Q. An interference of that kind lasting only a very short time would indicate a less velocity than actually existed, wouldn't it?

A. Yes.

Q. Would cause the indication of less velocity?

A. Yes.

Q. Is there any way you can guard against those things occurring except by frequent inspection?

A. The meter wheel is so built that it is designed to throw off anything of that kind and in my experience, with one exception I think, I have never found anything of the kind on the meter. In the canal of the Niagara Falls Power Compay, late in the fall, there was an enor ous mass of dead vegetation floating in the water, and at times that would wrap around the meter. I have never seen it anywhere else.

Q. Did you testify as to the effect in the St. Lawrence River of the diversion of water at Chicago?

A. Of the effect in the river? No, sir.

Q. The St. Lawrence River?

A. No, sir.

Q. How frequently did you find the effect of these weeds in the power canal?

A. It was only on two or three days which followed severe storms.

Q. Well, how frequently did you find the weeds interfering with the efficiency of the meter?

A. The weeds were removed from the meter about once every thirty minutes.

Q. And how many times?

A. During these—I think there were three days.

Q. Every thirty minutes for three days?

A. Yes.

Re-direct Examination by Mr. Wilkerson.

Q. I think you said you never had any experience with weeds except at the one place?

A. Yes.

Q. That was on the Niagara River?

A. Yes.

Q. Was there a bed of weeds in the river above where you made the observations?

A. Yes, sir.

Q. Very thick?

A. Yes, sir, very thick.

Q. And the effect of the storm was to loosen those?

A. Yes.

Q. What did you do with those observations, when you found the weeds?

A. They were all rejected.

Q. You didn't take those into consideration at all?

A. No.

Q. And they do not enter into this result about which you testified?

A. No.

Q. You did not have any trouble with weeds in connection with any of these other observations about which you testified?

A. No, sir.

Q. In either the St. Clair River or any other place concerning which you testified?

A. No, sir.

Q. Take the measurements in the St. Clair for instance,

was there anything present there which interfered with the operation of this meter, weeds?

A. There were no weeds there whatsoever. At times after a storm, when a meter occupied a position close to the bottom of the river, there was a little sand.

Q. Could you detect that situation?

A. Yes.

Q. What did you do with those observations?

A. Those observations where it was known that it occurred were rejected.

Q. What about your detecting them in that situation, did you watch for it closely?

A. Yes, it was watched for closely and the meter was examined each time after it had been to the bottom, and thoroughly cleaned so that the condition was remedied.

Re-cross Examination by Mr. Williams.

Q. What would be the effect upon the accuracy of your measurements of the passing of boats in the channel?

A. I have been unable to detect any effect in the observations.

Q. Is it your opinion then that the passing of boats at the time you were making your observations would not affect the accuracy of those measurements?

A. I do not think that the passing of boats did affect the accuracy of any of the measurements.

Q. There were boats passing through the channel during the time that you were making your measurements, were there not?

A. There were a few.

Q. When was it that you made these measurements in the St. Clair River?

A. Last November and December.

Q. How many days were occupied in making those measurements?

A. The measurements of the discharge of the river were made on nineteen days on the upper section.

Q. How many days were occupied on the other section?

A. Measurements were made on eight different days.

Q. Will you give us the dates on which you made the observations on the upper section?

A. On November 18, 27, 28, December 1, 2, 4, 9, 10, 11, 12, 15, 16, 17 and 19.

Q. What were the dates of your observations on the other sections?

A. November 7, 9, 10, 11, 21, 23, December 14 and 18.

Further Re-direct Examination by Mr. Wilkerson.

Q. Counsel asked you about passing boats. Were there many passing boats at the time you made these observations?

A. There were very few passing boats.

Q. Why?

A. Both on account of the lateness of the season and the unfavorable year for vessel commerce.

Q. I am not quite sure that I understood your answer as to the effect of a new pin on this meter.

A. The construction of the meter is such that each revolution of the wheel makes and breaks an electric circuit which operates a counting register at the surface. The contact is made on the back end of the wheel. There is a disc, half of it is hard rubber and half of it is silver, and bearing on this disc with a very slight pressure is a small silver headed pin which is insulated from the body of the meter. The pins wear out, and it is necessary occasionally to replace them. When a pin is replaced, it is ordinarily slightly longer than the old one which was removed, although an attempt is made to get the pressure as nearly uniform as possible. Any change from that cause is very slight, however.

Q. If the pin presses a little harder does it make the meter indicate a greater or less velocity?

A. It makes the meter indicate a greater velocity. I am mistaken; it would indicate a less velocity.

Q. Maybe I can clear that up. Does it make any difference in the result whether the pin is changed when you are rating the meter or when you are making these measurements?

A. When the pin is changed the pin is ordinarily changed during the rating, so that the rating is made under the new conditions. Occasionally it is necessary to change the pin during the measurements.

Q. Is there any difference in the result when the change is made in the rating or in the making of the observation; if so what?

A. When the change is made at the time of the rating,

the velocities are too large as the new condition is embodied in the rating.

Q. How often do you rate the meter?

A. Meters are ordinarily rated about—well the time varies. On the Niagara River work, the meters were rated about once a month. On the St. Clair River work, the meters were rated before beginning the work and after the work was completed.

Q. How many meters did you use?

A. We used four meters.

Q. In both pieces of work?

A. On the St. Clair River, and three meters on the Niagara River at one time.

Q. Did you make any tests from day to day which would indicate the rating of the meter?

A. On the Niagara River, at least once a week the meters were run side by side in the channel, and simultaneous observations obtained, which showed any change in the rating of any meter.

Q. That is there was a check?

A. Yes.

Q. A check among the meters?

A. Yes. On the St. Clair River every measurement of a vertical curve gave a check on the rating of the two meters employed, by observations when running at four-tenths depths side by side.

Q. Did you make any spinning tests, spinning the meter out of the water?

A. Once a day it was customary to spin the meters in the air and record the number of seconds they would run. The test is ordinarily made in the morning after the meters were cleaned, the first thing in the morning.

Q. Let me put this question to you: just tell us all the precautions you took to see that the meters remained in condition?

A. I didn't catch your question.

Q. You started out to state with reference to one precaution that you took to see that the meters remained in good condition. Go ahead with that and state any other precaution that you took to check up on these meters and see that they remained in condition?

A. The meters were always handled with extreme care. They were cleaned and oiled by one of two men; that is the cleaning was confined to two men, so that it was as nearly uni-

form as possible. Spinning tests in the morning indicated any abnormal condition in the meter. Current meter tests weekly on the Niagara River, and five and six times a day on the St. Clair River, showed up any temporary abnormal condition in the meter. And the meters were very carefully examined each night for any unusual condition in wear on the sides of the body, or anything which would interfere in their holding the rating. They were watched as carefully as it was possible to watch them.

Mr. Wilkerson: That is all.

F. G. RAY, a witness called on behalf of the Government having been duly cautioned and sworn, testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your name?

A. F. G. Ray.

Q. Where do you live?

A. Detroit.

Q. What is your occupation?

A. Civil engineer.

Q. How long have you been engaged in that occupation?

A. I graduated from the State University of Iowa in 1892; and I have been engaged in civil engineering work since then.

Q. In a general way, what work have you done since 1892?

A. I was engaged with the Mississippi River Commission, from the fall of 1892 until 1900. Since then I have been engaged with the Lake Survey.

Q. What has been the scope of your work on the Lake Survey?

A. I have had charge of field parties on triangulation, hydrography and topography during the summer seasons; and have been employed on reduction of notes, water levels, hydraulics, etc., in the winter.

Q. Have you done any work in connection with the determination of what you call critical areas on the lakes?

A. Our field work has been principally an examination of critical areas.

Q. What do you mean by critical areas?

A. Areas that show depths that are or are suspected to be dangerous to navigation; and investigation of channels where the navigable depths are narrow and close.

Q. What particular critical areas have you investigated? Start in with the lower end of Lake Michigan, for instance, and come around?

A. Last season I made a survey of the south end of Lake Michigan, extending from the vicinity of Gary to the mouth of the Chicago River.

Q. What was the nature of that work, what were you trying to find out?

A. It was principally sounding and sweeping for shoals, wrecks and other obstructions to navigation.

Q. Did you find any shallow places down there?

A. We found a number of shoals in the vicinity of Indiana Harbor, that were not charted correctly.

Q. What did you find? State specifically the facts that you found with reference to those shoals?

A. You mean the nature of the shoals?

Q. Yes, and how deep the water was; what limitation, if any, they imposed on the draft of vessels. You are referring, to refresh your recollection, to some chart or map?

A. This is a chart of the last season's work.

Q. That you caused to be prepared?

A. That I caused to be prepared.

Q. Refer to that now, refresh your recollection and just give us the facts with reference to those shoals?

A. There is a series of irregular sand shoals, hard sand bottom, lying off in a northeasterly direction from Indiana Harbor, extending out some five or six miles, in which the prevailing depths are from 16 to 18 feet.

Q. Of what extent are those depths of 16 to 18 feet, for how much of the lake?

A. The area of shallow water is very irregular. There are several parallel reefs that are from one to two miles long, extending about north by west and south by east in direction. There is deep water between them. These shoals start near the shore and extend, as I said before, out about five or six miles, and practically block the entrance to Indiana Harbor.

Q. Vessel men going to Gary or Indiana Harbor have to take what course?

A. Vessels bound for Gary still come by the way of South Chicago. There are no aids to navigation yet at the Gary harbor. They come to South Chicago, pick up the light station there and go due east about seven miles and then south into the harbor, in a roundabout course to escape these shoals.

Q. Do these conditions you describe here have anything to do with that?

A. Yes.

Q. What?

A. There is no navigable depth across these shoals. They are obliged to go around, with the present draft of boats.

Q. What other critical areas do you know anything about?

A. I might enumerate practically all of the harbors on Lake Michigan, though I have had nothing to do with some of them.

Q. I am speaking of your own observation. Go ahead, what is the fact with reference to the harbors of Lake Michigan, let us have in detail the facts about them?

A. Most of the harbors that I have had anything to do with are dredged to practically the present limits of navigation. Occasionally a boat goes in there with a specially low stage—

Q. When you speak of the present limits of navigation, what do you mean by that?

A. The present draft of the boats, that is, of the heavier laden boats.

Q. Well, now, take some of the harbors about which you know particularly?

A. The Milwaukee harbor, Racine.

Q. Tell us the facts about Milwaukee?

A. There are times when boats are obliged to wait for a rise in the stage to get across certain places that have shoaled to less depths than the general depth of the channel.

Q. That is to say, is Milwaukee harbor a harbor in which the depth of the water has anything to do with the size of boats that can come in?

A. All of the dredged harbors are affected by low stages of water.

Q. What other harbors are subject to that effect?

A. Racine Harbor and Green Bay, Sturgeon Bay canal. I suppose all of the harbors on the east shore. I am not familiar with them.

Q. I am asking you of the difficulties about which you know?

A. Cheboygan Harbor, Bay City.

Q. Do you know anything about the shoals in the straits off Cheboygan?

A. I made a survey of the shoals in the straits north and east of Cheboygan a year ago last summer.

Q. What is the fact about those, what did you find?

A. There are several shoals in that vicinity in which there are depths of 19 to 22 feet.

Q. Over what area?

A. They are small areas, several shoals.

Q. Does that have any effect upon the sailing course of vessels, if so, what?

A. The Lake Survey found it necessary to change the sailing courses on the Straits chart about a mile to the northward.

Q. Why?

A. To escape these shoals.

Q. Go on around, what other critical areas do you have knowledge of?

A. Alpena.

Q. What is the fact about that?

A. That is a dredged channel which is limited by the depth of dredging. The south end of Lake Huron is also shoal.

Q. Covering what area?

A. The channel from the head of St. Clair River for perhaps two or three miles northward.

Q. What harbors does that affect?

A. It is the south end of Lake Huron.

Q. Does that affect navigation to any points?

A. The entire navigation down the Detroit River passes through that channel. With a south wind, the boats drag the bottom there continually. The channel through the St. Clair—

Q. Is the navigation there limited by the depth of the water?

A. The navigation there is limited by the depth of the water at the present time.

Q. How deep is the water?

A. It is about 19 to 20 feet; depending considerably on the direction of the wind.

Q. What other critical areas have you investigated?

A. The channel through Lake St. Clair.

Q. What is the fact about that?

A. That is very little deeper than the present draft. There have been complaints of boats striking the bottom.

Q. Did you see anything of vessels dragging through the St. Clair?

A. I have followed boats through there when they stirred up the mud and sand from the bottom with their propellors.

Q. How many times?

A. I have a recollection of seeing that two or three times.

Q. Have you covered now the critical areas that you have investigated?

A. There is a large area at the west end of Lake Erie that is limited by the stage of water.

Q. How large?

A. Several miles from the mouth of the Detroit River out to deep water.

Q. What navigation does that affect?

A. Affects all the commerce on Lake Erie, commerce from upper ports.

Q. How deep is the water there?

A. It varies according to the stage of Lake Erie and the direction of the wind.

Q. Between what limits?

A. It would be between 19 and 21 feet.

Q. Over how extensive an area does that condition in the west end of Lake Erie affect navigation?

A. I am not prepared to say as to how large the area is.

Q. How many miles would you say? Vessels say coming down the river bound for Buffalo, how many miles—

A. Some three or four miles from the mouth of the river covers.

Q. That is, there is a space of three or four miles where that condition would affect the vessels?

A. From the mouth of the river.

Q. Have you investigated any other critical areas?

A. I should call the entrance to Green Bay through the Poverty Island passage a critical area.

Q. What do you know about that?

A. There is a varying depth of about 22 feet.

Q. Over what area?

A. It is just a short distance, perhaps a quarter to a half a mile.

Q. Is there any other critical area of which you have knowledge?

A. There is what might be called a critical area north of Thunder Bay Island.

Q. What is the fact about that?

A. There is quite an extensive area there with a prevailing depth of 26 feet and a minimum depth of 25.

Q. You say, "quite extensive." Can you define the limits a little more accurately?

A. The limits, within the five fathom curve is probably about sixteen to eighteen square miles.

Q. Vessels bound to what ports are affected by that condition there?

A. Practically all of the traffic from Lake Superior or Lake Michigan to Lake Erie passes over this area.

Q. You have had to do in your work with the Lake Survey with water gauge readings, have you?

A. I have had considerable to do with the reduction of the records.

Q. Have you had anything to do with the readings themselves?

A. I have inspected the gauges occasionally, and instructed the gauge tenders.

Q. I wish you would somewhat in detail describe these water gauges and tell us how the readings are made, and what part they play in these measurements?

A. The gauge that we use for our regular stations is an automatic self-registering gauge designed by Mr. Haskell, in which the stage of the water is shown on a continuous hydrograph. The gauge is run by clock work. The record is made on a continuous roll, generally for about a month's duration for each roll. The time is marked hourly by a separate device, and a stationary pencil on this gauge marks the datum plane. The records are derived from scaling between the datum plane and the stage line. The value of the datum is derived by a series of staff gauge readings and the scalings from the roll at the time the staff gauge readings are taken give the value of the datum plane. These staff gauges are referred to our standard bench marks. In reducing the records for purposes of getting daily and monthly means, we scale hourly readings, hourly ordinates. The mean of the twenty-four hourly ordinates constitutes the daily mean, and the mean of the daily means for the month gives the monthly mean.

Q. What do you know about the accuracy of these readings?

A. In what respect?

Q. Is there any checking up on that or verifying it?

A. A test of accuracy comes through a comparison of different gauges on the same lake or connnected lakes.

Q. What do you know about that now? Are you able to make any statements as to the accuracy of those readings?

A. We have gauges on Lakes Michigan and Huron which give a comparison in monthly means each month, and these

checked always, practically always, within a few hundredths of a foot.

Q. Between each other?

A. Between each other; sometimes there is a variation due to prevailing winds, but you can bank on the average.

Q. What does that agreement indicate with reference to the accuracy of the observations?

A. It indicates that any movement on one part of the lake is felt over the entire area of the lake.

In making our level adjustment for establishing datum, the water levels were used in connection with the precise levels, and were given the same weight as the line of precise instrumental levels.

Q. I think you said you had something to do with the computations determining the relation that exists between the stage of the lake and the outflow through the rivers?

A. Yes.

Q. What have you had to do as to those computations?

A. I have made up some of the computations, checked others, and have always studied the readings that have been sent in by the several assistants; am familiar with their work.

Q. You are familiar with the process used, are you?

A. Yes, sir.

Q. And with your practical work, and your knowledge of the subject as a basis, are you able to make any statement as to the relation that exists between the stages of Lakes Michigan and Huron and the outflow through the St. Clair River; if so, what is the fact?

A. I made a computation from the observations that were taken by other parties, and I derived an increment of outflow which is between twenty-one and twenty-two thousand cubic feet per second.

Q. What do you mean by increment of outflow?

A. Difference in outflow for a change of one foot stage on Lakes Michigan and Huron.

Q. Do you know anything about the relation that exists between the levels of Lakes Huron and Michigan and Erie, and Lake St. Clair?

A. The effect of a varying stage of Lake Erie on Lake St. Clair is about 44 per cent., and of Huron on Lake St. Clair about 37 per cent.

Q. What is the effect of the lowering of those lakes upon St. Clair?

A. They would have the same effect; the lowering of Lake

Huron would lower Lake St. Clair about 37 per cent. Lowering of Lake Erie would lower Lake St. Clair about 44 per cent. Those percentages are derived from the past gauge records that we have.

Q. You have gone all through those computations?

A. Yes, sir.

Q. You have had to do with them. You are speaking of work you have done yourself?

A. I have done that myself, yes, sir.

Q. If Lakes Michigan and Huron were lowered two inches, and Lake Erie two and a half inches, what would be the effect upon the level of Lake St. Clair?

A. It would be about an inch and three-quarters on Lake St. Clair.

Q. How do you determine that?

A. The effect on Lake St. Clair from the lowering of Lake Huron is about 37 per cent. I would give about three-quarters of an inch as the effect from the lowering on Lake Huron, and the lowering from Lake Erie would be about 44 per cent., of two and a half inches, or a trifle over one inch.

Q. You and the two together?

A. Add the two together.

Q. Which gives the total effect?

A. Total effect; would be an inch and three-fourths practically.

Q. You have come in contact, have you, Mr. Ray, with matters relating to navigation, in your connection with the Lake Survey?

A. Matters relating to what?

Q. Relating to navigation; that is to say, have you come in contact with matters relating to navigation to such an extent that you have any knowledge as to the effect of a lowering of two or three inches in the critical areas about which you have testified upon navigation?

A. I think I have.

Q. What would be that effect?

A. The effect of a lowering of two or three inches would be to lessen the draft of vessels by that much.

Q. Where would it have a practical effect?

A. It would have a practical effect on the load of vessels for passage through the critical rivers or into shoal harbors.

Q. Over the critical points and the critical areas about which you testified?

A. Yes.

Cross-Examination by Mr. Williams.

Q. In your opinion, Mr. Ray, would it be advisable to now proceed to deepen the lake at these critical points which you have testified about?

A. I did not catch the first part of your question.

Q. (The question was read to the witness.) In the interests of navigation?

A. I think it would be impracticable in some cases.

Q. Would it be necessary in order to serve the interests of navigation?

A. Any lowering of the waters of the lake would decrease the allowable draft of boats.

Q. You do not catch the purport of my question. I ask you whether or not in your judgment it would be in the interests of navigation to now proceed to dredge out and deepen the lake at these critical points that you have testified about?

A. It would be to the advantage of navigation to have some of these places dredged.

Q. Just indicate one of those places that you think it would be in the interests of navigation to dredge?

A. Lime Kiln Crossing.

Q. What is the depth of the water now at the Lime Kiln Crossing?

A. It varies with the stage. I think the limit now is about 21 feet.

Q. And in your opinion to what extent should that be deepened at that point?

A. I am not prepared to say as regards to that.

Q. Do you think it would be necessary to deepen it any? Would it be in the interest of navigation?

A. It would always be in the interest of navigation to have deeper channels.

Q. We are speaking now of this particular point, Lime Kiln Crossing.

A. (No response.)

Q. Are you familiar with the expense of deepening channels?

A. I am not.

Q. These critical areas that you have testified about, where the depth of water is from 23 to 25 feet, under what circumstances are those areas incapable of accommodating navigation, any navigation now taking place on the Great Lakes?

A. Vessels loaded to 20 feet would strike bottom and dam-

age themselves in considerably deeper water in a heavy sea; or during extreme low stages caused by prevailing winds. The rolling of the boat and the dragging down of the boat under headway also give a deeper draft.

Q. How many feet would you say that that rolling effect would be noticeable, or the diving effect.

A. I would not consider anything less than 30 feet would be safe depth, in a heavy sea.

Q. For a 20-foot draft vessel?

A. For the deep laden boats.

Q. That is if a vessel was loaded to a depth of 20 feet, you would consider it necessary to have a depth of 30 feet in order to protect that vessel in case of heavy sea?

A. That, of course, gives some margin of safety.

Q. Well, how much of a margin of safety is there in that ten feet?

A. I believe that a boat loaded to 20 feet would touch on 28 feet of water (mean stage) under the most adverse circumstances.

Q. How is that?

A. A boat would touch on something in the neighborhood of 28 feet, so they have reported.

Q. Then there would be, in your opinion, a margin of about two feet by providing for a 30 foot depth, a margin of safety of at least two feet and no more?

A. I don't think that is measurable precisely.

Q. In your opinion. You cannot testify to an accurate mathematical certainty, on a proposition of that kind, I assume?

A. I would not care to.

Re-direct Examination by Mr. Wilkerson.

Q. Coming back to those shoals again, and the relation of shallow water there to practical navigation of the lakes, is there any kind of weather which might have some effect on navigation, even though there were a channel around, if they went into South Chicago and went around that way?

A. It is very often the practice of masters to hug the lee shore to protect themselves from the heavy seas out in the open lake, and some of these critical areas are along the shores.

Q. You cannot always follow the channel around the shoals in thick weather, can you?

A. You cannot.

Q. Do you know anything about the improvements which are proposed and under way, which will make these critical points about which you have testified more important with reference to navigation?

A. I suppose the construction of the Livingston channel and the new lock at the Sault will have an effect of deepening the draft of boats.

Q. What would be the relation of that situation to these critical areas about which you have testified?

A. That will make depths of between 20 and 30 feet more critical than for shoaler draft boats.

Mr. Wilkerson: That is all.

Recess to May 26, 1909, at the hour of 9:30 o'clock a. m.

F. C. SHENEHON, a witness called on behalf of the Government, was first duly cautioned and sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your name?

A. F. C. Shenehon.

Q. Where do you live?

A. Detroit.

Q. What is your occupation?

A. Civil engineer.

Q. What position do you hold at present?

A. I am principal civilian engineer of the United States Lake Survey.

Q. Stationed where?

A. At Detroit.

Q. What has been your education as an engineer, college education?

A. I attended the University of Minnesota, and hold two degrees, Bachelor of Civil Engineering and Civil Engineer.

Q. What has been the nature of your work since you commenced the active practice of your profession?

A. I was on railroad location and construction between 1886 and 1888. In 1888, I opened an office at Sault Ste. Marie and was in general practice as a civil engineer; and in 1891 I entered the service of the Engineer Department of the Government in the construction of the Poe lock at Sault Ste.

Marie. I was at Sault Ste. Marie engaged on work connected with the building of the lock and the channellization of St. Mary's River up to 1898. The work there included also discharge measurements, on St. Mary's River made in 1896, and reduction of measurements and discussion of hydraulic measurements at that time.

Q. What next?

A. In 1898, July, 1898, I was transferred to Buffalo as engineer for the Board of Engineers on Deep Waterways, in the discharge measurements of the Niagara River; and for two months had charge of the office in that work. That included slope measurements on the river, and discharge measurements at the International Bridge. The Lake Survey then took up the work, and I had charge of the office at Buffalo up to August, 1900. During that period we were engaged in making discharge measurements and the reduction of the same. In August of 1898, I was transferred to the St. Lawrence, and made discharge measurements of the St. Lawrence River during the fall of 1900 and the spring of 1901. Then I was engaged on surveys, a resurvey of the St. Lawrence River for the balance of that year.

I should have stated that during the winter of 1901, I made discharge measurements of the upper St. Lawrence River through the ice, in corroboration of the measurements at Point Three Points. During 1902 I was engaged in surveys on the St. Lawrence River. In 1903, 1904 and 1905 I was in charge of surveys on the lakes, mainly Lake Erie, using the steamer General Williams. In connection with that work, I was afloat making surveys, and became acquainted with lake conditions. In 1906, I was engaged in work on the Niagara River in connection with the Preservation of Niagara Falls, hydraulic work; and during that season I was ordered to the Detroit office to relieve Mr. E. E. Haskell, Principal Assistant Engineer of the Lake Survey, Mr. Haskell going to Cornell University as Dean of the School of Civil Engineering. Since that time I have acted as principal Civilian Engineer of the Lake Survey.

Q. You have spoken, as part of your work and experience, of having had to do with the making of discharge measurements. What do you mean by that? What is the purpose of such measurements? You referred to the Niagara River, the St. Lawrence and the St. Clair River in that connection?

A. The object of the discharge measurements is to establish a relation between the elevation of the lake surface and

the river outflow. That is, for a particular elevation of the lake surface in the vicinity of the head of the Niagara River, for instance, there is a certain volume of outflow, perhaps 200,000 cubic feet per second. Now, when the lake rises a foot, the outflow is increased for two reasons, namely: because the water is deeper in the river, and because also it is flowing with a somewhat higher velocity. And when the lake at the head of Niagara River has gone up a foot, the discharge might be 222,000 cubic feet per second instead of the 200,000 cubic feet at the foot lower level. A long series of observations, or a series of observations in which the stage of the lake is at different elevations, allows us to state a relation between the elevation of the lake surface and the quantity of water flowing out of the river.

Q. You have given some consideration, have you not, Mr. Shenehon, to the question which is presented in this case, namely, the extent of the lowering of the Great Lakes system due to a diversion of the water from the lake at Chicago?

A. I have given very considerable attention to it.

Q. You have gone over the questions that are involved, and have made a special study of them, have you not?

A. Yes.

Q. With a view to reaching a conclusion on that subject?

A. Yes.

Q. Now let me put rather a general question to you first, before we go into those matters that relate to the determination of the exact extent of the lowering. As a result of your observations and study, which you have given to these questions, what have you to say as to the effect of the diversion of the water from Lake Michigan at Chicago upon the elevation of Lakes Huron and Michigan; and state your reasons for it?

A. It is certain to be followed by a lowering of Lakes Michigan and Huron.

Q. Why do you say that, independent of any obesrvations or computation as to the extent of the lowering; I mean the general principles that apply there that lead you to make that as an absolute statement?

A. The level of the lake is determined by the amount of water presented for discharge in its outlets, and the natural outlet (in the case of Lakes Michigan and Huron, the St. Clair River), at a given lake elevation, can do a certain amount of work in disposing of that surplus water. Now, if the work of the St. Clair River is assisted by an independent, or a new canal, as at Chicago, the amount of water to be disposed of by

the St. Clair River is lessened, and the lake will drop to a point where the sum total of the outflow in the St. Clair River and the drainage canal equals what it would be in the St. Clair River, at a higher lake elevation under the earlier conditions.

Q. A moment ago you made some reference to velocity, in connection with the depth of the lake. Will you state again and a little more in detail just what that relation is. I think you said the more water there was in the lake, the higher the lake was, the faster the water would flow?

A. It is flowing under a higher head.

Q. Is that the result of the application of natural laws?

A. It is a general principle that the speed of water bears some relation to its head, other things being equal.

Q. Now you have spoken of the lowering of the lakes as the result of the diversion of water at Chicago. With what meaning do you use the word "lowering"?

A. Lowering is referred to the lake surface which would have prevailed in the absence of the diversion; that is, the lake may actually rise, while this lowering is going on at the same time, in just the same way that a man who is on a railroad train traveling *east* may reach the tail end of the car he is in by walking *westward*. It is a case of two movements going on at the same time. This lowering is going on, and it is independent of the other fluctuations that may prevail at the same time.

Q. What is the relation between the lowering caused by the diversion of this water at Chicago and the outflow in the St Clair River?

A. I do not know that I understand the question.

Q. (The question was read to the witness.)

A. The level of Lakes Michigan and Huron would fall until the lake at a lessor stage is discharging in the two outlets what is discharged in the St. Clair River alone under the normal condition of lake level.

Q. In connection with the waters of the Great Lakes, you make use of the term "net supply." With what meaning is that term used?

A. Over a long term of years it is the amount of water discharged from the lake through its outlet.

Q. Now what are the elements that enter into the determination of this net supply?

A. In the case of Lakes Michigan and Huron, the water brought in by the St. Mary's River, and the rainfall upon the lake's surface itself, the rainfall upon its drainage area or

water shed, less the evaporation which takes place from the water surface and from this water shed.

Q. You speak of evaporation, rainfall, etc., as being elements in determining the quantity of water there is in the lakes to be disposed of. Those are variable elements, I assume; that is, they change from time to time?

A. Yes.

Q. Now what relation exists between those and this element of the diversion of the water at Chicago?

A. Why, the diversion is independent of it. It makes no change in these elements, evaporation, rainfall.

Q. That is to say that remains a fixed factor?

A. Yes.

Q. Which modifies what would be the resultant of the others, whatever that might be?

A. Yes.

Q. I think you have already stated that you have made considerable study and have done considerable work in investigating the outflow through the St. Clair River, did you, Mr. Shenehon?

A. I have done some work in investigating the St. Clair River.

Q. And in connection with the matter that we now have under consideration here, you caused to be made certain plates showing the result of the observations, did you?

A. Yes.

Q. Now I wish you would take up those plates. They have already been marked here for identification as "Complainant's Exhibits 1, 2, 3 and 4," respectively. Starting in with No. 1, will you state what the purpose of preparing that was, how it was prepared and what you had to do with the platting of those observations; what you know with reference to the correctness of the platting, and what the conclusion reached from the observations which are there platted is, with reference to the relation between the elevation of the lake and the discharge of the St. Clair River?

A. On this plat, the elevations of Lake Huron at Harbor Beach are platted in the vertical.

Q. These observations with reference to the stage of the lake were made from the records here in the office?

A. From the records of the United States Lake Survey.

Q. And the others, the observations as to the outflow, where did you get those figures?

A. From the measurements of the St. Clair River as derived from the records of the United States Lake Survey.

Q. Are those records here in Detroit, are they kept here?

A. Yes.

Q. In permanent form?

A. Yes.

Q. You have the names of the men who made the observations in each case, have you?

A. Yes.

Q. And that is a matter of record here?

A. Yes.

Q. What do you know as to whether or not the observations both as to lake elevation and as to the outflow through the river were correctly put down on the plate?

A. I have checked the platting of that, and know that they are correctly platted.

Q. The platting then is a correct representation of those observations as they appear from the records of the Lake Survey?

A. Yes.

Mr. Wilkerson: Are you gentlemen ready at this time to decide this question: whether this plat may be considered precisely as if the witnesses who made the observations were produced and testified; that these observations were made in the way in which it has already been testified in the case as to observations with reference to the determination of the stage of the lake and the outflow; and that if each one of the witnesses who had to do with the making of these observations were put on the stand, he would testify that he made the particular observation, and that it is correctly put down in the records of the office. What I desire to obviate is the necessity of producing what you would call the best evidence with reference to the observations, and to give to the records of the Lake Survey the same effect that would be given to the testimony of the witness, if he was on the stand and said that he made that observation.

Mr. Williams: We will accept the records of field work, as filed and reduced in this department, as being competent evidence, subject to an inquiry as to the probable limits of error of the original observations.

Mr. Wilkerson: Subject to the right on your part to inquire into probable error of individual observations.

Mr. Williams: Yes. Of course, I would say this, I do not know that we are prepared to admit the correctness of all the

methods of reduction. In using the word reduction of observations, I mean to include simply the determination of the actual elevation of a station, for instance, or the determination of the quantity of discharge in an individual observation. We would not want to admit the correctness of these methods in themselves. We will admit the correctness of the data on which they are based.

Mr. Wilkerson: That is the point. The agreement is that the records of the Lake Survey may be treated as of the same effect as the testimony of the witnesses who made the observations; and it is not necessary to produce, and introduce in the record in this case all of those records, but that the witness may say they are correctly represented on the chart. You have then, of course, the right if you want to, to take those observations and to recheck them to see whether or not they have been in fact correctly platted.

Mr. Williams: They would be as open to us as though the man was testifying.

Mr. Wilkerson: Yes. Now, we have Mr. Shenehon's statement that they are correctly put down. You have the unquestioned right to check that if you wish and to show that the platting is inaccurate in any respect, or that you reach different results from the ones he has reached. In other words we get the observations as the foundation.

Mr. Williams: Yes, the original data we accept.

Mr. Wilkerson: Each side can go ahead with its own method.

Q. Starting out now with the foundation that you have on this plat "Complainant's Exhibit No. 1" a correct graphic representation of the observations as they appear from the records of the Lake Survey, will you now go ahead with your description of the plat?

A. The elevation of Lake Huron at Harbor Beach is platted for a discharge observation in the vertical, and the volume of river flow is platted in the horizontal scale, increasing from the left hand towards the right. Using these two scales as a system of rectangular coordinates, an observation which here consists of a group of ten actual discharge observations, except as specifically stated on the plate itself, is platted in the vertical at its proper elevation of Lake Huron, and in the horizontal with the corresponding volume of outflow in cubic feet per second. After the observations thus grouped are platted, a straight line is drawn threading these observations, and this straight line is taken to indicate the

relation between lake elevation and volume of outflow. The exceptions to the groups having ten observations in each are: U has four, Y six, Z eight and Alpha seven. The total number of discharge measurements is indicated at 255. A note appears on this plate that observations of 1901 were adjusted for abnormal stage of Lake St. Clair. Those observations were not taken into account in drawing the line or deriving the increment. They are platted simply to show where they do fall when adjusted for the abnormal stage of Lake St. Clair.

Q. Why were those disregarded, Mr. Shenehon?

A. During the winter and spring of 1901, St. Clair River was blocked with ice, and Lake St. Clair showed an abnormally low stage.

Q. Was that an extremely extraordinary condition, the one that was prevalent that year?

A. Yes. I do not know another instance where Lake St. Clair was as low and held as low in its relation to Lake Huron, as that particular spring.

Q. Was the discrepancy a wide one?

A. They were rejected and treated in this way, because they do not represent normal conditions between Lake Huron and Lake St. Clair. The attempt to get the law of discharge is to get it for normal conditions and the use of these observations of 1901 would have falsified, rather than made the truth clearer.

Q. Having drawn that line representing the law of discharge, you derived what we refer to in this matter as the increment. How do you determine that after you plat the observations?

A. This diagonal line passes between two horizontal lines a foot apart in lake elevation, as between 580 and 581, and dropping a vertical line from the point of intersection with the upper horizontal until it intersects the lower, the base of the triangle formed is the increment. An increment simply means the rate of change of outflow for a change of a foot in elevation in lake surface. That description is perhaps rather involved, because the increment is an exceedingly simple thing. It bears the same relation in a discussion of this kind that interest does in financial discussions. It is the rate. It is the rate of change of outflow for a foot change in the lake level. If we had taken two observations, one of them being at 581 and another one at 580, and these observations

were absolutely correct, the difference between those would be the increment.

Q. The increment as derived from those particular observations is correctly stated on that plat is it?

A. Within such limits as I will state later in my evidence.

Q. Now I understand that the data relating to those observations have been placed in the hands of counsel on the other side?

A. Yes.

Q. For the purpose of going over them and making any question they desire with reference to the accuracy of the plat as shown?

A. Yes.

Mr. Wilkerson: It is understood that we need not put those figures in the record, is it not, Mr. Williams, unless you wish to have them in by reason of something which you may wish to question as to the accuracy of the plat as drawn?

Mr. Williams: I think we would like to have this material here bearing upon the summary of discharges of the Niagara River and of the St. Clair River, testified to as being correct transcripts from the original field data.

Mr. Wilkerson: Q. With reference to these original observations, just what data have you furnished the counsel on the other side, so that we may have it here in the record?

A. For the St. Clair River, tables marked: U. S. Lake Survey, discharge measurements, Dry Dock Section, St. Clair River 1899, 1900, 1902; Tables 1, 2, 3, 4, and 5. With the same heading, Table A, the measurements of 1901 showing the adjustment made for abnormal stage of Lake St. Clair, Table not indicated by letter or number, with the same heading, for the year 1908. A table marked: U. S. Lake Survey; hydraulics of St. Clair River; summary of discharge measurements, Section Gorge, Sherman Moore, Jr., engineer, April, 1909; marked Table 5. Table No. 2, summary of discharges, Open Section, Niagara River, F. C. Shenehon, U. S. Assistant Engineer 1906. Table No. 2, same heading. Table No. 1, summary of discharges International Bridge Section Niagara River, F. C. Shenehon, U. S. Assistant Engineer 1906. Continuation of the same table showing measurements, Number 5 to 68, inclusive. Continuation of the same table showing the measurements 69 to 124, inclusive, with such exceptions in the inclusion as noted on the last sheet. U. S. Lake Survey, Preservation of Niagara Falls, elevation of Lake Erie derived from discharge of Niagara River, Inter-

national Bridge, Buffalo, New York. Table 47 in three parts. These are the observations of 1907 and '8. Table No. 1, summary of discharges, Three Point Section St. Lawrence River, F. C. Shenehon, Assistant Engineer May, 1906, in two parts, including observations 1 to 96, inclusive.

Q. These tables show the facts with reference to the original observations upon which these plats are based?

A. Yes. A reservation should be made in making that statement for the St. Clair particularly of certain transfers of water level which are included in the reduction of the observations as for instance between Fort Gratiot, and Harbor Beach.

Q. Just explain that?

A. Where two water gauges are a short distance apart (and when I say short, that may mean as much as one hundred miles) the elevation of one may be derived from known elevations of the other; and the accuracy with which this may be done is so great that it is given the same belief as the best precise levels. In other words, the water surface is a great leveling instrument itself, and two water gauges and the water surface form a leveling instrument, so we can pass from one gauge to the other. This is true also of the equivalent relation between the lake water gauge and the river surface; and some changes have been made in elevations between the G. T. R. Gage near lead of river and Harbor Beach, in reducing these observations. The error in such a case is small. There may be an error as much as one-tenth in the transfers from Dry Dock section to Harbor Beach, one-tenth of a foot. The fall between Harbor Beach and G. T. R. Gage, as I recollect it is 77/100 of a foot; that is the normal ordinary fall.

Q. Now with reference to your checking up of these tables, as has been already indicated, is there any other explanation that you would like to make?

A. No.

Mr. Wilkerson: That covers everything that you wish to know, for the purpose of going over them. The question of actually incorporating these in the record, we will reserve until you gentlemen have the opportunity to go through them more in detail?

Mr. Williams: Yes. You can say now on the record, I think, that there will be no objection made to the admission of these tables, on the ground of their not being the best evidence, by either side.

Mr. Wilkerson: These tables will be taken as if supported by the testimony of the witnesses who made the observations?

Mr. Williams: That is it.

Mr. Wilkerson: And their correctness will be assumed.

Mr. Williams: That is that they are a correct representation of the work of those witnesses.

Mr. Wilkerson: With the additions and explanations that Mr. Shenehon has made as to one or two points here.

Mr. Williams: Yes.

Mr. Wilkerson: Of course it would be unnecessary for us to put them in the record, and it would only encumber the record unless there is some matter concerning which you wish to question the accuracy of our charts, because the way the record stands now we have that summarized on the plat, so that they become immaterial.

Mr. Williams: Unless we want to introduce them.

Mr. Wilkerson: Unless you want to put them in for some reason. I think now there is no question about either the plats that have been already identified or this data, as to its availability for use by either side as the best evidence in the case.

Mr. Williams: That is all that part of the plat which refers to this data. We are going to object to those parts of the plat which contain those scales, as conclusions. We are going to object to this part of the plat on the left side; in the first place, on the ground it assumes to show the difference between a situation with no diversion at Chicago and a situation where there would be 14,000 cubic feet diversion. That is not the issue in this suit. There is only 4,000 cubic feet involved in this suit. All of this we will object to going into evidence at all.

Mr. Wilkerson: I will put a question to the witness about that scale at the side. (Q.) You had that prepared, did you?

A. Yes.

Q. It correctly represents the result of the plat, does it?

A. It represents two parallel scales in which one corresponds with the horizontal side of the triangle referred to before, and the other the vertical side. It reduces to a scale of inches the relation between change of lake surface elevation and change of outflow. It permits the application of the rate of outflow, or increment, to a particular diversion, as 4,000 cubic feet per second, graphically and readily. And its purpose is none other than to make that process easy, and clear.

Q. Is there anything else now with reference to this Exhibit No. 1, in connection with its preparation, or in explanation of it, that you have to add to what you have said already, Mr. Shenehon?

A. The note on the plat states the discharge observations of 1899, 1900 and 1902 are shown by circles; the observations of 1901 are shown by triangles and those of 1908 by squares. The object of this is to distinguish them. The number of observations for each year: 1899, there were 90 measurements of the river flow; 1900, 66 measurements of the river flow; 1901, 36 measurements; 1902, 48 measurements; 1908, 15. This is on the Dry Dock section. In 1908, 22 additional observations were made on a new section not shown on this chart. This shows 219 measurements of the river flow made under conditions approaching normal. I say approaching normal because individual observations might have shown some tilt up of the lake, Lake Huron, to which St. Clair did not immediately respond; but part of these would be where the lake was a little high, and probably an equal number would be where Lake Huron was on the low side. The errors that may come from this are compensating, and the grouping of the observations as has been done would serve to eliminate or offset any error that might be introduced from this cause.

Q. Exhibits 2, 3 and 4 were also prepared under your direction?

A. Yes.

Q. What you have said with reference to the correctness of the observations as represented on Complainant's Exhibit No. 1 relating to the St. Clair is applicable to each of these other plats is it?

A. Yes, with such explanations as the plates themselves bear regarding the number of observations and the grouping.

Q. Let us take up No. 2: Is there anything in connection with No. 2 that you should add by way of explanation?

A. In the case of the discharge of the St. Lawrence, this represents the discharge as it was taken in 1901, 1902, and the relation between elevation of water surface and volume of discharge is for the water surface of the St. Lawrence River at Ogdensburg. The movements of the water surface at Ogdensburg are about two per cent different from those of Lake Ontario itself; that is when the water goes up a foot at Ogdensburg, it will go up a foot and two hundredths in Lake Ontario. A further reservation of statement should be

made regarding this chart that in 1903 one of the outflow channels at the Galops Rapids was dammed by the Canadian Government and the increment of discharge was lessened by that damming. The change in the discharge was 5½ per cent, and it is assumed that for a given stage of the river at Ogdensburg, the discharge after the Gut dam was put in place (and it was put in place in 1903) was 5½ per cent less than it was before. It is assumed that the increment has changed in the same ratio; that where the increment is shown as 28,870 here, it should be lessened 5½ per cent.

While touching on that point, it might be well to state that the 1908 observations on the St. Lawrence River verified the value of the 5½ per cent change within, I think, a half of one per cent. That loss of discharge by reason of the Gut dam was most accurately deduced by water gauge readings in the lower river at the Rapide Plat. The water gauge is read daily and has been for a great many years, and the discharge observations calibrate the weir. The same condition holds at the head of the Long Sault Rapids above Cornwall. There the Canadian authorities read the water gauge daily at noon, and that weir was also calibrated, so that when the Gut dam was put in place by the loss in level on these particular weirs, we knew very exactly what loss of discharge was occasioned by the building of this dam. So it is not an estimate; it is an accurately derived statement; and the corroboration of the 1908 observations is confirmatory of that.

Q. Those are the observations with reference to which Mr. Moore testified on yesterday?

A. Yes.

Q. Is there anything further you want to state with reference to that?

A. I might state that the total number of discharge observations is 93 in that 1901-1902 work.

Q. Is there anything further with reference to No. 2 or with reference to Numbers 3 and 4 that you wish to add by way of explanation?

A. No. 3 and 4 need no explanation, except as the explanations are contained on the sheets themselves. I might state here that the number of discharge observations in 1898 to 1900 at the International Bridge were 101, and in 1907 and '8 there were 118 that were utilized on this chart. Subsequent to this eight more observations were taken last fall, which are not incorporated. That makes a total of 219 observations utilized in this chart. In the case of the Open Section on the

Niagara River, the total number of discharge observations is 121.

Mr. Wilkerson: I think I made my statement broad enough about these original observations to cover all the plats.

Mr. Williams: Yes. It may be understood that what was said at the time of the discussion concerning Plat No. 1 applies to all these plats.

The Witness: Seventeen observations made in 1898 by the Deep Waterways Commission were utilized to this extent.

Q. Observations made where?

A. At the International Bridge, on the Niagara River. They were made under my direction, incidentally. The velocities at the different stations, the twenty-one different stations across the river were used, but in reducing them the coefficients and cross sectional areas, as deduced later and more accurately by the Lake Survey, were used, but to the extent of taking the velocity, the data is Deep Waterways data.

Mr. Williams: Q. That is they were used by applying to them the sections which you had later more accurately done?

A. Yes. It might be well to add that in this work the United States was in a measure collaborating with the Deep Waterways, as they were in the precise levels run on the St. Lawrence.

Mr. Wilkerson: Q. Now, Mr. Shenehon, what do you say as to the extent of the lowering of Lakes Huron and Michigan as a result of the diversion of 4,000 cubic feet of water per second at Chicago, and on what do you base your answer?

A. The lowering would be between two and two and a half inches in my opinion.

Q. And would that answer apply proportionately to the diversions of other quantities up to say fourteen or fifteen thousand cubic feet per second?

A. Yes.

Q. On what do you base that answer?

A. The observations made by the Lake Survey, the discharge observations, with a possible error in the increment of 25 per cent. The observations as platted indicate a lowering of two inches, and in my belief that is the least lowering that is probable.

Q. Why do you say that is the least lowering that is probable?

A. I base that on the fact that Sabin's earlier measurements indicated an increment of about 19,000 and the measurements made at the Gorge section during 1908 by Mr. Moore

indicate an increment in the neighborhood of 20,000. I base it further on the fact that the physical conditions in the St. Clair river are such as to indicate a fairly small increment. That is, a river that is narrow and gorged, and has to get its cross sectional area by depth in large part is more likely to have a small increment, than one with a broad outlet. That point is well illustrated in the Niagara River, where the upper river is considerably narrower than the river at the head of the Rapids at Niagara Falls. The broad river, something like three-quarters of a mile at Niagara Falls, with not much over a quarter of a mile at Buffalo, makes the increment about half at Niagara Falls of what it is at Buffalo, in the upper river. And we have a further illustration of that when we go down to Suspension Bridge and the Whirlpool. There the increment is somewhere in the neighborhood of 9,000, less than 9,000, and the reason for the small increment there is the narrowness of the river about 400 feet; the river is gorged. And the same is true of Suspension Bridge. A fairly similar condition exists at the head of the St. Clair River, at what is known as the gorge there; it has a width of about 800 feet. It has a depth of over 60 feet with a width of about 800 feet.

Another reason why I think the increment is likely to be smaller than 24,000 rather than larger than 24,000 is the certain relations holding between Lake Erie and Lake Huron. The movements of Lake Huron are larger than those of Lake Erie, which would indicate that the increment is smaller. Perhaps those are not very definite reasons for my belief that the increment is smaller than 24,000, but it has influenced my judgment and I believe it to be true.

Q. What would be the effect of the lowering of the level of Lakes Michigan and Huron upon the St. Marys River?

A. Well, the lowering at any point on Lake Michigan would be accompanied by a similar lowering throughout the whole of Lakes Michigan and Huron, and in all harbors and bays, and would extend up St. Mary's River with some small diminution; I should say it would reach the locks with a loss of 20 per cent. That is 80 per cent of the effect shown on Lake Michigan would be indicated in the floor of the Poe lock, or over the floor of the Poe lock.

Q. What is your reason for saying that 80 per cent of that effect would be found there?

A. That is an estimate, and is based in some measure on back water effects in the Detroit River and the St. Clair River,

and in the Niagara River as well. The fall from the level of the water at the locks to Lake Huron is not much over a foot at the present time, and with a deep stream with no rapids, the back water effect, the largest percentage of it would go up. Speaking rather roundly, if 60 per cent of the effect would travel up the Detroit River from Lake Erie to Lake St. Clair, or 66⅔ as the Deep Waterways estimate it, that is up a rise of 3½ feet, it seems very reasonable that 80 per cent would go up the St. Marys River, and if 50 per cent of the effects of a rise on Lake St. Clair would be transmitted to Lakes Huron and Michigan, that is up a rise of about 5 feet the 80 per cent for St. Marys River seems a very safe estimate. Under present conditions, it has not been computed; we have not observations enough. The taking away of the cofferdam in west Neebish has lowered the water at the Sault locks and brought in a new condition of back water effect, and 80 per cent I think is a conservative statement.

Q. Would the effect of a diversion of water at Chicago upon the elevation of the lakes manifest itself immediately?

A. No, it would take some months.

Q. How long would it take for it to assert itself?

A. Taking an increment for the St. Clair River of 23,820 or 24,000 speaking of it roundly, it would take about four years. If the increment were half that, it would only take two years. It varies directly as the increment.

Q. That is to accomplish how much of the total effect?

A. That would be nine-tenths.

Q. It would accomplish nine-tenths of it in about four years?

A. Yes. To get the other tenth would take just as long.

Q. You said you had to do with the measuring of discharges in the Niagara River?

A. Yes, I was in charge of the Buffalo office from July, 1898, until August, 1900.

Q. Give us some information with reference to the detail of measuring those discharges, and also with reference to the extent of the measurements?

A. The first section of the river measured was that under the lower chord of the International Bridge. The International Bridge crosses the river at what is known as Black Rock and consists of nine spans, and these spans were divided up so that each river width of about 80 feet was considered as a small stream by itself. The first three spans were divided into two stations each, and the spans four, five and

six (I am counting from the American side) had three stations, and spans seven and eight, two each, and span nine, one. There was very little flow in the ninth span; the water was very shallow and small current. The elevation of the water surface was determined by water gauges, one on each side of the river. These gauges were of the box and bottle type which accurately give the water surface to 1/100 of a foot. Later on a self registering water gauge was put in the slip at the foot of Austin street, which is about 3/10 lower down the river; that is 3/10 in elevation. The river was sounded at very frequent intervals, I believe as often as ten feet, very accurately sounded to get the cross sectional area, in conjunction with the water surface elevation.

In sounding, the water surface itself was used as the plane from which measurements were made. By that I mean to say that we did not take the plane of the water surface as indicated by the water gauge but the measurement of depth was between the water surface and the bottom, in each position. I state this because the possible curvature of the water surface is eliminated by doing that. The sounding was done with a 140-pound cast iron weight which was of a projectile shape. It was drawn out sharp at the nose and it was slotted at the stern and a tail put in it so that when it was in the current it was held nose-on, with very little current resistance. It was let down by $\frac{1}{8}$ of an inch wire from a reel; the reel having a circumference of exactly five feet. In order to insure the accuracy of the indications of the reel, it was tested before the soundings and built up, so that exactly 20 feet of the wire made four turns of the reel. Under the influence of current pressures the weight sagged down stream a short distance, and to compensate this it was hauled up above the water surface by guys, and a small correction was applied for the inclination of the submerged wire. In 50 feet of water this correction would not exceed, and I think in all cases was less than a half a foot. That is with water running five miles an hour and 50 feet deep, that was the condition. In most of the spans the depth is less and the current is less swift, and the correction amounted to only perhaps 2/10 of a foot.

After getting the cross sectional area by water gauges and soundings, a meter is let down at 3/10 depth, about midway of each of the stations, one at a time, and a second meter was made to traverse every tenth of depth over a number of sections throughout the station, as often as 20 feet in the

width of the river, each 20 feet, and in many cases, as when approaching the piers, more frequently; and the velocity relations were established between this traveling meter and the one that was stationary at the station or at the three-tenths depths of the station, which we call the index. These observations were made in great detail and over considerable periods, and in the end we derive the volume of the water passing per second, when the velocity indicated at the index is multiplied by the cross sectional area, and reduced by a coefficient which is determined by these velocity relations. After the work I have been speaking of, coefficient work, after that has been completed, a discharge measurement consists of taking a velocity measurement, or two velocity measurements as a rule of two minutes length each, on each station, each of the twenty-one stations of the Bridge Section. At the same time a self registering water gauge located in the lake above the head of the river indicates with a precision of one to two one hundredths of a foot the lake elevation at the time. The volume of outflow, as indicated by the current meters and the section gauge, is then determined with respect to the elevation of the lake as shown by the self registering gauge.

Q. Are those observations that you made in the Niagara River embodied in any one of the plates that are in this record?

A. Exhibit 3, International Bridge section.

Q. Those observations were made under your directions, and many of them by yourself?

A. Yes; personally in part and under my direction all of it.

Q. So that you had the opportunity to know very definitely with reference to the care with which they were made and as to their accuracy?

A. Yes, I made the program, and in some part the methods employed, and personally saw to it that every check that would insure the highest accuracy was used.

Q. I think you mentioned some other measurements of outflow you had to do with personally?

A. Yes. After completing the measurements at the bridge section, in order to verify the relations found there, a new section was established in the open river about 1,800 feet below the International Bridge. This is known as the Open Section. In that section there were seventeen stations, each one of a hundred feet in width. When I say "station" I am using it in two senses. The one hundred foot width of the river,

we sometimes speak of as a panel and sometimes as a station; and the point where we observe, the vertical line midway of the panel is spoken of also as the station; but in the Open Section we observed at the four-tenths depth at station in making discharge measurements.

On the Open Section we had water gauges at each end of the section, that is on each side of the river, and when I say on each side of the river I mean the Island side, that is the American side (there is an island coming in there), and the Canadian side. These gauges were constructed so that we could read from the instrument boat, the Catamaran, the elevation of the water surface to 1/100 of a foot, at any time. And as we made our observation for velocity we also read the gauge, one or both. The soundings were made on that section every ten feet by the same methods as indicated for the bridge section except that we needed no guying as we were close to the water. On that section 121 measurements of the flow were made, and are incorporated in Exhibit No. 4.

Q. What was the result of those measurements, so far as the increment was concerned? Was this second set of observations made for the purpose of checking the prior ones?

A. Yes, to verify the prior observations.

Q. What was the result?

A. The volume of outflow checks within 1.3 per cent that of the International Bridge.

Q. What does that indicate to you as an engineer with reference to the correctness of this work, the obtaining of that result?

A. It indicates correctness, that the work is correct.

Q. You have given us your statement with reference to the effect of the diversion of water at Chicago upon the elevation of Lakes Michigan and Huron. What would be the effect upon Lake Erie?

A. That is of 4,000 cubic feet?

Q. Yes.

A. Lake Erie would be lowered. All of the Great Lakes below Superior, below the foot of the locks in St. Marys River would be lowered.

Q. Speaking of the amount of water which it is proposed to divert at Chicago, I take 4,000 because that is the figure charged in the bill, and I assume when you make a statement with reference to 4,000, the statement which you make would apply proportionately to other quantities?

A. Yes.

Q. Within a limit of up to 14,000 cubic feet per second, I will say?

A. Yes.

Q. So it will not be necessary to speak of the effect with reference to all these different quantities, but when you speak of it with respect to 4,000, you will be understood as having your answer apply proportionately to other quantities. Is that correct?

A. Yes, that is correct.

Q. To what extent would Lake Erie be lowered, and upon what do you base your answer? Before you answer that, Mr. Shenehon, going back to the Niagara River, did you take the increment of the Niagara River also, as you did the outflow, those two sets of observations about which you testified?

A. Yes.

Q. How did that check?

A. The increment as indicated by the Open Section is 21,640 and the increment as shown by the International Bridge section is 21,900.

Q. Does that indicate the same thing to you as an engineer as to the correctness of this work, the fact of that agreement?

A. Yes.

Q. Now as to Lake Erie again?

A. I think while we are on increments I would like to say a little something.

Q. All right, if there is any further explanation of that, you may make it now before we take up the effect on Lake Erie?

A. In a report made by me in 1906, I make the increment at mean lake level, 21,720.

Q. What river are you now speaking about?

A. I am speaking of the Niagara River; that is by the Open Section, 21,720.

Q. To whom was that report made?

A. That was made to Colonel Luck, officer in charge of the Lake Survey.

Q. Is it published?

A. No, unpublished. It became eventually a part of the report to the Chief of Engineers for that year, but was not published.

Q. It is referred to in that report?

A. Not in the printed report. The policy of the govern-

ment is not to print technical publications at the present time.

The International Bridge section shows an increment of about 22,000. In these reports, the law of discharge was not taken as an exactly straight line, but the discharge was taken to vary as the 3/2 power of a certain depth at the head of the river. For the Open Section the increment between Lake Erie elevations 569 and 570 is about 19,290 and between elevations 574 and 575 is 23,210. In the plats Exhibits 3 and 4, the discharge line is given as a straight line, and the error of taking it as a straight line is insubstantial, so far as the matters in this case go.

Q. That is by that you mean that there is no substantial difference in the result obtained when you draw the straight line as it is in the plates which have been offered in evidence and when you draw it as a slight curve as drawn in the other computation?

A. As regards the effect on the lake level, I should say whether you take a straight or curved line, whether you use the increments as shown in my 1906 report or whether you use those shown on the plates, the effect on the level would not vary one-sixteenth of an inch; that is taking the lake in the four or five years in which it may be lowered. If you consider the lake at a pretty high stage, then the lake would be tending to lower at a lesser rate, but when the lake is lower, it is tending to lower at a greater rate, and the lowering at mean lake level is the thing that counts.

Q. As I understand one of your last statements—I want to be sure that I am correct in it and if I am not, correct me—you start out with these observations which are put down on these plates. There are two different methods of determining this increment, one used in your report, about which you testified?

A. Yes.

Q. And the other used on the plate?

A. Yes.

Q. I understand you to say that the difference which would come from using the one method of computation rather than the other would not amount to more than 1/16 of an inch?

A. That is right. I want to explain that a little further. Most of these discharge lines are doubtless curves instead of straight lines. There are several reasons for that. There are so many more forms of curves than there are straight lines, only one straight line, the chances are always that it

may not be exactly a straight line. Unless you are splitting hairs, or trying to get down to the last refinement, you are not warranted in using curved lines. I might illustrate that by considering the surface of the earth or the surface of a small pond. We think of that as being a perfectly straight line across. We know it is simply an arc on the globe, of the circle of the earth; it is curved, but substantially and for all practical purposes it is a straight line.

Q. That is if the radius of the circle was big enough, the curved part becomes practically a straight line?

A. The curvature is so slight it does not in any way negative the substantial accuracy of using a straight line so far as arriving at the lowering of the lake levels is concerned.

Q. And for that reason these lines were drawn on the plates which you prepared for the purposes of this case in the interest of simplifying the operation?

A. To simplify the process, that is all.

Q. Is there any further statement you have to make with reference to this increment?

A. I did not give the increment in the International Bridge Section.

Q. Just give that now?

A. Between elevations 569 and 570 of Lake Erie, the increment is 19,540, and between 574 and 575, it is 23,510.

Q. Now we will take up Lake Erie?

A. The effect on Lake Erie of the diversion of 4,000 cubic feet would be about 2¼ inches.

Q. Upon what do you base that?

A. That is based on my work on the Niagara River and my knowledge of the results obtained from that, which is corroborated by the charts.

Q. And by the later observations in 1908?

A. And by the later observations. Yes, those were made under my direction as Principal Civilian Engineer of the Lake Survey. The planning of the work of the preservation of Niagara Falls, the hydraulic work there, was part of my work, and the initiation of it.

Q. What would be the effect on the Niagara River?

A. At Austin street, which is just below Black Rock, about 82 per cent and at Chippewa which is just above the rapids at Niagara Falls about 56 per cent of the lowering of Lake Erie. The lowering at Suspension Bridge or in the pool below the Falls and above Suspension Bridge, would be about 230 per cent, and in the whirlpool about 250 per cent.

Q. What would be the effect of the lowering due to this diversion at Chicago upon the Detroit River?

A. It would be lowered. In the vicinity of the Lime Kilns on the lower river it would be practically the same as in Lake Erie. And as you go further up the river, up towards St. Clair, it diminishes slightly.

Q. What would be the effect of the lowering by this diversion in Lake St. Clair and in the St. Clair River?

A. Computations made by the Lake Survey indicate about 41 per cent of the effect of Huron present on Lake St. Clair and about 45 per cent of the effect of Lake Erie.

Q. And to get the total effect you would take the sum of those two, would you?

A. About 86 per cent of the mean of the two lowerings would give it very closely.

Q. Eighty-six per cent of the mean?

A. Eighty-six per cent of the mean would give it very closely. That is on St. Clair the mean of the effect on Erie and Huron. Other computations show 37 per cent of Huron and 44 per cent of Erie, and that would indicate about 81 per cent of the mean. Perhaps 80 per cent might be a safe statement to make on that, or an average statement, 80 per cent of the mean.

Q. Are those computations made by the Lake Survey published?

A. The computation made by Sabin, the former of the two I give, is published in the 1900 report, page 5398.

Q. Is that the last computation made by the Lake Survey?

A. The computation by Mr. Ray, the latter of the two, I think is as late as anything we have.

Q. Those are the two you had in mind when you were testifying?

A. Yes.

Q. The only thing I wanted to bring out for the information of the gentlemen on the other side was as to whether or not these computations were published and if they were we would give them the references in the record?

A. Mr. Ray's computation has not been published.

Q. But Mr. Sabin's has.

A. And I want to say in regard to getting at the distribution between Huron and Erie as to the percentage of the effect of each, it is a little indeterminate. The total effect on Lake St. Clair, if the effect on Huron was 2¼ inches and the same thing on Erie, 80 per cent would be a very close

approximation to the truth of the effect on Lake St. Clair. But the nature of the reduction with varying gauge readings, is such there is some indetermination as to where the effect comes from, Huron or Erie. The effect of Erie comes as backwater and the effect of Huron is that of less water passing through Lake St. Clair. Less backwater tends to increase the outflow through the St. Clair River, so the thing is a little complicated.

Q. Have you made measurements on the St. Lawrence, of the same nature?

A. Yes, I made measurements in 1900 and 1901.

Q. What were the details of those measurements and the extent of them?

A. A hydraulic section was taken at Point Three Points, which is about twenty miles below Ogdensburg, and very close to the narrowest point in the river, where the conditions are exceedingly favorable for accurate measurements. The river at this point is about 1,700 feet wide and we had seventeen stations or panels on that river. The detail is much the same as the measurement of the Open Section of the Niagara River. We made 92 measurements there and 26 measurements were made at the same place by Mr. Moore during the past season, under my direction. During the winter of 1901, February, 1900, I measured a second section in the St. Lawrence River above Ogdensburg where the river is three-quarters of a mile wide.

Q. How is that section designated?

A. Nevins Point section.

Q. Were those winter measurements?

A. Those were made through the ice in the winter season. As I recollect it, we had twenty stations there or panels, which were 200 feet in width. The current had a mean speed of about one foot per second on this section and the depth I believe was in the neighborhood of 60 feet, mean depth 51 feet. We made these measurements for discharge there. The conditions for soundings, of course, on a section of that kind were very excellent for accuracy; and the conditions for velocity measurements were not as good; the slow velocity of one foot per second is more difficult to measure. The winter measurements checked the summer measurements within less than one per cent.

Q. Was the work which you did on the St. Lawrence River embodied in any one of these plates that has been prepared here?

A. The winter measurements?

Q. Yes.

A. You mean the summer or winter measurements?

Q. Either one of them?

A. The 93 measurements of which I have spoken are incorporated on Exhibit 2; those made at the section Three Points.

Q. And the winter measurements check with the others that you have stated?

A. They corroborated the summer measurements so far as volume is concerned. The range was not sufficient to determine anything regarding the increment.

Q. What would be the effect of the diversion of this water at Chicago upon Lake Ontario and the St. Lawrence River?

A. It would lower them; lower Lake Ontario and the St. Lawrence River to the Gulf of St. Lawrence.

Q. And to what extent?

A. The river at Ogdensburg, for 4,000 cubic feet, would be lowered 1¾ inches; and substantially the same on Lake Ontario. In the lower river in the approach to the Morrisburg Canal above the Rapide Plats, it would be 50 per cent. greater, 150 per cent. of that. I am stating this roundly. Lake St. Francis, as I remember it, the lowering would be a little less, but that is in Canadian territory, and I do not know that we need to go into that.

Q. You have referred once or twice during the course of your testimony to the building of the Gut dam in the St. Lawrence river?

A. Yes.

Q. And the measurements made for the purpose of determining the effect of that upon the increment and the volume of outflow. I wish you would state a little in detail what the facts about that are?

A. I did state it.

Q. Is there anything in addition to what you have already stated?

A. By means of the measurements at the Three Point section, we write out the outflow relations for the river over the Rapide Plat. That is another weir and outflow, just the same as the Galops Rapids is above, and we did the same thing, also at the Long Sault Rapids; so we have now the Galops Rapids, the Rapide Plats and the Long Sault Rapids. There is water passing over three different weirs. We calibrated these three weirs. The Galops Rapids Weir was interfered with by the building of the Gut dam, but the other two were free to meas-

ure the water, so the loss of outflow in the Galops Rapids was shown by a lowering of the water at the head of the Rapide Plats and the head of the Long Sault Rapids. The lowering appeared as the dam went in; it is very determinable. I ought to say in this connection that preceding the building of the Gut dam, I made a report on what the effect would be if they did build that dam.

Q. Based upon what?

A. My general knowledge of the conditions.

Q. And upon observations that had been made before that time, and general methods?

A. Yes, based upon the discharge measurements of the St. Lawrence River. The conditions were such that an accurate statement could not be made. We had to scale off the cross-sectional area of the Gut; we had the soundings there.

Q. Your computations were borne out, were they, by the actual observations?

A. It came within the limits stated. The actual rise of Lake Ontario by reason of the Gut dam was about five inches.

Q. You used a phrase that I think counsel on both sides would like to have you explain a little more fully. You spoke of calibrating the weir?

A. That is simply taking the discharge measurements and gauge readings at the same time; we get a relation between the gauge height and the amount of flow. It does not have to be necessarily in the lake; it can be in the river at any point. We have calibrated the weirs of the Niagara River at the head of the Rapids, and again at the Suspension Bridge and the Whirlpool, as I have stated earlier. Each rapid in a river, where there is a pool above it, becames a measuring instrument to estimate the flow of the river. While you measure in one place, the same amount of water goes through the whole river; if you have gauge readings at different points, you get the relation between the gauge readings for any point and the volume of outflow, and you can make a plat, such as in this case, Exhibits 1 to 4.

Q. What do you say as to the precision of river gauging done by the Lake Survey?

A. I consider a discharge measurement, or rather a series of them, to have a precision of 1 to 2 per cent.

Q. What is the reason why you think it has that precision?

A. That is in volume, not increment; the precision of the increment is not as great, perhaps 10 per cent. And as I have already stated, in the case of the St. Clair River, the incre-

ment may be an error of as much as 25 per cent. The reasons for my belief in the precision of volume is the corroboration that has invariably accompanied the measurement of duplicate sections, that is, the measuring of two sections in the same river. I speak now of the recent Lake Survey work, the work since 1896. In the Niagara River, as I have already testified, the second section corroborated the first within about 1.3 per cent. The precision of the summer measurements on the St. Lawrence River were corroborated by the winter section. The measurements on the power canals at Niagara Falls, made by Mr. Moore, concerning which he testified yesterday, as these were made under my direction and with my knowledge, I presume it is proper for me to state those?

Q. Certainly.

A. The second section corroborated the first on the Niagara Falls Power Company's canal within half of 1 per cent., and in the case of the hydraulic canal, that is the Schoelkopf Canal, the second section corroborated the first within 1.3 per cent. In the St. Clair River, the measurements made under my direction by Mr. Moore in 1908 corroborate the earlier measurements within 2 per cent.; show about 2 per cent. less flow than in the earlier measurements. The evidence given by these measurements at two sections on a stream, canal or river, are very strong confirmation to my mind of the correctness of the method employed. In 1906, I urged upon the Principal Assistant Engineer of the Lake Survey the advisability of making tests of the current meters, to see whether or not they did give the true velocity of the water. I thought the Lake Survey had so many velocity measurements that in its own records it ought to have a test of the current meters, and to get at the clear truth, to apply a correction for the meters or have a co-efficient of correction, so that our data would be gotten down to the limits of precision, which was what we were working for in all respects. And I made tests on the Detroit River at Fort Wayne, or abreast of Fort Wayne, to find out whether or not the velocities shown by the current meters were the actual velocities at which the water was moving, and 76 measurements, traverses of colored water over a 200-foot base, showed that the current meters indicated the same velocity as the colored fluid was traveling, within one-fifth of one per cent. As the result of those observations my report to the Lake Survey was that we needed to make no corrections of our discharge observations for the meter error.

I can go into that more in detail if it is necessary. I have a report on the subject here, as a matter of fact.

Q. You have your report here, have you?

A. Yes, I have it.

Mr. Wilkerson: We will have it marked as an exhibit for identification, and if you gentlemen want to refer to it, or want to incorporate it in the record, you can do that hereafter. The paper produced by the witness is marked Exhibit No. 6 for identification. It is headed: "Current Meter Tests."

Whereupon document referred to by counsel was marked for identification "Government's Exhibit No. 6."

Q. In order to have a complete explanation of your reasons for saying that the measurements made by this current meter are accurate, you may read such portions of that paper as will explain, or add to what you have said already, and you may have the entire report, if deemed advisable hereafter, incorporated in the record.

A. In making these tests we used two of our steel pontoons. They are part of our pontoon sweep. These have overhanging decks and we extended the overhang of these pontoons further still so that we could drop a meter twelve feet beyond the hull, so as to get away from the hull influence. Then we took two of these pontoons and hung them in the current, one 200 feet below the other; the first suspended by an anchor above, and the second suspended from the first by two galvanized iron wires. On one of these wires a 200-foot length was laid off and beads were soldered on, and this 200-foot length was tested by steel tapes when the system was hanging in the river, or floating in the river current. Then we put one of two current meters about abreast of the upper up-stream bead, and the other one just below the down-stream bead. We injected with a bicycle pump about four ounces of a strong fluid bluing, or a strong solution of analine red; we tried both. This was injected in the river above the up-stream meter, and in injecting it, the bicycle pump was moved along at about the current speed, so that no change in the velocity of the colored water would take place. This ball of colored fluid, or the water itself which was colored by the injected bluing or red, was timed between the first meter and the second, with a stop watch, and the current meters were operated at the same time, which gave us two sets of velocities, the velocitiy shown by the colored fluid and the velocity indicated by the spinning wheels of the meter. If the two agreed, the test seems very

complete. I have already stated that 76 of these traverses, or 76 different colored balls going over the 200-foot base, the mean of these shows that the meter indications were within one-fifth of one per cent. of the velocity shown by the fluid.

These meters were rated immediately before the test on the still water base, following our customary methods.

Q. How do you rate a meter?

A. A meter is rated by moving it through still water over a 200-foot base, ordinarily. That is, a wire is stretched across a reservoir, or some still body of water, and on this wire are two beads soldered about 200 feet apart. The meter is suspended ahead of a boat, ordinarily ahead of a skiff, sometimes ahead of a catamaran or between the hulls of a catamaran. And in some of our rating, we even work on the ice, by suspending the meters through a slot in the ice. The meter is made to traverse this 200-foot base at a large variety of speeds, that is, such a variety as we are likely to find, or do find, in the stream that we are measuring; and the propeller wheel actually shows the relative motion between the water and the instrument. And our test indicated that it does not make any difference whether the water is moving, and the instrument is at rest, or the instrument is moving and the water is at rest; the relative movement is what the propellor shows. In stating this, I make the reservation that the flowing water should be fairly smooth water. I do not mean to say you could go out in rapids and measure the velocity very closely, with a float, or anything else, or with a current meter.

Q. What do you think about the precision of your observations as to soundings?

A. That is well within 1 per cent. in all cases.

Q. Why do you say that?

A. That is involved also in the check of two sections of a river. If the soundings were not accurate, why the results would be likely to diverge on two sections. We have also sounded the same sections a number of times over, and the precision indicated is very great. That came out in the resounding of the spans of the International bridge. The difficulty of sounding becomes greater as the water is swifter and deeper; and in the third span of the International bridge the water is running about five miles an hour and is about 50 feet deep; and the second sounding corroborated the first within one-tenth of a foot, that is, the mean sounding. Then the St. Lawrence, the duplicate soundings there, come very close. I do not know just how close it was, but it was within a

tenth of a foot, the mean. The soundings are certain, as we make them, to be well within 1 per cent.

Q. What do you think about the precision of the observations which you made with the water gauges?

A. That cannot be expressed as a percentage, as that means very little; it should be stated as absolute. The water gauge readings as made by me for the Niagara River and for the St. Lawrence do not have an error exceeding one-fourth of an inch on the water surface. And when I say that, I mean for individual discharge measurement, the mean, or the readings which give the final result are less in error than that; I should say within one one-hundredth of a foot, or one-eighth of an inch. I have already stated it is my opinion on the St. Clair River that the water level transfers may have made an error of as much as one-tenth of a foot, in some of the readings. There are some cases on some of our gauges in the lakes where settlement of a pier on which they are located may temporarily give us incorrect readings; but we test our gauges twice a year with a spirit level, we have inspections, and as I have already said two water gauges on one of the Great Lakes with a water stretch between, that forms a leveling instrument; and we are constantly watching our gauges. As an illustration of how we can detect from one gauge an error in another, I might state a case that occurred on Lake Erie. The District Engineer's office maintains a self-registering water gauge of the Lake Survey type at Amherstberg. The Lake Survey maintains a similar gauge at Cleveland. Upon examining the records at Cleveland and Amherstburg, I found that something was wrong with the Cleveland gauge. I told them that the Cleveland gauge was showing one-tenth of a foot too low; that is, about an inch and a quarter too low. An examination of the Cleveland gauge was made and they found a small leak in the float. Upon emptying the float and testing the gauge, the actual error of the gauge was found to be from that cause 11/100 of a foot, that is, an inch and three-eighths. That indicates how from one gauge we can state whether or not things are going on right at another; and a process we are watching pretty carefully.

Q. I do not know whether I quite understood what you said about the settling of the piers?

A. I mean that if a water gauge were located on a pier as at Milwaukee, and that pier should settle as piers sometimes do, that gauge might give an incorrect result for a while; but we are watching for those things.

Q. Are those errors involved in the discharge measurements?

A. No, those do not involve the discharge measurements. During discharge measurements, we are watching things with a care that we do not exercise at other times; everything is checked up very carefully frequently.

Q. You are just stating something that might happen, that did not happen in connection with any of these measurements that we have here under consideration?

A. No, that don't affect the measurements under consideration.

Recess to 1:30 p. m.

Parties met at 2:30 p. m.

Q. In connection with these plates about which you have testified, you made reference to the number of observations which had been made, laying stress upon that as one of the things to be taken into consideration in your opinion as to the accuracy of the result. I wish you would explain a little more in detail just what the effect of considering a large number of these observations is in eliminating any mistake which might appear if only one or two or three observations were taken?

A. In the case of the Niagara River, including both the International Bridge section and the open section we have 353 individual, separate measurements of the volume of flow of the river. The length of time over which these observations extended gave us a considerable range of Lake Erie stage. We have nearly four feet of range. The number of observations mean that we used not only a number of different current meters, individual meters, in making the measurements, but the rating of these meters was slightly different from time to time. That is, we would rate the meters and make a certain number of measurements; rate the meters again and make some more measurements and so on. And in the end this has the effect of eliminating instrumental error. Then the other minor errors that might enter into the work, there might be an error in an individual case in the gauge reading; there might be a clerical error in taking it off, but in the great multiplicity of measurements these are eliminated.

Q. Is what you said with reference to the number of observations in connection with the determination of this particular result a thing that is peculiar to this computation, or is it something that applies generally to scientific observations?

A. It is a fact that is general; the number of observations, within limits, increases the accuracy or the precision of the result. I want to make one correction in a statement that I made, I did not make it specific, on the increment of the Niagara River.

Q. You may make that correction.

A. I stated the possible error in the increment of the St. Clair River is 25 per cent., and in my judgment it would be below the increment as shown; that is, the increment would be less rather than greater, for reasons that I gave. And on the St. Lawrence River, the error in increment is probably 10 per cent., but in the Niagara River not over 5 per cent. That 5 per cent. is what I failed to state.

Q. When you were speaking of the degree of precision?

A. Yes, and I perhaps should give the reason why I say that, the range of four feet, in the case of Lake Erie, on the Niagara River, gives a high precision in the trend of the line, and on that the increment is based. In the case of the St. Clair River, with a less range, the exact inclination of the line is less determinate; that is one of the factors. On the St. Lawrence River, we had a range of about 2.4 feet which gave us a good determination, but not as good as the range of four feet on the Niagara River.

Q. What would be the effect of the diversion of this 4,000 cubic feet per second at Chicago on the water power in the St. Lawrence and Niagara River.

Mr. Williams: I object to that, for the reasons previously stated.

A. The fall of the Niagara River from the intake of the Niagara Falls Power Company to the level of the river at the portal in the gorge is about 220 feet. That means for each cubic foot per second of water 25 horse-powers, theoretical horse-powers; that is the potential in the water. For 4,000 cubic feet that would be 100,000 horse-power. The efficiency of turbines and the conditions at Niagara Falls are such that we may expect as high an efficiency as 80 per cent. of that. I should say 80,000 horse-power would be the amount of power in the fall at the cataract, that is, in the rapids above the cataract and at the cataract of the Niagara River. That is on the turbine shaft. The Whirlpool Rapids and the lower rapids of Niagara River have an additional fall of about 88 feet, and 4,000 cubic feet per second would mean 40,000 horse-power theoretical, or 32,000 on the turbine shaft. On the St. Lawrence River the Long Sault Rapids alone has a fall of

about 50 feet, and the loss of horse-power there by the abstraction of 4,000 cubic feet would be somewhere in the neighborhood of 23,000 horse-power, or 18,000 horse-power on the turbine shaft,—assuming the same efficiency there. The investigations, the hydraulic investigations of the Niagara River, which were very extensive and are still in progress, for the preservation of Niagara Falls, has a bearing on the matter of water power at that point. We were ascertaining in that investigation the effects of diversions of water for power purposes.

Q. Have you given any consideration to the question of the effect of ice on these rivers, the St. Clair, Niagara and St. Lawrence, on the outflow through the rivers?

A. In my report of 1902 I make a discussion of the ice effect on the St. Lawrence River; and it is found there that the month of December the ice has no retarding influence on the outflow. January, February and March are the months and the only months that have an influence on the outflow. In the Niagara River, the effect of the ice is less marked, and some discharge measurements were made during the ice season. We made 27 measurements during the winter season, and those show somewhat smaller flow during the winter season. The observations on the Niagara are not extended enough nor the conditions constant enough to determine the ice effect. As regards ice on the St. Clair River, if it is proper to do so, I would like to read an extract from the report of the Deep Waterways, 1896.

Q. You refer now to what report?

A. This is the earlier Deep Waterways Board, not the one referred to in my former evidence.

Q. Let us get the exact title of the book?

A. This is United States Deep Waterways Commission, bearing the date: Washington, Government Printing Office, 1897. The Commissioners were James B. Angell of Michigan University, John E. Russell and Lyman E. Cooley. Cooley, I believe, is the technical man, and he is also, I think, or has been, connected with the Drainage Canal. It is page 21.

Mr. Williams: Before Mr. Shenehon reads that, I would like to have him state whether or not the opinions expressed there or the facts stated there coincide with his own opinion.

Mr. Wilkerson: I thought I would have him indicate the portions of the report to which he refers, and then have him make such statements based upon his own investigation as he

sees fit. I thought that was preliminary to some statement he was about to make. Am I correct in that?

Mr. Williams: There is a part of the report he desires to make his own statement. I have no objection to that but I want Mr. Shenehon's judgment and not that of these gentlemen, unless he has made sufficient investigation so that he feels he has an opinion which coincides with the opinion expressed in the report.

Mr. Wilkerson: Let us first have the parts of the report. Read the parts of the report, Mr. Shenehon; then we will see what develops after you read it?

A. The paragraph marked E on page 21: "The average ice season in the Straits of Mackinac is from January 6th to April 15th, or ninety-nine days. It will thus be seen that through navigation is limited by the closing of Lake St. Clair and the opening of Mackinac, or from December 17th to April 15th, a period of one hundred and nineteen days. The Mackinac ice is understood to be largely the accumulated drift of the two lakes."

On page 199, the same report: "The average dates of closing and opening of St. Clair Flats Lighthouse, Michigan, is December 15th, and April 4." That, I believe, is from official records, and the tabulation goes into that more in detail. My own belief is that the ice season on the St. Clair River is ordinarily between, say December 15th and April 15th. Occasionally the ice does last through April, and I believe there are some records of its holding into May; 1901 was a case in point.

Q. What is that ice effect?

A. It is a lessening of the discharge through the ice retardation.

Q. What is the effect of that upon the lowering which would be caused by the diversion at Chicago?

A. Whatever retardation comes from that and whatever lifting of the Lakes Michigan and Huron there is, is something I should say navigation was entitled to irrespective of the Chicago Drainage Canal. If the ice shuts off half the flow of the river, as it does at times, the presumption is—and I state this only as a presumption—that the increment is lessened. And if the increment is lessened during that period, the tendency of Lakes Michigan and Huron is to lower at a greater rate than indicated by the open season increment. By that I mean that if the increment becomes 12,000 instead of 24,000, and that should be a continuous condition, the low-

ering would be four inches for 4,000 instead of two inches for 4,000; and during that period that the ice is in place, the tendency of the lake to lower is greatly due to the Chicago Drainage Canal. It is rising at the same time, but the drainage canal effect is towards a greater lowering than indicated by the open river flow. We have no observations that very clearly show that is the case with the increment, and I state it as a presumption. It looks that way to me.

Q. Is there anything else now that you have in mind, with reference to the ice effect in these rivers? Is there anything you have knowledge of that you have not stated?

A. I do not recall any other fact.

Q. You have covered that condition?

A. I think so.

Q. What knowledge have you on the subject of scouring in the St. Clair River?

A. The observations made under my direction by Mr. Moore last fall, 1908.

Q. Did you follow that work closely?

A. In a general way; not very closely. I knew the results.

Q. I mean with reference to the methods used?

A. Yes, I instructed him regarding the methods to be used and the sections to be sounded.

Q. And the observations which were made were the ones about which you testified yesterday, as the result of your directions?

A. Yes.

Q. What was the result of that investigation?

A. No scour; taking the sections as a whole there is no scour indicated. By that I mean no lowering of the river at that place in the period between 1901, I think, and 1908. I believe in one section the bottom seems to be a little deeper and there is a little less water, but there seems to be no evidence in the whole thing of scouring. There is a movement indicated of certain parts of the river bottom. I know of no evidence of scour in the St. Clair River as a whole, or in the head of the St. Clair River, that is making the discharge any different now than it was in 1898. The discharge observations made in 1908, the corroboration of those with the earlier discharges seems to be evidence of no change of regimen in the river.

Q. What can you say as to the effect on Lake Erie of the diversions at Niagara Falls?

A. Up to the present time it is practically nothing; that is,

Lake Erie has not been affected; while the diversions have caused some lowering of the river above the rapids, certain other elements have tended to compensate that lowering; and any lowering of Lake Erie that has resulted is exceedingly small.

Q. What other outlets in Lake Michigan and Huron are there other than the St. Clair River and the Drainage Canal?

A. I know of none.

Q. Is that a subject to which you have given some consideration?

A. In a humorous way.

Q. What do you say as to that for Lake Erie and Lake Ontario?

A. Lake Erie, of course, has the Erie Canal and the Welland Canal in addition to the Niagara River; and Lake Ontario has no other outlet than the St. Lawrence River.

Q. When you say you do not know of any other outlet, by that do you mean that nobody claims to have knowledge of any such outlet as that?

A. I know of nobody.

Mr. Williams: Let the record show an objection to the counsel asking the witness as to what somebody else claims.

Mr. Wilkerson: Well, what is the present state of knowledge on that subject, so far as you know?

A. I know of no claim that there are any subterranean outlets, if that is what you refer to.

Q. I mean by anybody who claims to have any knowledge on the subject.

A. I know of nobody that claims that there is such an outlet.

Q. In this work in which you have been engaged, have you had any occasion to give consideration to matters relating to data on rainfall, evaporation?

A. Not large consideration, no.

Q. Well, have you given any consideration to it?

A. It has been brought to my attention. I understand that it is one of the elements in an observation of lake levels, if you have adequate data, to take the rainfall and the run-off and the evaporation, and co-ordinate them with the discharge summer and winter and arrive at the lake level. I have never thought that in evaporation, particularly, we had any data that would permit us to figure in that way.

Q. You have studied it with a view to reaching a conclusion as to the reliability of those observations, have you?

A. Yes, I have an opinion on that.

Q. For such a purpose?

A. Yes, for such a purpose. I have an opinion on that.

Q. I wish you would state what that is and your reasons for it.

A. Observations on evaporation have been conducted in reservoirs on shore, and they are not extensive as I know them. We have no observations in mid-lake areas, on an area of the lake that is surrounded by water on all sides is likely to be very different from evaporation in a reservoir on shore. And any attempt to state with any definiteness what the evaporation is on any one of the Great Lakes has little weight in my opinion.

Q. I think you covered perhaps completely the point of the reliability of the data on outflow during the ice season, did you not? A. We haven't very definite knowledge for any particular year as to what the effect may be. Sabin on the St. Clair river made observations for flow during ice periods, and I believe that is all we have, on the St. Clair River. I have rather definite opinions on the St. Clair River, you understand, as I before testified. But one of the years that Sabin considered and made observations in was the year 1901, which was the most abnormal year as regards ice that I have any knowledge of; and I say that, after an examination of the elevation of Lake St. Clair with respect to Lake Huron. The effect of ice is to build up Lakes Michigan and Huron at the expense of Lake St. Clair, and after a period of this ice retardation, Lake St. Clair naturally is low; its supply has been cut off and the water drawn out of it. The same is true in a lesser degree of Lake Huron. 1901 is doubtless the most abnormal of the recent years as regards ice conditions; that is the ice retardation was greatest and continued longest into the spring. As regards rainfall, the absence of rainfall, stations upon the open lake areas themselves and the thin distribution of stations through the Canadian part of the water shed make the use of rainfall observations rather uncertain, and when I say that, what I mean is, that I do not see that observations on rainfall and evaporation and the winter flow of the St. Clair River could be used to detect the presence or absence of the effect of the present flow of the Chicago Drainage Canal. The two or three inches that might be the effect of the Drainage Canal, or that would be the effect of the Drainage Canal, masked by the conditions.

Q. What have you to say as to the effect of the fluctuations

of the lakes due to natural causes in making this loss of two or three inches which would result from the diversion of this water more or less serious?

A. I do not see that the fluctuation has any bearing on the case.

Q. Why do you say that?

A. Because whatever the water level is, if it had been lowered, say two inches, by a diversion, you would still be short your two inches where you needed it, in the critical places. The natural fluctuations due to winds and to seasonal conditions are independent of the drainage canal, and the loss in draft is always measured by the amount of the lowering; you are always two inches closer to the bottom in such a case, whether the lake is raised or whether the lake is tilted up or not; you are always two inches closer to the bottom than you would be otherwise; and when you are running over critical areas two inches may count. Perhaps I should say: when you are attempting to run over critical areas.

Q. As to the effect of the loss of two or three inches in the draft of vessels, do you give any consideration to that, do you add anything to the statements that have been made already on the subject, and do you know the statements that have been made?

A. I have been familiar with the subject for some time and I have spoken of the loss of draft or the loss of carrying power on one of the large lake freighters, due to loss of draft, as about a thousand tons (of 2,000 pounds) to the foot. That would be 83 1/3 tons to the inch. That is an approximate statement. That is, between say 19 and 20 feet; that is near the load limit.

Q. What do you mean by critical areas, critical places?

A. The areas that are shallow, and where the vessels passing are close to the bottom. In that I should extend it to areas where vessels will be close to the bottom when the deeper drafts on the lake, that are certain to come, are realized.

Q. I wish you would explain that a little in detail, telling us what some of these critical places are now; what changes there are likely to be and what the critical areas are that will be affected by that situation; and where the points are that this difference of two or three inches will make a difference in navigation?

A. The floor of the Poe lock is one of the critical points at the present time. The north end of Lake Michigan is an intricate place for navigation, with a good many shoals. And

when a shoal is two inches nearer the surface by the lowering of the lake level, it becomes more of a menace. The vessels in thick weather sometimes get astray, and loss of draft on a shoal may mean a very serious thing to a vessel. The Manitou Passage in Lake Michigan is a place of the same kind; Gray's reef passage, Sturgeon Bay canal is a critical point, and the entrance to Green Bay is a place where a vessel is likely to get into trouble. The foot of Lake Huron approaching the St. Clair River is another place; also Lake St. Clair; the foot of the Detroit River and Bar Point, which is just beyond the Detroit River, and the west end of Lake Erie; and more particularly that part of Lake Erie leading towards Toledo. The west end of Lake Erie is shallow. When the new lock is built at the Sault, giving greater drafts, the Poe lock will cease to be a critical point; and when the Livingston channel is built in the main Detroit River that will cease to be a critical point. But these others remain; these are fixed and that is what I mean by saying that the points that are critical at the present time, after improvements have been made permitting deeper navigation, those that are safely passed over now, two inches of lowering will reduce their efficiency.

Q. With reference to these plates that you have explained Mr. Shenehon, and with reference to the statements which you have made as to the effect of the diversion of this water, is there anything further that you have to add that suggests itself to you now, or any reports you have in mind that you wish to refer to, that bear on this matter? You think you have covered the ground now as far as you recall?

A. I think so.

Mr. Wilkerson: If there is anything in the way of explanation, or anything Mr. Shenehon wishes to refer to or put in, after reading over the testimony, I can recall him for that purpose.

Mr. Williams: Yes.

Mr. Wilkerson: With that reservation, you may cross-examine.

Mr. Williams: Before proceeding with the cross-examination, we have now introduced as an exhibit this chart showing lake levels. What I desire now is to have it appear in the record that the data from which this chart is compiled, in the way of published data concerning lake levels may be used by us without any objection as to its being the best evidence. The lake elevation observations are shown in the published reports, subject of course to the records from time to time. We

do not want to be obliged to call the men who read the gauge, if we want to show some of those lake elevations as published.

Mr. Wilkerson: You mean you would like to have the opportunity of checking this as against the data?

Mr. Williams: You may put it that way, although we have no question about it. But suppose we wish to make the computation concerning something or other on these lakes, where the scale is not sufficiently accurate to get what we want. What we want would be the opportunity to go back to the table of monthly means, which they have, and to use those tables rather than this chart.

Mr. Wilkerson: I suppose as to any particular data, you can furnish, on reasonable notice, the data which you have in the office?

Mr. Shenehon: Yes.

Mr. Wilkerson: I can see no objection to that.

Mr. Williams: All we want is, if we wish some of that data we will not be obliged to verify it by calling the men who made the reduction, but it will be accepted as evidence.

Mr. Wilkerson: I take it we can have the same understanding with reference to that as we had concerning the data on which the charts are based.

Mr. Williams: That is all we want.

Mr. Wilkerson: In other words, we take the records of the office here with the same effect as if the man himself were put on the witness stand and produced the data?

Mr. Williams: There is one other point: There is a regulation of the Engineer Corps that they shall not give out information in matters of this kind to parties engaged in suits against the government, so that it must be agreed to here.

Mr. Wilkerson: Of course you are entitled to it, because you would have the right—

Mr. Williams: I do not think that is the government's attitude, but I understand there is that rule.

Mr. Wilkerson: This chart having been produced, you are entitled to the data if you want it, for the purpose of cross-examining the witness who produces it. All that you have to do in order to get any data that has any bearing on this case is to let us know what the particular data is, and I think I am safe in saying we will let you have it, if it is in existence.

Mr. Shenehon: I see no reason why that should not be done.

Cross-Examination by Mr. Williams.

Q. The Livingston channel to which you referred is an improvement now in progress on the Detroit River, is it?

A. Yes.

Q. What is the nature of that improvement?

A. The Livingston channel is a proposed channel under improvement at present, passing to the westward of Bois Blanc Island. The present channel runs to the eastward of Bois Blanc Island. And this channel is intended as a channel for downbound traffic, for heavy laden traffic coming down. It starts in above the Lime Kiln crossing above Stony Island and runs out to the Detroit River light.

Q. Is that in American or in Canadian waters?

A. It is in American waters.

Q. What is the extent of the improvement; in other words what are the dimensions of the proposed channel, what is the proposed depth and width?

A. Three hundred feet width, and about 24 feet depth.

Q. What is the present depth of water along the course of the proposed channel; that is the original depth without the improvements?

A. Anywhere from 4 feet to 21, 22 feet, 27 feet in places there.

Q. This improvement is being carried on by what method, dredging?

A. The rock cutting in the vicinity of Stony Island is cofferdammed, and being taken out in the dry.

Q. And the remainder of it?

A. The balance is being taken out by dredging.

Q. What is done with the spoil, the excavated material?

A. It is being put into spoil banks, and I believe into compensating the loss of increased flow due to that channel in the river.

Q. What in your opinion will be the effect of the construction of the channel on the level of Lake St. Clair?

A. I cannot form an opinion on that, because I do not know the extent of the compensation. I think the intention is to put sufficient compensation in to take care of the additional channelway, or flow area, so that no change will be made in Lake St. Clair.

Q. Will the cross sectional area of the Detroit River be increased by the construction of this channel?

A. It will be lessened, as I understand the compensation.

Q. What compensating works are contemplated, other than the depositing of the excavated material in the shallower parts of the river?

A. None that I know of.

Q. If there are no other compensating works contemplated, would you say that the excavated material deposited in the shallow parts will take up more space and reduce the cross sectional area any more than it did in its original location?

A. I have not given sufficient study to that to give an intelligent opinion on the subject.

Q. Assuming, Mr. Shenehon, that in the construction of this channel the excavated material is taken out and deposited in the shallow parts of the river, and that nothing else is done for the purpose of compensating for the new channel, what is your opinion as to the effect of that work upon the amount of water flowing through the channel, as changed by the new work?

A. I have not investigated that sufficiently to give an opinion that would be of any weight.

Q. You have no opinion then, I assume, as to the effect of this work upon the level of Lake St. Clair, or upon the depth of water over the critical areas?

A. In Lake St. Clair you mean, and in the Detroit River?

Q. Yes.

A. My only understanding of the thing is that the compensation will be complete.

Q. And that therefore there will be no change?

A. There will be no change.

Q. In the cross sectional area, or the amount of water—

A. In the level of Lake St. Clair.

Q. —or the amount of water flowing through the Detroit River as modified by this channel?

A. Yes.

Mr. Wilkerson: Who is constructing this channel?

A. The United States engineer office for this district.

Q. It is a government improvement, is that right?

A. Yes. I should add that investigations regarding the water levels of the Livingston channel have been instituted by Col. Townsend and Major Kellor; and Mr. Ray has made some figures on the subject. I have given little attention to it myself. The intention is, however, to compensate.

Mr. Williams: You have testified with reference to the Neebish channel in the St. Marys River?

A. Yes.

Q. What is the nature of that improvement?

A. That is a new downbound channel in the west Neebish of the St. Marys River.

Q. What was the original depth of water approximately in that part of the river where this channel was constructed?

A. I could not testify to that without looking it up.

Q. Passing that for the moment, what is the nature of the dimensions of the new channel? Is it completed?

A. Yes, it is completed.

Q. When was it completed?

A. It was completed in winter of 1907-8.

Q. What are the dimensions of the new channel, width and depth?

A. I believe it is 300 feet wide and 22 to 24 feet in depth. I am not certain of the depth.

Q. What was the nature of the excavation there?

A. That was rock, with mud in upper approach.

Q. Rock excavation?

A. Yes.

Q. What was done with the excavated rock?

A. I am testifying in regard to this without having seen it since it was started, or completed; simply on general knowledge. I have not followed the thing closely and my testimony cannot be very accurate regarding the dimensions there.

Q. Do you know whether or not it was intended or attempted to make any compensation there?

A. I think not.

Q. What was the effect, so far as you know, of the construction of the channel upon the level of the water at the foot of the locks?

A. The effect was to lower it.

Q. To what extent?

A. I am not positive. I do not think the data is sufficient to enable us to state accurately. It may be as much as two or three inches; I believe it was fully that.

Mr. Wilkerson: That was a government improvement also?

A. That was a government improvement, yes. As regards compensation in St. Marys River at the West Neebish, I think an attempt to compensate there would have created currents in the channels that would have made navigation difficult.

Mr. Williams: The original depth was the question that you did not wish to answer until you had seen that document which you now have?

A. Make that 24 feet.

Q. That is for the original depth?
A. No, that is the finished channel.
Q. The finished channel?
A. Yes.
Q. Now the original depth?
A. The original depth is about 15 or 16 feet.
Q. What is the range from the minimum to the maximum, just generally?
A. From four feet, and some rocks are indicated above water so we will have to call it zero; from three to four feet, to 16 or 17.
Q. Now you have before you a map here showing another channel on the easterly side?
A. That is the middle Neebish.
Q. When was the work constructed?
A. The Hay Lake channel was opened about 1894, a little before the opening of the Poe lock. The Poe lock was opened in 1896, and my impression was that the—
Q. It was prior to 1896, that is near enough?
A. The Hay Lake channel was opened, the Northwest opened it when I went up on her, which was in the neighborhood of 1894. Some vessels were running through prior to that.
Q. Now, Mr. Shenehon, with the map before you, can you testify briefly what the original depth was along the course of the Hay Lake channel, and what the improvement consisted of?
A. That is the middle Neebish you are talking about now?
Q. Yes?
A. The original condition is not shown on this earlier chart here, but I should say it was not very different from the condition in the West Neebish. The old channel, the East Neebish, was the original channel, and they had 12 feet of water in the old days; and there was less coming up through the middle Neebish.
Q. What are the dimensions of the middle Neebish now?
A. That scales about 400 feet. I have not personally seen the middle Neebish, nor been very familiar with it since 1898.
Q. The depth of water through that Channel is what?
A. Twenty-two feet is indicated here.
Q. You testified, I believe, on direct examination as to the slope of the St. Marys River?
A. Yes.

Q. The slope from the foot of the locks to Lake Huron is about how much now?

A. Something over a foot. I said our elevations were not sufficient to accurately determine that; at least I have not personally looked into the matter.

Q. Do you know or have you available records from which you can ascertain what the change in that slope has been during the past twenty years, say since 1888?

A. From 1886 to 1890, the mean slope between the water at the foot of the locks and the Harbor Beach gauge is 1.99 feet, practically two feet. From 1891 to 1895, 2.40, 2.4 feet. From 1896 to 1900, 2.74 feet. 1901 to 1905, 2.14. Now that slope is in a measure, dependent on the amount of water going through the river; that has some effect on it, a lowering of stage of Lake Huron, as we stated in our back water effects, before.

Q. Was there any record prior to 1886?

A. Yes, they reach back to 1871, to 1875. That was prior to the improvements though there.

Q. Suppose we have them from 1871 down, if you have them conveniently before you?

A. Very well; 1871 to 1875—these are five-year periods—3.03; 1876 to 1880, 2.30; 1881 to 1885, 2.07; 1886 to 1890 you already have as 1.99.

Q. Now from 1905 to date, your information, you say, is not entirely accurate?

A. No, this is from a report dated 1906. I have not brought that up to date.

Q. Can you briefly indicate the improvements that were made these several periods, which caused the variation, or had a tendency to cause the variation in the slope. For instance from 1875 to 1880, there was a difference of about 7/10 of a foot in the slope. Was there any improvement constructed there at that time that might have had the effect of reducing the slope to that extent?

A. I know of none.

Q. Are there any of the variations in slope indicated by the figures that you have given that you would say in your opinion were attributable to any improvements constructed in the St. Marys River?

A. Perhaps I can get at what you are after by one single statement.

Q. That is what I would like?

A. I think it is very probable that the water has been low-

ered a foot at the locks by reason of improvements in the river.

Q. That is the several improvements?

A. Yes. At the Middle Neebish, there was some compensation; a dam was run through the shallow water, but I think the compensation was incomplete, and yet I speak without full knowledge of the hydraulics of that lower river. A compensation I think at Little Rapids was attempted also. I do not know to what extent it was effective.

Q. Has the effect which you have indicated as resulting from these improvements resulted in the lowering of the water over the mitre sills of the Poe lock?

A. Yes.

Q. To the same extent as you have indicated?

A. I should say a foot, yes. I will state that as strong as you like

Q. And that lowering would have the same effect upon navigation as the lowering caused by diversion at Chicago, which would be sufficient to lower the level of Lake Huron a foot, would it not?

A. I see no difference.

Mr. Wilkerson: You refer to that as in the St. Marys River; not over the lower lakes?

A. I refer to it simply on the floor of the Poe lock.

Q. Not over the lower lakes?

Mr. Williams: No, we do not understand it that way.

The Witness: In that particular case the alternative of introducing very swift current or accepting a lowering at the locks was presented, and the lowering at the locks, in view of a new lock, was considered the lesser evil.

Mr. Wilkerson: It was a choice between evils was it?

A. Yes.

Mr. Williams: What is the tendency of the several improvements now under way and in contemplation by the government, as to the lowering of the level of the upper lakes?

A. By the upper lakes you mean Michigan and Huron?

Q. All the lakes above where the improvement is either being made or contemplated?

A. You mean the effect on Lake Superior?

Q. Not the lake itself, but the effect upon the St. Marys River up to the foot of the locks, and the other lakes above where the improvement is being carried on. In other words, what I am getting at is: Isn't it the tendency of all the government improvements to lower the level of the lakes lying

above the point where the improvement is being made, and reducing the slopes?

A. I should say not.

Q. Are you familiar with the work done by the government in dredging at the foot of Lake Huron during the years 1889, 1891, 1892?

A. Not in detail.

Q. You are familiar with the fact that that work has been done?

A. Dredging has been done there, yes.

Q. Do you know what the tendency of that work has been upon the level of Lake Huron?

A. No.

Q. Do you know whether it had any effect?

A. No.

Q. You are familiar with the fact that dredging was done by the United States government in Lake St. Clair, during the years, 1893, 1894 and 1895?

A. I know dredging has been done, but not in detail.

Q. Do you know whether that work had any effect upon the level of the St. Clair River, and Lake Huron?

A. I do not know.

Q. Or either of them?

A. I do not know as regards amount; I should say a trivial effect would enter.

Q. There would be a tendency for it, would there not?

A. I should think so, yes; a small tendency to lower.

Q. Well, now, going back to the other question, wouldn't the tendency be in all improvements of this character to lower the level of the bodies of water lying above the point where the improvement was being carried on?

A. I should say the tendency would be on the side of the lowering rather than on the other side, but it is very small aside from the one case that I have testified about, regarding the water over the floor of the Poe lock. The tendency in creating channels has been to make a bigger opening, and a deposition of material elsewhere has tended to make a smaller opening there, and there has been compensation to a considerable extent; and that whole question of the lowering has to be taken altogether.

Mr. Wilkerson: These last dredgings you are speaking of now, do you know just where they have been made?

A. In Lake St. Clair?

Q. Yes.

A. In the neighborhood of the Flats and also at the foot of Lake St. Clair.

Q. Are those critical points?

A. Yes.

Mr. Williams: Assume that there was a natural channel 2,000 feet in width, with ten feet of water at the deepest point, having a slope of one foot in 10,000; the entire channel having a cross sectional area of 12,000 square feet. Then assume that the central portion of the channel was dredged to 20 feet in depth with a width of 240 feet, the excavated material deposited in the shallow portions so that when the improvement is completed the new channel has exactly the same cross sectional area as the original natural channel. What would you say as to the amount of water that would flow through the new channel as compared with the old, assuming that there has been no change in the slope. Mr. Williams has given you a diagram or sketch of the two channels such as are embodied in my question.

A. If I comprehend this question right, an approximate answer to this is that the amount of water would vary as the square root of 20 to the square root of 10. That is not accurate; it is simply an approximation.

Q. What I wanted to get was would the amount of water be increased or decreased?

A. For the same slope in the compact section, as compared with the shallow one?

Q. Yes.

A. The water would be increased, the amount of flow would be increased.

Q. Then if in a shallow channel a deep channel is constructed and the only compensation attempted is to deposit the excavated material in the shallow parts, so that the cross sectional area was not in any way decreased, the amount of water flowing through the new channel would be increased, assuming the same slope?

A. Yes, there would be more water, considerably more through the compact channel. That statement that it would be in the proportion of the square root of 20 to the square root of 10 was very approximate. It would be the square roots of the hydraulic radii.

Q. Your approximate answer would indicate an increase of about 40 per cent in the amount of water flowing through the same sectional area?

A. I think perhaps it would be a little less than that. There

would be decidedly more water under those circumstances; if the compensation was one square foot per square foot of cross sectional area, it would not compensate it.

Mr. Wilkerson: If they piled this up, so that they made the cross sectional area less, you mean?

A. I testified in the Detroit River the intention was to make compensation by making the area less. That is considered in the plans for compensation in the lower Detroit River.

Q. That in deepening, the cross sectional area is to be diminished?

A. To get an effective compensation.

Q. And that is done by piling up the excavated material in a way which diminishes the size of the cross section?

A. Cuts off part of the cross section that compensates the new cut, by that additional 40 per cent, or whatever may be needed to take care of it.

Mr. Williams: Assume in the previous hypothetical question that everything was filled in except the artificial channel, 300 feet at the top and 240 feet at the bottom, all the shallow part was filled so that the cross sectional area of the new channel would be considerably less than the total cross sectional area of the original channel. What would you say in that case as to the amount of water that would flow through the new channel as compared with the old, assuming the same slope?

A. Without careful computations, I would not care to give an answer to that question. The general proposition that in compensating you need to cut off more area of shallow water than the increased area in a compact section is well established; there is no question about that. And in discussing the working up of the method of this compensation in the lower Detroit River, that is taken into consideration; the form of the section, as to whether it was compact, and the form of the shallower section which has to be cut off to compensate it.

Q. In order to render the compensation complete, the cross sectional area in the new channel in the Detroit River will be less than the cross sectional area of the river at that point?

A. Yes.

Q. I will ask you, after having propounded this hypothetical question to you, whether or not the case presented by the question that I asked you does not fairly illustrate the con-

ditions of the connecting waters of the great lakes as they stand, without the improvements? In other words, isn't the problem which I have suggested a fair statement of the situation as it exists?

A. No, for the reason that other matters have come in that enter into the case. I have discussed them somewhat in my report on the preservation of Niagara Falls, on the Niagara River there. And there the narrowing of the river in places, the extension of docks out from the original shore line has a tendency to cut off part of the cross sectional area. At Tonawanda on the Niagara River, for instance, an encroachment has been made; dredged material is as a rule dumped in the river itself and has a compensating effect. In the Detroit River for instance, the advance of the dock line has narrowed the river along the Detroit front; and it is true on the Canadian side as well; and the tendency is encroachment, in a good many cases they compensate.

Q. But you cannot any more than fill up the shallow parts of the river with this excavated material?

A. There is no excavated material opposite Detroit, but the dock line has been advanced and cut off the river.

Q. The docks cannot extend further than the line of navigation?

A. The harbor line is the limit of the docks; that is established by the War Department. I might say that on Lake Ontario an improvement, if it may be considered such, the Gut dam, to which our government consented and is therefore a party to, raised the elevation of the St. Lawrence River and Lake Ontario four to five inches, as I have previously testified.

Q. What was the amount of head figured by you in estimating the water power at Niagara, at these power plants?

A. 220 feet; that is at the cataract and the rapids above the cataract.

Q. And you figured the entire fall from what point?

A. From the intake of the Niagara Falls Power Company to the portal, which is the outlet of the same company.

Q. Are there any losses in the head or in the tail race?

A. I took account of those in the 80 per cent. I made a reduction of 20 per cent for loss.

Q. You mean that your estimate of 25-horse power per cubic foot was theoretical horse power?

A. Theoretical, on the head of 220 feet. It is 220 divided by 8.8.

Q. And then your loss of 20 per cent in the actual is what you allowed for the loss in head and tail races?

A. Yes.

Q. What degree of efficiency do you figure then in the wheels?

A. Perhaps 84 or 85. For those wheels on the high heads, I understand the efficiency is very high. Higher than the ordinary turbines.

Q. 84 or 85, if you allowed for efficiency 85 per cent, that would only leave 5 per cent that would have been lost by reason of head and tail races?

A. That is something over ten feet; the actual head under which the Niagara Falls Hydraulic Company is operating is about 210 feet. That is between head water and tail water.

Q. Is this head you are testifying about on the American or Canadian side?

A. That is on the American side.

Q. You were asked by Mr. Wilkerson with reference to diversions at Niagara, and the effect of those diversions, if any, upon the level of Lake Erie. What diversions did you have in mind?

A. The diversions of the Niagara Falls Power Company; the Niagara Falls Hydraulic Power & Manufacturing Company, and the Ontario Company on the Canadian side.

Q. How many cubic feet per second would you say is involved in those relations?

A. Something less than 20,000.

Q. 220,000 cubic feet per second?

A. Per second, yes; that is there is not that much in use at the present time. Perhaps 15,000 cubic feet per second would be a closer estimate.

Q. Now what were the compensating influences that caused those diversions to fail to influence the level?

A. Why I should state in this connection that our earlier measurements of the river were made in 1898, when about half the present diversion of the Niagara Falls Power Company was in effect, and the added diversions since that time—I am speaking very roundly now—may be eight or ten thousand cubic feet per second. I think perhaps I have not stated that correctly. The effect of a diversion of about 11,000 cubic feet above the rapids there would lower Lake Erie about half an inch, 5/100, and during certain years, 1904 and 1905, the divertors of the Ontario Company were in place, and those backed the river up, so that there was a rise of something

like four inches in the river above the rapids there at Niagara Falls, and that would temporarily give Lake Erie a tendency to rise, but the rise would be very small; it would be 3/16 of four inches.

WILLIAM LIVINGSTON, a witness recalled for further cross-examination by Mr. Williams, testified as follows:

Q. Mr. Livingston, one of the questions that was asked you, which you said you would look up was with reference to the percentage of boats that would be affected by a diminution of draft of two inches, boats that ply in the northern lakes, and in the harbors of Lake Michigan, that do not pass through the St. Clair and Detroit Rivers?

A. That do not pass through?

Q. Yes.

A. I cannot give it to you. I have sent for the information but I have not obtained it. I want with your permission to correct one statement I made the last time I was in. I said that the average cost per day for the running expenses of a boat was $160. That of course was exclusive of loading and unloading; I am just talking about the operating expenses of a boat independent of that. It would be $160 a day including insurance. I started to get these matters in motion and I had to send over to get some data that I didn't have in the office, and I got to figuring over and looking over some statements which I have, and I would like to correct that. I think I made that too low; I think I should have made that $180 a day. I find there are two or three things I neglected to take into consideration. We always increase the wages of our employes, for instance, the first of October, increase them ten dollars and so on, depending on the positions they are in. And there are a number of other matters, and I find a difference too in many of our fleets in the way of computing expenses; the system of bookkeeping is a little different, so I am satisfied now, after spending a little time, that for that class of boats, 10,000 tons, I should have said $180 a day to have been safe. I would like to correct that. Ordinary maintenance and upkeep such as painting and minor repairs are included in the $180 per day; that also covers insurance.

Detroit, Michigan, June 4, 1909, 10 A. M.

Parties met pursuant to notice.

F. C. SHENEHON, resumed the stand for further cross-examination by Mr. Williams and testified as follows:

Q. You have charge, Mr. Shenehon, of the publication of charts showing the channels through the Great Lakes and connecting waters?

A. The Lake Survey issues those charts.

Q. And they are under your direction?

A. Under the direction of the officer of the Lake Survey. I understand you mean finished charts that were published?

Q. Yes.

A. The Principal Civilian Engineer, which is my title, has more direct charge of the field process, although as First Assistant to the officer in charge, he has an indirect charge of the whole office. But my supervision over the actual publication of the charts is rather small.

Q. Can you furnish us charts from which can be obtained cross sections of the Detroit River at the Lime Kiln Crossing?

A. The chart of the Detroit River will give that, but not with a high degree of precision.

Q. Within what degree of precision would you say the chart would give that cross section of area?

A. I should say within 5 per cent.

Q. Have you one of those charts available?

(Witness produced a chart which was marked for identification "Defendant's Exhibit A, June 4, 1909"; the same being a chart of the Detroit River projected from a trigonometrical survey issued under the direction of Major C. B. Comstock, of the Corps of Engineers, Brigadier General U. S. A., in 1873. Additions and corrections under the direction of Major W. L. Fisk, Corps of Engineers, U. S. Army, in 1902-4, and Colonel G. J. Lydecker, Corps of Engineers U. S. Army, 1905-6, and Major Charles Keller, Corps of Engineers, 1907-9.)

The Witness: I should like to change that precision to 10 per cent. I figured on about one foot of allowance there, and I see there is only about ten feet of water in place; 5 to 10 per cent, make that.

Q. Would you say that it was precise within one foot; that was the basis of the estimate?

A. Yes, I should say it was closer than that.

Q. By referring to that chart, can you readily give us the original depth along the section of the Detroit River in the Lime Kiln, or if you have other sources of information from which you can give the information, let us have them.

A. This shows the condition of the river on March 20, 1909, not in its original condition.

Q. Do you know, Mr. Shenehon, what the depth originally was along that section?

A. No, I do not.

Q. Can you state what the widths and depths of the channels through that section are, at the present time?

Mr. Wilkerson: You mean the dimensions before any improvements were made at all?

Mr. Williams: That was the other question, but he says he cannot give that. Now I ask for the width and depth of the present channel.

A. The width of channel given is scaled from the chart and shows for the Lime Kiln 600 feet.

Q. Six hundred feet in width?

A. Six hundred feet in width, yes; with a depth of twenty-one feet when Lake Erie is at elevation 571, by the levels of 1903.

Q. Have you in your custody or in your office surveys or charts or any other sources of information from which you could give us the original depth of the channel at that point?

A. I think so. I will have to have them looked up.

Q. What is the total width of the river at that point, the width of that section rather?

A. About 8600 feet.

Q. Is there a current over the entire width?

A. I think so.

Mr. Wilkerson: You are now speaking of the Lime Kiln crossing?

Mr. Williams: Yes, the section of the Detroit River at that point.

Q. Does Stony Island have any effect upon the current in that section?

A. Stony Island is above the section I measured, and in the wake of Stony Island, below Stony Island there should be dead water for a certain distance.

Q. At the point where you measured, you will say there is a current across the entire channel?

A. The section measured is about 2100 feet below Stony Island, and I should say there was current in every portion of that.

Q. In giving your answer as to the width of the present channels, 600 feet, did you include the Livingstone channel in that statement?

A. No.

Q. I believe you testified to it before, but so that we can get it all together, will you now state the dimensions of the Livingstone channel now in course of construction?

A. Three hundred feet in width at that point of the river, and 22 feet deep below Lake Erie elevation 571.

Q. Can you give the dimensions of the channels that are cut off by the cofferdam, which is shown on the chart?

A. The cofferdam from the east point of Stony Island extends eastward about 1400 feet, and the completed portion extends down stream about half a mile. The old pier of the Michigan Central Railroad, which coincides with the upper end of the cofferdam, had an original length of 1200 feet.

Q. What is the width of the channel at the upper end of the cofferdam; the entire river? The cofferdam is not situated at the point where you made the measurements of a few moments ago?

A. No, about 3200 feet above the section measured.

Q. At that point its width is what?

A. At that point the river width is about 3500 feet east of Stony Island and 1100 feet west of Stony Island.

Q. Can you give us the depth of water along the upper end of the cofferdam?

A. From five to fifteen feet.

Q. That is shown on the chart?

A. The nearest soundings indicated are five, six, ten and fifteen.

Q. What is the most accurate method of measuring water, Mr. Shenehon?

A. Such rivers as we have under consideration, the current meter method.

Q. Without reference to the rivers we have under consideration, what would you say was the most accurate method of measuring water? Isn't it by weight, the most accurate method?

A. By weight, yes.

Q. And next to that what would you say was the most accurate?

A. By volume, the size of the vessel containing it.

Q. And the next to that?

A. Current meters.

Q. What would you say as to the degree of accuracy that may be reached in the measuring of water by means of a weir as compared with current meters?

A. I should say the current meter method is as accurate.

Q. Is as accurate?

A. Is as accurate, yes.

Q. Would you say it was more accurate?

A. Very inaccurate work can be done with a weir.

Q. Assume the same degree of skill exercised in measuring with a weir as would be exercised in measuring with a current meter?

A. I am not familiar with weir measurements by having made any personally. I have a very general knowledge of the subject, and the exact degree of precision I am not prepared to state.

Q. In making your gaugings with a meter, you seek to get the meter in the same vertical section at each gauging?

A. That is at the same station, as we call it; it is the same vertical line; when I say the same, within a few feet of the same.

Q. You make an effort to get it as near the same as possible?

A. Within the limits we regard as required by the accuracy, yes.

Q. How close would you say you are able to do it?

A. Oh, four or five feet, or less.

Q. Are the velocities in a flowing stream uniform from one point to another?

A. No. Let me understand what you mean. You mean do they vary in uniformity from one point to another by regular gradations. What is the meaning of your question?

Q. I mean are they uniform; is there any law so that you can tell from the gauging at one point exactly what the velocity is at another point some feet distant from that?

A. Taking a station well out in the stream, of one of the sections that we have used in the Lake Survey measurements, the velocity four or five feet away from a particular station is very well known; the variation is sufficiently uniform so that we do know.

Q. Is it absolutely uniform?

A. I should say not.

Q. It would be practically impossible, would it not, to observe the velocity of a stream at every point?

A. Yes.

Q. Assume a circular pipe of a uniform diameter, and flowing water through it, what would you say as to the uniformity of flow through a river as compared with the uniformity of flow through that kind of a channel, opening?

A. I should say the uniformity through the river was very much higher, through such sections as we have used in our gauging.

Q. I call your attention, Mr. Shenehon, to page 5369 of Appendices III and KKK of the Annual Report of the Chief of Engineers for 1900, and particularly to this sentence appearing in the middle of the page: "The fluctuations in current velocity have usually rendered the determination of the distribution of the velocities in the vertical plane a difficult matter, for if the meter were left at one depth long enough to eliminate the effect of the short, wave-like fluctuations or pulsations of the current, a more permanent change might take place affecting the mean velocity at the station before all of the depths had been covered by the meter." Do you endorse that statement?

Mr. Wilkerson: This is from Mr. Sabin's report.

A. As I understand that statement, Mr. Sabin has reference to the older method of current meter measurements, in which you used a single meter; getting your vertical curve by starting at the surface, or a short distance below it and observing a certain definite time at each tenth of depth. The use of the multiple set, of which Mr. Sabin speaks, and the use of the two meter system that I have used myself, is intended to eliminate all possible sources of error or difficulties of which Mr. Sabin speaks. The water does come in pulsations to some small extent, and the more permanent change he speaks of, I take to mean a change coming with change of gauge.

Mr. Wilkerson: Did you read that sentence about the overcoming of the difficulty? I wish you would read that sentence so that we will have it all in the record.

Mr. Williams: The latter part of the sentence is as follows: "This difficulty is overcome by the use of the multiple meter set, with which the whole vertical curve is determined at one observation."

Mr. Wilkerson: That is the explanation that you referred to in your answer, is it?

A. Yes.

Mr. Williams: You endorse the statement then?

A. I state that the velocities in a river at a given point are fluctuating from minute to minute, and that a change of velocity does come with a change in the lake stage.

Q. And also that there may be certain pulsations that are not permanent in their character and not depending on lake stage, is that true?

A. Yes, if two observations were made, covering ten seconds, they would not closely agree.

Q. And the advantage of having this multiple meter set, which is mentioned in this paragraph, is in effect that the measurement is made at the several points simultaneously, so that anything that affects the meter at a given point would affect all the others at the same time?

A. That is the intention of the multiple meter set, yes.

Q. If that is an advantageous arrangement in the measurement of current velocity, what would you say as to the necessity for some arrangement being made by which the same degree of precision could be obtained by having horizontal measurements made simultaneously?

A. I think the gain to be made by the multiple meter set is one of time-saving rather than ultimate precision. I think just as high precision is gotten by two meters, as I myself have used them on the Niagara River and the St. Lawrence River.

Q. The purport of this report is that the multiple meter set was used for the purpose of curing the inaccuracies that might result from allowing the meter to be left at one depth long enough to eliminate these temporary effects, was it not?

A. The temporary effects that you speak of *are* temporary. The average relation in velocity between two points is fixed very decidedly. The only point is, how are you going to establish that relation, whether simultaneously by multiple meter sets, consisting of a number of meters, by two meters, or by a single meter that by a great many repetitions gets the average percentage relations in the curve. The *facility* of the operation is involved in the use of either two meters or a multiple meter set.

Q. And is not the accuracy of the observations also involved?

A. I do not think the accuracy obtained by the multiple

meter set is greater than the accuracy obtained by two meters.

Q. Is it greater than that obtained by one meter?

A. I think so, although a very large number of observations in the vertical with a single meter does give good results.

Q. Over what percentage of the area of a cross-section is the velocity actually measured in gauging?

A. Perhaps over 25 per cent.

Q. The same observation?

A. Perhaps I misunderstand your question.

Q. With a single gauging, you say that 25 per cent. of the entire area of the cross-section is actually measured.

A. I do not get the trend of your question. I do not know what you are getting at.

Q. Take the area of the cross-section occupied by the meter during a single observation on the St. Clair River.

A. That is a single discharge measurement?

Q. Single gauging?

A. Yes.

Q. The wheel has a certain diameter, and a certain area, hasn't it?

A. Yes.

Q. You observe at a certain number of points a single gauging?

A. Yes.

Q. Now what is the percentage of the actual cross-sectional area of a river covered by any single gauging; take the St. Clair River, for instance, as an illustration?

A. I should say about one-sixtieth of one per cent.

Q. I call your attention to Plate 12, following page 5400 of the report of the Chief of Engineers for 1900, Appendices III and KKK.

Mr. Wilkerson: Is it Plate 12 in connection with Mr. Sabin's report?

Mr. Williams: Yes.

Q. Will you explain that plate? Tell us just exactly what it means?

A. Figure I of this plate is a cross-section of the St. Clair River at Section Dry Dock, showing the bottom profile of the river, the water surface, of current meter stations 1 to 21; and velocities at or near percentage depths; that is close to the surface, close to the bottom and at each of the tenths of depth. These velocities are established by twelve discharge measurements, Nos. 49 to 60 inclusive. Using these velocities, contour

lines are drawn in, which are intended to show the lines of equal velocities.

Q. Each of the lines shown upon Figure I indicates a certain degree of velocity?

A. Commencing with the line at Station 6, that shows the location of the velocities having 3.4 feet per second. The next one to the right shows 3.6; the next one 3.8; the next one 4.0; the next one 4.2; and the small figure under Stations 13 and 14, 4.4. The lines to the left of Station 6, one line is the mean velocity that is a little heavier line than the others. And I think the lines differ by changes of .2 of a foot per second beyond.

Q. These stations numbered from 1 to 21 are a hundred feet apart?

A. I believe so. I should state in connection with this plate that it is my belief that it is the intention to give the velocities only in a general way, to show the distribution over the section; that the precision of the thing as it stands is not very high. It is made up from twelve discharges only.

Q. What degree of precision would you give this plate?

A. I could not make any statement on that point.

Q. What degree of precision would you say it would be possible to get in the drawing of a plate of this character?

A. What do you mean by precision?

Q. How accurately would it be possible to have a plate prepared, so that the lines drawn on it would represent the actual situation as to velocities?

A. Very close to one per cent.; and when I say that, I mean that instead of velocities being set down, the percentage relations of the velocities be set down The velocities indicated there are for twelve discharges.

Q. How many discharges would you say it would be necessary to have in order to prepare a plate to be of the accuracy that you have indicated?

A. The precision would depend more upon the co-efficient work than upon the discharge measurements.

Q. Then you would say that twelve observations would be sufficient?

A. I should say that twelve determinations of percentage relation between the index and any other point would give a very good determination of it.

Q. Will you explain what you mean by co-efficient work?

A. Co-efficient work is to establish the percentage relation between the velocity which measures by the meter at the sta-

tion index, (a particular depth as .3 or .4 depth in the river) and the velocities at other points. The object of co-efficient work is to establish a multiplier or co-efficient by which the velocity at the *index*, at a single station, is multiplied to get the mean velocity in that station. When I say "station" in the second case I mean in that 100-foot width of the river.

Q. Can you explain a little more in detail how you arrive at this multiplier that you have just mentioned? The actual observations occupied, as you say, about one-sixtieth of one per cent. of the entire area of the river being measured, cross-sectional area. How do you arrive at the velocities at the other points?

A. The process of river measurement is a sampling process. When I speak of the measurements in a river occupying a sixtieth of one per cent., I mean samples of the velocity taken cover that part of the area. A bridge engineer in building a steel bridge, I do not imagine takes more samples than one-sixtieth of one per cent. of the weight of the structure; probably less. Sampling of various kind, for wheat, and other things, I do not imagine takes more material.

Q. When you take that much of the material, what do you know about the rest?

A. When you take the measurement in the river, you know by a great many observations in support of that knowledge that the percentage relations is obtained. I will read certain testimony on that line if it is desirable.

Mr. Wilkerson: That is, you have a statement that will explain that.

The Witness: Showing the relations.

Mr. Wilkerson: Do you want that?

Mr. Williams: We are entirely willing. We want all the information we can obtain.

Mr. Wilkerson: I suggest if he has it in well worked out form, it would be perhaps better than the off-hand statement.

Mr. Williams: Now you may proceed. Give us the reference.

A. This is in the report of the Chief of Engineers for 1900, page 5343, and begins: "It has been demonstrated in river hydraulics that the velocities throughout a certain area maintain definite percentage relations, and when these relations are firmly established by ample observations, a single known velocity is the key to all others simultaneously existing, and hence to the discharge in the area involved. On this characteristic of river flow are based the methods used to determine the

volume of water which the river carries in its various stages and conditions. Like most hydraulic laws, this has its limitations and is more nearly absolute as the area considered approaches an element of river width. How accurate it is for the full river width is shown by the following tabulation, in which the mean velocities for each station derived from groups of discharge measurements are expressed as percentages of the mean velocity of all stations for the same group." And the table which follows is headed: "Open Section, Table 5, index velocities as percentages of mean index velocity. Now in this table, the velocities shown by groups—

Mr. Wilkerson: Q. What you have said heretofore is quoted?

A. Yes.

Q. Now you are testifying.

A. Yes, I am just talking. In this table the velocities shown by groups of *ten* discharge measurements are expressed for each station in the form of percentages of the mean index velocity, except that group No. 6, has *seven* discharge measurements in it. As an illustration of the precision with which the percentage relation is maintained, I take at random Station 9. The first group shows the velocity there to have a percentage of 118.2 of the mean velocity; the second group 121.1; the third group 120.5; the fourth group 121.4; the fifth group 121.6; the sixth group 122.1; and the mean of the whole is 120.7.

Mr. Williams: Q. Take Station 1, Mr. Shenehon.

A. Station 1 has a large variation and cuts very little figure in the discharge of the river. I took Section 9 because that carries a high percentage of the flow, and for a second reason because the mid river stations are less variable than those close to the shore.

Mr. Wilkerson: One is a station that is near the shore is it?

A. Yes, that is close to shore.

Q. How far from the shore?

A. Where the area change is fairly large at different lake stages.

Q. Just what percentage of the total flow passes through one?

A. It is less than one per cent., as I recollect it.

Mr. Williams: Q. Will you take Section 8, Mr. Shenehon, as shown by that table, that index?

A. Station 8 shows for the first group 121.3; second, 122.9;

third 124.6; fourth 124.9; fifth 124.5; sixth 123.3; mean 123.6.

Q. Will you look at plate No. 7, following page 5360 of the report of the Chief of Engineers for 1900 and explain the curve shown on that plate for Station 8?

Mr. Wilkerson: The cross-examination of the witness is, I assume, proceeding on the theory that the plates and protions of the reports referred to will be afterwards put in evidence by the defendant. That is correct, is it not?

Mr. Williams: Yes. We now ask to have this Plate No. 7 marked for identification as "Defendant's Exhibit C, June 4, 1909, cross-examination of Mr. Shenehon." Plate 12, following page 5400 of report of 1900 will be identified as "Defendant's Exhibit B, Shenehon's cross-examination."

Q. (Last question read as follows: "Will you look at Plate No. 7, following page 5360 of the report of the Chief of Engineers for 1900 and explain the curve shown on that plate for Station 8.")

A. Station 8 is marked at the bottom of the curve I am explaining. This shows the velocity at that particular station on the Open Section of the Niagara River, or rather the percentage velocity with respect to the velocity at the *index,* which is always 100 per cent. These percentage velocities are platted on the horizontal scale (in a system of rectangular co-ordinates), and the river depths expressed in elevations are shown in the vertical scale. Using this series of heights above the bottom, or elevations, and the percentage velocities, the observations are platted, as shown along the curved line. Those that are platted in solid black circles at the *sub-surface,* the index and the .8 depth and the bottom observations (except for the index always 100), were derived from discharge measurements in addition to the other co-efficient work. That is in measuring a discharge of the river, a current meter was run at the index depth, which is 4/10, roundly, of the river depth at a particular station. The second meter is run at the sub-surface for two minutes, then the second meter is dropped down alongside of the index meter and run for two minutes more. Then it is dropped down to the .8 depth and run for two minutes more, and on a part of the observations it is run down to what is called the bottom observation and run for two minutes more. So each discharge observation, in addition to giving the absolute velocity at the index gives also the percentage relations from surface to bottom throughout the vertical. And as I have already testified, the velocity relationship betwen the stations gives the trans-

verse curve. The observations shown by open circles were derived from special observations, made specifically as co-efficient work. After platting these observations, the curved line is drawn in as a fair line, and it is made to thread, or pass through, the sub-surface, index, .8 and bottom observation.

Q. In doing that, there are a number of points that were determined by several observations that are not touched by the curved line.

A. It is assumed that the law of gravitation under which the river is flowing will be expressed by a fair curve, for the vertical curve; and where we have but two observations as at elevation 547, to pass the curve through that would make a wavering line instead of a fair curve. The weight of the two observations does not warrant that. I wish to say, however, that if a line were drawn that did thread every observation in that curve and that of Station 6 on the same plate, that the results so far as the river discharge is concerned, would be the same; there would be no sustantial change.

Q. But as a matter of fact the observations at point 547, 545, 542, 537, were practically not considered in the drawing of the line?

A. The line was drawn for the most part so as to thread the obseravtions. When I say that, for instance take the observation at 545 and that at 547, the line is drawn between them. And the line cuts a point that might be a mean between those observations, in elevation as well as in velocity, percentage of velocity.

Q. As a matter of fact the line could just as well have been drawn from these index points to .8 depth, from that point on to bottom observation, without any reference to the observations of the points mentioned?

A. No, that is not so.

Q. Suppose that observations at 547, 545 and 542 were all eliminated from consideration; that you were drawing a curve that would pass through the observation of the sub-surface, the index, at .8 depth and bottom, what difference would there be in the shape of the curve?

A. That was 537, was it, Mr. Williams?

Q. Leave out 537, 542; the points determined by four observations there. Leave out 545, the point determined by six observations and 547, the point determined by two observations, eliminate all those, what would be the difference if any in the direction of the line? Eliminate everything between the index and the bottom observation.

A. The observations at 545 and at 547 have been given weight in drawing the line. You notice the line hugs the observation of 6 rather than it does the 2; perhaps I ought to reverse that and say the observation hugs the line a little more closely; the six observations having greater weight, it brings it closer to the line. The observation at 542 and that at 537 do not seem to have swerved the line largely.

Q. If the line passes through the observation at point 543, which is determined by six observations, and passes through the index point and the .8 depth point, how could you very well vary the direction of the line, even eliminating the points at 545 and 547?

A. Whether the observations at 545 and 547 were present or absent makes very little difference in the trend of the line at that point. The observations are confirmatory of the general trend of the line, as they stand.

Q. Would it not be a fairer indication of the actual result of the observation to have drawn your line so as to pass through the point determined at 545 as the result of six observations than to pass by that point and to pass through the points at 548 and 552, which were the result of only two observations each?

A. The object of drawing the line ought to be very clearly kept in mind. We are endeavoring to get the mean percentage velocity ordinate, and whether or not we draw a mean line between two observations or whether we waver the line and thread the particular observations, the result is the same substantially.

Q. Would your contour lines on a map or plate showing the cross sectional area be the same if the line were drawn through point 545 as it is drawn in the direction in which we find it? Wouldn't that make a difference in our contour chart?

A. If the line which we call the vertical curve were drawn so as to pass through 6 at 543 and also through the 6 at 545; through the 2 at 547, joining the line at the 2 at 549 again, the mean ordinate, which is what we are after, would be substantially the same. There would be substantially no effect on the discharge of the river.

Q. Now there is a variation in the velocity of this particular Station 8 within distances of two and three feet, isn't there?

A. In the vertical?

Q. Yes.

A. Very distinct towards the bottom, yes.

Q. That being true, what means of information have you, what knowledge have you as to what the variation may be between this vertical and the next one which is a hundred feet distant?

A. The general form taken by the vertical curve is such that we feel full confidence in view of the corroboration of results and extended river experience, that in midstream we may safely extend the coefficient.

Q. A distance of a hundred feet?

A. For a distance of 50 feet each side of our section. To illustrate that, let me look up the coefficients. I do not find that the coefficients are given for the Open Section, but for the St. Lawrence beginning with Station 4, we have a coefficiency of—

Q. What is the reference there?

A. This is the report of 1902, page 2803. This is my report on the St. Lawrence River, and I am reading from Table No. 19; beginning with Station 1, 88.8 per cent; Station 2, 90.8; Station 3, 88.5; Station 4, 85.6; Station 5, 87.7; Station 6, 89.5; Station 7, 90.7; Station 8, 94.8; Station 9, 94.1; Station 10, 92; Station 11, 92.2; Station 12, 90.5; Station 13, 89.9; Station 14, 92; Station 15, 92.7; Station 16, 91; Station 17, 92.7. The weighted mean is 89.8. Now, if these vertical coefficients, which represent the mean ordinate of this curve, if they vary very slightly from one station to another, even though they form a curve which is slightly different, the result would be no different in the volume of discharge. After a very considerable experience in river measurements, I have the utmost confidence in the continuity of changes of velocity in a river.

Q. And in their uniformity?

A. And in the uniformity, where we would expect it, as in midstream, or in the open part of an open river. Towards shore we do get eccentric conditions, but these by extra observations are considered. The shore end stations of a discharge section in a river carry but one to two per cent ordinarily of the volume of flow; and if in these stations we have an error as large as 10 per cent, the error of the whole volume of the discharge is only one to two-tenths of one per cent, which is insignificant. The big volume of flow is carried in the mid-river sections.

Q. You have finished your answer, have you?

A. I have found something I was looking for; that is the

mean velocity coefficients in the Open Section, that perhaps I had better read, as more pertinent than those in the St. Lawrence previously quoted.

Q. The reference is what?

A. This is page 5347 of the report of 1900. It is a tabulation headed "Open Section, Mean Velocity Coefficients." The depth on Station 1 of the Open Section is so small that velocity coefficients in the vertical are not given. I will give these for elevation 567: Station 2 is 92.8; Station 3, 92; Station 4, 92.5; Station 5, 92.6; Station 6, 92.6; Station 7, 92.6; Station 8, 93.2; Station 9, 92; Station 10, 89.9; Station 11, 89.5; Station 12, 91.2; Station 13, 92.9; Station 14, 91.2; Station 15, 90.6; Station 16, 91.1; Station 17, which is in extremely shallow water and which does not give a fair value for the coefficient is 84.8. That last explanation is not quite correct; I should have stated that for Station 17 it includes the transverse coefficient as well as the depth of water. These are the *mean velocity coefficients* including transverse as well as vertical. An examination of the coefficients derived by Sabin for the St. Clair River will show very close corroborations of these.

Q. I understand that these are the factors by which you multiply the velocity found at the index point?

A. Yes, multiply the velocity shown by a discharge measurement at the index point by the mean velocity coefficient, and that by the cross sectional area; that gives the discharge.

Q. And your judgment is that the mean velocity shown at the index point on one vertical and the velocity shown at the index point on another vertical a hundred feet distant indicates the velocity for the entire 100 feet between the two?

A. No, that is not quite accurate.

Q. Well, state what the fact is with reference to that?

A. From the shore out as far as the indications warrant, a transverse curve is taken; that is the velocity is taken every ten feet, and the relation of the velocity to that the index point for the .4 depth, every 10 feet is taken. As soon as the open river is reached, where the sweep of the transverse curve is broad, these observations are not always taken. I believe they always were in the St. Clair River, but not in the St. Lawrence, and not in the Open Section of the Niagara River. The transverse curve is taken from the fair curve line joining the velocities at the index, as derived from the discharge measurements. That will show you a number of percentages,

showing the relation. Then platting those and drawing a line through them gives the transverse curve.

Q. As a matter of fact you have no information as to the velocities between your verticals except such as you get by the drawing of the transverse curve?

A. That is true in the Open Section of the Niagara River, except towards the end, towards the shore—

Q. Towards the shore ends?

A. And the same in the St. Lawrence River except towards the shore ends.

Q. And in those points there is considerable variation?

A. In the International Bridge Section of the Niagara River, the transverse curve is very accurately determined, on account of the bridge piers and the nature of the bottom there. It was accurately determined for as often as every twenty feet, and towards the piers more frequently, ten or five in some cases.

Q. And how accurately was it determined on the St. Clair River?

A. It is my belief it was taken every ten feet all the way across the river. I am not positive of that, but that is my belief, in the measurements made by Sabin.

Q. How many points in the cross section were actually measured in the Niagara River at the Open Section?

A. In Stations 1, 2, 3, and 17, that is about 200 feet at each end of the river, the transverse curve was measured and used in coefficient reductions. At distances of 33⅓ feet some observations were made for the transverse curve, and these were made by having a single meter at the index point and a second meter 33⅓ feet away on overhangs on a catamaran at the *sub-station point;* but in the reduction, those observations were not used. I would like to state the reason why they were not used, as set down in the report here.

Q. What page?

A. Page 5353 of the report of 1900. "In getting out coefficients, however, these substation verticals were not utilized for two reasons: first, the fixed point in the station verticals" (those are the ones marked in solid black circles on the Plate No. 7) "made their weight so great in comparison with those of the sub-stations," (the sub-stations means the 33⅓ foot points) "that it was difficult to arrive at a rational scheme of combining them. Second, the absence of current ratings as a basis for correcting the ratios made the indications of a compound instrument somewhat unreliable, so that the danger

of introducing an error seemed greater than the possibility of error from neglecting in midriver the transverse curve between stations."

In Plate No. 7, the fixed point shown by the solid black circles at the .8 depths as determined by 45 observations and at the sub-surface by 21, the bottom observations by 17,—those points were so thoroughly well established that it seemed a dilution of the accuracy of the work to attempt to introduce the transverse coefficient.

Q. Can you explain a little more fully what this difficulty seemed to be that you had in combining the observations?

A. Unless we took an equal number of observations on these intermediates, these 33⅓ foot points, the computation of the coefficient would mean the weighting of the several observations; and when I say weighting I mean, if we have a quantity measured a hundred times and we are combining that measurement with a quantity measured ten times, that former measurement having a hundred observations would have a greater weight, other things being equal, than the other.

Q. Before we get to that, is it not a fact that the reason these were discarded and not used, the first reason was that if you followed those observations you would get a different result from that which is obtained in your more reliable and greater number of observations at the index point?

A. As regards the discharge of the river, I do not know that that is the fact.

Q. Would you be able to offer any other explanation why there was difficulty in combining those observations with these non-reliable ones that you do rely on?

A. Perhaps I would better go on with the second statement, then we can talk of the whole thing together. It was found in the use of the two meters that there were slight divergences from day to day for the ratings, and the apparatus we had for observing these intermediate verticals made it difficult for us to compare one meter with another. The integrity of the two meter system depends on the fact that you combine the two meters by running them side by side in the current, and rate one with respect to the other for each day of your current work. And the apparatus for getting these 33⅓ foot points was so cumbersome that it was not easy, and was not done, as I recollect it. It was estimated that the possibility of getting an error of two per cent in these intermediate verticals was likely to give us an error

in the result greater than by not introducing the transverse curve. I have spoken of that as likely; I do not know as a matter of fact whether it would have changed the result one way or another. I was steering clear of the possibility of error and believe, now, that I chose wisely.

Q. You speak of the possibility of the meters used in these 33 foot points being likely to vary from day to day or during the same day in their rating?

A. Yes, there might be a variation the same day, possibly as much as one per cent, and from day to day there may be as much variation as two per cent.

Q. And the only reason that you have for believing that that would not be true where the observations are made at the index points is the fact that you were using two meters, one acting as a check upon the other?

A. In using two current meters in coefficient work, any slight variation as two per cent in the rating in the meter did not make any error in the percentage results because the meters were run in the current side-by-side, and the ratings were interlaced and made common in that way, so that it became a single instrument for coefficient work. When it came to discharge measurements then an error of two per cent in the absolute rating *did* make an error of two per cent in the discharge, and that was taken care of by using a number of meters, and rating them frequently; any error that might come into an individual observation being eliminated in the great multiplicity of observations.

Q. Do you remember the number of points in the cross section of Niagara, the Open Section that were actually measured in making the discharge measurements?

A. Seventeen; there were seventeen stations and a measurement at each of the seventeen stations constituting a river traverse, was a discharge measurement, taken in connection with the gauge readings.

Q. And at the International Bridge how many points were actually measured?

A. Twenty-one.

Q. Will you give us what the cross sectional area of the Niagara River at the Open Section was, also at the Bridge Section?

A. (No answer.) At 567.0 O H levels. Open 42,063 square feet. Bridge 39,335 square feet.

Q. At how many stations were observations made in the St. Lawrence, in making discharge observations?

A. At seventeen stations.

Q. Do you remember how many points in each station observed?

A. As a rule six in each discharge.

Q. And in some instances eleven?

A. At each station? No. The method there was to do the coefficient work at the same time we were making the discharge measurements; that is we had two meters and one would start (on the measurement of the discharge); it would start at the subsurface as zero and go to the 2/10, 4/10, 6/10, 8/10 depths and bottom. On the way back again, or some other discharge, measurements were observed on the odd tenths of depth, so each discharge measurement gave us a full set of vertical curves.

Q. What was the cross sectional area of the St. Lawrence River at the point where discharge measurements were taken?

A. 51,000 square feet roundly. It varied of course with the stage of the river.

Mr. Williams: I would like to have at this point Plate No. 6 marked as "Defendant's Exhibit D, June 4, 1909, Shenehon's cross-examination"; the plate following page 5360 of the Report of the Chief of Engineers for 1900.

Q. Please state the cross sectional area of the Niagara River at the International Bridge, where discharge measurements were taken?

A. At elevation 567.3, that was in levels of 1903, the cross sectional area is about 39,000 square feet.

Q. And the cross sectional area of the Open Section, what was that?

A. For the same elevation, about 42,000 square feet.

Recess to 1:45 p. m.

1:45 p. m., June 4, 1909.

The cross-examination of Mr. SHENEHON was resumed as follows:

Mr. Williams: Q. Have you now, Mr. Shenehon, the data from which you can give us the information asked for with reference to the Detroit River as it was prior to the improvements made by the United States Government?

A. Yes, I think so.

Q. What was the original depth of the Detroit River prior

to the making of improvements by the general government in the stretch from Stony Island to Fort Malden?

A. That is along the channel, along the vessel track?

Q. Yes.

A. Reading the soundings within the channel lines from abreast of Texas Dock downward, down stream for a distance of about 6,000 feet we have: 25 feet, 22 feet, 24 feet, 24 feet, 25 feet, 25 feet, 24½ feet, 22 feet, 24, 21¾, 21¾, 22¼, 22, 22¼, 23½, 22½, 22½, 23½, 24½, 19½, 18½, 18½, 18½, 18½, 20, 18½, 17½, 18½, 14½, 16½, 15½, 15, 15½, 15½, 16½, 17, 19½, 18½, 17½, 16½, 19½, 17¾, 17½, 18½, 19, 18½, 17½, 16½, 19, 18½, 19½, 19½, 20½, 20½, 19½, 22½, 19½, 21½, 22½. That would be about the limit.

Q. To what does that refer?

A. That refers to elevation of Lake Erie 573.2. To compare it with the elevations on this chart, Defendant's Exhibit A, subtract from those depths 2.2 feet.

Q. Subtract from those that you have given?

A. Yes.

Q. Compute for us the discharge capacity of the Detroit River at mean stage of Lake Erie for the reach from the head of Stony Island to Fort Malden as it existed prior to the first improvements and as it will be on completion of the Livingstone channel, assuming the material from the latter work is to be distributed over the area in a reasonable manner.

Mr. Wilkerson: That question propounded to the witness is to be taken by him and answered as opportunity presents itself.

Mr. Williams: Yes, that is right.

Q. You were about to continue, giving the title of the map from which the soundings were taken?

A. The soundings read are from the Lake Survey map or Field Sheet of 1873 U. S. Lake Survey, files 1-550; and the elevation of water surface is referred to Lake Erie 573.2.

Q. Mr. Shenehon, do these tables which I now hand you, or which I have in my hand correctly show the levels of Lake Superior, Michigan, Huron, St. Clair, Erie and Ontario as indicated by the records of your office?

A. They were prepared from the records in this office and I believe correctly represent those records.

Mr. Williams: I will ask to have these papers marked "Defendant's Exhibits D, E, F, G, H, and I" cross-examination of Mr. Shenehon, June 4, 1909.

The Witness: In connection with my answer, my attention has been called to the fact that certain changes have been made on the Milwaukee record due to the settlement of the pier there; and I am not certain whether it is incorporated on this record for Milwaukee or not. It is on the *hydrograph* of one of the prior exhibits showing lake elevation.

Mr. Wilkerson: You say that change was made on the hydrograph?

A. Yes, it is correct here; I am not certain whether it was made on these tables. I believe it was though.

Mr. Williams: Q. That is on Exhibit 5, May 24, 1909, it is correctly shown?

A. That change was only a matter of a few hundredths of a foot.

Q. In the report of the Chief of Engineers for the year 1904, pages 4096 and 4097, appear tables of elevation referring to Lake St. Clair; in which tables there are elevations shown in addition to those indicated upon the sheet known as Defendant's Exhibit G. Now what would you say as to the probable reliability of those tables as showing the elevation of Lake St. Clair?

A. I don't know that these are accurate. I do not know the source of them, as a matter of fact. In the case of the Detroit River and St. Clair River, I believe Mr. Sabin gathered some data from gages outside the office; and I do not know what the reliability of the data is. I have not studied that part of the subject. Prior to, say 1870, possibly extending into the early seventies, there are in some cases doubts as to the elevations; in certain cases I believe after that time, but in the seventies was the time the Lake Survey —it was one of the periods when the Lake Survey was operating largely, and at that time things were established on a firmer basis than they ever had been before, as regards water levels. Prior to that, error may exist in some of the data.

Q. Have you any reason to believe that in these tables, which I have called your attention to, in the report of 1904, there are inaccuracies in the table of elevations for Lake St. Clair to a greater extent than, say, one-tenth of a foot?

A. I do not know. In answering that question I understand you mean the earlier observations?

Q. The earlier observations and those which are not included in this sheet after 1872?

A. In the case of Lake St. Clair, I ought to explain that some observations are interpolated from the Windmill Point

gage. Subsequent to the publication of that 1904 report, precise levels were run from Algonac to the St. Clair Flats. That was last fall and the result of those levels caused a small adjustment in the nominal elevations of Lake St. Clair. What I mean is the mean of the elevation changed by I think .06, somewhere in that neighborhood.

Q. These tables to which I have called attention were prepared in your office, were they not?

A. Yes.

Q. You considered them reliable or you would not have published them, of course?

A. Personally I had nothing to do with the publication.

Q. You made the reports, or worked on them?

A. I was not Principal Assistant Engineer at the time that report was made. I began to be Principal Assistant in 1906. I had nothing to do with the compilation or issuing of that report except my own portion of it.

Q. Will you tell us who would be the proper person to interrogate on the question of the reliability of these tables showing the elevation of Lake St. Clair?

A. Mr. E. E. Haskell, now Dean of the College of Civil Engineering at Cornell University, was the principal Civilian Engineer at that time, and the report itself was made by Assistant Engineer Thomas Russell, who is a member of the Lake Survey at the present time.

Q. Now if these tables which have been marked as Defendant's Exhibits E to I, inclusive, show that the years 1860 to 1865, inclusive, the mean difference of elevation between Lakes Huron and Erie was 8.92 feet, would that be the correct difference, as near as the same could be determined, in your opinion?

A. Is that the mean for the full year or for the open season of navigation?

Q. That is the annual mean.

A. I should say that that mean would be influenced by ice conditions and would not necessarily be the proper relation between Lakes Huron and Lake St. Clair.

Q. This is Lakes Huron and Erie I am speaking of. The question was whether or not, if these tables show that the mean difference of elevation between Lakes Huron and Erie for those five years was 8.92 feet, would that be the correct difference as near as it can be determined?

A. For that time?

Q. For that time, for that period?

A. That is between the Cleveland Gage and the Harbor Beach gage, or Milwaukee?

Q. Milwaukee gage.

A. The Milwaukee gage, for that time; I do not know of any better way of determining the difference in elevation at that time.

Q. And you would answer similarly, with respect to the period from 1866 to 1871. We are assuming that these tables show a difference of 8.68, as the mean difference between Huron and Erie?

A. That is 1866 to 1871. I do not know of any better way of determining the difference.

Q. Would your answer be the same respecting the period from 1872 to 1877 where the mean difference from these tables would appear to be 9.01, as to the correct mean?

A. I assume if the Harbor Beach gage or the gage in that vicinity were available, the results from that should be used, I think, in that determination. That was made about 1874, I think.

Q. Are the observations made at that time included in the tables?

A. For Harbor Beach, yes. Aside from any small correction from that, which would be very small, that 9.01, provided the computation is correctly made, would be the best evidence we have regarding the difference between the lakes.

Q. And for the period from 1878 to 1883, inclusive, using the mean difference of elevation of 8.8 feet?

A. The Harbor Beach gage should be used in that, in conjunction with the Milwaukee?

Q. Yes.

A. Or independent of it?

Q. Which did you mean, in connection with it or independent of it or both?

A. They give practically the same result, so it is rather immaterial, it will not make much difference.

Q. Then that would be the correct difference as near as you can arrive at it?

A. It appears to be, yes.

Q. And for the period from 1884 to 1889, if the mean difference of elevation between these lakes appeared from these tables to be 9.18, would that be correct as near as it can be determined?

A. Yes, I think that is the proper—

Q. For the whole period covered from 1860 to 1889, in-

clusive, the average difference appears to be, from these tables, 8.91 feet. Is that correct?

A. I am assuming the correctness of your computations in this.

Q. Assuming that that computation is correct, and that the computation is based upon these tables, would you say that that was a correct average for those years, or would you say that there was any method of determining that mean difference any more accurately than that?

A. The mathematical process used insured the fact that it is the average, by the definition of average.

Q. Can you give any explanation of the fact that Mr. Wheeler in his testimony gave the average for the period from 1860 to 1880 as 8.52; assuming that our computation is correct? Have you any information as to how he arrived at that conclusion?

A. What do your computations make it for the same period; that is from 1860 to 1880?

Q. The ten-year periods do not end with 1880. Taking it clear to 1889, and the period from 1884 to 1889, which is the highest of any of them, gives it 8.91; taking it up to 1883, it gives 8.8?

A. Well, I do not think the process that you are using is a valid one, of comparing periods other than the same periods Mr. Wheeler used.

Q. Do you know what periods he used?

A. You have just said he used the period from 1860 to 1880. You cannot compare different periods and get the same result, unless the mean elevation of one of the lakes, at least, is the same for the two periods.

Q. These ten-year periods, all of them, show a higher average than the value which Mr. Wheeler got, this group, and it does not seem as though it would be proper to drop in there with something that would give a greater average for those twenty years than that made up of the ten-year period running on through?

A. My own computation for the years 1860 to 1879, both inclusive, gives 8.85. I do not know how Mr. Wheeler got his result; and it is possible that it comes in the old levels, the adjustment. He might have used his own tables in the 1903 report.

Mr. Wilkerson: By that you mean there has been an adjustment in these tables from time to time?

A. Yes, in the adjustment of the levels a certain correc-

tion was applied at Cleveland to bring them up to what we call the levels of 1903, and there was a difference also at Harbor Beach and Milwaukee.

Mr. Williams: Q. Those were taken into consideration in these tables, were they?

A. Yes, those tables are on 1903 levels.

Q. And if these tables show a mean difference from 1890 to 1908 of 8.4 feet, that would be as nearly correct as you can determine it?

A. That is the last period from 1890 on?

Q. 1890 to 1908?

A. Well, I would like to point out that your method of extending your period beyond 1880 to include the high water of 1886, and then in your second period including the low water of 1895, is hardly a fair one.

Mr. Wilkerson: Q. That would explain that difference to a very large extent?

A. Yes.

Mr. Williams: What difference?

Mr. Wilkerson: The 8.8—

Mr. Williams: That was prior to 1880.

The Witness: In high water Lake Huron will go up higher than Lake Erie, so the difference becomes greater as the stage increases. Including that high water of 1886 in your earlier average and including in your later average the low water of 1895, you get the lights and shades contrasted in a way that is not fair. For the 10 years between 1860 and 1879, I get a difference of 8.85; and for the years from 1880, including the year 1908, I get 8.62 as the difference. For the two periods considered, the fall between the lakes is .23 less in the latter period than the earlier one; and just what the stage of Lakes Michigan and Huron was at that time I have not computed. That would have some small bearing on that.

Q. Can you very quickly compute and give us the result of the computation, showing the difference for the period from 1890 to the present time?

A. Yes. 8.41.

Q. Now taking it on this assumption that for thirty years from 1860 to 1889, inclusive, the average fall between Lake Huron and Lake Erie was 8.91; and that for the nineteen years from 1890 to 1908 it was 8.41, to what would you ascribe the change of .51 feet, .5 of a foot, practically six inches?

A. In the earlier of the two periods mentioned, Lakes Michigan and Huron had an elevation of 581.71, and in the

latter period 581.05, as I compute it, making a difference in the stage of Michigan and Huron of .66 of a foot. Now on account of the higher stage of Lakes Michigan and Huron, you would expect the difference on Erie to be 70 per cent of 66, that is the ratio of the movements of the two lakes. You would expect the difference in level between the lakes for those two periods to be 0.46 foot apart, and I think you made it out .50; it checks within half an inch.

Q. Do you mean that if Lakes Huron and Michigan were six inches higher at a certain period than at another period that two-thirds of that excess in elevation would remain as a difference of elevation between the two lakes?

A. I mean to say that if you will plat Lake Erie with respect to Lake Huron you will find out that their elevations vary somewhat in the ratio of 100 to 70 or 100 to 70 per cent. By that I mean if Lake Huron goes up a foot or is a foot higher in any particular period, Lake Erie is .7 of a foot higher at the same time. That is an approximation you understand.

Q. If Lake Huron goes down a foot, what is the effect on Lake Erie?

A. As shown by the gage readings, that relation holds, lake goes down 0.7 foot.

Q. About .7?

A. About .7; or if Lake Erie goes down a certain amount, Lakes Michigan and Huron will go down the reciprocal of 7, which is somewhere in the neighborhood of 40 per cent greater. That is about 43 per cent in excess; and that is one of the reasons that I gave why I considered that the lowering, in the case of Lakes Michigan and Huron by the diversion at Chicago was likely to be in excess of the lowering caused on Erie. I took the case where the increment is most accurate, in the Niagara River, where we have a range of four feet. We find that the lowering is 2¼ inches. And if the lowering of Michigan and Huron is derived by means of that relation, it will be 40 per cent greater on Lakes Michigan and Huron, but that process is rather involved, and hardly defensible, in getting at it in that way.

Q. Mr. Shenehon, diverting from the regular course of procedure outlined, will the effect upon the elevation of Lake Erie be greater or less than that upon the elevation of Lakes Michigan and Huron, assuming that the elevation is changed by reason of the diversion at Chicago?

A. In my evidence on that point I showed the increment

of the Niagara River to be 22,000; and I stated the increment of the St. Clair River was 24,000 with a possible error of 25 per cent, which would reduce it to 19,000 if the full percentage was applied; and that indicates that I consider that the lowering on Lakes Michigan and Huron will be greater than on Lake Erie; I stated between 2 and 2½ inches, and I did not give much weight to that consideration of the relative movement of the two lakes, and yet if you will plat them it is astonishing with what precision in five-year periods the lakes will follow this line.

Q. Assuming that is true, have you any explanation to offer as to why this difference in mean elevations actually occurs?

A. For one period there is a certain mean elevation that is higher than for another period?

Q. Why there is a greater difference in one case than in another. You testify you think it is true?

A. If the increment of the St. Clair River were greater than that of the Niagara River, we would expect the fluctuations in stage at different periods to be greater. In a small pool that is a very clear relation. In the big lakes, the reservoir effect masks it to some considerable extent.

Q. In 1889 it appears that the difference in elevation between Lake Erie and Lake Huron, assuming this (indicating chart) to be correct now, is practically 8.9 feet?

A. Yes.

Q. The next year the difference in elevation is 8.1, or less. Now what I would like to have you do, if you can, is to explain why those variations in difference exist. We can understand the reason why the lake is higher at one time than another and why one lake is lower sometimes than at other times, but why is there the variation in difference of elevation of the two lakes, in so short a period?

A. That is about 0.8 of a foot, is it, the difference?

Q. Yes.

A. The curve of the water level of Lake Erie, as shown on Exhibit 5, shows steadily rising water for Lake Erie, beginning with November, 1889; continuing through the winter and up to June of 1890. The curve of Lake Huron beginning with December, 1889, shows lowering levels, up to March, 1890. The indications are that ice in the St. Clair River did not interfere with the flow of the St. Clair River, but during the winter season it continued to send good volumes of water to Lake Erie. It is possible that ice conditions in the Niagara

River had something to do also with allowing Lake Erie to climb up. Local climatic conditions, as large rainfall on the Lake Erie basin might have entered, while the precipitation on Michigan and Huron basins might have been small. The year selected is, so far as I can see, the most abnormal year since 1875, and the discrepancy of 0.8 between those years is not one that need give us any serious concern. The ice conditions and local rainfall effects may accumulate in one year out of twenty-five or thirty, so that we will get a condition that is as extraordinary as the one you speak of.

Q. Look at the year 1903, would you consider that same explanation as applicable to that year?

A. You mean the year 1901?

Q. 1903?

A. That is 0.4 of a foot difference for that year.

Q. Yes.

A. That is between the year 1903 and 1904 on one side and 1902 on the other.

Q. I understood you to state you considered this an abnormal year. I was only calling attention to the fact—

A. I mean as regards the difference between the two years; this is 0.4. I said it was the most abnormal year—

Q. Take 1901-2?

A. 1901, I have already called attention to in this case as a year of extraordinary ice conditions; and I think perhaps the ice condition will explain most of these differences; that is this large difference. In 1901, my evidence earlier in the case, shows the conditions were very abnormal. Did you want an answer to 1903?

Q. Yes, if you can give it?

A. That 0.4 is probably due to absence of ice effects in 1903, and difference in local precipitation, evaporation, and those elements in the case.

Q. To what would you ascribe the general tendency of a decrease in the difference of elevation between the two lakes, indicated by the fact that the average difference during the past twenty years is approximately 6 inches less than it was during the twenty years preceding?

A. I have already testified along that line.

Q. I did not get the explanation in my mind. I do not know whether it is in the record as to why the general tendency decreased. You gave an explanation of the specific years where there were abnormal years. Now the general

average for the past ten years appears to show a difference of elevation of 6 inches less than the preceding twenty years?

A. In the early period from 1860 to 1889, inclusive, the elevation of Lakes Michigan and Huron was 581.84. In the latter period from 1890 to 1908, inclusive, the elevation was 580.53, a difference of 1.31. Now Lake Erie, we expect to go down 70 per cent of Huron's lowering, which is .92, and the difference between 1.31 and .92 is the increased difference in level you would expect, which is practically 0.39; and I think you stated it to be .5 of a foot.

Mr. Wilkerson: You substitute the figures you give now for the ones you gave a few moments ago, is that right?

A. Yes, if the period is the same.

Mr. Williams: Yes.

Mr. Wilkerson: Assuming the period is the same, this amended computation that has been made here gives the figures more correctly than the other ones?

A. Yes.

Mr. Williams: Q. I understand that when there is a variation in the elevation of Lakes Huron and Michigan of 1.31 feet, or a lowering to that extent, that there is a lowering in Lake Erie of 70 per cent of that amount; and the 70 per cent of that amount deducted from the lowering in Lakes Huron and Michigan accounts for .4 of a foot difference. But what I am trying to get at is, have you an explanation to give why there is 70 per cent of that difference noticeable in Lake Erie, instead of 100 per cent or 120, or any other per cent?

A. That 70 per cent is a very approximate figure.

Q. Why isn't there just as much of an effect in Lake Erie as there is in Lakes Huron and Michigan? Why is it 70 per cent, or any other per cent?

A. It is 70 per cent because the observations show that the thing is running that way.

Q. But do you have any reason for it except that you have noticed that it was a fact?

A. I have stated that the reason I think, the controlling reason, is the fact that the increment in the St. Clair River is really smaller than the increment in the Niagara River. Let me make that clear: in the case of small pools where the reservoir effect does not enter so largely, and we can see the thing very much more clearly, if we know the increments of two pools as for instance the Whirlpool and the pool in the Niagara River above the Rapids, above the cateract; if we

know that the increments are in the ratio of 2.50 to 0.56, we know very well that the fluctuations would bear the inverse ratio. It is not entirely certain that when you take larger reservoirs like Lakes Michigan, Huron and Erie that you can —rather it is very certain that you cannot—argue with the same certainty that you would in the case of these smaller pools. The local supply, local runoff, local evaporation, those elements are likely to enter in, and I do not want to state, on the face of that, clearly that I know the increment in the St. Clair River is smaller than it is in the Niagara River; but I think it is a clear proposition.

Q. Will you state it as your belief that the increment in the St. Clair River is smaller than that of the Niagara River?

A. I have already done that in my evidence, yes. I gave that as one of my reasons why I thought 25 per cent was not an improbable error in the increment as it was set down on the chart, which shows 23,820.

Q. Suppose, Mr. Shenehon, that when an examination of the discharges were made with reference to the lake elevations it were found that for a known elevation of the lake there were two different discharges. Would you account for this as being probably the result of erroneous gage readings, within the limits that you have previously stated for the several gages?

A. No.

Q. How would you account for that?

A. I would account for it, if it might be in the Niagara River, for instance, that with a rapidly rising Lake Erie level at Buffalo, the river might not be in stable equilibrium as regards the flow.

Q. Suppose it were in the St. Clair River?

A. In the St. Clair River, that comes with stronger force even than the Niagara River, on account of greater length and the more complex condition entering, from Lake St. Clair's backwater effect.

Q. Taking into consideration the methods employed by the government in making these discharge measurements, what in your opinion is the probability of the gaging showing too high a discharge?

A. In which particular river?

Q. Take the St. Clair River?

A. For the mean condition as regards Lake Huron elevation and Lake St. Clair elevation, I believe the volume of discharge is accurate within one to two per cent.

Q. And if there be any error, do you think it would be more likely to show too high a discharge or too low?

A. Just as likely one side as the other. I see no reason for either having a preference.

Q. What situation might conduce to an observation showing a discharge actually in excess of that which was in the stream?

A. If when the meters were being rated, additional friction on the wheel, due to some causes that might enter, possibly a little silt on the disc or the shaft, possibly a weed caught on the wheel,—and then the instrument were taken to the river and the discharge made in which there was no silt on the meter wheel, no silt on the shaft, no weeds caught on the wheel, you might have a very small percentage greater discharge indicated, under those conditions. The probability, however, of these frictions on the disc, or on the shaft of the meter coming in, or anything in the form of weeds coming across the meter wheel, are very remote.

Q. Assuming that the meter has been correctly rated, then what situation could arise that would cause the meter to show too high a discharge?

A. A possibility enters of a little oil getting on the disc of the wheel, so that in the revolution of the wheel, instead of getting a single movement of the register, it doubles up, that is what we call skipping; that is a thing that is constantly listened for while the meters are in operation, and if that escaped the attention of the observer, your register might show a few more revolutions than were made by the meter wheel. That condition, however, is constantly watched for, and is very apparent when it does occur. It breaks the rhythm of the register sound.

Q. What would be the effect on the meter of currents in the river running obliquely to the section?

A. That is taken into account in the reduction of coefficients. We make a reduction for the direction of the current. Observations are made as to whether or not the current is cutting the section at right angles; if it is not, we introduce that into our velocity coefficients. No error will enter from that cause.

Q. What will be the effect on the meter of having the current strike it obliquely as compared with having it strike at right angles to the section?

A. The tail which controls the direction of the meter holds it nose on to the current.

Q. So that the meter always is absolutely parallel with the direction of the current?

A. Absolutely is too strong a word. I should say that the meter bears the same relation in its truthfulness with the thread of the current as it does in its truth to the direction of the rating base. If this occurs at all, it is eliminated between the rating base and the river; so that no error enters of that kind.

Q. Is a meter likely to increase the number of revolutions for a given velocity during a gaging?

A. It might, yes.

Q. To what extent?

A. One to two per cent.

Q. Can you account for that?

A. The meter might show cause by this skipping I have mentioned, this oil on the disc, why it should be cleaned, and upon taking it out and cleaning it and putting a little more oil on the pivot, you might better the lubrication. The lubrication, however, has very small effect on the spinning of the wheel.

Q. If floating material such as grass or weeds were to catch on the meter, would that effect be to increase or decrease the amount of discharge shown?

A. The lodgement of weeds or grass on the meter wheels, in my experience, has been practically zero.

Q. Assuming that there was such a thing?

A. The claim made in the patent for the Haskell meter is that it will throw off weeds; that the wheel is pointed at the nose, and it is rounded for the purpose of throwing off weeds if they should come along. If a weed did lodge square across the nose, it would slow up the wheel,—give fewer revolutions.

Q. Indicate a smaller velocity of the stream?

A. Yes.

Q. Until the weed was thrown off?

A. Yes. I know of only one case where weeds have entered into consideration, and that was in the observations in the power canal at Niagara Falls, in the fall of the year. Weeds in the lower Niagara River grow to very large extent, and towards fall they are loosened up, come down the river, and for a few days in 1907, the fall of 1907, the weeds gave some considerable trouble, mainly in accumulating across the vertical standard which carries the lead weight, and across the cable. That was a transient condition and due to the fact that the power canal is below a great mass of weeds,

the mass of weeds is so great there that it is difficult to get a small boat through. It must be understood that in the Niagara River, and I presume it is true also in the St. Clair, that the rivers themselves are not silt bearing, and there are few weeds. That is equally true of the St. Lawrence; the water is running clear, and as to the coming down of weeds there, I recollect none in my experience on the St. Lawrence River.

Q. What is the effect on the discharge of the St. Clair River of a rise in Lake St. Clair, will it increase it or decrease it?

A. A rise on Lake St. Clair decreases the discharge of the St. Clair River.

Q. A fall in Lake St. Clair would increase the flow in the St. Clair River?

A. Yes.

Q. Taking the plate, Government Exhibit 1, is the effect of the elevation of Lake St. Clair, taken into effect in determining the increment of the St. Clair River?

A. The observations are platted as indicated by the Huron gauge without change, except in the case of 1901 which is explained in this note. That was adjusted.

Q. The observations as to the elevation of Lake St. Clair?

A. The 1901 observations are adjusted for the abnormal stage of Lake St. Clair. That was the ice year, in which Lake St. Clair was low.

Q. Those observations that are platted on that plate indicate the level of Lake Huron and Michigan and the discharge through the St. Clair River, and the relation that one bears to the other?

A. Yes; and when I say the elevation of Lakes Michigan and Huron, it is the elevation of Lake Huron at Harbor Beach, which is set down here.

Q. The question is are the elevations of Lake St. Clair platted on that plate in any way?

A. No.

Q. Are they taken into account in any way in determining the increment according to the formula that appears on that plate?

A. Aside from the observations of 1901, no attention is paid to Lake St. Clair. Lake St. Clair is eliminated by the relation between Huron and Lake St. Clair. I do not mean by that that any manipulation of the figures was made. I simply say the period between 1899 and 1900, excluding 1901, 1902

and 1908, Lake St. Clair is taken for that period as being at a stage that is normal.

Q. That is you assume Lake St. Clair to have a certain elevation, which you arrive at from the elevation shown in Lake Huron and not by actual gage readings in Lake St. Clair itself?

A. Derived from the gage readings, yes.

Q. Gage readings of Lake Huron?

A. Lake Huron and Lake St. Clair both; that is platting one with respect to the other, just as they are on here (indicating plate).

Q. Please explain how you took into account in determining the increment of the St. Clair River the elevation of Lake St. Clair, at the time that observations were made as to the elevation of Lake Huron, and the discharge measurements were taken?

A. The discharge observations extending through four years, 1899, 1900, 1902 and 1908, are taken as extended enough to warrant a normal relation existing between Lake St. Clair and Lake Huron.

Q. What is that normal relation?

A. It is somewhere in the vicinity of a change of one foot on Lake Huron showing a change of 0.66 of a foot on Lake St. Clair. That 0.66 enters in no wise into the making of this plate (indicating Exhibit) except as the observations of 1901, which are not used in the computation here, have been adjusted to bring them up to a normal relation of Lake St. Clair.

Q. What do you consider the normal difference between the two lakes?

A. The plat as made here is made just as if we had no gage relations on Lake St. Clair; it is ignored.

Q. That is what I was trying to get at.

A. The discharge is taken as depending on Lake Huron stage, with the understanding—

Q. And on the assumption that Lake St. Clair is in a normal relation to Lake Huron all the time, or is stationary.

A. (No answer.)

Mr. Wilkerson: Q. You ignored that because at the time of the observations the gage readings showed the relation to be normal, is that right?

A. The fact of the normal relation of Lake St. Clair with respect to Lake Huron depends entirely on the length of

time over which the observations existed, and nothing further.

Mr. Williams: Suppose that in the group of observations Lake Huron rose, and Lake St. Clair rose at the same time; would the effect of the rise in Lake St. Clair increase or decrease the apparent increment due to the change in Lake Huron?

A. If Lake St. Clair rose at such a relation or made such a proper percentage rise of Lake Huron, the increment would not be affected.

Q. Would the rise of Lake St. Clair in itself increase or decrease the apparent increment?

A. If Lake Huron remained stationary and Lake St. Clair should go up say a tenth of a foot, the discharge would be lessened about 1,600 cubic feet per second; that is at the time when the discharge was about 200,000 cubic feet per second.

Q. When the discharge was decreased to that extent, the increment would be larger?

A. The increment is the difference of the discharges per foot change in Lake Huron stage; and we have got to take into account two of them, instead of a single one, to get at the rate of change, or the increment.

Q. Assuming that the raising of Lake St. Clair would cause a decrease of flow, if Lake Huron rose a foot, that rise of Lake St. Clair would cause a decrease of the apparent increment, would it not?

A. Now, let me see: you want Lake Huron to go up a foot. What is Lake St. Clair to do meanwhile?

Q. Suppose it goes up a tenth of a foot. Suppose Lake St. Clair is stationary to start with, does not go up at all?

A. And Lake Huron goes up a foot?

Q. Yes, and the level of Lake St. Clair is not changed?

A. I do not think that our formula would give accurate results with so large a difference in Lake St. Clair and Lake Huron.

Q. Suppose that there was a rise of .2 of a foot on Lake Huron, and Lake St. Clair remained stationary?

A. That would show an increased outflow, say with an increment of 24,000 of plus about 88/100 of one per cent of the volume of flow for lessened backwater. We take the backwater effect, that is the retardation of the outflow due to Lake St. Clair as about two-thirds of one per cent for each tenth of rise in Lake St. Clair; two-thirds of one per cent

of the volume of flow. That is an approximation, and I do not know—

Q. Are you assuming Lake St. Clair has remained stationary and a rise of .2 of a foot in Lake Huron?

A. Yes.

Q. The increased flow in such an event would be how much?

A. If your base flow was 200,000, it would be about 6,570 cubic feet per second.

Q. And suppose there was a rise of .2 of a foot in Lake Huron and a rise of one-tenth of a foot in Lake St. Clair, what would be the increase of discharge in St. Clair River?

A. That would be 5,240 cubic feet per second increase.

Q. Assume both lakes rise simultaneously .2 of a foot, what would be the additional discharge of the St. Clair River?

A. That would be about 3,900 cubic feet.

Recess to June 5th, 1909, 9:30 a. m.

June 5th, 1909, 9:30 o'clock a. m.

Cross-Examination of F. C. Shenehon resumed.

Mr. Williams: Q. In dealing with the Niagara River, is it necessary to consider the changes of elevation anywhere except in Lake Erie, in determining the increment in the Niagara River?

A. As a mean of the open season flow, no.

Q. And in dealing with the St. Lawrence River, would it be necessary to consider changes of elevation anywhere other than in Lake Ontario?

A. The St. Lawrence River, at the head of the Galops Rapids is the place in the river where the elevation of the water determines the outflow; in the vicinity of the Galops Rapids.

Q. In determining the increment of the St. Lawrence River, did you observe the observations of elevation in Lake Ontario?

A. The observations of Lake Ontario are made simultaneously, that is the water surface observation, tri-daily observations at Oswego, and the self-registering gage at Tibbitts Point, which is at the head of the river; also self-registering gage at Ogdensburg. Aside from the time when ice condi-

tions enter, the elevation at any one point permits us to derive the elevations for the other three points mentioned. That is the slope in the river above Ogdensburg is something less than a foot, normally about 0.85 foot, as I recall it, and from Ogdensburg to the Galops in the neighborhood of two feet. And when the water goes down a foot at the head of the Galops Rapids, it goes down a foot and two hundredths at Ogdensburg and a foot and four hundredths in Lake Ontario. The movement is almost identical, a little bit larger on Lake Ontario.

Q. Did you take into consideration in arriving at your increment, anything other than the elevations of Lake Ontario, and your discharge measurements in the St. Lawrence River?

A. The increment as derived is with respect to the water surface at Ogdensburg.

Q. Is it necessary to take any elevations anywhere else other than Ogdensburg in arriving at the increment?

A. To arrive at the increment? None other aside from those incident to the discharge measurements on the section.

Q. Is it your opinion, Mr. Shenehon, that the average difference of elevation, or fall from Lake Huron to Lake Erie, as indicated by the observations from 1890 to 1908, will be substantially permanent?

A. The elevation for Lake Erie for that period appears to be nearly half a foot below the mean stage of Lake Erie, since 1860. The permanence of that level, and by that I presume you mean over long periods of years, as ten or twenty years, is likely to be interferred with by artificial changes. Increasing diversion at Niagara Falls may have some small influence in lowering Lake Erie; possible larger diversions in the Welland Canal; possible larger diversions in the Erie Canal.

Q. Eliminating the artificial changes, such as you have indicated, what would you say as to the probable substantial permanence of the average fall, as indicated by the observations from 1890 to date?

A. I know no reason why the difference in elevation between Lakes Huron and Erie should be largely different from the difference 8.4, for that period. And when I say that, it might vary a tenth or two either way. And in this statement I am assuming periods long enough to eliminate eccentric variation such as you pointed out in the year 1890, I believe it was.

Q. Now, going back perhaps a little: if the conditions existing today are substantially permanent conditions, and the present difference in elevation of these two lakes is not due to temporary local conditions, can you state why the difference in elevation between these two lakes for this period from 1890 to 1908 is less than it was for the period of thirty years preceding 1890?

A. In the thirty years, the earlier period to which you refer, the elevation of Lakes Michigan and Huron was 581.84, and the fall between Michigan and Huron and Erie is 8.92, as I have just computed it. In the latter period, beginning with 1890, the elevation of Lakes Michigan and Huron is 580.53, and the fall is 8.41. This shows that Lakes Michigan and Huron are 1.31 feet lower for the latter period than for the former, and that the fall between them is 0.51 feet less for the latter period, when the lakes were low, than for the earlier period when they were high. I explained yesterday that in a general way, when Lakes Michigan and Huron go down one foot, Lake Erie goes down about 70 per cent of that, .7 of one foot. In these two periods, Lakes Michigan and Huron went down 1.31, and 70 per cent of that would be .92, and the difference between these is 0.39. That checks within .12 of a foot or an inch and a half of where we would expect Lake Erie would be, knowing where Lakes Michigan and Huron were, which is a very close check.

Q. What was the average elevation of Lake Erie for the latter period as compared with the former?

A. For the earlier period, 572.92, and for the latter period 572.12; that is Erie is .8 of a foot lower, where the computation I have made would expect it to be .92 of a foot, which is within an inch and a half of—

Q. Do you ascribe the lowering of the elevation of Lake Erie entirely to the fact that the elevation of Lakes Michigan and Huron has been lowered?

A. I should say that while Lake Erie's stage depends upon the supply that it gets from the St. Clair River and Detroit River to a large extent, that its own particular elevation involves local conditions as well; and by that I mean local rainfall, runoff and evaporation and elements of that kind, that enter into the problem.

Q. Is there any other reason in your mind why Lake Erie has been, as an average elevation, .8 of a foot lower than it formerly was, except the change in elevation in Lakes Huron and Michigan?

A. I have made no analysis of the rainfall and evaporation and runoff data.

Q. Do you consider that the fall in the elevation of Lakes Huron and Michigan would be sufficient cause for the lowering of the elevation of Lake Erie?

A. I do not attempt to explain the elevations of the lakes, at any time; to say why this lake is there, or why the other lake is at that particular point. For the period mentioned, as indicated by the computation I made, the lakes seemed to bear the proper relation to each other, and that is simply a matter of history. If you plat the records of one lake with respect to the other, in a general way they line up so as to indicate a movement of 70 per cent on Erie for one foot on Lake Huron, and for the particular period that relation seems to be borne out by the computation I made very closely. If you mean local diversions, Mr. Williams, in your question, as to whether more water has been used in the Welland Canal in recent years—

Q. No. What I was trying to get at is why the level of Lakes Huron and Michigan has been lowered by 1.31 feet and the level of Lake Erie has been lowered .8 of a foot in a period from 1890 to the present time, what caused the lowering of those lakes, that is what I am trying to get at.

A. I think the inclusion in that period of the extreme low water of 1895 explains why the mean is lower than the earlier period. That as I understand was a period in which we had record low water all over the country; not only in the great lakes, but in other rivers as well. The former period includes the period of 1886, which was the record high water. Since 1860.

Q. Suppose we eliminated both of those years, you would still find, would you not—

Q. Suppose we eliminate the low water of 1895, eliminate it entirely?

Mr. Wilkerson: I understand the periods we are talking about are the periods ending in 1889 inclusive, and then commencing with 1890 and running down to 1908?

Mr. Williams: Yes.

Mr. Wilkerson: So that the high water period, high water year as they call it, is in the first period, and the low water is in the second period. That is correct isn't it?

Mr. Williams: That is correct.

Mr. Wilkerson: So there will be no compensation, if the

one would balance the other, because they are in different periods.

Mr. Williams: Eliminate them both.

The Witness: I think it should be written into the records that this latter period does contain the artificial diversions of which I have spoken, while the earlier period does not.

Q. Do you want to be understood as saying that in your opinion those artificial diversions are accountable for the lowering of the elevation?

A. I want to be very clearly understood as saying that whatever diversion has taken place at Chicago has had its effect upon the lakes, and increased diversions in the Welland Canal have doubtless had an effect on Lake Erie.

Q. The diversion through the Welland Canal amounts to how much?

A. 1800 cubic feet per second, as I understand it.

Q. And formerly it was how much?

A. When I state that, I take it from the statement of the superintendent of the Welland Canal. I have made no measurements there; the Lake Survey has made none. As to what they were the prior period, I do not know, but I assume that they have been increased somewhat.

Q. Assume that all the diversion through the Welland Canal has taken place during the second period, what would be the effect of that diversion on the level of Lakes Erie, Huron and Michigan?

A. It would be somewhat in the neighborhood of an inch on Lake Erie.

Q. Is there any other reason that you can give for the lower elevation of these lakes?

A. Other than artificial, or other artificial reasons?

Q. Any reason that appeals to your mind as a good reason why the level of the lakes is lower in the second period?

A. I think there is a fair presumption that improvements for channelways, if I am getting at what you desire, may have had some small influence in lowering the lakes.

Q. How small in your opinion?

A. And when I state that I wish to state at the same time that other changes entering into the rivers, as the building out of docks, the deposition of dredged material, the encroachments opposite cities, and so on, have tended to compensate any lowering that might come from improved channels. I do not see any evidence between these two periods, between the period of the earlier thirty years and the latter

period after 1890, in the relative elevations of Lakes Michigan and Huron, and Erie to indicate that any large change has taken place in the regimen of the St. Clair River or of the Detroit River. So far as that evidence goes, it would indicate that the compensation is very close to complete.

Q. Well, then, in your opinion, the improvements in the channels have not contributed to this lowering?

A. Have not largely lowered the levels.

Q. What we are trying to get at is, what are the elements that in your opinion have contributed to the lowering, not those which you have not found?

A. I assume that the latter period has an entire permanence, and as I stated earlier, that the lakes were during that period somewhat below the mean lake level; and I perhaps might read into the evidence here the elevation of Lakes Michigan and Huron: for the period 1865 to 1869 it is 581.12; and for the period 1870 to 1874 (these are five-year periods), 581.47; while for the period 1905 to 1908 the elevation is 581.02. The last is a period of four years, and the last four years we have compared with the period beginning at the Civil War, and for the ten years, 1865 to 1874, the mean elevation is 581.30, which is about 3½ inches higher than the water has been during the last four years. That is, a period of ten years beginning about the Civil War in which the elevation of the water surface is only 3½ inches higher than the period for the last few years. The comparison of the two periods, as the thirty year period of your former statement and the twenty year period of the latter, is not entirely conclusive as to the fact that the lakes are permanently lowering. Yet to a certain extent it is presumable that they are, by reason of the diversions to which I have already referred, by channel improvements and of possibly very small influence coming from the power development at Niagara Falls. That last I do not think would exceed over half an inch on Lake Erie.

Q. You spoke of the diversion of water through the Welland Canal lowering the level of Lake Erie. Does that affect the level of Lakes Huron and Michigan in any way?

A. On the assumption that the lowering of a foot on Lake Erie would have the backwater effect of one-third that amount on Lakes Michigan and Huron, it would, yes.

Q. The diversion through the Welland Canal is one influence which you have mentioned. The effect of that would be one inch on Lake Erie, and one-third of an inch approxi-

mately on Huron and Michigan. Now what other diversions do you have in mind when you speak of diversions—

A. There is about seven or eight hundred cubic feet in the Erie Canal. I do not think that has increased largely between the two periods.

Q. Assuming that it was all taken out during the latter period and that there was none diverted in the preceding period, how much of an effect would that have on the level of Lake Erie?

A. That is the sum of the effects of the Welland and the Erie, is that what you mean?

Q. Just the Erie. You have given us the Welland, give us the Erie alone?

A. For 800 cubic feet would be less than half an inch.

Q. In Lake Erie?

A. Yes, it would be just about a half an inch. Welland Canal I think is about an inch and the Erie Canal is less than a half an inch.

Q. And the diversion through the Welland would be 1800 cubic feet?

A. Yes.

Q. The effect on Lakes Huron and Michigan of that diversion through the Welland Canal would be about one-third of the half inch?

A. Yes, a little less than that.

Q. What other diversions are there?

A. There is a possible lowering of a half an inch due to the power companies at Niagara Falls.

Q. About 1/6 inch of a fall on Lakes Michigan and Huron from the same cause, then? Are there any other diversions?

A. I wanted to find in my report on the preservation of Niagara Falls a statement concerning the changes in Niagara River; I do not find that reference. The purport of it was to show that for any dredging of the river, creation of artificial channels for navigation, that compensating effects have been introduced by the depositing of material and by the encroachment of docks on the shore line.

Q. We are still on the question now of the diversions that you have in mind as having been responsible for the lowering of these lake levels; and in addition to diversions, any other evidence, which in your opinion contributed to that lowering.

A. I think I have stated them all; the Chicago Drainage Canal; the difference in flow in the Welland Canal (an un-

known quantity to me); possibly small effect due to the power diversions at Niagara Falls, and channel improvements.

Q. How much effect do you attribute to the diversion through the Drainage Canal?

A. In the ratio of 4,000 cubic feet to two inches and a quarter.

Q. What do you understand the diversion has been in the past nine years?

A. I do not have the total. I believe the license is to divert 4,167 cubic feet per second.

Q. You would attribute 2½ inches then about, or 2¼ inches of this lowering to the diversion at Chicago, that is in Lakes Michigan and Huron?

A. Yes.

Q. Assume that the maximum diversion through the Sanitary District Canal at Chicago has been 5,630 cubic feet per second, and figuring upon that basis, what has been the effect on the levels of Lakes Huron, Michigan and Erie?

A. That is figuring on a continuous flow of that amount since 1900?

Q. Assume that. It is more than the actual flow has been, but taking that as a maximum flow during any period, and assume that as a constant flow?

A. That is 56 hundred, roundly.

Q. Yes.

Q. Yes.

A. It, however, is not a fact that 56 hundred has been diverted continuously since 1906, so the answer is an assumption.

Q. Yes.

A. About three inches.

Q. That is for Lakes Huron—

A. That is Lake Erie.

Q. That is for Lake Erie?

A. Yes.

Q. What is the effect on Lakes Michigan and Huron?

A. Between 2¾ and 3½, speaking roundly, on Michigan and Huron.

Q. Now then, have you mentioned all the causes which occur to you as having—

A. I imagine variations in rainfall, evaporation and so on, enter in.

Q. Have you made any examination of the rainfall data for those periods?

A. No, I haven't.

Q. And if the data indicated that the rainfall had been greater during the latter period than the former, what would you say then as to that having contributed to the lowering of the lake level?

A. I should want the evaporation data and know that it was sound, taking it into account also with the rainfall data. I should want also to know the ice condition existing in the St. Clair River and the Niagara River. I should not want to make a judgment by leaving out much of the important data on which a judgment could be based.

Q. At present then, without further investigation, you know of no causes other than those which you have enumerated which in your opinion would contribute to the lowering effect which has been observed on these lakes?

A. No.

Q. We have accounted for 5 inches of the fall in Lake Erie, and 4.17 inches fall in Lakes Huron and Michigan, by assuming that the entire diversion through the Welland Canal has been, during the latter period—

A. Which I believe is not true.

Q. Which is not true?

A. I should say it is not true; I think there is no large increment through the Erie Canal.

Q. And allowing that the Erie Canal has been a source of or a means of diversion in the latter period, which had not been previously, which is not true; and assuming the maximum flow through the Sanitary District Canal, which is not true, and in spite of all those the results account for only 4.17 fall in Lakes Huron and Michigan, and a fall of 5 inches in Lake Erie. Do the fluctuations on Lake Erie depend entirely on those of Lakes Huron and Michigan?

A. Before answering that question, I would like to put in one other element that has entered into this case, I think.

Q. That is has contributed to the lowering effect?

A. Yes.

Q. All right.

A. That is the impounding of water in Lake Superior that came with the building of the International Bridge and the Chandler-Dunbar wing dam. Lake Superior was raised during this latter period by both of those effects; by the International Bridge in part, and by the Chandler-Dunbar wing dam cutting off the flow in spans one and two of the International Bridge; and whatever water was impounded in Lake

Superior at that time was held up from the lower lakes. Lake Superior made a rise of somewhere between 4 and 6 inches, as I remember it.

Q. In your opinion what would be the extent of the effect on the elevation of Lakes Michigan, Huron and Erie of the works that you have just mentioned?

A. I could not state that, without a rather long computation.

Q. Would it be greater or less than the effect on Lake Superior itself; that is the corresponding effect? You say that Lake Superior had a higher elevation of from 4 to 6 inches. Would it make more or less than 4 to 6 inches difference in the elevation of Lakes Huron, Michigan and Erie?

A Very much less. I ought to make that matter for Lake Superior a little clearer; that matter of the lowering due to Lake Superior is nothing permanent. It was simply holding up the water for a period, and then the natural outflow of the Lake Superior area is re-established; and when I say the natural outflow, the surplus waters of Lake Superior come down the St. Marys River, and the condition is the lower lakes get their proper amount of water from that time on.

Q. How long was that condition in existence?

A. Why the bridge piers went in in the latter eighties, and the Chandler-Dunbar dam in the early nineties. I do not remember the exact dates.

Q. Over how many years would you say that the effect was noticeable?

A. You are getting me into a pretty involved line of mathematics.

Q. Approximately; taking the latter period of eighteen years, how many of those latter eighteen years would you say were affected by the impounding of water in Lake Superior? Perhaps this paragraph in this report would answer the question substantially, the report of 1903 (handing witness same). Is that of any service to you?

A. That shows that the bridge piers and the—I do not know whether that term "other small streams" indicates the Chandler-Dunbar dam or not. It speaks of that between 1887 and 1892.

Q. Without reference to the actual number of years during which the elevation was affected by the impounding of water in Lake Superior part of that effect was observable during part of the thirty year period, and part during the latter period?

A. I could not answer that without extended figuring.

Q. Has the effect of that impounding disappeared at the present time; the effect on the elevation of Lakes Huron, Michigan and Erie?

A. I should say yes; I should say practically the effect had disappeared. But there is this to be said about that, Mr. Williams: The mean lake elevations will show some small effect coming from that.

Q. Whatever the effect of that impounding in Lake Superior was on the elevation of Lakes Huron and Michigan, in the way of lowering the elevation, the effect having now disappeared, may we reasonably expect that Lakes Huron and Michigan will rise to the former stage, so that they will regain the loss occasioned by that?

A. I testified I thought it had disappeared. It had, so far as the impounding of water in Lake Superior was concerned, it had regained whatever was lost by that.

Q. It has regained it?

A. I testified that was my opinion.

Q. In your opinion does that effect account for any portion of the rise in the elevation of Lakes Huron and Michigan for 1905-1908?

A. I could not answer that without extended computation; it is impossible. You are asking me to account for a rise in the lake levels or a lowering of the lake levels. We know that those things are occurring from year to year. I have attempted to state very plainly that the elements on which a determination could be made, the rainfall data, the evaporation data, of which we have practically nothing, and the inaccurate knowledge of the ice conditions in the outflow rivers, all that data is necessary.

Q. I am not asking you now, Mr. Shenehon, for an answer as to the exact effect in inches or tenths of a foot. I would like to know whether or not in your opinion any part of the rise in the elevation of Lakes Huron and Michigan from 1905 to 1908 is due to the fact that the effect on the elevation by the impounding of water in Lake Superior has disappeared; not as to the extent of it, but whether it does to any extent account for it?

A. I should not wish to answer that without an extended computation. The conditions at Sault Ste. Marie are rather involved; the power canals, tapping the lake, and the compensating works having been put in on the Canadian side, so that you are getting into a pretty complex problem in that.

Q. Before leaving that subject, Mr. Shenehon, I understand that the situation is this: that the impounding of water in Lake Superior did in your opinion have an effect on the elevation of Lakes Michigan and Huron. That effect has disappeared but you do not desire to express an opinion one way or another as to whether or not the cause having disappeared that it would not have any effect at all on the elevation of Lakes Michigan and Huron?

Mr. Wilkerson: He limited it to certain years. Your question was for a certain period, 1904-1908.

Mr. Williams: Since the effect of the impounding has disappeared.

Mr. Wilkerson: He said with reference to those years, he would not want to express an opinion without computation.

Mr. Williams: The reason I have asked the question is because I want Mr. Shenehon to have an opportunity to explain if he wants to. If he desires to leave it just as it is I am satisfied.

Mr. Wilkerson: Would you prefer to make that computation and answer the question later on?

Mr. Williams: This is not a matter of computation.

The Witness: I should prefer on that whole matter to await a computation. Whether or not the effect disappears is a thing I am a little bit in doubt of, as I think it over; and how long it might take for that effect to disappear.

Q. Then you would prefer to modify your answer?

A. I do not like to give an opinion on that right off the bat; it is rather a complex thing.

Q. Then do you want to modify your answer as to the effect having disappeared?

A. I should like to reserve that.

Mr. Wilkerson: He said he preferred to reserve the whole question.

The Witness: Yes; it is a complex question. If you are temporarily impounding water in Lake Superior, St. Marys River is supplying Lakes Michigan and Huron with less water, and the St. Clair River is carrying the water off all the while, so we are very certain to have a lowering effect due to that. Now, after Lake Superior is at a higher plane and pours out simply its normal surplus of water, I think it is very certain that Lakes Michigan and Huron would re-establish themselves as would also Lake Erie and Lake Ontario, which would also be lowered during the impounding or sub-

sequent to it. But that matter I should like to reserve and think over. I think that is the truth.

Q. And if it has not yet occurred it will at some time; that is if the effect has not entirely disappeared up to this time, it will disappear at some time?

A. Yes.

Q. Now I will ask the question propounded some time ago with reference to the fluctuations of Lake Erie: Do they depend entirely upon those of Lake Huron?

A. No; the St. Clair River supplies the largest portion of water—the St. Clair River, Detroit River, supply the largest portion of water for Lake Erie; that is the prominent supply.

Q. But there are fluctuations of Lake Erie independent of fluctuations in Lake Huron and Lake St. Clair?

A. Yes, small fluctuations.

Q. What would be the effect on the discharge of the St. Clair River of a rise of Lake Erie?

Mr. Wilkerson: Huron remaining stationary?

Mr. Williams: Huron remaining stationary?

A. It would have the effect of retarding the outflow of the St. Clair River.

Q. Then the effect of a fall in Lake Erie would be what?

A. It would have a tendency to accelerate the flow.

Mr. Wilkerson: Huron remaining stationary?

Mr. Williams: Yes.

Q. Now, in determining the increment for the St. Clair River, is the elevation of Lake Erie taken into account?

A. It was not considered except as the observations extended over a long period. It is assumed that the conditions for that period were normal. I may state further that during the seasons of 1899, 1900, 1902, Lake St. Clair which governs by its backwater effect the outflow in the St. Clair River to the extent that I have already testified was at a normal condition; and to that extent both Lake Erie and Lake St. Clair have been considered in establishing the rate of outflow from Lake Huron, or the increment.

Q. Do you consider that the relative positions of Lakes Huron and Erie, during the time of the discharge observations, from 1899 to 1908, was representative of the continued relations of the two lakes?

A. The relation of Lake Huron to Lake Erie during 1899, 1900 and 1902 (and that should be reserved to the open season when discharge observations were being made), was in accordance with the relations of those two lakes, as shown by the

terms of years from 1875 down. An attempt was made, and I think successfully, to make the increment rather favorable to the contentions of the Sanitary District in this case in the Plate Exhibit 1 by making the increment there the greatest, and when I say that, I mean the year 1901 was excluded in that determination of the increment. I should say that the line as drawn to the observations, is the computed line excluding the year 1901. And when I say the line is set down favorable to the contention of the Sanitary District, in my opinion I believe the increment is smaller and the effect is greater, as I have already testified; and the reasons, I have given for it.

Q. At the time that these discharge observations were made which form the basis of Exhibit No. 1, the level of Lake Huron and of Lake Erie was below normal, was it not; that is below the mean?

A. For the St. Clair River, the observations between the years 1899 and 1902, inclusive, are from Lake Huron elevation 579.65 to 581.39, a range of 1.74 feet.

Q. And the mean elevation is what?

A. The mean elevation of Lake Huron is 581.32.

Q. That mean is for the entire period?

A. That is from 1860 including 1908, I believe. That is the upper limit of the observations cut the mean lake level but did not extend much above it.

Q. What was the elevation of Lake Erie during the time of those observations, as compared to the mean elevation?

A. I have not that data for the seasons of the year. What I gave you there is for the times of the observations, the limits of the observations.

Q. That is for the months?

A. No, I mean those were the actual lake observations, during the observation.

Q. During the actual period?

A. During the individual measurements; the highest measurement was 581.39 and the lowest 579.65.

Q. Would you be able to state whether or not Lake Erie was above or below normal at the time these observations were made?

A. On the St. Clair River you are speaking of Mr. Williams?

Q. The observations on the St. Clair River, yes.

A. During 1900, Lake Huron shows elevation of 580.46; during 1899 (and this is the open season) Lake Erie is at

572.11; during 1900 about the same; during 1902, it is 572.20, and the mean level taken as 572.61 is the latest, and that indicates that as a mean of the season, the lakes were below the mean lake level; but for the individual months, perhaps that should be tabulated and put into the case, if you care to have it, what the elevation was for the individual months during the discharge observation.

Mr. Wilkerson: Have not the figures, which form the basis of such a computation been identified here?

A. I think so.

Mr. Williams: Assuming, Mr. Shenehon, that at the time of making these discharge observations, the relative elevation of Lakes Huron and Erie was normal; Lake Erie is at an elevation below normal. Then assume that Lake Erie was at a normal stage of elevation, and that Huron was correspondingly higher, so that they maintained their relative elevations, what effect would that higher elevation of Lake Erie and corresponding higher elevation of Lake Huron have upon the discharge of the St. Clair River?

A. Why, the discharge of the St. Clair River would be greater for a higher stage of the two lakes where they maintained their relative relation.

Q. And the increment would be larger, would it not?

A. As a rule the increment increases somewhat for higher stages.

Q. Would you be willing to express an opinion, Mr. Shenehon, as to whether or not the relations existing between Lakes Huron, St. Clair and Erie for the periods of your observation represent average conditions that may be expected to prevail in the future?

A. It depends upon what the future contains.

Q. Under normal conditions?

A. You mean assuming larger diversions at Chicago, for instance?

Q. Assuming natural conditions?

A. I see no reason why they should be largely different.

Q. Was the effect of the storage of water in Lake Superior present at the time these observations were made?

A. That whole line of questions I would rather reserve. Speaking off hand I should say some effect was present at that time, but not to an extent to interfere with the relative elevation of Lakes Michigan, Huron and Erie within such limits as we expect them, one to follow the other.

Q. You mean the relative elevations of Huron and Erie?

A. Huron and Erie, yes.

Q. Assume that the decreased difference of level between Lakes Huron and Erie, which during the past nineteen years has been on an average of about 6 inches less than that during the preceding thirty years, is due to temporary causes; and that Lake Huron may be expected to rise relatively to Lake Erie to the old average difference. If that should occur, what in your opinion would the effect be on the discharge through the St. Clair River?

A. That is, you want to get the effect of the discharge on the St. Clair River for the conditions governing the latter period of the two as compared with the former period?

Q. No. It is a hypothetical question. The last nineteen years shows that the difference in elevation between Lakes Huron and Erie is six inches less than it was during the former period of thirty years. Now, assume that that change in difference of elevation is a mere temporary change, and that in the future the difference in elevation between the two lakes will go back to what it was during the first thirty years, be six inches more than it is at present; what would the effect of the resumption of that difference of elevation be upon the discharge through the St. Clair River?

A. You assume that both Lake Erie and Lake Huron go up to the former elevation, elevation of the period of the earlier thirty years?

Q. Yes; irrespective of their both going up; if they resume the difference of elevation?

A. Of course, my belief is that the difference of elevation is practically now what it was before. When you take into consideration the stage or the elevation of the lakes, that when one goes up a foot the other goes up .7 of a foot, so for higher stages you get a bigger difference in elevation.

Q. Take my question as a hypothetical question: Assume that during the past nineteen years the difference of elevation has changed so that there is six inches less difference?

A. At a fixed elevation for Lake Huron or for Lake Erie?

Q. Take the elevations of Lakes Huron and Erie as they were during the thirty-year period; and their relative elevations?

A. Do you want me to give a quantative result what the discharge would be in cubic feet per second for a given lake elevation?

Q. No, would it be more or less?

A. For the higher elevation of the lakes as they were in the earlier period the discharge would be somewhat higher.

Q. Irrespective of the elevation of the lakes, would a resumption of the difference in elevation to the same amount as existed in the former period of itself have any effect upon the amount of the discharge?

A. No substantial effect; perhaps one per cent.; that is, I computed that Lake Erie was within .12 of a foot, as I recollect it, of where my computations for relative elevation would bring it. And I have shown in other places in my evidence that the backwater coming up from Lake Erie was somewhere in the neighborhood of 80 per cent. and that one-tenth change on Lake St. Clair, that is, an increase of one-tenth there, would have about three-quarters of one per cent. effect on the discount; two-thirds of one per cent., I think that was, so that it would be well within one per cent. I should think any change due to abnormal relations between the two would not vary more than one per cent.

Q. Do you know what the average slope between Lakes Huron and Erie was during the period of your observations?

A. Not in detail. The records that we have will show that.

Q. Assume that Lakes Erie and Huron have a certain difference of elevation during the thirty-year period. Assume that for some reason, temporary in its nature, the relative elevations changed, so that the difference in elevation is six inches less during the latter period of nineteen years. Then assume that the temporary conditions causing that change in difference disappear, and that either Lake Erie goes down or Lake Huron goes up, either one, so that the difference in elevation is six inches more than it is at the present?

Mr. Wilkerson: That is, as I understand it, you mean this: does the fact that Lake Erie is relatively higher have any tendency with reference to the level of Michigan and Huron, is that it?

Mr. Williams: No.

The Witness: You have the question as a matter of differences. If you state specific elevations for Lake Erie and Lake Huron, the difference you are getting at would show, and I could understand the question. But if the difference is gotten by Lake Huron being six inches higher up, the effect in the discharge is not the same as if Lake Erie was six inches lower down. By lowering Lake Erie you can increase your difference, or by raising Lake Huron.

Q. I am not asking for any figures in cubic feet per second.

Assume Lake Erie remains stationary, and that in order to get back the difference in elevation between the two, Lake Huron rises six inches, what would be the effect on the discharge through the St. Clair River and on the increment?

A. I think I have an answer to this now. I would make this reservation in regard to things that I figure in this way, that in case a refiguring of it shows me that I was in error as I figure it now, I may correct it in the record.

Mr. Williams: There is no objection to your making any correction that you see fit, if you find that you have made an error in your figures at any time.

The Witness: For a rise of half a foot or six inches in Huron, if Lake St. Clair should come up its proper relation also, the change in discharge would be 12,000 cubic feet according to our curve; that is, half a foot multiplied by 24,000, or by 23,820 more correctly; and on account of less backwater effect in Lake St. Clair, we would add 1,780 cubic feet to that, making it 13,780 feet, instead of 12,000 feet.

Q. What effect would that have on your increment?

A. If that relation should be maintained constant, the increment would be increased.

Q. How would that influence the effect of the diversion at Chicago?

A. It would indicate a less lowering of Lakes Michigan and Huron, should that condition become permanent.

Recess to 2 o'clock p. m.

June 5, 1909,
2 o'clock p. m.

Cross-examination of Mr. Shenehon resumed.

Mr. Williams: Mr. Shenehon, in the report of the Chief of Engineers for 1903, at page 2813, and continuing to 2817, appears a report upon the discharge measurements of the Detroit River. Were those measurements made under the direction of the Lake Survey?

A. Yes.

Q. And the tables shown on pages 2816 and 2817 are taken from original files on file in this office? Those reports are taken from data in this office?

A. I presume so. I have never personally seen the data. That was compiled before I was Principal Assistant Engineer; and I presume it is in the office.

Mr. Williams: Without offering in evidence the report, I would like to have the record show that this report by Mr. Blanchard, junior engineer, in the report of the Chief of Engineers for 1903, at pages 2813 *et seq.*, will be referred to by us hereafter.

Q. Did you ever examine these tables?

A. Not carefully. The discharge measurements of the Detroit River are not regarded by this office as having any great weight. The conditions were rather difficult.

Q. What would you say as to the degree of accuracy that was obtained in the making of these discharge measurements in the Detroit River?

A. I do not know. I have never investigated that matter of the Detroit River; I have never thought it essential. I have always thought that the discharge of the St. Clair River governed this whole proposition; and that Lake St. Clair could simply be considered an enlarged portion of the St. Clair River, and therefore the discharge measurements in the Detroit River were of little moment.

Q. If they were accurately made, they would be valuable as corroborating the results obtained in the St. Clair River, would they not?

A. I should say not, because continuity of flow is not present. Lake St. Clair acts as an intercepting reservoir in there, in between, and it is not a continuous flow. It would not correspond to two sections on the St. Clair River, as, for instance, in the Niagara or the St. Lawrence.

Q. What were the conditions which you referred to as not having been satisfactory conditions under which these measurements were made?

A. Slow current, small slope between Lake Erie and Lake St. Clair; the liability of Lake Erie to change during the discharge observation, so that the change in slope was a very considerable percentage of the total head due to the difference of level between Lake St. Clair and Lake Erie, and the complex condition arising from separating the effect of Lake St. Clair's elevation on the discharge, and Lake Erie's backwater effect on the discharge. I think I should add to that, small range in the discharge observations; that is, the stage on Lake St. Clair, during the discharge observations.

Q. Have you any information that would lead you to believe that the results shown by these measurements were inaccurate?

A. Not as regards volume of flow at mean stage of the ob-

servation. I do not know anything about what the increment is, or what its value is. I have not studied the observations in detail.

Mr. Shenehon, is this a fair statement of the situation: that you consider the results obtained from these discharge observations will be of very little value to you in arriving at the conclusions that you seek to arrive at; but that you have no doubt of the accuracy of the actual discharge, at the time of the measurements?

A. I have stated that I think the conditions were such that the measuring of the discharge becomes more difficult there.

Mr. Wilkerson: It is more difficult in the Detroit than in the St. Clair River?

A. Oh, very much, yes.

Mr. Williams: So that the measurement itself is not as accurate, and even if it were fully as accurate, the results would not be as helpful to you in arriving at your conclusions, as they would be in the St. Clair River, where the slope is greater?

A. The weight of the observations in the St. Clair River is very much greater. Lake Erie is likely to change very rapidly, and where your original slope is about 3½ feet and Lake Erie comes up a foot, making it only 2½, you have a change of condition that is likely to come during a discharge observation. I have never myself thought the measurement of the Detroit River important; and I have never thought that we had any data that was very valuable. But I have never studied in detail the discharge observations.

Mr. Wilkerson: That is as you have studied the St. Clair and the Niagara and the St. Lawrence?

A. I have studied the St. Clair to some extent, and the Niagara and the St. Lawrence to a very considerable extent.

Mr. Williams: Is it possible for Lake Huron to vary without a corresponding variation in Lake St. Clair?

A. Temporarily, for an hour or two hours or three hours.

Q. During a period required for the making of one of your observations?

A. Yes. The effect of that, however, is that it is just as likely to go down as it is to go up, that is, Huron, with Lake St. Clair remaining constant, so any error that comes in from that source is self-eliminating in a series of discharge measurements.

Q. If Lake St. Clair should remain stationary for a period and a set of discharge measurements were made on the St.

Clair River with Lake Huron varying, would it be possible from such a series of observations to determine the increment of the St. Clair River due to the changes in Lake Huron uninfluenced by Lake St. Clair?

A. That is, Lake St. Clair remaining at constant elevation, Lake Huron varies.

Q. Lake Huron varying?

A. Over a sufficient range—

Q. For a set of discharge measurements to be made?

A. Yes, your increment could be derived under those conditions.

Q. If from the observations already made on the St. Clair River a series of groups were arranged wherein Lake St. Clair was at a constant elevation for each group and Lake Huron was varying, would it be possible to determine the increment with change in Lake Huron independent of Lake St. Clair?

A. You mean following the process we actually have followed, without considering Lake St. Clair; taking into consideration the elevation of Lake Huron, the volume of flow, grouping?

Q. Yes.

A. I think so, yes.

Q. How would you do that?

A. Plat the discharge with respect to Lake Huron elevation; draw a line threading the platted observations. The increment then is the rate at which the discharge changes for each foot of change on Lake Huron.

Q. In your answer, do you assume one group or several?

A. In getting the increment?

Q. Yes.

A. A large number of groups.

Q. And do you assume Lake St. Clair to be at the same elevation for each group?

A. In constructing the chart, which is the exhibit?

Q. No, I mean in your answer now, as you have explained the method of determining this increment; do you assume that Lake St. Clair is at a constant elevation for each group, or a constant elevation for all the groups, that is the same elevation for the several groups?

A. As I understand the question, you ignored Lake St. Clair, paying no attention to what its elevation was.

Q. No. I say, you take a group of observations with Lake St. Clair at a constant elevation and Lake Huron varying.

Now in the different groups of observations, Lake St. Clair may vary, but it is constant through the several observations. Could you get an increment, determine an increment from those several groups, due to the change in elevation of Lake Huron independently of Lake St. Clair?

A. If I understand the question, it is equivalent to ignoring Lake St. Clair, just as if the river went over a cataract, and we were considering simply Lake Huron effect on the discharge. Am I right in understanding it in that way?

Q. My proposition was: Suppose we should group your observations into groups, wherein Lake St. Clair is constant for each group, of course different from group to group; and assume you would get a number of observations, I understand from your first answer that you could get an increment for Lake Huron for any position of Lake St. Clair by that process?

A. You mean out of observations already taken?

Q. Yes.

A. Or a supposititious lot of observations.

Q. No. I take it, if it were possible to get from your observations a series of observations in which Lake St. Clair was constant and Lake Huron varied—

A. By selection?

Q. —by selection, yes; you could then determine an increment for the St. Clair River with Lake St. Clair constant for that series of observations. I understood that to be your answer to the former question. Now what we were getting at was: if we took all such possible combinations in your observations and got a series of increments for each stage on Lake St. Clair, we could then determine a mean for the river in which the effect of Lake St. Clair would be eliminated, that is what I should assume?

A. I can't see that that process would be correct. If I understand it correctly, it seems to me that the increment is the increment shown with the conditions as they did exist.

Q. We would be assuming that these conditions did exist in this case. For instance, suppose that Lake St. Clair was at a certain elevation at the time that a group of observations was made, and it remained constant during that series of observations?

A. Yes.

Q. Lake Huron varied. From that group of observations, you would be able to determine the increment?

A. But it would be an abnormal increment. It would not

represent the conditions as we would meet them from week to week, month to month, and year to year.

Q. That would be a single observation and a single increment, determining it from one set of circumstances that might not recur again. But suppose that it were determined that immediately thereafter Lake St. Clair was at a different elevation when a series of observations was made, but it remained constant at that different elevation, and Lake Huron were constant, you could determine an increment for that condition of affairs also?

A. But that would be abnormal also.

Q. If you could get a series of those, each perhaps abnormal, would it be possible to get a mean increment from those several groups?

A. I should say if the individuals were abnormal and incorrect, the mean would not bring them correct as regards increments. That is, you are assuming a condition that is artificial, as regards the problem in hand. When Lake Huron rises, and the St. Clair River sends more water down into Lake St. Clair, Lake St. Clair rises because there is more water there. If Lake St. Clair is sending more water down on account of Lake Huron's rise, the supposition that Lake St. Clair would remain constant is rather—

Q. The St. Clair would not remain constant in that case, would it? From the reports of your observations, Mr. Shenehon, there are thirty-one observations where the elevation of Lake St. Clair is the same, and where in each instance the elevation of Lake Huron is different. Taking those conditions, they were natural conditions, were they not?

A. Natural, but temporary conditions, I should say; that is thirty-one out of how many observations?

Q. Thirty-one out of a series have fallen under that condition?

A. Out of two hundred or more?

Q. I do not know. As a matter of fact the majority of these observations fall into about ten groups; that is, would be included in about ten stages of Lake St. Clair?

A. Well, the effect of getting an increment in that way, which I regard as unfair and not applicable to the case we are dealing with, would be to get a larger increment, I should say. I should say it would make the increment larger, if you should consider it in that way. The proposition, as I see it, is to establish an increment which involves equivalent elevations of Lake St. Clair for Lake Huron elevations. That is

the state of nature, as I see it. Your proposition is, as I understand it, to establish an increment for a series of conditions that are not in a state of nature.

Q. They are all natural conditions?

A. That is, as a matter of fact, taking the open season for a number of months together, so that we can eliminate these little fluctuations which might be picked out of a series of observations, the condition is that when Lake Huron is at one place, Lake St. Clair is very close to another place; and when Lake Huron goes up a foot, Lake St. Clair goes up somewhere in the neighborhood of 66 per cent. of that amount. That, as the observations indicate, as the gage observations indicate, that is the relation holding between those two water surfaces.

Q. But suppose we did desire to obtain an increment based upon the variations in Lake Huron, and independently of the conditions in Lake St. Clair, how could we do it mathematically, now? Not as to whether or not it is going to do us any good after we have done that, or whether it is going to bring results that will be satisfactory to either of the litigants in this case; but the question is, mathematically how would you go about to do that?

A. There are three ways of doing it; one is to ignore Lake St. Clair entirely. Another way is to assume that it is at a fixed elevation all the while, and that Lake Huron varies. And the third way is to take note as to whether Lake St. Clair is occupying a normal position with respect to Lake Huron. If a series of observations covers a term of years, a long enough period so that Lake St. Clair holds an elevation with respect to Lake Huron that represents a state of nature, the increment derived is correct, as I see it. If on the other hand you hold Lake St. Clair stationary and move Lake Huron up and down, which I do not see is a state of nature, you get an increment, but I do not think it is a correct increment.

Q. We are not going into the question of whether it is correct or not; but would it be an increment based upon the variations of Lake Huron, without any influence being exerted by the conditions of Lake St. Clair?

A. No, Lake St. Clair's influence is present still ,although you keep it at the same elevation. What I mean is if you should take out Lake St. Clair and have a cararact there, you get your water flowing through your river, therefore Lake St. Clair is still exerting back water influence although you hold it stationary.

Q. Suppose, Mr. Shenehon, that we were to construct some sort of controlling works by which we could see to it that the level of Lake St. Clair did not vary one hundredth of an inch, and then we desired to obtain the increment based entirely upon the variations in Lake Huron, wouldn't the method that you have suggested be the method of obtaining that increment?

A. Yes.

Q. Now suppose, on the other hand, that we were able to and did succeed in maintaining Lake Huron at constant and unvarying elevation, and at the same time the elevation of Lake St. Clair should vary, what would be the method of obtaining, in that event, the increment of the St. Clair River caused by variation in the elevation of Lake St. Clair and unaffected by Lake Huron?

A. Plat your observations and draw the line.

Q. If an increment were obtained for the St. Clair River, first based upon the varying elevations of Lake Huron unaffected by the elevation of Lake St. Clair, and secondly by the varying elevations of Lake St. Clair unaffected by Lake Huron, would it then be possible by establishing the relation of changes of elevation of Lake St. Clair and Lake Huron, to compute an increment for the St. Clair River embracing the influence of both lakes?

A. Yes; that is, you get in the former case the influence of change of Lake Huron, and your backwater effect due to change in Lake St. Clair, and by combining the two you do get your equation, write out your equation—that is right.

Q. Would there be anything unfair about that method?

A. No, not provided you take both of them. If you took either of them individually, you have got an unfair result, but is is the combination of the two that gives the proper result.

Q. An increment obtained in that way would be likely to be at least approximately correct?

A. Yes.

Q. And the statement that you put in the record, Mr. Shenehon, a few months ago, that that method of obtaining increment would be unfair was based upon a misapprehension of the entire method?

A. I will repeat that and emphasizing it, taking—

Q. That was only a part of the method?

A. Taking either half by itself and not considering the other part, the thing is unfair; and that was my under-

standing of your proposition; not the conjunction of the two.

Q. You did not understand at that time what the proposition was in its entirety?

A. I had not surrounded your conception.

Q. Suppose that the observations made by you of the discharge of the St. Clair River showed that with Lake Huron at a certain elevation, and Lake St. Clair at a certain elevation; those same elevations prevailing at the time of different observations, and that the discharge as found from these observations varied from 600 to 8,600, with no change in the elevation of Lakes Huron and St. Clair, to what would you attribute the variation in discharge?

A. What do you mean by variation of from 600 to 8600?

Q. 600 cubic feet to 8600 cubic feet?

A. You mean from the mean of the lot?

Q. No, two observations, the difference between them, the stages of the two lakes being the same, they are that much apart?

A. That is how many observations?

Q. Take a series of them where it appeared that Lake Huron and Lake St. Clair were at the same elevation?

A. Half of the divergence, 4300 is a little over 2 per cent, and a divergence of 2 per cent from the mean is not an extraordinary error of observation.

Q. I ask how you account for it?

A. It is what is known as error of observation. The river might have been not in equilibrium at the time of the observation.

Mr. Wilkerson: That is it would make a difference whether you got it with an upward swing or downward swing, is that it?

A. Lake Huron during that observation might have gone up and come down again, and the mean elevation might be the same as for a case where Lake Huron went down and then came up. The direction of the travel of Lake Huron during the discharge measurements might have some influence on it. Lake Huron might be rising during one of the observations, and falling during the other; and while the mean elevation of Lake Huron is the same, the effect on the river is different. And Lake Huron is as likely to be rising as it is to be falling. In a large number of observations, the effect of this is eliminated.

Mr. Williams: If it appears from these observations that the variation in the flow of the St. Clair River amounting to

two to three thousand cubic feet per second might go unobserved, do you know whether that is true or not?

A. You mean that the error of observation might be as much as two or three thousand cubic feet in an individual observation?

Q. Yes.

A. I should say yes.

Q. If that be true, I wish you would explain to us why you think that a flow of 4,000 cubic feet, and the effect of a diversion of 4,000 cubic feet at Chicago, could be so accurately arrived at as to enable you to say it will lower the entire lake level two inches or more?

A. The question as I understand it is, if in an individual observation the error of observation may be as great as two or three thousand cubic feet per second, why our work is not so inaccurate that we cannot get the effect of influences of four thousand or five thousand at Chicago. I say that the error of a single observation is that one is large while another is small. This is what is known as a compensating error, and enters into all forms of observations, and it is eliminated in the large number of observations of a series.

Mr. Williams: I would like to have the record show that we will offer in evidence at the hearing tables 9, 10, 11, 12 and 13, appearing upon pages 2878-9 of Appendix FFF of the Report of the Chief Engineers for 1903.

Mr. Wilkerson: Are you going to offer them without any further explanation as to the manner in which they were prepared or the conditions under which they were made?

Mr. Williams: Mr. Wheeler testified as to the probable degree of accuracy of the rainfall observations and how the rainfall observations were made. And several of your witnesses have testified that they thought they were not reliable, but they were the best they had; and we want just what there is of it.

Mr. Wilkerson: Of course this is not the time to object to their reception in evidence, nor do I want to be understood as imposing on you any hard rule with reference to making these tables competent. But I suggest that if any particular tables relating to rainfall are to be offered in evidence there should be some evidence with reference to the compilation of the particular table which is offered. And I will say we would be very glad to find out who the witness is and make it easy for you to put in that testimony. I do not wish to be put in the position of consenting that these tables are to be re-

ceived as an accurate basis for computations which may be made upon them.

Mr. Williams: I am not asking counsel to stipulate that when these go in they mean one thing or another. The witnesses have testified as to what degree of accuracy they thought attaches to these tables.

Mr. Wilkerson: Mr. Wheeler's testimony is not now fresh in my mind. If in his testimony he has covered the manner in which these tables were prepared so you think that is all you would want as making them competent, there would be no necessity for recalling him on that point. I merely suggest that a table, of course, is the statement of a result which has been derived through a certain method; and I should want, and I would think you would want, the record to show the manner in which these tables had been compiled. You are not able to throw any light on that at all are you, Mr. Shenehon?

Mr. Shenehon: No.

Mr. Wilkerson: It is knowledge entirely outside the scope of your work; a matter with which you have had nothing to do. Am I correct in that?

Mr. Shenehon: Yes.

Mr. Wilkerson: I will say this, Mr. Williams: It is perfectly obvious it will be necessary for us to return, and I make this suggestion about those tables: If there is anything that occurs to you that you would want in the record to make them competent when they were offered, I would be very glad to have the witness present who can testify with reference to them. The matter having been suggested at this time, I did not want to have you understand that I was not going to object to these tables when offered at the hearing, because I think I shall object to them.

Mr. Williams: On the ground of their not being material, not on the ground that we have not laid the proper foundation. If you are going to object because the proper foundation has not been laid, we will have to call Mr. Wheeler and go into all the details as to how the tables were prepared.

Mr. Wilkerson: There are tables and tables. A table may be prepared from one set of observations which is perfectly competent, that is evident. I think that is true with reference to these discharge observations. As to the rainfall tables, I do not know how much is based on actual observation and how much is conjecture.

Mr. Williams: They are all based on actual observation,

but as every one of your witnesses testified the observations were at such different points—

Mr. Wilkerson: There was such a vast field to be covered, the points are so far apart, that the result which is reached is of necessity subject to a very large correction on account of error.

Mr. Williams: That is a matter to be addressed to the court as to the weight which he will give to the evidence, not as to the competency of the evidence itself.

Whereupon the hearing was adjourned to Tuesday, June 15, 1909, at the hour of ten o'clock, A. M.

Detroit, Michigan, June 15, 1909.

Parties met on the above date pursuant to adjournment.

WILLIAM LIVINGSTONE, was recalled for further cross-examination by Mr. Williams and testified as follows:

Q. Of the six hundred boats, approximately, mentioned by you as being owned by the members of the Lake Carriers' Association, you testified that about 70 per cent of them would be affected by a lowering of the water at these critical points?

A. I said so, approximately, yes.

Q. And then the question was as to what percentage of that 70 per cent would be affected by a change in levels of the Detroit and St. Clair Rivers?

A. Well, if you will pardon me, suppose we start with this as a basis: I find in looking over our list that we have had some changes. We have altogether 598 boats in our Association, and of these 90 are tugs and lighters, which we do not class with the others. That would be 598; I told you 600. We have had some changes, one or two losses, one or two withdrawals and some additions, so the result is today, the total number of boats we have in our Association is 598. Of these 90 are tugs and lighters; they are harbor tugs, and they are a class by themselves so that they are not affected at all. That leaves 508 steamers and barges. Some of these 508, a few, are tow barges towed behind the large vessels so that the 508 is really what we use for commercial purposes, trading purposes. The tugs, you know are used entirely for towing.

Q. Of that 508, does your estimate hold good, that is that there will be about 70 per cent affected by a change of level?

Mr. Wilkerson: If he has those figures compiled, I suggest that he might go ahead and give a complete compilation.

The Witness: Just repeat your question.

Mr. Williams: Of the 508 boats and barges in service owned by your Association, how many would be affected by a change such as has been discussed in this case in the levels of the great lakes at the critical points?

A. We have of steamers of 22 feet and over, 322. We have 22 sailing vessels. What I mean by sailing vessels are the barges that are towed behind; 322 steamers and 22 sailing vessels. That makes a total of 344. Mr. Marr, who is secretary of this Association, at my request tabulated the figures for me. Of steamers of 19 feet to 21.9, we have 76, and tow barges 10, that makes 86. That would make a total of 430 boats in our Association that would be affected if they were loaded to their full depth, we figure, by any change in the water, for instance at the Sault Locks or at Ballard's reef. That would make a total of registered tonnage of 1,837,000 tons; perhaps to be accurate it would make 1,837,737 tons. Then you asked me in addition to that about the percentage of vessels that traded from one lake to another.

Q. Yes. Have you prepared an answer to that?

A. You can't give that absolutely accurately. At the Sault of course the government officers keep an accurate account of the tonnage. In 1908, the passage of registered vessels at the Sault was 13,908. That is net tons. Everything at the Sault is computed on the two thousand pounds basis, net tons. That was 41,390,557 tons. That made the average tons per trip 2,976. Between Lake Superior and Lake Michigan (that was one of the questions you asked) there were four and a half million tons carried, or to be accurate 4,503,055 tons. Taking the average of 2976, and that is the only way we could get at it, per trip; that was the average of what passed the Sault, you understand; in other words there were 13,908 tons passed the Sault net; that amounted to 41,390,000. That made the average tons carried per trip 2979. So, take the four and a half millions of tons, there was 1513 trips made; and at 2976 tons per trip, that made the percentage of trips to Lake Michigan 10.9, or call it 11 per cent. Then between Lake Huron and Lake Superior there was 1,651,000 tons of freight carried, and averaging that on the same basis, between Lake Huron and Lake Superior, say 2976 tons per trip, that would make 555 trips. That would make the percentage of trips 4 per cent, that is from Lake Huron to Lake Superior. Then

you take between Lake Superior and Lake Erie—that is Lake Ontario inclusive, because what goes to the lake, some of it goes through the Welland Canal, there were 35,236,482 tons, and on the basis of 2976 tons per trip, that is 11,840 trips.

You want to clearly understand in giving this, this is not confined to the Lake Carriers. This takes everything in, no matter how little or big; everything that is in commission. These percentages are not confined to the Lake Carriers' Association because, although the largest tonnage on the lakes is in our Association, there is myriad of small boats that do not belong to the Association. Between Lake Superior and Lake Erie we have 35,236,482 tons; dividing that by 2976 tons per trip would make 11,840 trips. That would make the percentage of trips from Lake Superior to Lake Erie 85 per cent. I believe I testified before it would be approximately about 80 per cent. It seems to exceed that.

You have got to bear in mind, so you will get it intelligently that in making these averages there is a large number of small hookers you know, running up to a large amount, that are not in our Association. For instance the lumber carriers are not in our Association at all and a great lot of others; but all the large modern boats are in the Association; our percentage is very large.

Q. You testified, Mr. Livingstone, that you were getting out a printed list of all the boats in your Association?

A. Yes.

Q. Has that been brought out yet?

A. Mr. Marr tells me that will be out day after tomorrow. It is in the printer's hands.

Q. What is the name of the publication? Does it have any special name?

A. Just a list of vessels having membership in the Lake Carriers' Association; gives a list of all those. We will be glad to furnish you a copy.

Q. Is there any authoritative publication giving the names and dimensions of all the vessels now plying on the Great Lakes?

A. Oh, yes, the Commissioner of Navigation has a report which shows it in full.

Q. Is the Blue Book of American Shipping also an authority?

A. The report is made out by the Commissioner of Navigation in the United States, Mr. Eugene T. Chamberlain.

Q. And that Blue Book is considered an authoritative publication?

A. Oh, yes, it is supposed to be the—

Q. You gave us very briefly the other day your experience as a navigator of the Great Lakes. Will you give us a little more in detail your own experience, when you first became interested and in what way, in lake navigation?

A. I think that I first became interested in vessels, I won't be sure whether it was in 1866 or 1867; it was one of those two years. I would have to look back and see. And I became interested by buying the controlling interest in a tug called the John S. Noyes, which was a Canadian tug. I bought a couple of barges; I wanted her at that time for bringing wood down from Bear Creek, or as we call it really the river Sidney.

Q. And that was your first experience as a vessel owner?

A. That was my initial experience as a vessel owner, yes. I remember thinking I was quite a—

Q. Just go on from that and indicate the progress made by you in your career as a vessel owner?

A. We traded with her that season. That was the first boat I was interested in and consequently I happen to remember it more particularly than some others very much larger. I remember thinking, taking her up across the flats and down again, occasionally thinking I was quite a man. That was the start.

Q. Just sketch the history of your career?

A. Well, that would be rather difficult. I have been interested more or less ever since, one way and another. There was at one time here on the lakes—it is hard to explain unless you throw a little side light on it—there was a time here for instance in 1866, 1867, along about that time you know, that on the Great Lakes here 93 per cent of the tonnage was sailing vessels, and less than 7 per cent steam. You see it has become a regular transformation scene since that time because while 93 per cent of the vessels on the lakes at that time were sailing vessels and 7 per cent, less than 7 per cent were steam, today, for instance, all the figures have been changed. I think the figures if accurately taken would show about 96 per cent steam and about 4 per cent sailing vessels, and in those sailing vessels I include the barges that are towed behind, the steam barges.

Q. You are a considerable owner of lake vessels at this time?

A. I am interested more or less, yes, sir. What I was going to say was that I kept branching out. My business was on the dock, naturally would be at that time; and I think I was at that time one of the largest tug owners on the lakes here. The vessels at that time, on account of their being sailing vessels, there was a very large number of tugs used for towing vessels through. All the vessels at that time, running along down until steam began to supplant sailing vessels were all towed through the rivers. We used to build large heavy tugs, not like these little harbor tugs; and we would go away outside, way up on Lake Huron; sometimes go as far as the Straits to get the vessels; depending on whether business was dull or not, and we would tow them through the rivers. None of these vessels you know expected to sail through the rivers themselves; they were all towed from Lake Huron or Lake Erie, towed through the St. Clair River, Lake St. Clair and the Detroit River. And we had an association here in 1869, of which I was the treasurer, practically the manager of it. We found that we had more tugs than sufficient to do the business. We had some, I don't remember forty-five or fifty tugs, so we found that we had overstocked the market. So we rather pooled our issues that way; laid up the boats that we didn't want and just kept the number sufficient to do the work economically. Then as steam kept supplanting sailing vessels as the years rolled by, the demand for tugs became less all the time. I then became interested in steam barges and one thing and another.

Q. Very briefly stated, you started as a very small owner of lake craft?

A. Yes, sir.

Q. And you have grown to become one of the largest and most influential lake owners?

A. Oh, no, I do not say that; I do not say that.

Q. I am saying it.

A. Not as an owner, no, because there are some very large fleets on the lakes. For instance you take the Pittsburg Steamship Company, they have a hundred boats.

Q. Then I will withdraw my question, if I did not state it accurately.

A. I have attained more prominence, perhaps, in this way: not so much as being an owner, though I am interested in a number of fleets and all that sort of thing, but I have attained more prominence perhaps on account of my position as president of the Lake Carriers' Association.

I should have said during this time too I represented the Western Transportation Company here, a line of steamers owned at that time not by the New York Central; they did not own them then. They had a line of a dozen steamers and half a dozen passenger boats. The passenger boats ran between Buffalo and Chicago, and that is now called the Western Transit Company; now belongs to the New York Central Railroad, but at that time we ran under contract with the New York Central Railroad, so I handled these boats here as agent, represented them.

Q. Let me ask you this question: What would you say as to the opportunity presented at present for a man to start out with the same amount of capital that you had in 1866 or 1867 and alone achieve the same success that you have achieved, during that period?

A. Well, I have not said anything about achieving success, myself.

Q. I have considered it success, and assuming I am right in saying you have been a successful man, what are the opportunities today for a man to start out along the same lines, with the same amount of capital that you had at that time, and achieve the same degree of success?

A. That is a hard question to answer.

Q. Would you say a man could do it as easily now as you did then?

A. No, sir, oh no, you can readily see that.

Q. Will you give us a reason?

A. For instance, when I first went into the vessel business, the Welland Canal had not been enlarged at that time. A boat going through the Welland Canal, sailing vessel, that carried 20,000 bushels of corn, was considered a good sized vessel. And at that time, on the gold basis, we built those vessels on the basis of about a dollar a bushel; that is the cost of building. The cost of building was much smaller. And they had to be built then like a dry goods box, almost, so as to get the greatest possible carrying capacity. It was no uncommon thing then for half a dozen men, you know, to own one of these vessels. When I just turned my majority, at the time I spoke of the Noyes—if my memory serves me right, and it is pretty accurate on that—I think I put $4,400 in that boat and I borrowed half the money to do it. And you take boats now, you can see what an evolution there has been from those canal schooners, built on a gold basis, on the basis of a dollar a bushel, costing $20,000. Sometimes half a dozen men

would be interested, and the captain very frequently had some interest in her. Now, you take that class of boats today, if you shingled the lake with them from Detroit to Chicago, you would not take them as a gift, because the more you had of them the worse off you would be. It has evoluted from that little vessel of $20,000 cost until you can't build a modern vessel, such as we build today short of from—depending on her size, having 7,500 tons, and then depending on how she is fitted out—from $275,000 to four hundred odd thousand dollars. So that you see the vessel business has gone into entirely different hands; strong hands, men of capital and men of means. It had to be so. So the chances for the small men of course—don't misunderstand me in one thing in these United States of ours, and I never leave the country and come back but what I think it is bigger than the last time. There is always room at the top for the fellow that works right, and always men make a success everywhere. But I mean the chances as a general proposition; a man could not start with a small capital as he could before. It does not take but a little you know, you take about three vessels and a man gets into a million dollars or over.

Q. Now you have referred to the Lake Carriers' Association; you are the president of the Lake Carriers' Association. Will you please state the nature of the organization?

A. You have the whole of it in that book I gave you. It will give it to you more clearly than I could. It states clearly and succinctly the object of the Association. Our constitution and by-laws are printed, and Mr. Marr will send you that when he sends the other; and that will give you clearly and succinctly the object of the Association, what it is organized for and its purposes.

Q. Does the same book give the names of the members of the Association?

A. No, we have a membership list separate from that.

Q. How many members are there in the Association?

A. I can't tell you; about seventy or seventy-five.

Q. And that membership consists of corporations and individuals, I assume?

A. Oh, yes. Nearly all boats are put in corporations, on account of the way they place stock. There are practically no vessels now—that is it is exceedingly rare where a vessel is owned by an individual; almost all form corporations.

Q. So that substantially the entire membership consists of corporations owning and operating fleets on the Great Lakes?

A. Yes. If there are but three or four owners even, they prefer to have it in corporations; it handles better every way. Lots of single boats form a corporation. If she costs $400,000, they will organize under the state law and have a corporation; then they are only responsible for their stock; limited liability.

Q. How many members would you say there are?

A. Mr. Marr suggests something to me which perhaps I ought to explain to you. It is not an uncommon thing for one member to represent five or six different fleets; he will be the manager of these lines. For instance in building up fleets, they will start and build one up of two boats, and then be organized under one company, call it anything, American Company, Atlas Company; then the business progresses and he wants to build a couple more boats. He may take in the same stockholders and add some others, so there will not be exactly the same stockholders, and they will call that a different company; so that in some cases we have one man who manages really four or five corporations, and he is the representing member in our association.

Q. How many members would you say there were in your association that own only one boat, for instance?

A. Not very many.

Q. Eight or ten?

A. I should think that would cover them. Of course there are some men that have one boat. There are one or two, two or three men that have one boat, that are interested stockholders in other corporations, you understand. A man may manage one fleet and be interested in a number of others.

Q. Is the United States Steel Corporation a member of your association?

A. No, not in that name; it is the Pittsburg Steamship Company. But the Pittsburg Steamship Company is really owned by the United States Steel Corporation, and the president and general manager of that line is Mr. Harry Coulby. It is a separate organization from the United States Steel Company. It is a corporation organized of itself and by itself, but all the stock is owned by the United States Steel Corporation.

Q. What is the next largest owner in your association? I assume that the company you have just mentioned is the largest owner of vessels?

A. Yes, they are the largest single owner, have the largest number of boats.

Q. What is the next largest owner?

A. The Gilchrist Transportation Company comes next.

Q. With what other interests is that company affiliated?

A. That is entirely an independent company. The Gilchrist Transportation Company is the second largest on the lakes, and that is made up of stockholders. I don't know how many stockholders they have.

Q. It is not affiliated with one of these large corporations?

A. No, it is entirely a vessel company, organized of itself and by itself.

Q. How many boats do they have approximately?

A. They have got sixty odd.

Q. Can you recall what is the next largest owner?

A. G. A. Tomlinson; they have several corporations in their fleet. You see that is owing to the fact that they are not the same set of stockholders; there will be some stockholders in all the boats, but not all the stockholders in all the boats.

Q. And they have about how many vessels?

A. Seventeen or eighteen; I am not sure which. I think Tomlinson has the largest average of any single fleet, the largest average tonnage of any single fleet on the lakes because all his boats are modern boats and all built within the—

Q. And the next largest is what, the Cleveland Company?

A. I think the Cleveland Cliffs is probably the next largest, they and the United States Transportation Company. It is kind of a toss-up between them. The Cleveland Cliffs boats are the Cleveland Cliffs Iron Company.

Q. The Pittsburg Steamship Company, how many vessels did you say they have?

A. They have got over a hundred. 108 Mr. Marr says. Perhaps it might throw a little side light on this tonnage business if I were to say this, if you do not object: that is you know all of the smaller class of vessels, as they go out of existence, you understand they are not replaced; they are passé; they are things of the past. In other words to boil it down, the transportation problem of today is all boiled down to one sentence and that is this: what will carry the largest amount of freight for the smallest amount of money. And experience has demonstrated that the modern fleets of boats that we are building now (I don't know what they will reach in the future) for instance a ten thousand ton boat we will say; it is impossible for one of the old type boats, and we used to consider a 3,000 ton boat very large, when the 10,000 ton boat will make money and pay a good fair dividend, it would be impossible

for the smaller boat, you know, to pay expenses. We have 10,000 ton boats, for instance that with the improvements in machinery, etc., the triple expansion engines, or quads (very few quads on the lakes), that will make the round trip now, for instance, carrying 10,000 tons of ore, and their consumption of fuel would be less than some boats carrying only 2,500 or 3,000 tons. And then with all the modern machinery and every conceivable attainable thing—and there are no boats in the world that are more modern and up to date than our modern freighters, so the result is that they only carry a few more men than the smaller boats do, and they are of the cheaper class of men, because, of course you have to have officers, masters, pilots, engineers, etc., on the smaller boats the same as you do on the larger ones. Of course on the larger boats they get a little more salary, but that is small as compared with the whole, so that the fixed cost per trip of a 10,000 ton boat as against a 3,000 ton boat is not at all in proportion, you understand.

Mr. Wilkerson: About what percentage of the freight is carried by these large boats about which you are testifying?

A. What proportion of the general freight of the lakes?

Q. Yes, the boats that you speak of as the modern boats?

A. I can only estimate that now.

Q. Approximately?

A. Oh, I think 80 per cent would be a low estimate.

Q. I am distinguishing between freight on boats of that kind and what you referred to a little while ago as the package freight boat?

A. The package freight boats, all of them on the lakes, as a rule, are owned by the railroads. For instance the Western Transit Company line, that is owned by the New York Central Railroad; the Mutual Transit Company line is owned by a combination of three or four roads; the Lehigh Valley Transit line, that is owned by the Lehigh Valley road. So that outside of the railroads, there are practically no package boats. You understand package freighters are built expressly for the purpose of being the connecting water link between lake and rail; they make an all-rail rate, and that would be a trifle higher than lake and rail; so that all these boats now are either owned or controlled by the railroads, and they are built for a specific purpose, different from ore and grain, that can be handled by elevators and big clam shells, and all that sort of thing. That freight has to be handled by hand. Of course they have engine hoists that hoist it out of the hold

of the boat, but it has to be trucked; you can't handle it like grain and ore. It has to be trucked in trucks by the stevedores on the docks; trucked off the deck of the boat on to the dock. But that percentage is very small; that is a special trade of itself.

Mr. Williams: And the package freight steamers would not be particularly affected by any slight change in the level of the lakes?

A. No, I should think not. I have not investigated that specially. You take such boats, in the fall of the year they would be affected surely. I will have to look that up.

Q. You did not take them specially into consideration, or have them in mind in arriving at your conclusion as to the effect on navigation generally?

A. No, I did not, although there are some of the new order of boats they are building that have a considerable freeboard. I do not make the statement positive, but I have an impression that some of those newer boats run as much as 24 feet freeboard; but I will not state that as a fact for I might be mistaken. I think some of them are moulded for 24 feet but I will not make that as a positive statement.

Q. During the early days of navigation on the Great Lakes, I believe you have already stated that very frequently the Captain or sailing master had an interest in the vessels?

A. Quite frequently. I do not mean in all cases but in many cases.

Q. What is the general rule now?

A. Oh, well, it is the exception and not the rule now, although we have Captains on the Lakes, quite a number of them, that own stock in some of the companies. Of course you take a line like the Pittsburg Steamship Company, no outsider could own stock in that because it is a line owned by the corporation itself; the stock is all held by it. It is just one of the connecting links, you know, in their line of business.

Mr. Wilkerson: Of course there is a vast number of stockholders who hold stock in the holding company?

A. Yes, the profits of that company, I don't know how they arrange it, but it is just a subsidiary company.

Q. United States Steel Company is a holding company; it owns no property outright, but it owns stock in a large number of subsidiary companies?

A. This is one of its subsidiary companies. I will say

one thing for the company: it is one of the fairest and one of the best managed steamship companies on the lakes, in its dealings with its employes and everybody else.

Mr. Williams: Q. Is navigation interfered with to your knowledge to any considerable extent by the swiftness of currents in the St. Clair and Detroit Rivers?

A. If I understand the question clearly, of course a vessel going up stream would not go so fast, of course, as a vessel going downstream. Assuming there is a two and a half mile current, three mile current—

Mr. Wilkerson: You mean the effect of the current in producing accidents.

Mr. Williams: I want to know whether navigation is interfered with; that is whether it is more difficult to conduct a successful business in navigation where you encounter swift currents and whether there are such currents now in the Detroit and St. Clair Rivers?

A. Oh, it is always more dangerous; the liability to danger is almost always greater for a boat navigating with a current than slack water because you can readily see why.

Q. What I am getting at is: is there a sufficient current during normal conditions now in the St. Clair or Detroit River to interfere with navigation to such an extent as to make it dangerous?

A. Well, that depends altogether on circumstances. I would not say it would make it dangerous because if a man has his boat under full control and supposing he obeys all the rules of navigation, it ought not to be dangerous. But like machinery human nature is fallible and where there is a current, there is more danger than where there is slack water, and the greater the current the greater the danger.

Q. Are there such currents in the St. Clair and Detroit Rivers?

A. Yes, in the rapids and in other places. Of course in the rapids that is a dangerous spot, because you take a boat coming down a rapid, if it is meeting another boat, and there is danger of collision, she can't stop and back there, cannot control herself; whereas if it were slack water, supposing the Master or Captain desires to stop and back, and back her strong with the whole power of his engine, he may not be able to back her there where he could control her without any difficulty whatever in slack water, so a current is always more or less dangerous.

Q. Would you consider an increase in the current in the

St. Clair River or in the Detroit River objectionable to the interests of navigation?

A. Yes, sir, I would. May I say just there, there is one reason why we are constantly fighting for double channels, so that boats won't meet each other in the rivers.

Q. How swift would you say a current would have to be, to be a dangerous current?

A. I should think a four mile current would come under the head of a dangerous current, because in case of danger of collision or anything of that kind, with the difficulty in controlling, backing and stopping, you can readily see that coming down stream with her own way and the way of the current, it takes a great deal more power to stop. The boat going up stream, with the current against her she can stop very quickly, or if it was slack water. So just to avoid that very thing we have been striving, on account of the great increase in the tonnage on the lakes, which has grown by leaps and bounds the last seven years, we are trying as far as practicable to get double channels all the way up the rivers. When we get the so-called Livingstone channel down here completed, we will have a double channel there. We expect the Canadian Government to build another channel, at least we are hoping so, and from the assurances I had the last time I was at Ottawa, I think we will get it in the near future, on the Canadian side of Fighting Island; that is the Canadian island down the river here. And up in the St. Clair River, we are making double channels all the way up there.

Q. Do you know at what points there is a current substantially equal to four miles an hour?

A. The current in the St. Clair Rapids abreast of Port Huron, say from Port Huron running up to Fort Gratiot, my impression is—I do not speak by the card—my impression is that current is about six miles an hour, yet I am not positive about that. It varies a little; they used to call it seven, but that is an over statement I know.

Q. Are there any other points where there is a current of that velocity?

A. No, not on the rivers here. I do not know of any place on the Sault River that has that current, with the improvements.

Q. Suppose the channel were 21 feet deep and 500 feet wide, would it then be objectionable to have the current increased?

A. I would have to turn you over to the engineers on that. I could not figure out the difference in velocity.

Mr. Wilkerson: I wish to note an objection to this line of cross-examination, on the ground that it is not proper cross-examination of this witness, and on the further ground that the question of the determination of the modification of the current in navigable waters of the United States is one exclusively for determination by the government itself.

Mr. Williams: Q. I am just asking you, as one familiar with navigation, whether or not in your opinion, no matter what the current is today, in a channel 500 feet wide and 21 feet deep, whether you would consider it objectionable to increase the current?

A. Of course it is impossible under existing conditions not to have a current; but every foot, so to speak, that you increase the current, of course it makes navigation a little more hazardous; it is impossible to be otherwise.

Mr. Wilkerson: I assume my objection will be taken to apply to each question in this series with reference to current, without repeating it.

Mr. Williams: Yes.

Q. That would be true irrespective of the dimensions of the channel?

A. Oh, yes, that would be true. Of course the narrower the channel, the shallower the depth, the greater the danger would be. For instance you take a 500 foot channel and you have some obstruction, with our big vessels, a man would not have the room to put his helm to port or starboard and steer clear that he would have in the thousand foot channel. Another thing, the deeper you make the channel and the narrower you confine it, it stands to reason the velocity of the water would be greater. You have two men who can answer that, Mr. Randolph and Mr. Shenehon.

Q. I am speaking merely from the point of view of the practical navigator?

A. That is all I can talk from.

Q. I am asking you also as a practical proposition, and as an experienced navigator of the great lakes, which you would consider preferable, a 21 foot channel with a slow current or a 25 foot channel with a swift current, both channels having equal width?

A. You would have to give me some idea of the difference in the swiftness.

Q. Suppose the 21-foot channel had a current of a mile and a half an hour?

A. Yes.

Q. And the deeper current had a channel of say four miles an hour?

A. I would hate to tackle the four mile current; that is I would want double channels if I was going to tackle the four mile current; that is pretty swift.

Q. Well, take it two miles for the 21-foot channel, and 2½ miles for the 25-foot channel; which would you consider the best adapted to the needs of navigation?

A. If I had the money to build the boats, I would take the 25-foot channel.

Q. Assuming the present condition of navigation on the great lakes, which would you say was best adapted to the present navigable needs?

A. Oh, as we are situated at present, the 21-foot, about the 21-foot channel or thereabouts is the better channel at the present time. Why? Because you know a chain is only as strong as the weakest link in it; and it does not make any difference if you have a hundred feet of water outside, if you have only got say 19 or 20 feet in your harbors, because what governs the draft of vessels are the harbors in which you have to unload. Now, outside of the harbors, we can go to Congress, for instance, and if the engineers agree with us in our conclusions, and support it and recommend it, we can get appropriations to deepen the waters outside. But in the harbors, we run against this proposition: there are so many private interests to be consulted, and property that would have to be condemned, and all that sort of thing, a hundred and one difficulties, more than I could enumerate, that you have to contend with, that the getting of your harbors deepened, is a very, very much slower process than it is outside. So that it would take years, for instance, to accomplish the depth of harbor you would want for a 25-foot channel. That is the reason I make the statement. What you could accomplish in a comparatively short time outside is a very difficult proposition in the harbors. And that is one proposition that really is confronting navigation today, that there are many harbors or quite a number of harbors that should, even under present conditions, be deepened materially, and passages for large boats made.

Q. Would you consider, Mr. Livingstone, that an increase

in the current along the river front at Detroit would be any detriment to navigation?

A. Yes, sir, it would be some, depending on how much or how little it was.

Q. Depending on the amount of the increase?

A. Yes, sir. Where you have a current, there are always more elements of danger than where there is no current.

Q. If Lake Michigan were lowered two feet, would navigation be affected anywhere except where the water is less than 30 feet deep?

A. I think it would, sir. I would have to look the chart over; I would not want to make the statement off-hand.

Q. Where?

A. I think it would make a good deal of difference, and yet if you ask me to enumerate where, I could not at the present moment. For instance I will explain this way: They have adopted, which is by all odds the best way in the world, the Lake Survey have adopted a method of sweeping the lakes for obstructions; and the result is that since they have adopted this method and put it in force, they are continually finding obstructions that we did not know existed before. Then in addition to that, you have got to bear in mind, you take a boat in a heavy sea, heavy storm, for instance one of our big boats, let us suppose that boat draws 22 feet of water, whatever she would draw; you see she has got to have under her in a heavy storm quite a few feet of water more than that to keep her from striking the bottom.

Q. How many feet?

A. Well, it would depend on the velocity of the wind, extent of the waves, etc., how much it was tossed.

Q. Assume a violent storm?

A. A violent storm would take six feet.

Q. That would be 28 feet?

A. Yes, sir.

Q. That would make 28 feet of depth necessary, so that if the water was more than 30 feet in depth, and if it lowered two feet, you would still be within the range then?

A. Yes, but here is what you would find, based on the experience of the Lake Survey: We have found since they have adopted what I regard as the perfect way of obtaining the depths of the lake, this sweeping we have found sporadic—it is not confined in any scientific way, but in a sporadic way we find hummocks, obstructions that I think two feet would make a wonderful difference in, in many cases. In

other words we would have a great many accidents if you lowered the lake two feet that we do not have now. Every foot you lower the lake you bring obstructions in force that do not exist before. That stands to reason.

Q. At the point where those obstructions were, getting outside the limits of my question, the water would not be 30 feet deep?

A. You may take for instance the water of a lake, the average depth of it might be 30 feet, and yet there might be a number of places in that lake where there might be hummocks or rocks sticking up like that, perhaps not as abrupt as that, but we find a good many.

Q. Would navigation be interfered with except at those points where the water was not 30 feet deep?

A. Why, certainly not, why would it? I do not see how it could be. But where it was affected it would be affected bad.

Q. Certainly, but I was speaking of the point where the water was fully 30 feet deep.

A. Well, you talk about, if I understand you, if Lake Michigan was lowered 2 feet, wasn't that your question?

Q. I asked whether or not if Lake Michigan was lowered two feet navigation would be affected except in those points where the water was less than 30 feet in depth?

A. Yes, but if you lowered Lake Michigan 2 feet, it would carry the Sault River two feet, and see what a serious proposition that would be.

Q. That would make it there less than 30 feet?

A. There are lots of places we haven't got 30 feet now.

Q. I am assuming a condition where we admit that where the depth of water is less than 30 feet a lowering of two feet would be a serious interference?

A. Oh, yes.

Q. But would it be any interference anywhere else, except where the depth was less than 30 feet?

A. How would it be possible to lower Lake Michigan two feet without lowering all the harbors two feet?

Q. I concede in those harbors it would interfere, but I ask whether it would interfere anywhere except at those points where the depth of water was less than 30 feet?

A. Perhaps not. I should be afraid that like dynamite that two feet would be loaded. When we used to have on the Lime Kiln only 12 feet, we sailed over places on the lakes

that we can't get near now. Every foot makes a great difference.

Q. You just spoke of the period of time when there was only 12 feet of water on the Lime Kiln Crossing?

A. Yes, 1867, '8 and '9; yes 12 feet.

Q. For what distance was that condition prevalent?

A. At the Lime Kilns?

Q. Yes.

A. It ran down three or four, four or five miles all through the rock cut.

Q. Do you recognize any difference in the cost of fuel required to move a loaded vessel from Lake Erie to Lake Huron as compared with that required to propel the vessel from Lake Huron to Lake Erie?

A. I don't think I clearly understand that.

Q. Does it cost any more for fuel to run a vessel from Lake Erie against the current into Lake Huron than it does to run the vessel from Lake Huron back into Lake Erie?

A. You are figuring as to whether there would not be a margin in favor of the current, you mean?

Q. No. I am figuring whether or not there is a margin against the current; if it costs more to run against the current than it does to run with it?

A. Yes; I would not undertake to figure it out.

Q. What I am trying to get at is in making your estimates of costs of operating a vessel, would you figure more fuel in making the up stream trip than you would in making the down stream trip?

A. If you went loaded, yes.

Q. Loaded both ways?

A. That is assuming the draft of water was the same both ways. Yes, a little more.

Q. About how much?

A. I can't give you that; I would have to make some figures on that. The man sitting back of you ought to be able to give you that.

Q. He is not testifying and you are. I wish to get it in the record.

A. I am willing to go on record for anything I know something about, but I want you to understand the older I get, the more I find out, the less I know. But it stands to reason, let me put it this way: Supposing two boats started from Duluth, boats of exactly the same size drawing exactly the same water; one was coming down and the other going up. If both

boats make the same rate of speed, you can naturally see you would burn a little more fuel. I can't tell you just how much, but you would burn more on the boat going up against the current than you would in the other, because the resistance, displacement, everything else would be greater. But when you come to figure it out I could not give you that offhand. You understand that is based on the supposition she would make the same time. But if she went a little slower and made fewer turns, take more time, she would accomplish the same result with the same amount of fuel.

Q. How much more time would it take?

A. I would have to figure that out, because I would have to take the number of revolutions. For instance if you turned exactly the same number of revolutions, the fuel would be the same. Every turn, every revolution per minute you increase the engine, why you can readily see it would cost more fuel, a little more fuel.

Q. Suppose that the currents in the Detroit and the St. Clair Rivers were reduced say 20 per cent?

A. Yes.

Q. From what you have said, I infer you would say that would be a benefit to navigation, if you had the same depth of water?

A. Well, there is a problem comes in there that I can't answer in this way: If you take the current out entirely, it is a question in my mind if that would not reduce the level of Lake Erie, and if you reduce the level of Lake Erie then you reduce the harbors in Lake Erie.

Q. Assuming the levels of Lake Erie and Lake Huron are not changed in any respect, and the depth of water is not made any different?

A. It seems to me the level of Lake Erie is 8 inches less than Lake Michigan.

Q. Assuming there is no effect whatever on the level of any of the lakes or the depth of water through which you are navigating, or any of the channels, would the reduction of 20 per cent in the current alone be a benefit to navigation?

A. It would be a benefit to this extent, although there are experienced vessel men who might differ with me on that subject: it would be a benefit to the extent of lessening the chances of collision; that and that only. There are some men that would rather have the current and make the extra time and take the chances of collision, so there would be a difference of opinion there.

Q. Suppose under the same conditions that the currents were increased 20 per cent, would you say that was a detriment?

A. Yes, sir, I should say it was a detriment, because that would increase the elements of danger.

Q. Would you consider that it increased the expense of operation substantially in any way?

A. The expense of operation?

Q. Yes.

A. Oh, practically not. If you eliminated the question of danger of collisions, no, not particularly. A boat going up stream would take a little more fuel. A boat coming down stream would be propelled somewhat faster so the thing would about even itself up.

Q. What do you consider the season of navigation?

A. Two hundred and forty days; 235 to 240. It varies a little some years.

Q. From what time to what time?

A. From its opening, we will say, along in the latter part of April and boats usually, many of them the insurance expires on the 5th of December at noon and if a boat leaves ten minutes before noon on the 5th of December, the Insurance Company has to carry her insurance in on that trip, on the pro rata basis as to her insurance.

Q. That is the date on which the insurance rates change, the 5th of December?

A. They expire, yes, sir. There was a time here, under certain conditions policies would run to the 10th, but now the policies are made to expire on the 5th. But if you are out, you understand, supposing you are on your voyage, of course by notifying the Company and paying the pro rata, they have got to see you home, but you can't start away, unless you get a special risk.

Q. If you get a special risk, the rate is much higher?

A. Oh, yes; very much higher.

Q. And that special rate is in force from December 5th on until the opening of navigation in April?

A. Yes. You would have to pay a very much higher rate, you know; some companies might not insure you at all.

Recess to 2 p. m.

Parties met at 2 o'clock p. m.

WILLIAM LIVINGSTONE resumed the stand for further cross-examination by Mr. Williams and testified as follows:

Q. What, if anything, has the Lake Carriers Association to do with the improvements of the harbors and connecting waters of the Great Lakes?

A. What have they to do with it?

Q. Yes.

A. Only this: that, for instance, if they think there is a harbor that needs improvement, and the necessities of navigation are such that it is important for them to get the improvement, they go first to the United States engineers of the district, who have that particular district in charge, and give them their reasons, give the engineer in charge their reasons why a certain thing should be done, and urge its being done, and then they go to Washington, if Congress is in session; go before the Rivers and Harbors Committee, if it is a subject that comes before them, and they have a hearing before the Rivers and Harbors Committee, give them the reasons why and wherefore, that this is a needed improvement, and that it should be done.

Q. It is a persuasive influence only?

A. Oh, entirely, Mr. Williams. Of course, if the Rivers and Harbors Committee, or whatever the committee is—depends on what it is; it may be the Light House Board; it might be something in the War Department; depends on each particular department the thing you want comes under.

Q. What I wanted to get at was this: does the Lake Carriers Association, or any member of it, contribute either directly or indirectly in any way to these improvements, from a financial point of view?

A. No, sir. I will have to qualify that perhaps on reflection in this way: that we have lights which are kept and paid for by the Lake Carriers Association.

Q. You have what?

A. Lights, aids to navigation of that kind, and if there was a wreck, for instance, in the way of navigation, there is always a good deal of delay; there is always a good deal of red tape about everything pertaining to the government, and if it is in the way we promptly light it and see that it is

lighted. We have a lot of aids to navigation that we pay for exclusively.

Q. My inquiry went only to the question of deepening and improving the channels.

A. That we go to Congress for, and when we want light houses and so forth, we go to the Lighthouse Department, and the Rivers and Harbors.

Re-direct Examination by Mr. Wilkerson.

Q. In your cross-examination this morning, Mr. Livingstone, you spoke with reference to currents in rivers, and the relation of the current to navigation. What do you know about the Chicago River, for instance, now, as to the effect of the reversal of the flow there, and the current in that river on navigation?

A. I know that the current there, in that narrow river, adds very largely to the dangers of navigation there.

Q. From practical experience, you know that?

A. Yes, sir. I know that the number of bridge accidents in Chicago—

Q. Attributable to the current?

A. Yes. They are very much larger than any other harbor I know of; I should say approximately double any other harbor. The accidents are greater in number than any other port on the lakes.

Q. Has there been any change in that since the flow of the river was reversed?

A. Well, I can't talk very intelligently about that; that is from personal knowledge. The understanding was, you know, that when the lake water was turned in there, if I understood it correctly, they were to have practically slack water there, but that is not the case. I have an impression that sometimes they have a current there of about three miles an hour, but I am not sure about it. I will say this by way of conclusion, and I am sure I am right, although I am not so sure about the others; I know the number of bridge accidents, etc., in Chicago is greater than any other port on the lakes, very much greater.

Q. With reference to the relation of the current to navigation, you spoke of two channels. I wish you would explain that a little more fully.

A. The reason I spoke of two channels was because it is like a double track on a railroad. With double channels, for

instance, a boat bound up would take one channel and boats bound down would take another, and therefore there is no meeting of boats. The great danger from collisions, you know, of boats coming together, is two boats meeting in the same channel; where the up bound boat, for instance, takes the easterly side and the down bound boat takes the westerly side, it is just like a double track on a railroad; all the trains going one way on one track and coming on the other; the danger of collision is very much minimized.

Re-cross Examination by Mr. Williams.

Q. Speaking of the number of accidents in the Chicago harbor, bridge accidents, is it not a fact that there are more bridges across the Chicago River than across any of the other rivers that you know of?

A. Well, I guess there are more. There are quite a few in Cleveland. I think there are more in the Chicago harbor. I would have to look that up before I could answer intelligently.

Mr. Williams: That is all.

Mr. Wilkerson: That is all.

FRANCIS S. SHENEHON resumed the stand and testified further as follows:

Re-direct Examination by Mr. Wilkerson.

Q. I would direct your attention, Mr. Shenehon, to two or three matters about which you testified on your direct examination: first, with reference to the effect of government improvements in harbors and channels, and the compensation which has been attempted in connection with those improvements. Is there anything which you care to add to what you have already said?

A. Yes, I would like to read an extract from my report on the preservation of Niagara Falls, an unpublished report.

Q. That contains some statements which you say are true?

A. Yes.

Q. Will you read it?

A. This is from Chapter 4, The Outflow of Lake Erie, page 21; an unpublished report. I say: "Artificial changes in the river (speaking of the Niagara River) regimen have

doubtless occurred, and these in part have restricted the flow, and have tended to raise the level of Lake Erie; and in part have made the flow more facile and tended to lower Lake Erie. The building of the International Bridge at Buffalo, whose piers and the rock banks flanking them reduced the cross section of the river at the crossing 18 per cent. doubtless raised Lake Erie. The building of the water works intake pier further up doubtless had a small conserving effect. The encroachments on the river channel for docks along the water fronts of cities like Tonawanda have a slight tendency to raise Lake Erie, and the dumping of material from dredged cuts has a very slight tendency in the same direction. On the other hand, the dredging out of river shoals facilitates the outflow and tends to lower Lake Erie, and the diversion of water above the first cascades for power purposes, by increasing the river flow, tends to lower Lake Erie. In the case, however, of a company throwing a wing dam into the river to deflect water into its intake, and diverting no more water than in a state of nature flowed in the intercepted portion of the channel, no lowering effect on the river or lake may occur. Indeed, in such a case if the water used and that wasted were less than the natural flow over the appropriated river bed, the effect might be to raise the river and Lake Erie. Any change in the river regimen between Buffalo and the rapids above the cataract coming from scour or deposition is believed to be exceedingly small, and the effect on the outflow of Lake Erie in a decade is inappreciable. Scour would serve to facilitate the flow and lower Lake Erie; deposition would serve to increase the resistance and raise Lake Erie. Such small changes as are likely to occur balance each other and the effect on the lake levels is mostly compensated."

Q. Is that all you care to add from that report?

A. Yes.

Q. Is there anything further you would like to add?

A. Yes. In regard to the Detroit River, I would like to make a statement that I have recently seen a chart which indicates that the shore line along the river front at Detroit has been reduced 350 feet by the dock improvements; and how much the decrease in river width has come from improvements on the other side of the river, I am not aware of.

Q. What would be the effect of that filling in?

A. That would be to compensate any increased outflow due to river improvements.

Now, in my prior examination, I stated that it was my

opinion that any lowering of the lakes that might have come from channel improvements was small; and since that time I have made some examinations of water levels, and I would like to introduce them.

Q. There were some questions put to you with reference to the change in the level of the lakes, computed as between two different periods arbitrarily selected. Now, have you made investigation of that, and eliminated on the one side the period of extreme high water, which tended to inflate the figures for that period, and eliminated from the other period the period of extreme low water which tended to change the average for that period? I mean have you made that computation, taking the average years, and eliminating what might be called abnormal or eccentric years?

A. I explained in my prior testimony that a comparison of the water levels for Lakes Michigan and Huron, say from 1860 down to 1890, and a later period from 1890 on to 1908, would not be a fair comparison of any permanent lowering that might have taken place in the lakes, for the reason that in the former period the record high water since 1860, which is that about 1886, comes in, and in the latter period the record low water for all time that we have any record of comes in.

Q. That was for 1905, was it?

A. Yes. The counsel for the Sanitary District, Mr. Williams, suggested that I leave those out, and I have made that computation and will give the results. I have divided the period from 1860 down to 1908, so as to include in the prior period the twenty years from 1860 to 1879, inclusive. In the second period, I have taken the years 1880, 1881, 1882. Then I have cut out five years of high water, 1883 to 1887, inclusive. I have included the years 1888 to 1894, inclusive; then cut out the four years of low water, 1895 to 1898, inclusive, and included the years 1899 to 1908, inclusive. That gives twenty years in the latter period, plus any comparison with the twenty years from 1880 down, and the results of the computation indicate for Michigan and Huron (and this is by the Milwaukee gage) an elevation of 581.71 for the earlier period and 580.90 for the latter period, which shows the elevation of the lake in the latter period .81 lower than in the earlier period. For Lake Erie, the same years indicate 572.86 for the earlier period; 572.36 for the latter period, with a lower lake level of 0.50 for the latter twenty years as compared with the prior twenty years. For Lake Ontario, the

elevation for the prior period is 246.51 and for the latter period 245.98; showing a lower water by 0.53 feet for the latter period as compared with the prior period.

Lake Superior for the same periods shows for the earlier period 602.35 and for the latter period 602.33 or practically the same elevation for the two periods.

Q. I will ask you to enumerate those years in which you say the second period ran?

A. The 29 years from 1880 to 1908, inclusive. From those years I have excluded 1883 to 1887, inclusive, five years; and 1895 to 1898, inclusive, four years more, making an exclusion of nine years. In these exclusions I have cut out the mountain peak of 1886, and cut out the valley of 1895, and I think the resulting comparison is a fair one.

Q. Along back in that period from 1883 to 1887, there was what was generally known as a period of high water, wasn't there, all over the country?

A. Oh, yes. I am not certain about its being all over the country. I think I have mentioned the fact that the period of 1895 was a period of low water all over the country. I am not certain as to how it was in 1886.

I would like to make a little further statement regarding this matter of lake levels, and make another comparison. I stated in my prior testimony that a certain relation seemed to hold between Lakes Michigan and Huron and Lake Erie. That is when Lake Michigan and Huron went up one foot, Lake Erie went up .7 of a foot, that is comparing a number of years together. But I have selected a method of comparing the relative elevations of the lakes, which does not require us to use that 70 per cent. relation. I have selected the ten years from 1864, or between 1864 and 1880, and a second ten years between 1888 and 1908, in which the elevation of Lake Erie is practically the same for each of the two periods. For the earlier period, 1864, '5, '6, '7, '8, '9, 1872, 1873, 1879 and 1880. For the latter period 1888, 1889, 1890, 1893, 1894, 1904, 1905, 1906, 1907, 1908. Now the elevation of Lake Erie for the earlier ten years is 572.48, and for the latter period it is 572.46. Now, I have added .02 to the latter period, making it 572.48, the same as the earlier period. And I have added to the latter period for Lake Michigan .03 and for Ontario .02 and for Superior .02. That gives us a very fair comparison. Now, for Michigan and Huron, for the earlier period, I have an elevation of 581.18 and for the latter period 581.06. Remembering that I have added .03 to that latter period, this shows that

for the same level of Erie, Lakes Michigan and Huron are lower by 1½ inches in the period after 1886 as compared with the latter period. For Ontario, the earlier period shows 246.16 and the latter period 246.37, indicating that Ontario is .21 foot higher for the latter period. And for Lake Superior, the earlier period shows 602.15 and the latter period 602.39, showing Lake Superior 0.24 higher for the latter period than for the prior period. This would indicate that Lakes Michigan and Huron had lowered about an inch and a half with respect to Lake Erie. That Lake Ontario should be higher in the latter period is what we expect, because the building of the Gut dam in 1903 raised the elevation, as I have previously testified, about five inches. That Lake Superior also should show higher is proper, because the building of International Bridge, the bridge piers, come in in the second period, while it was not present in the first period.

I want to state with all possible frankness and clearness that the fact of channel improvements by giving a more concentrated section for the flow of the water does have a tendency to facilitate the river flow. And I wish to state with equal clearness the compensating effects which I have spoken of, the deposition of the dredged material, the encroachments on the shore along cities, the building of docks. And the testimony of the water levels themselves indicates that the compensation is very nearly complete; not entirely complete, I should say. But the case of St. Mary's River, where I testified that the pool below the locks had been lowered one foot, I believe is not reproduced in any such measure in any of the lakes, or in the Lakes Michigan, Huron and Lake Erie. We know as a matter of fact Lake Ontario has come up, and we also know Lake Superior has come up in the period since 1888 as compared with the earlier period.

Q. Suppose the compensating effect is not complete and that by reason of the improvements in the channels, government improvement in the channels, there has been some lowering. What would you say as to the comparative effect under that condition of the diversion of this additional quantity of water at Chicago?

A. I should say that if the lakes were lowering by reason of channel improvements or scour, or from any cause, and I should have mentioned earlier the possibility of deforestation entering into the problem.

Q. What do you mean by that?

A. I mean that as the shores are cleared of the timber

and the lands are plowed that the evaporation on the land may be greater than it was in the earlier days. That whole question is one that is in dispute, and I do not care to pass on what the effect may be. I mention it simply as a possible element in the case.

Q. Well, now, proceed, on the assumption that as a result of these natural causes and artificial improvements on the part of the government there has been this lowering tendency, what would you say as to the comparative effect of the diversion at Chicago?

A. I should say that if Lakes Michigan, Huron or Erie had been lowered by these improvements for purposes of navigation, and by reason of natural causes, that any further lowering by the diversion at Chicago would be all the more serious.

Q. I direct your attention to your testimony as to the backwater effect of Lake St. Clair. Is there anything that you wish to add to what you said on that subject?

A. I wish to state that the percentage of retardation of the flow that I have stated to be two-thirds of 1 per cent. for each one-tenth change in the elevation of Lake St. Clair is a very approximate quantity, and should not be applied through any large range. It was intended to apply to a few tenths on either side of the mean condition.

Q. Is there anything further, Mr. Shenehon, that you wish to add to your testimony on these different matters?

A. There is nothing that I now think of.

Re-cross Examination by Mr. Williams.

Q. You referred in your testimony, Mr. Shenehon, to the effect of the improvement of the St. Mary's River. Is it not a fact that it was found impossible to compensate for the increased carrying capacity of the channels there, without introducing such currents as would make navigation through the improved channels very dangerous?

A. I do not know as a matter of fact the elements governing the design of the regulating works or the compensating works. I simply know that as a matter of fact the level of the water has been allowed to drop down.

Q. Do you not know as a fact that the reason it was allowed to drop down was because compensation could not be made without introducing such a current—

A. I do not know; I have never heard any explanation. I testified that at the middle Neebish a dyke was thrown through the shallow water, and I think the compensation was impossible in the middle Neebish.

Q. In your opinion, if compensation had been attempted here would it have introduced into the channel a current that would have been considerable?

A. I think the method pursued, or what has come out of it, was the proper engineering design or engineering decision.

Q. But if the attempt had been made there to compensate, in your opinion would there have been a considerable current?

A. Oh, yes; the conditions there were extreme. In the case of the middle rapids cut, they cut through almost dry land; in the case of the west Neebish, as I testified, rocks are showing above water, two or three feet of water, and they cut down to twenty odd feet of water. And the middle Neebish, I don't know the original condition there, but I imagine it is not very deep; it was less than 12 feet of water, because the old vessel track through the east Neebish had about 12 feet of water in the old days.

Q. In tabulating these elevation, dividing them into periods, why did you make the division of periods at 1880, in making your comparisons?

A. I took the first twenty years and compared it with the second group of twenty years, excluding two groups, one of five years in the 1886 period and the other of four years in the 1895 period. Taking five years out of the latter period, and only four out of the prior period would have made very little difference in the comparison.

Q. As a matter of fact the differences in elevation between Lake Huron and Lake Erie were greater during the first three years of the second period, that is 1880, 1881 and 1882, than they were for any other year after 1890, except 1901, weren't they? The difference in elevation for 1880 was 8.82, was it not?

A. 8.72, I have it.

Q. You have the whole year. I was taking the season of navigation. 8.72 is correct for the whole year. 1881 is 9.14. Suppose a comparison were made of those two periods, a period of 30 years from 1860 to 1889, omitting the years 1883 to 1887, inclusive, and taking for the second period 1890 to 1908 and excluding the years 1895 to 1898, inclusive?

A. Your exclusions in the earlier period are what?

Q. From 1883 to 1877, the same exclusions that you made except we divide at 1890, the time when these improvements were made.

Mr. Wilkerson: That is you take a 25-year period as against a 14-year period.

Mr. Williams: Practically.

Mr. Wilkerson: You have that computation, have you, Mr. Shenehon?

A. Yes. Professor Williams and myself have made the computation for two periods, the earlier period being for 25 years, that is, from 1860 to 1889, inclusive, with the exception of the years 1883 to 1887, inclusive. That is it is a 30-years period, excluding five years. The second period is from 1890 to 1908, inclusive, with the exception of 1895 to 1898, inclusive; that is four years excluded. The earlier 25-year period shows for Lakes Michigan and Huron an elevation of 581.69; the latter period 580.67. The lakes were lower in the latter period of 15 years by 1.02 feet than in the earlier period of 25 years. For the same periods for Lake Erie, we have the earlier period 572.84 feet and for the latter period 572.23, showing Lake Erie 0.61 feet lower for the latter period of 15 years than for the earlier period of 25 years. For our relation of 70 per cent. in Lake Erie to one foot in Michigan and Huron, we would expect Lake Erie to be .71 feet lower in the latter period than it was in the earlier period. This computation we have just made shows it was 0.61 lower, which is corroborative of the statement I made earlier that Lakes Michigan and Huron appear to have lowered about 1¼ inches as compared with Lake Erie. This makes it 1¼ inches. As regards the actual lake levels, the comparison of these two periods is an unbalanced one, 25 years in the former and 15 in the latter, and should be considered with reference to that selection of years.

Mr. Wilkerson: There is nothing further, Mr. Shenehon, that suggests itself to you?

A. No.

Adjourned sine die.

Cleveland, Ohio, July 8, 1909.
11 o'clock a. m.

Parties met pursuant to notice.

Present: Mr. Wilkerson and Mr. Williams.

HARRY COULBY, a witness called on behalf of the government, was first duly sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name?
A. Harry Coulby.
Q. Where do you live?
A. Cleveland.
Q. What is your business?
A. President of the Pittsburg Steamship Company, lake transportation.
Q. How long have you been engaged in lines of business connected with lake transportation?
A. Since 1886.
Q. And in what different capacities?
A. Manager of steamships, docks and everything connected with lake transportation.
Q. What, in a general way, is the nature of the commerce which is carried on in the vessels of your company?
A. They carry iron ore, coal, sometimes grain.
Q. And between what points, principally, is that commerce conducted?
A. Two Harbors, Duluth, Superior, Ashland, Marquette, Escanaba and the Lake Michigan ports, Milwaukee, South Chicago, Chicago, Gary, and to all lower lake ports.
Q. And then on east, Detroit?
A. Yes, and these lower lake ports here.
Q. Cleveland?
A. Cleveland.
Q. Buffalo?
A. Buffalo, Erie, Conneaut, Ashtabula, Fairport, Lorraine, Huron, Sandusky, Toledo.
Q. What percentage of commerce of your company goes as far as Lake Superior, or comes from Lake Superior?
A. About 80 per cent. of it.
Q. Approximately how many vessels are operated by your company?

A. We own 106 vessels, and we generally charter about 100 more, in a normal season. We have about 200 ships in our employ.

Q. Now, with reference to those of your vessels in which commerce is conducted to and from points on Lake Superior, what is it that determines the size of the load that one of those vessels can carry?

A. It is the locks at the Sault.

Q. That is for vessels that are capable——

A. For the large model ships.

Q. Those that are capable of loading to a greater depth?

A. Yes.

Q. How many vessels has your company that are capable of loading to 20 feet, or more?

A. Sixty-one.

Q. Are you able to state approximately the number of tons carried on those vessels in a season?

A. About 12,500,000 tons.

Q. That is on the 61 vessels capable of loading to 20 feet, or more?

A. Yes.

Q. That is just on those 61 vessels?

A. That is on the 61 ships, we carry 12,500,000 in a season.

Q. As to the vessels that go to Lake Superior, you say the depth to which the vessels may load is determined by the water in the locks?

A. In the locks, yes.

Q. The Poe Lock?

A. Yes.

Q. How deep may the vessels that are going to Lake Superior be loaded now, do you know?

A. Nineteen feet, three, through the Poe Lock.

Mr. Williams: Three-tenths feet, or three inches?

A. Three inches.

Mr. Wilkerson: As to the vessels that are not going to Lake Superior, what determines the size of the load which they carry?

A. Ballards Reef, and the shallow waters across Lake St. Clair.

Q. And do you know to what depth those vessels may now be loaded?

A. They are loading to about 20 feet now.

Q. Are you able to state the number of tons for the average vessels, I mean the large vessels about which you have

testified, of your company, which will increase its draft one inch when loaded to a depth of about 19 or 20 feet?

A. About 100 tons to the inch.

Q. Assume that there should be a diminution in the depth of the water at these points with reference to which you have testified at the locks at the Sault and at Ballards Reef, assume a diminution of an inch, what would be the effect of that upon the quantity of freight which could be carried in these large boats?

A. It would reduce them about 100 tons per inch or 100 tons per trip.

Q. That would be for each ship?

A. Yes.

Q. Each ship per trip?

A. Yes, each voyage.

Mr. Williams: Do you go loaded both ways?

A. The round trip, for each cargo.

Mr. Wilkerson: About how many trips do one of those large vessels make in a season?

A. We average about 25 trips in a season.

Q. That is 25 round trips?

A. Yes, sir.

Q. With reference to the operating expenses, including fuel and dock and loading charges, how do those compare when a vessel draws, say 19 feet, as compared with the same vessel drawing 19 feet 6 inches?

A. There is no difference per trip in the operating charges but there would be a difference per ton, because of the reduced number of tons carried.

Q. How about the amount of fuel it would take?

A. Oh, it would not make any appreciable difference.

Q. And what do you say as to a vessel loaded 19 feet 6 inches, as compared with one loaded 30 feet?

A. It would be so slight you would almost lose sight of it. There would be no appreciable saving there.

Q. Are these 61 vessels, about which you have testified as being operated by your company, all of substantially the same size, or do they vary?

A. No, they run from 7,000 tons up to about 11,000.

Q. Can you give us approximately the dimensions of the largest of those vessels? Which is the largest?

A. The Cole is the largest, she is 605 feet long.

Q. What is the draft?

A. Fifty-eight feet beam and 32 feet deep.

Q. And if you had enough water at these critical points of navigation, how deep could you load that vessel?

A. Oh, that would be perfectly safe to 25 feet.

Q. How many vessels of approximately that size are there in the fleet of your company?

A. Of which size?

Q. The size of the one you have last testified about?

A. We have got 12; we are building two more. We will have 14 of the large size; but all of them have about the same depth; they are all of them from 30 to 32 feet deep, so that every one of those 61 ships could load to 25 feet.

Q. They could be loaded to 25 feet?

A. Yes.

Q. If you had the water?

A. If you had the water.

Q. As to all those vessels, what is the effect of a permanent lowering of the water in the lakes, one, two or three inches?

A. Every time you lower it an inch, you reduce the carrying capacity that much; reduce the earnings that much, without reducing the operating cost; in fact increase the operating cost on the per ton of freight carried, because you have a lesser number of tons per trip, over which to divide your operating cost.

Q. Are you able to give in a general way what the added expense is, or rather the added cost of transportation, due to diminishing the depth to which the vessel can be loaded, two or three inches?

A. I have not prepared any statistics on that.

Q. That could be easily determined from the figures you have given, could it?

A. Yes.

Q. How would you do that? About what is the cost per ton? If you have anything that will give us the basis for forming some idea as to what the effect of this lowering is upon the cost of transportation, I wish you would give it to us.

A. The cost of carrying the ore on about 19 feet 6 is 50 cents a ton.

Q. That is between what points?

A. That is from Lake Superior points to lower lake ports.

Q. You say that is to a depth of 19 feet 6?

A. Yes.

Q. About how many tons will one of these large vessels carry, loaded to that depth?

A. About 10,000 tons.

Q. Do you know anything with reference to the depth of the water in any of the harbors into which your boats go, as to whether or not the size of the load which can be carried is limited by the depth of the water in those harbors?

A. All the harbors have been dredged out to take care of the ships that could come over what I call the "necks of the bottle," that is the Poe Lock and Ballards Reef.

Q. Are there any which have been dredged only up to the point of taking care of the vessels which come over these points?

A. I do not think any of the harbors have been dredged beyond that point.

Q. So that as to practically all the harbors into which your vessels go, the lowering of the water in the lake would affect them?

A. It would be very disastrous to the harbors.

Q. That is to say it would affect them how?

A. It would affect the dock lines and the docks all around the harbors; I think the foundations of the docks.

Q. And with reference to the size of the load a vessel would carry into the harbor, would it have any effect on that?

A. It certainly would.

Q. The same effect as it would have with reference to going through the locks at the Sault?

A. Just the same.

Q. And through the river at Detroit?

A. Just the same.

Q. Have you any particular harbor in mind which would be affected that way?

A. Oh, I think every harbor along the south shore of Lake Erie would be affected.

Q. Are you able to state in a general way what would be the total effect upon the vessels which are operated by your company on the basis of the business for a season if there was a permanent lowering of say three inches, or six inches?

A. You mean per inch, on our 61 ships?

Q. Yes.

A. It would reduce the carrying capacity of the fleet 610 tons per trip; on 25 trips would be 15,000 tons.

Q. Is it 610 tons?

A. No, 6,100 tons.

Q. Sixty-one hundred tons?

A. Yes. That would be 152,000 tons a season.

Cross-Examination by Mr. Williams.

Q. The total tonnage of the 61 vessels that you have mentioned as having a draft of more than 20 feet, I understood you to say was about 12,500,000 a season?

A. Twelve and a half million tons.

Q. Per season?

A. Yes.

Q. And that is on the basis of not carrying to exceed 19 3 through the Poe Lock, and about 20 feet through the St. Clair River, Lake St. Clair and Ballards Reef?

A. That would be 19 feet 3; that is based on 19 feet 3, coming down, because it is the lowest draft that governs.

Mr. Wilkerson: That is 19 feet 3 for all the vessels that go to or come from Superior?

A. Yes. We do not trade many of these boats to Lake Michigan; that is from Lake Superior to Lake Erie.

Mr. Williams: All the vessels then that carry cargoes to the Lake Erie ports come from Lake Superior?

A. Not all of them.

Q. Are there any considerable number of the 61 vessels, concerning which you have testified, that get their cargoes this side of Lake Superior, and deliver——

A. Very few of those ships; occasionally we load some of them from Lake Superior to South Chicago or to Gary, and then run them down to Escanaba, and load them from Escanaba to Lake Erie; but as there is only about 20 per cent. of our business that comes from Michigan to Lake Erie, 80 per cent. of it comes through the Sault canal.

Q. So long as the draft of the vessels is limited at the Poe Locks to 19 feet 3 inches, any lowering of the Great Lakes, or any harbor or connecting water, which does not bring it below the 19 feet 3, would not have any effect on the greater portion of the navigation carried on by your company, assuming that there was still 19 feet 3?

A. Of course if there is still 19 feet 3 of water, we would be just where we are today, if the water is not lowered.

Q. So that in order to have any lowering effect on the business of your company it would have to be a lowering to an extent that would bring the water below 19 feet 3, at the present time?

A. Not necessarily.

Q. So far as the cargoes that come through the Sault locks are concerned?

A. On the present draft of water in the lakes, which of course governs the draft of water through these connecting places; the draft of water in the lakes.

Q. The Pittsburg Steamship Company is a corporation?

A. Yes.

Q. Organized under the laws of what state?

A. I think it is West Virginia.

Q. And the stock of the company is held by whom?

A. The United States Steel corporation.

Q. Who are the principal customers of the Pittsburg Steamship Company; that is, for whom is this transportation of iron ore and coal carried on by you?

A. For the subsidiary companies of the corporation.

Q. In other words, the United States Steel Corporation does its own transportation?

A. No.

Q. Carries on its own transportation through its subsidiary companies?

A. The Pittsburg Steamship Company carries part of the ore, probably 50 per cent. of the ore that the United States Steel corporation and subsidiary companies use; and then the United States Steel corporation, as the Pittsburg Steamship Company, has to go outside and charter independent ships.

Q. But does the Pittsburg Steamship Company carry any ore for any one except for the United States Steel Corporation?

A. No.

Q. Or one of its subsidiary corporations?

A. No.

Q. What percentage of the vessels owned by your company having a draft of more than 20 feet, the 61 vessels that you testified to, are loaded in both directions, when they make their trips through the season?

A. Loaded both ways?

Q. Yes.

A. You mean of the whole fleet?

Q. Of the 61 vessels?

A. Of that 61 vessels, we would not have probably over 2 per cent. loaded both ways.

Q. And when they are loaded going the other way, what is the nature of the cargo?

A. Coal.

Q. Do they load to the same capacity and depth as they do coming this way?

A. Yes.

Q. And for whom is the coal carried?

A. For everybody.

Q. As a common carrier?

A. We carry coal, corporation coal, and we sometimes carry coal for outside parties.

Q. Would an inch difference in draft of a vessel make the same difference in the capacity to carry coal as it would iron ore; in other words would an additional inch mean the same amount of coal?

A. Just about the same.

Mr. Wilkerson: That is, the point being whether one is as heavy as the other?

A. There is about 240 pounds difference; coal goes 2,000 pounds to the ton; ore, 2,240.

Mr. Williams: That would not affect the inch?

A. It is the inch of draft; it is not the inch of load inside the ship. It is the inch it puts the ship down that you are after.

Q. It takes the same amount of weight to put it down one inch with the one as with the other?

A. Yes, doesn't make any difference if you fill it with feathers, if you have the cubic capacity to put the ship down.

Q. Of the vessels that are chartered by your company, you say, in an ordinary season, you charter perhaps 100 vessels in addition to those owned by your company?

A. Yes.

Q. What percentage of those would you say have a draft of 20 feet or more?

A. I would say 90 per cent. of those.

Q. Have a draft of more than 20 feet?

A. Yes.

Q. What is the total tonnage of vessels operated by your company, that are owned or chartered by it, having a draft of more than 20 feet, per season?

A. The total tonnage?

Q. Yes.

A. I should say 20,000,000 tons.

Q. What would you say was the total tonnage of all your vessels of every description, both owned and chartered, whether they have a draft of more or less than 20 tons?

A. Whether they have more or less? About 23,000,000 tons.

Q. In other words the vessels having a draft of less than 20 feet would carry about 3,000,000 tons per season?

A. Yes.

Q. What is the total tonnage on the Great Lakes in a season?

A. I think about 75,000,000 tons.

Q. So that your company practically handles about 33 per cent. of the total tonnage on the Great Lakes?

A. Yes, sir.

Q. What has been the tendency during the past, say 10 years, in the building of vessels, as to size, capacity, draft?

A. Well, all the boats that cannot load to 20 feet, we scrap them or sell them as quick as we can. All the ships we build or that anybody else builds, are built looking to and hoping for a 25-foot channel.

Q. Your answer to my question as to the tendency during the past ten years is that there is a tendency to increase the tonnage capacity of vessels being built?

A. That is it.

Q. To what extent, what percentage would you say?

A. The last 10 years?

Q. Yes?

A. Oh, about 100.

Q. Looking to a capacity of 25 feet, depth of water of 25 feet at the critical points. Can you explain, just as briefly as you may, the reason why vessels are built with a draft of 32 feet, when you do not anticipate any more than a 25-foot depth of water?

A. We have to have some freeboard on a ship, to make her seaworthy.

Q. Will you explain why it is advisable, or proper, as I assume it is, to build a vessel with a greater draft than you expect to have depth of water for?

A. We have not built any of them yet.

Q. You have some now with a draft of 32 feet?

A. They are 32 feet deep; they could not load to 32 feet.

Q. You could load to 25 feet?

A. You could load them to 25 feet.

Q. They would not be capable of being loaded to more than 25 feet in any event?

A. No, I don't think so. That of course would be an engineering proposition to work out, as to what freeboard a ship ought to have. We never have got anywhere near the danger line yet.

Q. Do you know the depths at the harbors at South Chicago and Gary and Chicago?

A. No, I don't know just what depth they have there. They have got plenty of water there for the——

Q. Is it considerably deeper than the water at Ballards Reef, for instance?

A. Yes, they have deeper water there.

Q. How are the harbors at Cleveland?

A. Oh, that just depends on where you go; 21, 22 feet up the old river, and dropping down to 19 feet at the upper end of the river.

Q. Are there any other elements that you take into consideration in loading a vessel besides the depth of the water? Of course that you take into consideration first, but what other conditions would you take into consideration in determining how deep a vessel can load?

A. On these large ships that we are now talking of?

Q. Yes.

A. No other conditions but the depth of water.

Q. Does the velocity of the current in a stream have any effect on the cost of operating, or the danger of operating, or the general business of navigating the Great Lakes or connecting waters?

A. The velocity of the water makes it more dangerous to operate, of course.

Q. What velocity would you consider a dangerous current?

A. Well, that is a pretty broad question to answer. It would depend entirely on the channel, the width of the channel.

Q. Are there any dangerous currents now in any of the connecting waters of the Great Lakes?

A. No, there is only one at Port Huron; that is not dangerous; about a six-mile current through there.

Q. You think a six-mile current is not a dangerous current?

A. It is not as safe as no current at all; still it is not what you may term a dangerous current for operating ships through there.

Q. Would you consider that a decrease in the velocity of the current at any of those points where the current is from four to six miles an hour would be of advantage to navigation in any way?

A. No, not a particle.

Q. Would an increase of current be any detriment?

A. It would if you increased it enough.

Q. Any increase above six miles an hour?

A. Any increase above six miles an hour? That is a pretty broad question. That might be 6 or 10 or 25 miles. There is a danger line; I do not know what it is and nobody else knows.

Q. Assume there is a current of six miles an hour. Isn't it a fact that any increase in the velocity of that current above six miles an hour would be a detriment to navigation in the proportion the increase bore to the present current; that is a very small increase would be a slight detriment and a large increase would be a very great detriment?

A. Yes, you put it that way, and let some one else decide on the question of the small increase and the large one.

Q. Would any increase at all be a slight detriment to navigation?

A. The more you increase the current, of course, the more dangerous it becomes.

Q. Are the insurance rates based in any way on the condition of the currents, the dangers incident to swift waters?

A. No.

Q. You do not think that the insurance rate would be increased on you if the currents would be increased?

A. They would be if it increased the accidents; they are based on the accidents, the insurance rates are.

Q. And accidents would be more likely to occur with a swift current than they would with a slight current?

A. The more swift the current, the more likely you are to have accidents.

Q. Have you ever known of any accidents occurring at the Limekiln Crossing as a result of the current there?

A. I have known of a good many accidents there, but I am not prepared to say they were on account of the currents altogether.

Q. Do the currents have some contributing influence, in your opinion?

A. Yes, the currents and the crooked channel together.

Q. Now, do you know the velocity of the current through the Limekiln Crossing?

A. No, I do not know what it is there; what the current is through the Limekiln.

Q. Mr. Wilkerson asked you to make a hurried computation as to the effect upon the tonnage carried by your company

of a decrease of depth of one inch and I believe you figured 61 vessels with 100 tons per inch for each vessel, making 6,100 tons?

A. Yes.

Q. Would you say that in all your 61 vessels an inch meant 100 tons?

A. No, that would be the average. Some would go higher than 100 tons; that would be about the average.

Q. What would be the difference in tonnage for each inch in the Cole, for instance, which is the largest vessel?

A. That would probably go 120 tons. Of course the higher you go, the more she carries; that is the deeper down you go the more she carries.

Q. What would you say of the Corey?

A. Well, it would be a fraction; it would be pretty hard to tell the difference there; it would be pretty close to the same, probably 110 or somewhere along there.

Q. And you think 100 tons per inch is a fair average for the 61 vessels?

A. Yes.

Q. Do you figure that for 25 cargoes?

A. Trips, yes.

Q. For the season?

A. Yes.

Q. Do you know what the average tonnage for these 61 vessels is, for the year?

A. The average?

Q. Yes.

A. About 8,200 tons to the cargo.

Q. What is the average capacity?

A. About 200,000.

Q. The average capacity of the 61 vessels?

A. The average capacity would be about 8,200 tons.

Q. That is the average tonnage that is actually carried, is it not?

A. That is the average capacity of the 61 ships.

Q. Have they been carrying to their full capacity?

A. That is based on 19 feet 3.

Mr. Wilkerson: Of course most of them could be loaded to 25 feet?

A. They could all be loaded to 25. That is the average capacity of those ships per cargo, based on 19 feet 3 inches.

Mr. Williams: What was the actual amount carried on those 61 vessels last year?

A. I haven't got that figured up.
Q. Do you know what number of trips were made?
A. They averaged 25 trips.
Q. Was that the average for last year or the average for several trips?
A. No, that was the average for year before last, when we had a full season; that is the average full season's capacity.
Q. What was it last year?
A. I don't remember. We had a short season. We didn't get started last year until some time in June.
Q. Can you give us an approximation as to the number of trips, average number of trips for the 61 vessels last year?
A. No, I could not do that without figuring it up. I am giving you the average season's capacity of the ships.
Q. That is based upon one season, namely, season before last?
A. Based upon a season where we operate the full season.
Q. Your figures are based upon your actual experience season before last?
A. Yes.
Q. That one season?
A. Yes.
Q. You say that would be a fair average for any season providing the conditions were the same as then?
A. For 10 seasons provided the seasons average the same number of days, and we operated the entire season.
Q. But they don't always do that?
A. Without there are labor troubles, or something unusual happens.
Q. How about last season?
A. Last season they did not, because of labor troubles on the lakes.
Q. And this season?
A. This season we have had labor troubles.
Q. So that by reason of some condition, whether labor troubles or other matters, that does not make it an average for the last three seasons, does it?
A. No.
Q. What is the average cost of one of these large vessels?
A. About $400,000; $400,000 to $450,000.
Q. How many days do you consider an average season of navigation?
A. About 240.

Q. What is the operating expense of one of these large vessels, the average for the season?

A. About 50 cents a ton.

Q. Without reference to the tonnage, in dollars and cents?

A. Take the steamer Rogers, in 1907, she carried 323,000 tons of ore. Her operating expense was $127,000; about 40 cents a ton.

Q. What was the season that year, 240 days?

A. Yes. I will tell you how many days she was running, if you would like to have that.

Q. Yes.

A. She was actually operated 223 days.

Q. How many trips did she make?

A. Twenty-nine.

Q. Would you say that was a fair average of the operating expense of one of those large vessels, about $500 a day?

A. Yes, that is a fair average for operating expense.

Q. What is included in the operating expense?

A. Everything.

Q. Insurance?

A. Yes.

Q. Repairs?

A. Yes.

Q. Depreciation?

A. No.

Q. Just ordinary maintenance?

A. Just ordinary maintenance and operation.

Q. Coal?

A. Fuel, yes, everything that goes into operation but depreciation and interest.

Q. What would you consider a fair charge for depreciation and interest on a vessel of that kind?

A. Five per cent. a year.

Q. For both, or each?

A. For what?

Q. Depreciation?

A. Five per cent. a year.

Mr. Wilkerson: That is, you charge off 5 per cent. each year?

A. Yes.

Q. To get the value of the vessel?

A. That is what ought to be charged off.

Mr. Williams: What do you consider a fair charge for interest on your investment?

A. All that you can get.

Q. I mean you would charge off something for interest on your investment, before you figure any profit, wouldn't you?

A. Yes, you ought to charge off 5 per cent. a year.

Q. For interest?

A. Five per cent. a year for depreciation, and 5 per cent. a year for interest on steamship property is not enough.

Q. It is enough to start you out, and then anything above that would be profit?

A. Yes.

Q. You would not consider you were making a profit if you did not get more than 5 per cent. on your investment, would you?

A. No.

Q. So that 5 per cent. would be a fair charge for interest?

A. Yes.

Q. That is to say, the actual cost of transporting that 323,000 tons was about 40 cents a ton?

A. Yes.

Q. Does that include the unloading charge?

A. Yes, that includes the unloading charge.

Q. Does your company make a profit on that in addition? I do not want to try to get into the secrets of your business, but I mean is that what determines your earnings, what it actually costs, or do you charge the other subsidiary companies the same as you would a third party?

A. We charge the docks. We do not take it all to corporation docks. We take that ore to everybody's dock, that reaches the corporation; there is a regular dock charge for unloading.

Q. That is for unloading?

A. Yes.

Q. The charge for transportation, do you charge the actual cost, or do you charge something in addition to that?

A. We charge the actual cost of transportation, which includes the actual amount we have to pay to the dock companies for unloading it.

Q. Are the tons you speak of the vessels carrying gross tons?

A. Yes.

Q. Two thousand two hundred and forty pound tons?

A. Yes, ore goes by gross ton; coal by net.

Q. This was all iron ore that you are speaking about that the Rogers carried?

A. All iron ore that the Rogers carried; didn't carry coal at all.

Q. Do you carry your own insurance on your vessels?

A. Yes.

Q. And make a certain charge for it.

A. Yes.

Q. That is included of course in the actual cost of operation?

A. Yes.

Q. Does that include a profit to the company or is that the actual cost of carrying the insurance?

A. We charge our ships the insurance just exactly the same as it costs us to insure in old line companies, just the same rates.

Q. When was the William E. Corey built?

A. In 1906.

Q. Take the Corey for 1907, could you tell the number of days it ran, the number of trips it made and the actual operating expense?

A. The Corey was in commission 232 days. She made 29 trips. The operating expense was $123,404. You want the total tonnage now? She carried 295,802 tons; the cost was 41.7 cents per ton.

Q. What if anything has your company done, either individually or as a member of the Lake Carriers' Association towards improving the condition of navigation on the Great Lakes?

A. We do not do anything only as members of the Lake Carriers' Association.

Q. You are one of the directors of that association?

A. Yes, I am one of the directors.

Q. What have you done as an association?

A. We keep after the government, and keep trying to get them to spend money on this shallow water. The deeper the water the less per ton it costs to carry freight. The consumer pays the tax, you know.

Q. And you are working in the interest of the consumer?

A. This consumer right here. But on the broad proposition, the bigger load you can carry in a ship, the cheaper you can carry it; competition takes care of that.

Q. You are familiar with the iron ore trade I assume?

A. Yes, sir.

Q. Have you any opinion as to the length of time during which the supply of iron ore at Lake Superior will last?

A. I know just like everybody else knows that it will last until it is done; nobody knows when that will be.

Q. You haven't any opinion on the subject then?

A. Not a particle. It will last as long as I live, and I am not worrying much about the other fellow.

Q. What is the average length of time consumed in making a trip with one of these boats?

A. About nine days.

Q. For the round trip?

A. Nine days.

Q. About how long a time is consumed in loading and in unloading each, that is separately?

A. Oh, they probably load them in the average time of nine or ten hours; unload them in about the same length of time.

Q. Is there any difficulty in getting to the dock at times?

A. If the water is low.

Q. Any other difficulties?

A. None other that I know of.

Q. Suppose that there was difficulty in getting to a dock because the water was low. In your experience is it a fact or is it not, that there would be natural fluctuations in the lake level sufficient to overcome that difficulty within a few hours sometimes and sometimes within a day or two?

A. It just depends on the wind.

Q. And there are frequent variations in the depth of water in the harbors?

A. No, only in the windy season, the early spring or fall, and when we have heavy winds of course.

Q. And during the summer time, sometimes the water is driven away by heavy winds lasting for several hours?

A. It does not affect us very much in the summer. We do not get heavy winds in the summer to affect the levels of the lakes.

Q. I do not mean the lake in general, but at a particular point there might be fluctuations of several inches within a very short time?

A. Yes, not in the summer time, it does not amount to anything; you do not get wind enough to affect the water.

Q. Did you ever know of any of your vessels to be obliged to wait for a change, fluctuations in the depth of water at the Limekiln Crossing?

A. Yes, a great many times.

Q. How frequently in a season would you say that would occur?

A. Oh, I could not tell that. That comes in the early spring or in the fall, when we begin to get heavy weather.

Q. Does it ever occur in midsummer?

A. Yes, I presume it has, but so very rarely that we do not look for it or pay any attention to it.

. . . . . .

Adjourned sine die.

New York City, May 31, 1911.
1:15 o'clock, P. M.

Parties met pursuant to notice.

Present:

Mr. James H. Wilkerson, on behalf of the Government.
Mr. John C. Williams, on behalf of the Sanitary District of Chicago.

ALLAN HAZEN, a witness called on behalf of the defendant, was first duly sworn, and testified as follows:

Direct Examination by Mr. Williams.

Q. Please state your full name?

A. Allan Hazen.

Q. What is your occupation?

A. Civil engineer.

Q. You reside in the City of New York?

A. I reside in Dobbs Ferry at present.

Q. And your place of business is where?

A. Is in New York City.

Q. In what special line of civil engineering are you engaged?

A. Water supply work, sewerage and sewage disposal.

Q. Will you state the educational training and the practical experience that you have had in the line of your profession?

A. I studied at the New Hampshire State College, and afterwards at the Massachusetts Institute of Technology. From 1888 to 1892, I was at the Lawrence Experiment Station of the Massachusetts State Board of Health; the object of which

station was to determine methods of handling sewage and purifying water.

In 1893, I was in Chicago at the World's Columbian Exposition in the department of water supply, sewerage and fire protection, and operated a plant in which was treated the sewage of the fair grounds before it was discharged into the lake. I also had to do with the water supplies drawn from the lake and other sources used upon the grounds, and was familiar with the water supply system of Chicago.

Q. You were in charge of that work yourself, were you not, at the World's Fair grounds?

A. I was in charge of the sewage disposal plant under the direction of others in the department.

In 1894 I was abroad studying water supply and sewage disposal works; and also studied for a time at the Royal Technical High School at Dresden.

In 1895 and '6, I was in partnership with Mr. Noyes in Boston, as civil engineers, and commenced general work with water supply and sewerage problems, which I have followed since that time; beginning in New York in 1897.

Q. What works have you been connected with or had charge of having to do with the purification of sewage or the protection of water supply?

A. I built a few small sewage disposal works, and have advised in regard to some others; but especially, works at Altoona, Pennsylvania, at Spencer, Massachusetts, Plainfield, New Jersey; a little plant for Vassar College and a plant for the State Lunatic Hospital at Harrisburg.

I have advised cities in regard to sewage disposal problems; especially North Hampton, Massachusetts, Paterson, New Jersey, and I am advising the City of Pittsburgh at the present time.

I have designed and superintended the construction, and advised in regard to a considerable number of plants for purifying water, and have acted generally as engineer for cities and corporations in water supply matters.

Q. Have you acted in an advisory capacity in litigation involving engineering questions along the line of your experience?

A. Yes, sir, I have. I acted for the Town of Millbury in the case with the City of Worcester some years ago, involving the pollution of the Blackstone River. There are quite a number of cases of that kind. I remember being at Gloversville, New York, for the city, with reference to pollutions.

Q. Were you ever employed in any case where the Sanitary District was involved?

A. Yes, sir, I was employed by the City of St. Louis.

Q. That was the case of the *State of Missouri* v. *The Sanitary District of Chicago*?

A. It was, yes.

Q. You are now in partnership?

A. I am now in partnership with Mr. Whipple, Mr. Fuller and Mr. Babbitt. The firm name is Hazen & Whipple.

Q. Has your firm engaged recently in giving any advice in reference to sewage disposal to any city like the City of Chicago, on Lake Michigan?

A. Mr. Whipple has been a member of a commission advising Milwaukee with reference to sewage disposal, and that commission has just reported. I have been familiar with the progress of the work, but have not participated in it personally.

Q. What have you to say with reference to the City of Cleveland?

A. Mr. Whipple studied the water supply and sewerage conditions at Cleveland at considerable length; and I have had to do with those conditions at Toronto through several years.

Q. Having in mind particularly the questions relating to the matter of the purification of water supply, what particular works have you had to do with?

A. I designed and acted as engineer in the construction of the Albany Water Purification Works. I also had charge of the design, and advised with regard to the construction of the Washington, D. C., plant; and have also designed and been professionally responsible for at least a dozen smaller plants.

Q. I think you have already stated that you are now engaged in the City of Pittsburgh?

A. Yes, sir.

Q. Are you familiar with the lake and river conditions in Chicago?

A. Yes, sir, I am, to a certain extent.

Q. Over what period of time has your acquaintance extended, and to what extent have you been familiar with those conditions?

A. I first visited Chicago, I think, about 1889, and was shown the Chicago River which was pointed out as one of the notable institutions of the place. My next acquaintance with the conditions there was in 1893, when, as I have stated, I

spent the year in Chicago; and during that time I saw frequently the river conditions and the conditions along the old canal as far as Joliet and below. And I also was informed as to the water supply conditions existing at that time, and knew of some of them from personal knowledge.

Since that time, I have visited Chicago from time to time and have seen the Chicago River; have been informed as to the lake conditions, the water supply conditions.

At the time of the St. Louis suit, which has been mentioned, I made something of a study of them. At other times it has been simply the study of a very interesting phenomena professionally.

Q. Have you recently made any particular examination of the ground?

A. Yes, sir, during the last week I have been in Chicago; have been through the Chicago River and its various branches; through the Drainage Canal; have visited parts of the Calumet District, and in general looked up the things that seemed significant in the case now at issue.

Q. And from that examination, you are to some extent familiar with the qualities of the water and the effect of the sewage upon the water, at this time?

A. Yes, sir, I think I am.

Q. Are you familiar in a general way with the methods of improving the water supply of Chicago, methods that might be employed, and that are employed?

A. I am familiar with the methods that might be employed, and that are being employed in other cities.

Q. The law under which the Sanitary District is organized provides for the disposal of the sewage of the Sanitary District by dilution at the rate of 20,000 cubic feet of water per minute for each 100,000 inhabitants. I will ask you if you have an opinion as to whether or not that rate is a reasonable rate to ensure the rendering of the sewage harmless and innocuous?

Mr. Wilkerson: I object to that as incompetent, irrelevant and immaterial. The question of the reasonableness of the amount of water authorized by the Illinois statute can in no way whatsoever affect the power of Congress with reference to the matter in controversy.

A. In a general way, the legal amount of dilution is reasonable. The amount of dilution required to prevent the production of objectionable conditions is known within certain limits. Those limits are not absolutely fixed, but depend

upon various conditions, and some of those conditions are complex.

The amount required in this case might prove to be on full investigation a little greater or a little less than is fixed by law. The data that I have been able to collect during the past week, in addition to those that I had before, are not sufficient to determine this ratio precisely. I have a feeling, however, that the legal rate is at least a reasonable approximation to what is actually required for these conditions.

During my stay in Chicago, on May 23d, I went the length of the Drainage Canal and noted especially its conditions; and at my request the chemist of the district went along and made certain tests of things that I wished to know about, and it is my feeling that the water flowing in the canal on that date was carrying substantially as large a load of sewage matter as it was capable of carrying; and the record of flow given me by the chief engineer and the population tributary to the sewer, calculated at my request upon the census returns of 1910 with one year's estimated growth added, indicates that the amount of dilution on that date was very closely that corresponding to the legal dilution.

Q. You mean by legal dilution the rate established by the state law?

A. Yes, sir.

Mr. Wilkerson: 20,000 cubic feet a minute for each 100,000 inhabitants?

A. Yes.

Mr. Williams: You are familiar, are you not, Mr. Hazen, with other methods of sewage disposal, methods other than by dilution?

A. Yes, sir.

Q. Taking into consideration the fact that the Sanitary District has already expended a large amount of money approximating $66,000,000, in building its main channel, and having facilities and plans for the construction of adjuncts and additions sufficient to care for the outlying portions of the Sanitary District, I will ask you to state what is your opinion as to the most economical and appropriate method of providing for the additional sewage that may be produced within the Sanitary District during the coming few years, that is not now taken care of through the main channel?

Mr. Wilkerson: I assume that the objection which I have noted may stand to the whole line of examination, without repeating it for each particular question.

Mr. Williams: Surely.

Mr. Wilkerson: If so understood, I will not interpose an objection to each question, but it may be considered that the whole line of examination is under that objection.

Mr. Williams: I understand.

A. It is my judgment that from the standpoint of the Sanitary District, the most economical and efficient method of disposing of sewage from added population will be by extension of the existing system of dilution and discharge of the sewage towards the Illinois River. I may say that this is based upon general experience and judgment. I have made no detailed estimates of just what could be done in various ways in this case.

Q. That is insofar as the disposal of the sewage is concerned?

A. Yes, sir; but knowing a good deal of the cost of treating sewage, and the difficulties of doing it, I am perfectly clear that it would be much more expensive to treat the sewage so as to purify it and discharge it into the lake than it is to cut canals to carry lake water to dilute it and carry it harmlessly the other way.

Q. In a general way, are there any difficulties that are encountered in the treatment of sewage by methods other than dilutions, in a climate such as we have in Chicago?

A. Why, there are a great many difficulties in sewage purification. Sewage purification is comparatively a new subject. It is a new subject when carried out on any such scale as is represented by the sewage of the Sanitary District. Experience on a large scale is mostly European, and for the most part comes from places where the winter temperatures are not nearly as low as they are in Chicago.

Q. Does low temperature add to or decrease the difficulties?

A. Well, it increases the difficulties of treatment somewhat.

Q. Is there any difference in a general way between the character of the sewage in European cities and that found in American cities?

A. Yes. The European sewage is very much smaller in volume and more concentrated. In other words, the amount of water per capita is very much less, and that facilitates purification of sewage because the large quantities of water with which American sewage is diluted in the sewers render the problem of purification much more difficult.

Q. And also more expensive?

A. And also more expensive.

Q. That is per capita?

A. Per capita; probably would be cheaper per million gallons to treat dilute sewage than strong sewage, but per capita it certainly costs more.

Q. Do you know the amount of water per capita that is consumed in the City of Chicago?

A. The official records show about 230 gallons per capita for the last year.

Q. 230 gallons per day?

A. Per capita per day.

Q. And do you know what the average consumption of water per capita per day in European cities is?

A. It would range from 20 to 30 up to 50 or 60 gallons per capita daily, I should say. London uses about forty.

Q. Assuming that methods other than the dilution method were to be employed by the Sanitary District in carrying off the sewage of the additional territory, and the additional sewage produced which is not cared for by the main channel, what methods in your opinion would be most practicable?

A. I considered three possibilities for disposing of the sewage of an additional population beyond that which could be diluted by 10,000 cubic feet per second, assumed as available for the canal. I assumed as a starting point that that flow will be maintained, and that whatever sewage can be taken care of by it will continue to be so discharged.

It is necessary to state that, because with that as a starting point, the treatment of the rest of the sewage might be a little different from what it would be if that was all that there was to be considered. With that as my starting point, then, it will be possible to take care of the sewage from the added population—

Q. How much added population do you assume?

A. I assume a population of 1,200,000.

Q. That is the population that would be taken care of by 4,000 cubic feet per second, by dilution?

A. At the present legal rate, yes, sir. (Last portion of answer of the witness read, as follows: "With that as my starting point, then, it will be possible to take care of the sewage from the added population"), first by completely purifying the sewage of the added population so that the effluent may be discharged into the lake or into the lake or into the canal as may be most convenient.

Second, it will be possible to provide for it by treating a larger quantity of sewage by partial methods so that the total amount of sewage matter discharged into the canal

would not exceed that in the raw sewage from 3,000,000 people.

And third, it would be possible to let the sewage from the added population go to Lake Michigan through selected outlets, outlets selected I mean with reference to securing good dilution in the lake, and in connection therewith to purify the water supply, to protect it in that way from the polluting matter of the sewage. Which of these three general lines of treatment would be best, it is impossible to state off-hand. Very likely some combination of them would be better than either by itself; adopting each or at least two of them in places where the local conditions might lend themselves to such use.

Q. Assuming the first method were followed, namely, that works be built and operated for the complete purification of the sewage of the population assumed, in your opinion would the cost of such a plant or works be greater or less than the cost of constructing a channel such as is described in the pleadings in this case, having a capacity for a flow of 4,000 cubic feet of water per second?

A. It is my judgment that the cost would clearly be greater.

Q. You have not prepared any figures so as to be able to state to what extent the cost would be greater?

A. No, sir, I have not.

Q. Assuming the second method were employed, and works were built so that the sewage was treated, and the effluent was discharged into the lake, what is your opinion as to whether or not it would then be necessary to install any works for the purification of the water supply?

A. I think it would be desirable and necessary to purify the water in case any considerable amount of sewage effluent were discharged into the lake. It is my feeling that methods of sewage disposal now available to be used reasonably in a case like this are not adequate to protect the quality of drinking water; and if I were running the water supply I should want to protect it from the effects of sewage dilution, and I should look upon the discharge of sewage effluent from any such works as might be reasonably installed at the present time as only in a small degree less dangerous to the water supply than the discharge of crude sewage.

I am taking into account not only the theoretical possibilities of the sewage purification, but all the practical contingencies of operation that do arise in the operation of such plants.

Q. Assuming that the second method were employed, that is, the works constructed for partially purifying the sewage and the effluent discharged into the canal, would such a work or works be more or less expensive than the construction of the channel such as is proposed to be constructed by the Sanitary District, and involved in this suit?

A. Well, I can't say certainly as to that. That involves matters of design and local conditions that would have to be studied out.

Q. It would be necessary in that case to construct some kind of works to carry the effluent to the canal?

A. Oh, yes, that would be necessary. If such works were to be constructed, for instance, in the Calumet District, obviously it would require the construction of a canal similar to that which you propose, although not necessarily the same size. Of course, a sewer, a line through which the effluent was pumped, could be substituted for the canal; but in a locality with a topography like that shown by this map (referring to map spread before the witness), a canal would obviously be cheaper than any pipe line or artificial conduit.

Q. Having in mind the protection of the water supply of the City of Chicago, in your opinion would it be more advisable to discharge the raw sewage of 1,200,000 people into the lake at selected outlets, in the way you have indicated it might be done, and purify the water supply, or would it be cheaper to purify the sewage by the best method that you are acquainted with and allow the water to be used without any treatment or purification?

A. In my judgment it would clearly be better to treat the water and to allow the sewage to be discharged. It would be better because it would be more efficient in protecting the people who use the water from infectious matter from the sewage; and it would be better because it would be cheaper. I mean it is better than trying to purify the sewage and continuing to use the water without treatment.

Q. Are you familiar with the quality of the water now served to the people of Chicago?

A. Yes, sir.

Q. What did you learn in that respect?

A. In addition to my general information as to lake currents and the quality of water obtainable, I visited the Health Department of Chicago and learned what I could as to the character of the water from the different intakes as shown by their records; the water from all the intakes.

Mr. Wilkerson: In addition to the objection already noted,

let this go in subject to the further objection that it is secondary.

A. The water from all the intakes is generally of good quality. At the present time there are times when water of inferior quality is obtained from each of the intakes. The times when water of inferior quality is obtained are more frequent and last longer at the South Shore intake opposite 68th street. This is believed to be due to its being closer to the outlet of the Calumet River which is regarded as the principal local source of pollution of the lake in front of the city at this time.

Q. What effect upon this particular source of pollution would the construction of the Calumet Sag Channel and the reverse of the flow of the Calumet River have?

A. It would clearly tend to reduce this source of pollution.

Q. And suppose further that intercepting sewers were constructed to divert the sewage that otherwise empties into the river, so that it would empty directly into the canal, what effect would that have?

A. If the interception were carried to completeness, it would practically eliminate this source of pollution.

Q. Assuming, Mr. Hazen, a population of 1,200,000 people, producing sewage which is cared for by the construction of a channel with a capacity of 4,000 cubic feet of water per second and by the construction of intercepting sewers such as we have assumed in the preceding question, so that no part of the sewage of that population emptied into the lake, what is your opinion as to the necessity in that case of constructing purification works for the purpose of purifying the water supply of the city; and if such works are necessary, of what character should they be?

A. Under the assumed conditions, I believe that it would be reasonably sufficient to treat the water with hypochlorite of lime. I believe this treatment would be advantageous at the present time, and I should regard it or its equivalent as reasonably necessary under the conditions that you mentioned.

Q. What other sources of pollution are there other than the sewage which ordinarily empties into the Calumet River and the Chicago River, which would render it necessary to install purification plants?

A. There is pollution from shipping, from the dumping of various waste materials into the lake; from the sewers of other cities and towns, and there is almost certain to be

sometimes some overflow from the sewers in times of unusual rains.

Q. Have you made an estimate of the cost of such works as you have described for the treatment of the water supply of the City of Chicago by the hypochlorite system?

A. I considered the cost on the basis of the present works and the present amount of supply. I have made no very detailed estimates of the exact works, but I know from other cases some thing of what would be involved.

The cost of installing the works would not exceed $100,000; and the cost of operation for the present quantity of water may reasonably be estimated at about $60,000 per annum. The works for applying the chemical not being of the most permanent nature, I consider that 20 per cent. of the cost of construction might be taken as the annual charge, or $20,000 for the works and $60,000 for the operation, making $80,000 per annum as about the fair cost of treating the present supply of water by this method. These cost figures would increase proportionately or nearly proportionately with the amount of water drawn and used.

Q. Assume that the sewage of a population of a million two hundred thousand people were discharged in its raw state into the lake, what purification works would you then consider as proper and necessary for the protection of the water supply of the City of Chicago?

A. I consider that with such a discharge of sewage into the lake it would be desirable and reasonably necessary to filter the water before use; and I should use the hypochlorite treatment of the effluent from the filters.

The works proposed would correspond with those now being built by the City of Toronto to meet very similar conditions. The present use of water is five hundred and twenty million gallons per day. I assume that filters would be required with a nominal capacity of 40 per cent. in excess of this amount, to cover fluctuations in rate and to provide a reserve for units out of use, for cleaning or other purposes. This would call for about 120 acres of filters, operating at a rate of 6,000,000 gallons per acre daily distributed among the different intakes in proportion to capacity. These filters could be built on the lake shore, or on cheaper low lying land back of the lake shore, and not too far away from it; or just as well in shallow water near the shore.

Low lift pumps would take the water from the present tunnels to the filters and the effluent would go back into the tunnels beyond. The conditions of construction seem to be gen-

erally similar to those met at Toronto; and I am basing my idea of cost upon the prices actually being paid at Toronto. Upon this basis, the cost of the works complete with all connections with the present works, but exclusive of land, would cost about $10,000,000. The cost of land would have to be added.

I know about that only by inquiries of the most general kind, in connection with some knowledge of topography in the various locations; and I assume that the sites might reasonably cost $3,000,000, making the total cost of installation about $13,000,000.

The annual cost of operation I estimate at about half a million dollars. Both the cost of construction and operation, of course, would increase in the future in proportion or nearly in proportion to the amount of water drawn and used.

Q. If this system were installed and these works constructed, in your opinion, would it be necessary to install any additional works; would the hypochlorite system be reasonably necessary in order to render them perfectly efficient?

A. Well, I have included that in my estimate and in the statement. It would be necessary to have some added works to prevent offensive conditions in the Calumet River.

Q. Assuming that the sewage of the population assumed was completely diverted and treated by dilution through a channel such as is proposed to be constructed by the Sanitary District, and the hypochlorite system of treatment was adopted; then assume that the sewage was emptied in its raw state into the lake and the system last described by you were employed for purification of the water supply. Which would produce, in your opinion, the better result from the standpoint of purity of water?

A. As near as I can tell, or estimate ,the conditions would be about equivalent, as measured by the sanitary quality of drinking water produced.

Q. In your opinion, what would be the effect upon the lake and upon the Calumet River itself, if the sewage of 1,200,000 people in its raw state were emptied into the river and into the lake so far as producing nuisance is concerned?

A. I think the sewage of 1,200,000 people discharged mainly into the Calumet River would produce offensive conditions in it, which conditions would require some local treatment.

Q. Have you given any thought to any treatment that might be applied to obviate the nuisance thus created?

A. Yes, sir, I have given the matter some thought. In a

general way it would seem that the method of flushing that has been used by Milwaukee through a long term of years would be the best way of correcting such conditions in the Calumet River; I mean the best way looking at it as a local problem and excluding the channel which you are proposing to build.

Q. We are assuming that the channel is not built. Can you describe a little more in detail the flushing system to which you refer?

A. The flushing system at Milwaukee consists in cutting tunnels from the lake to points on the river above the points where the objectionable conditions exist and pumping water through the tunnel to produce a current in the river and to dilute the sewage discharged into the river to such an extent that it will not become objectionable.

Q. And also creating a current?

A. It also creates a slight current. The first of these tunnels was built in Milwaukee, I think, something like twenty years ago. A second one was added fifteen years ago. And a third and a more expensive one has just been recommended, as the conditions in parts of the stream are bad at the present time.

Q. Have you, from your investigation, an opinion as to what such a system would cost, if it were to be constructed and put in use in the Calumet River, assuming that the channel proposed is not built and the sewage became a nuisance in the river?

A. The first two tunnels and works at Milwaukee cost approximately $750,000. They have served their purpose well, but seem to be outgrown at the present time. The estimated cost of the canal recently recommended is about $1,150,000, which would bring the whole cost of the works to $1,900,000. Taking into account the fact that the two canals as built seem to be somewhat overtaxed, and the fact that the new canal anticipates growth, three dollars per capita for construction seems to be about a fair figure. And the cost of operation, which is made up mainly of pumping water, at Milwaukee seems to run from ten to fifteen cents per capita per annum.

Q. In your opinion, would those figures prevail substantially in the Calumet region if the same system were employed?

A. Why, I should suppose they would within certain limits. Of course tunnelling conditions may be more favorable or less favorable. I have not looked into that. It was my

feeling that what Milwaukee had actually spent was perhaps the best off-hand guide that I could get as to what Chicago might reasonably spend in this case.

Q. And in your opinion that is a good guide?

A. Yes, in a general way.

Q. Taking into consideration, Mr. Hazen, the fact that the Sanitary District has thus far proceeded to dispose of the sewage of the district by the dilution method and by the construction of channels, I want your opinion as to the advisability of either changing the system or attempting at this time to supplement the works that are already constructed by an entirely different system; and if such attempted substitution or addition were made, what would be the effect on the present sewerage system of Chicago; the costs and difficulties involved; not having in mind the figures at all, but the general wisdom of the substitution or change?

A. I think it would be very unfortunate to have to change the system at this time. The whole theory of the present system, as I understand it, has been to dilute the sewage matter as promptly and as largely with water as possible. To treat the sewage so as to purify it artificially in a chemical way involves carrying out the reverse system; that is, treating the sewage matters with as little dilution as possible up to the point where the sewage is treated. The whole district is sewered on the combined system; that is to say, all the rain water and street wash is carried to the sewer and flows in the same channel with the sewage matters. To completely and economically treat the sewage, it is necessary or at least very desirable to have the separate system; that is to say, to keep the sewage matters from mixing with the street wash and rainwater.

In order to treat the sewage thoroughly, adequately to its logical conclusion in any new district would mean the installation of separate sewers in place of the combined sewers, and this would involve a very great added expense. It is partly for that reason that it seems to me that a partial treatment of a larger quantity of sewage might have great advantges in connection with the present authorized flow rather than the complete treatment of all the sewage from a certain separated population. But certainly to change the system now would involve readjustments that would cost the district a great deal of money.

Q. If a separate sewerage system were constructed, in order to separate the sewage proper from the street washings and the rainwaters, those street washings would then flow

where, Mr. Hazen, assuming that this channel were not constructed through the Calumet region, and assuming that we are dealing with the Calumet region?

A. I presume that would flow to the Calumet River and ultimately to the lake.

Q. What effect would they have upon the purity of the water supply?

A. They would tend to pollute it.

Q. Will you state, Mr. Hazen, from your experience, what length of time it takes for fresh sewage to become putrified so as to become a nuisance?

A. I don't think there is a fixed limit on that. It is a question of temperature to a considerable degree. I can state my observations in going down the canal on May 23d as bearing upon this point. The mixture flowing in the canal after passing Western avenue must have been substantially the same that it was from that point all the way to Joliet; but in the upper part of the canal, that is to say, at Western avenue and for a few miles beyond, the sewage was comparatively fresh. There was plenty of dissolved oxygen in the mixture and the conditions were entirely unoffensive. Going down the canal, the amount of dissolved oxygen was steadily reduced and it was almost exhausted before the powerhouse was reached. The putrification of the sewage was apparent in the last miles; and there were evidently beginning to be deposits of sewage mud along the edges at several places, and especially in the fore bay at the power house. The mixture was almost up to the point of becoming offensive. This was especially interesting to me as showing the effect of time for these changes to take place. There was no increased pollution at the power house as compared with Western avenue of any practical significance, but there was a great increase in the effects of pollution.

The passage of the mixture by the power house partially aerated it, and considerably improved its appearance, so that it was in better shape below and in Joliet than it was right at the power house. Under the conditions of flow and temperature existing on this particular time, the greatest apparent effect of pollution occurred just above the power house. I can imagine, however, that with other temperature conditions, other conditions of flow, the maximum might occur at some other point.

Q. Suppose, then, Mr. Hazen, that the population of Chicago, that part of Chicago which sewers into the Chicago River, should substantially increase beyond the amount that

can be properly cared for by the dilution method according to the rate now prescribed by law, what would be your opinion as to the advisability of constructing a channel to discharge the water into the main channel at a point somewhere between Chicago and Joliet, for the purpose of further diluting the sewage as it proceeds down the channel?

A. It is my feeling that looking through a reasonable period of years, controlling points on the necessary amount of dilution will be at Joliet and in its neighborhood, and in the valley for some distance below; that through the closely built up part of the City of Chicago it is more a matter of time than a matter of dilution, and that with a sufficient current, meaning by that a current not less than the present current, the materials may be carried along—will be carried along so as not to become especially offensive in that part of the city, and with respect to these lower conditions, which it seems to me are going to be the controlling conditions in such a period of years, the mixture of water coming through this proposed Calumet Canal will be almost as useful as a corresponding quantity of water coming down the river all the way. Of course, if all the conditions permitted it, it would be better to have it come with the sewage all the way.

In speaking of the present current in the river, I referred to the current in the main stream. There is part of the North Branch where under the conditions on May 23d, the current was less than it ought to be; but there are new works under way that I understand will increase that.

Q. In your opinion, Mr. Hazen, is it desirable or necessary in order to properly treat sewage by the dilution method to have a current, so that the sewage is constantly in motion?

A. Why, yes, sir, I regard that as almost essential. If you have an extremely large dilution, it may do to put the sewage into quiet water; and on the other hand, if the available current is very strong, it is my feeling that the dilution may be a good deal less. I think there is a relation between the strength of current and the amount of dilution, and the stronger the currents, referring to the currents not only at the point of dilution, but all the way to the point where the sewage is disposed of, the dilution may be less than where the currents are sluggish.

Q. You have described your observations on May 23d, as to when you first noticed the putrifaction of the sewage. Can you state any more definitely how soon after you left Western avenue, that is, how short a distance from Western avenue, that condition first manifested itself?

A. It was manifest first in the chemical analysis in the determination of dissolved oxygen; that was going down steadily. But I can't say that I noticed much difference apparent to my senses until we had gone down the canal quite a long ways; and it increased most markedly within two or three miles above the power house.

Q. And what was the temperature on that day; that is, generally speaking, was it a warm day?

A. Yes, sir, it was a warm day.

Q. Would it make any difference, Mr. Hazen, in your opinion, as to where the point of putrifaction would become first appreciable to the sense as to what the temperature was; I mean having reference now to the chemical analysis?

A. I think it would. I think the temperature of the water would have more influence than the temperature of the air; and the highest temperature in the water would occur later in the season, in August or about the first of September.

Q. Would the putrifaction be noticeable—I am speaking now to the sense of smell—when it was warm sooner than when it was cold?

A. I should expect that it would occur sooner in the higher temperature. It is possible that to off-set that condition—I have observed that in Pittsburgh—where the discharge of certain kinds of manufacturing waste seemed to have the effect of stopping the putrifactive processes for the time being; and considerably postponing the point where the worst conditions appear; so the temperature does not necessarily alone control.

Cross-Examination by Mr. Wilkerson.

Q. Just what was the nature of the work which you did in the Lawrence Experiment Station?

A. We had experimental filters of various materials, of various depths, and to these we applied sewage, raw sewage, settled sewage and water of various kinds, in the endeavor to find out how sewage and water could be best purified, especially with reference to the conditions existing in the State of Massachusetts; and many other experiments along allied lines relating to the qualities of public water supplies and the methods of protecting them were carried out. It was an experiment station for the State of Massachusetts.

Q. It was for the purpose of finding out how much the water could be polluted and at the same time be taken care of by the filters?

A. Well, that is one line of investigation.
Q. Was that the principal line?
A. No, I should not say it was the principal line.
Q. What other lines were there?
A. The principal lines, that is your question?
Q. Yes.
A. They were to find the best available methods for taking care of sewage and water supplies in the state.
Q. And as the result of your work, was there any conclusion reached as to the best method?
A. Many important conclusions were reached. The work was not carried to the point of selecting any one method as being pre-eminent over others. That would hardly be possible, because there are different conditions that require different methods; and the work was rather to show what could be done by different methods under different conditions than to select one that was better than all others.
Q. Now, what was the nature of the plant that was constructed at Chicago during the World's Fair, which you spoke of?
A. That was a plant for treating the sewage by a process known as chemical precipitation. There is a description of the plant in the report of the Massachusetts State Board of Health for 1893, page 597.
Q. Give us just in a general way the main features of the plant and the method which was used?
A. The settling tanks were of the so-called Rockner-Rothe type. This was a German type tank which had recently been brought out and represented probably the most advanced practice and ideas at that time. There were four of these tanks. The sewage was first screened; then was treated with chemicals and went to the bottom of these tanks, the sludge deposited in the bottom; the sewage rose and overflowed weirs at the top and went to the lake. The sludge was drawn up from the bottom of the tanks from time to time; was pressed, and was burnt in a crematory near by.
Q. It was the intention that the sewage should be treated in such a way as not to pollute the waters of the lake, was it?
A. That in a general way was the intention.
Q. Was it successful?
A. The effluent, I think, produced no local nuisance around the discharge. So far as its effect upon water supply was concerned, the treatment might just as well not have existed.
Q. So far as the water supply was concerned?
A. So far as the water supply was concerned. In other

words, the treatment did not stop the bacteria representing any infectious material, which there might have been in the sewage.

Q. So it was more for the sake of getting rid of the offensive local condition that this was done?

A. That is what it accomplished. When you speak as to the intention, that goes somewhat back of my connection with the work. The World's Fair wanted to have everything up to date, and the best of everything; and they wanted a sewage disposal plant and they got it. I suppose that the people when they decided to build the plant expected that it would protect the water supply from any pollution that there might be in that sewage, but as a practical proposition it did not do that thing.

Q. Now, how many people did they have in mind in the construction of that plant as being taken care of?

A. The population tributary to the works is stated in the report mentioned on page 618. The greatest number of people was in October when there was a total attendance of 8,034,000 within the grounds.

Q. That is the whole month?

A. That is the whole month. In September there were 5,809,000. I could not say as to what number of visitors was contemplated in advance. This is a record of the number of visitors that there were.

Q. You say that the method which was used there did not result in destroying the bacteria?

A. It did not destroy them.

Q. It did not?

A. No, sir.

Q. Was it supposed that it would when the plant was constructed?

A. Well, I can't say as to that. The plant was authorized and started before I went to Chicago.

Q. Do you know how much the plant cost?

A. I, of course, knew from my experience at Lawrence that that method would not be efficient in stopping the bacteria. I doubt if many people in the department really knew that until they got the results. I can't tell you exactly what the plant cost; it is my impression it cost something like eighty to one hundred thousand dollars.

Q. What was the cost of operation?

A. Here I have it (referring to report). The cost of construction was $55,000; but I would say in regard to that that quite a part of the equipment was contributed as exhibits, so

that the fair cost of building it would have been considerably more than that.

Q. What would you say would be the fair cost of building it?

A. The machinery was nearly all contributed as exhibits. I think the figure I first gave you would be as nearly as I could tell you. The cost of operation from April 14th to October 27th was $14,207; 373,000,000 gallons of sewage were treated.

Q. Is that method used any more?

A. Yes.

Q. Where?

A. Providence, Rhode Island, uses it; the biggest sewage disposal plant in the United States.

Q. How long has it been in operation there?

A. I should think a dozen years, perhaps longer.

Q. Does this report to which you refer state that that did not result in destroying the bacteria?

A. It shows it.

Q. It is your report, is it?

A. Yes, sir.

Q. And the Providence plant was built after that time?

A. Yes, sir. I don't think the Providence plant was intended to remove the bacteria; I am sure it was not.

Q. What was it intended to do?

A. To keep the sewage sludge out of the bay.

Q. Is a plant of that kind in use any place else?

A. At Canton, Ohio, they have a plant of that kind, that I think is in service. Worcester, Massachusetts, has a plant of that kind; but in the last years, the greater part of he effluent from it has been subsequently filtered; but the chemical precipitation part of the plant is still operated. Plants of this description were used very generally in Europe at this time. I think it was the most widely used method of treating sewage at that time, perhaps in the whole world.

Q. At that time was it generally supposed that that method would destroy the bacteria?

A. It certainly was not in Europe, because the European plants as far as I know were not any of them intended to remove the bacteria. They were intended to remove the sludge which otherwise produced objectionable deposits in the rivers and channels; and the European engineers and chemists that I knew in charge of these plants were under no illusions in regard to their lack of bacterial efficiency.

Q. You say you studied in Dresden for a year or two?

A. No, for a semester—a term.

Q. Along the same general line of work that you had been doing at the Lawrence Experiment Station?

A. I took the course of Wasserbauer as they call it, water works construction, hydraulic construction.

Q. Now, you have spoken of some plants with the construction of which you have had something to do. You spoke of one at Altoona, Pennsylvania?

A. Yes.

Q. What kind of a plant have they there?

A. That was what was called intermittent filtration of sewage. A large sandy tract of land was taken and cut up into beds and underdrained; and the sewage is applied to that during the summer and crops are raised upon it, so that it is a partial irrigation.

Q. For what sized population was that plant intended to provide?

A. The population of Altoona, as I remember, is forty or fifty thousand, and this plant serves rather more than half the city. The other half of the city drains in another direction to another stream.

Q. What did that plant cost?

A. I should have to look up my records.

Q. Have you any general idea on the subject? I do not care for the exact figures.

A. Well, I should think $100,000.

Q. And what would be the cost of maintenance?

A. Well, probably $1,000 a year.

Q. And in order to provide for a larger population, would the cost be proportionately greater?

A. It would be if there was more sandy land, but we took all the land there was available.

Q. You have to have sandy land?

A. You have to have sandy land in order to do it.

Q. If you have lots of sandy land that kind of a plant works all right?

A. That plant worked all right. That is why substantially the same kind of plant has worked so well at Paris and Berlin.

Q. So if you had whole counties of sand that could be put in operation very easily?

A. That would be first rate, barring the transportation. I may say in regard to this Altoona plant, it is intended to treat the sewage in summer when it is otherwise objectionable in the stream. The process does not work very well in winter and I have never considered that it was necessary to treat

that sewage in the winter, and have advised them to bypass the plant and let it go through the winter.

Q. What kind of a plant was put in at Spencer, Massachusetts?

A. That was similar in its general character to Altoona; treated the sewage of the whole town. The sand was coarser and better at Spencer than Altoona.

Q. Was that as large a plant as the Altoona plant?

A. Not as large in area; not as large in any way, because the population was smaller.

Q. Was the plant at Plainfield the same kind?

A. That was, but Plainfield has grown rapidly and the sandy area not having grown, the plant has been rebuilt and modified since I had to do with it.

Q. You say you have acted in an advisory capacity to the City of Pittsburgh?

A. Yes.

Q. During how long a time has your employment continued?

A. I took that work up a year ago last January.

Q. Did they have in contemplation there the construction of a new system, or was it with reference to overhauling the old one?

A. It has been proposed to reconstruct generally the sewer system of Pittsburgh, with the object of taking the sewerage to one place and treating it before discharging it into the Ohio River. The whole question of the expediency of doing that and the methods to be followed, is being investigated.

Q. Has any conclusion been reached on that subject?

A. No conclusion has been reached.

Q. Have you reached any conclusion?

A. Not officially; I have personally.

Q. Well, without committing yourself in any way that would prejudice your employment there, just what are the available methods of handling the sewage?

A. I can tell you what the available methods are.

Q. I suppose what it is desired to accomplish is not to pollute the waters of the Ohio River?

A. Yes.

Q. To save the water in the river from that pollution?

A. Yes.

Q. So that the sewage will be treated before it reaches the river, so that it will be inoffensive?

A. That is the idea.

Q. Now, what is the general scheme that has been worked out with respect to that?

A. Several general schemes have been worked out.

To go back to your preceding question as to what the possibilities are, there is first the possibility of the present conditions where all of the sewage collected in the combined system and mixed with all the rainwater and street washings goes to the river at the nearest point. The first possibility of improvement consists in taking the dry weather flow from the larger sewers and taking it through settling basins to remove the heaviest part of the sewage mud and to prevent the deposit of sewage mud in the shallow water along the shore of the river at low water, especially between the shipping and the shore. That method of treatment is directed to correcting the physical appearance of the river opposite the city. That is the method that is usually used by cities in continental Europe. It has not been adopted in America to any appreciable extent. It is not directed at all to protecting the river water below from pollution with respect to water supplies.

The next possibility that may be mentioned consists in the collection of all the sewage at some central point where it might be treated and purified before being discharged. This involves in the first place installing a separate system throughout the city in place of the combined system, at a cost of untold millions of dollars. It is a very expensive operation and it is absolutely essential because no plant can possibly be built that is capable of carrying off the storm overflows from a city like Pittsburgh. The storm overflows from Pittsburgh are larger in proportion than in Chicago because the topography is abrupt and the run-off is quicker.

After the present sewers were all built over on a separate system, then great intercepting sewers would be built down each side of each of the main rivers to some central point, or some point below the city, rather, where a site may be selected, and where the sewage would be pumped to bring it from the low level which it had reached by its gravity flow up to an area where the disposal works would be built, above ordinary floods; and there works would be built on some system to purify it.

Q. Aside from the cost of reconstructing the system of sewers, have you reached the point of making any estimates, as to the cost of the purifying works?

A. Such estimates are in process of being made, but I am not in position to announce any results as yet.

Q. Are you able to give us a general idea as to the limits within which the cost of such a work would fall?

A. It represents a great many million dollars.

Q. Are you able to give any more definite an estimate than that?

A. No, I could not state it any more definitely.

Q. When you say a great many, do you mean more than ten?

A. The whole plant represents a good deal more than ten.

Q. I am speaking not of the reconstruction of the sewers but simply the purifying plant itself?

A. I could not state as to that.

Q. How large a population are you attempting to provide for?

A. The present population is about a million.

Q. How much growth are you anticipating in planning the plant?

A. We laid these works out for about double the population.

Q. About two million?

A. Pittsburgh is growing quite rapidly.

Q. You could not give an approximation, or what you believe such a purifying plant would cost to construct?

A. No, I could not. I could give you corresponding figures for Paterson, New Jersey.

Q. Let us have those?

A. Where the estimate was completed?

Q. For how large a population were you attempting to provide there?

A. The population of Paterson in 1905 was assumed to be, at that time, 111,000. The population contemplated in the estimates was 250,000, of which a part of the construction was to be postponed. The whole cost of the purification works was estimated at $3,028,000, of which $600,000 could be postponed for a time; and the cost of the works to be built at once was $2,428,000. That does not include the cost of separating the sewers. Paterson was sewered on the combined system, and this estimate did not contemplate an immediate and complete separation, but only the separation of the larger areas at once, to be followed up with a gradual separation of other areas. I find that I allowed $550,000 additional for separating surface drainage.

Q. I think you said you came in contact with this Chicago problem in the litigation between the Sanitary District and

the City of St. Louis, with reference to the pollution of the water?

A. I did.

Q. You were a witness for the City of St. Louis?

A. I was.

Q. And then had occasion to look into the effect of the discharge of sewage through the Drainage Canal, down through the Illinois River and into the Mississippi?

A. Yes, sir.

Q. And what conclusion did you reach about that?

A. I reached the conclusion that the sewage of Chicago was an undesirable addition to the St. Louis water supply.

Q. That was before it was treated?

A. The water was used as it came from the intake at that time.

Q. That was at St. Louis?

A. That was at St. Louis.

Q. That is to say, you reached the conclusion that the effect of the taking of this sewage from the Chicago Drainage Canal down through the Illinois and Mississippi Rivers polluted the water supply of St. Louis?

A. I believed it did. It certainly tended that way.

Q. It was your conclusion as an expert in the case that it did have an effect of polluting the water?

A. I believe it did.

Q. That was the effect of your testimony, was it not?

A. (No response.)

Q. Now, you have had to do with the construction of a plant at Washington, did you say?

A. For treating the water.

Q. Treating the water?

A. Yes, sir.

Q. What is it necessary to do there? What was done; just what was the plant constructed there?

A. The water is taken from the Potomac River. It flows from an intake above Great Falls through three reservoirs in which a considerable amount of mud is deposited. Before the plant was built, it was pumped directly from the last of these reservoirs into the mains, or flowed to some of the lower parts of the city by gravity.

The plant is a plant for filtering the water. It consists in passing through sand; the water is pumped from the last of these reservoirs to twenty-nine filters of sand and covered with masonry structures; and the water passes through the sand and is collected underneath and carried through suitable

works and conveyed to the distribution. The works are similar in their general nature to those which I suggested being used in treating the Chicago water, in case sewage were discharged in large quantities into Lake Michigan; but differ in many details because the Potomac water is different in its character from Lake Michigan water, and requires within certain limits a different kind of plant to handle it.

Q. Was the problem there a more difficult problem than the Chicago problem, assuming all the sewage was discharged into the lake?

A. Yes, I think it was.

Q. It required a more expensive plant than would have been required at Chicago?

A. More expensive per million gallons, yes; of course, not as large, not as expensive in the aggregate because Washington is not as large as Chicago.

Q. And for how many people did you undertake to provide in the construction of that plant?

A. Oh, we figured it to provide so many million gallons. The question of how many people depends upon how many gallons per capita they use.

Q. How many million gallons did you have in mind?

A. The consumption at Washington has decreased a good deal in the last years by cutting off useless waste, and the consumption is a good deal less now than it was when we first took this work up. The plant was built to treat eighty-seven million gallons of water per day, but it is actually capable of treating a somewhat larger quantity.

Q. Do you know how much that plant cost?

A. It cost about $3,300,000. That is a higher cost per million, no doubt, than I figured for Chicago, because, as I stated, the conditions are different and at Chicago I assumed that we should use a rate of 6,000,000 gallons per acre daily, which is the rate that we are proposing to use at Toronto and they actually use in some other cases.

Q. You are speaking of some estimates that you made for Chicago; when did you make them?

A. In this testimony. The Washington filters were only designed to operate at half that rate.

Q. Now, with reference to this study of the lake and river conditions at Chicago, which you made last week, at the time you made this study, how much water was being diverted from Lake Michigan through the Chicago River?

A. The quantity as calculated at my request from the

records available on May 23d was 421,311 cubic feet per minute.

Q. You spoke with reference to the amount authorized by the law of Illinois as 20,000 cubic feet per minute for each 100,000 inhabitants, and with reference to the reasonableness of that amount. Now, on the basis of the present population of the City of Chicago, how many cubic feet per minute were being diverted from Lake Michigan through the Drainage Canal, at the time you made these observations?

A. I took the population as 2,200,000, which was obtained by taking the population by districts according to the census of 1910, as Mr. Pearse worked it out, and adding the estimated normal growth for one year; and it came a few short of that, but we rounded it out, and it was 2,200,000. That would make 19,200 cubic feet per minute per 100,000 of population. I regard these as approximate and not exact figures.

Q. Did I understand that you had made an estimate of the cost of constructing the plant for treating the water supply of the City of Chicago on the basis of its present population?

A. Yes, sir.

Q. And what was the figure which you gave? This is assuming, of course, that all the sewage goes into the lake, and the water has to be treated?

A. Assuming that the sewage from an added population of 1,200,000 goes into the lake?

Q. No, I am speaking now of the cost of treating the sewage on the theory that it was all emptied into the lake, and that you closed up the present channel.

A. I have not made such an estimate.

Q. You have made no such estimate as that?

A. No.

Q. You made an estimate of the cost of treating the water supply on the theory that the sewage from 1,200,000 goes into the lake?

A. Yes, sir.

Q. Would it require a very much more expensive plant to treat the water supply, if the sewage from two and a half million went in rather than 1,200,000?

A. Well, that would depend largely upon the points that were available for the discharge of the sewage. It would be much more difficult and more expensive to get outlets for the sewage with the larger population which would be as well diluted and no more injurious to the water supply than it would to secure such outlets for a million two hundred thou-

sand population, which population naturally would be extra population and largely at the extremeties of the city as distinguished from the central part of the city.

Q. This computation which you made was on the theory that this 1,200,000 population is in the neighborhood of the Calumet River. What I am trying to get at is the exact elements that have entered into that computation?

A. I assume that it might all enter from the Calumet district, or that any part of it might enter from a somewhat similar district to the north, where it might be more convenient to let part of the sewage go.

Q. And you have made a computation on the basis of the sewage of 1,200,000 people?

A. Yes, sir, that is to say, I assumed that that amount of raw sewage was going into the lake.

Q. And have you made a computation having in mind the present approximate population of this Calumet district? What is that figure?

A. The estimated population now connected with sewers discharging into the Calumet River is 131,000; that is wholly within Illinois. And in addition thereto there are about 50,000 people in Illinois not connected with the sewers, on the best available data; and in Indiana there are estimated to be 97,000 people.

Q. Now, let us assume that this canal here connecting with the Calumet River is not permitted to be constructed, and that the sewage which is now going out through the Calumet River has to be provided for in some other way. Having in mind, we will say, that the population of the district is double what it is now and allowing for that element of growth, just what could be done in the way of taking care of the sewage of that district?

A. I should say that the first step would be to filter the water supply.

Q. That is to filter the entire water supply of the City of Chicago?

A. I should say so, starting perhaps with the south crib and working north.

Q. Well, wouldn't it be possible to treat the water that empties into the lake in some way so as to render it inoffensive?

A. Treat the sewage, you mean?

Q. Treat the sewage, yes?

A. It would be possible to do that, but in my judgment it

would cost more money and be less efficient than treating the water.

Q. How could the sewage be treated? I am speaking now of, say a population of 300,000 people, assuming that there were 300,000 people around that river?

A. It could be treated as was proposed for Paterson and as has been done at Columbus and other cities, by collecting it in intercepting sewers, by pumping it, by settling out the heaviest of the sludge, by screening it, by applying it to sprinkling filters; by settling again the effluent from the sprinkling filters to cut out the heaviest part of the mud, and finally by disinfecting the effluent with hypochlorite of lime. All these processes are successive processes, not alternate ones.

Q. What would be the result assuming that method were followed as to the condition of the water which would go into Lake Michigan?

A. If all the processes were carried out perfectly, and if all of them worked all the time, it would remove very much the largest part of the organic polluting matters, and the largest part of the bacteria, but it would not remove all of them.

Q. Would it then be necessary to filter the water?

A. I should say so.

Q. That is, you think even if that method were resorted to, you would still have to filter the water, at least from the Hyde Park Crib?

A. From the standpoint of water supply, I should make very little difference in the required treatment whether the sewage was treated before discharge or were not so treated. In other words, I do not believe that the methods of sewage treatment now available in a location of this kind are to be fully relied upon to protect the water supply.

Q. In the estimate which you made, you had in mind the population of 1,200,000, that is, the sewage from a population of 1,2000,000 people?

A. Yes.

Q. Have you made any estimate of the cost of filtering the water, assuming that the sewage of only one-fourth of that number of people emptied into the lake?

A. No, sir, I have not.

Q. That is 300,000. What difference would that make in the estimated cost of filtering?

A. It would not make a very large difference.

Q. Would it reduce it?

A. It would tend to reduce it, yes.

Q. Would there be the same necessity for filtering the entire water supply of the City of Chicago if the sewage of 300,000 instead of 1,200,000 emptied into the lake?

A. There would not be the same degree of need of filtering, certainly.

Q. Would you have to go any further north, in your opinion, than the 68th street crib, if the sewage of only two or three hundred thousand people emptied into the lake, in filtering the water, or would it be sufficient to simply filter the water that was taken in at that crib? I am assuming now that all that goes into the lake is from the Calumet District?

A. Yes.

Q. Instead of 1,200,000, you have only two or three hundred thousand people?

A. Discharging here (indicating on map)?

Q. Discharging there, and that is all that goes into the lake?

A. Yes.

Q. And having in mind that the water supply is taken from different places all along the lake shore. I am trying to get your best judgment as to how much of the water supply you would have to filter, on the basis of two or three hundred thousand people in that territory?

A. It is clear that all of the water ought to be treated, but it may be that from the northern tunnel water would be obtained which for the present would be of sufficiently good quality with simply the hypochlorite treatment carefully administered; and that might be true of some of the other tunnels, with the smaller population.

Q. That is, you think that with the hypochlorite treatment you could on the basis of merely two or three hundred thousand people, down there discharging sewage into the lake, you could remedy the difficulty with respect to a considerable portion of the water supply?

A. It would improve the situation very much, certainly.

We have found that at Toronto where unfortunately there was a break in the intake during the last winter, and where temporarily water has been taken of much more polluted character than is ordinarily used, we have found that by following out the hypochlorite treatment very persistently and carefully, the results have been very satisfactory.

Q. Now, with respect to this water at the 68th street crib, you went out you say with a chemist?

A. No, sir, I did not go out to the 68th street crib.

Q. Just what examination did you make of that water?
A. I only examined the records of the Health Department at this time.
Q. That was on the 23d of May?
A. Yes.
Q. And the records which you saw showed what with reference to that water at the 68th street crib?
A. The greater part of the time the water is of as good quality as the water from the other tunnel, but occasionally it falls off in quality very much, so that it cannot be considered good water.
Q. How much of the time is that?
A. I cannot state the extent of the time. That is a matter of degrees. It falls off a little in quality for longer periods, and falls off a great deal in quality for shorter periods.
Q. Of course there are always some bacteria in all water, and it is a matter of degree as to when the water is safe to drink?
A. Yes, that is true.
Q. It is hard to fix the absolute limit, where we know that water is safe to drink. It is difficult to get absolutely safe water?
A. I should say there was such a thing as absolutely safe water, practically safe.
Q. What I was trying to get at was, in as specific form as we could get it, just what and to what degree there is anything wrong with that water there at the 68th street crib?
A. This pollution is most effective when the wind blows the water directly in that direction. (Indicating on map.)
Q. That is north?
A. Yes. They tell me that at the Health Department; but I also know that from my experience with lake waters in other cases. The wind may blow it up here (indicating) on one day, so that it comes up and there is a good deal of pollution, and then the next day the wind may blow from some other direction and the water is of quite different quality. It is possible for the character of the water from a lake intake of this kind to entirely change its character in a half hour.
Q. When you spoke of the wind blowing, you meant blowing from the Calumet River?
A. Towards the intake.
Q. North towards the intake?
A. Yes, sir. I do not know as I completed the answer to your question.

Mr. Wilkerson: Pardon me.

The Witness: Having seen these records and knowing something of the pollution of lake waters and their subject to these influences, I can put it this way: If I lived in territory served by that intake, I should not want to drink the water without having it boiled.

Q. Or filtered?

A. Or filtered, yes, sir.

Q. Now, has it not been considered possible to take the sewage of this Calumet region here and dispose of it in some other way than by discharging it through the Calumet River, or have you given any consideration to any such plan as that?

A. I considered the possibility of collecting this sewage and treating it in the way that I mentioned a few minutes ago, and it certainly could be done. Treating the sewage of Milwaukee in that manner was considered by the Commission of which my partner was a member, but it was found on the evidence that they had that it was clearly better to discharge the sewage at selected points into the lake and filter the water. And at Toronto the question of purifying the sewage in some such manner was considered, and very carefully considered at great length, and the decision was reached there to discharge the sewage at one point after the removal of only the heaviest of the sewage mud by settling, the removal of which does not make any difference whatever with the bacterial conditions, and filter the water.

Q. Now, as to the cost of filtering the water supply for the City of Chicago, your estimate was on the theory that the sewage from a population of 1,200,000 discharged into the lake?

A. Yes.

Q. I do not recall the final figures which you gave, but in order that I may get my next question, just state what that estimate was?

A. $13,000,000 for the construction and land.

Q. $10,000,000 for the construction of the plant and an estimated cost of $3,000,000 for enough land on which to operate the plant?

A. Yes, sir, and the operation in addition.

Q. And the expense of operation was in addition to that. Now, if the Drainage Canal had never been built, the sewage from the entire population could have been handled in the same way, could it not?

A. I think it undoubtedly could have been, though it would have involved no doubt, the carrying the sewage some dis-

tance to get proper points of dilution for so large a quantity; and also carrying the waterworks intakes to a considerable distance, preferably in some other direction, to get as far away as possible from the sewage.

Q. I think you said you had made no study of the situation with a view of determining what it would cost to dispose of all the sewage, on the theory that the Drainage Canal was entirely closed?

A. No, sir, I have not attempted that. I started with the assumption that the Drainage Canal was a fixed fact; with 10,000 cubic feet of water that could be diverted through it.

Q. Of course, if they had 10,000 feet of water which could be diverted through the Drainage Canal, that would still take care of a good many more people than are in Chicago now?

A. On the basis of the legal rate, it would take care of 3,000,000 people.

Q. Then it is your judgment that at an outside expense of $13,000,000 it is possible to construct a filtering plant, which would insure the purity of the water supply of Chicago, upon the assumption that the sewage from a population of 1,200,000 people was discharged into the lake?

A. Yes, sir; that is for the present quantity of water. Of course, as I stated, if they draw more water in the future, that it would increase approximately in proportion to the quantity.

Q. That would be something that would be controlled by the growth in population?

A. Exactly.

Q. And with respect to the cost of filtering the water supply, you are quite clear as I understand it, that if you reduce the population from which the sewage goes into the lake, so that you have the sewage of only two or three hundred thousand people to provide for, as is now the situation in the Calumet District, the expense would be less even if you filtered all the water, and it would be very considerably less in case it were found necessary to filter only the water from certain cribs?

A. So far as it might be found unnecessary to filter the water of certain cribs, there would be obviously a corresponding reduction in cost, but if the water were filtered at all, reducing the amount of population providing sewage would not very greatly reduce the cost of filtering. In other words, the filtering that I have in mind for the conditions that I have stated, represents approximately the minimum cost of filtering.

Q. At the risk of perhaps repeating something I have already asked you, would you think the cost would be very materially greater, in case you undertook to filter the water on the theory that you had the sewage from 2,400,000 emptying into the lake, that is, double the 1,200,000 which you had in mind in the preparation of the estimate about which you testified on direct examination?

A. My feeling is in case the sewage canal were obliterated and all the sewage of Chicago were discharged, that the costs involved in taking care of the sewage and water so as to get a good water supply with filtration, would be very greatly increased. I do not think that a large part of the increase would be represented by the increased cost of filtering, but I do think that there would be a very great expense required to take the sewage to appropriate points of discharge far enough off shore to prevent the production of local nuisance, and separated from the waterworks intakes; and to build the longer intakes that would be necessary, and the intakes located away from the sewage outlets; and the land tunnels that would no doubt be necessary in connection with them.

That is to say, of course, I can't say what the scheme would be off-hand, without further study, but in case you threw the canal over and said you would treat the whole sewage of Chicago by dilution in the lake, very likely you would build a big intercepting sewer and take the whole sewage of the city down to some point on the south side and discharge it through a series of outlets going away out into the lake. And you would give up these south waterworks which are near them and perhaps the waterworks up here (indicating) near the mouth of the old Chicago River, which is a dangerous element, as soon as its natural flow is returned to the lake. And you would take the water, perhaps, for the whole city from some point up off Evanston and filter it at that point at one big station, and send it through a great big tunnel going down through the city away to the south side.

Now, I do not say that is what you would do. You might study the thing out and do something very different from that, but whatever it was, you would spend millions and millions of money in solving the problem adequately in that way.

Q. But you have a feeling now that under conditions as they now exist, and in view of the stage which has been reached in your profession, that it would be possible to deal with the sewage situation in the City of Chicago eliminating the Drainage Canal entirely and have good water?

A. It could be done, yes.

Q. Have you made any study of the system that is used in London?

A. The water supply or sewage?

Q. The sewage, disposal of sewage?

A. I have visited the London works, yes.

Q. How do they dispose of it there?

A. It is collected, except storm overflows, in intercepting sewers on either bank of the Thames. On the north bank it is carried down to a place called Barking; on the south side down to a place called Crossness. At those points the sewage is carried through large settling tanks in which the heaviest part of the sewage mud is removed by settling. The sewage is all pumped, I think, before it goes to the settling tanks, and it flows from the settling tanks into the Thames, which, of course, is tidal at this point.

The sludge from the tanks is loaded into steamers, tank steamers, and carried out to sea and dumped. Chemicals have been used at times in the treatment of the sewage so that the process is a chemical precipitation, and directly comparable with that which we mentioned in connection with the World's Fair at Chicago.

Q. Does the problem of the disposing of the sewage in London have anything to do with the water supply, the purity of the water supply?

A. Absolutely nothing.

Q. They are two entirely different problems?

A. Entirely different.

Q. What are the principal cities in which the disposal of the sewage and the water supply become parts of one problem, so that you have to have the disposition of the sewage in mind in dealing with the question of the purity of the water? I am speaking now of the principal cities?

A. The disposal of sewage is a matter of importance to all cities that take their water supplies from rivers receiving sewage above, but there are very few cases where sewage has been purified prior to discharging into such rivers, for the sole or principal object of purifying a water supply taken from the stream below.

Where water supplies are taken from small catchment areas with storage reservoirs as distinguished from large rivers, the problem is somewhat different. There the whole of the run-off, or a large fraction of it, is used for water supply, and the sewage discharging into the water is oftentimes more important relatively.

Boston, New York and many other cities are supplied in

this way. These cities have made efforts to have the sewage from the towns on their catchment areas purified. The towns involved are mostly small. The largest one that I think of is the City of Marlborough, certainly with not over 20,000 people. Boston and New York and some other cities have made persistent efforts to have the sewage from these towns purified, and they have paid the bills in connection with having it done.

There are many other cases where other cities have thought they would like to have it done; they have suggested it; sometimes taken legal means to bring it about, but without offering to pay the bills, and as far as I have heard the purification has not been accomplished in those cases.

In the Great Lakes, the sewage problem and the water supply problem are more intimately associated, in that the sewage and the water supply of the same city may become mixed, and in that respect differs from the river problem, where it is one town above another and the problem of sewage and water is one that almost all the towns on the Great Lakes have.

Q. Milwaukee is one of those?

A. Milwaukee has it, Toronto has it, Cleveland has it; Detroit and Buffalo have it, though in modified form, in much simpler form because there is a definite, strong current in front of them.

Q. Coming back again to the purification of the water of the Calumet before it empties into Lake Michigan, and dealing with that problem on the basis merely of the present population, or double the present population—I understand that is the population which you said you usually dealt with in problems of that kind; that is, you figured on about twice the population of the territory—I would like, if I can get it, as definite an idea as you are able to give us as to the approximate cost of doing that. I am proceeding now on the theory that if you do treat the water, there being the sewage of only two or three hundred thousand people emptying into the river, that perhaps will take care of everything except this 68th street crib, so that that would be the only crib the water from which you would have to filter. Can you give us anything like an exact idea of the expense of handling that situation in that way?

A. You are talking of filtering the water or treating the sewage?

Q. First of treating the sewage?

A. No, sir, I could not tell you about that. If the population of two or three hundred thousand were compactly placed

on the separate systems, it would be comparatively easy to approximate it; but this population is spread over a dozen miles, I should say, and there are various centers of population. There are manufacturing establishments here and there producing waste; and the matter of collecting the sewage and separating it from the storm waters and other flows with which it naturally mixes and which you build purification works for, would very likely cost a good deal more than the cost of the purification itself, and that is something I could not tell you off-hand.

Q. Could you tell what the works themselves would cost for a population of 250,000?

A. Why, I should say that the figures I gave you regarding Paterson were as good an approximation of that as I could give off-hand.

Q. That was about $3,000,000, wasn't it?

A. $3,000,000 exclusive of the cost of separating the surface water.

Q. A part of that, as I recall it, was an expense that could be deferred on account of the population being smaller?

A. Yes, sir.

Q. Now, then, have you given any thought to the cost of a filtering plant merely for the water that comes through the 68th street tunnel?

A. No, sir, I have not.

Q. Assume that one-third of the water supply of the city comes through that 68th street water tunnel, would the cost of building a filtering plant for that water be about one-third of the estimate which you gave for the whole supply? I mean do those figures which you gave run proportionately?

A. Generally they do. I think the real estate for the south one would be a little less in proportion.

Re-direct Examination by Mr. Williams.

Q. When you gave the figure of $500,000 as the annual cost of operating the filtration plant, did that amount include anything for depreciation of the plant?

A. No, sir, that is just the operating expenses, and that is made up of the cost of pumping the water to the filters; the cost of operating the filters themselves, and taking care of the grass, etc., that grows in the top; the cost of the laboratory and supervision and the cost of the final treatment of the effluent with hypochlorite.

Q. What would be a fair percentage of depreciation to figure in those plants?
A. I should say, off-hand, one per cent.
Q. Per year?
A. Yes.

Re-cross Examination by Mr. Wilkerson.

Q. They last a long while?
A. Yes, sir. I do not mean they last a hundred years, but one per cent. marked off for depreciation, I think, will take care of the wear and tear.

Subscribed and sworn to before me this ..... day of ....., A. D. 1911.

.....

June 1, 1911, 1:30 o'clock p. m.

Parties met pursuant to adjournment.
Present, same as before.

RUDOLPH HERING, a witness called on behalf of the defendant, was first duly sworn and testified as follows:

Direct Examination by Mr. Williams.

Q. Please state your name, place of residence and your occupation?
A. Rudolph Hering. My residence is Montclair, New Jersey; my business office in New York. My occupation is that of hydraulic and sanitary engineer.
Q. How long have you been engaged in the practice of your profession as a hydraulic and sanitary engineer?
A. Substantially since I graduated, 1867.
Q. Will you state in a general way the preliminary education and the experience that you have had in the practice of your profession?
A. I went to Europe and studied my profession at Dresden, Germany. When I came back, after a few engagements not exactly in the line of my present profession—I was then assistant in the construction of the parks of Brooklyn and Philadelphia,—I was engaged by the City of Philadelphia, m

native city, to make investigation on a new water supply for that city.

Q. Before we go on with your experience in the practice of your profession, I wish you would state what societies you are a member of professionally?

A. I am a member of the American Society of Civil Engineers; of the British Institution of Civil Engineers; of the Canadian Society of Civil Engineers; the Western Society in Chicago, and numerous others.

Q. Have you specialized on any particular line of civil and hydraulic engineering?

A. I have specialized since 1873—no, 1875, chiefly in sewerage and water supply engineering.

Q. Do you have any degree from any institution of learning?

A. I have an honorary degree of Doctor of Science of the University of Pennsylvania.

Q. Now will you continue your narration of your experience in a general way, especially with reference to your particular specialty?

A. I was assistant city engineer in Philadelphia, where I had charge chiefly of the sewerage work for some years. Then in 1880 I was commissioned by the United States Government to make a report on the sewerage works of Europe for the National Board of Health. I made that, and it is printed in the annual report of the National Board of Health for 1881.

Then I was engaged by the City of Philadelphia to make an investigation regarding a new water supply. The next engagement was by Mayor Carter H. Harrison in Chicago as chief engineer of the water supply and Drainage Commission, to ascertain what the City of Chicago should do with her sewage, and at the same time guard her water supply against pollution.

After that I was consulting engineer for the City of New York on sewerage work. Then I have been engaged in a number of cities in both water supply and sewerage, Boston, Philadelphia; recommended the present system of water filtration; also Baltimore, the present system of sewerage and sewage disposal; Washington's present sewerage system and also the present water supply filtration, in connection with other engineers; I was a member of a Commission that reported on those matters.

Then Buffalo, Cleveland, Toronto, Indianapolis, Atlanta,

New Orleans; and in all these cases both water supply and sewerage.

Then on the Pacific coast, San Francisco water supply and sewerage; Sacramento water supply and sewerage; Los Angeles sewerage alone; Tacoma, water supply; Victoria, sewerage; Winnipeg, water supply; Ottawa, sewerage.

Now we have the water supply of Montreal, at the present time, purification of the water supply of Montreal; Honolulu, sewerage and Santos sewerage and and water supply.

Q. Who are the other members of the Commission that acted with you in connection with the report which you made and the investigations which you made in connection with the disposal of the sewage in Chicago, and the protection of its water supply, in 1886, did you say that Commission was appointed?

A. Yes, sir. Mr. Benezette Williams and Samuel Artingstall.

Q. Mr. Artingstall was then the city engineer?

A. He was then the city engineer.

Q. As the result of your work, you prepared a report?

A. I did.

Q. And after the report was made, what, if anything, did you have to do with the legislation which was enacted by the General Assembly of Illinois, authorizing the organization of the Sanitary District?

A. I remember being a witness before the legislative committee.

Q. Your only connection with it was from the standpoint of engineering, and at the session of the legislature in 1887 you presented your veiws to the legislative committee?

A. I did.

Q. From that time to this have you in a general way kept informed as to the conditions in Chicago, lake conditions and conditions as to water supply and sewage disposal?

A. I have tried to keep myself informed in a general way. Having lived there, I had friends, and would stop over, and perhaps on other works, consultation and so on; and as one of my former assistants in Chicago was City Engineer, Mr. Erickson, I kept posted on his work very nicely. I also know Mr. Cooley very well, and also Mr. Williams, Benezette Williams, and in that way kept posted on the progress of the Drainage Canal. I went to see it during the construction; took a lot of European engineers over it during the World's Fair time, while it was under construction.

Q. During recent years, have you made any particular study of the situation as it has developed since the construction of the channel?

A. In 1906 I was engaged with my associate, Mr. George W. Fuller, by the International Waterways Commission to make a certain examination and report.

Q. That report you made and it was published?

A. That report was submitted on December 18, 1906, and was published as an appendix to the report of the International Waterways Commission, dated Toronto, Ontario, January 4, 1907.

Mr. Wilkerson: That is Appendix F?

A. That is Appendix F. Appendix A was the report that I made in January, 1887.

Mr. Williams: Q. Subsequent to the report that you and Mr. Fuller made to the International Waterways Commission, did you make any further detailed study of the situation with respect to the Calumet District and the Sanitary District, and make any report?

A. I did. At the request of Honorable Robert R. McCormick, president of the Sanitary District of Chicago, in the latter part of 1907, I made such a report, entitled: "Report on the Disposal of Sewage from the Calumet Subdivision of the Sanitary District of Chicago," dated October 15, 1907.

Q. Will you state in your own way, Mr. Hering, what different methods there are now successfully employed in the disposal of sewage, in a general way?

A. The most common method for large cities is a system by dilution, which means that the sewage is discharged into flowing water in a way to be thoroughly dispersed in it, and in such quantities that the oxygen dissolved in the running water is sufficient to oxidize the sewage matter.

The second way is to purify the sewage on land, according to several methods, depending upon the availability of land areas and certain kinds of land suitable for natural filtration, and upon other local conditions.

Q. Do climatic conditions enter into the consideration in any way?

A. They do. You can vary the system somewhat when you get into warm climates, generally in the way of economy. When you get into northern climates, you sometimes have to increase their cost by making your works perhaps larger or by preventing an injury to the works, relative injury to the works due to extreme cold weather.

Q. Taking into consideration, Mr. Hering, the fact that the Sanitary District has already constructed its main channel and has entered upon a plan of sewage disposal for the Sanitary District by the dilution method exclusively; and assuming that there is a capacity through that main channel to provide for the disposal of sewage by that method for a population of 3,000,000 people; and assuming that there is a large area on the south known as the Calumet District, a portion of which drains into the Calumet River which flows into Lake Michigan, a part of that area being sparsely settled; and taking into consideration the probable growth in population during the coming years, and the probable necessity to care for a population eventually of at least 4,120,000 in the entire sanitary district, what method of sewage disposal would you consider the most efficient and economical to carry on, for the added territory, and to provide for the added population at this time?

Mr. Wilkerson: Let this go in subject to the same objection that was made to the same line of testimony on the part of the witness Mr. Hazen on yesterday, without stopping to repeat the objection, either specifically with respect to this question or as to any other question; it may all be treated as going in subject to the same objection.

Mr. Williams: That is all right.

The Witness: It is my opinion that the proposed canal called, I believe, the Calumet Sag Canal, offers the most economical, and as I believe the most preferable method of disposing of the sewage of that part of Chicago.

Q. You prepared figures, did you, as to the cost of instaling other systems for the disposal of sewage for the Calumet territory?

A. I did.

Q. In the original plans that were suggested by you and your associates upon the Commission that was appointed by Mayor Harrison, was it contemplated at that time that the method now proposed should be carried out eventually?

A. It was contemplated; the matter was then seriously discussed, but our commission thought that it was a little bit distant to bring into the report at that time as regards details, because the money that we had was short anyway to complete the work that we had in contemplation for the built-up section of the city. And as you may know, the report that was issued was entitled a preliminary report with the expectation that we would make a final report. That was never made on account

of inability to get any further appropriation. His Honor, the Mayor, and his Council, stated that that preliminary report was entirely sufficient for them, and that they could proceed.

Q. In your investigation of the situation in the Calumet region and in the Sanitary District in general, did you have a report of the population and the growth of the population during the past numbers of years?

A. I did.

Q. The population curve, indicating the probable growth of the population?

A. I had prepared such data.

Q. From your investigation, aside from the dilution method what was the most economical method of disposing of the sewage of the Calumet district that you were of opinion was practical?

A. It was the method of purifying sewage on land to a degree which would make the effluent water non-putrescent. That method which we found to be the cheapest was one that we call the springling method, sprinkling filters, where the fluids, the liquids are sprinkled over beds of stone, coarse broken stone, and thus allowed to oxidize, and the solid matter which is previously settled out of the sewage is treated by itself, of course, in another way so that it would gradually rot out and constitute inoffensive solid material that can be used for filling or any other purpose for which material is used.

Q. How large an area of land would be necessary to dispose of the sewage by that method for a population of say 1,200,000 people.

A. It would require about 80 acres of sprinkling filters, and an additional area for tanks, and basins for sludge treatment, and for other purposes.

Q. Is any particular soil required for that kind of a plant?

A. No; no, it is entirely independent of the soil. The purification of the liquid is accomplished by oxidization in artificially prepared filters.

Q. You prepared an estimate of the cost of such a plant on the basis of a population of 300,000, which was regarded as being rather imminent, and an ultimate population of 1,200,000?

A. I did.

Q. Will you state the estimate of cost for both populations?

A. The estimate of cost for a population of 300,000 was

$4,761,000. The estimated cost of works for a population of 1,200,000 was $9,257,500. The annual cost of operation, and including interest on the investment, depreciation of machinery and so on for a population of 300,000 was $360,240, and for a population of 1,200,000 was $900,300.

Q. Did you separate, or have you the figures separate as to the annual cost of operation from the fixed charges of interest and depreciation?

A. I have.

Q. What was the annual cost of operation exclusive of the fixed charges?

A. For 300,000 population it is $139,000, and for a population of 1,200,000, $423,000.

Q. And at what rate per cent would you capitalize those annual expenses, in order to obtain a fund to perpetually maintain the plant?

A. I did not capitalize the annual cost, but I took an interest of 4 per cent. as the interest on the invested money, believing as we do, that a comparison between the cost of works is more in accordance with the actual condition if we compare the annual costs rather than the capitalized costs, which are more or less imaginary. I mean they are merely book figures; they are not real. They do not have to be expended.

Q. Since that report was made, have you given any further consideration as to the adequacy of the works that you have outlined in that report and of the figures that you have given to cover the cost of performing the work that you intended, expected would be performed by the works that you described in your report?

A. There has naturally been some progress made since then; and if I were to estimate the cost again today, I would increase it somewhat.

Q. For what reason and to what extent?

A. I would increase it because we are now able to treat the sludge in a manner so that there is no odor when it leaves the works, and for this additional advantage, I believe it is proper to pay an additional cost.

Q. Have you estimated any additional works in the way of treatment of the effluent?

A. I would also do that, which was not included in this estimate; that is a treatment with hypochlorate of lime so that the pathogenic bacteria that may escape from this rapid method of filtration would be destroyed, in the same way that we

now protect our water supplies, probably in much over a hundred cities in this country.

Q. In your opinion, in case the sewage of the Calumet district were disposed of by the sprinkler system and the effluent discharged into the Calumet River and from thence into the lake would it be reasonably necessary to treat that effluent with the method you described?

A. I should advise it today, because it is a fairly economical method and gives an assurance of protection against those diseases which are likely to be propagated by sewage bacteria.

Q. Have you made an estimate of what added cost would be involved in such treatment above the cost that was considered by you in making your report?

A. I have not; but I have reported such a method to the City of Oswego on the lakes; and also have been making some other studies for such treatment on the lakes; and I have made a general estimate.

Q. Will you give us a general estimate which in your opinion, as near as you reasonably can, would indicate the additional cost that would be involved in the installation of such a process?

A. The cost would depend mainly on the amount of very fine suspended matter that is still left in the effluent sewage. This treatment attacks the organic matter in the sewage, and in order to be sure that it is also destructive of the pathogenic bacteria, we assume that it must be rather severe in order to prevent such bacteria from escaping together with the organic matter in suspension.

We therefore allow a much smaller amount for water that is clear, such as would be used for water supply than we do for water that is an effluent sewage, with fine suspended matter still remaining.

I have made, therefore, two figures, and would say that in the Chicago case it would depend upon the carefulness and thoroughness of the treatment as to which of these figures, or what figure between, would be proper. I will say that it would require per million gallons of sewage between 75 and 150 pounds of hypochlorite powder, which is the main expense.

Q. Is that sewage raw sewage or effluent?

A. That is effluent sewage, and treated merely by sedimentation, not filtration, or a high degree of purification. Of course, there is some labor required, so that I would say the

cost per million gallons of sewage would range from $1.25 to $2.50 in round numbers.

There is no allowance made in that for interest or depreciation in the works; nor for high grade intelligence such as chemists, which in a large city would be fairly small per million gallons.

Q. Do you know the average rate per capita per day of sewage that is calculated to be produced by people like Chicago people?

A. The quantity of sewage is usually estimated the same as the water supply, which I understand is 230 gallons per capita per day.

Q. Assuming, Mr. Hering, that works such as you have described briefly and referred to in your report, sprinkling filters, were installed, and the sewage of the Calumet district is cared for by that system, and the effluent treated as you have indicated it should be treated, would there be any difference in the cost of operation of such a plant in the winter months from the cost during the summer months?

A. There would. The activity of the bacteria in purifying sewage is much less in winter than in summer, and you would either get a less degree of purification or you would have to increase your plant correspondingly to get the same purification as in summer. And then it requires watchfulness. The sprinkling beds if not covered by a roof will have snow and ice upon them, and it is certainly not as simple to keep the filters at work. It would require possibly a larger number of men to keep the nozzles free and have things working right than in summer.

Q. Do you recall whether or not those considerations entered into the estimates that you made at that time?

A. I can't remember that we made—certainly we did not make a material allowance for winter conditions, with the thought, as I remember, that as time went along there might be some way of increasing the efficiency, although none was known to me at the time. But I did not care to load the estimates with something that I was not entirely sure of, particularly as it appeared that the sprinkling filter project was the more expensive one.

Q. Now, assuming that we have in operation the sprinkling filter system and a population of either 300,000 or 1,200,000 in the Calumet district; and the effluent is treated in the manner that you suggest; and that the system works satisfactorily, as well as such a system can be expected to work; the effluent is

discharged into the lake and treated in the manner that you have suggested, carefully and as efficiently as it can be, what is your opinion as to whether or not that method would be as satisfactory in disposing of the sewage of that territory as it would to divert it by means of sewers into a channel, the Calumet Sag Channel, and thence into the main channel of the Sanitary District and down the Illinois River, so that no part of it entered the lake?

A. As an engineer, I should certainly prefer the dilution method; and I think I should also as a citizen, because it is more simple. You do not depend on a number of factors that have to work together.

Q. There are human agencies you must depend upon, and mechanical contrivances and climatic conditions in connection with the sprinkler system, which would not affect the dilution method?

A. Yes. While I would not in the least be afraid that the sprinkling system would not give satisfaction, if I had the choice I certainly would try to get the results in a more simple way.

Q. The rate of dilution provided for by the present law of the State of Illinois is 20,000 cubic feet of water for each 100,000 of population, per minute. Assuming that there are no auxiliary works to treat the sewage before it enters into the canals and is subjected to the dilution process, what do you say as to the reasonableness of that proportion of dilution assuming no—

A. May I ask you what you mean by no auxiliary works?

Q. Namely that the sewage goes in in a raw state, without any treatment before it goes in, not any of the coarse stone treatment, no sedimentation, no tanks; it just goes in as it goes in now. Assuming it goes in as it goes now, what do you say as to that rate of dilution?

A. I am always on record, and I would like to be so now; and I believe in coarse screening under all circumstances.

Q. Assuming that there is not even that?

A. Then so far as a nuisance is concerned, other than to see large floating matter parading down the river, I would say this dilution was entirely satisfactory.

Q. Do you think that any less proportion would be sufficient, assuming that there were no screens and no auxiliary—

A. I think that dilution ratio that we stated in our report is the least that will give satisfaction.

Q. Assuming that the population of Chicago, the sanitary

district rather, should reach a figure whereby it would be impossible to comply with the provisions of the state law respecting the amount of water to be diverted from Lake Michigan, in proportion to the population, without exceeding the 14,000 cubic feet of water per second which we are contending for in this suit, has the science advanced any in recent months so that you are able to give us an opinion as to any auxiliary works that can at that time be established to increase the efficiency of the dilution method, and render it possible to decrease the proportion of water that may be necessary to accomplish the same results as are now accomplished by the entering of raw sewage into the channel?

A. There has recently, that is within the last few years, been developed in Germany a method of treating sewage where as in all other cases of land treatment it is endeavored to separate the liquid from the solid matter, which allows us now after separating the solid matter from the sewage, to allow it to decompose under water and with certain restrictions, in such a way that anywhere from three to six months after, according to climate, temperature, character of sewage, the solid matter may be taken out and then have no odor, so that a nuisance at the works is not created.

This makes it possible to have the separation accomplished in the midst of habitation, without offense, and the sludge removed without offense. This discovery makes it possible hereafter to remove from the sewage that portion which causes the greatest amount of nuisance, and thereby allow the liquid to be discharged into water with much less dilution than the legal rate, controlling the work of the Sanitary District. And therefore a possibility exists of increasing the amount of population correspondingly that may discharge into a river, without offense.

Q. If this method were employed throughout the entire Sanitary District, and the present impressions as to the success of this system are borne out, to what figure could you reduce the dilution?

A. I would say by a quarter to a third.

Q. What expense would be involved in the installation of such a system?

A. I have not figured out that expense, but I would say that experience in Germany, as applied to our American conditions, would indicate that the construction of these tanks would cost about $1.50 per capita.

Q. And there would be some cost of operation?

A. Then there would be some cost of operation, which would consist of pumping out the sludge into barges and carrying it away to a point of disposal, which of course I can't estimate, not knowing where it would go.

Q. Mr. Hering, if the problem of the disposal of the sewage of Chicago and its environs were now presented to you for the first time instead of in 1886, in the light of your experience since that time, would you make any different or other report with respect to the method of disposing of the sewage than you made at that time?

A. I would still recommend the dilution method.

Cross-Examination by Mr. Wilkerson.

Q. These three reports to which you have referred, Mr. Hering, are the ones designated as Appendix A to the report upon the Chicago Drainage Canal by the International Waterways Commission and Appendix F to the same report; the same appearing in the government print under date of 1907, and the report which you made to Mr. McCormick, the President of the Sanitary District, are they not?

A. Yes, sir.

Q. Those are the three reports?

A. Yes, sir.

Q. The one to Mr. McCormick is dated Chicago, October 15, 1907?

A. Yes, sir.

Mr. Wilkerson: I should like to have those reports identified, and I now reserve the right to read at the hearing in connection with the examination of the witness either those reports in full, or any part of the reports. What I want to do is to get the record in the same shape as if in connection with the cross-examination of the witness I had him identify each one of these reports, and had had the reports copied at length here, for the purpose of identification as his report.

Mr. Williams: For the purpose of identification?

Mr. Wilkerson: And I reserve the right in connection with his examination to read any part of the report in connection with his testimony that I see fit. The point is this: that when the deposition of this witness is read, I may read, if I see fit, in connection with his testimony, any statements in these reports, without putting questions to him right now and asking him whether he said this or that. It is to save time, that is all.

Mr. Williams: All right.

Mr. Wilkerson: Of course I shall contend that any statement which he made in any one of these reports is legitimate cross-examination; that is the statement should be read as cross-examination.

Mr. Williams: If you want to controvert any statement he makes in his reports—if you want to introduce the reports in evidence in your proof afterwards, in order to dispute something he said today, you can do that; or if you want to call his attention to any particular thing he said today, when he said something to the contrary before, and ask him to explain it, that would be all right.

Mr. Wilkerson: I am making no contention of that kind. He has testified on the general subject, concerning which he made prior statements. I could sit down and read these statements, and that would be proper cross-examination.

Mr. Williams: There are two ways by which you can take up any statement today that may seem to you inconsistent in any of these reports; the first is to call his attention to the fact he said so and so before and, what is your explanation of the inconsistency, if there be any. Or if you do not want to say that, you come in and say having said this before—

Mr. Wilkerson: I hardly think I am limited to that, Mr. Williams. All I want to do is to shorten the record.

Q. The first report, Mr. Hering, to which you referred in your direct examination is the first report which is designated Appendix A?

A. Yes, sir.

Q. It is under date of "Chicago, January, 1887". It is signed "Rudolph Hering, Chief Engineer, Benezette Williams and Samuel G. Artingstall, consulting engineers."

A. Yes, sir.

Q. I will ask you to look at the document which I hand you and state whether that is the report (handing witness document).

A. This is the report.

Q. I will ask you to read it.

Mr. Williams: I will object; it is improper cross-examination, and it is not a question put to the witness, but a direction to the witness, and the witness is under no obligation to read anything. If counsel wants to read anything or have anything read, he can do it himself *voire dire*. I object to having it shown that he is reading it into the record. I haven't any objection to his reading it for his own informa-

tion, in order that he may understand any questions you are going to ask him.

Mr. Wilkerson: I ask the witness to read the report and Mr. Williams objects to it.

Mr. Williams: Read the report into the record?

Mr. Wilkerson: Yes.

Mr. Williams: And I object to it, on the ground, first, that the instruction to the witness to read a document is improper, and is not in the line of cross-examination; that the direction is not an interrogatory intended to elicit any fact bearing upon the direct testimony that has been given; and that the witness is under no obligation to comply with any direction of counsel to read documents into the record, when such documents have not been introduced and have not even been offered in evidence; and counsel is not in a position at this time to offer testimony in his own behalf.

Mr. Wilkerson: Now, I say, with respect to that that the witness on direct examination has testified as to the making of a certain report. He has testified that at the time the report was made, he had in mind certain other things.

The report is called to his attention as the foundation for a line of cross-examination, and in order that the cross-examination may be intelligible, it is essential that the report to which he has referred and upon which the cross-examination appears may be in the record. As to whether the report itself is to be treated as a part of the cross-examination of this witness, to the extent that it becomes a part of the defendant's case, I am perfectly willing to let that question be reserved for the ruling of the court at the trial.

I think that on neither side will there be any particular difficulty if this report appears as having been read by the witness into the record as the basis for this cross-examination; the counsel for the defendant reserving his right that it shall not be treated as a part of his case; and leaving it for the Judge to decide whether the report is a part of the estimony for the defense.

Mr. Williams: I am perfectly willing that the witness be permitted to examine the report, read it fully; and that counsel may read it for his own information fully.

I object to the witness reading into the record any document or paper not offered in evidence. So far as identifying the document is concerned, there is not the slightest difficulty. It may be marked as an exhibit for identification and attached to the deposition, so that it may be hereafter offered

in evidence and made a part of the record, but I shall object to, and ask the witness to refuse to read into the record a document which has not been introduced in evidence in the case.

Mr. Wilkerson: In order that the witness may not be embarrassed by the comflicting directions of counsel, and in the absence of the court, I will direct your attention, Mr. Herring, to this report, Appendix A, which is as follows:

"Chicago, January, 1887.

To the Honorable Mayor and City Council of the City of Chicago:

Gentlemen: On January 27, 1886, your honorable body passed a resolution authorizing the creation of a drainage water-supply commision. After being amended, February 23, it read as follows:

Whereas pure water and scientific drainage are necessities of this community, and the people demand a system of water supply and drainage adequate to meet the requirements not only of the present, but of years to come, nor will any temporary expedient or makeshift satisfy them; and

Whereas a thorough and permanent system of supplying pure water to our citizens and caring for the drainage of the municipality can not be paid for out of current taxation, therefor it is desired that a plan shall be devised and perfected before the next meeting of the legislature to the end that necessary legislation may be had.

For the purpose of carrying into effect the objects sought, there is recommended the appointment by the Mayor of a commission to consist of one expert engineer, whose reputation is so high that his opinion and report will command the respect of the community, and with him one or two consulting engineers of like experience in engineering and sanitary matters. The duty of this drainage and water supply commission, made up as above set forth, should be to consider all plans relating to drainage and water supply which may be brought to its attention; to make such examinations and investigations and surveys as may be deemed necessary; to collect all information bearing on this problem; to consider all recent developments in the matter of sewage disposal, and their application to our present and future needs; to consider and meet necessity of increasing our water supply and of

protecting the same from contamination; to remedy our present inadequate methods of drainage and sewage disposal; to consider the relations of any system proposed to adjacent districts, and whether there may not be a union between the city and its suburbs to solve the great problem; to determine the great question as to the interest which the State and the United States may have in the disposal of sewage by way of the Illinois River, and to devise plans to meet any objections thereto, if such a system shall be thought best; and in general to consider and report upon any and all things which relate to the matter of water supply and drainage of the City of Chicago.

The commission should report on the whole matter committed to it in the most full and comprehensive manner, with maps, plans, and diagrams complete, and accompany the report with estimates of the first cost and annual requirements for the maintenance of the system proposed.

The report of the commission should be made as early as practicable, and not later than the convening of the next session of the Illinois legislature, in January, 1887.

In consideration of the foregoing, be it,

Resolved, That the Mayor be, and is hereby, authorized and directed to employ on behalf of the city one expert engineer of reputation and experience in engineering and sanitary matters, at a salary not to exceed $10,000 per annum, and also to employ such consulting engineers, not exceeding two in number, as may seem necessary, and such assistant engineers as may be required, all to be paid according to services rendered, for the purpose of carrying out the objects set forth in the preamble hereto. For the fees of said assistant engineers and for all expenses connected with said work there shall be allowed not to exceed the sum of $20,000. All fees, salaries, and expenses connected with said work shall not exceed in the aggregate the sum of $30,000, and the same shall be paid from the water fund of the city upon vouchers audited by the Mayor and city comptroller.

In accordance with the terms expressed herein his honor, Carter H. Harrison appointed Rudolph Hering as chief engineer, Benezette Williams and S. G. Artingstall as consulting engineers, who together should constitute a commission. Mr. Hering entered upon duty March 28,

Mr. Williams September 17, and Mr. Artingstall December 21, 1886.

The investigation designated by the resolution was a formidable one, composing no less a task than the consideration of the entire subject of the future water supply and drainage of Chicago. It appeared doubtful from the beginning that a report such as was demanded could be furnished within the specified time, for the simple reason, if for no other, that observations of the lake phenomena and of the flow of certain rivers should be extended over at least one year, covering four consecutive seasons, in order to draw satisfactory deductions.

But the large amount of work alone that was asked for made it impracticable to present a complete report in so short a time. It was expected, however, that results could be reached sufficient to indicate the character of legislation required to carry out any project that might be determined upon, and that therefore a preliminary report having this end in view could be made at the stated time, leaving to a later date the presentation of a report outlining the detailed features of the scheme recommended and embracing the minor results of the entire inquiry.

The present communication is to cover the ground indicated for the preliminary report, and besides containing the conclusions reached regarding the main features of the proposed project, it contains also a brief review of the work done during the past year and of what still remains to be done.

The month of April was devoted to a general examination of the subject of the territory to be investigated, and of the various suggestions that had been made toward effecting a solution of the problem.

The examination disclosed the fact that the city is sometimes greatly suffering from the offensive condition of parts of the Chicago River and its branches, caused by the discharge of sewage into the same, and from the occasional contamination of its water supply, brought about by the discharge of the polluted contents of the river into the lake. It also disclosed the fact that almost every conceivable way of dealing with these questions had been suggested and in some forms applied during the past thirty years.

The problem therefore demands the attainment of two ends—the protection of the water supply and the removal

of the river nuisance. As the water must be taken from the lake, it is evident that both its pollution and the objectionable condition of the rivers should be prevented by a better disposition of the sewage. It is, therefore, the latter question which constitutes the main object of this investigation.

Among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy of an extended consideration, namely: A discharge into Lake Michigan, a disposal upon land, and a discharge into the Des Plaines River. The preliminary work, has, therefore, been confined to these three projects, and was classed as topographic, hydrographic, and miscellaneous.

At the time when the present commission began its labors the topographical work had already received some attention. Surveys were being made of the Des Plaines River from Bridgeport westward under the direction of Mr. Artingstall, city engineer. These surveys were continued, and have now been completed as far as Joliet. They include contours of the entire valley and borings to rock between Bridgeport and Lemont. In order to understand the hydrography of the Des Plaines Valley above the point where the Chicago sewage could be discharged into it, and also to ascertain the probable magnitude and effect of floods in the river, a survey was made of its bed as far north as Northfield township. To determine the area of the basin its entire divide was located. To ascertain the practicability of diverting the flood waters from the upper portion of the Des Plaines and North Branch water sheds directly into the lake, and thus avoiding the difficulties which would arise from their passing through the Chicago River, all feasible lines were surveyed. Finally, a few levels were taken of the area adjoining the city wherever no connected levels existed to show the general topographical features of the territory over which the future city will spread out and from which the drainage will require artificial removal.

The hydrographic work consisted in ascertaining the flow of the Des Plaines River, the rainfall upon its area, its flood discharges, the character of its bed, and the probable effect of discharging the Chicago sewage into it when diluted by a large and constant stream of water from the lake. It consisted, further, in examining the

nature of the currents in the lake and in studying the rise and fall of its level, and in ascertaining the amount and character both of the sewage discharged into it and of the deposits in the river and lake in front of the city to determine the effects of the present sewage disposal.

Inquiry and surveys were made to show the feasibility of purifying the Chicago sewage by filtration on land. Land damages were carefully estimated for the different schemes; existing records were searched concerning borings and excavations made in and about the city, so that the practicability of certain lines of tunnels could be discovered; the probable growth of the city and its suburbs, as well as the probable distribution of the future population, received a careful attention, and, finally, a large number of data were compiled which pertain to the existing works of water supply and sewerage in Chicago and the adjoining towns.

In reporting the result thus far gained we will present them in the order most convenient for discussion, but before doing so will briefly describe the present manner and effect of the sewage disposal, as shown by this investigation.

Present Sewage Disposal.

The sewage works of Chicago and suburbs have been planned on what is called the combined system, in which the sewers serve for the removal both of sewage and rain water. In the town of Evanston they empty into the lake. In the town of Lake View they partly discharge into the lake and partly into the North Branch. From the north and west divisions and part of the south division of Chicago, the drainage enters the Chicago River and its branches, and from the remaining part of the south division it flows into the lake at three outlets, situated respectively, at Twelfth, Twenty-second, and Thirty-fifth streets. The sewers of Hyde Park discharge into the lake excepting those of Pullman, where the sewage is disposed of on land. The town of Lake, including the Stock Yards district, drains into the South Fork of the Chicago River.

When the sewage works of this city were designed, in 1856, by Mr. E. S. Chesbrough, it was apprehended that ultimately some means would have to be found to change the water in the river from time to time or to keep the

sewage entirely out of it. The first step toward improving the condition of the river was taken by deepening the Illinois and Michigan Canal, so as to cause a current from the lake to the Des Plaines River at Lockport. The next step was the building of the Fullerton avenue conduit in order to produce a circulation in the North Branch; and the last step was the erection of the canal pumping works to increase the flow in the river, which had become greatly polluted.

The influence of these works is confined to the main river and its north and south branches. But the south fork of the latter, receiving a large amount of sewage from Chicago and the town of Lake, and charged with the waste from the Union Stock Yards and packing houses, has no artificial means for a circulation of its water, and as a consequence is in a condition of great filthiness.

The accompanying diagram (a) has been prepared to show the present pollution of the Chicago River and its branches during the time when all of their water is discharged into the canal by the Bridgeport pumps. On the left are shown the main river and the north branch, one above the other, their combined waters forming the south branch, and reaching Bridgeport on the right, where they are lifted into the canal.

At the latter point the south fork is shown as joining it. The shaded portions indicate the amount of sewage entering and passing the respective points, and the blank portions the lake water diluting it. The degree of dilution is shown by the relative areas. It diminishes in the north branch from Fullerton avenue to the south branch, and becomes still less toward Bridgeport, and finally receives the foul waters of the south fork.

The depth and character of sewage deposits in the river and harbor, as might be expected, vary considerably. They are not great in the track of the vessels, but increase toward the docks and quieter portions of the slips, where they reach a depth of from one to four feet. While the deposits in the channel are of a heavier kind, such as cinders, those in the docks are mostly a foul mass of decomposing organic matter. No form of life is found to exist above Clark street bridge as far north as Clybourn

(a) Omitted; printed in House Ex. Doc. No. 264, 51st Cong., 1st sess.

place and as far south as Ashland avenue. The effect of this condition of the river is to endanger the purity of the water supply whenever the river, with its accumulated deposits, flows into the lake, which occurs when the rain water that finds its way into the river exceeds the amount pumped into the canal. If this excess is great, as in the spring and occasionally in the summer months, the contamination of the lake is considerable, and must constantly increase.

From the foregoing it is seen that the present method of disposal of the sewage from Chicago and its suburbs is partly by discharging it into Lake Michigan, but mainly, except during floods, by discharging it into the Des Plaines River.

Future Population.

The first question which requires an answer, and upon which many of the subsequent inquiries depended, was the population which it is economical and advisable to consider at present, and the extent of territory upon which such a population will be located.

The growth of Chicago has been frequently quoted as phenomenal. Estimates made thereof for various purposes have turned out to be rather under than over the actual result.

It is taken for granted that Chicago and its suburban towns will have to dispose of their sewage so that the water supply for the entire community residing near the lake from the south line of Hyde Park to the north line of Evanston will be guarded against pollution by the sewage from any one of its separate communities. For this purpose the whole populated area within the above limits is considered as forming one city with a common interest.

The growth of this metropolis was obtained partly from the United States census and partly from the school census of Cook County, which gave a record up to the summer of 1886. In order to forecast the probably ratio of the future increase it was desirable to compare this growth with that of other cities. By considering the ratio in increase elsewhere, and including the natural suburbs of each city, a fair and instructive basis of com-

parison was obtained; and by realizing the respective natural advantages for growth in each of the communities the probable ratio for Chicago was determined with a satisfactory degree of exactness.

The accompanying diagram shows the results of this comparison. It represents by curves the population of the largest cities in the country since 1790, not as usually quoted from the census, giving the inhabitants on certain arbitrary areas fixed by law, but as virtually making up the population of the respective municipalities, by including adjacent towns and natural suburbs, the only method which enables the true growth of the great cities to be recognized. For instance, the New York center naturally includes Brooklyn, Jersey City, Hoboken, Newark and other suburbs, and Chicago the entire territory from Hyde Park to Evanston.

The diagram indicates that the character of growth of the different cities permits them to be divided into two distinct classes. Philadelphia, Boston, St. Louis and Cincinnati show very much the same character of increase, and represent by comparison the more conservative communities. New York and Chicago, on the other hand, while showing a remarkable resemblance to each other, form quite a contrast to the rest of the cities, and might be called the more progressive communities. The diagram finally indicates the time when the Chicago curve, which was the lowest one prior to 1864, intersected in turn those of St. Louis, Cincinnati, Boston, and there is a high degree of probability of its intersecting the Philadelphia curve in or before 1891—*i. e.*, in four years from now—after which Chicago will be the second largest center of population in America.

As it is not practicable in so young a city as Chicago to forecast a definite line of growth, it is preferred to give the probable maximum and the probable minimum between which the true line will most likely be contained. The minimum line represents a growth resembling that of New York and the maximum line assumes the ratio of increase per decade to be consistent instead of gradually decreasing as in most other cities. The result indicates that the population of Chicago and suburbs will be 2,500,000 between the years 1905 and 1915, or about three times the present population in 18 to 28 years.

In providing public works for large communities it

must be borne in mind that it is economical to invest only such sums as will bring a return within a certain number of years, leaving expenditures for benefits that will be realized only at a later time to a later generation. This fact, together with the probable growth of Chicago, shows it to be economical and judicious at present to plan works sufficiently extensive to dispose of the sewage of not less than 2,500,000 inhabitants.

In addition to the population the area that will be occupied by it has to be determined. While this is a far more difficult task, owing to the many accidental causes influencing the distribution of the population, it is possible nevertheless to outline the area sufficiently close for the present purposes.

The future metropolis, with a population three times as great, will be distributed along the lake from South Chicago to Evanston, and will reach inland to the Blue Island Ridge on the south to the Des Plaines River in the center, and to the higher parts of Niles Township in the north. Outside of these general limits, a more or less dense population will extend for some distance along the lines of railroad.*

As inferred above, it is proper to consider at this time the wants of the population that will reside upon this entire territory.

DISCHARGE OF THE SEWAGE INTO LAKE MICHIGAN.

To discharge the sewage from cities into comparatively large bodies of water is not only the usual, but often the best method for its disposal. Dilution and dispersion thoroughly expose it to the action of the oxygen contained in both the water and the superincumbent air; it is thereby gradually oxidized. Where the body of water is a large river with a strong current, the best conditions for such purification are found. Where it is a lake in which the circulation is slight and irregular, the efficacy of the method is less and depends for its success on the character of the currents and the relative amount of sewage to be discharged into it.

The hydrographic surveys of the lake made during the past season were therefore partly for the purpose of

*Here occurs a diagram showing the "growth of several population centers in the United States," not here reproduced.

ascertaining, if possible, the laws governing the currents, so that we would know their effect in dispersing the sewage discharged into the lake. The trend of the shore currents was actually ascertained by daily recording the direction of spar buoys placed at the Chicago waterworks crib, at Michigan City and at St. Joseph. A large number of bottle floats were thrown into the lake at different points and different times for the same purpose. They were partly single surface floats and partly double, the lower one being placed at varying depths, according to the depth of the water. More than half of them have been picked up and returned, with place and date noted. The currents were also observed by means of large can buoys from an anchored tugboat at different points in the lake, extending from Hyde Park to Evanston, about six miles from the shore. Two general lake trips were undertaken, one to St. Joseph and Back to Grosse Point, and another one parallel with the shore around the head of the lake.

When the observations are completed and compiled in detail, some valuable information will be available for the question of water supply. Light will be thrown on the movement of the water under different winds and the sudden changes of temperature of the water at the crib and on the turbidness of the same.

The following results have a bearing on the question of sewage disposal: Where not affected by local conditions, the currents practically go with the winds in water of moderate depth and quickly respond to any change. In deep water also the surface currents run with the wind, but at the bottom and even at mid-depth the direction is usually different. The prevailing current along the shore of Cook County during the past summer has been observed to be toward the north, but it is possible that this result may be different during the winter months. In the open lake wave action seems to be effective in preventing the permanent deposits down to a depth of about 60 feet; inside of the breakwater sewage deposits are found on the bottom.

The general deduction from these results is clear that, as no constant current exists which would carry the sewage away in one direction, it should be discharged into the lake at one end of the future city, while the water supply should be obtained as far away from it as prac-

ticable towards the other end, a conclusion which is being acted upon in the other large lake cities. The proper place from which to bring the water would be opposite Grosse Point, and the sewage discharge should be east of Hyde Park. While it might be practicable to allow the sewage in its crude form to enter the lake under such conditions for many years, the necessity would arise later for clarifying it at least partially previous to its discharge. It could not be allowed to run into the river as at present, but the dry weather flow and a considerable amount of storm water would have to be intercepted and carried to the outfall through many miles of special conduits. This entire quantity would have to be raised by pumping in order to get sufficient head to empty into the lake, while the diluted sewage during storms, in excess of the capacity of the intercepting sewers, would be allowed to discharge directly into the river.

The water supply would have to be brought from Grosse Point in large conduits to the several pumping stations scattered over the city and its present suburbs. The circulation of the water in the Chicago River and branches would have to be maintained practically as it is at present, because the removal merely of the dry weather flow of sewage would not altogether prevent its pollution.

Disposal of Land.

We shall not at this time enter into a general discussion of the principles underlying land purification of sewage, or make historical references showing the success or ill success of the method as practiced elsewhere. We will simply state that with good management under ordinarily favorable conditions a disposal on land proves satisfactory, so far as the purification of the sewage is concerned, and that with proper conditions in the way of good markets and a favorable soil and climate sewage farms can be operated on a large scale after the sewage is delivered upon the same without financial loss.

In speaking of a sewage farm of the magnitude required for the metropolitan area of Chicago, it is not understood as being land devoted primarily to the raising of crops, using the sewage only when and where it would most promote the growth of vegetation. The primary

object would be the purification of the sewage on an area of land as small as could serve the purpose. Technically speaking, the sewage disposal would be by means of intermittent filtration rather than irrigation. To carry out such a scheme for Chicago involves the following:

(1) The acquirement of sufficient land suitable for the purpose.

(2) A comprehensive system of intercepting and collecting sewers carrying the sewage to the farm.

(3) Pumping works of a capacity to handle all the dry weather flow of sewage and a certain proportion of storm water.

(4) A thorough underdrainage, leveling and preparing of beds for the filtration areas.

(5) A system of underground conduits and surface carriers for distributing the sewage over the ground and a system of open ditches for removing the purified water to the nearest water courses.

(6) Buildings, roads, and a complete farming outfit.

(7) An organization for properly distributing the sewage, for carrying on the farming operations, for conducting the business of disposing of the crops in the best market.

In making estimates for the size of intercepting sewers, conduits, pumps and area of land required, we have used as a basis a population of 2,500,000 people, with an average dry weather sewage discharge of 150 gallons, or 20 cubic feet, per head daily, and made provision for storm water equivalent to one-fifth of an inch in 24 hours over all portions of the district now drained or likely to be drained by a combined system of sewers, allowing surplus water to escape in the rivers and lakes.

The dry weather flow of sewage would therefore be 50,000,000 cubic feet per day, and the maximum flow of storm water 65,000,000 cubic feet per day, making a total maximum discharge of 115,000,000 cubic feet.

From an examination of rainfall tables we conclude that the annual amount of storm water that would be carried off by such an intercepting system would range from 9 to 12 inches, an average of which in round numbers may be taken at 40,000 cubic feet per acre per annum over the area drained by a combined system of sewers. It is practicable, however, to exclude the storm water from the sewers over a large portion of the future city

by adopting the separate system of sewerage. The area north of the town of Jefferson and of the middle of Lake View may be treated to advantage in this way, and also a large portion of Hyde Park, Lake Calumet and other adjacent towns.

Assuming that the area which does not allow the storm water to be entirely excluded is 140 square miles, the average daily amount becomes 10,000,000 cubic feet, which gives, when added to the sewage, 60,000,000 cubic feet, or 24 cubic feet per head of population per day to be provided for on the farm.

As the amount of land required to purify sewage can only be determined by experience, and as this has been very limited in our own country, we are forced to rely mainly upon that of Europe. Without going into details at present, we will simply state that a fair consensus of this experience justifies us in the conclusion that from 10,000 to 15,000 acres of land would be required to dispose of the sewage from the entire metropolitan area.

The only available territory for sewage filtration in the neighborhood of Chicago consists of two sandy ridges in the Town of Thornton, extending across the state line into Indiana, and in a sandy ridge crossing the Town of Niles. The soil is quite favorable, but the character of the surface is such that the necessary preparation to make it suitable for filtration beds would be comparatively expensive. An enormous cost is, however, represented by the fact that the sewage would have to be collected by large intercepting sewers, lifted altogether some 90 feet, and carried about 20 miles before reaching the farms. We therefore consider such a project entirely impracticable.

The land treatment can only be seriously thought of in connection with the sewage disposal from the smaller areas mentioned above and comprising the extreme northern and southern parts of the future metropolis. The drainage of parts of Evanston, Lake View and Niles might be taken to the sandy ground in the latter town, and that of the Calumet region to the sandy ridges in Thornton, should this method be found most advantageous when compared with others.

The preliminary investigation made for this purpose consisted in an examination of the grounds in the projection of a farm, and in an estimate of the cost of pre-

paring the same and delivering the sewage to it by intercepting sewers and conduits.

DISCHARGE OF THE SEWAGE INTO THE DES PLAINES RIVER.

A third solution of the drainage problem is rendered practicable by the fact that the divide between Lake Michigan and the Mississippi Valley lies about 10 miles west of Chicago, with so slight an elevation that it is not a difficult matter to carry the sewage from the city westward into the Des Plaines River, and thence into the Mississippi River. The method of disposal, as previously explained, is in fact mainly the present one, most of the sewage now being carried across the divide by the Illinois and Michigan Canal.

There are two low depressions between the future metropolis and the Des Plaines River—the Mud Lake Valley, with the present canal, and the Sag Valley west of Lake Calumet. Neither is more than 10 feet above the lake, nor do they present any engineering difficulties for canal construction. It is therefore quite feasible to carry all the drainage from the territory ultimately to be occupied by the metropolis, extending from Lake Calumet to Evanston, into the Mississippi Valley through these depressions, avoiding thereby all possible lake pollution and permitting the supply of water to be drawn from any number of convenient points in front of the city.

The possibility of this solution was recognized as early as 1856 by Mr. E. S. Chesbrough, and the first step towards its adoption was taken, as already mentioned, by turning the sewage into the Illinois and Michigan Canal. Not until quite recently, however, has it become practicable to consider the construction of a special waterway for sewage removal, because when the population was smaller the expense of the undertaking was too great.

The sanitary requirements demand a flow of water large enough to dilute sewage sufficiently to make it inoffensive along the river at all times. Beyond this, any increase in the size of the channel to provide for the storm water which naturally enters it should be kept at a minimum. A glance at the map and an examination of the ground show the possibility of diverting the greater part of the storm water from the metropolitan district without serious difficulty. Both branches of the Calumet River can be diverted west of the Indiana state line into Wolf Lake, and thence into Lake Michigan. The Des

Plaines River can have its flood water diverted into the North Branch near the north line of the Town of Jefferson, and the combined waters can be led from Bowmanville directly into the lake. Salt Creek, a branch of the Des Plaines River, can readily be turned southwardly near Western Springs, through a water course known as Flag Creek, at one time evidently its old bed, discharging into the Des Plaines opposite Sag, and thus reducing the necessary storm water capacity in the new channel between Sag and Summit.

In order to determine the probable quantity of flood water which can thus be excluded, it was necessary to ascertain the maximum flood discharges from all the watersheds in question. This requirement called for a gauging of Des Plaines, North Branch and Calumet Rivers; a gauging of the rainfall, which is a measure of the stream flow; a survey of the watersheds and an examination of the river channels. It was also necessary to make a reconnoissance of all possible lines for diverting the Des Plaines, the North Branch, the Calumet River and Salt Creek, and a survey of those which were most important.

The results indicate that each one of these diversions is both practical and economical. By adopting the "separate system" of sewerage for the territory lying north of the proposed Bowmanville channel, the surface drainage from this territory can be safely turned into the lake.

A second branch of the investigation extends to the elements governing the proper size of the waterway from which a large proportion of the storm water has been excluded. The area still draining into it will consist largely of paved streets and roofs, allowing of no absorption and shedding the water rapidly. It requires a careful consideration to determine the maximum quantity of water that may enter the proposed channel, and for which an ample allowance must be made to prevent a back flow of the polluted water to the lake.

The proper degree of sewage pollution in the new channel demanded a careful investigation. When sewage is mingled with a sufficiently large quantity of water it not only becomes inoffensive, but readily finds the oxygen which gradually purifies it. When the surface is covered with ice a greater dilution is necessary for this purpose than at other times when there is a constant

replenishment of oxygen from the air. The proposed waterway should, of course, provide immunity from offense at all times.

The information upon which definitely to decide this question will be given in the final report, as the data have not yet been all collected, owing to the necessity of making actual tests of the oxidization of the canal water under the ice, which is being done for the use of the commission by Dr. J. H. Rauch, secretary of the State board of Health. The summer conditions are presented in his late report on the water supply and sewage disposal of Chicago. The result of these analyses will be compared with those of other streams that are also polluted with sewage in order to show the rate of oxidization with varying degrees of dilution and aeration.

For the purpose of estimating the cost of the water channel we have assumed 3,600 square feet for the cross section and a velocity of the water 3 feet per second, or 2 miles per hour. This gives a discharge of 600,000 cubic feet of water per minute, or 24,000 cubic feet for each 100,000 persons, which we believe equal to the maximum requirements of a population of 2,500,000 people.

A third branch of the inquiry covers the selection of routes for the proposed canals.

Between Chicago and Summit three lines are practicable—one following the west fork and Ogden ditch, and another extending from the southwestern end of the south fork in a westerly direction to the Ogden ditch, and thence to Summit, and a third being an enlargement of the present canal. We are of the opinion that eventually both the first and second of these lines should be adopted, but that the second one should be built first in order to secure circulation in the south fork. From Summit westward the bed of the river and the present canal were the only lines to be considered. The best location has not yet been finally determined.

For the drainage of the Calumet region a simple inspection shows that a canal should start from the river at the southern point of Blue Island, and extend almost directly westward to the Des Plaines Valley at Sag.

A fourth branch of the inquiry relates to the study of such data as have reference to securing a proper circulation for the waterways within the city.

To throw light upon this point the variations of the lake level have been recorded since last spring by means

of an automatic gauge indicating an almost continual fluctuation, averaging several inches, and recurring at periods of about 20 minutes. During a low pressure of the atmosphere the amplitude of these oscillations increases, and not unfrequently reaches several feet. The accompanying diagram shows the level of the lake on August 16, 1886, at a time when an area of low barometer passed over it. From 6:40 a. m. to 6:55 a. m.—that is, in 15 minutes—the water fell 2 feet 10 inches.

A rising level causes an inflow to the river and drives the water of the latter into the slips, where it deposits a portion of its suspended sewage matter and becomes foul. A falling level reverses the flow, and the slips empty their foul water into the river and lake. During heavy fluctuations of the latter, such as the one referred to above, it has been traced more than a mile in the direction of the crib.

As the proposed canal from Bowmanville to the lake will lower the water of the North Branch at this point to the lake level, provision must be made for its circulation. The size of the Fullerton avenue conduit is not sufficient to furnish the water required for a current in both directions, nor would such an arrangement be satisfactory or economical. It will be necessary to establish a flow towards the South Branch from the lake opposite Bowmanville in order to prevent a future lake pollution by the proposed channel. This can be accomplished by placing a lock in the North Branch at any point that may be found most desirable and raising the water at the same time about one foot. If such a lock is placed at Fullerton avenue the present pumping works, with slight modifications, can be utilized.

Finally, it must be mentioned that circulation can be secured in the proposed waterways of the Calumet region, into which the sewage is discharged, by a gravity flow from Lake Michigan into the Des Plaines Valley through Lake Calumet and the Sag. The detailed features of this project have not yet been wholly matured the estimates of cost being based on a channel having a capacity of 1,000 cubic feet per second.

Comparison of Projects.

In the foregoing we have outlined the main features of the only three feasible methods of disposing of the metropolitan sewage, and have given the results of the investigation reached to date. A general conclusion as to the preferable method may be given at present, and also an approximate estimate of cost. But we are not able as yet to give either conclusions or detailed statements of the probable expense regarding all parts of the proposed work, and must defer them until the final report.

In comparing the projects we will first mention their probable cost and then their relative advantages.

The discharge of the sewage into the lake from a population of 2,500,000 in the manner described above, including the extra expense, otherwise not necessary, of taking the water supply of Grosse Point, would cost at least $37,000,000, with an annual expense for interest and operation of at least $2,400,000. It would require an immediate investment of about $20,000,000.

To dispose of the entire metropolitan sewage by filtration on land would require an investment of about $58,000,000, with an annual expense of over $3,000,000 for interest, pumping, and maintenance, after deducting the profit from the sale of crops. It would be necessary to invest at once about $34,000,000. Land disposal for the sewage from the Calumet region alone, with a future population of 300,000, would require an investment of about $4,000,000 and an annual expense of at least $250,000.

Finally, the cost of the Des Plaines project is approximately estimated as follows:

1. A channel from the South Fork to Joliet of the capacity heretofore given will cost between $17,000,000 and $21,000,000.

2. A diversion of the flood waters of the Des Plaines the North Branch, and Salt Creek will cost between $2,500,000 and $2,800,000.

3. Pumping works and locks for the North Branch will cost about $150,000.

Omitted; printed in House Ex. Doc. No. 264, 51st Cong., 1st sess.

4. A separate system of sewers to collect the sewage now discharged directly into the lake and to carry it into the river will cost about $600,000.

5. A channel from Lake Calumet to Sag will cost between $2,500,000 and $3,000,000.

6. A diversion of the flood waters of the Calumet River will cost between $350,000 and $400,000.

The total cost of the Des Plaines drainage project would therefore be, for the main district, between $20,250,000 and $24,550,000; for the Calumet district, between $2,850,000 and $3,400,000. The annual cost, including interest, etc., is estimated at about $1,300,000 per annum.

The pollution of the lake can be decreased and the present condition of the Chicago River, and particularly of the South Fork, can be improved by the immediate construction of the following works, which, with the exception of the pumping works at the South Fork discharging into the Illinois and Michigan Canal, are all a part of the final plan.

1. Channels diverting the flood waters of the Des Plaines, North Branch, and Salt Creek, as described above.

2. A modification of the Fullerton avenue pumping station and the construction of locks for the purpose of getting circulation in the North Branch.

3. A separate system of sewers to collect the sewage now flowing into the lake from the south division and to discharge it into the South Fork.

4. A waterway extending from the western end of the South Fork to the Illinois and Michigan Canal, with a new pumping station to promote circulation.

5. By raising the banks of the canal and by removing deposits this capacity can be increased 40 per cent. at a small cost, and thus provide for a greater flow of water in the same.

The cost of the works comprised under these five items is estimated to be between $5,000,000 and $5,500,000. They could be finished in three years, and would greatly lessen the liability of polluting the water supply, while the sewage would be disposed of in the best practicable manner until the final completion of the Des Plaines project.

It therefore appears that this project is decidedly the least expensive one for the present as well as for the future.

Besides the economical advantages of the Des Plaines, scheme, its superiority is still further emphasized by advantages of another kind. The proposed canal will, from its necessary dimensions and its regular discharge, produce a magnificent waterway between Chicago and the Mississippi River, suitable for navigation of boats having as much as 2,000 tons burden. It will establish an available water power between Lockport and Marseilles fully twice as large as that of the Mississippi River at Minneapolis, which will be of great commercial value to the state. The Calumet region will be much enhanced in value by having a direct navigable channel to the Des Plaines River and by a lowering of the flood heights of Calumet Lake and River. Within the city the water of the Chicago River and its South Branch will get a much better circulation if it flows by gravity than if it has to be pumped, the necessity for which would remain even if the sewage should be discharged through intercepting sewers, either into the lake or upon land. Upon either of the latter conditions an occasional overflow from the sewers into the river during heavy rains would be more objectionable than a constant discharge of sewage into a more rapidly flowing stream. Flood waters entering the lake by way of the Chicago River would carry into it much filthy matter, either suspended or deposited, notwithstanding the existence of intercepting sewers, but the proposed diversion of such waters before reaching the populated districts will for all time obviate this undesirable occurrence. Lowering the level of the North Branch at Bowmanville by its diversion to the lake will be equivalent to raising the low prairie extending towards Evanston and Niles and greatly benefit parts of these towns.

The Water Supply.

In reaching the conclusion that the sewage of the city should be discharged into the Mississippi Valley the question of water supply is materially simplified, because the lake will then at all times furnish good water wherever intakes are desired for an extension of the works.

The preliminary inquiry made with a view to ascertain the main features of an increased supply, comprised first, a compilation of data concerning the existing works both in Chicago and its suburban towns, which were collected

mainly through the courtesy of the respective authorities; and, secondly, a study into the most economical method of distributing the water over the metropolitan area. The following is a brief description of the existing works:

The present intake for the public water supply of Chicago is located in Lake Michigan about two miles from shore and the water is conducted to the city in two circular brick tunnels 5 and 7 feet in diameter. They extend parallel to each other under the bed of the lake, and 50 feet apart, to the north pumping works, where they are connected and where the 5-foot tunnel terminates. The 7-foot tunnel is continued under the city for a distance of 20,500 feet, to supply the west works on Ashland avenue near 22d street.

The tunnels from the source to the shore are built at a depth of 80 feet below city datum, or low water in the lake, and the 7-foot tunnel is continued on the same level for a distance of about 11,500 feet, where, to avoid rock excavation, it is inclined upward until at the west pumping station, the top is but 21 feet below city datum. The economical capacity of the two tunnels is between 90,000,000 and 100,000,000 gallons per day, or less than the present average daily consumption of water. Their maximum capacity is reached when delivering about 150,000,000 gallons per day, which is now nearly equaled by the demand during the hours of greatest consumption, and at the present rate of increase it is estimated that during the summer of 1887 the maximum demand for water will be at the rate of 145,000,000 gallons per day; during 1888, 150,000,000 gallons per day; during 1899, 167,000,000 gallons per day; and in 1890, 180,000,000 gallons per day.

To provide against accident or obstruction from ice or other cause in the main tunnels, and to provide against an inadequate supply in the near future, which appeared inevitable, a new tunnel is in progress of construction. The intake is located 1,500 feet from shore, and connection is made with the other tunnels at the north pumping works.

The distribution of the water is effected by pumping it directly into the water mains at the north and west stations. At the north works the three tunnels are so arranged and constructed that any one of them can be emptied when desired for repairs or cleaning, and both the

pumping stations still be supplied with water from the other tunnels. The total pumping capacity of this station is at present 67,000,000 gallons per day, but it will be increased to 91,000,000 gallons per day as soon as the new pumps now in process of erection are in operation.

The connections between the pumps, standpipes, and the distribution mains at these works have become so complex by the successive additions to the plant that an unnecessary loss of head is the consequence. As this can be remedied to some extent without great expense, we recommend that it be done at the first favorable opportunity. The station being on the shore of the lake, is not centrally located with reference to any part of the city, which renders it necessary to use a greater length of main pipe, with a consequent loss of pressure, to reach the consumers than would otherwise be the case. The total pumping capacity of the west side station is 60,000,000 gallons per day, and the connections between the pumps, standpipes, and mains are simple and effective, and the loss of pressure from this cause is a minimum. The location is better adapted to secure economical and satisfactory results than that of the north works, and with reference to additional pumping stations, which will later be necessary in other parts of the city, these works are well situated.

The following table compiled from the annual reports for 1884 and 1885 gives a detailed comparison of the cost of pumping at two stations, anthracite coal being used at the north side and good bituminous coal at the west side:

COST OF PUMPING 1,000,000 GALLONS 1 FOOT HIGH.[a]

Nature of expenditures.	1884.		1885.	
	North Side.	West Side.	North Side.	West Side.
Salaries	$0.01488	$0.02022	$0.01560	$0.01667
Fuel	.05313	.02855	.04590	.02482
Lubricants ...	.00064	.00186	.00057	.00160
Miscellaneous.	.00323	.00417	.00133	.00401
Total	$0.07188	$0.05480	$0.06340	$0.04710

[a]Here appears a "diagram showing water pressure in the Chicago water pipes." Not here reproduced.

The hydraulic merits of the system are shown on the diagram of water pressures from a survey made in December, 1886. The pressures have all been reduced to a common height above city datum and to a uniform height of water at the works. That diagram shows a greater loss of head in the vicinity of the north side station than at the west side. This is accounted for by the complex arrangements heretofore mentioned, and also by the relatively small area of mains, being only 16¼ square feet at the north side and over 21 square feet at the west side. Nearly equal quantities of water are pumped at each of the stations during the middle of the day.

The following table shows the pumping capacity of all the suburban towns having a public water supply, and the pressure ordinarily maintained at the works. With the exception of South Evanston, all take water from Lake Michigan.

Locality	Individual pump capacity.		Total pumping capacity per day.	Ordinary head at pump, in feet.
	Pumps.	Capacity per day.		
		Gallons.		
Hyde Park	2	3,000,000	.....	.....
Do	1	12,000,000	18,000,000	103 to 150
Lake	2	4,000,000	.....	.....
Do	2	2,000,000	12,000,000	100 to 190
Lake View	1	5,000,000	.....	.....
Do	1	3,000,000	10,000,000	92
Do	1	2,000,000	.....	92
Village of Evanston	1	3,000,000	3,000,000	92
Total	11	.....	43,000,000	.....

At the artesian well supplying the village of South Evanston there is a head of about 53 feet.

The pressure at different parts of the pipe system is very irregular. In Hyde Park it varies from 165 feet at the pumps to 10 or 12 feet at Forty-third street. In the Town of Lake the average head at the town hall is reported about 10 feet, with 188 feet at the pumps. In Evanston, South Evanston, and Lake View the difference of head in various parts of the villages is not very great.

The following table gives a comparison of the consumption and cost of water in Chicago and the suburban towns:

Locality.	Year.	Average head at pumps.	Average daily pumpage.	Cost per 1,000,000 gals., delivered.	Cost of pumping 1,000,000 gals. 1 ft. high.
Chicago (North side)	1885	113	38,369,134	$ 7.17	$0.06034
Chicago (West side)	1885	105	53,280,880	4.95	.04071
Evanston (Village	1886	113	787,000	17.00	.15000
Lake View	1886	...	1,983,000	11.85	.....
Town of Lake	1886	163	7,292,023	8.80	.05400
Hyde Park	1886	...	3,410,000	8.92	.....

The second point of inquiry was a study into the most economical method of distributing the water over the metropolitan area. We will at present refer to it but very briefly, mentioning only such conclusions as pertain to the immediate demands and leaving a fuller discussion of the details of this important question to the final report.

The comparatively level area upon which the city is located, and the practicability of taking the water from the lake along the city front at any desired point, after the sewage has been diverted, permits the most economical distribution to be ascertained by mathematical investigation to a much greater degree of exactness than is usually possible.

It is found to be less expensive for the densely populated areas to have pumping stations about 2 or 3 miles apart, because the loss of head and cost of mains and pumping to obtain the least allowable pressure are thus reduced to a minimum. In planning new works this fact should be considered, and locations so selected that they will be advantageous for the future as well as for the present.

The localities which we believe to be most suitable for additional pumping stations are near 12th street, in the central part of the city; near the Union Stock Yards; near Humboldt Park, and near Fullerton and Racine avenues.

When it is considered that at the present time the pumps are delivering during the busy part of the day at the rate of 120,000,000 gallons in 24 hours, which is nearly the maximum capacity of all the machinery, and that even with this large consumption of water it is impossible in some parts of the city to obtain water in the second story

of the buildings, it becomes evident that an increased supply is imperatively required, and being a work of years to build new tunnels, inlets, buildings, and machinery, the necessity of deciding upon the location of the new works as soon as possible, is readily seen. The locality which is suffering most from the want of water is the business section and the south part of the city, the lowest pressure extending from 12th street to the city limits. It will become necessary in the future to have two stations in this territory, one between Harrison and 12th streets and the other to be somewhere east of the Union Stock Yards. We are strongly of the opinion that of the two stations it will be advisable and most advantageous to build the one north of 12th street first, for the following reasons:

1. It will require a shorter tunnel from the lake to the proposed station and less expenditure for main discharge pipes to connect with the present system than would be the case with the proposed southern station. This is equivalent to less cost and a saving of time in construction.

2. If the southern station is built first it will require mains of larger capacity leading toward the city than will be ultimately necessary when the central station is built.

3. The location recommended is near the center of the greatest consumption of water, and will be a gain not only in obtaining greater pressure in the business district, but in removing the cause for complaint on the south side by increasing the pressure so that the water will flow to the upper floors of the highest dwellings.

4. All other parts of the city will gain by the construction in this location, as the north and west works will be relieved of the enormous drain upon them to supply water for the business part of the city. They will be better able to give a good head on the north and west sides, where the population is increasing very rapidly, and which will very soon be in the same unsatisfactory condition as now obtains in the southern end of the city, unless relief is afforded in the manner indicated.

The other pumping stations will gradually become necessary as the population increases, and for a population of 2,500,000 there will be a need for a total combined capacity of 375,000,000 gallons to provide for a daily consumption of 150 gallons per head. With several in-

takes and tunnels the danger from stoppage of the water supply by ice or accident will be reduced to a minimum, as it is not probable that more than one of them would be so endangered at the same time.

We believe that a submerged intake will afford a more reliable and safer structure so far as injury from passing vessels and stoppage by ice are concerned than a structure projecting above the water.

With the sewage kept out of the lake there is no need of locating the intake farther than two miles from the shore where water can be obtained sufficiently free from suspended earthly matter, and where a depth of about 30 feet is generally found, which is the least depth desirable for a submerged inlet.

After presenting the results thus far gained, indicating the general solution of the Chicago drainage and water supply problem, it remains to point out certain facts which may be useful in discussing some of the legal measures required to carry out the proposed work. We desire to state that in order to reach the best results it is imperative to have all the main drainage works, such as intercepting sewers, waterways, and pumping stations, executed and maintained under a single management. It would be economical also to design and operate the main works for supplying water to the entire metropolitan area on a uniform plan and under one management, for the same reason that it is economical to keep the north and west side pumping works under one control, thus giving facilities as far as practicable for a supply proportioned to the demand to the entire metropolitan area, including the towns not bordering on the lake. We do not wish to imply, however, that such a general authority need necessarily extend further than to the construction and maintenance of the tunnels and conduits furnishing water to the respective pumping works.

Regarding the limits for metropolitan drainage, the investigation has shown, as already indicated, that topographical conditions clearly define two districts for the future metropolis. The main district extends from the line of 87th street on the south to the north line of Evanston and from the lake westward to the Des Plaines River. Its sewage is collected into one channel and discharged into the Des Plaines Valley at Summit. The Calumet district extends over the natural drainage area of Calu-

met Lake and River south of 87th street, and has its outfall channel running from Blue Island to Sag.

The final report will contain several maps, showing certain features of the metropolitan area, namely, the distribution of the population in 1886, the existing works and main distribution pipes for water supply, and the existing main sewage works and five-foot contour lines over nearly the entire area. It will also contain maps and profiles of the proposed waterways and storm-water-diversion channels mentioned in the present report, and a map showing the lines of the main collecting and intercepting sewers of the proposed drainage district, and also the lines of new tunnels and the general distribution of the water supply.

In carrying on the present investigation its various branches are placed in charge of the gollowing gentlemen, of whose ability and industry we desire to make special mention: Mr. L. E. Cooley, principal assistant, had special charge of the hydrographic work; Mr. Charles H. Swan, of the sewage disposal on land; Mr. Francis Murphy, of the topographical work; Mr. O. Guthrie, of the river pollution, land damages, etc., and Mr. T. T. Johnson, of the water supply, sewerage and miscellaneous work.

Respectfully submitted,
RUDOLPH HERING,
Chief Engineer.
BENEZETTE WILLIAMS,
SAMUEL G. ARTINGSALL,
Consulting Engineers."

I will ask you whether or not the statements in that report to which I have just directed your attention are the statements to which you referred in your direct examination as the ones which you made on this subject in the year 1887?

Mr. Williams: I object to the form of the question. I object to incorporating in the question the report referred to as not being proper cross-examination; and I object further on the ground that in the reports are statements referring to matters concerning which the witness has not been asked on his direct examination, and the entire question is improper as cross-examination.

A. They are.

Q. And the statements in that report which purports to be signed not only by yourself, but by Mr. Williams and Mr.

Artingstall represented at the time the report was made your own best judgment on the subjects with reference to which you have been testifying, did it not?

A. It did.

Q. That is to say the report is one which appears to be signed by three engineers, but so far as the report itself is concerned, it represents your judgment on all of the matters that are there set forth?

A. It does.

Q. Now, I will direct your attention to the report Appendix F, which appears on page 42 of this document to which I have last called your attention, the same being a report to the International Waterways Commission on the disposal of the sewage of Chicago and vicinity by Rudolph Hering and George W. Fuller under date of December 18, 1906, which is as follows:

"New York City, December 18, 1906.

To the International Waterways Commission:

Sirs: In response to your recent request we beg to report herewith upon several propositions connected with the question of extending the method of disposing of the sewage of Chicago and vicinity by means of dilution with Lake Michigan water. Your instructions may be briefly summarized as follows:

1. Examination into the sanitary situation at Chicago so far as it is affected by sewage disposal.

2. Latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive.

3. Is the extension of the dilution method to the outlying territory the only way to preserve the lives and health of the people of Chicago?

4. For the Calumet area, are there not other methods of sewage disposal which may be applied at a cost not exceeding much, if at all, the cost of the method of dilution proposed, and which will be equally effective in preventing the pollution of the lake water?

5. Description of the various systems of sewage disposal which are available for the Calumet area, with a statement of their relative efficiencies.

6. Statement of the approximate relative costs of the last mentioned so far as they can be given without the preparation of detailed plans.

You further state clearly in your letter of instructions

that you do not desire an investigation into the effect of the present method upon the navigation interests of the Great Lakes, as that has already been officially considered by yourselves. Further, you state that you accept as a fixed fact the Chicago Drainage Canal as designed and built, with its attendant diversion of 10,000 cubic feet per second of lake water through the Chicago River and its branches.

In accordance with further instructions we have not given consideration to questions of a legal or legislative nature. We have viewed this problem solely as an engineering proposition without regard to inter-state questions and other features associated with the fact that a portion of the future metropolitan area of Chicago will obviously lie within the State of Indiana. It is further understood that under the existing circumstances we are to give you our opinion without entering into such details as would be required by additional surveys or other field work beyond a personal inspection of the areas.

Sewage Disposal at Chicago.

Drainage Canal.—Nearly all of the sewage from the population of Chicago now connected with sewers is diluted with Lake Michigan water, which, since January 17, 1900, has been allowed to flow through the new drainage canal and thus reach the valley of the Illinois River. This method of disposal is the outcome of various investigations, particularly of a commission on the drainage and water supply of Chicago in 1886-87. It was formally adopted in 1889 by State legislation, creating the 'Sanitary District of Chicago,' specifically providing that the volume of lake water for purposes of dilution shall be 3½ cubic feet per second for each 1,000 of population connected with the sewers, or 20,000 cubic feet per minute for each 100,000 population.

Early Methods.—In early days part of the sewage of Chicago flowed directly into the lake and part into the Chicago River and its branches. From the latter a portion of the water and sewage, beginning over thirty-five years ago, has been pumped at Bridgeport into the Illinois and Michigan Canal, as is true to some extent today. It is understood that the old canal is to be discontinued by legislative action as soon as equivalent transportation and

power facilities can be arranged for by means of the new canal.

Area of Sanitary District.—In 1903 an act of legislature was passed extending the area of the sanitary district from 185 to 358.1 square miles, and including the 'North shore addition' of 78.6 square miles, and the 'Calumet addition' of 94.5 square miles. The area of the City of Chicago is 190,638 square miles, leaving 167,462 square miles as the area of the present sanitary district outside of the city limits.

There are several features to be noted in connection with the method of sewage disposal of the City of Chicago as adopted in 1889. It had been found to be the cheapest method then available for disposing of the sewage so that it would not pollute the public water supply, which was then and is now diverted from Lake Michigan through a series of intake cribs located at various distances from shore.

Intercepting Sewers.—To prevent such pollution it was of course necessary first to divert all of the sewage into the Chicago River. A pure water commission was appointed by the Mayor in 1897 to consider the question of intercepting sewers for that purpose. It recommended among others a large intercepting sewer to collect the sewage from the area along the lake front between Seventy-third and Thirty-first streets, and about a year ago a 20-foot conduit was completed on Thirty-ninth street, through which the diluted sewage from this area now passes to the south fork of the south branch of the Chicago River. At present there is a gravity flow of lake water ordinarily of about 40,000 cubic feet per minute. Pumps are now in process of erection by which ultimately there will be pumped through this conduit about 120,000 cubic feet of lake water per minute, or 2,000 cubic feet per second.

On Twenty-second street there was formerly a main sewer draining the area bordering on the lake front between Thirty-first and Sixteenth streets, and discharging into the lake. In 1898 the flow in this sewer was reversed so that its contents now discharge into the river.

On Twelfth street in 1898 the flow in the main sewer was also reversed.

In the heart of the city, or business section, the sewers have always discharged into the river and not into the

lake. The same is true of a considerable area lying north of the Chicago River and along the lake shore. To facilitate this discharge a conduit was put in service in 1880 at Fullerton avenue, through which there has been pumped about 12,000 cubic feet of lake water per minute into the North Branch of the Chicago River.

At the present time there is no sewage entering the lake between Surf street (just north of Lincoln Park) on the north side and Seventy-third street on the south side of Chicago.

Plans are under way for the construction of the necessary works to collect the sewage along the lake front between Seventy-third and Eighty-seventh streets and to pump it into sewers west of Halsted street, which lead to the Chicago River. There is very little or no sewage from this area now reaching the lake, as the district is yet practically unsewered.

On the north side there is an area between Surf street and the northern city limits and between the lake shore and the ridge between the lake and the river, which now discharges sewage into the lake, but which will be diverted next summer. This sewage is to be collected by interceptors conducting it to Lawrence avenue, where will be located a pumping station and a conduit for pumping the sewage and about 35,000 cubic feet of lake water per minute into the North Branch of the Chicago River.

Farther north, at Wilmette, a conduit is proposed to be built with a pumping station near the Northern Railroad bridge in Evanston, where about 60,000 cubic feet of lake water per minute will be diverted into the North Branch of the Chicago River.

SUMMARY OF FLOW TO CANAL.—The projected flow of the lake water to the canal through the Chicago River and its branches to the Drainage Canal may therefore be divided and summarized as follows:

	Cubic feet per minute.	Cubic feet per second.
Main stream, Chicago River	373,000	6,217
Thirty-ninth street conduit	120,000	2,000
Fullerton Avenue conduit	12,000	200
Lawrence Avenue conduit	35,000	583
Wilmette conduit	60,000	1,000
Total	600,000	10,000

The volume for the main stream of the Chicago River as above stated is obtained by deducting the remaining quantities from the total.

The satisfactory disposal of the sewage of Chicago by means of the new drainage canal requires that, at and after heavy rainfalls, the storm water and sewage from the watershed of the Chicago River shall not flow into Lake Michigan, and therefore it is necessary to secure a practical reversal of the original flow in the Chicago River.

The drainage area of the Chicago River is about 270 square miles. Flood flows in the river have reached a maximum of about 10,000 cubic feet per second, or 600,000 cubic feet per minute, and this fact was also an important element in fixing the minimum size of the present drainage canal.

As to the efficiency of arrangements for the reversal of flow, our inquiries lead us to believe that this has been accomplished in a satisfactory way. Up to the present time, and owing to the insufficient waterway of some parts of the Chicago River, the volume of Lake Michigan water going through the river has not approached the volume above stated. But there have been times when a continuous flow of the Chicago River has been toward Lake Michigan for perhaps two or three hours. This time is necessary to properly regulate the water level at the controlling works near Lockport.

Population of Chicago Now Sewering Into the Drainage Canal.

We find that the present population of Chicago is, in round numbers, 2,000,000 people, of which between 100,000 and 200,000 reside south of Eighty-seventh street, tributary to the Calumet district, but within the city limits. Of the remaining population about 300,000 reside in the southern lake front district. This area is tributary to the Thirty-ninth street pumping station, which, since about January 1, 1906, has brought about the diversion of the sewage from the lake into the South Fork of the south branch of the Chicago River.

There is still an area in the northwestern part of the city north of Lincoln Park, spoken of as the northern

lake front district, which drains directly into the lake. Its population may be very roughly estimated at 70,000.

There is a considerable area south of Seventy-third street and west of Halsted street, and also a portion of the northwestern part of the city, which are of a semi-suburban character. Some portions have been provided with sewers and receive the overflow from cesspools.

So far as we are able to ascertain from local officials and without making a personal canvass as to details, it appears that there are now, in round numbers, about 1,500,000 people sewering into the drainage canal. In addition to the sewage there enters it a considerable quantity of trade wastes, notably about 2,000,000 gallons from the stock-yard district, and from quite a number of other industrial establishments, such as tanneries, wool-pulling establishments, etc., as stated by the sanitary inspector in the last report of the health department.

It is our understanding that the present sewage disposal project for Chicago is not intended to provide for the disposal of trade wastes now discharged into the sewers. While comparatively little has been done as yet to remove them from the sewers, we have been informed that it is proposed to take up this matter actively.

Influence of Sewage on Chicago Water Supply.

The City of Chicago receives its water supply from Lake Michigan through a series of tunnels of various lengths, ranging from about one to five miles from shore. Most of them extend from the shore about two miles. The total pumping capacity for this supply is stated to be 529,000,000 gallons in twenty-four hours. In 1905 the average daily pumpage was recorded as 399,000,000 gallons.

Since the removal of the sewage through the drainage canal was systematically begun in January, 1900, the appearance of the water of the Chicago River has shown marked improvement.

The effect of the drainage canal upon the hygienic quality of the public water supply may be studied in connection with the typhoid fever death rates at Chicago, which are recorded in the next table, together with corresponding death rates for a number of other American cities. It is not to be assumed

that typhoid fever is entirely due to the pollution of the public water supply at Chicago or elsewhere, as it is well known that there are other means of transmitting this disease. But its relation to the public water supply is so intimate that it gives, perhaps, the best general idea of the sanitary quality of the water, and therefore it frequently has been used as a rough means of such measurement.

There are other factors besides the drainage canal to be considered carefully in connection with the typhoid fever statistics at Chicago, and some of which should be mentioned here. Prior to 1900 there was a substantial improvement in the public water supply, partly due to the extension of some of the intake cribs and tunnels farther into the lake and partly to the reversal of the flow of a number of sewers from the lake into the river, such as those at Twelfth and Twenty-second streets, in 1898. These are important factors in explaining the absence in the late nineties of such excessive typhoid death rates as were noted at the beginning of that decade.

Since the opening of the drainage canal typhoid fever in Chicago has been rather unusually prevalent at times. This was especially true in 1902-3, when, it is understood, portions of the supply became contaminated after leaving the intake crib. These accidental pollutions have since been corrected.

The report of the city chemist of Chicago, as given in the last annual report of the department of health, shows that on an average in 1905 the city water supply was considered by him to be safe about 85 per cent of the time.

While there has been a marked improvement in recent years in the quality of the Chicago water supply, due to the progressive elimination of sewage from the lake, there is still room for more improvement. These improvements refer to the pollution along the lake front north of Lincoln Park, which is being corrected, and to the "Calumet area" south of Eighty-seventh street, which is now under consideration.

COMPARISON OF THE ANNUAL NUMBER OF RECORDED DEATHS FROM TYPHOID FEVER PER 100,000 POPULATION AT CHICAGO AND OTHER AMERICAN CITIES, 1890-1905.

Year.	Chicago.	Milwaukee	Detroit.	Cleveland.	Buffalo.	Toronto.	Boston.	New York.	Philadelphia.	Baltimore.	Washington.
1890	83	33	18	69	44	80	43	21	64	57	89
1891	160	33	13	50	56	90	33	22	65	34	86
1892	103	31	64	59	38	40	25	14	40	42	72
1893	42	37	29	52	37	40	26	20	40	47	72
1894	31	26	27	29	62	20	23	17	32	49	72
1895	32	25	24	35	28	30	32	17	40	28	69
1896	53	18	23	43	22	24	32	16	34	37	51
1897	29	11	15	23	19	18	33	16	33	37	42
1898	38	17	18	34	29	16	34	20	51	38	64
1899	26	17	13	32	26	19	30	16	75	30	82
1900	20	21	18	54	27	19	25	21	35	37	77
1901	29	21	20	36	27	16	25	20	33	27	67
1902	44	16	17	33	33	13	35	21	44	42	79
1903	31	17	17	114	35	15	20	18	70	36	48
1904	19	13	16	48	91	22	18	17	..	36	43
1905	16	20	12	15	23	..	20	16	48	36	45

LATEST CONCLUSIONS AS TO THE REQUIRED DEGREE OF DILUTION FOR THE DISPOSAL OF SEWAGE WITHOUT NUISANCE.

The disposal of sewage by dilution depends on the amount of oxygen in the diluting water being sufficient to prevent putrefaction of the organic matter in the sewage as the latter undergoes bacterial decomposition. If the oxygen is deficient bacterial decomposition produced what is called "putrefaction," with its various attendant bad odors, such as noted for years in Chicago at "Bubbly Creek." If there is a sufficient amount of oxygen dissolved in the water to combine with this organic matter, decomposition goes on without any foul odors and the organic matter is reduced to inert matter in an inoffensive way.

This question is one of balancing the amount of oxygen in

a given volume of water with the amount of decomposing organic matter in the sewage, which naturally must vary greatly.

There are many observations of more or less accuracy available to give figures for this relation. The Massachusetts State Board of Health made a special inquiry into this subject for all local rivers in 1902, with conclusions, stated on page 452 of their annual report for that year, as follows:

"The results of the investigations show that where the quantity of water available for the dilution of the sewage in a stream exceeds about six cubic feet per second per 1,000 persons discharging sewage, objectionable conditions are unlikely to result from the gross pollution of all the water of a stream in dry weather. Under favorable circumstances, such as in cases where the sewage is discharged at many outlets into a large body of water, objectionable conditions may not result where the dilution is somewhat less than six cubic feet per second per 1,000 persons; but objectionable conditions have resulted in all of the cases thus far examined where the flow has been less than 3.5 cubic feet per second per 1,000 persons discharging sewage into the stream."

These conclusions apply for the most part to comparatively small streams into which much manufacturing waste is discharged and upon which mill ponds are situated.

There are times when the flow of water in the drainage canal appears to have been insufficient to eliminate objectionable odors entirely. How far this may be explained by confusion on the part of observers of the putrefactive odors emanating from the Illinois and Michigan Canal with those of the new canal, and how far it may be due to temporary reductions in the rate of flow in the new canal and river to facilitate constructive work, and also to the effect of rainfalls and to old deposits in the South Fork, we are unable to say.

The new canal appears to serve at present about one-half the population for which it was designed, and through it flows a volume of lake water which is variable, but which averages not far from one-half of the ultimate quantity.

It is our judgment that for large canals with the trade wastes eliminated a dilution of 3 1-3 cubic feet per second for each 1,000 population connected with the sewers also receiving storm water is as low a figure as it is now possible to state. Local conditions, especially temperature, which affects bacterial activities and the coefficient of absorption of oxygen by water, and still other matters, bear upon this question, the detailed discussion of which is not now neces-

sary. We feel certain that a dilution of 2 1-2 cubic feet per second would cause offenses at times, and probably also a dilution of three cubic feet per second.

Future Population on an Area Tributary to the Chicago River and Drainage Canal with Reference to Sewage Disposal.

On the basis of the diversion of 10,000 cubic feet per second of Lake Michigan water, on the present assumption of 3 1-3 feet per second as being the volume to be provided for each 1,000 population connected with the sewers, and on the assumption of eliminating objectionable trade wastes, the present method of disposal may serve until the population on the drainage area of the Chicago River reaches 3,000,000 people.

On the further assumption that through the Chicago River and various conduits connected with its branches there will be a flow equal to 14,000 cubic feet per second, which is the capacity of the rock section of the drainage canal, the maximum population which might be taken care of in this way is about 4,200,000 people.

With a large portion of the 270 square miles draining into the Chicago River, but not yet built up, even on a suburban basis, it is evident that in future years there will be a much greater population than now exists.

We have considered the rate of growth in Chicago from various viewpoints, notably the density of its population, and have compared its growth with that of other metropolitan districts. There is, of course, no way of predicting accurately how rapid will be the growth of Chicago in future years; but it is a reasonable assumption that before many years it will become a city of some five or six million of population. It seems reasonable to infer that the population residing upon the area tributary to the Chicago River and its branches will ultimately exceed both the 3,000,000 and 4,200,000 estimates above mentioned. In other words, the present dilution method will certainly not alone for all time take care of the crude sewage of this area.

There are several available methods for the purification of sewage, depending upon the degree of purification desired, as will be noted beyond in connection with the Calumet area.

It is not probable that the sewage of the old part of Chicago will ever be purified by artificial means, as it would be proportionately much more difficult and expensive to deliver

the sewage to suitable sites for purification than to continue the present dilution method. It is different with the outlying districts tributary to the Chicago River. In the future, when these districts become built up so that the population exceeds the limits above stated, the installation of sewage purification works will necessarily follow.

The more essential feature of this proposed canal, as obtained from local officials, may be summarized as follows:

Location.—The canal would extend from a point on the Little Calumet River near Blue Island, through the Sag Valley, and enter the drainage canal near Sag Station.

Territory Tributary.—The total drainage area of the Calumet River is 825 square miles, of which 473 are in Indiana. Within the limits of the sanitary district of Chicago and south of Eighty-seventh street, the area is 94.5 square miles, with a population of about 100,000 in 1900. It is stated that the population has nearly doubled within the past six years, and it is expected to reach a million people or more within a fairly short period, as the conditions for a manufacturing district are very favorable.

Size.—The size of this canal, as proposed, is such as to give a flow of 4,000 cubic feet per second.

Reversal of Flow.—The natural flow of the Calumet River exceeds 12,500 cubic feet per second. It is proposed, if suitable legislation can be secured, to construct a dam below Thorn Creek, at the southern boundary of the sanitary district, and divert into Lake Michigan, through a channel to be built about 17½ miles east of the state line, the flow of this stream, with a drainage area of about 587 square miles. The size of the proposed Calumet Canal is too small to secure at all times a reversal of flow of the remaining portion of the area, which is about 240 square miles. It is proposed to put a controlling lock on the canal east of Blue Island to prevent flood waters from this low area entering the canal, at which times sewage entering the river on the lake side of the lock would go into the lake.

The proposed canal is insufficient to carry in the future all the storm flows of the Sag Valley itself. These would, at least, in part, require diversion through present or other channels.

Cost.—The estimated cost of this proposed canal is $12,000,000.

Population to be Served.—On the assumption already stated, this canal, by dilution, would dispose of the sewage

of about 1,200,000 people, not including objectionable trade wastes. This makes the cost of sewage disposal $10 per capita for the entire future population, or about $60 for the present population. The sewage would for the most part reach the canal by gravity through the Calumet River, so that the cost of maintenance would be comparatively small.

In passing, we may say that the Calumet area, both in Illinois and Indiana, is certain to develop rapidly, and its population will eventually far exceed the above figure.

Relation of Sewage Disposal for the Calumet Area to the Water Supply of Chicago.

For the reasons above stated in connection with the reversal flow, the sanitary effect upon Lake Michigan water at the Hyde Park intake and vicinity of this proposed Calumet Canal would not be nearly as effective as that of the main canal for the Chicago River territory and neighboring intakes. This fact is important in connection with the degree of sewage purification required by artificial purification works to give a sanitary effect equal to that of the proposed canal.

There seems to be no doubt that at times the sewage entering the Calumet River under present conditions from this district pollutes the lake water from the Hyde Park intake crib. It may pollute the water at other intakes, but our evidence is not conclusive. In the future, when the Calumet area is built up, it is possible that intake cribs may be built nearer to the mouth of the Calumet River than is the Hyde Park intake.

In view of the fact that the proposed Calumet Canal can not keep all sewage out of Lake Michigan at times of heavy rainfall, it is important to note that the water supply of this section of Chicago will eventually have to be purified by modern filtration works. This can be done at moderate cost, and it will be the cheapest and best solution of this problem to filter the water supply of this district and to purify the sewage to such a degree that the effluent will be fairly clear and nonputrescible, that is, free from disagreeable odors. With additional expense the sewage effluent (of the quality just stated) can be given a supplementary purification, making it practically free of bacteria by treating it with a germicide or by filtering it according to water purification practice.

Under existing conditions we are firmly of the opinion that

all the purification required of the sewage of the Calumet district is to make it fairly clear and non-putrescible.

Available Methods of Sewage Disposal Other than that of the Dilution Method Proposed for the Calumet Area.

The degree of purification of sewage by various forms of treatment differs naturally under different local conditions, but from general experience approximate results may be compared, substantially as follows:

	Percentage purification.		
Method.	Suspended matter.	Organic matter.	Bacteria.
Fine screens (30-mesh or finer)..	15	10	15
Sedimentation	65	30	65
Septic treatment	65	30	65
Chemical precipitation	85	50	85
Contact filters* 85-90		65-70	80-85
Sprinkling filters* 85-90		65-70	90-95
Intermittent sand filters*.....95-99		90-98	98-99

*The figures for the last three forms of treatment are on the assumption that the sewage is given some form of preparatory treatment before it is applied to the filters, and that with the sprinkling filters the effluent is allowed to settle.

It is to be stated that none of the first four treatments above tabulated will by itself give a non-putrescible effluent. Therefore they can be used here only in connection with some form of filtration.

For large works filters can be more economically operated if the sewage is first clarified in part, as stated in connection with the above summary. The most appropriate method for this preparatory or preliminary treatment is considered by most sanitary engineers in this country and abroad to consist of septic tanks, which is the expression applied to sedimentation basins in which the deposited sludge is allowed to accumulate to undergo bacterial action.

There are several forms of filters, the most widely known of which, in this country, is the intermittent sand filter sometimes mentioned as the so-called "land treatment" for sewage disposal. This method was considered in 1886-87 for the entire Chicago area and reported upon unfavorably on

account of its being more expensive than the adopted method of dilution.

LOCAL EXPERIENCES.—We find that a feeling appears to prevail among some persons at Chicago against land treatment of sewage, due perhaps to the unsuccessful operation of the sewage farm at Pullman, which is situated within this Calumet area.

We are familiar with the facts and experiences at Pullman, and are clearly of the opinion that they are not necessarily a criterion for the Calumet area. This opinion is based partly upon the small size of particles of the soil at the Pullman farm, and partly upon the fact that the farm was devoted principally to agricultural rather than sewage purification purposes.

SAND AREAS.—We have examined the tracts of lake sand which are found in Indiana and to a limited extent in the township of Thornton, Ill. The latter areas are too limited in extent and too shallow to be considered for present purposes. The only areas of suitable porous sand for land treatment of the Calumet sewage are in Indiana.

We have collected five samples of this sand for mechanical analysis, and have obtained the results as to size of sand grains. Representative results average substantially as follows:

	Millimeters.
Effective size	0.15
Uniformity coefficient	1.45

If we disregard the state boundary line, a large tract of sand of a suitable character is available for the disposal of the sewage of this district. The best area lies between the Little Calumet and the Grand Calumet rivers, and extends east of Hammond for many miles.

Within the past six or eight years great strides have been taken in the field of sewage purification in connection with works of wholly artificial construction. We refer particularly to filters of coarse, firm material, such as broken stone, slag or clinker, and usually spoken of as "coarse-grained filters," as distinguished from fine-grained sand filters.

Coarse-grained filters are of two types, spoken of as "contact filters" and "sprinkling filters," according to the method by which the sewage is applied to them. These filters produce an effluent which will not putrefy when they are operated at a rate far greater than that which is possible for sand filters.

We shall describe briefly each of these types of sewage-purification methods and state their approximate cost of construction on suitable sites for the Calumet area, based upon unit prices in accordance with experience elsewhere.

An outline is first required, however, of the intercepting sewers, pumping stations, and rising mains necessary to collect and deliver the sewage to the filter sites, of which there are several available.

Regardless of the particular kind of filter found most suitable for the Calumet area, there are a number of features common to all methods, and which may be stated as follows:

Separate Sewers.—With the adoption of sewage filters for this district we are clearly of the opinion that it would be advisable hereafter to build a separate system of sewers for domestic sewage only. Some, if not all, of the existing main sewers could be used for the removal of storm and surface water only, and new sewers parallel them for sewage removal; or, some of the existing sewers could be utilized for sewage removal, requiring new structures for storm-water removal. Trade wastes should be excluded from all sewers. We have obviously not included in the cost of purifying the sewage any expense for the main sewers or laterals to collect it and deliver it to the interceptors.

Volume of Sewage.—We have assumed that the sewage of this district will approximate 130 gallons per capita daily on an average. With a population of 1,200,000 the total volume of sewage would therefore be about 156,000,000 gallons daily. We have also allowed for ground-water seepage up to 1,000 gallons per square mile per day.

Interceptors.—For purposes of making approximate but liberal estimates of cost of purifying the sewage of this district, we have prepared sketches showing the intercepting sewers which will be required in order to collect the sewage of the district at four or more centrally located pumping stations. We have assumed that these intercepting sewers will be built of concrete, and when flowing full have a capacity of 250 gallons per twenty-four hours for each person resident upon the area tributary to the interceptor. When full, these interceptors have been assumed to have a velocity of 2.5 feet per second. We have also assumed, after excluding that portion of the Calumet district reached by extreme high water in the lake, that on an average the population contributing to the four or more pumping stations would be about 20 to 25

persons per acre. On this basis the length and size of the necessary intercepting sewers have been obtained.

PUMPING STATIONS.—For convenience we have located four main pumping stations near Riverdale, Harvey, South Hammond, and South Chicago. There will be required, when the district is built up to the extent herein considered, a total pumping capacity of about 340,000,000 gallons daily, including necessary reserve capacity at each station.

SEPTIC TANKS.—Regardless of the type of filter adopted, the sewage would be screened at the pumping stations, and then flow through septic tanks having a capacity of eight hours' flow on an average. These tanks would be about 12 to 15 feet deep, built of concrete, and arranged in compartments, so as to facilitate septic action on the deposited sludge, but without such action taking place in the flowing sewage itself. Owing to the severe winter climate in this vicinity, it is our opinion that it would be wise to cover these tanks.

Of the solid matters in suspension in the sewage about 65 per cent would deposit in the septic tanks, and of these deposited solid matters about one-half would be liquidified and gasified by bacterial decomposition.

The sludge which would be removed at intervals of once a year or so from the tanks, is estimated to contain about 85 per cent water and to amount to about 2 cubic yards per 1,000,000 gallons. Bacterial action converts this sludge to a practically inert mass which can be pumped in thin layers on to adjoining land and allowed to dry.

This is the form of preliminary treatment in use in some 40 places in this country, including Plainfield, N. J., Saratoga, N. Y., Mansfield, Ohio, Champaign, Ill., etc. It is the preliminary step in the works under construction at Columbus, Ohio, after elaborate tests of different methods were made for a period of nearly one year. It has also been adopted recently at Baltimore, Md., Reading, Pa., and Waterbury, Conn., and has been recently proposed for Paterson, N. J., in a somewhat modified form.

This form of preliminary treatment has been and is now extensively used in Europe with satisfactory results where the tanks are built and operated to meet local conditions as to volume and strength of sewage.

The odors from large open septic tanks are seldom noticeable a few hundred feet away. Under good management a septic effluent can be applied to sprinkling filters so that no objectionable odors should be carried one-quarter of a mile.

The cost of building and operating septic tanks would be substantially the same for all filter projects, and is considered under each as a common factor.

Intermittent Sand Filters.

This well-known method consists of applying the partially clarified sewage coming from the septic tanks to areas of porous sand, below the surface of which at depths of from three to five feet are underdrains of open-jointed pipe to convey the purified sewage to the nearest water course. The sewage is applied only at intervals of once a day or so to a depth of perhaps six inches. Between applications the sand layer is allowed to drain so that its pores may fill with air. This aeration of the pores of the sand allows bacterial processes to convert the organic matter to a large extent to harmless mineral matter. The effluent is practically free of noticeable suspended matter and objectionable organisms and can be discharged directly into the nearest water course.

This method is now in successful use in 40 to 50 places in this country where porous sand areas are available. It serves a total population of about 350,000 people. Well-known plants are to be found at Framingham, Brocton, Clinton, and Worcester, Mass.; Pawtucket and Woonsocket, R. I.; Meriden and New Britain, Conn.; Saratoga, N. Y., etc.

From time to time it is necessary to rake, harrow, or plow the surface of intermittent sand filters and to remove the scum which slowly accumulates there. At intervals it is necessary to scrape off several inches of the upper portion of the sand layer when it is found that they are so clogged that harrowing and plowing no longer prevents the surface from remaining covered with sewage.

With crude sewage it appears from Massachusetts evidence, especially from the tests conducted for a period of nineteen years at the Lawrence Experiment Station, that it would be necessary to provide one acre of intermittent sand filters for each 500 persons connected with the sewers. When the sewage is given a preliminary treatment in septic tanks and when the filters are operated under intelligent supervision the area may be reduced so as to provide one acre per 1,000 persons.

The most suitable natural site for sand filters for the Calumet area is to be found in the State of Indiana, between the Little Calumet and the Grand Calumet rivers, east of the City of Hammond.

It is possible to build artificial sand filters within the Calumet district, but the cost would be much greater than for any of the projects considered in this report.

Based upon our knowledge of these filters elsewhere, and without considering interstate complications, we estimate that the cost of installing and operating such a plant, with its various appurtenances, east of Hammond, and of a capacity of about 180,000,000 gallons daily to serve a population of 1,200,000 people, would be as follows:

ESTIMATED COST OF CONSTRUCTING SAND FILTER PLANT AND APPURTENANCES.

Intercepting sewers, pumping stations, and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$5,070,000
Septic tanks, 60,000,000 gallons capacity, covered, including sludge disposal facilities	950,000
Intermittent sand filters, 1,200 acres, with distributors, drains, office laboratory, etc	3,600,000
	$9,620,000
Contingencies and supervision, 15 per cent	1,443,000
Total	$11,063,000

ANNUAL COST OF OPERATION.

Pumping, fuel, labor and repairs	$300,000
Supervision, analytical and clerical assistants, etc	25,000
Care of septic tanks, including sludge disposal	36,000
Care of sand filters	480,000
Supplies and miscellanies	25,000
	$866,000

Capitalizing the operating expenses at 5 per cent per annum there is obtained $17,320,000, which, when added to the estimated construction cost, makes a total sum of $28,383,000 for the sand-filter project.

Contact Filters.

These filters consist of beds of broken stone, slag or cinders, placed in uncovered basins to a depth of from three to five feet. The size of material ranges from about one-fourth to one inch.

The filters are ordinarily operated upon the fill and draw plan, that is, the gate on the outlet pipe is closed until the voids of the bed are filled with sewage from the septic tanks. After filling, the filters are allowed to stand full for an hour or so, then the sewage is allowed slowly to drain out, and this cycle of operation is repeated once or twice a day.

When the filtering material is drained the voids fill with air, and it is during these periods of draining that bacterial processes accomplish the purification of the organic matter, which to a large degree is lodged upon the surfaces of the filtering material as the sewage is slowly withdrawn from the bed. The rates of filling and drawing the beds may be satisfactorily controlled by a number of automatic devices on the market and which are in successful use in a number of places.

Contact filters are an English adaptation of studies made some fifteen years ago upon the gravel filters by the Massachusetts State Board of Health at the Lawrence Experiment Station. These studies were begun about thirteen years ago at London. As an outcome of these and numerous other investigations, contact filters have been adopted and are in successful use for dozens of English cities, the largest of which is Manchester, with a population of about 600,000.

In this country contact filters have been installed for a dozen or more small cities and numerous institutions. Perhaps the best known plants are at Plainfield, N. J., Mansfield, Ohio, and Charlotte, N. C. They are especially applicable to projects where only a small amount of head is available and where pumping would be required for sprinkling filters.

For large projects, and where pumping is not a factor, recent experiences with sprinkling filters show that as a rule they are more economical. Notwithstanding this, contact filters have served and will serve a useful purpose in the field of sewage disposal in this country. Their convenience of operation makes them especially suitable for small installations.

Many contact-filter plants have their beds arranged in terraces so that the sewage may be passed successively through

two or three filters. There are a number of advantages of this arrangement, but it is not applicable to the Calumet district, owing to the level area of the available sites. One of the advantages of the double and triple contact filters is that they may be operated from below during winter weather and thus guard against reduction in the rate of filtration due to freezing.

The most available and suitable local sites are: A tract west of Harvey and between the Illinois Central and Rock Island railroads; a track west of Hammond and the local branch of the Fort Wayne Railroad, and a tract between lakes Calumet and Wolf.

As to the rate of filtration, we have assumed that contact filters should be five feet in depth and that they would satisfactorily purify the effluent from septic tanks at the rate of 600,000 gallons per acre per twenty-four hours. This means that one acre of contact filters should be provided for every 4,000 persons connected with the sewers.

The effluent from contact filters operated under these conditions would be ordinarily free from objectionable amounts of suspended matter, and the amount of organic matter would be so reduced that it would not putrefy upon standing. On an average about 15 to 20 per cent of the bacteria in the crude sewage would be present in the effluent. It would not be improper to discharge such an effluent as it came from the filters directly into the nearest water course.

The amount of attendance required for contact filters is not great, and is covered mainly by the necessary gatemen, analysts, and foremen. At intervals of all the material would have to be removed from the filters, washed, and replaced.

The approximate cost of building and operating a contact-filter plant with all needed appurtenances of a capacity of about 180,000,000 gallons daily to serve 1,200,000 people may be estimated as follows:

ESTIMATED COST OF CONSTRUCTING CONTACT-FILTER PLANT AND APPURTENANCES.

Intercepting sewers, pumping stations, and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$3,300,000
Septic tanks, 60,000,000 gallons' capacity, covered, including sludge, disposal facilities	950,000
Contact-filters, 500 acres, with all piping, appurtenances, office laboratory, etc.	6,000,000
	$10,250,000
Contingencies and supervision, 15 per cent	1,537,500
Total	$11,787,500

ANNUAL COST OF OPERATIONS.

Pumping, fuel, labor, and repairs	$200,000
Supervision, analytical, and clerical assistants	30,000
Care of septic tanks, including sludge disposal	36,000
Care of contact-filters	260,000
Supplies and miscellanies	25,000
Total	$551,000

Capitalizing the operating expenses at 5 per cent per annum there is obtained $11,020,000, which when added to the estimated construction cost makes a total sum of $22,807,500 for the contact-filter project.

SPRINKLING FILTERS.

Sprinkling filters differ from contact filters principally in the method of application of sewage, which in our northern climates is discharged upon them in the form of spray from a series of fixed sprinkling nozzles placed about 12 to 15 feet apart. The filters are usually deeper and of somewhat coarser material than contact filters.

These filters are also an English adaptation of the Lawrence investigations with gravel filters some fifteen years ago. The English studies began at Salford in 1892 and have resulted in the adoption of this form of filter for many of the principal cities of England, the largest of which is the metro-

politan district of Birmingham, with a population of over 900,000. Some of these filters have been in successful practical operation for more than eight years. On the Continent this method is being adopted for portions of the suburbs of Paris and Berlin.

In this country this method has been studied with care at Lawrence, Mass.; Columbus, Ohio; Boston, Mass., and Waterbury, Conn. Filters of this type are now under construction at Columbus, Ohio, and Reading, Pa. They have been recently adopted for Baltimore, Md.; West Chester, Washington, Pa., and Waterbury, Conn. They have been recommended for use also at Paterson, N. J.

The important element of aeration is secured in sprinkling filters partly by applying the liquid as a spray and partly through the use of coarse material with voids of a size so that there is a vertical circulation of air through the filtering material at all times.

Suspended mineral and organic matters and some of the dissolved organic matters are retained upon the surface of the filtering material as the liquid passes in thin films over the surface of the particles. Bacterial activities reduce the organic matter to a material degree, and from time to time the remaining inert material cracks and peels and passes through the filter bed to the bottom. In order to be able to remove this accumulated matter, it is necessary to provide false bottoms for these filters. Filters of this type have been in successful use for more than eight years, without cleaning, and it is believed that under favorable conditions cleaning is not required oftener than once in ten or fifteen years.

The amount of suspended matter in the effluent of sprinkling filters due to this unloading of stored material is sufficient to require passing the effluent through settling basins, holding about two hours' flow, before discharging into the nearest water course. The settled effluent, of satisfactory appearance and with its organic matter so reduced that it will not putrefy, usually contains less than 10 per cent of the bacteria in the crude sewage.

There is a considerable range in size of broken stone and in depth of material as adopted in various large plants now built or building. Avoiding extremes, it may be stated that the depths average about seven feet, and the size of material ranges from about one to 2½ inches, mean diameter. We have assumed these figures for sprinkling filters for the Calumet area, to be built of broken stone at the sites already men-

tioned for contact-filters, namely, west of Harvey, west of Hammond, and between Lakes Calumet and Wolf.

We have carefully considered the climatic conditions at Chicago, and compared them with temperatures where practical experience with sprinkling filters have been obtained. There is no trouble from the freezing of the sprinkler nozzles through which sewage is applied under a head of six or seven feet. During zero weather some frozen sewage accumulates on the surface of the filter and at such times it is necessary to have some reserve area. We have assumed that under these local conditions one acre of sprinkling filters should be provided for every 15,000 people connected with the sewers, making a rate ordinarily of about 2,250,000 gallons per acre per 24 hours. As was demonstrated at Columbus, such rates for several weeks at a time may be doubled and still obtain a satisfactory non-putrescible effluent. This rate, expressed in persons served per acre-foot of sprinkling filter material, is only about one-half of that provided for at Columbus, Ohio, and one-third of that in several plants in England.

The approximate cost of building and operating a sprinkling filter plant with all needed appurtenances, of a capacity of 180,000,000 gallons daily, to serve a population of 1,200,000, may be estimated as follows:

ESTIMATED COST OF CONSTRUCTING SPRINKLING FILTER PLANT AND APPURTENANCES.

Intercepting sewers, pumping stations and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$3,300,000
Septic tanks, 60,000,000 gallons' capacity, covered, including sludge disposal facilities	950,000
Sprinkling filters, 80 acres, with all appurtenances, office, laboratory, etc.	3,600,000
Settling basins, 15,000,000 gallons' capacity	200,000
	$8,050,000
Contingencies and supervision, 15 per cent.	1,207,500
Total	$9,257,500

ANNUAL COST OF OPERATION.

Pumping, fuel, labor, and repairs	$200,000
Supervision, analytical and clerical assistants	30,000
Care of septic and settling tanks, including sludge disposal	54,000
Care of sprinkling filters	110,000
Supplies and miscellanies	25,000
Total	$419,000

Capitalizing the operating expenses at 5 per cent per annum, there is obtained $8,380,000, which when added to the estimated construction cost makes a total sum of $17,637,500 for the sprinkling filter project.

CONCLUSION.

In recapitulating the substance of the foregoing inquiry and referring specifically to your instructions, summarized at the outset, we conclude as follows:

1. The examination into the sanitary situation at Chicago, so far as it is affected by sewage disposal, revealed that since removing the sewage through the drainage canal the appearance of the water of the Chicago River has shown marked improvement. As regards the hygienic quality of the public water supply there has also been an improvement, due to the progressive elimination of sewage from the lake, which elimination should be completed within a few years.

2. The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive, are that a dilution of 3 1-3 cubic feet per second for each 1,000 persons connected with the sewers, as provided for in the enactment of the Illinois legislature in 1889, is as low a figure as it is now possible to state. We believe that with the elimination of objectionable trade wastes and the occasional dredging of the river, this amount of dilution will be sufficient to prevent offensiveness.

3. The extension of the dilution method to the outlying territory is not the only way to preserve the lives and health of the people of Chicago. The application of this method with flows of 10,000 and 14,000 cubic feet per second, respectively, for the area tributary to the present drainage canal will serve population not exceeding 3,000,000 and 4,200,000 respectively. For greater populations, other methods of sewage disposal will be required.

4. For the Calumet area, as well as other districts, there are several methods for the disposal of sewage, as effective as the present method of dilution in preventing the pollution of the lake waters.

5. All of these methods involve intercepting sewers and pumping stations to collect and deliver the sewage at suitable sites. Septic tanks are used for partially clarifying the sewage, which may then be applied to any one of three methods of filters, viz., intermittent sand filters, contract filters, and sprinkling filters.

All of these filters, if well built and well managed, remove the suspended and organic matters so that the effluents are practically clear and are non-putrescible. The removal of bacteria by these three types of filters averages at least 98, 80 and 90 per cent respectively. Such effluents may be discharged directly into any of the water courses of the Calumet region.

6. The approximate total cost, liberally estimated, without the preparation of detailed plans, for a population of 1,200,000, are as follows:

A.—Intermittent Sand Filters.

Construction	$11,063,000
Annual cost of operation, $866,000, capitalized at 5 per cent	17,320,000
	$28,383,000

B.—Contact Filters.

Construction	$11,787,500
Annual cost of operation, $551,000, capitalized at 5 per cent	11,020,000
	$22,807,500

C.—Sprinkling Filters.

Construction	$9,257,500
Annual cost of operation, $419,000, capital at 5 per cent	8,380,000
	$17,637,500

The present population on the Calumet area of the sanitary district being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expected at the outset.

Of the available methods of disposing of the sewage of the Calumet area, other than by dilution, the sprinkling filter method, being the cheapest, both in cost of construction and of operation, and accomplishing an adequate degree of purification, is clearly the most advantageous one.

Very respectfully,

RUDOLPH HERING,
GEORGE W. FULLER.'"

I will ask you whether or not the statements in that report are the statements on this subject to which you have referred in your direct examination as having been made by you in the year 1906?

Mr. Williams: I object to the form of the question. I object to incorporating in the question the report referred to, as not being proper cross-examination; and I object further on the ground that in the reports are statements referring to matters concerning which the witness has not been asked on his direct examination, and the entire question is improper as cross-examination.

Q. (Last question read.)

A. They are.

Mr. Wilkerson: Now that report appears to be signed both by yourself and by Mr. Fuller. Each one of the statements in that report on the subjects with reference to which you have been testifying today represent your own judgment on that subject, does it, your best judgment in 1906?

A. It does; each one does.

Q. Now, with reference to the disposal of the sewage from Chicago, I note that in this report of 1906 you refer to three methods, the intermittent sand filters, the contact filters and the sprinkling filters.

A. I do.

Q. And as a result of your analysis of the three different methods which are there discussed, you reached the conclusion that the sprinkling filter offers the most economical as well as the best method of handling the sewage?

A. I did.

Q. That is the substance of your conclusion?

A. It is excepting that I state other than by dilution.

Q. Other than by dilution of course. That is you were dealing there with methods which could be employed aside from the dilution method?

A. Yes, sir, but I also state that in my opinion the sprinkling filter is the best method other than the dilution method.

Q. Now, in determining the advisability of these different methods of handling the sewage of Chicago, did you in the studies which you made of this subject in connection with the preparation of the reports to which I have just directed your attention give any consideration to the question of the injury, if any, which would be inflicted upon the people who lived along the river below Chicago by diverting the sewage in that way?

A. I did.

Q. Or were you considering the question merely from the standpoint of the people of Chicago?

A. No, sir.

Q. You took that into consideration?

A. Surely.

Q. Of course it is a fact that there would be some injury inflicted on those people by the diversion of so much sewage through the Desplaines River, isn't it?

A. If the people would use the water as a drinking supply; not otherwise.

Q. That is to say it would destroy the possibility of their using the water for drinking purposes for a considerable distance below Chicago, would it not?

A. It would unless it were purified by filtration, as is done in other places. For instance, the City of Hamburg and the adjoining City of Altona, constituting together about one million inhabitants, discharge all their raw sewage into the river Elbe, and both cities take the water supply from this river and furnish it to the people after filtering it.

Q. That of course is possible. It would be possible for the people who live along the river below Chicago to get their water supply in that way, by filtering the water?

A. Yes.

Q. In determining whether or not Chicago is to be permitted to dispose of the sewage in that way, you would regard that as a fair element to be taken into consideration, would you not?

A. Yes, sir,

Q. That is to say, the injury which might be inflicted upon the people who live along the river and the difficulties they

would encounter in purifying the water, in case they wanted to use it for drinking purposes; I say that is a fair element to be taken into consideration?

A. I should hardly put it that way.

Q. Just how would you put it?

A. I would say anybody taking a water supply from a river, and I even extend that to the lakes where there is navigation and commerce, should have its supply filtered before use as a potable supply.

Q. That is to say that is your judgment, is it not, that in order that the people of Chicago should have the kind of water they ought to have, the water even now ought to be filtered?

A. I think the time will come when all cities on the lakes will filter their water supply.

Q. And in order that Chicago should be absolutely on the safe side, this filtration system should be installed now, even though the sewage is taken down the other way?

A. I should hardly think that it would be necessary at the present time.

Q. But it would be desirable?

A. It is always desirable to improve, if you have the money to pay for it.

Q. Isn't it a fact in considering as to whether or not it is necessary, there is always an element of chance as to what is in that water; that you never can tell with absolute certainty, but the only safe way is, as you say, to have the water filtered, the only absolutely safe way?

A. That is the general opinion now, apparently.

Q. Now, with respect to the extent of dilution which is regarded as reasonable, I think is the term we have been using here, the purpose of the dilution where the sewage is taken away through a canal such as is at Chicago, is to get rid of the local nuisance, as I understand it; the odor in the water and offensive matters of that kind?

A. It is, generally speaking.

Q. That is, you can have just as much sewage in the water as is possible to get into it without having the water so bad that it becomes offensive locally?

A. Well, I should want a margin of safety. I would not go so far as to just get to the place where it might make a nuisance.

Q. Allowing a reasonable margin of safety?

A. Yes. Our limit is governed by that degree of dilution where we feel sure that there is going to be no nuisance.

Q. That is the purpose of having such a large dilution?

A. Yes, sir.

Q. It is merely to get rid of the local nuisance?

A. It is also to oxidize the sewage, make it disappear.

Q. So as to take care of the people who live along the river further down?

A. So as to remove it, so as to purify it, oxidize it.

Q. Well, what is the necessity for that? I am assuming now that the people who live along the river further down do not use the water for drinking purposes unless it is filtered?

A. Well, we certainly want to have as good rivers, as good water in the rivers as we possibly can for navigation purposes and for the riparian dwellers, people living along the river. We do not wish to create an objectionable river.

Q. What I am trying to get at is just the process of reasoning by which the conclusion is reached that 10,000 cubic feet per second taken from Lake Michigan will give a reasonable dilution for the sewage from a population of three million people. I would like to get the process of reasoning?

A. The process of reasoning was this: because I had to go through it at the time, before I made this report; I collected information where I could find it in our own country and also in Europe, as to how many people could discharge their sewage into a river of known capacity, without making the river objectionable, without making it apparent that sewage was discharged into it. Now of course that information was not often obtainable, but sufficient evidence existed to find that when a certain amount of water, let us say it varied from three to seven cubic feet of water per second for every thousand persons, was discharged into this water you didn't notice it. Now, the lower figure is one that is found in larger streams. The higher figure is one that seems necessary in smaller streams and where conditions are rather unfavorable for the effect of oxidation and dispersion.

Now, with this information before us, it was concluded that for the case of Chicago four cubic feet per second a thousand persons was a proper figure. This was afterwards reduced to 3 1-3 cubic feet per thousand persons per second. Evidence obtained subsequent to making the report seemed to make it safe to allow, instead of two million and a half of people, three millions of people to discharge into the water for which we have designed the canal.

Q. Now, I think you said that during recent years there had been some improvements devised whereby this sewage can be treated so that you can diminish the dilution; I think you said by a third to a fourth, so that if these methods were used in Chicago and the sewage were treated in that way, those tanks constructed and the sewage screened—is that it?

A. No, the sewage settled.

Q. The sewage settled, the 10,000 cubic feet per second upon which the original estimate was made would take care of more than 4,000,000 people, wouldn't it, 4,200,000?

A. Yes, sir.

Q. It would take care of approximately 4,000,000, if the sewage were treated in that way?

A. Approximately; you can't tell exactly.

Q. Now, in connection with the construction of this system of sprinkling filters, you spoke about the treatment of the sewage by hypochlorite?

A. Hypochlorite of lime.

Q. Hypochlorite of lime? That being a process to be used in connection with the sprinkling system?

A. Only if you desire to destroy pathogenic bacteria.

Q. Well, what kind of bacteria are pathogenic bacteria?

A. Pathogenic bacteria are disease producing.

Q. Would you regard that treatment as essential, even where you have the sprinkling system?

A. That depends on conditions. I would say, for instance, that I would not regard it nearly as essential under ordinary conditions as such a treatment of the lake water, because what I should fear in the lake water would be the sewage from navigation.

For instance it is known that the discharge of a typhoid patient from a steamer in the lake will be drawn, might be drawn into a water supply intake, and possibly communicate this typhoid fever to those who consume this water in the city. That is entirely independent of the question of the disposal of the sewage of the city.

Q. Then is it your view that all the drinking water that is taken out of the lake should be subjected to that process?

A. To filtration, to guard more against lake pollution than against any pollution by sewage, if that is reasonably purified.

Q. Then of course with reference to the lake water, there is always the danger which comes in time of flood, when the

water is not carried away through the river or the canal but goes out into the lake, is there not?

A. I do not think that exists in Chicago, does it.

Q. Well, if it does there would be—

A. If it does, there would be all the more reason for treating the water supply with hypochlorite.

To go back again to your first question, it is of course better to treat effluent sewage from sprinkling filters with hypochlorite than not. There may be some cases where the cost is hardly justifiable, and that is the reason why I say you can't make a general answer to that question. I did recommend it, I did recommend this treatment for a city on the lake.

Q. Where this German method to which you have referred is used, is there any element of value in the sludge after it has been subjected to that treatment?

A. The value would be equivalent to garden soil, no greater.

Q. It is equivalent to so much fertile dirt?

A. Yes, although garden soil sometimes must receive a fertilizer.

Q. Certainly?

A. This sewage sludge would have to, because it has been pretty well rotted out, and that which is of fertilizing value is to a large extent gone.

Q. Just go ahead, Mr. Hering, and explain fully what your views are with reference to the value, if any, in this sludge, after it has been subjected to this German treatment about which you testified?

A. At the present time in the German cities it has a very small value. Some of the farmers take it away and pay a very small amount, but most of it is dumped as an embankment, perhaps 15 feet deep, so that it is clearly of no value in that instance.

It clearly has no manurial value, and it contains naturally the undecomposed remains of sewage matter; a lot of hair is in it, fibres, which does not make it as uniform as leaf mould. It also contains bits of wood. I should not consider it worth as much as the ordinary garden soil as it is bought.

Q. Did I understand you to say that you had made any definite estimate of the cost of constructing means for subjecting this Chicago sewage to the treatment whereby the degree of dilution could be diminished by one-third to a fourth?

A. I have not.

Q. Have you any idea on that subject?

A. I have not.

Q. Can you give us that within wide limits?

A. I have made no estimate whatever.

Q. Would it be very expensive or would it be comparatively inexpensive from an engineering standpoint?

A. No, it would not be extraordinarily expensive. The tanks would cost to erect about perhaps $1.50 per capita.

Q. So that for that expense it would be possible to provide means so that 10,000 cubic feet of water per second would take care of 4,000,000 people?

A. After adding the expense of operation, maintenance, and removal of the sludge, and so on.

Q. Which I understand is not very large?

A. I have made no estimate; it would take care of a population of about 4,000,00.

Q. Have you given any thought to this phase of this question: Assume that the people of Chicago are allowed to take 14,000 cubic feet a second out of the lake, and no more than that, and the population grows to a point where that amount taken out of the lake will not give the proper degree of dilution, as a matter of fact we are still up against this question of constructing a filtering system, are we not, ultimately?

A. I could not say, because, as we have observed in the last 25 years, we are progressing, and we may not then build works just as we would today.

There is only one certain thing, and that is that the oxygen of the air will be required to oxidize the sewage when treated on land, and the oxygen of the water will be used to oxidize sewage when it is discharged into water. Those are the two elements, I believe, that will still hold us for many hundreds of years, if not forever.

Q. Speaking from the standpoint of what we now know on the subject, if we had 5,000,00 people in Chicago today and could take only 14,000 cubic feet of water per second out of Lake Michigan, we would be face to face with this necessity for filters, wouldn't we, a filtering system? Here is what I mean: I am putting the question now on the hypothesis that the Sanitary District were today permitted to divert 14,000 cubic feet of water per second from Lake Michigan. Assume that that were the fact, and also assume that Chicago had more than 5,000,000 inhabitants today, whose sewage had to be taken care of by that 14,000 cubic feet of water per second. I say on the basis of what we now know on the sub-

ject, there would be the necessity of constructing a system of filters?

A. If Chicago had 5,000,000 population today, with the present knowledge we have, the outlying districts of Chicago would probably have to have some separate treatment for their sewage.

Q. Either that or if all the sewage were attempted to be handled in the same way, we would have to have a system of filters. I am trying to get pure drinking water for Chicago.

A. I do not understand that.

Q. I mean, the excess sewage would have to be filtered?

A. Yes, that is what I understood. The excess sewage would have to be filtered.

Q. The excess over 2,500,000 population, in the light of what we now know today.

A. In the light of what we now know today. That would be, as I think, the best method today. Regarding the filtering of the lake water, I believe that would be necessary on account of the lake pollution.

Q. That would come from such a large population?

A. Not from the city pollution; the lake pollution coming from the population on the ships in the lake, or the lake pollution.

Mr. Williams: Q. That is a different problem entirely.

A. Yes.

Mr. Wilkerson: Q. That is to say if we had 5,000,000 people in Chicago, the conditions of trade and commerce would be such that in all probability the water of the lake would be so polluted as the result of those commercial conditions, that the water should be filtered?

A. I would not like to answer it that way, because it could not be very highly polluted. I do not care to use even the word "polluted." Water has caused typhoid epidemics that was as clear as any drinking water that you have on your table. I mean that the danger of getting disease producing bacteria into your water supply from the traffic on the lake, and if you like, from shore population, will in the future make it desirable in this country, as it is already in Europe, to filter the water supplies taken from lakes.

The Swiss lakes are not polluted. Lake Vyrnwy is not polluted. They are beautiful lakes. They supply the adjoining cities of Geneva, Zurich and Liverpool with water. Liverpool does not adjoin the lake but it gets its water from the lake; and that is done simply to ensure the purity of these

waters because of the incidental, accidental pollution of disease producing bacteria.

Q. The best learning on the subject is all in favor of filtering the drinking water, isn't it?

A. That is the best thing that will ever be done today. I do not think in a thousand years anything more than that will be done.

Q. It is the most effective thing that can be done to get the best results?

A. Yes, sir. May I state something more?

Q. Certainly.

A. I was going to say in none of the cases that I have mentioned does any sewage whatever go into the lakes.

Mr. Wilkerson: I understand that.

Mr. Williams: They are separate problems, sewage disposal and water purification.

The Witness: Yes.

Mr. Wilkerson: Q. So far as Chicago is concerned, however, the problem of pure water and the problem of sewage disposal are not absolutely separate problems, are they, because if the water supply of Chicago were filtered, it would not make any difference whether the sewage emptied into the lake or not would it?

A. I do not hold that view. I should, in the case of lakes, I should hereafter as heretofore advocate either the purification of the sewage, treatment in some degree or a separation between the sewage out-fall and the water intake, that is sufficient to make a mixture practically impossible, a mixture of the sewage and the drinking water practically impossible.

Q. That is to say, taking the first method that you have spoken of, you would have the sewage treated before it comes into the water of the lake, and if that were done and the water were filtered, then you would have as a result, pure water?

A. Yes. I want to be sure that the sewage could not be detected at the water intake.

Q. Why?

A. And after that still treat the water. Because you cannot detect the pathogenic bacteria. They are diffused in the water. They may be in very clear water, and as a matter of public safety, I believe the practice of both sewage purification and water filtration should be provided for wherever expedient; not because I am in that business, but because I think so.

Q. In response to the last question, which Mr. Williams

put to you you said that even if you had enjoyed in 1887 the same light on this subject which you enjoy today in view of the advancement of the science, you would still adhere to the idea that the dilution method was the better method for Chicago. I think that was the substance of what you said?

A. That was the substance.

Q. It is true, however, is it not, that in view of the new light which we have on that subject as the result of the investigation of the last twenty-five years, it would be possible for a city like Chicago, situated as it is there on the lake, to handle this sewage problem without the construction of any such works for the dilution of the water as were constructed; I say it would be possible to do it?

A. It is possible.

Q. And that would be by treating the sewage and by the construction of a system of sprinkling filters, that would be your method?

A. That would be the method that I would advocate today.

Q. Would the cost of such a sprinkling filter plant for two and a half million people be substantially double what it would be for 1,200,000?

A. Generally speaking, yes, but local conditions might make it necessary to remove these treatment works to sections that are available for the purpose, and that might in one case—for one part of the city, might cost a good deal more than for another part of the city.

Q. But generally speaking, would the cost increase about in proportion to the extent of the population for which you wish to make provision?

A. Yes, when you get the large figures, that is true.

Q. Of course, for the smaller plants you have to add more?

A. Yes.

Q. It would be more than half when the plant was a small one, but where you deal with large figures, where you get up into the millions in population spread out over a large territory, the cost is approximately in proportion to the territory which you serve?

A. Provided the territory was equally available.

Q. Besides the cost of constructing the plant, I assume that there would be an additional cost growing out of the necessity for altering the system of sewers?

A. There would, if you propose to treat the sewage on land, and treat it sufficiently well so that it could be dis-

charged into the lake; it would require a new system of sewers for the entire City of Chicago.

Q. Did you ever make any study of the City of Chicago with a view to determining how much it would cost to install one of these sprinkling filter plants to take care of the entire sewage of Chicago?

A. Not for the entire sewage of Chicago.

Q. You made it on the basis of 1,200,000?

A. I did.

Q. I mean studying the system of sewers with a view to ascertaining how much reconstruction would be necessary?

A. No, sir, never made that.

Q. You have never made an analysis of that?

A. No, sir.

Q. But the plan is one which from the engineering standpoint is entirely feasible, I understand?

A. Well, I don't know.

Q. That is, you would not want to express an opinion without having made a study of the subject?

A. I would not because—oh, I understand with the separate system it is entirely feasible?

Q. Yes.

A. I should say it was with the separate system completely installed, it is feasible to have sewerage purification works, to receive the sewage and to purify it; but I never made a study of the cost.

Q. Now, with respect to the construction of this sprinkling filter system to take care of a population of 1,200,000 inhabitants, I notice you have a figure for a population of 300,000 and also a figure for a population of 1,200,000. Would the figures for cost for a population of say 300,000 or 600,000 run about in proportion as the cost you have given for 300,000, 1,200,000; are those large enough figures so that if you wanted to find how much it would cost to build a plant for a half million people, you could determine it with a fair degree of accuracy from your figures for 300,000 and the 1,200,000?

A. I think if you draw a curve—

Q. You are referring now to the diagram in the report to Mr. McCormick which has already been identified here?

A. Page 39.

Q. Page 39 of that report?

A. There is a curve which gives the cost of introducing sprinkling filters on the Calumet area.

Q. The sprinkling filter cost line crosses the Calumet Sag canal cost line at the population of 900,000, doesn't it?

A. Yes, sir.

Mr. Williams: I object to counsel's asking what the diagram shows. The diagram shows for itself. It is not necessary to ask the question and it is not proper in the record.

Mr. Wilkerson: Now, with reference to this estimate of cost, I think you said the figures which you had stated in your first reports would be subject to some increase, on account of the advisability of using the hypochlorite treatment. Am I correct in understanding that that was the principal element of increased cost that you had in mind?

A. You said my first reports.

Q. Or reports.

Mr. Williams: The report to Mr. McCormick.

Mr. Wilkerson: The report to Mr. McCormick.

The Witness: That is the last report.

Mr. Wilkerson: The last report. I stand corrected.

The Witness: I would today add the cost of hypochlorite treatment. Just how far I would go with that, I could not say without a study.

Q. You have made no figures?

A. No, sir.

Mr. Williams: And in addition to that you would add—what was it you just stated?

Mr. Wilkerson: I thought that was all.

Mr. Williams: No, he testified with reference to the—

The Witness: I would change the estimate by increasing it so far as the tanks are concerned for collecting the sludge. I would today make them more expensive because of their being double instead of single, for the purpose of getting non-odorous sludge.

Mr. Wilkerson: Q. What per cent. of increase would there be for these sixty million gallons capacity septic tanks?

A. I could not say without making the figures.

Q. As to the amount of increase for the cost of tanks, I understand you to say you have made no estimate on that?

A. No, excepting what I gave you, the cost being $1.50 per person.

Q. That would be, on a population of 300,000, about $450,000; that would be an increase of about $175,000 on the tanks.

Mr. Williams: That is on 300,000.

Mr. Wilkerson: Yes.

Q. On the basis of a population of 1,200,000, the revised figures would be $1,800,000 instead of $950,000 as given in the table?

A. Yes, sir.

Q. Now, as to increasing the capacity on account of climatic conditions, have you made any particular estimate as to that?

A. I have made no estimate of cost on that.

Q. Would you increase it by a percentage?

A. If the conclusion would be that the increase in the size of the beds would be 25 per cent., then that would pretty nearly indicate the increase in the cost, although I would not like to be held exactly to those figures.

Q. And these items of increase, you state, are not because the matters which they cover are regarded by you as absolutely essential, but because you think it would make the plant have a higher degree of efficiency?

A. Well I should say that it was the proper thing to do for a first class city.

Q. You would say it was a proper thing to do, but would you not say that the figures which you gave in the report in 1907 would provide a plant which while it might not be as good as it might be, would in all essential respects answer the requirements?

A. Well, at that time we thought it was a proper figure. As I stated before, I did not wish to load it with anything that might possibly be cut off or postponed because it was for the system that was to be ruled out; and I would rather be under than over in my estimate in this particular case.

Q. Referring again to this hypochlorite treatment, I understood you to say that the cost varied from $1.25 to $2.50 per million gallons; and I wanted to bring out if I could what were the elements that entered into that variation in price?

A. The reason for that variation in price is the character of the sewage. If the sewage is loaded with more organic matter, it requires a greater amount of hypochlorite. If the sewage is very clear and comparatively free from suspended matter, it requires less.

Now, I am not able to judge as to the character of the sewage that you have in the Calumet region, therefore I gave you those two figures, between which I am quite sure the amount would be.

Q. Now, assuming that the quantity of sewage which is diverted through the present drainage canal is increased to the point where there is more sewage than would be permitted by this reasonable dilution of which we have spoken, and eliminating the looks of the water, the appearance of the water and any effect it might have on navigation, what other in-

jury would result from that increase in the quantity of sewage?

A. An increase beyond this figure that I gave you as being the proper dilution?

Q. Yes, beyond the point where there would be 10,000 cubic feet of water per second for three million people?

A. Well, if you did not take out the suspended matter or sludge, then you would get a pretty good sludge deposit that would decompose, putrify, develop gases; and these gases would rise to the surface, coming out in little bubbles which you see in such cases. These would bring up little particles of light floating matter, and then you would get an offensive appearance.

Q. An offensive appearance, and any odor?

A. And very likely some odor.

Q. Any very considerable odor?

A. That would depend on the amount of decomposition that was going on, or rather I should say of this putrifaction that was going on.

Q. You would hardly say there would be very much odor unless the quantity of sewage was increased very considerable above the point which you have indicated?

A. Well, yes, sir, I am making this limit of 3⅓. I found that later on when the Massachusetts State Board of Health made similar investigations they rather tended to increase that amount, and whether that was just simply a sensitiveness of the nostrils or not, I don't know.

Q. What I am trying to do is to eliminate the aesthetic elements and get down to the elements of substantial injury.

A. That is very difficult to say, because one person will have a different judgment from another.

Now take the standard given by Massachusetts, it varies I think from 3 to 7½, a very great variation, and you can't fix that exactly by any reasoning resulting from odor. You might fix it by assuming a certain chemical analysis, we will say a certain amount of free ammonia, or a certain amount of albuminoid ammonia; but even then in my opinion, two engineers or two chemists might fix different limits. It is a matter of judgment to a large extent.

Q. Isn't it a fact that the results that would come from increasing the proportion, if I may use that term, of sewage in the water would not do substantial injury to health or property or navigation, but would be largely the injurious effect upon the appearance of the river and the odor, if any, which might come?

A. That is certainly a difficult question to answer because it is so personal. One person has a very different idea about that than another; and in dealing with this question, which has been up to me many a time, I have always thought that the only safe figure is one which goes well inside of all the opinions that are likely to be obtained; apply, as we engineers do, a factor of safety, to be sure to get inside.

Q. Be sure and have enough water?

A. Have enough water.

Q. And that is what you tried to do when you made this estimate?

A. Well, I thought I was doing that when I fixed 4 cubic feet per 1,000 people, when that report was published; but afterwards it was changed to 3½; I think that factor of safety was taken out, to some extent.

Q. Of course so far as making the water unfit for drinking purposes or use of that kind, it would not make much difference would it because there is enough going in there now to make it unfit for that?

A. I do not think the drinking water question would cut any figure in that, because that water should not be used for drinking at all of course, without very thorough filtration.

Q. But so far as navigation is concerned, you would have to get a great deal more in to really affect navigation, wouldn't you?

A. I would not think so, since we had this discussion over here in Brooklyn. The navigation interests are objecting to some sewage in the Gowanus canal.

Q. I am referring to the condition as it is now in the drainage canal; you would have to put a good deal more sewage into it, very many times as much as goes in now before you would have any effect on navigation?

A. Well, the only effect on navigation would be a blackening of the paint of the vessels, such as occurs over here in Brooklyn, and the odor.

Re-direct Examination by Mr. Williams.

Q. Do you know what is the amount of solid matter in ordinary sewage per capita per day?

A. I can't tell you by heart. I have got lots of data at home on that subject, and I am going to publish a paper, I did want to publish it two years ago, on that subject.

We assume in our calculations for sludge treatment works about 0.007 cubic feet per capita daily.

Q. And the weight of it is about 75 pounds per cubic foot, is that what it would weigh?

A. That is what I think it would weigh, about a half a pound per person.

Q. In your answers, Mr. Hering, to the questions put to you by Mr. Wilkerson, respecting the desirability of purifying the water supply of Chicago and other lake cities, were those answers made with reference to general conditions, irrespective of the disposal of sewage, or as a matter of protection from sewage?

A. They were made irrespective of the sewage discharge from the city.

Q. And the necessity for installing purification plants as a result of the discharge from cities of the sewage out of the city is a different problem from the general desirability of having purification plants as a matter of precaution from the natural conditions arising from lake traffic and shore sewage and washings and things of that sort?

A. Yes, sir.

Q. In your opinion, would it be safe to discharge the effluent of the sewage of a population of a million two hundred thousand people into Lake Michigan, after that sewage had been treated by the sprinkling filters such as were designed and reported on by you in your report to the International Waterways Commission in 1906?

A. I think it would be safe, although today in view of the comparatively slight cost, I would add the hypochlorite treatment.

Q. I am speaking now of the filter systems that were designed and reported upon by you and Mr. Fuller to the International Waterways Commission?

A. I understand.

Q. That is the same system you reported on to Mr. McCormick?

A. Yes, sir.

Q. That is assuming no purification of the water supply?

A. Yes, sir, assuming no purification of the water supply.

Q. What percentage of organic matter would you reasonably expect to find in the effluent after it had been treated by that process; that is by the sprinkling filter process, and before it had been subjected to the hypochlorite of lime process?

A. I would have to look that up.

Q. In your opinion what percentage of bacteria is destroy-

ed by the sprinkling process, without the treatment by the hypochlorite process?

A. The usual assumption is from 95 to 99 per cent.

Re-cross Examination by Mr. Wilkerson.

Q. With reference to the percentage of bacteria removed by the sprinkling filters, what further have you to say with reference to the desirability of removing all the bacteria, and with reference to the relation of the percentage removed by some other part of the plant?

A. I will say that if you have final settling basins and expect some of the suspended matter to leave the filters for the purpose of being further purified in the settling basin that a higher percentage of bacteria in the effluent would rather be desirable than otherwise, because they would assist in the final purification.

The tendency is, however, to accomplish as complete a purification as possible in these sprinkling filters, so that no subsequent bacterial oxidation will be required in the settling basins, if they are at all put in for the purpose of turning out at all times a clear effluent. The sprinkling filters sometimes discharge a slightly turbid effluent when it is unloading, as the term is.

At the present time, the exact details of construction or operation of sprinkling filters, which is best, is not yet known and is in the process of development; with all prospects, however, of improvements being developed within the next few years.

.....

Adjourned.

End

VOL. 2

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS,
EASTERN DIVISION. } ss.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,019, and Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

MR. JAMES H. WILKERSON,
United States Attorney, and
MR. ALBERT L. HOPKINS,
Assistant United States Attorney,
For Complainant.
MR. EDMUND D. ADCOCK and
MR. ALFRED S. AUSTRIAN,
For Respondent.

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UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS,
EASTERN DIVISION. } ss.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,619.

Depositions taken pursuant to stipulation of counsel for the respective parties, statutory notice being duly waived, at the Hotel Netherlands, New York City, on March 18, 1913, and on subsequent dates.

Appearances:

Mr. Wilkerson, representing the Government.

Mr. Adcock and Mr. Austrian, representing the Sanitary District.

All objections to questions, answers and exhibits shall be considered as having been made except as to questions involving form, and secondary evidence.

GARDNER S. WILLIAMS, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testifies as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your full name?
A. Gardner S. Williams.
Q. Where do you live?
A. Ann Arbor, Michigan.
Q. Your place of business?
A. Ann Arbor, Michigan.
Q. What is your business?
A. Civil engineer.
Q. Are you a member of any societies of civil engineers?
A. I am a member of the American Society of Civil Engineers, and a member of the American Institute of Consulting Engineers; member of the Detroit Engineering Society; American Water Works Association; New England Water Works Association, and some other less important societies.
Q. Where did you take your early training?
A. I was graduated as Bachelor of Science in Civil Engineering from the University of Michigan in 1889.
Q. Have you had any experience in the hydraulics and hydrography of the Great Lakes, and studies of these subjects?
A. I have been interested in and connected with the study of hydraulics and hydrography of the Great Lakes since I became the civil engineer of the Board of Water Commissioners of Detroit in 1893. In fact prior to that, I was considerably interested in the problems of navigation and hydraulics on the Great Lakes from the standpoint at that time of the student, not having any official connection with it in any way. But I was at that time familiar with the discussions of the effects upon lake levels of various changes that were under contemplation at that time.
A. After you graduated from college in 1889, what did you do?
A. After graduation, I was located at Owosso, Michigan, in charge of water works construction for the season. Then I was with the Russel Wheel and Foundry Company in Detroit as engineer until 1893, when I went with the Board of Water Commissioners of Detroit as civil engineer to the

Board. I remained there until the fall of 1898 when I went to Cornell University and became Professor of Experimental Hydraulics, and Engineer in charge of the Hydraulic Laboratory.

I remained there until 1904 when I came to the University of Michigan as Professor of Civil, Hydraulic and Sanitary Engineering, which position I held until October 1, 1911, when I resigned, and since that time I have been engaged entirely in consulting practice.

Q. What general experience have you had, Mr. Williams, as an engineer, and with what projects have you been connected, in a general way?

A. I started with the water works construction at Bismarck, Dakota; then at Greenville, Michigan, and Owosso, Michigan; then with the Detroit Board of Water Commissioners, in which latter position I began consulting work.

I was the consulting engineer to the Ithaca Water Works Company, or Water Works construction, construction of purification plants, etc. While located at Cornell I was consulting engineer to the Michigan-Lake Superior Power Company on hydraulic installations for their power plant at Sault St. Marie; also upon discharge measurements of the St. Marys River, which were undertaken by them in about 1899 or 1900.

I was consulting engineer to the Edison Sault Electric Company and the Chandler-Dunbar Water Power Company, and as such designed and supervised the construction of the power plant in the Rapids at Sault St. Marie.

I was consulting engineer for the Eastern Michigan Edison Company on water power developments on the Huron River. I designed and supervised the construction and the overhauling of several water power plants. I designed and constructed a water power plant on the St. Joseph River, Michigan, for the City of Sturgis. I was consulting engineer to the United States Corps of Engineers on the substructure of the power house in connection with the lock and dam of the Mississippi River improvement between Minneapolis and St. Paul.

I was consulting engineer to the Canadian Light & Power Company in connection with power development and incidental improvements to navigation on the Couteau and Cedar Rapids of the St. Lawrence River near Montreal.

I was employed to advise the Central Colorado Power Company on the construction of certain dams and their effect upon the channels of some of the rivers in the vicinity of

Colorado Springs, particularly as to effects of floods. I have had meanwhile engagements in numerous other places, but I think those are the principal ones.

Q. Have you held any official position in societies of civil engineers?

A. I was a director of the American Society of Civil Engineers for one term, for a term of three years, which I think expired in 1910, I will not be certain.

I have been, for five years I believe, the chairman of the Board of Managers of the Association of Engineering Societies, which is composed of societies in Boston, St. Louis, Detroit, San Francisco, Milwaukee, New Orleans, and several other cities; the purpose being to provide for the publication of the papers and discussions that are presented before the Society.

Q. Are you connected with any publication relating to civil engineering?

A. Well, the Journal of the Association of Engineering Societies was published by the Board of Managers, of which I am the Chairman.

Q. Outside of your business connections have you made any special studies or presented any papers in connction with the hydraulics, hydraulic engineering and sanitary conditions, etc.?

A. I presented a paper before a sanitary convention in Detroit, in 1897, I think, upon the transmission of typhoid fever from Port Huron to Detroit through the channels of the St. Clair River and through Lake St. Clair, which involved of course a considerable study of the hydraulics of that section of the connecting waters of the Great Lakes.

I presented a paper to the American Society of Civil Engineers, which was published in 1902, I believe, upon experimental investigations upon the flow of water in pipes. And I have contributed to numerous discussions at one time and another on hydraulic and sanitary subjects. Those are the two principal ones.

Q. In connection with your engagements at Cornell University and the University of Michigan in the capacities which you have mentioned, what was the scope of the work there, and what studies did that cover?

A. The engagement at Cornell placed me in charge of the first, in fact the only large experimental hydraulic laboratory that has ever been constructed; in fact the largest that there has been in the world. The scope of investigations that were

carried on there, during my connection with it, involved first some investigations upon the flow of water in pipes, but more particularly investigations of the methods of measuring water in open streams, open channels.

Experiments were made upon the measurement of water over weirs by means of floats, and by means of current meters. And this work was carried on during the entire period of my residence there, which was substantially six years.

Q. When you speak of measurement of water by means of weirs and floats and current meters, will you explain just what those terms mean?

A. The measurement of water may be accomplished in a variety of ways. The most accurate method of course is to measure it by the weight that is delivered or involved. That of course is limited to comparatively small quantities of water.

The next method in accuracy is the measurement by volume, which may be done in considerable quantities in reservoirs and large basins, where the area of the surface is known and the rise of the water can be measured.

The next method in accuracy as ordinarily accepted, and as I believe it to rank, is the measurement over a weir. A weir is another term for a dam, but in this country it is ordinarily applied to a dam which is used for the measurement of water.

Extensive and elaborate studies have been made to determine the quantity of water which will pass over a weir or partition in a channel of known height and form for different heights of water above the crest or top of the dam or partition.

The most extensive series of experiments upon the flow of weirs on record are those made by the French engineer Henri Bazin at Dijon in France, from about 1886 to about 1889. In these investigations, the quantity of water that was measured over the weir, or that was passed over the weir was measured volumetrically in a basin which was composed of a part of a canal.

In America the first extensive investigations and perhaps the best known ones were made by Mr. James B. Francis at Lowell, about 1850. The volume of water handled by Mr. Francis was very much greater than had ever been attempted by anybody else, and was greater than was handled by Bazin.

The experiments which have the largest scope in the measurement of water over weirs of any that have ever been made

were made by Messrs. Fteley, Mr. Alphonse Fteley, who is now deceased, and Mr. Frederick P. Stearns of Boston, which were made in connection with the Boston Water Supply for the purpose of determining the quantity of water that was supplied from the Sudbury aqueduct which furnished the water to the City of Boston. The quantity of water measured in that case far exceeds anything that has been volumetrically measured anywhere in the world to date.

The investigations at Cornell did not involve volumetric measurements except in the instance of small quantities, but were based upon the comparison of two measuring devices; that is two weirs so situated that the water which passed over one would be passed over the other, and so that the conditions at the two weirs were markedly different, one of them being very large, that is nearly twice as high as the other, so that the water approached it with very much less velocity than it approached the other, and by comparing the discharges over these two, according to formulae which were derived from a study of the experiments of Bazin, Francis and Fteley and Stearns. These measurements of water over weirs were also compared simultaneously with measurements by means of rod floats and current meters.

The rod float is simply a weighted rod, which is so weighted and balanced that it will float with its top just above the water, and stand in a vertical position.

Q. Where is the bottom of it?

A. And the bottom of the float is made to pass near to the bottom of the channel.

In the experiments at Cornell, we had a perfectly smooth channel with vertical sides and we experimented with floats of different depths, ranging from a depth of 1/10 of the depth of the water down to about 98 per cent. of the depth, and compared the discharge so obtained with the discharge as indicated simultaneously by the weirs at the upper and lower ends of the channel. At the same time or at other times, measurements were made in the ordinary way with current meters which were located at various points along the canal between the two weirs, and in that way a comparison of the relative accuracy of the several methods was obtained.

Q. Will you describe the current meter as it is ordinarily used, as the term is used?

A. The current meter consists essentially of a revolving piece of apparatus, which is caused to revolve by the motion of the current when the meter itself is held still in it, or when

it is moved by an external force through the water. It also is furnished with a tail or vane which so directs it that if left free to assume its normal position it will point directly against the current. It is usually pivoted both in the horizontal plane and in the vertical plane, so that it is free to revolve in both directions, and assume the position in which the current is moving.

The revolutions of the wheel are caused to make and break an electric circuit, which are repeated in a sounding device that is held by the observer, ordinarily a small telephone which is simply fastened to its head, and at each revolution of the wheel there is a click so that he is able to count the revolutions of the wheel and at the same time with a watch thereby determine the number of revolutions that take place in any unit of time that is desired.

In transferring the revolutions to velocity of water, it is necessary to have the meter rated; that is to know how many revolutions per minute represent, say, a foot of velocity. That is ordinarily done by dragging the meter at known rates through still water, and recording the revolutions for the distance passed through in a given time, it being assumed that the velocity of the meter in still water has the same effect in creating rotation that the velocity of water past the still meter would have in creating rotation. That process of dragging the meter in still water and determining the revolutions which correspond to a velocity of translation through the water is called rating.

The meter as operated in small channels where it can be done, is ordinarily held upon a rigid staff, when both its direction and position can be very accurately determined. In working in deep channels, it is necessary to suspend the meter on a cable, in which case its direction cannot be determined with the ordinary meter and its position is more or less influenced by the necessary curvature of the lines, due to the effects of the current. To overcome the former objection, a current meter has been devised for that, which is known as the direction current meter, in which there is a magnetic needle that transmits its position electrically to what is known as a repeater at the surface, which indicates on the surface the position in horizontal direction which the current meter occupies, so that it is possible with that device to tell so far as the horizontal plane is concerned in what direction the meter is pointing; but with an ordinary meter it is not pos-

sible to determine that, unless the meter is within the range of vision through the water.

Q. When you speak of ordinary meter, what make of meters do you refer to?

A. Well, when I say "ordinary meter" I refer to all except those equipped with the direction meter device, which is only used in connection with the so-called Ritchie-Haskell direction current meter.

Q. What period of years did your investigations and work at Cornell cover?

A. About 1899, from early in 1899 or the fall of 1898 until 1904.

Q. What was the scope of your work at the University of Michigan?

A. At the University of Michigan, my work so far as that connected with the University was concerned, was mainly in the teaching of the subjects indicated by the title of my chair.

At that time I was engaged upon numerous investigations involving the measurement of water, the flow of water; made several investigations of the quantity of water flowing over various structures as dams, under particular conditions; that is the effect of various forms of crests and so on upon the low discharge of such structures, with a view of being able to determine more accurately the quantity of water that was flowing in rivers where such structures were in use, in connection with measurements of run-off of streams.

Q. During the time that you were at Cornell, and also at Michigan, were you engaged in any way in connection with your business as consulting engineer as you are carrying it on now?

A. Yes, all the time I was at Cornell, and even before that, and all the time I was at Michigan I was engaged as consulting engineer, maintaining a regular office and devoting probably from one-third to one-half of my time to my outside practice.

Q. Did the construction of the plants and your work in connection with that have anything to do with navigable waters?

A. The construction work at the Sault St. Marie was in what was assumed to be navigable water in that the War Department of the United States exercised control over the structures which were put there, and such structures could only be erected upon a permit from the Secretary of War.

The constructions with which I was connected at Detroit for the Board of Water Commissioners, which involved matters of intakes in the Detroit River, and for which I made extensive surveys both with regard to the hydrography and character of the bottom and so on of portions of the Detroit River and also Lake St. Clair; and as to the temperatures of the water at different places in the river; and also as to the currents which incidentally involved a considerable amount of current meter work, were all carried on in navigable waters, and subject to the interruptions of navigation. The work of gauging the St. Mary's River which was attempted by the Michigan-Lake Superior Power Company, under my direction, was also carried on in the navigable water of the river above the locks, at a point where vessels were passing, several every hour.

Q. What year was that?

A. Those measurements were made during the summer of 1900, I believe.

Q. Did you make any further measurements on the flow of the St. Mary's River subsequently to that time, or have you made any special studies in that regard?

A. I made no measurements subsequent to that time, but I made a very careful study of the records of flow and the conditions of flow in connection with the development of the water power in the Rapids for the Edison Sault Electric Company; and also in connection with the problems which were introduced in a suit between the United States Government and the Chandler-Dunbar Water Power Company and the Edison Sault Electric Company and others, for the purpose of condemning the property of the aforesaid companies. The general problem of the hydraulics of that part of the river was I think quite carefully considered.

Q. Have you made any study of measurements of the flow of the St. Clair River; and if so, what time did they cover?

A. I have made a very careful study of the flow of the St. Clair River. You mean a study of the measurements.

Q. Study and measurements both?

A. The measurements on the St. Clair River, the early measurements, date back to the early sixties, 1864, I believe, when discharge measurements were made under the old Lake Survey organization, at which time the current meter as it is now known was really developed, the first use of the telegraphic current meter, so-called, that is when the electric

device was made, at that time, in discharge measurement of either the St. Clair or the St. Mary's River or both, as both were gauged about that time.

The next work that was done on the St. Clair River so far as is known to me—and I have searched the records with some diligence—was in 1899 when the present Lake Survey organization took up the problem of measuring the discharge; and those measurements which were continued through 1902 and latterly taken up again in 1908 and carried on through 1910 have in the main been incorporated in the data already presented in this case. My study of those measurements began about with the inception of this case, although I had a general knowledge of them prior to that time; and had discussed them with various engineers of my acquaintance who were interested in them.

Q. Take the Detroit River, I will ask you the same question.

A. The gaugings of the Detroit River were made in 1901-2 at a section in the vicinity of Fort Wayne below the City of Detroit, and the results of these gaugings were published in the report to the Chief of Engineers for 1903, I believe. The work which I did myself on the Detroit River involved the gauging of the American channel through the ice in the winter of 1896 I think, or possibly January, 1897. There were also several gaugings of the Detroit River in the vicinity of Amherstburg made during 1908, 1909. I am in doubt about 1908. I think they were made in 1909 and more in 1912, in which measurements were made of the several channels, during the construction of the so-called Livingstone Channel, and after the opening of the channel. Those gaugings were made by the United States Government through the River Improvement office at Detroit; the work being in charge of Mr. Charles Y. Dixon, Assistant Engineer in charge of the work in the Lower Detroit River.

Q. What have you had to do with the measurements or consideration of the flow of the St. Lawrence River, and during what period did that cover?

A. The St. Lawrence River was gauged in 1900 and 1901, and there have been gaugings within the past two years I believe.

The data of the 1900-1901 measurements have been utilized in the preparation of exhibits for this case. My individual study of those measurements began at the time that this case was opened. Succeeding that I had occasion to be associated

with the gauging of the St. Lawrence River at a point considerably lower down, being at the bridge across the river just above the Couteau Rapids. This work was done for the Canadian Light & Power Company of Montreal, in connection with the proposed power development and navigation improvements which they were contemplating through the Couteau and Cedar Rapids; and the work was in charge directly of Mr. Murray Blanchard, who was formerly an assistant engineer or junior engineer in the United States Lake Survey service, and was an assistant upon the work on the St. Clair River during the first three years and in charge of it during 1902, and then was in immediate charge of the measurements on the Detroit River in 1901 and 1902.

These gaugings were also supplemented by gaugings of individual channels in the Couteau Rapids, carried out by the same organization.

Q. Have you made any study or investigations concerning the Lake levels and the relation of the levels of the different lakes to each other, with reference to run-off and rainfall, etc., and if you have state what investigations you have made, and what studies you have made?

A. The subject of the discharge of the Great Lakes, in its various phases, has been one that has attracted my attention for a good many years, and I have made, I think, a very careful study of the elevations of the lake, the discharge of the lakes as indicated by such measurements as have been made, the effects of rainfall so far as those effects can be determined, or so far as I have been able to determine them from such records as are available in the files of the United States Weather Bureau, Smithsonian Institution, War Department, and from various other sources, as for instance some State observations and so on.

Q. Are those the recognized sources of information that you refer to, the War Department, Smithsonian Institution, etc.?

A. United States Weather Bureau. They are the best, and I may say the only reliable sources of information that are known to me; and other records are to be found in Government publications.

Q. If there were other sources, would you be likely to know them?

A. I think I would.

Q. Have you made any investigations or studies of hy-

draulics or sanitary problems, in connection with any litigation in which you have been engaged?

A. Yes, I was one of the witnesses retained by the City of St. Louis in the State of Missouri, in the case of the State of Missouri *vs.* The State of Illinois and the Sanitary District of Chicago, before the United States Supreme Court, being what is ordinarily known as the Drainage Canal case. My investigations there had particularly to do with the sanitary phases of the case, and latterly with the hydraulic questions of time of flow and the effects of various works in the connecting waters between Chicago and St. Louis.

Q. Are there any other cases with which you have been connected, in which these questions have been involved?

A. I was connected with the case at London, Ontario, involving the general hydraulic problems of back water and damage to millwright properties. I do not recall any other case that I have been connected with in which the sanitary element was important.

Q. Were there any in which water power or hydraulic questions have been involved?

A. Yes, I was engaged in a case here in New York between the City of New York, the New York Water Department and the New York Sugar Refining Company, the water stealing case which involved measurements of water by certain devices.

I was engaged in a case at Kalamazoo, between the City of Kalamazoo and the Standard Paper Company. I believe it was another water stealing case, which involved the measurement of water.

I was engaged in a case between the City of Flint and Mrs. Loranger involving the case of damage to water power by diversion of water.

I was engaged in a case in Illinois involving constructions in the Desplaines River, and their effect upon certain lands.

I was engaged in the case of United States *vs.* the Chandler-Dunbar Water Power Company and the Edison Sault Electric Company and others, to which I have already adverted, which was pretty nearly the essence of hydraulic engineering. And I was also engaged in the case of City of Ithaca *vs.* The Ithaca Water Works Company and others, for the condemnation of Water Works Property, which involved numerous hydraulic problems.

Q. What were the subjects involved in the case of United States *vs.* Chandler-Dunbar Water Power Company?

A. That was a case brought by the United States to acquire the property and lands of the Chandler-Dunbar Water Power Company and the rights of its lessee, the Edison Sault Company in the St. Mary's River, for the alleged purpose of utilizing the said property for the construction of locks in the improvement of navigation. The case involved the determination of the value of the property, and incidental thereto was of course the question of the amount of water power that could be developed there, the fall in the river, the natural and high and low flows and the benefits to navigation and various other collateral items.

Q. Those were the hydraulic questions involved that you just last mentioned?

A. Yes.

Q. Now your practice has taken you over a considerable scope of the country, hasn't it?

A. Yes.

Q. Will you state in a general way what States or cities your practice has involved?

A. I have practiced very largely in Michigan and New York; to a less extent in Illinois, Wisconsin, Minnesota, Massachusetts, both the provinces of Ontario and Quebec, Ohio, Colorado, Dakota, Missouri, and have had occasion to report upon and advise in the construction of works in Arizona, Washington, Pennsylvania. I think that is the list.

Q. Are you familiar with water purifications and the ordinary problems of sewerage, and if you are, state what investigations you have made, or what your practice has been in connection with those problems?

A. I have been for many years interested in the subject of water purification, my attention having first been called to it when I was serving as civil engineer to the Board of Water Commissioners of Detroit; and later I was associated with Mr. Allen Hazen, in the design and construction of a water purification plant for the City of Ithaca, New York, which was built under our supervision. And following that, I designed and constructed for Cornell University a plant for the purification of its water supply; and have been called upon to investigate and examine into various propositions or plans for water supply improvement. I was recently called upon by the Board of Water Commissioners of Detroit to make an examination of the conditions of the Detroit Water Supply, and submitted a report a few weeks ago, which has not yet been published, covering that subject. That involved an in-

vestigation of the lake water supplies in general, including those of Chicago, Milwaukee, Cleveland, Buffalo, Erie, and some of the others.

In the matter of sewage, I have done less. I have designed one or two small sewerage systems, in which case water disposal was used.

I have of course been familiar with the problem of the disposal of sewerage along the Great Lakes, from my acquaintance with it in my birthplace, the City of Saginaw, and later from my extended residence in Detroit, where I was brought into close contact with problems of that nature.

Q. In a general way, how are the waters of the Great Lakes used?

A. The waters of the Great Lakes afford the principal source of water supply for a very large portion of the population resident along their borders. All the large cities on the Great Lakes take their supplies from them or their connecting waters; and these supplies are used for domestic and manufacturing purposes, for the ordinary requirements of urban populations.

They are further used for the purposes of transportation or of navigation. And they are used, at places where circumstances permit, for the development of power; so that you might say that the water of the Great Lakes are used for practically all purposes for which water, natural waters are used.

Q. In your study of the Great Lakes system, and the water supply, have you considered whether there was any relation between the levels of the different lakes?

A. Yes, there is a very marked relation between them, which is influenced in two ways. Beginning with Lake Superior, it discharges through the St. Mary's River into Lake Huron, and any variation in the discharge of Lake Superior will be felt in the amount of water that is received by Lake Huron and Lake Michigan, which are practically one lake; so that a decrease in the flow of the St. Mary's River will have the effect of decreasing the quantity of water supplied to these lakes; and if other conditions remain the same, the lakes will be lower. An increase would raise them, other conditions being the same.

Any change in the levels of Lake Michigan and Lake Huron will be reflected in the discharge of the St. Clair River, which, emptying through Lake St. Clair into Lake Erie, will have the effect of raising or lowering the level of Lake Erie.

Similarly Lake Erie discharging through the Niagara River, if any change in its elevation occurs, it will change the quantity of water flowing through the Niagara, and this in turn will be reflected in the elevation of Lake Ontario, which finally supplies the water to the St. Lawrence River. So that we may say that a change in the amount of water reaching Lake Superior will be felt in the amount of water flowing in the St. Lawrence River.

Then there is, excluding Lake Ontario and Lake Superior, a reflex action. If a large quantity of water be supplied to Lake Erie, for instance, from its drainage area, that will have the effect of raising the lake and thereby decreasing the fall between Lake Erie and Lake Huron, reducing the flow into the St. Clair and Detroit Rivers, and raising the level of Lake St. Clair and likewise Huron and Michigan. So that we may say, so far as the three lakes are concerned, Erie, Huron and Michigan, that a change in one will be reflected in the other; and by reason of the fact that the different latitudes, or slightly different latitudes leads to the melting of the winters snows at slightly different times, and also on account of the storage possible in the lakes themselves, we find that the fluctuations of one lake follow the fluctuations of the other at quite regular intervals; the increase of level of one producing or tending to produce the high water in the one next lower down, at some later period.

Q. Are there any changes in the levels from day to day, month to month or year to year?

A. Very marked changes appear from day to day.

Q. Or from hour to hour, I may ask?

A. Yes, from hour to hour, under certain circumstances, quite extensive vibrations. Changes of one foot or two feet within an hour are not uncommon. And while the average changes from month to month are not so great as that ordinarily, the changes from year to year are considerable, covering a range of some two or three feet on Lakes Huron and Michigan; and I do not recall just the change of stage on Lake Erie at the present moment.

I wish to make a correction there: In speaking of daily changes or hourly changes, they are not changes of stage; they are changes of water at particular points. The monthly changes we call stages.

Q. Those last are sometimes designated oscillations?

A. Oscillations of the lake.

Q. What are the different causes as far as is known, which effect change of stage and oscillation of the lake?

A. The changes of stage are of course brought about by variations in the quantity of water which flows into the lake, and variations in the quantity which flows out. The oscillations are due to the effects of wind and the changes in barometric pressure; the barometric pressure at one end of the lake perhaps being greater than at the other, naturally depresses the surface of the water at that end and causes a rise at the other end. Or the same may occur across the lake. Those effects are, of course, of limited duration, but they cause decided changes of elevation at the extremeties of their effects. As for example on Lake Erie, it is not infrequent, or has not been in the past, that a variation of four feet might occur at one end of the lake; that is, it might be two feet below its natural position or two feet above, and in some cases higher fluctuations than those have been recorded. Those are usually due to the effects of wind sweeping lengthwise of the lake, possibly accompanied by barometric inequalities at the two ends.

I believe there is on record, in fact I know that there is a variation of six feet at the western end of Lake Erie; that is three feet below and three feet above the normal water plane; and that the fluctuations of Erie are sufficient at times to temporarily reverse the flow of the Detroit River so far as the same can be observed by ocular observation. Such occurrences are rare, but one of them has been within my individual observation.

Mr. Wilkerson: Are you able to fix the date of that?

A. It was somewhere between 1893 and 1897, while I was connected with the Detroit Water Works, between 1893 and 1898, I will say.

Mr. Adcock: What is the greatest range of the daily oscillations or changes in level at any particular point of Huron that you know about, Lakes Huron and Michigan being treated as the same lake?

A. I don't think that I can testify from personal observation to a daily change on Lakes Michigan and Huron.

Q. Have you any records or observations made of gauges which would show that?

A. Yes, I have, which would show some. That is, the records are based upon the records furnished from the office of the United States Lake Survey. I find I do not have them in the room; I can produce them later.

Q. Do you know the drainage areas of the different lakes?

A. I know them, yes, as I know other things which are matters of common knowledge.

Q. Do you know what the extent of the areas is?

A. Yes. The drainage area of Lake Ontario, exclusive of the lake itself is about—and that is exclusive of anything tributary to the lake above Niagara, above the head of the Niagara River—is about 25,737 square miles.

Q. What is the area of the lake itself? You might give that at the same time?

A. And the area of the surface of Lake Ontario is about 7,243 square miles. The drainage area of Lake Erie and St. Clair, exclusive of the lakes themselves and of anything above the head of the St. Clair River is about 30,296 square miles.

Q. And the lake area?

A. And the area of the lake surfaces is about 10,471 square miles of which about 500 square miles is in Lake St. Clair. The area of Lakes Michigan and Huron together, or rather, the drainage area of Lakes Michigan and Huron, exclusive of the drainage above Sault St. Marie is about 92,493 square miles, and the area of the lake surface is about 45,314 square miles.

The drainage area of Lake Superior exclusive of the lake surface is about 44,074 square miles and the area of the lake surface is about 32,060 square miles.

The land drainage area of Lake Michigan is about 43,463 square miles and the area of the water surface is about 22,336. The land drainage of Lake Huron is 49,710 and of the water surface 22,298.

Q. How is the water supplied to the Great Lakes?

A. The water supplied to the Great Lakes comes directly on to their drainage areas, and on to their surfaces as rainfall.

Q. Sometimes called precipitation?

A. Sometimes called the precipitation. And the source of this supply is probably to a very large extent the Atlantic Ocean and the Gulf of Mexico. In fact whatever is contributed to the ocean through the St. Lawrence River must be brought back in the form of rainfall and redeposited upon the drainage areas; otherwise the lakes would run dry and the ocean would fill up and drown out all the land.

Q. That would be true also of any water supplied to the Gulf of Mexico, wouldn't it?

A. Yes.

Q. Has there been any measurements of rainfall from time to time in the last period of years by any one?

A. The measurements of rainfall have been carried on at various places on the drainage areas of the Great Lakes for a great number of years. In the early days, these measurements were taken usually by individuals who were interested in the subject; and search of the old records will find in almost all our larger cities the history or record of some one who kept rainfall observations for a greater or less time. These observations were taken up by the United States Government along in the late sixties, I think, or indirectly the Smithsonian Institution apparently either collected the records from various sources or exercised some charge over their collection. Then there was for a time a so-called United States Weather Service which was later incorporated or transferred to the corps of engineers of the United States Army. I think not to the corps of engineers but the officers at United States army posts were expected to take and report rainfall observations.

Later, the present Weather Bureau was organized and since that time a systematic, a more systematic administration of rainfall and general meteoriological observations has been kept up. These observations, as we meet with them now, are comprised in perhaps three classes: First, and best, those taken by the regularly established weather bureau stations, which are located in most of the large cities and in some other strategic points, you might say, throughout the country.

The next in order is the record of various observers who have worked or are working under the authority of various states; there having been in several of the states a weather service at one time or another, and in some I believe it is still continued.

Then beyond that, and that upon which we are to a large extent dependent for the rainfall in the more remote regions, is the records prepared by you might say a vast army of volunteer observers. The United States Weather Bureau encourages any one who is interested in the observation of rainfall, temperature, evaporation or anything of that sort, by furnishing them now with a set of standard instruments for the observations which they are preparing to take, and asking that they make reports monthly to the Section Director of the Weather Bureau Service, in the particular state or region where they are located. In that way a large amount of information is gathered from localities which could not be reached or represented by the stations at which paid observers are

maintained. And still there is undoubtedly a large margin of error in this, as the observer will be found frequently to neglect to observe for a month or two here and there, or probably they oftentimes omit days of rainfall and so on, still taken as an average the country over it is probable that the relative values are reasonably correct. That is, we have no reason to suppose that observers in Minnesota would be any less lax or more lax than those in the State of New York; and that when we take the result of the observations of a large number of these observers and compare them with the results of a large number in some other locality, the relative indications we may assume to be quite reliable while the absolute indications, that is as to the actual amount, may be very largely in error.

The observations of the United States observers themselves, I think we are safe in saying, are quite accurate for the places where they are observed, but of course they do not cover the entire region by any means, and only represent accurately as to time a comparatively small area; though when considered as the mean of a year, the mean rainfall indicated for a year by these government observations, it is probably—I may say thoroughly representative of the mean rainfall for the region, unless you happen to meet with those conditions which change the character or the amount of precipitation, such as a mountain range or range of high land, or proximity to a large body of water.

For example, in the State of Michigan, the western side of the state receives appreciably more rain than the eastern side. That appears to be due to the fact that the rain mainly comes up through the Mississippi Valley from the Gulf of Mexico, and the western side of the state gets it first.

It is also noticeable, that where a mountain range intervenes between the source of the water in the atmosphere that the side away from the source will be dry and the side towards the source will receive much more rainfall. That is particularly noticeable in the western part of the United States, where the area between the coast range and the Pacific is supplied very bountifully with rainfall; after you pass the coast range, there is less, and by the time you get past the Sierras, you have practically a sterile—practically a desert, except at times of melting snow.

Q. What becomes of all this rain that falls upon the drainage area and the lake surfaces of the lakes?

A. The rain which falls upon the drainage area, upon the

land area, is disposed of usually, we say, in three ways: By evaporation, that is, the evaporation, by surface run-offs, and by percolation. A large part of it, in fact more than half, is re-evaporated either through the direct action of the rays of the sun upon the particles of water, as they lie upon the surface of the earth, or the branches and leaves of the trees and so on, or may be through the agency of the trees and vegetation itself, which takes up the moisture from the soil through its roots, passes it through its stem in the form of sap and exhales it from its leaves in the form of moisture.

The evaporation of different plants is markedly different; some apparently evaporating three or four times as much as others. The rain that falls upon the earth's surface in times of heavy downpours, or when the surface is frozen, or in the time of thawing of snows in the spring—or rather I should say that is on the surface under those conditions, a considerable portion flows off from the surface as visible run-off, as we see it in the ditches along the side of the road and in the small streams which you notice flowing through the fields, after heavy rains. It flows off into the rivers, creeks, and ultimately to the Great Lakes and to the ocean, speaking of the drainage of the Great Lakes.

Another portion, depending very largely upon the character of the soil, and to some extent on the character of the vegetation, finds its way into the soil and flows through it and furnishes the water supply which we ordinarily obtain from wells, either shallow or deep. This water, to a large extent, appears to return to the streams themselves and influences the discharge or the run-off as we call it, that is measured as surface run-off. Some of it of course reaches the Great Lakes through their sides and through the bottom, but——

Q. That is called subterranean passages, isn't it?

A. We hardly would call it subterranean passages, because there is really no passage in the sense of its being a channel or conduit, but it is simply the gradual percolation of the water through the sands and between the grains of the soil. And while it has never been possible to measure the amount of that flow into the Great Lakes, such information as is available on the subject, namely, as to the yield of wells which have been put down along the lake shore at various points where the supply comes from this current of water that is moving slowly through the earth, indicates that the amount of that run-off to the Great Lakes must be small.

Mr. Wilkerson: That is entirely in the realm of speculation, isn't it?

A. No, I don't think it is entirely. No, I think we have good reason to come to the conclusion that the amount reaching the Great Lakes through the underground surface is relatively a very small factor.

Mr. Adcock: Is there in your experience and from the records which you have examined, can you state whether there is any relation of evaporation to rainfall?

A. There is a relation, or there are certain relations. The law connecting rainfall and evaporation has not yet been worked out, and it is one of the most complicated problems that is to be encountered. Some of the conditions which must be included in the statement of any such law are quite well understood.

In the first place, as I have already said, rainfall falling upon the ground when it is frozen will run off very rapidly into the water courses, and a very large per cent. of it will appear as run-off. Rainfall falling on a sandy area which is not frozen will to a very large extent be absorbed by the earth; will pass through in the form of percolation to the streams which drain that area, and will ultimately reach the Great Lakes. The rainfall falling upon a cultivated area, at times when crops are growing, will to a very large extent be re-evaporated by the crops, and of course would appear in the atmosphere.

The evaporation is influenced by temperature, and by the wind, and by the amount of moisture in the air, so that we are pretty safe in saying that during a rain there is not much evaporation, so that it follows if you have, for instance, say three inches of rainfall in a month distributed in small showers, so that it covers a large number of hours, that is .02 of an inch at a time, perhaps the evaporation from water surfaces would be materially less, very much less under those conditions than it would be if it came in one or two large showers and evaporation was allowed to continue during the intervening periods, or would continue, as it must, without interference. That is one of the things that makes it extremely difficult to correlate the amount of rainfall with the amount of run-off or the amount of evaporation, because the same amount of rainfall delivered in one way may be productive of a very relatively large amount of run-off, whereas delivered in another way it nearly all goes off in evaporation and you have very little left in the run-off.

The comparisons of run-offs of various streams in Michigan which I have studied for a number of years show a quite wide variation in the amount of water—in the percentage of rainfall that appears as run-off; those streams coming from sandy areas giving relatively large run-offs; those streams coming from highly cultivated areas giving small run-offs.

The comparison of the streams in the west, that is, in the Central States with those further east, say in Central New York, where the country is much more precipitous indicates that the percentage of run-off in the New York streams is considerably greater than that in the Michigan and Wisconsin and Illinois streams, by reason of the fact that the rain that falls flows quickly into the streams and is carried off quickly before it has time to evaporate. There are all those conditions that have to be taken into account. For example, the run-off from the State of Ohio is noticeable for its smallness relatively to the others. The high cultivation apparently, combined with the character of the soil, which is a loam, and with the character of the surface, which is moderately rolling, seems to conduce to a very high evaporation or a very large absorption by plant roots, and subsequent evaporation so that the run-off from the Ohio streams, both those which flow into Lake Erie and those which flow into the Ohio River, is considerably less than is run-off of those streams that flow into Lakes Michigan and Huron, or into Lake Ontario.

Q. Is there any difference in evaporation of different drainage basins of the Great Lakes, drainage areas of the Great Lakes?

A. Yes, there undoubtedly is. Such observations as have been made indicate such to be the fact. And there appears to be a larger evaporation from the basin of Lake Erie than from either that of Ontario or of Michigan and Huron; and the evaporation from Lake Superior, though the observations are less complete than elsewhere, appears to be materially less than that from the lakes lower down, which is of course to be expected on account of the general lower temperature, both of the air and of the water.

Q. As a result of the evaporation taking place more rapidly in the summer time, when is the lowest stages of the lakes usually, during the year?

A. They are usually in the fall or winter, if I remember rightly; rather in the winter, for the lake stages during the navigation season are in general higher than they are during

the average of the whole year. In general the low period is in February and March; that is the late winter.

Q. You are referring now to what?

A. Complainant's Exhibit 5.

Q. Has the run-off of the various rivers supplying the lakes been measured in any way?

A. Run-off observations have been taken covering periods of years on a large number of rivers flowing into the Great Lakes. These observations are largely compiled by the United States Geological Survey, although the observations covering the New York streams—a very considerable amount of information covering those streams is to be found in the reports of the State Engineer of New York, and some other sources; the report of the Board of Engineers on Deep Waterways contains a discussion of them.

From an examination of that information and other information, with which I was personally familiar, I find that run-off observations have been taken covering about 37 per cent. of the drainage area of Lake Ontario; about 33 per cent. of the drainage areas of Lakes Erie and St. Clair, and about 32 per cent. of the drainage areas of Lakes Huron and Michigan, all being exclusive of the drainage areas of the lakes next above. The run-off observations of streams supplying Lake Superior are limited to one or two streams, and are too limited to give any very definite information.

Q. We have heard a good deal about the terms "increment," Mr. Williams. I would like to ask you to define that word if you can?

A. The term increment as used in this case has a peculiar significance. As used in general, it means any change or increase of a changing quantity. In this case it means a specific change or the amount of change in the discharge of one of the rivers—of any of the rivers that is due to an increase of elevation of one foot in the controlling lake. So that when we use the term increment here, we mean the amount of water by which the flow of the river in question would be increased by the rise of one foot in the lake which is supplying the water or which is controlling or assumed to control the discharge.

Q. Is it applied in the same way to the lowering of one foot?

A. Yes. It is the amount of water by which the discharge would be changed by a rise of a foot or the fall of a foot, and for the purposes of this case within the range it has been used, it has been assumed that the increment due to a rise of

a foot is the same as the increment due to the fall of a foot; and the observations show that to be substantially correct, while absolutely or theoretically it is not.

Q. For all practical purposes it is the same?

A. For all practical purposes, within the ranges that are dealt with in this case, it is the same; or within the ranges that have been dealt with thus far in this case.

Q. So that you, in using the term increment, you refer to the increment say of the St. Clair River, Detroit River or Niagara or St. Lawrence Rivers?

A. Yes.

Q. Why is it necessary, in connection with the investigations that have been made to determine the effect of a diversion of water, say at Chicago, why is it necessary to obtain an increment of, say the St. Clair River?

A. Because that is the only way in which the effect of a diversion of the magnitudes considered could be determined. The magnitude of the diversion is so small as to be insusceptible of any direct observation or measurement; and the only way in which a measure of its effect can be obtained is by ascertaining how much the flow would be increased or decreased by the change of a foot. Then conversely the change of so much flow would change the level a foot, and of less than so much would change it a proportional part of a foot.

Q. Do the fluctuations of, say, the controlling lake have any relation to the increment of the outlet of that lake?

A. Yes, they are very intimately related considering or dealing with the changes of stage over a considerable period of time as a year, for instance. The greater the change of stage in annual fluctuation, or in fluctuation from year to year, the less must be the increment, and vice versa, a lake which changes but slightly in its surface elevation gives indication of a large increment and one which changes greatly gives indication of a small increment of the quantities of water flowing into the two lakes, is reasonably near the same amount. If, for instance, a lake having a smaller quantity of water shows a higher fluctuation than a lake having a larger quantity of water flowing into it, the indication is conclusive that the increment of the lake which shows the higher fluctuation is less than the increment of the lake having the lower fluctuation.

This can perhaps be illustrated by taking a trough and putting two partitions in it, and allow water to flow down it. If you have an opening in one partition that is, say, four inches square, and an opening in the other partition of the same size,

if you raise the water in the upper section of the trough, in a reasonable time it will rise correspondingly in the lower section. But if in the lower section there is an opening which, let us say, is four inches deep and eight inches wide, the water in the lower section will not rise as high, in fact actually something less than half as much as it is raised in the upper section.

In other words, the increment of the discharge through the lower partition is more than twice as great, for these exact figures, than the increment of discharge of the upper section. So that it follows that the relation of the increment is inversely as the relation of the fluctuations.

In other words, you can say if the fluctuation of one lake is twice as great as the fluctuation of the other, then the increment of the first lake must be about half as great as the increment of the other.

Mr. Wilkerson: You are speaking now with reference to continuous flow?

A. I am speaking now with reference to continuous flow.

Mr. Adcock: So that if you found in one period of a number of years the fluctuations of a particular lake, like Lake Huron, for instance, were greater than another period of years, it would be assumed that the increment had changed?

A. I think that would be conclusive evidence, if both covered reasonably long periods. I would not say that a comparison of fluctuations for one or two years would be sufficient, but if you had 15 or 20 years in a period, I think you would be quite safe in drawing that conclusion.

Q. When you refer to fluctuations of the lake in connection——

A. I mean real change of stage for considerable periods of time.

Q. Real change of stage, and yearly fluctuations?

A. Yes, from year to year.

Q. Not of monthly?

A. Not the monthly.

Q. Why do you eliminate the monthly fluctuations in connection with determining the relation of the increment?

A. Because in the monthly fluctuations there is not time for the effect of the storage in the lakes to work out. It takes time for the lake to rise, and if you deal with monthly fluctuations, one lake would not have yet followed the other closely enough to warrant a judgment. That is, your second lake

would be lagging too far behind the first one, so that you might be misled in your conclusions.

Q. Is there any relation between the increase of the increment and the discharge of the river?

A. Yes, that depends upon the form of the channel to some extent, but it may be demonstrated by the ordinary laws of hydraulics and physics that the change of increment cannot be greater than the change of discharge. That is, that if you have a certain channel which has a certain increment, and by changes in that channel made below the surface of the water you increase the increment, you must have increased the discharge in at least as great a proportion.

Q. Why do you say in at least as great a proportion?

A. Because that is the limit. They could only be equal in the case of an extremely large channel, with an extremely small change, but in any change that becomes appreciable the magnitude of discharge will be changed to a greater extent than the increment is changed.

Recess to 2 p. m.

After recess—2 p. m.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Mr. Adcock: From your study and experience have you become and are you now familiar with navigation upon the Great Lakes?

A. Yes, I have been familiar with the conditions of navigation and with navigation for the greater part of my life.

Q. What is the general course of travel, of boats carrying freight upon the lakes, the Great Lakes?

A. The largest part of the traffic of the Great Lakes above Ontario is composed in tonnage, the largest part in tonnage is composed of ore.

Q. That is iron ore?

A. Iron ore. This traffic originates mainly at Lake Superior ports; Superior, Duluth, Ashland, Marquette.

Q. You are referring now to Complainant's Exhibit 6?

A. Complainant's Exhibit 6.

Q. Entitled "General Chart of the Great Lakes?"

A. General Chart of the Great Lakes. It passes through Lake Superior, the St. Mary's River, and divides, a small

portion of it going to the Straits of Mackinaw to South Chicago; and by far the largest portion going through Lake Huron and St. Clair River, Lake St. Clair and the Detroit River to Lake Erie ports, Cleveland and Ashtabula particularly.

There is also a considerable amount of ore from Escanaba, which is at the northern end of Green Bay. This passes out into Lake Michigan and divides, a portion of it going to South Chicago down to Lake Michigan, and the other portion passing eastward through the Straits of Mackinaw, and joining the traffic from Lake Superior on its way to the Lake Erie ports.

Q. What is the traffic below Lake Erie, or from Lake Erie to other points?

A. Going down from Lake Erie, the depth of navigation is controlled by the depths of the Welland Canal, first which connects Lake Erie and Ontario; and then by the depth of the Canadian canals along the River St. Lawrence, so that it follows that deep draft boats are not in use on Lake Ontario; and in 1911 there was no boat on Lake Ontario drawing more than 14 feet.

Of course in addition to this ore traffic, there is a large passenger traffic, and a considerable traffic, in package freight, which moves in both directions, up and down through the lakes. And a traffic in coal northward at certain seasons of the year which moves from the Lake Erie ports to ports along Lake Superior and Lake Michigan. This coal traffic is largely carried by the ore boats on their return trips; and there are comparatively few boats used in it alone and the draft of their boats is very much shallower than that of the ore carrying boats. I have a memorandum of that, I think, which I took the other day. A few days ago I examined the boats of the Detroit & Cleveland Navigation Company that were tied up at Detroit. These embraced the two largest boats of the fleet, the City of Cleveland Third, and the City of Detroit Third, upon which the highest marks were for 15 and 16 feet. Those were at the stern. The bow marks were 14, in the case of the City of Cleveland. I was in error in stating that 16 was the highest on the Detroit. The stern mark on the Detroit was 17. The City of Mackinac and City of Alpena, both being "Second" so-called, which ply from Detroit to Mackinac, at their sterns were marked 11 and 12 respectively.

Q. That is feet?

A. That is feet. And it is not customary for those boats to load beyond their marks, as I have seen them many times

and I have never seen them when the marks were obscured. In fact they could not load lower than that, without interfering with their paddle boxes.

Q. Now you have described in a general way the course of travel of the boats, of the freight carrying boats. I have here a chart marked "Lake Superior," issued by the United States Lake Survey. I ask that it be marked Defendant's Exhibit 1 of this date.

(Whereupon chart referred to was marked Williams Exhibit 1, March 18, 1913.)

Q. What does that chart show?

A. That chart shows the geography and hydrography of Lake Superior, the outline of the lake and the immediate shore topography is shown and also the depth of water at various places throughout the lake, where soundings are indicated by figures, and also the courses of navigation, which are indicated in general by dotted lines from point to point along the lake.

Mr. Wilkerson: These small figures are depths?

A. They are depths in fathoms.

Mr. Adcock: How much is a fathom?

A. Outside of the blue, the depths are in fathoms of six feet. Inside the blue the depths are in feet.

Q. Now a boat, an ore boat, for instance, passing from Marquette out of Lake Superior, at what point does such a boat leave Lake Superior?

A. At the head of the St. Mary's River; that is it enters St. Mary's River.

Q. Is there a bay called Whitefish Bay?

A. Whitefish Bay.

Q. Now, I show you another chart issued by the United States Lake Survey, which I ask be marked Williams Exhibit 2 of this date, entitled "Chart 3. St. Mary's River." From that chart, Mr. Williams, can you indicate or state what course a boat will follow going down through the St. Mary's River and the lakes?

A. It will come into the head of St. Mary's River from Whitefish Bay and follow down through the deep water in the river, angling to the left above Round Island, and following the river down to a point about two miles about the locks, where it may choose between taking the Canadian Channel to the northward, or coming through the American locks, which are on the south side of the river at the Falls.

Q. When you say Canadian Channel, you mean also Canadian locks, don't you?

A. I mean also the Canadian locks; passing through the canal either on the Canadian side or the American side. It then passes into the lower river and proceeding down below the City of Sault Ste. Marie it has a choice of taking the Canadian Channel or the American channel. The practice at present is for the loaded boats to take the American channel I believe. The Canadian channel, the Lake George Channel communicates with the Georgian Bay, and is used mainly by boats plying in that direction?

Q. Is the depth of the water indicated on this chart by the figures?

A. It is indicated on this chart in feet.

Q. All the way in feet?

A. Yes, sir, apparently all the indications are in feet.

Q. In the blue as well as the white?

A. Both in the blue and the white.

Q. I show you another chart issued by the United States Lake Survey entitled "St. Mary's River. Chart 2," which I ask be marked Williams Exhibit 3 of this date. In a general way what did that chart show with reference to the St. Mary's River and the channel there?

(Chart shown to witness and marked Williams Exhibit 3, March 18, 1913.)

A. That chart shows the river below Sault Ste. Marie, or practically from the lower end of Sault Ste. Marie to Mud Lake.

The Lake George Channel is seen in the northern end of the chart, going into Lake George and thence out to St. Joseph Channel into Georgian Bay. The main improved channel from Sault Ste. Marie to Hay Lake is close to the American shore, and below Hay Lake the channel divides, one passing down through the West Neebish, and the other to Mud Lake, or through Little Mud Lake, and the two uniting in Mud Lake Proper.

Q. What does the blue on that map indicate?

A. The blue indicates shoal water, and the white indicates water deeper than 21 feet.

Q. Now take the course of the boat from where you left off on the other chart.

Mr. Wilkerson: Is that same thing true of the preceding charts?

A. That is true of all of them until you get to Ontario.

Mr. Adcock: Will you state what course the boat would follow in its downward course?

A. The loaded boat would pass down into Hay Lake through the main improved channel on the American side and then take the right-hand or western channel through the West Neebish; the eastern channel through by way of Sailors' Encampment, Little Mud Lake being reserved for up-bound boats. From Mud Lake the channel passes or the course passes through the lake southeasterly to the next chart.

Q. Which is Chart 1, which I have in my hand, which may be marked Williams Exhibit 4 of this date, entitled, "Chart No. 1, St. Mary's River." Now will you state in a general way what that chart shows?

(Chart shown to witness was marked Williams' Exhibit 4, March 18, 1913.)

A. That chart shows the lower end of the St. Mary's River with the outlet into Lake Huron. The course from Mud Lake is bearing southeastward and then turns almost due south and then to the eastward again; finally south through the Detour Passage.

Q. Is the depth of water indicated on that chart in the same manner that it is on the other charts that you have mentioned?

A. Yes, the indication here is in feet, both in the blue and in the white, and the blue represents water less than—the white represents water 21 feet in depth.

Mr. Wilkerson: How far is it from the falls down to Lake Huron?

A. I don't remember, but about 40 miles.

Q. About 45 miles?

A. I may add that the St. Mary's River enters Lake Huron a comparatively short distance east of the Straits of Mackinaw.

Mr. Adcock: I show you another chart here entitled, "Lake Michigan," issued by the United States Lake Survey, and ask that it be marked Williams' Exhibit 5 of this date. What does that chart show?

(Chart shown to witness was marked Williams' Exhibit 5 March 18, 1913.)

A. That chart shows Lake Michigan, including Green Bay and the Straits of Mackinaw. It does not extend quite over to the mouth of the St. Mary's River.

Q. Boats bound for Chicago and points at the lower end of Lake Michigan, what course would they take?

A. They would pass westward through the Straits of Mackinaw and may then pass west to the westward of Beaver

Island, or the Beaver Island group, in which case they will have a good depth of water; or they may take the passage to the east of the Beaver Island group, which is somewhat narrower, but involves a shorter distance. This permits them to pass either east or west of the Manitous, and down Lake Michigan.

Q. Is the depth of water indicated there upon the map in fathoms or in feet, by the figures?

A. That is indicated in fathoms in the white and in feet in the blue.

Q. Take the boats going from Escanaba to South Chicago, will you describe their course?

A. Escanaba is on the northern arm of Green Bay. A boat would pass south in Bayde Noch and then southeasterly through some one of the passages between the islands which divide Green Bay from the main lake, and then southward the length of Lake Michigan.

Q. Will you describe the course of those boats which are going from Escanaba to Cleveland, say?

A. They would pass eastward, as soon as they pass out of Green Bay, and pass through the Straits of Mackinaw, either by going north of the Beaver Island group or south of it.

Q. Here is a similar chart entitled "Lake Huron," which I ask to be marked Williams' Exhibit 6 of this date. State in a general way what is shown on that chart.

(Chart shown to witness was marked Williams' Exhibit 6, March 18, 1913.)

A. That chart shows the outlet of the St. Mary's River, or the mouth of the river, Georgian Bay, or the north channel, more properly called, and Georgian Bay lying to the eastward, and Lake Huron; also the Straits of Mackinaw in the northwestern corner of the chart.

Q. Is the depth of water indicated there in fathoms or in feet?

A. The depth of water is indicated in fathoms in the white and in feet in the blue.

Q. Now will you describe the course of a boat going from the St. Mary's River to the St. Clair River?

A. Coming out of the St. Mary's River it bears somewhat easterly of south, perhaps south southeast, and the line is very nearly straight, having a slight curvature to the eastward.

Q. At what point?

A. I mean it is very nearly straight from here to the mouth of the St. Clair River, having a slight curvature to the east to

avoid the region in the vicinity of Alpena and again at Sand Beach.

Q. I have here a similar chart entitled "St. Clair River," which may be marked Williams' Exhibit 7. Will you indicate what is shown on that chart in a general way?

(Chart shown to witness was marked Williams' Exhibit 7, March 18, 1913.)

A. That chart shows the St. Clair River from Lake Huron to Lake St. Clair. It is made up in two principal sections, one reaching from Lake Huron to the town of St. Clair and the other reaching from Stag Island, or from the foot of Stag Island, which is above St. Clair, through the delta into Lake St. Clair.

Q. How is the depth indicated on that map?

A. The depth is indicated in feet both in the white and in the blue.

Q. And the course of a boat going to Cleveland would be what, through the St. Clair to Lake Huron?

A. It would enter the St. Clair River at Fort Gratiot, and pass down the river following the main channel to a point opposite Algonac, when it takes the so-called "South Channel," or what is now known as the main channel through the St. Clair Flats Canal and out into Lake St. Clair following the dredged cut across Lake St. Clair.

Q. How many channels are there there which boats may take?

A. Through the Flats, or through the canal proper there are two channels, one used for down-bound and the other for up-bound traffic.

Q. How wide are these channels, do you know?

A. One of them is 290 feet and the other is 300 feet wide.

Q. Do you know the width of the St. Clair River from Huron down to the St. Clair Flats?

A. It is something less than 2,000 feet in the narrow portion, but generally between 2,500 and 3,000 feet. There are places where it is somewhat wider.

Q. Then from the St. Clair River, or St. Clair Flats, boats pass through—

A. Lake St. Clair.

Q. Lake St. Clair, which is shown on the chart entitled, "Lake St. Clair," similar to the ones which have been introduced in evidence, which I ask to be marked Williams' Exhibit 8. Now, Mr. Williams, what in a general way does that chart show, the one to which I have just referred?

(Chart shown witness marked Williams' Exhibit 8, March 18, 1913.)

A. That shows the outlet of the St. Clair River, or the lower end of the St. Clair River, beginning at a point about six or seven miles above Algonac and extending through Lake St. Clair to the head of the Detroit River.

Q. How is the depth of water indicated there?

A. The depth of water is indicated here in fathoms in the white and in feet in the blue.

Q. What would be the course of a boat going down on its way to Cleveland, say?

A. (No answer.)

Mr. Wilkerson: When you speak of the course of a boat, you mean the straight cut, so to speak, in fair weather, and not the course it might be obliged to take in the time of storms or when meeting with an accident that obliged it to lay up some place for repairs; you mean the straight cut?

Mr. Adcock: The ordinary course.

Mr. Wilkerson: In fair weather.

Mr. Adcock: Simply in a general way, the ordinary course so that it can be followed through.

A. The boat passes out of the St. Clair Flats Canal and through the dredged cut, which is something less than two miles in length into the deep water in the middle portion of Lake St. Clair. Then it passes in an almost straight line—

Q. In a general way, how deep is that water in the middle?

A. The water runs about 3½ fathoms, it is about 21 feet below the reference plane of this chart.

Q. The reference plane is what?

A. The reference plane of this chart is elevation 575.16 above sea level, which is about a foot and a half above the lowest monthly mean water as indicated on this chart.

The boat then passes into what is known as the Grosse Point Channel, which is six miles or five miles in length, perhaps, which is dredged through the shoal at the lower end of Lake St. Clair.

Q. Is the Grosse Point Channel indicated by any terms on that map?

A. The Grosse Point Channel is indicated by the white channel through the blue at the lower end of Lake St. Clair. It lies just north of a deep blue patch indicated as Grosse Point dumping ground, which is where material from the channel was wasted at the time the channel was built or constructed. And that takes them into the head of the Detroit River,

in the vicinity of Windmill Point and Isle Lopesch, which has been translated in the vernacular into Peach Island.

Q. At that point you enter the Detroit River?

A. The Detroit River.

Q. Which is shown on a similar chart entitled "Detroit River," Williams' Exhibit 9. That shows the Detroit River, does it, Mr. Williams?

(Chart shown witness marked Williams' Exhibit 9, March 18, 1913.)

A. That shows the Detroit River.

Q. From the head of St. Clair?

A. From the foot of Lake St. Clair at Windmill Point down past Belle Isle, City of Detroit, turning to the southward, passing by numerous channels, past Fighting Island and Grosse Isle to the region known as the Lime Kilns or Ballard's Reef, which constitutes the line of demarcation between Lake Erie and the river.

Q. How is the depth of the water indicated there?

A. The depth of the water is indicated on this chart in feet, in all cases.

Q. Both in the blue and the white?

A. Both in the blue and the white; the white indicating depth above 18 feet below the reference plane. The reference plan of this chart is 573.11, which is about 2½ feet above the lower recorded monthly mean as indicated on the chart.

Q. What do the new charts refer to?

A. In the right-hand portion of this chart is shown the Lower Detroit River to a larger scale, but this is more clearly shown on another chart.

Q. Entitled "The Lower Detroit River"?

A. Yes, entitled "The Lower Detroit River."

Q. What is the width of the Detroit River above Fighting Island?

A. Well, it is from 2,200 to 3,000 feet at most places.

Q. What is the width of the channel at Belle Isle, to the right of Belle Isle?

A. Opposite Belle Isle is a little over 2,000 feet wide on the Canadian side. It is considerably wider on the American side, but the channel is not so deep, and it is not used for navigation except by boats having local freight to take on or deliver at the docks along the front of Detroit, above the foot of Belle Isle; and by some passenger boats.

Q. So that the course of the boat would be on the Canadian side of Belle Isle?

A. Yes, passes to the south of Belle Isle.

Q. Then it would follow the channel down from Belle Isle to Fighting Island?

A. Follows the channel from Belle Isle to Fighting Island, passes to the westward of Fighting Island, to the eastward of Grosse Isle; then down through the Lime Kilns, or now through the Livingstone Channel into Lake Erie at Bar Point.

Q. I show you a chart here entitled "Lower Detroit River," which I ask to be marked Williams' Exhibit 10. I will ask you to state what that chart shows?

(Chart shown witness marked Williams' Exhibit 10, March 18, 1913.)

A. That chart shows that portion of the Detroit River lying to the eastward of Grosse Isle, from a point about a mile and a half above the head of the Livingstone Channel to Lake Erie. It is designated "Lower Detroit River," showing Livingstone Channel.

Q. From Stony Island down, what course would the boats follow generally, the ordinary course?

A. Down-bound boats at the present time are supposed to use the Livingstone Channel, which goes almost directly south from a point a short distance above Stony Island, while the up-bound boats take what is known as the Amherstburg Channel, or was formerly called the Lime Kiln Channel, which is to the right of Bois Blanc Island.

Q. Where is Ballard's Reef shown, if at all, on that map, that chart?

A. Ballard's Reef is shown at the top of this map. It is marked "Ballard's Reef" in the line of the main channel.

Q. And where is what is called the Lime Kiln Crossing?

A. The Lime Kiln Crossing is pretty nearly opposite Stony Island, a little bit to the south. It does not seem to be marked.

Q. Well, what points does it cover, can you indicate on the map?

A. The Lime Kiln is represented almost as being in the range of river that is covered by the coffer dam of the Livingstone Channel, which is indicated here parallel to the side of the main channel.

Q. Do you know how the elevation of Lake Erie compares with the elevation at the Lime Kiln Channel, what relation they have?

A. Well, ordinarily the elevation of Lake Erie is slightly lower than that at the Lime Kiln. I think there is about a fall of possibly, ordinarily, something around five inches.

Q. Is there a gage at Amherstburg, has it been maintained for some years?

A. There is a gage maintained at Amherstburg, and at times a gage has been read known as the Lime Kiln gage, which is opposite about the middle of the Lime Kiln or the lower end of it; also there have been numerous other gages at different times located along the river here; one at Mamajuda Light, which is at the upper end of this particular chart, which has been observed at times.

Q. Do you know the widths of the Lime Kiln channel as it exists today, at the present time?

A. The Lime Kiln Channel at the present time is 600 feet wide in its narrowest portions.

Q. That is the channel that the down-bound boats take?

A. No, that is the up-bound at present. It is the old channel.

Q. And the Livingstone Channel, what is the width of that?

A. The Livingstone Channel is 300 feet wide in its narrowest section, which is through that part of the rock that was excavated in the wet. Through the rock which was excavated within the dry, within the coffer dam, it is 450 feet wide, and down in the soft material it is widened to—I think gradually widens to about 1,200 feet.

Q. Will you indicate on the map where it was excavated in the soft and in the wet, and where the coffer dam is?

A. The coffer dam extends from a point practically opposite the upper end of Stony Island south for a distance—south, or down the river, for a distance of about 6,000 feet. Then comes the rock section which extends from this point—

Q. That was excavated in the wet?

A. That in the coffer dam was excavated in the dry. The lines of the coffer dam are shown here extending from Stony Island down to the—

Q. To a point indicated by—

A. Indicated by Light No. 6, Lights Nos. 5 and 6, which are on the west and east sides of the Livingstone Channel respectively, at the foot of the coffer dam.

Q. Then how far does that portion of the channel extend, which was excavated in the wet that you mentioned?

A. In the rock?

Q. In the rock.

A. That extends from the foot of the coffer dam to a point practically opposite Bar Point, and has a length of about 3½ miles. We then come to the portion which was excavated in earth, which extends for another four miles about, or 3¼, into the lake.

Q. Before the Livingstone Channel was constructed, was

that portion of it that is now Livingstone Channel earth or water except where it was excavated?

A. It was water, but in many places quite shallow. At some points the water was not over four feet deep, at ordinary stages through the section where the channel now has been excavated.

Q. I show you a similar chart here which is entitled "Lake Erie," and ask that it be marked Williams' Exhibit 11 of this date. In a general way what does that chart show?

(Chart shown witness marked Williams' Exhibit 11, March 18, 1913.)

A. That chart while showing primarily Lake Erie also shows the foot of Lake Huron, the St. Clair River, Lake St. Clair and the Detroit River, to a rather small scale, but indicating their relative positions with reference to Lake Erie.

Q. How is the depth indicated on that?

A. The depth is indicated upon this chart in fathoms in the white and in feet in the blue.

Q. Now, will you indicate the ordinary course of boats going to Cleveland from the Detroit River, after they pass through the Detroit River?

A. Coming out of the Detroit River the boat bears a little south of east and passes through the passage between Pelee Island and Point Pelee and then bears directly into Cleveland Harbor.

Q. Is the Welland Canal indicated on that map?

A. Yes, the Welland Canal. This map also shows the Niagara River and the upper end of Lake Ontario. It shows the Welland Canal starting at Port Coburn on Lake Erie, and extending through to Port Dalhousie on Lake Ontario. It is located to the westward of the Niagara River.

Q. Do you know in a general way the freight that is carried to and from Buffalo or other harbors about Lake Erie?

A. I don't know the exact magnitude of freight that is carried to Buffalo. It is made up now largely of package freight and some grain. But the transportation of grain on the Great Lakes has been decreasing of late years, so that it is of less importance than it was some years ago.

Q. I show you a chart entitled "Buffalo Harbor," similar to the charts that have been introduced, and ask that it be marked Williams' Exhibit 12. What is indicated on that chart?

(Chart shown witness marked Williams' Exhibit 12, March 18, 1913.)

A. This chart shows the lower end of Lake Erie and the

Niagara River as far down as Niagara Falls. It also shows the start of the Erie Canal, bearing eastward from the river at Tonawanda.

Q. How is the depth indicted there?

A. The depth in this case is indicated in feet, both in the white and in the blue.

Q. What traffic is there on the Niagara River?

A. It is very insignificant, mainly passenger traffic except that which passes into the Erie Canal which really is not in the river.

Q. Do you know the depth of the Erie Canal?

A. The Erie Canal is being developed for barges 12 feet in depth.

Q. And the Welland Canal you stated to be what?

A. About 14.

Mr. Wilkerson: What do they call that canal? They are reconstructing it, aren't they?

A. New York State Barge Canal.

Mr. Adcock: I show you a chart here entitled "Niagara River," which has been marked Williams' Exhibit 13 of this date, and ask you to state what that shows.

(Chart shown witness marked Williams' Exhibit 13, March 18, 1913.)

A. That shows the Niagara River from the pool above the falls to Lake Ontario, and a small portion of Lake Ontario at the outlet of the river. The depths are marked in feet, both the white and the blue.

Q. I show you a similar chart entitled "Lake Ontario," which I ask to be marked Williams' Exhibit 14, and ask you to state in a general way what it shows.

(Chart shown witness marked Williams' Exhibit 14, March 18, 1913.)

A. This map shows Lake Ontario with the lower end of Niagara River and the upper end of the St. Lawrence River. The depths on this chart are in fathoms in the white, in feet in the blue.

Q. Are there any canals shown on that chart?

A. It also shows the Welland Canal, or a portion of it, that is all. It does not reach down far eough to catch the St. Lawrence Canal.

Q. Do you know what the character of freight is that is carried on that lake?

A. Mainly package freight.

Q. And from points—

A. From port to port.

Q. From port to port on the lake?

A. On the lake.

Q. I show you a chart here entitled "Chart No. 6, St. Lawrence River"; I ask that it be marked Williams' Exhibit 15. Will you indicate what that chart shows in a general way?

(Chart shown witness marked Williams' Exhibit 15, March 18, 1913.)

A. That chart shows the upper end of the St. Lawrence River, or what might almost be called the lower end of Lake Ontario, although it is really a part of the river. It represents a portion of the famous Thousand Islands. The soundings on this chart are in feet, both in the white and the the blue.

Q. As they are indicated by figures?

A. As indicated by figures. This does not reach yet to the head of the canal system.

Q. I show you another chart here which is entitled "Chart 5, St. Lawrence River," to be marked Williams' Exhibit 16. What does that chart show in a general way, Mr. Williams?

(Chart shown witness marked Williams' Exhibit 16, March 18, 1913.)

A. This chart shows a section of the St. Lawrence River from a point above Alexandria Bay down to Chippewa Point. This is still in the navigable portion of the river.

Q. At all points?

A. At all points.

The depths are given in feet both in the white and in the blue.

Q. I show you another chart here entitled "Chart 4 St. Lawrence River," which I ask to be marked Williams' Exhibit 17. What does this chart show?

(Chart shown witness marked Williams' Exhibit 17, March 18, 1913.)

A. This shows a portion of the St. Lawrence extending from Chippewa Point to about four miles below Brockville. The depths are indicated in feet both in the white and in the blue.

Q. I show you another chart here which is entitled "Chart 3, St. Lawrence River," to be marked Williams' Exhibit 18. State in a general way what this chart shows.

(Chart shown witness marked Williams' Exhibit 18, March 18, 1913.)

A. This chart shows a portion of the St. Lawrence River from a point about eight miles above Ogdensburg to a point about a mile below the Galop Island. We now come to that portion of the St. Lawrence River which is only half navigable. That is, boats may travel it in one direction but not in the

other. And we then get into the artificial channels along the Canadian side of the river which permits the return of boats which have passed down through the main stream.

Q. What channel is that, it is called the Northern Channel, is it?

A. The name is not on it here. It is the north channel, but that is not the canal. There are no locks there.

Q. How far is Ogdensburg from Lake Ontario, the foot of Lake Ontario in a general way?

A. About 67 miles.

Q. Is there any gaging section on the St. Lawrence River at or near Ogdensburg?

A. About 15 miles below at point Three Points which is not shown on this chart, there is a gaging section.

Q. Can you indicate about where that is?

A. Well, it will be on the next chart.

Q. Is there any gaging point—is there an Oswego gage?

A. Oswego gage is out in Lake Ontario, but the gage at Ogdensburg was used as the reference gage in the gaging of the St. Lawrence River.

Q. I show you chart marked "Chart 2, St. Lawrence River," which may be marked Williams' Exhibit 19 of this date. Will you describe that in a general way?

(Chart shown witness marked Williams' Exhibit 19, March 18, 1913.)

A. This shows the St. Lawrence River from the head of the Galop Canal down to Weaver's Point.

Q. Was there a gage section on the St. Lawrence River? Can you indicate where that was on this map?

A. That was in the vicinity of point Three Points, which is about a mile and a half below the Village of Iroquois on the Canadian side. That is one of them.

Q. I show you another chart here entitled "Chart 1, St. Lawrence River," which may be marked Williams' Exhibit 20 of this date. Will you describe that in a general way?

(Chart shown witness marked Williams' Exhibit 20, March 18, 1913.)

A. This shows the St. Lawrence River from Weaver's Point to St. Regis Island, and includes the Farron Point Canal, the Cornwall Canal, and gets us to the upper end of Lake St. Francis.

Q. Have the channels of the St. Mary's River, and the St. Clair and Detroit Rivers, been improved at any time by the United States Government?

A. Yes. These improvements have extended over a period

beginning back in the fifties, to date, and work is going on now, or was until the winter interfered with it.

Q. What was the original depth of the water in the St. Clair and Detroit Rivers before the improvements were commenced?

A. The original depths of the St. Clair and Detroit Rivers at the controlling points was about eight feet on St. Clair Flats; that is the foot of the St. Clair River, and about the same at the Lime Kiln Crossing or Ballard's Reef in the Detroit River. I mean by "controlling points" the points which regulated the depths or draft of boats that could pass up or down the river, passing through the system. That was the shallowest place in the river; those are the controlling points.

Q. In other words the shallowest place in the St. Clair River was at the St. Clair Flats, at the head of Lake St. Clair?

A. Lake St. Clair.

Q. At that time?

A. Yes.

Q. Then the controlling point or the shallowest place in the Detroit River, was at the Lime Kiln Crossing and Ballard's Reef?

A. Yes, in the region through the Lime Kiln.

Q. When was the first improvement made at those points if you remember?

A. The St. Clair Flats Canal was constructed about the time of the Civil War, or before; completed in 1858, giving a depth of 12 feet. Then between 1857 and 1871 it was deepened to 13 feet, and following that improvements were made both at the St. Clair Flats and the Lime Kiln, deepening the water to 16 feet. These improvements were practically completed in 1876.

Q. Then what was the next improvement made in the depth?

A. The next improvement was the removal of the bar at the mouth of Black River, at Port Huron.

Q. At what time was that?

A. Which was where the work was carried on between 1874 and 1879; and in 1876 the further improvement of the Lime Kiln Channel designed to give a depth of 20 feet of water was begun, which improvement was completed in 1891.

The 1876 enlargement contemplated a widening of the channel as well as deepening, and the work seems to have been carried on in a more or less desultory sort of way at first.

Q. In a general way, what proportion of the improvements have been made subsequently to 1890 and before, in those two rivers, the St. Clair and Detroit?

A. Well, something more than 20 times as much material

has been removed from the Detroit and St. Clair Rivers since 1890 as had been removed up to that time.

Mr. Wilkerson: What do you mean by "removed"?

A. Removed from its original place.

Q. And put in some other place in the river?

A. Put some place else; may have been put in the lake or the river.

Q. You mean the total quantity moved?

A. I mean the total quantity moved.

Q. Without regard to where it was put?

A. Without regard to where it was put.

Mr. Wilkerson: You have the figures on how much went back in the river at some other point?

Mr. Adcock: And how much washed out; yes, we have an exhibit on that which will show exactly.

Adjourned to 10:30 a. m. March 19, 1913.

March 19, 1913—10:30 a. m.

GARDNER S. WILLIAMS resumed the stand, testified further as follows:

Mr. Adcock: When was the United States Lake Survey established, Mr. Williams?

A. Well, the old original United States Lake Survey dates from somewhere in the 'fifties, I believe, and its work was substantially completed somewhere around the late 'seventies or 1880. The Lake Survey office was revived, I believe, about in the 'nineties. There was a period of a year or two, I think, when there was no work done under the Lake Survey, so-called; but the work of the Lake Survey was taken up again and appears prominently in the reports of the Chief of Engineers for the year 1900.

Q. What has been the scope of their work, briefly?

A. Primarily the purpose of the Lake Survey—

Q. I mean in the later years.

A. The same statement covers both. Primarily the purpose of the Lake Survey was to provide adequate information as to the channels, possibilities of navigation on the Great Lakes and their connecting waters; and the scope of this was extended to involve or include measurements of the outflow of the Great Lakes and the recording or the collection of observations of the elevations of water in the Great Lakes at various points. So that at the present time the scope of the Lake Sur-

vey work embraces practically everything in the way of hydrography of the Great Lakes; that is, the preparation of charts for navigators and charts for general information as to the depths and areas and contours of the Great Lakes, and also in regard to meteorological conditions, the discharge, and the rise and fall of the lakes and their connecting waters.

Q. The term "hydrography of the Great Lakes" has been used by you, also the word "hydraulics." Will you define those two, with reference to the Great Lakes?

A. The term hydrography is of kindred derivation to the word geography with which we are all familiar; geography being the depicting of the characteristics of the earth or of the land, and hydrography being the depicting of the characteristics of the water. Hydrography has been extended to include also questions of measurements of water flowing and so on, though originally the word was intended to cover simply the mapping of the conditions, or the representation of the conditions, examination into such conditions as would be shown upon a map, or described in some such way.

The term hydraulics is used to designate that branch of physical science which has to deal with the stability, equilibrium and motion of fluid bodies. As we apply it in this case, we confine it to the laws of the motion and equilibrium of water, leaving out the lighter fluids.

Q. What was the scope of the work of the International Waterways Commission, and the Board of Engineers on Deep Waterways?

A. The scope of the Board of Engineers on Deep Waterways was to investigate and report upon a plan for a deep waterway to connect the Great Lakes with the Atlantic Ocean. That report was made in furtherance of the earlier report of the so-called Deep Waterways Commission, which pointed out the possibilities of such a connection and the advantages which might accrue from it.

In connection with that work they also investigated and reported upon the feasibility of regulating the levels of the Great Lakes for the maintenance of deeper channels therein, by means particularly of a regulating dam or weir to be placed near or at the foot of Lake Erie.

The International Waterways Commission was appointed to further investigate the question of the regulation of the lakes, with particular reference to the international complications which might be involved, and among their instructions was that if they should find it advisable to regulate the levels of the lakes thereby involving international action, that

they should present a draft of a treaty to cover the points which would have to be adjusted between the United States and Canada.

The Commission had also various other matters appertaining to boundary waters referred to it, and was delayed for some time in taking up the matter of the regulation of Lake Erie; but in 1910 they published a report upon that subject which contains the computed discharges of all the outlets of the Great Lakes, and tabulated discharges of the St. Mary's, Detroit, Niagara and St. Lawrence Rivers. These discharges are based upon the observations for discharge which have been made under the direction or by the Lake Survey office and upon the records of lake elevations as recorded in that office. The assumptions and computations of discharge were, however, made entirely independent of the Lake Survey office, and are an independent deduction from the data obtained by the Lake Survey office. That report is known as the report upon the regulation of Lake Erie, report of the International Waterways Commission upon the regulation of Lake Erie, and is dated 1910.

Since the finishing of that report the Commission has been engaged in the demarcation of the international boundary line through the lakes, and upon some further studies upon the possibility of raising the level of Lake Erie by the construction of a dam elsewhere than at the foot of Lake Erie.

Q. You spoke of the regulation of Lake Erie. Will you state just what that work contemplated, its effect and so forth?

A. The original contemplation, which is due to a suggestion of the late Mr. George Y. Wisner, who was a member of the Board of Engineers on Deep Waterways, was to construct at the foot of Lake Erie a submerged dam, and a series of sluice gates, so that when Lake Erie was at a high stage the gates might be opened.

Mr. Wilkerson: Is this contained in some proceeding of the Commission?

Mr. Adcock: No, he is simply describing the regulation works as they were contemplated.

The Witness: So that when Lake Erie was high, or reached near the high water mark, the gates could be opened and additional water discharged, while as Lake Erie fell the gates would be closed, and with the obstruction which was provided by the submerged dam, the lake would be prevented from falling to its low water plane. This of course would maintain the lake at a more constant elevation, and at a

higher elevation than it has occupied on the average under the present conditions.

It was contemplated to regulate the surface of Lake Erie within average range of about two feet, if I remember correctly, and at a plane somewhat higher than the present low water plane; I think about two feet higher. The raising of the water of Lake Erie would reduce the fall in the Detroit River, thereby decreasing its discharge and raising Lake St. Clair, which in turn would decrease the fall in the St. Clair River and thereby raise Lake Huron, the effects being probably about one-half as much in St. Clair and about one-fourth as much in Lake Huron.

Mr. Wilkerson: Is this your conclusion or that of some one else?

A. It is mine; coincides with the Board's practically.

Mr. Adcock: When were discharge measurements made by the United States Lake Survey of the St. Clair River?

A. The earliest ones were made in the 'sixties, but they may be neglected, as the means by which they were made were so crude and the methods pursued were so inaccurate that although for many years they were the best we had and the only ones we had, they are to be entirely superseded by the results obtained from the later, more precise determinations or work of the Lake Survey, which began with the measurements of the St. Clair in 1899 and continued through 1902, and was taken up again in 1908 and continued through 1909 and 1910.

Q. How many discharge measurements were made, if you remember, in 1909 and 1902?

A. I don't think I can recall and I do not have the memoranda at hand. That has, however been testified to by the complainant's witnesses.

Q. For what period during each year did they cover?

A. In the main they covered the open season of navigation, although some measurements were made during the winter.

Q. That is on the St. Clair River?

A. On the St. Clair River.

Q. Where were those measurements made?

A. Those measurements were made at what is known or designated as the Section Dry Dock on the St. Clair River about five miles below the foot of Lake Huron.

Q. Can you designate on the map or chart entitled "St. Clair River," Williams' Exhibit 7, where that measurement was made?

A. Well, it was made in the vicinity of the legend "Reid

Wrecking Company Dry Dock Abandoned," which is found printed across the St. Clair River.

Q. Were there measurements made at any other place in the river during that period?

A. There were measurements made during the winter at a point further up stream, in fact within I think about a mile or less of the foot of Lake Huron.

Q. Do you remember what winter that was?

A. That was in the winter of 1900 and 1901, I believe.

Q. Were those measurements made at the same time that the measurements were made at the Dry Dock Section?

A. No, they were not simultaneous. There were measurements made at the Dry Dock Section during that winter, and then the party went from the Dry Dock Section to this upper section, and later returned to the Dry Dock.

Q. Were there any measurements made in the St. Clair River at the same time measurements were made in the Dry Dock Section?

A. No, there were no simultaneous measurements at two stations in the St. Clair River, so far as I have been able to discover.

Q. Was there a Gorge Section there, what they call the "Gorge Section"?

A. There is a section which has later been designated as the Gorge Section, which is about the narrowest section of the river and is about half a mile below the foot of the lake. Measurements were made at this section in 1908, 1909 and 1910, but no measurements were made there during the earlier period of gages.

Q. Were there any measurements made on the Niagara River?

A. (No answer.)

Mr. Wilkerson: These later measurements you have referred to were not before the International Waterways Commission, were they?

A. No, unless it is possible that the 1908 measurements may have been used.

Mr. Adcock: That is by the International?

A. By the International Waterways Commission. I don't know that they were, and I think it probable that they were not, but it is possible that they might have been.

Q. Were any measurements made of the discharge of the Niagara River by the United States Survey?

A. Yes, there were measurements made at the Niagara River by the United States Lake Survey at the request, first,

of the Board of Engineers on Deep Waterways, and subsequently additional measurements were made by the Lake Survey itself. Prior to these measurements, there had been some others made either by the Lake Survey or by the U. S. Engineer office at Buffalo, which appear to have been made in the early 'nineties. The reliable measurements, or the most reliable measurements of discharge of the Niagara River are, however, those made since 1899.

Q. Were they made during the period from 1899 to 1902, the measurements on the Niagara?

A. They began in September, 1898, and continued into 1900.

Q. Where were those measurements made, referring to Williams' Exhibit 12 entitled "Chart Buffalo Harbor"?

A. Those measurements were made from the International Bridge, so-called, which is about 2½ or 3 miles, say 3 miles, below the foot of Lake Erie, and also at another section in that vicinity about 2,000 feet further down stream.

Q. That was called what?

A. That was called the "Open Section", the former being designated as the "Bridge Section" in the records.

Q. They are designated on the map here, the first one is mentioned as International Bridge.

A. International Bridge; the location of the second one is near the foot of Squaw Island.

Q. Will you state how discharge measurements are made by the use of the current meter?

A. The process of measuring discharge by means of the current meter is, first, to make a measurement of a section, a cross-section of the stream to determine the area of the wetted portion, or the area of the body of water passing the point in question.

Points are then selected at intervals across the stream at which measurements are taken with the current meter, by lowering it from the surface to the bottom and occupying various positions as it passes down for a sufficient length of time to enable the meter to take up and repeat the velocity of the current. The number of points that are observed in a vertical, of course depends upon the degree of precision with which it is desired to get the changes of velocity from point to point. But common practice has been to make use of an observation at every tenth of the depth. The average velocity indicated by the meters at the several positions, when adjusted for difference of distance between successive positions,

if there be any, is taken as the mean velocity for that vertical, and a second or another vertical is observed in the same way.

In this way a series of readings of the velocity of the current is obtained at numerous points throughout the cross section, generally arranged in a series of vertical columns. The mean velocity of the vertical, when multiplied by the sum of half the areas between that vertical and the one next to it on either side is assumed to represent the velocity through that portion of the stream; or the mean velocities of the verticals may be plotted and a curve drawn through the observations indicating the total velocity which, when the mean ordinate of the area enclosed between this curve and the base is measured, gives the mean velocity of the water; and this in turn, when multiplied by the area of the cross section would give the discharge. For rapid gauging, it is customary after having examined the distribution of velocities through the vertical to select certain points which are called "index points" which bear a fixed relation to the average velocity of the vertical, so that in making a gauging of the stream, after the preliminary work has been done, it is only necessary to occupy one or two points in a vertical in order to get a measurement, instead of having to occupy all ten or more, as the case might be. In that case the measurement of the discharge of the river comprises the occupying of one or more points on each vertical across the stream, or if conditions warranted it, the number of verticals might be reduced, and certain controlling ones simply observed.

Q. Is it more difficult to measure the discharge of a large river than a small river?

A. Very much.

Q. Why is that?

A. Principally because of the difficulty of knowing what the condition of your measuring apparatus is. In a large river it is impossible to see it. In a small stream you can generally see the instrument and know in which way it is pointing, and whether there is any obstruction upon it, and what its condition is generally; whereas in a deep stream it is out of sight, and you can only judge by the information that is clicked to you through the telephone.

Q. Would that be true of a stream of the depth of the St. Clair River for instance, and Niagara?

A. Oh, yes, certainly.

Q. St. Lawrence?

A. There is a further difficulty in measuring in the deep stream as compared with a shallow one that whereas in the latter it is possible to hold the meter rigidly at a position by means of a rod, so that its position is exactly known, in the deep stream the meter has to be suspended upon a cord or cable or wire, and it then becomes a matter of some uncertainty as to just where the meter is, and in what direction it is pointing.

Mr. Wilkerson: I just wish to suggest that you have him define a little more definitely what you mean by the term "difficult", whether you mean difficult in the way of making the observation, or the possibility of a precise result after the difficulties are overcome?

Mr. Adcock: I will get to that in time.

Mr. Austrian: Just let him explain what he means by "difficult". You say "difficulty in measuring"? What do you mean by that?

A. I use that as applied to the difficulty of obtaining precise results. It also applies to the mechanical difficulties, the physical difficulties. It is very much easier to measure a small stream than it is a large one.

Mr. Adcock: Do you know how wide the St. Clair River is or was, at the time these gaugings were made at the Dry Dock Section and the Gorge Section?

A. The Dry Dock Section was somewhere in the neighborhood of 2500 feet, and the Gorge Section I think was about 1800 feet.

Q. How far apart were the verticals?

A. I think originally every 100 feet.

Q. In a river of the velocity of the St. Clair River, how often would the electric current make a break to indicate the revolutions of the current meter?

A. That would depend altogether on the type of meter used, and its rating. The revolutions per second will probably be about 2/3 of the velocity per second with the type of meters that were used, so that with a velocity of three feet a second, you would have about two revolutions per second or 120 a minute. And there would be a break at each revolution.

Q. And the way those 120 revolutions would be counted, would be by the ear, as we hear, the same way a doctor counts the pulse?

A. Yes. They do have recording devices, which record on a recording mechanism.

Mr. Wilkerson: How about the Lake Survey?

A. I think the Lake Survey has used the recording devices almost entirely, so that the counting is done mechanically.

Mr. Adcock: You mean it may be done mechanically?

A. It may be done mechanically and that was the practice.

Q. In the Lake Survey?

A. In the Lake Survey.

Q. Is the accuracy with which the current meter determines or records the velocity dependent in any way upon the rating of the meter?

A. Entirely. That is, that is the only means we have of knowing the number of revolutions of the meter wheel, which corresponds to any velocity.

Q. In a large river like the St. Clair, does the velocity change from time to time?

A. It does, very rapidly.

Q. Is the velocity in different portions of the river different?

A. It is.

Q. That is at different depths?

A. Both at different depths and at different points across the river.

Q. So the velocity at one-tenth depth or two-tenths depth to one vertical might change in how short a time if at all?

A. Why it would change somewhat in a few seconds. That is, it is vibrating, pulsating all the time.

Q. Would the current meter wheel be running continuously at a certain rate, or would there be pulsation or changes?

A. According to my own observation I never have found a current meter wheel to run regular in flowing water. There is always pulsation present.

Mr. Wilkerson: You are speaking now of two kinds of changes of velocity, one at a given point?

A. Yes.

Q. At the cross section; and the other as between the various points in the same cross section?

A. Yes, and my last statement refers to the changes at a certain point.

Mr. Wilkerson: At a certain point in the cross section. That is the one with reference to which he uses the term "pulsation"?

The Witness: Yes.

Mr. Adcock: Have you been present at the taking of the testimony of the complainant?

A. I was present at the taking of the testimony of all the witnesses of the complainant except Colonel Townsend and Mr. Coulby, and one day of Mr. Wheeler.

Q. You have read the testimony, have you not?

A. I have read the testimony of all the witnesses, and reread that of several.

Mr. Adcock: These documents (referring to same) are the ones that were offered in evidence.

Mr. Wilkerson: If you have any papers that have been obtained from the Government records that you want to use, you may have them marked, offer them and use them in any way you please, for the purpose of this examination, providing that we reserve the right to check up on them and verify them to determine if they are inaccurate in any way, or if we conceive they are not complete to add to them such other portions of the record as we claim are essential to make them complete.

Mr. Adcock: There are certain records or measurements which offered, in evidence, by the complainant.

The Witness: No, they were not offered in evidence; they were identified at the request of the defendant.

Mr. Adcock: They were identified and they were the basis of those exhibits of yours, weren't they?

Mr. Wilkerson: There are some measurements which were produced by the Government in connection with the examination of the Government's expert witnesses. They were identified as the figures and tables upon which the computations of the Government's witnesses were based, and they were produced for inspection of the experts and counsel for the defendant, at their request. And they are here in this case to be used by both sides for whatever purposes they may be legitimately used in this case. They are not formally offered and they may be treated—

Mr. Adcock: As though they were in evidence?

Mr. Wilkerson: As if in evidence, at the hearing.

Mr. Adcock: They are in evidence now, and so that they may be identified, I will ask that the Commissioner mark them.

The Witness: They have been marked once.

Mr. Wilkerson: Are those all the tables we produced?

Mr. Adcock: I think so.

Mr. Wilkerson: Are you using all that we did produce?

A. Yes.

Q. And in addition to that you are using some other which you have since obtained?

A. In addition to that I am using some others I have since obtained.

Q. From the same source?

A. From the same source.

Q. As the ones which you produced?

A. (No response.)

Mr. Adcock: Referring to the records of measurements which Mr. Wilkerson has spoken about, I have here a paper entitled "United States Lake Survey, Discharge Measurements Dry Dock Section St. Clair River 1899 to 1900 to 1902"; also record of discharge measurements made in 1908, consisting of seven sheets, which will be marked Williams' Exhibit 21.

(Whereupon documents above referred to were marked by the Commissioner Williams' Exhibit 21.)

Mr. Adcock: This was identified by complainant's witness, Shenehon, in File 6, page 14, being page 472 of the continuously paged record.

I now submit to the Commissioner for identification (of the series of tabulations above referred to) seven sheets of tabulations, the first sheet being entitled "United States Lake Survey, Hydraulics of St. Clair River, mean slope for period November to December, 1908"; the second sheet being entitled "United States Lake Survey, Hydraulics of St. Clair River; Summary of Discharge Measurements Section Gorge, Sherman Moore, Junior, Engineer, April, 1909"; the third sheet being entitled "Hydraulics of St. Clair River, Summary of Discharge Measurements Section Dry Dock, Sherman Moore, Junior, Engineer, April 1909"; the fourth page being entitled "United States Lake Survey. Hydraulics of St. Clair River, Discharge of St. Clair River Section Gorge, Sherman Moore, Junior, Engineer, March, 1910"; the fifth sheet being entitled "United States Lake Survey. Hydraulics of St. Clair River; Discharge of St. Clair River Section Gorge, Sherman Moore, Junior, Engineer, March, 1910"; the sixth sheet being entitled "United States Lake Survey, Hydraulics of St. Clair River, Discharge of St. Clair River Section Dry Dock, Sherman Moore, Junior, Engineer, March, 1910;" and ask that all these be marked Williams' Exhibit 22, being a series of tabulations not heretofore identified in this case, but furnished by the United States Lake Survey.

(Tabulations above referred to were marked by the Commissioner Williams' Exhibit 22.)

Mr. Adcock: I hand to the Commissioner for identification a file of blue prints furnished by the Lake Survey office, each of which is marked "U. S. Lake Survey", and being tables comprising 37 sheets, the same being blue prints accompanying the report of Junior Engineer W. T. Richmond, on the hydraulics of the St. Clair River under date of April, 1911, not heretofore identified. To be marked Williams' Exhibit 23.

(The 37 sheets above referred to were marked by the Commissioner Williams' Exhibit 23.)

Mr. Adcock: I now submit to the Commissioner for identification a series of five sheets of records of discharge measurements entitled "Summary of Discharge Measurements International Bridge Section and Open Section of the Niagara River for the years 1898, 1899 and 1900", each sheet being identified by the signature of F. C. Shenehon, United States Assistant Engineer 1906. These sheets have been identified by complainant's witness Shenehon, and are of the series referred to by Mr. Wilkerson. I ask that they be marked Williams' Exhibit 24.

(The five sheets above referred to were marked by the Commissioner Williams' Exhibit 24.)

Mr. Adcock: I submit to the Commissioner for identification two sheets containing records of discharge measurements of the St. Lawrence River, each sheet being entitled "Summary of Discharges, Three Points Section," covering the discharge measurements in 1900 and 1901; the sheets being also identified by the signature of F. C. Shenehon, Assistant Engineer, May, 1906. These were identified by complaintant's witness Shenehon. I ask that they be marked Williams' Exhibit 25.

(The two sheets above referred to were marked by the Commissioner Williams' Exhibit 25.)

Mr. Adcock: I submit to the Commissioner for identification a group of six tables or six sheets of elevations of the Great Lakes as follows: Superior, at Superior, Wisconsin, and Marquette, Michigan; Michigan, at Milwaukee, Wisconsin; Huron at Harbor Beach, Michigan; St. Clair at St. Clair Flats Canal; Erie at Cleveland, Ohio; Ontario at Oswego, New York; being duplicates of Exhibits D, E, F, G, H and I for identification, identified by complainant's witness Shenehon, the same being extended from 1908 through 1912, fur-

nished by the office of the United States Lake Survey. The original of 1908 was identified by witness Shenehon. I ask that these be marked Williams' Exhibit 26.

(The six sheets above referred to were marked by the Commissioner Williams' Exhibit 26.)

Mr. Adcock: I now submit to the Commissioner for identification two sheets of tables furnished by the United States Lake Survey, one giving the mean monthly elevation of the Detroit River at Amherstburg, Ontario, and of Lake St. Clair at Windmill Point; and the second giving the mean monthly elevation of the Detroit River at Fort Wayne. These have not been heretofore identified. To be marked Williams' Exhibit 27.

(The two sheets above referred to were marked by the Commissioner Williams' Exhibit 27.)

Mr. Adcock: I now submit to the Commissioner for identification tables of mean daily elevations of water surface of Lakes St. Clair and Huron for selected periods, such tables having been furnished in conformity to a request of the United States District Attorney by the United States Lake Survey, and not heretofore identified. To be marked Williams' Exhibit 28.

(Tables above referred to were marked by the Commissioner Williams' Exhibit 28.)

Mr. Adcock: I now submit to the Commissioner for identification a series of tables embracing 17 typewritten pages and one blue print of daily mean gauge elevations for Lake Erie at various points for selected periods, furnished in conformity with the request of the United States District Attorney by the United States Lake Survey, and the United States engineer offices on Lake Erie. To be marked Williams' Exhibit 29.

(Tables above referred to were marked by the Commissioner Williams' Exhibit 29.)

Mr. Adcock: I now submit to the Commissioner for identification a series of tables consisting of five typewritten sheets representing the mean monthly elevations of Lake Ontario, Lake Erie and Lake Huron, and mean daily observations of Lake Ontario at Oswego and Ogdensburg for selected periods. These were furnished in response to a request of the United States District Attorney by the United States Lake Survey. To be marked Williams' Exhibit 30.

(Five typewritten sheets above referred to were marked by the Commissioner Williams' Exhibit 30.)

Mr. Adcock: I now submit to the Commissioner for identification a series of two sheets showing the mean monthly and annual rainfall in inches on the drainage areas of the Great Lakes, for a series of years terminating with 1906, having been furnished in response to a request of the United States District Attorney by the United States Lake Survey and not heretofore identified. To be marked Williams' Exhibit 31.

(The two sheets above referred to were marked by the Commissioner Williams' Exhibit 31.)

Mr. Adcock: I now submit to the Commissioner for identification pages 2855 to 2883, being appendix FFF2 of the annual report of the Chief of Engineers for 1903, with charts and tables, being the report upon the outflow rainfall and evaporation of the Valley of the Great Lakes, prepared by complainant's witness Wheeler and identified and referred to by him in his testimony in this case. To be marked Williams' Exhibit 32.

(Pages of Appendix FFF2 above referred to were marked by the Commissioner Williams' Exhibit 32.)

Mr. Adcock: I now submit to the Commissioner for identification pages 90, 91 and 92 of the water levels of Lake St. Clair, to be marked Exhibits 33 A, B and C respectively; page 94, the water levels of Lake Erie at Buffalo breakwater to be marked Exhibits 33D; page 95, water levels of Lake Ontario at Charlotte, to be marked Exhibit 33E; page 101 of the discharge from Lake Superior to be marked Exhibit 33F; page 102 on the discharge from Lake Huron-Michigan to be marked 33G; page 103 of the discharge from Lake Erie from the Report of the International Waterways Commission on regulation of Lake Erie under date of 1910 to be marked 33H; page 104, discharge from Lake Ontario to be marked Exhibit 33I.

(The pages above referred to were marked by the Commissioner as already indicated.)

Recess to 1:30 P. M.

After recess—1:30 P. M.

GARDNER S. WILLIAMS, resumed the stand, and testified further as follows:

Mr. Adcock: Since the institution of this suit, Mr. Williams, have you made any further study than you have mentioned heretofore with reference to the hydraulics and hydrography of the Great Lakes?

A. I have made a very careful study of the evidence presented by the complainant, and of tables of reduced data, which have been furnished to me through the courtesy of the complainant, being derived from the original sources upon which complainant's testimony in regard to the discharge and effects upon lake elevations is based.

Q. Have you made any particular studies and deductions from the records of discharge measurements made on the St. Clair River, the Niagara River and the St. Lawrence River, which have been referred to?

A. I have.

Q. I show you here Williams' Exhibit 21 referring to discharge measurements Dry Dock Section St. Clair for certain years, and ask you to state in a general way what is shown by that exhibit?

A. This exhibit shows the record for the several gaugings of the St. Clair River between 1899 and 1908, exclusive of those made during the ice season and indicates the consecutive number of the measurement, the date of the measurement, the elevation of the water surface of Lake Huron at the time of the measurement, the elevation of the water surface at St. Clair Flats at the time of the measurement, the fall from Lake Huron to St. Clair Flats at the time of the measurement, the direction and velocity of the wind at the time of the measurement, and the discharge; and also arranged in groups of ten observations at similar stages, the stages being based upon the elevation of Lake Huron, the mean elevation of Lake Huron for the several observations in each group, the mean elevation of St. Clair Flats, the mean fall from Lake Huron to St. Clair Flats, and the mean discharge in cubic feet per second.

Mr. Shenehon: How many in each group?

The Witness: I said there were 10 in general. There are 10 in all groups of the observations for 1899, 1900 and 1902; and these groups are indicated by the letters from *A* to *U*

inclusive, there being 10 in all groups from *A* to *T* inclusive, and four observations in group *U*. These groups are also indicated by number, from 1 to 21, group 21 being that having but four observations. In the observations for 1901 there are four groups, Groups 1, 2 and 3, which are also designated as *V*, *W* and *X*, containing 10 observations each and Group 4, which is designated also as *Y* contains six observations

In the observations for 1908 there are two groups, one designated Group 1 or *Z*, which contains seven observations, and one designated Group 2 or Alpha, which contains eight observations.

Q. The elevation of Lake Huron is referred to there. Do you know at what point the gauging was made?

A. The elevation of Lake Huron referred to is understood by me from the testimony of the complainant to be at Harbor Beach. It has been my understanding that it is Harbor Beach.

Q. Do you know how the elevation indicated there, the Harbor Beach gauge, was derived?

A. It was not observed simultaneously with the discharge measurements in all cases. It might have been in some. Where it was not observed, it was derived from a gauge relation, first, between the gauge at the Grand Trunk Railroad Dock and Fort Gratiot, and then by a relation from Port Gratiot to Harbor Beach.

Q. Will you indicate on Williams Exhibit 7, Discharge of St. Clair River, where the Grand Trunk gauge is located, and the Fort Gratiot gauge?

A. (Referring to Exhibit 7) The Grand Trunk gauge is located within a mile of the foot of Lake Huron; I think a little less than a mile. The Fort Gratiot gauge is practically at the foot of Lake Huron, and is indicated on this chart by the legend "Fort Gratiot Light and Fog Whistle". The Harbor Beach gauge is some 60 miles I think up Lake Huron.

Q. Do you know when the Grand Trunk Gauge was read with reference to the time when the observation was made?

A. It was read I believe simultaneously—or continuously during the periods of observation, at frequent intervals, and through part of the observations I think a self-registering gauge was used there.

Q. When you speak of getting the Harbor Beach gauge from the relation between that and Fort Gratiot and Grand Trunk, just state how that was done.

A. Simultaneous observations of the water stage are

taken at two of the gauges in question, and by the relation thereby established from one to the other, the reading of one gauge or the mean reading of one gauge corresponding to the mean reading of the other is established, and that correction is then applied to the readings of one to get the reading of the other.

Of course it may be found that there is no mean correction, but that there is a change depending upon the change of elevation of the lake surfaces, in which case where the law of the change can be established, the corrections are made in accordance with that law; the difference possibly being greater for high elevations than it is for low ones.

Q. Do you know how long a time it took to make one gauging on the river at the Dry Dock Section, say?

A. As I remember the complainant's testimony it was about three hours.

Q. Have you made any study of the records of the observations in the three rivers which I have mentioned, or have you made any calculations to determine the accuracy or inaccacuracy of the observations and the results reached by the complainant?

A. I have so far as it has seemed to be possible from the information that has been at my disposal.

Q. Have you made any examination of the records of the observations, measurements and with reference to lake stage and so forth?

A. I have.

Q. I will ask you in a general way if the records of the measurements, discharge measurements of the Niagara and St. Lawrence Rivers are arranged in substantially the same manner as the records of the discharge measurements of the St. Clair?

A. They contain the similar information as to lake stage or lake elevation and discharge, wind. Of course in these observations there is no question of a gauge below the station, that is of another lake being involved other than the one at the head. Nevertheless the elevations of the lake, and of the gauge at the gauging section are given in these tabulations, and the observations are not grouped as the observations on the St. Clair, but this tabulation simply shows them in chronological order on the St. Lawrence and on the Niagara River, both.

Q. Based upon the records of these discharge measurements that have just been referred to, and upon the facts

which have been stated by the complainant's witnesses, have you reached any conclusions, or do you find any indications which would tend to determine the accuracy or inaccuracy of the observations made and the results reached by the complainant from such observations?

A. I do.

Q. I show you, Mr. Williams, certain tables, being marked 1 to 54 inclusive, and plates from 1 to 8 inclusive following in numerical order, and ask you to state what they are? They may be marked Exhibit 34, being Tables 1 to 54 and Plates 1 to 8, and I will ask you to state what that exhibit contains.

(The documents above referred to were marked by the Commissioner Williams' Exhibit 34.)

A. That exhibit embraces the computations or the reduced computations which I have made in determining the hydraulic questions which seem to me to be involved in this case.

Tables 1 to 17 inclusive deal with the examination of the precision of the Complainant's observations. Tables 18, 19, and 21 present the elevations of the water surfaces of the Great Lakes, Huron, St. Clair and Erie, and the falls between them and the relation of the fluctuations or changes of annual elevation of these lakes.

Tables 22 to 39 deal with the derivation of the increments of the St. Clair River.

Table 40 is a computation of the discharge of the St. Clair River from 1900 to 1907 by the use of the equations or the equation derived from the preceding tables.

Tables 41 to 43 deal with the increment and the discharge of the St. Lawrence River.

Table 44 deals with the fluctuation or annual change of stage of Lakes Erie and Ontario.

Tables 45 to 47 deal with the increment of the Niagara River.

Table 48 presents an estimated rainfall upon the drainage areas of the several lakes, based upon the rainfall records for Lake Superior at Marquette, for Lakes Michigan-Huron at Milwaukee and Detroit; for Erie and St. Clair at Detroit, Cleveland and Buffalo, for Ontario at Buffalo, Oswego, Rochester and Toronto.

Tables 49 and 50 present the average annual elevation of Lake Ontario and of Lake Superior; and Table 51 is a summary of the annual elevations and differences of elevation from lake to lake of Lakes Superior, Michigan-Huron, St. Clair, Erie and Ontario.

Table 52 is a further summary of similar information.

Table 53 represents the amount of material that has been dredged from the channels of the St. Clair River, from Lake St. Clair and the Detroit River, from 1870 to 1910, inclusive.

Table 54 presents the relative change of annual stage of Lakes Erie and St. Clair.

Plate 1 is a reproduction as accurately as it was possible to reproduce it by the services of an accurate draftsman of Complainant's Exhibit 1; the purpose of the reproduction being to get it to a size which would be convenient for reference in connection with the other data presented in these tables.

Plate 2 is a similar reproduction of Complainant's Exhibit 2. Plate 3 is a similar reproduction of Complainant's Exhibit 3. Plate 4 is a similar reproduction of Complainant's Exhibit 4.

Plate 5 is a representation of the increment for the St. Clair River as derived by the methods indicated in the reductions made by myself.

Plate 6 is a similar representation of the increment of the St. Lawrence, as similarly derived.

Plate 7 is a photographic reproduction of a portion of the chart of the head of the St. Clair River, said chart being one obtained by me from the United States Lake Survey office about 1897, which is stamped with the legend "Aids to Navigation corrected from information received to April 20th, 1892." To this chart has been added by me two parallel lines at the head of the river enclosing Fort Gratiot.

Plate 8 is from a chart of the same river, a duplicate of the one placed in evidence as Williams' Exhibit 7, which was obtained from the United States Lake Survey office in February, 1913, and by its stamp purports to be corrected to "December 26th, 1912."

On this chart there has also been drawn two parallel lines enclosing Fort Gratiot, which I believe to be in a position corresponding to those drawn on Plate 7.

Q. From what data and information were these tables compiled?

A. With the exception of Table 48 of precipitation, Table 53 on dredging, they have all been derived from the original tables furnished by the complainant through the office of the United States Lake Survey, or from one or two of the other United States engineers' offices along the Great Lakes, which were in possession of special information which had not at that time been transmitted to the Lake Survey office.

The table of estimated precipitation, Table 48, is made up from the published information in regard to precipitation which is to be found in the records of Government observations, including those which were collected by the Smithsonian Institution; those which were obtained while the Weather Service was under the United States Army, and those more accurate ones which have been presented by the work of the United States Weather Bureau as latterly constituted.

Table 53 showing the quantities of material dredged from the several channels of the St. Clair River, Lake St. Clair and the Detroit River has been compiled from the published reports of the Engineer Officers in charge of the River and Harbor District in which this work has been carried on, as presented in the annual reports of the Chief of Engineers of the United States Army from 1870 to date.

As to the plates, as already said, Plates 1, 2, 3 and 4 are copies of the exhibits of the complainant. Plates 5 and 6 are graphical representations of my own computations. Plates 7 and 8 are photographs of charts published by the United States Lake Survey, with the addition of two parallel lines for the purpose of indicating a particular locality.

Q. Were the computations as represented upon the tables correctly made?

A. To the best of my knowledge, belief and ability and that of my office.

Mr. Wilkerson: How much did you do personally?

A. I outlined practically every table; made preliminary computations of most of them; checked the computations of nearly all, and have watched the construction of every one of them from the time the first pencil mark was made until it was finished, and had received a third or fourth check.

I have devoted a considerable part of the last four years to doing it.

Mr. Adcock: The computations that you have arrived at, and the conclusions you have reached are based upon the series of tables heretofore identified by you, and the facts and circumstances testified to by Complainant's witnesses and the documents identified by them, already in evidence?

A. They are.

Q. Will you state your conclusions as to the accuracy or inaccuracy of the observations made and the results reached by the complainant, taking it up by the different subjects; and also state the basis upon which you reach your conclusions;

and also the method which you have used in arriving at your conclusions?

Mr. Wilkerson: I will not interrupt the witness while he is making this statement, with reference to an explanation of these tables, but I reserve the right in the future to move to strike out of the testimony any statements of the witness which I deem to be statements of an improper conclusion, or which I regard as otherwise incompetent, irrevelant and immaterial.

Mr. Adcock: That is when the statement is concluded, or at some reasonable time afterwards.

Mr. Wilkerson: Yes, after we have had an opportunity to consider it.

Mr. Austrian: So as to give us an opportunity to recall him.

Mr. Wilkerson: Undoubtedly, before his testimony is finished I will concede it to be my duty to indicate to you any such motion as I may have, so that you will have an opportunity to recall the witness and put to him such questions as you conceive to be proper to cover the objectionable matter, if it be manifest it is objectionable from a legal standpoint.

A. The accuracy of the observations on discharge appears from a comparison of observations made at each place, and a comparison of observations made at two places on the Niagara and on the St. Clair Rivers to be equal to that of any similar series of observations known.

However, certain inconsistencies, as will be hereafter shown, appear between the results on the Niagara and those on the other two rivers. But even granting the highest degree of accuracy indicated, the magnitudes measured are so great that the differences due to the diversion considered in this case are too small to be the subject of direct measurement.

On the St. Clair River there are 33 observations referred to the Harbor Beach gauge, in which the reported elevations of Huron and St. Clair were repeated in two or more, giving 21 observations of discharge measured under the same observed conditions, as to the two locations; and these are presented in Table 1 of Exhibit 34. The variations of these discharges range from 600 to 8,600 cubic feet per second, with a mean of 3,305; or the maximum difference is 2.22 per cent., the minimum .15 of one per cent., and the average variation from the mean is .844 of one per cent. of the average discharges.

Mr. Austrian: What do you mean by "mean"?

A. I take the mean discharge of the whole series, and the mean variation.

Q. By that you mean average?

A. The average variation from the mean would be one-half of the mean variation; that is, assuming that the variation is above and below, so that the average from the mean would be one-half of the mean variation.

Taking the Grand Trunk gauge instead of that of Harbor Beach, there are 33 observations giving 18 comparisons shown in Table 2; of which the maximum variation is 8,600, the minimum 400 and the mean 3,350 cubic feet per second. And giving the maximum difference as 2.14 per cent., the minimum as 0.104 of one per cent. and the average variation from the mean .831 of one per cent. of the average discharges.

On the Niagara River at the Bridge Section are 40 observations giving comparisons of two or more with the same stage reported for Lake Erie and shown in Table 3, and from these 23 comparisons are obtained giving a variation ranging from zero to 21,600 cubic feet per second, with an average of 4,578 cubic feet per second. The maximum difference is 5.27 per cent., the minimum, zero; the average variation from the mean 1.202 per cent. of the average discharges.

On the Niagara River at the Open Section there are 54 observations at the same stage of Lake Erie shown in Table 4, giving 29 comparisons, with differences ranging from zero to 7,800 cubic feet per second, and a mean variation of 2,962 cubic feet per second. The maximum difference is 2.007 per cent., the minimum zero, and the average variation from the mean .79 of one per cent. of the average discharges.

On the St. Lawrence River, the discharges refer to the gauge at Ogdensburg, and does not include the full fluctuations of Lake Ontario. The gauge location is over 60 miles from the lake and the gauging station some 15 miles further. There are 51 comparable observations which are shown in Table 5 giving 36 differences ranging from zero to 4,200 cubic feet per second, with an average of 1792. The maximum difference is .844 of one per cent.; the minimum, zero, and the average variation from the mean .37 of one per cent. of the average discharges.

If these last gaugings were referred to the actual simultaneous elevations of Lake Ontario, it is improbable that they would show a degree of accuracy above those on the St. Clair River, there being an advantage so far as the gaugings are concerned in the reference to the near-by gauge.

A comparison of the St. Clair gaugings is shown in Tables 6 and 7, based upon the gaugings in 1908, 1909 and 1910, a part of them being at the original or Dry Dock Section, and a part

of them at the Gorge Section of the St. Clair River. The Dry Dock Section is below and the Gorge Section above the mouth of Black River, which probably contributed from 100 to 200 cubic feet per second to the flow of the river.

On account of the Lakes Huron and St. Clair being alike involved—

Mr. Adcock: Just a moment: On those Tables, 1 to 5 inclusive, at the top there are numbers stated. What are those figures underneath there, what do they indicate?

A. Those are the numbers of the experiment as numbered in the records of the complainant.

Q. When you say "experiment" you mean of the observation?

A. Of the observation as numbered in the records of the complainant corresponding to the numbers in the first column on Williams' Exhibit 21.

The second column gives the elevation of Lake Huron, as given in the third column of Exhibit 21.

Mr. Wilkerson: You are speaking of Table 6?

A. Table 1.

Mr. Adcock: All the rest are in the same way.

A. Column 3 headed "St. Clair elevation" corresponds to the fourth column of Exhibit 21.

The fourth column headed "Discharge" corresponds to the last column of Exhibit 21. The column headed "Difference" is the difference between the two discharges which is seen in the fourth column; and the percent variation from mean is the percentage which this difference is of the mean discharge of the two measurements considered.

Q. Then they are arranged in groups, where Huron and St. Clair were at the same elevation, is that right?

A. Yes, sir, and are arranged in order of elevation of Lake St. Clair.

Q. So that if the observations should indicate the exact discharge, they ought to be the same in each group, ought they not?

A. That would be expected if there were no conditions which are unaccounted for in the discharge.

Q. That is, you have the elevation of the lake the same?

A. The elevation of the two lakes the same.

Q. The two lakes being the same?

A. The slope of the river, the fall of the river is the same.

Q. Why do you take Huron and St. Clair at the same elevations?

A. Because both lakes affect the discharge of the St. Clair River, and it would not be proper to consider only one of them, as the variation in position of the other would influence the discharge.

Q. Will you indicate just how that would affect the discharge, that is, the raising of St. Clair?

A. If St. Clair were to rise, it would decrease the fall between Huron and St. Clair. The flow in the river is dependent upon this fall to overcome the resistancies which are encountered in the motion of the water, so that if the fall be decreased, the forces which are to overcome the resistencies are decreased, and the discharge is reduced.

Q. And the velocity is decreased?

A. The velocity is reduced, and the change of velocity is greater than the change in section which may result from the raising of the lower part of the river.

Q. That is the area of the cross-section?

A. That is the area of the cross-section is increased by the raising of Lake St. Clair, but the change in velocity is greater in proportion, so that the net result is a reduction in the discharge.

Q. Now will you continue your answer to the general question?

Mr. Wilkerson: In regard to this first table, take this Table 1, take the fifth line, Huron elevation?

A. St. Clair elevation is 575.36; the ditto marks have not been put in, but the St. Clair elevation appears until it is changed in the column.

Q. There is a difference there of 6,000?

A. Yes.

Q. As to those two particular observations. Might the fact that one observation was made when the river was in the rising stage and another when it was in the falling stage, might that factor account for that difference?

A. It would very likely account for it, and that is one of sources of inaccuracy of current meter gaugings.

Q. But in a long series of observations, the river being in a rising stage about as often as it is fallen, that will be eliminated to a much greater extent than if you compared two observations?

A. Certainly.

Q. That is the thought I had in mind, that I wanted to get clear.

A. Or stated another way, the average of a large number

of results will be more accurate than the average of a small number of results.

Q. Then the comparison of two?

A. Assuming them to be taken under general conditions.

Continuing the comparison of the St. Clair observations, on account of Lakes Huron and St. Clair, both being involved, it is difficult to find observations at each section when both were at the same elevation, but some instances of the kind are shown in the lower half of Table 7. In four of the six cases presented—

Mr. Wilkerson: By the lower part, you mean commencing with which line?

A. I mean in the lower portion of the table. There are two tables on 7, one marked "By Single Observations."

Q. The one headed "By Single Observations?"

A. Yes, the one headed "By Single Observations."

In four of the six cases presented there was a difference of .01 in the elevation of Lake St. Clair, and in one a similar difference in that of Huron. These differences have been corrected by the values for the separate increments computed in Table 24. The observed differences for similar conditions when so corrected at the two sections range from 380 to 2,410 cubic feet per second. If the corrections had not been made, the difference would still remain at approximately the same figures. The corrections are indicated in this sixth column.

In the upper part of Table 7 is presented the comparison of the groups of observations which have been assembled in Table 6; corrections of variations of either lake being made as in the previously considered case.

Then in Table 6, I have given the individual observations which are considered at each location, and we have taken the means of these several groups to make the comparison that is presented in the upper portion of Table 7. The differences here range from 140 to 4,172 cubic feet per second; the mean being 1,851 cubic feet per second. The maximum difference is 2.24 per cent., the minimum .75 of one per cent. and the mean less than one per cent. of the average discharges.

Further evidence of the accuracy of discharge measurements of the St. Clair River is to be found in a comparison of Tables 24, 31 and 33, showing the results of the 1899 and 1902 gaugings, with Tables 27, 37 and 39 of the 1908 and 1910 gaugings. The observations of the earlier table were in general at higher stages than the later ones, so that the center of gravity of the lower half in Table 33 is at very nearly the same

elevation as the center of gravity of the upper half of Table 39.

Mr. Adcock: What do you mean by the center of gravity?

A. The observations of these tables are divided into two groups, first the center of gravity, or the mean point or the mean of both lake stage and the discharge is taken. This divides the observations into two groups, and the mean point or centers of gravity of the upper portion and the lower portion are then taken. This gives three points on the straight line, which most nearly represent the observations that are included.

Q. Is that a well known method of getting at the correct, true line showing the center of gravity of all the observations?

A. That is the mathematically accurate method of deriving the straight line which most nearly fits a series of points.

Q. Is that a line such as is referred to in Complainant's Exhibits 1 to 4 inclusive?

A. It is the line which the complainant was endeavoring to locate, by a purely ocular method of stretching a string across his observations. It might have been mathematically computed by the process which has been indicated here, and which I may say is based upon the well known theory of moments in mechanics.

Q. How did they get their line?

A. The points were plotted and a string was stretched across the plotting and adjusted by the eye until it seemed to fit most nearly the position of the points.

Q. Will you continue the answer?

A. By the former table, Table 33, a stage of 580.404 of Lake Huron corresponded to a discharge of 189,064 cubic feet per second, and the increment was 28,872.

By the latter table, Table 39, a stage of 580.460 of Lake Huron corresponds to a discharge of 191,591 cubic feet per second. The difference between 580.460 and 580.404 is .056 foot, and the increase in discharge due to this increased stage by Table 33 would be 28,872 times .056, equals 1,617 cubic feet per second, which added to the discharge at 580.404 gives 189,064 plus 1,617 equals 190,681 as the discharge by the 1899 to 1902 gagings corresponding to the elevation at which a discharge of 191,591 cubic feet per second was found in 1908 to 1910; thus showing a difference in observed discharged capacity of 910 cubic feet per second, or less than one-half of one per cent.

In view of the fact that during these later observations the Detroit River was obstructed by the Livingstone Channel cof-

fer dam, which is stated to have raised the water above it about 2 inches, thus decreasing the flow, it is interesting to note that the later measurements show the larger discharge.

Q. You say it is stated to have raised the water about two inches? That is from gauge records which you have?

A. That is shown by gauge records which I have, but was stated by Colonel Mason M. Patrick upon oath on the witness stand before the International Joint Commission at a hearing in Detroit within the past month in my presence.

Q. Who is Colonel Patrick?

A. He is the engineer officer in charge of the river improvements on the Detroit River at the present time, located at Detroit.

Mr. Austrian: He is a government officer?

A. He is a United States engineer officer.

Mr. Adcock: If there is any question about that fact as to the raising there of two inches on account of the coffer dam, if you let us know, we will verify it by some other method.

Mr. Wilkerson: We will check the statement. If there is any question we will let you know so that you can make your proof in your own way.

The Witness: For the Niagara River, Table 8 shows a comparison of the gagings at the Bridge and Open Sections, the comparison being made between the mean results at the several stages.

For 1899, the observations show a maximum positive difference of plus 1.03 per cent. and a maximum negative difference of minus 9.06 per cent. of the average discharge, with the Bridge Section positive; the Open Section discharge being the greater in seven out of nine comparisons.

Q. What do those negative and positive quantities mean?

A. I considered the bridge section as being a positive quantity and subtracted the discharge of the Open Section from it, so that if the Open Section discharge were greater than the discharge of the Bridge Section my result would be negative.

Q. That is you arbitrarily in this Table 8——

A. I arbitrarily subtracted the Open Section from the Bridge Section in each case and gave the result the algebraic sign.

Q. And indicated the Bridge Section positive and the Open Section Negative?

A. Yes. Combining the 1898 and 1899 observations in Table 9, we get the maximum positive difference as 3.75 per

cent., the maximum negative difference minus 2.06 per cent.; the bridge section being positive as before. In this comparison, the Bridge Section shows the higher discharges in 21, and the open section in four cases.

Combining the 1898 and the 1900 observations in Table 10, the maximum positive difference is 4.5 per cent., the maximum negative difference is 0.3 per cent. The Bridge Section shows the higher discharge eight times and the Open Section once.

Combining the 1899 and 1900 work in the bottom of Table 10, there is no positive variation, the difference being all negative and ranging from minus 7.5 per cent. to 1.58 per cent. It will be seen by comparing these results with those on the St. Clair that the agreement of these observations is only about half as close as those in the St. Clair River.

If we compute the discharge of the Niagara River from the monthly mean stages of Lake Erie at Buffalo, by the equations derived by the complainant, which computations are shown on Tables 11 and 12, from 1900 to 1907, inclusive, we have an average discharge at the Bridge Section, by the equation derived from the Bridge Section observations of 201,436 cubic feet per second, and at the Open Section of 198,-708 cubic feet per second, a difference of 2,728 cubic feet, or 1.36 per cent. of the mean.

Q. When you say "by the equations derived by the complainant," what do you mean?

A. I mean by the use of the increments which the complainant has introduced in its testimony in this case, the increment being applied for an elevation of 571, with a discharge of 175,000 cubic feet per second in the case of the Bridge Section, and for the same elevation with a discharge of 172,-600 cubic feet per second in the case of the Open Section.

Q. That was for the Niagara River?

A. Yes. I should state that the elevations of Lake Erie at the Buffalo gage have been derived from the report of the International Waterways Commission on the regulation of Lake Erie for 1910, being marked Williams Exhibit 33D.

Considering the relative reliability of the several sources of observations, the observations on the St. Clair River cover periods in five different years for the original group, and two additional years for the subsequent group, while those at the Niagara are confined to three years, and those on the St. Lawrence to two years.

The observations on the St. Clair, as testified to by the complainant, have covered a range of stage from 579.65 to

581.39 approximately; on the Niagara from 570.00 to 573.92 at the Bridge Section and 570.67 to 573.41 at the Open Section, approximately. And on the St. Lawrence from elevation 242.85 to 245.28 approximately.

From 1890 to 1907, inclusive, Lake Huron at Harbor Beach has ranged in monthly mean elevation from 579.02 to 581.71; Lake Erie at Buffalo from 570.79 to 573.92, and Lake Ontario at Ogdensburg from 242.66 to 246.82.

The method of gaging and the location of the section on the St. Clair River leads me to expect more reliable results than on either of the other rivers, and the range of stage covered relatively to the lake fluctuations give a larger proportion of the lake variations included than on the St. Lawrence, the former covering 65 per cent. and the latter 58 per cent. of the lake range.

Q. Just what do you mean, with reference to that latter statement, as to the range of stage?

A. That the actual observations covered a larger percentage of the rise and fall of the lake, of the space passed over by the lake in its natural rise and fall by monthly means in the case of the St. Clair than it did cover in the case of the St. Lawrence, and of course the greater range that you cover with your observations, the more accurately can you determine the relation of changes of elevation to the discharge, assuming the same degree of accuracy in both sets of observations.

Q. Well, is it necessary in order to get accurate results from the discharges of rivers in determining the increment, that the observations cover the range of stage of the lake normally?

A. Well, it is not necessary that they should cover the entire range, but the more nearly they cover it, the more accurately the increment is determined. That is the greater the range between the high and low points of the lake in the observations used for the determination of the increment, assuming equal accuracy for all observations, the more accurately would the increment be determined.

Gagings of the St. Lawrence River from the Bridge at Valley Field, with which I was associated in 1909, give a discharge about 5 per cent. higher than would be indicated by the United States Lake Survey measurements when corrected for the added drainage area.

From all the foregoing, it is my conclusion that the St. Clair gagings as representing changes of discharge due to varia-

tions of lake level are intrinsically more accurate than those of Niagara, and, when the location of the reference gage is considered, more accurate than those of the St. Lawrence. The close coincidence of the 1899 to the 1902 results with those of 1908, 1909 and 1910, and the proved close coincidence of the latter, by the Dry Dock and Gorge comparisons, establishes in my mind beyond question the rank of the St. Clair measurements as the first among those considered.

It however appears that with all their care, experience and scientific apparatus, which I may say I believe has not been exceeded in any series of similar observations that have ever been undertaken, the government engineers by the complainant's method of deduction, are unable to detect variations of 3,000 to 4,000 cubic feet per second in the discharge of the St. Clair and Niagara Rivers; and by their discharge equations for the Niagara, there is a difference of nearly 3,000 cubic feet per second in the average discharge of eight years.

Q. Mr. Williams, in the measurement of the discharge of large rivers like the St. Clair, St. Lawrence and the Niagara, is there anything to which you can tie the observations of the discharge, from which you can determine the accuracy or inaccuracy of the measurements.

A. No, there is nothing outside of the measurements themselves. Of course we could detect an inconsistent observation, as one, for instance, that might show a larger discharge for a lower stage of the lake, we would say on the face of it that was wrong, but that would be on the evidence of the observations themselves. There is nothing outside of the observations to which you can tie them to determine their accuracy.

Q. Take for instance, a case where observations were made 1896 under the conditions, natural conditions which existed, showing a certain discharge of the river, certain volume; then suppose that in 1900 a diversion at some other point than the ordinary outlet had been made of 10,000 to 14,000 cubic feet of water per second; and suppose that, say in the year 1907, under natural conditions, you then make a series of discharge observations, would you be able to detect from the observations made in 1896 or observations made in the latter period in 1907, the obstruction or diversion of water at some other point.

Mr. Wilkerson: I object to that. It is a hypothetical question and does not pretend to include all the elements to be considered in this case.

A. You would not. I just want to correct that answer. I

understand that this question applies to measurements in any of the rivers that are outlets of the Great Lakes, and that the quantity involved is that mentioned near the beginning of the inquiry, from 10,000 to 14,000 cubic feet per second.

Q. Yes.

A. My answer is no.

Q. Will you state your reasons why you could not?

A. Because there are so many other conditions which enter in to affect the outflow of the lakes that having simply the gagings at the two periods, if nothing were known of this diversion by the parties making the gagings, they would be unable,—they would not be able in their gagings to find anything that would lead them to even suspect that such a diversion were taking place, because of the uncertainty of the large number of other factors that enter in, particularly rainfall and evaporation and the effects of ice.

Mr. Wilkerson: Suppose the other factors all remained fixed, could you tell it?

A. If they had all remained fixed, it could be told, not in its full magnitude, but that there was a diversion.

Mr. Adcock: You could not tell how much?

A. Not accurately. A diversion of the amount, of 10,000 cubic feet, would be detected in the measurement if all other conditions had remained the same during the periods intervening.

Q. Would you be likely to find the conditions, all conditions the same in two periods of measurements?

A. It would be about as easy as to find two leaves alike on a tree.

Q. Now, Mr. Williams, have you made any computations and calculations as to the increments, or have you derived any increments from the discharge measurements of the St. Clair, Niagara and St. Lawrence Rivers?

A. I have.

Q. Will you state what increments you have derived, how you have derived them, and the methods used in making your derivations?

A. I first examined the increments as derived or as presented by the complainant in his Exhibits 1, 2, 3 and 4, with a view to ascertaining the accuracy with which those increments had been derived from the data which had been used. I then investigated to see what would be the effect upon the increments had data which the complainant did not include in his derivation been introduced, introducing separately the

gagings of 1908 and 1901, first as corrected by the complainant, and second as actually observed.

Those computations are indicated upon tables 13, 14 and 15. Table 13 represents the computations, or the results of the computations for determining the increment upon the principle which was attempted to be applied by the complainant in the derivation of its increment in Complainant's Exhibit 1, and is based upon the observations of 1899, 1900 and 1902; the observations of 1901 having been neglected, upon the assumed ground that they do not represent normal conditions, and the observations of 1908 having been received too late to have been included in the computation at the time it was made, if I understand the circumstances correctly.

Applying the mathematical method of determining the three centers of gravity of the whole group and the two divisions of the group into which the center of gravity of the whole divides it, we find that the increment as represented by observations from *A* to *U*, giving each equal weight, would be 24,157 cubic feet per second as compared with the complainant's rough and ready determination, or approximate determination, by means of stretching a string of 23,820.

Q. The groups *A* to *U* inclusive, are those the groups of observations which the complainant used?

A. They are the groups of observations shown on Williams' Exhibit 21, which were used by the complainant and are indicated by the letters on this Exhibit 1.

Q. Is the line shown on chart, plate—

A. Plate 1 shows the complainant's line, the line of these observations—this reduction has not been put upon that chart.

Q. And plate 5?

Mr. Wilkerson: Q. There would not be very much difference?

A. No, it is only about 1½ per cent.

Q. That is, if you draw the line on plate 1, the lines are pretty near together?

A. The top of it would be a little bit lower than the line that is drawn there. I must say that as a piece of work of stretching a string, it was an excellent job of stretching.

Mr. Adcock: Q. And does plate 5 show the line which you have—

A. No, it does not. That refers to another determination of an increment to which we will come later on.

By a similar examination of the data, including the obser-

vations of 1908 which are presented in table 14, I find that had this data all been included and the observations given equal weight and the line mathematically determined, the increment would have been about 3½ per cent. higher than the value appearing on the complainant's chart.

Q. How does that table differ from table 13?

A. By the introduction of the observations of 1908, which are indicated by the letter Alpha and *Z*.

Mr. Wilkerson: Q. I want to ask you this question: You combine here different cross-sections. Now, there are certain fixed errors, are there not, where you have different cross-sections, which make it improper, if I may use that word, to combine the different cross-sections in figuring the increment?

A. I fail to see that. The increment is referred to the stage of lake, not to the stage at the gaging station, as I understand these observations. If this increment for each place has been figured with reference to a gage at a gaging station, then I have misunderstood the trend of the complainant's testimony entirely, and I would say that the deductions which have been drawn from it are absolutely incorrect. It is my understanding that the same reference gage is used, both in the Gorge measurements and in the Dry Dock measurements as presented in its table. If that is not the case, then these computations—

(Former answer of witness read as follows: "By the introduction of the observations of 1908, which are indicated by the letter Alpha and *Z*.")

The witness (continuing answer): On table 15 are presented the computations when introducing in addition to the observations of 1908 the observations of 1901, first using the corrected value adopted by the complainant. This is shown in the fourth column, and the increment is shown at the bottom of the page. Introducing these observations as adjusted or corrected by the complainant, the increment derived is about 2½ per cent. greater than that presented on Complainant's Exhibit 1.

Mr. Wilkerson: Q. That is 24,436?

A. 24,436. It is intimated by the complainant's witness, in file 7 at page 82 of the record, continuous paging 630, that excluding the 1901 observations gave an increment favorable to the contentions of the defendant. If, however, the observations of 1901 be included with all the rest without correction, the resulting increment as shown on table 15, in the third, sixth and seventh columns is 27,861 cubic feet or nearly 17

per cent. greater than that given on the chart; and if the increment be increased, the effect of the diversion is decreased and the foregoing suggestion of the complainant's witness is therefore shown to be an error.

In this table 15, the first column indicates by letter the groups of observations as they have been used; column 2 indicates the average elevation of Lake Huron for each group of observations in question as given upon Williams' Exhibit 21.

Column 3 is three centers of gravity of the elevations. Column 4 is the value of the discharge with the corrected values for 1901 included. Column 5 gives the centers of gravity of these discharges in Column 4. Column 6 gives the observed discharges without correction. Column 7 gives the centers of gravity or means of these observed discharges, and the increment then is as stated and shown in the bottom line of the table, 27,861 cubic feet per second.

Mr. Adcock: Q. You say "corrected values for 1901." What do you mean by that, Mr. Williams?

A. In Complainant's Exhibit 21, at the foot of that table, referring to discharge measurements, Dry Dock Section St. Clair River, 1901, we find this note: "Discharge was decreased two-thirds of one per cent. for each tenth foot Lake St. Clair was below normal as expressed by equation; St. Clair equals 574.79 plus 0.66 (Harbor Beach minus 580)." This correction to these observations has been made in accordance with that equation and introduced to cover groups *V*, *W*. and *X* in the fourth column of table 15.

Q. Why were those corrections made, if you know?

A. On the assumption of the complainant that Lake St. Clair was in an abnormal position with reference to Lake Michigan. In other words, that it was too low, and therefore the discharge measured was higher than would have existed with St. Clair in its normal position.

Adjourned to Thursday, March 20, 1913, at 10 a. m.

March 20, 1913, 10 a. m.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Mr. Adcock: During the period of these gagings on the St. Clair, 1899, 1900, 1901 and 1902, what was the relation of the stages at St. Clair and Huron during those periods, as compared with the normal relation?

A. Your question is with reference to St. Clair and Huron?

Q. St. Clair and Huron.

A. The relations between Lakes St. Clair and Huron are shown on Table 17, in which the monthly mean elevations of Lakes Huron and St. Clair are shown in Columns 3 and 4 respectively for the months during which gagings were in progress on the St. Clair River, during the several years indicated in Column 1.

Column 5 shows the difference or fall from Huron to St. Clair. Column 6 gives the number of gagings each month, and the seventh column shows the weighted difference, or rather the difference multiplied by the number of gagings, the mean weighted difference being indicated in the eighth column.

And finally, in Columns 9 and 10 we have for each year the mean weighted elevations of Lakes Huron and St. Clair during the period of gaging, the weightings being dependent upon the number of gagings that were taken each month.

Q. Now will you explain just a little bit more in detail what you mean by weighting measurements or observations?

A. Yes. If during any month there had been one gaging, that difference of elevation, or the elevation for that month in the weighting would have been given a weight of one. If in the next month there were, say, 10 gagings, the elevations, the differences of elevations would have been given a weight of 10. And in the summation for those two, if they only were involved, the sum of the weights for the two months would be divided by 11, that is the sum of the number of gagings; thereby getting an average elevation or difference of elevation for the series of gagings. It happens that the number of gagings per month does not vary greatly. The highest number during 1899 is 16, which occurs in both July and November. The lowest number is seven, which occurs in September.

In 1900, the range was from 19 in December to seven, which occurred both in June and November. In 1901 there are but

two months, May having 16 and June 20. In 1902 there are two months, August having 18 and September 30; 1908 there are two months, November having 12 and December three. For the entire period covered by the gagings from 1899 to 1908, inclusive, the mean elevation of Lake Huron was 580.644, as derived by the previously described weighting, and that of St. Clair, corresponding, was 575.174, showing a fall from Lake Huron to Lake St. Clair of 5.47 as the weighted mean fall.

Q. That is feet?

A. 5.47 feet as the weighted mean fall during the periods of gagings involved.

Comparing this with Table 19 it is found in the second column, the third line from the bottom, the mean elevation of Lake Huron as given by the exhibits for the Lakes Michigan and Huron in Williams Exhibit 26, for the period from 1860 to 1908, inclusive, was 581.36. The mean elevation of Lake St. Clair as given in the said exhibits, and extended by the aid of the tables in the report of the International Waterways Commission, being Table 7, Water Levels of Lake St. Clair, page 90, or Exhibit 33 A-. The reason for reference to the report of the International Waterways Commission being that the gage elevations supplied by the United States Lake Survey for the St. Clair Flats begin with July, 1872, and that there are omissions in 1877, 1878, 1879, 1880, 1881, 1882 and 1883; also in 1902 and 1903. And in order to get a comparison it was necessary to have the record extended, for which purpose reference was made to the work of the International Waterways Commission. The mean elevation of Lake St. Clair so derived is 575.76, showing a difference or fall of 5.6 between the two lakes, as compared with 5.47 as derived on Table 17.

A similar comparison may be made by reference to Table 18 with the open season elevations, by open season understanding the period from April 1st to November 30th, inclusive. From 1860 to 1910 the mean elevation of Lake Huron was 581.52. The mean elevation of St. Clair, similarly derived to that testified regarding Table 19 was 575.98; giving a mean fall of 5.54 feet as compared with the 5.47 feet as shown on Table 17. Inasmuch as the records of Lake St. Clair for the period prior to 1872 have been derived by comparison with other gages, it has been thought wise to make a comparison between the elevations of Lake Huron and Lake Erie, both during the gaging periods, and during the period from 1860 to 1908, for the rea-

son that we have a continuous record of the elevations of Lake Erie, and that there is a relation between the elevation of Lake Erie and Lake St. Clair and Lake Huron, which is approximately constant for a large part of the time considered.

Table 16 presented in a similar manner to Table 17 differences of elevation between Lakes Huron and Erie during the months of discharge mentioned. The preparation and treatment of data in this table is similar to that in Table 17, the elevation of Lake Erie as taken from the tables of lake elevations in Williams Exhibit 26 being used in place of the elevations of Lake St. Clair, which, as before stated, were partially derived from Exhibit 26 and partially from the report of the International Waterways Commission, Exhibit 33.

At the bottom of Table 16, in the column headed "Mean Difference," second line from the bottom, we have the mean fall for the gaging periods, being the weighted mean fall from Lake Huron to Lake Erie given as 8.61 feet; the weighted mean elevation of Lake Erie being 572.033.

Referring now to Table 18 for the open season, the last page of the table, the third line from the bottom, we find as before the mean elevation of Lake Huron from 1860 to 1908 to have been 581.56, and in the next to the last column of the table, the third line from the bottom, the mean elevation of Erie for the same period to have been 572.85, showing a difference of 8.71 feet, as contrasted with the difference between these lakes in Table 16 of 8.61 feet. That is for the gaging period, using all the years included from 1899 to 1908. If the observations of 1901 be omitted, we have shown in the bottom line of Table 16, the mean weighted elevation of Lake Huron to have been 580.608, and the mean weighted elevation of Lake Erie to have been 572.115, giving a mean fall between the two lakes as shown in the column headed "Mean Difference" of 8.49 of a foot.

It therefore appears that between the mean elevations of these lakes for the open season and the weighted mean elevation as derived in Table 16 for the gaging periods, exclusive of 1901, there is a difference of over two-tenths of a foot, and if compared with the mean elevation of the lakes, as shown in Table 19, which embraces the full year, we have the mean elevation of Lake Huron given in the third line from the bottom of the last page of the table from 1860 to 1908 as 581.36, and the mean elevation of Lake Erie for the same period as 572.61, giving a difference of elevation of 8.75 feet, or nearly

.3 of a foot greater than that obtained by the use of the observations of the complainant, excluding 1901.

Table 19 is intended to be, so far as Columns 2, 4 and 6 are concerned, an accurate transcript of the mean elevations for the lakes in question as shown upon Williams Exhibit 26, furnished by the United States Lake Survey, with the additions from page 90 of the report of the International Waterways Commission necessary to complete the record of Lake St. Clair.

This change in fall has been due mainly, or we may say fully speaking relatively, to the fact that Huron was higher as an average from 1860 to 1908, than it was during the periods of gauging, by approximately .3 of a foot. And referring to the complainant's testimony as given in File 7, page 60, of the original record, or continuous paging 608, wherein it was stated that if the other lakes remained stationary, or more specifically if Lake St. Clair remained stationary and Lake Huron should raise .2 of a foot, the discharge would be increased 6,570 cubic feet per second, then it would follow, if Lake Huron had been .3 of a foot higher during these gaugings, the discharge would then have been increased by about 9,855 cubic feet per second.

If we were to take the actual differences of elevation between these lakes, the discharge of the St. Clair River would, according to our own computations, as will be explained later, have been something over 20,000 cubic feet per second greater, had the stages of the lakes been at their average position for the period from 1860 to 1908 instead of in the positions which they actually did occupy during the gauging period.

If the 1901 gaugings be included, the average difference of elevation between Huron and Erie, as already pointed out, during the period of gaugings as shown in Table 16, was 8.61 feet, or 50 per cent. nearer to the normal difference of elevation as established from the open season records of the 49 years from 1860 to 1908 than is the fall derived from the observations without 1901, which seems to be that used in the derivation of Complainant's Exhibit 1 of the increment of the St. Clair River. And it has therefore been concluded by me that the value of the increment derived from all these observations being based solely upon a variation of elevation of Lake Michigan-Huron is a more nearly correct value to be applied than the one adopted by the complainant; that value being 27,861 cubic feet per second.

It may be remarked here that the complainant's witness,

Mr. Wheeler, File 4, page 45 or page 141 of the continuously paged record, gives the St. Clair increment from his own computations as 25,300 cubic feet per second.

Q. Upon what theory, as shown by the testimony adduced by complainant, are the increments for the St. Clair River derived, and what errors of assumption appear to you in that derivation?

A. The increments derived by the complainant for the St. Clair River are based on the assumption that an increment can be derived for that stream without reference to Lake St. Clair, and that the observations considered are sufficient for that purpose. While it is probable that if for a sufficient period of years gaugings were made every day so as to cover all possible positions of both Lake Huron and Lake St. Clair, and no changes occurred in the channels connecting the two meanwhile, the assumption of the complainant might lead to accurate results. A comparison of the conditions existing between the two lakes during the gauging periods as shown in Table 17 with the average conditions existing as shown in Tables 18 or 19, being Williams' Exhibit 34, shows the incorrectness of the assumption with the limited number of observations thus far made, for while the average fall between these lakes for the periods of gauging as shown on Table 17 was 5.47 feet, the average fall for the full year for the period from 1860 to 1908, as shown on Table 19, third line from the bottom, was 5.6 feet. Since the velocity in an open channel is very nearly proportional to the square root of the fall, other things remaining the same, the increased fall for the latter period would theoretically increase the velocity by the square root of 5.60 divided by the square root of 5.47, or by about 1.2 per cent.

The discharge would be further influenced by the elevation of Lake Huron. During the gaugings, the mean elevation of Lake Huron as shown in Williams' Exhibit 24, and compiled in table 19 of Exhibit 34, from 1860 to 1908 was 581.36. If we accept for the purpose of this discussion the contention of the complainant that there has been no change in the conditions of outflow of the St. Clair River, it appears that the depth of water at the head of the river in which the discharge measurements were made, was .65 of a foot less during the measurements than during the average of the 49 years under consideration.

Q. Look at the printed book which I now hand you and state what that is?

A. This is Appendix III to the report of the Chief of Engineers for 1900, of which pages 5379 and 5380 show in the seventh column the area of the Dry Dock Section used in gauging the St. Clair River as 60,935 square feet. The width of the section is stated on page 5364 to have been a little over 2100 feet, and the depth is shown on Plate 12 of the same report as approximately 35 feet, over something more than half of the section.

Mr. Adcock: We offer for identification pages 5362 to 5401 inclusive of the Report above described for 1900. And it is stipulated between counsel that the book itself need not be marked, but that it may be considered as identified so as to avoid the necessity of encumbering the record with so large a publication.

Mr. Wilkerson: Either such portions as are indicated or such other portions of the report as we may wish to direct attention to if occasion requires.

The Witness: If the depth were increased .65 of a foot, there would be an added area of at least .65 times 2100 or 1365 square feet, or about 2 1/4 per cent. of the total cross section. This added depth increases the hydraulic mean depth so-called from about 28 to about 28.7 and increases the discharge approximately in the ratio of the square roots of these mean depths, or as the square root of 28.7 divided by the square root of 28, which gives an increase of about 1 per cent.

The combined influence of increased slope, increased area and increased depth are then 1.012 multiplied by 1.0225 multiplied by 1.01 equals 1.045 and the average discharge of the St. Clair River, if there have been no changes in the channel affecting the discharge must have been very nearly 4 1/2 per cent. above the gaugings of 1899 to 1902 as an average of the period of 1860 to 1908. And if the discharge were increased, the increment in all probability would have been increased to some extent. The increment deduced by the complainant would indicate that the quantity of flow under average conditions for the open season, when the difference in stage of Huron is .92 of a foot.

By tables seventeen and eighteen, higher than during the average of the gaugings, must have been fully 10 per cent. greater than that observed.

In other words, during the average period from 1860 to 1908, the discharge through the St. Clair River must have been something over 20,000 cubic feet a second greater than

it was during the periods in 1899, 1900, 1901, 1902 and 1908, when the complainant made its gaugings.

However, as it appears to me that the normal relations between Lakes Huron, Erie and St. Clair as established by the relative positions by the annual elevations of those lakes for the period from 1860 to 1908, inclusive, did not exist during the period covered by the observations, I think it necessary to derive an increment in such a manner that it can be applied with the normal relation to get a more accurate value of the discharge, and consequently of the effects of diversions. To do this, the influences of Lakes St. Clair and Huron must be separated, which may be done by determining increments for the effect of each when each lake was at a constant elevation, and the other changing. If the observations from 1899 to 1908, inclusive, be arranged in groups with Lake St. Clair at a uniform elevation for each group, which arrangement has been made in table 22 of Exhibit 34, there are fifteen such groups of from four to thirty-one observations, and an increment may be determined from each group, according to the methods already discussed in the examination of the increments derived by the complainant in connection with testimony relative to Tables 1 to 4 of Exhibit 34, and these increments with the essential figures of the computation, therefore, are presented on Table 22 of Exhibit 34.

In this Table 22, column 1 gives the number of observations in each group. Column 2 gives the elevation of Lake St. Clair for the observations in that group. Column 3 gives the elevation of the center of gravity, or the center of gravity of the elevations of Lake Huron for each group; and column 4 gives the center of gravity of the discharges for each group. Column 5 gives the center of gravity of the elevations of Lake Huron for the upper portion of the group; column 6, the center of gravity of the discharge for the upper portion of the group; column 7 the center of gravity of the elevations of Lake Huron for the lower portion of the group; and column 8 the center of gravity of the discharge for the lower portion of the group. Whence the equation in column 9 is derived, and the increment then is the coefficient of Y in said equation, and is shown in column 10. The arithmetic mean of these increments is shown at the bottom of column 10.

There are shown in the Table 15 such groups, of from four to thirty-one observations, and the increments determined from the several groups range from eighteen thousand, six hundred cubic feet per second from a group of

six observations, to forty-four thousand, three hundred and twenty-five cubic feet per second, from a group of fourteen observations. The mean of the fifteen determinations being 34,385 cubic feet per second, as the arithmetic mean, or when weighted by the number of observations in each group as shown in Table 24, the left hand portion, the weighted mean is 36,187 cubic feet per second as the effect of a rise of one foot on Lake Huron on the discharge of the St. Clair River, when Lake St. Clair does not change.

To introduce the effect of Lake St. Clair, we make a similar arrangement of the observations which is shown in Table 23 of Exhibit 34, arranging the observations in groups, with Lake Huron at a uniform elevation for each group.

In column 1 of this table is shown the number of observations in each group; column 2 the elevation of Lake Huron for that group, and columns 3-4, 5-6, 7-8, giving the three centers of gravity of the elevation of Lake St. Clair, and the discharge. Column 9 gives the derived equation and column 10 the increment and the mean of the increment is stated at the bottom of the page.

There are twenty-one groups of from three to seven observations, giving increments ranging from minus thirty-one thousand to plus 12,800, with a mean of 14,072 cubic feet per second, unweighted, or as shown in Table 24, Exhibit 34, a mean of minus 12,995 cubic feet per second, when weighted according to the number of observations in each group, as the effect upon the discharge of the St. Clair River of one foot rise of Lake St. Clair when Lake Huron remains stationary. Or, in other words, when Lake St. Clair rises one foot if there were no other change in the river, the discharge would be decreased 12,995 cubic feet per second, and if Lake Huron raised one foot and there were no other change, the discharge would be increased 36,187 cubic feet per second.

To explain the meaning of the term "weighted", as used in this answer, I would say that we conceive that if a group has three observations, and another group has six observations, that the second group is entitled to twice the reliability of the first group on the theory that all observations are of equal accuracy, and that all are somewhat in error. Therefore, in reducing these observations, we have multiplied the result of each group by the number of observations in it, added those sums, and divide by the total number of observations to get a weighted mean; thereby giving ourselves the benefit of a large number of observations, in which each is

treated as of the same value over the average of the same number of observations, where they would not be treated of the same value if we took the direct or arithmetic mean of the last columns of Tables 22 and 23.

In connection with this method of deriving an increment for the St. Clair River, I would call attention to the testimony of complainant's witness Shenehon, it appearing in file 7, at page 102-103 of the record, or on pages 650 and 651 of the continuous paging of the record, in which the propriety and correctness of an increment derived in this manner was submitted, when, in answer to the question: "Q An increment obtained in that way would be likely to be at least approximately correct," the witness answered "Yes."

Complainant's witness Shenehon, in file 7, page 60 of the record, or at page 608 of the continuous page record, states the back water effect of Lake St. Clair to be about two-thirds of one per cent. of the discharge for one-tenth foot rise, which when applied to the mean of the gaugings of 1889 to 1908, which is given in Table 15, being part of Exhibit 34, in the last column in the middle, as 196,908 cubic feet per second, gives minus 13,130 cubic feet per second as the increment for one foot rise of Lake St. Clair.

It is further stated by the same witness in file 7 at page 58, or page 606 of the continuously paged record, that the normal relation between changes in elevation in Lakes Huron and St. Clair is that 66 per cent. of the change of the former appears in the latter.

I might at this point call attention to the fact that the increment derived from the complainant's testimony above cited, on page 606, of 13,130 cubic feet per second coincides very closely with the value derived in Table 23 of Exhibit 34, as weighted in Table 24 of the same exhibit, which is 12,995 cubic feet per second.

It is also stated by the same witness in file 6, at page 38, or one page 496 of the continuously paged record, that the effect on the elevation of Lake St. Clair is eighty per cent. of the average of the changes in elevation of Huron and Erie, and Lake Erie is stated by the same witness, in file 7, page 43, being page 591 of the continuously paged record, that the elevation of Lake Erie varies by 70 per cent. of the change of the elevation of Lake Huron. Then the mean change of the two lakes, based upon the last two citations, is 1.00 plus .70, divided by 2, equals .85 of the Huron change; and the Lake St. Clair change then is .80 times .85, equals 68 per cent. of

the Huron change. In other words, the testimony of the complainant's witness leads us to substantially the same relation between a change of elevation of Lake Huron and a change of elevation of Lake St. Clair, whether it be derived from the direct statement in file 7 at page 58, or by a combination of the two statements of file 6, page 38, and file 7, page 43.

It then follows that under normal relations, if Lake Huron rose one foot and increased the flow 36,187 cubic feet per second, Lake St. Clair would rise .66 to .68, or say 66 2/3 per cent of a foot, and reduces the discharge by 66 2/3 per cent. of 12,995, or by 8,664 cubic feet per second, leaving the net increment for one foot of change on Lake Huron, under normal conditions, as 36,187 minus 8,664, or 27,523 cubic feet per second, or within 1 1/2 per cent of the value previously obtained by using the 1901 observations with the rest. The value, 27,523, is about 11 per cent. greater than the value mathematically determined from the observations of 1899, 1900, 1902 to 1908 by the previous computation, when the relative elevations of the two lakes were neglected; and over 15 per cent. greater than the value given on Complainant's Exhibit 1.

Recess to 1:45 P. M.

After recess—1:45 P. M.

GARDNER S. WILLIAMS resumed the stand and testified further, as follows:

The relations between the elevations of Huron, St. Clair and Erie, to which the complainant's witness testified in the citations to which reference has just been made, were based apparently upon average conditions from 1860 to 1908; but these conditions changed materially about 1890, and while as shown by Table 21 of Exhibit 34, the changes of annual elevation of St. Clair are about 68 per cent. of those of Huron for the period from 1860 to 1889 inclusive, the changes of elevation of St. Clair for the period from 1891 to 1910, inclusive, are about 89 per cent. of those of Huron.

In Table 21 of Exhibit 34, in the first column, are indicated the periods 1860 to 1889, and 1891 to 1910. In column 2 are given the years; and in column 3 the elevation of Lake Huron for each year enumerated in column 2.

In column 5 is given the elevation of St. Clair for the same years as enumerated in column 2. Column 4 gives the centers of gravity of the two groups, and the whole of the elevations of Lake Huron in column 3 for each of the periods; and column 6 gives the similar centers of gravity for the elevations of Lake St. Clair.

At the foot of the table, under 1860, it is shown by a subtraction of the lower center of gravity, for the period 1860 to 1889, from the upper center of gravity of the same time, that the mean elevation of Lake Huron changed 1.131 feet. During the same time, as shown by the subtraction of the lower center of gravity of the elevation of Lake St. Clair from the upper center of gravity for the same period, the mean elevation of Lake St. Clair changed .767. The ratio of the change of elevation of Lake St. Clair to the change of elevation of Lake Huron is therefore .767, divided by 1.131, or 67.8 per cent., which coincides with the relation testified to by the complainant's witness before cited.

For the period from 1891 to 1910, similarly, subtracting the lower center of gravity of the elevation of Lake Huron from the upper center of gravity for this period, the difference of mean elevation is 0.577. Similarly, for Lake St. Clair, subtracting the lower center of gravity from the upper center of gravity of the elevations as given in column 6, the difference of mean elevations is found to be 0.516.

The ratio of the change of Lake St. Clair to the change of Lake Huron for the period from 1891 to 1910 is therefore found to be 0.516 divided by 0.577, or 89.4%.

If instead of using the relation between St. Clair and Huron, as testified to by the complainant's witness, we use the relation which is derived for the period since the apparent change of conditions in 1891, the increment for the St. Clair River as derived from the computations in Tables 22, 23 and 24 of Exhibit 34 becomes 36,187 minus .89 times 12,995, equals 24,620 cubic feet per second.

In the reduction of the observations for discharge so far considered, it has been assumed that the discharge observed is that due to the elevation of the Lake surfaces existing during the actual gaging. In many observations this was not simultaneously observed, and has been determined, as stated by the complainant's witness in file 6, at page 16, being page 474 of the continuously paged record, by a series of comparisons between a gage at or near the gaging station, and the controlling lake gage. The gage elevations set down as thus

corresponding to the discharge measurements in Exhibit 21 can then be regarded as representing only approximately the conditions producing the discharge, which will also be influenced by the situation of the lake surface during many antecedent hours.

In other words, it is my conception that the discharge of the river cannot instantly respond to a change of lake elevation in its entirety; that while the change of lake elevation increases the discharge of the river immediately, it does not get its full increase, the discharge does not get its full increase due to that change of elevation or that rise of elevation until some time afterwards. The values determined in the preceding investigation and those presented by the complainant, are therefore all subject to an error which has yet been nowhere considered. On account of the inertia of the water, the discharge does not respond instantly to a change of lake elevation, nor is the full effect of a change felt until its influence has traveled through the entire length of the river in question, and caused an acceleration or a retardation of every particle in it, and the rise or fall of stage throughout its full length.

In Appendix EEE of the Report of the Chief of Engineers for 1904, at page 4093 there appears the following statement: "In 6.4 days, therefore, after a rise occurs in Lake Huron, 9/10ths of the resulting rise will have taken place in Lake St. Clair." In other words, it takes, according to this statement, practically a week for the effect of a rise of Lake Huron to travel through the St. Clair river, and the full and final effect of that rise cannot therefore be said to have taken place in that river until after the expiration of this time.

As the change in discharge is an effect of the change in stage, it cannot precede it on any supposition; and on account of the tremendous mass of matter involved, a river of water nearly half a mile wide and forty miles long, weighing about three hundred million tons, the effect cannot be simultaneous or even approximately contemporaneous with the cause, so that it necessarily follows that the variations recorded in Lake stage from one observation to another will ordinarily be greater than the true variation corresponding to the change of discharge.

In other words, changes of discharge obtained by observations on fluctuating reservoirs will under all ordinary circumstances, be too small in relation to the changes of surface elevations. Incidentally it follows that the nearer the gaging

station is to the outlet of the lake, the more closely will the effects there coincide in time with the causes in the lake producing them. To fully correct this error from the observations in hand is impossible.

Mr. Adcock: What do you mean by "The observations in hand?"

A. The observations which have been furnished by the complainant relating to these discharges. And it would require many times the number we now have to eliminate it. But the observations in our possession may be grouped chronologically and periods selected when for a considerable time the range of variation of the lake surfaces was small, and from these groups an increment may be obtained by a more precise method than any yet used, for the conditions existing during the period covered by the observations.

In other words, instead of using a single simultaneous elevation of the lakes at the time of gaging, it is proposed to use the mean of a series of elevations, consecutively observed, and the mean of the gagings during the period over which those elevations extend, to get a more correct relation between change of lake stage and change of discharge.

Examining the data on the St. Clair from 1899 to 1902, we find eleven periods ranging in length from four to ten days, and including from four to eleven discharge measurements, during which the variations of the lake surfaces and the times of the discharge observations were such as to permit the computation of a mean elevation and a corresponding mean discharge, that, in our judgment, should be reasonably representative. These observations, their groupings, are presented in Table 28 of Exhibit 34, comprising three sheets.

These observations were grouped first, by periods when, according to the records furnished by the United States Lake Survey as presented in Williams' Exhibit 28, Lake St. Clair was at a uniform elevation during the full period of each group. They were also selected during such periods as the elevation of Lake Huron appeared to be either approximately constant or as the variations balanced and brought the initial and final position of the lake to substantially the same level.

In the first column of Table 28 is found the number of the group. In the second column is given the date of the observation, and it will be noticed that in each of these groups the elevation of Lake St. Clair has been started one day ahead of the elevation of Lake Huron, and has been stopped one day prior to the cessation of the record of the elevation of Lake Huron.

In the third column is presented the elevation of Lake Huron as indicated on Exhibit 21, and in the fourth column the elevation of Lake St. Clair as presented upon the same exhibit. In the fifth column is presented the mean daily elevation of Lake Huron as shown in Exhibit 28, being the mean daily elevation of Lake Huron at Harbor Beach. In the sixth column is presented the mean daily elevation of Lake St. Clair as shown in Exhibit 28, it being the mean daily elevation at the St. Clair Flats. In the seventh column is presented the observed discharge, which is taken directly from the last column of Exhibit 21.

In the eighth column is indicated the weight given to each discharge, said weight being determined by the length of time which the discharge is assumed to represent, it being assumed to extend or cover one-half the period each way to the next observation of discharge, except in the case of the first observation, when it is assumed to begin at the beginning of the day on which it is taken, and in the case of the last, when it is assumed to terminate at the end of the day on which it is taken.

In the last column of the table are given the products of the weight by the observed discharge, and in the footing of each group the averaged weighted discharge for the period, while the fifth column gives the average elevation of Lake Huron at Harbor Beach; and the sixth column the average elevation of Lake St. Clair at St. Clair Flats.

The data of this table as presented is sufficient to enable the accuracy of the transcription to be checked by comparison with Exhibits 21 and 28.

In this particular table, the discharges have been weighted, as just stated, by the time interval which they are supposed to represent; it being assumed that the discharges represent consecutively the changes of condition in the river from time to time. If a discharge had been taken every day, and only one, there would be no occasion to weight them. We should then simply take the mean of the discharges, but as on some occasions a day elapsed between the measurement of discharges, it becomes necessary to give those discharges which were taken before and after the interval, an additional weight in order to cover the interval in order that the time covered by the discharges may correspond with the time covered by the record of lake elevations.

Mr. Wilkerson: If two observations were taken on three days, you would give each one a weight of one and a half?

A. A weight of one and a half, that is the proposition.

We then have eleven observations showing a mean position of the surface of Lake Huron, mean position of the surface of Lake St. Clair moved twenty-four hours ahead, and the mean discharge observed for this time.

Q. Why do you take twenty-four hour periods?

A. Because we had to cover the full period that the lake was in the position. We could not select periods of elevation of the lake. We are taking a continuous period from the beginning to the end, in order that we may get at the mean position of the lake during that time.

Q. You say you take St. Clair twenty-four hours after Huron?

A. I take it twenty-four hours ahead. I assume the effect of Lake St. Clair, being so much further away from the gaging station, will not bring its full effect to bear as rapidly or as soon as Lake Huron.

Q. Why do you assume twenty-four hours?

A. I might have assumed some other period.

Q. Might have assumed six or eight hours?

A. I would have assumed more rather than less, or six days and a quarter to be precise. In these cases it would have very little bearing, as according to the record Lake St. Clair was at a constant position all the time. We find for several weeks in this record that Lake St. Clair did not vary one-hundreth of a foot.

As there are not a sufficient number of observations to enable us to determine a series of equations for periods of approximately uniform stage, when Lake Huron would be quiescent and Lake St. Clair moving, it is not possible to derive a new increment for the back water effect of Lake St. Clair by a method in harmony with the one which has just been outlined. We would need a great many more observations, and it is doubtful if the process could ever satisfactorily be applied, by reason of the fact that the surface of Lake Huron will not remain stationary for more than a very limited length of time. In view of the fact, however, that the back water effect as derived in my previous computations substantially coincides with that which has been testified to by the complainant, in the further production of an increment from the groups of observations in Table 28 of Exhibit 34, it has been assumed that the back water effect of Lake St. Clair is minus 13,000 cubic feet per second, upon the discharge of the St. Clair River.

In other words, it has been assumed, on the basis of the tes-

timony of the complainant, and the results of my own computations, as set forth in Tables 22, 23 and 24 of Exhibit 34, that the effect of one foot rise of Lake St. Clair upon the discharge of the St. Clair River, is to reduce that discharge 13,000 cubic feet per second.

Accepting for the purpose of argument the statement of the complainant's witness that a rise of one foot in Lake Huron is normally accompanied by a rise of two-thirds of a foot in Lake St. Clair, we proceed to the derivation of an increment by correcting the positions of Lake St. Clair to its normal position, with reference to Lake Huron, in accordance with the above mentioned ratio.

Table 19 of Exhibit 34, presents the first step in this reduction. The mean elevation of Lake Huron for the open season from 1890 to 1910, as has been shown on Table 18, was 580.70; and the mean elevation of Lake St. Clair from 1890 to 1910 was, as shown on the same table, 575.36. And it is assumed that for every change of Lake Huron above or below 580.70, Lake St. Clair should change two-thirds as much from 575.36. We are therefore able, by taking the changes of Lake Huron to compute a normal position for Lake St. Clair.

In Table 29, the first column shows the number of gagings included in the groups. The second column gives number of the groups; the third the days in the groups, and the fourth the period covered by each group, the fifth the average elevation of Lake Huron, all being as indicated in the preceding Table 28. In the sixth column of the table headed "Change from mean," is shown the change of Lake Huron from the mean elevation of 580.70.

In the seventh column is shown the mean elevation of Lake St. Clair as taken from Table 28; and in the last column again marked "Change from mean," is shown the change of Lake St. Clair from the mean position of 575.36.

We now come to Table 30 of Exhibit 34. Column 1 gives the number of the group. Column 2 gives the observed change from mean of Lake Huron. Column 3 gives the observed change from mean of Lake St. Clair, those three columns being taken directly from Table 29. Column 4 gives the normal change of Lake St. Clair; that is, that change corresponding to 66⅔ per cent. of the change of Huron as indicated in Table 2. And Column 5 gives the difference between the normal change of Lake St. Clair and the observed change of Lake St. Clair, with its proper sign, as to whether the normal would have been above or below the observed change. A rise of one

foot in Lake St. Clair being assumed to cause a decrease of discharge of the river of 13,000 cubic feet per second, it is then possible, by multiplying the differences in Column 5 by 13,000 to get the results in Column 6, which are the corrections to the discharge due to the abnormal position of Lake St. Clair.

Column 7 is the observed discharge of the St. Clair River for the period in question, as taken from Table 28. And Column 8 gives the observed discharge plus the correction for the abnormal position of Lake St. Clair in Column 6, and represents, on the foregoing theory, the discharge of the river which would have existed had Lake St. Clair been in its normal relation to Lake Huron, as shown by its average position from 1890 to 1910; assuming, according to the testimony of the complainant, that the change in Lake St. Clair is two-thirds of the change in Lake Huron, and that the effect of one foot rise in Lake St. Clair is to decrease the discharge of the St. Clair River 13,000 cubic feet per second.

Table 31 presents the next step in the computation of the increment. Column 1 again represents the number of the group; Column 2 the mean daily observed position of Lake St. Clair taken from Table 28. Column 3 the corrected discharge taken from Column 8 of Table 30. Column 4, a multiplier being the number of days that are included in each period of gauging, in order that the several values of the several periods may be weighted according to the length of time. Column 5, the corrected discharge multiplied by the factor in Column 4. Column 6, the mean daily elevation of Lake Huron taken directly from Table 28. Column 7, the product of multiplying the mean daily elevation of Lake Huron by the number of days over which the observations extend. Column 8, the centers of gravity of the weighted discharges, or the weighted products of discharge, when divided by the sum of the multipliers involved in each portion of the series, and Column 9, similarly, the weighted centers of gravity of the position of Lake Huron.

Mr. Wilkerson: Q. I think you have explained already, Mr. Williams, but I wish you would tell us again why in Group 1. Column 1, Group 1, in the fourth column, where you have a multiplier of ten, why you put ten there.

A. Turn back to Table 29, and you will find that Group 1 covers a period of ten days, and we have weighted according to time.

We then find from Columns 8 and 9, subtracting the lower center of gravity of discharge from the upper, that a change of 15,820 cubic feet per second, corresponded to a change of

elevation, subtracting the lower center of gravity from the upper center of gravity in Column 9 of 0.507 feet. Whence the deduced increment of the St. Clair River is 31,203 cubic feet per second.

In Table 32 we start again with the data of Table 29, Exhibit 34, this time assuming that the change of St. Clair corresponding to a change of Huron has been such as is indicated by a comparison of the annual changes of the lakes from 1890 to 1910; or that a change of one foot in Lake Huron is accompanied by a change of 89 per cent. of one foot in Lake St. Clair, and that the effect of a rise of one foot in Lake St. Clair is as before to reduce the discharge of the St. Clair River 13,000 cubic feet.

Table 32 then corresponds to Table 30, in the previous computation. And it is perhaps interesting to note that in this instance Group 1 represents normal relations, there being no correction required to the position of Lake St. Clair.

Column 1, as in the previous table, gives the number of the group. Column 2, the change of the elevation of Huron from the mean. Column, 3, the observed change of elevation of Lake St. Clair from the mean. Column 4, the normal change of Lake St. Clair from the mean, as determined by multiplying the change of Lake Huron by .89.

Column 5, the difference between the normal position of Lake St. Clair, and the observed position. Column 6, the correction due to the change of St. Clair from its normal position, being the product of 13,000 by the difference indicated in Column 5. Column 7, the observed discharge, corresponding to Column 7 in Table 30, and taken directly from Table 28. And Column 8, the corrected discharge or the discharge which it is assumed would have existed, had Lake St. Clair been in its normal relation to Lake Huron, as determined by its mean relation from 1890 to 1910, and by the annual changes of elevation of the two lakes throughout the same period.

Table 33 then corresponds to Table 31, in which column 1 gives the numbers of the groups; column 2, the mean daily elevation of Lake St. Clair, Column 3, the corrected discharge as taken from Column 8 of Table 32. Column 4, the multiplier, being the number of days over which each group of observations extends. Column 5, the product of the multiplier by the discharge. Column 6, the mean daily elevation of Lake Huron. Column 7, the product of the multiplier by the elevation of Lake Huron, Column 8 the centers of gravity of the weighted

discharges and Column 9 the centers of gravity of the weighted elevations.

Subtracting the lower center of gravity of Column 8 from the upper, we find that the discharge was increased 14,638 cubic feet per second, for the change of elevation of Lake Huron indicated by the difference between the lower center of gravity and the upper center of gravity in Column 9, or 0.507 foot, which represents an increment of 28,872 cubic feet per second.

I now examine the gaugings of the St. Clair River made at Dry Dock Section, Section Gorge, during the years 1908, 1909 and 1910, as presented in Exhibits 22 and 23. These gaugings embrace 58 measurements at the Dry Dock Section, covering a range of Lake Huron elevation from 580.54 to 579.45; and 209 measurements at the Gorge Section, covering a range from 580.75 to 579.45, all of which have been combined.

In view of the testimony of complainant's witness Shenehon, file 6, page 44, or page 502 of the continuously paged letters, in which in answer to "Q. What do you say as to the precision of River Gauging done by the Lake Survey? A. I consider a discharge measurement, or rather a series of them, to have a precision of one per cent.," and in view of the further testimony of the same witness in file 6, page 49, or page 507 of the continuously paged record, in answer to the question: "Q. What do you think to be the precision of your observations as to sounding? A. That is well within one per cent. in all cases," it does not seem to me that it was necessary to separate the discharges at the Dry Dock Section, as taken in 1908, 1909 and 1910, from those at the Gorge Section taken during the same years by the same parties, who had already had the benefit of the previous experience to which the complainant's witness testified.

These observations have been examined in a manner similar to those of 1899, 1900, 1901 and 1902. The determination for the case of Lake St. Clair at a constant elevation during this latter period is given in Table 25, in which there are 47 groups ranging in number from two to seventeen observations, in which the elevation of Lake St. Clair was the same in each.

I may remark, during these later observations, Lake St. Clair does not appear to have been nearly so accommodating as it was during the previous period, where for weeks it remained conveniently at one elevation, but during this period it seems to change almost daily.

This Table 25 corresponds with Table 22 already described.

Mr. Adcock: What does that indicate?

A. It might indicate two things; one that he had a different—

Q. That is your last statement?

A. One, that we had a different kind of water, something approaching to molasses, or syrup during the observations of 1899 and 1910; and that during the later periods we had a more volatile liquid approaching perhaps to the ordinarily recognized water, or possibly to alcohol. Or, it may indicate that during the earlier period, the gauge reader slept at his watch at times, and failed to record the elevation that actually existed, and later, some days later, filled his note book with a record connected from his mind, in which he carried on the same elevation that he had last observed, until he happened to go to the gauge and take another one.

I think this is a fair commentary upon the general accuracy of the readings that have been introduced in this case, during particularly the earlier periods covered by the testimony, and it shows one of the great sources of error, which no refinements of mathematics or assumptions of the investigator can possibly eliminate.

Columns 3-4, 5-6 and 7-8, give the centers of gravity of the elevations of Huron and the discharges for the respective periods.

Column 9 gives the deduced equation, and Column 10 the increment, whose arithmetic mean would seem to be 34,510. When these values of the increment are weighted in proportion to the number of observations included in each group, as shown in the first half of Table 27, of Exhibit 34, in a manner similar to that described with reference to Table 24 of the same exhibit, the increment of the St. Clair River due to a change of one foot in Lake Huron, as indicated by the combined gaugings at the Dry Dock and Gorge Section of the observations of 1908 to 1910, inclusive, is found to be 35,797 cubic feet per second, or within 400 cubic feet per second of the value similarly deduced from the observations from 1899 to 1902 by a similar process of investigation.

Table 26 presents the increments due to changes of Lake St. Clair, when Lake Huron was at a constant elevation, or at the same elevation, and corresponds to Table 23 of Exhibit 34 previously described, and embraced forty groups of from two to eleven observations; the number of observations in each group being indicated in Column 1, Table 26.

Column 2 gives the elevation of Lake Huron. Columns 3-4, 5-6, 7-8, give the respective centers of gravity for the elevation of Lake St. Clair and for the discharge.

Column 9 gives the derived equation and Column 10 presents the individual increments, whose arithmetical mean is minus 12,230 cubic feet. And when these increments are weighted by the number of observations in each group as presented in the right-hand half of Table 27 of Exhibit 34, they being weighted in proportion to the number of observations in each group, the weighted mean effect of the rise of one foot in Lake St. Clair upon the discharge of the St. Clair River, other things remaining unchanged, is found to be eleven thousand eight hundred and seventeen cubic feet per second, or about 900 cubic feet per second less than that in the previous computation.

If we now apply to these computations the ratios stated by complainant's witness of the rise in Lake St. Clair to the rise in Huron, namely, that when Lake Huron rises one foot, Lake St. Clair rises two-thirds of a foot, we have as the net increment of the St. Clair River, 35,797 minus two-thirds times 11,817, equals 27,919 cubic feet per second.

If we apply the ratio for changes of St. Clair to changes of Lake Huron, as derived from the annual changes or from the mean annual elevations from 1890 to 1910, we have as the net increment 35,797 minus .89 times eleven thousand eight hundred and seventeen (11,817), equals 25,280 cubic feet per second.

In Table 34 of Exhibit 34, I have examined the observations of 1908 to 1910, at the Dry Dock and Gorge Sections, of the St. Clair River, by a method similar to that presented with reference to the earlier observations in Table 28, in which case it has been possible to select seven groups of observations when for considerable periods the surfaces of Lake St. Clair and Lake Huron showed moderate divergence from their mean position during the periods selected.

These observations are arranged in Table 34 in a manner entirely similar to that adopted in Table 28, with reference to the preceding observations.

Column 1 gives the number of the group, the numbering having been continued from that of the previous table.

Column 2 gives the dates of the observations indicated. Column 3 gives the mean daily elevation of Lake Huron, Column 4 gives the mean daily elevation of Lake St. Clair. The observed elevations of Lake Huron and Lake St. Clair have been omitted from this table.

Column 5 gives the dates of the discharge measurements, and it appears that in this case several measurements were made in a single day, frequently as many as five and in one

case at least six. Column 6 gives the observed discharge of the several measurements, and the mean discharge for the period. The mean elevations of Lakes Huron and St. Clair are given in Columns 3 and 4, in addition to the daily elevations.

The discharges observed as presented in the sixth column have been weighted by the time interval which they represent, which in this table is usually fractional, on account of there generally having been more than one observation in a day, and the last column of the table gives the weighted discharge, said discharge being weighted in proportion to the time covered between it, and the intermediate point between it and the next. The last column also gives the mean weighted discharge for the groups.

On Table 35 of Exhibit 34 is shown the information corresponding to that previously presented in Table 29 of the same exhibit relative to the first service of gagings.

In the first column is presented the number of the gagings in each group, which is seen to range from ten to fifty-five. The second column gives the number of the group, and the third the number of days in the group, which is seen to range from five to twenty. The fourth column gives the dates covered by the period. Column 5 gives the observed mean daily elevation of Lake Huron during the period of gagings, and Column 6 the change from the mean daily elevation of Huron, the mean elevation of Lake Huron from 1890 to 1910 for the open season, of 580.70, being taken as the mean position, and for Lake St. Clair the mean elevation during the open season, of 575.36, for the period from 1890 to 1910, being taken as the mean position.

The seventh column gives the mean daily elevation of Lake St. Clair, and the eighth column the change in the elevation of Lake St. Clair from its mean position of 575.36.

Table 26, which corresponds to Table 30 previously described, gives first, in the first column the number of the group; in the second column the observed change of Lake Huron from the mean as derived from Table 35. Column 3, the observed change of Lake St. Clair from the mean as derived from the same table, Table 35. Column 4, the assumed normal change of Lake St. Clair from its mean position, being the change of Huron multiplied by 66 2/3 per cent. in accordance with the testimony of the complainant's witness. Column 5, the difference between the observed change from mean of Lake St. Clair and the computed normal change from the mean position.

Column 6 then gives the correction due to the position of St. Clair, being the difference in Column 5 multiplied by the previously computed increment of the effect of Lake St. Clair as shown in Table 27, which is there given as minus 11,817; but has been taken for our computations as minus 12,000 cubic feet per second.

It is unnecessary, I assume, to call attention to the fact that any increase in the back water effect of Lake St. Clair in this computation is not to the advantage of the defendant; or, perhaps, is not to the prejudice of the complainant.

Column 7 gives the observed discharge as obtained from Table 24 and Column 8 the discharge corrected for Lake St. Clair in its assumed normal position in reference to Lake Huron by the addition, with its proper sign, of the correction in Column 6 to the observed discharge in Column 7.

Table 37 corresponds to Table 31. The first column gives the number of the group. The second column the mean daily elevation of Lake St. Clair; the third, the corrected discharge; the fourth, the multiplier for weighted observation, being the number of days in each period; Column 5, the product of the discharge by the number of days; the sixth column, the mean daily elevation of Lake Huron; Column 7, the product of the mean daily elevation of Lake Huron by the number of days; Column 8, the weighted centers of gravity of the discharge; Column 9, the weighted centers of gravity of the elevations of Lake Huron. When it appears, by subtracting the lower center of gravity of the discharge from the upper center of gravity as shown in Column 8, there is a difference of 11,389 cubic feet per second, which occurs during the range indicated by the difference between the upper center of gravity in Column 9 and the lower center of gravity in the same column, or .268 of a foot; and gives, therefore, an increment of 30,948, or less than five hundred cubic feet per second difference from the increment obtained in Table 31 from the observations of 1899 to 1902, by a similar process of examination.

Table 38 corresponds to Table 32, in that, instead of using the ratio for change of Lake St. Clair with reference to Lake Huron, testified to by the complainant, there has been used the ratio determined by the annual comparison of the elevations of the two lakes from 1890 to 1910. Whence it was shown that the change of Lake St. Clair had been 89 per cent. of the change of Huron, instead of 66 2/3 per cent. as testified to by the complainant's witness.

Column 1 gives the numbers of the group; Column 2, the observed change of Lake Huron from its mean position as

previously defined; Column 3, the observed change of St. Clair from its mean position; Column 4, the change of St. Clair from its mean position, assuming that change to be 89 per cent. of the Huron change. Column 5, the difference between the observed change and the computed normal change, the normal change being 89 per cent. of that of the change in Huron. Column 6, the corrections to the discharge due to the variation of Lake St. Clair from its normal position, being the increment, minus 12,000 cubic feet per second, for the effect of one foot rise on Lake St. Clair upon the discharge of the St. Clair River, multiplied by the difference in Column 5.

Column 7 gives the observed discharge for the periods in question, which has been taken from Table 34, and Column 8 presents the discharge corrected for St. Clair in its normal position.

Table 39 corresponds to Table 33, and Column 1 presents the numbers of the group; Column 2 the mean daily elevation of Lake St. Clair; Column 3 the corrected discharge; Column 4 the multiplier, being the number of days included in each period; Column 5 the product of the discharge by the multiplier; Column 6 the mean daily elevation of Lake Huron; Column 7 the product of the mean daily elevation of Lake Huron multiplied by the multiplier in Column 4; Column 8 the centers of gravity of the weighted discharges; Column 9 the centers of gravity of the weighted elevations of Lake Huron. Whence it is seen that, subtracting the lower center of gravity for Column 8 from the upper center of gravity in the same column, there is a change of 10,417 cubic feet per second, and the change of elevation corresponding to this change, is found by subtracting the lower center of gravity in Column 9 from the upper center of gravity in the same column, to be .0368 foot. And the increment therefore derived is shown at the foot of Table 39, 28,307 cubic feet per second, which is within 575 cubic feet per second of the increment previously derived by a similar process of reasoning from the observations of 1899 to 1902, inclusive, as shown on Table 33 of Exhibit 34.

The shorter range, both in time and stage for this last series, and the possible criticism that the combination of observations at two sections may involve errors in the derived increment, leads me to consider these last computations as in the nature of checks upon the accuracy of the work of 1899 to 1902, and upon the reasonableness of the increment derived from those gagings, as presented in Table 33 of 28,872 cubic

feet per second, as being the most probable increment of the St. Clair River that has yet been derived. And as in future investigations of the problems involved, it will be desirable to be able to use the increment of Lake Huron as separate from the increment of Lake St. Clair, we proceed to obtain the increment for one foot change of Lake Huron, other conditions remaining unchanged, as follows: The net increment for the river as just obtained—28,872 cubic feet per second—when increased by the effect of back water from Lake St. Clair, due to one foot rise of Huron, or by .89 times 13,000, gives as the increment of the St. Clair River due to a rise of one foot in Lake Huron, assuming that Lake St. Clair does not change its position, 40,442 cubic feet per second.

Table 40 of Exhibit 34 gives at the top, on the left-hand side, the equation of discharge of the St. Clair River as derived by the investigations heretofore, and is: The discharge of the St. Clair River equals (Huron elevation minus 580.70), times 40,442 minus (St. Clair elevations minus 575.36), times 13,000 plus 197,610, being in cubic feet per second.

Column 1 in this table gives the year in question and also underneath the average discharge of the river for that year, as computed by the equation at the top of the page.

The second column gives the months; the third column gives the mean elevation of Huron for the months; the third column gives the rise or fall of Huron above or below its mean position; rises being designated as plus, and falls as minus. Column 5 gives the increased or decreased discharge due to the position of Huron. Column 6 gives the mean elevation of Lake St. Clair. Column 7 gives the rise or fall of Lake St. Clair above or below its mean position. Column 7 gives the decrease due to the position of Lake St. Clair. Column 8 gives the net increase of discharge over the normal discharge, or the discharge at mean position of 197,610. And the last column gives the monthly discharge as computed by the formula.

This table covers the years from 1900 to 1907, inclusive; and at the bottom of the second page of the said table is given the mean discharge from 1900 to 1904, as 191,023 cubic feet per second, and at the bottom of the third page of the table the mean discharge from 1900 to 1907 as 197,633 cubic feet per second.

The mean discharge by the complainant's equation, as shown on Table 20 of Exhibit 34, for the period from 1900 to 1904, is 188,787 cubic feet per second; and from 1900 to 1907, inclusive, as shown on the same table, is 193,528; the

discharges computed by the defendant's equation being for the shorter period, about 2,300 cubic feet, and for the longer period, about 4,000 cubic feet per second, greater than those shown by the complainant.

Adjourned to Monday, March 24, 1913, at 10:00 a. m.

Monday, March 24, 1913, 10:00 a. m.

Met pursuant to adjournment.

Present same as before.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Mr. Adcock: Have you made any calculations from, or examination of the records of the discharge measurements of the St. Lawrence River; and have you made any comparison between the records of such discharge measurements and those of any other of the rivers mentioned?

A. I have.

Q. Will you state the results of such examination and comparison?

A. The increment of the St. Lawrence River is given on Complainant's Exhibit 2 as 28,870 cubic feet per second for one foot change of stage of the St. Lawrence River referred to the Ogdensburg gage. If this quantity be computed mathematically on the assumption that the discharge curve is a straight line, and all observations are given equal weight, the value of the increment is found to be 29,230 cubic feet per second.

When, however, the observations are grouped chronologically, as is done in Table 41 of Exhibit 34 in which the observations have been grouped into six groups, varying from four to 23 observations in a group, and the mean discharges, and mean lake elevations of each group have been weighted according to the number of days covered by each discharge, in a manner similar to that which has already been explained with reference to the observations on the St. Clair River, the results are grouped in Table 42 in which the first column presents the number of gagings; the second, the number of the group; the third column, the number of days covered by each group; the fourth column, the mean daily stage at Ogdensburg; the fifth column ,the multiplier by which stage and discharge are multiplied, being the number of days included in

the group. Column 6 presents the product of the elevation by the multiplier; Column 7, the centers of gravity of the elevations; Column 8, the discharges as observed; Column 9, the multiplier, being again the number of days in each group; Column 10, the product of the discharge by the multiplier; Column 11, the centers of gravity of the discharge.

Whence, taking the lower center of gravity of Column 7 from the upper center of gravity of the same column, we have a range of 1.029 foot, on the gage at Ogdensburg, representing a change of discharge determined by subtracting the lower center of gravity in Column 11 from the upper center of gravity in the same column, giving 32,844 cubic feet per second.

Whence, dividing the change in discharge by the change in elevation, we get the increment as 31,918 cubic feet per second for one foot change in stage of the elevation of the St. Lawrence River at Ogdensburg.

The fluctuation of the Ogdensburg gage, that is, its variation in rise and fall, is approximately 95 per cent. of that of the Oswego gage, which is at the foot of the lake itself; the Ogdensburg gage being about 60 miles down the St. Lawrence River, which is, however, through this region wide and deep; and may be looked upon as practically an arm of the lake.

It, therefore, follows in view of the fact that the increment varies inversely as the fluctuation, that the increment when referred to the Oswego gage would be approximately .95 of 31,918 or 30,322 cubic feet per second.

For the period from 1900 to 1907, inclusive, the average discharge of the St. Lawrence River, by the complainant's equation, has been computed in Table 43, the elevation of the Ogdensburg gage being taken from the report of the International Waterways Commission on the regulation of Lake Erie, dated 1910, being presented in Table 14, on page 97 of the said report. From this table as shown on the same, the mean discharge from 1900 to 1907 inclusive, was 247,762 cubic feet per second. For the same period the discharge of the Niagara has been computed and is presented in Table 11 for the Bridge Section, and in Table 12 for the Open Section, the discharges being computed by the complainant's equation, using the height of the Buffalo gage as indicated in the Report of the International Waterways Commission on the Regulation of Lake Erie for 1910, and shown in Table 11, page 94 of the said report.

The average discharge of the Niagara River by the complainant's equation for the Bridge Section as derived from

the observations at the Bridge Section, is 201,436 cubic feet per second. The average discharge for the Niagara River, as derived from the complainant's equation from the Open Section, is 198,708 cubic feet per second, showing a difference of about 2,700 cubic feet per second.

For the purposes of the present investgation, that is, of the relations between the discharges and increments of the several rivers, as shown by the complainant's evidence, a mean of the average discharges of the Niagara River at two sections has been used, which is 200,072 cubic feet per second. For the same years—1900 to 1907, inclusive—Table 20 gives the discharge of the St. Clair River computed by the complainant's equation; the reference being to the gage at Harbor Beach, which is shown upon Exhibit 26. The mean discharge is found to be, as shown on Table 20, 193,528 cubic feet per second. Comparing the figures for the mean discharge of the St. Lawrence with those for the mean discharge of the Niagara, it appears that approximately 81 per cent. of the discharge of Lake Ontario came from Lake Erie, or 200,072 divided by 247,762 equals 0.81, nearly.

From 1860 to 1903, a period previous to the construction of the Gut Dam, so-called, which according to the complainant's testimony in file 6 at page 21 of the original record, being page 479 of the continuously paged record, disturbed the relation causing a rise of Lake Ontario due to a reduction of the discharge of the St. Lawrence River on account of obstruction of one of its channels. The fluctuations of Lake Ontario or the annual changes of elevation, or more properly the changes of mean annual elevation, when compared with those of Lake Erie as shown on Table 44, are found to be 44.6 per cent. greater than those of Lake Erie. Remembering the principle that the variation of elevation of the water in a reservoir is inversely as the magnitude of the increment, if the same quantity of water were delivered through both the Niagara and the St. Lawrence Rivers, we would expect the increment of the Niagara to be 44.6 per cent. greater than the increment of the St. Lawrence. But in view of the fact that only 81 per cent. of the water of the St. Lawrence, according to the complainant's evidence, comes from the Niagara River, it is to be expected that approximately 81 per cent. of the fluctuation of Lake Ontario is due to the water received from Niagara, and therefore it would be expected that the changes in Ontario corresponding to or comparable with the changes in Erie, would be 81 per cent. of 144.6 per cent., or 117 per cent. of the changes in Erie.

If, then, the increments are inversely proportional to the changes of elevation, and if the increment of the St. Lawrence River is 30,322 cubic feet per second, as deduced from the chronological groupings of the complainant's gagings on Table 42, when reduced to the Oswego gage, as already explained, it is to be expected that the increment of the Niagara must be 1.17 times as great, or about 35,480 cubic feet per second.

Proceeding now to a similar comparison of the fluctuations of Lake Erie and Lake Huron, we find, first, comparing the average discharges of the St. Clair and Niagara Rivers, that according to the testimony of complainant's witnesses, about 96.7 per cent. of the water discharged from Niagara comes from the St. Clair River, or that the quantity discharged by the St. Clair River into Lake Erie is about 96.7 per cent. of that purporting to be discharged by the Niagara River; that is to say, 193,528 cubic feet per second, the average discharge of the St. Clair River divided by 200,072 cubic feet per second, the average discharge of the Niagara, gives approximately 0.967.

Q. The discharge of the Niagara referred to, according to the discharge measurements?

A. Yes, the discharge of the Niagara being the mean of the discharges computed from the complainant's equations for the Bridge and Open Sections on the Niagara River, for the period from 1900 to 1907, inclusive.

For the period from 1860 to 1889, inclusive, the changes of mean annual stage of Lake Erie, when compared with the same for Lake Huron, as shown in Table 21 of Exhibit 34, the right-hand portion of the page shows that the changes of mean annual stage of Lake Erie have been about 75 per cent. of the changes of mean annual stage of Lake Huron for the period in question. However, as already pointed out, an examination of the relations of the lake stages indicates that about 1890, or 1889, there was a marked change of some sort in the conditions affecting lake stage, and since 1890, that is from 1891 to 1910, as shown in the right-hand bottom portion of Table 21, the changes in Lake Erie have been 85.5 per cent. of those in Lake Huron.

The method of derivation of this information, as shown on Tables 21 and 44, has been to plot the simultaneous mean annual elevations of the lakes in question and to derive the equation for the straight line which most nearly fits those elevations, by the center of gravity method. So that we have in Column 9 of Table 21, the three centers of gravity for the ele-

vations of Lake Huron; and in Column 11, the three centers of gravity for the elevation of Lake Erie. Subtracting the bottom from the top center of gravity in each case, and dividing the average change of elevation of Erie by the average change of elevation of Huron, we get the percentages in the lower right-hand corner of Table 21; and similarly, with reference to Ontario and Erie in Table 44, Column 4 gives the centers of gravity of the elevations of Lake Erie, and Column 6 the centers of gravity of the elevations of Ontario, and dividing the difference of the top and bottom centers of gravity for Ontario by the difference for Erie, we get 144.6 per cent. as indicated in the lower right-hand corner of the table, for the relation of the changes of mean annual elevation of Lake Ontario and the similar changes of Lake Erie.

In Table 21, it will be noticed that the year 1890 has been omitted. This has been done because apparently there were greater changes in conditions during the year 1890, that seeming to be a part of a transition period from the conditions of the period of the previous 30 years to the conditions of the following 20 years, and the year in which changes seemed to be taking place most prominently.

As the discharge observations submitted in the complainant's testimony have all been taken since 1891, the relations for the later period are utilized, and it is to be expected that inasmuch as 96.7 per cent. of the water discharged by the Niagara River, is represented by the inflow from the St. Clair River, that 96.7 per cent. of the fluctuation of Lake Erie would be due to that supply, approximately, or that the fluctuations of Lake Erie which correspond to the fluctuations of Lake Huron would be as 0.967 times 0.86 equals 0.83. And referring again to the principle that the fluctuations are inversely as the increment, it would be expected that since the fluctuations of Huron are greater than the fluctuations of Erie, that the increment of the St. Clair River should be 83 per cent. of the increment of the Niagara River. And taking the value of the increment of the Niagara River, which is deduced from the St. Lawrence, of 35,480 multiplying by 0.83, we get 29,450 cubic feet per second as the increment of the St. Clair River, assuming the increment of the St. Lawrence to be correctly determined and deriving it therefrom by means of the fluctuations of the intervening lakes, and Lake Huron.

If instead of the discharges from the complainant's equation, we use those of the St. Lawrence and St. Clair Rivers

from the equations submitted by the defendant, the result is as follows:

By Table 43-A, defendant's equation for the St. Lawrence, the mean discharge of the St. Lawrence River for the period from 1900 to 1907 is 248,721 cubic feet per second. Using the Niagara discharge as before, 200,072 cubic feet per second, as derived from the complainant's equations, it represents 80.2 per cent. of the flow of the St. Lawrence; and combining this with the relation of fluctuations, the ratio of the increments of the St. Lawrence and Niagara become 0.802 times 1.446 equals 1.16 and the increment of the Niagara then becomes 1.16 multiplied by 30,322 equals 35,200 cubic feet per second, or approximately the same as before.

The mean discharge of the St. Clair River from 1900 to 1907, based upon the equations of the defendants is 197,633 cubic feet per second, which is 98.8 per cent. of the Niagara discharge. And we would then expect the St. Clair increment to be, taking into consideration the percentage of discharge coming from the St. Clair River and the ratio of the fluctuations, 0.988 times 0.85 equals 0.84, multiplied by 35,200, the increment of the Niagara as just deduced, equals 29,600 cubic feet per second.

As will be shown later, the increment of the St. Clair River appears to have been increasing during the period from 1891 to 1907, and as the fluctuation relation is deduced for the average condition of the period from 1891 to 1910, it follows that at the present time the Erie fluctuations will be more nearly those of Huron, and the increment of the St. Clair therefore somewhat larger than for the average condition of the period. And hence it is concluded that the value which is derived of 29,600 cubic feet per second for the increment of the St. Clair River is somewhat low.

Comparing this value of 29,600 cubic feet per second for the St. Clair River derived from the St. Lawrence gaging, and the fluctuations of the intervening lakes and Lake Huron, with that of 28,872 cubic feet per second, as deduced from Table 33 from an examination of the measurements of the complainant by periods of consecutive stage, the coincidence of the two values, the one being derived from the St. Clair gagings, without reference to any others, and the other being derived from the St. Lawrence gagings, using only the St. Clair gagings to determine the quantity of water flowing, seems to me to be a remarkable coincidence if based on any but a rational procedure.

In this connection, attention is to be called to the fact that this computation gives an increment for the Niagara River entirely out of harmony with anything presented in the testimony of the complainant. The increment based upon the discharge at the International Bridge Section, as presented by the complainant, is 21,900 cubic feet per second, and as based upon the observations at the Open Section, as presented by the complainant, is 21,640 cubic feet per second; but by this comparison which, starting from the St. Lawrence and concerning which work in his testimony the complainant has raised no suspicion, and checking by the increment derived from the St. Clair, a similar process of derivation being used on the two rivers, and all the intrinsic evidence of the observations indicating that the discharges as measured on the St. Lawrence and the St. Clair are the more accurate of those presented, an increment is obtained for the Niagara of over 35,000 cubic feet per second, or something over 60 per cent. greater than the increment presented by the complainant.

I would in this connection refer to the testimony of complainant's witness Shenehon, folio 7, at pages 50-51 of the original record, being pages 598 and 599 of the continuously paged record, where the witness referring to the fact as testified to by him that the variations of Lake Erie are 70 per cent. approximately of those of Lake Huron is asked this question: "Q. Why isn't there just as much of an effect in Lake Erie as there is in Lakes Huron and Michigan? Why is it 70 per cent. or any other per cent.? A. It is 70 per cent. because the observations show that the thing is running that way." "Q. But do you have any reason for it except that you have noticed that it was a fact? A. I have stated that the reason, I think, the controlling reason, is the fact that the increment in the St. Clair River is really smaller than the increment in the Niagara River. Let me make that clear: In the case of small pools where the reservoir effect does not enter so largely, and we can see the thing very much more clearly, if we know the increments of two pools, as for instance the Whirlpool, and the pool in the Niagara River above the Rapids, above the cataract; if we know that the increments are in the ratio of 2.50 to 0.56, we know very well that the fluctuations would bear the inverse ratio. It is not entirely certain that when you take large reservoirs like Lakes Michigan, Huron and Erie, that you can—rather, it is very certain that you cannot—argue with the same certainty that you would in the case of these smaller pools. The local supply, local run-off, local

evaporation, those elements are likely to enter in, and I do not want to state, on the face of that, clearly, that I know the increment in the St. Clair River is smaller than it is in the Niagara River; but I think it is a clear proposition."

It therefore appears that the deductions of the previously described investigation as to the relations between the increments of the St. Lawrence, Niagara and St. Clair, are corroborated by the inner consciousness of the complainant's witness, although contradicted by the physical facts of the complainant's gagings.

Mr. Wilkerson: I will move to strike that out as argumentative.

The Witness: The Niagara gagings, when referred to the mean daily gage height on the Buffalo Gage, and treated by chronological grouping as shown in Table 45, give an increment of 27,336. The construction of this table is exactly similar to that of the table for the St. Lawrence, and the two tables that were similarly constructed for the St. Clair. The table of preliminary groups has not been included in the exhibit, but will be furnished to the complainants for inspection if they so desire.

The Buffalo Gage is situated at the east end of the lake near its outlet, and is undoubtedly the gage which controls most nearly the discharge of the river. It is not the gage, however, by which the mean elevation of the lake is established, as the record of the Cleveland Gage has been accepted for that purpose, I think for two reasons; one, that there was some question as to the early accuracy of the elevation of the Buffalo Gage, and the other, that the Cleveland Gage being situated near the middle of the lake, is less affected by the fluctuations of surface due to wind than would be a gage at either end.

If the elevation of Lake Erie be established by the mean of the gage at Buffalo at the east end of the lake and the gage at Amherstburg, at the foot of the Detroit River at the west end of the lake shown on Table 46, the increment becomes 28,359 cubic feet per second. And if the Cleveland Gage be used, as shown on Table 47, the increment becomes 32,060 cubic feet per second.

Lake Erie is noted for its violent fluctuations, due particularly to wind effects, which on account of the shallowness of the lake preventing the free flow of the return currents, causes the water to pile up at one end or the other as the direction of the wind may be; and there exists a

continual surging from end to end due to these wind effects and barometric changes. This contributes largely to the difficulty of accurate measurement of the discharge from this lake. The swiftness of the current at the gaging station, and the always accompanying pulsations of swift running water, together with the depth of the measuring section, all introduce elements affecting the absolute accuracy of any current meter gaging. And while at the Bridge Section the possibility of working from a rigid platform afforded a noticeable advantage over any of the other sites, this was to a large extent counteracted by the irregular currents set up as the water passed the piers, its flow being disturbed and eddy motions created, which may lead to very serious errors in current meter work.

Furthermore, the fact that there is a fall of about five feet between the lake and the gaging section tends to obscure to a considerable extent the effects of changes in the lake, so that bearing in mind that when the discharge from a reservoir whose surface is fluctuating is measured, while the discharge itself may be accurately measured, the increment derived from those discharges will necessarily be too small by reason of the fact that the discharge does not increase or decrease as rapidly as the elevation of the lake surface changes.

Considering all these elements as affecting the gagings at the Niagara River, as well as the evidence of the comparisons of those gagings, already discussed and presented in Tables 9 and 10 of Exhibit 34, it is not surprising to me to find that the results of these observations do not harmonize with those of the other two rivers; and it is my belief that the value of the increment, 35,000 cubic feet per second, derived from the St. Lawrence and St. Clair discharges and the lake stage relations covering a long period of years, is more nearly correct than that deduced from the Niagara gagings, which covered only a brief period of time, and were subject to many very difficult conditions.

At this time I want to say that my criticism of the Niagara work is a criticism of the conditions and not of the work which was done, for it is my belief that there is nowhere on record a more painstaking example of experimental work in the nature of stream gaging, than that which is exhibited in the record of the Niagara gagings.

In this connection, I would refer to the Report of the International Waterways Commission, being Exhibit 33, Report of the International Waterways Commission on the Regula-

tion of Lake Erie, 1910, where it is stated in paragraph 147, page 81:

"Artificial storage of water in Lake Superior between December, 1888, and December, 1907, inclusive, by the placing of obstructions in the upper St. Mary's River, has had the effect of raising the mean stage of Lake Superior by about 0.87 foot in 1904 and of lowering Lakes Michigan, Huron, Lake Erie and Lake Ontario by the maximum of 0.15, 0.12, 0.10 foot respectvely."

What I would call particular attention to here is the fact that the lowering of Lake Erie is placed intermediate between that of Lake Ontario and Lake St. Clair, and indicating a ratio between the increments of the St. Clair River and the Niagara of 15 divided by 12 or 1.25 per cent. If this relation were correct, and the increment of the St. Clair River be as assumed and computed by the defendant, 28,872 cubic feet per second, the increment of the Niagara would be a little over 36,000 cubic feet per second.

Mr. Adcock: Have you made any examination of the complainant's discharge equations with reference to the physical conditions of the Great Lakes?

A. I have.

Q. Will you state the result of such examination and the different steps by which you reach the result which you claim to be the correct result; and give the basis for your conclusions?

A. The complainant's discharge equations, and the results to be derived from them have been examined with a view to testing the accuracy of the experimental conclusions by applying the results to the physical conditions to which they are related on the Great Lakes. And for the purposes of such a comparison, the hydraulics and hydrography and hydrology of the Great Lakes system have been examined in the light of the complainant's discharge equations.

The preliminary examinations embraced a comparison of the discharges from 1900 to 1907, inclusive, when, as before stated, by the complainant's equation as presented in Table 43, the mean discharge of the St. Lawrence River was 247,762 cubic feet per second. The total land drainage tributary to the St. Lawrence River, being the land drainage areas of all the Great Lakes, based upon the Report of the International Waterways Commission on the Regulation of Lake Erie of 1910 and presented there, or derivable from the table presented on page 9 and designated as Table "A," by subtract-

ing the area of the lake surface from the drainage area including lake surface, given in the said table, is found to be 192,600 square miles.

Mr. Wilkerson: Let me make a statement, Mr. Commissioner, about this report of the International Waterways Commission on the Regulation of Lake Erie for 1910. It is understood that this document, as it is referred to in connection with the testimony of this witness and other witnesses, is to be treated in evidence to the extent that either side, in either the direct examination of the witness or the cross-examination of the witnesses, may refer to such portions of it as may be deemed pertinent to the inquiry; that being for the purpose of avoiding the necessity of copying the entire document into the record.

Mr. Adcock: And offer in evidence such portions as you may refer to.

Mr. Wilkerson: Each side will indicate such portions as they want. It may be before we get through with the discussion that the whole document will have to go in.

The Witness: The discharge of the St. Lawrence River as given above 247,762 cubic feet per second is equivalent to a run-off from this land drainage area of 192,600 square miles of an average of 1.28 cubic feet per second per square mile.

If we take the total drainage area, including the lake surfaces tributary to the St. Lawrence River, which is, as shown in the report of the International Waterways Commission on the Regulation of Lake Erie, 1910, in Table "A" on page 9, 287,688 square miles, the average run-off per square mile represented by the discharge of the St. Lawrence River for this entire drainage area is 0.861 cubic feet per second.

Taking for the Niagara the mean discharge of the Open and Bridge Section equations for the period from 1900 to 1907 inclusive, 200,072 cubic feet per second, and from the table on page 9 of the Report of the International Waterways Commission, the land drainage tributary to the Niagara River derived by a simple process of subtraction as 166,863 square miles, the above discharge of the Niagara is equivalent to a run-off per square mile of 1.2 cubic feet per second from this land drainage.

The total drainage area including the lake surfaces tributary to the Niagara River, from the aforesaid authority, is 254,708 square miles, and the discharge of the Niagara River as presented by the equations of the complainant therefore

represents a run-off of 0.785 cubic feet per second per square mile for the total drainage area above it.

The discharge of the St. Clair River from 1900 to 1907, as computed from the complainant's equation in Table XX, is 193,528 cubic feet per second; the land drainage tributary to the St. Clair River, as shown in the table of the Report of the International Waterways Commission, above referred to, is 136,567 square miles, and the above discharge is equivalent to an average run-off per square mile from this land drainage of 1.42 cubic feet per second.

The total drainage area of the St. Clair River is 213,941 square miles, and the average run-off from this total drainage, as represented by the above computed discharge of the St. Clair River from the complainant's equation is 0.905 cubic feet per second per square mile.

The St. Mary's River has not been introduced into this case as yet, but as the conditions of run-off and evaporation may be appreciably different upon Lake Superior from those on Lakes Huron and Michigan, for the sake of following this process of investigation to the end, the average discharge of the St. Mary's River from 1900 to 1907 has been taken from the Report of the International Waterways Commission upon the Regulation of Lake Erie, the same being shown on page 101, being marked Exhibit 33-F. This average discharge from 1900 to 1907 of the St. Mary's River is found to be 78,200 cubic feet per second. The land drainage tributary thereto, from the report of the International Waterways Commission, is 44,074 square miles, and the above discharge is equivalent to an average run-off of 1.78 cubic feet per second per square mile for the land drainage.

The total drainage tributary to the St. Mary's River is 76,134 square miles, which gives as the equivalent of the above discharge, an average run-off per square mile of 1.028 cubic feet per second, from the entire drainage area.

It will be noticed in passing that the run-offs per square mile show a progressive increase both for the land drainage and the total drainage, from the St. Lawrence to the St. Mary's, with the exception of Niagara, which shows a reduction of average run-off from its drainage area.

We next consider the evidence of local discharge, and by local discharge we mean that portion of the river which comes from the drainage area between it and the river next above. The local discharge of the St. Lawrence would then be represented by the difference in the discharge of the St. Law-

rence and Niagara River; and the local discharge of the Niagara would be represented by the difference between the Niagara and the St. Clair; and the local discharge of the St. Clair would be represented by the difference between the discharge of the St. Clair and the St. Mary's Rivers. And in the case of the St. Mary's, the total discharge and the local discharge would coincide. Subtracting from the discharge of the St. Lawrence, the discharge of the Niagara above, as previously computed from the complainant's equations, the former being 247,762 cubic feet per second, and the latter 200,072 cubic feet per second, the difference is 47,690 cubic feet per second, which represents the discharge due to the drainage area of Lake Ontario, and so much of the Niagara River as is below the gaging station at which the discharge of the Niagara River was measured.

Similarly, subtracting from the discharge of the Niagara River 200,072 cubic feet per second, the discharge of the St. Clair River, 193,528 cubic feet per second, there remains as the discharge from the drainage area of Lake Erie and St. Clair, and so much of the Detroit and St. Clair Rivers as are below the gaging station on the St. Clair River, 6,544 cubic feet per second.

Subtracting from the discharge of the St. Clair River 193,528 cubic feet per second, the discharge of the St. Mary's River as derived from the Report of the International Waterways Commission 78,200 cubic feet per second, it leaves as the discharge from the drainage areas of Lakes Michigan-Huron, and so much of the St. Mary's River as is below the point of gaging on the said river, 115,326 cubic feet per second.

Referring again to Table "A," page 9, of the Report of the International Waterways Commission upon the Regulation of Lake Erie for 1910, the land drainage tributary to Lake Ontario and so much of the Niagara River as lies below the point of gaging of the Niagara, is 25,737 square miles. The excess of run-off of the St. Lawrence River over that of the Niagara, 47,690 cubic feet per second, then is equivalent to a run-off from this land drainage, of 1.85 cubic feet per second per square mile. Similarly the land drainage of Lakes Erie and Ontario, and so much of the Detroit and St. Clair Rivers as lie below the point of gaging on the St. Clair River, is shown by the above authority to be 30,296 square miles, and the excess of discharge of the Niagara River over that of the St. Clair River 6,544 cubic feet per second is equivalent to a run-off from this land area of 0.216 cubic feet per second per

square mile, or about 1/9 of the amount that runs off, apparently, from the watershed of Lake Ontario.

From the Report of the International Waterways Commission it appears that the land drainage tributary to the St. Clair River, on Lakes Michigan and Huron and so much of the St. Mary's River as lies below the gaging station for that river, is 92,493 square miles, and the difference in discharge between the St. Clair and St. Mary's Rivers 115,328 cubic feet per second is equivalent to a run-off from this land drainage of 1.25 cubic feet per second per square mile, or about six times as great as that appearing from the Lake Erie drainage, and about 2/3 as great as that appearing from the St. Lawrence drainage.

If instead of taking the land surfaces only upon these drainage areas we take both the land and water surfaces which are given directly in Tables "A," page 9 of the Report of the International Waterways Commission on the Regulation of Lake Erie for 1910, we find that the total drainage tributary to the St. Lawrence River below the point of gaging of the Niagara River to be 32,980 square miles, the difference between the St. Lawrence and Niagara discharges, 47,690 cubic feet per second, for this area is equivalent to an average run-off of 1.45 cubic feet per second per square mile, for the Ontario drainage. The total drainage including lake surface tributary to the Niagara River between the point of gaging on that river and the point of gaging on the St. Clair River is obtained from the aforesaid report to be 40,767 square miles, and the difference of the Niagara and St. Clair discharges, 6,544 cubic feet per second is equivalent to an average run-off upon the drainage area of Lake Erie and Lake St. Clair and so much of the Detroit and St. Clair Rivers as are below the point of gaging of the St. Clair River of 0.16 cubic feet per second per square mile, or, again about 1/9 of that of the St. Lawrence.

The total drainage area of Lake Huron and Michigan including the lake surfaces is found from the aforesaid authority to be 137,807 square miles, and the difference of discharge between the St. Clair River and the St. Mary's Rivers 115,328 cubic feet per second, is equivalent to an average run-off of 0.84 cubic feet per second per square mile for the entire Michigan-Huron drainage, or something over five times as much as that from the drainage area of Lakes Erie and St. Clair.

In order, if possible, to check the probable accuracy of the derived figures of run-off from the several lake basins, an

examination was made of the records of the discharges of rivers as presented in the reports of the United States Geological Survey, of the State Engineer of New York, and of the Report of the Board of Engineers on Deep Waterways, and of unpublished data of the London-Ontario Water Works, and of numerous gagings of rivers in Michigan, mainly from my individual experience, and taking all the information that we were able to find, but probably not all that exists, there was deduced therefrom an average run-off per square mile for each month, and these were combined into an average annual run-off for the drainage area tributary to each lake. For Lake Ontario gagings were found representing 37 per cent. of the drainage area; and the average run-off per square mile of these gagings per year was 1.44 cubic feet per second. For Lakes Erie and St. Clair gagings were found representing 33 per cent. of the drainage areas, and the average run-off from these drainage areas as shown by those gagings was 0.66 cubic feet per second per square mile. For Lakes Huron and Michigan gagings were found covering about 32 per cent. of the drainage areas, and showing an average run-off of 0.85 cubic feet per second per square mile.

Comparing these results with those previously deduced for the average run-off from the entire drainage areas of the lakes taken separately, it is seen that whereas in the first computation, the average run-off of the drainage area of Lake Ontario, including the lake surface as derived from the difference between the Niagara and St. Lawrence discharges, was 1.45 cubic feet per second, the average run-off per square mile as derived from the streams tributary to Lake Ontario was 1.44 cubic feet per second, and, whereas, the average run-off from the land and water surface tributary to the St. Clair River, exclusive of Lake Superior drainage, was 0.84 cubic feet per second, the average run-off indicated by the stream gagings tributary to Lakes Huron and Michigan was 0.85 cubic feet per second, while for Lake Erie from the difference of discharge between the Niagara and St. Clair Rivers, the average run-off from the total drainage tributary to Lakes Erie and St. Clair exclusive of that coming from Lakes Michigan, Huron and Superior, was 0.16 cubic feet per second, the average run-off indicated by the streams gaged tributary to Lakes Erie and St. Clair was 0.66 cubic feet per second, or about four times as much.

The result of this comparison for the drainage area upon Lake Erie being so far out of harmony with the results for

the drainage areas of Ontario and Michigan-Huron led to a further examination to ascertain if it were possible to account for the very remarkable difference which exists between the apparent run-off per square mile from the drainage area of Lake Erie as indicated by the outflow of the Niagara River upon the complainant's figures, and the average run-off from the same drainage area as indicated by the gagings of streams representing about one-third of that drainage area.

Mr. Wilkerson: I move to strike out the answer thus far made and each statement in it on the following grounds: That in each one of the statements of the answer there are assumptions which are wholly unsupported by anything in the record in this case, or in the evidence in the case; as well as references to facts, which nowhere appear from any portion of the record or the evidence in this case.

(In connection with the objection made by the Government's counsel the witness states that he will produce for such examination as may be desired to be made of the same, the different items of facts which he has used as the basis of his computation; and if desired will present the same as an exhibit.)

Recess until 2 o'clock p. m.

After Recess—2 p. m.

GARDNER S. WILLIAMS resumed the stand and testified as follows:

The Witness: My attention having been directed to the apparently abnormally low run-off from the drainage area of Lake Erie and Lake St. Clair, I then proceeded to examine the question in more detail, by reference to the discharges for the period from 1900 to 1904; my reason for selecting this period being that it was the period covered, or most nearly covered, by the drainage measurements which have been presented in this case; and it also avoided the interference with the levels of Lake Ontario due to the construction of the Gut Dam, to which reference has already been made.

The average discharge of the St. Lawrence River by the complainant's equation, as shown on Table XLIII for the period from 1900 to 1904, inclusive, is 240,820 cubic feet per second.

The mean discharge of the Niagara River by the average

of the two equations of the complainant, that at the Bridge Section being 198,068 cubic feet per second, and that at the Open Section 195,390 cubic feet per second, as shown in Tables XI and XII for the period from 1900 to 1904 is 196,739 cubic feet per second.

Complainant's witness Wheeler, file 4 at page 70, being page 166 of the continuously paged record, states the diversion through the Erie Canal to be 1,200 cubic feet per second, and that through the Welland Canal to be 1,100 cubic feet per second, and adding these to the average of the discharges of the Niagara River as just stated, makes a total of 196,739, plus 2,300 equals 199,039 cubic feet per second. Subtracting this discharge from Lake Erie from the discharge from Lake Ontario, we have 240,820 minus 199,039 equals 41,781 cubic feet per second as the quantity contributed from the drainage area of Lake Ontario.

The drainage area of Lake Ontario, exclusive of the lake itself, is, as already stated, 25,737 square miles, and the average run-off per square mile of the streams on which gagings are recorded, which embrace about 37 per cent. of the drainage, and which gagings are of record in the reports of the United States Geological Survey, State Engineer of New York and in some other sources which will be presented for the examination of the complainant, is 1.44 cubic feet per second.

Assuming the 37 per cent. of the area covered by the run-off records to be representative of the whole drainage, the land drainage would contribute to Lake Ontario 37,061 cubic feet per second, being the product of the area, 25,737 square miles by 1.44 cubic feet per second, being the run-off per square mile. Subtracting 37,061 cubic feet per second from the land surface from the run-off from the entire Ontario drainage, as computed above, 41,781 cubic feet per second, leaves to be contributed by rainfall on the lake surface, and subterranean supply, if any, 4,720 cubic feet per second.

The average precipitation at the several United States and Canadian Weather Bureau Stations on the shores of Lake Ontario for the years in question was 35.78 inches. The records of these stations, from which this figure is obtained, will be furnished to the complainant. The area of the surface of Lake Ontario is, as already stated, 7,243 square miles, and the average rainfall when reduced to cubic feet per second, being the product of the 35.78 inches multiplied by 7,243 square miles, and reduced by dividing by the proper factor,

is therefore equivalent to a flow of 19,150 cubic feet per second.

Subtracting from this 19,150 cubic feet per second the excess of the run-off from the Ontario drainage over the run-off from its land surface, as previously computed, which was 4,720 cubic feet per second, leaves 14,430 cubic feet per second more than the run-off of the river accounts for, and this difference, therefore, represents the least amount of evaporation from the surface of Lake Ontario consistent with the premises upon which this discussion is based; which evaporation is equal to 1.99 cubic feet per second per square mile, or to 27.0 inches of rainfall on the lake.

The mean discharge of the Niagara River from 1900 to 1904 has already been stated to be 196,739 cubic feet per second. The Erie and Welland Canals, according to the complainant's witness, added 2,300 cubic feet per second, making the total outflow from Lake Erie 199,039 cubic feet per second for the average of the period from 1900 to 1904 inclusive.

The mean discharge of the St. Clair River, by the complainant's equation for the same period, is 188,787 cubic feet per second, as shown in Table XX. This leaves the amount of water to be contributed to the Niagara River by the Erie and Lake St. Clair drainage as 10,252 cubic feet per second, being the difference between 199,039 cubic feet per second flowing from Lake Erie and 188,787 cubic feet per second flowing into Lake Erie through the St. Clair and Detroit Rivers.

The drainage area of Lake Erie and St. Clair, exclusive of the lakes themselves, is 30,296 square miles, as already stated, and the average run-off per square mile of the streams on which gagings have been examined, which embrace about 33 per cent. of the drainage area, is 0.66 cubic feet per second.

Assuming the run-off as shown from this 33 per cent. of the drainage area to be representative of that from the entire drainage area, the land drainage, therefore, would contribute 30,296 times 0.66 equals 19,995 cubic feet per second, which is more than the remainder of the outflow by the difference between 19,995 cubic feet per second and 10,252 cubic feet per second, or by 9,743 cubic feet per second; and this must then disappear by evaporation from the lake surface, together with rainfall on the lake surface, and the subterranean flow, if any, basing the conclusion upon the premises already stated.

The average precipitation at the several United States and Canadian Weather Bureau Stations on the shores of Lake

Erie for the period in question was 33.77 inches; and the detail of this information will be furnished to the complainant.

The area of the lake surfaces is 10,471 square miles, and multiplying this area by the rainfall and dividing by the proper factor, the average rainfall is therefore equivalent to a flow of 26,050 cubic feet per second. This added to the 9,743 cubic feet per second of excess from the drainage area over the difference between the outflow from Erie and the inflow through the St. Clair River gives a minimum evaporation of 35,793 cubic feet per second, which is equal to 3.42 cubic feet per second per square mile of lake area, or to 46.4 inches of rainfall annually.

Coming to Lakes Michigan-Huron, the mean discharge from the St. Clair River, from the complainant's equation, has already been stated as 188,787 cubic feet per second. The mean discharge of the St. Mary's River as given in the report of the International Waterways Commission on the Regulation of Lake Erie for 1910, from 1900 to 1904, is 76,060 cubic feet per second. Subtracting the latter from the former, we have 188,787 minus 76,060 equals 112,727 cubic feet per second as the amount of water contributed from the Michigan-Huron drainage.

During this period the Chicago Drainage Canal diverted an average of 4,200 cubic feet per second, which makes a total discharge from Lakes Michigan-Huron for this period of 112,727 plus 4,200 equals 116,927 cubic feet per second.

The drainage area of Lakes Michigan-Huron, exclusive of the lakes themselves, is, as already stated, 92,493 square miles. The average run-off per square mile of the streams on which gagings are recorded, which embrace about 32 per cent. of the drainage areas, is 0.85 cubic feet per second. The detail upon which this run-off is based will be furnished for the examination of the complainant.

The land drainage, therefore, contributes 92,493 times 0.85 giving 78,619 cubic feet per second, which leaves to be contributed by the rainfall on the lake surfaces, and subterranean flow, if any, the difference between 116,927 cubic feet per second, the total outflow and 78,619 cubic feet per second, the total inflow from the land drainage, or 38,308 cubic feet per second; the assumption here being, as in the case of the other two lakes, that the run-off from the 32 per cent. of the drainage area is representative of that from the entire drainage.

The average precipitation at the several United States and Canadian Weather Bureau Stations on the shores of Lakes

Michigan-Huron for the period in question was 30.26 inches. The information upon which this is based will be submitted to the complainant. The area of the lake surfaces is 45,314 square miles. Multiplying the average rainfall of 30.26 inches into the area, 45,314 square miles of the lake surfaces and dividing by the proper factor gives an equivalent flow for the rainfall on the lake surfaces of 101,020 cubic feet per second. Subtracting from this the quantity, 38,308 cubic feet per second, which it was necessary to have contributed from the rainfall on the lake surfaces to complete the discharge from the lake, there remains 62,712 cubic feet per second more than the discharge from the lakes account for. And this difference, again, is the minimum evaporation, on the premises on which this investigation is based, which is equal to 1.38 cubic feet per second per square mile, or 18.7 inches.

The foregoing computations have not taken into account the change of stage of the several lakes, during the period considered.

Q. Why is it necessary to take that into consideration?

A. Because if the lakes raised, a certain amount of the water which has been computed as flowing in, was absorbed and stored in the lake; and if the lakes fell, an additional quantity must have flowed out beyond that which came from the land, so that if the lakes raised, then the inflow, or the amount left as evaporation, should be decreased, and if the lakes fell the amount charged to evaporation should be increased.

Between December, 1899, and December, 1904, using the monthly means, Lake Ontario raised 1.45 feet; Lakes Erie and St. Clair raised an average of 0.445 feet; Huron and Michigan raised an average of 0.542 feet; and Superior fell 0.26 feet.

This storage was equivalent to an evaporation from the lake surfaces of the amounts represented in feet when reduced to inches, which is for Ontario 3.48 inches; reducing the evaporation by that amount for Erie and St. Clair 1.07 inches, reducing the evaporation by that amount, and Huron-Michigan 1.29, reducing the evaporation by that amount.

We then have, from the previous computations, an evaporation from Lake Ontario of 27.0 inches which when reduced by 3.48 inches equals 23.52 inches; from Erie and St. Clair, by the previous computation, 46.4 inches, which when reduced by 1.07 becomes 45.33 inches and a computed evaporation from Lakes Michigan-Huron of 18.7 inches which, when reduced by 1.29 becomes an evaporation of 17.41 inches.

The evaporations for Lakes Ontario, 23.52 inches, and Michigan-Huron, 17.41 inches, vary from the mean of the two by less than 15 per cent. as above computed. The total Ontario evaporation is equal to 23.52 divided by 35.78, or 65¾ per cent. of the rainfall on its water surfaces. The total Michigan-Huron evaporation is 17.41 divided by 30.26 or 57½ per cent. of the rainfall on its water surface. Assuming the complainant's testimony and the preceding computations to be correct, the total evaporation from Erie and St. Clair must be as follows——

Q. You mean the testimony which you have referred to?

A. Yes, assuming the complainant's testimony, to which reference has been made in this connection, and the computations and assumptions herein made to be correct, the total evaporation from Erie and St. Clair must be at least 45.33 minus 33.77 divided by 33.77, equals 11.56 divided by 33.77, or about 34.3 per cent. more than the rainfall on its water surface.

The Erie evaporation herein deduced as correct for the storage is nearly 2 1/5 times the mean of that of the other lakes. That the rate of evaporation from Lakes Erie and St. Clair would exceed that from the other lakes has been expected from the shallowness of the water and the effects of winds upon its surface; and by some has been attributed to the direction of its major axis, but so far as the position of its major axis is concerned, Ontario occupies a similar position, and the width of Lake Huron is nearly as great as the length of Lake Erie. Whether or not the shallowness of the water can account for an increase in evaporation of 121 per cent. is to be determined, if at all, by an examination of related data, as there are no direct observations known to me that solve the question.

In 1887 and 1888, there was carried on at the several United States Weather Bureau Stations along the Great Lakes simultaneously for a period of twelve months, with dry and wet bulb thermometers, and the Piche evaporemomeeter, a series of evaporation observations. These observations are published by the United States Weather Bureau in the Monthly Weather Review for September, 1888; and if desired, a transcript of them will be furnished to the complainant.

The evaporation at the Lake Ontario Stations, which were Oswego and Rochester, for the period 1887, 1888, was found to be 30.65 inches, or 60 per cent. more than the rainfall. At Lake Erie Stations it was 35.6 inches, or 20 per cent. more than the rainfall. At the Michigan-Huron Stations it was

29.37 inches, or 7 per cent. less than the rainfall. And at the Lake Superior Stations it was 23.75 inches, or about 22 per cent. less than the rainfall.

On Lake Erie, the evaporation was observed at Buffalo, Erie, Cleveland, Sandusky, Toledo and Detroit. On Lakes Michigan-Huron, evaporation was observed at Port Huron, Alpena, Green Bay, Grand Haven, Milwaukee and Chicago. On Lake Superior, evaporation was observed at Duluth and Marquette.

At the same time, evaporation observations were carried on with similar apparatus by the Weather Bureau at Boston Massachusetts. Rainfalls during this period were for Ontario, 22.49 inches; for Erie, 29.34 inches; for Michigan-Huron, 31.55 inches, and for Superior, 30.39 inches, based upon the observations at the same stations where the evaporation observations were made.

Q. What period do you refer to?

A. 1887-8.

Q. Why is it important to consider the rainfall at that time?

A. Because that has its bearing upon the evaporation. In the case of a large rainfall, it would probably mean that it was distributed over a large number of days, although not necessarily; and while it is raining there can be no evaporation. So that the evaporation would be expected to increase as the rainfall decreased, speaking of evaporation from water surfaces.

This would not hold true upon the land because the land surface would become dry, and there would be no more water to evaporate; so that on land surfaces the evaporation is likely to increase with the rainfall, up to a certain limit at least, but on the water surface, the opposite is generally true.

The evaporations for Ontario and Michigan-Huron is indicated by these observations, varied by about 4 per cent. from the mean, and the Erie evaporation exceeded that of Ontario by about 16 per cent., and that of Michigan-Huron by about 18 per cent.

These observations, while in my opinion they are not to be taken as representative of absolute quantities, I do believe them to represent relative conditions within a reasonable degree of accuracy, and that being the case it does not appear to me that they account for or even suggest the enormous evaporation from Lake Erie which is necessary to account for the discharges derived from the complainant's equations. And it therefore seems evident that there must be some other ele-

ment entering into this question of lake discharge, which has not been considered in the discussion thus far.

In this connection I would refer to the statement, Appendix EEE of the Report of the Chief of Engineers for 1904 at page 4130, paragraph 10, which is as follows:

"The average discharge of the Detroit River for 11 years, 1893 to 1903, is 193,854 cubic feet per second. The average discharge of Niagara River for the same time is 197,328 cubic feet per second. The discharge of Niagara River should be greater than the discharge of Detroit River by the quantity of water coming from the drainage area of Lake Erie. This quantity if taken as a part of the outflow through Niagara River, proportional to the area of the Lake Erie drainage area as compared with the whole drainage of the lakes above Niagara, should be 30,100 cubic feet per second. Either the Detroit River discharge, therefore, is too much, or the Niagara River discharge is too small. If there is no greater difference in the discharges of the Detroit and Niagara Rivers than the observations show, it would indicate an evaporation from the surface of Lake Erie of 81.4 inches for the year, a quantity greater than seems admissible. This assumes a run-off of .6 of the rainfall on the land part of the drainage area of Lake Erie."

This report is signed by Thomas Russell, assistant engineer, addressed to Major W. L. Fiske, Corps of Engineers United States Army.

Q. Where was he located at that time?

A. An assistant engineer in the office of the United States Lake Survey.

Q. At Detroit?

A. At Detroit.

Mr. Wilkerson: Please note the same motion with respect to the remaining portion of this discussion of this subject as was made this morning; and also on the further ground that it appears, from the testimony of the witness, that the data which are assumed as the basis of this conclusion are entirely too indefinite to furnish any foundation for any conclusion such as that which has attempted to be drawn. And I reserve the right to specify further grounds, in support of the motion to strike the discussion of the witness, after the conclusion of the cross-examination, not stopping at this time to cross-examine as to the data upon which the conclusion was based.

Mr. Austrian: You are not objecting at this time on the

ground that you have not been furnished the data that he said he would furnish?

Mr. Wilkerson: Oh, no. I reserve the right to specify further grounds when we have examined the data. But the ground that I last specified here was suggested by the comments made by the witness himself upon the data which he has used as the basis of the conclusion.

Mr. Adcock: Have you made any investigations and conclusions, with reference to the general subject of the changes in lake levels?

A. I have.

Q. Will you state the facts upon which you have made these calculations, the basis of any conclusions which you have drawn, and such conclusions as you may have drawn from such investigations and facts stated?

Mr. Wilkerson: By that you mean he is to tell what changes have taken place in the levels of the respective lakes, and then give us his theory as to why the change has taken place?

Mr. Adcock: With reference to the subject-matter of the investigation, the increment, and so forth; discharge measurements, and the increment derived from the measurements of the different rivers.

A. From Table XIX from Exhibit 34, it appears that the mean elevation of Lakes Huron-Michigan for the 30 years from 1860 to 1889, inclusive, was 581.91, and from 1890 to 1907, inclusive, it was 580.48, or 1.43 foot lower.

Similarly, during the earlier period, Lake Erie was at elevation 572.92, and during the later period at 572.08, or .84 foot lower during the latter period.

Complainant's witness Haskell, file 2, page 46, being page 64 of the continuously paged record, has attempted to explain this lowering on the grounds of deficient precipitation. Table 48 of Exhibit 34 presents the precipitation at typical stations on the various drainages, derived from the records of the United States Weather Bureau, United States Army, Smithsonian Institution, at typical stations on the various drainages. It was necessary to confine the investigation to these typical stations, because they were practically the only ones upon which continuous observations extended back over the period of years in question.

The record for Lake Superior is dependent upon the observation at Marquette; for Lakes Michigan-Huron it is based upon the observations at Milwaukee and Detroit; for Lakes Erie and St. Clair, it is based upon the observations at De-

troit, Cleveland and Buffalo; for Lake Ontario, it is based upon the observations at Buffalo, Oswego, Rochester and Toronto.

As indicated at the foot of the table for a total of six years in the group, the record of Toronto is missing; and during a short period during the three years 1867, 1868 and 1869, the record at Detroit is missing, and is supplied by taking a mean of obseravtions at Lansing and Monroe.

From the data so compiled and presented in Table 48, Exhibit XXXIV, it appears that from 1860 to 1889, as shown in that table, the average annual rainfall on Lakes Michigan-Huron was 32.35 inches; from 1890 to 1907 30.90 inches, giving an excess during the shorter period of 1.45 inches.

On Lake Erie, the average precipitation during the earlier period was 35.77 inches and during the later period 33.71 inches, a difference of 2.06 inches, of excess in the earlier period.

On Ontario, the average precipitation for the earlier period was 35.06 and for the later period 34.13 inches, showing an excess in the former period of 0.93 inches.

As the record of rainfall on Lake Superior is incomplete, in order to eliminate Lake Superior from the computation, I have taken from the report of the International Waterways Commission on the Regulation of Lake Erie for 1910, the average discharge of the St. Mary's River from 1860 to 1889, as 85,300 cubic feet per second, and from 1890 to 1907 as 76,400 cubic feet per second, showing a decrease in the second period of 8,900 cubic feet per second. During 7 of the 18 years of the second period, or 39 per cent., the Chicago Drainage Canal has been diverting an average of about 4,300 cubic feet per second, which would be equivalent to 1,675 cubic feet per second for the whole period.

The total average decrease of outflow due to the above causes, that is, the change of flow of the St. Mary's River, and the Chicago diversion, has been 10,575 cubic feet per second. That is, it is the sum of 8,900 cubic feet, decreased flow of St. Mary's River, and 1,675 cubic feet per second, flow of the Chicago Drainage Canal, which makes 10,575 cubic feet per second. And with an increment in the St. Clair River of 28,872 cubic feet, as derived in Table 33 of Exhibit XXXIV, this would account for a lowering of Lakes Huron and Michigan of 0.366 foot. Of the total lowering of 1.43 foot in Lakes Michigan and Huron, therefore, approximately 0.37 foot seems, by the above analysis, to be accounted for, leaving 1.06 foot of lowering to be charged to deficient precipitation.

Using the same increment as before, this must be due to an abstraction of 1.06 times 28,872, or 30,600 cubic feet per second, which is 30,600 divided by 197,633, or about 15.6 per cent. of the present decreased outflow. The difference of precipitation for Michigan-Huron already cited, is about 4.7 per cent. of the precipitation during the last period, so that if precipitation accounts for this lowering, we find that, reasoning conversely, an increase of precipitation of 4.7 per cent. should increase the outflow of Lakes Michigan-Huron 15.6. The reasonableness of this conclusion may be tested by a comparison with the conditions on Lakes Erie and Ontario.

The discharge of Lake Erie has been increased during the later period by increased diversions through the Erie and Welland Canals, which amount to about 1,000 cubic feet per second, so the total decrease of outflow of the Niagara River, by diversions and decreased flow in St. Mary's River, would be the sum of the decrease of St. Mary's River, 8,900 cubic feet per second, the outflow through the Drainage Canal of 1,675 cubic feet per second, and the increased diversions through the Welland and Erie Canals of 1,000 cubic feet per second, or 11,575 cubic feet per second.

Assuming an increment for the Niagara River of 34,000 cubic feet per second as derived from the comparison between the St. Lawrence and St. Clair Rivers, this would account for a lowering of 11,575 divided by 34,000, or about .34 of a foot, which subtracted from the .84 foot which Lake Erie lowered between the two periods, leaves .5 of a foot to be due to decreased precipitation.

A fall of .5 of a foot represents an abstraction, using the increment of 34,000 cubic feet per second, of 17,000 cubic feet per second. The decreased flow of the St. Clair, previously computed for the same period, was 30,600 cubic feet per second, which is 13,600 cubic feet per second in excess of the abstraction which the fall of Lake Erie accounts for. So that if there had been no change in the rainfall on Lake Erie during the two periods, the lake should be at the least calculation, about 4/10 of a foot lower than it is, were it not for the draft upon storage in Lake Huron-Michigan, which would reduce the lowering about .1 foot; or Lake Erie should be .3 of a foot lower than it was if there had been no change in precipitation.

Now, the precipitation on Lake Erie between the two periods shows that in the former it was 6 per cent. greater than it was in the latter; so that as Lake Erie is too high in the later period, we have the anomaly of a decrease of 6 per cent. in

the rainfall causing a rise in Erie of .3 of a foot, and a decrease of 4½ per cent. on Huron-Michigan, causing a lowering of 1.06 of a foot. So that it does not appear that the two results are consistent, and one or the other or both must be in error.

The level of Lake Ontario by Table 49, Exhibit XXXIV, has fallen from a mean of 246.52 for the period from 1860 to 1889 to a mean of 245.65 for the period commencing 1890 to 1907.

In 1903 there was constructed the so-called Gut Dam across one of the channels of the St. Lawrence, which raised the level of Lake Ontario, according to the complainant's witness Shenehon, file 6, page 43, being page 501 of the continuously paged record, about 5 inches for the period after 1903.

In answer to a question, after the witness had testified that he made certain prophecies based upon computations of the effect of the construction of this dam, the computations being based upon the discharge measurements of the St. Lawrence River, the question is:

"Q. Your computations were borne out, were they, by the actual observations?

A. It came within the limits stated. The actual rise of Lake Ontario, by reason of the Gut Dam, was about 5 inches."

This Gut Dam is indicated on Chart 3 of the St. Lawrence River, being Williams' Exhibit 18, and is shown extending from Galops Island to Adams Island, at the head of the channel marked "The Gut;" and is indicated by the legend "Gut Dam."

The width of the channel cut off is about 450 feet, according to scale on the map. This is located about 6 or 7 miles below Ogdensburg, which makes it about 67 miles below Lake Ontario. Apparently it cut off the flow through that channel entirely.

This dam was constructed by the Canadian Government in American waters, with the consent of the American Government, for the purpose of preventing a bad cross current in the Galops Rapids channel, which was used for navigation by boats going down the river, particularly; and this cross current striking the channel nearly at right angles, was liable to drive boats over against the farther side of the channel. It was constructed, according to the testimony, in 1903. A rise of 5 inches for three years of the 18 in the period, would raise the means 5/6 of an inch.

Q. You are speaking of the rise on account of the—

A. In Lake Ontario on account of the Gut Dam, which cov-

ers three years of this period, and if we distribute that over the whole 18, it becomes 3/18 times 12 times 5, I believe is the way it works out; it comes out about 5/6 of an inch, or .07 of a foot.

Q. The effect of the Gut Dam on the rise of Lake Ontario is still present, is it not?

A. Yes. So that if the Gut Dam had not been constructed, the mean elevation of Ontario during the later period, that is, from 1890 to 1907, would have been 245.65 minus 0.07 equals 245.58, showing a fall between the means of the two periods of 246.52 minus 245.58, or 0.94 feet, or slightly more than Erie. The diversions from Lake Ontario, effective during the later period only, are similar to those from Huron and amount to substantially the same quantity, or about 10,000 cubic feet per second, which, with an increment of 30,322 cubic feet per second, as derived from Table 42 when referred to changes of stage of Lake Ontario, would reduce the level of the lake about 0.33 foot. A further lowering of Lake Ontario of 0.94 minus 0.33 equals 0.61 foot is to be explained. This would represent a decrease of outflow of 0.61 multiplied by 30,322, or about 18,000 cubic feet per second. The decreased outflow of Huron, assuming it to have been due to deficiency of precipitation, as suggested by the complainant, must have been, as before stated, 32,900 cubic feet per second, which is, as in the case of Lake Erie, about 15,000 cubic feet per second more than the fall of Ontario accounts for, assuming no change in rainfall; the difference being 32,900 minus 18,000.

To this a correction should be applied for the contribution from storage on Michigan-Huron of approximately 3,170 cubic feet per second and a similar contribution from Lakes Erie and St. Clair of about 430 cubic feet per second, making a total of about 3,600 cubic feet per second, which would account for about 0.12 foot of this lowering. This reduces the amount unaccounted for to about 11,400 cubic feet per second. But the rainfall on the Ontario drainage appears to have been, from the figures already given, about 2.7 per cent. greater during the earlier period than during the later.

To summarize: on the complainant's theory that a reduction of rainfall accounts for the changes of lake levels—

Mr. Wilkerson: You mean on the statement of one of the complainant's witnesses.

A. Yes. On the statement of the complainant's witness that a reduction of rainfall—

Mr. Adcock: Is that the same witness you referred to—Haskell?

A. I refer to complainant's witness Haskell—that a reduction of rainfall accounts for the changes in position of the lake surfaces, we have a reduction of rainfall on the Michigan-Huron drainage of about 5 per cent., decreasing the discharge of the St. Clair River about 15 per cent., while a decrease of rainfall of about 6 per cent. on the Erie drainage increased the discharge of the Niagara River about 7 per cent.; and a decrease of rainfall of about 2.7 per cent. on the Ontario drainage increased the discharge of the St. Lawrence River about 6 per cent.

It therefore seems impossible, with the information which is available, to derive from the precipitation records satisfactory explanation of the changes in lake levels. And it is my conclusion that a considerable part of these changes is due to causes to be sought elsewhere.

An examination of Table XIX of Exhibit 34 shows that a reduction of the level of Huron-Michigan took place about 1889-90. For the six years preceding, 1884 to 1889, the mean elevation was 582.35; and for the six years following, 1890 to 1895, the mean elevation was 580.53, or 1.82 feet lower.

Lake St. Clair shows a drop at the same time from elevation 576.27 to 575.12, or 1.15 foot; and Lake Erie, a drop from elevation 573.04 to elevation 572.12, or 0.92 foot.

In the report of the Chief of Engineers for 1903, Appendix FFF, pages 2878, 2879, are given tables of precipitation on the several watersheds of the Great Lakes, which were identified by complainant's witness Wheeler.

Q. That was the mean annual precipitation?

A. Gives the monthly also. On the several watersheds of the Great Lakes, such tables being identified and testified to by the complainant's witness Wheeler in file 4, pages 92, 93, being pages 188 and 189 of the continuously paged record.

The mean annual rainfalls as shown in these tables for the periods last under consideration, namely, 1884 to 1889, and 1890 to 1895, were, for Lake Superior in the former period, 26.7 inches, in the latter period 25.60 inches, a decrease of 0.47 inches, or 1.8 per cent. On Michigan-Huron, for the former period an average precipitation of 32.07 inches, for the later period 31.91 inches, showing a difference of 0.16 inches, or 5/10 of 1 per cent. On St. Clair-Erie, for the former period, an average precipitation of 32.39 inches, for the latter period 34.94 inches, showing an increase of 2.55 inches, or 7.3 per cent. On Ontario, during the former period, an average pre-

cipitation of 34.83 inches, during the latter period 38.97 inches, showing an increase of the latter over the former of 4.14 inches, or 10.6 per cent.

From the Report of the International Waterways Commission, page 101, being the Report upon the Regulation of Lake Erie for 1910, to which reference has already been made, the flow of the St. Mary's River during the period from 1884 to 1889 is shown to have been at the rate of 78,616 cubic feet per second, and during the later period at the rate of 71,600 cubic feet per second, showing a decrease of 7,016 cubic feet per second between the two periods. And the surface of the lake, by Tables L of Exhibit 4 was at the same mean elevation for both periods.

The discharge, therefore, appears to have been reduced 9 per cent. by a decrease of rainfall of less than 2 per cent.

Complainant's witness Wheeler, in the report above, makes these discharges for the St. Mary's River, 70,388 cubic feet per second for the former period and 65,789 cubic feet per second for the later period, giving a difference of 4,590 cubic feet per second, discharge of the St. Mary's River, as computed by Mr. Wheeler and identified by him, as shown upon page 2,873 of Appendix FFF to the Report of the Chief Engineers for the year 1903.

The holding back of 7,016 cubic feet per second in Lake Superior would lower Lakes Michigan-Huron 7,016 divided by 28,872, equals 0.24 foot. So that on the theory of the complainant's witness Haskell, a reduction of 5/10 of 1 per cent. of the rainfall lowered these lakes 1.82 minus 0.24, equals 1.58 foot, equivalent to reducing the discharge 1.58 times 28,872, equals 45,600 cubic feet per second; and a rainfall of 0.16, which is the difference between the rainfall of the earlier and later period on Michigan-Huron, on the area of the land and water drainage of Michigan-Huron, would only amount to 1,624 cubic feet per second on a lowering of 0.056 of a foot, if we assume that all of this decreased rainfall would have reached the lake if it had not decreased, thus leaving 1.52 of a foot lowering, or a discharge of 44,000 cubic feet per second to be accounted for.

The rainfall of St. Clair and Erie shows an increase in the second period over the first, as does also that of Ontario; the former of 2.55 per cent., and the latter of 4.14 per cent.; yet Lake Erie lowered 0.92 of a foot between the two periods, and Lake Ontario lowered 0.53 of a foot.

From the foregoing it seems clear that some other cause

than reduced rainfall must be found to account for the changes of lake levels about 1889.

Mr. Wilkerson: I make the same motion with respect to this discussion on precipitation; with the same statement as to the furnishing of data, and as to the opportunity for cross-examination. And if I may be permitted, I would like to have this understanding, not only with reference to the testimony of this witness, but with reference to the witnesses who are to be examined in the future. It is obvious that the competency of a great deal of this hypothetical testimony, which is based upon assumptions of fact made by the witness, cannot be determined until the data from which the conclusions are drawn have been subjected to the test of the cross-examination of counsel; and I will reserve making any such motions at the time the evidence goes into the record, with the understanding that upon the conclusion of the Government's cross-examination of the witness, I will reduce these motions to strike the evidence, and such objections as go to the competency, materiality or relevancy of the evidence, to writing, and submit them to the counsel on the other side, and hand them to the Commissioner.

Mr. Austrian: And we will have an opportunity then, to supply and correct so far as we can, any testimony, to which the objection goes.

Mr. Wilkerson: Of course, you would have an opportunity for further examination of the witness after the objection is made.

Adjourned to Tuesday, March 25, 1913, 10 o'clock a. m.

March 25, 1913, 10 o'clock a. m.

Parties met pursuant to adjournment.

Present same as before.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Mr. Adcock: Referring to Table LIII, Mr. Williams, will you state how you have compiled that table and what it refers to?

A. Table LIII presents the cubic yards of material reported as removed from the channels of the St. Clair River, Lake St. Clair and the Detroit River from 1870 to 1910, the table being based upon the reports in the annual reports of

the Chief of Engineers covering the several localities that are indicated at the top of the table.

The first column gives the year in question; the second column covers the region at the lower end of Lake Huron, being the head of the St. Clair River, at which in the early days there was a bar upon which the depth of water appears to have averaged about 12 or 13 feet. The second column is headed "Mouth of Black River," and refers to the shoal which has been repeatedly dredged in front of the City of Port Huron; this shoal apparently reforming to a considerable extent after having been removed on altogether five different occasions.

Mr. Austrian: Are you referring to sheet 1?

A. I am referring to sheet 1 and sheet 2.

Q. Taken in connection with each other?

A. Taken in connection with each other.

Mr. Adcock: They are all a part of the same table?

A. All a part of the same table.

Mr. Austrian: What do the figures indicate?

A. The figures indicate the number of cubic yards of dredging reported as being done in these localities in the reports of the United States Engineer in charge of the work in the district, as published in the reports of the Chief of Engineers.

Mr. Adcock: And you refer to the specific portions of the reports, or any particular reports which make this up, if there is any dispute about it.

Mr. Wilkerson: This I understand is a compilation made from the Government's reports?

A. This is a compilation made from the Government reports.

Q. And you have a memorandum indicating what—

A. It indicates the year. I have the memoranda giving the information in detail. It is all compiled from the report of the engineer in charge of the Detroit office; begins with the reports, I believe, of General Poe. It is the report of the Detroit office, all the time.

Q. This, I understand you to say, shows the total quantity moved, without showing the disposition?

A. This shows the total quantity moved or reported moved from the channel.

Mr. Adcock: At the particular points indicated?

A. At the particular points indicated, or in the particular localities indicated.

The third column, which is headed "St. Clair River," cov-

ers those portions of the St. Clair River below the Black River shoal and above the St. Clair Flats Canal.

The fifth column headed "St. Clair Flats Canal," covers the excavation in connection with the improvement of the St. Clair Flats Canal; that is, at the foot of the St. Clair River.

The sixth column headed "Grosse Point Cut," refers to that channel which was dredged in the nineties across the lower end of Lake St. Clair, cutting away the bar at the head of the Detroit River, which prior to that time had restricted navigation—or given a restricted depth of about 16 feet at low water.

The next column, that is, the seventh, gives the total amount of material removed from the St. Clair River and Lake St. Clair.

The eighth column gives the amount of material removed from Ballard's Reef, so-called, which is the upper obstruction in the Detroit River, and is situated a short distance above Amherstburg, on the Canadian shore.

The ninth column gives the excavation reported for the Lime Kiln Crossing, which is a short distance below Ballard's Reef; and from the reports, it is evident that at times the work on the Lime Kiln Crossing included work on Ballard's Reef, and *vice versa,* so that these two improvements are to be considered as practically one and the same thing, except that there is not a duplication in the figures.

The tenth column, which is marked "Outlet," indicates the material removed from the Detroit River below the Lime Kiln Crossing in the shoals, mainly of earthy material, which existed at the mouth of the Detroit River, or at the head of Lake Erie. The excavations at Lime Kiln and Ballard's Reef were to a considerable extent in rock.

The eleventh column is headed "Livingstone Channel," and gives the excavations as reported from the Livingstone Channel for the years 1908, 1909 and 1910. This channel was completed in 1912, but the figures have not been extended to cover that date, as they were not accessible to us at the time this table was prepared.

The next to the last column gives the total excavation in the Detroit River from Ballard's Reef to the outlet inclusive, and the last column of the table gives the grand total of all excavations reported for the St. Clair and Detroit Rivers in the years in question. At the bottom of the table—

Q. When you say, "St. Clair and Detroit," that includes Lake St. Clair, doesn't it?

A. And Lake St. Clair, yes. At the bottom of the table,

the first page, are given the totals of each column for the periods from 1870 to 1892, inclusive; and at the bottom of the second sheet are given the totals for the periods from 1893 to 1910, from 1870 to 1892 and for the entire table from 1870 to 1910 inclusive.

There is also at the lower right-hand corner of the table a statement of the total amount of material removed from the channels from 1903 to 1910, which is 14,975,331 cubic yards, out of a total for the entire period of 25,290,830 cubic yards.

Q. What other investigations have you made with reference to channel improvements of the St. Clair and Detroit Rivers and Lake St. Clair?

A. I made, in the late nineties, an examination of the effects of the channel improvements in the St. Clair River upon the water supply of Detroit, and had occasion at that time to examine very carefully the original records of the dredging inspectors in the United States Engineer's office at Detroit, through the courtesy of the chief officer in charge; and also to refresh my personal recollections of a considerable portion of this work which was carried on under my observations, to the extent that I could see it going on during my connection with the Detroit Water Works. And it was my recollection of the large amount of work that was done at this time that first directed my attention to that as a possible explanation of the change in lake levels which occurred about 1889 and 1890, as shown by the tables which have been put in evidence heretofore.

This led to a more careful investigation of the relations between the excavations in the channel—I will say of the apparent relations between the excavations in the channels and the changes in lake levels, which has been made by a study of the reports of the Chief of Engineers upon the subject, by conversations with engineers and others who were associated with the work, and by reference to personal memoranda which had been taken from time to time, bearing upon the subject, in the course of my professional work independent of this case.

Mr. Wilkerson: All the work in these channels, about which you are speaking now, was work done by the Government under the authority of the War Department?

A. Yes, sir. There is nothing included in LIII which has not been done by the authority of the War Department under the direction of the engineer officer in charge of the district.

There has been in certain localities considerable further excavation for commercial purposes, particularly recently in

the vicinity of Port Huron, at the head of the St. Clair River, where, within a few years, the removal of material for building purposes (that is, for the sand and for the gravel) was stopped, as a result of the influence brought to bear by the United States Engineer Office upon the Canadian authorities, as I am informed.

Mr. Wilkerson: That is, it was work that was being done by Canadians?

A. It was work being done by Canadians, which it was conceived would interfere with—possibly increasing the outlet of Lake Huron, and interfering to that extent with navigation.

Q. The War Department protested, with the result that the work was stopped?

A. The protest was lodged, and as a result the work was stopped. I do not know whether it went clear through the official channels, or was arranged locally. It is all a matter of record; it could be looked up.

Mr. Adcock: Will you state what conclusions you have reached, and the basis of such conclusions, giving the facts which you have considered in connection with such channel improvements, as to their effect upon the lake levels?

A. The first important work done towards improving navigation in the waters connecting Lakes Huron and Erie was the creation of a 12-foot channel through the St. Clair River, which was completed about 1858, by the construction of the St. Clair Flats Canal. Prior to this, the limiting depths in the latter river, which was at the Flats, was about 9 feet. My impression is that was the mean.

Q. That is prior to what time?

A. Prior to 1858. It is difficult to discover any effect of this improvement upon the level of Lake Huron, for the reason that there are on record no accurate or reliable elevations of the lake for this period, by which it can be compared with the elevations of other lakes for the period prior to this improvement. There are some elevations about this time, but they do not extend back far enough to give a sufficient average to warrant a statement as to the actual effect of these improvements.

The St. Clair Flats Canal, at which these improvements were made, is shown on Williams' Exhibit 7 entitled "Chart of the St. Clair River, including foot of Lake Huron and St. Clair Flats Canal," in the lower left-hand corner of the chart; and the original channel, which was improved in 1858, is represented by the legend, "St. Clair Flats Canal," and extends

between the two upper lighthouses indicated as "St. Clair Flats Canal, Upper Light," and "St. Clair Flats, Lower Light;" the lighthouses being indicated by red dots in a yellow field.

It will be noted that beyond the portion of the channel which is marked "St. Clair Flats Canal," there is an extended dredged area reaching out into Lake St. Clair, indicated by the white through the blue, and the excavations from this channel have been included in the column marked "St. Clair Flats Canal," in Table LIII just described.

Between 1867 and 1871, the St. Clair Flats Canal was deepened to 13 feet, and progressively until 1874, to 16 feet. At the same time, the Lime Kiln, at the mouth of the Detroit River, was similarly deepened. The location of the Lime Kiln is shown upon Williams' Exhibit 9, being a chart of the Detroit River; being located approximately opposite and just above Ft. Malden, which is about a mile above the town of Amherstburg; and is substantially opposite the coffer dam represented attached to Stony Island in the lower half, or lower quarter of the chart.

This early improvement of the Lime Kiln consisted largely in the removal of loose boulders, and did not involve the removal of any large quantity of material. These improvements were followed, in 1874 to 1879, by the removal of the bar at the mouth of Black River at Port Huron, which is shown on Williams' Exhibit 7, "Chart of the St. Clair River, etc.," the bar being indicated by the blue coloring opposite the lower end of the City of Port Huron, at the upper end of the St. Clair River and near the top of the chart. The Black River is seen emptying into the St. Clair, cutting the City of Port Huron into two parts. The purpose of this improvement was to produce a navigable depth along the city frontage of 15 feet.

After the completion of this work, the famous Lime Kiln Channel enlargement was begun, in 1876, and continued until its final completion in 1891. This enlargement was in the locality indicated previously on the chart of the Detroit River, and contemplated a depth of water of 20 feet at the average stage.

In 1888 the Lime Kiln Channel had been completed to a width of 300 feet throughout its length, giving a depth of about 20 feet of water; and in 1889 a width of 350 feet could be depended upon.

Mr. Austrian: You say "throughout its length;" have you given its length?

A. I have not. The improvement covers about, altogether, that improvement which extended not only through the Lime Kiln, but up through Ballard's Reef, covers about four miles of river, the aim being to dig out the shallow spots. There were deep spots in that length, where no improvement was necessary.

During the same year, and the year following, 1889 and 1890, a large amount of material was again removed from the bar at the mouth of Black River; a depth of over 16 feet being secured, and a consequent enlargement of the carrying capacity of that portion of the St. Clair River being produced.

The effect of the improvements between 1876 and 1891 does not appear in its completeness until about 1890, although the changes in lake levels coincident with it are indicated, as shown in Table XIX by the decrease in fall between Lake Huron and Lake Erie, as far back as 1887.

In 1893, four, five and six, very extensive channel improvements were made at the foot of the St. Clair River, and through Lake St. Clair, by the dredging of a 20-foot channel through the bar at the foot of Lake Huron. The location of this dredging is shown on Exhibit 7, "Chart of the St. Clair River" at the top of the chart; the dredging taking place right at the head of the St. Clair River, and extending up some three or four miles into the lake. That channel, if my memory serves me correctly, was 2,500 feet wide, and the bottom was cleaned off to a depth of 20 feet.

The amount of material excavated at this point, as shown in Table LIII during the years 1893 to 1897, was nearly one million cubic yards.

In 1893, work on the Grosse Point Channel was commenced, and extended to the end of May, 1897. Grosse Point Channel is located at the head of Detroit River, at the foot of Lake St. Clair; and is shown on Williams' Exhibit 8, "Chart of Lake St. Clair," the lower left-hand corner of the chart. It extends from the deep, or white water indicated in Lake St. Clair, to the head of the Detroit River, a distance of between two and three miles. From this locality, over five and a half million cubic yards of material was reported to have been handled during the period of this improvement, giving a 20-foot depth entirely across Lake St. Clair.

Mr. Austrian: When you say "reported," you mean what?

A. Reported in the reports by the Engineer Officers, or reported by the Engineer Officer, to have been removed. In 1908, work began on the Livingstone Channel, through the

Lime Kiln, and in 1908, 1909 and 1910 nearly 9,000,000 cubic yards of material are reported by the Engineer Officer to have been removed; and about 400,000 cubic yards more were removed along the old channel, in this vicinity.

The Livingstone Channel is shown upon Williams' Exhibit 9, "Chart of the Detroit River," the upper end of it being enclosed in the coffer dam attached to Stony Island just above the town of Amhertsburg on the Canadian shore, all of which is in the lower left-hand quarter of the sheet.

During the construction of the Livingstone Channel, the upper end of it was enclosed in a coffer dam, that the excavation through the rock might be made in the dry. And the first effect of this improvement was to reduce the discharging section of the Detroit River, raising the water above the coffer dam, and ultimately in Lake St. Clair to a small extent. This channel was completed in 1912 and the coffer dam removed, so that water was free to flow through the excavation in the rock underneath the coffer dam as made in August, 1912, since which time it has added to the discharging capacity of the river as it existed prior to the opening of the coffer dam.

The change in conditions at the head of the St. Clair River is shown by a comparison of plates 7 and 8 of Exhibit 34, of which plate 7 is a photograph of a portion of the chart of the St. Clair River, secured from the United States Lake Survey Office in 1897, by me, which is stamped with the legend, "Aids to Navigation corrected from information received to April 20, 1892." To this photograph have been added in ink two parallel lines enclosing the bar opposite Fort Gratiot; and there has been added in ink "Datum 582.489," being the elevation to which the soundings are referred, when corrected for the revised levels of 1903. The soundings on this chart—

Mr. Adcock: What do you mean by "Revised levels of 1903?"

A. The revised levels of 1903 is a term used to designate the correct elevations of bench marks along the lakes, as a result of precise level determinations, which were made between 1900 and 1903, connecting the benches in this section of the Great Lakes with the benches which had been previously connected to tidewater. It was found as a result of these levels, which were very carefully run, that there were small errors in the old elevations of the benches, in some of them the errors being greater and some less. And in the report of the Chief of Engineers for 1904, Appendix EEE, page 4070, are given the elevations in Table I of bench marks by

what is designated as the old and new levels. The old levels are now referred to ordinarily as 1877 levels, being based upon the determiantions made by the Lake Survey in 1877; and the new levels are referred to as the 1903 levels, being based upon the determinations made by the Lake Survey in 1903.

It will be noticed that the changes which are shown in the third column of the table are comparatively small. The largest change in this table appears at the U. S. bench mark E at Harbor Beach, which, according to the new levels, is 0.507 feet higher than it was according to the old levels.

I would say that all the elevations of lakes given in the exhibits so far introduced have been those referred to the 1903 levels, but it is necessary to keep that fact in mind, because in connection with some of the records, or in connection with all of the records published prior to 1903, the reference is to the 1877 levels, and the elevations would be in error by the amount of the correction which is indicated in this table, for the particular locality.

Since 1903 there has been an additional correction of 6/100 of a foot, or .06, affecting the levels of Lake St. Clair; and this correction has been taken into account in the elevations presented in the exhibits so far in this case. That will be detected by a difference in the elevations of Lake St. Clair, as presented in the report of the International Waterways Commission on the Regulation of Lake Erie for 1910, and the elevations for Lake St. Clair as presented in the blue print exhibits in this case, so that by the levels of 1903, as readjusted, I think in 1910, the level of Lake St. Clair has been found to be .06 higher than was indicated prior to that time, and as shown in the reports of the International Waterways Commission.

Plate 8 is a photograph of a portion of the chart of the same river, being Williams' Exhibit 7, "Chart of the St. Clair River," upon which two parallel ink lines have been drawn, as near as I was able to draw them in the same position as those on plate 7, and the datum elevation has been entered in ink as 578.50, which is taken from the legend on Exhibit 7.

On Plate 7 the soundings marked in the area between the two ink lines enclosing Fort Gratiot Light, omitting only the eight fathoms which is just above the bar on the left-hand side, and which by comparison with the latter chart appears to be an error, as it is hard to conceive how there could have been eight fathoms of water there in 1877, and only 24 feet

plus the change of datum in 1910, for that reason I have omitted that eight fathoms from the computation. Taking the average depth of the other soundings indicated between those two lines on the chart, based on the surveys of 1877 and purporting to be corrected to 1892, the average depth through this area is 22.1 feet below the datum of 582.49, or an average bottom elevation of 560.4 feet above sea level.

Plate 8 is from a chart of the same river, stamped: "Issued May 10, 1911," and at the bottom in the center bears the legend, "Aids to Navigation, corrected from information received to May 10, 1911, March 23rd, 1912, August 24, 1912."

On this latter plate, photographed from the chart purporting to represent the conditions of the channel at the head of the St. Clair River, the soundings in the area enclosed between the similar parallel lines show an average depth of 28.4 feet below the datum elevation of 578.50, or the average bottom elevation of 550.1 feet. Comparing this with the average bottom elevation shown on the photograph of the former chart, Plate 7, it indicates a difference of average bottom elevation through this section of 560.4 minus 550.1, or 10.3 feet. In other words, it is apparent by the comparison of these charts, that the channel through the bar at the foot of Lake Huron, which must have been to a very large extent the controlling factor in the outflow of Lake Huron, has been deepened 10 feet for its average width from shore to shore, between the times covered by the information contained in these two charts.

Since the conclusion of the discharge measurements of 1902, there has been removed from the waters connecting Lakes Huron and Erie, about 15,000,000 cubic yards of material. If this excavation were concentrated in a continuous stretch of 20 miles, 20 miles covering the entire distance over which such improvements have been made, it would make a channel 600 feet wide and 6¼ feet deep.

The effect of this work has been, according to the report of the Chief of Engineers for 1911, page 3013, to increase the discharge of the St. Clair River for the same stage by about 3 per cent. And 3 per cent. of the discharge of the St. Clair River, as indicated by the measurements from 1889 to 1902 would be about 5,700 cubic feet per second.

Mr. Wilkerson: You spoke of averaging these figures on Plates 7 and 8?

A. Yes.

Q. You mean to say that you averaged the figures just as they appeared on those plates?

A. Just as they appeared.
Q. As they are photographed here?
A. Yes.
Q. And giving equal weight to each figure?
A. Equal weight to each figure. There was no attempt to reduce at all.
Q. And you took the figures as they appeared on Plate 7, and the figures as they appeared on Plate 8?
A. Yes. Now, comparing the information on Table LIII with Table XIX of Exhibit 34, which shows the mean annual elevations of the Great Lakes, and the difference in elevations, it is noticed at once that the very marked fall which occurred in Lake Huron with reference to Lake Erie, about 1889, was coincident with the completion of the Lime Kiln Channel at the foot of the Detroit River, which removed what had been, up to that time, an effective weir, controlling to a very large extent the discharge of the Detroit River. This bar was cut through during the previous years, the channel being gradually widened until, as stated, in 1888 it was 300 feet wide. By that time, the increased discharge of the Detroit River had lowered Lake St. Clair and produced an increased flow through the St. Clair River, which in turn lowered Lake Huron, and the effect upon Lake Huran became apparent suddenly about 1889 or 1890. The lowering of Lake Huron is seen, by Table XIX, to continue through the following ten years, being coincident with the large excavations across Lake St. Clair, at the head of the St. Clair River, and further excavations in the Detroit River. The comparisons of these two tables offers to my mind a clear explanation, and a sufficiently complete one, of the changes in the lake levels which occurred about 1889, and which has been heretofore attributed to changes in precipitation and evaporation.

The mean elevation of Lake Huron from 1860 to 1889 was 581.91; the mean elevation from 1890 to 1912 has been 580.43, or 1.48 feet lower.

The mean elevation of Lake Huron from 1884 to 1889 inclusive, was 582.35; and the mean elevation from 1890 to 1895, inclusive, was 580.53, or 1.82 feet lower. In other words, between those two six-year periods—and I take six years in order that I may eliminate any influence of deficient precipitation in a single year; ice, or anything that might make the reference to a single year misleading—the difference of elevation between these two six-year periods has been 1.82 feet. No such sudden drop in the level of Lake Huron is observable anywhere else in its history, so far as our data of elevations

go, and it must have been caused by some particular and special cause, some unnatural cause, as no natural cause can be conceived, which would produce such a remarkable change as this one. That unnatural cause is found in the evidence of Table LIII, in the excavation of material from the Lime Kiln Crossing at the foot of Detroit River, which, prior to its excavation, had controlled the discharge of the river. When this channel was cut through, it enabled the water to flow away more freely, the discharge of the River was increased; the result was a lowering of Lake St. Clair, which increased the fall from Huron to St. Clair, thereby increasing the flow of the St. Clair River and decreasing the level of Lake Huron, as indicated in the actual observations of elevations.

It is possible to determine approximately the amount by which the discharge of the St. Clair River has been increased between its mean discharging capacity for the period from 1860 to 1889, and the period from 1890 to the present time. This may be determined by reference to Table XXI of Exhibit 34, which shows that the fluctuations of Erie, with reference to Huron, during the period from 1860 to 1889 were 75.3 per cent.; and during the period from 1891 to 1910 85.5 per cent., during the latter period. As there has been no marked change, so far as we know, in the discharging capacity of the outlet of Lake Erie during this period, it follows—

Mr. Adcock: During which period?

A. During any of the period from 1860 to 1910. It follows that the conditions of fluctuation, as related to increment, must have been practically constant for Lake Erie during this time; and therefore, it affords a saisfactory standard of comparison for the fluctuation of Huron during the two periods. This fluctuation, as presented in Table XXI, is based upon the mean annual change of elevation of the two lakes.

Then the fluctuations of Huron in the later period as compared to those in the earlier period will be as 75.3 divided by 85.5, or as 0.88; or the fluctuation in the later period will be 0.88 of the fluctuation in the earlier period.

Q. That is the fluctuation in Huron?

A. Of Huron,

Q. That is, the two periods being from—

A. The two periods being, the first from 1860 to 1889, and the second from 1891 to 1910.

This being the same reservoir involved, there are no modifying influences to affect the general rule that the fluctuation is inversely as the increment, and therefore the increment

of the St. Clair River during the earlier period must have been about seven-eighths per cent. of the increment during the later period.

Q. That is, the smaller the increment, the greater the fluctuation?

A. The greater the fluctuation.

Q. The greater the increment, the smaller would be the fluctuation?

A. The smaller will be the fluctuation, because in order to discharge a given quantity of water with a small increment, the lake must rise higher in order to get that water out; and conversely to discharge a given quantity of water with a large increment, it is not necessary for the lake surface to rise so high.

Now, by the principle already enunciated, that when a change is made in an open channel, which increases the increment, the discharge will be changed in a greater proportion than the increment is changed, it follows that the discharging capacity during the period from 1860 to 1889 must have been at the greatest not to exceed 87½ per cent. of that for the period from 1891 to 1910.

Q. You mean the discharge or the discharging capacity of the channel?

A. The discharging capacity. The average discharge of the St. Clair River, from 1900 to 1907, has been computed by the defendant's equation, as shown on Table XL, to be 197,633 cubic feet per second, and it therefore follows that for the same stages as existed between 1900 and 1907, under the conditions of channel existing from 1860 to 1889, the discharge of the river must have been less than 87½ per cent. of 197,633, or less than 172,500 cubic feet per second.

It therefore follows that the changes which have been made in the channels of the St. Clair and Detroit Rivers, beginning with the work upon the Lime Kiln Channel, which was completed in 1891, have had the effect of increasing the discharging capacity of the St. Clair and Detroit Rivers for an average stage, as represented by that existing from 1900 to 1907, by not less than 25,000 cubic feet per second, which is equivalent to an ultimate lowering of these lakes, of not less than 10.4 inches, using the increment derived by the defendant for the conditions of the later period as shown in Table XXXIII.

Q. Have you computed the increment for the previous period?

A. The increment for the previous period would be 87½

per cent. of that for the later period, or about 25,300 cubic feet per second.

Q. What would have been the lowering by this increased discharge, according to the increment deduced for the earlier period?

A. Approximately one foot. It has already been pointed out in my testimony that the effect of the storage in Lake Superior and the diversion through the Chicago Drainage Canal would account for a lowering of Lake Michigan-Huron of about .37 of a foot, and by the changes in the channel, we have accounted for a lowering of nearly 9/10 of a foot, which leaves about 3/10 of a foot to be explained by conditions not definitely determinable, as rainfall and evaporation effects, and other climatological influences.

Direct examination of witness adjourned.

Recess until 2 o'clock p. m.

Depositions in the above entitled cause, taken pursuant to stipulation of counsel for the respective parties, before the Commissioner, statutory notice being duly waived, at the Plaza, New York City, commencing July 17, 1913.

Appearances: Mr. James H. Wilkerson, representing the Government. Mr. Edmund D. Adcock and Mr. Alfred S. Austrian, representing the Sanitary District.

All objections to questions, answers and exhibits shall be considered as having been made, except as to questions involving form and secondary evidence.

GARDNER S. WILLIAMS resumed the stand for further direct examination by Mr. Adcock, and testified as follows:

Q. I think in your previous examination, you stated that the discharge of the Detroit River was measured in the year 1901. Have you made any examination of the discharge measurements of that river, as shown by the records in the Lake Survey office?

A. I have made an examination of the published reports of the discharge measurements of the Detroit River, as they are presented in the Report of the Chief of Engineers for 1903, Appendix FFF, pages 2816-17.

There is also some further information in regard to these

measurements in the report for the year 1902, page 2867; but the 1903 report is the summarization of all the work.

Q. Will you state what investigations and examinations you made, and the conclusions that you have reached?

A. These discharges were examined with a view to ascertaining whether they would support the conclusions drawn from the other observations, whether by any chance they might corroborate the Niagara discharges, or whether they would corroborate the St. Clair and St. Lawrence discharges, or whether they might be inconsistent with all of them.

As previously stated, the discharge of the Detroit River was measured at Ft. Wayne, just below the City of Detroit, by Mr. Murray Blanchard, under the direction of Professor E. E. Haskell, a witness for the complainant in this case, between June and December, 1901, and between June and November, 1902, all inclusive. The results are published, as previously stated, and the discharges are there referred to gauge readings at Windmill Point, on Lake St. Clair, which is a short distance above the head of the Detroit River, and at Ft. Wayne, the gauging section, and at Amherstburg, at the foot of the Detroit River which is really a short distance upstream from the mouth. As published, the gage heights are in terms of the so-called "1877 levels" and when transferred to the "1903 levels," the mean results are:

	Windmill Pt.	Ft. Wayne	Amherstburg	Discharge
1901	574.84	573.99	571.55	201,237 cfs
1902	575.12	574.39	572.71	196,871 cfs
1901–2	574.99	574.20	572.34	198,960 cfs

In explanation I might say that the results for 1901-2 are not the averages of the figures given above, but are the means of all the observations during the entire period; the number of observations being different in the two years. The discharge of the Detroit River is influenced, not only by the elevation of Lake St. Clair, but also by that of Lake Erie, so that an increment cannot be derived by the simple processes used for the Niagara and St. Lawrence Rivers, but must involve a procedure similar to that adopted for the St. Clair.

The number of observations involved on the Detroit does not permit so thorough an investigation as that made on the St. Clair, but by grouping the observations with first one lake constant and then the other, the increment due to Lake St. Clair alone appears to be 45,380 cubic feet per second; and that due to Erie alone, 17,290 cubic feet per second.

From Table XXI of Exhibit 34, it has been shown that Lake Erie's annual fluctuations are 0.855 of those of Huron,

while those of Lake St. Clair are 0.894 of Huron, whence the fluctuations of Erie are the ratio of these two, or 0.956 of those of Lake St. Clair.

The average net increment of the Detroit River from 1890 to 1910 would therefore be 45,380 minus .956 times 17,290, which equals 28,850 cubic feet per second, or substantially the value previously determined for the St. Clair.

The reason for saying that this covers the period from 1890 to 1910 is that we accept these observations made in 1901 and 1902 as representing an average of the conditions of the Detroit River from 1890 to 1910 except as the lake was affected by the work at the Livingstone Channel.

It is to be recalled that the similar process of computing an increment, when applied to the St. Clair gave a value about nine per cent. less than that finally obtained by a more precise determination, and a similar discrepancy may be expected in the case of the Detroit, so that an increment for the latter of about 32,000 cubic feet per second is to be predicted from the preceding result.

The number and range of the Detroit observations are not sufficient to permit of such a treatment as that finally adopted in the case of the St. Clair, but the observations on the Detroit River may be divided into five groups, including altogether 93 out of a total of 117 observations.

Q. What is the treatment you refer to there, with reference to the St. Clair?

A. The treatment of grouping is at times when the stage of the lakes were uniform, or that is, were reasonably constant. There are not enough points to be derived to get a satisfactory equation.

Q. Do you remember what tables those were referred to?

A. Yes. As set forth in Tables XXVIII and XXXIV.

Q. Of Exhibit 34?

A. Of Exhibit 34. I was able to get 93 out of 117 and thereby form five groups, which covered periods as follows:

July 19 to August 3, inclusive, 1901, 11 observations.

August 15 to September 7, inclusive, 1901, 25 observations.

October 7 to October 21, inclusive, 1901, 11 observations.

July 1 to August 2, inclusive, 1902, 26 observations.

October 14 to November 4, inclusive, 1902, 20 observations.

Mr. Wilkerson: Have you a statement there of the ones which you did not consider?

A. No; they can be identified in the table. The reason for leaving out any was, there was either a break in the time of observation, so that they were isolated observations, or

there was a marked change in the conditions as indicated by the change in discharge, so that what I was endeavoring to get here was a group of observations that represented reasonably constant conditions on the two lakes.

Q. I was just inquiring as a matter of convenience so that we would know if you have any tabulation formed of the ones not considered.

A. No, I have not. They are in the report, and you can refer to them.

Having the gage elevations at Windmill Point and Amherstburg, and the discharge for those five groups, it seemed that it should be possible to derive an increment for the Detroit River from these five equations. The method of least squares was applied, and most absurd results were obtained, or absurd results were obtained; the net increment being about 16,000 cubic feet per second, which is on the face of it impossible, since the Detroit increment must be greater than that of the St. Clair, and nobody as yet has conceived a method to bring the increment of the latter to a value less than 16,000. This indicates that the relations between the variables in the equations are not sufficiently established to permit the derivation of an increment from them, although the discharges may be measured with a reasonable degree of precision. The average of the discharges measured for the five periods is 200,880 cubic feet per second. The average discharge of the St. Clair River for the same periods determined by taking the average lake elevations at Harbor Beach and St. Clair Flats for the entire time covered by the five observation periods, and applying the defendant's equation is 201,500 cubic feet per second, or within 620 cubic feet per second of the average of the Detroit measurements.

During the time included in the selected periods, Lake St. Clair as shown by the gage at Windwill Point, comparing its elevation on the first and last days of each group rose .39 of a foot. Since Lake St. Clair has an area of 503 square miles, a rise of one foot in one day would be equivalent to a storage of 162,300 cubic feet per second, and a rise of .39 in the 140 days covered by the selected periods would, therefore, represent a storage of 450 cubic feet per second, so that in the preceding comparison the computed discharge of the St. Clair River for the entire length of the five periods exceeds the average of the observed discharges of the Detroit River plus the storage in Lake St. Clair by 170 cubic feet per second.

During the period from June to November, inclusive, the

average run-off per square mile for the Lake Erie-St. Clair watersheds is 0.252 cubic feet per second, as shown in Table LXIXa of Williams' Exhibit 34. The area of the land watershed tributary to Lake St. Clair and the St. Clair below the Dry Dock Section is 5,691 square miles, by the report of the International Waterways Commission, whence there is to be expected an increase of discharge of the Detroit River over the St. Clair River of about 1,430 cubic feet per second. This quantity is reduced by the water abstracted by the Detroit Water Works that is used for the generation of steam and for lawn and street sprinkling, which does not find its way into the sewers. During 1901 and 1902, from an examination of the records of the pumping at the Detroit Water Works, this is estimated at about 15,000,000 gallons daily during the period of the gagings, which is about 230 cubic feet per second. The net result is that the Detroit River discharge should have been about 1,000 cubic feet per second greater than that of the St. Clair for the periods in question. The gagings of the Detroit River, therefore, disagree with those of the St. Clair by about 1,200 cubic feet per second, which is less than 0.6 of 1 per cent. The gagings of the St. Clair being reduced by the defendant's equations.

The Detroit measurements then afford a further check upon the accuracy of the St. Clair and St. Lawrence observations, and a further proof of the incorrectness of the Niagara results. As already shown in Table XXI of Exhibit 34, the annual fluctuations of Lake St. Clair are 89.4 per cent. of those of Lake Huron, and as the water contributed by the Lake St. Clair drainage is relatively insignificant, the increment of the Detroit must be 1 divided by 0.894, or 1.12 times that of the St. Clair.

As previously shown, the St. Clair increment is about 28,872 cubic feet per second, and that of the Detroit then is is about 32,300 cubic feet per second, or slightly more than the value of 32,000 previously predicted from the investigation of separate increments.

We, then, have the following equation referring back to the fact that the fluctuation of Erie is 0.956 that of St. Clair; S minus 32,300 plus 0.956 E equals Zero; that is the algebraic sum of the increments due to Lake St. Clair designated as S and Lake Erie designated as E must equal the net increment of the Detroit River; in which equation S is the increment due to Lake St. Clair and E that due to Lake Erie.

By a comparison of the monthly changes in mean eleva-

tion of Lake St. Clair and Erie for months when Lake Huron was at the same mean elevation as presented in Table LV, these observations being taken for the open season only as the presence of ice entirely nullifies the value of any such comparison, a rise of one foot in Lake Erie is accompanied by an average rise of .49 in Lake St. Clair.

A rise of 0.49 foot in Lake St. Clair will reduce the flow of the St. Clair River by 0.49 times 13,000, equals 6,370 cubic feet per second, since the increment of the St. Clair River due to the changes of Lake St. Clair is minus 13,000, as previously derived by the defendant and substantially the same figure being arrived at by the complainant, and since the inflow from the land areas to Lake St. Clair is not appreciably changed, the discharge of the Detroit River must be correspondingly reduced, whence it follows that 0.49 S plus 6,370 plus E must equal Zero, where S is as before the increment of the Detroit River due to changes in Lake St. Clair and E the increment due to changes in Lake Erie.

Solving these two equations for the values of S and E, we find that S equals 72,200 cubic feet per second, and E equals minus 41,750 cubic feet per second, or a rise of one foot in Lake St. Clair would increase the discharge of the Detroit River by 72,200 cubic feet per second, and the rise of one foot in Lake Erie would reduce the discharge of the Detroit River by 41,750 cubic feet per second.

At first sight, having in mind the increments of Huron and St. Clair for the St. Clair River, one is inclined to doubt the correctness of these values, but an examination of the characteristics of the two rivers makes it evident that with its shorter length, greater cross section and less slope, any change in either lake will produce a very much greater effect in the Detroit than in the St. Clair. This is also established by the fact that if, under average conditions, Lake Erie were suddenly to rise 2.61 feet, it would be at the same level as Lake St. Clair at Windmill Point and the flow of the Detroit River would be reduced to zero. It then follows that for this extreme variation the average increment of Lake Erie would be about 200,000 divided by minus 2.61, equals minus 76,500 cubic feet per second. On account of a steeper slope between Mamijuda Light and Lake Erie, this being the lower quarter of the river, the increment for the changes near the normal stage of Erie would be less than for those as the level of Lake St. Clair was approached.

Similarly if under ordinary conditions, by reason of ice jams in the St. Clair River and its local tributaries, the in-

flow to Lake St. Clair should be cut off and the lake should fall 2.61 feet at Windmill Point, it would be at the same level as Lake Erie, and the flow of the Detroit River would be again reduced to zero, in which case the average increment of Lake St. Clair would be 76,500.

As a combination of these conditions led to a reversal of flow of the Detroit River in February, 1896, there is nothing forced in these assumptions, and no reason appears for doubting the correctness of the increment of 72,200 cubic feet for Lake St. Clair and 41,750 cubic feet per second for Lake Erie above derived for average conditions.

Referring again to the results of the comparisons of discharges with Lake Erie constant and then with Lake St. Clair constant, if there be excluded from the former, those cases would show a decrease of discharge for a rise of St. Clair and an increase of discharge for a rise of Erie, both of which conditions are inconsistent with the laws of nature, the separate increment would be 81,300 for St. Clair and minus 38,720 for Erie. In other words, the two methods of derivation of an increment, even though the number of observations to be used is too limited to render the results certain, agree within certainly a fair range for observations of this kind.

For the purpose of some further comparisons, the discharge of the Detroit River will be computed for the average open season elevations from 1900 to 1907, inclusive, which will be designated as the reference condition. The purpose of using this period from 1900 to 1907, inclusive, is that it is the period most closely comparable with the conditions at the time of the gagings in 1901 and 1902, as since 1907 the presence of obstructions in connection with the Livingstone Channel, and later the opening of the channel itself, have caused a change of conditions in the river,which has made the flow to follow somewhat different laws since 1907 than it followed from 1900 to that date. During this period from 1900 to 1907, as shown by Williams' Exhibit 27, the mean elevation at Windmill Point was 575.13, and at Amherstburg, 572.65. The mean elevations during the gagings of the Detroit River were: Windmill Point, 574.99 and at Amherstburg 572.34.

During the month of July, 1902, there were 23 discharge measurements made at Ft. Wayne extending from the 1st to the 31st inclusive, no two being made the same day, and giving a mean of 204,506 cubic feet per second. These measurements must therefore represent fairly the average discharge of the Detroit River during that month.

The mean elevation at Harbor Beach for July, 1902, was

580.76, and the mean at St. Clair Flats was 575.76. The discharge of the St. Clair River of July, 1902, was by the defendant's equation 201,013 cubic feet per second. To this should be added the inflow from the Lake St. Clair drainage, which for the month of July has an average value of .3 cubic feet per second per square mile, and for 5.691 square miles would amount to 1,707 cubic feet per second.

The Detroit Water Works was abstracting about 230 cubic feet per second, as previously computed, and the rainfall exceeded the evaporation based on the Rochester Observations of evaporation, which are presented in table LXII of Williams' Exhibit 34, by about .25 of a foot. This is equivalent to a flow of 1,309 cubic feet. During the month, Lake St. Clair rose .27 of a foot, which represents a storage of 1,414 cubic feet per second. The expected discharge of the Detroit River would then be the discharge of the St. Clair as above quoted, 201,013 cubic feet per second, run-off from St. Clair drainage 1,707 cubic feet per second; excess of rain over evaporation on the lake surface, 1,309 cubic feet per second or 204,029 cubic feet per second less storage of 1,414 cubic feet per second and the use of water by the Detroit Water Works of 230 cubic feet per second, that being the water which does not reach the sewers, amounting to a total subtractive quantity of 1,614 cubic feet per second, leaving a net discharge for the Detroit River of 202,415 cubic feet per second. The measured discharge was 204,506 cubic feet per second, showing an excess of 2,091 cubic feet per second, or about 1 per cent. of the measured discharge. This may be almost wholly, if not wholly accounted for by the excess run-off over the average from the St. Clair drainage, as the rainfall for July, 1902, at Detroit was 4.19 inches, or more than 100 per cent. in excess of the normal which would be expected to increase the discharge or the inflow to Lake St. Clair by something in the neighborhood of 2,000 cubic feet per second.

This again shows a close agreement between the Detroit and St. Clair discharges when reasonably interpreted, and we may therefore use the conditions of July, 1902, to establish the reference discharge of the Detroit River for the period 1900 to 1907 inclusive. The elevation at Windmill Point for the reference period was .37 of a foot lower than it was during July, 1902. The elevation at Amherstburg was .66 of a foot lower than it was in July, 1902. The observed discharge of 204,506 cubic feet per second should then be reduced for the decreased height of Windmill Point by 0.37

times 72,200 or 26,700 cubic feet per second, and should be increased on account of low stage of Erie by .66 times 41,750, or by 27,555 cubic feet per second, making a net positive correction of approximately 800 cubic feet per second. The reference discharge then is 204,506 plus 800 equals in round numbers 205,300 cubic feet per second.

The mean dscharge of the St. Clair for the reference period by the defendant's equation is, as already stated, 197,163 cubic feet per second, and allowing 2,000 cubic feet per second as the net increase of discharge between the Dry Dock Section of the St. Clair and the Ft. Wayne Section of the Detroit, the difference between the two determinations of the reference discharge, the one based on the Detroit measurements directly and the other on the St. Clair observations, is 6,100 cubic feet per second, or about 3 per cent. of the average of the two determinations.

Q. By reference discharge there, you mean for a certain period?

A. That is the reference, I said I would call that period from 1900 to 1907 the reference period.

As the St. Clair discharge is based on the larger number of observations, it is entitled to the greater weight, and it is therefore concluded that the reference discharge of the Detroit River is about 199,000 cubic feet per second.

In the month of August, 1912, there was completed through the reefs at the foot of the Detroit River a new channel, 300 feet wide, having a navigable depth of 22 feet, where in places there were formerly only about four feet of water. In the construction of this channel, a considerable portion of the river was closed by a coffer dam from early in 1908 until the completion, and the material from the excavation was spoiled in the shoaler water on both sides of the work. Prior to the beginning of the work, no discharge measurements were ever attempted in that portion of the Detroit River, so far as it has been possible for me to learn. But during the construction, and since completion, several discharge measurements have been made.

The effect of the cofferdam prior to the completion of the work was to raise the level of the river above it, and also both Lake St. Clair and Lake Huron, as shown in table LXIII of Williams Exhibit 34, the slope from St. Clair to Erie being increased about 0.10 foot by the backwater raising the former, and Lake Huron would in time be raised about one-fourth as much. On the opening of the channel, the river very soon assumed its usual slope, and it becomes of interest

to ascertain whether the discharge under normal conditions of slope and stage will be greater or less than before the work commenced.

The river in the locality in question, as shown by Williams Exhibit 9, is divided by Grosse Isle into two channels. The Western or Trenton Channel being unaffected by the improvements except as they affect the slope between its two extremities, and the velocity and depth of the approaching water. Discharge measurements made in this channel on August 29th and 30th and December 5, 1912, after the opening of the Livingstone Channel, when reduced to the conditions corresponding to a normal determination by the mean stages of Lake St. Clair and Erie for the open season from 1900 to 1907, that is to our reference discharge as shown on charts 1, 2, and 3 of Williams Exhibit 34, gives a discharge of 35,818 cubic feet per second.

Mr. Wilkerson: Are those observations published?

A. They are published; I have blue prints here. Part of them are published and part are in the form of blue prints, which I got from the Government Office.

To the east of Grosse Isle as shown on Williams Exhibit 9 and to a larger scale on Williams Exhibit 10, entitled "Lower Detroit River," the river is divided again by a small island known as Stony Island, and the channel between it and Grosse Isle is designated as "Stony Island Channel." The discharge of this channel was measured on August 20 and 21 under conditions closely approximating the normal above adopted, that is the reference condition, and when these discharges are reduced to the reference condition as shown on chart 4 of Exhibit 34, the discharge becomes 11,203 cubic feet per second. The Livingstone Channel cofferdam extended eastward from Stony Island as shown on Williams Exhibit 10 to the so-called Lime Kiln or Amherstburg Channel, and the new cut opens through the middle of it, that is through the middle of the cofferdam. A discharge measurement was made on this channel December 17, 1912, when the conditions were not far from the reference conditions, when reduced to those conditions as shown on chart 5 gave a discharge of 37,400 cubic feet per second. Measurements made on the Lime Kiln Channel October 24, and December 18, 1912, when reduced to the reference conditions as shown on chart 6 give an average discharge of 106,098 cubic feet per second.

Combining the discharge of the several channels reduced to the condition of the river from 1900 to 1907, as indicated

by the mean stages of Lake St. Clair and Erie, we have: Trenton Channel, 35,818 cubic feet per second; Stony Island Channel, 11,203 cubic feet per second; Livingstone Channel, 37,400 cubic feet per second; Lime Kiln Channel, 106,098, making a total of 190,519 cubic feet per second.

The International Waterways Commission in the report on the regulation of Lake Erie for 1910, at page 102 give the discharge of the Detroit River for the several years from 1900 to 1907 from which the average is found to be 189,900 cubic feet per second. This result is out of harmony with that which is obtained from the Detroit gagings when the relation that the velocity varies as the square root of the hydraulic radius times the slope is applied to the whole series of the Detroit River gagings. Applying this well known relation, we have the mean fall from St. Clair flats to Lake Erie during the gagings was 575.36 minus 572.12 equals 3.24 feet. The mean elevation at Ft. Wayne was 574.20, or .2 of a foot below elevation 574.40 at which the area of the section is given in the report of the Chief of Engineers for 1903, page 2814, as 76,770 square feet; and from the cross section of the river at Ft. Wayne which is published in the report for 1902, opposite page 2870, the width appears to be about 2235 feet, although it is not marked.

The area of the section during the reference period then would be approximately 76,770 minus 0.2 times 2,235 or 76,323 square feet. The hydraulic radius was approximately 76,323 divided by 2,235 or 34.15. The mean velocity was 198,960 divided by 76,323 or 2.60 feet per second. The mean elevation of the Ft. Wayne gage for the open seasons of 1906 and 1907 was 574.596; that of St. Clair Flats was 575.675, and that of Lake Erie 572.635. The fall from St. Clair Flats to Ft. Wayne was 1.08 and to Erie 3.04. The fall to the former was therefore 35.5 per cent. of the latter. The mean elevations of St. Clair Flats and Lake Erie for the open seasons from 1900 to 1907 were 575.43 and 572.41 respectively, showing a fall of 3.02 feet. The fall to Ft. Wayne from St. Clair Flats would therefore be 0.355 times 3.02 equals 1.06 feet for the reference period, and the elevation at Ft. Wayne would be 575.43 minus 1.06 equals 574.37 or 0.03 less than 574.40 at which the area as above stated is given as 76,770 square feet. This reduces the area of the section by 0.03 times 2,235 equals 67 square feet or to 76,703 square feet. The hydraulic radius would be approximately 76,703 divided by 2,235 equals 34.32. The discharge for reference conditions then would be 76,703

times 2.60, times the square root of 34.32 divided by 34.15 times the square root of 3.02 divided by 3.04, which equals one finally, as it happens, the influence of the hydraulic radius almost cancelling the influence of the change in slope, so that our final result is 76,703 times 2.60 which equals 199,428 cubic feet per second, or substantially the same value obtained for the reference discharge by reference to the St. Clair discharge. This incidentally affords further evidence of the consistency of the St. Lawrence, St. Clair and Detroit measurements and the inconsistency of those at Niagara. It therefore appears that the net result of the Livingstone Channel work has been to decrease the discharge of that section of the Detroit River about 8,500 cubic feet per second, that is the difference between 199,000 cubic feet per second, the reference discharge for the period from 1900 to 1907, and 190,500 cubic feet per second, the discharge obtained by the summation of the separate discharges measured after the opening of the Livingstone Channel, which may be expected to ultimately raise Lake St. Clair about 1.4 inches, and Lake Huron about one-fourth as much. An increase in the width of the Livingstone Channel is contemplated from 300 feet as at present to 450 feet, and the excavation through the rock section included in the cofferdam has already been extended to the greater width. When the entire channel is increased to its width, this width, for the same stages of water above and below, the discharge will be increased by about 50 per cent.; or at normal stages by nearly 20,000 cubic feet per second, and if this be uncompensated it may be expected to lower Lake St. Clair something over three inches, or somewhere about three inches, and Lake Huron by an amount corresponding to a diversion of about 3,000 cubic feet per second at Chicago.

Q. That is according to the deductions from the discharge measurements?

A. Deductions from the measurements made by the complainants.

I will now call attention to table LXIII of Exhibit 34 entitled "The effect of the Livingstone Channel." The first column represents the year upon which the information is based. The comparisons have been made with October, November and December only, for the reason that the Livingstone Channel was opened in September, and no observations covering the other months were available to us at the time this table was prepared; so that we were forced to make the compari-

son with the last three months in the year. And it will be noticed that in 1909, the December elevations have been omitted. That is for the reason that during December, 1909, there was an ice gorge in the Detroit River which caused conditions to be entirely unnatural and therefore we were forced to reject December, 1909, and base the average for that year on the two months of October and November.

The fifth column gives the mean elevation for the months of October, November and December for each year. The sixth column gives the fall from Lake Huron to Lake St. Clair. Columns 2, 3 and 4 give the elevations of Lake Huron at Harbor Beach. Column 5 gives the mean elevation. Column six gives the fall from Harbor Beach to St. Clair Flats. Columns seven, eight and nine give the elevation of St. Clair Flats for October, November and December. Column ten gives the mean elevation. Column 11 gives the fall from St. Clair Flats to Erie, and columns 12, 13 and 14 give the elevation of Lake Erie for October, November and December.

Column 16 gives the mean elevation of Lake Erie for the three months, and the last column gives the fall from Huron to Erie.

It will be seen that during the period 1900 to 1907, the mean elevation of Lake Huron was 580.63; the fall from Huron to St. Clair was 5.41 feet; the mean elevation of St. Clair Flats was 575.22. The fall from St. Clair to Erie was 3.28 feet. The mean elevation of Erie was 571.94 and the fall from Huron to Erie was 8.69, so that the fall from Huron to St. Clair was 62.2 per cent. and the fall from St. Clair to Erie was 37.8 per cent. of the fall from Huron to Erie.

For the conditions from 1908 to 1911 inclusive, or during the construction of the Livingstone Channel, the average fall from Huron to St. Clair was 59.2 per cent. and from St. Clair to Erie was 40.5 per cent. of the fall from Huron to Erie. For the three months of 1912 after the opening of the Livingstone Channel, the fall from Huron to St. Clair was 61.2 per cent., or within one per cent. of what it was during the period from 1900 to 1907, and the fall from St. Clair to Erie was 38.8, or again within one per cent. of what it was during the previous period, and the elevations were as indicated in the line opposite 1912.

A summary of the results is presented at the bottom of the table headed "Changes in feet" whence it appears that from the conditions of 1900 to 1907 and the conditions of 1908 to 1911 Huron fell 0.62, St. Clair fell 0.21 and Erie fell 0.34.

The slope from Huron to St. Clair was reduced 0.41; from St. Clair to Erie the slope was increased 0.13 and from Huron to Erie the slope was decreased 0.28.

Comparing 1908 to 1911 with 1912, the elevation of Huron increased 0.41, St. Clair increased 0.18 and Erie increased 0.27.

The fall from Huron to St. Clair was increased 0.23; from St. Clair to Erie was decreased 0.09 and the fall from Huron to Erie was increased 0.14.

Comparing the period 1900 to 1907 with 1912, we find that the elevation of Lake Huron was decreased 0.21, St. Clair was decreased 0.03 and Erie 0.07. The fall from Huron to St. Clair was decreased 0.18, from St. Clair to Erie was increased 0.04, and the fall from Huron to Erie was decreased 0.14.

To interpret the indication from this table, it is that the opening of the Livingstone Channel restored very nearly the conditions which existed prior to the obstruction of the river during its construction; the slopes in the two rivers, the St. Clair and the Detroit, being returned to within one per cent. of the relations which they occupied to the whole slope prior to these constructions.

Q. Since the date of the taking of the testimony at the last hearing, have you prepared any further tables to be added to Exhibit 34?

A. Yes.

Q. Will you state what they are?

A. As a result of inquiries which were made at the previous hearing, certain tables have been added for the information of the complainant, and also other tables to be used in connection with the testimony just given and to follow have been appended; and by agreement they are incorporated as a part of Williams Exhibit 34, and will now be identified.

The first table that has been introduced is table XVIII a, which is a table showing the elevations of Lakes Huron, St. Clair and Erie and the falls between the several lakes for the closed season, December to March inclusive, from 1861 to 1912. The arrangement of this table is similar to that of table XVIII, which gives similar data for the open season, and to table XIX, which gives similar data for the full year. They are based upon the records furnished by the United States Lake Survey and presented as Williams Exhibit 26.

The next table that has been introduced is table XLV a, consisting of five sheets, and shows the preliminary computa-

tions for the discharge of the Niagara River referred to the Buffalo gage, which were summarized in table XLV previously. This table has been introduced at the request of the complainant, and a copy of it previously furnished.

The next table in question that has been added is table XLVI a, which is a recomputation of the increment of the Niagara River when referred to the mean elevation of the Buffalo and Amherstburg gages. It was found that in the computations of table XLVI, the method of weighting the observations was slightly different from that which had been used in the other computations; that is instead of distributing each gaging over the period covering half the elapsed time between the preceding and following gaging, they had been simply taken as the average of the days in question; and in order that the tables might be on the same basis, although we lay no particular stress upon them, we recomputed and have added this table XLVI a, which shows what the increment based upon the Buffalo and Amherstburg mean daily records would be, if those observations were treated in exactly the same way that the Buffalo observations are treated in table XLV.

It will be noticed that the change in the increment due to this change in the method of weighting is inconsiderable.

The next table, table XLVI b, is an increment for the Niagara River derived by reference to the Amherstburg gage, being treated in the same manner as the Buffalo gage in table XLV, and the Buffalo and Amherstburg in table XLVI a.

This is interesting as showing an increment for Lake Erie when referred to the Amherstburg gage of 47,217 cubic feet per second.

The next table that has been introduced is table XLVII a, which bears the same relation to table XLVII that table XLVI a bears to table XLVI. That is it was found that in computing table XLVII, the observations had been simply averaged for the period covered, instead of distributed with reference to the time elapsing between them and table XLVII a then represents the increment computed in a manner entirely analogous to that computed for the Buffalo gage in table XLV. The increment as obtained here is 33,590 as compared with 32,060 in the previous one.

Q. That is the Niagara River?

A. That is the increment for the Niagara River referred to the Cleveland gage; and by this computation, which is analagous to that used for the Buffalo gage is 33,590, whereas

by the other method of weighting the individual observations, it is 32,060.

Table XLVIII-a gives the annual precipitation at various stations on the Great Lakes, and comprises three sheets. This table was previously summarized in table XLVIII, but the entire data is presented for such reference as may be desired.

Table LV is the next table, and that follows table LIV and shows the relative fluctuations of Lake St. Clair and Erie during the open season, April to November inclusive; these fluctuations being based upon the changes of elevations with Lake Huron at constant or practically constant elevations.

In other words it was to establish the relation between St. Clair and Erie independent of changes of Lake Huron; and results in the relation that the change of Lake St. Clair when Lake Huron remains at a constant elevation is 49 per cent. of the change of Lake Erie.

Table LVI gives winter temperatures, that is the closed season from December to March inclusive, at Detroit, Buffalo and Oswego for the period from 1889 to 1912.

Table LVII is a table of drainage areas of the Great Lakes and is based upon the report of the International Waterways Commission. The first column gives the names of the rivers. The second column of this table gives the total drainage area tributary to the river in question in both land and lake.

The third column gives the total area of lake surface in the drainage, and the fourth column gives the total land area. The fifth column gives the local land and lake area; that is that of the particular river in question, or between that river and the one next following. The sixth column gives the local lake area. The seventh column gives the local land area.

The last column in the table gives the amount in cubic feet per second which would be represented by a run-off of one inch per year on the local lake surfaces.

Table LVIII gives a comparison of the river discharges; the first column giving the names of the rivers; the second and third column giving the discharges; the second column being the total discharge of the river and the third column being the discharge of the river less the discharge of the river next upstream; in other words being the local discharge.

This information is here given as derived by the complainant's equation for the period from 1900 to 1907, as presented in the report of E. S. Wheeler for 1882 to 1898, in the report of the Chief of Engineers for 1903, and as reported by the

International Waterways Commission, in their report on the regulation of Lake Erie for 1910, covering the period from 1890 to 1904, that is winter and summer.

The fifth and sixth columns give the run-off per square mile, the fifth being the total land and lake surfaces and the sixth column the total land surfaces.

The seventh and eighth columns give the local run-offs per square mile; the seventh column being for land and lake surfaces; the eighth column for land surfaces alone.

The last column represents the run-off per square mile in cubic feet per second of the streams that have been gaged upon the several watersheds.

Table LXIX-a gives a summary of the observations of run-off from the several drainage basins of the Great Lakes for each month in the year covering the basins of Huron, Michigan, Erie, St. Clair and Ontario; also for the full year for the open season April to November inclusive, and for the period June to November inclusive.

From this table it appears that the average run-off per square mile for the full year from the Huron-Michigan drainage area is 0.866 cubic feet per second; for the St. Clair-Erie drainage area 0.664 cubic feet per second, and for the Ontario drainage area 1.440. For the open season period from April to November inclusive, for the Huron-Michigan drainage, the average run-off is 0.844; for Erie 0.415; for Ontario 1.339. For the June to November period inclusive, the average run-off from the Huron-Michigan area is 0.640; for the St. Clair area 0.252, and for the Ontario area 0.924.

Table LXIX-B presents in detail the run-off from the Huron-Michigan drainage areas by months, and represents the method of computing the run-off as summarized in the preceding table. This method was to take the total discharges that were observed in each month and divide by the total areas which were represented by those discharges so that the average all the time is the average discharge of the entire area on which observations were available.

Table LXIX-c gives the similar information for the Lake Michigan drainage alone, and shows the rivers upon which the gagings were taken and the years over which the gagings extended, and also the months in the years which the gagings actually covered. This is composed of 14 sheets.

Table LXIX-d gives similarly the run-off from the Lake Huron drainage; and is composed of five sheets.

Table LXIX-e gives similarly the run-off from the Lake Erie drainage, and is composed of seven sheets.

Table LXIX-f gives the similar information, the run-off from the Lake Ontario drainage, and is composed of 11 sheets.

Table LX-a, composed of two sheets, gives the summary of the rainfall upon the drainage areas of Huron-Michigan, Erie and Ontario respectively from 1900 to 1904, by months and also for the full year, the April to November period and the June to November period.

Table LX-b, composed of five sheets, gives in detail the precipitation on Lakes Huron and Michigan for the period from 1900 to 1904 inclusive.

Table LX-c, composed of 3 sheets, gives similar information as to precipitation on the Lake Erie drainage area.

Table LX-d, of three sheets, gives similar information for the Lake Ontario drainage area. These tables have been compiled from the published records of the United States Weather Bureau.

Table LXI-a gives the summary of the mean temperatures observed by various observers on the Great Lakes. The two sources of information are the reports of the City Water Works at Chicago and Milwaukee on Lake Michigan, and Detroit on Lake St. Clair, at Cleveland on Lake Erie and at Toronto on Lake Ontario; and also the records of the United States Lake Survey give temperatures taken at various light houses and light ships on the several lakes and cover Lake Michigan, Lake Huron, Lake St. Clair, Lake Erie and Lake Ontario. This table is composed of two sheets.

Table LXI-b, embracing five sheets, gives in detail the temperatures of lake water and of air at the several water works, pumping stations just referred to; being those at Chicago, Milwaukee, Detroit, Cleveland and Toronto.

Table LXI-c gives the information obtained from the United States Lake Survey of temperature observations of air and water at various light house and light ship stations on the Great Lakes; it embraces six sheets.

Table LXI-d gives surface water temperatures observed by representatives of the United States Lake Survey from boats in passing through Lakes Superior, Michigan, Huron, the St. Clair River, Lake St. Clair, Detroit River and Lake Erie, and covers five sheets.

Table LXII gives the meteorological records at Rochester as published in the annual report of the Board of Public Works of Rochester for 1907, which is the last report that has been printed. It shows records of evaporation from a tub floating in the Mt. Hope reservoir, and also from a tub above

the water, mounted on a raft about 30 inches above the water's surface.

The table presents in its first column the years in question; in the second column the month. The third column gives the evaporation from the exposed tub, being the one mounted about 30 inches above the water's surface of the reservoir. The fourth column, the evaporation in inches from the tub floating in the reservoir and filled with water substantially to the level of the water outside it.

The fifth column gives the temperature of the water in the exposed tub in degrees Fahrenheit. And the sixth column gives the temperature of water in the floating tub, in degrees Fahrenheit.

The seventh column gives the temperature of the water in the reservoir at the same time in degrees Fahrenheit and the eighth column gives the temperature of air in the shade, in the vicinity of the tub. And the last column gives the precipitation in inches observed at the Mt. Hope reservoir.

In the lower half of the table is given the records at the United States Weather Bureau's station at Rochester; the first column representing the years; the second column the month; the third column the precipitation in inches; the fourth column the normal precipitation or the mean precipitation for that month since 1870. The fifth column, the mean temperature for the month in question. The sixth column, the normal temperature for that month, or the mean since 1890. The seventh column, the mean humidity during the month in question, and the last column the normal humidity or the average since 1870.

This table is of interest in connection with estimates of the evaporation from the lake surfaces, and constitutes the most extensive observations upon the evaporation from water surfaces that have been made anywhere in the world, so far as an extended investigation of the authorities on the subject reveal.

Table LXIII has already been described, being the table referring to the effect of the Livingstone Channel.

Table LXIV shows a comparison of results obtained with the Haskell meter at the Hydraulic Laboratory of Cornell University, when the rating was made by moving the meter at a regular speed through the water, and when a rating was made by moving the same meter under similar conditions at irregular speeds through the water.

This table will be discussed further.

Q. By whom were those observations made?

A. The observations were made by myself.

Q. Table LXV shows the average elevation of Lakes Michigan, Huron, St. Clair and Erie for each of ten years, and for the ten years preceding the opening of the Chicago Drainage Canal; and also the average elevation of the same lakes for each of the ten years immediately succeeding the opening of the Drainage Canal; and the mean for the period of ten years.

Q. One for the period immediately preceding, and one immediately following?

A. And the one for the period immediately following.

Chart 1 shows the computations involved in the reductions of the observations of discharge of the Detroit River in the vicinity of the Livingstone Channel, to reduce them to the reference condition of average lake elevations 1900 to 1907.

Q. Charts 1, 2 and 3 refer particularly to the Trenton Channel?

Q. Those are charts. We did not have charts before?

A. No, we did not have charts before. Chart 4 refers to the Stony Island Channel; chart 5 to the Livingstone Channel, chart 6 to the Lime Kiln Channel.

Plate 9 has been added, which shows the cross sections of the St. Clair River, the Niagara River, Bridge Section, Niagara River Open Section, St. Lawrence River and the Sanitary District Canal, all drawn to the same scale; the relations between the horizontal and vertical sections being natural.

The scale is: One inch equals 250 feet; the cross sections for the several rivers being taken from the reports of the Chief of Engineers of the United States army, as presented in connection with the gagings of the several rivers. The section of the Drainage Canal is the rock section, which has the largest carrying capacity of any portion of the channel.

Plate 10 is a profile of the St. Clair and Detroit Rivers and Lake St. Clair, being based upon the profile published in the report of the United States Deep Waterways Commission, and corrected for the recent deepening of channels and changes in water surface. The solid areas, first at the foot of Lake Huron, then at the head and foot of Lake St. Clair and finally at the foot of the Detroit River, represent the material that has been removed and the increased depth of channel that has taken place in those localities as a result of the Government's improvements of navigation. That is the solid white as distinguished from the cross hatching representing

the bottom of the stream. This is of course distorted; the scale being as indicated in miles at the bottom, and as indicated in feet along the left hand side of the plate; but it is an exact copy except for cutting deeper to the present depth of channel.

Recess to 2:30 p. m.

After recess, 2:30 p. m.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Mr. Adcock: Now you have those tables before you?

A. Yes, sir.

Q. Ready to substitute them?

A. To substitute these in place of Exhibit 34.

Mr. Adcock: I submit to the Commissioner a number of sheets and offer them in evidence as Williams Exhibit 35, consisting of 18 sheets, designated as charts 1, 2, 3, 4 and 5; chart 1 consisting of five sheets; chart 2, one sheet; chart 3, consisting of four sheets; chart 4, six sheets, and chart 5, two sheets.

(Whereupon the charts so submitted to the Commissioner were marked Williams Exhibit 35.)

Q. Mr. Williams, will you describe the exhibit that has just been identified?

A. This exhibit consists of five charts numbered from 1 to 5. Chart 1 consists of five sheets and is a plotting of the gage elevations of Lake Huron at Harbor Beach, and Lake St. Clair at St. Clair Flats, covering the periods during which gagings were in progress on the St. Clair River and somewhat antecedent thereto. There is indicated on these charts in numbers the discharge found on the respective days when gagings took place. There is further indicated by arrows on this chart the periods which were included in the preparation of table 28 of Williams Exhibit 34. This chart 1 represents the gagings of 1899 to 1902 inclusive.

Chart 2 gives similar information for the gagings of the St. Clair River for 1908, 1909 to 1910 inclusive, and the periods indicated by the arrows and the Roman numerals correspond to those in table 34 of Williams Exhibit 34.

Chart 3, consisting of four sheets, gives similar information as to the elevation of Lake Erie at Cleveland during the

gagings, and the periods represented are those of table XLVII.

Chart 4, consisting of six sheets, gives similar information as to the elevation of Lake Erie at Buffalo, and the periods are those indicated in table XLV-a of Williams Exhibit 34.

Chart 5, comprising two sheets, represents the similar information for the St. Lawrence gagings, gage heights both at Ogdensburg and Oswego being plotted. The periods are those used in table XLI of Exhibit 34.

These plottings show, of course, the daily indicated fluctuations of the lake levels during the periods covered by them, and are noticeable as indicating that during the earlier gagings of the St. Clair, Lake St. Clair was apparently at a uniform elevation in some cases for as much as three weeks, which is, of course, a physical impossibility, as the elevation of the lake changes from day to day. The only reasonable inference to draw is that the gage reader did not read the gage, but simple put down from day to day the same reading that the gage had at some time when he did read it; and, of course, the resultant inaccuracies of gage reading must be reflected in any deductions of discharge, in which those gage readings play a part. If the readings of Lake St. Clair for the period of June, 1899, for instance, be compared with those of June and July, 1910, shown on Chart 2, sheet 6, the impossibility of the condition appearing in chart 1 must be evident.

Q. From the examination which you have made and the facts and data which you have heretofore presented in evidence, and your investigations of the discharge measurements of the various rivers under consideration, the St. Clair, the Detroit, Niagara and St. Lawrence Rivers, and the relative sizes of the drainage areas, will you state what conclusions if any you have reached with reference to the accuracy or possible inaccuracy of the discharge measurements of those rivers made by the Lake Survey?

A. In beginning to answer this question, I would like to repeat what I said earlier in my testimony, that so far as the work done by the Lake Survey parties in the field, so far as the possibility of accomplishment with the means at their hands is concerned, I think that they did a most remarkably creditable piece of work.

The criticisms which I have to make upon it are criticisms that to a large extent are at present beyond the power of man to remedy.

The gagings of the St. Lawrence, Detroit and St. Clair Rivers when considered with the variations of the elevations of the lake surfaces show a remarkable agreement, and indicate that whatever errors exist in the observations are of similar magnitude in all. As to the absolute accuracy of any of the measurements, there is no means of determination except the consistency of the observations themselves; and they all might easily be in error as much as ten per cent. On account of the size of the rivers involved, there is no possibility of making a comparison of this method of measurement with any other method of measurement.

Q. You are referring to the methods used and described heretofore?

A. Yes, in making a comparison of the methods of measurement used by the Lake Survey with any other method of measurement. So the accuracy of the observations are dependent: First, upon the accuracy of the reading of the meters; second, upon the consistency with which the meters retain their rating during the periods of observation. Third, upon the extent to which the position observed in the cross sections of the stream are representative of the flow in other parts of the stream. Fourth, as to whether the index velocities are always in the same ratio to the vertical and horizontal curves which they are supposed to represent.

And, fifth, as to whether it is possible to connect the discharge of any of these rivers at any particular time with any particular elevation of the Lake Surface.

The fact that at all of these gaging stations the discharge was actually affected, with possibly a single exception, by the elevation of a body of water below as well as above the gaging station, whose elevation, though dependent in a measure upon that of the water above, does not fluctuate with it according to a continuous law, and owing to the fact that any influence must travel from one lake to another before its full effect can be measured at any point between, all these make the possibility of accurate measurements extremely doubtful.

In a considerable experience with current meters and comparisons of their discharge with that of weirs, it has never been possible to get the two to agree within less than about 2 per cent., and differences of 10 to 20 per cent. have not been infrequent. I am speaking now of my own experience.

A long series of comparisons were made at the Hydraulic Laboratory of Cornell University by the New York State Barge Canal Survey, and are reported in the "Barge Canal

Report'' of the New York State Engineer for 1901, pages 932 to 951.

In these experiments, the current meters usually underregistered about 3 per cent., the situation being one where the conditions were extremely favorable for accurate meter work, in that the channel was rectangular, and it was possible to determine the area of the cross section with great accuracy and also to locate the position of the meter.

The meters were handled from rigid rods and were not allowed to drift upon lines or be dependent upon weights to maintain them in position. Moreover, the water was sufficiently clear so that the observer could see the position of the meter and visually observe whether it was operating in a rational manner or not.

In the rating of a pair of current meters for the Lake Superior Power Company in 1900, the effect of moving the meter through the water at speeds varying from point to point was investigated to determine the influence of the pulsations ordinarily felt in the lower parts of all large streams.

The meter was suspended on a rod from a truck which ran upon tracks spanning the canal.

The canal at the laboratory is 16 feet wide between side walls which are vertical and approximately 10 feet deep and about 30 feet in length.

The truck was built of wood and was propelled by hand at that time, as they had not yet installed the electric apparatus for driving the truck. A crew of men was employed to push the truck along the track, and the distance was taken by trips, forming an electric contact, at 10 feet intervals along the rail, and communicated by a chronograph to a sheet of paper.

The revolutions of the meter were similarly taken by the chronograph and the time was taken from a chronometer, all records being taken electrically, so that there was no step with which human agency was involved in getting the record of revolutions, velocity and time.

In the regular readings of the meter, the car was propelled at as nearly a uniform rate as was possible throughout the full length of the course, and the ratio between the revolutions of the meter and the velocity of propulsion recorded. Later it was suggested it would be interesting to ascertain what would be the effect on the meter if instead of being propelled at a uniform rate, the car would be propelled at an intermittent rate; that is to say, if a car were given a shove and then allowed to slacken its speed as the result of friction, and then

given another shove so as to give it a jerky or pulsating motion.

This method of rating was then carried out, so far as it was possible to do so with the apparatus. You will see at once that as high speeds were reached, it was impossible to give very many pulsations in going over the course, as the men could not accelerate the car to a velocity much beyond its average velocity.

The result of these observations are presented in table LXIV. In the left hand side of the table are the observations at a regular velocity. I may say that the observations presented in these tables were made with a Haskell Current Meter, which was owned by the Michigan-Lake Superior Power Company. It was similar in every respect to those which were being used by the United States Lake Survey at the same time. These observations were made in, I think, 1899.

Q. Were they made by you personally?

A. They were made by me. I was assisted in these observations by Mr. J. A. Vogleson, who is now the chief of the Bureau of Health of Philadelphia. He had at that time just been graduated from Cornell University, and was going to the Soo to assist in discharge measurements which the Lake Superior Power Company contemplated making on the St. Marys River at that time.

The first column of the table gives the group of observations.

The second column gives the number as they appear in the note books, each observation being numbered.

The third column gives the revolutions observed during each observation and the fourth column gives the velocity. The fifth column gives the ratio of the velocity to the revolutions.

In the right hand half of the table is presented similar information for the ratings at the irregular speeds.

Column 6, again, gives the number of the observations as found in the note book; column 7, the revolutions observed; colnmn 8, the observed velocity, and column 9, the ratio of the velocity to the revolutions.

It will be observed in comparing columns 5 and 9, that while at a velocity of about two feet a second the ratio of velocity to revolutions is practically the same for both the regular and irregular rating, that as the speed increases the number of revolutions corresponding—or rather the velocity corresponding to a given number of revolutions, increases in the case of the irregular rating over the similar ratio for the regular rating. So that at a velocity in the neighborhood of three feet

per second, the meter was under registering about 4 per cent. on the regular rating.

When the velocity had gotten up to between $3\frac{1}{2}$ and $3\frac{3}{4}$, the meter was under registering about 6 per cent. Beyond that it was, as I said, impossible to maintain the irregularity of speed to the same degree as was obtained at the lower velocities, so that by the time a velocity of four feet was reached, the under registration amounted to only about 3 per cent., and by the time a velocity of six feet was reached, the variable or irregular impulses practically integrated into a regular impulse, and the ratio comes back to the same figure.

These experiments showed that when moved through the water at irregular speeds, if the instrument be free to turn about both its axes, the Haskell Meter will under-register as much as 6 per cent. and very probably more at higher velocities.

These observations afford an explanation of the disagreement of the Niagara gagings with the others, as at the Niagara the current is much more disturbed and irregular than at any of the other stations. Eddies and whorles are constantly appearing at the surface, and so pronounced that they can be seen in crossing the International Bridge on the cars, and if this turmoil appears at the surface, we perhaps can imagine to some extent what it must be down in the depths of the river, where the agitation starts.

The condition is very well expressed in the language of Mr. F. C. Shenehon, in his report upon the gaging of the Niagara, in the report of the Chief of Engineers for 1900, page 5342, where he says:

"In such a section as that at the International Bridge, the proper derivation of the velocity co-efficient is the most difficult part of the river gaging. To obtain it, the writhing mass of waters streaming through the bridge openings and eddying about the piers, spurting and lagging in minor pulsations, speeding faster as the lake rises and flowing leisurely in low stages must be congealed to a solid by some instantaneous method of survey, and its dimensions taken."

It is not difficult to conceive of one of these eddies catching the tail of the meter and whirling it around at right angles to the direction of the main current.

Q. Will you describe the Haskell Meter somewhat in detail, so that we can get some idea of how it operates in the water?

A. The Haskell Meter consists of a shaft upon one end of which, the front end, is a wheel shaped similar to a propeller

wheel, so that the current as it comes towards the meter striking the blades of this propeller causes it to revolve. As it revolves, a contact is made and broken with an electrical recording or sounding apparatus, so that each revolution is transmitted to the recording device in the hands of the observer.

At the other end of this shaft, there is a vane or tail, which keeps the meter pointed upstream, or is intended to keep it pointed upstream, and in a reasonably straight current does so.

The meter is supported a short distance back of the propeller, and is allowed to vibrate, or to rotate both in the horizontal plane and in the vertical plane so that it may assume a position parallel to the direction of flow whichever way that may come.

The length of the ordinary Haskell meter from tip to tip is about 30 inches. I am speaking from memory, and I have not measured one in a long while. The direction meter is about 3½ feet long. I should say it was between 30 and 36 inches.

The point that I have in mind in connection with these eddies is that it is entirely possible that the head of that meter might be in a current that was moving fairly straight, while the tail of it was caught by an eddy and whirled around so that the wheel no longer pointed against the current, but might be in an angle away from parallelism with the directions of flow; and if it does not point in the direction of flow then its revolutions will be less for the same current than they would be if it pointed directly towards the oncoming current.

Q. I take it the Haskell meter is not unlike the weather vane that we sometimes see built by boys, a toy with a wheel revolving at right angles to the plane?

A. The same principle is involved, exactly. Of course, the Haskell meter is a more delicate instrument and more strongly built, being designed to resist the flow of moving water. And I may say that it is an exceptionally creditable instrument to its designer, but like other instruments it cannot be expected to perform impossibilities.

Q. Your idea is that as this meter is suspended in the water, the eddies may cause the tail to turn around at right angles to the regular current, or the way the river is flowing?

A. It is entirely possible that it might turn it as much as at right angles.

Q. Or pretty near so?

A. Or pretty near so.

Q. That would reduce the rotation of the wheel?

A. That would reduce the rotation of the wheel, while the quantity of water passing would not be changed.

Q. And would thereby register inaccurately?

A. And would thereby under-register.

Q. That motion might be horizontal—

A. Or vertical.

Q. —or vertical, or any other way?

A. Or any other way.

Q. According to the conditions of the water?

A. There is always of course the possibility of some obstruction getting upon the meter, which may remain for a short time and then be washed off, as floating grass or string, or even grit and sediment in the water will oftentimes cause a meter to change its rating in a comparatively short time.

The meter being suspended on a cable a long distance below the surface, out of sight, where the only indication that the observer could have of the performance of the meter was the record on the recording apparatus, and possibly the feel of the line, makes it practically impossible for him to tell whether the meter is pointing upstream or in any other direction.

There is a special attachment for the Haskell meter which indicates the direction in which it is pointing; but if the direction current meter was used at all it was only used at certain stations, and not for all the observation.

On the St. Clair, the direction current meter was used in combination with the other meters to give an indication of the direction of the current at certain points in the vertical; but it is a much more complicated machine to use, more liable to get out of order and consequently adds to the trials and tribulations of the observer. I speak from experience.

Q. You have spoken of the difficulties encountered in the use of the current meter in the Niagara River. Do the conditions there compare, are they similar to conditions in the St. Clair and St. Lawrence Rivers?

A. The conditions at the Niagara are very much worse than those encountered on the other rivers. The pulsation of the water in open channels, or in our rivers, is practically always present. I have observed it personally in the Detroit River in the vicinity of Belle Isle, both in current meter work and Pitot tube work, which I have had in the river, where the current will apparently run swiftly for a few seconds and then there will be a perceptible slowing down

for a few seconds, and then again a pulsation which will accellerate it again.

These pulsations were the subject of an extended discussion some years ago before the American Society of Civil Engineers, in which their presence in the St. Clair, the St. Marys River and the Detroit River were referred to by Mr. D. Farr and Henry, as a result of his experience in connection with the original Lake Survey current meter measurements.

Mr. Wilkerson: Have you a reference to the book?

A. I am speaking from memory on it, but the reference is to the discussion of a paper by Emil Kuichling on the resistance of a 24 inch stop valve. I think it is along about 1892. So that the other stations are undoubtedly affected similarly, but to a less degree, and all the gagings may therefore safely be assumed to be less than the true discharge.

Mr. Adcock: Q. Would that affect the determination of the increment?

A. Yes, the increment would be decreased in the same ratio as the discharge itself were decreased, assuming the error in discharge to be the same at different elevations; that is assuming the percentage error of discharge to be the same at different elevations.

To further examine the accuracy of the Haskell meter indications in disturbed water, a series of experiments were arranged for at the Hydraulic Laboratory of Cornell University, wherein the water was measured over a weir, and also simultaneously by a Haskell meter at various points along the experimental canal under varying conditions of disturbance. The meter used was one belonging to Cornell University.

The work was done by Professor E. W. Schoder, in charge of the laboratory, and Professor K. B. Turner, formerly junior engineer in the United States Lake Survey.

The arrangements were made with the kind permission of the dean of the College of Civil Engineering, Professor E. E. Haskell, the inventor of the Haskell meter, to whom I explained the purpose of the investigations and the scope which we hoped to have it cover.

Q. When were these made?

A. They were made during June and July.

Q. Of this year?

A. Of this year; better say during May and June of this year. I am not certain whether they ran over into July or not. My impression is they were all finished during June.

In these experiments, the data of which will be presented later in this case, the meter was found to register from 3 to 10 per cent. too low, depending on the disturbances of the water, although the conditions for accurate measurement were very good.

An error of 6 per cent. in the Niagara gaging would amount to about 12,000 cubic feet per second, and would about account for the discrepancy in the Niagara comparisons with the other three rivers. That such an error exists seems to be certain, for all the information on evaporation from lake surfaces and as to the surface temperatures of the Great Lakes, data upon which are presented in tables LXa to LXII inclusive, disprove the possibility of such evaporation as has been shown to be necessary to account for the small discharge of the Niagara River shown by Complainant's gagings.

Q. Am I correct in understanding this: That the disturbances in the Niagara River are so much greater than those in the St. Clair and St. Lawrence Rivers that you would expect that the meter would under register 6 per cent.

A. More than it does in the others.

Q. More than it does in the other two rivers, is that right?

A. That is the point, that the error is 6 per cent. greater there than it is elsewhere.

Mr. Wilkerson: I do not just get the basis for that 6 per cent. yet, as that answer now stands. Just explain that.

Mr. Adcock: That is my understanding.

Mr. Wilkerson: Yes.

A. In our first experiments at Cornell with the truck, we found at a velocity around three feet per second the meter under registered about 6 per cent. The velocities at Niagara were above three feet per second in general, so that I would expect a somewhat larger under-registration in those observations.

I think I am correct in making that statement of three feet, Mr. Shenehon. If I am in error, will you kindly correct me?

Mr. Shenehon: They are above three feet per second; fully as high as five.

The Witness: For that reason, I would expect the under-registration to be greater than 6 per cent.

Again, the experiments in the actually disturbed water in the canal at Cornell University showed discrepancies as high as 10 per cent., so that it seemed to be quite reasonable to suppose it possible that an error of 6 per cent. could have occurred in the Niagara gagings. That is all there is of it.

Mr. Wilkerson: I understand the point of this to be that if you increase the Niagara measurements 6 per cent. that brings St. Clair, Niagara and Detroit into harmony?

A. Yes.

Q. It makes them consistent, if you increase the Niagara 6 per cent.?

A. Yes, as far as discharge is concerned.

Mr. Adcock: As far as the records of the discharge are concerned?

A. Yes, as far as the recorded discharge, as far as recording the discharges are concerned, they become consistent.

Q. But still you would expect the measurements of the St. Clair and the St. Lawrence to be low under the current meter gaging?

A. I think it is entirely probable. I feel satisfied they are somewhat low.

Mr. Wilkerson: Your point is, if you increase the discharge 6 per cent., you would increase the increment 6 per cent.?

A. No, the increment is an entirely separate thing in this case, because as far as the increment derived for the Niagara River is concerned from the gagings, I consider it absolutely worthless. The relation between lake stage and discharge there is so variable that I think it is absolutely impossible to tie the discharge to the lake stage at the Niagara, the fluctuations are so sudden.

Q. Then I still do not get the point to your 6 per cent.

A. The 6 per cent. is that while it may be possible to measure the discharge of the Niagara River accurately at any particular time, or with a certain degree of accuracy, I will say, my conclusion is that whatever the error is on the others it is 6 per cent. greater at Niagara—or, I will not say that is my conclusion, but I say that if the error at Niagara be 6 per cent. greater than it is in the other measurements, then the Niagara gaging becomes consistent with the other gagings.

But when you talk of increment, that is another proposition entirely, because the increment is dependent upon the measurement of a stage in the lake and the masurement of discharge. Both may be correct, but they may not be the ones that correspond to each other; and with Lake Erie changing position as rapidly as it does, it is impossible that the full effect of any change could be transmitted to the gaging station before the lake had assumed some other position. Therefore I say it is impossible to connect the discharge accurately

with the lake stage, and hence it is impossible to get a correct increment of the Niagara River.

Q. That is your point, that you cannot get the correct increment of the Niagara from measurements there?

A. That is it.

Q. You have to work it either backward or forward?

A. That is my point. There may be some other way of getting it, but you can't get it the way you tried to get it.

Q. I have not examined these last tables you have produced, but have you any place figured out what the Niagara increment would be, assuming you could get it, making this 6 per cent. correction for the readings?

A. I did not make the 6 per cent. correction because I think the determination of the increment has got to be separate from that thing. I have made an estimate; I have an estimated value of the Niagara increment.

Q. I say, assuming that you could get the Niagara increment in the same way that you get the St. Clair, the Detroit and the St. Lawrence increment, correcting the gage readings by the 6 per cent. to which you have referred, have you figured out what the Niagara increment would be?

A. No, because I consider that this method of obtaining the increment at Niagara is absolutely unreliable, and therefore I did not spend any time on it.

Q. You did not spend any time on it?

A. (No response.)

Mr. Adcock: Have you made any comparison of the elevations of the lakes for a period or periods before January 17, 1900, and for a period or periods subsequently thereto? If you have, will you state what comparisons you have made and the results that you have reached?

A. The Drainage Canal so-called was opened in January, 1900. Table LXV of Exhibit 34 shows the elevation and mean elevations of the lakes for 10 years prior and for 10 years subsequent to the opening of the Chicago Drainage Canal.

In the first column is given the year.

In the second column is given the average elevation of Michigan-Huron for the year, and the mean of the 10 years; the first 10 years being 1890 to 1899 inclusive; the second 10 years being 1900 to 1909 inclusive.

The third column gives the same information for Lake St. Clair. And the fourth column the same information for Lake Erie.

From this it appears that during the decade next prior to

the opening of the Sanitary and Ship Canal, the average elevation of Lakes Michigan-Huron was 580.342, and that during the decade next following the opening of the Drainage Canal, the elevation was 580.665, showing a rise of .323 feet, or approximately 4 inches.

The mean elevation of Lake St. Clair for the decade preceding the opening of the canal was 575.013 and the mean elevation for the decade following the opening of the canal was 575.255, showing an increase of elevation during the second decade of .242 feet, or approximately 2.8 inches.

Mr. Wilkerson: This table is just a table of——

A. Of actual readings.

Q. Without any attempt to take into consideration any element of change of fact?

A. No, just setting forth the fact.

Mr. Austrian: It is putting it in concrete form.

The Witness (continuing): The mean elevation of Lake Erie for the decade preceding the opening of the canal was 572.012, and the mean elevation of the same lake for the decade following the opening of the canal was 572.210 showing the rise of the lake the second decade over that in the first of .198 feet, or about 2.3 inches.

It is further to be stated that a comparison of the decade next preceding the opening of the Drainage Canal with any decade since the opening of the Canal will show the lakes to have been on the average at a higher elevation during the decade since the opening than during that preceding; and that a comparison of single yearly elevations will show that in no case since the opening of the Drainage Canal has the average annual elevation of the lakes been so low as it was during a single year preceding the opening of the canal.

Mr. Adcock: What increments do you derive for the various rivers? Take the St. Lawrence, Niagara, Detroit and St. Clair Rivers, based upon the facts already in evidence?

A. Considering all the evidence in this case and the fact that, as heretofore stated, the increments derived by direct mathematical computation have been in every case lower than the true increments which would exist, for reasons heretofore stated, the values of the several increments for normal open season conditions appear to be, for the St. Lawrence, about 30,500 cubic feet per second, for the Niagara not less than 34,000 cubic feet per second, for the Detroit about 32,000 cubic feet per second; for the St. Clair about 29,000 cubic feet per second.

Q. When you say "appear to be," do you mean there that is the conclusion which you have reached from the investigations you have made and the facts which you have set forth in your evidence heretofore?

A. Yes, I mean by that that I do not consider that any information that we have is sufficiently accurate or positive to enable any one to say what they are. It is my belief that they cannot be less than the figures which I am giving.

Mr. Wilkerson: Is it your opinion that they are more?

A. I think that the chances are very good that they are more.

Q. I want your opinion. What is your best judgment?

A. Well, I am very well satisfied that they are more rather than less.

Q. I want a statement as to whether you think they are more; if so I want to know how much more; your professional judgment on that.

Mr. Austrian: Whether that is your best professional judgment.

Mr. Wilkerson: If that is your judgment I would like to have you say so.

Mr. Adcock: You mean——

Mr. Wilkerson: Let him answer the question.

Mr. Adcock: You mean from the records?

Mr. Austrian: From the facts that appear in evidence and the deductions made.

Mr. Wilkerson: He is now testifying to a conclusion as an expert. I do not want him to leave the conclusion unfinished. I want him to give his best opinion as an engineer what the correct figure is, so that I may know what I am to go on as a basis for cross-examination.

Mr. Adcock: You mean from the data and material that he has at hand?

Mr. Wilkerson: Yes.

Mr. Adcock: Or what his opinion may be from general conditions.

Mr. Wilkerson: No, I mean his opinion, in the way in which he has reached his opinion, whatever it may be. He has reached an opinion. Now I want to know what it is.

A. I do not think that the increments are any less than the figures which I have given here, and I do not think that they would be more than 10 per cent. greater.

Mr. Adcock: Have you made any calculations from the increments that you have above stated as to the possible effect

upon the lakes of a diversion of 10,000 cubic feet per second? If so state what the results of your computations are?

A. For a diversion of 10,000 cubic feet per second, Lake Ontario would be lowered about 0.327 feet, or slightly less than 4 inches. Lake Erie would be lowered about 0.294 feet or a little more than 3½ inches. Lake St. Clair would be lowered 0.312 feet, or a little less than 4 inches. Lake Michigan-Huron would be lowered 0.345 feet or a little more than 4 inches, about 4⅛ inches.

Mr. Wilkerson: In view of the fact that this testimony is likely to be used in the consolidated case, it would be very convenient if you would give us the figures for 10,000 or 14,000 and 16,000. Of course it is a mere matter of computation, but it would help if we could have the table with those figures.

Q. You haven't them prepared for 14 or 16?

A. No.

Mr. Adcock: As I understand it, the answer to the question that I just asked you is based upon the increments which you have derived there?

A. Yes.

Q. Is that correct?

A. It is.

Q. Would the effect be the same, that is be in the same ratio, for a diversion of over 10,000 second feet up to, say, 14,000, or for any amount under 10,000 feet?

A. Yes, for a diversion of 14,000 feet, the effect would be 1.4 times that which I have given; and for a diversion of, say, 7,000 feet, it would be .7.

Q. Have you considered the question of compensating for any possible lowering of the lake levels?

A. Yes, I have.

Q. Will you state what conclusions you have reached with reference to that subject?

Mr. Wilkerson: I object to the word "possible." I think now it appears that there will be a lowering.

Mr. Austrian: You mean possible lowering by diversion?

Mr. Adcock: By diversion.

The Witness: Or otherwise; they compensate for any lowering.

Mr. Austrian: Yes.

The Witness: The backing up of the upper Detroit River by the Livingstone Channel works and the raising of Lake Ontario by the Gut Dam in the St. Lawrence illustrate the

ease with which it is possible to compensate for diversions from Lake Michigan.

For example, referring to Williams Exhibit 10, it would be entirely feasible to close the Stony Island Channel, and thereby reduce the discharge of the lower Detroit River by about 11,000 cubic feet per second, which would raise Lake St. Clair in the neighborhood of two inches.

The capacity of the Trenton Channel, which was found to be about 36,000 cubic feet per second, could be easily reduced to an extent equal to the reduction of the Stony Island Channel, or even more, by a judicious filling in of material, and thus the compensation of Lake St. Clair obtained for the diversion at Chicago.

The cost of this filling, based upon the prices paid for moving the material in the vicinity of the mouth of the Detroit River, would be about $250,000. The approximate discharges of the several channels at the mouth of the St. Clair River, as measured by the Lake Survey, and given in Williams Exhibit 23, are as follows:

Chenal Ecarte, 11,600 cubic feet per second.

Blind Channel, 400 cubic feet per second.

Bassett Channel, 12,000 cubic feet per second.

South Channel (the one connected with the canal), 59,000 cubic feet per second.

Middle Channel, 33,000 cubic feet per second.

North Channel, 78,000 cubic feet per second.

This makes a total of 194,000, which represents a rather low stage of the river.

From these discharges it appears that either the North or the Middle Channel might easily be restricted to the extent of 15,000 cubic feet per second without detrimental effect, and this would compensate for the lowering of Lake Michigan-Huron by the contemplated Chicago diversion.

The cost of this compensation would be about $500,000, which makes a total of about $750,000 to compensate for the lowering of Lakes-Michigan-Huron, the St. Clair, and the St. Mary's, St. Clair and upper Detroit Rivers.

The construction of the Gut Dam in the St. Lawrence has already compensated for the abstraction of water from Lake Ontario; and the International Waterways Commission are submitting a report upon works to regulate the level of Lake Erie, which, if constructed, would provide for a compensation for the diversion from Lake Erie and the lower Detroit River.

Mr. Adcock: I think that is all. I submit the witness for cross-examination.

Whereupon an adjournment was taken to Friday, July 18th, at 10 o'clock a. m.

Friday, July 18th, 10 a. m.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Cross-Examination by Mr. Wilkerson.

Q. How much time have you spent on this case, Mr. Williams?

A. I could not say.

Q. Well, approximately?

A. When was the case begun?

Q. Maybe we can get at it another way: What is the rate of compensation at which you are employed in the case?

A. I am employed at $100 a day when in court; when in conference away from home, $75 per day; $50 per day for office work at home.

In addition to that, there is the services of my office. If you want to get at the time, I can work it out.

Q. I would like to know within reasonably accurate limits how much time you have expended in these different kinds of work.

Mr. Adcock: You mean on this case?

A. I began work in the case very shortly after matters got down to business; I don't know how long after the bill was filed, but I recall it in this way that I had a letter from the Lake Survey Office asking me for my terms; or rather from Major Keller, asking me for my terms in connection with the case. And after thinking it over, as I remember, I did not feel that I wanted to take that side of the case. And the same day I got a letter from the Sanitary District asking me if I would assist them; and I went over to Chicago immediately and began work on the case then. My recollection is that was in November or December but I can't say what year. It was the year that the suit started. I think the bills were filed along in August or some such time as that and I began then.

Since that time, I have devoted a considerable amount of my time, from time to time, as things got warm in the case and they got ready to do something, I would go to work and put in

perhaps the major part of my time for a month, with my office. And then things would be postponed, and I would drop it. Afterwards it livened up again and I would go at it some more.

Mr. Wilkerson: I would like to know if you have your memoranda from which you can give us the information as to the amount of time you have actually put in?

A. I haven't it here in New York; it is in my office. I did not imagine that would be asked for or I might have brought my time sheets for the past five or six years.

Q. It is a matter you can easily determine?

A. Yes.

Q. It involves, as you stated on your direct examination, the expenditure of perhaps half your time for four years, as I understood your statement to Mr. Adcock?

A. I don't think I put it quite as strongly as that, though I might have.

Q. That is my recollection of what you said to Mr. Adcock, that you spent about half your time for four years in the study of this case?

A. I do not believe——

Mr. Austrian: No question of time was asked him.

Mr. Wilkerson: Let him finish the statement.

The Witness: I don't remember the statement at all, but that would indicate more time than I think I individually put on the case.

Q. Your office has put in a good deal of time?

A. My office has put in a good deal of time.

Q. How much time has it put in?

A. I can't say that, because there have been times for three months at a time when we have had active work on this case continuously.

Q. How many men have you had assisting you?

A. I have had anywhere from two to six or eight; not for as long periods as that. I have frequently had two men working on it continuously. I have had two men working continuously; I don't say frequently because that did not cover periods of more than a month or six weeks now and then.

Q. Maybe we can get some idea of the amount in this way: Do you remember how much has been paid you up to the present time, for the combined services of yourself and your office?

A. I think it is somewhere in the neighborhood of $10,000 or $12,000.

Q. That does not cover the services rendered to date?

A. Does not cover the services rendered at the last hearing nor for a considerable time before that. I was paid up to some time——

Q. That would come to about what time, the first of this year?

Mr. Adcock: I think about the middle of March.

A. I think I can tell that; I think that bill either came to the first of March——

Mr. Wilkerson: I will take your statement of the time spent up to the 1st of March.

Mr. Adcock: I think practically that was the time. It might have been later than that or earlier. It was about that time though.

The Witness: That bill apparently was until the 1st of March.

Mr. Wilkerson: To the 1st of March?

A. I think so. I won't say positively.

Q. For what you and your office have done since the 1st of March, the bill has not yet been rendered?

A. The bill has not yet been rendered. I have not figured it up, as a matter of fact.

Q. That would include all the time you spent in the immediate preparation for your own testimony, and in giving it?

A. Yes.

Q. And the services of the employes of your office?

A. Yes.

Q. In working with you?

A. Traveling expenses also.

Q. Compiling the data you have given here?

A. Yes.

Q. And of course your traveling expenses?

A. Yes.

Q. You haven't any idea how much they would amount to, have you? I do not ask you to bind yourself, in a law suit against the District?

A. I think that the services since the 1st of March have amounted to somewhere between $6,000 and $7,000, is my guess, without figuring it up.

Q. That would make your bill for work up to date in the neighborhood of $18,000 or $20,000?

A. I think that is somewhere near right.

Q. If that figure is not approximately accurate, I wish you would refer to your records when you get back.

A. It is approximately accurate.

Q. Refer to your records when you get back to Ann Arbor, and give us the correct figure later on.

Now you have, as a result of this work which you have been doing, you have arrived at or have accomplished certain net results in this case from your standpoint, as I understand it. Let us see whether I am correct or not: As to the effect of the diversion of 10,000 cubic feet of water at Chicago upon the lake levels as measured in the St. Lawrence River, the figure of the International Waterways Commission was 4¼ inches, wasn't it?

A. I do not remember.

Q. I wish you would refer to that to be sure. That is upon the level of Lake Ontario.

A. You refer to the level of Lake Ontario, in the St. Lawrence River, I understand.

Q. Yes, and for convenience I refer to page 76 of the report of the International Waterways Commission for the year 1910, Table XXXVII.

A. That is the figure given in that report.

Q. The figure which was given by Dean Shenehon, witness for the Government in this case, for the effect of the diversion of 10,000 cubic feet per second at Chicago was 4⅛ inches, was it not?

A. I do not remember. I can refer to it.

Mr. Austrian: That is for Lake Ontario?

Mr. Wilkerson: Yes.

The Witness: I assume that is correct. You asked about the St. Clair, about Michigan-Huron?

A. No, St. Lawrence. Mr. Shenehon's figure, as I recall it, was given at Ogdensburg?

A. According to Complainant's Exhibit 2, the scale indicates for a diversion of 10,000 cubic feet, something over 4 inches. I should say between 4⅛ and 4¼ inches for the Ogdensburg gage, as I read the exhibit.

Q. Your own figure for the effect of that diversion, as I recall your testimony, is that it is slightly less than four inches?

A. Yes, sir, I think that was my statement; yes, just under four inches.

Q. It is what you call four minus. That is to say it is slightly less than four inches, and that is your opinion as to the effect of the diversion of 10,000 cubic feet per second upon

the level of Lake Ontario as determined from the observations in the St. Lawrence River, is it?

A. That is my opinion and my best judgment as to the maximum effect of the diversion of 10,000 cubic feet at Chicago upon the levels of Lake Ontario, based upon all the information which I have been able to secure up to date bearing upon the discharge of the St. Lawrence River and its increment.

Q. Well, now, what is your best judgment as an engineer as to the effect of that diversion?

A. That it will not be more than 4 inches.

Q. And that it will be at least within 10 per cent. of that figure, as I understood you yesterday?

A. I don't think I want to put it as strong as that. I would be surprised if it should be more than 10 per cent. less than that figure. But I conceive that it might be.

Q. Your best judgment as an engineer then is that you would be surprised if there was a difference of more than 10 per cent.; you think there would not be more than a variation of 10 per cent. from that figure?

A. I would say my judgment at the present time is: That effect will be between $3\frac{1}{2}$ and 4 inches.

Q. That is your best opinion as an engineer?

A. That is my best opinion at the present moment.

Q. As to the effect of the diversion of 10,000 cubic feet per second at Chicago upon the level of Lakes Michigan-Huron, the figure of the International Waterways Commission is $6\frac{1}{2}$ inches, is it not?

A. Yes.

Q. The testimony of Dean Shenehon for the Government was that five inches plus was the lowest figure which could be accepted as expressing the effect of that diversion upon the levels of Lakes Michigan and Huron?

A. In his opinion.

Q. What is that?

A. In his opinion.

Q. He gave that as his opinion?

A. Yes.

Q. That five inches was the lowest figure which would express it. Your statement of the effect of the diversion upon the levels of Lakes Michigan-Huron is that in your opinion the effect of the diversion is $4\frac{1}{8}$ inches plus. Am I right in that?

A. Approximately.

Q. Well, I want to get—if it is not 4⅛, if there is any other fraction, what is it?

A. Well, that is the closest, I guess the closest that you could get; slightly over 4⅛.

Q. Between 4⅛ and 4¼ inches?

A. Yes, very close to 4⅛.

Q. That is your best professional opinion as an engineer with reference to the effect of the diversion of 10,000 cubic feet per second at Chicago upon the levels of Lake Michigan-Huron?

A. That it will not be greater than about 4⅛.

Q. The same as you said about the other figure, you would be surprised if it should be determined that it was more than 10 per cent., less than that?

A. At the present time, I would put the limits to that at about three and three-quarters.

Q. That is, it could not be less than 3¾?

A. I think it could, but I don't believe it would be.

Q. Your best opinion is it would not be?

A. My opinion at the present time, in the light of such information as I have is that it is not less than 3¾.

Q. What I want is your best judgment.

A. That is the best I can give you.

Q. Your best judgment as an engineer as to the effect of that diversion?

A. All right.

Q. And the figures which you state, 4⅛ to 4¼, with the possibility of a diminution down to 3¾ is your best opinion?

A. Yes.

Q. As to the effect of the diversion of 10,000 cubic feet of water at Chicago upon the level of Lake Erie, I understand the figures of the International Waterways Commission to be 5½ inches?

A. That is as stated in the report.

Q. The statement of Dean Shenehon, the witness for the Government, was that the effect of the diversion of the 10,000 cubic feet upon the level of Lake Erie was 5½ inches?

A. That appears to correspond with the scale on Exhibits 3 and 4.

Mr. Adcock: Complainant's exhibits?

A. Complainant's Exhibits 3 and 4.

Mr. Wilkerson: Your best opinion as an engineer as to the effect of the diversion at Chicago upon the level of Lake Erie is, as I understand you, 3½ inches?

A. Yes. I put 3¼ inches as the maximum limit.

Q. What do you put as the minimum limit?

A. Well, the increment of Lake Erie is so doubtful as to what it is, that is the conditions make its determination so uncertain, that I never have really given very serious thought as to what the upper limit of increment and minimum limit of diversion might be.

Q. What is your best opinion as an engineer as to the minimum figure that could be assigned as representing the effect of that diversion upon Lake Erie?

A. Well, I think I would say at the present moment that it would not be less than two inches.

Q. It would not be less than two inches; and that 3¼ is your best judgment, while it might be as low as two?

A. Th ee and one-half is my judgment of the upper limit?

Mr. Austrian: That is the maximum?

A. The maximum.

Mr. Wilkerson: That is to say, it is your opinion as an engineer that the effect of the diversion of 10,000 cubic feet at Chicago would be less upon the level of Lake Erie than it would be upon the level of either Lake Ontario or the level of Lakes Michigan-Huron?

A. That is my opinion.

Q. And it is your opinion that the conclusion of the International Waterways Commission in assigning to the effect upon Lake Erie a higher figure than upon Lake Ontario is an erroneous conclusion?

A. I believe so.

Q. When did you first confer with Mr. Stearns about this case?

A. Some time early this year.

Q. Approximately?

Mr. Adcock: You conferred with him about the early part of February.

Mr. Wilkerson: How many days in the aggregate have you spent in conference with Mr. Stearns?

A. Prior to his appearance, that is prior to the last hearing, I spent the time from Ann Arbor to Buffalo on the Wolverine, and during the hearing, when I was on the witness stand, and during the days that you gentleman were in Washington, we were all working together on certain phases of this question; and such other time—such other conferences as have been had with Mr. Stearns, limited to a trip down the Sanitary Canal along in May or June, in which there was a

large party of us. Mr. Stearns was along, and in the evening we had a conference of about an hour with various experts, on this case.

There has been no private conference at which Mr. Stearns and I were the only ones present, so far as I can remember, except that first one on the Wolverine, when I presented to him an outline of my testimony and asked him to examine it and see whether he could be of assistance to us in this case.

Q. When you said Washington, you meant New York?

A. No, you and Mr. Adcock went down to Washington and left us there in New York, and we had a three days' recess.

Q. You mean the time when Mr. Adcock and I went to Washington?

A. Yes. When we were in New York, Mr. Stearns was there, and we spent that time in working up data in this case.

Q. How many days all together would you say it amounted to?

A. If you count that in, it might amount to four or five days.

Q. When did you first confer with Mr. Freeman about the case?

A. I conferred with Mr. Freeman at Niagara Falls the day after I conferred with Mr. Stearns on the Wolverine. I got off at Buffalo and went up to Niagara Falls that night to meet Mr. Freeman, and met him the next morning and had a conference of about 20 minutes with him on the subject, and then later in the afternoon had another conference of about, something less than an hour. The next time I saw him was when he appeared here in New York.

Q. Prior to the time when you conferred with Mr. Stearns and Mr. Freeman, are you aware of any engineer who has ever studied this question, who has stated the conclusion that the effect of the diversion of this water would be greater upon Lake Ontario than it would be upon the level of Lake Erie?

A. I don't recall anybody.

Q. And up to that time was it not the unanimous opinion of engineers who had studied this question that the effect of the diversion of this 10,000 cubic feet would be greater upon Lake Erie than it would be upon Lake Ontario?

A. I don't know of any engineers who had studied this question up to that time, outside of those connected with the United States Lake Survey and the International Waterways Commission; and I assume that their opinions are represented by their published reports.

Q. Who are the engineers, as you now recall them, who were connected with the Lake Survey Office, who studied this question?

A. Mr. E. E. Haskell, Mr. Shenehon, Mr. Russell, Mr. Ray. I think those are all you would really put in that class, outside of the Engineer Officer.

Q. Mr. Sabin?

A. I beg your pardon, I should have included Mr. Sabin. That was an oversight; I would say Mr. Sabin also. He should have been put early in the list because he was one of the first ones.

Q. How about Mr. Wilson?

A. I was going to put him with the International Waterways Commission. His study of this thing did not take place until after he went with the International Waterways Commission, so far as I am aware. He worked on the discharge of the St. Mary's River, but I am not aware that he gave any special attention to the general problem until he went with the International Waterways Commission.

Q. Didn't Mr. Wilson investigate slope conditions in the Niagara River in 1903?

A. I think he did, but as I say, it is my impression he did not give any particular study to the general problem.

You can bring in a list of men; I can identify probably 20 who have been connected with this work in one way or another, and have performed certain parts of it, but when you ask who made a study of it, I think the list I gave practically completes it, outside of the Engineer Officers themselves and who I am very much in doubt——

Q. How about Mr. Blanchard?

A. I was not aware that Mr. Blanchard had made any study of the proposition as a whole. Mr. Blanchard was engaged on the St. Clair gagings and also the Detroit River, and then left the service shortly after.

Q. Who are the engineers, who by reason of their connection with the International Waterways Commission have given study to this question?

A. Well, Mr. E. E. Haskell has principally. I don't know to what extent General Ernst has given it study. He may or may not have devoted particular attention to it. And Mr. Wilson, the Secretary of the Commission, has given it a great deal of attention.

Q. Any Canadian engineers, with whom you are familiar?

A. I think that Mr. Stewart has.

Q. Any one else, any other Canadian engineer that you know at all?

A. I do not think that Mr. Coste, who was formerly the engineer member, is likely to have given very much attention to this phase of the question.

Q. Did any one connected with the Deep Waterways Commission ever make any study of this question?

A. I can't be certain whether the Deep Waterways Commission considered the effect of the diversion at Chicago. Their problem was the question of a deep waterway from the lakes to tide water, and they considered various problems connected with that, and incidentally, probably, the Chicago diversion. But at the time that they were working, there was not sufficient definite information to enable a very comprehensive study of the problem to be made.

I think it is probable they did make an investigation along the line of this effect, but I don't recall what it was.

Q. Without regard to whether the effect of the diversion was concerning 10,000 cubic feet per second, they did make a study of the question of the relation between lake levels and the volume of discharge in these respective rivers, did they not?

A. They did in regard to the Niagara, for the reason that they were very suspicious of the supposed outflow of the Niagara River, they having had their attention drawn to the conditions which have been pointed out in this case, of the inconsistency of the supposed river discharge with the discharges apparent in the other rivers, and the later gagings of the upper rivers having reduced the apparent discharge of those rivers slightly, helping to bring the results more nearly into harmony. And the earlier Niagara gagings were undertaken by the Board of Engineers on Deep Waterways in an attempt to ascertain what the discharge of the Niagara actually was, in order to determine the effect of the proposed regulating works upon the level of Lake Erie. And of course incidentally with that, they considered the effect of those works upon Lake Ontario.

As I said before, I do not know to what extent the diversion of Chicago entered into that problem. Of course it was a study of the same thing, in its essentials, but at that time, if my memory serves me correctly, they did not have the St. Lawrence gagings.

Q. I understand that the net result of your work is the expression of the opinion by you as an engineer that the fig-

ures which have been deduced by these various engineers who have been mentioned, as representing the effect of the diversion of water, are incorrect?

A. I think they are in error.

Q. And so far as the Niagara River is concerned, or rather so far as the effect upon the level of Lake Erie is concerned, they have been in error to an extent of between 60 and 100 per cent. of the figure which you state as the correct figure.

Mr. Austrian: No, you do not mean that.

Mr. Wilkerson: Yes.

Mr. Austrian: No, it is the difference between 2 1/5 and $5\frac{1}{8}$.

Mr. Wilkerson: He made his figure $3\frac{1}{2}$. Their figures were $5\frac{1}{8}$. The difference between $5\frac{1}{8}$ and $3\frac{1}{2}$ is $2\frac{3}{8}$. What per cent. of $3\frac{1}{2}$ is $2\frac{3}{8}$—what per cent. of $5\frac{1}{8}$?

The Witness: I have answered the question.

Mr. Wilkerson: The witness gets my point.

The Witness: According to my best judgment the effect of the diversion as reported by the International Waterways Commission is in error approximately 100 per cent.—or no, I should say 50 per cent. when speaking of them.

Q. When speaking of their figures?

A. When speaking of their figures, it is 50 per cent., and 100 per cent. of mine.

Q. You get a figure about half of theirs?

A. I get a figure about half of theirs.

Mr. Austrian: Three and one-half is not a half of $5\frac{1}{8}$.

Mr. Wilkerson: He said 2 to $3\frac{1}{2}$.

Mr. Austrian: He said not less than two nor more than——

Mr. Wilkerson: I was assuming the average of the two limits. I wanted to get his conclusion.

Mr. Austrian: I beg your pardon for interrupting. I didn't understand.

Mr. Wilkerson: Stated in as simple a way as possible, so that we will understand what the net result of his computation is.

Q. Now, as another one of the net results of your work in this case, you have suggested, if I understand it, that there has been a lowering of the level of Lakes Michigan and Huron by the dredging which the Government itself has done in the St. Clair and Detroit Rivers?

A. Not only suggested it, but I have affirmed it and I reaffirm it.

Q. So that we may have it here in the record, what is your opinion as an engineer as to the extent to which the levels of Lakes Michigan and Huron have been lowered by the dredging which has been done in the St. Clair and Detroit Rivers?

A. At least .6 of a foot.

Q. By that you mean .6 of a foot is the lowest figure?

A. Yes, I mean it has not been lowered less than that in my judgment.

Q. What is your maximum figure?

A. Oh, about twice that, 1.2, say.

Q. Is it your opinion that that is merely a possibility, or is that your best opinion as an engineer that it has resulted in a lowering of 1.2 feet?

A. I think that is the upper limit.

Q. That is to say it is a possibility?

A. It is a possibility.

Q. But not probable?

A. I would say that it is not probable the effect has been more than a foot. I hardly think it is possible it has been more than 1.2.

Q. So between .6 of a foot and a foot——

A. Below a foot is where I really think that the result is to be found.

Q. Now, I understand as another one of the results of the work which you have done in this case, you have presented a statement and a table which show, in your opinion that since the diversion of water through the Chicago Drainage Canal, the level of Lakes Michigan and Huron has actually increased?

A. I think that is correct. They have actually increased, placing my faith upon the records of the United States Lake Survey.

Q. Is it your opinion as an engineer that the diversion of water by the Sanitary District at Chicago has had the effect of raising the levels of the lakes?

A. Certainly not.

Q. What then, so far as the question of effect upon the lake levels is concerned, is the weight which in your opinion is to be given to that table?

A. Merely a statement of fact?

Q. Merely a statement of fact? That is Table LXV?

A. I guess so. That is the table is a statement of fact.

Q. In other words, what inference, as an engineer, is it

your intention that the court at the hearing of this case shall draw from your table number LXV, so far as it throws light upon the question of fact which is involved in this case?

A. That the lakes are actually higher now than they were before the diversion. That is all.

Q. In your opinion, does it throw any light at all upon the question of fact as to the effect of diversion?

A. None whatever.

Q. None whatever?

A. (No response.)

Mr. Austrian: May I ask you this question, to clear up the record a bit: You do not question the accuracy of that Table LXV, as I understand it; that is that the lake levels are higher now than they were in 1900?

Mr. Wilkerson: I am the counsel. I would not care to question the accuracy of the table. I am merely trying to find out from the witness what aid he expects the court in this case to get from his table number LXV, from which he has reached a conclusion of fact.

Mr. Austrian: Just for the sake of putting it in readable form.

Mr. Wilkerson: In other words you put it in there because counsel told you to?

A. They didn't tell me to, but they asked me to; and it being a plain statement of fact, with no opinion connected with it, I saw no reason why it should not be put in.

Q. As a matter of fact, you say, when asked today about it, that it did not have the slightest thing to do with the facts in this case?

A. I don't think I would put it as strong as that.

Mr. Austrian: I object to that.

Q. You took it from records compiled by the Government itself?

A. I did, and I believe the table to be a correct statement of fact. That is all there is to it.

Mr. Wilkerson: Isn't it perfectly obvious to you as an engineer that the only effect which could result from the use of that table would be somebody might use it in an attempt to confuse the court as to the testimony in this case.

Mr. Austrian: That is objected to. I ask the witness not to answer the question.

Mr. Wilkerson: The witness, under the instruction of counsel, declined to answer the question.

Q. I understand as a result of the work which you have

done in this case, another one of the net results is that you have indicated a scheme of compensation which might be employed for the purpose of bringing the level of the lakes back to the point where they would be if water was not diverted at Chicago?

A. Yes.

Q. And that scheme in general, as I understand it from your testimony yesterday, and I have not had the benefit of reading your testimony, so I am speaking from memory, involved the filling in of certain channels?

A. Portions of certain channels.

Q. Portions of certain channels. Those channels which it is proposed to fill in are navigable channels, are they not?

A. Yes, and the proposed filling would not interfere with navigation.

Q. That is to say in your opinion it would not?

A. That is the fact——

Q. It would be the placing of material in a navigable channel of the United States?

A. Yes.

Q. That is what it amounts to, isn't it?

A. Yes.

Mr. Adcock: You started a sentence that you did not finish.

A. I said it would not be an interference with navigation.

Mr. Wilkerson: But of course whether it would interfere with navigation or not is something for the Government itself to determine.

Mr. Austrian: I object to that. That may be a conclusion of law from your viewpoint, but you are asking this witness to testify to facts and not law.

Mr. Wilkerson: I am satisfied if I understand from the witness that the scheme of compensation involves the filling in of channels which are navigable.

The Witness: Yes, it involves the adoption of the same plan which has been adopted by the Government in the lower Detroit River.

Q. In addition to the contradiction of the figures of the Lake Survey and the International Waterways Commission, the statement as to the effect upon the level of Lakes Michigan and Huron by the dredging which the Government itself has done in the St. Clair and Detroit Rivers, the scheme of compensation which has been suggested and the statement as to the actual condition of the Lake levels since the diversion of the water at Chicago, do you now recall any other

general propositions that you have put forward here as representing your conclusions in this case? I am not now speaking of comments upon methods of computation but I am speaking of what might be called ultimate net results of your work.

Mr. Adcock: Do you understand the question?

A. It is a little hard to say just where you would draw the line.

Mr. Wilkerson: He understands it.

The Witness: It is a little hard to say just where you draw the line between what are, as you say, the ultimate facts and the subordinate facts; the ultimate conclusions and preliminary conclusions.

Q. Indicate a subordinate conclusion, which in your opinion is not covered by one of those general propositions which I have stated?

A. The proposition that would seem to me might be included in that category, although quite possibly would be relegated to a minor position would be that the gagings at Niagara cannot be depended upon for the establishment of the increment that comes in the——

Q. That comes in the criticism of the other conclusions as to the effect of the diversion. And the basis for your conclusion of fact is that you have an idea as to the value of the Niagara measurements?

A. Yes.

Q. Do you think of anything else now except that?

A. So far as I recall the testimony, and dividing it into the categories as you suggest, I think you have covered it; although I would like to add this: That the showing that the International Waterways Commission and the Lake Survey are in error in the effect of diversion is not what I have in mind in thinking of this proposition. I would have been very glad to have agreed with them in their conclusions.

Q. But you did not?

A. But I did not, and my conclusion is that the effects are so and so; not that the other fellow's are wrong.

Q. Of course if your conclusions are right they are necessarily wrong?

A. Yes, but I do not have to conclude that.

Mr. Austrian: That is a polite way of giving the lie direct.

Mr. Wilkerson: I think the counsel on the other side has stated the effect of it accurately.

Q. In speaking of your experience as an engineer, I think

you mentioned that you had been connected with another phase of litigation, to which the Sanitary District was a party?

A. I was.

Q. That was the case of the State of Missouri versus the State of Illinois and the Sanitary District of Chicago?

A. It was.

Q. A suit, an original bill as I recall it, brought in the Supreme Court of the United States?

A. It was.

Q. About 1903, or rather your testimony was in 1903?

A. It was about that time, yes, I think 1903. I think that is correct.

Q. What was the question that was involved in that case?

A. It was an application for an injunction on the part of the State of Missouri for the benefit of the City of St. Louis to restrain the City of Chicago from discharging its sewage into the Illinois River, on the theory that it would pollute and injure the water supply of the City of St. Louis.

Mr. Austrian: And thereby promote disease and be a public nuisance and so forth.

Mr. Wilkerson: Q. You were retained in that case as an expert witness for the State of Missouri?

A. I was.

Q. How much time did you spend on that case?

A. About a month.

Q. Including the time of preparation and testimony, at the same rate of compensation that you have in this case?

Mr. Austrian: I object to that question because the law is that it is perfectly permissible to inquire as to the compensation of an expert witness in the case at bar; not in other cases; and especially where the compensation is not paid by the same person to the controversy.

Mr. Wilkerson: Let him answer, subject to objection.

A. I think my charge was on the same basis as this.

Q. That it amounted to about $3,000 all together?

A. Something of that sort.

Q. That is approximately the figure?

A. Yes.

Q. Your testimony in that case was before the Supreme Court, was it not?

A. It was.

Mr. Austrian: You do not mean before the Supreme Court. You mean before a commissioner?

Mr. Wilkerson: It was taken before a commissioner and was in the record when the case was argued before the Supreme Court, so that it was before the Supreme Court.

Mr. Austrian: Yes.

Mr. Wilkerson: Q. You are familiar with the printed record in that case, are you?

A. I have seen the volumes, but I think I have not seen the testimony.

Q. I direct your attention to pages 2467, 2468 and 2469, from which I shall read into the record and ask you—

Mr. Austrian: Whose testimony?

Mr. Wilkerson: Testimony of Gardner Stewart Williams, taken at the Southern Hotel, St. Louis, Missouri, at 2 p. m., on Tuesday, the 26th day of May, 1903. Present: The commissioner, and the same counsel representing the respective parties. That was John Hamline and Mr. Todd, as I recall it, for the State of Illinois and the Sanitary District, and General Crow and Judge Johns.

Mr. Austrian: Is that testimony in abstract form or verbatim?

Mr. Wilkerson: It purports to be question and answer.

The Witness: I think it is verbatim.

Mr. Wilkerson: Q. I ask you to look at the portions I have marked on pages 2467, 2468 and 2469. I ask you to state whether or not, according to your best recollection, that is the testimony, or part of the testimony which you gave on that hearing?

Mr. Austrian: That is the questions that were put and the answers given.

Mr. Wilkerson: The questions that were put and the answers given as there set down according to his best recollection.

A. I think that is my testimony.

Q. I now invite your attention to the following, page 2467: "Q. Mr. Williams, I will ask you as an expert on water supplies, for cities and towns, passing your opinion upon the subject broadly, in your judgment is there any present or impending or future danger to the people of the State of Missouri using the waters of the Mississippi below the mouth of the Illinois for drinking purposes, which danger would be due to the discharge of the mixed sewage of the Sanitary District of Chicago and the waters of the Drainage Canal into the

Illinois River other than the infection with typhoid fever germs of the waters of the Mississippi River."

Mr. Austrian: We make special objection to the question put, and the answer thereto, and all subsequent questions because thus far it does not appear that that testimony would tend to prove any issue involved in the present controversy. And it is stipulated that all this testimony, question and answer, may go in subject to objection.

Mr. Wilkerson: We have a stipulation that was made at the outset of the testimony, that any objection which did not involve the form of the question, or something which could be corrected at the hearing, might be pressed at the hearing of the case with the same effect as if there made; and it was understood that that applies not only to questions on the direct examination, but, of course, to the questions on cross-examination.

Mr. Austrian: Very well.

Mr. Wilkerson: I would think, however, that if the objection is that it is not proper cross-examination, and the objection were one which could be obviated at the taking of the testimony before the commissioner, it would be proper to indicate the reason why it is not proper cross-examination, so that if it can be corrected, we may have the opportunity of doing so.

Mr. Austrian: You would have to call him as your own witness, but we do not make that point.

Mr. Wilkerson: Your objection is the particular objection.

Mr. Austrian: Yes, you could cure that by merely calling the witness as your own.

Mr. Wilkerson: Yes.

Mr. Austrian: We do not make that objection.

Mr. Wilkerson: Your objection is that the testimony itself is inherently incompetent.

Mr. Austrian: Yes; does not tend to prove any issue, so far as I know anything about it. It might develop later that it does tend to prove the issue.

Mr. Wilkerson: (Q.) (Continued.) "A. In the history of water-borne diseases in America, while typhoid fever plays an important part, it comes far short of playing the entire part. Not only Asiatic cholera, but a large number of our common American diseases are undoubtedly transmitted through the water. Among those germs which have been found to have a considerable length of existence in the water

are the germs of diphtheria, tetanus and anthrax, as well as a considerable number of germs which are derived from the diseases of the lower animals.

The germ of anthrax, for instance, is capable of producing very serious disease in both man and beast, and there have already occurred in the City of St. Louis cases of anthrax, one of which has been traced apparently to the water supply, and the germ of anthrax is reported to have been already found in the waters of the Illinois River. Anthrax is primarily a disease of the lower animals, and in France, where it has been specially prevalent, in some provinces it has been no uncommon thing for 10 per cent. of the sheep to be destroyed by it in a single year.

A peculiarity of anthrax is the remarkable length of life of the spores or seeds—whichever you may choose to call them—in water, they having been known to exist in it not only for months, but for years, and are practically indestructible. Should anthrax be present among cattle which are daily slaughtered in the Chicago Stock Yards, and from them be transmitted by the discharges from the nostrils, mouths or bowels of these cattle, into the sewers of Chicago, there would be no question that the germs of anthrax might easily find a lodging in the people of Missouri with extremely fatal results. The germs of anthrax may not only be taken into the human system and produce disease by passing into the intestinal tract, but it is also susceptible of producing disease as the result of inoculation, so that a person bathing in water in which there were present germs of anthrax, if he had on his body any abrasions of the skin would be particularly liable to receive an infection from anthrax which might very probably end fatally.

It is not an uncommon thing for anthrax to be communicated to those who are handling the skin of animals and who may become scarred or bruised in the course of their occupation.

The germs of anthrax being practically indestructable under ordinary conditions, is frequently conveyed in hides and skins, and in the refuse from leather manufacturing establishments might easily get into the sewage of the City of Chicago as well as by way of the Stock Yards.

The people of the State of Missouri resident in the counties bordering upon the Mississippi River are largely engaged in stock raising, and in times of drouth, the Mississippi River is practically the only source of water for the stock so raised,

and it has come to my knowledge that in such times, this water is parted for many miles from the shores of the Mississippi River to be used by both stock and the human inhabitants of the country adjacent. Should the sewage of Chicago become infected with the germs of antharx, and should those germs be transmitted as they undoubtedly would be into the waters of the Mississippi if the Chicago Drainage Canal continues to discharge the sewage of Chicago into the Des Plaines and Illinois Rivers, at such times there would be great danger of the occurrence of an epidemic of anthrax, not only among the human inhabitants of the State of Missouri, but also among the lower animals using the water.

Anthrax is recognized as one of the worst of water-borne diseases with which we have to contend, for the reason that when once it becomes established in a community it may attack both man and beast, and its eradication can only be accomplished by the absolute destruction of the bodies of animals so infected.

It is able to live for long periods of time in the earth, and may thereby be communicated long after the death of the primarily infected animal to other animals grazing over the surface.

I may add further that the disease commonly known as glanders is also transmitted through water, and that it is not an uncommon disease among the stock of this country at the present time, and the discharge of the sewage of Chicago, which is at any time liable to be contaminated by glanders, into the Illinois River, is another source of danger to the inhabitants of Missouri.

In fact, as we look into the future and see the probable growth of Chicago, both in industries and in population, and the added probability of infection of its sewage due to the more general spread of infectious diseases, it seems to me that the danger impending over the citizens of Missouri as the result of the discharge of the sewage of Chicago through the Drainage Canal into the waters of the Illinois River is a most fearful menace to the life and welfare, not only of the citizens of Missouri but of the citizens of other cities below the mouth of the Illinois River leaving entirely out of consideration the question of typhoid fever."

You recall that as having been given in the course of your testimony?

A. I do.

Mr. Austrian: Just here I think it is only fair for the coun-

sel for the Government to state the purpose of reading that part of the testimony into the record.

Mr. Wilkerson: The question is put to the witness because we conceive, first, that it is proper cross-examination of the witness upon the matters with reference to which he has testified in this case. That the opinion which he has there expressed is a proper subject of comment to be made upon his testimony as a whole, in the case at bar.

In addition to that we conceive that, passing the question of proper cross-examination which I understand is not specifically pressed as an objection to the question, the testimony is unquestionably competent because it deals with an issue as to which a large amount of evidence has already been presented by the defendants in this hearing.

Mr. Austrian: Will you stipulate that so far as this testimony is concerned, that question and answer which you have read, the witness shall be considered your witness, we not objecting to the form of the question.

Mr. Wilkerson: No, I am not making him my witness.

Mr. Austrian: On that point.

Mr. Wilkerson: I do not know any rule of evidence by which testimony, if it is proper cross-examination, then I am entitled to use it for any purpose in the case.

Mr. Austrian: If you conceive it is proper cross-examination. Inasmuch as it does not tend to show his interest, and inasmuch as it does not tend to elucidate any question put to him on direct examination, I don't think it is proper cross-examination.

Mr. Wilkerson: I think it is. I do not care to argue it.

Mr. Austrian: To get the record right, you have no objection to my raising the objection at this time that it is not proper cross-examination.

Mr. Wilkerson: Nor at the hearing; you may raise it at the hearing.

Mr. Austrian: I did waive it.

Mr. Wilkerson: Because if it is not proper cross-examination, I am frank with you when I say I do not see that there is any way we can cure the matter at this hearing. If it is not cross-examination you may make the objection at the hearing.

Mr. Austrian: Very well.

Mr. Adcock: You suggested that specific objection should be made.

Mr. Wilkerson: I stipulate you may reserve the right to make at the hearing the objection this is not proper cross-ex-

amination. And I suppose you will give me the stipulation if it is proper as our own testimony and it should be held it is improper cross-examination, I may use it as my own testimony, if I see fit to do it at the hearing, without recalling the witness.

Mr. Austrian: Yes.

Mr. Wilkerson: You gave that as your best professional opinion upon that subject, did you, Mr. Williams?

A. I did.

Q. And it is your opinion, I assume?

A. With some slight modification due to the advances of science in the past ten years.

Q. But it is substantially correct?

A. Substantially.

Q. And I direct your attention to page 2472, to the following: "Q. Mr. Williams, assuming that an epidemic of Asiatic cholera should occur at the City of Chicago under existing conditions of sewerage in said city, and existing conditions in an open drainage canal, the Des Plaines, the Illinois and the Mississippi River, and the existing conditions with reference to the intake tower of the St. Louis Water Works, and the storage and distribution of the water from the chain of rocks to the consumers in the City of St. Louis, I will ask you as an expert on water supplies for cities and towns is it possible or probable that the germs of that disease might find their way into the intake tower of the St. Louis Water Works at the chain of rocks and thence to the consumer?

A. In the event of an epidemic of Asiatic cholera in Chicago under the conditions now existing in the waters between Chicago and the chain of rocks, through which the sewage of Chicago now flows, there is not only a possibility but a probability, and almost a certainty, that the germs of the disease would be communicated or transmitted to the water supply of the City of St. Louis and the consumers thereof.

Q. Now, Mr. Williams, what effect if any would the conveyance of Asiatic cholera germs have under those circumstances upon the people of the City of St. Louis?

A. It would undoubtedly lead to an outbreak of Asiatic cholera in the City of St. Louis."

You recall that, do you?

A. I do. Wait a minute; I do not specifically recall that answer, but I have no reason to doubt it as it is what I would have said under the circumstances exactly.

Q. You gave it as your professional opinion?

A. Being in the record, it is undoubtedly what I said. It is my opinion.

Q. You adhere to it?

A. I adhere to it, yes.

Q. I direct your attention to another portion of the same record beginning on page 2475 of the volume to which I have above referred.

"Q. Now, Mr. Williams, looking forward into the future and considering not this generation alone, but those that are to follow, and considering the relation of the filth and infection of the Chicago sewage to the water of the Mississippi River as it flows along the Missouri shore, I will ask you to state your views as an expert on public health matters, regarding the above mentioned conditions, considered as a broad practical proposition.

A. . With regard to the effect on future generations of the discharge of Chicago sewage into the Illinois River and thence into the Mississippi River, and its effect upon the water of the Mississippi River, I would say that there is no question in my mind but that the problem before future generations is one of far more difficult solution than that which we face in the present.

A careful study of the relations existing between the flow of the rivers which contribute to the water flowing past the chain of rocks, and the prevalence of water borne diseases in the City of St. Louis among those of her citizens who are users of the public water supply has led me to the conclusion that at the present time the remarkable immunity from serious typhoid infection which the citizens of St. Louis have thus far experienced, although they have been using water which is unquestionably at the time of entering the intake considerably polluted, is due very largely to the character and amount of water contributed by the Missouri River.

I long ago learned to appreciate the importance from a sanitary standpoint of Missouri River mud. As the Missouri River enters the Mississippi River, the amount of silt in suspension in this water amounts oftentimes to over 1,200 parts in a million. A large portion of this silt is of such a nature as to be quite readily deposited as the water approaches a state of approximate quiescence, and such a vast quantity of depositing mineral matter mixed thoroughly throughout the water of the settling basins of the St. Louis Water Works cannot fail and analyses show that it has not failed to remove a very considerable percentage of the bacteria which are daily

brought into these settling basins in the water as it comes from the Mississippi River.

Laying aside the question for the moment of the possible increase of infectious matter in the water supplied through the intake at the chain of rocks due to the increased growth of the City of Chicago and the other populations upon the drainage area of the rivers which contribute to the St. Louis water supply, it is to be borne in mind as time goes on the history of the Mississippi River will become the history of every other stream upon whose borders the hand of man has rested, and that while the total quantity of water which that stream will deliver from year to year will remain about the same as now, the quantity of water which will be delivered in times of drouth will be decidedly less than heretofore, and that larger and larger portions of the discharge will be concentrated in a few floods. The result of this upon the waters mingling to form the supply of St. Louis will be that in the future, the Missouri River will show a greater diminution in the percentage which it represents of the flow past the city than will the waters derived from those other two streams upon which the hand of man has rested for so long a time, that comparatively small changes are to be anticipated in the future in the quantity of their low water run-offs. It will therefore follow that the amount of silt furnished by the Missouri River will be less and less sufficient to remove from the mixed water the number of disease germs which even now exist there, leaving alone the possibility, or probability and the certainty that the number of those germs will vastly increase as time goes on.

It therefore seems quite clear to me that any added pollution of the waters of the Illinois or the Mississippi River will have from year to year a greater and greater effect upon the healthfulness and quality of the water which will be delivered under circumstances similar to those now existing in the treatment of the water delivered to the citizens of St. Louis by their water works system, and when we consider that in the City of Chicago there is now a population representing about one-third of the total urban population upon the watersheds tributary to the Mississippi River at St. Louis, and probably representing more than one-sixth of all the population resident upon those water sheds, and that now no city in this portion of the United States, or indeed in any portion of it, has shown such remarkable and rapid growth both in population and in industries as Chicago, there can be no ques-

tion that in the future the menace to the health of St. Louis arising from the discharge into the Illinois River of the sewage of the Chicago Sanitary District will be a much more tremendous and impending danger to the citizens of Missouri living along the Mississippi River below the mouth of the Illinois, than exists at the present time, grave though the present condition be."

Do you recall that question and answer?

A. I do in general, yes.

Q. And you state the same with reference to it as you did with reference to the other questions and answers, as to your having given it as your professional opinion?

A. I gave it.

Q. And as to your present opinion as to its correctness?

A. I gave it as my professional opinion at that time, and I think it is substantially correct at the present time.

Q. Do you know what happened in that case?

A. I do.

Q. The bill was dismissed, wasn't it?

A. Without prejudice to either side.

Mr. Austrian: With leave to re-file, if the menace to the people of Missouri became imminent.

The Witness: Yes.

Mr. Wilkerson: I asked that question, so that it might not be necessary to put in the opinion. We can refer to it if we want to.

Mr. Austrian: Certainly.

Mr. Wilkerson: Q. The result of the litigation was, was it not, that St. Louis adopted a different method of treating its water supply?

A. Yes, instead of trying to preserve it in its natural purity, they adopted methods of purification.

Q. Of course the method which St. Louis adopted is one which could be used in Chicago or any other large city.

A. No, it is a materially different proposition. The conditions at St. Louis are peculiar and require a treatment suited to those conditions. It is like treating ague or treating smallpox; you treat them differently.

Q. That is it would make a difference in the kind of works?

A. In the method of procedure.

Q. In the method of procedure?

A. In the method of procedure.

Q. In this work which you did in the Missouri-Illinois case, did you come in contact with current meters?

A. I do not recall. I think there were some gaugings involved in the discussion.

Q. In estimating the time it would take germs to go from one place to another, were there any measurements made by current meters?

A. No, that was done by floats. Floats were put in at Robey street, and were actually traced down the river; the floats being followed by parties in boats, and the time taken from point to point.

Q. My understanding and recollection was that there was a specific mention in that litigation of the use of current meters, and that use was made of them on your side of the case for the purpose of measuring the velocity of the water and determining the rapidity with which germs get from one place to another?

A. They might have been used. I do not recollect that detail at present; but the fact was time of transmission was established by the time it took the floats to pass down the river, by actual observation.

I think that records of the discharge of the Illinois River and Des Plaines were introduced to show that these floats were sent down, not at flood time but at low water. And it is quite possible that use was made of those results to indicate the probability of the time being greater or less..

Q. Your recollection is not definite?

A. My recollection is not definite, but I think it is quite probable, in fact, I am sure there was some information furnished as to the flow of the streams at different seasons of the year, whether it was obtained from current meters or from discharges over the dam at La Grange and Kampsville; there were three, in fact, or four.

Q. What I was getting at is whether current meter observations were used in that case, and were taken and accepted as results which were entitled to credit by scientific men.

A. Oh, they would be within reasonable limits, certainly.

Q. Now in your direct examination you made mention of a service which you performed as engineer for the Detroit Water Board. Is that the correct name of that?

A. Board of Water Commissioners of the City of Detroit.

Q. And in that connection you made measurements in the Detroit River?

A. We made some current meter measurements in the Detroit River, yes.

Q. Just what was the purpose of the measurements?

A. The purpose of those measurements was to determine the locations of the main currents in the American channel, for the purpose of locating the intake for the water works. It was not primarily for the purpose of measuring discharge.

Q. How extensive were those measurements?

A. There was a considerable amount of work of measuring velocities and direction of current done. I don't recall now just how much time it covered; and there was a gauging of the American channel made through the ice during the winter of 1896 and 1897 or else 1897 and 1898, I guess.

Q. Were the measurements limited to the American channel?

A. The current meter work was limited to the American channel.

Q. What instruments did you use?

A. Used a Ritchie-Haskell Direction Current Meter.

Q. How did you rate the meter?

A. We did not rate it, because the question of the magnitude of the current was unimportant; it was simply the relative—wait a minute, I say we did not rate it. I would not be sure about that, either. For the bulk of our investigations we did not care about an accurate rating, and we took the maker's rating.

My recollection is not altogether clear, but I have in mind that the meter was rated in the canal at the water works, on second thought, by attachment to a boat and dragging along the side of the canal.

Q. This was not a piece of work which was of the same kind and magnitude as the work which has been under discussion in this case, was it?

A. No, there was no attempt made to make an accurate examination of the quantity of water passing. It was purely an approximate determination so far as the quantity was concerned. We cared very little about that. It was rather to find out how the currents were distributed.

Q. Was this rating a still water rating?

A. It was still water; any rating we made was still water.

Q. Was the ratio of velocities fairly stable at the different stations?

A. No, not at all.

Q. I think you said you did not aim at a very high degree of precision in this work?

A. Oh, no, we were not trying to measure the quantity of water?

Q. Did you make a report?

A. No, there was no formal report made. The results were reduced and an approximate measurement of the flow in the American channel was derived, which surprised us at the time on account of the smallness of it. We had supposed more water was going down that channel than appeared to be.

Q. You say this was to locate the intake?

A. It was with a view of locating the intake, yes.

Q. How did you finally locate it?

A. We finally gave up the current meter as being too difficult to operate and too deceptive in its indications for our purposes, and resorted to the thermophone, which is an instrument which records the temperature at the points where the instrument may be, and transmits it by means of a telephone, or something in the nature of a telephonic recorder, to the ear, and with that we made cross sections of the river from the water works well up into Lake St. Clair, and in the spring, of course, and summer—in the summer particularly, the colder water was coming from Lake Huron, and the warmer water from the shore, and the variations of temperature enabled us to locate quite fairly the position of the Lake Huron current.

In the winter, of course, the conditions were reversed, the shore water being the colder and the lake water the warmer; and we did some work late in the fall and early in the winter, but the bulk of the work was done in the summer.

Q. There was not anything in this work that involved what might be called a careful or critical study of current meter work, was there?

A. I think we got pretty thoroughly familiar with the idiosyncrasies of the instrument, and the difficulties which are encountered in current meter measurements.

Q. Was that the first time you had come in contact with those idiosyncrasies and difficulties?

A. That was the first work I did with the current meter.

Q. That was not your last current meter work, was it?

A. Hardly.

Q. You mentioned some work which you did in the Cornell Hydraulic Laboratory, did you not?

A. I think so.

Q. Do they have a canal there for the purpose of making this kind of obversations?

A. The Hydraulic Laboratory consists in part of a canal about 400 feet long, controlled by sluice gates at its upstream end, and having in normal condition two bulkheads across it, one about 75 feet from the inlet end, and the other at the lower end, where there is also provision for letting the water out through sluice gates.

The lower portion of the canal is equipped with a track, and a trolley is now operated on it electrically, which affords an opportunity for rating current meters or other instruments of that sort in still water, by simply filling the canal with water and closing the inlet gates.

Q. How large is the volume of flow in that canal?

A. When you are rating it is not anything, that is when it is closed. We have handled—

Q. I should have said at the different velocities at which the water flows. I want to get some idea of the size of that canal.

A. That canal is 16 feet wide and 10 feet deep at its upper end, and has a slope of 1 in 500; 1 foot in 500; so that the lower end is about 11 feet 4 inches deep, as I remember it. And water may be run through it at any depth from just enough to wet the soles of your feet to 10 feet.

Q. Take a depth of 10 feet, and with the weir conditions which you had there, how much water went through this canal?

A. We have handled very close to 500 cubic feet per second through that canal.

Q. Well, how does that compare with the quantity flowing through the Sanitary District Canal, through the diversion of 10,000 cubic feet? That would be about 2½ per cent. of it?

A. Oh, more than that.

Q. Five per cent.?

A. It bears about the same ratio to the water flowing through the Sanitary Canal that the water flowing through the Sanitary Canal bears to the water flowing out of the Great Lakes.

Mr. Austrian: That is, if the Sanitary Canal was running 10,000 cubic feet per second?

A. If the Sanitary Canal was running 10,000 cubic feet per second.

Mr. Wilkerson: Q. Which is 5 per cent. of 10,000 cubic feet per second; and of the water flowing out of the Great Lakes, say through the Niagara River, what per cent. would it be?

A. A quarter of one per cent., about ¼ of 1 per cent.

Q. You made some measurements in the St. Marys River?

A. We did.

Q. When and where were those made?

A. Those were made between Point Brush and Pointe Aux Pins, about six miles above the locks.

Q. For what purpose were those made?

A. They were made for the Michigan-Lake Superior Power Company, who were at that time interested in showing the effect of a diversion of water through their power canal upon the flow of the river, or upon something in the vicinity. I do not know that I am entirely clear as to just what their purpose was.

Q. You had some specific work in which you were engaged, some project?

A. These measurements were undertaken before the permit for the opening of the power canal was granted, if I remember correctly; and it was thought at that time, I think, that there might be some controversy in regard to the amount of water that could be diverted. At any rate the Lake Superior Power Company wished to either make, or pretend to make some measurements of the St. Mary's River at that point.

Q. I do not just understand that phrase "make or pretend to make." Was there any significance in the use of the word "pretend"?

A. Yes, there was.

Q. What was there?

A. The history of the Lake Superior Corporation shows that it was generally pretending to do things, and whether that it really meant to make those measurements or not, I am very much in doubt.

Q. You were not pretending, were you?

A. I was not.

Q. Was there anything that took place before you made the measurements that gave you the impression that you were just merely going there to go through the form of doing something, without regard to the accuracy of the results?

A. No, not at all; the precautions that were taken to insure accuracy were certainly such as I think would meet the criticisms of the representatives of the Lake Survey, at that time at least.

Q. What method did you use?

A. Well, meters were rated in the ordinary way in still

water by dragging from a truck in the laboratory in Cornell University. A provision was made for re-rating them in the Bay at Pointe Aux Pins, Wheeler Cove, for re-rating in Wheeler Cove, in a similar location to that used by the Government Engineers in the rating of their meters for the St. Marys River discharge; and various propositions were considered for handling the boat.

One contemplated stretching a cable across the channel, which I never could quite agree to, as I felt very sure that it would be, not an imaginary but a real obstruction to navigation, no matter how expertly the ends of it might be handled, when steamboats came down there with the frequency that they did. The work was finally done by shifting anchors.

Q. You are speaking of the gaging?

A. I am speaking now of the method by which what might be termed the co-efficient work was carried out, or rather the determination of index velocities—perhaps that is a more proper term—the establishment of the co-efficient. And we encountered very serious obstacles, which also must have been encountered in the work of the Lake Survey, although until recently there has been little mention of it, namely the effect of passing boats upon the distortion and disturbance of the vertical curve. We found that the vertical curve would be very greatly disturbed by passing boats, even though they were a considerable distance away.

I regret that I do not have with me the results of those observations, as there is some rather instructive information in there as to the effect of that sort of disturbance.

Q. You say the difficulty was on account of passing boats?

A. Yes, of steamers coming down. The water was about 50 feet deep there, and of course boats were then loading to about 18 or 19 feet.

Q. What year was that?

A. No, they were not loading as deeply as that because the lower channels in the St. Marys were not large enough. I hardly think they were loading more than 16 feet at that time.

Q. What year was that?

A. That was in 1900, I believe, or 1889. I will not be certain.

Q. After your Detroit measurements?

A. Yes, that was either 1899 or 1900.

Q. This difficulty arising from passing boats was a difficulty which was encountered in some of the earlier observations on the St. Clair?

A. I do not recall there was much said about it in the earlier reports. Latterly in some more recent ones, the matter has been treated.

Q. It was not encountered, was it, in the measurements that have been made by the Lake Survey in the Niagara and St. Marys?

A. No, it was not in the Niagara. It might have been in the St. Lawrence, though I do not know.

Q. I wish you would give us the particulars of the cross section which you selected for this work; the depth and other physical characteristics.

A. In my office I have the information that would enable me to give specifically what you are asking; but I can give you in general an idea what that cross section was.

Q. I will ask you to give it in general?

A. On the American Shore, there was for a distance of perhaps 500 feet more or less a shallow that I think at no point was more than 8 feet deep; running from that to practically nothing, and beyond that the channel deepened quite abruptly, and to a depth of in the neighborhood of 50 feet. Referring, for the purpose of refreshing my memory, to William's Exhibit 2 entitled "Chart 3 of the St. Marys River," the channel was about 1300 feet wide at this point, and the depth indicated on this chart is 53 feet, which coincides with my recollection of about the depth we had in the deepest portion of the section.

The total width of the river appears on the chart to be about 2400 feet.

Q. What was the speed of the current?

A. I don't recollect it at the present moment.

Q. Pretty slow water, was it?

A. No, that was moderately swift. I should say it was somewhere around three feet a second.

Q. Mean velocity?

A. I will not be sure. Of course the flow through the shallow portion was negative part of the time; it was flowing backward, so that that was treated separately.

Q. Was it exposed to wave action?

A. Not to any—at least at no time when I was there did the waves interfere. In the case of the wind in a certain direction, you might have, I would think, very considerable waves there, as there was quite a long—

Q. How much time were you there?

A. Oh, I was there probably a week.

Q. Out of how long?

A. Oh, they were working on the thing from about the beginning of August until cold weather, intermittently. I do not know that they were working continuously. A considerable part of the time was spent in preparation, getting things ready to work with, establishing ranges and all that sort of thing; and I rather think that they were not actually engaged in gaging operations, not more than a month, and in that time they probably were not on the river half the time.

Q. You were there that week during the month when they were making the observations?

A. No, I was there during the time they were making the preparations, laid out the scheme, and then did not go up again. I got weekly reports of the progress, and lack of it.

Q. Well, when there was an upstream wind, wasn't there difficulty in keeping the boat on the section line?

A. So far as the location of the boat on the section is concerned, that was controlled by ranges, and the boat was kept there within a comparatively narrow margin. As to the amount of difficulty they had doing it, I can't say, but the boat was manned with a number of oarsmen, in addition to the anchors.

It is quite possible that if the wind were blowing up-stream, it would have been more difficult to hold the boat in place.

Q. Did you use anchors?

A. We used two anchors ordinarily.

Q. To hold it when the wind was down-stream, as well as up-stream?

A. We used it wherever the anchors were needed.

Q. Now the result of your experience on the Detroit River has been such as to give you the opinion that these current meters ought not to be used when you wanted to get very accurate results out of them?

A. It gave me the opinion that we could do considerable better by the use of floats, wherever floats could be used. And we did make some runs on the St. Marys with floats, but on account of the extreme depth of the water, it was impossible to get a float that would measure the lower portion of the stream, so that the current meter was all you could use?

Q. So you reached the conclusion that that was the best method of making these measurements?

A. For that situation, yes.

Q. Where were your water gages located?

A. There was a gage located at Brush Point and across

the river at Foot's Dock, and the gage below at the head of the canal, maintained by the Government. The records were assumed to be available to us, so that we didn't attempt to put anything down below.

Q. You took the Government measurement as accurate?

A. We took the Government gage record at the Soo for anything we wanted below the section.

Q. And accepted that?

A. Oh, yes.

Mr. Adcock: Q. That was the gage record showing the elevation of the lake at the time?

A. The elevation of the water.

Mr. Wilkerson: Q. You superintended the work of combining these observations so as to reach a result, did you?

A. We never got far enough to reach a result.

Q. Did you attempt to reach a result?

A. No, because we never got clear across the river. All we did was the reduction of the individual verticals, the plotting of the observations.

Q. Why didn't you go across the river?

A. Well, it was partly on account of the difficulty of getting through the steamers, and partly for lack of satisfactory equipment for handling the apparatus. The difficulty of handling the thing from a row boat was very considerable, on account of the slowness with which you were able to move from place to place, and it was proposed to make use of a launch the following season. And the work was finally suspended with that understanding, so that we considered the work that we had done up to that time as of a preliminary nature, and indicating to us the difficulties we were likely to encounter.

Q. So the result of your work was that between August and November, you really failed to get any result as to the measurement of the river, was it?

A. That is correct; we did not make a complete gaging of the river except—let me see, the floats I think gave us information extending across the channel but I cannot be certain, because I have not looked at those results for several years. I do not remember now just to what extent they did go.

Q. You made no attempt to derive an increment?

A. Oh, no.

Q. Nor did you derive any equation of discharge?

A. No.

Mr. Adcock: Q. Was there any question of increment involved there?

A. No, there was no question of increment involved at the time. The question of lowering was not being considered at all. It was a question as to whether they had the right to take a certain amount of water.

Mr. Wilkerson: Q. You were measuring the quantity of water?

A. We started out to measure the quantity of water simply.

Q. Have you in mind a similar experience which the Deep Waterways Commission had on the St. Lawrence River?

A. I never was familiar with the work which the Deep Waterways Commission did on the St. Lawrence. It was my impression that they made no gagings there; whether they attempted it or not, I don't really know.

Q. I assume from what you have said, Mr. Williams, that your final conclusion was that the section which had been selected for this work was an impracticable one, wasn't it?

A. No, I should not say that. The passage of boats interfered very materially, and for satisfactory work there it would have been necessary to make the observations at times when boats were not passing. It would have had to have been done late in the fall, or times of fog.

Q. Or select a cross section some place else?

A. Well, you could not get a cross section in the St. Marys River, or it would be very difficult to get a cross section in the St. Marys River, where you would not have more or less trouble with passing boats.

Q. You could have obtained a better section than you had, couldn't you?

A. I rather doubt it. Of course at first sight, one would prefer the International Bridge.

Q. That is to say if you had a swifter velocity, a more compact section, you would expect better results?

A. Provided it was not too swift, provided there was not too much disturbance there.

Q. Von Schon measured a section above the bridge, didn't he?

A. Not that I know of.

Q. You are not familiar with that piece of work?

A. No.

Q. You said, not that you know of. Did you ever hear about it?

A. I have no recollection of it. This work, of course, was done by direction of Mr. Von Schon, as Chief Engineer of the Lake Superior Power Company.

Q. You do not know what he might have done on another occasion?

A. I do not know what he might have done on another occasion, but Mr. Von Schon had previously been in the service of the United States Engineer's Office, and whether he made any gagings at that time or not I could not say.

Q. You would not be surprised if it were a fact that he did pick out another section, and actually make final, definite measurements?

A. I would not be surprised if Mr. Von Schon made some further measurements. I think he did not, however, after this date.

Q. Do you know whether Mr. Von Schon ever made any hydraulic measurements for the United States Government?

A. I am not aware that he did. I am not particularly familiar with his experience while he was connected with the United States Engineer Office. I think Mr. Shenehon, who was a colleague of his in the office at the time, could give abundant information on that head.

Q. What I was trying to find out is: I understand it to be a fact, and I thought we could get it here, that after the time you embarked on this work, which was only partially completed, there was in fact another section which was measured, and the work was prosecuted through to a finality.

A. I think not. To the best of my knowledge and belief that is not the case.

Q. That is you mean by Von Schon?

A. Yes. The United States Engineers were measuring the discharge prior to this and afterwards, which measurements of course are of record. But I am speaking of the work done by the Lake Superior Power Company.

Q. You have spoken of the Detroit and the St. Marys Rivers. Are there any other rivers of that size, on which you have done any work?

A. Current meter work you mean?

Q. Yes.

A. Which I have personally done?

Q. With which you have had anything to do in the way of supervising the work, or being responsible for the results of the work?

A. No, I think not.

Q. So that as preparation for, and as a basis for your criticism of these engineers who have done successful work, you have never done any successful work yourself, have you, Mr. Williams?

Mr. Austrian: I object to the form of the question.

Mr. Wilkerson: That is a fair question.

Mr. Austrian: No, "These engineers who have done successful work" that is a matter of opinion.

Mr. Wilkerson: If the witness has done any work in which he has ever successfully measured a stream such as the ones under consideration in this case, I would like to have him state it.

Mr. Austrian: There is no objection to that question.

Mr. Wilkerson: All right.

The Witness: What is the question?

Q. (Question read.)

A. I have not, and I doubt if anybody else has.

Q. Your doubt is based upon your experience, isn't it?

Mr. Austrian: His doubt is based upon his conclusions.

A. No, my doubt is based upon the records of such observations by other people, as well as my own experience.

Whereupon a recess was taken to 3 o'clock p. m.

After Recess 3 p. m.

GARDNER S. WILLIAMS resumed the stand for further cross-examination by Mr. Wilkerson and testified as follows:

Last question and answer read as follows:

"Q. Your doubt is based upon your experience, isn't it? A. No, my doubt is based upon the records of such observations by other people, as well as my own experience."

Mr. Adcock: Q. Does that complete your answer to the question put?

A. Yes. I am entirely willing to strike out the last part of that answer if you want to. I think it is not responsive.

Mr. Wilkerson: Q. I think you said in your direct examination, Mr. Williams, that you had measured some small streams?

A. Yes.

Q. Which ones?

A. I measured the Huron River, that is to say I supervised the measurement of it. I never actively—

Q. What river is that?

A. Huron River, Michigan; the Tittabawassee River, and a number of other small streams that I have measured.

Q. Let's have some of them.

A. Fall Creek, or better say Six Mile Creek, Ithaca, New York, Taughannock Creek, near Ithaca. I can't think of the name that the stream went by in the northern part of the state, near Traverse City, a small stream; the Black River in Michigan; the Chippawa, Cedar, Pine. That is all I think of at the present moment.

Q. Please take them up in order and state as nearly as you can the volume of flow of each one of them, and mean flow.

A. The Huron River mean flow is about 400 cubic feet per second. The Six Mile Creek mean flow, I have forgotten what the mean flow of that stream is at the present moment. The minimum of the creek about 25 cubic feet per second, the maximum running it up to about 10,000 for a maximum.

Q. What were the measurements?

A. 10,000 on one measurement, and others in between. I think I measured it down as low as about 15 cubic feet a second, as I remember now.

Q. What river was that?

A. That is Six Mile Creek, near Ithaca, New York. I am not speaking of current meter measurement wholly. I do not want to be misunderstood as to that.

Q. I understood you did not use a current meter on an of these?

A. Oh, yes, I have used the current meter a good deal.

Q. Let us have the volume first; then we will get the detail of the measurements?

A. I can't recall those figures, Mr. Wilkerson. I will be very glad to supply them to the Commissioner and introduce them in the testimony.

I will say now I do not think there is a stream involved, whose average flow is over 2,000 feet a second. My memory is 1500 for the largest, but I will give you the actual average discharges.

Q. That is all right, unless you think you are able now to state them approximately.

A. I am not because I do not try to remember those things. I have a memorandum, but the only one I remember is Huron.

Q. You think no one has more than 2,000?

A. As an average discharge, there is nothing more than 2,000 cubic feet per second.

Q. Do you remember at this time the particulars of the work which was done with reference to the Huron River?

A. Oh, yes, the discharge of the Huron River has been measured various ways, by current meters, by floats, by the measuring of the head over dams, or measuring the water that went through wheels; that is using the water wheel. As a matter of fact it has been gaged all those ways, and finally for a very low flow we went so far as to gage the water that flowed over a dam, in barrels.

Q. In any one of the pieces of work you did on the Huron, did you use the current meter?

A. Oh, yes.

Q. How many times?

A. Several times. I don't remember exactly but we always had one around the office; used it more or less.

Q. What was the thing you were endeavoring to determine, the quantity of water?

A. The quantity of water passing.

Q. On which one of the other rivers that you have named did you use the current meter?

A. We used the current meter on the Black; used the current meter on the Tittabawassee, on the Chippewa. I don't know, we used it every little while as far as that goes, used it frequently.

Q. In your experience then in the measuring of these various streams and rivers, you have made use of the current meter as an instrument by which you thought you could arrive at a conclusion with reference to the volume of water flowing through the river?

A. Yes, and expect to continue to do so.

Q. And made reports with reference to each one of them, in which you gave your conclusions based upon observations taken with the current meter.

A. I frequently make reports in which I make use of current meter measurements as a basis of approximating the flow in the stream, yes. I won't say I have done it in all these cases, but I have in several of them.

Q. In your professional experience, you assume as one of the elements which has entered into the result which you have stated, that the current meter is a proper instrument to be used for that purpose?

A. Certainly.

Q. And that is not only your own experience, but it is that of engineers generally, is it not?

A. It is generally accepted as a proper instrument, and in many cases as the only instrument that can be used; under certain circumstances it is the only one that can be used.

Q. And in the great majority of cases, it is the best way, isn't it?

A. It is not the best way—

Q. The best practical way?

A. No, I would not say that. What I would say is this: That there are a large number of cases, and probably at least 75 per cent. of the cases, where you are called upon to measure the flow of water, where the current meter is the best means that can be applied. Where the channel is of such a nature as to permit of the use of floats, a more accurate measurement can I think be obtained, and oftentimes better results can be obtained by the combination of the two than could be obtained by either one alone.

Q. The use of the floats is subject to very considerable mathematical uncertainties, is it not?

A. Not so much as the use of the current meter. The float passing in a vertical plane down through the stream, you are quite assured that you have the mean velocity of the water from the surface to the bottom of that float represented by the velocity of that float. Now, the current meter to get that same information has to occupy sundry positions in the depth that is covered, so that the float is integrating the velocity through the area over which it travels.

Q. Can you use the float in measuring—

Mr. Austrian: Let him explain fully, in detail.

A. (Last answer read.) And when a number of floats are run down through a stream at various points in the cross section, each one of these floats covers points covered by the current meter in a vertical only it covers it more completely, as far as the length of the float goes. The difficulty with, or the limitation of the float lies in the fact that if the bottom be rough, the float has to be a considerable distance above the bottom to prevent its being stopped by the obstructions; and you also have to take into consideration a possible change in area of your cross section through the course that your float travels over, so that it means that you must have a channel of practically uniform section for a reasonable distance; that is one over which you can time the passage of the float, and without introducing large error in the time element.

The other limitation is that it is not ordinarily practicable to use floats in very deep water, for the reason you can't handle a float that must be weighted sufficiently to stand erect and have buoyancy enough to carry it down a large stream. I think that about 30 feet is about the limit of depth that any one has handled floats in, so far as I know; I mean vertical rod floats.

I have no particular confidence in the so-called double float. That is only a shade better than the surface float to my mind.

Mr. Adcock: Q. What is the double float?

A. The double float consists ordinarily of two balls, one of which drifts on the surface, and the other is connected to it by a chain or wire or string. and floats at some distance below the surface; and it is supposed in that way they would get some sort of a measure of the velocities below the surface.

The objection to that method is that there is no certainty as to where the lower ball is; it may be vertical under the upper one, or lagging behind or moving ahead; the cord may be inclined or curved; and it is practically impossible to tell what the lower one is doing.

Q. How is the float you have mentioned here constructed and used?

A. We ordinarily take a pole of dry wood and load it at the bottom. One way of doing it in the field is to load it with sheet lead, load sheet lead upon the bottom by wrapping it around the bottom until the float will stand erect in the water, with a small amount of the top exposed. Then this float is released in the current in a vertical position and floats with the current over a measured course, the time of travel being taken, and of course that measures the velocity through the range that it travels; and by putting in a series of floats across the river you get the same thing you attempt to get with your current meter by taking a series of verticals.

Mr. Wilkerson: Q. Does the water flow with the same velocity at the surface as it does down near the bottom?

A. No, it does not.

Q. What determines the rapidity with which the float moves down?

A. The average volicity of the water.

Q. Do you have to apply a mathematical correction to determine what the mean velocity is?

A. Not for the portion of the channel that is covered by the float itself. When you come to extend the discharge to the bottom of the stream, then in the lower portion of the stream

you must make a—some sort of a correction. You must either do as you do with the current meter, sketch in the curve at the bottom, just as all these observations have been done, or you must adopt some mathematical method of computing it.

There has been devised a formula for application in that case, which I have tested in reasonably smooth channels and have found to give very accurate results, considerably better than we were able to get with the current meter. But when you come to apply it in a stream with a rough bottom, why it—

Q. Or a deep stream?

A. Or a deep stream, where you can't reach to the bottom, that lower portion of the curve must be investigated in some way.

Q. 30 feet is the limit?

A. I think 30 feet is as deep as any one has operated. And I would not like to be positive that that depth has been handled.

It is perhaps interesting in that connection to note that when the Haskell Current Meter was first put upon the market, its accuracy was established by a comparison with floats; and it was shown that they agreed, that the meter agreed with the floats within a small percentage. That statement was published in the catalog of the Ritchie Company, and in fact I think I saw it not long ago in print.

Q. By what process of reasoning do you reach the conclusion embodied in the statement which you make that the float travels at the mean velocity of the stream?

A. Because the observations which have been made on that head show that to be the case. That subject is investigated quite at length in the Lowell Hydraulic experiments by Mr. James B. Francis, published about 1855 I think. I think you will find it discussed in the first volume, I mean the first edition; and while it is theoretically possible to prove that the float will slide down hill, will slide down the water plane a little faster than the water moves, even that correction is one in fractions of a per cent., and experimental observations indicate that the float is measuring the water through which it passes with a more satisfactory degree of precision than I have been able to get out of any current meter work that I have known of.

Q. Is it not a fact that Mr. Francis has reached the conclusion that the current meter travels at a mean velocity, by a mathematical deduction?

A. He reached the conclusion that the float would theoretically travel faster than the water, by a mathematical deduction.

Q. Then he devised the formula by which it was to be corrected?

A. No, he did not. His formula was based upon his experiments. He measured the quantity of water flowing in channels with floats, and compared it with the measurement of water flowing over a weir, and by using floats of different lengths he was able to determine an expression for the correction to be applied to cover that portion of the stream which the float does not actually traverse, if you choose to make that computation mathematical. If you do as in the current meter measurements simply plot your curve and draw your curve in, you do not need any mathematical computation. Then it becomes a matter of experience to draw that somewhere near where it ought to be.

Q. Do you know how many days Mr. Francis covered in his observations, which were used as the basis for this conclusion which you have just stated?

A. I do not. A portion of his work is published in the Lowell Hydraulic Experiments. Whether it is all there, I am unable to say. But independent of Mr. Francis, I caused a series of investigations to be made at Cornell upon the same subject, and in that we spent—oh, we were working on it parts of two years. We worked almost continuously on it for pretty nearly a month, and from those results we found that our float gagings ordinarily checked the weirs within about 1½ per cent., 1½ to 2. At the same time, the current meters were checking within from 3 to 4, ordinarily.

Q. These observations as to which you have just testified were made in this 16 foot channel which you mentioned this morning, weren't they?

A. Those at Cornell, yes.

Q. And at Lowell they were measured in a canal?

A. They were measured in a canal there, the width of which I do not remember positively. I have in mind that it was somewhere in the neighborhood of 50 feet in width, but I am speaking solely—

Q. Do you know the range of velocities which was covered by the floats in either one of the two sets of measurements about which you have testified? Have you got the figures in mind at the present time?

A. I haven't the figures in mind at the present time. At Cornell, let me see—I do not want to say; I thought I could

tell but I can't. My guess at the present moment would be that we did not go over 5 feet.

Mr. Adcock: That is 5 feet a second?

A. Five feet a second.

Mr. Wilkerson: At Lowell, was it any more than that?

A. I think not.

Q. Was it much less than that?

A. My recollection now of the Lowell experiments is they were around 2 feet. Is that your recollection, Mr. Shenehon?

Mr. Shenehon: That is my recollection.

The Witness: That is as I recall it. That is a matter that can be looked up.

Mr. Wilkerson: You and Mr. Shenehon are agreed?

The Witness: If Mr. Shenehon has looked them up within a few days, I will take his word.

Mr. Shenehon: No, I have not.

Mr. Wilkerson: Let me ask you this question: Is it not a fact that the data which are at hand relating to the measurement of streams by floats are comparatively meager and are in small streams compared with the ones on which the data in this case were taken?

A. Well, floats were used quite extensively on the Mississippi River of, I think all types. In general however the float measurement is not used for the reason that it requires a large party to operate; that is you cannot handle float measurements in a stream of any size without a party of three or four times the men that are necessary for current meter measurement.

Q. So that comparatively speaking, the data available with reference to the use of floats would properly be said to be meager?

A. Well, it depends a little bit on just what you mean by meager. The floats have been compared with the number of gagings made by current meters, I think within the past 20 years have been at least 1 to 10; that is, there have been at least ten meter gagings to one float gaging.

Q. So that it is fair to say that the current meter is the generally accepted instrument to use?

A. Oh, no question about that; it is the instrument ordinarily used for this purpose.

Q. It has been your experience that the results have been correct within 3 or 4 per cent.?

A. No, I would not say that.

Q. I understood you to say that?

A. No; where under exceptional conditions we were check-

ing them against the weir, at Cornell, we were able to get within sometimes as close as 2 per cent. of the weir, but the conditions there were extremely favorable. There was no question as to the character of the section, as to the area. The bottom and sides were smooth, so that it was possible to get the current meted down very close to the bottom, closer than is possible in ordinary streams; and the velocities were screened and smoothed out, so as to give quite regular flow, so that the conditions there it seems to me would be more favorable than ordinary field measurements.

Q. Is that the only place where you had an opportunity to check absolutely the accuracy of current meter measurements, where you had the opportunity of measuring the quantity of water passing over the weir?

A. No, we had a case recently for the Sanitary District, in connection with the test of some pumps at Wilmette, where the water delivered to the pumps was measured by current meters, and the water after passing the pumps was measured over a weir. We had an opportunity to check there.

Mr. Adcock: Did I understand you to say the Ritchie Company, the manufacturer of these current meters that have been used by the United States Lake Survey, in their catalog representing the value of their meter, and so forth, the accuracy of the meter, state that they approach or are designed to approach the accuracy of floats?

A. They show a comparison in there of discharge measurements, by float and meter, and show how closely the meter checks the measurements by floats.

Q. Do I understand that they consider the float as the most accurate measurement?

A. Apparently, as the generally accepted method at that time. Bear in mind that was—

Mr. Wilkerson: This was a statement in a catalog 20 years ago, is that it?

A. No, this was a statement that applied to the time the Ritchie-Haskell Meter was invented. When was that, 1880 or 1890?

Q. At least 20 years ago.

A. As I say, it is 20 years ago.

Q. It was a statement in a catalog 20 years ago?

A. No, I saw that statement, I received that catalog considerably less than 20 years ago. But the point I am getting at is this—

Q. Some old statement, like most catalogs, they continue from year to year?

A. No, let me explain: At the time the Haskell meter came into use, the float was recognized as a standard method.

Q. That was the only method before they invented the meter?

A. That was really the—that was the only method of reasonable accuracy that was available for field measurements on a large scale, up to the time the current meters were introduced, and naturally the comparison was made with them.

Now, my purpose in referring to them was simply to call attention to the fact that at the time the current meter was introduced, the float was recognized as a standard method. Now it has been superseded by the current meter on account of the greater ease with which the observations can be made, not on account of greater accuracy, except in cases where it would be, you might say, practically impossible to measure with a float, on account of the depth or irregularity of currents.

Q. In these Sanitary District measurements which you have testified about as being made at Wilmette, what was the velocity of the water which was being measured?

A. I think the average velocity was about 4 feet a second.

Q. What was the volume?

A. It was around 280 cubic feet a second.

Q. Just one more question about this catalog statement to which Mr. Adcock has made reference: I will ask you whether you remember whether the float which was used as a check against the accuracy of the current meter measurement was a surface float or a sub-surface float?

A. Rod float.

Q. How deep?

A. I don't recall now.

Mr. Adcock: When you speak of the rod float, it is the float that you described a little while ago?

A. As a rod floating vertically in the water.

Mr. Wilkerson: But not reaching close to the bottom?

A. At Cornell University, we used floats with an immersion of 98 per cent. That is to say, we got within 2 per cent. of the bottom of the channel.

Q. You had a smooth bottom?

A. Yes, we had. That is why I say our deductions there established the fact that the float moves with the mean velocity of the water through which it travels, because we covered something over 90 per cent. of the cross-section of the channel with the float; that is taking both the variation from the sides and the bottom.

Q. There are not many cross-sections you can get that way, in measuring actual streams?

A. That is what I say.

Q. That is why we use the current meter instead of the float usually?

A. That is one reason why.

Q. As a matter of fact, Mr. Williams, there is no use in talking about using a float to measure the rivers that we have been discussing in this case, whatever may be said about small canals or small creeks or little rivers? You cannot use a float to get the measurements to refer anything to, in the kind of rivers we are discussing in this case, can you?

A. I think they would have gotten more accurate results if they used floats to cover as much as they could, and leave the current meter to take care of the bottom, where they could not reach it.

Q. But they did not?

A. They did not. You asked whether they could.

Q. As a matter of fact it has never been done successfully?

Mr. Austrian: Where?

Mr. Wilkerson: In large rivers; the size of the rivers connecting the Great Lakes.

A. There has been a good deal of that work done on the Mississippi River. How successful they regard it is more or less a question. It all comes to a question of relative precision.

Q. What is your opinion as an engineer as to the degree of precision with which the flow in the Mississippi was measured by floats?

A. I am not in a position to express an opinion in regard to the rod float work that has been done on the Mississippi River, as I have never studied the details of it. As I said a short time ago, so far as the double float work is concerned, I consider it practically worthless. But that is another proposition. The float measurements usually criticised on the Mississippi River are those double-float measurements.

Q. You know nothing about the rod floats?

A. I have never examined any records of the rod float gagings, and am not ready to speak of it.

Q. Do you know how engineers generally regard it?

A. Those with whom I had discussed the matter, who had experience with both the current meter and the rod float expressed a preference for the rod float wherever they could use it.

Q. Who did express that?

A. I think at this moment of George Y. Wisner.

Q. Anybody else?

A. I think that is the only one I happened to discuss the subject with.

Q. In connection with what river?

A. We were speaking generally, wherever you could use the float. The float was to be preferred to the current meter but there are a good many places where you could not use it at all, and there were other places extremely inconvenient or expensive.

Q. When was that opinion expressed?

A. That was expressed about 1899 or 1900. It was during the work at Cornell when we were experimenting with floats for the Board of Engineers on Deep Waterways.

Q. He had a good deal to do, didn't he, with the measurements made in connection with the compensating works on Lake Erie?

A. He was a member of the Board of Engineers, the Deep Waterways Commission.

Q. They did not use any rod floats there?

A. No, because it was not a suitable place to use them, for one reason.

Q. He used the current meter?

A. Yes.

Q. And he treated the current meter measurement as entitled to scientific credit, didn't he?

A. He always was very critical—

Q. I am speaking about his published reports?

A. All right, then his published reports speak for themselves. If you are asking me what Mr. Wisner thought about it, that is another matter.

Q. We haven't any way of knowing what he thought except through the reports.

Mr. Austrian: He may have expressed himself.

Mr. Wilkerson: We have his expression in the published reports.

Mr. Austrian: That may not have been his entire expression.

Mr. Adcock: Did he ever express himself to you in regard to the matter?

A. I do not know whether there is to be anything gained by going into that. I will say this in answer to Mr. Wilkerson's question, that Mr. Wisner—that the Board of Engineers on Deep Waterways made use of the current meter at Niagara as the most available means of measuring the flow of Niagara,

and they used it—and being the only information, and the best information, they based their conclusions upon it. I know however that Mr. Wisner, up to the time even of his death, was always skeptical of those Niagara measurements. I talked with him about that only a short time before he died.

Mr. Wilkerson: You do not recall any published documents, in which he said he lacked faith in them?

A. I think not. In the report of the commission, of course nothing of that kind would have been in good form, or permitted, perhaps, by the other members of the commission.

Q. He undoubtedly would have given expression to his real professional opinion in any report which he made?

A. I do not think that that thing got to the point of a professional opinion. I say he was suspicious of those records but they were the best that he had and he used them.

Q. In what years were those measurements made?

A. I say I discussed that matter with him a very short time before he died.

Q. In what year?

A. He died in 1905, 1905 or '06 somewhere around there.

Q. You say you made some measurements on the St. Lawrence River?

Mr. Adcock: Were you going to go into that question? You asked him about the measurements for the Sanitary District of Chicago. As you have referred to it, I think it only fair that he explain his connection with that matter and the results of the measurements.

Mr. Wilkerson: I think he covered that.

Mr. Adcock: No.

Mr. Wilkerson: If there is anything further that is proper, I am entirely willing to have him state it.

Mr. Adcock: And the results of his experiments there, in connection with it, because as it stands now it is merely referred to. You may draw deductions and so forth that may or may not be proper.

Mr. Wilkerson: Is there anything about that, Mr. Williams —I think you answered my question.

A. I did, I answered the questions you asked me. I think all you asked me was if I had compared current meters with weirs anywhere else than at Cornell. I mentioned that case; gave the volume.

Q. I asked you about the size, the volume of water that was measured and the velocity, and we had some such discussion here.

A. Yes.

Q. The effect of which was that was hardly a proper kind of stream with which to make an appropriate comparison?

A. (No response.)

Q. Now about the measurements which you made on the St. Lawrence River, when were they made?

A. The measurements on the St. Lawrence were made in, I think, about 1909 or 1910. I will give you the dates if you allow me to go upstairs.

Q. We can have them approximately; I do not care for the exact dates.

A. I will say about 1910. I will not be certain as to the year without looking it up. Time has been passing pretty rapidly since I got into this case.

Q. For what purposes were they made?

A. They were made to determine the flow of the St. Lawrence River, in connection with the proposed power development in the Couteau and Cedar Rapids.

Q. Did you measure the full flow of the river?

A. Yes. Don't misunderstand me; you say "Did I"? I didn't do the measurement myself. I advised in regard to the measurement, and recommended the parties who were engaged to do the work. The results were submitted to me and examined by me and criticised and were made use of in connection with some further work in connection with the power development; but I was not present during the gaging.

Q. Who was selected to make the measurements?

A. Mr. Murray Blanchard.

Q. Who is he?

A. He had charge of the gagings on the St. Clair, during 1902, wasn't it, Mr. Shenehon?

Mr. Shenehon: He was under Sabin.

The Witness: He had charge of them the last year according to Mr. Haskell's testimony. I am quite sure the last year's work that was done under Mr. Haskell, prior to 1908, was done by Blanchard as Chief of the party. And he then came down and had charge of the Detroit measurements. Let me settle that, because I do not want anything wrong in here. I am speaking from recollection of Mr. Haskell's testimony. (Referring to same.)

On page 51 of the continuously paged record, the question is asked: "Who was in charge of the work there?" the reference being to the St. Clair. "A. Mr. L. C. Sabin for the first two seasons, and Mr. Murray Blanchard for the third season. Q. Were they competent men for that work? A. They were."

Mr. Wilkerson: Was he hired on your recommendation?

A. He was.

Q. What method was used in measuring the flow of the river?

A. The ordinary methods of the United States Lake Survey.

Q. Used with your approval?

A. They were.

Q. Were water gages used?

A. Yes.

Q. How were the readings taken?

A. By observers at regular intervals during the observations. They did not use recording gages if I remember rightly.

Q. Were current meters used?

A. Current meters were used.

Q. What kind?

A. Haskell, and a Price.

Q. How were they rated?

A. Rated in still water by dragging in the usual manner, the procedure being similar in every respect to that adopted by the United States Lake Survey, which was then and is now regarded as the best practice in current meter work.

Q. Was there a law of discharge established as the result of those measurements?

A. There was not. The purpose of the measurements was to determine what correction should be applied to the gagings of the Lake Survey to make them applicable to the St. Lawrence in the location where the work was done, that being a considerable distance further down the river; and it was desirable to know how much greater or less the flow of the river at that point was than was indicated by the gagings at Waddington by the United States Lake Survey.

Q. For that purpose, you accepted the report of the Lake Survey at that point as accurate?

A. We accepted it as relatively accurate, yes.

Q. Did you make any report which was based upon the work of the Lake Survey as supplemented by your own work?

A. No, there was no written report made. We appeared in court, or rather appeared at a hearing before the Prime Minister and his Cabinet.

Q. And gave testimony?

A. And gave some testimony in regard to it. That is, we did not as a matter of fact give the testimony; we appeared but the testimony was given by others, and Mr. Noble and myself, who were interested in the matter, were not called upon to participate.

Q. You and Mr. Noble were on the same side of the case, were you?

A. We were.

Q. At that time you both agreed as to the manner in which the observations on the St. Lawrence were to be viewed?

A. That particular question did not come up at all. They were the best information we had as to the discharge of the St. Lawrence.

Q. You did not suggest there any necessity of recomputing the work of the Lake Survey by any methods of weighting the measurements, did you?

A. No, the matter of 10,000 cubic a second more or less was not of any particular consequence in that case.

Q. Well, did you suggest the necessity of rejecting any observations?

A. We did not discuss those observations at all.

Q. You just simply took the work of the Lake Survey as accurate for the purpose for which it was to be used?

A. We did.

Q. That was in a lawsuit—

A. Except to this extent: That we investigated to see what the difference was at our section over what was indicated at theirs.

Q. But in the work of the Lake Survey at that point, the gage elevation was used for the time of measurement and not for 24 hours prior, or a period of several days prior?

A. The question of gage elevation did not enter. We simply took the results as the United States Lake Survey had published them, and accepted them as being sufficient for our purposes. As I say, the matter of 10,000 cubic feet per second was of small consequence there.

Q. That is to say for the purpose of that case, it would not have made any difference whether the flow was determined accurately within 10,000 cubic feet?

A. It would not, no.

Q. Within what degree of accuracy were you interested in the result?

A. Well, we were contemplating on leaving somewhere between 40,000 and 60,000 cubic feet for the uses of navigation, as I remember it; 20,000 was sufficient for all they really would need, and we were going to leave them a large surplus, so that the question whether it was 10,000 feet more or less in that particular case had very little bearing. That is all there is to it. We made these measurements of our own to be sure, or to be able to say that we had measured it, or that the river had

been measured at this locality and that it was so and so, and we compared those measurements with the measurements by the United States Engineers. The gagings on the St. Lawrence referred to were made in 1909.

Q. I referred this morning, Mr. Williams, to some of these engineers who had done work and had reached conclusions on this subject involved in this case, in connection with their position on the International Waterways Commission and the Deep Waterways Commission and the Lake Survey. I direct your attention particularly to Mr. C. B. Stewart. What do you know about his work?

A. Mr. Stewart was in charge of or connected with the gagings on the Niagara for the Board of Engineers on Deep Waterways.

Q. Do you know anything about his hydraulic investigations at Wisconsin University?

A. Mr. Stewart has been engaged on hydraulic investigations at Wisconsin for some years back. I have received bulletins concerning the investigations from time to time.

Q. What is his standing as an engineer?

A. I am hardly qualified to say, as I have not followed his work closely and I do not know that I have ever discussed his work with anybody. I should regard Mr. Stewart as a very capable investigator.

Q. What do you know about the work of Mr. E. E. Haskell?

A. Mr. Haskell is recognized as an authority on current meter work; particularly on river hydraulics; had a long experience with the Government in the United States Lake Survey; and also has been engaged on hydraulic work for the Government in various capacities, on the Mississippi River Commission and with the Coast and Geodetic Survey; and was connected with the measurements of the Gulf Stream a number of years ago. And then he was Principal Assistant Engineer in charge of the Lake Survey; now Dean and Director of the College of Civil Engineering at Cornell, and a member of the International Waterways Commission.

Q. Is he in charge of the Hydraulic Laboratory at Cornell?

A. The Hydraulic Laboratory at Cornell University is attached to the College of Civil Engineering, and as Director, he of course has control of the laboratory. I think Professor E. W. Schoder is recognized as the engineer in charge, being of course under Mr. Haskell, so far as the supervision of the head of the department is concerned?

Q. What chair does he hold there, what is his title?

A. Who, Mr. Haskell?

Q. Yes?

A. I think he is Professor of Hydraulic Engineering. I do not remember what else.

Mr. Shenehon: Experimental hydraulics.

The Witness: I do not recall ever having noticed what the title actually was.

Mr. Wilkerson: He has had a very extensive experience, has he not, in water measurements?

A. He has done a great deal of it.

Q. He has had to do with water measurements on a large scale?

A. Yes, he is one of the leading authorities on the subject. There is nothing that I can say that would be too high commendation of Mr. Haskell's attainments.

Q. And in your opinion as an engineer, any conclusion which he might reach as to a fact concerning water measurements is entitled to great weight?

A. It would be. I should hesitate very much to question a conclusion at which he arrived until I had made a very thorough investigation of the facts on which it was based.

Q. Even then, would the fact that Mr. Haskell had reached one conclusion and you reached another, cause you to pause?

A. It would, until I had checked my work and satisfied myself that my conclusions were correct.

Q. Of course, as a matter of fact, Mr. Haskell in the measurement of large streams has had actually more variety of experiences and a more extended experience than you have had, has he not?

A. Yes, sir, that is entirely correct.

Q. And also in handling the observations which have been made, and in drawing conclusions from them, he has had a long record of work in that line, has he not?

A. He has a long record of work in that line, yes, sir.

Q. He is regarded as accurate, painstaking and very thorough, isn't he?

A. Very.

Q. Mr. Williams, you are also familiar with the work of Mr. Sabin, are you not?

A. I am. Mr. Sabin and I were college mates. We began our professional lives together, roomed together on our first job, and have had a very intimate acquaintance ever since.

Q. He has had long experience in connection with measurements of this kind?

A. I think he was the pioneer in those measurements of the later date.

Q. He had to do with the measurements on the St. Clair River?

A. He made the original measurements on the St. Clair River.

Q. He was Secretary of the International Waterways Commission?

A. Yes, sir.

Q. He built the Soo Lock?

A. He is building it.

Q. Building it?

A. The new lock.

Q. He has had as wide, if not a wider experience, in measuring water in the large streams than Mr. Haskell, has he not?

A. Well, that is more or less of an open question.

Q. Well, they are pretty well up?

A. Let me explain: The work of Mr. Sabin was all done under the direction of Mr. Haskell. Mr. Haskell before that time went through the elementary steps of stream gaging and got to the point where he no longer went out and listened to the tick of the meter, or read the register; and Mr. Sabin had immediate charge of the St. Clair measurements, and in my judgment he did a very excellent piece of work.

Considering that he had no previous experience; that there had not been two or three years of stream gaging going on in the development before he took hold of it, he I think handled that work and got results which are highly creditable to him. Mr. Sabin had had some experience in hydraulic work on the St. Mary's River, but the conditions there were quite different from those that were encountered on the St. Clair.

Q. Have you before you the report of the International Waterways Commission for the year 1910?

A. Yes, sir.

Q. I wish you would turn to page 10 of that report, paragraph 7. I call your attention to the following statement: "Actual values assigned to rainfall and evaporation are not well determined and cannot be used. It is of relative value and it has elements which it is necessary to know, and that value is found in the discharge measurements." In your opinion as an engineer is that opinion true or untrue?

A. So far as the statement that they cannot be used is

concerned, it is incorrect. So far as the statement that they are not well determined is concerned, it is in a measure correct, depending upon what you consider as the limitation of "well determined." Concerning the statement that the value is found in the discharge measurements, I would raise the question that it would be found there if the discharge measurements were accurate. If they are not accurate, then it is not found there.

Q. And the relative value of the elements which it is necessary to know would be in proportion to the percentage of accuracy of the observations, is that your opinion?

Mr. Austrian: Necessary to know for what purpose?

Mr. Wilkerson: To determine the water levels.

A. My answer is no.

Q. Well, would it have any relation to the degree of accuracy of the observations?

A. Not necessarily. There might for example be some condition that it was absolutely necessary to have, and still you might know nothing about it; and I think there are some such conditions involved in the problem that we are dealing with.

Q. That opinion is the opinion of Mr. Haskell, is it not?

A. I don't know whether it is or not.

Q. His name is signed to this report?

A. I see Mr. Clinton's name signed to that report also. Mr. Clinton is a distinguished attorney, whose principal practice has been in maritime law.

Q. And you think that Mr. Haskell's name to that report is entitled to no more weight upon an engineering proposition than the opinion of Mr. Clinton?

A. I think that it may be questioned whether Mr. Haskell would state that proposition in exactly those words; and if he does not state it in exactly those words, it does not mean exactly what it does here. The general interpretation that would be put upon that by a casual reading would undoubtedly be subscribed to by Mr. Haskell, and as a matter of casual reading I would subscribe to it myself. But where we come to specifically consider the meaning of the words involved, I do not agree with it—I would not say what anybody else would do.

Q. I direct your attention to page 84 of that report of the International Waterways Commission and ask you whether you observe the name there, "E. E. Haskell, member American Section?"

A. I do.

Q. That is signed to a document which is entitled "Appendix," which commences on page 23 of the volume in which that report appears?

A. Yes, sir.

Q. Now I direct your attention to page 76 of the Appendix, signed by Mr. Haskell. You have no doubt, have you, that Mr. Haskell intended to certify as an engineer that in his opinion the diversion of 10,000 cubic feet of water would result in a lowering of the level of Lake Erie of 5⅛ inches, have you?

A. Mr. Haskell, testifying in this case, at a date not far different from that at which this report was signed, and saying under oath that the lowering of Lake Erie in inches by the diversion of 4,000 cubic feet per second at Chicago would be two inches, which statement appears on page 56 of the continuously paged record, and saying later in his testimony that the same proportion would apply—or saying in answer to a subsequent question that the same proportion would apply on 5,000, 6,000 or 10,000, and a diversion of 10,000 cubic feet per second on this basis representing 5 inches, I am somewhat in doubt as to whether he meant to say that a diversion of 10,000 cubic feet would represent 5⅛ inches when he signed this report.

Q. From both the report and the testimony, you have no doubt he would fix that figure at five inches, have you?

A. In his testimony he did fix it at five inches, and I assume that he did it knowingly.

Mr. Austrian: On the same basis, in the report he fixed it at 5⅛ inches, and you must assume that he did it knowingly?

A. Allow me to say in justice to Mr. Haskell, that Mr. Haskell's testimony was taken on February 17, 1909, and this report is dated December 4, 1909, so that he may have changed his mind in the interim.

Mr. Wilkerson: To the extent of ⅛ of an inch?

A. Yes.

Q. Isn't it pretty clear to you Mr. Williams that his statement in his testimony about the two inches is a good deal like some of your statements, an approximate statement of the effect in round figures, as nearly as possible?

A. I think that Mr. Haskell would be very careful about making any other statements.

Q. You have spoken about Mr. Haskell and Mr. Sabin and their work in connection with these measurements. What do

you know about the work of Mr. Shenehon? You are familiar with his experience, are you not?

A. I am to a considerable extent.

Q. I want to know whether you are familiar with the extent of the work he has done in this case?

A. I think I am. Mr. Shenehon was connected with the United States Lake Survey and the United States Engineer Office for many years; was intrusted with responsible charge of important work at various times, particularly with the Niagara and St. Lawrence gagings. On the resignation of Mr. Haskell from the Lake Survey to accept the position of Director and Dean of the College of Civil Engineering, Cornell University, Mr. Shenehon then became his successor as Principal Assistant in the United States Lake Survey; and I have frequently expressed my regret that circumstances were not such as would have made it desirable for Mr. Shenehon to remain in the service of the Lake Survey Office.

He was called to a position at his alma mater as Dean of the Department of Engineering, or College of Engineering, for which position I had the pleasure of giving my most cordial endorsement as to his qualifications.

Q. He had to do with work on the St. Lawrence River?

A. He had been engaged on the St. Lawrence River. I am not familiar with the detail of his work there, though from his superiors I had heard very commendatory reports of his performance of such duties as had been left to his execution.

Q. And in connection with the investigation relating to the preservation of Niagara Falls, what do you know about that?

A. That was one of his pieces of work in connection with the Lake Survey.

Q. And the measurements of the Niagara River?

A. And the measurements of the Niagara River, than which, I say again, there is not on record a more carefully conducted series of investigations in natural science.

Adjourned to Saturday, July 19th, 9:45 a. m.

Saturday, July 19, 1913, 9:45 a. m.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Mr. Wilkerson: On yesterday, I directed your attention to a statement appearing on page 10 of the report of the International Waterways Commission for the year 1910, relating to the values to be assigned to rainfall and evaporation. And I called your attention to the fact that that report was signed by Mr. E. E. Haskell. In the answer which you made to the question that I put to you on yesterday, did you have in mind the following testimony given by Mr. Haskell in this case on the 16th of February, 1909, on page 67 of the deposition as filed in this case? I read: "I want to ask your opinion regarding the propriety of using any existing data in regard to evaporation, in the attempt to detect the presence or absence of the effect already produced on the lakes, by the diversion made at Chicago since 1909."

A. Are you sure about that paging. I have the reference all right, but according to my notes that is page 53. Is the paging the paging of the continuous record?

Mr. Adcock: You better follow that.

The Witness: I have referred everything here to the continuous paging.

Mr. Wilkerson: I will state parenthetically the portion of the testimony now referred to appears on page 67 of the deposition as filed in the case, and on page 53 of the record as it has been made up and paged continuously. "A. It is hardly permissible to use that data at the present time. Have you any knowledge as to how large the errors in those figures would be? Mr. Williams (Counsel for the District): I object to the question on the ground it is manifestly beyond the range of human knowledge to know, if they are not worthy, how unworthy they are. A. Do you wish me to answer? Q. Certainly. A. I should think one might easily get into an error of 20 to 25 per cent. Q. Now, the same question in regard to the precipitation, on the drainage of the Great Lakes? A. Precipitation is a great deal better known. I think it is safe to say that the observations of the Weather Bureau is given within 12 to 15 per cent., that is particularly the observations made during the later years."

My question is, did you have that in mind when you answered that on yesterday?

A. I would like to have the question that was asked yesterday and the answer read. I do not recall just what I did have in mind.

(Question and answer requested by the witness were read as follows: "Q. And you think that Mr. Haskell's name to that report is entitled to no more weight upon an engineering proposition than the opinion of Mr. Clinton? A. I think that it may be questioned whether Mr. Haskell would state that proposition in exactly those words; and if he does not state it in exactly those words it does not mean exactly what it does here. The general interpretation that would be put upon that by a casual reading, would undoubtedly be subscribed to by Mr. Haskell, and as a matter of casual reading I would subscribe to it myself. But where we come to specifically consider the meaning of the words involved, I do not agree with it—I would not say what anybody else would do.")

The Witness: I had in mind Mr. Haskell's testimony.

Q. I direct your attention to a chart marked in this case: "Haskell's Exhibit 1 for Identification 2/17/09," and to your testimony on yesterday in which your attention was directed to the statement on page 76 of the report of the International Waterways Commission concerning the effect of the diversion of 10,000 cubic feet of water per second upon the level of Lake Erie, and ask you whether or not in the answers which you made relating to that subject you had in mind the testimony of Mr. Haskell appearing in the deposition to which I have above referred, beginning on page 82, and in the continuously paged record page 63, as follows:

"Q. And your testimony is based upon the computations made by you from the plate which you hold in your hand? A. Yes. Q. And used by the International Waterways Commission? A. Yes. Mr. Williams: Now I would like to have that plate marked as Haskell's Exhibit for Identification and attached to the deposition so we will have it. Plate marked Haskell's Exhibit Number 1 for Identification 2/17/09 H. J. R. X Ex."

A. The question is what?

Q. Whether you had that in mind?

A. I had.

Q. I ask you whether or not you do not find that the increments which are marked on "Haskell's 1 for Identification" to which I just directed your attention, and which was identified by the witness as above stated, correspond with the in-

crements appearing on Table XXIII of the same Appendix to the report, in which Table XXXVII referred to on yesterday appears?

A. I do.

Q. I wish you would take the increments appearing on Table XXIII on page 53 of the report of the International Waterways Commission, for the St. Clair, Detroit, Niagara and St. Lawrence Rivers, and reduce those increments to the corresponding loss of level of lake surface, in inches?

A. For 10,000 cubic feet?

Q. For 10,000 cubic feet.

A. What is the particular one you want reduced?

Q. Commencing with the St. Clair, Harbor Beach.

A. You want them all, or the mean?

Q. All stages.

A. The first one given as a mean. As the result of the division of 10,000 by 18,900, I read from Barlow's Tables, .5291005.

Mr. Austrian: That was for St. Clair?

A. That is for the mean stage of St. Clair, according to the table in the International Waterways report.

For the division of 10,000 by 16,300, I read in Barlow's Tables .613.

Q. What is that for?

A. That is for the elevation from 579 to 580, for elevations of Lake St. Clair.

Mr. Austrian: You are asking for all those?

Mr. Wilkerson: Yes.

A. For the division of 10,000 by 17,500, I read .571.

For the division of 10,000 by 19,100, I read .524.

For the division of 10,000 by 20,900, I read .478.

You do not wish anything about the Detroit?

Mr. Wilkerson: Yes, go right down, because I have some other questions that may make it convenient for you to have those right before you for your own computations.

A. For the division of 10,000 by 20,600, I read .485.

For the division of 10,000 by 18,300, I read .546.

For the division of 10,000 by 20,900, I read .478.

For the division of 10,000 by 22,500, I read .444.

Coming to the Niagara:

For the division of 10,000 by 23,400, I read .427.

For the division of 10,000 by 19,600, I read .510.

For the division of 10,000 by 21,400, I read .467.

For the division of 10,000 by 23,200, I read .431.

For the division of 10,000 by 25,100, I read .398.
Coming to the St. Lawrence:
For the division of 10,000 by 28,100, I read .356.
For the division of 10,000 by 26,800, I read .373.
For the division of 10,000 by 27,600, I read .362.
For the division of 10,000 by 29,300, I read .341.
For the division of 10,000 by 29,800, I read .336.
Please reduce those to inches.

A. You want them all, or do you want the maximum, minimum and mean?

Q. No, I would like to have them all.

A. The first value given for the St. Clair gives 6.33 inches.

Q. Give it the nearest eighth, quarter or half.

A. I would say approximately for St. Clair mean increment 6⅜; for the minimum increment 7⅜.

Next I would make 6½; the next 6¼, and the last on the St. Clair 5¾.

Mean for the Detroit about 5⅞, minimum 6½, the next 5¾, 5⅜. 5½, that is mean for Niagara. For the minimum increment of Niagara 6⅛; the mean is 5⅛; minimum 6⅛.

The next is 5⅜.

The next is actually about 5 3/16. The last one, that is the highest increment for Niagara 4¾, and the St. Lawrence the mean is 4¼; minimum is 4½.

The next 4⅜; the next 4⅛; the last 4 inches.

Q. It is a fact, is it not, that the effect upon the level of the lakes for the diversion of a given quantity of water is greater at low stages of the lake than it is at high stages of the lake?

A. Yes.

Q. I call your attention to your Table Number LXV?

A. Yes.

Q. The same being table of elevations and mean elevations of lakes, 10 years prior and for ten years subsequent to the opening of the Chicago Drainage Canal?

A. Yes, sir.

Q. The figure which you have put down there for the mean elevation of the lakes, the mean elevation of Lake Michigan from the year 1890 to the year 1899, is 580.342?

A. That is from 1890 to 1899?

Q. Yes. That represents a stage how much lower than the mean stage as stated in Table Number XXIII?

A. Substantially 13 inches, a foot and one-tenth.

Q. So that if we were to take the figure from Table XXIII which applies to the conditions represented by an average of

580.342, that would take the figure 580.581, which would be 6⅞ inches, would that not, approximately?

A. That is according to the table.

Q. I am speaking according to the table?

A. Yes.

Q. Now take the St. Clair elevation, the mean is 575.013 if we were going to take a figure which would represent that condition, we would take——

A. You ask what I would take from this table?

Q. Yes.

A. From Table XXIII for the elevation of Lake St. Clair, I would split the record from 574 to 576 and call it 19,600 for the increment, which would be 6⅛ inches.

Q. Now take the Erie elevation of 572.012.

A. That is the same situation that we had before, and I would call that 5⅝.

Q. So far as these figures in inches are concerned, the figures for the mean as you have stated them for the period 1900 to 1909 would not be substantially different?

A. No, you would reduce—that is depending on reading from this table, one would naturally reduce the effect slightly on St. Clair and Erie, that is having gotten well up into that foot by reading from this table, a person would hardly split, but the results would be substantially the same.

Q. So that in arriving at the real effect which must be kept in mind for the purpose of the inquiry which we have here, it is necessary to take into consideration the effect of the given diversion at the low stages of the water, is it not?

A. That is contrary to the testimony of every witness in this case, they all having specifically stated that for the purpose of this investigation the increment could be represented by a straight line, which means that the increment for the purposes of this case and for the range covered by it is substantially the same at all stages.

Q. I am speaking of the effect of the lake level as the result of the diversion of a given quantity of water. I think you misunderstood my question.

Mr. Adcock: In other words your proposition is there might be some slight difference between high and low stages?

Mr. Wilkerson: What I have in mind is this: That the effect of the diversion of a given quantity of water would be greater at the low stages of the lake. That is a fact, is it not?

A. Theoretically.

Q. Yes, theoretically it is greater and practically so.

A. Let me make this correction to my previous answer, where I said every witness answered, make it: Every witness of whom the question has been asked.

Mr. Adcock: That is they did not make any distinction so far as this case is concerned?

A. That is it, for the purpose of this investigation, for the line covered in this investigation.

Mr. Wilkerson: Without regard to what these other witnesses have said, it is a fact that for the low stages, you have to increase the figures showing the effect upon the lowering of the lakes to an extent as indicated by the figures which you have given.

A. Not at all.

Q. I am speaking of the table itself.

A. Oh.

Q. I am not asking whether in your opinion the table is inaccurate, because of course you have said the engineers are wrong. I am asking you to assume the accuracy of the figures which have been prepared by the Government Engineers.

A. I did not understand that assumption to be included in your question.

To state an answer formally to your question, I would say this: That according to the table which is presented on page 53, and upon theoretical conditions which I believe to be accurate conditions the effect of a diversion at the elevations existing from 1890 to the present time would be greater than the effect of a diversion at the elevations which are presented as the means in Table XXIII of the report of the International Waterways Commission on Lake Erie.

Mr. Adcock: That is the mean for the entire period?

A. No, what they state here as the mean. That is a fair answer to your question.

Mr. Wilkerson: By mean stage as used in this table is meant the mean from the year 1860, isn't it?

A. I can't say as to that for the moment. I think that it is, but it does not make any difference whatever that mean is, it is higher than the stages that have existed since 1890 to the present time.

Q. I understood you to say it was your opinion that the effect of excavations which had been made in the Detroit and St. Clair Rivers has been to permanently lower the levels of Lakes Michigan and Huron by about a foot, .6 of a foot to a foot?

A. Six tenths to a foot I think was my estimate with possibly one foot and .2.

Mr. Adcock: You mean under the conditions as they exist now, as far as "permanently" is concerned.

Mr. Wilkerson: I mean assuming that condition remains as it is, it would be the effect of it according to his testimony.

Q. Now what are the influences which in your opinion have a tendency to reduce the actual mean level of the lakes?

Mr. Adcock: You mean to reduce them or affect the levels?

Mr. Wilkerson: To reduce, I said.

A. You mean other than the deepening of the channels?

Q. Yes.

A. The clearing of the lands on the water sheds of the tributary areas and the diversion of water at Chicago; and of course the levels of the lakes are subject to variation, on account of variations of rainfall and evaporation.

Q. Is it your opinion that the effect of the removal of the forests and cultivation of the soil is to diminish the quantity of water which flows into the lakes?

A. No, sir.

Q. And thereby reduce the level?

A. No, sir.

Q. What do you have in mind?

A. It increases the rapidity of the discharge into the lake and gives it an opportunity to get out of the lake more rapidly, so that the low water is lower.

Q. And that is the process of reasoning by which you reach the conclusion that it does have a permanent lowering effect?

A. That is the process by which I arrive at that conclusion.

Mr. Adcock: Do the extensive drainage operations have anything to do with that?

A. I had that in mind also in my answer, whether I stated it specifically or not, that with the cutting off the forests comes the cultivation of the land, all of which tends to increase the rapidity with which the water reaches the lakes.

Mr. Wilkerson: You stated, Mr. Williams, that no one had been absurd enough to suggest an increment of 16,000 for Lake St. Clair?

A. I said less than 16,000, I think.

Q. You do find in Table Number XXIII an increment of 16,300 feet?

A. I do.

Q. Stated for the stage 579.580?

A. I do, but that is not an average stage, not an average increment, however, and it is not within the range of my answer, either, as I said less than 16,000.

Q. You have produced in evidence a number of charts, plates and tables.

Mr. Adcock: You are referring to all of Williams Exhibit 34?

Mr. Wilkerson: Referring to a compilation which we have been designating as Williams Exhibit 34 in this case.

Q. About when did you begin the preparation of these tables, charts and plates?

A. As soon as Mr. Shenehon's evidence was presented, or in fact while it was being presented, that being the first opportunity we had to get any reliable information, or information which we understood would be accepted along the line of evidence bearing upon these problems.

Q. Were most of these tables, plates and charts prepared about the time he testified?

A. Oh, no.

Q. They were prepared some time afterward?

A. From that time until a few days ago.

Q. When did you prepare the first table in which you made use of the method of referring the discharge measurements to a different elevation of the lake from the method which had been employed by the Government Engineers in that respect?

A. I don't understand the intent of your question. I don't understand what you are trying to get at.

Q. (Question read.) I am referring now to the tables in Exhibit 34, and you have a series of tables there in which you have corrected, as you say, the stage to which the discharge measurements are to be referred.

Mr. Austrian: Don't you think you ought to separate that question?

Mr. Adcock: You ought to designate the tables.

The Witness: You are referring to the tables of the discharge of the St. Clair River.

Mr. Austrian: The question is involved, incorporates two questions in one.

Mr. Wilkerson: I think the witness understands what I want.

The Witness: You are referring to the St. Clair River, are you?

Mr. Wilkerson: Any river.

Mr. Austrian: Just give him one table for example. When

did you prepare the first table that is computed upon the basis other than that employed by the Government?

Q. (Question read as follows:) ("When did you prepare the first table, in which you made use of the method of referring the discharge measurements to a different elevation of the lake from the method which had been employed by the Government engineers in that respect?")

A. That question really, Mr. Wilkerson, I must say is not clearly intelligible to me. I think it is possibly my fault; that I do not understand the terms that you are using. I will be very glad to do my best to answer the question for you if you will tell me what you are trying to get at.

Let me ask if this is what you mean: Do you mean to ask when it was that I first began the investigation of the effect of the discharge based upon what I have considered normal conditions since 1890?

Q. When you prepared your first table, which is of the same kind as table number——

A. You mean something in the nature of Table XXIX?

Q. (Question re-read.)

A. If you mean by that when did I first combine the observations in consecutive groups, for the purpose of comparing them with the lake elevations existing over a period of several days, that work was done during the summer of 1909, or immediately following the conclusion of Mr. Shenehon's examination.

Q. Were the tables which have been produced in this case prepared then?

A. Some of them were.

Mr. Austrian: You mean all the tables?

Mr. Wilkerson: Which ones were prepared as early as 1909?

A. Table XXVIII was prepared at that time.

Q. Any others about that time?

A. Oh, yes, there were a large number of them.

Q. I would like to have the ones that were prepared in 1909.

A. Table 1 was prepared at that time. The table of which this print is made is a redrawing of it due to the fact that the sheet became damaged. Table II, I think is a print of the original table.

Table III, Table IV, Table V, Table XIII, XIV, XV, XVI, XVIII, XIX, XXII, XXIII, XLI, XLII, XLV, XLVI. In this answer, I must be allowed to extend over into 1910, because I

cannot exactly distinguish between what was done in 1909 and 1910.

Q. I understand you to say it takes in 1909?

A. No, and I am giving you the tables here of those that were prepared in the first investigation of the subject, after Mr. Shenehon's testimony was presented, and that covered the balance of 1909 and some work in 1910.

As we went on with the work, we found we wanted additional information and we asked for it, and got information that was not put in the record at the time that Mr. Shenehon testified.

Q. You have some idea; I want the order in which you did this work.

A. I am giving this to you. The work on this embraces, you might say, three periods, leaving out an amount of preliminary work that was done before any testimony was taken in the case, which was based upon solely what might be found in reports, and was not at all conclusive.

The testimony of the complainant closed on June 5, I believe, 1909, or rather, the testimony of Mr. Shenehon closed June 5, 1909.

Mr. Austrian: That is the same thing.

The Witness: No, they examined Mr. Coulby after that. And we immediately began work on this data and continued until along into 1910. Then there was a cessation of activities, and quite a lapse of time which I do not recall, until the matter was stirred up again, and some further investigations were carried on. And then finally last fall the matter came to a head a third time and we proceeded to make further investigations, or to complete, rather, the investigations that we had under way.

As a matter of fact, when the need for the work had apparently disappeared temporarily at least, we having numerous other things to attend to, we simply shelved it in our office and left it for future study.

Mr. Austrian: Then the numbers you are calling off are the numbers prepared in the second period?

A. No, first period.

Q. And that centered in 1909, along in 1910?

Mr. Wilkerson: Along into 1910.

The Witness: Table XLIX, the first sheet of Table XLIX, and the first sheet of Table L and the first sheet of Table LIII; I might also say in regard to Tables XVIII and XIX, that the original table—that the portion of that actually presented here which was compiled during this first period of

investigation as represented on the first sheet of those respective tables, that the second sheet has been re-drawn to extend the observations to 1912. The original sheet stopped in 1908 and we simply copied the preliminary portion of the sheet and added to it what is necessary to bring the information to 1912.

Q. Were any of these tables you prepared in 1909 and 1910 ever submitted, either to the Secretary of War or the Chief of Engineers, in connection with any matter there pending relating to the Sanitary District?

A. Not to my knowledge. It is possible that there might have been, as copies—well, I won't be sure whether a copy was in the possession of anybody who may have submitted it.

Q. You were never called upon to make a statement or any explanation to accompany those tables, to be presented to the War Department?

A. No.

Q. I direct your attention to Table XLV a, consisting of five sheets.

A. Yes.

Q. When was that table made?

A. That table as presented here was made recently, at the request of Mr. Shenehon. It was copied from a table made in pencil, which was made in 1909. We simply had the thick paper with its computations in pencil. We did not regard that as of sufficient importance to introduce ourselves, but when they were asked for we had them copied in blue prints.

Q. Have you utilized this table in deriving an increment as to which you have given evidence in this case?

A. That table is the basis, I believe, of Table XLV.

Q. I direct your attention to sheet 2 of that table and to group 5, and ask you to state the dates on which the observations which are there utilized were made?

A. Group 5?

Q. Yes?

A. The date would indicate that they were made in February. I suspect that that, too, is an error.

Mr. Shenehon: That is correct.

The Witness: Were they made in February?

Mr. Shenehon: Yes.

The Witness: I have forgotten that there were observations made in February.

Mr. Wilkerson: What is the answer?

A. I say the date would indicate they were made in February.

Q. February 14, 15, 16 and 17, 1899?

A. Yes.

Q. If you have any doubt on this subject, I ask you to refer to the tables from which observations 93 to 102, inclusive, were taken.

A. I haven't any doubt. The thing that I had forgotten was that observations were made in February. Yes, that is all right.

Q. To what tables are you now referring?

A. I will have to get my copy of it so as to see what that exhibit is.

Mr. Adcock: I think that is Williams' Exhibit 24.

A. Williams' Exhibit 24.

Mr. Wilkerson: These observations on which the conclusions are stated, as the result of which this table was made, were picked out by you with particular care, were they not, Mr. Williams, so as to get observations which would represent the normal conditions?

A. They were picked out with reference to the mean elevation of Lake Erie for the days during the observations, as indicated in the record of the Buffalo gage.

Q. And for open season conditions?

A. For the conditions which existed when the observations were made. I don't know whether the river was open, or closed with ice, but I assume it must have been open.

Q. You do not understand that in reaching a result with reference to this increment, it would be proper to include observations taken when the river was closed with ice, do you?

A. Not for direct comparison with those for the open season, no.

Q. Now, I call your attention to the note at the bottom of Table Number 1: "Summary of discharges International Bridge Section Niagara River," and to the following.

Mr. Adcock: You are referring to Exhibit 24?

Mr. Wilkerson: The same being Exhibit Number 24 as follows: "Numbers 116, 117 and 118, span 1 blocked with ice. 114, span 9 blocked with ice. 91, 92, 100, 101, 102, spans 1 and 9 blocked with ice. 93 to 99 inclusive, spans 1 and 9, and east half of span 2 blocked." I will ask you whether or not those notes do not indicate to you that there was ice in the river at that time?

A. They indicate that to my mind at the present moment, yes, sir.

Q. In your opinion as an engineer, do you regard it as proper to incorporate those observations taken in February, 1909, with the open season observations with which they have been incorporated?

A. Well, that is an error which escaped my attention until this moment. I may say—

Q. Do you know now whether as a matter of fact you have used these observations in which the river was blocked with ice in any other comparisons which you have made?

A. I presume that they have been used in all of them, as all of these comparisons with gages have been based upon this same table.

Q. Were any of those used in Table Number 3?

A. In Table Number 3?

Q. In which you have made a criticism of the Niagara work, comparing its accuracy with the work on the St. Clair and the St. Lawrence Rivers, having derived the average variation from the mean?

A. So far as I see, this table of comparison of observation 83 with observation 116 would be an unfair comparison, for the reason that in 116 span Number 1 was blocked with ice, whereas in 83 it was not. Let me go through these and make sure that there are not any more.

Q. How about 18 and 121?

A. Apparently there is nothing to indicate that there was anything wrong with 121. Am I right, Mr. Shenehon? I do not see it here in the notes.

Mr. Shenehon: The date indicates it.

Mr. Wilkerson: March 24th?

A. You specifically state what is the matter with these various ones, and omit 121. I simply want this for my own protection, that is all, that so far as the notes on Exhibit 24 are concerned, there is nothing there stating that there were any abnormal conditions in the case of measurement 121. It is, however, a fact that that observation was taken on the same day as observation 120, which states that the discharge for span 2 was interpolated, and the measurement 119 which states that the discharge for spans 1 and 2 was interpolated.

Q. Referring to the comparison based upon the use of observations Number 83 and 116, I direct your attention to the fact that the per cent. of variation from the mean which you get by reason of the use of that observation 116, is 5.27 per cent.?

A. Yes.

Q. State whether or not that would not indicate to you

that the improper use of these ice observations has been an important factor in getting the figure of 2.89 as the summary of the—

A. It is entirely correct that that comparison should not have been included in this table; and it was included through a neglect on my part to take cognizance of this note at the foot of this discharge table, and to that extent—

Q. Or the date?

A. Or the date. That was a clean oversight, and the average variation as shown in this table should be reduced by the effect of eliminating that 5.27, shown by the comparison of observations 83 and 116.

There may be another one here, Mr. Wilkerson. Let me be sure.

Q. There are observations 112 and 92?

A. 112 and 92 were both under ice conditions. Whether the conditions were the same or not—there is nothing in the note apparently to indicate directly what the condition in 112 was, and we may or may not assume that it was similar to the conditions in 116 or 102. If similar to 102, it is similar to 92.

Q. Of course, the open season conditions, it would not be proper to use either one of those observations, would it?

A. Yes, for this purpose, we are not considering whether it was open season or closed. What we are endeavoring to do is compare observations under similar conditions. These observations 112 and 92 would compare with each other. They are not compared with any others—

Q. Did you use the same method on the St. Clair, incorporating winter observations?

A. On the St. Clair we took into consideration all the observations that had been introduced in the testimony and we compared those that had been taken under what the evidence indicated, as we understood it to be, similar conditions.

I am perfectly frank to say right here, gentlemen, that I based these comparisons on similar stages, and overlooked the fact that these were winter observations. I am perfectly frank to say that, and I am very glad my attention has been called to it; and I will have this table corrected to eliminate observations in which comparisons are made under conditions which are not similar. I will be glad to sit down with Mr. Shenehon and ask him to assist me in selecting the ones that do represent similar conditions.

Q. So that any place in which these tables have been used as the basis of conclusions reached in this case, the conclusions which have been reached and the use which has been

made of them, so far as their effect upon other witnesses is concerned, will be subject to the correction of these tables by the elimination of these observations.

A. They will be subject to that correction.

Mr. Adcock: You say the elimination of the observations?

A. Oh, no, they will be subject to a correction to meet the action conditions. If during a winter measurement when the conditions were the same on two days, we have these variations, then they are entitled to be in here. But it is not right to compare a case when we had spans blocked with ice with a case when we did not; nor is it right to compare cases when only one span was blocked with ice with cases where more than one were blocked with ice.

Q. As a matter of fact, aren't the conditions such in the winter season that it is regarded as improper to use the winter observations for any purpose, in comparison or otherwise; the ice conditions changed so from time to time. There may be ice around the Niagara Falls?

A. I will answer that question by asking, then, why the Government wasted the money to take them if they are improper to use for any purpose?

Q. I think I referred to Table Number 3, as to the use which was made of that as to the correction which would have to be made, and I applied it also to Table XLV a. If I did not, I ask you whether that is true as to Table XLV a, also?

A. It is.

Adjourned to Monday, July 21, at 10:30 a. m.

Monday, July 21, 10:30 a. m.

GARDNER S. WILLIAMS resumed the stand for further cross-examination by Mr. Wilkerson, and testified as follows:

Q. Referring to the increment of the Niagara River, Mr. Williams, is it a fact that in deriving that increment you utilized the principle of the ratio of increment to fluctuations of lake surfaces over periods of years?

A. You mean the increment as testified to finally, the value of 34,000?

Q. I mean in your computations of the increment for this river, did you make use of that principle in any of the tables which have been presented by you?

A. It was not used in connection with any tables from

XLV to XLVII a, inclusive. It was used in getting at the value which I finally adopted as being the most likely, or as being a probable value.

Q. I will ask you to explain how you made use of the principle of the ratio of increment to fluctuations?

Mr. Adcock: What fluctuations do you refer to, oscillations?

Mr. Wilkerson: To the fundamental proposition on which that principle is based.

Mr. Adcock: You mean the monthly, yearly or daily?

Mr. Wilkerson: Well, a given period.

Q. If you will, explain that to us first in a general way, and then take it up by reference specifically to your tables; it might be clearer?

A. I will have it for you in just a moment. The general principle involved is that if any reservoir, or if rather, two reservoirs, have openings of different sizes and water flows into both of them in amounts varying, that the one which has the opening with the larger increment will change its level less than the other for the same quantities of inflowing water, or the same rate of inflow.

Q. And it is your opinion that this proposition is applicable to the Great Lakes, treating them as water reservoirs, as you have stated?

A. It is.

Q. The proposition is still applicable where the quantities of water are different, as in the case of the three lakes we have under consideration here, is it not?

A. Yes, it is still applicable.

Q. Except that you have to make allowance for the difference in quantity. The proposition remains the same. Do I state that correctly?

A. Yes, that you must take into account the difference in quantity.

Q. The difference in quantity of water, but that, making allowance for that, the general proposition applies?

A. (No response.)

Q. Now, coming back to the use which you made of it in this case, I will ask you to explain a little more in detail by reference to the tables which you have submitted, in just as simple a way as you can, just what use you have made of them, having in mind that this case is to be argued by lawyers and heard by a judge?

A. Take, for example, Table XXI, we find that if the elevations of Lake Huron, for instance, be plotted as ordinates

to the elevations of St. Clair abscissas, that they fall in a line, or they approximate to some sort of a line; and that if the mean line be constructed a ratio will be derived for the fluctuation of one lake in terms of the other, as testified to by the complainant's witness Shenehon, page 592 of the continuously paged record, that when Lake Huron goes up a foot Lake Erie goes up .7 of a foot. This is more specifically explained previous to that, but that happens to be the reference I have a knowledge of just now.

Q. In your own opinion, that portion of his testimony is correct, is it?

A. Based upon what he was stating, that is, upon the average results extending from 1860 to 1908, which I understand is what was included in the basis of his answer, I think agrees substantially with the results which we have obtained.

Mr. Austrian: On that point.

A. On that point. Then if for the same quantity of water flowing in to both Lakes Huron and Lake Erie, Lake Erie is raised .7 of a foot as Lake Huron is raised a foot, it means that the increment of Lake Erie must be to the increment of Lake Huron inversely as the changes, or as 100 to 70.

If in addition to that, there is a further inflow into Lake Erie not accounted for or not received through the outlet of Lake Huron, then the indication would be that the increment of Lake Erie must be still larger, as it has to take care, not only of the water coming from Lake Huron, but such as comes from its natural drainage.

Mr. Wilkerson: Now, you spoke of plotting these elevations. If when you plot the elevations of these two lakes, in the way in which you have stated, they tend to arrange themselves in a line, is that an indication to your mind that the relation which is represented by that line is the correct relation for the observations used?

A. That line is a correct representation of the relations between the observations used, considered as a whole.

It must be borne in mind that by taking short periods, different results are obtained than in the case of long periods; that individual years may show apparently erratic indications, but for a general relation covering the period considered, that line indicates the ratio of one change to the other, based on the whole period. It might be a straight line, of course, or it might be a curve. For the purpose of this case the straight line has been utilized.

It is entirely possible that a final analysis might show that at high stages the relation between the fluctuation was differ-

ent from what it is at low stages. But that was a phase of the matter that has not been considered up to the present time; and I question very much if the information we have is sufficient to arrive at any satisfactory conclusions along that line, because the observations do not cover a sufficiently long period; and are influenced by changes in the conditions of the discharging channels.

Q. That last statement has to do with the curvature of the line?

A. Yes.

Q. And not to the establishment of the law?

A. No, that deals with the question of curvature of the line.

Q. I understand it to be the effect of your testimony, looking over these tables which have been submitted, that you by a similar process of reasoning worked back from the increment of the St. Lawrence to that of the Niagara, is it?

A. It is.

Q. So that we may have it here, state just briefly, and as simply as you can, your process of reasoning by which you work back from the St. Lawrence to the Niagara?

A. The process is simple; by a plotting of the elevations of Lake Ontario and Lake Erie, and an analysis of the results presented in Table XLIV, we get the relation of the change of Ontario to the change of Erie.

Q. It is there stated at 136 per cent.?

A. Yes.

Q. And you have adopted that ratio, and then combined with it your computations relating to rainfall and evaporation?

A. The tables of rainfall and evaporation, I believe, are not combined with this increment. The treatment of rainfall and evaporation does not involve the fluctuation of the lake surfaces except as actually measured to determine the storage that has accumulated or been lost from one lake to another. It has nothing to do with this relation.

Q. Does not enter into this 136 per cent. at all?

A. Does not enter into that 136 per cent.; at least that is my present recollection.

Q. In the case of this table which you have before you, Number XLIV, do the rainfall evaporation and run-off interfere materially with the operation of that law which is there deduced?

A. The rainfall and evaporation has not been taken into consideration in this table, it being based solely upon the relations of the lake elevations, and this ratio is that which is

shown by the actual changes of elevations, without inquiring as to their cause.

Q. In making this transfer, do you regard it as proper to ignore the elements of run-off, rainfall and evaporation?

A. It is reasonable to make a correction for the effect of local supply, which I assume to be the point that you are getting at.

Q. Yes. But you regard the method as substantially correct, notwithstanding any differences that might result from the rainfall, evaporation and run-off?

A. I would say that so far as this analysis is concerned of connecting the St. Lawrence with the St. Clair that the corrections on the outflow of Ontario due to the rainfall there are of the opposite sign to those that would be applied at Erie. And when those corrections have been made, it is my opinion that you will get to the same result at the St. Clair, substantially. In other words, that the St. Lawrence discharge will check St. Clair as it is in this computation.

Q. You can pass from the St. Lawrence to the St. Clair and also from the St. Clair to the St. Lawrence?

A. Certainly.

Q. According to the method which is stated here?

A. Yes.

Q. It applies eitherway?

A. It applies either way. Of course, you must realize that it is only as approximation, inasmuch as you cannot accurately determine the effect of that local supply. That is the thing that coming in there makes this an approximate comparison.

Q. What, in your opinion, are the limits of the precision, in the method of going from one lake to the other in the way in which you have just explained?

A. If there were no variations of inflow and outflow due to the local supply and local evaporation, the method would be strictly accurate, assuming that the data upon which it is based are accurate; that is, that the ratios are the correct ratios. It will be affected to the extent to which the variations of local supply and local evaporation cause fluctuations of the lake surface in the second lake in the comparison.

Now, as to how much that is, I am not prepared at this moment to say, for the reason that at times the inflow from the local drainage may accentuate the fluctuations, and at other times it tends to suppress them, and considering a long period of years these effects will to a greater or less extent

neutralize, and it would involve quite an extended study for me to be able to express an opinion in a percentage.

Q. Just what is the increment, according to your method, of the Niagara as derived from the St. Clair?

A. I don't recall that I specifically derived the increment of Niagara from the St. Clair. Considering the results of computations both ways from the St. Lawrence and the St. Clair, I arrived at 34,000 as being as low a value as seemed to me reasonable for the Niagara.

Q. The increment of the Niagara as derived from the St. Clair is more intimate, so to speak, than the increment of the St. Lawrence as derived from the St. Clair?

A. I would say not necessarily, for the reason that going through Lake Erie, and Lakes Erie and Ontario, the local supply effects of one balance the similar effects of the other, and I think that the relation between the St. Lawrence and St. Clair increment is more nearly correct than a relation that would be derived from either for the Niagara.

Q. It may be that I do not catch your idea.

A. Perhaps I do not catch the trend of your question, Mr. Wilkerson. I am trying to follow you.

Q. We are working from the increment of one river to that of another. The Niagara River, of course, is much nearer to the St. Clair than the St. Lawrence; and the question was whether the Niagara River stands in your opinion in a more intimate relation, as far as the determination of this increment is concerned, to the St. Clair than did the St. Lawrence, on account of the greater distance?

A. I think, considering all the factors of the problem, that the derivation of the increment of the St. Lawrence from the St. Clair, or the increment of the St. Clair from the St. Lawrence is more likely to be correct than the derivation of the Niagara increment from either one, for the reason, as I stated before, that the local supply effects and local evaporation act in one sense in the case of Erie, and in the opposite sense in the case of Ontario and tend to cancel each other's influences.

Q. Just about how much more nearly accurate do you think you could go from the St. Clair to the St. Lawrence than you could go from the St. Clair to the Niagara?

A. Depending altogether upon the magnitude of the local influences in Lake Erie and Lake Ontario.

Q. Have you in your own mind any opinion that could be expressed in the language of percentages?

A. I have not at this moment.

Q. And what you have said would apply in going back from the St. Lawrence to the St. Clair?

A. Yes.

Q. You think you could go more accurately from the St. Lawrence to the St. Clair than you could from the St. Lawrence to the Niagara?

A. I think your results would be more accurate when you had gotten there, in the former case.

Q. Of course, the method which you have used could be used starting at the Niagara and working either way, provided you had an increment?

A. Yes, if you had an accurate increment.

Q. Which is derived from observations at Niagara?

A. If you had an accurate increment for the Niagara River you could go both ways from that and expect to get reasonable results. If you didn't have an accurate increment, you could work both ways and get unreasonable results.

Q. In deriving the increment of the St. Lawrence River, did you take into account the changes which were produced by the construction of the Gut Dam?

A. I don't see from the dates on the St. Lawrence gagings, as I understand it, that the Gut Dam had anything to do with the situation at that time.

I will correct this answer of mine by saying that I understood that the effect of the Gut Dam was not effective until 1904, as the year 1903 has been included in the table, showing the relative elevations of Lakes Ontario and Erie. If the Gut Dam were influential in 1903, then a very small correction, the sign of which I am unable to state at this moment, would have to be made in that ratio.

Mr. Austrian: For that year?

A. No, the ratio for this whole table; it would be one year out of forty-three.

Mr. Wilkerson: The effect of the Gut Dam was to lessen the flow of the St. Lawrence River for a given stage, about 5½ per cent., was it not?

A. It was to raise Lake Ontario about 5 inches. I don't remember the percentage of that. I think, on recollection, that the 5½ per cent. is approximately correct, as I believe I connected those two figures, that it was substantially the same number of inches as it was per cent.

Q. And that change of 5½ per cent. would have to be made in the increment, in order to give expression to the effect of this dam, would it not?

A. The effect of that dam should be corrected in Table

XLIV. Whatever effect it had in 1903 should be used to reduce the elevation of Ontario for that year.

Q. The thing to which I had reference in my question was the effect upon the increment, and I understand that effect is one which would show itself immediately, or substantially so.

Mr. Austrian: Immediately upon the completion of the dam?

Mr. Wilkerson: Yes.

A. The increment as derived in this testimony and applied is based upon the increment of the St. Clair River, as is shown by the information which was presented by the complainant in this case.

I am not aware that the complainant anywhere in its testimony introduced the subject of the effect of the Gut Dam upon the increment of the St. Clair River—or the St. Lawrence River, or corrected his (Mr. Shenehon's) increments to compensate for it.

With that obstruction it is possible, though not certain, that the increment of the St. Lawrence River now is less than it was prior to the construction of the dam. But there has been since then constructed another compensatory work of a different character, a channel in the vicinity of the Gut Dam, which is shown upon Williams' Exhibit 18 and is there designated at the North Channel. This is a channel which has been constructed through a portion of Drummond Island and is from 17 to 19 feet deep and about 300 feet wide. The Gut Dam closed a channel about 400 feet wide and less than 18 feet deep, and was located within a mile of the North channel. It would seem, therefore, that the construction of the North Channel must have to a considerable extent compensated for the effect of the Gut Dam.

Q. But dealing with the effect of the construction of the Gut Dam is an independent element, in order to determine the effect of the loss of outflow upon the increment, you would reduce the increment by approximately the same per cent. as the outflow was reduced. If you were dealing with that just as an independent factor and wanted to determine what its effect was upon the increment, you would reduce the increment by a per cent. which would be in accordance with the loss of outflow?

A. That would be only true during the period when the lake was re-adjusting itself. When the lake arrived at its new elevation, it is very probable that the increment would be found to have been increased by reason of the probably

broader channels that would be available for the discharge of water on account of higher elevation.

During the period when the lake was rising, the increment would be smaller than it was in the first case, and would gradually approach its final value, which would be either smaller or greater, but probably would be greater.

Q. Have you personal knowledge as to the physical conditions under which the dam was constructed? Do you know the facts about the steepness of the banks and the channels?

A. I saw the dam the other day. It is rather an insignificant structure, cutting off a channel that extends obliquely to the general trend of the current. This new channel opens directly into the main opening of the river through the Galops Rapids, and from that inspection, it certainly appears to me that there can have been very little effect, very little ultimate effect, very little net ultimate effect of the two improvements.

Q. Is there anything further, Mr. Williams, that you care to state about the effect of the construction of the Gut Dam?

A. No response.

Q. But for a given stage, if you lessened the outflow of the river a certain per cent., you would reduce the increment by the same per cent., as a general proposition, and for small variations?

A. Yes.

Q. That is the method which you have accepted as a correct method in this case, is it not?

A. Yes, understanding you to mean that for two given stages, if the outflow is reduced for both of them by a percentage, the increment would be reduced by a similar percentage. That is what you really meant to say, I think.

Q. That is a correct principle, as I understand your testimony, that there is a relation between the outflow and the increment, and where you have a small outflow you have a small increment; and so starting in with the St. Clair, you have a given increment without regard to what it is. When you get to the Niagara you have a little larger one; when you get to the St. Lawrence, you have a still larger one, there being a relation between the amount of the outflow and the increment?

A. There is no such relation. The increment is dependent upon the cross section and slope of the outlet. For example, you might have such an outlet to Niagara that you could have an increment ten times as great as you would have through the St. Clair or through the St. Lawrence.

Q. Or even smaller?

A. Or you could have it smaller.

Q. Now, referring to the three rivers, the St. Clair, the Niagara and the St. Lawrence, I desire to get a summary of your opinion as to the elements of precision with reference to each one of those rivers, or to put it another way, the relative precision of the three rivers; I am referring to those measurements of volume.

A. Measurements of volume?

Q. Measurements of volume that you have under consideration in this case. Let us take first the stability of the lake at the outflow weir, and compare those three rivers.

A. Now, let me get your question clearly in mind. You wish me to express my opinion as to the relative dependence that is to be put upon the measurement of quantity independent of increment of the St. Lawrence, Niagara and St. Clair Rivers. Is that correct?

Q. Well, let us make it the law of discharge.

A. I do not think that the law of discharge has been established. Certain specific measurements of discharge have been made, and I have some opinions as to their relative reliability. But as to the establishment of the law of discharge, I am very clearly of the opinion that it has not been established for any of the rivers. And that is what I had in mind when I said in answer to a question on Friday that I doubted if anyone had successfully measured one of these large rivers; it being the purpose of the measurement to establish the law of discharge. And it is my belief that that law of discharge is not established.

Q. You have spoken in your testimony of certain difficulties which have been encountered in attempting to arrive at this law of discharge, and you have throughout your testimony, you have here and there stated facts and expressed opinions, which have related to those difficulties, related to the degree of credibility to be given to the conclusions which have been reached by those who have thought they could derive the law of discharge with reference to the different rivers. What I would like to have you do is to summarize, if you can, your opinion, having in mind the difficulties which have been encountered, having in mind the effect which you think those difficulties have produced.

I would like to have you summarize your opinion as to the relative degree of credibility which is to be given to these conclusions which have been reached as to the three rivers. And in connection with that I was about to direct your attention to certain particular points as to which I desire you to make the comparisons. Now, do I make myself clear as to

the general line of opinion which I wish to have you express?

A. I think I know what you wish me to express, and I must confess that I am afraid I am unprepared to express an opinion on that subject further than to say that I do not believe the law of discharge of any one of these rivers has been established. The measurement of quantity, I am ready to express opinions on, but the law of discharge means, or involves the connection of the discharges of the river with the other factors which enter into it. The discharge is an effect. The causes of that discharge are to be looked for elsewhere.

Now, the law of discharge must take into cognizance those causes, and up to the present time I feel very sure that the correct relation between cause and effect in the discharge of the rivers flowing from the Great Lakes has not been established.

Q. Well, let us take certain particular points, then: I direct your attention to certain particular points which would appear to be factors to be taken into consideration in arriving at a professional opinion as to the degree of credibility to be given to these conclusions of the Government's Engineers as to the law of discharge of these respective rivers. Now. I would like to have you take the three rivers and compare them from your point of view upon the points to which I have called your attention. Let us take first the stability of the lake at the outflow weir, and take the three rivers.

A. Considering the outflow weir as the point where the gaging measurements were made, I think the St. Lawrence has the advantage.

Q. We will specify the particular points: Lake Huron at the head of the St. Clair River; Lake Erie at Buffalo, and the St. Lawrence near the Galops Rapids.

A. The St. Lawrence has the decided advantage.

Q. I want all three of them compared.

A. The St. Clair ranks next and the Niagara is the most difficult, most unfavorable.

Q. As to the stability of the lake?

A. Well, as to the conditions that are encountered—

Q. I am speaking now of the stability of the water surface at those three points.

A. I think that is correct.

Q. Now, let us take the distance of the gaging section from the lake.

A. The gaging station on the Niagara was the nearest to the lake; the St. Clair would be next and the St. Lawrence the furthest away.

Q. And in your view, what effect does that have upon the credibility to be given to the deductions as to each of the three rivers, that factor alone, and other things being equal?

A. That would be a factor in favor of the Niagara.

Q. And which would come next on that?

A. St. Clair.

Q. And the St. Lawrence last?

A. Yes.

Q. Now, let us take the range of lake stages covered by the observations.

A. The range of lake stages are 3.92 feet for the Niagara; 2.43 feet for the St. Lawrence, and 1.74 feet for the St. Clair.

Q. Now, other things being equal, and dealing with that as a separate factor, would the fact that as to one river the observations had been so conducted that a larger range of lake stage was covered have a tendency to give added weight to the deductions which were based upon those observations?

A. Considering all other things being equal, including the maximum range of variation of the lake surfaces, that is, that the rise and fall of all the lakes is the same, we would consider the observations the most reliable which covered the widest range.

Q. I am speaking of that as an independent—

A. I will not be sure we got that in, because it is not a fact at all. The ranges covered—the proportion of the total variation of lake surfaces covered were greater on the St. Clair than on either of the other rivers, if I remember correctly.

Q. How do you make that?

A. Would it be agreeable to you to pass that question and go to the following one, and let me answer that a little later, because I find the computation is not here. The result is here, but on what I base it, at the present moment I am unable to recall.

Q. The ratio of fluctuations between Lake Huron and Lake Erie, I understood you to say a little while ago, was 70 per cent.?

A. That is the ratio of the average annual fluctuation. The maximum fluctuations, however, of Lake Erie at Buffalo are between two and three times as great as those of Huron, according to the best information that I have.

Q. You mean monthly means?

A. No, I mean daily.

Q. Daily means? And you mean including the effect of storms?

A. Yes, they affect the gage to which reference is made. Therefore, I would include them.

Q. Well, is it not your opinion that so far as the questions which we have under consideration here are concerned, it is the monthly mean level which is the correct criterion?

A. For the purpose of this comparison, I think I would make it with the monthly mean.

Q. Well, then, I don't exactly understand your last statement in its relation to what you have said before, Mr. Williams, about these variations. We are discussing these different elements of precision?

A. Yes.

Q. And I have taken them up in order, and one of them is the range of lake stages which were covered by the observations.

A. I would like to make a statement here, that I will answer a general question, if agreeable to you now, just because I am not prepared to answer this specific question.

I arrived at these percentages by reference to some value of lake fluctuation. What it is, I have not in mind now; and if I am in error, of course, I will be glad to acknowledge it. I want to find what I thought I had. The question, I would answer frankly—I will answer them all frankly as far as that goes—what I mean is, I will answer this general question: Of a series of gagings, that gaging which covers the largest proportion of the range of stage to which the discharge equation is to be applied would be considered the more probably accurate or reliable gaging.

Q. And you take the monthly mean as the criterion?

A. You should take whatever you are going to apply the gaging to as your criterion. For your general readings, you are applying to monthly means. That is as fine, I think, as anyone has attempted to go.

Q. And so far as the lowering of the lake and the diversion is concerned, what would you take, monthly mean?

A. You mean the effect of the diversion?

Q. Yes.

A. Well, the smallest unit in which the opinion is taken has been monthly mean. It has been applied to ten-year means, and monthly means, and since the increment is assumed to be derived from a straight line curve—or as long as it is assumed that the increment is constant for all elevations of the lake, it makes no difference whether you take it by the year or the month.

Q. Isn't it a fact, so far as the Niagara observations are

concerned, which have been under consideration in this case, that if you take the monthly means you have observations which are lower than the lowest monthly observations, and observations which are higher than the highest, so that the range of observations covers the whole range of lake stage?

A. That is true as to Niagara. It is also true as to the St. Clair, confining the period of investigation to that since 1890, before which time it is our belief that the gagings do not in anywise apply.

Q. Having in mind that one factor, you would expect results from the Niagara observations which would have a higher degree of credibility than on either one of the other rivers, would you not, just from that element alone?

A. Just wait a moment there, I was just thinking whether—

Q. But more particularly with regard to the increment?

A. Assuming all other conditions equal, the longer range in elevation covered by the observations would lead to a more accurate determination of the increment.

Q. For the obvious reason, if you plot the observations, the longer the line you have, the more accurate the trend.

A. Exactly. The increment is that factor in the equation which determines the inclination of the line, and that can be more accurately determined the longer the line is.

Q. Let us take as a factor in determining the credibility of these different pieces of work the number of observations and what you find as to them?

A. The St. Clair ranks first, Niagara second and the St. Lawrence third.

Q. Let us take now, the fifth to be taken into consideration in reaching a conclusion as to the credibility of these different pieces of work by the Government engineers, the duplication of sections and the opportunity for a corroborative check, what do you find as to the three rivers?

A. I would consider, as far as duplication went, the Niagara has the advantage. The St. Clair, of course, ranks next.

Mr. Adcock: When you say duplication, what do you mean by that?

A. That they had two sections—well, now, just wait a minute on that answer; I think that is pretty nearly an open question between the St. Clair and the Niagara. On the Niagara the two sections were quite close together, whereas on the St. Clair they were further apart. Considering the relative number of observations, I think I will give the Niagara a slight advantage on that.

Q. Referring again to the question as to the number of

observations, I will ask you to refer to the charts which were introduced in evidence by the Government and state what you find there indicated as to observations in the years 1907 and 1908?

A. Chart Complainant's Exhibit 3 states that the number of discharge measurements from 1898 to 1900 was 101; from 1907 to 1908 was 118, making a total of 219.

Mr. Adcock: That is on the International Bridge Section?

A. Bridge Section Niagara River.

Mr. Wilkerson: Let us take the sixth fact and consider it. Let us take the different conditions as to velocity and so forth in the various sections of the same rivers which were gaged. Take first the St. Clair now.

A. The velocities at the Dry Dock Section of the St. Clair were lower on the average than they were at Niagara, and I think lower than at the St. Lawrence.

Q. I want to first compare the conditions at the different cross sections of the same river. Take the cross sections of the St. Clair which were measured, what were the sections?

A. The section at the Dry Dock was below Port Huron, below the mouth of Black River, about five miles from the foot of the lake; and the Gorge Section, which is within about a mile of the foot of the lake.

Q. As to the velocity, the Gorge Section was about twice the velocity of the Dry Dock Section?

A. I do not recall those things.

Q. I want to get the substance, of course.

A. I should say that statement was substantially correct, without looking at the actual figure.

Q. Then take the sections in the several channels at the Delta, they have a smaller velocity than the Dry Dock Section?

A. Generally.

Q. Do you know how much smaller velocity the sections in those channels have than the Dry Dock Section, roundly speaking?

A. I would prefer not to answer those questions without an opportunity to make the necessary computations because I see that the—

Q. It is a fact that at the Gorge Section the velocity is about twice as much as the Dry Dock?

A. I am not prepared to say so at the present moment. I was under the impression it was materially greater.

Q. And that the Dry Dock was materially greater than the Delta?

A. No, I was not prepared to say that, but I would rather expect that.

Q. Notwithstanding the difference in those conditions of velocity, and other conditions which have been referred to already by you in your testimony how do those three sections on the St. Clair River check with each other?

A. The Gorge and the Dry Dock check very well. I have made no comparisons of the others.

Q. What do you mean by observations taken at two different sections checking?

A. Well, when referred to the same lake stages, lake elevations, they should give similar discharges.

Q. I will ask you to refer to the reports relating to these observations and ask you to give us the facts with reference to the velocities at the Delta Section.

A. In answering that question, I wish to say that I have as yet made no study of these discharges here, except as indicating the relative magnitude of discharges in the different Delta Sections. And to answer that question, I would think would take some little time.

Q. I will ask you, Mr. Williams, for the definite facts as to this, to look it up when we take an adjournment to-day, so that it can be put in the record to-morrow morning.

A. What is it you want?

Q. The facts with reference to the velocities in the channels of the Delta Section as compared with the velocities in the Dry Dock Section?

A. I do not find in the report as yet that those statements are given anywhere. It will involve—

Q. I pass that, and now I say, assuming that there is a material difference in the velocities between the Delta Section and the Dry Dock Section, and that the Gorge Section has a velocity about twice that of the Dry Dock Section; assuming that those sections check substantially with each other, what weight in your opinion is that fact entitled to in determining the degree of credibility which is to be given to those measurements?

Mr. Adcock: When you say "check," you mean comparing the observation with reference to similar observations?

Mr. Wilkerson: By "check,"I will accept the definition which he gave of "check."

A. The coincidence in magnitude of discharge measured at different points under different conditions of section would indicate the similarity in degree of accuracy of the work involved. It would indicate that aside from such sources of

inaccuracy as were present in all gagings—in all the measurements considered, that the observations were entitled to a degree of credibility dependent upon the coincidence of the measurements.

Q. So that the more accurately they checked, the higher the degree of credibility to be accorded to the work, even though the velocities at these different sections were different, as assumed in the question that has been put to you?

A. That is correct, bearing in mind always that those coincidences can have no effect upon errors which are continuing through all the observations, if there be any such.

Q. Wouldn't the fact that these three sections checked substantially in the way assumed in the question eliminate the item of any difference in velocity as one of the—.

A. You mean difference in velocity at the sections?

Q. Yes; as one of the sources of inaccuracy, in connection with the work?

A. Yes. I do not recognize the differences in velocity as being a source of inaccuracy, however, up to date.

Q. Now, then, I wish you would explain to us a little more in detail just what you mean by one of these sections checking with another, and try to put it in just as concise form as you can, what that checking of the two sections means to an engineer as to the kind of work which has been done in the measuring of the different cross sections?

A. If when applied to some reference condition, due consideration being made for the time element involved, if the measurements at consecutive sections on a stream agree, it would give to any engineer great confidence in the accuracy of those measurements, subject only to such conditions of error as errors of rating and errors of general method, which would be applicable alike to all points in observation?

Q. What were the sections on the St. Lawrence which have been measured?

A. The only one that has been considered in my testimony is the section at Point Three Points, which is that covered by—being Table Number I, summary of discharges, Three Point Section, St. Lawrence River, F. C. Shenehon, Assistant Engineer, May, 1906, and including 96 observations.

Q. There was a check, was there not, at Little Church Bay?

A. As to that I have no information, as no records of gagings at that section have come into my hands, as being exhibits in this case.

Q. Do you know as a matter of fact whether on the St.

Lawrence River, the measurements were checked by a check section at Little Church Bay?

A. I do not.

Q. That that you last referred to was Williams' Exhibit 25, was it?

A. Williams' Exhibit 25.

Mr. Wilkerson: Do you remember now whether or not the Government's principal witness in presenting these tables upon which the Government relies stated that the observations in the St. Lawrence had been checked by a section in the way in which I have indicated?

A. I do not recall.

Q. But so far as you are concerned, you have made no analyses of the St. Lawrence observations?

A. Except as indicated in the table.

Q. Except as indicated in the table, and no analysis for the purpose of determining how accurately the observations there relied upon check with the section which was measured at Little Church Bay?

A. No.

Q. Referring to the Little Church Bay Section check, do you find now the portion of the record in which that matter is described?

A. Little Church Bay is not mentioned. A section at Nevins Bay, Nevins Point, is mentioned, and the statement—

Q. It appears that the correct name of that section is Nevins Point Section, and not Little Church Bay Section?

A. That is the name that was used by the complainant's witness. The statement is made: "The winter measurement checked the summer measurement within less than one per cent." And in answer to further questions: "They corroborated the sumer measurements, so far as volume is concerned. The range was not sufficient to determine anything regarding the increment."

Q. Now I direct your attention to the fact that it is there stated that there was slow velocity of one foot per second, and that the measurements check within less than 1 per cent. What does that indicate to you as an engineer as to the accuracy of that work?

A. That work was of the same high degree of accuracy in its performance, as the standard established by the work of the United States Lake Survey would lead one to expect.

Q. What was the mean velocity at the Three Point Section? And I refer you in that connection to the report of the Chief of Engineers for the year 1902, page 2803?

A. According to the testimony of the complainant's witness Shenehon, page 498 of the continuously paged record, the current had a mean speed of about one foot per second on this section, referring to Nevins Point.

Q. I am referring to the Three Point Section, and I direct your attention to page 2803 of the report of the Chief of Engineers for the year 1902.

A. According to the testimony of complainant's witness Shenehon, on page 579 of the continuously paged record, in answer to the question, "What was the cross sectional area of the St. Lawrence River at the point where discharge measurements were taken?

A. 51,000 square feet, roundly."

Now, the discharge of the St. Lawrence was approximately 225,000 cubic feet per second, which would give a mean velocity of about 4.4 feet.

Q. Having in mind the fact that the measurement of one of these sections corroborates in the way indicated the measurement of the other, and having in mind the wide divergence of the velocity of the river at the two sections which were measured, what does that indicate to you as an engineer as to the degree of credibility which is to be given to the measurements made by the engineers based upon those observations?

A. Subject always to those sources of error, which would be inherent in both measurements, it indicates exceptionally good work.

Q. Of which the difference of velocity does not appear to be one of the factors which would cause doubt or uncertainty as to the result of the work?

A. Within those ranges, no.

Q. What were the two sections of the Niagara River which were measured?

A. The International Bridge Section and the Open Section so called.

Q. And what were the different conditions as to velocity in the two sections which were there measured?

A. The cross section at the International Bridge is stated by complainant's witness Shenehon, on page 580, to have been 39,000 square feet, and that at the open section 42,000. The discharge reported is about 190,000 cubic feet per second. This would indicate a velocity, an average velocity of about 4.9 feet for the International Bridge Section and about 4.5 feet for the Open Section.

For a discharge of 200,000 cubic feet per second, the aver-

age velocity at the International Bridge Section would be about 5.12, and at the open section about 4.75.

Q. Well now those sections checked with each other, did they?

A. On the average discharge from 1900 to 1907, the equations derived by the complainant from the gagings at these two sections, show a difference of about 2,700 cubic feet per second or a little over ¼ of 10,000 cubic feet per second.

Q. Expressed however in per cent. of the volume of discharge, within what per cent. would it be?

A. Slightly over one per cent.

Q. They check within slightly over one per cent.?

A. Yes, about 1¼.

Q. Now having in mind the facts to which you have heretofore referred in your testimony with reference to the physical conditions at the place of each of these sections, and the fact one was an open section and the other was a bridge section, and the other physical conditions, what does the fact as to the checking of these sections indicate to an engineer, as to the degree of credibility to be given to the work of the Government Engineers in this respect?

A. That so far as the performance of those labors which it was possible for the individual to perform, the work has been exceptionally well done; that whatever errors are present are inherent in both series of observations to practically the same extent.

Q. I wish to direct your attention to another element as affecting the accuracy of the work done in the measurement of these rivers, namely passing boats. That I think you have mentioned several times in your testimony as a disturbing factor, particularly in connection with the prosecution of some work done on the St. Marys River. What were the conditions so far as passing boats were concerned in the three rivers, the St. Clair, the Niagara and the St. Lawrence when they were measured, how did they compare?

A. The effect of passing boats in both the Niagara and the St. Lawrence would have been relatively insignificant. They would I think have been of importance on the St. Clair.

Q. In that respect then there were elements of advantage when the Niagara and St. Lawrence were measured, which were not present when the St. Clair was measured?

A. Yes, sir.

Q. Let us take the situation which was presented to the engineers in measuring the St. Clair River. Is there anything in the presence of Lake St. Clair and in connection with

the effect of Lake St. Clair upon Lake Huron—I mean anything in the presence of Lake St. Clair in the place it is, which injected into that situation an element of complexity which in your opinion was not present in the case of the measurement of either the Niagara or the St. Lawrence?

A. The presence of Lake St. Clair would have only a very limited, if any influence upon the measurement of the quantity of water passing. It has an important influence upon the connection of that quantity of water with the stage of lake to which it is related.

Q. That is the increment?

A. No, that is not the increment. That is with the establishment of the quantity of water which will be delivered for any given stage of lake.

Q. Does it not make the derivation of the increment of the St. Clair River a more difficult problem than it would otherwise be?

A. Than of the other two?

Q. Yes.

A. It does.

Q. It is a harder problem to derive the increment for the St. Clair, other things being equal, by reason of the presence of Lake St. Clair, than it would be to derive the increment of either the Niagara or St. Lawrence. That is an element of complexity that is not present in the other two problems?

A. It is the most serious element of complexity that is encountered in the entire investigation.

Q. Now were there any water gage troubles encountered in the measurement of the St. Clair which caused any difficulty in the measurement of that river?

A. Yes, there were.

Q. What were they?

A. The gagings originally were attempted to be referred to a gage at Fort Gratiot Light. This gage became choked up, the pipe connecting to the gage became choked up with sand, and it was necessary to transfer the reference observations to Harbor Beach, by means of a series of simultaneous observations upon the gage at Fort Gratiot and at Harbor Beach. The gage in Lake St. Clair appears to be of very questionable reliability on account of the inattention, apparently, of the gage reader there.

Q. So there was an element of uncertainty in the St. Clair problem which was not encountered in the case of either Niagara or St. Lawrence?

A. There is an element of uncertainty which was encountered in attempting to connect the gagings of St. Clair River to the lake elevations corresponding to them. Whether there were similar difficulties on the Niagara or the St. Lawrence, I am not informed. It is my impression that there were certain difficulties with the Buffalo gage.

Q. You say that is your—

A. That is an impression that I have. I will say that there has been certain difficulties with the Buffalo gage. Whether they were present during the observations or not, I am not certain, but I noticed that there were some changes of gages at that time, as shown by the gage records.

Q. So far as this Buffalo gage is concerned, you are not to be understood as indicating that you have any specific information of trouble of the kind mentioned by you, are you?

A. No, I simply say that I have seen references to trouble with the Buffalo gage at various times. Whether there was any trouble during these observations, I don't know, and I would anticipate that with the experience that had been had before, that if there were any such that they would have been looking out for such trouble and probably pretty promptly eliminated, if it had been discovered.

Q. That is by that you mean they lose a record of a day occasionally?

A. Well I do not recall specifically what the difficulty was with that gage, but I have known of criticisms of it from time to time.

Q. It was not a very serious difficulty, was it?

A. I don't know; it might or might not have been depending on its location. I could conceive that there might be some question as to whether the gage at all times represented the true surface elevation of Lake Erie in that location. That would, however, have no bearing upon the accuracy of the measurement of the quantity of water passing. Don't let us get confused on that point, that any criticism of a reference gage away from the section would have no bearing whatever on the quantity of water passing at the time the measurement was made.

Q. But it would have a bearing in deducing the law of discharge of the river?

A. It would have a very important bearing on that.

Q. Now I understand you to say that it has been your view in the study which you have made of these observations that the reason for rejecting the law of discharge which flows from

the observations as a mathematical proposition is that Lake Erie at Buffalo is so capricious that it does not remain steady long enough to secure good results in gaging. I understand that to be true?

A. That is an element and an important element.

Q. Well, is it the most important?

A. If you change the word "capricious" to "unstable", I think it would come more clearly conveying the meaning.

Q. That is to say your reason for rejecting the conclusions which necessarily flow from the Niagara observations is that in your view Lake Erie at Buffalo is unstable.

A. That is one reason.

Q. I gathered from your analysis of these figures that that was your prinicpal reason?

A. No, I don't think it is. I think there are other reasons that are as potent.

Q. Well, that is a reason?

A. That is a reason and a strong reason.

Q. You give great weight to that?

A. I do.

Q. In arriving at the conclusion that the same use cannot be made of the observations of the Niagara River as are made of those of the St. Clair and the St. Lawrence?

A. (No response.)

Q. How did you get that impression that Lake Erie at Buffalo was so unstable that it did not remain steady long enough to secure good results in gaging?

A. From its performances at Buffalo, and from its performances at the other end of the lake at Amherstburg. The rise at Buffalo must be followed by a fall at Amherstburg, when the gage at Cleveland remains at the same elevation, and the changes of level at Amherstburg have been sudden and unexpected many times.

Q. Is it your opinion that the elevations of Lake Erie at the head of the Niagara River governed the outflow of that river?

A. Not entirely.

Q. Does it have anything to do with it?

A. Considerable.

Q. Is it a principle factor in determining the outflow of the river?

A. Ordinarily.

Q. By ordinarily you mean what?

A. I mean under ordinary circumstances.

Q. Under ordinary circumstances. That is to say any other circumstance is an exceptional circumstance?

A. Yes.

Q. What are the other circumstances when the volume of water going through the Niagara River is not controlled by the elevation of Lake Erie?

A. By the elevations of Lake Erie where?

Q. At the head of the river.

A. In cases of variable barometric pressure along between the two ends of the lake.

Q. Which lake is this, Lake Erie?

A. Between the two ends of Lake Erie; that is, I could conceive of a barometric pressure at the lower end of the lake, with a lighter one at the upper end, which would cause a tilting of the water in Lake Erie, independent of wind effects, in which the discharge would be larger for the lowered elevation at the east end of the lake than would normally occur there.

Q. Is this purely theoretical, or is that based upon some study which you have made of that subject?

A. Well, it is based upon the well known laws of physics.

Q. Why is that true, in your opinion?

A. Because the pressure producing the discharge is not only the pressure of the weight of the water itself, but pressure of the superincumbent air, and if the pressure of the air changes and the pressure of the water did not change, the effect would be to force out more water. Now if the pressure of the air changes, to maintain a uniform pressure, the pressure of the water must decrease, in other words the water must drop, and consequently measuring your forces producing discharge by the elevation of the surface of the water would cause an apparently lower discharge than might actually be taking place, and conversely.

Q. Is it not a fact that the air column at the Buffalo gage, or at the head of the Niagara River is balanced by the air column in the river two miles below, as at Austin street, and that it is therefore eliminated in causation of flow?

A. That is not necessarily so. Observations which I have made barometrically have indicated to me that where you come in from a broad open reach into a constricted area, particularly such as exists in the neighborhood of a large city where buildings obstruct the free passage of air, that there may be quite sudden and appreciable barometric changes or differences of barometric pressure at the same time, and it is entirely possible that the barometric pressure at Austin street, or even at the International Bridge, might be appreciably different from that at the foot of Lake Erie.

Q. What is your view as to the limit of the variation produced by this cause, which you have just specified?

A. Why it might easily amount to as much as .05 of a foot.

Q. .05 of a foot?

A. Yes.

Q. What percentage of the volume of discharge would that be?

A. About ¾ of one per cent.

Q. Now that is a factor, if I understand the situation that is just as likely to be on the one side as on the other, so that over a period of time there would be a tendency to balance, would there not?

A. Yes. It is not an important consideration, but when you ask the broad general question, I think that it points—

Q. I want some other factor you have in mind as indicating to you as an engineer that you cannot deal with these Niagara observations in the same way as engineers deal with the St. Clair and the St. Lawrence, besides this barometric pressure condition?

A. Well, the barometric pressure condition would apply to the other observations, to some extent at least.

Q. That is to both the St. Clair and the St. Lawrence?

A. Both the St. Clair and the St. Lawrence, probably less to the St. Lawrence than to the St. Clair.

Q. It would be a greater factor at St. Clair than Niagara, wouldn't it, on account of the greater distance between Lake Huron and Lake St. Clair?

A. I would be in doubt about that on account of the question of the elevation of the land and the height of buildings coming in. I think that it is the obstruction by elevations of free flow of the air back and forth that has considerable to do with these changes of barometric pressure that you get on occasions.

Q. You do not regard this as a particularly important factor, as distinguishing the Niagara from the St. Clair and the St. Lawrence?

A. Not at all.

Q. What influence on the discharge of the Niagara River does the elevation of the water at the west end of the lake have, that is to say at Amherstburg?

A. Not very much.

Q. Does it have any?

Mr. Adcock: You mean the elevation different from the elevation at the other end?

Mr. Wilkerson: With the lake tilted up.

A. When the lake is covered with ice, it might have an influence.

Q. We are speaking about the open season, aren't we in this case?

A. Oh, I didn't know that you were,

Q. Now as a matter of fact isn't it a statement of the fact, a statement of a correct fact to say that the flow through the Niagara River is governed by the elevation of the lake at the head of the river?

A. That is substantially accurate, and accurate enough for all practical purposes.

Q. Why did you put in the tables showing an increment derived from the mean of the observations taken at Amherstburg and Buffalo?

A. Because the elevations of Lake Erie upon which discharge is computed is referred to the mean elevation of the lake; that is in all the discussions of the effect of the increment, we have been dealing with the lowering of the lake as a whole, and the true elevation of Lake Erie cannot be represented by any single gage, but requires at least four. We have only three, Buffalo, Cleveland and Amherstburg. The mean elevation of the east and west ends of the lake is perhaps as near an average elevation of the lake as is a gage on the south side of it, and is certainly nearer to a mean elevation than a gage at one end.

Q. But in a series of observations taken over a number of days, the observations at Buffalo must control, do they not?

A. Yes, must control, except that that is not a sufficient control, for the reason that we should also know what the elevation of the lake is on the Canadian shore; that for an accurate comparison we should have the relation between the elevation of the lake at the Buffalo side and at the Canadian side, as there may be appreciable variations between the two sides.

Q. You mean for the control of a single observation, or are you considering water level?

A. I am considering connecting the discharge with the elevation of the lake, whether it be for a single observation, or a series.

Q. At Buffalo?

A. Buffalo or anywhere else; that an observation taken on one side of the lake is not a sufficient establishment of the elevation of the lake controlling discharge to lead to an accurate determination.

Mr. Adcock: Of the increment?

A. No, the relation between discharge and stage.

Mr. Wilkerson: Are you aware of the fact that under the supervision of the Deep Waterways Commission there was a gage maintained on the Canadian side as well as on the American side?

A. I recall that there were gages on the Canadian side of the river during some of the work of the Board of Engineers on Deep Waterways.

Q. And are you aware of the fact that they corresponded so accurately that as a result of the experiment, it led to the abandonment of one of them?

A. I am not aware of that fact. I am not surprised that it has been abandoned, but even with the experience that might have been gained in a short period of time such as that covered by the observations of the Board of Engineers on Deep Waterways, it does not seem to me to be conclusive.

Q. Have you ever examined the observations?

A. I have not.

Q. Made any study of them?

A. I have not, of the comparison of those two gages.

Q. Do you know the period over which they were taken?

A. I do not, but I know the period during which the Board of Engineers on Deep Waterways were in operation, approximately.

Adjourned to Tuesday July 22, 10 a. m.

Tuesday, July 22, 10 a. m.

GARDNER S. WILLIAMS, resumed the stand for further cross-examination by Mr. Wilkerson and testified as follows:

Q. We were speaking yesterday about the checking of different cross-sections of a river, and with reference to what is meant by the instability of a river. You expressed your opinion that the Niagara River was too unstable to be dealt with in the way in which engineers generally deal with rivers in this respect. Did you have in mind a statement appearing on page 284 of the report of the Board of Engineers on Deep Waterways, part 1? I direct your attention specifically to the page which I have indicated, and read the following:

"In connection with the direct observations made to determine the outlet from the lake at different stages, continuous

readings were made of the gages from which the slope of the foot of the lake and the river surface has been computed for the corresponding volume of discharge, which with the carefully measured cross-sections of the river shown on plate 8 y furnishes a check on the equation of discharge given above and shows a discrepancy of less than 3 per cent. for maximum volume of outflow used in this discussion"?

A. I am not aware that I expressed the opinion that the Niagara River itself was too unstable. I did express the opinion that the variation between Lake Erie and the Niagara River was too unstable, and I still maintain that conclusion.

Q. In your opinion, why is it that the relation of the discharge of the Niagara River and Lake Erie is such that the law of discharge cannot be derived?

A. The first reason is on account of the instability of Lake Erie. In order to create the flow through the Niagara River that corresponds to any stage or elevation of the surface of Lake Erie, time must be given for the river to be affected clear to the Falls.

Lake Erie does not remain in one position long enough for this effect to take place, or if it does it is only on very rare occasions.

A second reason is that when Lake Erie rises at Buffalo it almost—when it rises as the effect of winds on account of which it is vibrating daily almost, as the plottings in exhibit, William's Exhibit 35, chart 4, will show, wherein are plotted the gage readings at Buffalo daily, as derived from William's Exhibit 29, there is presented graphically the fluctuations of the surface of the lake at Buffalo. Now when the water rises at Buffalo and lowers at Amherstburg, that rise at Buffalo is caused by a flow towards Buffalo along the surface of the lake created by the action of the wind. At the same time there is a counter flow from Buffalo towards Amherstburg through the lower portions of the water; during the time that the lake is rising, the flow towards Buffalo necessarily is greater than the flow back towards Amherstburg, but at the moment that the lake becomes stable in any position the flows in the two directions, are for the time being, alike. As the lake at Buffalo begins to fall, the flow towards Amherstburg increases.

Now, it does not take an elaborate computation to show that the velocity of flow towards Amherstburg to be observed at such times and with such differences of elevation, as have frequently occurred between Buffalo and Amherstburg; the flow away from the mouth of the Niagara River is greater than the

flow into it. At those times the discharge—I should say the velocity of flow away from the mouth of the Niagara River is greater than the velocity into it. At those times the discharge for the Niagara River, while corresponding to the high stage of the lake, will necessarily be less than they would be were the lake at that elevation throughout its entire area.

Consequently, a considerable proportion of the measurements of discharge of the Niagara River at the higher stages give a discharge lower than those which naturally belong to the elevation of the lake to which they are alleged to correspond. This is outside of the fact that the discharge of the river does not come to that corresponding to the elevation of the lake for some considerable time after the lake has risen to the point, as it is necessary to fill a prism extending from the Falls to the entrance to the lake with water, the base or upper end of which is the change of elevation of Lake Erie; the lower end is zero and the area is the area of the surface of the river between the outlet of Lake Erie and Niagara Falls before the conditions of flow corresponding to that elevation of the lake are established.

Q. By that you mean that a velocity of approach enters in the movement of Lake Erie towards or from the river?

A. A velocity both of approach and of departure.

Q. In your opinion what is the measure of that velocity?

A. The measure of that velocity would be the volume of water which changes ends of the lake and the space through which it has to pass in that motion.

Q. What in your opinion is the velocity, say within a mile of the head of the river?

A. Within a mile of the head of the river, that is a matter of computation. It would be the volume of water which passes the section a mile from the river divided by the area through which it passes.

Q. Have you any opinion as to how much it would be?

A. It will vary greatly because sometimes the differences of elevation between Amherstburg and Buffalo are zero, frequently they are .6 of a foot, not for long periods; not infrequently they are more than a foot. On occasions during which observations were made, they have been something over three feet; and there are records, I am informed, of a difference of elevation between Buffalo and Amherstburg approaching 12 feet.

Q. That is sometimes one is higher and sometimes the other is higher?

A. Yes.

Q. Those are things that in the long run, one practically neutralizes the other?

A. That is correct. If you should take observations every day for a long period of time and refer them to the Cleveland gage and the observations were accurate, it would be possible to get an increment of Lake Erie that would be applicable in this case; but it is not possible by a reference to the Buffalo gage unless the observations should extend over a very much longer period of time.

Q. With Amherstburg one foot below Buffalo, in your opinion what volume of discharge would be added to the Niagara River?

A. That being the stable condition? That being the condition, having arrived at that condition you mean?

Q. One of these derivation conditions?

A. Lake rising or lake falling?

Q. Would it make any difference? Give both the rise and fall.

A. It would make a difference; if it is falling the tendency would be to decrease the discharge. If it is rising the tendency would be to increase it to a less extent.

Q. Well, take the case where the rise at Buffalo was within the last two hours preceding the taking of the observation.

A. A rise of a foot at Buffalo and a fall of a foot at Amherstburg?

Q. Where Amherstburg is a foot below Buffalo?

A. Where Amherstburg is a foot below? I should have to have some cross sections of the lake, in order to make that computation; but I wish to assure you that it is a figure well worth consideration, in dealing with this problem.

Q. Have you made any study of the Niagara observations for the purpose of determining whether the effect of a rising stage is shown in the discharge measurement?

A. I have not, any very extensive one.

Q. And from such examination as you did make, what was the conclusion at which you arrived?

A. I arrived at no conclusion from that examination, except that it is probable that the measurements are too inaccurate to represent these conditions.

Q. Did you not make any attempt to find that in the observations?

A. I have not, specifically.

Q. Take these observations during the two periods which are under consideration, 1899 to 1900 and 1907 to 1908, as I

understand it, how many times does it appear from those observations that there was a rise of as much as a foot at Buffalo within two hours?

A. As far as I recall, I have seen no data which would give that information.

Q. I direct your attention to hourly water levels as recorded by the self-registering gage at the United States Lake Survey, Buffalo, New York, during the months of June, July and August, 1908. I wish you would take those tables and state for each day what the variation in level is, and how much the variation for each day is from the mean level for the particular day, as indicated on the table?

A. I do not see that that information is in the tables here in such form as to be gotten readily. It will take some time to get what you want, as it involves both a searching through the columns here, if I understand the table, of 24 readings each day, and a subtraction from the mean; and it is a thing that any clerk can do. I have no reason to question the record here, or criticise it.

Q. I show you a document in three parts, consisting of three sheets, being marked table XLVII, 1, 2, and 3 respectively. They purport to be certain figures of the United States Lake Survey, Preservation of Niagara Falls, Elevation of Lake Erie, derived from discharge of Niagara River, International Bridge, Buffalo, New York, for the years 1907 and 1908, during the months of October and November, 1907, and June, July and August, 1908; and I ask you to state what appears on this table with reference to the change of lake level during the measurements; and in connection with the question, I ask the Commissioner to mark this Williams' Exhibit Cross Examination Number One; the same being the document referred to on page 473 of the record as one of the tables furnished to the counsel for the defendant.

Mr. Adcock: Counsel for the defendant state that they have no record or recollection of having or receiving the table.

Mr. Wilkerson: There is also a reference to this table in the plate which was introduced in evidence by the Complainant, based upon these Niagara River observations.

Mr. Adcock: I do not believe that is shown on the plate introduced in evidence. That has a reference to the table, but there is a statement that there were observations made in 1907 and 1908 on that plate referred to.

The Witness: You want an answer so this may be put in the record?

Mr. Wilkerson: Yes.

The Witness: Columns 5 and 6 of Williams Exhibit Cross Examination Number 1, purport to show the change of lake level during measurement for the several measurements which are identified by date in column number 2 and by number in column number 1, being measurements of the discharge of Lake Erie taken during the years 1907 and 1908.

Column 5 purports to give the rise in feet of lake level during the measurement and column number 6 purports to give the fall in feet during the time of measurement.

Mr. Wilkerson: I think you might as well incorporate this whole table in the record at this point, so there will be no misunderstanding about it.

U. S. LAKE SURVEY

PRESERVATION OF NIAGARA FALLS, ELEVATION OF LAKE ERIE, DERIVED FROM DISCHARGE OF NIAGARA RIVER, INTERNATIONAL BRIDGE, BUFFALO, N. Y.

Number	Date 1907	Wind		Change of Lake Level During Measurement		Fall Lake Erie to Bridge Feet	Meter U. S. L. S.	Discharge Cubic Feet Per Second	Lake Erie Elevation Feet		Difference Feet	
		Direction	Estimated Velocity Miles	Rise Feet	Fall Feet				Computed	Observed	Lake High	Lake Low
a	b	c	d	e	f	g	h	i	k	l	m	n
1	Oct. 21			0.02	0.13	4.95	2B	224070	573.26	572.98		0.28
2	22	S. W.	25	0.14	0.00	4.94	2B	225850	573.34	573.12		0.22
3	22	S. W.	30	0.09	0.07	5.03	4A	235600	573.75	573.54		0.21
4	22	S. W.	10	0.03	0.41	4.93	1B	225700	573.33	573.37	0.0'	
5	23	N. W.	25–30	0.13	0.26	4.71	1B	202510	572.26	572.42	0.16	
6	23	N. W.	30	0.29	0.01	4.75	1B	202870	572.27	572.39	0.12	
7	23	N. W.	30–20	0.21	0.02	4.86	2B	211320	572.67	572.61		0.06
8	24	N. W.	6	0.08	0.04	4.93	1B	212030	572.70	572.66		0.04
9	24	N. W.	6	0.00	0.16	4.85	2B	215140	572.84	572.57		0.27
10	24	S. W.	8	0.01	0.11	4.84	2B	209230	572.57	572.54		0.03
11	24	S. W.	10	0.16	0.07	4.84	1B	207170	572.47	572.41		0.06
12	25	N. W.	15–30	0.00	0.38	4.58	1B	205550	572.40	572.57	0.17	
13	25	N. W.	20	0.12	0.01	4.71	2B	198900	572.10	572.35	0.25	
14	25	N. W.	20	0.31	0.00	4.78	2B	207120	572.48	572.54	0.06	
15	26	N. E.	6	0.02	0.07	4.87	2B	205470	572.40	572.49	0.09	
16	26	N. E.	6	0.16	0.04	4.86	1B	208220	572.53	572.48		0.05
17	26		0	0.06	0.14	4.65	1B	196450	571.99	572.10	0.11	
18	26		0	0.02	0.24	4.60	2B	190050	571.72	571.94	0.22	
19	28	N. W.	35	0.03	0.32	4.61	2B	208370	572.53	572.48		0.05
20	28	N. W.	35	0.07	0.08	4.51	1B	196210	571.98	572.13	0.15	
21	28	N. W.	35	0.05	0.02	4.69	1B	204220	572.33	572.35	0.02	
22	28	N. W.	35	0.32	0.00	4.90	1B	211430	572.67	572.63		0.04

23		29	N. W.	10	0.10	0.04	4.92	1B	213770	572.78	572.82	0.04	
24		29	N. W.	20	0.03	0.15	4.76	2B	210540	572.64	572.64	0.00	0.00
25		29	N. W.	25	0.04	0.29	4.74	2B	212070	572.70	572.56		0.14
26		30	N. E.	3	0.14	0.08	4.85	2B	212380	572.72	572.44		0.28
27		31		0	0.06	0.06	4.84	2B	214080	572.80	572.45		0.35
28		31	N. W.	2	0.02	0.10	4.81	2B	208650	572.54	572.38		0.16
29		31	S. E.	3	0.08	0.16	4.67	2B	201650	572.22	572.19		0.03
30	Nov.	1	S. E.	10	0.13	0.10	4.57	46A	208330	572.53	572.32		0.21
31		1	S. E.	10	0.15	0.07	4.81	46A	211080	572.66	572.40		0.26
32		1	S	2	0.04	0.09	4.77	46A	210220	572.62	572.39		0.23
33		1	S.	2	0.05	0.10	4.78	46A	209780	572.60	572.38		0.22
34		2	S.	40	0.33	0.07	5.04	46A	219360	573.04	572.80		0.24
35		2	S.	40	0.03	0.23	4 99	46A	216660	572.92	572.84		0.08
36		2	S.	40	0.02	0.30	4.80	46A	207810	572.50	572.55	0.05	
37		4	W.	4	0.09	0.01	5.01	46A	224720	573.28	573.00		0.28
38		4	W.	4	0.12	0.20	4.85	46A	213380	572.76	572.87	0.11	
39		4	W.	7	0.15	0.02	4.79	46A	213230	572.76	572.81	0.05	
40		4	S. W.	10	0.04	0.23	4.94	46A	218840	573.02	572.93		0.09
41	June	26	S. E.	4	0.00	0.26	4.96	14B 1	228820	573.46	573.39		0.07
42		27	S. W.	3	0.12	0.01	5.17	14B 1	219030	573.03	573.28	0.25	
43		27	W.	5	0.07	0.03	5.23	1B 1	229760	573.51	573.49		0.02
44		27	W.	5	0.08	0.10	5.20	1B 1	227780	573.42	573.48	0.06	
45		29	W.	8	0.39	0.15	4.90	1B 1	225460	573.32	573.32	0.00	0.00
46		29	S. W.	7–20	0.10	0.22	4.97	1B 1	227050	573.39	573.39	0.00	0.00
47		30	S. W.	8	0.15	0.17	5.11	14B 1	239770	573.94	573.71		0.23
48		30	S. W.	7–12	0.08	0.37	5.05	14B 1	236730	573.80	573.60		0.20
49		30	S. W.	15	0.16	0.24	4.99	1B 1	221500	573.15	573.40	0.25	
50		30	S. W.	10	0.14	0.15	4.95	1B 1	219980	573.08	573.28	0.20	
51	July	2	E.	5	0.07	0.16	4.85	14B 4	213620	572.77	572.92	0.15	
52		2	N. E.	6–25	0.18	0.07	4.88	14B 4	218670	573.02	572.91		0.11
53		2	N. E.	15	0.06	0.14	4.89	1B 1	208410	572.54	572.85	0.31	
54		2	N. E.	20–7	0.03	0.17	4.88	1B 1	211690	572.69	572.77	0.08	
55		6	S. W.	15	0.06	0.09	5.04	14B 4	230740	573.54	573.52		0.02
56		6	S. W.	12	0.00	0.27	4.96	14B 4	220380	573.10	573.34	0.24	
57		6	S. W.	10	0.03	0.17	4.90	1B 1	240590	573.11	573.23	0.12	
58		6	S. W.	15	0.21	0.12	4.85	1B 1	217380	572.95	573.07	0.12	
59		7	S. W.	18	0.12	0.03	5.15	14B 4	222100	573.17	573.54	0.37	
60		7	S. W.	18	0.08	0.19	5.20	14B 4	230400	573.53	573.54	0.01	
61		8	N. W.	38	0.51	0.11	5.25	15B 1	239400	573.92	573.80		0.12

U. S. LAKE SURVEY—Continued

PRESERVATION OF NIAGARA FALLS, ELEVATION OF LAKE ERIE, DERIVED FROM DISCHARGE OF NIAGARA RIVER, INTERNATIONAL BRIDGE, BUFFALO, N. Y.

Number	Date 1908	Wind		Change of Lake Level During Measurement		Fall Lake Erie to Bridge Feet	Meter U. S. L. S.	Discharge Cubic Feet Per Second	Lake Erie Elevation Feet		Difference Feet	
		Direction	Estimated Velocity Miles	Rise Feet	Fall Feet				Computed	Observed	Lake High	Lake Low
a	b	c	d	e	f	g	h	i	k	l	m	n
62	8	N. W.	38	0.00	0.66	5.00	15B 1	224320	573.27	573.46	0.19	
63	8	N. W.	10	0.12	0.07	5.18	15B 1	231060	573.55	573.63	0.08	
64	8	S. W.	25–40	0.20	0.13	5.06	15B 1	229470	573.49	573.54	0.05	
65	10	S. W.	6	0.04	0.06	5.23	1B 1	223380	573.23	573.30	0.07	
66	10	S. W.	6	0.09	0.07	5.20	1B 1	220520	573.10	573.27	0.17	
67	10	S. W.	6	0.01	0.04	5.15	15B 3	230220	573.52	573.30		0.22
68	10	S. W.	6	0.05	0.09	5.08	15B 3	222770	573.20	573.23	0.03	
69	16	S. W.	5–15	0.23	0.02	5.04	1B 8	229180	573.48	573.33		0.15
70	16	S. W.	8	0.02	0.11	5.03	1B 8	231750	573.58	573.39		0.19
71	18	S. W.	10	0.00	0.93	4.88	1B 8	234300	573.70	573.69		0.01
72	18	S. W.	10	0.09	0.31	4.69	1B 8	221470	573.14	573.21	0.07	
73	20	N. W.	4	0.00	0.21	4.83	14B 7	223100	572.22	573.24	0.02	
74	20	S. W.	8	0.06	0.13	4.77	14B 7	222480	573.19	573.10		0.09
75	20	N. W.	3	0.09	0.02	4.83	1B 8	222340	573.18	573.00		0.18
76	21		0	0.26	0.43	4.81	14B 7	216400	572.91	573.16	0.25	
77	21	N. W.	10	0.14	0.21	4.73	14B 7	213930	572.78	572.91	0.13	
78	21	N. W.	10	0.21	0.03	4.80	14B 7	215200	572.85	573.08	0.23	
79	22	S. W.	5	0.11	0.07	4.95	14B 7	228150	573.43	573.38		0.05
80	22	S. W.	12	0.10	0.02	4.94	1B 8	231250	573.56	573.42		0.14
81	July 22	S. W.	10	0.05	0.10	4.83	1B 8	224090	573.26	573.29	0.03	
82	22	N. W.	5	0.04	0.09	4.81	1B 8	226780	573.37	573.20		0.17
83	23	N. W.	5	0.16	0.08	4.80	1B 8	221610	573.14	573.00		0.14

84		23	N. W.	5	0.06	0.11	4.84	1B	8	221950	573.16	573.08		0.08
85		23	N. E.	8	0.13	0.14	4.83	1B	8	222880	573.20	573.12		0.08
86		23	N. E.	8	0.06	0.06	4.81	1B	8	222660	573.19	573.09		0.10
87		24	N. E.	5	0.06	0.03	4.78	14B	7	213120	572.75	572.84	0.09	
88		24	N. E.	5	0.14	0.12	4.80	14B	7	208520	572.54	572.87	0.33	
89		24	N. E.	12	0.15	0.65	4.70	1B	8	216060	572.90	572.85		0.05
90		24	N. E.	10	0.18	0.25	4.72	1B	8	212990	572.74	572.72		0.02
91		25	N. E.	4	0.14	0.12	4.86	14B	7	220410	573.09	573.20	0.11	
92		25	N. E.	6	0.15	0.19	4.72	14B	7	218340	573.00	573.00	0.00	0.00
93		25	N. E.	10	0.13	0.18	4.84	1B	8	225010	573.30	573.08		0.22
94		27		0	0.05	0.01	4.75	1B	8	221150	573.13	573.02		0.11
95		27	N. E.	3	0.05	0.02	4.76	1B	8	216700	572.93	573.00	0.07	
96		29	S. W.	5	0.06	0.05	4.81	14B	7	221010	573.13	573.10		0.03
97		29	S. W.	3	0.06	0.04	4.86	14B	7	226680	573.37	573.18		0.19
98		30	S. W.	8	0.02	0.07	4.85	14B	7	224840	573.29	573.21		0.08
99		30	S. W.	8	0.02	0.09	4.83	14B	7	221770	573.16	573.15		0.01
100		30	S. W.	10	0.10	0.03	4.83	1B	8	226800	573.38	573.15		0.23
101		31	S. W.	8	0.03	0.06	4.84	1B	8	227870	573.42	573.20		0.22
102		31	N. W.	15	0.00	0.03	4.81	1B	8	222820	573.20	573.20		0.00
103		31	N. W.	15	0.04	0.08	4.74	1B	8	223320	573.22	573.08		0.14
104		31	N. W.	15	0.12	0.00	4.78	1B	8	226370	573.35	573.11		0.24
105	Aug.	1	N. E.	10	0.26	0.01	4.90	14B	7	212960	572.74	572.67		0.07
106		1	N. E.	18	0.22	0.01	5.10	14B	7	221310	573.13	573.07		0.06
107		4	S. W.	15	0.04	0.28	4.79	14B	7	220370	573.09	573.18	0.09	
108		4	S. W.	15–8	0.09	0.07	4.82	14B	7	218710	573.02	573.18	0.16	
109		4	S. W.	15	0.17	0.03	4.76	1B	8	227110	573.39	573.06		0.33
110		4	S. W.	8	0.14	0.05	4.71	1B	8	225180	573.31	572.98		0.33
111		5	S. W.	8	0.64	0.06	4.98	1B	8	234750	573.72	573.39		0.33
112		5	S. W.	8	0.02	0.48	5.06	1B	8	237330	573.83	573.61		0.22
113		5	S. W.	35	0.25	0.80	5.05	14B	7	234570	573.71	573.77	0.06	
114		5	S. W.	20	0.30	0.47	5.02	14B	7	238630	573.89	573.88		0.01
115		6	S. W.	50	0.06	0.02	4.86	14B	7	233020	573.64	573.56		0.08
116		6	S. W.	20	0.00	0.69	4.71	14B	7	225050	573.30	573.27		0.03
117		6	S. W.	30	0.29	0.03	4.67	1B	8	213850	572.78	572.94	0.16	
118		6	S. W.	20	0.05	0.26	4.77	1B	8	217220	572.94	573.03	0.09	
						Means						572.586		

Mr. Wilkerson: Q. The figures to which attention has just been directed appear on pages 46, 47 and 48 of the document entitled "Preservation of Niagara Falls."

A. They do, but I am informed that the copy in the report "Preservation of Niagara Falls" has not been checked by the author of the table, and two typographical errors have been discovered in it up to the present time.

Q. What were they?

A. Errors as to the year in which the gagings at the bottom of page 46 and the top of page 47—

Q. That is to say observation numbered 41?

A. 41 was taken in 1908.

Q. And 46 was taken in 1907?

A. No, 46 was taken in 1908 also. The report shows all the observations that have been taken in 1907, whereas the major part of them were taken in 1908.

Mr. Adcock: Q. And I understand those inaccuracies were discovered by simply a casual reading of the exhibit, of the record?

A. They were called to my attention a moment ago by the principal witness for the Government.

Mr. Wilkerson: Q. How much time does it take ordinarily to make one of these observations?

A. I do not recall that that time has been specifically stated in any of the testimony regarding the Niagara River. Do you remember whether you stated it, Mr. Shenehon?

Mr. Shenehon: I do not remember whether I stated it. I know about the time.

The Witness: What I asked was whether there was a statement of it. My impression is about two hours.

Mr. Shenehon: That is right.

Mr. Wilkerson: Your understanding is that it takes about two hours to make one of the discharge measurements?

A. My understanding is that it takes about two hours to make one of the discharge measurements, according to the methods that have been used.

Q. Now this table number 47 to which I have directed your attention, identified as Exhibit 1, Cross Examination of Williams, shows the change of lake level during the time of measurement?

A. Yes, it purports to.

Q. And the same is true of Table Number 1, summary of discharges of International Bridge Section of the Niagara River, the observations were made in 1898 and 1899?

A. It was regarding that latter table that I was testifying, but the statement is true in regard to both.

Let me make a suggestion that may simplify reference to these exhibits, unless you specially desire to have that exhibit identified, that is to have it as number 1, why not let it appear consecutively in my testimony, and you can enter a note that the exhibit is introduced in cross-examination, beginning with number so and so.

Mr. Wilkerson: We will have to get the matter of numbering these exhibits straightened out. It appears to be an exhibit which apparently was produced at the taking of the Government's direct testimony, and it was stated that it was part of the information which was furnished to the defendant; so properly it goes into the record as one of our exhibits.

Now, for convenience, in connection with your testimony, I have referred to it as Exhibit number 1 in your cross-examination, but we will have to give it a number when we come to print this record; it will have to be numbered as a Government exhibit. We will have to go through the exhibits and arrange them in that way because it is really one of our exhibits.

Mr. Adcock: It is absolutely confusing, the way those exhibits are in there; tables and so forth all mixed up, A, B, C and so on, and there is no way of arranging them.

The Witness: They were only marked for identification. There were I think seven exhibits put in by the Government in their direct testimony if I remember right.

Mr. Wilkerson: Q. Referring to these Niagara River observations, and to the column which indicates the change of the lake during the time of making the observation; let us take the first observation that appears in the 1898 observations: Measurement number 5 September 10, 1898, shows that during the time of the measurement the lake rose .02 of a foot, and fell a little more than .2 of a foot?

A. That is correct.

Q. And taking number 6 observation made on the 13th of September, 1898, that shows that during the time of the measurement there was a rise of .06 of a foot and a fall of .22 of a foot?

A. That is corerct.

Q. Take observation number 7, the same being made on the 13th day of September, 1898. That shows no rise, and a fall of .21 of a foot?

A. That according to this record was on the 13th.

Q. The 13th of September, 1898?

A. No rise, and a fall of .21.

Q. And observation number 8 for September 15, 1898, shows a rise of .07 and a fall of .11?

A. Correct.

Q. And number 9 for September 15, 1898, shows a rise of .44 and a fall of .02?

A. Correct.

Q. And number 10 for the 17th of September, 1898, shows a rise of .06 and a fall of .15. Number 11 for September 17, a rise of .18 and a fall of .06. Number 12 for September 20th, shows a rise of .13 and a fall of .20. Number 13 for September 20th, 1898, shows a rise of .15 and a fall of .06. Number 14 for September 22, shows a rise of .02 and a fall of .12?

A. You said the 15th or 14th?

Q. 15th.

A. Number 15 shows a rise of .25 and a fall of .07 according to this.

Q. Number 14 is the last I read.

A. I misunderstood. I thought you said 15, and that is what I caught here.

Q. Considering this table as a whole, Mr. Williams, what in your opinion does it indicate to an engineer as to the stability of the lake during the larger portion of the periods covered by these observations?

A. Understanding by "periods covered by these observations" to mean the time elapsing between the moment of beginning and the moment of closing a single observation of discharge, it shows that the lake was reasonably stationary at that time.

Q. Would you say the same thing with reference to the observations which are set down in what has been called table XLVII, the same being the observation on "Preservation of Niagara Falls" for the years 1907 and 1908?

A. Without a minute examination of the table I can't say that that is so. There should be an exception made in regard to certain observations in both tables, where the rise and fall becomes an appreciable factor, or at least is larger than I would consider represented stable conditions; as for example observation 113 of William's Exhibit 1 on Cross Examination Number 1, where there is a rise of .25 and a fall of .8. That is followed by one the same day, wherein the rise was .3 and the fall was .47.

Also a few of those observations in William's Exhibit 24,

as notably observation 58 on November 9, which shows a rise of .45 and a fall of .27; observation 62 on the 10th shows a rise of .67 and a fall of .03.

These are rather exceptional and considering the series as a whole I would say that the stage of the lake, the elevation of the lake was reasonably constant during the observations of discharge.

Mr. Adcock: You mean during the time—

A. During the actual time the observation of discharge was being made.

Mr. Wilkerson: Q. Referring specifically to observation number 113 in table number XLVII William's Exhibit on Cross Examination number 1, and directing your attention to the last two columns of the table relating to that observation, I will ask you whether it is not a fact that observation appears to be consistent with the other observations appearing in the table?

A. Let me have that exhibit will you please until I see if this is an actual transcript (examining same).

Q. (Question read.) A. So far as the comparison shows between a computed elevation of the lake based upon a discharge equation and the observed elevation of the lake, I see nothing to particularly mark this observation from the other. In fact the coincidence of the two quantities, the computed elevation and the actual elevation is closer than in several others of the series.

Q. You referred to one or two others, which you refer to as being rather exceptional. What did the table show with reference to those, as to their being consistent with the other observations?

A. To answer your question specifically, the other observation referred to in this table was number 114. I do not find that similar information is given in regard to the previous measurements, but so far as observation number 114 goes, the coincidence is even closer, very much closer, than in observation 113. I would say however that I do not wish my answer to the previous question to be misunderstood. The question that was asked me was whether those elevations given in this table indicated a stability of the lake surface during the measurements. Now, to my mind, the instability of the lake surface during the particular hours of the measurement can be quite readily corrected, the stability or instability can be quite readily taken care of in the reduction of the observations, and I assume it has been.

Q. I call your attention to observations Nos. 57, 58, 60 and 61, and ask you to state what appears as to the change of lake during the measurements and also what appears as to the effect which the changing lake stage appears to have had upon the volume of discharge.

A. Observation 57 shows a rise of nothing during the observation; a fall of .46 of a foot.

Observation 58 shows a rise of .45 during the observation and a fall of .27. The elevation of the lake in observation 58 was .03 of a foot higher than in observation 57. The discharge was increased 1,600 cubic feet, which would indicate an increment of 53,000.

That elevation for observation 57 is given here as 570.11 and for 58 as 570.14. The discharge for observation 57 is given as 155,600 cubic feet per second, and the discharge for observation 58 is given at 157,200 cubic feet per second.

Mr. Adcock: Q. The difference is how much?

A. The difference I make 1,600 cubic feet per second. Dividing that by .03 seems to give 53,000 as the increment.

Mr. Wilkerson: Q. Is it your opinion as an engineer that increments can be derived in that way?

A. That, if the gaugings were accurate, that is the increment indicated by those two discharges. If the measurements were accurate, that is the increment of those two conditions.

Q. Well, is it your opinion as an engineer that engineers would take the derived increment from two observations, where there was a difference of only .03 of a foot in the level?

A. If the errors of the observation are as stated by the principal witness for the complainant, namely, something like 1 per cent., an increment so derived ought not to be in error more than the 1 per cent.

Q. Referring to the column at the extreme right of the table, with reference to these observations, what is the discrepancy as indicated by the percentage there shown?

A. Well, I don't know what that percentage represents. They are, opposite observation 57, minus 0.9, and opposite observation 58, minus 0.2.

Q. Does that indicate to you as an engineer whether or not the rising or falling stage has an effect upon the volume of discharge; and if so, what?

A. That shows on the face of it that the larger discharge occurs on the rising stage.

Q. By what per cent.?

A. Well, that depends altogether upon what the correct value of the increment is, and without knowing that I can't say. In the increments the value which was assumed in the complainant's equation, it is about 100 per cent. It affects the increment to the extent of about 100 per cent.

Recess to 3 p. m.

After recess, 3 p. m.

GARDNER S. WILLIAMS resumed the stand for further cross-examination by Mr. Wilkerson and testified as follows:

Q. You have the three plates that were submitted to you this morning?

A. Yes.

Mr. Adcock: You mean the photographs?

Mr. Wilkerson: I will ask you now to refer to the three copies of hourly water levels as recorded at Buffalo, during the months of June, July and August, 1908, which for the purpose of this question I ask to have marked "Williams Cross-Examination Exhibit 2," the same being three sheets, and ask you to state what those observations show with reference to the variation of the water level of Lake Erie, say, the difference between the maximum and the minimum and the variation from the mean at Buffalo.

(Document referred to in the question was marked Williams Cross-Ex. 2.)

BUFFALO GAGE.

COMPARISONS OF HOURLY READINGS.

June. 1908.	Maximum Less Mean.	Mean Less Minimum.	Maximum Less Minimum.
1	0.37	0.36	0.73
2	0.38	0.25	0.63
3	0.31	0.25	0.56
4	0.21	0.30	0.51
5	0.22	0.16	0.38
6	0.17	0.17	0.34
7	0.07	0.11	0.18
8	0.56	0.26	0.82
9	0.43	0.44	0.87
10	0.21	0.24	0.45
11	0.39	0.36	0.75
12	0.13	0.21	0.34
13	0.24	0.29	0.53
14	1.56	0.86	2.42
15	0.39	0.43	0.82
16	0.25	0.19	0.44
17	0.33	0.30	0.63
18	0.20	0.17	0.37
19	0.47	0.36	0.83
20	0.50	0.47	0.97
21	0.57	0.30	0.87
22	0.36	0.24	0.60
23	1.02	1.08	2.10
24	0.53	0.45	0.98
25	0.39	0.27	0.66
26	0.35	0.33	0.68
27	0.29	0.25	0.54
28	0.24	0.28	0.52
29	0.78	0.51	1.29
30	0.53	0.38	0.91

BUFFALO GAGE.

(Continued.)

COMPARISONS OF HOURLY READINGS.

July, 1908.	Maximum Less Mean.	Mean Less Minimum.	Maximum Less Minimum.
1	0.26	0.26	0.52
2	0.36	0.38	0.74
3	0.22	0.21	0.43
4	0.30	0.19	0.49
5	0.55	0.41	0.96
6	0.28	0.28	0.56
7	1.10	0.46	1.56
8	0.35	0.37	0.72
9	0.23	0.20	0.43
10	0.10	0.08	0.18
11	0.20	0.29	0.49
12	0.24	0.26	0.50
13	0.59	0.41	1.00
14	0.36	0.43	0.79
15	0.57	0.36	0.93
16	0.42	0.42	0.84
17	0.67	0.78	1.45
18	0.81	0.61	1.42
19	0.30	0.32	0.62
20	0.23	0.23	0.46
21	0.35	0.33	0.68
22	0.27	0.16	0.43
23	0.15	0.14	0.29
24	0.37	0.36	0.73
25	0.35	0.12	0.47
26	0.18	0.21	0.39
27	0.17	0.18	0.35
28	0.09	0.13	0.22
29	0.14	0.16	0.30
30	0.16	0.08	0.24
31	0.22	0.40	0.62

BUFFALO GAGE.

(Continued.)

COMPARISONS OF HOURLY READINGS.

August, 1908.	Maximum Less Mean.	Mean Less Minimum.	Maximum Less Minimum.
1	0.46	0.53	0.99
2	0.32	0.85	1.17
3	0.24	0.42	0.66
4	0.52	1.08	1.60
5	0.63	0.67	1.30
6	0.77	0.67	1.44
7	0.25	0.29	0.54
8	0.21	0.24	0.45
9	0.33	0.33	0.66
10	0.24	0.28	0.52
11	0.23	0.21	0.44
12	1.08	0.50	1.58
13	0.99	0.46	1.45
14	0.22	0.36	0.58
15	0.36	0.46	0.82
16	0.28	0.37	0.65
17	0.41	0.45	0.86
18	0.28	0.52	0.80
19	0.58	0.39	0.97
20	0.20	0.34	0.54
21	0.17	0.13	0.30
22	0.37	0.30	0.67
23	0.16	0.07	0.23
24	0.16	0.18	0.34
25	0.38	0.55	0.93
26	0.58	0.50	1.08
27	0.71	0.48	1.19
28	0.24	0.31	0.55
29	0.54	0.22	0.76
30	0.16	0.12	0.28
31	0.12	0.13	0.25

Mr. Austrian: Those computations, Mr. Williams, were made from Williams Cross-Ex. 2, were they not?

A. They were.

Q. And this document Cross-Exhibit 2, was handed to you for the first time this morning and those computations were made by your assistant during the noon recess?

A. They were.

Mr. Adcock: Have you given us the tables showing the hourly elevations during the remaining period of the gagings? I want the record to show that we make request on the complainant for those tables which we understand the complainant now has in his possession here at the hearing, and which we are advised by complainant's counsel supplement the three sheets known as Complainant's Exhibit 2, carrying readings for continuous periods much beyond those indicated on this exhibit. And the Government's counsel very courteously and kindly now hands to defendant's counsel the documents now called for.

Mr. Wilkerson: Just state, Mr. Shenehon, which ones of the tables were produced.

Mr. Shenehon: Photographs of the actual record of the United States Lake Survey for the Buffalo gage for the month of June, 1899, July, August, September, October, November, December of 1899, May, 1900 and June 1900.

Mr. Adcock: What are there left there?

A. July, 1900, October and November, 1907.

Mr. Shenehon: I haven't those.

Mr. Adcock: That is all you have at present, as I understand it.

Mr. Shenehon: Yes.

Mr. Adcock: Then we make a request for the similar tables covering the months which are not included in these tables.

Mr. Shenehon: I have some more: There is July, 1900, and May, 1899, October, 1907, and November, 1907. That is all.

Mr. Adcock: What months are not there?

A. We are then short July, August, September and October, 1898, January, February and March, 1899.

Mr. Shenehon: There are not any sheets of this kind for 1898. The gage was established February, 1899.

The Witness: Then there are similar records for February and March, 1899, which have not been furnished. Is that right, Mr. Shenehon?

Mr. Shenehon: We feel that February and March do not

enter into any gagings we are displaying in this case. That is open season flow. Of course there are gage records consecutive on that gage from the year 1900 to the present time, and still going on.

The Witness: Then the statement as I understand it is that this gage was established in February.

Mr. Shenehon: 1900.

The Witness: In 1899, wasn't it?

Mr. Shenehon: Yes, 1899, that is right.

The Witness: February, 1899, and there are no records of recording gage prior to that time.

Mr. Shenehon: That is my recollection.

The Witness: All right.

Mr. Wilkerson: As to the sheets which were submitted to you this morning, the same being three sheets marked Williams Cross-Examination Number 2, have you familiarized yourself with and given consideration to the facts relating to the subject about which inquiry was made this morning?

A. I have forgotten just what the inquiry was. If you will, inform me.

Q. The inquiry related to the range?

A. To what they indicated?

Q. The range of variation from day to day as shown by those sheets.

A. Do you wish me to enumerate the particulars, or give a summary?

Q. The figures of course now appear in the record?

A. Yes.

Q. I merely want to know whether you, the witness, have personally examined the results of that compilation, and have familiarized yourself with the facts shown?

A. I have to a moderate degree, yes.

Q. What do you find the maximum variation during any 24 hours to be?

A. I will give you the range of it in just a minute. The daily variation, as indicated by these scalings from the record of the recording gage varies from .18 for the 24 hours on the 7th of June, 1908, to 2.42 feet on the 14th of June; the change of 2.42 feet appearing in consecutive hours as did also a change of 1.24 feet on July 17th, a change of 1.16 feet on August 12th and of .89 of a foot on August 13th. A change of 1.44 of a foot occurred in two hours, that is between three consecutive hours, on July 7th, and a change of one foot

within two hours on July 13th, and numerous other smaller changes.

Q. How many days all together is covered by that?

A. Ninety-two.

Q. And for how many days do you find the variation more than a foot?

A. I will have to count them—15 days.

Q. How many days do you find more than a foot and a half?

A. Four.

Q. Now referring to table Number XLVII, being sheets marked Williams' Exhibit Cross Examination Number 1, on how many of the days where the variation was more than 1 foot were discharge measurements made?

A. 18 observations, which were taken on six days.

Q. That is 18 observations you say?

A. Yes.

Q. Out of a total of how many?

A. 78.

Q. 18 out of a total of 78?

A. 18 out of a total of 78, yes, sir.

Q. And as to the 60 other observations, the variation on the day on which they were taken was less than a foot?

A. That is correct.

Q. On how many of those days when the variations were more than a foot was the variation during the day time on the dates on which observations were taken?

A. I could not say without an examintaion of the table. That particular inquiry was not contemplated when these figures were prepared, and they do not give the information.

Q. There are only a few days. I will ask you to look at that, so that we can get it into the record now.

A. There is nothing on the chart to indicate what is noon. I think there should be a statement to show that is noon. A man might start them at midnight.

Q. The hours on these sheets are numbered from 1 to 24, commencing, as I understand it at midnight. Is that your understanding about it?

A. That is my understanding now.

Mr. Adcock: Subject to verifying that statement.

Mr. Shenehon: The first hour is one o'clock in the morning.

The Witness: I am so informed by the complainant's principal witness.

Mr. Wilkerson: With that in mind, answer the question.

A. Just what is the question?

Q. (Question read as follows: "On how many of those days when the variations were more than a foot, was the variation during the day time on the dates on which observations were taken.")

A. On five days covering 16 observations.

Q. So far as the element of the movement of Lake Erie is concerned, what is your judgment as an engineer of the effect of that upon the accuracy of the 60 observations, where there was a variation of less than a foot in 24 hours?

A. I don't see as the fluctuation of the lake had very much to do with the discharge observation; that is with the accuracy of the observation itself.

Q. That is to say the accuracy of the observation was not in your judgment materially influenced by that element?

A. That is my view of it.

Q. I think there has been submitted to you, Mr. Williams, and you have been asked to check the correctness of, certain computations in which the level of Lake Erie has been computed from the discharge measurements by means of a certain law, which is taken as the law expressing the relation between the level of the lake and the volume of the discharge; and you have also checked the elevation of Lake Erie as thus computed against the observed elevation of Lake Erie for the same time. I ask you to state, so that we may have it in the record, what was the law which was taken as expressing the relation between the volume and elevation of Lake Erie?

A. The law which was applied appeared to be the same and was certainly very similar to that presented on Complainant's Exhibit 3; being the discharge curve for the International Bridge Section of the Niagara River.

Q. Just look at it so as to make sure that it is the same law.

A. I did examine it. I say that it was very nearly, and it was assumed to be, and to all appearances was, very nearly.

Q. Substantially the same law?

A. So far as I was able to detect, and so far as the accuracy of the plotting could control, it evidently was the same law.

Q. Now, as to how many observations did you check the computation by which the elevation of Lake Erie was determined with reference to a given discharge?

A. 107.

Q. Over what range of lake elevations do those 107 observations extend?

A. The minimum of 570.03 to a maximum of 573.92.

Mr. Adcock: You have handed him something here; let us have that identified.

Mr. Wilkerson: I did not intend to put the whole memorandum in the record. The paper which the witness is examining is a memorandum, which shows the result of these computations. I think for the purpose of this inquiry it will not be necessary to put the whole computation in the record. I am merely going to have him state certain facts with reference to the computation which he has checked.

Mr. Adcock: I wanted to have a copy of that in our possession.

Mr. Wilkerson: You may look at it any time you want to.

Mr. Adcock: Will it be understood that we may have a copy?

Mr. Wilkerson: It will be understood you may have a copy of the memorandum, of any memorandum which the witness refers to, to refresh his recollection in testifying.

Mr. Adcock: All right.

Mr. Wilkerson: Q. Now, over what range of time do the 107 observations extend?

A. That I can't say. Have you got the dates in here? Substantially over the five years.

Q. Embraced by the observations which were taken on the Niagara?

A. The observations which were taken on the Niagara at the International Bridge Section.

Q. And used in this case?

A. Yes, sir. It does not however include all the observations, nor half of them.

Q. That is to say we have 107 observations taken out of 219?

A. That is correct.

Q. How nearly do you find that the elevation of Lake Erie as computed according to the law there stated corresponded with the actual elevation of Lake Erie, as measured at the particular time when the observation was taken?

A. On seven occasions, the computation agreed with the observed elevation of Lake Erie through the 100th place, which was as far as it was attempted to establish it.

Q. That is to say for two decimal places—

A. For two decimal places.

Q. It was zero?

A. Yes. The maximum error on the high side, that is the maximum amount by which the actual elevation of the lake

exceeded the computed elevation was .08 of a foot of the maximum—

Q. That is how much in inches? That is an inch?

A. This is feet.

Q. Approximately an inch, less than an inch?

A. .96 of an inch, slightly under an inch. And the maximum variation by which the computed elevation exceeded the observed elevation was also .08 of a foot.

Q. That is less than an inch, slightly less?

A. Just slightly less than an inch. The average variation was .042 on the one side, and .041 on the other.

Q. That is practically half an inch.

A. That is practically half an inch, slightly less.

Q. And there are about as many in which the computed observations were high—

A. There were 52 in which the lake was higher than the computed value, and there were 48 in which it was lower, and 7 in which they agreed.

Q. If you didn't know what the elevation of Lake Erie was in these 107 instances, how nearly would you be able to predict by the application of this law expressing the relation which we have under consideration the actual elevation of Lake Erie?

A. In all cases you would have predicted it within one inch. In approximately half of the cases you would have predicted it within one-half an inch.

Mr. Adcock: That is the Buffalo gage?

A. Yes, that is referring to the Buffalo gage.

Mr. Wilkerson: Referring to the Buffalo gage?

Mr. Adcock: That applies to these 107 observations?

A. Yes, applies to 107 observations.

Q. And as I understand it these 107 observations referred to are selected observations are they not?

A. I assume that they are.

Mr. Wilkerson: Q. So that if you took these 107 observations, and took the mean of the discharge observations, by the application of this law you would be able to predict the mean elevation absolutely, wouldn't you? It appears that you would be able to do so?

A. It appears that that would be the case. I do not see anything the matter with the mathematics of that.

Q. Now taking into consideration the range of these observations, nearly four feet, and the length of time over which they have extended, five different years, taking into consideration the fact that you would thus be able to predict

absolutely by the application of the law expressing the relation between volume of discharge and lake elevations which is here applied, what is your opinion as an engineer as to the conclusiveness of the law expressing that relation which has been applied?

Mr. Adcock: When you say "these observations" you refer to the 107?

Mr. Wilkerson: That is referring to the 107 at Buffalo?

A. As to mean relations between the discharge of the Niagara River at the Bridge Section and the elevations of the Buffalo gage under the conditions represented by these 107 observations, I would say that the law appears to be well established.

Q. Does it appear to you to be as well established for the upper end of the curve, that is to say for the higher water, as it does for the lower part of the curve, the lower water?

A. I don't think there is much if any difference.

Q. The one appears to be as well established—

A. The one appears to be as well established as the other.

Q. The one appears to be established with as great a degree of accuracy as the other?

A. Yes, I say I do not see any distinction between them, still referring to the 107 observations under discussion.

Q. You have spoken now in your testimony of the equilibrium of the river as one of the elements which has entered into the accurate determination of the law expressing this relation between volume of discharge and lake elevation. I wish you would state what you mean by the equilibrium of the river, as you have used the term, specifically the Niagara River.

A. I had forgotten just how I used it, at the present moment. Can you refer to the point where I did use it, whether it had any special significance.

Q. Is that one of the elements which you think enters into the determination of the accuracy with which this relation has been expressed?

A. What is the question?

Q. (Question read as follows): "You have spoken now in your testimony of the equilibrium of the river as one of the elements which has entered into the accurate determination of the law expressing this relation between volume of discharge and lake elevations. I wish you would state what you mean by the equilibriu mof the river as you have used the term, specifically the Niagara River?

A. I don't think I have used that term. I may have used

it; I will not be certain. I have in mind some sort of a definition of it at the present moment, but I would not want to give it here as referring to the use of it that I made the other day.

Q. Do you know what the relative fluctuations between the Buffalo gage and the Chippewa gage are?

A. I do not recall at this moment. Of course fluctuations at Chippewa would be expected to be materially less than they are at Buffalo.

Q. Do you think that a definite relation could be worked out as expressive of the relation that these fluctuations bear to each other?

A. I think it would be rather difficult on account of the rapidity of change at Buffalo. I think that anything that was worked out would show a less effect at Chippewa than actually would apply there for the Buffalo gage elevation.

That is, to state it this way, I think if you took the information you have and worked out that relation, and then it were possible to raise Lake Erie successively to the various elevations you have considered and hold it there, you would find a different relation existed between the Buffalo gage and the Chippewa gage.

Q. Are you familiar with the discussion of the slope relations of the Niagara River as set down in the document on the Preservation of Niagara Falls, the same being as I understand it a public document?

Mr. Adcock: The same being the one heretofore referred to.

Mr. Wilkerson: Senate Document Number 105, Sixty-Second Congress First Session?

A. I read that discussion some time ago. I can't say I would consider myself at the present moment familiar with it.

Q. If as a matter of fact a relation has been worked out which would enable you to predict with substantial accuracy from the elevation at Buffalo what the elevation was at Chippewa, would that indicate to you as an engineer that that relation had been established with satisfactory accuracy?

A. It would depend upon the amount of information that was used in establishing it. I can, of course, conceive of having a very large number of observations with varying quantity, where the effects of the excesses and the deficiencies may ultimately cancel each other, and you get to the effect of a true mean.

Q. I ask you to refer to page 41 of this document, Senate

Document 105, Sixty-Second Congress First Session, and direct your attention to the equations numbered 5 and 6 on that page?

A. (Referring to same).

Q. You have looked at those, have you?

A. Yes.

Q. I will ask you whether or not from an engineering standpoint, the check between the equation for 1906 and for 1906-7 is a substantially accurate and satisfactory one?

A. The variation in the computed elevation at Chippewa for elevation of Lake Erie at 573 seems to vary by about 1/10 of an inch.

Q. Between 1/8 and 1/10?

A. About 1/10 of an inch, and it would seem to be a very close check, and would indicate that the conditions covered in the two cases, or that the mean of the conditions covered in the two cases must have been very similar.

Q. By water leveling, can you pass from the Buffalo gage to the Cleveland gage?

A. If you have a sufficient number of the observations, with a reasonable degree of precision.

Q. Is it your opinion that we have a sufficient number of observations to pass from the Buffalo gage to the Cleveland gage?

A. I think with all that we have, we could.

Q. That is from the year 1887?

A. I think that ought to be sufficient.

Q. From that on to the present time. You think that should be sufficient for an engineer to do that?

A. That is you mean now in passing from one gage to the other, to say that—let's see if we understand each other: You mean by that to be able to say that the mean elevation at Cleveland corresponded with a certain mean elevation at Buffalo. But I doubt if we have enough observations to enable us to say that, when the gage at Buffalo reads, say 573, what the gage at Cleveland would read.

Q. Do we have enough observations to establish the ratio of fluctuations?

A. What do you mean by "ratio of fluctuations" in this question?

Q. The monthly mean.

A. For any month, you mean? That is from month to month? Yes, I think so. Wait a minute, hold on; I do not think that we have observations enough to be able to predict

from the monthly mean of the Buffalo gage what the monthly mean of the Cleveland gage is.

Q. For a season?

A. For a season you have, but I don't think that you have for a month.

Q. Having the observations for the season for Buffalo—or two seasons for Buffalo and Chippewa—can we establish that relation?

A. Can you establish what?

Q. The ratio of fluctuations.

A. As I said before, you can establish what the mean elevation of each gage is with reference to the other, but I question if you would be able to establish what the maximum elevation of one gage would produce on the other.

Q. Have you stated what the ratio of fluctuation between Buffalo and Cleveland is?

A. I think I have not.

Q. What is it?

A. I don't recall.

Q. Taking it for a single season, an open season?

A. Well, I should have to look at the gage records. I don't recall what the relative fluctuation at Buffalo and Cleveland is at all.

Q. Is it not a fact that it is unity?

A. Let us understand "fluctuation." I understand fluctuation to be the variation of elevation between the high and low of the gage. If we are understanding it the same, then my answer is correct, or at least I believe it to be. If you mean something else by fluctuation, then possibly my answer is not correct. If a thing fluctuates, we understand it to be vibrating back and forth. I don't know what the variation between high and low at Buffalo is, as compared with the variation between high and low at Cleveland.

Q. Well, can you establish the ratio, of annual or monthly mean over a term of years?

A. I don't think I got all of that question.

Q. (Question read.) That is to say over a series of months or series of years?

A. I think that taking the year as a unit, you can. I question if you can for any particular month.

Q. Isn't the lake substantially level?

A. Taking the year as a unit it is. If you take a month, I question if it is.

Q. With that understanding, isn't the ratio of fluctuations unity between Cleveland and Buffalo?

A. I don't understand your term "fluctuations." If at Buffalo the lake fluctuates 12 feet, and at Cleveland fluctuates three feet, it certainly is not unity.

Q. Take the same meaning that you had when you passed from Michigan-Huron to Erie, in your direct testimony.

A. That was the annual change of elevation; that was annual fluctuation, or other fluctuations from year to year over a long period of years.

I have already answered that question by saying that I thought you could establish it for a year; that I question if you could for a month.

Q. That is to say when Lake Erie is 571 over a term of months or years at Cleveland, it is 571 at Amherstburg or at Buffalo?

A. The average would be, I think.

Q. And the same for 572?

A. Oh, yes.

Q. Then the ratio must be unity?

A. Well, you are using the term "fluctuation" in a little different way. I would call them relation of stage rather than fluctuation.

Q. Well it follows then that if the relation between Cleveland and Buffalo is unity and the relation between Buffalo and Chippewa is .56, that the relation between Cleveland and Chippewa would be .56?

A. Just read that question.

Mr. Adcock: That is over a number of years.

The Witness: Over any time.

Mr. Wilkerson: Q. Over a period of months.

A. That is just a concrete fact there, that if the relations are so, then the things that are equal to the same thing are equal to each other. That is all there is to it.

Mr. Wilkerson: We will submit to you, Mr. Williams, between now and the next session, certain computations from which the Chippewa gage has been predicted from the gage at Buffalo, and checked with the gage as observed at Chippewa.

Adjourned to Wednesday, July 23, 1913, at 10 o'clock a. m.

Wednesday, July 23, 1913, 10:00 a. m.

GARDNER S. WILLIAMS, resumed the stand for further cross-examination by Mr. Wilkerson and testified as follows:

Q. In connection with these computations for the purpose of establishing the relation between the levels of the lakes and the volume of discharge of the lakes respectively, you made use of the method which is designated as the "Three Point Method," did you not Mr. Williams?

A. I never so designated it. I always called it the Center of Gravity Method.

Q. The Center of Gravity Method?

A. Yes.

Q. But it is the method—

A. The method that has been designated I think by the "Three Point Method" by some who use it.

Q. Where did you get that method?

A. I developed it out of my inner consciousness. I do not claim to be the originator of it, but so far as my use is concerned, I developed it myself. It is so simple, I assume many others developed it before me.

Q. Is it not in common use among engineers?

A. I don't know to what extent it is. It is an absolutely rational method based upon the fundamental principles of physics; and I don't know whether anybody else uses it or not.

Q. Do you know whether or not it is an accepted method among engineers?

A. I don't know whether—well, yes it is an accepted method, because it is an absolutely accurate method.

Q. Is it a generally accepted method?

A. It is accepted by anyone who has occasion to use it. It is the most accurate method of determining the line, the straight line which represents a series of observations, where all observations are given equal weight.

Q. In what technical publications is it described? I mean if as a student of mathematics I wanted to get some information about this method, where would I go to find some place where I could study it?

A. I do not recall at the present moment where it has been described. I think it will be found in some of the transactions of the American Society of Civil Engineers, and I think also in the Journal of the Association of Engineering

Societies, but I won't be sure as to the latter, whether it has ever been described there or not.

Q. By whom was the description written, if you remember?

A. I had in mind a paper of Mr. George H. Fenkell, but on second thought I rather think the method was not described there.

Q. Did you use it in the analysis of the pipe observations described in the transactions of the American Society of Engineers?

A. It was used there, yes.

Q. You used it?

A. I used it. In fact it was at that time that it was developed, as far as I was concerned.

Q. And Mr. Fenkell was in colaboration with you?

A. He was.

Q. Now on what process of reasoning does the validity of that method, in your opinion, depend?

Mr. Adcock: As applied to the proposition we have under consideration.

Mr. Wilkerson: No, I am speaking of this method, the method called the gravity method or the Three Point Method for deriving a relation between observations relating to two conditions?

A. On the theory of resultant force of a system of forces.

Q. Why do you have three points? Why aren't two enough?

A. Because you have to have three in order to make the division at the intermediate center of gravity to give the observations all equal weight. If you divided them arbitrarily, you would not be giving them all equal weight.

Q. If you should take your observations and divide them into two groups with the same number of observations in each group, would you not as a matter of fact get a line as accurately, to say the least, as you would if the result of that division of observations was to give the groups in which there would be an unequal number of observations in the respective groups?

A. I think not. When considering the moments which the various observations have about the center of gravity. The first thing that we do is to balance the entire series of observations about a point. That point then divides the groups, divides the observations into two groups. And we then find the straight line through the centers of gravity of those two groups. Thereby we get a mathematical balance; that is

we balance the whole system first about the center of gravity, and then balance each end about its center of gravity.

Q. You think the result arrived at by grouping the observations, whether you would have more observations in the one group than another, would be essentially a more accurate result than if the observations were divided into two groups, each containing the same number of observations?

A. I think that when the observations are divided by a line passing through the center of gravity for the whole group, at right angles to the direction of inclination of the average line that the division gives the most accurate process of determining the mean line that can be derived.

Q. You have spoken of the weight of the observations as referred to the distance from the center of gravity of the whole system. Doesn't that in your opinion mean that the range of observations in a given state in lake stage very greatly increases the weight of the observations, or the conclusions to be drawn from those observations?

A. Each observation is given the value which is represented by both its co-ordinates; does not depend upon the value of one. I think that answers your question.

Q. But the weight of the conclusion is greatly strengthened by range of lake stage in the discharge observations, other things being equal?

A. The weight of any conclusion as to the variation of discharge, with change of stage, is increased as you increase the range of the observations; other things being equal.

Q. When you spoke of the adoption of the method by Government Engineers in your direct testimony, what did you have in mind specifically?

A. I had in mind having seen a reference to it in some one of the Government publications. At that moment I was not able to recall it. I have looked for it, not very exhaustively, since. I don't find it where I thought it was.

Q. Was it among the Lake Survey publications?

A. I surmised that it was and looked for it there and didn't find it. Whether it was or not, I am not prepared to say at this moment.

Q. Isn't it a fact that the use, the only use which was ever made of it by the Government Engineers, was in an unpublished report by Mr. Richmond?

A. I doubt if that is where I saw it, although I may have. I have not read that report in full, although I have looked through it.

Q. Do you recall now whether the method was made use of in any way, in that report?

A. I don't recall that it was.

Q. So it is your recollection that appeared, or there was a reference to it some place else?

A. My recollection was that I saw it in print. I may be in error about it because I have only a very dim recollection.

Q. Aside from that indefinite recollection, you have no specific knowledge that the Government Engineers have accepted this as a recognized and established method for reaching conclusions such as are under consideration in this case, on a series of observations?

A. I have no specific citations.

Q. Do you know whether it is made use of by scientists in general for handling observations of the same general kind; by physicists, astronomers and other scientists who have occasion to derive laws from series of observations?

A. I do not. It is of course only applicable to straight line observations. It is not applicable to those where a curve would be the *locus*.

Q. Now there has been another method to which you have referred; there has been reference made to it throughout this testimony, called the method of "least squares".

A. Yes.

Q. Isn't it a fact that is the method which is in general use among scientists in dealing with a series of observations of the kind we have under consideration?

A. It is a method which is extensively used by some scientists in dealing with observations. But early in my career I had that method characterized in a manner which I must say it—I have found to be quite accurately descriptive of its use, in many cases where it is attempted to use it. An old Professor of mine said that the method of least squares was a device of lazy engineers to make up in the office for deficiencies in the field. And my observation of those men who have in the main introduced it into ordinary calculations has been that the intricacy and complication of the method has led them to lose sight of the fundamental physical elements which are involved in the problems being investigated.

I am not applying this criticism to such experts as some of the witnesses in this case, nor to many eminent scientists who use the method properly, and whose use of it no one would venture to criticise. But it is a method in which the

manipulations tend to obscure and smooth out and eradicate the characteristics of the original observations.

Q. It is a method however which has been adopted to the extent that a number of very eminent mathematicians have written books about it, and have given credit to it, is it not?

A. Yes, it is a very useful method, and is probably at the present day the most accurate one that we have for deriving the locus or equation where the locus is a curve.

Q. Is it still applicable where the line is a straight line?

A. It is applicable, but it is no more accurate than the method I have used, and involves very much more labor.

Q. That is your opinion, it is no more accurate?

A. That is my opinion of the matter, certainly.

Q. It is a fact that many of the laws which have been derived by scientists from observations have been derived from the method of lease squares, is it not?

A. It is.

Q. Who are some of the mathematicians who have written books giving validity to that method?

A. I don't know that I recall at the present moment.

Q. Do you recall Merriman's Treatises?

A. I would hardly classify Mr. Merriman as a mathematician.

Q. Who was he?

A. He was at one time Professor of Civil Engineering at the Lehigh University. He was the editor of the American Civil Engineers' Pocketbook. He is an author of certain treatises on certain engineering subjects and is the author of a book on the method of least squares. I never heard him classed as a mathematician.

Q. Perhaps there is something in the use of the word "mathematician" that involves a distinction in your mind. You spoke of the American Civil Engineers' Pocketbook, Mansfield Merriam Editor in Chief. That is a standard authority among those who make engineering and scientific observations?

A. I hardly think that the book has been in use long enough to be called a standard.

Q. You contributed something to it, didn't you?

A. I did.

Q. Is it a book that is in general use?

A. Becoming so.

Q. What I am trying to get at is this, Mr. Williams: We have a situation where it is necessary to determine a relation growing out of a series of observations. Now if we

wanted to find out the method which was to be used in deriving that relation, not by working out a method ourselves but by going to the authorities for it, where would we go to find a recognized authoritative way of deriving that relation except we go to these books on least squares, which have been written by Mr. Merriman and other men who have dealt with that question.

A. To determine a straight line passing through a series of observations, I would go to the fundamental principles of mechanics.

Q. Would the other scientists go there too?

A. I suppose they would.

Q. Isn't it a fact that the least squares is based on that?

A. In part, and in part on the theorum of probabilities which is a mathematical proposition as distinguished from a mechanical.

Q. Through how many editions has Mr. Merriman's book gone?

A. I don't know.

Q. It has gone through several, hasn't it?

A. I presume so.

Q. What other authorities are there in which this method of least squares has been considered?

A. I think it is generally discussed on works of mathematical astronomy.

Q. Chauvenet?

A. I think Chauvenet discusses it.

Q. Comstock?

A. I don't recall but I assume so because it is a process that is used particularly by the astronomers where they have to deal with complicated curves.

Q. How about Wright's Adjustment of Observations?

A. I am not familiar with it, but I would expect it would be practically certain it would be found in that.

Q. You have made a study of it have you?

A. To a limited extent.

Q. You have not studied the books to which we have been referring here this morning?

A. No, not to any great extent.

Q. Is it your opinion that assuming the accuracy of the observations, the curve derived for the Niagara River by the use of the method of least squares is rendered inaccurate because that method has been used in deriving the curve?

A. Not at all.

Q. Or in deriving a straight line?

A. Not at all.

Q. Treating a straight line as expressive of the relation within the range of the observations which have been studied?

A. Certainly. I have no criticism of the method of least squares, as far as applied to accurate observations.

Q. So that it is your judgment that so far as the determination of the relation for the Niagara River is concerned, it does not make any particular practical difference whether the method of least squares is used or whether the gravity method is used?

A. No, as long as you are confining both to a straight line relation. If you introduced the curve relation, then the method of least squares gives results which do not compare with the other, and which of course would be more accurate.

Q. You referred in your direct examination to the method of using a string as a method which was sometimes used, and it was referred to in the Government's testimony in this case. What part of the Government's testimony did you have in mind when you referred to this string method?

A. To the cross-examination of the Government's principal witness, Mr. Shenehon, in which I believe he used the expression: Stretch your thread or draw your line.

Q. I would like to have you refer to the particular part of the testimony in which there is that reference to this method which you have discussed in your direct examination, namely the use of the string?

A. I find your reference to threading the observation. Now, whether you used the word "thread" or not, I won't be certain; I mean in your testimony.

So far as a cursory examination of the record at the present time goes, I do not find a reference to either a string or a thread in the language reported as that of the complainant's principal witness. I find on page 251 the statement:

"After the observations as thus grouped are platted, a straight line is drawn threading these observations, and this straight line is taken to indicate the relation between lake elevation and volume of outflow."

It is my recollection that either in the record or out of it the witness explained that these lines were located by stretching a thread across the observations, and adjusting it by the eye to the position which seemed to most nearly fit the group of observations.

Q. Now in your testimony in which you have presented an analysis, a criticism from your point of view, of the work done by the Government Engineers in drawing conclusions

from these measurements, you indicated, as I understood you, certain reasons why the work of the Government Engineers was not to be accepted with full faith and credit. And among the reasons assigned by you was the one that the method which had been used by the Government Engineers was a rough method and not really very accurate, and that therefore these results were to be discredited for that reason. Was that what you had in mind?

A. To the extent to which they varied from a correct location of the line in question.

Q. And another reason which you assigned for discrediting the conclusions of the Government Engineers was that the method of least squares was not to be taken as an accurate method of combining these observations?

A. I think not.

Q. You had no criticism to make based upon the use of the method of least squares?

A. Except the broad one that the method of least squares in no wise compensates for errors of one sign.

Q. But you do believe that both of these two things, namely the extreme refinement of the method of least squares and the rough and ready method of using a string are sources of inaccuracies?

A. Not at all.

Q. In the work of the Government Engineers?

A. Not at all as to the method of least squares; it is not a source of inaccuracy; but it does not eliminate the inaccuracies that it is assumed to do.

Q. Have you ever made use of this method of drawing a thread through observations, yourself, in work?

A. Oh, yes.

Mr. Adcock: When you say drawing a thread through, how do you mean it is drawn?

Mr. Wilkerson: Q. You understand what I mean. You plot your observations and you take—

A. You adjust the line through by the eye, in order to have a line that can be shifted readily.

Q. And you use one that most nearly represents the direction represented by the observations plotted?

A. Exactly.

Q. You have made use of that?

A. I have.

Q. And within what degree of precision have you found you could get results, by doing that?

A. It depends very largely upon the manner in which your observations are located.

Q. I asked you within what degree of precision you found you would get a line that way?

A. I don't know that I have in mind the specific range.

Q. Would the line be likely to be wrong to the extent of 50 per cent.?

A. Hardly.

Q. Or 100 per cent.?

A. Oh, no.

Q. Or 25 per cent.?

A. Not likely.

Q. Or assuming the accuracy of the observations, in dealing with observations such as those we are dealing with in this case for the Niagara River, would it possibly be 5 or 10 per cent.?

A. I hardly think you would be as far off as 10.

Q. Do you think you would be as far off as 5?

A. Just what is that question?

Q. (Question read as follows: "Or assuming the accuracy of the observations, in dealing with observations such as those we are dealing with in this case for the Niagara River, would it possibly be 5 or 10 per cent.?")

A. The question is as to the Niagara observations as they are, as I understand it. I think in that case it should have been right within 2 per cent.

Q. Taking into consideration the 219 observations utilized at the International Bridge Section, what accuracy do you give to the center of gravity or mean of all of these observations?

A. Well, the center of gravity is the mathematical point at which the resultant or counter resultant of that system of observations considered as forces would be applied to balance the observations.

Q. In your judgment as an engineer, what accuracy do you give to the mean volume of flow at the mean lake stage of these 219 observations?

A. Somewhere inside of 20 per cent.

Q. I show you a chart, which for the purpose of this cross-examination I ask to be marked Williams' Exhibit Cross-examination No. 3; the same being marked: "Discharge measurements of the Niagara River plotted from the records of the United States Lake Survey, International Bridge Section, Buffalo, New York. Measurements of 1898, 1899 and

1900 shown thus: By a circle. Measurements of 1907 and 1908 shown thus: By a plus mark. 101 measurements in 1898, 1899 and 1900; 118 measurements in 1907, 1908, making a total of 219 measurements."

I wish you would take this chart and assume that the observations have been accurately plotted; draw a thread which in your judgment correctly represents the law expressing the relation between the level of the lake and the volume of discharge.

(Chart shown to witness was marked Williams' Exhibit Cross-examination No. 3.)

A. That is between the level of the lake as indicated on this chart, and the volume of discharge as indicated on this chart?

Q. Exactly.

A. It is my opinion no line that can be drawn through those observations will represent that true law.

Q. Assuming they have been accurately plotted, draw a line which would represent the relation which is indicated by them.

Mr. Adcock: Don't you think that is too long to use a thread? Is the witness going to do this?

Mr. Wilkerson: He can have as many co-laborers or assistants as he thinks necessary.

(Witness draws line as requested.)

Mr. Wilkerson: Q. Will you please state what you have done, in response to my last question?

A. Will you take out the word "correctly" in your question? The point is this: I have drawn this as nearly as I can by the eye to what is a correct representation, but I do not want to say that it is a correct representation, because it is not. I object to the word "correctly."

Mr. Wilkerson: Well, take that out. We merely want your judgment in the drawing of the line.

A. If you will put it in this way: Will you draw a line which represents to the best of your ability the relation between the gauge height as indicated, or the lake elevation as indicated and the discharge as indicated?

Mr. Wilkerson: I will substitute that for my question.

The Witness: I have drawn such a line.

Q. Now, what does the line which you have drawn indicate?

A. This line passes through the alleged center of gravity of all the observations on this plate which I find to be indi-

cated by a star, and concerning which I am informed by the complainant's principal witness is the plotting of the center of gravity of these observations.

Q. You spoke of drawing that through a star which indicates the center of gravity. Would the line as you have drawn it have been substantially different, if that star had not been there?

A. Not substantially. I had as a matter of fact located the line within a very short distance of the star before I knew that it was the center of gravity.

Q. In accordance with the line which you have drawn, what volume of discharge is indicated by lake elevation 574?

A. 240,450 cubic feet per second.

Q. What is the volume of discharge indicated by lake elevation 570?

A. 154,000 cubic feet per second.

Mr. Austrian: Q. You are testifying from the plat in question?

A. I am testifying from what is indicated on that plat.

Mr. Wilkerson: Q. What is the increment which is indicated by the line, as you have drawn it?

A. 21,600 approximately.

Q. I am submitting to you, Mr. Williams, a computation of that increment by your three point method, and I will ask you to check the computation which is submitted to you and which for the purpose of the examination may be marked William's Memorandum Cross-Examination A, and after you have checked it to give us a statement of the increment for the Niagara as derived by the application of your Three Point Method. You find on the paper which has been submitted to you for examination a certain increment indicated. That would be 21,860?

A. 21,860.

Mr. Adcock: As I understand it, you have not checked those yet.

Mr. Wilkerson: Q. The memorandum submitted to you indicates an increment of 21,860 cubic feet.

A. I find on computation this increment to be 21,870.

Q. Assuming that the memorandum which has been submitted to you is accuraetly computed, I will ask you to state whether or not the increment derived by the Three Point Method is not substantially the increment which is indicated on Government's Exhibit plate number 3, showing the loss of

level in Lake Erie corresponding to loss of outflow in the Niagara River?

A. It is.

Q. And you understand that this is derived from the same 219 observations as was plotted on the chart which you have examined?

A. That is my understanding.

Q. Now that being true, isn't it a fact that this discussion of the method of stretching a string, and of the method of least squares, as compared with the three point method, is something which has no real substantial bearing upon the accuracy of the results which have been testified to by the Government Engineers in this case?

A. So far as the three point method and the method of least squares is concerned, my answer would be yes. I would say in a case of the importance of this, it does not seem to me that an engineer should rely upon the thread method for more than an approximate value.

Q. Would you regard it as an improper procedure for an engineer to take the thread method and see what it indicated; and use the result provided he found it tallied substantially with the result given by the application of the more intricate mathematical computation?

A. Oh, not at all.

Q. And for the purpose of simplifying evidence of this kind, wouldn't that be, in your opinion, the proper way of dealing with observations of this kind, to find the simplest method, one a layman could understand, and use that method and if he found on checking with the other computations that it was accurate, to make use of that method as explaining the way in which the law was derived?

A. I think as an illustrative method, its use was entirely correct.

Mr. Adcock: Q. But if it did not check what would you do about the line you had drawn, by drawing a string?

A. I would shift it until it did.

Mr. Wilkerson: Q. Assuming a possible inaccuracy of 2 per cent. in the computation of the increment due to the use of the string method or the thread method, what effect would that have upon the result as to the loss of lake level corresponding to the difference in the increment?

A. The error of increment—the proportionate error of increment would be the same as the proportional error in the lowering derived from it.

Q. And for a loss of level of four inches, say, the difference

would be 2 per cent. of four inches or .02 of 4 inches, .08 of an inch?

A. I think your mathematics is correct.

Q. Now, Mr. Williams, I wish you would draw on there with a dotted line or something, a line that would represent an increment of 34,000 cubic feet, the line passing through the center of gravity.

A. I have drawn such a line and marked it "Increment 34,000 c. f. s."

Q. In your opinion, does that line express the law of those observations, assuming the observations to have been made correctly and correctly plotted?

A. Not at all.

Q. With reference to the accuracy of the center of gravity, you stated in reply to a question that it was within 20 per cent. in your opinion. I wish you would state what in your judgment are the reasons for such inaccuracy, if there are any.

A. The difficulties of properly connecting the discharge at any given time with the elevation of the lake stage which produces that discharge, or the elevation of the lake surface which produces that discharge, and the difficulties of accurate measurement at the sections involved. Those are the primary elements; and the inadequacy of the number of points observed in the cross sections to determine the discharge accurately.

Q. Then there are two elements involved: One is the gage, and the other is the measurement of the volume.

A. One is the relation of the gauge to the discharge, and the other is the measurement of the discharge.

Q. Is the mean lake elevation indicated by these 219 observations practically the mean lake elevation at Cleveland?

A. For the same time?

Q. Yes.

A. I would expect it to be, approximately.

Q. Well, it would be so nearly it would not make any substantial difference in result.

A. I find on examination of the report of the International Waterways Commission on the Regulation of Lake Erie, tables X and XI, that the average elevation, the mean elevation of the Buffalo breakwater gage from 1860 to 1907, a very considerable portion of which has been derived by reference to the Cleveland gage, shows an elevation of the lake surface .07 of a foot higher than the elevation of the Cleveland gage as shown in table X.

I find that for the eight years from 1900 to 1907, inclusive, the average difference of elevation is .17 of a foot, and this in every case indicating the Buffalo water surface to be higher than the surface at Cleveland.

I find that this difference ranges from .05 of a foot in 1905 to .26 of a foot in 1906, those being the maximum limits of the range during these eight years. In view of that, I question somewhat whether one is warranted in saying that the indication of the Buffalo gage is to be taken as coincident with or corresponding to that of the Cleveland gage for the observations in question.

Q. What bearing do the years 1901 to 1906 have upon this inquiry which we now have under consideration?

A. The inquiry as I understand was whether or not the elevation as indicated at Buffalo for these 219 observations corresponded practically with the elevation at Cleveland at the same time; and I have examined the records of annual elevations of the two places for eight years, and I find this difference and as the result I draw the conclusion that they probably do not. I take these years as being the ones when there was a self-registering gage at Buffalo; and being the only ones when the self registering gage was there, during the entire year.

Q. Would it not be more pertinent to the inquiry to take the monthly mean of the gage for the months during which the observations in question were taken?

A. Yes, and more pertinent to take the daily observations at the two points during which they were taken.

Q. Is it not your judgment as an engineer, based upon an examination of these figures, that there is not a discrepancy of more than 1-10 of a foot between the Buffalo gage and the Cleveland gage, during the periods covered by these observations?

A. I have not examined the elevations of the Cleveland gage and the Buffalo gage critically for the periods covered by these observations. I would think that the probability was that the difference was greater than 1/10 of a foot.

Mr. Adcock: That is the mean?

A. The mean.

Mr. Wilkerson: Q. Do you think it would be substantially greater than 1/10 of a foot.

A. I am unable to say. I find differences here as the average of a year of .26 of a foot.

Q. Isn't it a fact if you take the Cleveland gage readings

during the period covered by these observations that they check very closely with the Buffalo gage observations?

A. I don't know.

Q. Isn't it your opinion that they do?

A. If you take the Cleveland gage readings during the times when the observations were actually taken, I think they do not.

Mr. Adcock: You are referring to the mean?

A. I am referring to the mean.

Mr. Wilkerson: Q. If those two gages were in substantial agreement during the time when the observations were taken, wouldn't that eliminate the element of fluctuation as governing the flow at the mean stage of the 219 observations?

A. It would not in my judgment.

Q. Why?

A. Because, as I have said before, we have no knowledge of what the stage of the lake is that corresponds to the discharge, except as it is secured by discharges carried over long periods of time, when this element of constantly changing lake can be eliminated by the balance of ups and downs.

If you will compare the continuous discharge of the Niagara River, measured for say a month, with the average elevation of the lake for that month, you should get an increment that would be somewhere near the approximately correct one, assuming the discharge observations to be correct.

Mr. Adcock: You mean at high and low.

A. Yes, if you compare the observations taken on the Niagara River for one or two or three months when the lake was at an average high stage, taking the mean of those discharges and the mean elevation of the lake for that period covered, and compare that with the mean discharges and mean elevations of the lake for a period of one, two or three months when the lake was at a low stage, and thereby derive an increment, you will be approximating to a correct increment, assuming that your discharge has been correctly measured. But so long as you are dealing with daily observations applied to daily gage readings, or to hourly observations applied to hourly gage readings, it is my opinion that you never can get a correct increment for Lake Erie, or any other of the Great Lakes.

Q. Throwing out of consideration the variation of discharge for the different lake stages, is it not your opinion that the Cleveland gage shows substantially the same elevation

during the times of the 219 observations under consideration as the Buffalo gage?

A. As I have made no specific comparison, I am not prepared to answer that question, and its answer would also depend upon the limitations that are put upon the word "substantially." If you mean within a foot my answer is yes. If you mean within 1/10 of a foot, my answer is no.

Q. Will you check up and make a computation as to the mean of the Cleveland gage, compared with the mean of the Buffalo gage during the times covered by the observations?

A. The following table represents the computation of the mean of the Cleveland gage compared with the mean of the Buffalo gage during the times covered by the observations.

Year.	Month.	Cleveland Elevation.	Buffalo Elevation.
1898	July	572.59	572.50
	September	572.01	572.08
	October	571.81	571.91
	November	571.69	572.01
	December	571.52	572.07
1899	February	571.46	571.59
	March	571.83	571.85
	May	572.44	572.32
	August	572.09	572.09
	September	571.85	571.90
	October	571.61	571.48
	November	571.62	571.55
	December	571.34	571.96
1900	June	572.47	572.41
	July	572.34	572.43
1907	October	572.69	572.79
	November	572.41	572.71
1908	June	.....	.....
	July	.....	.....
	August	.....	.....

Q. Now did you not state on yesterday that the relation between the volume of discharge and the level of Lake Erie at Buffalo was very definitely established by the computation of lake level from 107 observations of discharge, as stated by you in your evidence yesterday?

A. I think not. What I stated was that the relation between certain discharge observations and certain gage observations appeared to be very accurately established. I did not say that that was an establishment of the relation between

the level at Buffalo and the discharge at Niagara, as I do not believe that it was.

Mr. Adcock: These were the 107 selected observations you had?

Mr. Wilkerson: Yes.

Q. Now assuming that the relation between the volume of discharge and the level of Lake Erie at Buffalo was shown to be definitely established as was worked out on yesterday, and assuming that the stage at Cleveland is substantially the same as the stage at Buffalo during the times of the observations, wouldn't that indicate that you had a relation between the volume of discharge and the stage of the lake at Cleveland established?

A. I think not, for the reason that the simultaneous elevation of a lake with the discharge measurement is not the elevation that entirely controls the discharge.

Q. What do you mean by the term "entirely" as you have used it?

A. I mean when you consider simply the elevation of the lake at the moment the discharge measurement is taking place, you are ignoring the question of what the lake was doing during the antecedent minutes or hours, and thereby eliminating entirely the question of inertia, which is a very considerable one, as well as the question of the influence of elevations below the discharge station.

Q. When you said "not entirely," did you have anything in mind, any per cent.?

A. No.

Q. Is it about as substantial as the barometric column?

A. I think fully.

Q. And greater?

A. Very much. I think it is enough to change that increment from about 21,000 to about 34,000. And in bearing that out, I will show what just a little change will do.

During 1898, there were discharge measurements at Buffalo, from June 26th to August 6th. These were made, sometimes four a day, and ordinarily not more than one or two days was skipped.

Observations of discharge were made as follows: June 26th, one; June 27th, three; June 29th, two; June 30th, four; July 2d, four; July 6th, four; July 7th, two; July 8th, four; July 10th, four; July 16th, two; July 18th, two; July 20th, three; July 21st, three; July 22d, four; July 23d, four; July 24th, four; July 25th, three; July 27th, two; July 29th, two; July

30th, three; July 31st, four; August 1st, two; August 4th, four; August 5th, four; August 6th, four.

The mean discharge or the average——

Q. What year is this?

A. That is 1908. The average of all these discharge measurements is 223,774 cubic feet per second.

The average elevation of Lake Erie at the Buffalo gage for the same period, computed from the mean daily elevations is 573.26.

In 1898, between September 10th and October 21st, inclusive, there were observations made as follows:

September 10th, one; September 13th, two; September 15th, two; September 17th, two; September 20th, two; September 22d, two; September 24th, two; September 27th, two; September 29th, two; October 1st, two; October 4th, two; October 6th, two; October 8th, two; October 11th, two; October 13th, two; October 15th, two; October 17th, four; October 19th, two; October 21st, one.

The average discharge of all these observations is 190,097 cubic feet per second.

The average elevation computed from the average daily elevation of the Buffalo gage for the days included is 571.96.

The difference between the elevations in the first period, 573.26 and 571.96 is 1.30.

The difference between the discharge for the first period 223,774 and that for the second period 190,097 is 33,677.

33,677 the difference in discharge divided by 1.3, the difference in elevation, gives an increment of 25,900 cubic feet per second.

I submit, in my judgment, that is a more accurate increment than any that has been derived by the complainant in this case, and that it should be further corrected for the lack of more continuous observations, and a more extended period, to fully eliminate the effect of fluctuations on the Buffalo gage.

And it should be still further corrected by the necessary errors involved in the complainant's measurements of the Niagara Section.

Q. Do you think that 25,000 is more nearly accurate than 34,000?

A. I do not. I think that other is in the effects of these vibrations still that are not accounted for in this collection of data, and in the errors of discharge measurement.

Mr. Adcock: Do I understand if you had a great number of observations where the lake was at an even stage, low

stage, and a number of observations where it was at a higher stage, that you believe the increment would approach the 34,000 that you speak of?

A. It would, if the observations of discharge were accurate, but they are probably in error anywhere from 10 to 20 per cent., and therefore the increment is bound to be low.

Mr. Wilkerson: An error of 10 per cent. in the observations would make a difference, dealing with increments from 23,000 to 25,000, would make a difference of about 2,000 cubic feet a second, or a little more.

A. Depends altogether on how those errors were distributed.

Q. According to the law of probability, it would be so distributed it would tend somewhat to balance, wouldn't it?

A. That would depend upon whether the errors introduced greater effects at high discharges than they did at low, or *vice versa.*

Q. You have spoken of two kinds of fluctuations at the Buffalo gage, one of which you think affects the discharge and one of which does not. I wish you would explain just what you mean by that.

A. Well, the term fluctuation, as I have been using it recently, I have had mainly in mind what might be called vibrations or rapid changes of level. We also, unfortunately, used the term fluctuation to apply to the change of level in the mean from one year to another. That would be more properly——

Q. That is a variation of stage?

A. That is a variation of stage, and would more properly have been designated as the change of average annual elevation. I think in my testimony it was so designated; I endeavored to so designate it every time, in order that there might be no misunderstanding.

Q. So you have in your mind the distinction between the level of the lake at Buffalo at a particular time, and what might be called the stage of the lake?

A. I would understand by stage that average elevation which continues over an appreciable period of time, as say a month or a year.

We speak of monthly stages, and we mean the average elevation during that period.

Q. Now let us take this case: Take a difference of two feet in the gage readings at Amherstburg and Buffalo, the Buffalo gage reading 573. Now suppose at one time the Am-

herstburg gage read 571, and at another time the lake was level and the reading was 573, what in your opinion would be the effect of those two different conditions upon the volume of discharge of the Niagara, assuming that the 573 was continuous for several consecutive days?

A. You mean you are comparing two periods, one in which the lake is permanently tilted up to the extent of two feet in its length, so that the highest point, that at Buffalo, is at 573, with the case where the lake is level for several days, at the same elevation.

Q. Yes?

A. I would expect the larger discharge in the second case.

Q. You would expect to find a larger discharge during the period when the lake was level?

A. That is my opinion.

Q. To what extent? A. I am not able to say.

Q. Have you any definite opinion on that subject?

A. I have not except that it is one of the elements that accounts for the discrepancy between what the relations with the other lakes show to be the true increment of Lake Erie, and the apparent increment as derived from the observations that have been presented in this case.

Q. This example which I have given illustrates what you have meant by the two different kinds of elevations at Buffalo, the one where the lake is level and the other where it is tilted?

A. No, I don't think so; and I don't know as I used the term, two kinds of elevation. I think there is only one kind of elevation; that is when the water is up or down, or somewhere all the same level.

Q. This is so far as effect on the discharge is concerned?

A. That is only a part of the story, because in the actual procedure the lake did not generally remain tilted in this position for several days, but in fact was changed from hour to hour and day to day.

Q. Let us take over a period of one day then.

A. What is the question?

Q. The same question as I put to you before, taking it over the period of a single day?

A. I question, taking it over the period of a single day, whether in either case you would get the discharge that corresponded to the elevation of the lake, in either case.

Q. Why do you reach that conclusion?

A. Because it seems to me that it may take more than a

day for the full influence of change of lake elevation to make itself manifest in the discharge measurement.

Q. How would you establish that fact, by an investigation of the river slope, and other elements to be taken into consideration?

A. I don't think it can be established, because of the fact that the lake will not stand still long enough to let you establish it.

Q. Is it your opinion that the outflow of the Niagara River may be indicated by a gage at Chippewa?

A. I think so, subject to such variations in gage indication as would be due to changes in the flow of the Welland River.

Q. Do you know how large that flow is?

A. It is not large, but of course at times I would think it would cause an appreciable variation in the elevation of the gage. That is simply a judgment I have from looking at the map. An inspection of the locality might change my mind in regard to that entirely.

Q. Do you know whether there is an outflow of 100 cubic feet a second in the river, under ordinary conditions? It is a fact, isn't it, that the Welland Canal intercepts the river and takes off most of the flow?

A. I am not prepared to testify from personal knowledge in answer to either of those questions. My impression is that the flow of the Welland River on the average would not be more than 200 cubic feet per second; but the possibility occurs to me that in the event of a heavy local rain, or something of that sort, that the flow might be increased enough to affect the indication of the gage, and as I conceive, at Chippewa change of gage elevations will be comparatively small for changes of discharge. A small change in the elevation of the gage might have a significant influence upon the computed discharge of the river.

Q. That ratio is indicated by the relation of the gage at Chippewa to the one at Buffalo, to which reference was made on yesterday?

A. No, I don't think it is.

Q. Eliminating the Buffalo gage for the time being, may not the volume of flow be indicated by the gage at Chippewa?

A. I think so, if we had correct measurements to connect it with the discharge.

Q. By making the measurements at Chippewa and by measuring the volume of discharge at the International

Bridge, you can work out a relation between the stage of the lake at Chippewa and the volume of discharge, can you not?

A. Approximately.

Q. Within what limitations?

A. That would depend upon the influence of the volume between Chippewa and the gaging station that had to be filled with the flowing water before the full indication, the full effect of the increase or change of discharge would appear on the Chippewa gage.

Q. What is the source of inaccuracy?

A. The source of inaccuracy in connecting the discharge at Buffalo with the gage at Chippewa is involved in the volume of water that must be used in filling or emptying the prism of the river, to bring about the change in the Chippewa gage which corresponds to the condition at Buffalo.

In other words, if the discharge at Buffalo is that corresponding to an elevation one foot higher than corresponded to the elevation of the Chippewa gage at the time the discharge measurement began, then before the Chippewa gage would indicate the elevation corresponding to that discharge the water in the river must be raised by the addition to it of a volume whose base would be one foot at Buffalo, and whose area would be the area of the water surface between Buffalo and Chippewa, and whose lower edge would be the change of elevation of the Chippewa gage corresponding to the change of the foot at Buffalo.

This would take a certain amount of time and prevents the transmission of the measurement directly to Chippewa without an investigation and correction for this influence, the added or subtracted water depending on whether the water be rising or falling.

Q. For the river rising one foot in an hour, what would be the volume, the cubic feet per second, in the prism of water to which you have referred? I will ask you to compute that, and give the answer to the Commissioner, making an approximate computation?

A. It must be borne in mind that all the time that this water is rising, or being added, at Buffalo, it is also flowing away over the falls; that with each rise of the Chippewa gage, the flow over the falls is increased, so that it is not simply a measurement of the volume of that prism, but it is a computation of the volume of water that must be put into the river to fill this prism, which is more than the volume of the prism

actually is by the amount which flows out at Niagara over that which flowed out under the conditions with which you started.

Q. You will make the computation I have asked you?

A. I will endeavor to make it.

Q. How often do changes of a foot in the river come about, in your judgment?

A. Well, as I remember the testimony of yesterday, we found some thing like 18 of them in a matter of three months.

Q. The remaining days would be sufficient, wouldn't they?

A. Sufficient for what?

Q. To derive a relation between the Chippewa gage and the volume of discharge?

A. I think a relation could be derived.

Q. And if you did that the uncertainties as to Lake Erie's level would be eliminated, would they not, in the result?

A. They would be eliminated so far as the discharge of the Niagara River is concerned, assuming the discharge measurement itself to be accurate. But they would not be eliminated so far as connecting that discharge with the elevation of Lake Erie at the particular time of observation.

Q. In your judgment, Mr. Williams, may a relation be worked out connecting the varying stages of the lake at Cleveland with the elevation of the water, as indicated by the Chippewa gage?

A. I think so. You said "varying stages?"

Q. Yes.

A. Understanding stage to mean the elevation of the lake over a considerable period of time, as a month, I think that is correct.

Q. And if that were done, the effect would be to eliminate these inaccuracies which were due to the level of the lake at Buffalo, which you have specified in your discussion of this subject?

A. As a general proposition.

Q. That is to say, that a way of eliminating those inaccuracies would be to establish a relation between the gage at Cleveland and the gage at Chippewa, and having that relation in mind, to take that in connection with the volume of discharge as it was measured, and that would eliminate these inaccuracies due to the condition at the head of the Niagara River and Lake Erie?

A. To a very large extent, insofar as they affect the discharge measurements themselves.

Q. I will ask you to compute the elevation of the Niagara

River at Chippewa from the elevation of Lake Erie at Cleveland for the months of July and November inclusive, 1906. You may use for that purpose the elevations of Lake Erie appearing on page 93 of the report of the International Waterways Commission and you may make use of the law of gage relations established by the Lake Survey and described in the document entitled "Preservation of Niagara Falls," to which your attention has already been directed?

A. I will do so.

Q. Have you made the computation?

A. No, sir.

Q. Do you know whether it has been made or checked by Mr. Ayers, your assistant?

A. I know that Mr. Ayers has made some computation here with Mr. Shenehon. As to what that computation is, or what it represents, I am not informed at the present moment.

Q. This computation is a computation that as you understand has been made under an arrangement by which Mr. Shenehon and Mr. Ayers made some computation?

A. I assume so, but up to the present moment this computation has not been explained to me, nor did I know at the time it was made what it was, nor do I know what it is now, nor the result of it. And until I have an opportunity to examine it I am not prepared to testify about it. I presume in five minutes I will be ready to testify.

Mr. Wilkerson: We will adjourn for five minutes.

(After recess.)

The Witness: I now have made such computation.

Q. You are now ready to answer my previous question, are you, Mr. Williams?

A. The question I understood you to ask was if I would. I said I would. I now say I have made a computation.

Q. You have made the computation?

A. I have.

Q. What are the results of your computation?

A. The results of the computation indicate that for the period from July to November, 1906, and June to November, 1907, the monthly mean elevation of the Chippewa gage has been computed from the monthly mean elevation of the Cleveland gage by the application of the equation connecting the Buffalo gage with the Chippewa gage; and that the maximum variation of the computed elevation at Chippewa from the observed elevation was .18 of a foot, the computed elevation

being low; that the minimum was a check of zero in the second decimal place; and that the maximum excess of computed elevation at Chippewa over the observed was .07 of a foot.

Q. That is to say, Mr. Williams, you have been able in the manner indicated to take the water level at Cleveland, and from that to predict the water level at Chippewa, that is 180 miles across Lake Erie and 20 miles down the Niagara River, with a difference of 10 feet in slope, to within an inch?

A. In some cases the elevation being the monthly mean elevation, and not a daily elevation.

Q. The monthly mean elevation?

A. The monthly mean elevation. In one case, the error is something over two inches, but that is only for November, 1907. The others all falling within the inch.

Mr. Adcock: These were not daily or hourly elevations, but the monthly mean?

A. Monthly mean elevations.

Mr. Wilkerson: So that taking the elevation of Lake Erie as indicated by the monthly mean stage at Cleveland, and applying to that the relation between the discharge through the Niagara River, and lake elevation deduced by the Lake Survey officers, you find that you get a result as to the elevation at Chippewa which is precise, within the limits as stated by you?

A. Yes, sir.

Q. And the average of that is about a half an inch?

A. No, if you take them all in, it would be I think over one-half an inch; or, to state it another way perhaps would make it more clear: There are three months in which the computed elevation is within half an inch of the level of the actual. The others all exceed the half inch.

Mr. Adcock: How many months are involved?

A. Eleven months.

Mr. Wilkerson: What does that indicate to you, as an engineer, as to the correctness of the relation established between the stage of Lake Erie, as indicated by the gage at Cleveland, and the elevation of the Niagara River at Chippewa?

A. That, considering the monthly mean elevations at the two points, the relation is established with a reasonable degree of precision for gage comparisons.

Q. Well, is not the elevation of Lake Erie at Cleveland, as indicated by these monthly means, substantially the stage of Lake Erie?

A. That is what has been taken as representing the stage of Lake Erie.

Q. Have you computed the elevation at Chippewa from the mean elevation at Buffalo for similar months?

A. That computation has been made.

Q. And with what result?

A. It shows that for the period in 1906, July to November, inclusive, and the period in 1907, June to November, inclusive, the mean elevation of the Chippewa gage as being predicted from the mean elevation of the Buffalo gage, with a maximum variation of the computed from the observed of .03 of a foot, the observed elevation being greater than the computed; that both the computed and observed have agreed through the second decimal place on one occasion, and that on three occasions, the computed has exceeded the observed by .02 of a foot.

Q. That is to say from the mean elevations at Buffalo you have been able to predict the Chippewa gage within substantially a quarter of an inch?

A. That is correct.

Mr. Adcock: What is that monthly or mean?

A. That is the mean monthly.

Mr. Wilkerson: What does the accuracy of this prediction indicate to you, as an engineer, as to the reliability of the gage readings which are concerned here?

A. Why it indicates the probable accuracy of the monthly means of all the gages involved.

Q. Indicates a very high degree of accuracy, does it not?

A. Why it does not seem to me that is a high degree of accuracy for observations with a recording gage. You ought to get as close as that.

Q. What does it indicate as to the estimate of a relation between the monthly mean variations at Buffalo, and the monthly mean variations at Chippewa?

A. It indicates the establishment of a relation with a satisfactory degree of precision, so far as gage elevations are concerned.

Q. And I understand that the period covered is 11 months?

A. Yes.

Q. I show you two sheets, which for the purpose of your cross-examination I ask to have marked Williams Exhibit Cross-Examination Number 4, the same being the hourly water levels as recorded by self-registering gage at Chippewa, Ontario, during the month of November, 1906. And I am

using here photographic copies of those. These original documents have all been introduced in evidence in this case. One is for the Buffalo gage, November, 1906, and the other is the Chippewa gage November, 1906.

Mr. Adcock: Do I understand that the original of that has been in the record, or referred to in some way? I understand that is the first time that any gage readings of the Chippewa have ever come into the case, except so far as they have been referred to in the last day or two?

Mr. Wilkerson: However that may be, they are photographic copies of the hourly water levels, as recorded by the Government gages and are a part of the official records and reports of the Lake Survey office; all of which have been utilized in this case on both sides.

Mr. Adcock: Yes, there is no question about that.

(Document shown witness was here marked Williams Exhibit Cross-Examination Number 4; same consisting of three sheets.)

Mr. Wilkerson: Will you compute from the daily mean elevations at Buffalo the corresponding daily mean elevations at Chippewa and the Niagara River?

A. These computations have been made.

Q. And have been checked as correct, as you understand it?

A. As I understand it.

Q. In the same way as the other computations were made and checked?

A. I assume so.

Q. What range of elevation at Buffalo is covered by that sheet?

Mr. Austrian: As appears from that table.

Mr. Wilkerson: Yes.

A. I see that elevations 571.48 for a mean daily and 574.60 for a mean daily appear as the record of the Buffalo gage.

Q. That is a range of more than three feet?

A. Yes, about 3.12 feet.

Q. What do you find as to the agreement between the computed elevation at Chippewa and the actual elevations?

A. They agree within about two inches.

Q. Do you mean that is the agreement of the——

A. That is the agreement of the means of individual days.

Q. That is the mean agreement?

A. No, not the mean. I say that they all agree within two inches.

Q. That is the outside figure?

A. That is the outside figure.

Q. What is the average of the agreement?

A. There is one case in which the agreement is exact; I find two cases in which the agreement is exact; another case in which it is within .01. From a casual inspection, I would say that the majority of these computations agree within less than one inch. I find that 14 of the observations, including three which agree exactly, agree within half an inch.

Q. Well, you have been able then to predict from the Buffalo gage, the gage at Chippewa within this limit that you have just stated?

A. Based on mean daily observations.

Q. Now I call your attention particularly to the observations for November 4th. The mean is 571.48, the predicted elevation at Chippewa was 562.05, was it not?

A. Yes.

Q. The actual elevation, mean elevation, 562.09?

A. Correct.

Q. The difference being .04 of a foot, or less than half an inch?

A. Slightly less than half an inch.

Q. Well, take the observations for the 27th of November. You find the mean elevation at Buffalo 573.31?

A. Yes.

Q. You find the predicted elevation at Chippewa 573.07?

A. 563.07.

Q. 563.07, which corresponds exactly?

A. Exactly.

Q. With the observed elevation at Chippewa, is that right?

A. That is correct.

Q. Now we have a range there of more than 2½ feet in the two days to which I have directed your attention, have we not?

A. I think so.

Q. 2.53, is it not?

A. You started out with the fourth, did you?

Q. 571.48, 573.31, difference 2.53?

A. I thought you were referring to this same pair that we had before.

Q. My question is how much of a range do we have?

A. You are referring to those two observations you just cited, or the entire range of the series.

Q. The two just cited.

A. I make that 1.83 feet.

Q. There is a range of 1.83?
A. That is it.
Q. Well, now, I direct your attention to the 22d.
A. Twenty-second of November?
Q. You find the mean elevation at Buffalo 574.60.
A. Correct.
Q. The predicted elevation at Chippewa 563.79; the observed elevation at Chippewa 563.92?
A. About an inch and three-quarters.
Q. What was the range between the 4th and the 22d?
A. 3.12 feet.
Q. 3.12?
A. Yes.
Q. Are these daily mean elevations what you could call a stage of Lake Erie?
A. Not according to the definition that we have been applying the word stage to. I would call them elevations. Of course you could call them daily stages if you want to.
Q. They would be daily stages?
A. Daily stages.
Q. The average daily stage of the lake?
A. The average daily stage of the lake.
Q. At Buffalo?
A. At Buffalo.
Q. Having in mind the data to which your attention has been directed in connection with this cross-examination, what is your opinion as an engineer as to the correctness of the formula or law by which the mean elevations at Buffalo have been connected with the elevations at Chippewa?
A. I think it is about as close as could be derived.
Q. And would indicate, from an engineering standpoint, a high degree of precision, would it not?
A. The characteristic precision of the United States Lake Survey.
Q. Now, the monthly mean elevation of the lake at Buffalo was 572.319?
A. That appears to be stated on the second sheet of this exhibit.
Q. How much above the mean was the mean level on the 22d and the 27th, above the monthly mean?
A. On the 27th, it was roughly a foot; and on the 22d roughly 2.3 feet.
Q. Now is it your opinion that under those conditions Lake Erie was tilted up, as you have been using that term?

A. Well, I could not tell without reference to the Amherstburg gage. I suspect that it probably was during the higher period.

Q. How else could the elevation at Buffalo be accounted for, except that the lake was tilted up?

A. Being November, I think it would be rather difficult to account for it in any other way.

Q. Then it is your opinion that those mean observations for those two days indicate that at those times the lake was tilted up?

A. I think so.

Q. And this indicates that even with the lake in that condition, the slope relations are maintained between the Buffalo gage and the Chippewa gage?

A. Within the limits shown in this comparison.

Q. Which are very close?

A. Well, that depends again on your definition of "close."

Q. As closely as you have pointed out? On the 27th it corresponds exactly, doesn't it?

A. I haven't the exhibit here at this moment.

Q. The 27th is the day on which we found the computed elevation at Chippewa corresponded exactly with the observed elevation?

A. On the 27th they corresponded exactly, that is certainly a very close coincidence.

Q. Well, now, you could go from the Chippewa gage to the Buffalo gage in the same way, could you not, Mr. Williams?

A. In the inverse way.

Q. Yes. The Chippewa gage is in a secluded position, and what would be your opinion of the results which you would reach if you worked back from the Chippewa gage to the Buffalo gage?

A. You mean results as to what?

Q. As to getting an accurate expression of the elevation of the lake at the Buffalo gage, the stage of the lake at the Buffalo gage?

A. For these particular observations, I should expect, if you worked them backwards, you would get the same result as working them forward. I do not see anything in the process which would lead you to anything when you add a certain quantity and then subtract the same quantity from the result, I do not see why you would not arrive at your original quantity.

Q. And in the absence of the Buffalo gage, you would be

able to predict substantially what the level was at Buffalo, would you not?

A. Within three or four inches.

Q. And at the outside, and with the same degree of precision as indicated with respect to predicting the Chippewa gage from the Buffalo gage?

A. Well, I consider that a comparison of 30 days is hardly sufficient to warrant one in saying what you could do generally. In these particular cases, you would have done so and so.

Q. Have you made any examination of this subject for the purpose of determining whether or not the results which are reached with the observations of 1906 as a basis, would be substantially the result reached at other times?

A. I have not, but I have no reason to expect that there would be very marked deviations.

Q. Now, Mr. Williams, you have computed the elevation of Niagara at Chippewa from the monthly mean stages at Cleveland with a certain degree of accuracy, to which you have testified; and with a still higher degree of accuracy, you have computed the elevation at Chippewa from the monthly means at Buffalo; and you have also computed with a degree of precision, which you have stated, the daily elevation at Chippewa from the daily mean at Buffalo, even at times when Lake Erie was tilted up to the extent of a foot or more. What is your conclusion as an engineer, having that in mind as to the identity of effect in outflow conditions in the lake elevations at Buffalo, whether the lake is tilted up or not?

A. Having in mind the fact that the computed differences on the daily observations are something more than 100 per cent. greater than those on the average monthly, it appears to me that it does indicate an influence due to tilting of the lake.

Q. How large an influence, now that this additional data has been called to your attention, do you think there is?

A. That is very difficult to say, because there is an effect of tilting in both, and you haven't got it eliminated in either case, so that it is not possible to make a direct comparison. The one in which the effect of tilting seems to be the larger seems to increase the error of the computation, as I said, about 100 per cent.

Q. Does it apparently increase or diminish the discharge?

A. In the one particular case of the high elevation, it appears that the discharge is increased, due to the tilted position

of the lake; and in the case where the lake is 1.1 foot lower, the computed agrees with the observed.

Adjourned to Thursday, July 24, 10 o'clock a. m.

(In chronological order, here follows the testimony of Mr. Joseph Ripley on Thursday, July 24, and the morning session of Friday, July 25th.)

After Recess Friday, July 25, 3 p. m.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Mr. Wilkerson: Q. I wish to call your attention to a paragraph from Appendix Number 7 to the Report of the Board of Engineers on Deep Waterways Part 1. Appendix Number 7 is signed by C. B. Stewart, Assistant Engineer; page 299, referring to the discharge measurements made in the Niagara River at Buffalo between the dates September, 1897, and September, 1898, at the discharge section on the line of the guard rail, on the north side of the International Bridge. The paragraph is as follows:

"Eddies are produced by the piers, to some extent, but they do not extend more than about 5 feet from the pier, and in most cases the current remains practically linear, with about the same amount of fluctuations as near the middle of the span. It is thought that little error has been introduced from this source."

I will ask you whether or not in reaching your conclusion as to the measurements in the Niagara River you had in mind that statement?

A. I did not have that particular statement in mind when I made that answer, but I had in mind statements made or appearing in a paper read by Mr. Clinton B. Stewart, before the Western Society of Civil Engineers on December 20, 1899, or some three months after the date of this Appendix, in which it is stated, first:

"For the location of the stations on the discharge section, the shorter spans 1, 2, 3, 7, 8 and 9 were divided into eight equal parts, and the longer spans, 4, 5 and 6, in 12 equal parts; thus making the distance between stations about 20 feet. These stations were marked on the guard rail, etc."

Then later he says, speaking of observations with the direction current meter:

"The direction was practically constant between the 2-8 and 6-8 stations of the short spans; and between the 2-12 and 10-12 stations of the long spans. Next to the piers, the direction was somewhat variable, and the meter would swing through an angle of 10 or 15 degrees. In such cases, the mean of several determinations was taken as the direction."

Now, the stations being 20 feet wide, I would interpret that as meaning that between the 2-8 station it was constant, but it was not constant between the 0-2, or for a distance of about 40 feet.

Mr. Wilkerson: May I see the pamphlet from which you have just quoted?

The Witness: (Handing document to counsel.)

Mr. Wilkerson: Q. I direct your attention to page 488 of the document from which you have just quoted, which is a written discussion by Mr. E. E. Haskell of the paper of Mr. Stewart, from which you have quoted, and ask you to read the paragraph which I have marked there into the record; and I will ask you whether you had that statement of Mr. Haskell's in mind when you criticised these Niagara measurements?

A. (Reading.) "In regard to the bridge section, it is a much better one for discharge work than many would suppose. As Mr. Stewart has shown in his paper, the current sets very squarely through the bridge in all spans. Aside from the small eddies along the sides of the piers, and those caused by the sunken caisson, there were few of any magnitude to be seen. The ease and rapidity and the small expense with which observations can be made from such a bridge are a large consideration. The meter can always be set at the same point for a station, and in general the time required for measuring a full discharge is very much less than in work from boats."

That is quoted from a discussion by Mr. E. E. Haskell.

Q. Did you have that in mind?

A. I did.

Q. Now I call your attention to the report of the Chief of Engineers United States Army for the year 1900, page 5332. I direct your attention to the following statement commencing on page 5332:

"The analysis of meter positions was first made by Mr. C. B. Stewart in discussing the Deep Waterway observations

on this river, and out of this germ has been developed our own tables for meter location and a static method of sounding."

A. I had and also the next paragraph of the reference.

Q. If you will go ahead and read, or I will read it:

(Reading.) "The wetted perimeter of the Bridge Section, as developed by the soundings, is so broken and irregular, and the water is so perturbed and deflected by the bridge piers, and by a caisson that escaped during construction, and lies across a portion of span 6, that the validity of results derived from such a section may be questioned.

A discussion of this point, however, points to an error to be expected from this source but little in excess of that of an open-river section.

Let it be assumed that the eddies and boilings close to the piers make correct estimates of the flow impossible in areas extending for certain distances from them, and that the caisson lying across a portion of span 6 adds another uncertain area. The resulting indetermination as affecting the total volume of flow may be closely estimated as follows:

Taking the doubtful regions as those portions of the cross sectional area extending 10 feet in spans 1, 2; 8, 9, and 20 feet from the piers in the remaining spans; adding 300 square feet for the caisson, they are as follows:

	Square feet
Span 1	90
" 2	110
" 3	500
" 4	680
" 5	960
" 6	940
" 7	440
" 8	340
" 9	200
Total	4260

This is about 10 per cent. of the total cross section. With a velocity taken as half that of the mean velocity of the river, the discharge in question is 5 per cent. of the total volume.

It is not probable that the errors in estimating the flow in these 19 doubtful places will have the same sign. In some the quantity will be taken too great, and in some too small, so that the summation will balance error against error and eliminate a part of them. It will therefore be entirely safe

to assign 10 per cent. as a maximum error in the sum of the partial discharges.

With this liberal allowance, the indetermination in the volume of flow in the full river from this cause is seen to be 10 per cent. of 5 per cent., which is but ½ of 1 per cent."

Did you have that in mind?

A. By whom is that report signed?

Q. By Francis C. Shenehon, assistant engineer, and Mr. E. E. Haskell, assistant engineer, signed on page 5361?

A. I had that in mind, and also what to me seems a much more correct description of the conditions, which is to be found at the top of page 5342 which has already been read by me into the record. And I want to say that at the time I read that in, there seemed to be an idea that I was attempting to criticise the language. I read it because to my mind it was a most exact description of the conditions which existed between the bridge piers of the Niagara River; not with the idea of criticising the rhetoric or description but, as I say, now, as a most exact description of the conditions that existed in the Niagara gaging station, and as they were believed to exist by Mr. Shenehon, at the time he wrote this report.

Mr. Adcock: What is the quotation you refer to? Just read it.

Mr. Wilkerson: Q. What you read as justification for your comment on the measurements in the Niagara River was the general statement, whereas in both the writings of Mr. Shenehon and Mr. Haskell, and in those of Mr. Stewart, we do have a specific statement of the precise conditions, and of the error which it was deemed might possibly result from the difficulties.

Now, isn't it your view, if you were going to get a correct expression of an effect, you would go to that portion of the report which gives the data.

Mr. Adcock: What is the quotation referred to, Mr. Williams?

A. (Reading.) "In such a section as that of the International Bridge, the proper derivation of the velocity coefficient is the most difficult part of the river gaging. To obtain it, the writhing mass of water streaming through the bridge openings and eddying about the piers, spurting and lagging in minor pulsations, speeding faster as the lake rises, and flowing leisurely in its low stages must be congealed to a solid by some instantaneous method of survey, and its dimensions taken."

Now that is also signed by Francis C. Shenehon, assistant engineer, and Mr. E. E. Haskell, assistant engineer, and occurs somewhat later than this exact computation of the effect of these disturbances; and I would assume that the man, as he went on with his work, became more qualified to pass judgment on what he has done; and these concluding statements, these later statements were entitled to as great weight as his earlier ones.

Furthermore, from my personal investigation of the Niagara section, of the conditions of the river as I have passed over the bridge in the cars in the day time, and have seen the eddies come up to the surface, not only at the bridge piers, but elsewhere, I am convinced that the description on page 5342 is a correct description and that the estimates made on page 5332 are not sufficient to account for the errors introduced into the gagings by these oblique and turbulent currents.

Q. I direct your attention now to page 5361 of the report, which appears to be later than page 5342 of the report, and call your attention there to the paragraph where it says:

"It is exceedingly satisfactory to be able to report so close a check in the results of the measurements of the two sections."

A. Just where is that?

Q. Page 5361.

A. Yes, I see it now; I have got it.

Q. (Reading.) "The sections are very different, and received different methods of treatment. The Bridge Section index velocities depend on the B meter under the Detroit rating of this instrument by an excellent observer.

The open section velocities depend on the A meter, on the Buffalo base, by different methods and by different observers. The Bridge measurements were in 1898. Those of the Open Section, in 1899 and 1900. The former was from a fixed structure, the latter from a survey boat, whose influence on the current lines might be a factor in the result. The coefficient work has some elements common to both, especially the rating of the traveling meter. Yet it will be seen by a reference to the tables 4 that the co-efficients would not be appreciably changed by using any other established rating for the traveling meter. The co-efficients in both sections have been established by overwhelming numbers of observations, by accurate methods, and were derived by different methods of reduction.

Having a splendid equipment, the entire work has been carried out with greatest attention to fundamental principles and to details, and with the infinite patience demanded in gaging the many moods of this great river."

Did you have that in mind?

Mr. Adcock: What is the report signed by?

Mr. Wilkerson: By Mr. Shenehon and Mr. Haskell.

A. I had that in mind, and also this at the top of page 5334:

"The B meter is credited with a somewhat greater range in its diurnal fluctuations"—I don't know what the diurnal fluctuations are, but evidently are something or other—"And has a remarkable record for the pertinacity with which it clings to a mean rating. The original calibration of this instrument was in September, 1898. In February, 1900, an elaborate rating gave a value to the mean wheel revolutions but one per cent. different from its original rating. In the interim, the meter had suffered the vicissitudes of gaging a wicked section; it had been fouled on a ragged bottom and caught in the sheet iron sheathing of a bridge pier; had bent the blades of its wheel, and had then retrued; it had lost its tail and had it replaced by a somewhat different one; its standard lead had been changed for one three times as heavy; its pivot had been dulled by passing upwards of 5,000 miles of current thread through the wheel."

In view of that, it does not seem to me that was a particularly delicate instrument, nor one which would respond readily to these changes of velocity to which it was subjected. That it was, in fact I would almost call it a crude instrument, and it does not seem to me that this extreme exactness that is claimed can be predicated upon the work of an instrument which would stand any such handling as that; nor do I think that shows particularly good handling.

Mr. Adcock: How about the use of an instrument that had been through all that trouble?

A. (No response.)

Mr. Wilkerson: Q. Let me read some more:

"The strength of the instrument may be judged by this test; its sensitiveness may be gathered from its rating observations. These are necessary in order to interpret the registered revolutions as the meter spins in the stream into length of water thread, and thus obtain the speed of the current in feet per second."

The point is that in these reports with reference to these

measurements, it has been stated with exactness the data as to the error which might result from the section being located where it was; and also it has been stated that that checked with another section, and is that not the thing that is to be taken into consideration rather than any general statements about the appearance of the river?

A. I think not. One does not—

Q. The appearance of the river next to the piers?

A. One does not need to be told that there are oblique currents, or are not, when we can see the visible evidence of them on the surface of the river. When an eddy reaches the surface, it is an indication of a disturbance further down, and those disturbances in the water decrease as they pass away from the point where they originate, so that if an eddy appears on the surface, you can be sure that there was a much larger one where it started from, near the bottom. As to this analysis as to the effects and so on, that is the opinion of the observer.

So far as the comparison of the two sections is concerned, the Open Section was not far enough away to be entirely free of the same influences that caused disturbance in the Bridge Section.

Further than that, it is checking the same tool against the same tool, which is no check at all. It is simply two measurements with the same thing.

You may take a yard stick that is an inch short and measure the width of this room, and go out in the hall and come back and measure it again and you will get the same width; but the width will not be right. That is the situation here. You take an instrument that you do not know whether it is right or wrong. You measure, and you get a certain result. You go somewhere else and measure with the same instrument and get a similar result, and call that a check.

Now, it is a check upon the performance, the manual performance of the operation and a check upon the mental operations used in its reduction; but it is not a check upon the instrument itself nor upon the accuracy of the result. On the direct line between the accuracy of the work and the accuracy of the result, this work was very accurate. The result I do not believe to be accurate.

And furthermore I will say that had these results been made with a Price meter, which we all recognize would not have agreed with this within probably 3 or 4 per cent., every check that has been applied in this case could have been

applied to those results, with equal facility and equal agreement. If it had been made with a meter which registered 20 per cent. over the Haskell, every check that has been applied in this case could have been applied then. As far as these checks are concerned, you are simply jumping over a fence and then crawling back under it, and that is all there is to it.

Q. Let us take the case of the St. Clair River where there are such differences in velocities as are found in the different cross sections which have been measured there. Does the fact that a comparison of those results shows accuracy of the measurement within comparitively small limits have any effect upon your mind in reaching a conclusion as to the credit which may be given to water measurements of this kind?

A. They have. But the same thing applies there; that it is the same instrument and the same operation checked against the same instrument and the same operation.

Q. But under widely different circumstances?

A. Not very widely different circumstances. Let us assume that you had a meter there that registered 20 per cent. more, which rotated sufficiently more easily to have registered 20 per cent. more in the same current; and that by some mistake or other the rating of an instrument like the one here had been applied to it, your discharge would have been 20 per cent. greater, and every comparison you make now could have been made then; every check applied that you made then you could make now, and similar results obtained, but it would not have been an indication that the measurement was correct there. But these checks you have applied indicate exceptional workmanship; that the work has been very carefully done, but there were conditions there beyond the control of the observer.

Q. How far out of the way do you think on the average, as a general rule, these current meter observations have been?

A. In the large rivers?

Q. In the large rivers?

A. I think about 10 per cent.

Q. You think there is a possibility of their being 10 per cent. out of the way or as a matter of fact they have been 10 per cent. out of the way?

A. I think as a matter of fact they have been. I think it is very doubtful if there has ever been one made that was within 5 per cent.

Q. Have you been influenced in reaching that conclusion by the tests which were made on the Detroit River, and which

have been put into the record in this case; that is rating the current meters in the current itself?

A. You mean by the coloring matter, by the use of coloring matter?

Q. Yes?

A. I have, but bearing in mind that in the measurement of the Niagara River, the cross section of which was, if I remember correctly, something over 40,000 square feet, that there were actually occupied positions in that river by the meter of—while I will not undertake to be definite, I will say less than a thousand square feet were actually covered by the position of the meter wheels, at any time during the observations.

The current meter is an inferential device. It is not an absolute device that measures the velocity at a certain point, and it may measure it more or less accurately, but if it does, if you have only occupied 1 foot out of every 40, you cannot say within 5 per cent., or even within 10 per cent., that the velocities of the other 39 feet are the same. There you have got the measurement of 1 foot, and 39 feet that you have not investigated.

Now I say, gentlemen, that the chances of your getting within 5 per cent., or even 10 per cent. under those circumstances is extreemly remote, and I base that opinion, not only upon all this information, but upon my experience in measuring the velocity of water by inferential measurements, where the area of the cross section was absolutely determined, and where the quantity of water measured was absolutely determined.

Q. Is it your opinion that the Haskell meter registers, as a general rule, too high or too low?

A. Well, as a general rule, taking it in smooth water and without disturbances, it depends on its rating. If it is properly rated, it registers very nearly what it is rated, but when you apply to still water ratings or those taken at the surface of a body of water the conditions that the meter meets submerged 40 feet below, in a turbulent current, I feel that there is no reasonable comparison, that there is no limit that we can set upon the variation which that meter may show from the rating which it showed at the surface.

Q. If comparison of these conditions of turbulence shows the meter sometimes registers too high, and sometimes registers too low, isn't it a fact that is well understood in combining observations of this kind that the error on the one side

at one time is compensated by an error on the other side at another time, and in the long run these errors cancel each other to a large extent?

A. I see no reason for believing those particular errors would cancel each other. All the information I have indicates to me the meter registers low in those disturbed currents.

Q. Let us assume that the meter registers low a certain uniform per cent. low, if you used that meter over a long period of time, when speaking of relative results, you would have the same element, that the meter registers too low through all of them, so that for purposes of comparison the error in your reading is not such a material matter?

A. For purposes of comparison of one section with another, that is of very little consequence, but that has nothing to do with the measurement.

Mr. Adcock: The measurement would be too low?

A. The measurement would be too low.

Mr. Wilkerson: Q. And the measurement at another time would be correspondingly too low?

A. Yes.

Q. So that the difference would be about the same as if the meter had registered right?

A. That depends altogether upon the percentage by which the meter registers low. The difference will be affected by the same error that there is in the original registration.

Q. That is to say if you were comparing observations where there was a difference of say 40,000 cubic feet a second, and your meter was 5 per cent. out of the way, it would affect that difference by 2,000 cubic feet?

A. Exactly.

Q. As to this other point which you make, that you have measured only a small part of your cross section, and that it is unfair to assume that from measurements on a small number of points in a cross section you can reach a conclusion as to the entire body of water that goes through, have you been influenced in reaching your opinion by the corroborative check of the different cross sections of the rivers which have been measured, as the St. Clair River? Wouldn't that indicate that it is a proper process of reasoning to assume that the average of the conditions at the points measured is substantially the average condition of the whole cross section. Wouldn't these corroborative checks tend to show that you might properly use that method of reasoning?

A. I think not, because you would find if you adopted some

one point in the cross section, and used a meter only at that point, that your gagings would coincide more closely than they do when you use several points. And if you were to use a thousand points in a gaging, and compare it with another gaging in which you used a thousand points, those two gagings would not correspond as closely on an average as they do, perhaps, when you use twenty or forty points.

Q. You do not attribute to any inaccuracy in the rating of the meter any such difference in results between the increments in the Niagara River which you reach, and that reached by the Lake Survey, do you?

A. I don't know where to place it. I feel very sure that it is there.

Q. Do you think there is any possibility that any appreciable part grows out of the inaccuracy in the meter measurement?

A. I think that an appreciable part of it has come out of inaccuracy due to applying a rating over a straight course to the indications of the meter in disturbed water.

Q. I direct your attention to page 74 of the "Preservation of Niagara Falls", the same being a Senate document heretofore referred to in the evidence in this case; chapter 15 the first paragraph of which is:

"The hydraulic work of the Lake Survey on the outflow of the Great Lakes depends fundamentally for its accuracy on the proposition that the Haskell Current Meter rated on a still water base gives the true velocity of flowing water. The work of the Lake Survey, up to the time of the experiments here briefly described, contains no demonstration of this vital point."

And then there are tables given of tests of the accuracy of the Haskell Current Meter in the Detroit River, table LXVI, and with this conclusion:

"On June 1, 44 observations showed a mean velocity of 2.818 feet per second by the fluid and 2.806 by the meters; the meters giving a lower velocity by merely $\frac{1}{4}$ of 1 per cent.

On June 2, 32 observations showed a mean velocity of 2.922 by fluid and by the meters 2.933; the meters giving a higher velocity by about $\frac{1}{3}$ of 1 per cent. These small divergencies are the accepted errors of observation characteristic of hydraulic work. Individual observations show larger divergencies coming from fluctuating velocities. The tests demonstrate conclusively the correctness of the indications of the Haskell meters."

Mr. Adcock: The year was 1906 that the tests were made?
Mr. Wilkerson: Yes.

A. That evidence is in this case, testified to by Mr. Shenehon, and was given consideration, and I believe that for the conditions which are represented here those tests were about all that is claimed, but they were not tests made under conditions which the meter encountered in gaging the Niagara River, and therefore they do not apply.

Q. Were they made under the conditions under which the St. Clair River was measured?

A. In which the surface measurements of the St. Clair were made, they were reasonably comparable.

Q. How about the Detroit River?

A. The Detroit River would be the same; they apply to measurements near the surface of the stream.

Q. Do you attribute any part of the difference between the result which you have reached as to the increment for the St. Clair River and the result of the Lake Survey, to any inaccuracy in meter measurements; if so, what part of it?

A. Yes, I attribute some of it to inaccuracy in meter measurement.

Q. In your opinion, in what way would any inaccuracy of meter observations be reflected to a greater extent in the conclusions reached by the method of the Lake Survey, and those reached by your method?

A. I don't see that there would be any difference.

Q. Then why would meter observations have anything to do with the difference in the result which you have reached? I understand you have taken these observations and simply combined them by a different method; and have you eliminated the inaccuracy of the meter in the St. Clair, so far as any difference between your results and the Government is concerned?

A. For the value which I finally gave to the increment, I had in mind the possibility or probability, in fact I may say the certainty, of errors in the meter measurements.

Q. That is to say you took—

A. I allowed myself a variation of 10 per cent. in my mean.

Q. You made an increase of 10 per cent.?

A. I allowed myself a variation of 10 per cent. and gave the minimum figure.

Q. Why did you increase rather than decrease it?

A. Because all the information I had leads me to believe that these measurements are low.

Q. And you have no information on the subject except what appears from these reports and tests?

A. And from the experience of some 20 years on hydraulic work, in which I have been engaged in measuring water by various devices, current meters and others, comparing one device with another, studying the peculiarities of water under conditions where it could be studied to greater advantage than it has been able to be studied in these gagings.

Q. You never spent any time making studies at the International Bridge Section?

A. I never did stop to observe the condition of the water, or the current as it passes through.

Q. You say you did look at the water?

Mr. Austrian: He said he observed it.

Mr. Wilkerson: Where was that observation made?

A. All the way across the bridge.

Q. From the car window?

A. From the car window.

Q. That was the only observation?

A. I made it several times.

Q. But you never got off?

A. I never got off and examined the condition there at the bridge.

Mr. Austrian: That is you never walked over the water?

A. No.

Mr. Wilkerson: The point is you never stopped for purposes of making any kind of detailed investigation of the subject; it was a superficial examination made, in the time it takes the car to go over the bridge?

A. On one occasion the train was stopped on the bridge for some considerable time. The train was late and could not get its entrance, and I had an opportunity to make—of course it was only an observation of the surface, which I suppose may be called superficial, but I doubt if even the Government Engineers have seen anything below the surface.

Mr. Adcock: You know something about the bed of the river and so forth?

A. Based upon the evidence and information regarding it that is presented in these various reports and various papers that have been written on the subject.

Q. And the currents?

A. And the discussions which I have had with men who were members of Mr. Shenehon's party on these gagings. Three of them were students of mine, and I knew more or less of what was going on, naturally.

Mr. Wilkerson: You presented certain statements here regarding the dredging of material in the St. Clair River, and the effect of that dredging in your judgment upon the level of the lakes?

A. I did.

Q. And you spoke about computing the volume of the prism, as I recall it, which was equal to the quantity of work which had been done?

A. I think I gave an estimation of what the equivalent area would have been, if concentrated in a given length, in a given section.

Q. Now do you know what disposition was made of the material which was dredged from the different points in the St. Clair River?

A. Why it was dumped at various points, various places in the river, in the shallows generally, or in the lake.

Q. Do you know specifically where it was dumped?

Mr. Adcock: You mean each shovel full?

Mr. Wilkerson: No, in a general way what disposition was made of the material which was dredged out of the lake?

A. I know a very large amount of material was at one time dumped in the St. Clair River about over where the tunnel is, below Port Huron.

Q. That is to say there has been 584,982 cubic yards dumped there, has there not?

A. I don't remember the figures now. I presume I could look them up as I think I have them in detail.

Q. Is it your understanding that of the material which was removed from the St. Clair River practically all of it, that is to say, all of it except a little more than 7,000 cubic yards, which was dumped in Lake St. Clair, was deposited in the St. Clair River in the vicinity of the work?

A. No, I have no particular understanding about it. That material is reported in the report of the Chief of Engineers as having been removed. It was removed from the channel. It was put somewhere where it was not supposed to get back into the channel, and I assume the engineers were able to so locate it.

Q. Is it your understanding that there was removed from Black River at Port Huron more than 400,000 cubic yards, which was dumped in the St. Clair River in the vicinity of the International Tunnel?

A. I would have to look at my notes on the St. Clair River dredging before I answer that question; but it is my understanding the majority of the material removed from the

Black River in 1891, 1892 and 1893 was dumped in the St. Clair River over the tunnel at Port Huron.

Q. How about the material which was removed from Pine River?

A. I don't know where that was dumped.

Q. How about the material removed from Bell River, at Marine City, Michigan?

A. I don't know where that was dumped specifically, at the present time at least. I might have known once.

Q. And about the Detroit River, did you understand that a large amount, 800,000 cubic yards, which have been removed from the river Rouge at Detroit had been deposited in the Detroit River?

A. I assumed that it was. I didn't know.

Q. In the statement which you made with reference to the lowering effect of this dredging upon the level of the lakes, did you include anything except the material which had been dumped into the St. Clair River from the Black River?

A. I had in mind all those things.

Q. I do not recall that you stated anything about them?

A. No, nor did I—

Q. In the statement which you presented?

A. No, I did not state specifically that.

Mr. Adcock: You mean in his testimony?

Mr. Wilkerson: Yes.

The Witness: Here is the proposition: That is this material was moved from the channel. It was put somewhere else than in the channel. It was moved from the critical points in the channel to increase the discharging capacity of the channel at those points; and, its deposition in the shallows, or in very deep water, would have comparatively small influence upon the discharge of the river as compared with the effect of the excavation through the controlling point and through the shallow point.

Q. It unquestionably had some effect, though, didn't it?

A. Oh, some effect certainly.

Q. And is an element which ought properly to be taken into consideration in determining the effect of the dredging upon the level of the lakes?

A. And it was so considered.

Q. How did you consider it?

A. Why I considered it in this way: Here was a visible lowering of the lakes taking place suddenly; a change such as is not to be found elsewhere in the records of the lakes. It must have been brought about by some great cause. No

great effect is produced without some great cause. There could have been various causes for it. There might have been an extreme drouth for several years. There might have been something in the nature of excessive evaporation perhaps that would have affected it; or there might have been an increase in the discharging capacity of the river.

An examination of all the records that were available points to no extreme drouth, points to no remarkable change of evaporation; but we do find that large and important changes were made in the channels connecting the lakes at this time. The time of opening those improvements is coincident with the time when this rapidity of fall takes place; and unless some other reason can be found to explain that fall—and I might say that the principal witness of the Government was asked to explain it, and I think he succeeded in explaining about 0.4 of a foot of a fall out of something like 1 foot. His testimony can be referred to. I assumed that he was possessed of all the information that there was available in the Government archives bearing upon that point, and that after his testimony it was hardly necessary for me to search them further.

I had up to that time made a diligent search for a cause for that lowering, and the one which I found was the improvement of the channels. And I believe that that was the cause, and I believe that it will be impossible to find any other cause that will be adequate to explain even a small part of the lowering of Lakes Michigan-Huron which took place about 1889.

Q. Wasn't the testimony of the Government witness, Mr. Shenehon, to the effect that there was a general lowering of the lakes at that time, something that included Lake Erie as well as Lakes Huron and Michigan? We can get this straightened out, if you will refer us to just what you had in mind in connection with your reasoning on this subject.

A. I have in mind particularly the information set forth in tables XVIII and XIX of Williams' Exhibit 34. Table XVIII shows the average elevation of Lakes Huron, St. Clair and Erie, for the open season, being the months from April to November inclusive, from 1860 to 1912.

The first page of that table contains a summary showing the average elevation of these lakes for the period from 1860 to 1889. In that table, the average elevation for the open season of Lake Huron, for the period from 1860 to 1889 inclusive, is shown to be 582.10.

On the second page of that table are presented similarly the average elevations of the same lakes, and they are sum-

marized in periods, 1890 to 1907, 1890 to 1908, 1890 to 1910, 1890 to 1912, 1860 to 1908, 1860 to 1910, and 1860 to 1912; I will take as being the most complete information we have the average from 1890 to 1912; the mean elevation of Lake Huron for that period as being 580.64, showing that Lake Huron has changed in elevation 1.46 feet.

Referring to page 1 of table XVIII, the average elevation of Lake Erie for the period from 1860 to 1889 is 573.16; and on page 2 the average elevation of Lake Erie for the period from 1890 to 1912 inclusive is 572.32, which shows that Lake Erie in the same time was lowered .84 of a foot.

In other words, Lakes Michigan-Huron have lowered .62 feet more from their average position for the period from 1860 to 1889. Over the average from 1890 to 1912, this lowering is to be accounted for the same way. If it were produced by a drouth, by excessive evaporation, it should have affected all the lakes alike. It affected Lake Huron to a much greater extent than it affected either of the others. Therefore it was a cause which was effective and influential upon Lake Huron to an extent that it was not upon the others, and is to be looked for in the outlet to Lake Huron, or in a diversion of water somewhere from Lake Huron.

Now there is no diversion of water which came into play in 1890, and the evidence is that since the diversion of water at Chicago occurred, the average elevations of the lakes have been greater than they were during the ten years immediately before. So it follows that this change of Lake Huron has to be looked for in changes in the outlet of the lake. If you wish to make the comparison of the full year, the data is presented in table XIX, and perhaps it would be interesting.

The mean elevation of Lake Huron from 1860 to 1889 inclusive, for the entire year was 581.91. And its mean elevation, 1890 to 1912, was 580.43, showing a lowering of 1.48 feet.

The mean elevation of Erie from 1860 to 1889 inclusive, for the full year, was 572.92. And the mean elevation of Erie for the period from 1890 to 1912, inclusive, was 572.07, showing a lowering of Lake Erie of 0.85. Of that, Lake Huron had lowered .63 foot more than Lake Erie.

Mr. Adcock: You also compared the fluctuations during the former period with the fluctuations during the second period, as a further check, didn't you, Mr. Williams?

A. I did.

Mr. Adcock: That is the fluctuations of Huron.

Mr. Wilkerson: How much was the difference in elevation of Lake Huron for the period in question?

A. Between the two periods, you mean?

Q. Yes.

A. 1.48 feet based on the mean annual elevation.

Q. How much was the difference of Lake Erie?

A. .85.

Q. Assuming that the relation between the movement of Lakes Erie and Huron be, according to this rule of fluctuation which you derive here, 70, what would you expect the lowering of Lake Erie to be, based on the lowering of Lake Huron?

A. 1.036.

Q. What was the actual lowering?

A. .85.

Q. Your actual lowering you say was what?

A. .85.

Q. And the expected lowering?

A. The lowering obtained by multiplying the lowering of Lake Huron by .7 was 1.036.

Q. And the difference between them?

A. The difference is .186.

Q. The evidence of Mr. Shenehon on that subject was, as he advises me, .17, which is substantially the same thing?

A. I think so. I don't find it just at this moment, but my recollection is that Mr. Shenehon applied this method of computation to this data.

Q. Isn't it a proper method?

A. If you want to find out how much Lake Erie had lowered, if it had lowered 70 per cent. of Huron, yes.

Q. In deriving the increment of the Niagara River, did you not make use of that ratio of fluctuation, or a similar one?

A. I made use of the ratio .753, which represents the conditions of the period from 1860 to 1899. It did not seem to me proper to include in that ratio the conditions on the years after this change of condition.

Q. The difference due to the difference of periods would be very small, would it not?

A. Well, it is the difference between the 70 which he took and .753 which I took. That is all there is to it.

Q. For the purpose of this comparison we were making a little while ago, it would not make any substantial difference?

A. We are dealing with rather small quantities. We will

see what this .753 gives. If you apply the percentage .753, the lowering of Erie should have been 1.114, checking this actual lowering by .26 of a foot.

Q. Doesn't that in your judgment indicate the extent, that is .26 and .18, the lowering in Lakes Michigan-Huron caused by any change in the outflow conditions of the St. Clair and Detroit Rivers?

A. No.

Adjourned to Saturday, July 26, at 9 o'clock a. m.

(In chronological order here follows the testimony of Mr. Frederic P. Stearns, on Saturday, July 26, and Monday, July 28, 1913.)

Monday, July 28, 1913.

GARDNER S. WILLIAMS resumed:

Mr. Wilkerson: What lowering in your judgment as an engineer is indicated by these figures?

A. Those figures indicate the difference between the actual lowering of Lake Erie, and that which would be expected for a lowering of Lake Huron corresponding to the figures given, assuming the ratios of change of elevation of the two lakes to be correct.

Q. Based upon these figures, in your judgment as an engineer, what lowering of Lakes Michigan-Huron is indicated?

A. The lowering of Michigan and Huron indicated, is, of course, the difference between the elevations for the means of the two periods, if that is what you have in mind. If, however, you wish me to say what lowering of Michigan-Huron would be expected from the change of position of Lake Erie, then another computation is necessary.

Q. Assuming the ratio of fluctuation of Lake Huron and Lake Erie as 1.00 to 0.70, and assuming the value of the center of gravity of the mean elevations of the lakes for the 54 years, 1860 to 1912 (open season), shown on bottom line of table XVIII, second page, Williams' Exhibit Number 34 to be Lake Huron 581.46 and Lake Erie 572.79, compute the elevation of Lake Huron for the open seasons of the period 1860 to 1889 inclusive, from Lake Erie's elevation?

A. The computed elevation of Huron for the first period, to correspond with the elevation of Erie for that period would be 581.99 approximately.

Q. How much higher was the observed elevation of Lake Huron for the same period?

A. .11 of a foot.

Q. Now make the same computation for the period 1890 to 1912 inclusive.

A. 580.79.

Q. What was the observed elevation of Lake Huron for this latter period?

A. 580.64.

Q. A difference of how much?

A. .15.

Q. That is, the lake is .15 lower than your computed elevation?

A. Yes.

Q. Now in your judgment as an engineer, what do these figures indicate as to the lowering of Lakes Michigan-Huron between these two periods?

Mr. Adcock: Based on those figures?

Mr. Wilkerson: Yes, as to the lowering caused by change of regimen or channels, in the St. Clair River?

A. To my mind, the sum of these two quantities which amounts to .26 of a foot shows the difference of the difference between the positions of Lake Huron for the two periods, and the difference between the positions which it would have occupied had the assumed ratio of its movement with reference to Lake Erie maintained, indicates a quantity less than the effect of the change in regimen of the St. Clair River.

Q. Why is that true, in your opinion?

A. First because the ratio of change between Lake Huron and Erie changed about 1890. Prior to that time, according to my own computations, that ratio was .753 and since that time it has been .855.

It does not seem to me therefore, that either of these ratios is necessarily properly applicable to the problem in determining what the position of Lakes Michigan-Huron would have been with reference to Lake Erie, when extended over this wide range; the average for the first period being one during which the relation was .753 while the average for the second period, being one during which the relation was .855.

Q. But taking into consideration the figures which you have derived, do you still adhere to your original conclusion that Lakes Michigan-Huron have been lowered by changes in the St. Clair and Detroit Rivers to an extent of about a foot?

A. I still think that it is entirely possible that the levels

of Lakes Michigan and Huron have been changed to this extent, by the works under consideration.

Q. In view of the figures that you derived this morning, do you think it is a reasonable conclusion, or do you think it represents the maximum possible?

A. Considering only the elements involved in the preceding question, I would not think that a lowering of one foot was to be attributed to those improvements.

Mr. Adcock: What other things do you consider?

A. The actual lowering which did occur at this time, and the fact that it occurred within practically two years; that it was a sudden and we might say very great change of condition of the lake surfaces, and must have been brought about by some very exceptional cause.

Q. Didn't you make some comparison of the fluctuations of the mean, lake mean annual fluctuations during the former period as compared with the latter period?

A. I did.

Mr. Wilkerson: On what figures as to water levels do you base your conclusion that Lakes Michigan-Huron have lowered out of proportion to their proper lowering to the water surface of Lake Erie?

A. Upon the fact that the ratio of variation of annual mean has changed for the two periods.

Q. Isn't your conclusion that the ratio has changed for the two periods contradicted by the evidence of the agreement of the water levels themselves throughout the whole range of years, as indicated by the six-year groups in table XVIII of the Exhibit referred to?

A. I think not.

Q. Will you compute from the elevation of Lake Erie for each of the several six-year periods the elevation of Lake Huron, using the ratio previously used, and the mean elevation as a center of gravity? Compute also for the five-year period 1908 to 1912 the same elevation, Michigan-Huron.

A. I will, the results are as follows:

Period		Erie Change	Computed Huron Change.	Observed Huron Change.	Period	Computed Huron Elevation	Observed Huron Elevation
I to	II	—0.516 ft	—0.74 ft	—0.698 ft	I	.....	582.305
II "	III	—0.054 "	—0.08 "	+0.364 "	II	581.565	581.607
III "	IV	+0.294 "	+0.42 "	+0.117 "	III	581.527	581.971
IV "	V	+0.055 "	+0.08 "	+0.427 "	IV	582.391	582.088
V "	VI	—0.907 "	—1.30 "	—1.795 "	V	582.168	582.515
VI "	VII	—0.35 "	—0.50 "	—0.31 "	VI	581.215	580.72
VII "	VIII	—0.61 "	+0.87 "	+0.55 "	VII	580.22	580.41
VIII "	IX	—0.30 "	—0.43 "	—0.54 "	VIII	581.28	580.96
					IX	580.53	580.42

Q. What conclusions do you reach from these computations?

A. That there was a decided change of relation between the periods V and VI or about 1889.

Q. How close, and in detail, what are the computed elevations of the Lake Huron surface, as compared with the actual observed elevations as indicated in Table XVIII?

A. The elevations are shown in the computation submitted.

For Period II the computed was 0.04 ft. low.
Por Period III the computed was 0.44 ft. low.
For Period IV the computed was 0.30 ft. high.
For Period V the computed was 0.35 ft. low.
For Period VI the computed was 0.50 ft. high.
For Period VII the computed was 0.19 ft. low.
For Period VIII the computed was 0.32 ft. high.
For Period IX the computed was 0.11 ft. high.

Q. In your opinion what does this computation show as to the extent to which Lakes Michigan-Huron have been changed by the condition in the channel of the St. Clair and Detroit River?

A. Nothing definite, except a change of relation about the time the dredging would have been most effective.

Depositions in the above entitled cause taken pursuant to notice before the Commissioner at the rooms of the Sanitary District, Karpen Building, Chicago, beginning October 8, 1913, 10:45 a. m.

Appearances: Mr. James H. Wilkerson and Mr. Albert L. Hopkins, representing the Government; Mr. Edmund D. Adcock and Mr. Alfred S. Austrian, representing the Sanitary District.

GARDNER S. WILLIAMS resumed the stand for further cross-examination by Mr. Wilkerson and testified as follows:

Q. One of the subjects about which you were testifying in New York, Mr. Williams, was certain conclusions which you expressed with reference to the change of the regimen of the St. Clair River?

A. That is correct.

Q. And as preliminary to a question or two which I wish to ask you at this time, I wish you would summarize what your conclusion was as to the time when that change occurred?

A. It occurred about 1889. The effect seems to appear along about 1886 or 1887, begin to appear, but the most marked change was between 1889 and 1891; during the years 1889 and 1890.

Q. The change as you concluded it had taken place was rather pronounced during the period 1886 to 1889?

A. Well, more particularly between 1888 and 1891. It is rather pronounced, yes.

Q. Now what cause did you assign for that change of regimen?

A. A considerable portion of it, the deepening in the channels of the St. Clair and Detroit Rivers.

Q. And what was the duration, as nearly as you can give it in your opinion of the scour causing this change of regimen, at the time you have indicated?

A. I don't consider it was a scour at all. I do not understand that the scour played any very marked part in it. It was due to the excavations in the channels very largely.

Q. Due to the excavations in the channels?

A. Yes.

Q. During what period?

A. Well, those excavations began a number of years earlier

than that, but they did not strike the critical points until along towards the end of this period.

Q. And you take the fact that there have been certain excavations during that period, and from that you reach the conclusion that there had been a change in the regimen of the river which would correspond to the excavations which you understood had been made?

A. Not exactly. What I did say was, having discovered a very pronounced change in the relations of the lake elevations at that time, I naturally looked for a cause for it, and failing to find it in the variations of rainfall, changes of temperature, probable evaporations, effects and so on, I naturally looked elsewhere and discovered that at that time the controlling sections, or the controlling section in the Detroit River was cut away by the construction of the original Lime Kiln Channel, thereby permitting an increased flow in the Detroit River; and that during this whole period improvements had been made in the St. Clair, which would tend to produce similar effects.

Q. Now, there having been a change in the channel, as you say, by which more water went through the river—

A. Yes.

Q. —I am trying to get this in as simple language as I can —where did that water go, in your opinion?

A. It goes into Lake Erie.

Q. And what effect would that have upon Lake Erie?

A. It raised Lake Erie.

Q. Now I suppose it would be possible, would it not, to make a plat which would show the observed elevations of Lakes Michigan-Huron and Lake Erie, extending over a period?

A. Why, there is such a one in evidence in this case, what is known as a hydrograph.

Q. Then it would be possible to take an equation or formula which would express the relation between the elevation of Lakes Michigan-Huron and Lake Erie, and to compute the estimated elevation of Lakes Michigan and Huron from Lake Erie, and *vice versa;* and show that upon a plat, would it not?

A. It would be entirely possible to compute a relation for the period of time that you chose. How accurately that would fit the conditions would depend of course upon the variables in the equation.

Q. Suppose a plat of that kind were prepared, which showed the observed elevations of the lakes, Lakes Michi-

gan-Huron, Lake Erie and Lake Ontario, and upon the same plat was shown the computed elevations of the lakes determined from a certain formula; and it were found that the estimated elevations corresponded with substantial accuracy to the observed elevations, what would that indicate as to the correctness of the formula or equation which was used in that computation?

A. It would depend all together upon the premises upon which the formula was based, as to whether it was a correct formula or not.

Q. If you take a formula and apply it over a long period of years, and you found that by applying that formula your computed elevation tallied with substantial accuracy with the observed elevations, would not that indicate a correct equation had been used in making the computation?

A. It would indicate that the mathematical treatment coincided substantially, or to whatever degree the coincidence was, with that which occurred, but it would not prove necessarily that the equation was founded upon sound theoretical grounds.

Q. Why wouldn't it?

A. Well, simply because you can get a relation between two varying quantities which may express for different periods, or through different ranges a quite close coincidence between computed and observed results, but that equation may as a matter of fact have no relation whatever to the actual causes or conditions which produce those results. That is the relation may be what we call purely empirical; that is not based upon reason but based simply upon the fact that this thing happens to fit.

Q. It would show that there was coincidence between the observed elevations and the computed?

A. It would show whatever existed. Of course, it would show that so far as the result of the computation was concerned that it agreed more or less closely, or however closely it might, with the observed condition. It would not show that the basis upon which that equation was founded was necessarily correct.

Q. That is, you mean to say it would not demonstrate absolutely that was true; that is there might have been some cause present at one time which was not present at another. Is that what you had in mind?

A. It might—it would not prove that the equation was based upon the reasons or the causes of the conditions. It

would prove that a relation had been found which for a range appeared to produce quite similar results.

Q. It would show that the figure which was adopted as expressing the relation between the elevation of the two lakes was the correct figure would it not, for the years in question, without regard to why that was the correct figure?

A. I don't quite get that question.

(Question withdrawn.)

Q. You gave us a figure which you said expressed the relation between the elevation of Lakes Michigan-Huron and Lake Erie.

A. Yes.

Q. That is a change of so much in Lakes Michigan and Huron would be reflected, a certain percentage of it would be reflected in Lake Erie?

A. That is it, depending on the average.

Q. You had a period before this period of marked change?

A. Yes.

Q. To which you testified you gave the figure. What was the figure you finally reached?

A. I think that the change in Lake Erie appeared to be about 75.3 per cent. of the change in Lake Huron prior to 1889.

Q. That is, prior to 1889. Then you took the period from 1889 to 1890—

A. From 1890 on; the two years there do not fit in; that is when this change occurred, and it does not fit into either period.

Q. Those two years are 1888 and 1889?

A. 1889 and 1890.

Q. 1889 and 1890?

A. I believe so.

Q. And then after those two years, what was the figure?

A. The changes of Lake Erie are about 85.5 per cent. of those of Huron. I think I will refer to the table, to make sure of it.

Q. 85 per cent., was that the figure?

A. 85½ per cent.

Q. So that in your testimony on the subject of the change of regimen of the St. Clair River, the years 1889 and 1890 are the ones that you have pointed out as being the years during which the sharp change had taken place?

A. That is as I recollect it.

Q. What was your conclusion as to the amount of that change?

A. Anywhere from six-tenths to a foot.
Q. That is, six-tenths of a foot was the lowest figure?
A. I think so.
Q. What was the highest figure of the range?
A. I will have to look and see. I think about a foot.
Q. That is, you reached the conclusion that during the years 1889 and 1890, there had been a change in the regimen of the St. Clair River, which had resulted in a change in the elevation of Lakes Michigan-Huron from .6 of a foot to a foot?
A. I don't know that I want to conclude it in just exactly those words.
Q. State it in the way you would like to have it stated?
A. The conclusion was that between the six-year period from 1884 to 1889 and the six-year period from 1890 to 1895, there was a change in average elevation of Lake Huron of 1.82 feet, and between the same periods there was a change in elevation of Lake Erie of .92 feet, or about half as much.
Q. The inference which you intended to be drawn from that is that during those two years, 1889 and 1890, something happened in the St. Clair River?
A. Or the Detroit River.
Q. Something happened in either the St. Clair River or the Detroit River—
A. Or both.
Q. —or both, which resulted in a change?
A. Which had its effect at that time.
Q. Which had its effect at that time, which resulted in a change of from .6 of a foot to a foot?
A. To a foot, yes.
Q. How could that be expressed in volume of flow, during those two years?
A. That depends altogether upon what the increment of the river was before the change occurred. Or, going backwards, it depends on what it was at the time the change was completed.
Q. Take the different figures which have been discussed here as representing the outside statement for the increment of the river, and how much of that change in outflow would that change in elevation be equivalent to?
A. Well, the outflow of the river at the end of the second period could not have been very different from what it was at the beginning of the first period, speaking now in averages. I am not speaking of a single year. We must confine our-

selves to a sufficient period to take care of ordinary fluctuations.

Q. What I am trying to get at is this: It is your theory in this case that during those two years, 1889 and 1890, there was what has been characterized as a marked change in these two rivers?

A. Yes.

Q. Or in one of them; the result of which was that during those two years, necessarily more water flowed out of Lake Michigan and Lake Huron than had flowed out during the corresponding period before?

A. That is correct.

Q. I want to get from you an expression of about how much more water during those two years went through the rivers, in your judgment, as the result of that change than had been going through the rivers before, or than would have gone through the rivers had there been no such change in regimen as you have assumed?

A. I am not prepared to answer that question at the present time. I was under the impression that I had some figures here which might enable me to answer it.

Q. I do not care for an absolutely exact answer so far as decimal points, or even so far as cubic feet is concerned, but I want to get from you some expression of about how much water must have gone through those rivers during those two years, how much more than before; that is, how much water the rivers would have drawn out of Michigan and Huron than they would have drawn if the change had not taken place?

A. Well, I am not prepared to answer that question at the present moment. I will endeavor to answer it for you during the day or to-morrow. But at the present moment I haven't in mind the quantity, for this reason; that at the beginning of the period—that is, this did not come as a sudden increase all at once, a large quantity of water suddenly flowing through the river, and suddenly stopping, but it increased over a period of years preceding, came to the maximum at about the time the Lime Kiln Channel—the cut was completed through the Lime Kiln Channel—and then gradually decreased until Lake Huron fell to a position where the discharge of the St. Clair and Detroit Rivers came back to substantially what it was in the first place.

Q. You have not as the result of your studies of the situation there in mind now any figure which would express the quantity of water, the excess quantity of water so to speak,

which went through those rivers during the two years you have spoken of, the years of marked change, the years which are taken out of the list of years because they do not tally with the other years?

A. I have not, in terms of the water which actually passed out, no, because I have never computed that.

Q. I call your attention to page 1309 of this record testimony of Mr. Stearns where he says, speaking of these two periods: 'The average increment during this period would have been 27,100 cubic feet per second, and as the difference in the discharging capacity of the channel as above estimated was not less than 24,700 cubic feet per second, the lowering would have been not less than 24,700 divided by 27,100, equal to .91 of a foot, or substantially 11 inches.'' The figure to which I am calling your attention particularly is that 24,700 cubic feet per second as representing the increased discharging capacity of the channel. Does that represent your view on that subject?

A. Very nearly. But bear in mind that is the discharging capacity, not the measure of the water that actually went down there because it did not discharge that quantity except for a very brief time. The lake immediately began to fall and the quantity of water passing down was decreased.

Q. There would be a small decrease? There would still be an increase in the amount discharged?

A. No, the river came to equilibrium finally after a time.

Q. How long a time would that take?

A. Well, it began falling, or rather the highest elevation of Lake Huron was in 1886. It then fell quite continuously until 1892. It raised slightly for the next two years and fell again in 1895. It apparently reached its minimum about 1896. I should say that it took about ten years.

Q. But these two years 1889 and 1890 were years which you eliminated for the reason that the change was going on so rapidly?

A. Yes, between 1888 and 1891 the lake fell 1.24 feet.

Q. So that if the change was going on rapidly during the years 1889 and 1890, a very considerable portion of this increased capacity, 24,700 cubic feet per second, would be reflected in increased outflow during those two years, wouldn't it, the change going on rapidly?

A. I will answer that question this way, that a greater increased flow would be apparent during these two years than during any other part of the period considered.

Q. About how much would be reflected during those two years?

A. That is the part I am not prepared to answer at the present moment. Whether I can arrive at an estimate of that quantity, I am unprepared to say at the present moment. As to the increased discharging capacity of the river, I feel pretty well satisfied with that quantity of 24,000 cubic feet per second. That is about the figure that I had.

Q. And it is true that if there was a rapid change going on during the two years 1889 and 1890, that there would be a very considerable part of it reflected during those two years?

A. There might be more than half of it. I do not say that there would be.

Q. The case presented there is analagous to the case presented by the construction of a dam in a river, is it not, only it is the converse of the situation?

A. Yes, the converse.

Q. Take the case of the Gut Dam in the St. Lawrence River, the effect of that is to diminish the capacity of the channel so that there would be a smaller discharging capacity?

A. Yes.

Q. And that would be reflected necessarily in the elevation of the level of the lake above the obstruction which was placed in the channel?

A. Certainly.

Q. And that would be seen in this way: If you had a computation of what the level ought to be and then you compared it with the observed elevation, the observed elevation would be higher than the computed elevation owing to the construction of the dam, just as in the case of the deepening of the channel the observed elevation would be lower than the computed elevation?

A. Understanding the computed elevation to be based upon the conditions before the changes were made.

Q. Yes, certainly?

A. That is correct.

Q. Now, if an excessive or extraordinary rainfall occurred for any year, for instance, on Lake Erie or Lake Ontario, and not excessive rainfall on Lakes Michigan-Huron, what would be the effect of that upon the computed elevation with respect to the observed elevation?

A. It would raise Lake Erie and Ontario to a greater extent relatively than Lake Huron would be raised.

Q. So that if there had been a difference in the rainfall

on the two lakes and if there had been an excessive rainfall on the one lake, that would have to be taken into consideration in determining what the real effect was due to the change of the channel?

A. Understanding your term "excessive' 'to mean excessive as related to the ordinary conditions on that lake.

Q. Yes.

A. That is the rainfall on Lake Ontario may be materially greater than that on Lake Huron normally. It has got to be based upon the fact that the normal rainfall of the drainage area is considered.

Q. Now, let us take the effect of an ice blockade in the river: Suppose ice blocked the St. Clair River in a particular year, what effect would that have on the curves of computed elevation as compared with actual elevation?

A. It would raise the level of Lake Huron and depress the level of Lake Erie during th period of its existence, and for a limited but unknown period thereafter.

Q. When you say unknown, you mean what?

A. I mean that we cannot tell; we don't know how long the effect would last.

Q. It would be more than a few weeks, wouldn't it?

A. Why, it would be on the St. Clair. I am not so sure of what the condition might be on Erie.

Q. I show you a chart which we will introduce in this case later, but which I wish to use in connection with some questions which I am going to ask you. I ask to have it marked Complainant's Exhibit A. October 8, 1913. (So marked.) The same being a chart headed: "Mean elevations of Lake Michigan-Huron, Lake Erie, Lake Ontario," on which appear to be plotted, first, the observed elevations of these lakes respectively, as shown by horizontal full lines. There is plotted the computed elevation, shown by horizontal dotted lines. In the first horizontal column, the dotted lines show elevations computed from Lake Erie by the equation: "Michigan-Huron elv. equals 577.595 plus 1.4286 (Erie minus 570.).

In the second horizontal line, the dotted lines show the elevations computed from Michigan-Huron by equation: Erie el. equals 571.68 plus 0.70 (Michigan-Huron el. minus 580). The circles there show elevations computed from equation:— Erie el. equals 567.99 plus 0.74 (Ontario el. minus 240).

In the third horizontal column the dotted lines show elevations computed from Lake Erie by equation:—Ontario el. equals 242.71 plus 1.3[illegible] (Erie minus 570).

Now, on the right-hand side of the paper there is another

chart in which the same things have been plotted according to five-year means. The scale on which the chart has been prepared appears at the extreme right-hand side, as well as at the left. The scale in inches appears in the column so marked, near the right-hand side of the chart.

This is offered as Complainant's Exhibit for Identification at this time.

On this chart, where the observed elevation is below the computed elevation, the difference is indicated by a red rectangle and where the observed elevation is higher than the computed elevation, there is a corresponding indication by a blue rectangle.

Look at these formulas which appear on this chart, Mr. Williams. Is that a correct method of computing the elevation of the one lake from the other, with the exception of the particular decimal which is adopted as expressing the relation between the levels of the two lakes as you understand it, leaving out of consideration the correctness of the decimal .70, .74?

A. It is an approximate method of predicting the elevation of one lake with reference to the elevation of the other, its accuracy depending upon the accuracy of the variation involved.

Q. When I use the word decimal there, I mean that figure which expresses the ratio of fluctuation.

A. You meant in one case the mixed number 1.4286.

Q. 0.70, 0.74, etc.

A. We in mathematics usually call them "coefficients."

Q. We will call them coefficients.

A. That is the ordinary term for them.

Q. When you say it is an approximate method, what do mean?

A. Well, I mean that I think a more exact relation could be derived.

Q. How much more exact?

A. I don't know until I try it.

Q. You mean that the degree of accuracy with which the elevation is predicted depends upon the particular coefficient which is used?

A. Exactly.

Q. And that is to say whether this is accurate or not depends upon the accuracy of the figures 1.4286, 0.70, 0.74 and 1.35, on the chart?

A. Yes.

Q. If those were accurate then the method of predicting would be accurate?

A. I will say that the method is a proper one to use for such comparisons. I question the accuracy of the coefficient involved.

Q. In my questions I was eliminating that.

A. Oh, I beg your pardon.

Q. I am assuming that the coefficient is accurate, then the chart, assuming the mechanical work is done correctly, would represent correctly the situation which we have been discussing here.

A. The charts show for themselves what they do represent. Here is a computed elevation by a certain formula, and an actual elevation which is somewhat different. Now, that is all there is to it. If the relation was correctly expressed, the computed would coincide with the actual, but it is impossible with any such simple expression as that that is involved here to get a relation or to get an equation which would correctly express these changes; and all we can do is to approximate. Now, the accuracy of the comparisons depends upon the closeness of the approximation.

Q. Having in mind how this chart has been prepared, would the fact that there was either a close coincidence or a wide divergence between the observed elevations and the elevations which have been predicted from the formula throw any light upon the correctness of the coefficient which had been used in the formula?

A. I rather object to the term "correctness" because I do not think any coefficient in a formula of this type could be correct.

Q. Well, say approximate?

A. I was going to say applicability.

A. I will accept your word, the word applicability; would it throw any light upon the applicability of the coefficient used?

A. It certainly would.

Q. What light would it throw?

A. The more closely the computed results coincide with the actual, the more applicable the coefficient becomes or appears to the conditions involved.

Q. And if you take these five year mean periods on the right hand side, the more nearly the computed elevations coincide with the observed elevations, the more nearly accurate the coefficient which had been employed would be?

A. That is correct.

Q. So that we may understand this chart in the record, we find there that for the period 1860 to 1864 the computed elevation coincides how nearly with the observed elevation according to the chart?

A. Well, the scale is in shape here where we cannot read it very well.

Q. I am doing this so that we will get it in inches in the record.

A. I will say about an inch and a half.

Q. And for the period 1865 to 1869, how nearly?

A. Oh, probably half an inch.

Q. 1870 to 1874?

A. About two inches.

Q. 1875 to 1879?

A. About two inches and a quarter.

Q. 1880 to 1884?

A. About a quarter of an inch.

Q. 1885 to 1889?

A. About three and three-fourths inches.

Q. 1890 to 1894?

A. Two and three-fourths inches.

Q. 1895 to 1899?

A. About three-quarters of an inch.

Q. 1900 to 1904?

A. About half an inch.

Q. 1905 to 1909?

A. About an inch and a quarter.

Q. And 1910 to 1912, the three year mean from 1910 to 1912?

A. Well, about two and three-fourths inches.

Q. On this chart it appears, does it not, that during the period from 1860 to 1864 the observed elevation was lower than the computed elevation?

A. Yes.

Q. And that during 1865 to 1869 it was lower than the computed elevation?

A. Yes.

Q. From 1870 to 1874 it was higher?

A. Yes.

Q. From 1875 to 1879 it was higher?

A. Yes.

Q. From 1880 to 1884 slightly lower?

A. I would call that a substantial coincidence.

Q. From 1885 tc 1889 it was higher; from 1890 to 1894 it was lower; from 1895 to 1899 it was lower; from 1900 to 1904 it was lower; from 1905 to 1909 it was lower, and the three year mean from 1910 to 1912 it was lower?

A. Yes.

Q. By the amounts which you have already indicated?

A. Which have been approximately indicated.

Q. The range of the lake covered during these five year periods is from 579.0—

A. Say roughly from 580 to 582½, or if you want it exactly—

Q. It is nearly 583.

A. 582½; each one of those squares is five-tenths of a foot.

Q. From 580 to 582½. So that we may have it here in the record, because I am going to have some questions follow here, let us take the second one of those horizontal columns, the five year mean period for Lake Erie, and just run through that and state what appears as to the coincidence between the computed elevation and the observed elevation.

A. Well, the coincidences should be within about seven-tenths of what the others were.

Q. Let us see what the chart shows.

A. I guess it shows about that; if it does not the work is not right; but should be of the opposite sign; that is when you have a red in the upper portion, you should have a blue in the lower, and you do.

Q. Now let us take the Ontario chart. If these were plotted in this way, and you had in any year an extraordinary condition as for instance an ice condition in 1901, or the construction of the Gut Dam to which we have referred, you would expect to see that reflected would you not on this chart?

A. That is what you would naturally expect to find, yes.

Q. And you do find it reflected here, do you not?

A. I at the present moment have not the data to locate the ice conditions. I would expect they would be reflected here, and I assume they are.

Q. Look at the year 1901, the observed elevation of Lakes Michigan-Huron there is very much higher than the computed elevation, is it not?

A. Yes.

Q. And that is what you would expect to find?

A. Yes.

Q. You are familiar with these ice conditions in the year 1901?

A. Somewhat.

Q. We have been talking about those all through this case, and that is what you would expect to find if those were plotted in this way. And you are familiar with the construction of the Gut Dam. We have that fact brought out?

A. That brought us into 1903.

Q. It begins to show in 1904, and it shows a marked effect there; your observed elevation is greater than the computed elevation continuously, and that is very marked on the chart, is it not?

A. Yes.

Q. Are you familiar with the difference in flow out of Lake Ontario prior to the construction of the Gut Dam and after the construction of that dam?

A. Well, my recollection of the testimony was to the effect that the construction of the Gut Dam reduced the discharging capacity of the river about five per cent., and of course the lake has risen or has pretty nearly risen by this time, I assume, so that it would now be discharging its normal quantity of water.

Q. But as soon as the dam was completed, it is indicated on the chart here that the effect was immediately reflected?

A. Certainly.

Q. Or very soon thereafter?

A. Certainly.

Q. Now let us take the year 1890, down in the column there. Suppose that for that year the average mean rainfall for both Ontario and Erie was extraordinary and excessive as compared with Michigan and Huron, what would you expect to find on this chart?

A. I would expect to find that Ontario and Erie would be high.

Q. Also assume in answering the question that there was an excessive rainfall, 12.4 inches on Ontario and 6.2 on Erie, what would you expect to find that is over the mean?

A. I should expect to find a greater rise in Ontario than I would find in Erie.

Q. And the elevation of Michigan-Huron, computed from Erie, would be higher than the observed elevation?

A. Yes.

Q. For the purpose of the question, assume that during the year 1890 there was an excess on Michigan-Huron of 1.6; that is to say that the rainfall was practically normal, so that assuming that state of facts you would expect to account for

the fact that Erie and Ontario were higher for those years and Michigan and Huron lower, that would be attributed to a difference in rainfall?

A. Partially, but the fact that Erie was very much higher than Ontario although the increase of rainfall was materially less would indicate to my mind that there must have been some other contributing cause to the high elevation of Erie.

Q. You are speaking of now as between Erie and Ontario?

A. I am.

Q. That is that there would be some cause operative between Erie and Ontario which would show a higher effect on Erie than it does on Ontario. Do you know of any important cause during that year that would account for that?

A. Why the discharge of water from Lake Huron into Erie of course would be expected to raise Erie before it raised Ontario.

Q. Well, Ontario is a foot higher as compared with the year before, isn't it?

A. Yes, but it has not increased its elevation with respect to Erie.

Q. And Erie is only seven inches higher?

A. To the extent that the difference in rainfall would seem to call for, especially bearing in mind the different characteristics of the watershed, that heavy rainfalls on Lake Erie are not likely to find their way to the lake in as great proportions as they are on Lake Ontario.

Q. Isn't it a fact that for that year 1890 the rise on Ontario was greater than the rise on Erie, the observed elevation, the actual rise of Ontario—

A. You mean the difference between the elevation that year and the year preceding?

Q. Yes?

A. Yes.

Q. So that if the condition as to rainfall were an ordinary condition, the observed elevations for Ontario would be much lower than it is; that would be the effect, would it not?

A. I would expect so.

Q. Assuming that this table has been drawn accurately, and assuming the facts to be on the rainfall as I have indicated to you, isn't it a fact that the year 1890 was a year of such abnormal conditions so far as rainfall is concerned that there was a wide divergence between the observed elevation of the lakes and the predicted elevation applying the ordinary coefficient?

A. There evidently was a wide divergence. Whether that is to be accounted for in rainfall is to be determined by comparing with other years when there were similar discrepancies of rainfall or irregularities and ascertaining whether under those conditions similar changes of elevation can be produced.

Q. There can be no doubt in your opinion it is partially attributable to that?

A. It is partially.

Q. To a very considerable degree?

A. I am not so sure about the considerable degree at the present moment.

Q. It must be, must it not?

A. It depends quite materially on the time when this rainfall occurred, distribution through the year and some other conditions.

Recess to 2:45 p. m.

After Recess 2:45 p. m.

GARDNER S. WILLIAMS, resumed.

Mr. Wilkerson: Q. Looking at this chart in the column for the year 1890, we were speaking of the observed elevation of Lakes Erie and Ontario as compared with the computed elevation?

A. Yes.

Q. And it was stated that the excess rainfall on Ontario was greater than the excess rainfall on Erie. Now if as a matter of fact the excess rainfall on Erie and Ontario had been the same, other conditions being equal, the observed elevation of Ontario would have coincided with the computed elevation, would it not?

A. I don't think it would quite inasmuch as the normal rainfalls on the two drainage areas are not the same.

Q. (Question read.)

A. The answer I think is correct understanding excess rainfall to be measured in inches. If it was in percentage then the answer would be yes substantially.

Q. It has been measured in inches?

A. If you mean by that question to ask it as measured in inches, then my answer was correct. If you want to say that

the excess was in percentage, then the relation should take care of it and the computation would coincide with the answer, assuming no other conditions enter in.

Q. Will you turn to the figures you used showing rainfall, run-off, etc., on the three drainage basins for the year 1890.

A. 1890; as I make it, it is 40.23 inches. That figure has not been checked recently.

Q. That is Erie?

A. That is Erie. That is taken from the report for 1903—Wheeler's.

Q. What was Ontario?

A. Ontario at the same time 48.72, as I make it.

Q. And Huron-Michigan?

A. Huron-Michigan is 33.78.

Q. Now, isn't it a fact that the rainfall on Erie and Ontario for the year 1890 was the largest rainfall for those two basins of any recorded year from 1883 to 1905?

A. That is correct.

Q. And so far as Michigan-Huron is concerned, the rainfall for 1890 was not the largest but was exceeded by that of several years?

A. It appears to have been exceeded in three years, namely, 1883, 1884 and 1893. I will have to correct that; I have got to put in two more years, also 1885 and 1886.

Q. How much above the mean was the rainfall on Michigan-Huron for 1890?

A. It was about 1.5 inches.

Q. Now, I understood you to say that you did not think that this difference between the observed and computed elevations for 1890 as shown on this chart could be accounted for entirely on the basis of the excessive rainfall on Erie and on Ontario. What other element did you think entered in?

A. I think the deepening of the channels in the St. Clair and Detroit Rivers.

Q. I call your attention to the manner in which the effect of the construction of the Gut Dam is reflected on the elevation of Lake Ontario as shown by this chart; there being a change there of about 10,000 cubic feet, 10 to 12,000 cubic feet in the discharge of the St. Lawrence River. Would you not think if that had entered into the situation in 1890, so far as the St. Clair and Detroit Rivers were concerned, to any appreciable extent, that the change of 24,700 cubic feet would be reflected in the chart in the same way?

A. No, because the construction of the Gut Dam was accomplished in a very short space of time, something like three

months. The effect was practically instantaneous, you might say, as far as yearly averages were concerned, whereas the effect of the work on the St. Clair and Detroit Rivers extended over a period of some 10 or 15 years; and it culminated in its maximum effect at the time I pointed out. The effect was increasing previous to that time and gradually diminished thereafter.

Q. You said that there was such a marked change for the years 1889 and 1890 that they had to be rejected as not being explained on the ordinary basis?

A. Yes.

Q. Wouldn't the effect of a marked change in 1889 and 1890 be reflected in the same way as a marked change brought about by the Gut Dam was reflected?

A. I think it is so reflected. You see that Lake Michigan is markedly lower than it should be; Lake Erie is higher; Lake Ontario is higher. There is nothing to account for the extreme heights of either Erie or Ontario, nor the lowering of Michigan except the change in the channels in between there.

Q. How about this rainfall in 1890?

A. I call your attention to 1893 when the rainfall on Lake Erie—1892, I should say—when the rainfall on Lake Erie was only 1.2 inches less than it was in 1890, and you do not find that it caused any rise in the elevation of Lake Erie as compared with the year before when the rainfall was substantially five inches less.

It, therefore, does not seem to me that this difference of one inch of rainfall between 1892 and 1890 can account for the increase of elevation of Lake Erie, as contended by the complainant; but that the rise both of Erie and Ontario is very largely made up of water delivered to them through the St. Clair and Detroit Rivers, which temporaririly raised those lakes until the increased value of the increment caused a delivery which brought them back to their normal stage.

Q. Will you make the same explanation as to Lake Ontario for the years 1890 to 1892?

A. Well, the excess rainfall on the drainage area of Lake Ontario in 1892 was something like 4½ inches above normal and was about the same amount—4½ inches—higher than in 1891; and we find that Lake Ontario fell so that I again cannot conceive how if an increase of rainfall, as claimed, of some 13 inches, 12 or 13 inches above the average in 1890 produced a rise of Lake Ontario here of something like a foot

that an increase of rainfall of some 4½ inches in 1892 has been accompanied by a fall of the lake level of about 3 inches.

Q. Where there is an excessive rainfall, it is a fact, is it not, Mr. Williams, that you get a greater percentage of run-off than where the condition is normal; that is, where the ground is saturated there will be a greater run-off?

A. As I said, it depends somewhat on the distribution of that rainfall throughout the year. If it was distributed in small showers you would not get as much, perhaps, as you would some other year when the rainfall was less, but came in accumulated heavy doses.

Q. Well, then, of course, it would necessarily follow in view of that situation, that any discussion of lake levels based upon a consideration of rainfall has introduced into it so many elements that it is a very unsatisfactory method of reasoning, is it not?

A. Oh, no, if you record it over a long enough period so as to get at average conditions, it is correct enough for relative conditions; but when you have two years only two years apart, you must look for some other causes than your rainfall to account for such fluctuations as you have here.

Q. I direct your attention to another chart, which I ask to have marked Complainant's Exhibit B of this date for Identification. It is entitled "The Relative Fluctuations of Water Surface, Lake Huron and St. Clair, Means of Six Months Period June to November inclusive, years 1883 to 1906." The elevation of Lake Huron at Harbor Beach is plotted in the vertical; the elevation of Lake St. Clair at the Flats is plotted in the horizontal. Do you see from the plotting of those elevations any evidence of an unusual amount of water passing down the St. Clair River in the years 1889 and 1890?

(Chart referred to in the question was marked Complainant's Exhibit B October 8, 1913; marked for Identification.)

A. I do not see that this plotting would indicate whether there was or was not.

Q. Having in mind the year 1901 and the conditions which were prevalent during that year.

A. I know that the years 1889-1890 show the lakes to have been at a higher level than they have been at any time since if I read the charts right, except in 1894, 1895, in which case St. Clair was a trifle higher; not so high as 1890, however.

Q. It does appear, however, that for those years they followed the law of fluctuation as indicated by the line which is drawn there in accordance with that equation, does it not?

A. It seems to fit those particular years better than any of the rest, so that I imagine the line was drawn to cover those years.

Q. I call your attention to the statement on the chart: "U. S. Lake Survey Equation from all Data: Elevation of St. Clair equals 574.85 plus .66 (Harbor Beach minus 580)." Assuming the line is drawn according to that information, you would hardly think it is fair to say it was drawn with reference to those two years?

A. Yes, those two years are included. The conditions of those two years are included in the total. They happen to be about the middle of the line and as you take average conditions, the upper end of the line being high and the lower low, it naturally passes through this average condition which occurred at this time when the lake was falling from one stage to the next. The method of drawing a line would cause it to pass through those two years under the conditions that actually existed, and matched them probably more closely than any of the others in the series.

Q. Suppose, referring to the Niagara River now, Mr. Williams, that a set of observations had been made at a third section of the river, and that the volume of discharge as computed from those observations tallied within ½ per cent. or 1 per cent. of the discharge as computed from the observations at the other sections what would you say of the weight which was to be given to that fact in determining whether or not it was possible to measure the discharge through the Niagara River?

A. I would say in the first place that it would indicate the accuracy with which the manipulations were carried out. In the second place, that if it was made with the same instruments that were used in the other measurements, that it proved very little as to the actual absolute accuracy of the work.

For example, you may take the width of this room, which I would say is substantially uniform, and measure it with a yardstick from which one inch had been cut off, and you might measure it at four or three different places, or as many different places as you want to, and you would get substantially the same result. They would all check, but they would all be in errror by the amount represented by that one inch which would be off in the length of the yardstick. That is just the case you have in your measurement. You are using the same apparatus all the time; the same inherent errors are there, and therefore you would have no proof any more than the

proof of the accuracy of the manipulation. It is not proof of the accuracy of the result.

Q. What were the reasons which you assigned why the observations could not be made accurately on the Niagara River?

A. Well, among them were the disturbed conditions of the water in the sections that were selected.

Q. Well, now, suppose the section selected in this was in an undisturbed condition, would the inaccuracy which would deal with that cause be present there, also?

A. If this disturbance were not there, certainly the inaccuracies due to it would not be present.

Q. That was the chief reason that you assigned for the inaccuracy of measurement of the Niagara, was it not, the disturbed condition of the water?

A. Well, I think that was a very important one. No, I don't think that is the chief reason. I think the variation of elevation of Lake Erie is another one; that is the difficulty of connecting the discharge with the elevation of the lake. If, for example, continuous measurements of discharge had been taken over a considerable number of days; that is, a meter had been kept at some index point in the section continuously and the observations are there taken, and at the same time investigations made of the condition of the vertical curve at various elevations of the lake, we would then have been in position to have come very much closer to a discharge than we are now.

Q. Are you to be understood as saying in your opinion there is something either in the construction of the current meter or the manner in which it was used or the conditions which are generally present in every part of the Niagara River, which causes the results derived from those measurements as to outflow from the Niagara River to be uniformly smaller than it is in fact?

A. I would not say that would be the case at every point in the Niagara River. I think it is quite possible there may be places where current meter gagings would over-register.

Q. Where do you think that would be?

A. In the slower portions of the river.

Q. In about what part of the river would that be?

A. At the present moment I am not prepared to say exactly.

Q. So you think there might be portions where the manner in which the current meter is constructed, and the manner

in which it registers would cause it to register too small an outflow?

A. No; too large.

Q. Too large an outflow rather than too small an outflow?

A. As ordinarily manipulated, yes.

Q. Would you say that if observations were made by the current meter, which we understand were used for these observations in this case at the two points which I have indicated to you on the map, being marked on the map by a red line, how would you say the current meter would register there in that part of the river?

A. What is the area of those combined sections as compared with the area at the International Bridge?

Q. You say it would depend on that?

A. I ask what it is before I answer.

Mr. Shenehon: It is considerably bigger.

Mr. Wilkerson: Assuming that the combined area of the two cross sections to which your attention has been directed is larger, is considerably larger than the cross section at the International Bridge Section?

A. The section at Oakfield does not appear to be to me a particularly good one. The other one is somewhat better, but I think both of them are subject to disturbances on account of shallows up-stream.

Q. Well, now, assume that the section in the West Channel, which is called the Oakfield Channel—assume that these measurements are made in two sections, one in the West Channel, called Oakfield, and the one in the East Channel, called Wickwire, and that the channels are sufficiently smooth for some distance above and below the sections, and that there is no boiling nor eddying of the water past or near the section, and that the computed velocity was less than three feet per second, would you say that the conditions for gaging were good if that were true?

A. As usually understood, yes; but in the light of the information on the chart, I would question both those sections as being particularly good.

Q. What do you see on the chart that indicates to you that good conditions for gaging are not obtainable in those two cross sections?

A. Well, the bar at the Red Spar Buoy Number Six some distance up-stream, about half a mile I should say, from section Oakfield, the curvature of the channel at that point which must have induced more or less oblique currents would be the principal criticism of that. And at section Wickwire, we also have

a bar on which there apparently is a buoy located considerably nearer the section, which occupies something over half the width of the river. After water has passed over an obstruction of that kind in the bottom, there is always a considerable disturbance in the lower portions of the river, and those would not for that reason be ideal sections. I would think that they were better than the International Bridge Section, though.

Q. And would the disturbance be of the same kind that you have indicated in your testimony prevailed at the International Bridge Section?

A. Probably not exactly.

Q. How would they differ?

A. I do not think there would be so much eddying, but there would be, I think, more of the forward and back pulsation. That, however, is largely speculative because nobody has been down those places.

Q. What about this effect of Lake Erie that you testified concerning upon the sections down there?

A. Well, so far as the effect of the rise and fall of Lake Erie is concerned, in connecting the gaging there with the elevation which produces it, it would be fully as difficult there if not more so than it would be here (indicating on map); that is, it would be fully as difficult at the lower sections as it would be at the International Bridge.

Q. But if there were inaccuracies of measurement due to the disturbed condition of the water in all three of these places, would you expect the effect of the disturbed condition to be such that the results would be substantially the same in all three sections?

A. No, I would not. I would at the bridge and open section. I would expect the results to be somewhat different down there.

Q. How much different?

A. Well, I am not able to say.

Q. I hand you a report here which is to be marked Government's Exhibit C of this date for identification, and two charts which will be marked Governments Exhibits D and E of this date for identification, one being a preliminary report showing the measurement of the Niagara River, two channels, called Oakfield and Wickwire, the one being chart showing still water ratings number 1 and 2, 1913, Smelting Works base, August, 1913, and the other discharge plotted against the Buffalo gage, September, 1913.

Assume that as a result of the measurement of that section as shown there in that report the volume of discharge as

deduced was half a per cent. less than that at the International Bridge, while the discharge as deduced from the observations at the open section was 1¼ per cent. less than that at the International Bridge section, what weight would you say that had on the question of whether or not it was possible to measure this volume of discharge at the Niagara River with substantial accuracy?

A. It would depend altogether upon the accuracy of the measuring instrument, assuming that similar manipulations have been carried out in both cases.

Q. Wouldn't it show that the measuring instrument had a pretty high degree of accuracy for the reason if the measuring instrument was inaccurate, the results would vary more than 1¼ per cent., and half of a per cent.?

A. I think not, because the conditions that you are dealing with are in a measure of the same nature all the time. You have certain dynamic forces in the water that have to be taken care of. In a still water rating those don't exist, and they have an influence. As to how great an influence, we do not know. But we do know this, that in disturbed water the Haskell meter registers low. If it registered similarly in all three places, the indications would be that the conditions must have been similar and inasmuch as we know the conditions were disturbed at the bridge, the inference is pretty fair they were also disturbed at these other locations, and from the contour of the bottom it appears they would be very likely to be.

Q. Assume for the purpose of your comment, Mr. Williams, that it will appear in this case by the overwhelming evidence of competent witnesses that the water there was not disturbed as it was at the International Bridge Section, and that the statemen which is contained here in the report that there were good conditions for gaging is a true statement of the conditions of the river, now assume that, what weight would you gave to that in reaching a conclusion as to whether or not this meter does register accurately?

A. It would be entitle dto considerable weight.

Q. I show you another chart which I ask to have marked Government's Exhibit F of this date for Identification, the same being entitled: "Water Level and Discharge Curves, Hourly Plottings Lake Erie and Niagara River." The first horizontal curve has under it elevations of water surface of Lake Erie at Buffalo gage in feet above sea level. Below is the curve of computed discharge based upon the equation Q equals 15,330 plus 21,900 (H B minus 570.00). Q is the volume of flow of cubic seconds feet. H B is height of Lake

Erie at Buffalo gage. The dots show measured discharge volume. That is to say for a given elevation at a particular hour we have the estimated discharge, and we plotted on that the actual observed discharge according to the measurements. Then immediately below that is plotted elevations of water surfaces in Gorge Pool of the Niagara River at Suspension Bridge Gage.

There are four sheets of this and I ask to have the other three marked Government's Exhibits G, H and I, for Identification.

I show you another chart which is to be marked Government's Exhibits for Identifications J, K and L, October 13, 1913, the same being the water level and discharge curves, hourly plottings Lake Erie and Niagara River, these being the discharge observations of the open section only.

(Whereupon the various documents shown to the witness were marked respectively Government's Exhibits C, D, E, F, G, H, I, J, K, and L, October 8, 1913.)

Adjourned to October 9, 1913, 10:00 o'clock a. m.

October 9, 1913, 10:00 a. m.

It is stipulated between the parties hereto that Messrs. Williams and Shenehon shall indicate upon the chart Williams' Exhibit 12, entitled "Buffalo Harbor and Niagara River to the Falls, N. Y.," the location of Section Oakfield and the location of Section Wickwire, at which it is represented by the Government discharge measurements were made during the months of July and August, 1913; it being understood that the Government is to introduce further evidence as to such discharge measurements.

GARDNER S. WILLIAMS, resumed:

Mr. Wilkerson: Q. Now please refer again to Government's Exhibit B of date October 8, 1913, for Identification.

A. All right.

Q. That is a chart designed to show the relative fluctuations of the water surfaces of Lake Huron-Michigan, taking means of six month periods June to November inclusive during the years 1883 to 1906 inclusive. The line appears to be drawn from United States Lake Survey equation from all data, the equation being stated on the face of the chart. I will not read it into the record again. There is a reference given there to the report of the United States Lake Survey

with reference to the determination of these relative fluctuations.

Now do I understand you to say that it is your opinion that the method which the United States Lake Survey has used in deriving this law of fluctuation between the water surfaces of the two lakes in question is not accurate?

A. Why, the result speaks for itself. It depends altogether upon what you call accurate. If you wish to follow the fluctuation of those lake surfaces, it would be necessary to use a broken line, because the same law does not apply after 1890 that applies before, referring now to the levels of Lake Michigan-Huron and Lake Erie; and the same is true as to St. Clair. Of course you can get a straight line which will approximate these results over the whole period, but its coincidence with the points for the various years will not be so close as the broken line would be.

If it is desired to get a single line through there, I have no objection to this one particularly. I presume it is the best single line that can be drawn.

Q. I rather gathered from what you said yesterday that perhaps you had in mind the fact that the method that had been used in the derivation of the line should have been this three point method?

A. Oh, no, I am not objecting to that at all.

Q. It is your view as an engineer that the line drawn by the three point method would be substantially the same as the line drawn by the Lake Survey?

A. I would not expect it to be different.

Q. So that if it was desired to obtain a law which would express the relative fluctuations of those two lakes during the period in question, the line drawn,—that is the method pursued—is not subject to criticism so far as the process itself is concerned?

A. Well, understanding that it is desired to get a single line which will represent approximately the variations of these lakes with reference to each other, I have no objection to the method that has been used here, so far as I can interpret it or criticise it from this drawing. I have not checked the plottings, anything of that sort, but I assume that the work has been accurately done.

Q. But it does appear from that line as drawn that there is nothing to indicate any radical change in the quantity of water going through Lake St. Clair during the year 1900, is there?

A. I think there is.

Q. Just so far as the line itself is concerned. Let us not debate the propriety of the line, but take the line itself.

A. The line has no bearing upon that question at all. If for instance the points prior to 1889 when arranged had plotted so that a line at an angle of 45 degrees with the horizontal axis would fit them and the points below them were so plotted that a line drawn at an angle of 45 degrees would fit all of them, but in order to get from one to the other there would have to be a vertical drop, these lines would be parallel, and several inches apart.

A single straight line would not show that break. If you are plotting the observations prior to 1889 and the line that fits them, and those subsequent and the line that fits them, you will find that there is a change about 1889.

Q. If you draw a single line and all the observations fit that approximately, wouldn't that indicate to you that was a correct line for the whole period?

A. No, not if when you draw the separate lines, they fit better.

Q. Look at the years 1893 to 1906 as they appear with reference to the line in question, the one being before 1889 and the other after 1906, wouldn't the fact that those—

A. What was the year?

Q. 1893 and 1906.

A. They are both of them after 1889 if I understand.

Q. 1893 and 1906?

A. Both of them since 1889.

Q. 1893 was very close to this period?

A. Yes.

Q. During which you say the radical change was going on, and was a time when according to your view of the situation the change was in process, as I understand it?

A. Yes.

Q. Take 1889 and 1905?

A. All right, what of it?

Q. What do you say of it?

A. I don't say anything of it. I say if you draw a line that fits your observations prior to 1889, it will have a different slope from the line you have drawn on that. If you draw a line which fits the observation since 1889 it will have a different slope from the line you have drawn and these two lines will not be parallel, and they will have a considerable intercept between them about 1889; and that indicates the change of condition in 1889.

Q. Look at the line running through 1887 and 1906. Now, both are right on the line.

A. That is entirely possible. They happened to be about—at some point this line has got to intersect the other lines.

Q. Well, 1885, 1887, 1905, 1906, 1897 and 1896?

A. With the small variations that there are in Lake St. Clair due to this cause, the range of difference here is not sufficient to demonstrate any very great inconsistency, in having two points fit this line. Here are 1901 and 1892.

Q. 1901 was the year of admittedly extraordinary conditions, was it not, on account of the ice condition, so that you would expect to find that off the line?

A. All right. Here is 1895 and 1896, two adjacent years under approximately the same conditions so far as conditions in the channel are concerned, you find a wide variation there, and it is simply due to the varying conditions of two subsequent years. You have 1889 and 1890, about the same difference there.

I call your attention also to the fact that this chart only goes back to 1883; that is they have only taken about six years before the critical period and then they compare it with some sixteen years since. If they will extend this period back to the beginning of their records, they will find this line will look different.

Q. It appears that it is an equation derived from all the data. That is the apparent statement here of the United States Lake Survey. Do you undertake to say that there are any data of which you have knowledge that are not included?

A. I say there was data not in this chart.

Q. The point to which I am directing your attention is, it seemed to me to be obvious to a mere layman that if as against the line which is drawn you have put down your observations for the years 1885, 1887, 1889, 1905, 1906, 1897 and 1896, and the line went through all those observations including observations before and after, and that they coincided very closely with the line, it seemed to a mere layman to indicate that was the correct line; that there was not such a radical change in 1890 as you have indicated?

A. On the other hand, if we introduce a line which divides this up into two, and we show it more nearly fits the points in question, and shows the break in 1889, it would be obvious to a layman our work would be more likely to be correct than the work presented here.

Q. I direct your attention to the chart in this case which has been marked J. R. F. Exhibit number 1, and ask you

whether you had in mind the statement or rather the inference drawn from that chart, so far as this dredging in the St. Clair and Detroit Rivers was concerned, that practically all of it was after 1890 and the most of it was in 1894 and 1895 and 1896?

A. I had in mind that to be the fact, but the critical point at which the dredging took place, namely, at the Lime Kiln, was in 1888 and 1889, if my memory serves me correctly. There was a large amount of material dredged afterwards at other points, very much more than there was then, but it was right then they cut the crest off the weir which held up Lake St. Clair.

Q. So that the result of your study of the effect of these large amounts of dredging in 1894, 1895 and 1896 was that that was of minor importance as compared with the smaller amount of dredging done in 1888 and 1889?

A. As affecting the levels of the lakes, it was. As affecting their fluctuation, no.

Another thing I am a little bit in doubt about; that is I would not want to cover that phase of the question, because the enlargement of the channel that took place likely enough tended to equalize the change of elevation of the two lakes.

Q. So that it would not be right to draw any conclusion in this case based upon the fact that we have high chimney peaks here in 1895 and 1896, and which refers to the change in the cross section of the St. Clair River?

A. You must interpret those in connection with the physical conditions which were involved. Those were, deepening the channels through long reaches. Here your deepening was at the Lime Kiln. There was a barrier which Nature had put there, which separated Lake St. Clair from Lake Erie, and when that barrier was broken through, cut through, it was just the reverse of your construction of the Gut Dam. It was the thing which was the most influential in maintaining the level of Lake St. Clair.

Q. So that it is possible in your opinion for a very small thing, physically speaking as far as the amount of excavation is concerned, or the physical change is concerned, to produce a much greater effect than a very large piece of work?

A. Certainly it would be. For example, if you go to deepen a channel, if you are going to deepen it materially, you will not get the effect of your deepening until you have taken out a channel clear enough. When you start at the upper end and come along down half way, you have a given depth and the probability is you will not have increased its discharge very

much. It depends all together, all the time, upon the contour of your bottom. If you are taking out a series of shallows, that is one thing. If you are deepening a continuous reach where there is a large flow, that is another.

Q. If you used a chart on which the drainage canal was put down as being a thread, a microscopic thing almost, on a piece of paper, it is hardly a fair kind of chart from which to draw the conclusion as to the effect that may be produced upon navigation and the Great Lakes, is it?

A. I don't see why it is not, inasmuch as that chart indicates the relative areas and the approximate hydraulic conditions.

Q. Here we have Mr. Freeman putting down on his chart for the year 1890 a little line where you almost need a reading glass to see it, and yet the great effect is produced by that, and you find things looking like chimney stacks that produce no effect.

A. The fact remains it was the removal of the Lime Kiln that had the greatest effect upon the level of Lake St. Clair.

Q. What legitimate use do you think ought to be made so far as an argument as to the change of the cross section of the St. Clair River is concerned, ought to be made from this chart J. R. F. Exhibit 1, in the light of what you testified to yesterday and today with reference to the change in 1889 and 1890? What use as an engineer do you think ought to be made of that chart as indicating the change in the cross section of the St. Clair and Detroit Rivers?

A. I think that clearly indicates that there has been a very material change in the cross section of the St. Clair and Detroit Rivers.

Q. But one which did not produce nearly the change you claim is produced by that very small excavation in 1890?

A. Yes, I think that statement is correct. That is large quantities do not produce as great an effect as the excavation of a small quantity from critical points.

Q. Or anything like it?

A. I am not prepared to say anything like it. I would like to call your attention to Plate 10 of Williams' Exhibit 34, where is indicated these quantities that have been taken out. It will be seen at the right hand end of the plate what was done at the Lime Kiln. They took out those marked points which had been serving really as weirs. That is Plate 10, entitled "Excavated Material."

Q. My point is that in your opinion produced a much great-

er effect than the taking out of this much larger quantity of material at a later date?

A. I think it did. I won't say a much greater effect, but it did have a greater immediate effect. That was like taking a dam out of a river.

Q. Just refer to that Plate 10 again. The effect of shaving off these rocky peaks, so to speak, was to make possible through the whole river navigation to a greater depth?

A. That was the purpose of it.

Q. And the effect; that was its effect, was it not, to increase the navigable capacity of the entire channel?

A. No, because it reduced the navigable capacity of the channel in certain places as the result of the lowering of the waters immediately above.

Q. I am speaking so far as the size of the boats which would go through is concerned.

A. I am speaking of the size of the boats; the opening of the Lime Kiln caused strandings in the vicinity of Grosse Point by the lowering of the water there.

Q. It did increase the depth of the navigable channel at the critical points?

A. It increased the depth of the channel at the Lime Kiln, but when you said throughout the whole depth, the whole channel, that is not true.

Mr. Hopkins: Q. A deeper boat could go through that channel after the excavation, deeper than before, even though it did lower it perhaps at some other places?

A. That statement is correct, Mr. Hopkins. A boat passing from Lake Huron to Lake Erie could be loaded to a deeper draft after this improvement than before, but a boat passing from Lake Huron to Detroit could not.

Mr. Wilkerson: Q. Now, with reference to these new Niagara observations, assuming them to have been made as indicated yesterday, and to show what it is represented they show, would the fact that they tally so far as the discharge measurements are concerned pretty closely with the former observations which had been made, would be a fact to which weight should be given in determining whether the entire series of observations formed an accurate basis for measuring the discharge of the river, did I understand you correctly as to that?

A. The agreement in the quantity of discharge as stated in Complainant's Exhibit C for identification between measurements made on the Niagara River previously and those made or reported to be made more recently at sections further down

the river would indicate either that both series of measurements were entitled to a high degree of confidence, and to be accepted as accurate within the usual limits of accuracy of such work, or that both series were influenced by similar conditions, or by conditions producing similar results.

Q. When you spoke of the degree of accuracy with which observations of this kind are generally accepted, you agree that is a high degree of accuracy?

A. I agree it is a high degree of accuracy; that is that these particular measurements of their kind are of a very high degree of accuracy.

Q. And what you said about checking the sections of the Niagara against each other would apply to the checking of the sections of the St. Clair?

A. Certainly.

Q. And the St. Lawrence also?

A. Yes, it is a general statement; would apply to sections at different points.

Q. Independent of some element which might enter into this which would influence the result largely, or in the same direction, it would indicate that so far as the making of the observations themselves was concerned, they had been made with a very high degree of precision?

A. It would indicate the precision which we have credited to the work of the United States Lake Survey on the occasions we have had opportunity to do so.

Q. That is, it would indicate that the men who made the observations so far as recording what actually happened with the instruments concerned, that they had been very accurate in recording what was measured?

A. I am not prepared to say that until I see what they recorded.

Q. If you did not know that, the fact it checked so nearly with the other, that all three checked would indicate accuracy in the work itself?

A. One would expect that it would, yes, sir.

Q. Naturally. Now, then, you said that it would indicate that there was some influence which was operating uniformly and to about the same extent throughout all three of the series of observations.

A. Or that there was some influence in each one which produced a result similar in each one. It might not be the same influence.

Q. Which in your opinion would it indicate?

A. I have not seen the observations yet. I am not pre-

pared to pass any judgment critically upon these last observations. They may turn out to be the best that have ever been made and prove these others are the best that have been made previously, as contended for by the Government, but I am suspicious that they may not.

Q. When you said it would indicate a common influence operating through all the series of observations, what did you have in mind?

A. Why, any influence that might be common to them all, more particularly—that is, the first one you would naturally think of would be meter errors.

Q. Let us take meter errors; you had in mind that the meter might under-register, and that the under-registration might be uniform.

A. Or that it might be so nearly uniform that minor variations in other cases would cause the net result to be practically uniform.

Q. And the fact that they check in that way would indicate that the error of registration was the same in different velocities?

A. Not necessarily. If you are confining it to meter errors alone, that would be a fair inference.

Q. I am speaking of meter errors. I am trying to find out just what you had in mind as to a constant source of inaccuracy in all three sets of observations. Now, this meter which was used was what is called the screw meter; that is it is of that type?

A. It is usually spoken of as propeller meter, I think. I don't know as it is called screw meter.

Q. As distinguished from a cup meter?

A. Yes, usually refer to it as propeller meter type.

Q. Do you understand it to be generally accepted by engineers who have made a study of this subject that where a cup meter is running in perturbed water it will register a larger number of revolutions per second than the still water rating would indicate?

A. It is likely to.

Q. That is the generally accepted view among the engineers who have studied that?

A. I think so.

Q. So much so it is regarded as one of the fundamental principles applicable to this subject?

A. One reason for it is that the direction of the meter has very little if any influence upon the speed of the rotation of the wheel because it receives its impact tangentially

all the time; makes no difference what direction the current comes from; it has the same effect in the rotating of the wheel.

Q. I understand from your testimony you regard it as established that where a propeller meter is run in perturbed water it will register a smaller number of revolutions than still water?

A. That seems to be the result of experiment.

Q. Do you know whether or not engineers who have made a critical study of this subject have reached a conclusion as to the possible extent to which a cup meter may over-register?

A. The subject has been discussed, but I doubt if anybody has established the limits.

Q. Isn't there among engineers a generally understood notion as to the limit of the over-registration of the cup meter?

A. No, I think not, because I have in mind a case in my own experience where the over-registration was, if I remember correctly, somewhere around 30 per cent.

Q. From 25 to 30 per cent. is as high as anybody has ever claimed for that?

A. It is not the case of a claim this time. It is a case of actual fact.

Q. I intended to say it has been found?

A. Generally speaking, though, Mr. Wilkerson, I think you would not ordinarily expect to find any such variations.

Q. Isn't it a generally accepted fact that the propeller meter will under-register by not more than 3 or 4 per cent.?

A. I don't think so, because I have seen observations where they under-registered more than that.

Q. I am speaking now of the results based upon a series of observations. It might happen in one particular observation under extraordinary circumstances where you would get more than that, but if you took a result derived from a series of observations, isn't it generally understood that the under-registration will not be more than 3 or 4 per cent.?

A. I don't think so.

Q. Do you understand that it is regarded as an established engineering fact that a propeller meter if it is run in perturbed water will give uniform records in equal times, provided those times are sufficiently long?

A. I presume that it would, provided they were sufficiently long, but they might have to be pretty long.

Q. How long do you think they would have to be?

A. That depends altogether upon the conditions of the disturbance. You must give time for those conditions to repeat themselves in the two periods that are compared. They might repeat themselves in a few minutes or a few hours or a month or a year.

Q. If you assume that a uniform amount of water was flowing through the channel to be measured, the meter would give uniform records in equal times provided the times were long enough to get it—a series of observations adequate for the purpose?

A. With those restrictions, I would say yes.

Q. So we have there as a possible element which you think should be taken into consideration the under-rating of the meter?

A. I think that is one possible element, yes.

Q. Now, what other element did you have in mind that might be a constant element?

A. You don't mean under-rating. I mean an under-reading.

Q. Under-registration?

A. Under-registration.

Q. I mean under-registration.

A. Yes, I answered your question as I thought you meant it and then I observed that what you said was the reverse of what you meant.

Q. What other element did you have in mind?

A. Where have we gotten to?

Mr. Adcock: Is this in determining the volume of discharge or computing the increment?

Mr. Wilkerson: First in computing the volume of discharge, what other element execept the under-registration of the meter did you have in mind?

A. The fact that the section is not properly covered and that large portions of it are not measured or investigated at all.

Q. That would be something peculiar to the section itself. Now I am speaking of these general influences applicable to all three sections.

A. I think that is applicable to all three sections, because as a matter of fact you only occupy about 5 per cent. of the area of your cross section. In the other 95 per cent. there are great possibilities of things taking place that you get no indication of.

Q. Would the error growing out of the selection of the cross-section be uniformly in the same direction? Wouldn't

it very likely operate one way in one section and another way in a different section at a different time?

A. I conceive it might operate either way. It might happen to operate the same way in all three sections or might operate different ways.

Q. So isn't it a fact the only thing which you had in mind as an element of error which might operate to cause these observations to be influenced uniformly in the same direction is the element of the under-registration of the current meter?

A. There is also the element of inaccuracy of measuring the cross section. That would be another element that might very possibly be practically uniform.

Q. You mean the soundings?

A. Yes.

Q. How great do you think that would be as a percentage?

A. I am not prepared to say, because I have not given that very careful investigation. I should think there might be an error of 3 or 4 per cent.

Q. Assume a depth of 20 feet for the water, what would be the average?

A. I said 4 per cent.

Q. Four per cent. of 20 feet would be .8 of a foot. So that there would hardly be a constant error of 8 or 9 inches in the soundings, would there, Mr. Williams, sounding it in duplicate and every ten feet across the river?

A. Each sounding of course is subject to the same conditions, or pretty nearly. While I am aware that very elaborate attempts were made to get those soundings accurate, I am not yet entirely satisfied that they do possess the accuracy that is claimed for them, nor am I satisfied that the section at the International Bridge has remained in the condition in which it was when sounded.

Q. Why did you say that there were errors in sounding that would all be in the same direction, so that they would be uniform?

A. I did not say they would.

Q. Then we are still back to the proposition that so far as any element of error is concerned which might not compensate, which would operate uniformly in the same direction, we get back to the under-rating of the current meter, do we not?

A. No, because I think it is quite possible that all the sections might have been—there might be an error in the sounding or in the determination of the area of all the cross section, which would be of a similar sign.

Q. And expressed in volumes of discharge would be—

A. Well, I said it might be 4 per cent. It might be half of that; it might be one-fourth of it.

Q. While it is possible that that thing might have happened, it is hardly within the range of probability that all those soundings, if there were errors, should have all been in one direction?

A. If they are treated in the same manner I think the errors should be in the same direction.

Q. And if the depth were 30 feet that would be an error of over a foot, isn't it, possible error of over a foot?

A. Yes.

Q. In what direction?

A. I was applying that correction to area, not to depth. Of course, if you talk about mean depth, your question is correct.

Q. In what direction would that be?

A. Well, I conceive that it might be in either direction.

Q. So that with the three series of observations made at different times and under different conditions, that is the kind of error which is largely eliminated by compensation?

A. No, I think not, because if the observations were treated alike in all three sections, I would expect the error to go in the same direction in all of them.

Q. In what direction would you expect it to go?

A. Whichever one did go.

Q. It might result in making the measured discharge too large, or it might result in making it too small?

A. It might.

Q. It might result in helping to compensate the error growing out of the under-registration of the meter, and it might aggravate it?

A. Certainly.

Q. Now, about this computation of the error of the cross section and the error in soundings, is it your opinion as an engineer that engineers who understand their business would make errors in soundings which would average from eight inches to a foot, in a depth of 20 to 30 feet?

A. It might be done in swift water.

Q. It might be done. Take the open section of the Niagaga and its lower section.

A. I think it is not likely.

Q. Would not the probability of errors in soundings made in the more quiet water, to which I last directed attention, be

much lower than 3 or 4 per cent., assuming the work to be done by competent, skilled engineers?

A. Well, you must bear in mind that, if I understand the process used, these soundings were corrected to account for the obliquity of the cable. Whether correction was applied to the observations in the slower water, or not, I am not informed. I have no information as to what was done there. I can conceive that in applying that correction they might apply too much or they might not apply enough.

Q. That is conceivable, of course?

A. In applying the correction, of course it is obvious the error could not be greater than the correction.

Q. You would feel yourself pretty competent to make that correction with a fair degree of accuracy, wouldn't you?

A. Not in 50 feet of water, with the velocities that are reported.

Q. Take 20 to 30 feet?

A. That is somewhat easier.

Q. You would think you could do that pretty well, couldn't you?

A. Well, it is pretty hard to tell what sort of a kink the cable will get into in going down through 20 feet, even, of swift water.

Q. You would undertake to do that with a degree of accuracy where you would feel confident of the result?

A. It depends on what you call "confidence." I would expect to do it within 5 per cent.

Q. Or less than that?

A. If I felt sure that I had it within two, I would think that I had done pretty well.

Q. And that is an error which might operate either way?

A. It might, but if the observations were treated similarly, it would operate in one way.

Q. That is to say, it might operate either way, but under a certain process it might all operate the same way?

A. It would in all probability operate in one direction.

Q. So that, after all, when we come to this element of error that is acting in the same direction, whose influence is uniformly in the same direction, we have left just one element of the under-registration of the current meter, do we not?

A. I do not think you have the one; I think you have the question of section, but that one element of under-registration of the meter covers a multitude of evils. There is not only the initial error in rating but there is the possibility of change in the condition of the meter during the observation, and the

possibility of incorrect observations; the effect of oblique currents as well as the effect of disturbed currents, and maybe other things. I do not know that I have completely listed them.

Q. All those operate in one direction or another; they are, in other words, what you engineers call compensating errors?

A. It depends on how they are treated, whether they compensate.

Q. I know, but they are all errors that might be one way or they might be the other?

A. No, I think not, Mr. Wilkerson. A man is not likely to have a meter over-registering a number of revolutions because you cannot very well get in an extra break in the circuit, but you can skip one, and the man, his position may be such, the speed may be such that you should get the break just about the time that you stop your observation. You frequently can drop one revolution or three-fourths of a revolution in an observation; that is quite possible.

Q. That would come in the rating as well as the measurement?

A. It is not so likely to come in the rating as it is in the measurement.

Q. Why not?

A. Because your rating time is usually longer than your measurement at a single point. That effect would be eliminated in your rating, because when you come to plot up your observations and get your line, you take a mean curve for your rating curve; and if any single observation is short, it is corrected in part by its neighbors, whereas you do not have that opportunity for comparison in your actual measurement. I think in your rating that effect is pretty nearly wiped out, when you take a series of different speeds, even if two or three should be a revolution short; and when you get through you reduce the error due to that to a very small fraction; whereas in an observation in a river, if you are short that much, that whole effect is short.

Q. Now, having all these things in mind which may be the cause of inaccuracy, which you say is the error in the rating of the meter, the error made in reading the meter, the error due to the Niagara registration of the meter, and all of these things, is it not your opinion, as an engineer, that if three different series of observations made under different conditions and at different times gave substantially the same result, that

would indicate that those errors were all of a kind which compensated each other?

A. I would refer you to my answer to the original question.

Q. Would not engineers generally so regard that as the necessary effect of the coincidence in the result of three series of observations of that kind; that is to say, that the errors were of a kind which balanced each other to a very large extent, so that in the end the correction that it was necessary to make would be negligible, or substantially so?

A. For ordinary purposes, such a coincidence of results would be accepted as establishing the correctness of the observations in question.

Q. Now your reason for the rejection of the Niagara River measurements, and the conclusions drawn from them, involve, in the first place, the perturbed condition, alleged perturbed condition of the water, and we have been discussing that in going over this subject of current meter measurements. Now, what other thing did you have in mind in rejecting the Niagara River discharge measurements? I am not speaking of the increment now; just the discharge measurements themselves.

A. Well, the reason for rejecting them in the first place was their failure to agree with the discharges of the other three rivers.

Q. I am not speaking of the reasons which you had, or the process of reasoning, in which evaporation, rainfall and all those tangible things have been employed, but I am speaking of things which grew out of the physical condition of the river itself. What else besides the fact that they do not coincide with the process of reasoning did you have in mind?

A. We did not start at that end of the line. We discovered by our comparison of the physical conditions of the lakes that the Niagara did not agree with the other rivers, and we sought for the reason. Whether we have found it or not I do not know. We have offered all the explanation we think of. We may not have explained the fact, but the fact is there.

Q. That is according to the computation you have made?

A. According to my best knowledge and belief at the present moment.

Q. You have been seeking for the reason in the condition of the river itself, and you found the turbulent condition of

the river at one of the cross sections which were measured?

A. Two.

Q. Two of the cross sections which were measured. Do you have anything else in mind relating to the physical condition of the river itself, as distinguished from the St. Clair and the St. Lawrence Rivers?

A. Well, it is all included in that term "turbulence"; the causes for it, of course, are various.

Q. You found, however, another reason for the rejection of the increment as established by the Government Engineers which did not grow out of the physical condition of the river. I understand that was because of the condition of Lake Erie, the so-called tilting of Lake Erie?

A. The reason for rejecting the increment again was that it was entirely out of harmony with the increments of the other rivers, and we sought again for a reason to explain it. We may not have found the explanation, but the fact remains. I think really it is the business of the complainant to explain it, but we have endeavored to help him all we could.

Q. Of course it is not the business of either side to reject what is established by scientific methods according to an approved process and take in place of it a process of reasoning in which inference is piled upon inference, and assumption upon assumption. But you do give some weight to the fact that the discharge measurements of the Niagara River were referred to the Buffalo gage readings, and to the fact, as you say, that at times, the lake being tilted, a given discharge measurement was referred to a gage reading which was higher than the mean lake level, so that you would have a small discharge referred to a high lake level, when it should have been referred to a lower lake level. Do I understand that to be the substance of the point which you make against the use of the Buffalo gage reading?

A. That is substantially correct. I might modify your wording slightly in one or two ways. I think you convey the same idea.

Q. I would like to get clearly what you have in mind. If I have not stated it as you understand it, I would like to know how I am in error as to your idea?

A. Just read the question.

Q. (Question read to the witness.)

A. My criticism of the Niagara increment is in part based upon the fact that on account of rapid changes of level in

the surface of Lake Erie, the discharge is frequently referred to an elevation of the lake which is different from that which actually produced that discharge. And in general, at the high points, the discharge is lower than that corresponding to the elevation indicated, and at the low points, it is higher than that corresponding to the elevation, which has the effect of reducing the increment.

Q. Are you able to give us an expression of your opinion of the discrepancy, in the form of percentage?

A. Yes. Basing my opinion upon the plottings submitted by the complainant as Complainant's Exhibit F, October 8, 1913, and also Exhibits G, H and I, of the same date, I notice that in every instance when a discharge measurement was made at a time when the lake was at a summit, the measured discharge is greater than the computed discharge; and that in every instance when a discharge was measured with the lake at a minimum, the measured discharge is less than the computed discharge, which indicates to me that the increment used by the complainant is certainly too low.

Now, if we take on these charts the observations at the summits, as we go along, take them in pairs, a maximum and a minimum, beginning with Chart 1, I have compared Observation No. 3 on October 21st, with Observation No. 18, which is on October 26th, and I find that the increment indicated there is 28,500.

I then compare Observation No. 20, which is on October 28th, with Observation No. 27, which is on October 31st, and I find the increment indicated to be 55,800.

I then compare Observation 29, which is on October 31st, with Observation 37, which is on November 4th, and I find the increment indicated to be 28,500.

I also compare Observations 27 and 29, which were both made on the same day, October 31st, and I find the increment indicated to be 47,800.

I then go to the next sheet, sheet No. 2, and compare Observations 42 and 43, which were made on June 27th, and find an increment of 51,100.

I then compare Observation 47, which was made on June 30th, with Observation 53, which was made on July 2d, and which evidently does not represent a minimum, but was put in there because it gives a good long range, and get an increment of 36,500.

I then compare Observation 55 with Observation 58, both being on July 6th, and get an increment of 29,700.

I then compare Observation 70, which is taken July 16th, with Observation 72, taken July 18th, and get an increment of 57,100.

I then compare Observation 88, which was taken July 24th, with Observation 93, which was taken July 25th, and I get an increment of 78,500. The average increment of all these comparisons is 45,944.

In view of that, these being taken at times when the lake was changing its position, having previously been either rising or falling, and now changing in the opposite sense, it might be considered therefore to be stationary, or in one case taken where the lake appears to have been stationary for some time before, it sems to me to be a pretty reasonable method of getting at an increment. I think this indication of 45,944 is so far above that which the complainant has derived, and these plottings show the observed observations to deviate so uniformly above for the high points, and below for the low points, that is the computed discharges, that I feel very well satisfied that the complainant's increment is in error, and that the increment arrived at by myself, by other processes, is more nearly correct than theirs.

Recess to 2 o'clock p. m.

After recess, 2 o'clock p. m.

GARDNER S. WILLIAMS resumed:

(Last paragraph of witness' answer previous to recess read.)

The Witness: And making an allowance for those errors of individual observation which are aside from constant errors, this result seems to indicate that the complainant's increment is in error by between 50 and 75 per cent.

Mr. Wilkerson: Q. And you have reached that conclusion from a study of the observations which were plotted upon the chart which was shown to you on yesterday, independent of any other consideration?

A. Oh, no, not independent of any other consideration, but mainly—no, I will not say mainly.

Q. I want you to confine yourself now to the chart that was shown you on yesterday; limit your conclusion merely to the observations as there plotted upon the chart which was shown to you on yesterday, and I ask you whether or not, upon what appears upon those charts themselves independent

of any other consideration, there is any basis upon which an engineer can predicate the statement that the increment derived by the Government Engineers is from 50 to 75 per cent. in error, in your opinion? I want you to limit this solely to what appears upon the chart.

A. I think that is indicated by the information on these charts.

Q. That is your conclusion and judgment, as an engineer?

A. That is what they indicate to me at the present time.

Q. You have been studying them, and you have no doubt that you have given that subject all the thought that it ought to be given prior to making a statement of that kind?

A. I see no reason to change the statement.

Q. Well, have you anything in mind that might lead you to change it in the future?

A. Erroneous plotting of the observations.

Q. That is all?

A. The erroneous plotting of the computations. I have not checked any of those things.

Q. You picked out this morning for us some sets of observations, in which you offset one observation against another?

A. Yes.

Q. And by a comparison of two of the observations, you got a very high increment. And your conclusion was based upon the high increments which were shown by putting one observation against the other, by separating sets of observations. You could have picked out from the same sheet, had you started out to do so, could you not, sets of observations which would have shown an increment much less than 22,000 cubic feet?

A. It would have been rather difficult to have attached those observations definitely to a stage of the lake.

Q. You could have picked out sets of observations, had you seen fit to do so, which would in fact show a negative increment, could you not?

A. That could have been done, yes.

Q. Do you undertake to say as an engineer that a method of deriving an increment by comparing sets of two observations in the way in which you did this morning is a correct way of deriving an increment from a series of observations?

A. I undertake to say that in a series of observations, it is wise and proper to select those which indicate that they represent most truly the natural condition, and it may be

that in a set of observations there might be one hundred and only one of them worthy of consideration. The fact you have a mass of observations having no better conditions does not make that mass good.

On these plates, Exhibits F, G, H and I, we have the computed discharge of the Niagara River and we have the observations plotted. It is very peculiar that wherever they have a maximum, in almost every case, and have at the same time, or in that vicinity, a measurement, that measurement exceeds the maximum; and wherever they have a minimum, in almost every case, and have a measurement, that measurement is less than the minimum, which indicates clearly that the increment used in computing that curve is too small.

Q. Isn't it a fact those two things compensate?

A. Do not compensate at all in determining the increment.

Q. That is your opinion?

A. Yes. I can see no reason why, when they had a high stage the measurements were high, and when they had a low stage the measurements were low, I can see no reason why they should compensate.

Q. You say they do not compensate?

A. I say they do not as far as the increment is concerned.

Q. That is to say, they indicate, when the lake is at a high stage, or going up, the observation as actually observed is higher than the computed?

A. It indicates that when the lake is turning from a rising to a falling stage, at the point where it forms a cusp, or the maximum, the observed results are greater than the computed.

Q. And when it is going down?

A. When it is changing from a downward to an upward stage, the observed are less than the computed.

Q. And those two do not compensate?

A. They do not compensate as far as the increment is concerned.

Q. You say in order to get a correct increment, your observations should be taken under normal conditions?

A. I think so.

Q. What do you understand to be the normal condition of Lake Erie with respect to the Niagara River, is it quiescent, or is it going up and down most of the time?

A. I have not been able to discover. You can, however, utilize similar conditions.

Q. Assuming that these charts which were shown to you

yesterday are accurately plotted, are you able to get any light on that subject as to what is the normal condition of Lake Erie?

A. I should say its normal condition was vibrating.

Q. About 90 per cent. of the time, isn't it?

A. I guess all the time.

Q. So that if you wanted to take the lake at its normal condition, you would take it as it was going up and down, and the flow of the river with reference to the lake when going up and down?

A. Not in determining the increment, however.

Q. You would take it then for the purpose of determining the increment at the abnormal times when it is in a comparatively quiescent condition, would you?

A. In determining the increment, it is necessary to connect the discharge with the lake stage at a certain time and a certain place, because your increment is dependent upon the difference of elevation of your lake. If you do not get that difference correctly, you do not get your increment correctly.

Q. Now let me direct your attention, Mr. Williams, to two sheets that were produced yesterday, one being sheet 2, one curve series, marked Exhibit K, October 8, 1913; and the other being sheet No. 3, of the three curve series, marked Exhibit H, October 8, 1913.

I direct your attention to the observations plotted on Exhibit K for November 4, 1899, and ask you to note there the level of Lake Erie at Buffalo was approximately 573.3; the mean lake level at Cleveland, the monthly mean, 571.62; the discharge, approximately 220,000. The curves drawn there indicate a tilting up of the lake, do they not?

A. It indicates high water on November 4th, apparently. I should say that the lake was tilted, yes.

Q. As compared with the level at Cleveland, 571.62?

A. Yes.

Q. That is a tilting up of the lake?

A. Yes.

Q. Take the observations for July 31, 1908, on Exhibit H, the same being sheet 3 of the so-called three curve charts. I direct your attention to the fact that the elevation of Lake Erie, 573.32, the figure which I just gave you, is the mean lake level at Cleveland; the curve showing at the Buffalo reading was very slightly below that. The discharge observations for that day show approximately 220,000. I ask you

to observe there was obviously a quiescent condition of Lake Erie.

A. The observations of that day, as I should read them, would show considerably more than 220,000 on that occasion.

Q. 225,000?

A. That is better.

Q. The other one shows about 222 or 223,000, on the other sheet. Now, assuming the accuracy of the work of plotting these observations, would that indicate to you as an engineer that that which controls a volume of discharge is the elevation of the lake at the particular time at Buffalo, without regard to whether the lake is tilted or not? I will limit my question to this particular instance.

A. Just how does that question terminate?

Q. (Question read.) That is Lake Erie.

A. No, it does not, for the reason that the observations on July 31st fall considerably further away from the computed discharge which is based upon the simultaneous elevation, or nearly simultaneous elevation of the lake than do those of November 4th. For that reason, it appears to me that it does not indicate that they are controlled by the same conditions.

Q. I do not understand your answer. Just restate that.

A. (Answer of witness read.)

Q. By that you mean on July 31, 1908, we have two observations that seem to be right together?

A. You have four observations that day, and I was considering them all.

Q. You refer to the one being made in the forenoon of that day?

A. I was referring to the observations made on July 31st.

Q. You are considering them all, and you say they are further away from the computed line than the other?

A. Yes, showing a higher discharge.

Q. How much further away are they? If you averaged the ones on July 31, 1908, there is a difference of more than 2,000 cubic feet, is there not?

A. Somewhere around 3,000 cubic feet it is.

Q. Between two and three thousand?

A. I should say it was over three, but I may be in error.

Q. That would not be 50 or 75 per cent. of 220,000, would it?

A. No, nobody intimated it would be. I say the incre-

ments were from 50 to 75 per cent. in error. That is very different from saying the discharges were.

Q. It would not be 50 or 75 per cent. of 22,000, would it?

A. Let's see, what is it?

Q. It would be about 10 per cent.

A. That is only one end of your scale.

Q. Take the observations now for July 23, 1908, on the three curve chart. Your monthly mean lake level at Cleveland is 573.32. The elevation at Buffalo is 573.2 approximately. The reading is 222,000, and there are four observations for that day, all of which are practically on the line.

A. All of which are slightly above the line. Start with 83, which was the first; what was the elevation that caused that, a reading an hour or so later or the one before?

Q. Take all of them.

Mr. Shenehon: At the time.

A. At the time, then it is above; it is above by at least 2,000 feet.

Mr. Wilkerson: Q. Which one is that?

A. The first one.

Q. It does not look to me to be more than 1,000 feet above.

A. I am trying to get the times you represent these.

Q. Isn't it a fact that it is hardly more than 1,000 feet?

A. I think not, according to this scale, if the center of the dot is plotted right. I assume that the position of the measurement is represented by the center of the dot.

Q. What do you say about the second one, how much is that?

A. About 2,500.

Q. The third one?

A. About 1,500.

Q. And the fourth?

A. Something over 1,500, and always larger.

Q. Now, going back to November 4th on the one curve series, how much is the plotting there above the line, looking at it the way you have looked at these other observations, about which you have just testified?

A. About a little over 1,500.

Q. Look at that straight, the way you did the other ones. It looks to me to be like 2,500.

A. I would say it is under 2,000, slightly nearer 2,000 than it is 1,500, but it is still high.

Q. Expressed in either case in percentage of volume of

discharge, it would be a very small percentage, wouldn't it, 1 or 2 per cent.?

A. One or two per cent. covers them.

Q. It would be 1 per cent. in the last case?

A. In the last case.

Q. Now I understand that one of the points of difference in the method which you used in deriving your increment for these different rivers, and the method which is used by the Lake Survey and the Government Engineers, consisted in referring particular discharge observations to a gauge reading which was 24 hours before the time of the making of the discharge measurements?

A. I think not.

Q. Perhaps I should have said groups of observations.

A. No, that is not correct exactly. The elevation producing the discharge was assumed to be the elevation of the period over which the observations extended, with one day added at the beginning, so that if you had a period of 10 days, if the observations covered 10 days, the period over which the elevations are computed would cover 11, if I remember correctly.

Q. And you subtracted one day from the end?

A. I think not. I was under the impression we had carried it through the full—those were not advanced 24 hours; we took in the elevation the last day in every case, I think.

Q. As a preliminary to what I am going to ask you, let us have just what you did to shoving these days back, so far as—

A. We did not shove it back, we did not shove the day back. We added one day at the beginning, which would be equivalent, of course, to shoving the center of the group that determines the elevation half a day, 12 hours.

Q. Twelve hours?

A. It really has the effect of shoving it 12 hours.

Q. So that the observation is, in fact, referred to an elevation of 12 hours—

A. Twelve hours previous.

Q. —previous to the time the observation is made?

A. That statement is not exactly right. The elevation which is assumed to control the discharge has its center of gravity 12 hours earlier than the center of gravity of the measurements which I have included in the group. I presume that is what you mean.

Q. There is a slight difference between the two, but it is not a material difference?

A. I think the understanding of counsel was substantially the same as my method of procedure.

Q. Now take sheet 1, for instance.

A. Of the three curve series?

Q. Of the three curve series. Have you considered the elevations of water surface of Lake Erie at the Buffalo gauge, as compared with the elevations of the water surface in the gorge pool of the Niagara River at Suspension Bridge gauge, for the purpose of seeing how long it takes the effect to travel from one point on the river to the other. (Handing witness Exhibit G.)

A. I have, and also the relation between the Buffalo gage and the Chippewa gage, which is somewhat nearer the outlet of the lake.

Q. How long does it take the effect to travel from the Buffalo gage to the Gorge Pool?

A. Four to six hours apparently, usually. In some instances it may take a little longer, and some will come a little more rapidly. Of course sudden changes, large changes would travel more rapidly than smaller ones.

Q. Let us take Sunday, November 3d, on Exhibit G, Sheet 1.

A. Sunday, November 3d, Sheet 1?

Q. Yes.

A. What is the question?

Q. You notice the peak of the line?

A. Yes, that is four hours.

Q. In the upper column. Now, take October 25th.

A. Four hours.

Q. Would you say three or four?

A. Four hours. I think the range that I gave covered it. I said six to four; some occasions longer, some a little less. I think I did find one that was as low as three hours.

Q. The open section and the International Bridge section are nearer the Buffalo gage than this Gorge Pool?

A. Yes.

Q. So it would not take so long to travel?

A. Assuming this represents the time it takes the full effect to travel, which is not the case for the lake does not stay stationary long enough for the full effect to be felt there; you would find, for instance, when it had been lowering if it would stop at some elevation, the water in the pool would continue to drop for some time after the period indicated here, and then of course would remain stationary, so that this wide vibrating lake-like expanse below never corresponds completely

to either the low or the high point that is reached by the controlling body.

Q. If you took a discharge observation which had been made on Sunday, November 3d, in the morning, and referred that to a gage reading 12 hours earlier than that, it is perfectly obvious that you would have your discharge measurement referred to a gage reading which would give an erroneous result, isn't it?

A. It would be entirely incorrect to refer a single observation in that way; and such reference could only be properly introduced in groups; and in the light of the information that has come into my hands for the first time within the past 60 days, it is my opinion that the setting back of the time of observation 24 hours, or the center of gravity 12 hours, is too far for the Niagara River.

Q. How much too far?

A. That is a somewhat difficult question to answer.

Q. Do you think it is so much that setting it back 12 hours would make a very material difference in the result obtained by referring——

A. Not in the average of a series of days.

Q. An allowance of three or four hours would be sufficient?

A. For individual observations I would say that setting back an hour is probably about as much as you need.

Q. Setting it back an hour?

A. For individual observations and they would cover all that is warranted in dealing with individual observations.

Q. If you average your center of gravity, it would be an hour or more later?

A. No. It is my opinion you cannot deal with individual observations and get a satisfactory increment because as I stated before no observation represents the discharge of the elevation to which it would then be referred.

Q. To further illustrate that, look at your Table 45A, Sheet 5, and also look at Sheet No. 3 of the one curve series, Exhibit L, October 8, 1913.

A. What is the inquiry?

Q. I direct your attention to group 12. You find those observations plotted on the chart which I directed your attention to, do you not, Sheet No. 3 of the one curve series?

A. June 27th and 30th, yes.

Q. There are six of them plotted?

A. There are six observations, yes, sir.

Q. You notice that the day before there was low water apparently. What I was going to say was—and I want to get

it into the record—that illustrates what you have said about the propriety, or rather the impropriety of referring those back 12 hours. That is all I wanted to direct your attention to. That is a concrete illustration of how that might work?

A. What is it?

Q. That is a concrete illustration of how it might work, if you referred them back 12 hours?

A. But it will be found if you refer them back 12 hours, or refer them to the actual time here, the difference will not be very material. You would have 2.65 instead of 2.62, which makes a difference of .03 of a foot.

Q. Now another point of difference between yourself and the Government Engineers in the method of deriving this increment consisted in weighting the observations. And by referring to Sheet 1 of this three curve series, the same being Exhibit F, October 8, 1913, I direct your attention to the fact that on October 26, 1907, you have four observations. They are plotted there; and, for example, on October 30th, you have one observation.

A. What is the question?

Q. I have directed your attention to the fact that on one day you have four observations and on the other day you had one?

A. Yes. You are referring to the 29th and 30th?

Q. I am referring to the 26th and the 30th.

A. All right.

Now as I understand your method, you took the four observations that were made on the 26th and averaged them and gave to that average the weight of one?

A. Yes.

Q. And you give to the sole observation on the 30th, the weight of one?

A. Yes.

Q. Equal to the average of the four observations?

A. The average on the basis of time, assuming the observations to be correct.

Q. Now then if according to your method on the 26th of October, 1907, there had been only one observation made, namely, the one which is on the line 343.0——

A. That is the lowest one?

Q. The lowest one, you would have given that a weight of one?

A. I would have given that a weight of one.

Q. The same weight as you would the other?

A. Exactly. That is the only thing we could do, it being all the information we have.

Q. If you had the highest one, you would give that the weight of one?

A. Certainly. If you only had one that day, it would have had the weight of one.

Q. Now, take Sheet No. 2 of the one curve series, Exhibit K, October 8, 1913. Look at the observations for October 21st, and then the observations for the 22d, 23d, 24th, 25th, 26th and 27th.

A. What was the day?

Q. October 21st down to October 27th. Now, according to your method, if you were considering a group of observations commencing on the 21st and ending on the 27th, you would take the average of the two on the 21st and give that a weight of one; and the average on the 27th and give that a weight of one; and then you would give the whole thing a weight of how much?

A. I would not apply such a method as that, because there is too much intervening space; at least I doubt if I would, although the elevation is comparatively uniform. It is possible I might use such a case as that; in that case, the group would have the weight of the time over which it is extended.

Q. You say it is comparatively uniform. You regard a difference of 10,000—speaking of discharge now—a difference of elevation would make a difference of discharge of 10,000 cubic feet, you regard that as being comparatively uniform, having in mind the whole situation?

A. It is so far as the accuracy of the evidence presented in this case is concerned. That would only mean a variation of somewhere around three-tenths of a foot, which is not a high one.

Q. It is evident, isn't it, Mr. Williams, that this method which we have just been illustrating here, by pointing out this specific instance, applied to any series of observations of this kind would necessarily result in producing a greater increment than the method adopted by the Government Engineers?

A. Not necessarily. It might produce a less one.

Q. It is hardly conceivable it would; it is hardly conceivable you could get a set of observations where it would be less; it would have to be most extraordinary and the groups would have to be most extraordinarily selected?

A. It is hard to conceive that any one could get a lower increment by any process than the Government Engineers have presented, but the fact as to one method or another giv-

ing a higher or lower result is not established in the method at all.

Q. It gets a larger result for the St. Clair, doesn't it?

A. It does.

Q. It gave a larger result for the St. Lawrence?

A. It did.

Q. As applied to each series of observations produced, or any group of observations which you have been able to make. In your studies of this case, did you strike a set of observations which if you applied this method of weighting observations to, gave an increment which was lower than that of the Government Engineers?

A. No, sir, I did not, and I do not think that you could select observations from here, in any way, and apply them to the elevations and get a lower increment than the Government Engineers have gotten, if you make a uniform increment for the whole range.

As far as selecting observations is concerned, they were selected solely upon the uniformity of lake levels during the period which was covered, as that uniformity was indicated by the mean daily elevation, which was all we had to work from. If we had had this information which we now have, we might have made different selections.

Q. I don't remember whether you were present or not when Mr. Freeman testified, Mr. Williams?

A. I think I was.

Q. You recall his testimony; you have read it at any rate?

A. I have not read it.

Q. I read you a paragraph from his testimony as follows, speaking of the ice effects in the St. Clair River; he says:

"These ice effects were observed with considerable care by the United States Engineers only in the year 1901, and at that time periods were found when the flow of the river was cut down about one-half. A reference to this may be found in the report of the Chief of Engineers for 1902, on pages 2835 and 2836.

On the other hand, in winters like that which we have just passed through, there would be little or no clogging of this kind. Obviously when the St. Clair River is thus clogged, Lakes Huron and Michigan must rise, and Lakes St. Clair and Erie must fall, because of the cutting off of their most important source of water supply. Lake Erie doubtless also suffers some impediment to its discharge, because of ice in the Niagara River. But the records indicate that the extent of this clogging is far less than in the St. Clair River.

Perhaps this is as good a place as any to go into this question of ice obstruction, in some detail. I regard this matter as extremely important, because I am led to believe that failure to appreciate its influence has led to serious error in the studies of the levels of the Great Lakes by the Government Engineers; and to the best of my judgment and belief, sufficient compensation for its effect has not been made in their computations and estimates of the yearly discharge of the several lakes, and in the relation of their levels."

You have given some attention to that subject, have you?

A. Somewhat.

Q. What do you say as to the correctness of the observations which are there made by Mr. Freeman?

A. I think they are correct substantially.

Q. Have you given consideration to this ice effect in your studies that you have presented here?

A. You mean as to determining increments?

Q. Yes.

A. I have not. I have followed the Government Engineers in that, as we were dealing with the facts which they presented.

Q. You have made in this case, Mr. Williams, a study of the physical conditions of the Great Lakes and rivers, in order to determine the consistency of the flow of the three rivers, taking account of rainfall, run-off, evaporation, reservoir effect and river flow. In that analysis, which you presented here, did you consider the winter conditions of the flow of the various rivers, the St. Clair, Niagara and St. Lawrence?

A. Not in the analysis as presented.

Q. I mean in your testimony?

A. In the testimony up today, I have not.

Q. That has not been taken into consideration?

A. (No response.)

Q. Is it not a fact that that should be taken into consideration?

A. Possibly it should be; however, it does not materially modify the results obtained.

Q. But you did——

A. I did examine it, to ascertain whether it would make an important difference.

Q. When did you do that?

A. Oh, I did that several months ago; in fact, I guess over a year ago, and found that it made very little difference, and for that reason did not introduce it inasmuch as definite information on it had not been introduced on the other side.

Q. Then Mr. Freeman is a little extreme in his statement of the effect of those ice conditions, isn't he?

A. I think not, when he is considering the effect upon navigation, which I assume is the condition to which he is referring.

Q. No, he is speaking of the effect on the condition of the rivers.

A. With reference to the work of the United States Corps of Engineers, which, as I understand it, has to do with navigation.

Q. Well, with reference to the effect on the outflow of the rivers?

A. Their only reason for having anything to do with it is on the ground of the Commerce Clause in the Constitution, as I understand it.

Q. I do not see why it should have been important from his standpoint, and not important from yours. Is it your understanding you have been studying this case from one point of view and Mr. Freeman from another?

A. Not at all, but I say it is unimportant as to the relations of the discharges of the several rivers.

Q. You are familiar with the statement as to the effect of ice in the St. Clair River during the winters of 1900, 1901 and 1902, appearing on page 2837 of the report of the Lake Survey, 1900, 1902?

A. I have the reference.

Q. Does that indicate to you that in the physical study of a river you cannot leave out of consideration the ice effect?

A. It depends altogether upon what the purpose of your investigation is. In dealing with a long period of years, you find that ice effects in one river compensate for the effects in another. The effect in your final result is not material whether you should take them specifically or not, if you are dealing simply with the relations between one river and another.

Q. You found that to be true as between the St. Clair and the Niagara, did you?

A. I find that to be true between the St. Clair and the St. Lawrence; and I can see no reason from my own personal observations why the conditions that exist in those two rivers are not substantially duplicated on the Niagara, and from inquiry I have learned, from the testimony of those familiar with the situation, that those conditions are to a very large extent duplicated.

Q. Where did you get that information; what is your authority?

A. Some of it from Mr. Emil Kuichling; some of it from Mr. Louis H. Knapp; some of it from my own personal observation; some of it from Mr. Freeman.

Q. Did you ever get any information of that kind from any report of the Government, or from any statement by anyone who had made a continuous observation of the situation, in the discharge of his duty?

A. I am not aware of any government discussion of the subject.

Q. Now, if you have, in your physical study of these rivers, assumed this ice condition in the Niagara to be as you have stated when as a matter of fact it is different from your assumption and understanding on the subject, then your physical analysis of these rivers would be subject to the necessary correction on account of that assumption, would it not?

A. A rather moderate correction, because the effect of ice when distributed over a period of years, it is very small; in a single year it may be very great, but when you distribute it over a considerable period, it is quite small.

Q. In the St. Clair River, during the winters of 1900, 1901 and 1902, as shown on page 2837 of this report, of the Chief of Engineers for 1900, 1902, there is a loss over the full year, in 1900 of over 12,000; 1901, more than 20,000; 1902, almost 10,000, is there not?

A. I call your attention to the fact these are based on observations for the year 1901 only; that the rest are computations. Those investigations have been discussed in another report at a later date. And I will call your attention to page 4107 of Appendix EEE of the Annual Report of the Chief of Engineers for 1904, in which there is a table showing the St. Clair River monthly mean discharges in cubic feet per second, referenced to the report of 1902, giving the ice effect as shown by that report, and as determined by this subsequent examination in which the discharge both of the St. Clair River and the Detroit River was considered; and whereas in the 1902 report the ice effect is given as 30,300, in the 1904 report it is given as 8,070 for January.

For February, in the 1902 report, it was given at 85,900, and in the 1904 report as 34,070.

For March, it was given in the 1902 report as 53,800, and in the 1904 report as 18,970.

For April, it is given in the 1902 report as 66,300, and in the 1904 report as 56,770.

For May, the ice effect is given in the 1902 report as 11,800, and in 1904 report as 16,770. And in commenting, the report says:

"The method of deriving the quantity of water held back by an ice gorge as given in the 1902 report dependent on the relation between the restricted discharge and the slope at the head of river as observed in some particular year is not a method strictly applicable to other years, unless the ice obstruction is located in the same part of the river. The relation of slope to discharge must depend upon the location of the obstruction. For this reason it is believed the computed discharge of the Detroit River is a better measure of the quantity of water passing through the St. Clair River during the ice gorges than any derivation based on slopes over short stretches of the river. The determination by the Detroit River is by no means certain. When there is a gorge in the Detroit River the gage readings give an erroneous result for the discharge. Ice gorges in the Detroit River are, however, less frequent than in the St. Clair."

In view of that, it has seemed to me it was hardly wise to include the full effects indicated in Table No. 7 of the Report of 1902.

Q. There still remains, however, some effect?

A. Some effect.

Q. And the necessity of giving that effect some consideration?

A. Yes, sir, and it was given some consideration.

Cross-examination closed.

Adjourned to Friday, October 10, 1913, 10:30 a. m.

Friday, October 10, 10:30 a. m.

Parties met pursuant to adjournment.

Adjourned to Saturday, October 11th, 10 a. m.

Saturday, October 11th, 10 a. m.

Parties met pursuant to adjournment.

GARDNER S. WILLIAMS, resumed the stand and testified further as follows:

Re-direct Examination by Mr. Austrian.

Q. Mr. Williams, you were interrogated by counsel for the Government with reference to your compensation in this case. The compensation paid to you by defendant in this case was in no wise dependent upon the result or outcome of this litigation?

A. Not at all.

Q. Prior to your employment by the defendant in this case, were you approached by the complainant, with reference to becoming employed by it in this case?

A. I was.

Q. Did you accept a proffer of employment by the Government?

A. I did not.

Q. You have been interrogated with reference to certain testimony given by you in the case of the State of Missouri——

Mr. Wilkerson: When you say the Government, I assume the Government is a creature of many arms. It might be well to say who.

Mr. Austrian: I have no objection.

Mr. Adcock: He has the correspondence.

The Witness: To state the thing clearly, I received a letter from Major Keller, asking me if I would be available to serve the Government in this case.

Mr. Austrian: Q. Who is Major Keller?

A. Major Keller was the engineer in charge of the Lake Survey office in Detroit at that time. The letter stated that he was acting under the authority of the United States District Attorney. And I replied to that letter that I was considering an engagement with the Sanitary District, and that if my views proved acceptable to them, I should take that side of the case; and thanked him for the compliment and declined the case.

Mr. Wilkerson: That is at the time you got the major's letter, you were already negotiating with the Sanitary District?

A. I had had correspondence with the District. At the time

I referred to this letter before, I was not clear on the subject, and my testimony would indicate that I had not had any correspondence with the District. But on referring to my files, I found that I had entered into correspondence with the District, although no engagement had been made with them, at the time I declined the engagement with the Government.

Mr. Austrian: Q. Counsel referred upon your cross-examination to some testimony that you had given in the case of State of Missouri versus the State of Illinois. Have you that testimony in mind?

A. I have in a general way.

Q. I desire to direct your attention particularly to that part of your testimony in which you refer to the danger of infection to the people and to the stock of Missouri, on account of anthrax and cholera germs being carried by means of the channel into the lower waters, into and about the State of Missouri.

A. I have in mind that testimony.

Q. Were your conclusions as there stated based upon any assumptions?

A. Well, they were based upon the assumption of the existence of anthrax in the vicinity of Chicago, or the existence of the diseases considered in such locations as to permit of the germs being distributed through the sewage of Chicago into the Drainage Canal.

Q. Since the opening of the Drainage Canal, from your observations, what if any conclusions have you reached with reference to that subject?

A. So far as I have been able to learn, and I have had the subject more or less in mind, there has been no indication of an outbreak, of a serious outbreak of water borne diseases in the State of Missouri due to anthrax, or the particular germs considered in that answer; nor do I know nor have I learned of their existence at Chicago.

The testimony at that time was given in the light of the best information that I had in regard to the transmission of disease germs, which was necessarily based to a considerable extent upon the observations of the life of such germs in various kinds of water, and the transmission of typhoid fever; particularly in some streams in New England, in the St. Clair River, and in the Red Lake River in Dakota. There was nowhere available information upon a case similar to the specific one which we have to deal with here, and no one appreciated the importance, or at least I did not, and I think very

few of us appreciated the importance of the excess of oxygen which is contained in the Lake Michigan water.

It is very considerably higher than in running streams, and on that account is of especial value in the reduction of sewage products.

Mr. Wilkerson: Q. That is it will take care of more sewage products than ordinary water?

A. Yes. On account of this, the results of the drainage works have apparently been much better than was anticipated, at the time the testimony was given.

Mr. Austrian: Q. Mr. Williams, bearing upon the subject of the amount or the quantity of oxygen in Lake Michigan waters, do you draw any conclusion from the present state of the fish in the Illinois River as compared to that in the stream prior to the opening of the Drainage Canal?

A. Though I have no personal knowledge of the conditions, it is my understanding from the reports and statements which have come to me regarding it, that there has been a large increase in fish life in the Illinois River since the opening of the Sanitary Canal; and this would indicate an increase both in the food supplies and in the oxygen supplied in the river—supply of free oxygen.

Mr. Wilkerson: If that should be material, that issue in this case——

Mr. Austrian: We will prove that the fish industry has increased 300 per cent.

Mr. Wilkerson: It is not competent evidence. It does not occur to me it is at all material to any issues in the case.

Mr. Austrian: It is a matter of public knowledge that the fish industry in the Illinois River has increased between 250 and 300 per cent.

Q. At the time that you testified in the case of Missouri versus Illinois, you had in mind did you not the general character of the work that the Drainage Canal would perform?

A. I did.

Q. Since the opening of the canal, and from your observations and studies of the subject, has the Drainage Canal performed its purposes as well or better than you anticipate?

Mr. Wilkerson: I object to that as not proper re-direct, and as the statement of a witness who is not qualified to testify on the subject; and not only that, but it is stating certain things which he had in mind which were accomplished. We do not know what he had in mind.

Mr. Austrian: I desire to supplement that question by this question:

Q. The testimony which you gave in that case, to which your attention has been directed by the Government, was in the light, was it not, of the work which you anticipated the Sanitary Canal would perform?

A. It was.

Mr. Austrian: Then I will put the pending question.

(Question read as follows: "Q. Since the opening of the canal, and from your observations and studies of the subject, has the Drainage Canal performed its purposes as well or better than you anticipated?")

A. So far as disposing of the sewage wastes of Chicago, the performance has been substantially what was expected, namely, the removing of them from a location where they threatened the purity of the water supply of Chicago. So far as their affecting the quality of the water in the Mississippi River, judging from the vital statistics of the communities which were in locations to be affected, it appears that the purification taking place in the sewage, as it passes through the Drainage Canal to the Des Plaines and Illinois Rivers is better, more complete, than was anticipated at the time the testimony in the St. Louis case was given.

Q. When you say was anticipated, you mean was anticipated by you, among others?

A. I mean was anticipated by me, referring to my own testimony.

Q. Does the mere fact that the current meter method of measuring large streams is the only available one known give any evidence or indication of the accuracy of that method, in your opinion?

A. I can't see that it does.

Q. In your cross-examination, Mr. Wilkerson called your attention to certain observations which were made during the time when there were ice conditions in the Niagara River included in Table No. 3 and other tables of Exhibit 34. Have you made any correction in those tables to meet the corrections or criticisms indicated, and if so what corrections have been made, and with what result?

A. Table 3 of Williams' Exhibit 34, the observations objected to, have been canceled by black ink lines; and the resulting computations have been—the original computations have been canceled with black ink lines; and corrected computations inserted in black ink.

The result of excluding the observations which were made during the winter shows the average variation from the mean of the mean discharge of the Niagara River at the Bridge Sec-

tion to be .872 per cent., as against 1.202, with the observations in.

There has been added Table 3 A, consisting of three sheets, which includes not only comparisons in the original series of observations covered by the original Table 3, but also comparisons with the observations of 1907 and 1908. This computation, considering all the observations made at the International Bridge, and comparing those made under similar conditions, gives an average variation from the mean of 1.007 per cent. of the mean discharge, still showing that the Niagara observations, by this comparison, are not within themselves as consistent as those on the St. Clair, as was heretofore testified.

In Table XLV, the group including the winter observations has been stricken out by a white line across the blue print, and the footings have been stricken out in a similar manner and the new results, corrected results, have ben inserted.

The same has been done in Table XLV A on sheet 2; on Table XLVI, Table XLVI A, Table XLVI B, Table XLVII and on Table XLVIII A, so that these tables show the original figures with a line drawn through them to indicate those that are in error, and the corrected figures added below; and, in general, the effect upon the increment was to reduce it about 1,500 cubic feet a second.

I would suggest that this corrected set of tables, which also contains now an index, be substituted for the Exhibit 34.

Mr. Wilkerson: The one which you have made is omitting the winter observations?

A. I have omitted the winter observations.

Q. And you have recomputed the increment according to Williams' Exhibit 34 and marked Williams' Exhibit 34, and the same method which you used when the winter observations were included?

A. Yes.

Q. So that the table on its face shows—

A. That it was in error in the first place.

Q. Shows what the first figures were, and what the second are?

A. Yes.

Mr. Austrian: It is agreed this may be substituted for the original Williams' Exhibit 34 may be withdrawn from the record.

Mr. Wilkerson: Very well.

Mr. Austrian: Q. Mr. Williams, what is the difference

between the method adopted by you in the application of rainfall records and the method attempted to be used by the Government, in connection with certain of the exhibits which have been offered for identification, on your cross-examination on October 8 and 9, 1913?

A. The method of the Government in applying its rainfall data seems to have been considered the rainfall for a single year as a unit, whereas in the application of the rainfall data as I have used it, I have considered the effects of a series of years. The effect of the rainfall is influenced by the manner in which it operates. Two years may have exactly the same rainfall and produce materially different results, on account of the distribution of that rainfall through the year, so that if it is intended or attempted to make use of the rainfall record of a single year, a study must be made of the distribution of that rainfall during the year, oftentimes goin back so far as to consider the daily distribution, in order to arrive at safe conclusions. When, however, it is possible to take a group of a number of years, these variations from year to year become eliminated in an average, upon which it is much safer to predicate results and which have been known, in many cases, to permit the drawing of very accurate and reliable conclusions.

In my use of rainfall data I have confined myself, so far as I can now recall, in this case, to averages for periods of years, for the very purpose of eliminating the possibility of erroneous conclusions being drawn from an abnormal condition in a single year.

Q. What, if any, comment have you to make as to the propriety of applying an increment derived from Lake Erie in its fluctuating state, in the determination of the effect upon that lake by the Chicago diversion?

A. The criticism would be this: The Chicago diversion will be substantially a constant and continuous effect. The quantity of water taken, while it necessarily varies somewhat from day to day, is in general an approximately constant quantity. The determination of an increment from Lake Erie, in that condition in which it exists for perhaps 90 per cent. of the time, while it might be satisfactory for some purposes, though I can hardly conceive now what, is decidedly inapplicable to a case where the quantity to be measured is a constant one.

In other words, we might say that it is the case of trying to determine a constant and continued and finished effect by

comparison with a variable instantaneous and incomplete one.

Mr. Adcock: Q. When you say the fluctuating state, you mean the oscillation?

A. The oscillation from hour to hour.

Q. You did not refer in that to the mean annual?

A. No.

Mr. Austrian: Q. In your opinion, should the Niagara measurements be discarded?

A. They should.

Q. Will you state your reasons for this conclusion?

A. The reason is that considering the lake system as a whole, while the St. Lawrence, Detroit and St. Clair observations agree with the observed facts of the conditions of the Great Lakes, the Niagara observations do not. And the Niagara observations contradict flatly the proposition which is uncontrovertible that where the quantity of water handled is within reasonable limits, the increment must be inversely as the variation in the annual stage of the lake surface. The variation in the mean annual stage of Lake Erie is less than that of Lakes Huron and Michigan; therefore its increment must be larger. The variation of mean annual stage of Lake Erie is also less than that of Ontario, and therefore its increment must be larger than that of Ontario.

In view of these physical conditions, and the fact that the Ontario increment, the St. Clair increment, and the discharges measured in the Detroit River check each other, and the Niagara observations have nothing to support them, it is my conclusion that the weight of evidence is against the Niagara observations, and they are therefore discarded by me.

Re-cross Examination by Mr. Wilkerson.

Q. In what you have said on your re-direct examination, with reference to the discarding of the Niagara observations, you have assumed that the exhibits relating to the subject of the new measurements were accurate, and have given consideration to that in your answer?

A. In giving that answer, I have not given consideration to the new measurements, for the reason that I know nothing of them.

Q. So that if it should appear that the observations as made, and the computations from them, fully warrant what is

shown on the face of those exhibits, you might wish to modify your statement?

A. I might change my view.

Adjourned to Monday, October 13, 1913, 2 p. m.

After recess—2 P. M.

FREDERIC P. STEARNS, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?
A. Frederic P. Stearns.
Q. Where do you reside?
A. Boston, Massachusetts.
Q. Where is your place of business?
A. In Boston.
Q. What business are you in?
A. Civil engineering, chiefly with reference to hydraulic and sanitary work.
Q. You do consulting engineering work?
A. I do.
Q. Will you state your early training, experience, qualifications, official positions, if any you have held, positions with private concerns or corporations, and the duties which you were called upon to perform in connection with any and all the positions which you have filled?
A. I began engineering work in 1869, 44 years ago. I had a high school education; did not attend a technical school or college, but pursued the studies in mathematics which are taught in such schools, to a considerable extent.

From 1872 to 1880, I was engaged upon the preliminary work, the construction, and in the last years in the operation of a new system of water supply for Boston. In the construction, I was in charge of a division of the work. Incidental to this work, I had occasion as early as 1874 to measure the flow of the Sudbury River, using a current meter; and to do other hydraulic work. It was during the construction of these works that in collaboration with Mr. Fteley, I made several series of hydraulic experiments upon the flow of water over weirs, upon the flow of water through channels and pipes, and upon the current meter; these experiments being made for the purpose of deducing hydraulic

laws. The results of such experiments were published in the Transactions of the American Society of Civil Engineers, one of the papers receiving a Norman Medal for that year.

From 1880 to 1886, I was connected with the construction, and in the last years with the operation of the Boston Main Drainage Works, which is a main system of sewerage and sewage disposal for the City of Boston.

From 1886 until 1895, I was the chief engineer of the Massachusetts State Board of Health, being employed at first in connection with a legislative act which was entitled: "An Act to protect the purity of inland waters." It involved the consideration of the discharge of sewage into streams, the care and control of streams used for water supply, and the study of the condition of polluted rivers. A provision of the act required that all proposed systems of water supply in the state should first be submitted to the State Board of Health, before legislative action was taken regarding them.

Besides the work of the State Board of Health, of the character which I have mentioned, the legislature required the Board to devise a system of sewerage for the suburban cities, and parts of the City of Boston. And this system of sewage disposal, which was estimated to cost about six million dollars, was devised while I was Chief Engineer of the Board of Health.

Another legislative act required the Board to make an investigation for a water supply for Boston and its surrounding towns and cities, known as the Metropolitan Water District. This investigation was made, and the plan devised, under my direction, the estimated cost of the works being $25,000,000. From 1895 to 1907, I was Chief Engineer of the Metropolitan Water Board and its successor, the Metropolitan Water & Sewerage Board.

While holding this position, I had charge of the construction and operation of the Metropolitan Water Works, and was consulted in some matters relating to the sewerage works of the Metropolitan District, which were under the charge of the Metropolitan Water & Sewerage Board.

That is the end of my regular engagements as a Chief Engineer of a board. I resigned in 1907, so as to have time for consulting work. Apart from my regular occupation as chief engineer of these various works, I have been consulted in many cases. The first important engagement was in 1888 and 1889, when I was a member of a board of sanitary engineers, to report upon the sewerage of the District of Colum-

bia. This board advised a plan, which has since been carried out.

In 1892 I was one of the consulting engineers of the First Rapid Transit Commission of Boston. From September, 1903, for about five or six years, I was consulting engineer to the Charles River Basin Commission of Boston, which built a dam with a lock for navigation across a tidal estuary. This involved sanitary questions as to the pollution of the water, as the dam created a tidal basin into a fresh water basin.

From August, 1905, to date, I have been one of the consulting engineers of the Board of Water Supply of the City of New York. This is a work estimated to cost $162,000,000. I have not been actively engaged upon this work for the last two years or three years.

From August, 1905, to January, 1906, I was a member of the International Board of Consulting Engineers for the Panama Canal, to consider and report upon the plans for a canal across the Isthmus of Panama; and was one of the minority of five, whose plans were finally adopted.

From September, 1905, to June, 1906, I was a member of a Board of Advisory Engineers to the Sewage Commission of the City of Baltimore, to investigate and report upon a system of sewage disposal for that city.

In November and December, 1906, I was a member of a Board of Consulting Engineers to examine and report upon a proposed project for supplying water to the City of Los Angeles, California, from the Owens Valley. This project includes an aqueduct upwards of 200 miles in length.

In March and April, 1907, and again in January and February, 1909, I was a member of a Board of Consulting Engineers to visit the Isthmus of Panama and report upon certain questions for the Government.

From October, 1911, to January, 1912, I was engaged a part of the time on a study of the sewerage problem at Pittsburgh, Pa. Other engagements have included the valuation of the water supply of San Francisco; valuation of the water supply of Denver; valuation of the water supply of Oakland, California, which gave me an opportunity to become acquainted with the conditions in the arid sections of the country, including questions of rainfall and evaporation.

I have been connected within a year or two, with a hydro-electric project in Mexico, which also led to a study of questions of rainfall, run-off and evaporation. I have been connected with other hydro-electric projects in West Virginia,

in Pennsylvania not so very far south of Lake Erie; also with the construction of two large dams in Pennsylvania at Johnstown. And in the winter of 1913, I made a study of run-off and rainfall in Wisconsin.

I am still consulting engineer to the Metropolitan Water and Sewerage Board.

As to positions with engineering societies, I was president of the Boston Society of Civil Engineers in 1891, and of the American Society of Civil Engineers in 1906; and am an honorary member of the New England Water Works Association.

In June, 1905, I received the honorary degree of Master of Arts from Harvard University; and of Doctor of Science from the University of Pennsylvania in October, 1906.

Q. You commenced to practice your profession in 1874, was it?

A. In 1869.

Q. Have you been engaged continuously since that time in the practice of civil engineering?

A. I have.

Q. Has your practice brought you in contact with the questions of the measurements of discharges of rivers, and the use of instruments to measure such discharges?

A. It has, in the measurement of small rivers and of aqueducts, not of large rivers.

Q. Has your practice brought you in contact with question involving the effect upon lake levels of the enlargement of discharge or change of channels of an outlet?

A. My hydraulic studies have given me information in that matter, and I have this year made studies of the changes of lake levels.

Mr. Wilkerson: That is in connection with this case?

A. Yes.

Mr. Adcock: Q Have you made any study of the hydraulics, hydrography and hydrology of the Great Lakes, in connection with this case, or at any other time?

A. I have.

Q. Mr. Stearns, have you in your practice had any experience in the use of rainfall data as furnished by the United States Weather Bureau?

A. I have.

Q. Will you state what your experience has been?

A. The data has been satisfactory, when there have been a sufficient number of stations, so that one could take an average. I have found, at times, that a single station was

in error, referring particularly to the Boston station, for a number of years.

Q. Is there any data relating to the amount of rainfall derived from any other sources than the Weather Bureau?

A. Yes, it is customary in the case of extensive water works, and generally in the case of the smaller water works in the East, to have rain gages maintained by the Water Departments as a basis and they use those rain gages, which they are familiar with, rather than the Weather Bureau records.

Q. Is that because of the location of those gages with reference to a particular area, that which they wish to get the record of?

A. Yes, generally. For instance, on the Metropolitan Water Works of Boston, there are four gages located on the Wachusett drainage area, and four others located upon the Sudbury drainage area; the idea being in placing the gages to get a fair average of the amount of rainfall upon the drainage area, so that it can be compared with the measurements of the flow of the streams, and thereby deduce the relation of the flow of the streams to the rainfall.

Q. Have you made any investigation with reference to the evaporation, or the amount of evaporation at various temperatures; or are you familiar with investigations that have been made?

A. I am.

Q. And familiar with the results that have been obtained?

A. Yes.

Q. Will you explain the investigations that have been made, and your familiarity with such investigations, and the results accomplished?

A. The most elaborate measurements and tests for evaporation in the United States, and perhaps anywhere, have been made by Mr. Desmond Fitzgerald, who was for years in charge of portions of the Boston Water Works, and afterwards became a member of the staff of the Metropolitan Water Board, of which I was chief engineer. I was also on the Boston Water Works for a part of the time that Mr. Fitzgerald was engaged upon this work.

He made a very elaborate study of evaporation experiments, which are given in detail in a paper published in the Transactions of the American Society of Civil Engineers. I have examined the apparatus which he used, and knew of the results which he was obtaining from time to time; and have made a study of the results as published in that paper.

He not only used the experiments which he made himself, but other measurements that were made in some preceding years under the direction of the city engineer of Boston, and directly by Mr. Dexter Brackett. These experiments were made at what is known as the Beacon Hill Reservoir of the Boston Water Works. It was a reservoir supported upon arches, that had been thrown out of use so that no water was drawn from it or run into it; the only supply that it received being from the rainfall. And in that case, as in all other evaporation experiments, the rainfall is allowed for in such a way as to get the effect of evaporation.

Q. Was there any measurement of the rainfall?

A. Yes, the rainfall is measured in rain gages nearby the evaporating pans; but it also is deduced, to some extent, from the records of the rise of the water in the evaporating pans or tanks, as well.

The most accurate experiments made by Mr. Fitzgerald were with a tank made of copper, so that it would not leak, 10 feet in diameter and 10 feet high, which was suspended in the middle of Chestnut Hill Reservoir, from a very large raft; the raft being made large so that the waves could not possibly spatter in to the water in the tank, and therefore affect the accuracy of the observations. He had a recording gage that multiplied the effect of evaporation. It recorded it on a larger scale than the actual evaporation upon a diagram which was revolved by clock work, so that he could trace the evaporations from day to day; and also, of course, he took accurate measurements, with gages to determine precisely the amount of evaporation.

To go a little further, he collected his information from this tank and from the work done at the Beacon Hill Reservoir, and determined the evaporation for ten years. This has shown one feature, namely, that evaporation from water surfaces does not vary very much from year to year, even if the rainfall varies, but is fairly constant; so that in applying the results obtained by him to other places, one can do it with a fair assurance that there will not be any very wide change in the evaporation from year to year at a given place. The range in ten years was from 34.05 inches to 43.63 inches.

The comparisons between rainfall and evaporation for these ten years, in detail, are as follows:

Years	Rainfall.	Evaporation.
1876	49.56	39.06
1877	44.02	35.97
1878	57.93	37.76
1879	41.42	40.07
1880	38.18	40.47
1885	43.55	43.63
1886	46.06	40.80
1887	42.70	41.51
1888	57.46	38.60
1889	49.95	34.05
Average	47.08	39.20

I have had occasion to look into the question of evaporation in other places; that is, evaporation from water surface, in other places, especially with reference to determining the probable evaporation from a reservoir in the northern part of Mexico; and recently with reference to determining the evaporation from Lake Winnebago in Wisconsin. In connection with that, I obtained certain experiments upon evaporation, or measurements of evaporation, made by the United States Engineer Officers.

Q. Were you in touch with the experiments made at the place you have just mentioned, from time to time; that is, in Boston?

A. I was.

Q. Do you know anything about the accuracy or precision that was used in the making of those experiments?

A. I do. I saw the apparatus. I knew the man who conducted the experiments; and I know they were made with the greatest care.

Q. Among engineers, how are those experiments considered, with reference to accuracy?

A. I think they are considered as the best experiments for that section of the country, and as far as the care with which they were taken and the accuracy, as good as any—better than any in the United States.

Q. Will you describe a little more in detail how the experiments were made, the character of the instruments, etc., the time of reading and the time of taking?

A. I don't recall the time of taking the observations, as they were not under my direction. I merely visited the place on a few occasions, to see the apparatus and to have it explained to me. And I remember, as I have already described, this very delicate apparatus that was made by

an instrument maker, by which they could obtain a graphical record on an automatic diagram of the evaporation. But that was not the method by which they obtained the monthly and yearly evaporation. That work was done with the use of delicate gages that would register the height of the water to a thousandth of a foot, or even more closely.

I remember seeing one of these gages set upon certain metal points, a measurement being taken down to the surface of the water with that degree of accuracy. And those I know were done from day to day continuously throughout the season, so as to record all of the evaporation.

And as already stated, due allowance was made for the effect of rainfall, not only by the rise which occurred in the tank from which the evaporation was being measured, but also by rain gages located, I think, on the roof that held the tank. The object of the tank being made of copper, with only sufficient wood to support it thoroughly, was to have it maintain the temperature of the reservoir water so that it would represent that temperature, as temperature is a very important item in the amount of evaporation.

Q. Will you explain how temperature or other conditions affect the amount of evaporation?

A. The temperature practically is a very important item, the most important item in producing evaporation. We know water evaporates very rapidly when it is heated. The other governing features, or the principal governing features, in addition to the temperature, is the relative humidity of the air; that is the amount of moisture contained in the air. When air is saturated with all of the moisture it will hold, it reaches what is known as the dew point; that is the condition under which dew is deposited on the ground. And then there is no evaporation, unless the water is warmer than the air. At other times, the air contains a percentage of the amount of water required to saturate it, and that is known as the relative humidity. That is an important factor.

Wind is also a factor of importance, because the evaporation of water is governed by the relative humidity of the layer of air directly in contact with the water, perhaps only 1/8 of an inch thick, and that may have a greater humidity than the air higher up. If there is a good strong wind, it very quickly removes the layer of humid air next the water, and in that way facilitates evaporation. So that there are the elements: temperature of water, relative humidity and wind, as aiding in the removing of this damp layer.

Q. Does the temperature of the water depend somewhat on the depth of the reservoir?

A. To a very limited extent, in reservoirs of the size with which I am acquainted, for the reason that in the summer, the upper layers of the reservoir become warm and the lower layers remain cold, so that the amount of water to be warmed by the air is only a moderate depth from the surface.

Q. How large is this Chestnut Hill Reservoir which you mention?

A. I don't recall its exact size, but I should say less than a hundred acres—not a great deal less.

Q. And where was that located with reference to Boston?

A. It is five miles west of the center of Boston.

Q. How far from the coast?

A. About eight or ten miles from the general line of the coast; less than five miles from the inner parts of the harbor.

Q. Have you made any study or investigations, or have you been familiar with investigations made, and results reached, with reference to the run-off of streams?

A. I have.

Q. Just state what investigations you are familiar with, and what has been under your supervision or observation?

A. During a large part of my professional career, I have have had to consider closely, or have considered closely the run-off of streams in comparison with the rainfall.

I first began to measure the flow of a stream with reference to determining the ratio in 1874. In 1878 to 1880, I had occasion to compile such information. From 1886 to 1895, when I was chief engineer of the State Board of Health, I was continually using the information as to the relation between the rainfall and the run-off, as represented by the flow streams, and every year, in the reports of the State Board of Health, had occasion to incorporate such tables.

Also in making investigations for the Metropolitan Water Supply, as well, I determined the quantity which could be depended upon from a new source, on the basis of the relation of the run-off to the rainfall. Since I was chief engineer of the Metropolitan Water Works, up to about 1906 or 1907, I inaugurated the gaging of the streams represented by the new supply for use of the Metropolitan district, and had rain gages installed, and have kept those records.

I have also had occasion to use this method of determining the quantity of water which could be expected in storage

reservoirs, in other places, in connection with my consulting work.

Q. From these experiments, do you find any relation between the run-off and rainfall?

A. There is a fairly definite relation, when one takes an average of a series of years. It is much more definite than one might expect. As an instance of this, I will call attention to the amount of water in a series of years, which has run off from different drainage areas along the Atlantic coast, giving the percentage of the rainfall.

The Wachusett drainage area has an area of 118 square miles of land, that is partly wooded and partly cultivated land; and the run-off in 16 years has averaged 49.8 per cent. of the rainfall.

From the Sudbury drainage area, an area of 75 square miles, the run-off in 38 years has averaged 47 per cent. of the rainfall.

Upon the Croton drainage area, of nearly 400 square miles (this is one of the sources of supply for New York), the run-off in thirty-two years has averaged 47.10 per cent. of the rainfall.

There were three streams near Philadelphia that were gaged with reference to a probable water supply for that city, for 14 years. I do not recall the sizes of the drainage areas, but they were of several hundred square miles; that is, the drainage areas sufficient to supply the city of Philadelphia. And from one, the Perkiomen, the run-off was 49.2 of the rainfall; from another, the Neshaminy, 48.5 per cent. of the rainfall; and from another, the Tohickon, 57.6 per cent. of the rainfall.

Here are six different streams, with different conditions, and yet the variation has not been very much, and in many cases the percentages agree closely.

Q. How was the amount of run-off there compared with the rainfall determined, in those instances that you have mentioned?

A. As a general statement, it is made by measuring the water in various ways; and where the water is discharged from an aqueduct, it generally is measured in the aqueduct for that portion. Some portion flows over the dams, and that is measured by some formula for the flow over weirs.

Different methods are adopted in different cases, but with an idea of obtaining correct results, and such results are obtained where special appliances are used to get good results.

Especial care has been taken upon the Wachusett and

Sudbury watersheds, and I believe the Croton results are such as are trustworthy.

Q. Can you describe the methods used, for instance, for the Croton drainage, or the Wachusett, or both?

A. I can for the Wachusett drainage area. At first the stream was gaged, when there was no dam, no reservoir upon it; that is none built by the Metropolitan Water Board. At that time there was a recording gage at the side of a stream to show the height of the water, and very frequent current meter measurements were made, both winter and summer, so that by the use of the current meter measurements, in connection with the height of the stream, the quantity was deduced accurately.

Q. Were there any measurements of the rainfall taken at the same time?

A. Yes, continuously. The Metropolitan Water Board built a dam upon this stream, and an aqueduct to lead the water towards Boston. After the completion of the aqueduct, that was calibrated by means of current meter measurements, so that the water running through the aqueduct could be determined on the basis of a recording gage at the head of the aqueduct; but this was checked frequently by current meter measurements, because even in a masonry aqueduct, a little coating of fibrous material gathers on the side, a coating of slimy water which does affect the quantity flowing; and therefore, current meter measurements were taken frequently to check the change of the flowing capacity of the aqueduct.

I should say, in addition to this method, that a weir was placed at the lower end of this aqueduct, with a self-recording gage; and that was used also as a check upon the flow of water through the aqueduct.

More recently, a hydro-electric equipment has been placed at the base of the dam in the gate house so that the water before going through the aqueduct passes through turbines, and as the operation of the turbines would cause irregular discharges of water, so that the record could not well be kept by means of gage heights, and it also became necessary to remove the weir at the lower end of the aqueduct to give capacity, Venturi meters were installed, and the quantity is now gaged by means of Venturi meters, checked by current meter measurements in the aqueduct.

Q. Just describe the Venturi meter?

A. The Venturi meter is an appliance that is now used quite extensively. It is placed on the line of a pipe and

consists, in its ordinary form, of two cones; one which reduces the diameter of the pipe, we will say, to one-half or two-thirds of its size; and by means of gages connected with the pipe on the up-stream side of this tapering portion, and another pipe at the contracted section, which is known as the throat, it is possible, taking advantage of certain hydraulic laws, to record the quantity of water passing the meter.

The scientific demonstration is somewhat involved, and I think will not add any information.

The second cone is a long tapering cone that is enlarging as the water passes through it; and it helps to prevent the narrow throat from being a serious obstruction in the pipe to the flow of water.

The Venturi meters at the Wachusett dam are of a somewhat different pattern, created for that special case, but working upon the same principle and giving the same results.

In addition to the measurement of the water which goes through the aqueduct, it is necessary to measure the water which flows over the crest of the dam; but that represents a very small proportion of the water in this particular case, as the water has run over only a few days in the many years that it has been in existence.

Another factor is the quantity of water stored in the reservoir. If at the beginning of one year the water is low, and at the end of the year it is high, an account is taken of the quantity of water stored between the high and low water levels of that year, in determining the quantity for the year. That is, every precaution is taken to get an accurate measurement.

Q. Where are the records of these experiments kept, Mr. Stearns?

A. The results of the measurements are kept by the local superintendents at the different places, and sent in to the office of the Metropolitan Water and Sewerage Board each month; and that is true also of the rainfall records.

Q. What is the Metropolitan Water and Sewerage Board; how is it organized, and what are its functions, just in a general way?

A. It was created by an act of the legislature, on account of the peculiar condition of Boston and the towns in its vicinity. Within ten miles of the center of Boston, there are 28 cities and towns; not one municipality, as there would be in some other places within the same distance, and the necissity of water supply and sewerage required that there be

joint action, somewhat like the action of the Sanitary District of Chicago.

In this case, the legislature appointed a board of three men, giving them very large powers to carry out these plans of water supply and sewerage; and to have control of the operation of the water supply and sewerage works.

Q. While these experiments in run-off of the Wachusett drainage area were being made, were you associated in any way with those experiments?

A I was chief engineer of the work, and the returns were made to me, until I resigned from the board. I still have an office and see those records as they come in from time to time.

Q. Is there any difference in the evaporation on water surface as compared with land surfaces?

A. Yes.

Q. Will you explain just what the different processes are of evaporation under the two different conditions?

A. Except in the winter, when the lakes are frozen over, there is a very marked difference between the evaporation from land and water surfaces. The water surfaces are always available for evaporation, while the land may be dry at times. Hence, there is much less evaporation from the land than from the water. The records of run-off that are obtained are the measurements of the evaporation from land surfaces.

I have stated that in the case of the Wachusett drainage area 49.8 per cent., practically 50 per cent. of the rainfall has run off in the last 16 years. The other portion has practically all evaporated. A little of it has gone into plants, but very little stays in the plants. It is evaporated from their leaves, and otherwise.

Q. Have you had occasion in your practice to use the results of these experiments as to run-off and evaporation rainfall, etc.?

A. I have.

Q. In your practice, have you had occasion to consider the reliability of the experiments of the data of run-off, rainfall and evaporation?

A. I have to a very large extent in my work, in connection with this State Board of Health; and in investigating and determining upon various water supplies. That is the method that has been used to determine the quantity of water in nearly all cases.

And further than that, I have been for two years the chair-

main of a committee of the New England Water Works Association upon the yield of drainage areas. And in that capacity I have received from two places in Connecticut, one in Rhode Island, four or five in Massachusetts, one in Vermont, and some others that I don't recall as to their location, returns of the run-off from drainage areas in connection with the rainfall, and have had occasion to compare the results obtained in different places. And as a result I have been able to determine the relations between run-off and rainfall, and to ascertain how far, by deduction, the practical application of that method can be trusted.

Q. Have you made any study of the rainfall records of the United States Weather Bureau, with reference to Erie, Ontario, St. Clair, and Michigan-Huron?

A. I have not of the Weather Bureau records directly, but I have examined the rainfall records given in the report of the chief of engineers for 1903, which are said to be deduced from the United States Weather Bureau records; or deduced at least in part.

Q. How frequently were gages placed in those drainage areas, if you remember?

A. The only information I have is shown upon the map contained in the report of the chief of engineers for 1903, Appendix FFF following page 2856. This map shows the location of stations from which the United States Weather Bureau and the Canadian Meterological Service obtained their records.

Q. How are they indicated on that map?

A. The report at page 2859 states that the Weather Bureau stations are indicated by special marks. The other stations are volunteer stations. They are all shown by circles; some being circles filled in with black, and the others open circles. The black dots represent the regular stations, and the circular the volunteer stations.

Q. What period of years do the observations as to rainfall in these drainage areas of the lakes cover?

A. Sixteen years, from 1882 to 1898, are shown in this report. There is a supplementary table, Williams' Exhibit 31, which continues the records to the end of the year 1906.

Mr. Adcock: I understand this whole report of the chief of engineers, the appendix, is in evidence, Appendix FFF for the year 1903; identified and it being agreed that either party may use any portion they desire.

Q. From examination of the Appendix FFF, report of the chief of engineers for the year 1903, the map which you

have examined, and Williams' Exhibit 31, have you reached any conclusion with reference to the reliability or unreliability of the rainfall data shown?

A. It is apparently good data, much better probably in later years than in 1882 and 1883, because of the increased number of Weather Bureau stations.

Q. That is, as a matter of fact, the best available and most accurate data that there is in existence, isn't it, with reference to those particular areas?

A. So far as I know, it is. The statements in the report indicate that, with the data at hand, the mean rainfall over the drainage areas was determined as well as it could be. That is to say, proper deductions were made as to the rainfall upon the portions of the drainage areas where the rainfall stations were omitted.

Q. Now, have you considered the relation between the conditions, atmospheric and otherwise, at Erie, Ontario, and Huron-Michigan, with reference to the similar conditions at the places where observations of rainfall, evaporation, etc., have been made, that you have mentioned?

A. I have.

Q. What is the relation?

A. The temperature upon the drainage area of Lake Erie, as given in the report of the chief of engineers for 1903, Appendix FFF, page 289, for the years from 1882 to 1898, are in very close accord with the temperatures in eastern Massachusetts, the average for the year varying less than one degree, by a comparison which I made.

Q. That is one per cent., you mean?

A. No, one degree of temperature, and for the different months in the summer being very nearly the same in the two places.

In regard to the temperature elsewhere, as to its variation from Erie and St. Clair, I have been governed by the tables in this report of the Chief of Engineers of the temperature at Ontario and Huron.

I have also compared, from this same group of tables in the report of the Chief of Engineers, the relative humidity at the respective lakes, and the mean monthly velocity of the wind.

Q. How do those conditions, the wind and the humidity, compare with the conditions in Massachusetts and other places where the experiments were made?

A. I did not make the comparison between Massachusetts

and these lakes in regard to wind or humidity. I could do so, but I haven't any data here.

Q. Would that comparison be material in investigations as to storage and local supply of the lakes?

A It would not, as to the relative humidity of two lakes, nor of the relative wind on two lakes.

Q Would it be material in connection with the use of these experiments which you have mentioned?

A I don't think it would be material.

Q. I will draw your attention, Mr. Stearns to Appendix FFF, Report of Engineers 1903, page 2862, which shows the relation of wind, velocity, temperature and humidity between the St. Clair and Erie basins, and the Ontario basin. Will you state just what the comparison shows?

A. The mean velocity of the wind per hour from 1882 to 1898, for the St. Clair and Erie basins, is given as 10.4 miles; for the Ontario basin 10.6 miles. The temperature for the St. Clair and Erie basins, for the same period of 16 years, is for the St. Clair and Erie basins 48.01; for the Ontario basin 44.10 degrees Fahrenheit.

The humidity, that is, the percentage of saturation, for the same term of years, was, for the St. Clair and Erie basins, 73.6 per cent and for the Ontario basin 74.9 per cent.

It is to be noted that there is very little difference in the amount of wind; only a small difference in the amount of humidity, but that there is a difference of nearly four degrees Fahrenheit in the average temperature of the air.

Mr. Adcock: I now submit to the Commissioner certain series of Tables and ask that they be marked Stearns' Exhibit 1 Tables A to G; and they may be marked with the understanding that we will substitute blueprints, immediately.

Q. I show you these tables, Mr. Stearns, and ask you to state what they contain and how they were made up; what you had to do with their compilation?

A. I wished to check the discharge as measured at the St. Lawrence River, at the Niagara River and at the St. Clair River by determining the local supply and storage of each of the lakes; that is Lake Ontario and Lake St. Clair and Erie, taken collectively. If this could be done so as to obtain accurately the quantity of water which these lakes would derive from their local drainage areas, as well as the amount of water that they would gain or lose through the difference of rainfall and evaporation upon the lake surfaces, then there would be a check upon the discharges at the different rivers.

The difference in the discharges, as for instance at Niagara and at the St. Lawrence River, should be equal to the local supply and storage of Lake Ontario.

The Table marked "A" shows the local supply and storage of Lake Ontario for the years 1883 to 1906. The second column contains the rainfall. This was taken for the years 1883 to 1894 inclusive, from the report of the Chief of Engineers for 1903, Appendix FFF page 2879; and for the remainder of the years contained in the table, from the last page of Williams' Exhibit 31.

The third column contains the estimated evaporation from the surface of Lake Ontario.

I should say with reference to both the rainfall and the evaporation, that for each year the table covers the period from June to November inclusive, and not the whole year, as it was desired to omit any effect of ice.

The evaporation for this period has been determined for each year to be 21.8 inches; and I will give the basis upon which that quantity was arrived at.

The experiments of Mr. Fitzgerald upon evaporation, as above stated, gave an average evaporation annually of 39.2 inches. This was subdivided by the different months as follows:

January	1 inch
February	1 inch
March	1.8 inches
April	3.1 inches
May	4.5 inches
June	5.4 inches
July	5.9 inches
August	5.5 inches
September	4.2 inches
October	3.1 inches
November	2.2 inches
December	1.5 inches

This shows clearly the much larger evaporation in the summer months. In making the table referred to, I adopted as the yearly evaporation of Lake Ontario, the amount determined by the Piche evaporometer, as testified to by Mr. Williams, amounting to 30.6 inches annually. The evaporation at Lake Ontario would be less than in Massachusetts, on account of the colder weather; and I thought there might be reasons why it would be somewhat less than the evaporation in Mr. Fitzgerald's experiments, on other grounds, namely,

that the increased humidty, due to a large lake, might rather more than offset the greater effect of the wind upon such a lake, as compared with the effect of the wind upon a small reservoir.

It is not very material to the computations that the precise amount of evaporation should be determined; and I concluded to use the quantity given, as stated for the annual evaporation. This I divided, for the different months of the year, so as to conform to the variation from month to month in the Fitzgerald experiments. And as a result, I obtained 21.8 inches for the six months from June to November inclusive, which I have used in the table. I afterwards saw the results of the monthly evaporations by the evaporometer mentioned, and they coincided with this amount that I had otherwise determined within less than one inch.

The rainfall and evaporation being known, the effect of the lake surfaces is directly the difference between the two for a given period. That is to say, of the rain that falls on the surface of the lake, every particle of it becomes at once a part of the lake and of the water supply. The evaporation that takes place from the lake, that of course is immediate. If a half an inch is evaporated in a day, or a quarter of an inch, it is gone. And hence the difference between the two represents the gain or the loss from the lake surfaces.

The fourth column of the table represents this gain or loss due to evaporation, in inches, and as sometimes the rainfall is in excess, and at another time the evaporation is in excess, a plus or minus sign has been added before each quantity.

Q. What does the plus sign indicate?

A. The plus sign indicates that the evaporation is in excess of the rainfall, and the minus sign represents the rainfall in excess of the evaporation.

The fifth column is a mathematical deduction from the fourth column. It represents the number of cubic feet per second during the six months period, which corresponds to the number of inches of excess of evaporation or rainfall.

The plus and minus signs are applied in this column, in the same way as in the previous column.

The sixth column represents the run-off from the land into Lake Ontario, and this is determined by taking the area of the land as one factor, the amount of rainfall as another, and by the assumption that 21 per cent of the rainfall upon the land during those six months found its way into the lake, through streams, or by percolation. It is an assumption

based upon the experience with run-off in other places under similar conditions.

Q. What other places?

A. I have not the places at present here; that is as applied in this particular case. It is the result of my experience, where I have looked into the records of the run-off of other places, the Sudbury watershed, and others, and have applied them in other cases and it was my judgment that 21 per cent. of the rainfall during six months, under these conditions, would run off into Lake Ontario.

The only record that I have with me at present is one of 16 years' flow from the Sudbury River drainage area, during these months; and in that case, for the average of 16 years, the rainfall was 22.748, while the run-off was 4.855.

In this particular instance the run-off was 21.3 per cent. But I did not base it upon that alone, but rather upon my judgment that I had used elsewhere, and remembered. I could furnish, if necessary, a large amount of material bearing upon that point.

Q. Which will you do, if requested?

A. I will. The 7th column takes account of the storage in Lake Ontario. If during a six months' period, such as is included in this table, the lake either lowers or rises, it has its effect upon the relation between the discharge of water going into it, and the discharge going out. For instance, if one had a lake without any inflow or evaporation, and it were to lower during the six months, then more water would run out at the lower end than ran in at the upper end, by reason of the amount of water drawn from the lake; and this column is intended to provide a correction for the change in level.

That can be made perfectly accurate if the elevations of the lake at the beginning and end of that period are correct. And I think there can be no doubt they are sufficiently correct, so that no error is introduced by reason of column 7, in a six months' period.

Q. In making up column 7, then, you had to take into consideration the elevations of the lake, at the beginning and end of the period for each year, did you not?

A. Yes. And I should say that those were taken from the Report of the International Waterways Commission on the Regulation of Lake Erie in 1910, Table XXVII, beginning at page 141. The elevations taken were those on the first day of June and on the first day of December, as before, representing the period from June to November, inclusive.

Q. That is the beginning and end of a period?

A Yes. The summation of the quantities in column 5, 6 and 7, with due regard to the algebraic signs, gives the total local supply and storage, which is given in the final column, 8.

Q What do you mean by local supply and storage, as applied to the column referred to?

A. It means that it is the quantity of water which, if it were determined accurately, if subtracted from a discharge measurement below Lake Ontario, would give the correct discharge at Niagara. That is, it is the correct difference—it would be, if correct, the correct difference between the discharge at Niagara and at the St. Lawrence River.

Q. That column, then, represents the storage and local supply?

A. Yes, sir.

Q. Correctly, as you have deduced it from the other columns that you have referred to in the table, is that correct?

A. It does. And it is as correct as, in my judgment, it is practical to make it; and sufficiently correct to be used as a measure of the difference between the discharges of Niagara and at the St. Lawrence River.

Q. For the period of years which is indicated on that table?

A. Yes.

Q. Now, Mr. Stearns, directing your attention to the other tables in Stearns Exhibit 1, will you explain those, and also whatever reference Table 1 may have to the other tables.

A. Table B gives the local supply and storage for Lakes St. Clair and Erie, and is obtained in the same way as the last table, with two exceptions. The rainfall is taken from the same sources. The evaporation in this case for the six months is determined to be 24.4 inches, instead of the 21.8 inches determined for Lake Ontario. This is a proportional change made on account of larger evaporation at Lake Erie, as determined by the Piche evaporometer, as testified to by Mr. Williams, and is a proper proportion of a total evaporation of 35.6 inches annually, as determined by that instrument. It also is a reasonable difference from the evaporation found for Lake Ontario, because the average temperature of the air at Lake Erie and Lake St. Clair is 4 degrees warmer than the average temperature of the air at Ontario, as already stated.

Q. Have you taken into consideration the difference in the depths of Erie and Ontario, if there is any difference?

A. I have not.

Q. Did you or did you not consider that was material in determining the difference, the probable difference of evaporation of the two lakes?

A. It did not seem to me that it was material for the reason that the temperature of water, in cases where I have knowledge of such temperature, follows very closely the temperature of the air, for the portion of the year from April to August. After that date, it is generally higher than the temperature of the air.

I make this statement as the result of a great many studies of the temperatures of lakes, in which I have compiled the results and compared them with the temperature of air. I have not made any studies of so large a lake, and did not have available any material other than a diagram, which I found in the report of the Chief of Engineers for 1903, Appendix FFF, preceding page 2687. This diagram gives the temperature of the Detroit River at Fort Wayne, on several occasions in 1901 and 1902, in degrees Fahrenheit. The average temperature of the water for July was 67 degrees.

I have no records to show the mean temperature of the air for this particular month; but the average temperature of July for the years 1882 to 1898 was 71.1 degrees, as given in the report of the Chief of Engineers, Appendix FFF, 1903, page 2880, Table 16.

In August, the temperature of the water was 73 degrees, and the mean temperature of the air, from the table aforesaid, 68.6 degrees. In September, the temperature of the water 65 degrees; temperature of air 63.2 degrees; October, temperature of water, 54 degrees; temperature of air, 50.7 degrees.

These results indicate in a general way that the temperature of the Detroit River water is not very different from the temperature of the air; and I think that relation would hold fairly well in the different lakes.

Q. How about Lake Erie?

A. It would apply to Lake Erie as well as Lake Ontario.

In smaller lakes, the water in the lower part of the lake does not become warmed; and I think that is true of the Great Lakes; that they do not overturn from the effects of the wind to the bottom, during the summer season, and consequently the water in the bottom of the lakes is not a factor in the temperature of the surface water.

Q. Have you taken into consideration the comparative humidity and the wind of the two lakes?

A. I have not, for the reason that there is practically no difference.

Q. As you have explained heretofore, in the reference to the Appendix FFF, Report of Chief of Engineers for 1903?

A. I have.

Q. Now, will you continue with the explanation of the tables of Stearns Exhibit 1?

A. The 4th and 5th columns, giving the excess of evaporation, correspond with the similar columns in Table "A," as already explained.

The 6th column contains the run-off into St. Clair and Erie in cubic feet per second. And this differs from the 6th column in Table A only in this: That the run-off in this case has been determined to be 20 per cent. of the rainfall, and not 21 per cent.

Q. How did you determine that percentage of run-off compared with rainfall?

A. On the same basis as I determined the percentage of run-off of Lake Ontario, by taking into account that the rainfall is slightly less on Lakes Erie and St. Clair than on Lake Ontario; and that the temperature, and consequently the evaporation, are somewhat greater.

Q. In that connection, were you referring to the areas of the lakes, or the drainage areas of the lakes?

A. I was taking the drainage basins as a whole. The temperatures and rainfall are given for the basins as a whole, including the lakes, as I understand it.

Q. That included the area of the lake surface?

A. It has a minute correction, and yet the tendency would be for the percentage of the run-off to be somewhat less, as I believe, on Lake Erie than on Lake Ontario, for the reason stated.

Column 7 which gives the storage in Lakes St. Clair and Erie, is similar to the same column in Table A; but in computing it, there has been taken into account the elevations at the beginning and end of the period, of both Lake Erie and Lake St. Clair, as given in the report of the International Waterways Commission on the Regulation of Lake Erie, for 1910, Table XXVI, beginning on page 131 for Lake Erie, and Table XXV, beginning on page 117, for Lake St. Clair.

The 8th column gives the total local supply and storage for Huron, Erie and St. Clair, and corresponds to column 8 of Table "A."

Adjourned to Wednesday, March 26, 1913, 10 A. M.

Wednesday, March 26, 1913; 10 A. M.

Parties met pursuant to adjournment.

Present same as before.

FREDERIC P. STEARNS resumed the stand and testified as follows:

The Witness: In Table C, the discharge of the Niagara river is deduced from the discharge of the St. Lawrence river by subtracting from the latter the total local supply and storage of Lake Ontario, as given in Table "A."

The principle involved is this: That if the outflow from a lake has been accurately determined, the amount of water flowing into that lake can be determined if the amount of water yielded by the intermediate drainage area is known, and due allowance has been made for the rise or fall of the water of the lake.

Column 1 of this table gives the year; column 2 the discharge of the St. Lawrence river for the six months from June to November, inclusive, as given in the Report of the International Waterways Commission on the Regulation of Lake Erie for 1910, Table XXVII, beginning on page 141, in cubic feet per second.

Column 3 is the total local supply and storage of Lake Ontario, as given in Column 8 of Table A.

Column 4 is the deduced Niagara discharge in cubic feet per second, obtained by subtracting the quantities in Column 3 from the quantities in Column 2.

Q. Just describe what is in Column 3, being the storage and local supply, is that right?

A. Yes, being the local supply and storage of Lake Ontario.

Column 5 is the discharge of the Niagara river, as determined by the International Waterways Commission, and given in Table XXVII aforesaid. The difference in the deduced discharge of the Niagara river, as given in Column 4, and the computed discharge of the Niagara river as given in Column 5, shows the error in the computed discharge, by this method of checking the results. The error in the computed discharge as given in Column 5 averages 16,390 cubic feet per second, when the years 1895 and 1896 are omitted; these two years being omitted because the results appeared

to be especially inconsistent, on account of the low stage of the lakes at that time.

The comparison in this table has been made with the Niagara discharge, as determined by the International Waterways Commission, as a matter of convenience in computation, afterward a comparison was made between the discharge as given in the tables of the International Waterways Commission, and the discharge as given in Williams Exhibit No. 34, Tables XI and XII.

Q. That being the complainant's equation?

A. These tables representing the discharge of the Niagara river by the complainant's equations for the Bridge Section, and for the Open Section, from 1900 to 1906 inclusive.

Table D differs from Table C only in the basis used for the discharge of the St. Lawrence river. In Table D, the discharge of the St. Lawrence has been computed by defendant's equation as given in Table XLIII-A of Williams Exhibit 34.

By this change in the basis of computation, the average error for the 24 years from 1883 to 1906, inclusive, excluding however the years 1895 and 1896 for the reasons before given, and the years 1904-05-06 on account of the effect of the Gut Dam, is 16,070 cubic feet per second, in the place of 16,390 cubic feet per second; and this comparison shows that the discharge of the Niagara river based upon the measurements made at that place, is too low by these quantities.

Table E is similar to the last two tables described, except that it starts with the discharge at Niagara, as computed by the International Waterways Commission, and as given in column 5 of Table C and Table D, and from that discharge deduces the St. Clair discharge. The deduced quantities are obtained, in the way before described, by subtracting the local supply and storage of Lakes St. Clair and Erie, as given in column 8 of Table B, from the Niagara discharge, and obtaining a deduced St. Clair discharge.

Q. That is by the method you are pursuing here?

A. Following exactly the same method described in reference to the former tables.

This deduced discharge is given in column 4; and in column 5 is the discharge of the St. Clair river, by the complainant's equation.

Column 6 shows the differences between the deduced discharge of the St. Clair river, as given in column 4, and the discharge by complainant's equation as given in column 5. It shows in general that the differences were much greater in

the earlier periods, say from 1883 to 1889, than in the later periods, but I have made no general deductions from this table by averaging, because the complainant's equation does not take into account the elevation of Lake St. Clair, which is an important factor; and that is taken into account by the defendant's equation which is used in the preparation of Table F, and should therefore make the results in Table F more accurate than the corresponding results in Table E.

Table F is similar to Table E, being changed only by the introduction in Column 5 of the St. Clair discharge by the defendant's equation, in place of the St. Clair discharge by the complainant's equation. The differences between the deduced discharge and the computed discharge of the St. Clair river are given in Column 6. It is not feasible in this case, as in the case of a comparison with the St. Lawrence discharge, to use the whole period to ascertain the error in the relation of the Niagara and St. Clair discharges, because there have been deepenings of the St. Clair and Detroit rivers, and improvements of channels, which makes any equation deduced from measurements in the years 1899 on inapplicable to the earlier years.

I have therefore taken for the comparison to ascertain the error in the Niagara discharge or the St. Clair discharge, the years from 1897 to 1906. The difference for that period is 20,700 cubic feet per second. If the St. Clair discharge is assumed to be correct, then the Niagara discharge as computed by the International Waterways Commission for these years, is 20,700 cubic feet per second too low, confirming quite closely the determination made by a comparison of the St. Lawrence and Niagara.

Q. In other words, on that table, you use as a basis the measurements made by the International Waterways Commission, is that correct?

A. At Niagara.

Q. On the Table F that you have just mentioned?

A. Table F.

Q. Which compares with the outflow shown by the defendant's equations?

A. Yes; and reached the conclusion that the Niagara discharges are too low rather than that the St. Clair discharges are too high, because that view is confirmed by the fact that the Niagara discharges are also shown to be too low by the comparison with the St. Lawrence measurements, and to nearly the same extent; that is, the difference being from an

average of 16,230 cubic feet, when the computation is based on the St. Lawrence discharges, and 20,700 feet, when the computation is based on the St. Clair discharges, the average of the two results indicating that the Niagara discharges are 18,465 cubic feet per second too low, or, say in round numbers, 18,000 cubic feet per second.

The average difference between the deduced St. Clair discharge, and the discharge obtained by the defendant's equation for the years 1883 to 1888 inclusive, was 55,200 cubic feet per second. This is a quantity that was in excess of any probable error during those years, in the estimated discharge at Niagara, and consequently must be ascribed to the fact that the channels of the St. Clair and Detroit rivers were smaller in those early years, and that the discharge as computed by the defendant's equation is not correct, for the reason that it was deduced on large channels, and cannot be applied to smaller ones.

I will not refer to the extent of enlargement of channel indicated in this case, because the column is based upon the incorrect Niagara discharges; and the extent to which they were incorrect in those years is not represented by the average error in the discharges for a long period of years; it was more in those years when the water was higher than in other years, for the reason that there is another table G, which makes a comparison that eliminates the effect of the errors of the Niagara discharge.

This is a table in which the discharge of the St. Clair river is deduced directly from the discharge of the St. Lawrence river, in the same manner as has been described for the other cases. In this table, the years have been grouped into three periods, the first covering the years 1883 to 1888; the second, the years from 1889 to 1891; and the third, the years from 1892 to 1903 inclusive. The remaining three years, which have appeared in the other tables were omitted, so as to eliminate the effect of the Gut Dam.

Column 2 of this table contains the average discharge of the St. Lawrence river from the month of June to November, inclusive, as determined by the defendant's equation already referred to. From the discharge at the St. Lawrence, as given in column 2, there has been deducted both the local supply and storage of Lake Ontario, as given in the 8th column of Table 1, and the local supply and storage of Lakes Erie and St. Clair, as given in column 8 of Table B; producing in the

5th column the deduced St. Clair discharge for the three periods.

In the sixth column of the table is given the discharge of the St. Clair river for the three periods, as obtained by the defendant's equation already referred to.

The 7th column gives the difference between the deduced discharge, and the discharge as computed by the equation. For the first period, from 1883 to 1888, this difference is 27,900 cubic feet per second. For the second period, 1889 to 1891, the difference is 14,400 cubic feet per second; and for the third period, from 1892 to 1903, 10,100 cubic feet per second.

The quantity for the last period represents about 5 per cent. of the total discharge; and is the result of what may be called unavoidable inaccuracies in the determination of the discharge of the St. Clair and the St. Lawrence rivers, and of the local supply to Lakes Ontario, Erie and St. Clair. Such hydraulic measurements and determinations do not permit of mathematical accuracy, and a variation of only 5 per cent. in results obtained by the methods followed, I regard as a good check upon the general methods.

Q. Will you explain what you mean by the use of the expression "unavoidable inaccuracies of measurements", to what measurements and methods you refer?

A. I refer to all of the determinations included in the computation; the measurements of the flow of rivers by current meters in connection with lake stages, the determination of the run-off into the lakes, the amount of evaporation and rainfall, and the effects of storage, although the effects of storage are subject to very small error. But it is not to be expected that in a comparison of this kind the results would come nearer than 5 per cent. They are sufficient, however, to detect the greater errors with certainty, such as the inaccuracies of the measurements of the Niagara river, which is a very much larger quantity.

Q. Can you, by this method, detect the enlargement, the material enlargement of a channel, where it was enlarged so that it would flow 24 or 25,000 cubic feet per second more, in channels the size of the St. Clair river?

A. Yes. The uncertainty would relate only to the small percentage which I have referred to. The difference between the deduced and computed discharge in the first period, from 1883 to 1888, was 27,900 cubic feet per second. If it is assumed that the St. Lawrence discharge is absolutely correct, and that the local supplies and storage of the three

lakes are also exactly correct, then this would show that the channels had been enlarged so that they will carry 27,900 cubic feet per second more than they would have in the years 1883 to 1888 inclusive.

If, however, we make the assumption that the difference of 10,100 cubic feet per second between the deduced and computed discharge in the last period, from 1892 to 1903 inclusive, means that the inaccuracy is in the measurement of the St. Lawrence river, and in the determination of the local supplies and storage of Lakes Ontario, Erie and St. Clair, which is also an assumption that the discharge of the St. Clair river for this period, as computed by the defendant's equation is correct, then there should be deducted from the 27,900, 10,100, leaving 17,800 cubic feet per second as the effect of the deepening of the channel.

As we cannot tell which of these two results is correct, I should say that the deepening of the channels may be represented by any quantity between 17,800 and 27,900 cubic feet per second. I do not think the determination could be made to say just what the amount is between those limits.

The difference between the deduced and computed discharge of the St. Clair river, during the second period, was 14,400 cubic feet per second, which is intermediate between the results of the first and the last periods, and indicates that there has been some deepening of the channel since 1889 to 1891.

Q. Now, referring to the deductions on Table G, the last line, the period from 1892 to 1903 inclusive, if there could be eliminated all the possible inaccuracies of the measurements of the discharge of the St. Lawrence river, and all the possible inaccuracies in the method which you have followed in determining local supply and storage, what would the result in the last column be, column 7?

A. It would show that the discharge of the St. Clair river, as computed and given in column 6, was 10,100 cubic feet per second too large.

Q. Now, Mr. Stearns, how closely is it necessary, in dealing with such large quantities of water as we have to deal with here, to determine the percentage of run-off and the amount of evaporation, in order to obtain reasonably accurate results? Will you just explain how an error in that regard would affect the ultimate result?

A. In determining the amount of water which runs off into a lake, as for instance Lake Ontario, one is dealing with quantities which are small in comparison with the quantity of

water running in the main rivers, the Niagara and the St. Lawrence. For instance, the run-off into Lake Ontario, as determined and given in column 6 Table A, averages approximately 16,000 cubic feet per second, while the discharge of the St. Lawrence and Niagara rivers is, by inspection of Table C, about 230,000 cubic feet per second. That is, the run-off into the lake is about 7 per cent. of the whole quantity.

Q. That is, from the drainage area, the local supply?

A. From the drainage area, the local supply. Consequently an error of 14 per cent. in determining the run-off from the drainage area into the lake would represent only one per cent. of the whole quantity, so that an error in the determination is greatly minimized when it becomes a part of the flow of the whole river. In a similar way, an error in the computed amount of evaporation of 4 inches, which in the case of Lake Ontario amounts to about 13 per cent., would affect the results as applied to the discharge of the main rivers only to the extent of about 1½ per cent.

As already stated, the storage factor, which is a large part, in the case of Ontario, of the deductions made to obtain the amount of inflow, can be determined accurately for periods of six months, or longer.

Q. Is the run-off from the drainage area per cubic feet per second one of the items of local supply?

A. It is.

Q. What are the other items of local supply, if any?

A. There is one other item, which is the yield of the lake surfaces, and it is represented by the difference in the rainfall upon the surface of the lakes, the evaporation from the surface of the lakes. These two quite nearly balance one another, so it is a small item.

Q. How do you determine the amount of water stored or drawn from a lake, in cubic feet per second, for a certain period?

A. The height of the lake at the beginning and end of the period is ascertained and the difference between the two heights is taken. If this is in feet, it is multiplied by the area of the lake in square feet, and in this way the number of cubic feet of water added to or drawn from storage in the lake is ascertained. This result is divided by the number of seconds in the period, and in this way the number of cubic feet per second is ascertained.

Q. Now, having the outflow of a lake for a certain period, the cubic feet per second, the run-off from the drainage area

of the lake per cubic feet per second, and the difference between the precipitation and evaporation of lake surfaces, in cubic feet per second, and the amount of water stored or drawn from the lake in cubic feet per second for a certain period, how do you determine then from those items, if at all, the inflow from another drainage area?

A. That can be explained the most clearly by taking each one of these elements separately.

The amount of water running into a lake from its drainage area evidently adds to the quantity flowing out its outlet. Hence to get the quantity coming in at the inlet, it is necessary to subtract the water which has been contributed to the lake from its drainage area through the streams that enter the latter. That is, they furnish a part of the water at the outlet, and hence the quantity of water at the inlet is smaller by the amount so supplied to the lake.

In regard to the precipitation upon, and evaporation from the surface of the lake, this may be either an additional quantity supplied to the lake, when the rainfall is greater, or it may cause a loss of the part of the water flowing into the lake, if the evaporation is greater than the rainfall. In that case it furnishes an outlet for a part of the water. Hence when the rainfall is greater than the evaporation, the resulting quantity should be subtracted from the outflow to obtain the inflow, and when the evaporation is in excess of the rainfall, then the reverse is true.

The third item, which is the number of cubic feet per second due to the amount of water stored in, or drawn from the lake, from the beginning to the end of the period, is, first, in case the lake has lowered during the period, the quantity represented by the lowering should be subtracted because a part of the water measured at the outlet is derived from the lowering of the water in the lake. While if the lake rises during the period, the quantity of water represented by the rise should be added to the outflow from the lake, in order to obtain the inflow.

Q. Have you made any other computations, Mr. Stearns, or comparisons between the discharge measurements, records of discharge measurements of the St. Clair, Niagara and St. Lawrence rivers?

A. I have.

Q. Will you state the facts which you have used in making your computations and the basis of your computations and

the conclusions that you may have reached from such calculations?

A. These computations were made before the detailed computations already testified to. They were based upon information furnished by Mr. G. S. Williams, which has since been included in the testimony in this case.

Q. Is that testimony that you have heard?

A. I have heard it, yes. I first made a comparison between the discharge of the St. Clair and St. Lawrence Rivers for the years 1900 to 1904 inclusive. The mean discharge of the St. Lawrence river for this period, as determined by the complainant's equation, Table XLIII, Williams Exhibit 34, was 240,820 cubic feet per second. The mean discharge of the St. Clair river, by complainant's equation given in Williams Exhibit 34, Table XX, was 188,787, cubic feet per second; a difference of 52,033 cubic feet per second.

During the five years, Lake Ontario raised 1.45 feet, and Lakes Erie and St. Clair, an average of 0.445 feet, so that some water was stored in these lakes which, had it not been stored, would have increased the St. Lawrence discharge, and consequently the difference between this discharge at St. Clair and St. Lawrence. This amounts to an average, during the five years, of 826 cubic feet per second, due to the storage in Lakes St. Clair and Erie, and 1855 cubic feet per second, due to the storage in Lake Ontario, a total of 2,681 cubic feet.

Q. Now the storage that you refer to there is the amount that was drawn from or added to those lakes?

A. It is.

Q. According to the difference in elevations in the period?

A. It is.

Q. In this case it was added to?

A. During the same five years, the average annual rainfall on Lakes St. Clair and Erie amounted to 30.92 inches and on Lake Ontario, to 33.42 inches. The evaporation experiments with the Piche evaporometer, already referred to, indicate an annual evaporation in the vicinity of Lake Erie of 35.60 inches, and near Lake Ontario 30.65 inches.

Judging from evaporation experiments elsewhere—and I am referring to those made by Mr. Fitzgerald—it seems reasonable to accept these quantities of evaporation as applicable to the lakes, and on this basis there was, therefore, an average annual excess of evaporation over rainfall, on Lake St. Clair and Erie of 4.68 inches, and an excess of rainfall over evaporation from Lake Ontario, amounting to 2.77 inches.

The excess of evaporation from Lakes St. Clair and Erie is equivalent to 3,610 cubic feet per second, during the five-year period, and the excess of rainfall upon Lake Ontario is equivalent to 1,480 cubic feet per second for the same period, making the net excess of evaporation equivalent to 2,130 cubic feet per second.

This amount is to be added to the difference in discharge already stated, as well as the 2,681 cubic feet per second attributable to storage in the lakes, already stated, making a total addition of 4,811 cubic feet per second.

The corrected difference between the discharges at the St. Clair river and the St. Lawrence river is, therefore, 52,033 plus 4,811, making a total of 56,844. The average annual rainfall, during the five years, upon the drainage areas of the lakes, exclusive of the lakes themselves, was, upon the 5,691 square miles of drainage area of Lake St. Clair, 31.602 inches; upon the 24,605 square miles of drainage area of Lake Erie, 35.046 inches; upon the 25,737 square miles of drainage area of Lake Ontario, 36.254 inches.

If all of the rainfall upon these drainage areas had run off into the lakes, the discharge for the five years would have averaged as follows:

St. Clair drainage area	13,250	cubic feet per second
Erie drainage area	63,000	do
Ontario drainage area	68,800	do
make a total of	145,650	cubic feet per second.

The difference in the discharge of the St. Clair and St. Lawrence rivers, corrected as above stated, for storage, and the difference between rainfall and evaporation upon the lake surfaces, was 56,844 cubic feet per second. Hence the run-off from the drainage areas, by the comparison, is 56,844 divided by 145,650, equal to 39 per cent. of the amount of rain falling upon the drainage areas, a figure which accords well with other experience.

A similar comparison made between the discharge of the St. Clair and Niagara rivers, covering the same period, from 1900 to 1904, inclusive, gave these results. The mean discharge of the Niagara river by the complainant's two equations, as given in Williams Exhibit 34, Tables XI and XII, was 196,739 cubic feet per second. The mean discharge of the St. Clair river, by the complainant's equations, as before stated, was 188,787 cubic feet per second; the difference being 7,952. Three corrections are needed to this difference: first, a correction for storage in Lakes St. Clair and Erie, as before

stated, 826 cubic feet per second; a correction for the excess of evaporation over rainfall of Lakes St. Clair and Erie, as before stated, 3,610 cubic feet per second; third, a correction for the amount discharged through the Welland and Erie canals, as stated in the report of the Chief of Engineers of the United States Army for 1904, Appendix EEE, page 4116, 2,300 cubic feet per second. All of these, amounting to 6,736 cubic feet per second, should be added to the difference between the discharges of the Niagara and St. Clair rivers—giving a total of 14,688 cubic feet per second, which represents this difference corrected for storage, yield of the lake surfaces, representing the difference between rainfall and evaporation, and the diversion through the Welland and Erie canals.

The difference also represents the amount of water derived from the drainage areas of the lakes. If all of the rainfall upon the drainage areas of the lakes, St. Clair and Erie, had run off into the lakes, the quantity of water would have averaged, for the five years, 13,250 cubic feet per second, plus 63,600 cubic feet per second, as before stated, making 76,850 cubic feet per second. Hence, the run-off from the drainage areas, during these five years, is by the comparison 14,688 divided by 76,850, equal to 19 per cent. of the rain which fell upon the drainage areas, a figure so far below the results of other experience as to be unreasonable.

Q. When you refer to drainage areas, do you include there the lake surfaces as well?

A. No, these are the drainage areas, exclusive of the lakes.

A similar comparison was made of the discharge of the Niagara and the St. Lawrence rivers, for the same period as before, 1900 to 1904, inclusive. The mean discharge of the St. Lawrence river was, as before, 240,820 cubic feet per second.

Q. That is, by complainant's equation?

A. Yes. The mean discharge of the Niagara river by the complainant's two equations was, as before, 196,739 cubic feet per second, a difference of 44.081 cubic feet per second. Adding a correction for storage in Lake Ontario, as before, 1855 cubic feet per second, gives as the sum 45.936 cubic feet per second. Correcting for an excess of rainfall over evaporation at Lake Ontario, as before stated, there is a deduction of 1,480 cubic feet per second, and correcting for the amount of water discharged through the Welland and Erie canals, as before stated, a further deduction of 2.300 cubic feet per second, making a total deduction of 3,780 cubic feet per second, which,

subtracted from the 45,936 cubic feet per second leaves 42,156 cubic feet per second to represent the yield from the drainage area of Lake Ontario, exclusive of the area of the lake itself.

If all of the rainfall upon the drainage area of Lake Ontario had run off into the lake, the quantity of water would have averaged for the five years, 68,800 cubic feet per second. Hence the run-off from the drainage area, during these five years, is, by the comparison, 42,156 divided by 68,800, equal to 61 per cent. of the rain falling upon the drainage area; a percentage so large that it does not agree well with other experience, and is especially unreasonable when compared with the run-off of 19 per cent. from the drainage areas of Lakes St. Clair and Erie, during the same period.

It will be noted that the comparison between the St. Clair and St. Lawrence discharges gives reasonable results, while the two comparisons in which the Niagara discharge is involved, give unreasonable results; especially in view of the fact that the conditions at the two lakes are quite similar, and that they are not very far apart.

The discharge at Niagara will be computed from the discharge at the St. Clair and St. Lawrence stations, by making the corrections already described, and assuming that the yield from the drainage areas is 39 per cent. of the rainfall upon them, as deduced by the comparison between the discharges at St. Clair and St. Lawrence. Upon this basis, the discharge of Niagara, during the five-year period, amounts to 212,040 cubic feet per second, which is equal to 15,301 cubic feet per second or 7.8 per cent. more than the discharge as determined by the average of the complainant's two equations.

It will be noted that this result, obtained by using the full year for the five years mentioned is not far different from the result obtained by using the six months from June to November, when there certainly was no ice. I have noted that the discrepancy between the discharge of the St. Clair and Niagara rivers has been noted by others.

Q. What do you refer to, Mr. Stearns, when you say you had noted that this discrepancy has been noted by others?

A. In the Report of the Chief of Engineers for 1904, Appendix EEE, page 4125, this page being a part of the report of Thomas Russell, Assistant Engineer, this statement is made:

"The discharge of Detroit river for 11 years, 1893-1903, is on the average 193,854 cubic feet per second. The dis-

charge of Niagara river for the same time, is 197,328 cubic feet per second. The discharge of the Niagara river should be 30,100 cubic feet per second greater than the discharge of the Detroit river. It would require a very great, a totally inadmissible, evaporation from the lake to have the difference in discharges as small as the observations indicate."

The conclusions of Mr. Russell were based upon the records for the 11 years, 1893 to 1903, and therefore cover a different period from that used in the comparison before made, based upon the years 1900 to 1904.

Q. In determining the effect of a diversion from Lake Michigan-Huron, is it necessary to determine an increment for the St. Clair river?

A. Yes.

Q. Why is that necessary?

A. The increment, using the definition that has been given in this case, is the variation in the discharge of the river, due to a rise or fall of one foot in the lake; and it is necessary to know how much the quantity varies with the rise and fall of the lake of one foot, or any other unit, in order to determine the effect upon the lowering of a lake of the abstraction of water from the Chicago drainage canal, or any other diversion of water.

Q. Any diversion other than the ordinary outlet?

A. Other than the ordiary outlet.

Q. May an increment be determined for, say a river like the St. Clair river, the size of that river, by taking one discharge measurement when the lake is at a certain elevation, say 580, and another discharge measurement when the lake is at another elevation, say 581?

A. It could not be determined accurately in that way.

Q. What would be the difficulties in connection with the determination of an increment, with those two measurements?

A. The difficulty might rise with the current meter measurements of the river and the discharge, but are more likely to arise with the relation of the discharge to the stage of the lake.

As I am informed by the facts appearing in evidence in this case, and already testified to by the complainant's witness, Lakes Michigan and Huron and the other lakes do not remain quiescent, at a constant level, but they fluctuate in an irregular way, in the course of short periods and longer

periods; that is short periods, I don't know exactly how long, but of minutes or hours; and in longer periods, from day to day, from the effect of barometric changes and winds. The lake in general never keeps at a constant level, and to make accurate discharge measurements, to obtain the laws governing the flow of water in any channel, it is essential, in order to get the best results, that the flow should be uniform and continuous and not varying from time to time.

Q. Are there any greater difficulties attendant on making discharge measurements of a large river than there are in connection with making discharge measurements of a small stream?

A. Yes.

Q. You know the width of the St. Clair river at the different sections where discharge measurements were made, do you not?

A. I know approximately.

Q. Will you state what, if any, difficulties there are connected with making discharge measurements by the use of the current meter, and as those measurements may be referred to stage of lake?

A. The difficulties are greater in a large stream than in a small one, for the reason that in a small stream, such as I have had occasion to measure myself, the current meter can be placed upon a rigid handle or pole, put down into the water in an exact position, and held so that it will face the current; while in a deep river, especially where there is a swift current, the current meter must be attached to a cord. It has to depend upon a vane or tail to maintain its direction, and hence may not be at right angles to the line of the cross section where the measurement is being taken.

There is also greater difficulty in determining whether the current meter is at the depth indicated by the depth of the lines by which it is suspended, as one cannot see its position. It certainly is less definite in location than where it is on the end of a rigid pole, which will not bend.

I think there is one other feature that may have some bearing in this case, namely: That current meters for measuring the discharge of large rivers with swift currents are necessarily of heavier construction than some of the meters used for measuring the discharge of small channels.

The difficulty in connecting discharge measurements with the stage of the lake is, as already stated, the difficulty of maintaining a steady flow in the stream. It is bound to vary

with the frequent changes in the lake level, which introduces considerable uncertainty into the results; and they may not be nearly as accurate as they appear to be from a comparison of different measurements. This has been thoroughly indicated by the comparisons to which I have testified between the gagings at different points upon the same river; that is, at the St. Clair, Niagara and St. Lawrence stations, which prove to my mind conclusively the difficulties in the way of obtaining the discharge corresponding to different stages of a lake.

If you had the two measurements, two discharge measurements to which you have referred heretofore, say of the St. Clair river when the lake was say at stage 580, and the other measurement when the lake was at say stage 581, you could derive an increment from that, couldn't you, from those measurements?

A. Yes.

Q. Would that increment so derived be accepted by engineers as having any value?

A. It would have very little value.

Q. Well, then, is it because of probable errors in the measurements and as referred to lake stages, or for some other reason?

A. One would not in any case, I think, wish to depend upon two measurements, because there might be an error in any part of them that would lead to uncertainty. It requires a much larger number before one would feel that even the possible mistakes had been avoided.

Q. What is the advantage of a large number of measurements, if any?

A. The advantage is in several ways: First, it shows the accuracy with which a measurement may be repeated as compared with a gage near at hand. Then, different results would be obtained, even if there were no frequent oscillations of the lake; that is due to wind and other temporary causes, or rising and falling stages of the lake. And the frequent measurements, if made both on the rising and falling stages, would to a certain extent eliminate errors which would appear, if the measurements were confined wholly to one or the other of these conditions.

Q. So that the errors, in one measurement, may be offset by errors in another, taking the mean of all?

A. The errors due to certain causes may be offset, but there still may be left errors which are not offset. The mul-

tiplicity of observations will tend to offset certain classes of errors.

Q. Might there be errors in all the measurements, that is similar errors in all the measurements, which would materially interfere with determining the correct result or increment?

A. Yes.

Q. What would you suggest as probable errors?

A. The full effect of changes in lake stage are probably not felt in a measurement taken in a river. For instance, to take an extreme case, if one were making measurements 100 miles down a river from a lake, there would be many fluctuations tending to increase and decrease the discharge through the river. And the effect of these fluctuations would be felt only to a limited extent at a point so far down the stream.

Q. Would that be true of a measurement of the river taken at a gaging section located at, say 75 miles, from the foot of the lake

A. I believe it would to a somewhat less extent than at a hundred miles.

Q. And the same would be true where the gaging section is within six miles of the foot of the lake?

A. Yes, but to a less extent.

Recess to 2 P. M.

After recess—2 o'clock P. M.

FREDERIC P. STEARNS resumed the stand and testified further as follows:

Mr. Adcock: Q. Would the agreement between the volume of the water measured at two gaging sections on a river, like the St. Clair, necessarily indicate the accuracy of the measurements made at either of the sections, or the increment derived from the measurements made with reference to the stage of lake, at either one of the sections?

A. In my judgment it would not.

Q. Will you give your reasons, if you have any, for that statement.

A. The agreement of measurements at two sections on a river would be an indication of the accuracy of the measurements as referred to a gage near by; but would not neces-

sarily show that the measurements were correct, or that the increment derived from the measurements was correct.

This has already been indicated in connection with the two sets of measurements in another river than the St. Clair; that is in the Niagara river, where the measurements of two sections agreed well, and yet the discharge and the increment derived from those two sets of gagings is not correct.

Q. On a large river like the St. Clair river, of that depth and velocity, etc., is it possible to determine the accuracy of the discharge measurements made, from any other source than from the precision or accuracy of the current meter measurements made, and the soundings and measurement of the cross-section, etc.?

A. Not at all precisely. The discharge of the St. Clair river can be deduced from gagings at another point on the river, in the manner that has already been included in my testimony; but one could not determine the gagings at that river with sufficient accuracy to be used as a basis for determining an accurate increment.

That is to say, an accurate increment could be obtained only by gagings on the St. Clair river, or some point near, and only if those gagings were sufficiently extended and sufficiently accurate to be trustworthy.

It is questionable whether the lake would ever remain at a sufficiently constant level for a sufficient time to enable wholly trustworthy measurements to be made, as referred to the stage of the lake.

A limited number of measurements, made without reference to whether the lake was remaining at a nearly constant level, or was fluctuating considerably through the action of winds and other causes, would not give as good results as a series of measurements made at different elevations of the lake surface, when the lake surface remained nearly constant.

For instance, if an attempt were made to obtain the discharge for a high level of the lake caused by a strong wind blowing towards the outlet of the lake, it would not give results as satisfactory as if the lake were at the high stage for a period of weeks.

Q. Are the results of a series of measurements by the use of the current meter such as is shown by the records of measurements on the St. Clair introduced in evidence, approximate or absolute results?

A. I do not know the local conditions in that case well enough to answer the question; that is, as to the character of

the current meters used, and the extent of the irregularities of the current.

Q. Would it be possible to get an absolutely accurate result by current meter gagings, in any case?

A. I think that absolute accuracy cannot be obtained by any kind of gaging. A close approximation to accuracy may be obtained by several kinds.

Q. And where the river is large, those difficulties, as you have stated before, are increased?

A. Yes.

Q. Is it necessary, in view of those conditions, if possible, to refer the results obtained to physical conditions, conditions of rainfall, evaporation, etc., in order to determine and test their accuracy?

A. It is desirable to do so, but not necessary in many cases, as with moderate currents and conditions which obtain in the measurements of some large rivers, the actual measurement by the current meter can be quite well checked by a comparison of two sections. But in referring the measurements to lake stages, I think it very important that there should be a check where there can be.

For instance, gagings have been made of the St. Clair river and of the Detroit river, which is practically a continuation of the same stream with only a small lake and a small drainage area between, and such comparisons as could be made in those cases are important as checking the accuracy of the measurements; and yet such comparisons do not do away with the difficulty of properly relating the discharge measurement to the lake stage.

Q. Do you have any record of any discharge measurements made in the Detroit river?

A. I have not examined them. I know that they have been made, and that they were used by the International Waterways Commission on the Regulation of Lake Erie, in making a comparison between the discharge of the Detroit river and the discharge of the Niagara river.

Q. Do you know when those discharge measurements were made at the Detroit river?

A. In 1901 and 1902, as stated in the Annual Report of the Chief of Engineers for 1903, Appendix FFF, pages 2814 to 2817.

Q. Were those discharge measurements made about the time discharge measurements were made on the St. Clair river, the records of which have been introduced in evidence?

A. They were made at about the same time as the first set of measurements on the St. Clair river, which were made in the years 1889 to 1902.

Q. Do you know whether or not the discharge measurements on the St. Clair river were used by the International Waterways Commission in making up the report of 1910 on the Regulation of Lake Erie?

A. They were not so used except on occasions when the measurements indicated that the Detroit river was blocked with ice, and at such times the St. Clair measurements were used.

Q. Do the fluctuations of the stage of lake have any relation to the increment?

A. Yes.

Q. What is the relation?

A. The greater the fluctuation of the lake, meaning by this term not the small fluctuations, or the short period, but the fluctuations in longer periods is substantially inversely, other things being equal.

Q. That is, the greater the increment, other things being equal, the less will be the fluctuations?

A. Yes.

Q. And vice versa, the greater the fluctuations, you would expect a less increment?

A. The less increment.

Q. Is the discharge of the St. Clair river affected in any manner by the rise or fall of Lakes St. Clair and Erie, or either of them?

A. It is.

Q. Just explain, will you please, how the discharge may be affected?

A. The discharge of the St. Clair river, assuming Huron to remain constant and the St. Clair lake to rise, the effect would be to diminish the slope of the water between these two lakes, and that diminution of slope would diminish the speed with which the water would pass from one lake to another; and hence would diminish the quantity flowing. And similarly, the lowering of Lake St. Clair would increase the quantity flowing. The same is true of Lake Erie; a rise in Lake Erie will increase the level of Lake St. Clair, with a given quantity of water flowing, and hence would have the effect through St. Clair upon the discharge through the St. Clair river. That is the effect is first felt in Lake St. Clair,

raising that lake and consequently affecting the flow through the St. Clair river.

Q. Can you determine a proper increment, then, from discharge measurements of the St. Clair river, as referred to the stage of lake, without taking into consideration the stage of Lake St. Clair as compared with Huron?

A. No, not unless St. Clair maintains a constant relation to Lake Huron.

Q. Where you have a number of discharge measurements, and it is possible to group the discharge measurements, when Lake St. Clair is at a constant stage, is it proper to determine an increment therefrom for the St. Clair river, as affected by Huron alone?

A. Yes, as a step in the determination of the increment for the St. Clair river, with both lakes St. Clair and Huron having their normal relations.

Q. What would be the next step, then, to determine the correct increment for St. Clair, if you find a number of discharge measurements made when Huron was at a constant stage?

A. And Lake St. Clair changing?

Q. And Lake St. Clair changing.

A. That also would give an increment for Lake St. Clair, which could be combined with the increment for Lake Huron obtained by the previous method, and furnish a proper increment, in one way, for the St. Clair river.

Q. I refer you to Tables XXII, XXIII and XXIV, Williams Exhibit 34. Have you made any examination of the manner in which those tables were made up and the results shown on those tables?

A. I have.

Q. Referring to Williams Exhibit 34, Mr. Stearns, will you indicate such of the tables on that exhibit as you have examined, and know the methods of their compilation?

A. I think I have examined all of them and know the methods of computation.

Q. Referring to Tables XXVIII to XXXIX inclusive of Williams Exhibit 34, will you state whether you have examined those tables, and whether you consider the basis of computation and the results reached from those computations correct?

A. I have examined the tables, have considered the basis of computation, and believe that the results obtained are correct, for the assumptions made.

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In some cases the results are deducted from two assumptions, and obviously both cannot be correct.

I would say in regard to these tables, and others made by Mr. Williams and introduced as a part of Exhibit 34, that I have not checked the accuracy of any of the numerical computations.

Q. That is, your answer is on the assumption that the computations have been accurately made, and that the discharge measurements referred to were accurate?

A. Yes.

Q. In those tables the discharge measurements are grouped chronologically, are they not, for substantially the same stage of lake?

A. They are, in Table XXVIII and Table XXXIV.

Q. The Table XXVIII refers to the discharge measurements of the St. Clair river from 1899 to 1902, does it not?

A. It does.

Q. And the Table XXXIV, 1908 to 1910?

A. Yes.

Q. And tables 29, 30, 31, 32 and 33 are based upon Table 28, is that correct?

A. Yes.

Q. And Tables 35, 36, 37, 38 and 39 are based upon Table 34?

A. Yes.

Q. Do you consider that the method of treating the observations in the tables referred to XXVIII to XXXIX inclusive leads to more accurate results than the method of treating them without reference to chronological grouping, with reference to the similar stage of the lake for each group?

A. This is not only a chronological grouping, but also one in which the lake stages are nearly constant, and it necessarily eliminates some of the observations. If, however, it does not eliminate too many of them, I believe this method is the most correct, in that it deals with nearly constant stages of the lake, and with observations which were made near together, in point of time.

Q. Why is it necessary to use observations where the lake was nearly constant, and refer to the same time?

A. It is better to do so, and more accurate results could be obtained, because while the lake is falling rapidly, or fluctuating at short intervals, the results would not be as good as if there were a more constant stage of the lake.

Q. Referring to Table XXXIII, columns 8 and 9 of that table, where the increment is derived mathematically, do you consider that a proper method of deriving the increment?

A. I do.

Q. Do you consider that method more accurate than to plot the discharge measurements, and then from the position of the discharge measurements upon the plate, pass a string through to indicate the mean line?

A. Where the different measurements should be given even weight, there is no method of obtaining the line of an increment better than the method used in columns 8 and 9 of Table XXXIII, and in many other of the tables in Williams Exhibit 34, by determining the center of gravity of all the points, and the centers of gravity of the upper and lower half; that is, the upper and lower parts into which the main center of gravity divides the results.

Q. In considering the discharge measurements to determine the increment, do you believe it necessary to give the groups of measurements equal weight?

A. No, they should not be given even weight, where they represent different number of observations or different number of days, but as a part of the determination, these observations in Table XXXIII have been weighted in accordance with the number of days represented by each group of observations, and after they had been so weighted, I see no reason why each should not be given equal weight.

Q. Is there any other method as good as the method which is pursued in Table 33 for deriving the increment?

A. There is no method that is the more correct, where the observations should have equal weight. The method of using a thread or string, in connection with a plot, should give very nearly the same results, but this is the more perfect method to get exactly the right line.

Adjourned to Thursday, March 27, 1913; 9:30 A. M.

Thursday, March 27, 1913; 9:30 A. M.

Met pursuant to adjournment.

Present same as before.

FREDERIC P. STEARNS resumed the stand and testified further as follows:

Mr. Adcock: Q. Referring to Table XXVIII of Williams Exhibit 34, where 81 observations of discharge measurements on the St. Clair River, during the period from 1899 to 1902, are grouped chronologically and according to substantially the same stage of lake for each group, and assuming that those 81 observations extend over the entire period during which the discharge measurements were made, and assuming that there were approximately 265 measurements in all, do you consider that the 81 used in Table XXVIII are sufficient to give reasonably accurate results in the determination of the increment for the St. Clair River?

A. The number is sufficient to give accurate results if the observations are accurate, and that number—

Q. That is, assuming that the observations were accurate?

A. And while I have not examined the selection of these experiments from the whole number, I should think that they would give better results than the whole number if they represented nearly constant stages, and those experiments which were rejected represented more variable conditions in the lake.

Q. That is when you say "represented," you mean were taken at a time when the lake stage was varying?

A. Yes, when the lake stage was varying to a considerably greater extent.

Q. At what rate do the fluctuations of a lake decrease, as compared with the increase of an increment?

A. They decrease in a direct proportion as the increment increases, other conditions remaining constant.

Q. As compared with the increase of increment, at what rate does the discharge capacity of an outlet to a lake increase?

A. The discharge at a given stage of the lake increases at least as rapidly as the increment increases.

Q. So that the enlargement of a channel, causing an increase of discharge at the same stage, results likewise in the increase of increment, as a general proposition?

A. It does as a general proposition, under nearly all circumstances.

Q. Assuming that from say 1860 to 1910, the outlet of Erie remained unchanged so far as the discharge capacity was concerned, how would you determine the relation of mean annual fluctuations of Huron in the period from 1891 to 1910 both inclusive, to those similar fluctuations of Huron during the period from 1860 to 1889?

A. The method shown in Table 21 of Williams Exhibit 34 appears to me to be a proper one. In this table, for the period from 1860 to 1889, the years were arranged in the order of the height of Lake Huron, and the corresponding heights in Lake Erie were recorded in another column for the same years that the heights are given for Lake Huron. The line representing the fluctuations of Lake Huron, and also of Lake Erie, was determined by the center of gravity method, which has been so fully described; and the relation of the fluctuations in Lake Huron to those in Lake Erie were determined, as set forth in that table, to be in such proportion that 75.3 per cent. of the fluctuations of Lake Huron were represented by the fluctuations of Lake Erie.

The observations from 1891 to 1910 inclusive, were arranged separately in the same order, and following precisely the same processes. It was found that during this period the fluctuations of Lake Huron were represented to the extent of 86.1 per cent. in Lake Erie. By comparing the 75.3 per cent. and the 86.1 per cent., it will be found that the fluctuations of Huron in the later period were 87½ per cent. of the fluctuations in the earlier period.

In both cases this is determined on the basis of the conditions contained in your question, that the discharging capacity of Erie remains unchanged.

Q. That is, you mean by the discharging capacity of Erie, the outlet to Erie remains unchanged?

A. Yes.

Q. Why do you use Lake Erie as a comparison, that is, the fluctuations of Erie?

A. The difference in fluctuations in the two periods might otherwise be due to differences in the quantity of water and the rain fall. And by using Lake Erie as a standard, and bearing in mind that by far the greater part of the water discharged from Lake Erie comes from Lake Huron, and that the wet and dry years would be likely to affect both Lake Huron and Lake Erie in a similar manner, I reach

the conclusion that Lake Erie may properly be used as a standard for determining the relative fluctuations of Lake Huron in the two periods.

Q. Assuming that as stated in your answer to the preceding question, Huron has fluctuated 14 per cent. more in the earlier period, that is, from 1860 to 1889, inclusive, than it did from 1891 to 1910, inclusive, what do you say as to whether the discharging capacity of the St. Clair and Detroit rivers was greater or less in the former or in the later period?

A. It was greater.

Q. Assuming that the discharge of the St. Clair river was 197,600 cubic feet per second at certain stage of lake during the latter period, that is stage of Huron, what would have been the discharge of the St. Clair river at the same stage during the earlier period?

A. I cannot give a definite amount, but on the basis that the discharge at a given stage increases at least as rapidly as the increment increases, and since the increment varies inversely as the fluctuations, it would not have been more than 87½ per cent. of 197,600 cubic feet per second, equal to 172,900 cubic feet per second.

Q. What would then be the difference between that and the discharge in the former year?

A. Not less than 24,700 cubic feet per second.

Q. Assuming that the increment of the St. Clair river during the latter period was 28,872 cubic feet per second, what then was the increment of the St. Clair river during former period?

A. 25,300.

Q. How much, if any, then, was Lake Michigan lowered by the enlargement of the channels of the St. Clair and Detroit rivers, assuming that the increment in the latter period was 28,872 cubic feet per second, and the increment in the former period was 25,300 cubic feet per second?

A. The average increment during this period would have been 27,100 cubic feet per second, and as the difference in the discharging capacity of the channel as above estimated was not less than 24,700 cubic feet per second, the lowering would have been not less than 24,700 divided by 27,100, equal to .91 of a foot, or substantially 11 inches.

Q. How does the result which you have reached, when you have considered the effect of the enlargement of the channels of the St. Clair and Detroit rivers by comparing the fluctuations of Huron from 1891 to 1910, both inclusive, with

the fluctuations of Huron from 1860 to 1889, both inclusive, coincide with the results reached and shown by Stearns' Exhibit 1, tables A. B. C. D. E. F. and G, and the results shown by your testimony heretofore given, in connection with Stearns' Exhibit 1?

A. The testimony referred to, based upon Stearns' Exhibit 1, was to the effect that there had been an increase in the the discharging capacity of the St. Clair and Detroit rivers from the period including the years from 1883 to 1888 as compared with the period including the years from 1892 to 1903, of from 17,800 to 27,900 cubic feet per second. The average of those two quantities is 22,850 cubic feet per second, which may be compared with the amount of not less than 24,700 cubic feet per second obtained by the method based upon the relative fluctuations of Lake Huron in the periods 1860 to 1889, and 1891 to 1910.

Q. In other words, you have arrived at practically the same results by two entirely different methods, have you not?

A. I have, except in this one particular; in one case it represents not less than a given sum, while in the other case, the quantities are fairly well defined between limits.

Q Do you consider that the results reached, which are substantially the same by the two entirely different methods which you have described, are in any manner a corroboration of the results of either?

A. I do.

Q. Give your reasons for that latter answer?

A. I regard the first method, that is, the one based upon the discharge of the St. Lawrence, to be the better one, the more certain one, but the other one, is based upon correct principles, and should give an approximate result, and it does confirm the other.

Q. Well, do you consider that each result may be a confirmation of the other?

A. Yes.

Direct examination of this witness adjourned.

Further hearing of testimony in said matter adjourned sine die.

Saturday, July 26, 9:00 A. M.

FREDERIC P. STEARNS, a witness called on behalf of the Sanitary District, having been previously sworn, testified as follows:

Direct Examination by Mr. Adcock.

Q. Do you know Mr. Stearns to what extent the dilution method of sewage disposal is now utilized in cities of the United States, as compared with other methods?

A. I do in the larger cities.

Q. Will you state the comparisons?

A. Taking the 19 largest cities, there is only one which does not use the dilution method. All others use it. And of the 15 cities next in size, having a population of more than 146,000, all use the dilution method with the exception of four.

Q. How do they treat the sewage?

A. By various methods. I can describe that in detail, if you wish it now.

Q. I think you might as well, yes.

A. Of the 19 largest cities, all of which have a population of more than 250,000, Baltimore is the only one, as I have said, which uses other than dilution. And Baltimore treats its sewage by taking it to sprinkling filters located some six or eight miles north of the city near the Back River, and there purifies it by what is known as the sprinkling filter method.

This system in Baltimore has just been adopted within the last few years and is only in partial operation at the present time. The city had no system of sewers, and in establishing a new system they were required by the charter to purify the sewage, with a view to not affecting the oyster industry in Chesapeake Bay, which is a very great industry.

Shall I mention the others?

Q. Yes.

A. The smaller cities of those already mentioned which treat their sewage are Providence, Rhode Island, which had a population in 1910 of 224,000, and it uses a chemical precipitation process for treating sewage, and subsequently disinfects the effluent with hypochlorite of lime before it is discharged into tide water at the head of the Providence River.

Columbus, Ohio, population in 1910, 182,000, has a system of sprinkling filters with their usual appurtenances for the

treatment of its sewage. These works were constructed and are operated for the purpose of preventing offensive conditions in the Scioto River at times when the flow is insufficient to properly dilute the sewage.

At other times the sewage goes untreated by dilution, and they not only discharge into the stream the whole of the sewage, but they wash out into it the matters they have taken from the sewage previously. It is wholly a question of preventing a nuisance in a certain place, and not with regard to its effect upon the water supplies below.

Atlanta, Georgia, population in 1910, 155,000, has recently begun to purify a part of its sewage by means of sprinkling filters and their appurtenances, so as to prevent offensive conditions in three small streams.

Q. Are they connected in any way with the water supply?

A. I don't know in regard to that, but the statement is made in the official reports that it is to prevent offensive conditions, and I presume there is no question of water supply from those streams; there should not be.

Worcester, Massachusetts, population in 1910, 146,000, uses the chemical precipitation process for a part of its sewage, filtration through land for other parts and also filters through land a part of the effluent from the chemical precipitation works. All of this is for the purpose of preventing offensive conditions in the Blackstone River, in which the quantity of water is entirely inadequate for properly diluting the sewage.

Q. To recur for a moment, the cities that you have mentioned come within the class known as the class of 15 cities smaller than the great metropolises of the United States. Will you recur to the larger cities in which the population is over 250,000?

A. Yes.

Q. Such as New York?

A. Yes.

Q. And state the condition?

A. One of the cities was in this 19 larger cities.

Q. Which one was that?

A. Baltimore.

Q. Now take up the larger cities such as New York, Chicago Sanitary District, Philadelphia, and so forth.

A. I have here a table giving the population in 1910 of these cities. In two cases I took the Sanitary District—

Q. As a municipal corporation which it is.

A. As a corporation, rather than the city.

Q. The sewerage district?
A. Yes, sir.
Q. Also the Boston sewerage district you treat as a city?
A. Yes, sir. The list is as follows, in order of the size of the city:

New York,	4,767,000
Chicago Sanitary District,	2,312,000
Philadelphia,	1,549,000
Boston Sewerage District,	1,277,000
St. Louis,	687,000
Cleveland,	561,000
Baltimore,	558,000
Pittsburg,	534,000
Detroit,	466,000
Buffalo,	424,000
San Francisco,	417,000
Milwaukee,	374,000
Cincinnati,	364,000
Newark,	347,000
New Orleans,	339,000
District of Columbia,	331,000
Los Angeles,	319,000
Minneapolis,	301,000
Jersey City,	268,000

Q. Mr. Stearns, you have now mentioned the 34 larger cities of the United States, have you not?
A. Yes.
Q. Of these 34 larger cities of the United States, I understood you to say that all but five at the present time use the dilution method of disposal of sewage, is that correct?
A. Yes.
Q. And those five that use a method other than the dilution method have no connection with any water system?
A. They have not as I believe.
Q. The effluent from purification works, whatever they may be, is not discharged into any water supply of that city or other cities?
A. It is in the case of Columbus, but the purpose of purifying the sewage is not to protect the water supply, because at seasons of the year all the sewage goes into the stream, and they wash also into the stream, as I stated, the matters removed from the sewage at other times. It is wholly for the purpose of preventing offense.
Q. To what extent was the dilution method of sewage disposal used in the United States between 1885 and 1890?

A. Well, it was used by all of the large cities which had sewage disposal systems.

Q. To what extent were other methods of sewage disposal utilized, both in America and abroad, prior to 1890?

A. The use of other methods in America prior to that time was very limited. Sewage from certain public institutions, and from a few small towns, was disposed of by irrigation upon or filtration through land. The more notable places were the sewage farm at Pullman, which was not successful, largely on account of the impervious character of the land, and the sewage disposal area for the Village of South Framingham, Massachusetts, which was successful, as the land consisted of coarse sand well adapted to filtration. This system however was not operated until near the end of 1889.

At Los Angeles, and probably at other places in the arid regions, sewage was used during the irrigation season to promote the growth of crops, but the prime object in these cases was not the disposal of the sewage but the raising of crops. During a portion of the year the sewage was disposed of by dilution.

In the large cities abroad, much more was done prior to 1890 in the matter of sewage purification, mainly for the purpose of avoiding a nuisance where large cities were located upon comparatively small streams. In London, the offensive condition of the Thames led to the introduction of chemical precipitation works for clarifying the sewage. At Berlin, the sewage was purified by irrigation. At Paris, part of the sewage was purified by irrigation and filtration through sandy land, the remainder being discharged into the river Seine.

The dense population of England and the large amount of manufacturing wastes, taken in connection with the small sizes of the streams, made necessary many works for treating the sewage before it was turned into the streams. These works included broad irrigation upon land, a few cases of intermittant filtration through sand and several chemical precipitation plants, as well as a variety of methods of straining the sewage through coke and other materials. Many of the plants which existed in these places prior to 1890 have since been abandoned or materially modified as methods better, adapted to the conditions existing then, have become available.

Q. Referring back to the Baltimore plant, Mr. Stearns, you stated that one of the prime objects of that system was to protect the oyster industry in Chesapeake Bay. Is that correct?

A. Yes, sir.

Q. A separate system of sewers, from which the storm water was excluded, was adopted in Baltimore under their system?

A. It was.

Q. And all the sewage was collected by intercepting and main sewers and carried out to a point near Back River where sprinkling filters and other appurtenances were constructed, is that correct?

A. Yes; that is the work has not been completed yet. It is only a small part of the city sewage that now goes there.

Q. The appropirations for the work and for drain for the removal of storm water amounted to how much if you know?

A. I think the amount was $20,000,000.

Q. Did that system deal in any way with the contamination of the harbor waters?

A. It did in this way that the sewage was intercepted and prevented from entering the harbor and carried to these other points. The storm water and street wash still goes into the harbor.

Q. And to that extent, that is the street drainage and polluted brooks and so forth which flowed through the city into the harbor, was not contemplated in the improvement, the protection of that or the purification of it?

A. It was not except as these brooks will be improved somewhat in their condition by the interception of the sewage which now goes into them, the domestic sewage.

Q. At the time of this appropriation and the contemplated improvement Baltimore had no system of sewerage, did it?

A. It did not.

Q. They were starting just like a new municipality?

A. Yes.

Q. Isn't it a fact that the sewage is discharged so far from the oyster beds that it would probably be purified by dilution before it reached them anyway?

A. It will; the purification by dilution is a very important factor in that plant.

I was a member of the Commission of Advisory Engineers who recommended the plant, and one reason for going to this Back River was that sewage could be discharged there less thoroughly purified than if it were discharged nearer where the oysters are; and it would obtain a further purification by dilution on account of the long distance that it would travel before reaching the oysters.

Q. So that you do not rely upon the purification works entirely to eradicate the impurities of the sewage?

A. That is true, as the works are built, and also in accordance with recommendations of this Commission. There was a secondary purification that was provided for in the original plan by filtration through land, and that is not being carried out, it being thought that the purification due to dilution will accomplish the purpose.

Q. Is there anything about the topography of Baltimore that made it possible to use this sort of method better than most any other city?

A. Yes, the conditions there are extremely favorable to sewage disposal. Baltimore is a hilly country, and as a consequence the sewage from by far the greater part of it can be carried with sewers having good grades by gravity to these sprinkling filters, and the whole process completed by gravity. Now, from a portion of the city it is necessary to collect the sewage by intercepting sewers down near the water front, and pump that portion of the sewage, but by far the greater part is easily carried to the works by gravity and by comparatively small sewers, because of the high grades.

Q. Did Baltimore have a convenient outlet for the discharge of the effluent?

A Yes, I should say so because the distance is not very great, and there was a good line on which to construct a sewer leading to these sprinkling beds.

Q. And these sprinkling beds were so far removed that under ordinary conditions the water containing this sewage effluent would not reach any spot that would affect the oyster beds?

A. Not for a very long time.

Q. Mr. Stearns you made a compilation showing the 19 largest cities and sewage districts. Have you totaled the population of those 19 cities or districts for the year 1910?

A. I have.

Q. What was the aggregate population?

A. The aggregate population of the 19 cities was 16,195,000. The population of the city of Baltimore was 558,000, or 3.4 per cent. of the aggregate population of these cities.

Q. I understood you to say that this Baltimore plant is still under construction, and just what the service will be is problematical to some extent at least?

A. Yes, and in any case only a very small part of the sewage of Baltimore is now purified. That is it would be

pretty near a true statement to say that almost none of the sewage of the 19 largest cities is at the present time purified.

Q. Have you considered the adaptability of other methods of sewage disposal for a city such as Chicago?

A. I have.

Q. Will you give us your views as an engineer and expert upon that question?

A. The situation is extremely unfavorable for any other system of sewage disposal than that which the city of Chicago now uses. It is impracticable to obtain a water supply for the city from any other source than Lake Michigan, and in no other way can the water supply taken from the lake be as well protected from contamination as by the present general method of sewage disposal, which not only keeps the sewage from entering the lake but creates a constant tendency to draw from the lake any water that may become contaminated along its shores, and it keeps from the lake the necessarily contaminated water of its rivers.

The usual methods of sewage disposal which could be considered if an outlet draining from the lake were not available are:

1. The thorough purification of all of the sewage before it enters the lake.

2. The partial or thorough purification of a part of the sewage before it enters the lake.

3. The discharge of crude sewage into the rivers and lakes.

Q. Will you take up and consider these different methods, in the order in which you have mentioned them?

A. The thorough purification of the sewage before it enters the lake—

Q. That is system number 1 that you have indicated, or method number 1?

A. Yes, with a view to eliminating all danger to the water supply, is impracticable in a city already provided with a combined system of sewerage, on account of the enormous cost and the inability to provide complete protection of a water supply in this way. The complete purification of the sewage cannot be accomplished with a combined system of sewers, meaning by the words "combined system" one which takes in the same sewers the sewage proper and the storm water. The quantity of mingled sewage and storm water discharged from such a system during heavy rains is so great that at such times the whole volume flowing cannot be puri-

fied by any practicable means. No community has ever attempted such complete purification.

It is the rule where such sewers are in use to provide for the purification of the dry weather flow of sewage and, in addition, the storm water flow from light rains, but at times of heavy rains a part of the mingled sewage and storm water is permitted to overflow with practically no purification into some convenient stream or body of water.

The purification of all of the sewage can be accomplished only when the sewage is collected in a separate system of sewers from which the storm water is excluded. Even with such a system in a city like Chicago, it would not be feasible to keep all contaminating matters out of the rivers and lake. Rivers in the midst of such a populous district, and used by ships, cannot fail to become contaminated and to require an artificial current to prevent them from becoming offensive, which would force the contaminated water from the rivers into the lake. During rains all of the street wash and storm water would necessarily be turned into the lake or into the rivers and thence into the lake.

As one of the consulting engineers engaged to advise as to a method of sewage disposal for Pittsburg, Pennsylvania, which would protect the water supplies of communities on the Ohio River below Pittsburg, I had occasion to study the problem of the complete purification of all the sewage. The first necessary feature was a separate system of sewers, in addition to the combined system already in use by the city. The estimated cost of installing the separate sewers in that city was $14,900,000. Pittsburg in 1910 had a population of 534,000, hence the estimated cost was $27.90 per inhabitant.

On the same basis the cost of providing a separate system for the 2,312,000 inhabitants of the Sanitary District of Chicago in 1910, would be $64,500,000. This sum does not include the whole of the burden which the community would suffer as the result of digging up every street in the city in order to lay the additional system of sewers.

The estimated cost at Pittsburg for providing the intercepting and main sewers to intercept and convey to the sewage disposal works the discharge from the separate system of sewers, of a pumping station to lift the sewage to the disposal works, and of the disposal works, amounted to $22,400,000, which is substantially $42 per inhabitant in 1910. In this case, the works were planned as they would be in any case to provide sufficient capacity for a reasonable time in

the future, the pumping stations and disposal works for a population 50 per cent. in excess of the population in 1910, and the main and intercepting sewers for a population rather more than three times the population in 1910.

Estimating the cost for the Sanitary District of Chicago at the same rate per inhabitant as at Pittsburg gives $97,000,000 as the estimated cost of main and intercepting sewers and pumping purification works, which added to the $64,500,000 already estimated for the separate system gives a total of $161,500,000 as the first cost of works for completely purifying the sewage of the Sanitary District.

In addition, such works must be operated and extended from time to time. The estimated annual cost of operation at Pittsburg was $435,000 equal to $0.81 per inhabitant in 1910. On the same basis per inhabitant, the cost to the Sanitary District of Chicago would be $1,870,000 annually, which capitalized at five per cent. would be $37,400,000, making the total cost, including the capitalized operating expenses $198,900,000.

In comparing the conditions which would affect the relative cost of works at Pittsburg and Chicago, I do not find any reason why there should be a radical difference in the cost per inhabitant at the two places and therefore believe that the above estimate gives an approximate idea of the cost of installing a separate system and of constructing and operating main and intercepting sewers, pumping stations and purification works for the Sanitary District of Chicago.

The above estimate does not include the cost of works for producing an adequate artificial current in the Chicago River, and it is well to state once more that even if the sewage removed by a separate system of sewers were thoroughly purified, the polluted river water which the artificial current would force out into the lake and the storm water contaminated with street washings from so large a territory would probably render it unsafe to use the water supply taken directly from the lake by the present methods.

I regard this method of sewage disposal, as already stated, to be impracticable on account of its excessive cost, and it would not adequately protect the water supply from contamination.

Q. What is the second method that you have above referred to?

A. The second method is the partial or thorough purification of a part of the sewage before it enters the lake.

A more practicable method of sewage disposal than that above described would involve the use of the present system of combined sewers, the interception of the dry weather flow and a small amount of storm water, in addition, and the treatment of the sewage so intercepted, with the ultimate discharge of its effluent into the river or lake. With such a system, it would be necessary to protect the water supply by sterilization or filtration, preferably by filtration. This method would furnish a safer water supply than would be afforded by the first method if the water supply in that case were not to be sterilized or filtered and should not cause any local offense, except in the vicinities of the sewage disposal works.

The cost of the sewage purification by this method, as compared with the first, would be diminished by a large part of the cost of the separate system of sewers, as the increased cost of main and intercepting sewers, pumping stations and disposal works, due to the necessity of providing for a limited amount of storm water, would be only a small part of the cost of installing a separate system. The remaining cost, however, would still be a very great sum of money, amounting on the basis before given to $134,400,000 for the main and intercepting sewers, pumping stations and purification works. The additional cost for the increased size of the works required for the removal and disposal of a small part of the storm flow might be offset by the diminution of cost due to the less thorough purification of the sewage by this plan.

Q. Will you take up the third method that you have referred to?

A. The third method is the discharge of crude sewage into the lake.

With this method of sewage disposal, the main purpose would be to prevent offensive conditions at any place. If a strong artificial current were to be created in the Chicago River flowing towards the lake, similar to that now created in the opposite direction by the Chicago Drainage Canal, it might continue to be feasible to discharge the existing sewers into the river, although the screening or sedimentation of the sewage might be necessary to prevent offensive conditions along the lake shore near the mouth of the river. In other parts of the city, it might be necessary to collect the sewage by intercepting sewers, and pump it through pipes discharging at several out-lets so far out into the lake that

it would become diffused and finally purified by the dilution method.

The difference between this method and the one in which only the dry weather flow of sewage is purified is one of degree only, because some crude sewage would reach the lake in either case and the water supply would have to be protected by sterilization or filtration or by both.

If the policy of discharging crude sewage into the lake were to be adopted, it would be advantageous to discharge all of the sewage south of the Chicago River and to take the water supply through intakes located well out into the lake, opposite some thinly settled part of the lake front north of the City Limits. This separation of sewage outlets and water supply inlets would diminish the opportunity for the mixing of the sewage and water supply, and would permit a considerable purification of the sewage by the various processes which accompany a high degree of dilution before the water receiving the sewage had time to reach the water works intakes.

Intermediate between the second and third methods of sewage disposal as here outlined, it might be possible to remove many of the floating and suspended particles in the sewage by screening or sedimentation, or to destroy some of the disease germs contained in the sewage by the use of a disinfectant, without carrying the sewage a long distance to sewage purification works. But none of these modifications would affect the general proposition that sewage disposal works other than by the method now used would necessarily cause the lake to receive much matter injurious to the quality of the water supply which is now kept from it.

Although there is abundant evidence that the filtration of water is an important safeguard and that a water supply which has caused many deaths from typhoid fever before it was filtered may be made reasonably safe by filtration, there is no direct evidence that filtration even when properly conducted wholly eliminates the danger from the use of contaminated water, and if the filtration is not properly conducted, there is obvious danger to the health of the water takers from the use of such water.

It is upon this ground that I have in the past and still advise against the use of a contaminated water after filtration, when it is practicable to obtain a purer source of supply. For instance, in 1894, I made estimates of the cost of the additional works for the water supply of the Boston Metropolitan District of Massachusetts, and recommended that an

unfiltered supply be taken from an unpolluted source at a first cost of $19,000,000, in preference to a filtered supply from a slightly polluted source at a first cost of $14,900,000, to which may be added $2,600,000 as the capitalized cost of operating filters and pumping stations in the last project. I then made this statement, which still represents my views:

"Even if it were admitted that sand filtration with scientifically constructed filters and intelligent management will entirely remove disease germs from water, there is still the chance in the administration of a work of this kind that the preparation may be unscientific and the management unintelligent, which may cause the water to be either imperfectly purified by filtration, or, by accident, carelessness or the necessity of maintaining the supply, sent to the Metropolitan District without any filtration whatever."

It is, in my judgment, useless to say that in a problem of this kind the sanitary conditions only are important and that the cost is unimportant. The two cannot be divorced one from the other under the common sense practical conditions of municipal government. Many important sanitary conditions are desirable but they cannot be realized because of the direct relation of sanitation to cost. The resources of a city or district are necessarily limited, in some cases by law and in some cases by practical conditions. The enforced use of a vast sum of money for a given sanitary purpose, even if it were possible to obtain such sum by borrowing or taxation, would necessarily limit the amount which could be used for other sanitary purposes.

It is therefore in my judgment impossible for the Sanitary District of Chicago to reproduce by any other method of sewage disposal than that now used as sanitary conditions in relation to its water supply and sewerage as can be maintained by the use of the Chicago Drainage Canal, with the right to take from Lake Michigan the quantity of water commensurate with the needs of the District from time to time.

Q. Mr. Stearns, have you given consideration to the subject as to what extent prior to 1890 sewage was discharged into water used for drinking purposes, and the state of the art of water purification at that time, in America?

A. Yes.

Q. Will you state what your conclusions and views are upon that subject, and the facts pertaining to that subject?

A. Sewage was very generally discharged prior to 1890 into the largest rivers and the lakes from which water was

taken for water supply. There were, however, prior to that year, many smaller streams and rivers and lakes and ponds from which water was taken for drinking purposes and into which the disposal of sewage was prohibited; as, for instance, the streams, ponds and reservoirs used by the cities of New York, Boston and Rochester.

Prior to 1890, water purification, with a view to the removal of disease germs, could hardly be said to exist in America. There was before this date a small sand filtration plant at Poughkeepsie, New York, and a much larger number of so-called mechanical sand filters, most of them filtering at a high rate, using alum as a coagulant and operating under pressure.

The State Board of Health of Massachusetts began to experiment upon the purification of water by filtration through sand in the latter part of 1887, but the results were not published until 1890.

It may fairly be said that the available knowledge in regard to water purification prior to 1890 was nearly all based upon the practical work which had been done along these lines in England and in other parts of Europe.

Q. Have you made a study of the history of sewage and water purification in the United States?

A. Yes.

Q. And are familiar with the methods of sewage disposal of the cities of the United States having a population of over 250,000?

A. Yes.

Q. Will you state the facts concerning those two situations?

A. The history of sewage and water purification in the United States may almost be said to begin with the experimental work of the State Board of Health of Massachusetts, begun in 1887. There were, as already stated, sewage purification plants for certain public institutions, and a few very small towns prior to this time, and the Pullman Sewage Farm had been constructed. Moreover, a number of engineers and health authorities had studied conditions in Europe and had made reports upon the methods of sewage disposal in use there.

The experiments of the State Board of Health furnished for the first time a scientific basis for sewage disposal by filtration through sand and gravel, and demonstrated the limitations of some other methods. The experiments of this Board have been carried on continuously from 1887 to the

present time and have furnished an increasing amount of knowledge with regard to the various methods of water and sewage purification.

The construction of systems of sewage disposal in many places in the United States, using a variety of methods which have been developed by experimental and practical work in this country and abroad, has added greatly to the information regarding sewage disposal and purification, and has at the same time developed many sanitary engineers who can determine with a fair degree of accuracy the results to be obtained by the adoption of different methods.

As a result of this progress in the art of sewage disposal, if Chicago had constructed works for disposing of the sewage by any other method than dilution on the basis of the information of 1890, it probably would have had only a small measure of success, and would have found it necessary to entirely remodel the works.

While there has been a great advance in methods of sewage disposal since 1890, a further advance is to be expected. With all the knowledge now available, the disposal of the sewage of a great city is a difficult and very expensive problem unless it can be accomplished by the dilution method, and it is for this reason that the dilution method is used almost universally, wherever there is an opportunity to use it.

In regard to water purification, there were the mechanical filters and the Poughkeepsie Filter already referred to before 1887. The experiments and investigations of the State Board of Health of Massachusetts resulted in the completion in 1893 at Lawrence, Massachusetts, of the first large sand filtration plant in the United States, the city having at that time a population of 48,000. The results obtained with this first large filter were under continuous observation by experts, and it was soon found that the water filtration greatly diminished the death rate in the city from typhoid fever and reduced to a considerable extent the death rate from other diseases.

Many causes, of which the results obtained by this filter were one, lead several large cities having water supplies from polluted rivers to agitate the question of the filtration during the decade ending in 1900, and many experiments were made under the direction of experts and with many kinds of water, which added greatly to the available information regarding water purification.

Among these were experiments at Providence, Rhode Island, in 1893-1894; Louisville, Kentucky, in 1895; Pitts-

burg, Pennsylvania, in 1897; Cincinnati, Ohio, in 1898; Washington, D. C., in 1899; and New Orleans, Louisiana, in 1900. These experiments furnished information as to the relative merits of slow sand filters used without a coagulant and of rapid sand filters using a coagulant and as to the character of the waters to which each of these types was best adapted.

The next large filter for the purification of the water of a city, after that of Lawrence, was put in operation in Albany, New York, in 1899.

This was followed by filters for other cities, which were first put in operation at the following dates:

Philadelphia, Pa.; Little Falls, N. J.....1902
Providence, R. I. 1904
Washington, D. C. 1905
Louisville, Ky.; New Orleans, La.; Pittsburg, Pa.; Cincinnati, Ohio; Denver, Colo. 1907
Columbus, Ohio 1908

In addition to these filtration plants and many others for smaller cities, St. Louis, Missouri, began to clarify and purify its water by the addition of a coagulant and subsequent sedimentation in large settling basins in 1904, and the East Jersey Water Company began to sterilize the water it supplied to Jersey City by the addition of hypochloride of lime in 1908.

To sum up the history of water purification for large cities, it may be said that prior to 1890 the knowledge was mainly that derived from European experience. The decade ending in 1900 was one in which much was learned by experimental work and a little by actual operation of large water filtration plants.

The decade ending in 1910 is one in which a large number of important water purification plants have been constructed and operated, adding much more to the fund of knowledge of water purification.

The present method of sewage disposal in the cities of the United States having a population of over 250,000 is, as already stated, by dilution in practically all cases. This method is frequently adopted for small communities without any expert investigations, because it is the easiest method of disposal, but in the case of the larger cities it has been adopted or retained after expert investigations. For instance, the City of Boston up to the year 1876 discharged its sewage at numerous outlets into the waters which surrounded the city, with the result that offensive conditions were produced. Expert investigations at that time showed that the best method

of disposal would be to intercept the dry weather flow of sewage, convey it in a main sewer to a pumping station where it could be lifted so that it would run thence by gravity to an outlet into the harbor at a favorable place about five miles from the city, where it would receive a proper degree of dilution.

In 1888 the State Board of Health of Massachusetts was instructed to consider the problem of the proper disposal of the sewage of the other cities and towns of the Boston District and some portions of Boston not provided for by the original main drainage works. This Board after investigating in detail the available methods of sewage disposal recommended the dilution method for this additional Boston District.

Still later, when the original main drainage works of Boston became overtaxed, a further investigation was made which resulted in a third main system of sewers, discharging at a point where the sewage could be satisfactorily disposed of by the dilution method.

In all of these large cities, with the exception of Baltimore, the changes which have been made in sewage disposal have been in the line of obtaining better dilution and not a departure from the system of sewage disposal by dilution.

Q. Mr. Stearns, in considering the methods that you have referred to, do climatic conditions enter into such consideration?

A. They do.

Q. Will you state your views upon that subject?

A. In disposal by dilution, climatic conditions have very little to do with the case. Sometimes there is a covering of ice that makes a little trouble by keeping the sewage or the polluted water away from the air and the oxygen. But in the case of any other method, except possibly chemical precipitation, the cold weather of winter such as is experienced at Chicago makes the problem much more difficult, that is difficult to obtain purification, and very much more expensive and troublesome than where there is a warmer climate.

In Baltimore, for instance, there will be very little trouble from ice, in connection with the sprinkling filters, but in a place like Chicago ice would form over the beds to such an extent as to render them very much less effective, if it didn't actually put them out of commission.

Q. Have you given consideration to the necessity of keeping the water supply free from raw sewage pollution or effluent?

A. Yes.

Q. Will you state your views and conclusions upon that subject?

A. Abundant evidence has been obtained since 1890 to show that if water polluted by raw sewage goes directly into the water pipes of a water supply system, within a few days after the sewage enters the water much sickness and many deaths will occur among the water takers. One of the first striking proofs of this in the United States was furnished by the City of Lawrence, Massachusetts, where the deaths from typhoid fever before the water filter was put in operation were many times in excess of the deaths from the same disease in other cities having an unpolluted water supply.

That this was due to the water supply was clearly shown by the great decrease in the death rate from typhoid fever after the filters were put in operation. Similar results have been found where other cities have begun to filter their water or where they have changed from a polluted to an unpolluted water supply.

I have here a table headed "Death Rates per 100,000 of the Population Before and After the Filtration of the Water." The table is as follows:

Death Rates per 100,000 of the Population Before and After the Filtration of the Water.

	Before.		After.	
Lawrence,	121	(5 years)	26	(5 years)
Albany,	104	(5 years)	26	(5 years)
Cincinnati,	53	(3 years)	12	(4 years)
Columbus,	63	(4 years)	17	(3 years)

One of the most definite cases of sickness and death caused by a water supply which received raw sewage occurred in the manufacturing city of Lowell, Massachusetts. The mills of that place have a joint supply for manufacturing purposes, which is contaminated by sewage and under somewhat greater pressure than the city supply. On the occasion of an extensive fire, the connection between these two systems was opened, and although check valves were provided to prevent the water in the mill pipes from passing into the city pipes, a large quantity of contaminated water passed into the city pipes owing to some defective apparatus. In the section of the city which this contaminated water entered, typhoid fever began to develop in about 13 days, and in the course of a month 161 cases had been reported, with a total in four months of 231, resulting in 10 deaths.

This epidemic was undoubtedly caused by the contami-

nated water, as it was limited to the section of the city which received this polluted water and the disease was first noticed the proper number of days after the date when the water in the pipes was infected.

Such evidence shows clearly both the necessity of keeping the water supply free from raw sewage pollution, and that a water supply can be protected to a large extent from the effects of sewage pollution by the filtration of the water.

If the Sanitary District had in 1890 adopted a purification process before discharging the sewage into the lake, it would probably have adopted the process of chemical precipitation, a process which was adopted in 1892 for the treatment of the sewage of the Columbian Exposition at Chicago. Such a process would have protected the water supply only to a limited extent. Modern processes such as sprinkling filters when properly operated remove a large percentage of the bacteria, and with subsequent sedimentation and sterilization, the effluent may be made nearly free from disease germs, but it should be kept in mind that no process of purification in connection with a combined system of sewers can prevent raw sewage from being discharged during heavy rains to endanger the water supply.

Q. Have you given consideration to the minimum amount of water required to properly dilute sewage?

A. Yes.

Q. Will you state your conclusions upon that subject?

A. In 1889 I wrote a paper on this subject, which was published in the Special Report of the State Board of Health of Massachusetts upon the examination of Water Supplies, 1890. At that time, I reached the conclusion from the limited data then available that where the volume of water was less than 2.5 cubic feet per second per 1,000 persons, offensive conditions would be created and that with more than seven cubic feet per second per 1,000 persons offensive conditions would not be created.

None of the cases upon which these conclusions were based included the waste from slaughter houses.

In 1902, a further examination was made by the State Board of Health with much more data than was available in 1889 and the conclusion was reached that under some circumstances "Objectionable conditions may not result where the dilution is somewhat less than 6 cubic feet per second per 1,000 persons; but objectionable conditions have resulted in all of the cases thus far examined where the flow has been less than 3.5 cubic feet per second for 1,000 persons discharg-

ing sewage into the streams." (Report of State Board of Health of Massachusetts, page 452.)

For purposes of comparison, it may be stated that the Illinois law requires that the amount of dilution of the Sanitary District sewage shall not be less than 3½ cubic feet per second for each 1,000 of population, and that the recommendation in the original report of Messrs. Hering, Williams and Artingstall was that there should be a dilution equivalent to 4 cubic feet per second for each 1,000 of the population.

From all of the information available except that derived from the Chicago Drainage Canal itself, I should have concluded that 3½ cubic feet of water per second was less than the proper amount for the dilution of the Chicago sewage, including as it does strong sewage from the Stock Yards and slaughter houses, but the best information available is that derived from the Chicago Drainage Canal itself.

The report of the sewage disposal made to the Board of Trustees of the Sanitary District of Chicago by George M. Wisner, Chief Engineer, on October 12, 1911, gives the result of many observations, showing that the dissolved oxygen is exhausted from the water and putrefactive conditions are created in the downstream half of the Drainage Canal in the summer time when the quantity of water flowing from the lake through the canal is substantially the minimum quantity required by the State Law. These observations show that the 3½ cubic feet per second per 1,000 of population is not enough to properly dispose of the sewage under the existing conditions, although it approximates the required amount.

This statement refers mainly to the summer time, but since the time when I made that conclusion from Mr. Wisner's report, I have been down the Chicago Drainage Canal in warm weather, although not in the hottest weather, and I was satisfied from my inspection of the canal that more than 3½ cubic feet per second was required to properly dilute the sewage in the summer season.

Mr. Wilkerson: Q. How much more, Mr. Stearns?

Mr. Adcock: 3½ cubic feet per second per thousand people?

A. Per thousand people. It is difficult to say how much more, from mere observation. The date of my visit was May 27, not the warmest weather, and at that time it seemed to me that the quantity of water which was flowing, which was substantially the 3½ cubic feet per second, was as little as could be used.

Mr. Wilkerson: Q. How much water was going through at the time you mentioned?

Mr. Adcock: The presumption is the 3⅓ cubic feet per thousand.

Mr. Wilkerson: The presumption is there was 4,162 cubic feet taken out of Lake Michigan. All I care for at this time in the record are the figures upon which Mr. Stearns based his statement, at the time he made his inspection. He understood there was substantially 3½ feet. I want to know whether he was merely told that by someone, whether it is all right or whether he was given the figures on which he based the statement.

Mr. Adcock: Q. How did you get that information as to the 3⅓ cubic feet at that time?

A. I received that information in a letter.

Q. In a letter? From the Sanitary District?

A. Yes.

Q. Or from someone connected with the Sanitary District?

A. From someone connected with the Sanitary District.

Mr. Wilkerson: On what basis do you figure the present population of the Sanitary District, how many inhabitants? What do you figure it is now?

Mr. Austrian: I understood about 2,300,000.

Mr. Wilkerson: That would make about 7,666 cubic feet per second you were taking?

Mr. Adcock: Q. These oyster beds that they undertook to protect at Baltimore, to preserve the industry, and to keep the germs from filtering to those spots and polluting the oysters, were located something like 20 miles from the City of Baltimore, were they not?

A. I don't think they were as far as that from the City of Baltimore, but from the sewage outlet.

Q. I mean from the sewage outlet at the City of Baltimore?

A. They were located something like that distance. I should say from 15 to 20 miles. I have not the exact distance.

Q. You have made an exhaustive study of this subject, I understood you to say, in your previous examination, and as disclosed by this examination; and you have inspected the Drainage Canal, and you have familiarized yourself thoroughly with the various systems for taking care of sewage disposal. You are also familiar with the topography of the City of Chicago, I take it, Mr. Stearns, in a general way?

A. Yes.

Q. And the expense of the territory covered by the Sanitary District, in a general way?

A. Yes.

Q. You also are generally familiar with the climatic conditions in Chicago?

A. I am, yes, sir.

Q. And the location of the water used for health purposes, the intakes and the like in the City of Chicago?

A. Yes.

Q. From all your investigations, and from the facts concerning which you have testified, have you reached any conclusion as to whether any system for sewage disposal other than the one now in use, that is by means of the Sanitary District, is a practical, feasible, proper, efficient method for sewage disposal for that district?

Mr. Wilkerson: You include in that question the element of the cost of construction?

Mr. Adcock: I said all the facts and circumstances.

Mr. Wilkerson: I did not know whether you were going to have the thing rejected as improper because it cost so much.

Mr. Adcock: Q. Have you reached a conclusion?

(Question read.)

A. I believe the method in use is by far the best method; and I think it is also the only practicable method, practicable and efficient method of taking care of the sewage and protecting the water supply; but there may be some combinations of purification, or there may be some partial purification of the sewage which could be used in connection with the present method. But I do not see how the present method could be abandoned, or greatly restricted in the quantity of water, and obtain results that should be obtained.

Cross-Examination by Mr. Wilkerson.

Q. Have you made any computations based upon the assumption that the Sanitary District is permitted to take from Lake Michigan 4,167 cubic feet of water per second for the purposes of this canal, and utilize that in taking care of part of the sewage disposal, and combining with that proper works which would take care of the sewage of a population in excess of the amount which could be handled by taking care of 4,167 cubic feet of water from the lake?

A. I have considered the matter.

Q. And have you reached any conclusion about it?

A. Yes.

Q. The 4,167 cubic feet a second would take care of how large a population, on the basis of 3½ cubic feet per second, per thousand inhabitants?

A. 1,250,000.

Q. That would leave about a million people in the district unprovided for, on that basis?

A. It would at the present time; but the population is growing, so that million would increase rapidly.

Q. So far as growth is concerned, it is only a matter of a few years when the district, even if it uses 10,000 cubic feet per second, will have to provide some other way of taking care of the additional population?

A. On that same basis, 10,000 cubic feet per second would provide for 3,000,000 people; but it is easier to provide new arrangements as the city grows for additional population than it is to reconstruct works already in existence.

Q. Now with reference to the cost of your plant, you gave some figures based on the experience of Pittsburg?

A. Based upon estimated figures for Pittsburg, not upon actual experience.

Q. And what was the result per capita? That is, I cannot carry these figures in my mind; I am leading up to the question: The population of Pittsburg was how much?

A. The population of Pittsburg, 534,000.

Q. 534,000, and the estimated cost of the contemplated works, including cost of maintenance capitalized, was how much?

A. It was $86.10 per inhabitant.

Q. The total amount was how much?

A. $46,000,000 for Pittsburg.

Q. Now, to provide for a city of 1,200,000 on the same basis would cost how much?

A. That is another city of 1,200,000?

Q. Yes, another city of 1,200,000.

Mr. Adcock: I object to that. I do not see as it has anything to do with this case; it is not pertinent to any inquiry.

A. $103,000,000.

Q. That will be $103,000,000 on the same basis that it cost to provide for the disposal of sewage of a 1,200,000 city, so that even if the Drainage Canal could be utilized to take care of the sewage of a million two hundred thousand people, the expense for that part of the sewage disposal is smaller than it would have been if the other methods had been adopted at that time?

A. The figure that I gave of one hundred and three million dollars was for a city of 1,200,000, and not for a part of the city. I do not think it follows that the conditions would be the same.

Q. You did use that as the basis for your computation as to what it would have cost in Chicago for a system of the same kind as designed for Pittsburg?

A. Yes, for Chicago as a whole.

Q. For Chicago as a whole?

A. But not as to the cost for a part of it.

Q. My question is based upon the assumption, if we had at Chicago a city of only 1,200,000 in place of a city the size that we have, the cost—

A. On that basis?

Q. —on that basis would have been $103,000,000?

A. Yes.

Q. On the same basis as you applied in making the estimate of the cost for the entire City of Chicago?

A. Yes, sir.

Q. I think it is stated here that the figures for the cost of the Sanitary Canal are between seventy and seventy-five million dollars?

Mr. Adcock: You can assume $75,000,000.

Mr. Wilkerson: Q. And then as against the cost of maintaining a sewage system such as the one that was contemplated for Pittsburg, there would be, so far as Chicago was concerned, a credit which would come from the use of the water power derived from the water which was taken from the lake.

Mr. Austrian: That would depend on whether the water power was utilized at a profit or at a loss.

Mr. Wilkerson: That would be an element as against the cost of maintenance of one method as against the other?

A. The estimated cost of sewerage works for the complete purification of the sewage of Chicago, based upon the estimates made for Pittsburg, did not include the use of any water from the lake. Hence there is no water power question that comes into that.

Q. Obviously, I did not make my meaning clear. I was contrasting the expense which the City would have been put to for 1,200,000 of its population if it had used a method similar to the one which was contemplated for Pittsburg, with the situation where it was able to utilize for 1,200,000 of its population the water to a limited extent from the lake. And what I had in mind was this: That with the system which

was devised for Pittsburg, with the cost of maintenance, which was pretty large, is it not a rather large cost of maintenance?

A. Yes.

Q. With a system of that kind, with the method of diluting the sewage by the water taken from the lake, if that water was utilized for power purposes, or any other similar purpose, there is a credit there rather than a cost of maintenance?

A. No.

Q. What is your opinion as to the cost of maintenance of the two methods, as an engineer familiar with projects of that kind?

A. The cost of operating sewerage works is more than could ever be obtained from water power, in my judgment, taking the whole cost, but it may be a feature in favor of a dilution method that there is some small rebate obtained, or may be obtained from the use of the water for power.

Q. It costs more to maintain a system such as was devised for Pittsburg than it does to maintain a dilution system such as there is in Chicago, does it not?

A. Yes, certainly.

Adjourned to Monday, July 28, 1913, at 10:00 o'clock.

July 28, 1913, 10:00 A. M.

Cross-Examination of Mr. Stearns Resumed.

Mr. Wilkerson: Q. Of the nineteen large cities which you mentioned Mr. Stearns as utilizing, with the exception of Baltimore, the dilution method of sewage disposal including Chicago, in how many of them is the sewage discharged into salt or brackish water? That is to say I want you to put those into a class by themselves.

A. Five.

Q. Which ones?

A New York, Boston.

Q. How about Philadelphia?

A. That is fresh water I believe. I am not entirely certain about that point. To continue: San Francisco, Newark and Jersey City.

Q. In the case of Philadelphia, the diluting body is not the source of the drinking water supply is it?

A. It is the source of the drinking water supply, but the sewage is, nearly all of it, put in below; and possibly all at the present time. Years ago it was not all put in below the point at which the water supply was taken.

Q. That is to say in the case of Philadelphia, you have a stream in which the drinking water is taken from the upper portion of the stream, and the sewage discharged at a point below that where the water is taken?

A. I think that is the case at the present time, but I am not certain. The points of taking the water and of discharging the sewage are not very far apart.

Q. What is the fact with reference to New Orleans?

A. New Orleans discharges its sewage, as I believe, into the Mississippi River but I am not sure but what some of it goes into Lake Pontchartrain. Both of them however are bodies of fresh water.

Q. How about the District of Columbia?

A. That is a fresh water stream. The sewage is discharged into the Potomac.

Q. And where does the District get its supply of drinking water?

A. From the Potomac above Great Falls. That is far above the tidal portion of the stream.

Q. All these streams at Philadelphia and New Orleans, the District of Columbia, the portions of the stream into which the sewage is discharged are tidal portions, as you understand it, so the water at times is brackish?

A. At New Orleans, there is no effect of the tide. At the other places there is a tidal effect but the water is never brackish, for the reason that the fresh water pushes the salt water down the stream, except possibly in the case of Philadelphia. I am not fully informed as to that.

Q. Now in the case of Los Angeles where is the sewage discharged?

A. I am not certain at the present time whether it may not be carried down as far as the tide water and possibly into salt water. Formerly it was discharged, as I believe, into a stream that led to the tide water.

Q. Now, of the nineteen cities which you named, which ones are on inland rivers?

Mr. Austrain: You mean located on inland rivers?

Mr. Wilkerson: Yes, or so situated that an inland stream has to do with the drinking water and sewage problems.

Mr. Austrian: And by an inland stream do you mean a stream—

Mr. Wilkerson: Like the Mississippi.

Mr. Austrian: Or the Chicago River?

Mr. Wilkerson: No, I do not mean an inland stream running the wrong way from what it would run naturally.

Mr. Austrian: The Chicago River is certainly an inland stream. The Chicago River is not a manufactured stream; it is a natural stream. I do not mean to complicate it, but I do not quite understand what you mean by an inland stream.

Mr. Adcock: Most all streams are inland, aren't they?

Mr. Wilkerson: Q. In order that Mr. Adcock may understand the question I will call your attention to the cities of St. Louis, Pittsburg, Cincinnati and Minneapolis, and ask you to tell us what the facts are with reference to those cities as to the drinking water supply, and disposition of their sewage in its relation to the body of water.

A. St. Louis discharges its sewage into the Mississippi River. I do not know the details, as to whether any of it is discharged above the point of intake of the water supply.

Q. It takes its water supply from the Mississippi does it?

A. Yes. Pittsburg discharges its sewage into the Alleghany and Monongahela Rivers, and also into the Ohio River, which is formed by the confluence of the other two.

Q. Cincinnati?

A. Cincinnati discharges its sewage as I believe, into the Ohio River.

Q. Before we come to Cincinnati, where does Pittsburg get its water supply?

A. It gets it from the Alleghany River near the upper portion of the city of Pittsburg.

Q. Now Cincinnati?

A. Cincinnati takes its water supply from the Ohio River.

Q. And where does it discharge its sewage?

A. I believe it discharges it into the Ohio River, but I don't know the details as to where the outlets are.

Q. And Minneapolis?

A. Minneapolis discharges into the Mississippi River.

Q. And it gets its water supply from what river?

A. The Mississippi River above Minneapolis.

Q. Now let us take two larger cities; let us take Detroit and Buffalo. Give us the particulars about their supply of drinking water and sewage disposal.

A. The drinking water of Detroit is taken from the Detroit River and the sewage is discharged into the Detroit River, I presume, at a point below the place where the drinking water is taken. What is the other one?

Q. Buffalo?

A. Buffalo takes its water supply from Lake Erie. And its sewage is discharged into Lake Erie, or the waters that flow from it.

Q. Now take the remaining cities of these 19 and we have 3, do we not, which originally had the same problem; that is to say a city lying on the lake brim, with the lake as the source of water supply, and as the basin into which the sewage was discharged, Chicago, Cleveland and Milwaukee?

A. Yes.

Q. Of the 15 smaller cities of 146,000 population or more, how many of those discharged their sewage into salt water, or water usable as a water supply, either unusable as a water supply or unnecessary as a water supply, as for instance at Portland, Oregon?

A. I haven't the list of those cities with me.

Q. Now let us eliminate all cases where the potable quality of the diluting basin or stream is not involved for present use, or use in the near future, how many cities remain which are utilizing the dilution method without any treatment, either screening or purification of the sewage?

A. Doesn't that eliminate every case?

Q. In how many of the cities which you have named is the water with which the sewage is diluted used in connection with the water supply of that city?

A. In Cleveland.

Q. How about Milwaukee?

A. Milwaukee.

Q. Columbus?

A. That is not on my list.

Q. How about Rochester, New York?

A. In Cleveland and Milwaukee, of the nineteen larger cities.

Q. Do you know the facts about Toledo, Ohio?

A. I know that the sewage is discharged into the lake and the water supply is taken from the same lake.

Q. Now, is there any treatment of the sewage at Cleveland?

A. There is not so far as I know.

Q. Do you know as a matter of fact whether at Cleveland the hypochlorite treatment is in contemplation?

A. I think it has been in contemplation for the water supply.

Q. How about Milwaukee?

A. In Milwaukee, a report has recently been made by a

Sewerage Commission of three engineers, and they have proposed treatment of the sewage. I do not think there is any treatment at the present time.

Q. It is in contemplation, as you understand it?

A. Yes.

Q. Or under investigation? What is the practice as to the water supply and sewage disposal of Duluth?

A. I am not certain, from memory.

Q. West Superior?

A. I don't know about West Superior. It is the general custom of all those cities to take the water supply from the lake.

Q. Do you know the facts at Toronto?

A. To some extent; that the water supply is taken from Lake Ontario. I understand that it is filtered now, and the sewage is turned into the lake.

Q. Is the sewage screened or purified there, or the water supply treated chemically or filtered?

A. I think the water supply is treated by filtration. I don't know in regard to the sewage.

Q. Now you have spoken of the work which was done in this country in sewage purification prior to 1890. Is it not a fact that prior to 1890 the work done in England, Berlin and Paris, and in other places where the density of population had resulted in nuisance and unsanitary conditions, that this work was well known and had become accepted practice?

A. It was well known, but had hardly reached the point of being accepted practice. There was very frequent changes in methods, and different engineers had radically different views.

Q. It was undergoing what might be called a process of rapid development, was it not?

A. I should rather put it rather slow development at that time.

Q. Of course the terms "rapid" and "slow" are relative terms. What might be rapid for one thing would be pretty slow for another.

A. (No response).

Q. You are familiar with the reports of engineers Herring, Williams and Artingstall, made in January, 1887, to the Mayor and City Council of Chicago?

A. I knew about the report at the time, and I have read it once since.

Q. If you have a copy of the record in this case, you will

find it commencing on page 261 at the top of the page of the printed abstract of the record?

A. I haven't that with me.

Q. I will refer you to a particular part: I refer you to page 278 of the printed abstract of this testimony, as prepared by the counsel for the defendant in the case; the paging at the side is 861. I will ask you whether you have in mind the fact that those engineers outlined three feasible methods of disposing of the sewage.

Mr. Adcock: You mean whether they concluded that they were feasible?

Mr. Wilkerson: Three feasible methods, yes. I asked him whether he had that in mind in connection with his—

The Witness: Will I wait, and get it in mind?

Q. I wanted to know first whether you had it in mind when you testified on Saturday.

Mr. Adcock: Are you stating their conclusion?

Mr. Wilkerson: Q. I am quoting the language in the report in which these three distinguished engineers say: "We have outlined the main features of the only three feasible methods of disposing of metropolitan sewage."

A. I did not.

Q. I wish you would read that Mr. Stearns.

A. (After referring to same.) I have read it.

Q. Now, have you read that portion of the report in which after stating the features of the three different methods of disposing of the sewage, it is stated with reference to the proposed construction of the canal, "That this project is decidedly the least expensive one for the present, as well as for the future."

A. What is the reference to that?

Q. Page 280.

A. Yes.

Q. Are you familiar with the work of the three gentlemen whose names are signed to this report, Mr. Hering, Mr. Williams and Mr. Artingstall?

A. I am with regard to the work of Mr. Hering; not with regard to the others, except to a limited extent.

Q. He is regarded as an engineer whose opinion is entitled to some weight in your profession?

A. Entitled to great weight, but I should add that he had not the fact and information to base an opinion upon in 1887 that he would have at the present time.

Q. That is obvious.

A. Nor the experience.

Q. Is it your opinion that the trend of practice in sanitary science is towards the avoidance of the discharge of crude sewage into rivers, lakes, and even the sea?

A. The discharge of sewage has to be governed by local conditions, and a city that is situated upon the sea can discharge its sewage into the sea under many conditions. One situated upon the lakes may have to discharge it into the lake. The trend is not away from dilution, in my opinion.

Q. Is from it?

A. It is not away from dilution.

Q. It is not away from dilution. I am speaking of crude sewage now, which is not treated or purified in any way before it is turned into the lakes or rivers?

A. That is what I have in view. Perhaps, in order to explain a little more fully, I should say that the trend is quite decidedly in favor of purifying sewage in cases where it will cause a nuisance in a stream. That is people are not as ready to recommend creating a nuisance in a stream as they formerly were.

Q. That is to say if you have a stream where the amount of water available for diluting purposes is not sufficient to meet the requirements of the pure dilution method, the tendency is to treat the sewage in some way before it is discharged into the water, so that a given quantity of water will handle more sewage?

A. Yes.

Q. And that is a well recognized, and a very rapidly, or slowly developing branch of your profession is it not?

A. The growth of population on small streams is forcing the purification of sewage, in order to avoid a nuisance.

Q. That is to say the volume of the stream is not sufficient to handle the sewage?

A. Where the volume of the stream is not sufficient to properly dilute the sewage.

Q. And where you have a stream of that kind, even though the quantity of water available is rather small, it is recognized as a problem with which you may hope to cope successfully if the sewage is properly treated before it is turned into the water, is it not?

A. It can be coped with in practically all cases, if the treatment of the sewage is made adequate to the necessities of the case. That is I know of some very small streams which receive the effluent from sand filtration, where the sewage is almost perfectly purified, and no nuisance is caused.

Q. Are you familiar with the contemplated purification and screening of the sewage of Pittsburg?

A. I am familiar with the sewage problem in Pittsburg, but I don't think anything of that sort is contemplated at the present time. I was one of the Commissioners to report upon that case. I was very familiar with the Pittsburg case from having been engaged upon it, but do not know any such thing was contemplated. I understand it is not contemplated at present.

Q. Are you familiar with the method which is used for handling the sewage of London?

A. To a limited extent. I visited the chemical precipitation works at Barking.

Q. I wish you would describe that to us in a general way.

A. London provided many years ago a system of rather small intercepting sewers, which overflow into the Thames with any considerable storm. Whether they have supplemented those or not I do not know. My information dates back a number of years. This intercepted sewage from the combined system of sewers is carried, on the north side of the Thames, to Barking, which is quite a number of miles below the center of London; and there it was at that time treated with chemicals, to a rather limited extent. Then it is passed through settling basins in which the solids were supposed to settle, and did settle to a very considerable extent; and then the effluent flowed out, at a place where I saw it discharged, and it looked just about as bad as the sewage that was turned in. But evidently there was a large amount of solid matter taken out of the sewage at that place. This was pumped up by means of pumps into high tanks, and from them it was discharged into ships or lighters, ocean-going craft, that carried it down beyond the mouth of the Thames and dumped it into the sea.

Q. How long ago was this when you—

A. That was in 1899 that I made that visit. I have not been at the works since.

Q. Have you any information as to how many gallons they treated in London?

A. I think that substantially all of the dry weather flow, and while I am not sure what that is, it is approximately 250,000,000 gallons. I am judging that from the amount of the water supply.

Q. Do you know the cost per year per capita of treating that sewage?

A. No.

Q. Do you know the cost of the works?

A. No.

Mr. Adcock: Q. Was the purpose there to purify the sewage, or was it really to take the solids out?

A. It was to prevent a nuisance in the Thames.

Q. By simply taking the solids out?

A. Yes.

Mr. Wilkerson: Q. By purifying it, wasn't it?

A. It could hardly be called purifying. It was settling a part of the solids in these tanks, and the sewage went on with a very large part of the bacteria, disease germs, if there were any, in it.

Q. What are the conditions at Berlin?

A. I am not at all familiar with Berlin. I have not visited it. There was an irrigation farm there years ago, and it is still there so far as I know. Very extensive farm, on which the sewage was treated.

At that time the quantity of the water supply—and this dates back 25 years anyway—was about 30 gallons per inhabitant; a very small total quantity of sewage, considering the size of the city.

Q. They conserve their water; they do not waste it?

A. Yes, and do not use it very freely either.

Q. What are the conditions in Paris?

A. I am not familiar with any recent conditions in Paris. Years ago they irrigated to some extent, and to some extent filtered through sand, but the greater part of the sewage was turned into the Seine River.

Q. Now as to the purification of the supply of drinking water, is it not a fact that as early as 1890 water purification was practiced successfully, and on a large scale, in England and on the Continent?

A. It was practiced on a large scale, and I should also say successfully in England and on the Continent, but it was done by a rule of thumb method, rather than with a thorough knowledge of the processes. That is the knowledge of disease germs, and that they transmitted typhoid fever was rather limited at that time.

Q. But it was practiced?

A. It was practiced.

Q. You have stated certain conclusions as to the degree of dilution of crude sewage necessary to avoid offensive conditions, and as I remember, expressed the opinion that in the summer months at least, the legal requirement of the

Illinois law for the Drainage Canal is not sufficient. Did I understand you correctly?

A. Yes, it is nearly sufficient, but not in my opinion as much as it should be for the hot months.

Q. And in the winter months you think that a smaller amount of water could be gotten along with?

A. I think so at times, except when the streams are frozen over so that they will not take up oxygen from the air. It may be that fully as large a quantity would be required in winter, under those circumstances.

Q. What in your judgment would be the proper ratio for the month of August?

A. I have not definite enough information upon that to fix a definite quantity. I went over the canal in May, and I read the records of the absorption, of the reduction of dissolved oxygen, and it seemed to me that the quantity of water run was rather insufficient. There is no hard and fast line. It is a question of how much an odor coming from the water the communities below will stand. But it was my general judgment that it should be more than the quantity that is fixed by law.

Q. How much less could be gotten along with in January than in August?

A. As I have said, it might be necessary to have as much in January as in August, on account of the freezing over of the stream. There are some intermediate periods where less could be used.

Q. Take November.

A. But I have never attempted to define the amounts. I have not studied the question sufficiently.

Q. Of course by varying the amount which is used from month to month, the available supply of water could be still further conserved, could it not?

A. It could.

Q. That is, use less in one month than in others, and bringing the annual average up to a certain point?

A. That would be much better than to make a hard and fast rule of a uniform quantity throughout the year.

Q. You referred in your direct examination to the report of Mr. Wisner, the Chief Engineer of the Sanitary District. I wish you would refer to page 8 of that report, and notice particularly the paragraph on page 8 headed: "Condition of Canal." It says: "At present there is a large deposit of sludge in the forebay of the power house extending over two miles north to the controlling works and into the rock

section" and then further along it speaks of "Gas Ebullition." Were any of the offensive conditions which you noticed in those portions of the canal in which sludge deposits have formed, as stated in this paragraph?

A. The odor was most noticeable in the portion close to the Bear Trap Dam, and from there down to the power works, and especially where the water was going over the dam near the power house.

Q. Did these sludge deposits do you think have anything to do with the offensive condition of the canal?

A. Yes.

Q. If the sewage of Chicago were screened, a gain in the quantity of dilution necessary would be made?

A. I could not answer that question because I have not studied it.

Q. There would be a gain would there not?

A. Yes.

Q. That is to say if I understand you, if the sewage were screened, it would not require as much water to handle a given quantity of sewage as would be required if it were not screened?

A. Yes, if the screens were made fine enough to take out the solid matter.

Q. If, in addition, settling tanks were utilized to remove the finer suspended matter, would there be a still further gain?

A. The use of anything, either settling tanks or screens that would take out what I should call the coarser suspended matters would be a gain.

Q. If in addition to this the dry weather flow, and that of light rains, were adequately treated with hypochlorite, would that still further make a gain in the quantity of dilution that was necessary?

A. I do not know what the effect of hypochlorite would be upon the sewage effluent. I should think it might do harm as well as good.

Q. What would be the effect of proper treatment of the industrial waste of the Stock Yards District, assuming those great concerns were required to treat the matter before it was discharged into the sewer system?

A. When I examined some of those works, they were treating the industrial wastes, so that that treatment was already in effect.

Q. When you made your examination?

A. Yes.

Q. Do you know to what extent they practice it?

A. No, I saw them running the effluent through settling basins and taking off the grease and taking up some material from the bottom, which had settled.

Q. Of course the proper treatment of that by these great concerns is a factor in this problem?

A. Yes, if it can be accomplished.

Q. Right at the close of your testimony on Saturday, we had some figures in the record with reference to the cost per capita, on the assumption that 4,167 cubic feet per second would, under the Illinois law, take care of the requirements for a population of 1,250,000 people. I want to get that figure now, assuming that the cost of the canal was $40,000,000, how much would it be per capita?

Mr. Austrian: For how many inhabitants?

Q. For 1,250,000.

A. $32.

Q. $32 per capita?

A. Yes.

Q. And at a cost of $60,000,000, assuming the cost of the canal to be $60,000,000, it would be $48 per capita?

A. Yes.

Q. Do you know what the cost of the water supply of Chicago is compared with that of New York and Boston, to the people of the city?

A. No, except that it is less.

Q. The cost per capita in both New York and Boston is very considerably larger than it has been in Chicago, is it not?

A. I think so.

Q. But you do not have in mind the figures which would enable you to state that comparison with any degree of accuracy?

A. No.

Q. Or approximately so?

A. No.

Q. Let us assume Mr. Stearns that this canal with a flow of 4,167 cubic feet per second remains a part, a permanent part of the sewage disposal works of Chicago, having in mind the highest possible use of the canal as a sanitary canal purely, and having in mind the avoidance of offensive conditions to the health and well being of the people in the Des Plaines and Illinois Valleys, and at St. Louis, what use would you say should be made of that quantity of water, so that the utilization would be the highest possible? And let me direct

your attention in that connection to, first, the restriction of any water waste in the city of Chicago. What do you think could be done to reduce that?

A. In answer to the first question, if the City of Chicago were limited to that amount, a part of it should be used possibly to dilute crude sewage from those districts where it would be most difficult to purify it, and another part should be used to take care of the effluent from sewage which had been partially purified. But the quantity would be very inadequate, in my judgment, as an offhand judgment to prevent nuisance and trouble, or very undue and impracticable expense for purification of the sewage.

Q. What do you mean by "undue and impracticable expense"?

A. With so small a quantity of water, it might be necessary to go to an expense for sewage purification before the sewage was turned into the canal, which a city could not meet as a practical condition.

Q. If this quantity of water were utilized for the treatment of the sewage of a portion of the city, how could the sewage of the portions which were not included in that system be treated? Could you use sprinkling filters?

A. That would be one method.

Q. Could you use separate sewers in the unsewered portion of the city?

A. Yes, if it proved advisable, it could be done.

Q. And the sewage could be purified and discharged into the lake; that would be still another method?

A. I think it would be more advisable to turn it into the current running from the lake, in any case.

Q. Have you made any study of the hypochlorite treatment of water supply?

A. Not a special study. I have never applied it in any of my work, but I know it is used.

Q. Have you given consideration to the cost of the use of such a treatment of the water supply, as an accessory to a canal, with 4,167 cubic feet per second as the maximum limit?

A. Do you mean the treatment of the water supply taken from the lake?

Q. Yes?

A. I have not made any figures in regard to that.

Q. Is it not a fact that without screening, or sedimentation and chemical treatment, the water dilution of the Drain-

age Canal is not used with as high a degree of economy as is possible?

A. Yes.

Q. Without that, it is not being as economically used as would be possible if they did screen?

Mr. Adcock: You mean economy in the use of water?

Mr. Wilkerson: I mean economy in the use of the water of the lake for purposes of sanitation.

A. A smaller amount of water could be used if the sewage were treated and somewhat purified before being discharged into the canal, but that involves expense and difficulty, especially for the part of the sewerage system which is already established.

Mr. Adcock: Q. You are speaking now without reference to the run-off of the drainage area of the Chicago river in High water times, etc.

A. Yes.

Mr. Wilkerson: Q. Having in mind the fact that Chicago has been increasing very rapidly in population, even with an allowance of 10,000 cubic feet per second, Chicago is bound to be face to face with that question some time, isn't it?

A. Yes, it is practically face to face with that question now because in any question of improvement of conditions of sewerage, one has to consider the time necessarily used to produce those new conditions; and 10,000 cubic feet will be needed, even if works were to be started as soon as they could be under any municipal conditions; as soon as they have been, in any other city.

Q. And is it not a fact, without regard to what the difference in expense is, that the question of the use of 4,167 cubic feet per second, or the question of the use of 10,000 cubic feet, is entirely and absolutely one of cost?

A. No, that is not true, as I believe. The canal was built for 10,000 cubic feet a second, and I believe has a still larger capacity. And it was built to reverse the current in the Chicago River, so that that river which receives sewage should not be turned into the lake. And time is an important element in producing any change in sanitary conditions; and I do not believe that if the quantity were diminished to 4,167 cubic feet per second, that the city could catch up with those conditions, even. If the quantity had been fixed originally, they might possibly have purified the sewage to the extent so that they could get results from that quantity which were fairly satisfactory, except for the reversal of the river currents. There is a necessity for reversing, also, in ordinary

times, the current of the Calumet River, in my judgment, so that the ordinary flow of the Calumet River should not be into the lake.

Q. If the sewage were purified and the waste properly taken care of according to modern scientific methods, along the Calumet, would there be any necessity in your opinion of reversing the flow of the Calumet?

A. It would be very desirable.

Q. Well, would it be necessary?

A. Practically so.

Q. Is it your judgment as an engineer that there is no way of adequately taking care of the sewerage problem of the Calumet District, without reversing the flow of the Calumet River?

A. I consider it so highly desirable that I think it should be done. I think it is impossible to keep a river of that kind entirely pure. It is, I understand, impossible to prevent it from flowing into the lake at times, and as a sanitary measure it ought to be made to flow from the lake into the canal during as much of the year as is possible.

Q. In your answer to the question, do you have in mind the possible treatment of the water supply of Chicago by the hypochlorite method?

A. I know that that can be done, either by the hypochlorite method or by filtration.

Q. Isn't that the same question that Cleveland is confronted with today?

A. It is a similar question, I believe.

Q. And Cleveland is a larger city than the Calumet region of Chicago, is it not—has a larger population?

A. Yes.

Q. Will you refer to page 314 of the printed abstract of the testimony, to which reference has already been made this morning? Near the bottom of the page you will find the following statement which was made by Mr. Hering:

"I would say anybody taking a water supply from a river, and I even extend that to the lakes, where there is navigation or commerce, should have its supply filtered before use as a potable supply."

What is your opinion as to the correctness of that statement?

A. It is desirable that practically all water supplies should be filtered. It is a question of cost whether a community can afford to do it. They have to limit themselves on these matters because of the lack of cash. And I also notice that while

he says that "Anybody taking a water supply from a river, and I even extend it here to the lakes, should have its supply filtered," he also says: "I should hardly think it necessary for Chicago to filter the water at the present time. It is always desirable and important if you have the money to pay for it." That quite agrees with my mind.

Q. Speaking of the question of cost, which runs through this whole thing, is it not a fact, both with respect to water supply and sewage disposal, that the City of Chicago has its outfit at a very low expense, compared with other cities of the United States, when you take the two together, water supply and sewage disposal; that it is a cheap plant in both cases, compared with other cities?

A. I don't think that that is the case, because the sewage disposal at Chicago has cost a large sum of money, while in some other cities the question of sewage disposal has been a very limited one.

Q. How about water supply?

A. The water supply is small in Chicago, and all of the lake cities, as compared with cities like New York and Boston which are required to go long distances, and are compelled to build storage reservoirs and aqueducts. But leaving out those two cities, I think other cities have spent much less money for their sewage disposal and water supply combined, as for instance Detroit and Buffalo.

Q. I call your attention to the statement of Mr. Hering on page 316 of this record: "By settling the sewage, the 10,000 cubic feet per second would take care of approximately 4,200,000 people." I will ask you whether in your opinion that is a correct statement on that subject?

A. I don't know, but I should think it might be a reasonable statement.

Q. And it would be proportionately true for smaller populations?

A. Yes, I suppose it would hold good for smaller populations. I take it that this is assuming that the sewage is settled?

Q. Yes. As commerce grows, there is an increasing danger from the sewage which comes from navigation, is there not?

A. It depends on how it is regulated.

Q. In the lakes. What do you mean by "how it is regulated"?

A. Why, it would be entirely feasible, I think, to prevent that danger from navigation, to a very large extent.

Q. But without any such regulation, on the part of the Government, what then?

A. Without regulation, increase of navigation certainly would increase the danger.

Q. Speaking of the effect of the Des Plaines River, is it not your opinion that in order adequately to protect the cities along the Des Plaines and the Illinois and the Mississippi down as far as St. Louis, there should be some treatment of this sewage before it is discharged into the canal, even with a dilution of as high as 3½ cubic feet per thousand?

Mr. Austrian: We specifically object to that question, because it is not within the issues in this case.

Q. (Question read.)

A. There is no need of protection to those places, if there is an adequate supply of lake water to properly dilute the sewage. The question of using smaller quantities of lake water and treating the sewage is, to a considerable extent, an economical question as to cost; and, second, to a considerable extent a question of whether one would produce unsatisfactory conditions to other people.

Sewage cannot be treated by any method that I know of, without causing more or less odor and trouble. There is generally less in the dilution method than in any other method with which I am acquainted, when the amount of water is adequate.

Q. I direct your attention to page 322 of the printed abstract of the record, to a statement made by Mr. Hering as follows: "I think it would be safe to discharge the effluent of the sewage of a population of 1,200,000 people into Lake Michigan, after that sewage had been treated by the sprinkling filters, such as were designed and reported by me in the report to the International Waterways Commission in 1906. And today, in view of the comparatively slight cost, I would add the hypochlorite treatment, that is assuming no purification of the water supply." Do you agree with the conclusion of Mr. Hering?

A. I do not, wholly.

Q. In what respect do you not?

A. I do not favor the discharge of the sewage of a great population into a lake from which a water supply is to be taken, in any case.

Q. Without purification of the water supply, I assume?

A. Yes; and even then I would place the intakes of the water supply far from the place where the sewage is turned into the lake, if it were necessary. But it is very much bet-

ter from a sanitary standpoint that neither the sewage nor the effluent should go into the lake.

Q. I want to get your view as an engineer, Mr. Stearns, concerning certain conclusions of the Secretary of War, in connection with this case. He says, first, that this question at bottom is a question of cost. Do you agree with that?

A. To a considerable extent, but not wholly.

Q. He says that: "Other adequate systems of sewage disposal are possible, and are in use throughout the world." Isn't that true?

A. No; other systems which would have to be adequate if there were no means of doing better, but it does not seem to me they are adequate when something better can be done.

Q. He says: "The problem that confronts Chicago is not different in kind, but simply larger and more pressing than that which confronts all of the other cities on the Great Lakes, in which nearly 3,000,000 of this country are living." Is that a correct statement of the situation as you know it?

A. No, it is not, because the other cities on the lakes cannot divert their sewage away from the lake and necessarily have to put it into it, and do the best they can under the circumstances. But Chicago has the natural facilities, and also the works already built and paid for, through which they can do something better and different.

Q. He further says: "The urban population of those cities like that of Chicago is rapidly increasing, and a method of disposing of their sewage which will not injure the potable character of the water of the lakes must sooner or later be found for them all, and that includes Chicago." Isn't that true in your judgment?

A. I do not think it is, because I do not think that method has to be found for Chicago, and all the rest of the cities have got to get along with the best that they can do.

Q. It would have to be found for Chicago in time, even if they were allowed to take 10,000 cubic feet a second?

A. I do not think that is the case, because with 10,000 cubic feet per second they could continually discharge their sewage, or the effluent from sewage disposal works, into the canal, so that it would not go into the lake. So that as long as they can discharge 10,000 cubic feet a second away from the lake, they are not confronted with the same problem that the other cities are.

Q. Up to what limit of population do you think 10,000 cubic feet of water per second would take care of the sewage problem of Chicago, without making it necessary to purify

any of the sewage before it was permitted to be discharged into the lake?

A. To an unlimited extent, because with that quantity of water, as I conceive the case, it would always be possible to keep the sewage and effluent out of the lake.

Q. That is to say in your opinion, with 10,000 cubic feet of water per second taken out of Lake Michigan, a sewage system can be devised which will answer the requirements of Chicago permanently, and as far as it can reasonably be anticipated?

A. Yes. I am only comparing the two things, the one the case of discharging in the future into the lake, and discharging the effluent into the channel, if the city were permitted to take 10,000 cubic feet per second. That is, with 10,000 cubic feet per second, I should say by all means spend all the money that is required to purify the sewage, and put the effluent into the channel, rather than to purify it and put it into the lake. That is, of the two dilemmas the best thing to do would be to purify it and put it into the channel, with that quantity of water.

Q. What would you say if all they were allowed to take was 8,000 cubic feet per second?

Mr. Austrian: When, in the future?

Mr. Wilkerson: Permanently, indefinitely in the future.

A. I should advise that with any quantity of water, which would reverse the Chicago River and prevent it from going into the lake.

Q. And the amount that is necessary to do that is 4,157 cubic feet per second, isn't it?

A. No, it is a good deal more than that.

Q. I want to get your view: You advise the method of handling the sewage which you have indicated, where the permitted diversion from Lake Michigan was sufficient to keep the Chicago River running away from the lake?

A. Yes.

Q. That is the plain Anglo-Saxon of it, isn't it?

A. And the Calumet River to a limited extent.

Q. And the Calumet River to a limited extent?

A. Yes. By "limited" I mean ordinary flow.

Q. Why do you draw a distinction between the Chicago River and the Calumet River in that respect? Why wouldn't you recommend it for the Chicago River, even though the permitted diversion did this under ordinary circumstances?

A. The Chicago River is highly polluted and the sewers in large numbers discharge into it. While I have not inves-

tigated the Calumet region. I know it as a more sparsely settled place in which the sewage can be taken from the river, except to a limited extent. It will be impossible, I think, to keep it entirely clean.

Now, if by means of some moderate amount of diversion from the lake through that river the ordinary flow can be reversed, and by that means the water can be kept flowing from the lake into the river for, say 350 days in the year or 360 days, it is a great gain over having it run into the lake the whole 365 days in the year; and it would not mean, as I believe, a very large quantity of water. I do not know the amount, but the ordinary flow of streams is fairly small, and hence I think that there should be a reversal of that river for as much of the year as is practicable. The physical conditions are such that it cannot be reversed in the time of extreme flood.

Q. That is the Calumet?

A. Yes.

Q. Now I call your attention to another statement made by the former Secretary of War to this effect: "The evidence before me satisfies me that it would be possible in one of several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition." In your opinion as an engineer, is that an accurate statement of the situation?

Mr. Austrian: I object to the question, because it appears from the statement read by counsel that it is based on evidence presented to the former Secretary of War.

Mr. Wilkerson: I call your attention to the following statement: "It would be possible in one of several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition." Does that state the fact accurately?

A. Not wholly, because it makes no provision for the growth of the city. I suppose that may be intended. But it is true that if the sewage were purified and the effluent turned into the Chicago River, that less would be required per thousand of population than if the crude sewage were turned into the stream.

Q. Then there is this statement to which I call your attention: "A recent report of the Engineer of the Sanitary Commission, October 12, 1911, proposes eventually to use some such method, but proposes to postpone its installation for a

number of years to come, relying upon the present more wasteful method in the meanwhile. It is manifest that so long as the city is permitted to increase the amount of water which it may take from the lakes, there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage." Calling your attention to that statement, I will ask you whether you have given consideration to the report which is there mentioned?

A. I have read it.

Q. Have you considered the estimates of expense which are there made and the conclusions which are reached, and the recommendations which have been made?

A. I have not examined the estimates of expense with any care. In regard to the general recommendations that some purification can be accomplished in the future before turning the sewage into the stream, I have noted that.

Q. And do you agree with the conclusion that there should be some immediate steps taken towards this work of purification?

A. I think that the steps should be taken, as they have been, in getting the information necessary, and if there should be a restriction of the quantity of water from the lake, further steps would have to be taken.

Q. You made some estimates of the cost of providing a new sewerage system for Chicago, the estimates being based upon the comparison with the experience of other cities, as I recall it. Those figures were prepared upon the assumption, were they not, that Chicago did not have the 4,167 cubic feet of water from Lake Michigan, which it is now taking?

A. Yes.

Q. That is to say those figures were prepared on the assumption that it was allowed to take no water out of Lake Michigan?

A. Yes.

Mr. Austrian: You do not mean that.

Mr. Wilkerson: Yes, precisely.

Mr. Austrian: You mean not diverted by means of the Sanitary District. They would have to take some water out of Lake Michigan to run in the sewers.

Mr. Wilkerson: No water for sewage dilution.

Mr. Austrian: By means of a canal such as the Sanitary District Canal.

Mr. Wilkerson: Q. Please state just what the assump-

tion with reference to the taking of water from Lake Michigan was, upon which those figures were prepared?

A. It was assumed that no water would be taken from Lake Michigan for the purpose of diluting the sewage; that is that was assumed in my direct testimony.

Q. But you also assumed that the combined sewers could not be used, but would have to be replaced by a separate system?

A. Yes, that they could not be used for a complete purification of the sewage. I suggested different methods by which the sewage might be treated; and the one to which these estimates refer requires a separate system because it was the intention in that system to purify all of the sewage and not to allow a portion of it to run into the lake or river during storms, as it otherwise would.

Q. And you prepared no estimates, in which there was not the separate system of sewers?

A. Yes, I gave also an estimate for that condition, based upon the Pittsburg, Pennsylvania, estimates, using the same amount per capita.

Q. Just what would you do, Mr. Stearns, as an engineer, supposing you were told it was finally and definitely decided that the maximum amount of water which could be taken out of Lake Michigan was 4,167 cubic feet per second, and you were asked for an opinion as to what Chicago were to do for sewage disposal?

A. That is a question that would be very difficult to answer offhand, but so far as I now know I should favor utilizing any quantity of water for which permission might be given, that is any fairly large quantity of water, and keeping the sewage effluent away from the lake.

Q. You have no doubt the 10,000 cubic feet per second would be ample for that purpose?

A. I believe it is only a question of cost as to the quantity, when one gets up to say 10,000 cubic feet per second.

Mr. Adcock: That is for the Chicago River, you are speaking of?

Mr. Wilkerson: Both the Chicago and the Calumet.

Q. You had in mind the whole Chicago problem?

A. I had the whole thing.

Mr. Austrian: The Sanitary District.

Mr. Wilkerson: And you have no opinion as to whether there is any quantity between 4,167 and 10,000 cubic feet which would answer the requirements?

A. As an offhand judgment, I should say that 10,000 cubic

feet per second was the smallest quantity that was practicable and reasonable, and that it might be and probably would be advisable to furnish more water, having in view the value of the water for this purpose as compared with other purposes in connection with the lakes or the St. Lawrence River.

Q. And having in mind the question of expense?

A. Having in mind all the time the question of expense.

Q. Just one more question so that I may be sure there is no misunderstanding between us: That is when you reach the point where the water in the Chicago River flows away from the lake, then the extent of dilution of that for sewage disposal is one of expense?

A. I should add to that a small quantity of water from the Calumet, to reverse its ordinary flow.

FREDERIC P. STEARNS, recalled for further direct examination by Mr. Adcock and testified as follows:

Q. Mr. Stearns, since you were on the stand the last time, at the request of Mr. Shenehon, the Government's chief expert, I believe you furnished certain evaporation records and rainfall records to him, did you not?

A. I furnished certain records of rainfall and run-off.

Q. Rainfall and run-off?

A. I do not recall that I sent him any evaporation experiments.

Q. Will you state what records you have furnished him and what conclusions you had deduced from the additional records which you have considered since testifying on this subject before?

A. Shall I read these letters to him?

Q. I presume you might just give your data, etc., and your conclusions.

A. I sent him first the average rainfall and the run-off of various streams for a term of years. There was the Wachusett drainage area, in Eastern Massachusetts, where there was 16 years' records, and for the months from June to November, inclusive, of those years, the average rainfall was 22.70 inches. The amount of water running off in the streams collected, what is known as the run-off, was equivalent to a depth of 5.737 inches on the whole drainage area, including the reservoirs.

As a result of those two figures, I found that 25.2 per cent. of the rainfall was represented by the amount running in the

streams. Similar figures were sent for the Sudbury Drainage area, also in Eastern Massachusetts; one 38 year record covering the years 1875 to 1912 inclusive, with an average rainfall of 21.64 inches, an average run-off of 4.110 inches; the ratio being 19 per cent.

The years 1898 to 1912 inclusive are generally excluded from consideration, as the conditions for obtaining an accurate record during those years was less favorable than in previous years. Omiting these years, there is a record for 23 years, 1875 to 1897 inclusive; rainfall 22.608 inches, run-off 4.703 inches; per cent. of run-off 20.8.

I also divided this 23 year period into two parts. In the first 11 years, the rainfall was 21.612 inches, the run-off 3.709, making the per cent. 17.2.

In the second period of 12 years into which the 23 were divided, 1886 to 1897 inclusive, the rainfall was 23.523, run-off 5.615, per cent. 23.9.

Cochituate, Eastern Massachusetts, 50 year record 1863 to 1912 inclusive, rainfall 22.73, run-off 4.98; per cent. represented by run-off 22.0.

The Croton Drainage Area in Southeastern New York, the source of water supply for the City of New York, 32 years record, 1868 to 1899 inclusive, rainfall 25.04 inches, run-off 6.23 inches; per cent. of rainfall represented by run-off 24.8.

12 years record of the same drainage area, 1900 to 1911 inclusive rainfall 25.57 inches, run-off 7.01 inches; per cent. of run-off 27.4.

The Perkiomen, in Eastern Pennsylvania, this was one of three streams investigated for a water supply for Philadelphia; record of 13 years 1884 to 1897 inclusive, omitting the year 1889; rainfall 23.26, run-off 5.85, per cent. of run-off 25.1.

Neshaminy Eastern Pennsylvania, 13 years record, 1884 to 1897 inclusive, omitting 1899; rainfall 23.24 run-off 4.69, per cent. of run-off 20.2.

Tohickon, Eastern Pennsylvania, 13 years. 1884 to 1897 inclusive, omitting 1889. Rainfall 24.51, run-off 6.50, per cent. 26.6. The year 1889 was omitted from the record of these three streams, because of an abnormally large rainfall and consequently an abnormally large run-off. The average rainfall at those three places in 1889 was 44.56 inches for the six months under consideration; the average run-off 23.45 inches and the average per cent. of run-off 52.6.

That this rainfall was very abnormal is shown by the fact that the highest rainfall in any other year of the fourteen,

taking an average of the three places, was 27.37 inches as against the average of 44.56 inches the abnormal year.

I furnished also the information as to what the averages would be if that abnormal year was included. It seems to me unnecessary to put that in.

To show that a large rainfall generally results in a large percentage of run-off, and that the run-off is smaller when the rain-fall is lower, certain comparisons were made. First, Wachusett, the highest four years of the record above mentioned, the average rainfall was 54.48 inches, per cent. of run-off, 53.7. This is for the whole year and not for the months from June to November; lowest four years, average rainfall 38.65 inches; per cent. of run-off 44.2. The corresponding figures for other drainage areas: Sudbury, highest six years, rainfall 55.17 inches, per cent. of run-off 52.7; lowest six years, rainfall 36.39 inches, run-off 37.2 per cent. Croton, highest six years, rainfall 59.42, per cent. 53.8. Croton, lowest six years, rainfall 40.59, per cent. 45.7. Perkiomen, highest four years, rainfall 54.28 per cent. 52.6. Perkiomen, lowest four years, rainfall 42.29, per cent. 37.1. Neshaminy, highest four years, rainfall 54.23, per cent. 47.7. Neshaminy, lowest four years, rainfall 41.15, per cent. 44.4. Tohickon, highest four years 56.68, per cent. 58.5. Tohickon, lowest four years, 43.61, per cent. 50.3.

The four years period was selected in some cases and six years in others, in accordance with the length of the record. Where there was a long record, a longer number of years could be chosen for the high and for the low.

The next information sent Professor Shenehon referred to various streams of which I had learned the run-off, as compared with the rainfall in recent years. The first series referred to the discharge of a number of streams in Western Pennsylvania; and in that case I was endeavoring to ascertain the run-off in different months of the year per square mile of drainage area, in connection with investigations for a hydro-electric plant. I studied all of the streams, and got their records in that section of Pennsylvania, and in the Northern part of West Virginia, although I did not use the West Virginia records. And from all of those observations, I determined in accordance with my judgment the run-off of a stream where the hydro-electric power would be located. And what I am giving is not the actual record of any one stream, but my determination made at that time for that purpose. It covers the years 1902 to 1911 inclusive. The rainfall was not the rainfall at a given place, but the average of a

number of places, so as to get the general conditions for that section of Western Pennsylvania.

The streams referred to were in the Allegheny basin, Pennsylvania: Crooked Creek, Black Lick Creek, Kiskiminetas Creek, Allegheny River at Red House, Allegheny River at Kitanning, Clarion Creek, Mahoning Creek, Tionesta Creek, and Broken Straw Creek, Kinzua Creek, and the Quemahoning River. It is not necessary, I think, to mention three other streams in the Monongahela Basin, because they were used to so small an extent.

The final result of this study was that in the year 1902, the rainfall for the six months from June to November inclusive was 23.83 inches, the run-off 8.81 inches and the per cent. of rainfall represented by the run-off 37.0.

The corresponding figures for the succeeding years are:

Years.	Rainfall inches.	Run-off.	Per Cent.
1903	25.77	7.04	27.3
1904	17.84	5.07	28.4
1905	28.05	10.20	36.3
1906	23.24	6.24	26.9
1907	24.04	8.25	34.3
1908	12.74	2.16	17.0
1909	17.42	3.03	17.4
1910	18.00	2.94	16.3
1911	29.27	9.49	32.4

I was engaged by the Manufacturers' Water Company of Johnstown, Pennsylvania, in the building of a dam on the Quemahoning River, and obtained from the company while I was there a series of records of the run-off of the river. That series is as follows:

Years.	Rainfall inches.	Run-off.	Per Cent.
1902	22.10	6.50	29.4
1903	24.80	5.83	23.5
1904	19.79	3.04	15.4
1905	32.18	11.31	35.1
1906	25.80	6.70	26.0

I am Chairman of the Committee on the yields of drainage areas of the New England Water Works Association, and quite a series of reliable records covering the years 1908 to 1911 have been sent in to the Committee, and I have had occasion to study them.

The first three streams of this group are the Esopus Creek, Rondout Creek and Schoharie Creek, which were measured

by the city of New York. They are located in the Catskill Mountains, and one of them at present, and the others later, are to be sources of water supply for the city of New York.

Mr. Wilkerson: This testimony about these records is all subject to our objection and right to call for the original data, just as you called for these Niagara measurements.

Mr. Adcock: I assume so, certainly. I presume that Mr. Shenehon has probably checked them up already.

Mr. Wilkerson: I mean if we want to check them over.

Mr. Adcock: Yes.

The Witness: The discharge of Esopus Creek should be particularly good; that is, in other words, the measurement should be especially accurate, because a weir has been built for measuring the discharge, and the measurements are under the direct control of the engineers engaged upon the construction of the new works for the city of New York.

The drainage area in this case is 239 square miles, and there are at present no reservoirs upon it. The statistics are as follows: (This is for the same six months.)

Years.	Rainfall inches.	Run-off.	Per Cent.
1907	31.92	15.293	47.9
1908	17.89	3.979	22.2
1909	18.82	3.434	18.2
1910	20.47	4.043	19.8
1911	29.21	11.238	38.5

The records for Rondout Creek, which has a drainage area of 105 square miles are:

Years.	Rainfall inches.	Run-off.	Per Cent.
1907	30.19	11.458	38.0
1908	16.52	2.537	15.4
1909	17.59	3.164	18.0
1910	20.43	4.473	21.9
1911	29.68	11.316	38.1

Schoharie Creek, which has a drainage area of 240 square miles, the record is as follows:

Years.	Rainfall inches.	Run-off.	Per Cent.
1907	27.09	13.398	49.5
1908	16.47	2.362	14.3
1909	15.32	2.175	14.2
1910	18.76	4.891	26.1
1911	22.19	7.885	35.5

The next statistics relate to Abbott Run watershed, which

has a drainage area of 26.94 square miles, and is situated in Rhode Island near the Massachusetts boundary.

Years.	Rainfall inches.	Run-off.	Per Cent.
1907	26.10	7.63	29.2
1908	18.40	3.42	18.6
1909	15.75	2.15	13.7
1910	14.26	1.59	11.2
1911	24.83	4.90	19.7
1912	16.10	2.32	14.4

Manhan River drainage area 13 square miles, situated in Massachusetts west of the Connecticut River.

Years.	Rainfall inches.	Run-off.	Per Cent.
1899	18.92	2.92	15.4
1900	18.02	3.26	18.1
1908	15.69	3.77	24.0
1909	17.00	3.18	18.7
1910	19.23	4.09	21.3
1911	31.09	9.88	31.8

Tillotson Brook drainage area 5.84 square miles, situated near the Manhan River.

Years.	Rainfall inches.	Run-off.	Per Cent.
1908	16.88	4.12	24.4
1909	18.48	3.67	19.9
1910	19.16	4.05	21.1
1911	33.40	7.86	23.5

In all of the foregoing records where there are reservoirs for water supply, the measurement does not take the quantity of water that runs in each month from the reservoir, because that would be a nearly uniform quantity, on account of the water stored in the winter and spring for use in the summer; but the effect of storage, so far as it relates to the quantity of storage, is eliminated by the computations so that they represent the natural flow of the stream with the exception of the evaporation from the surface of the reservoirs; and no correction is made for that.

There is one other record of the Merrimack River at Lawrence, Massachusetts, which has a drainage area of 4452 square miles. In this case the effect of storage reservoirs could not be eliminated and hence the run-off during the summer months, during the six months in question, is somewhat greater than the natural flow of the stream, as there are quite a large number of mill reservoirs, and one lake of 36 square

miles upon it used to store water and let it down in the summer. It would affect the results, so there should be a correction for that. In other words, the per cent. of run-off should be somewhat less than the figures shown by the records.

Years.	Rainfall inches.	Run-off.	Per Cent.
1908	13.96	3.611	25.4
1909	15.99	3.339	20.9
1910	16.36	3.488	21.3
1911	21.98	4.015	18.3

In a subsequent letter to Professor Shenehon, dated October 3rd, I sent him the details for the six months of each year for the rivers Perkiomen, Neshaminy and Tohickon, where before I had given only the average results; and these rivers are shown in the following tables:

Perkiomen.

Years.	Rainfall. inches.	Run-off.
1884	23.07	5.66
1885	19.32	4.06
1886	20.76	5.37
1887	23.96	5.71
1888	26.60	9.57
1890	24.66	7.62
1891	26.47	5.94
1892	20.39	5.04
1893	22.38	5.15
1894	24.17	7.23
1895	17.13	2.07
1896	29.67	7.02
1897	23.76	5.34

Neshaminy.

1884	20.76	2.30
1885	21.47	2.81
1886	20.27	2.53
1887	26.85	5.47
1888	26.01	7.03
1890	24.51	5.48
1891	23.98	4.91
1892	21.71	3.25
1893	23.28	5.44
1894	25.40	7.94
1895	17.62	2.31
1896	23.45	5.06
1897	26.76	8.61

Years.	Tohickon. Rainfall. inches.	Run-off.
1884	25.49	7.88
1885	21.31	4.48
1886	20.15	4.31
1887	25.90	5.71
1888	29.00	11.83
1890	25.69	7.99
1891	26.93	7.02
1892	21.87	4.99
1893	26.13	6.16
1894	24.58	8.95
1895	19.08	1.74
1896	26.34	7.43
1897	26.10	7.10

I have reached certain conclusions from the records of which copies were sent to Professor Shenehon, and which have just been referred to. And before giving the results I may recall the past testimony. In last March, referring to tables A to G, of Stearns' Exhibit Number 1, I stated on page 1256 that I assumed on the basis of past experience that during the months from June to November inclusive 21 per cent. of the rainfall upon the land surface which forms the local drainage area of Lake Ontario would find its way into the lake, through streams or by percolation. The corresponding figure for Lakes Erie and St. Clair (See page 1262) is 20 per cent.

At the time tables A to G were made up in New York, I had to use my best judgment as to the percentages which should be used, because statistics of run-off were not available at that time; but I stated (See page 1257) that the per cent. was based on my memory and that "I could furnish, if necessary, a large amount of material bearing upon that point." And it is this material that has just been entered in the record.

I also stated (Pages 328 and 329 top paging, 1274 and 1275 bottom paging) that it was not necessary to determine the per cent. of run-off with great accuracy, in order to obtain a substantially accurate ultimate result.

As an illustration of the last statement, I testified on page 1275 to the effect that an error of 14 per cent. in determining the run-off from the drainage area of Lake Ontaria would result in an error of only 1 per cent. of the whole quantity of water discharging into and from the lake.

The rainfall and the per cent. of run-off that has been given in these records shows a wide variation; but is a vari-

ation in accordance with the law that the larger the rainfall, the larger will be the per cent. of run-off. And in order to apply those results to Lakes Erie and St. Clair, and to Lake Ontario, it is necessary to ascertain as well as can be from those records, what the run-off would be with the rainfall upon the drainage areas of the lakes under consideration. The average rainfall on the drainage areas of Erie and St. Clair, including the lakes, during the six months under consideration, as taken from the table in the report of the Chief of Engineers for 1903, Part 4, Appendix FFF, Page 2879, is 17.47 inches; on the drainage area of Lake Ontario, including the lake, 19.97 inches.

Where there is a record covering a series of years with high rainfall and with low rainfall, they can be divided into two groups, and I have divided them in each case where the rainfall is 22 inches, with one exception, where I made the dividing line 22.1 inches, as that gave me two observations in the lower group where otherwise I should have had only one.

As an illustration, I took the ten year records of streams in Western Pennsylvania, and there was six years in which the rainfall was more than 22 inches. Averaging these years of what I wil call high rainfall and also the run-off, I obtained rainfall 25.70 run-off 8.34, per cent. 32.4. For the four years when the rainfall was less than 22 inches, I obtained as an average rainfall 16.50, run-off 3.30, per cent. 20. This gives the run-off in per cent. corresponding to two rates of rainfall, and it is only a matter of simple proportion to deduce the per cent. of run-off for other rainfalls.

The result of such simple computations shows that upon the basis of the ten year records referred to, the per cent. of run-off for 17.47 inches, which is the rainfall for Erie and St. Clair would be 21.3 and for the Lake Ontario rainfall of 19.97 inches, the deduced per cent. of run-off would be 24.8.

Treating each of the other records which I have given, in the same way, with one exception, I obtained results as follows:

Name of stream.	No. of years covered by records.	Deduced per cent. of run-off.	
		Lake Erie and St. Clair.	Lake Ontario.
Western Penn. streams	10	21.3	24.8
Quemahoning River, Pa.	5	19.7	21.9
Esopus Creek, N, Y.	5	16.8	21.9
Rondout Creek, N. Y.	5	17.5	21.6
Schoharie Creek, N. Y.	5	20.6	28.1
Abbott Run, R. I.	6	16.1	18.8
Manhan River, Mass.	6	19.0	21.4
Tillotson Brook, Mass.	4	21.6	21.9
Perkiomen Creek, Pa.	13	19.5	21.8
Tohickon Creek, Pa.	13	12.8	17.6
Average		18.5	22.0

The above tabulation does not include the records of certain streams, for these reasons: The Wachusett, Sudbury, Cochituate and Croton Rivers were excluded because the storage reservoirs upon them cover so large an area that the per cent. of run-off during the six months under consideration would be less on account of the evaporation from the large water surfaces than from drainage areas which did not have large reservoirs upon them, making the results somewhat inapplicable to such drainage areas as those of Lake Ontario, and Lakes Erie and St. Clair. The difference is only small, and if allowance were made for evaporation from the reservoirs the results would coincide very closely; but there is considerable labor in making the computations for evaporation, and I did not attempt to do it. I know that they confirm the results obtained from the others.

The records of the Merrimack River were excluded because the discharge of the stream is augmented by water drawn from storage reservoirs as I have already described, and consequently it would be slightly too large. But still it confirms the others within a small percentage.

The Neshaminy Creek, Pennsylvania, was excluded because the results differed greatly from those obtained from the ten sources referred to in the table. It seems probable that those results are in error by reason of underground percolation during the drier portions of the year. It is often the case where streams are rather steep and the ground is gravelly or

sandy, that a part of the flow passes underground and would not be measured at the weir erected for the purpose of measuring flow. I do not know whether that is the case here or not, but it was far away from the others, the deduced percentages for Lakes Erie and St. Clair being 5.4, and for Lake Ontario 11.9.

I have stated in my testimony that I adopted originally 20 per cent. as the run-off from the drainage areas of Lakes Erie and St. Clair; and I should now, with this information before me, adopt 18.5 per cent., and for Ontario I should now adopt 22 per cent. instead of 21.

These changes would affect the final result only a fraction of 1 per cent.

Mr. Wilkerson: You mean 1 per cent. of the run-off?

A. No, 1 per cent. of the total result in the flow of the Niagara and St. Lawrence Rivers. I said less than 1 per cent.

Mr. Adcock: Have you considered any records of evaporation, to determine the amount of evaporation upon the lake surfaces of Erie and Ontario and St. Clair?

A. I have.

Q. State what records you have considered, and the conclusions that you have reached.

Adjourned to Wednesday October 15, 9:30 A. M.

Wednesday October 15, 9:30 A. M.

Met pursuant to adjournment.

Mr. Shenehon: In a statement made yesterday, in response to a suggestion that the equation used by me in computing the discharge of Niagara River in U. S. Exhibit M, reference was made to a 1912 Report. This is the Report of Mr. Sherman Moore, Assistant Engineer; and it was stated that a blue print showing the curves of discharge for the condition of the outflow by the St. Lawrence River prior to the building of the Gut Dam in 1903 and after that time had been made. It was also stated that the annual report of the Chief of Engineers for 1912 showed the equation indicated on the blue print for that period of time after the building of the Gut Dam.

On reference to the annual report of the Chief of Engineers, Appendix FFF referring to the Northern and Northwestern Lakes, on page 3547, I find that the equation given, the second

one from the bottom, has a broken type where the exponent should be outside the parenthesis. Three halves is the power indicated, or the exponent indicated.

In the last equation, St. Lawrence River for 1908 to 1911, the exponent does not appear at all. It should have a three halves exponent outside the parenthesis.

Mr. Williams: The St. Clair should have an exponent also, one half.

Mr. Shenehon: No reference was made to that.

Mr. Williams: I will make the statement from the authority of Mr. F. G. Ray, principal assistant engineer United States Lake Survey, for the Lake St. Clair, for the river, the last quantity in the parenthesis, Ft. Gratiot minus St. Clair Flats should have an exponent of one half.

Mr. Shenehon: You had these corrections.

Mr. Williams: I had the corrections, yes. I would like to make a request now for a copy of that sheet; also I would like a copy of Mr. Moore's full report, as the observations were only part of them published, I believe. His observations in 1912 have not yet been printed. I find those of 1908 and 1909.

Mr. Shenehon: I believe the report is unpublished.

Mr. Williams: We would like a copy of that report.

FREDERIC P. STEARNS, Resumed.

(Last question read)

The Witness: I testified in this case as to the probable amount of evaporation from Lakes Erie and Ontario during the months from June to November inclusive; the testimony being based, as stated, on my previous studies of the temperature of small lakes and reservoirs and of evaporation. The testimony was to this effect: That the temperature of water is the most important item affecting the amount of evaporation. (See page 1236.) And that there were other features affecting the amount of evaporation, namely the relative humidity of the air and the force of the wind.

Subsequently attention was called on page 1251, to the fact that the items, relative humidity and force of wind had no importance in a comparison between the evaporation from Lakes Erie and Ontario, because both of these features were so nearly the same at the two lakes, leaving only the temperature of the water as the important item affecting the amount of evaporation from these lakes.

My testimony also stated (see page 1237) that the temperature of water depended only to a very limited extent upon the depth of the reservoir, in reservoirs of the size with which I was especially acquainted. But on page 1260, the testimony states that I had not taken into account the difference in the depths of Lakes Erie and Ontario in connection with the amount of evaporation, because it did not seem to me that it was material, for the reason that the temperature of water in cases where I had knowledge of such temperature followed closely the temperature of the air.

On page 1254, I described the method of obtaining the probable evaporation from Lake Ontario for the six months from June to November inclusive, and adopted as the total amount of evaporation for those months from that lake 21.8 inches.

On page 1259, I adopted as the corresponding evaporation from Lakes Erie and St. Clair 24.4 inches. All of these determinations were made at a time when I did not have access to the records of the temperature of the water of these lakes, and also I did not have available evaporation records which are now available.

In the line of new information, I found extended records of evaporation at the Mt. Hope Reservoir of the Rochester, New York, Water Works. The experiments for the warmer months cover 17 years from 1891 to 1907, and for the colder months 12 years from 1896 to 1907. The more trustworthy experiments appear to be those made in a tub floating in a reservoir and the corresponding mean temperature of the water in the floating tub is given. The mean humidity of the air during these years was 73.8 per cent., or substantially the same as at Lakes Erie and Ontario. The average velocity of the wind in the last two years at the evaporation tub, taken 4 feet 5 inches above the water surface, was 6.2 miles per hour, or about 59 per cent. of the average velocity of the wind at Lakes Erie and Ontario.

An examination of these records shows, as do other records of evaporation, that with a given temperature of water there is more evaporation during the months when the temperature is increasing; that is, during the months of April, May and June, than in the months when the temperature is decreasing; as for instance, August, September and October. Upon the basis of these records, the number of inches of evaporation corresponding to a given water temperature may be computed with sufficient exactness for the present purposes by subtracting 24.5 degrees from the water temperature and multiplying

the remainder by .103. This rule may be expressed by the formula E=T—24.5×.103, in which E equals evaporation and T, the temperature of the water in degrees Fahrenheit.

A copy of these records and a comparison with the evaporation as computed by the above formula is shown in the following table:

Rochester Evaporation Records.

Month.	Temperature of water (Degrees Fahrenheit)	Evaporation as recorded (inches)	Computed evaporation (inches)	Difference of computed from observed evaporation (inches)
Jan.	32.8	0.75	0.86	+0.11
Feb.	32.4	0.79	0.81	+0.02
Mar.	36.4	1.44	1.23	—0.21
Apr.	46.5	2.61	2.27	—0.34
May	58.6	3.74	3.51	—0.23
June	67.9	4.52	4.47	—0.05
July	72.3	5.14	4.92	—0.22
Aug.	71.3	4.86	4.82	—0.04
Sept.	65.6	3.86	4.23	+0.37
Oct.	53.6	2.74	3.00	+0.26
Nov.	42.8	1.52	1.89	+0.37
Dec.	34.3	1.16	1.01	—0.15
Total and averages,	51.2	33.13	33.02	—0.11

It may be noted that Table 62 of Williams' Exhibit 34 is a transcript of the published records of the evaporation experiments at Mt. Hope Reservoir, Rochester.

As already stated, and as shown by the table submitted by me, a given water temperature causes more evaporation when the temperature is rising than when it is falling. It is therefore feasible to deduce a somewhat different rule or formula, which will express better than the one already given the evaporation during the months from June to November inclusive. This formula is: E=T—30×.118.

Other evaporation experiments have been made at the University of North Dakota, and the results for the years 1905 to 1911 inclusive, are given in the Water Supply Papers of the United States Geological Survey, of the following numbers and pages: Number 245, pages 66 and 67, number 265 page 74, number 285 page 74, number 305, page 53.

In this case, as at Rochester, the evaporation of water from a floating tank was determined. The tank was in the center of a raft in a pool on a small stream which runs through the campus of the University of North Dakota, immediately west of Grand Forks and two miles west of the Minnesota boundary. The water temperature is the temperature observed at about six P. M. The observations are reasonably complete only for the months from May to October, inclusive.

A formula has been deduced to cover the amounts from June to November, inclusive. It is E=T—27×.114. A copy of the records from June to October inclusive, and a comparison with the evaporation as computed by the above formula is shown in the following table:

University of North Dakota Evaporation Records.

Month.	Temperature of water. (Degrees F.)	Evaporation as recorded. (Inches)	Computed evaporation. (Inches)	Difference of computed from observed evaporation. (Inches)
June	67.0	4.51	4.56	+0.05
July	73.0	5.82	5.24	—0.58
Aug.	69.6	4.60	4.86	+0.16
Sept.	59.5	3.51	3.70	+0.19
Oct.	45.0	1.92	2.05	+0.13
Totals and averages,	62.8	20.36	20.41	+0.05

The evaporation experiments at Chestnut Hill near Boston have already been described in my testimony. The formula representing the results of these experiments for the whole year is E=T—22×.110.

The recorded evaporation for all months of the year and a comparison with the evaporation as computed by the above formula is shown in the following table:

Chestnut Hill Evaporation Records.

Month.	Temperature of water (Degrees F.)	Evaporation as recorded. (Inches)	Computed evaporation (Inches)	Difference of computed from observed evaporation. (Inches)
Jan.	32.0	0.96	1.10	+0.14
Feb.	32.0	1.05	1.10	+0.05
Mar.	36.7	1.70	1.62	—0.08
Apr.	44.3	2.97	2.45	—0.52
May	57.7	4.46	3.93	—0.53
June	67.9	5.54	5.05	—0.49
July	73.7	5.98	5.69	—0.29
Aug.	72.9	5.50	5.60	+0.10
Sept.	66.9	4.12	4.94	+0.82
Oct.	55.2	3.16	3.65	+0.49
Nov.	44.1	2.25	2.43	+0.18
Dec.	36.1	1.51	1.55	+0.04
Totals and averages,	51.6	39.20	39.11	—0.09

To apply these various formulas so as to determine the evaporation from Lakes Erie and Ontario for the months June to November inclusive, it is necessary to know the temperature of the surface water of these lakes. Such records in the cases of Lakes St. Clair and Erie have been kept by the United States Lake Survey and at the Water Works Pumping Stations at Detroit and Cleveland; on Lake Ontario they were kept by the United States Lake Survey. I have here a table giving the average temperatures of surface waters of the Lakes under consideration for the months from June to November inclusive, in degrees Fahrenheit. It is as follows:

Average Temperatures of Surface Waters of Lakes for the Months from June to November, inclusive, in Degrees Fahrenheit.

Lake.	Authority.	Mean Temperature.
St. Clair	United States Lake Survey records, 1905-06. Williams' Table LXI c, sheet 4, and diagram furnished by F. C. Shenehon.	61.9
St. Clair	Detroit Water Works Pumping Station, July, 1907, to June, 1910. Williams' Table LXIb, Sheet 3.	61.7
	Average of above, adopted as temperature of Lake St. Clair.	61.8
Erie	United States Lake Survey records, as given in Williams' Table LXIc, Sheet 5, and diagram furnished by F. C. Shenehon:—	
	Toledo Harbor Light Station, 1905-07.	63.4
	Southeast Shoal Light Vessel, 1905-1906.	64.6
	Horse Shoe Reef Light Station 1905-08.	62.1
Erie	Temperature by United States Lake Survey Records, average of all observations	63.1
Erie	Cleveland Water Works Pumping Station 1907-11, Williams' Table LXIV, Sheet 4.	63.0
Erie	Cleveland Water Works Pumping Station, 1906-10; taken from Annual Reports of Water Works Division, Department of Public Service, Cleveland, by F. P. Stearns.	63.2
	Adopted as average mean temperature of Lake Erie.	63.1
Ontario	United States Lake Survey Records, 1905-06. Williams' Table LXIc, Sheet 6, and diagram furnished by F. C. Shenehon. Charlotte Light Station, omitting the observations in July and August, 1906, because of their great variation from observations at the Galloo Island Light Station and from the usual temperatures during these months.	59.8
	Galloo Island Light Station.	60.4
	Average temperature of Lake Ontario by United States Lake Survey records.	60.1

By giving due weight to the much larger size of Lake Erie as compared with Lake St. Clair, the mean temperature of the water of Lakes St. Clair and Erie combined during the months from June to November inclusive is 63.0 degrees. The mean temperature of Lake Ontario during these months is, as above stated, 60.1 degrees. With these temperatures and the formulas for evaporation already given, it is feasible to compute the number of inches of evaporation from each of these lakes during these months, and this is done in the following table:

Evaporation in Inches, June to November, Inclusive, from Lakes St. Clair and Erie and Lake Ontario, by the Various Formulas Already Given.

Formula based on	Computed evaporation from Lakes Erie and St. Clair.	Computed evaporation from Lake Ontario.	Difference.
Rochester records for whole year (E=T—24.5×.103)	23.8	22.0	1.8
Rochester records June to Nov., (E=T—30×.118)	23.4	21.3	2.1
University, North Dakota records, June to Oct., (E=T—27×.114)	24.6	22.6	2.0
Chestnut Hill records for whole year, (E=T—22×.110)	27.1	25.1	2.0

All of the comparisons given in the tables show that the excess of evaporation from Lakes Erie and St. Clair over the evaporation from Lake Ontario during the six months under consideration is substantially two inches. In my previous testimony, I had adopted 24.4 inches as the evaporation from Lakes Erie and St. Clair during these six months and 21.8 inches as the evaporation from Lake Ontario for the same period, making the difference between the two 2.6 inches.

On the basis of the new determinations, and taking into account the greater applicability of the Rochester records on account of the location of Rochester upon the drainage area of Lake Ontario, I have no reason to change the amount of evaporation previously adopted, namely 21.8 inches. With the added information now available, I should adopt for the

evaporation from Lake Erie 23.8 inches instead of 24.4 inches, as stated in my previous testimony. It is not certain that these are the exact amounts of evaporation from a Great Lake, because there may be a greater humidity of the air immediately over a great lake than over the small bodies of water where the experiments have been made, but whatever this effect is, it is the same for each of the lakes. All of them are subject to that condition of the greater humidity of the air immediately over the lake.

On the other hand, large lake surfaces are very much disturbed by waves caused by wind and oftentimes spray is thrown up into the air, thereby increasing the evaporation; and it may be that the effect of waves in increasing the evaporation offsets the greater humidity. The point I wish to make clear is that neither of these causes has any material effect upon the relative amount of evaporation from the two lakes.

Q. Now from your examination of the records of evaporation, which you mentioned and per cent. of run-off, have you reached any conclusion from these new records which would change your previous deductions? If you have state what the conclusions are?

A. I have reached conclusions which I will explain, and they do not change the final results.

Q. That is the final results as stated in the tables in your testimony that you gave in New York?

A. Yes.

Q. In March, I think that was?

A. Yes.

Q. Is there anything you would like to say in explaining the results of these new records?

A. Yes. Slight changes have been made both in the percentage of run-off and in the evaporation from Lake Erie. The change in the percentage of run-off from Lakes Erie and St. Clair amounts to 1200 cubic feet per second, but the change in the evaporation off-sets this 1200 cubic feet to the extent of 900 cubic feet, leaving a net decrease in the local supply to Lakes Erie and St. Clair, during the years under consideration, of 300 cubic feet per second.

According to my former testimony, the difference between the discharge of the Niagara as deduced from the St. Clair measurements, and from measurements made at Niagara was 20,700 cubic feet per second, which should be diminished by the 300, leaving 20,400 cubic feet per second.

The correction due to the change in the per cent. of run-off into Lake Ontario required a correction of 750 cubic feet per second, and reduced a discrepancy formerly estimated as 16,230 cubic feet per second to 15,480 cubic feet per second.

The average of these two corrected results is 15,480 plus 20,400, divided by 2, equals 17,940 cubic feet per second as the present amount of the discrepancy.

My former testimony made the amount 18,465 cubic feet per second, which I called in round numbers 18,000 cubic feet per second, and that is almost precisely the amount now determined, so that the former testimony does not require correction.

Recess to 1:30 P. M.

After recess 1:30 P. M.

FREDERIC P. STEARNS:

Direct Examination Resumed.

Mr. Adcock: Q. Mr. Stearns, I show you four charts which are marked Charts 1, 2, 3 and 4, respectively, and ask that they be marked Stearns' Exhibit 2; (chart so marked) also table which may be marked Stearns' Exhibit 3 (table so marked); and ask you to explain these charts and the table; how they have been prepared by you; also to explain what they show.

A. Chart number 1 of Stearns' Exhibit 2 is a plotting of the figures contained in Stearns' Exhibit Number 1, Table C. On the chart there is a scale, on the left, which shows the elevation of Lake Erie, the Buffalo gage, and the elevations are taken from the report of the International Waterways Commission on the Regulation of Lake Erie for 1910.

Q. That is the elevation as shown by the International Waterways Commission report?

A. Yes.

Q. Why did you chose those elevations in preference to the Lake Survey elevations?

A. They were taken in the first instance as being the most convenient elevations, and in view of the statement made here yesterday by the Government's Chief Expert, Mr. Shenehon, a comparison was made between the heights at Cleveland and at Buffalo, using both the records of the International Waterways Commission, and the United States Lake Survey. This

is for the years from 1890 to 1907. At Cleveland, the two records are practically identical. At Buffalo, from 1890 to 1898, the records of the International Waterways Commission are .1 foot lower than the records of the United States Lake Survey. And it is stated in the report of the International Waterways Commission above referred to, page 94, that their records were derived from the United States Lake Survey tables by subtracting .1 of a foot from the records there given.

Comparing the results given in the report of the International Waterways Commission of Cleveland and Buffalo, the lake elevations at Buffalo from 1890 to 1898 are .083 higher than at Cleveland. In the remaining years, from 1899 to 1907, a corresponding comparison shows that the Buffalo gage is .056 higher than Cleveland. If instead of taking the International Waterways Commission information at Buffalo, the United States Lake Survey information had been taken for the years 1890 to 1898, the difference would have been 0.183, in the same direction as the other. It will be seen from these statements that using the results of the International Waterways Commission makes the relations between the gages at Buffalo and Cleveland for the period 1890 to 1898 much more consistent with the relations in the later period. These are all annual means. During the later period, a self recording gage was used at Buffalo.

Q. That was during the time when they more closely agreed, is that correct?

A. Yes.

Q. Then in your opinion the International Waterways Commission acted properly in making the correction for the preceding period?

A. That is my judgment.

To resume the statement with regard to Chart number 1, the scale at the bottom shows the discharge at Niagara in cubic feet per second. On this diagram has been plotted the deduced Niagara discharge given in Table C of Stearns' Exhibit number 1; and a straight line has been drawn to represent those deduced discharges. This line was obtained mathematically by the principle of centers of gravity. That line shows an increment of 36,580 cubic feet per second.

There is also shown upon the same diagram Complainant's equations for the Niagara discharge at the Bridge Section and the Open Section, with only this change: That there has been added to the discharge 2100 cubic feet per second to represent the flow through the Welland and Erie Canals, and this

2100 is the amount adopted by the International Waterways Commission.

Also on the same diagram has been shown the discharge determined by the International Waterways Commission, as given in their report on the regulation of Lake Erie, 1900, the quantities and heights being taken directly from the table. The purpose was to show the degree of agreement between the various discharge curves or equations, based upon the measured discharges at Niagara.

A comparison of the results of these equations, based on measured discharges at Niagara with those deduced shows that there is one point where they agree, at about elevation 571.50. But there is a wide divergence at high levels of the lake, amounting at elevation 574 to substantially 32,000 cubic feet per second.

The diagram shows that with low levels of the lake, those below elevation 571.50, the deduced discharges are less than the discharges based upon actual measurements at Niagara.

The plottings from Table C, of Stearns' Exhibit 1, already referred to, are shown on the chart by small circles and the year is placed against each circle.

Q. That is the discharge is shown for that year and at the elevation?

A. Yes. The circles are plotted with reference to the scales at the left and bottom of the map, and show the discharge corresponding to the given elevation of Lake Erie for that year.

The circles show the results of measurements from June to November inclusive of each year; but by taking shorter periods of time, one can get the results for lower lake elevations than when the average for six months is taken. I am referring to the years 1895 and 1896, when Lake Erie was lower than ever before. During the last three months of 1895, the average elevation of Lake Erie at Buffalo, according to the report of the International Waterways Commission for 1910 was 570.96. Treating the case exactly in the same way that it has been treated for longer periods, I obtained these results: The St. Lawrence discharge, International Waterways basis for those three months average 171,000 cubic feet per second. The rainfall during the three months was 8.89 inches, on the authority of the annual report of the Chief of Enginers for 1903, Appendix FFF, Page 2897, Table XIII.

The evaporation estimated on the basis of the Rochester formula for the six months from June to November inclusive,

already given in testimony today, was 4.86 inches leaving 4.03 inches as the excess of rainfall over evaporation on and from the surface of Lake Ontario. This is equivalent to an average discharge of 8600 cubic feet per second. A run-off of 22 per cent. of the 8.89 inches from the drainage area exclusive of the lake amounts to 14,900 cubic feet per second.

Lake Ontario lowered during this periof 0.42 feet, equivalent to a discharge of 7400 cubic feet per second, making the total local supply and storage during the three months in question 30,900 cubic feet per second. Deducting this from the 171,000 St. Lawrence discharge gives a deduced Niagara discharge of 140,100 cubic feet per second, which is indicated upon the diagram.

The St. Lawrence discharge, by the Complainant's equation, would have been 185,200 cubic feet per second. Deducting the local supply and storage as before would leave the deduced Niagara discharge, based upon the Complainant's equation for the St. Lawrence 154,300. This is also shown upon the chart.

Similar computations were made for the month of November, 1896. The St. Lawrence discharge by the International Waterways equation or tables was 175,400 cubic feet per second. The excess of rainfall over evaporation was equivalent to 5700 cubic feet per second; the run-off 22 per cent. of 2.68 inches of rainfall, 13,500 cubic feet per second; and there was drawn from storage in Lake Ontario 10,100 cubic feet per second, making the total local supply and storage for this month at the rate of 29,300 cubic feet per second; and the deduced Niagara discharge 146,100 cubic feet per second. For this same month of November, 1896, the St. Lawrence discharge by Complainant's equation was 196,900 cubic feet per second. Deducting the total local supply and storage as above, 29,300 cubic feet per second leaves as the deduced Niagara discharge 167,600 cubic feet per second. The surprising feature, when one considers the extremely low lake levels is that the equations, or at least the equation of the International Waterways Commission, gives a larger discharge at Niagara than at the St. Lawrence, reversing the usual rule that the size of a river increases towards its mouth. The figures are, for November, 1896: Niagara discharge 184,200 and St. Lawrence discharge 175,400. And this result is obtained notwithstanding the fact that the streams are all the time flowing into Lake Ontario. The evaporation in such a month as November is almost invariably less than the rainfall, and the

lake was being drawn down so that as the result of the drawing down of the lake, there should have been some flow from the lake out of the St. Lawrence, in addition to what came in from the Niagara and other sources. It seems to show very clearly that the results obtained by local gagings do not conform with what we know, from a common sense view, to be the facts of the case.

Chart number 2 is made up in the same way as number 1, and therefore does not require explanation except as to the source of the deduced discharge plotted upon it. It is based upon the St. Lawrence discharge as before, but in this case the St. Lawrence discharge is that determined by the equations given for 1912, and the Sherman Moore report of 1912; and more especially as shown on the chart entitled "United States Lake Survey, discharge of St. Lawrence River, Compiled under the direction of Lieutenant Colonel C. S. Richie, Corps of Engineers U. S. A., by Sherman Moore, Junior, Engineer, 1912."

Q. You used in connection with that chart the diagram entitled "United States Lake Survey, discharge of St. Lawrence River," referred to as Sherman Moore's Report of 1912, which I ask may be marked for identification Government's Exhibit O.

A. Yes. A line was computed to represent the mean of the deduced discharges, and this shows that the Niagara increment obtained on this basis is 33,800 cubic feet per second. The increment obtained by the plottings on Chart Number 1, was 36,580 cubic feet per second, which averaged with the result just given makes the increment for Niagara based upon the St. Lawrence 35,190 cubic feet per second.

Chart number 3, is drawn upon the same plan as the others, but in this case the basis is the discharge of the St. Clair River.

In deducing the discharge of the Niagara as given on Chart Number 3, the defendant's equation was used for determining the St. Clair discharge, and the number of years was limited to those from 1895 to 1906 inclusive; the earlier years not being used, for the reason that the channel of the St. Clair and Detroit Rivers was smaller in the former years, and it was thought best to go back to 1895, only.

The increment obtained in this case for Niagara was 38,200 cubic feet per second.

Chart Number 4, is precisely the same as Chart Number 3, with the exception that the complainant's equation was used in determining the St. Clair discharge. The increment for

Niagara deduced on this basis is 34,700 cubic feet per second. The Niagara increment obtained by averaging the two deduced from the St. Clair discharges is 36,450 cubic feet per second, in comparison with 35,190 cubic feet per second obtained from the St. Lawrence basis.

If, again, we average these, the average Niagara increment is 35,820 cubic feet per second.

It is worthy of note that this agrees very closely with Niagara increment deduced by Mr. Williams, on the basis of the relative fluctuations of Lakes Erie and Ontario, and the measured discharges at St. Clair and St. Lawrence.

There is one thing to be noted in connection with all four of the charts, namely, that the increment is practically independent of questions of per cent. of rainfall representing the run-off and evaporation, because the results of changes in those features would be to affect the deduced discharges at Niagara, but not to affect the deduced increment. That is the deduced discharges are always much larger than the discharges based on local measurements at Niagara when Lake Erie is high, and less when Lake Erie is low.

Now the questions of run-off and evaporation do not depend upon the height of the lake to any appreciable extent. The lake is of the same size when it is high or low. They depend upon rainfall and evaporation, which, as I say, are independent of the height of the lake. And a tabulation of the local supply, including the effect of evaporation, shows that it is practically independent of the height of the lake.

Stearns' Exhibit 3 is a table made up on the same basis as Government Exhibit M for Identification and differs from it only in that it is extended so as to cover the years from 1883 to 1890 inclusive; and some changes were made in column 5 as the result of using the elevations of Lake Erie at the Buffalo gage, given in the Report of the International Waterways Commission, instead of the elevations of the United States Lake Survey.

Q. Why did you use the additional years, and did not confine yourself to the years which are indicated in Government's Exhibit M for Identification?

A. The information relating to those years seemed to be as good as the others, and it was very important to use them because they represent high stages of the lake. As shown by the charts just described, it is at high stages of the lake that the difference between the deduced discharges and the discharges computed on the actual measurements at Niagara vary

the most. In a long series of years, that is from 1860 to 1912, the average elevation of Lake Erie was 572.79. The average elevation during the period from 1891 to 1906, being the years covered by Government's Exhibit M, was 572.22. That is it was more than half a foot below the average for a long period of years. By including the years back of 1883, the average becomes 572.62, which, even with this inclusion, is .17 less than the average for the long period of years. I will state in reference to these elevations that for convenience they were taken from Williams' Exhibit 34, Table 18, and in that the months from April to November were used to represent the open season. It would not make any change if the months from June to November had been used, in my judgment.

Mr. Williams: I have to state that Mr. Shenehon and myself have examined the plottings of the sections at Wickwire and Oakfield, which have been made upon Williams' Exhibit 12 now in evidence in this case, and that we find them to be correct transcripts of the original plottings in the possession of the Complainants in this case, and that we accept those plottings on the said Williams' Exhibit 12 as representing the position of these discharge measurements and as replacing or avoiding the necessity of introducing a duplicate chart to show the said location.

Mr. Shenehon: Mr. Williams' statement is verified by me.

Cross-Examination by Mr. Wilkerson.

Q. I understand Mr. Stearns that the method which you have followed in your analysis of the question which is here presented, for the purpose of determining whether or not in your opinion the increment deduced for the Niagara River is correct has been to take the discharge measurements for the St. Lawrence River first, and by combining those observations with the run-off into Lake Ontario, and storage in the lake, making an allowance for evaporation, to determine what in your opinion would be the correct increment for the Niagara, assuming the St. Lawrence to be correct. That is your process, is it, the first step of it?

A. Yes.

Q. Then you have taken the discharge measurements for the St. Clair and combining that with an allowance which you think should be made for the run-off and storage, and making an allowance for evaporation, you have determined what in

your opinion the increment of the Niagara should be, assuming the observations on the St. Clair to be correct?

A. Yes.

Q. Now the determination therefore of the run-off becomes a vital part of the problem from your standpoint, does it not?

A. No.

Q Well, it becomes a part of it?

A. It becomes a vital part in connection with the determination of the discharge at Niagara, but not in the determination of the increment.

Q. Well let us take the discharge now. We will come to the increment after a while. Of course to determine what the run-off is, you must have data as to rainfall; that is the data as to rainfall from the basis of the deductions as to run-off?

A. It does of the deductions that I have made myself but not necessarily because if one had the measured run-off that could be used.

Q. I am speaking about your method now.

A. Yes.

Q. You have tried to derive a percentage of run-off and rainfall which is based upon observations with which you have come in contact upon a number of rivers, drainage basins in New England and Pennsylvania?

A. Yes, and New York.

Q. And New York. Some of which you have accepted as applicable to the situation here, and some of which you have rejected for one reason and another?

A. There is one that I rejected on that account, not others.

Q. You rejected only one, did you?

A. There are several that I didn't work up the results for, because it would have required some computations of evaporation, and one, the Merrimack River, that I didn't use because it included some storage water in the discharge. But they were not inapplicable, and the results that I got from them show that they would have agreed very nearly, although I did not make the computations.

Q. This whole situation would be materially changed, would it not if it is the truth, or the fact would turn out to be contrary to your conclusion here that the run-off into Lake Erie is very considerably less than what you have concluded that it is?

A. It might be materially less, and still make very little change in the final results, as I have already testified that a

14 per cent. change in the run-off, in the per cent. of run-off, would only affect the final results 1 per cent. I think that applied to Lake Ontario, as I stated it, but it would be very nearly applicable also to Lake Erie.

Q. Well, if as a matter of fact the run-off into Lake Erie were such that when taken into connection with the evaporation from the surface of the lake, Lake Erie contributed little if anything to the water supply, it would make a very marked difference as to what you have concluded here?

A. If Lake Erie contributed nothing whatever, it would make a marked difference; but that is not conceivable in view of the results obtained on so many drainage areas with which I am acquainted, some of them not far from Lake Erie, or in view of the results obtained when one takes Lake Erie and Ontario together, independent of these other drainage areas.

Q. In the measurements which were made in different drainage areas about which you testified yesterday, how many rain gages were there to the square mile; or rather how many square miles were there to a rain gage? Take some of them, and let us have the benefit of your information on that subject.

A. On the Sudbury Drainage area there are four gages.

Q. How many square miles in the Sudbury area?

A. On 75 square miles. In the Wachusett, there are four rain gages on 120 square miles. Lake Cochituate, there are two rain gages on the drainage area, but others that are so near by that they can be used. That has a drainage area of 19 square miles.

On the Esopus Drainage area of 239 square miles, as nearly as I can recall, there are ten gages. I only state that number from remembering a list that looked to me to be about ten.

On the Rondout Creek, with a drainage area of 105 square miles, they were about in the same proportion to the number of square miles; I think four or five.

Schoharie Creek with 240 square miles, about the same, rather a less number to the number of square miles.

On the streams in Western Pennsylvania, I used the general rainfall as obtained from about 11 stations.

For the Quemahoning Drainage Area, which is about 92 square miles, there was only one upon the drainage area, but the mean rainfall there was determined also from two others, one at Somerset and one at Johnstown, which were some miles beyond the limits, but not more than ten.

Q. Was use made in studies of these drainage areas, about which you have just testified, of any observations made by volunteer observers, or were they all made where the gage readings were taken under the supervision of an engineer?

A. Nearly all of them were under the supervision of engineers on these Water Works water sheds.

At Quemahoning in Pennsylvania, two of them were either United States Weather Bureau Stations or volunteer, Somerset and Johnstown; and in connection with those Western Pennsylvania streams generally, they were all Weather Bureau Stations or volunteer observations, given in the Weather Bureau Reports.

Q. What is the size of the Erie Drainage Basin in square miles, as you have taken it for your computations?

A. The land surface 24,605 square miles, water surface 9,968, total 34,573. That does not include St. Clair.

Q. If you included St. Clair, it would be what?

A. It would add to those figures, for land, 5,961, water, 503 square miles, a total of 6,194 square miles.

Q. What is the area of the Ontario Basin?

A. Land 25,737 square miles, water 7,243 square miles, a total of 32,980.

Q. Do you know how many rain gages were taken in this Erie Basin as the basis of the estimate of the rainfall which has been used on your side of this case?

A. I used the figures given in the report of the Chief of Engineers for 1903, and the diagram contained in that report, which shows the location of the rain gage stations.

Q. The map shows for itself. I was wondering whether you had ever given any thought to the question of about how many square miles was undertaken to be covered by one of these gages?

A. I had not looked upon it in that light; with a large area and a large number of rain gages, as there were in this case, the territory is well represented. There are some portions of the territory where the rain gages do not appear on the map and the—

Q. That is on the Canadian side?

A. On the Canadian side; and the statement is made in the report of the Chief of Engineers as to how they deduced the rainfall for those sections.

Q. It was kind of a speculation from what was on the other side?

A. I think they had other data.

Q. Now in the Erie basin, the Weather Bureau Stations are marked in black dots, as I understand it, so on the whole basin you see only about half a dozen or so stations where the observations were made by scientific observers; the others being reports made by volunteers?

A. There are six within the drainage area and one at Detroit just outside.

Q. And how many in the basin of Lake Onatrio?

A. Three are shown there.

Q. You are familiar with the physical characteristics of these two drainage basins are you?

A. I am somewhat familiar, but there are many parts that I have not visited.

Q. Well with the drainage basins which you used as the basis for your figures expressing the relation of run-off to rainfall, you are familiar with those basins are you?

A. Reasonably so. With some of them I am very familiar.

Q. What kind of streams are they?

A. They covered all kinds. There were three Mountain streams, coming off of the Catskills, with the high points up to elevation 3,000 feet above the sea, if not higher, as nearly as my memory serves me, distinctly mountain streams.

The Merrimack River, not used but still supporting the evidence. It has a drainage area, as stated, of upwards of 4,000 square miles, a very large stream; a part of it is mountainous; a part of it is not.

The Abbott Run watershed, which is one of those stated, and the Cochituate watershed are both low and sandy.

The Croton watershed has a good many hills in it.

Q. That was a high rainfall and sandy land?

A. Not necessarily high rainfall, because there were years of low rainfall as given in the figures presented. One drainage area was only 5 square miles, and yet it gives substantially the same results as the upwards of 4,000 square miles of the Merrimack drainage area.

Q. As to the streams which you considered in Western Pennsylvania, were they in rough country?

A. In a very rough country. That is hilly right there near the Allegheny Mountains and the Laurel Ridge.

Q. What was the condition as to the presence or absence of forests?

A. Why about the average conditions I should say that one finds on almost all of these drainage areas. There are a

good many forests, if you include in that term woods of moderate size.

Q. What was the condition in the Neshaminy basin?

A. I never have visited either of the three basins near Philadelphia, but the gagings were started when they thought of taking those sources for water supply.

Q. Why was it you threw out Neshaminy?

A. Because the results were entirely out of accord with any of the other ten than I mentioned specifically, and out of accord with the results that would be obtained from the records of the Croton, Wachusett, Sudbury, Cochituate and other sources which I did not use.

Q. Do you know whether or not the results in the Neshaminy basin could or could not be accounted for by reason of the physical condition of the country?

A. I believe that it could not be accounted for on that basis for this reason, that taking the whole year and not part of it, during the summer time, the run-off from the Neshaminy averages for a series of years 48.5 per cent. of the Perkiomen, which is near it, 49.2; and of the Tohickon, also near it, 57.6. That is it does not show any abnormal conditions when the year is taken as a whole. But in taking the driest six months when the flow would be very small compared with the whole year, the results were not so consistent and the record showed that if one had tried to deduce from the Neshaminy the run-off corresponding to a rainfall a little less than that on Lake Erie, the run-off would have been Zero.

Q. That is to say you get about the same kind of result from that river as you would have had if you studied the rivers in the Lake Erie basin?

A. Not in the least. There is clear evidence, as it seemed to me, that was a case where a weir had been placed on the ground, and it measured only a part of the run-off, and when the run-off was very small during the summer season, quite a percentage of water was lost from the measurement by running underground. You see that with a higher flow during the whole year, that would be unimportant; that is a large per cent. of the low summer flow is a small percentage of the average flow throughout the year.

Q. What rivers in the Lake Erie basin have you studied?

A. I have never given any special study to any of them.

Q. Isn't it a fact that the physical condition of the country, of the drainage basins which you had used as the basis of your computations here are in practically every case which

you have taken entirely different from the condition of the country around Lake Erie, both as to the kind of soil and as to the level condition of the country, and the presence of hills and forests, and the cultivation?

A. I believe they are not materially different in some of those cases, and not nearly as different as the difference between the various water sheds which are included in those estimates. There has been such great variation in the physical characteristics of the various drainage areas included in those estimates, and they agree so well, that it does not seem as if any change that could result from the different conditions at Lake Erie would make a great difference. It would make some.

Q. That is your testimony in this case is based upon your conclusion that the average of the conditions of the water sheds which you have used as the basis for your computation is a situation which is fairly applicable to the Lake Erie basin?

A. It is not the average of the drainage areas. What we found is that with these great differences the results agree, and you could take the one that seems to be most nearly like Lake Erie, or the one that is furthest from it, and get practically the same results.

Q. Are you familiar with a discussion of the relation of rainfall tc run-off, by George W. Rafter, which was printed in 1903, by the Department of the Interior, U. S. Geological Survey, Water Supply and Irrigation, paper number 80?

A. I am not familiar with it but I have seen it and read parts of it.

Q. He states in this discussion of the subject: "There is no general expression giving accurately the relation of rainfall to run-off. The run-off of a stream is influenced by so many complex elements that the data are lacking for final conclusions. Every stream is in effect a law unto itself. And empirical formula however may be made, which will give for some streams approximately the run-off for a series of years." Does that accord with your view on this subject?

A. The statement that no general formula has been arrived at—I don't remember what his words were—is probably true, because the results which are obtained in the Northern States, under the conditions of humidity which exist here would not apply in the least to the conditions of the Southwestern part of the United States, in the arid country where the evaporation is enormous and conditions are absolutely

different from what they are here. But it is not a correct statement as applied to the Northern and Northeastern section of the country, because the coincidence of results, the close agreement of results taken from different places shows that it is not so; that we can derive a formula within a reasonable degree of accuracy.

Q. He states again: "The errors in rainfall measurements are so large that one may safely state that nearly all measurements are merely approximations." You do not agree with that?

A. No. There are many rainfall measurements that are incorrect.

Q. Which ones would be likely to be incorrect?

A. A number of years ago, the Weather Bureau Station in Boston kept the rainfall record on the top of a high building, with the result that it did not coincide with other rain gages in the vicinity, giving only about 2/3 as much rainfall.

Q. It is a well understood fact that where the rain gage is on top of a building, it registers less than a rain gage on the ground, is it not?

A. That is often the case but I do not know that it is certainly the case, if proper precautions are taken. The Weather Bureau record in Boston at the present time agrees well with other records.

Q. It is perfectly obvious that that would be the result, if the wind were blowing when it is raining, isn't it?

A. No, not if precautions were taken to protect the rain gage.

Q. But if those precautions are not taken, then what?

A. If the precautions are not taken, that is true.

Q. Reading from Mr. Rafter, he says again: "The run-off of streams has been generally over estimated. The minimum flow may be as low as from .05 to 0.1 of a cubic foot per square mile per second. Streams issuing from sand plains may show from 0.5 to 0.6 of a cubic foot per square mile per second. Generally speaking, the range will not be outside of from .05 to .5 of a cubic foot per square mile per second." Does that agree with your experience?

A. The question of overestimating the flow of streams depends on whether it is some good strong promoter of a hydro-electric claim, or whether it is an engineer that knows what he is doing.

Q. It is true, of course, that the streams which issue from

sand plains show a higher amount than where there is a different kind of soil, is it not?

A. It is frequently the case, and depends on whether there is storage in those sand plains that maintains the flow in summer. I am assuming now that question is with reference to the summer flow.

Q. Yes.

A. If one takes the whole year, there is comparatively little difference.

Q. He says again: "The extent of forestation seems to have considerable effect on the run-off of streams, catchments with dense forests showing larger run-off for the same rainfall than those which are deforested. Is that in accordance with your view?

A. I have never been able to know which way forestation affected the flow of streams. I have tried to find it out sometimes, but I have not succeeded.

Q. According to the principle which you deduced, as applicable to Lakes Erie and Ontario in this case, what was the run-off from the drainage basin of Lake Erie, expressed in cubic feet per second per square mile for the period from June to November. I do not care to have that figured out to the third decimal point, but I would like to get approximately what that is; that is the average for the whole period.

A. That would require an averaging of these 20 odd figures.

Q. Pick out a year that looks like an average year, and see what it is?

A. All right, I will take the year 1897 when the rainfall was 17.45 inches, as being nearly an average; 18.5 per cent. of this quantity equals 0.475 cubic feet per second per square mile.

Q. That is for that one year?

A. For that year, which represents nearly an average. If that were a direct average, it would be the average of the whole period.

Q. We can easily get the exact figure by averaging all of the years?

A. Yes.

Q. But the year which you took, which is pretty nearly an average year, it is a little less than half a foot?

A. Yes.

Q. Now let me direct your attention to Williams' Exhibit number 34, table LIXe, Sheets 1, 2, 3, 4, 5, 6 and 7. Let us

take the Maumee River, and see what the actual observations on that river show for the months from June to November, with respect to the run-off in cubic feet per second per square mile. That is one of the largest rivers, as I understand it, that flows into Lake Erie. Do you have a table there in which you have that for each river reduced to cubic feet per second per square mile?

A. Not for that period.

Q. I wish you would take the figures presented by the Defendant in this case with reference to the Maumee River, and let us have an idea about what the shows as to the run-off in cubic feet per second per square mile. I direct your attention to Sheet 5, Table LIXe, Williams' Exhibit number 34. If we take the period from June to November for the Maumee River, which is put down here as having a drainage area of 6,111 square miles, for the month of June, the discharge in cubic feet per second is .514, for July .289, for August it is .113, for September .07, for October .04, for November .169, or on the average about .201, which is less than half of the figure obtained by applying your principle. Wouldn't that indicate that the situation of the drainage basin of the Maumee River, during the period from June to November, is such that the ratio which you have deduced cannot be applied?

A. I know nothing about the facts in this case. I have often had occasion to discriminate a great deal in using the records of the flow of streams, but would not wish to testify as to any one without knowing the facts.

Q. I am merely taking the figures that are put in here by the Defendant in this case as representing the flow of this river. Assuming that these figures are correct, and that the mathematical part of the table is correct, it would indicate that there is a situation with respect to the Maumee River that is different from the drainage basins from which you derived the ratio which you have applied to this situation, wouldn't it? I do not ask you to pass upon the correctness of the measurements, or anything of that sort, but I ask you to assume that they are correct?

A. I do not know the rainfall during these years as applied to this case. The run-off varies a great deal on different streams during the months from June to November, as I have shown by these records which I have introduced today.

Q. But it is perfectly obvious, isn't it, that Mr. Williams

gets one result from the measurement of the river itself, and you get a result about twice as large by the application of the ratio based upon experiments in New England and in Pennsylvania.

A. I do not know the results as to that particular river.

Q. They are here. It gives the Maumee River. I understand they are put down on Table LIXe, Sheets four and five, and we are given the figures which show the measured discharge of the Maumee river for the years 1899, 1900, 1901, 1903, 1904, 1905 and 1906; and from that there is deduced the discharge in cubic feet per second per square mile on Lake Erie, that is it is reduced to that. Assuming the figuring is done correctly, that would indicate a much smaller result for that river wouldn't it than your result?

A. My result applied to the drainage area of Lake Erie as a whole. My rainfall applied as a whole to that. I do not know where the Maumee River is nor what the rainfall is.

Q. Suppose that the Maumee River was about 1/4 of the whole drainage basin of the lake, would you think that was entitled to some consideration?

A. It would be, certainly.

Q. It is about 1/4, about 1/5 of the drainage area. Having in mind that the Maumee River, as Mr. Williams has stated, is about 1/5 of the drainage basin, if you measured the Maumee River and got a result of that kind, wouldn't that indicate to you that there was something in the physical condition of that country that made inapplicable this formula based upon New England and Pennsylvania experiments?

A. I should want to know the rainfall of the Maumee River and the character of the gagings, assuming the gagings were right, if that were proved.

Q. I ask you to assume it is all correct, for the purpose of my question you may assume that the gagings are correct and that the computations are correct?

A. Yes, but that does not cover the question of the rainfall in that place. If the rainfall on that drainage area were the same as the average rainfall of Lake Erie and if all those results were correct, and if those years represented the rainfall as represented by the whole 24 years that are included in the tables—

Q. It is a matter of fact isn't it that what data we have with reference to rainfall show that the average rainfall for

the basin of the Maumee River is substantially the average rainfall of the whole Erie basin?

A. I don't know.

Q. Suppose that it should turn out that was the truth?

A. I was answering on that basis, when I was interrupted.

Q. On that basis, what have you to say about it? I will try not to interrupt you again.

(Answer of witness read as follows: "Yes, but that does not cover the question of the rainfall in that place. If the rainfall on that drainage area were the same as the average rainfall of Lake Erie, and if all those results were correct, and if those years represented the rainfall as represented by the whole 24 years that are included in the tables"—) then it would mean much.

Q. Now let us take another record in this basin. Let us take a small river. We have taken a large river, the Maumee; let us take the Sandusky River. That is on Sheet 6; this same table, LIXe?

A. Yes.

Q. And I find the discharge in cubic feet per second per square mile in June .238, July .07, August .185, September .03, October .05 and November .03. Now there we find the same situation, do we not, only more marked than in the case of the Maumee?

A. Yes, but that record, it should be noted, covers two years, and as I remember they were fairly dry years, weren't they?

Mr. Adcock: Q. What years were they?

A. 1899 and 1900.

Mr. Wilkerson: Q. The rainfall for that year on Lakes Erie and St. Clair was 20.06, which appears to be a heavy rainfall?

A. I do not find that figure on my table.

Q. I am referring to your own table B.

A. 1899 was one of those years, and the rainfall was 14.01.

Q. 1900 was the other?

A. 19.50.

Q. That is pretty nearly an average, not much below. Well let us take another one of those rivers. Let us take the Huron River. That has a drainage basin of 757; we have figures there on Table LIXe, sheet 4, for the years 1904, 1905, 1906, 1907 and 1908. The discharge, cubic feet per second per square mile for June is .644, for July .270, for August

.226, for September .214, for October .267, for November .365, making an average of about .331 as I get it. That still shows considerably below your figure, does it not Mr. Stearns?

A. Yes, a little more than 2/3.

Q. A little more than 2/3?

A. 2/3 of the figure.

Q. Now assume for the purpose of your answer to this question, Mr. Stearns, that the study which has been made of practically every river which has been studied in the Erie basin on your side of the case indicates a result materially less than the one which you have stated here as expressing the effect in cubic feet per second per square mile; and assuming that the average of all the rivers which have been studied for all of the years is as stated in Table LIXa, Williams' Exhibit 34, for the period from June to November, that the figure is .252, wouldn't that indicate to you that the data which have been compiled from the observations in New England and Pennsylvania are not applicable to the situation in the Erie basin?

A. It would not without investigation, but even the information from a number of rivers without knowing the accuracy would have some weight.

Q. And in the light of what I have directed your attention to here from Mr. Williams' Exhibit number 34, do you not believe now, having in mind all these things about the uncertainty of rainfall and run-off, that there is more reason to believe that Mr. Williams' figure of .250 is more nearly correct than your figure of .475.

A. I do not. I should still believe that the deductive method was more likely to give correct results than the ordinary measurements such as are contained in the reports of the United States Geological Survey.

Q. And that would be true, even though it would appear that the drainage area covered by the study of these rivers in the Erie basin embraced 1/3 of the whole drainage basin?

A. Yes.

Q. In your opinion?

A. I say that because I have had so much difficulty in getting results that were at all trustworthy from those United States Geological Survey records.

Mr. Adcock: That is, of run-off?

A. Yes.

Mr. Wilkerson: Q. Isn't it a fact this Lake Erie drain-

age basin is a most peculiar one, in that there are practically no rivers that come into it on the Canadian side?

A. I have never examined them.

Q. Just look at the map. I show you here the map of the Lake Erie Drainage Basin (presenting same to witness); just look at the utter absence of rivers that come in on the Canadian side.

A. The map seems to be very much a blank on the Canadian side, this particular one, as far as towns or rivers or railroads or anything else.

Q. It shows the rivers that come in, that is all a mile back on the Canadian side. (Question read as follows: "I show you here the map of the Lake Erie drainage basin (same being Williams' Exhibit 11) look at the utter absence of rivers that come in on the Canadian side" of any size, I mean.

A. The map does not show railroads and other features, and apparently does not show the rivers in a way that one can form any judgment from it.

Q. You have no independent knowledge on the subject?

A. I know that there is a Grand River coming in towards the easterly end of the lake, and the Thames coming into Lake St. Clair; and those are only shown for a very short distance, and do not indicate how much of the territory they cover.

Q. And you have no knowledge about the size of the river?

A. No.

Q. But in the study which you made of this case, did you give any consideration to the difference between the drainage basins of Lake Erie and Lake Ontario, with respect to the size and volume of the rivers which empty into Lake Ontario, as compared with those which flow into Erie?

A. I did not.

Q. Did you take into consideration the fact that the country all around the lake is flat; that it is cultivated; that there is a clay soil, and did you hear it suggested in the course of your study of this situation that during the period from June to November, practically all of the water is absorbed by the soil, and very little of it runs into the lake?

A. That last statement is correct nearly everywhere, that one does not see the water running off much during the months from June to November, unless there are some very heavy rains in the Autumn. I should expect that would apply to Lake Ontario as well as Lake Erie.

Q. Now is it a fact, so far as the records of humidity for Lake Ontario have been studied, they show a very much larger

run-off measured in cubic feet per second per square mile than do those of Erie?

A. I should expect they would show a larger run-off; and they are so shown by my computation.

Q. How much larger do you show it? What is your figure for Lake Ontario, so far as run-off in cubic feet per second per square mile is concerned?

A. I prepared that figure on one occasion, but I don't find it.

Q. It is not very much larger than the one you have given for Erie, is it?

A. It is considerably larger because one is 18½ per cent. of a smaller rainfall, and the other is 22 per cent. of a larger rainfall.

Mr. Shenehon: Those are revised figures?

The Witness: Yes.

Mr. Wilkerson: I direct your attention to the fact that Mr. Williams in his table LIXa, for the months of June and November gives an average run-off of cubic feet per second per square mile for the Ontario basin of .924, which is between three and four times as much as the run-off for Lake Erie. Your figure has no such difference as that, has it?

A. It has not.

Q. As a matter of fact your figure would be, I assume, not much more than 10 per cent. more for Ontario than Erie, would it?

A. Much more than that.

Q. 20 per cent.?

A. The percentage of run-off—

Q I would like to get the figure for Ontario, because the point I am trying to make Mr. Stearns, and I think it is a legitimate one, is that the drainage basins of Erie and Ontario are absolutely different; and that that is shown by the study which has been made of every river that empties into Erie and Ontario.

A. The run-off of Ontario for the whole period from 1883 to 1906 inclusive, by my computations was .637 cubic feet per second per square mile.

Q. Now have you giver any consideration to this table, Table LIXb, sheets 1 to 11, Williams' Exhibit number 34, in which there is a study made on behalf of the Defendant in this case of the run-off from the drainage areas of different rivers which empty into Lake Ontario?

A. No.

Q You have not studied that. Let us take some of those

ivers, without going into the details of the particular river, he summary of it which appears in Table LIXa, is that of un-off in cubic feet per second per square mile for Ontario rom June to November, that it is .924. That is to say the esult of Mr. Williams' study of the rivers themselves which mpty into Lakes Erie and Ontario is to give for Erie a very onsiderably lower figure than your figure, and for Ontario very considerably higher figure?

A. Yes.

Q. You had in mind that you were not willing to accept, as n engineer, the gagings of these different streams without nore specific study of them. You thought the probability as that they were in error?

A. That many gagings are in error. I have no doubt that ome of them are well taken, but I don't know which ones.

Q. As a matter of fact, in a large number of observations f that kind, would you think that some were taken reasonbly accurately, and there were errors in others; that in the umber of records the errors might balance each other; that as been the method you have applied right along in your easoning in this case, has it not?

A. It is not.

Q. Didn't you apply that, as far as rainfall was concerned hen you gave credit to the observations of these volunteer bservers; didn't you have in mind that while one might have nade a mistake in one direction, another would have made a nistake in another direction, so that in the end they would alance up?

A. No. In studying, to take a specific case, the run-off of treams in Western Pennsylvania, I compared carefully the esults at different places, and a great many observations were nrown out as having internal evidence that they were incorect. And the same was true in measuring the flow of streams. took a sheet as much as 18 inches long, and put the flow of ifferent streams side by side, and from that deduced what he flow would be, not by direct averaging, but throwing out nose that were anomalous. As a result, my yearly run-off as less than half of the quantity that had previously been onsidered to be a proper quantity based upon a given stream. The run-off records of that stream were in my judgment at east double what they were really; that is the result given in he tables was double the actual discharge.

Q. Is it not your conclusion, after having your attention irected to the studies of these rivers in the Lake Erie basin nd the Lake Ontario basin, which have been made by Mr.

Williams, that there is reason for the view that there is a greater difference in the condition of the two drainage basins than is indicated by the figures which you yourself have given in this case?

A. I think it very probable that there is. That is I should give weight to measurements, even without examining them; but I would not give the weight that would be indicated by any direct averages, and especially if they covered the drier years.

Q. Is there not as much reason for accepting the data about the measurement of these rivers in the basins of Lake Erie and Ontario in this case as there is for accepting the observations of rainfall in Erie and Ontario?

A. I do not think that that is the case.

Q. Why not?

A. Because in the experience I have had with rainfall, the results have checked from one station to another.

To revert once more to that Western Pennsylvania situation, I drew contours showing the lines of equal rainfall in all Western Pennsylvania, and they were very consistent, seeming to indicate that the rainfall observations were on the whole very well taken.

Q. Suppose these rivers checked very well too?

A. My similar experience with rivers as reported by the United States Geological Survey has been in the line that they did not check, or come anywhere near it.

Q. Now, as bearing on the condition of this Erie basin, I want to read to you something from the testimony of Mr. Williams in this case, and see whether you agree with him, serial pages 988,989:

"The comparisons of run-offs of various streams in Michigan, which I have studied for a number of years, show a quite wide variation in the amount of water—in the percentage of rainfall that appears as run-off; those streams coming from sandy areas giving relatively large run-offs; those streams coming from highly cultivated areas giving small run-offs.

The comparison of the streams in the West, that is, in the Central States with those further East, say in Central New York, where the country is much more precipitous, indicates that the percentage of run-off in the New York streams is considerably greater than in the Michigan and Wisconsin and Illinois streams, by reason of the fact that the rain that falls flows quickly into the streams and is carried off quickly, before it has time to evaporate.

There are all those conditions that have to be taken into account. For example, the run-off from the State of Ohio is noticeable for its smallness relatively to the others. The high cultivation apparently, combined with the character of the soil which is a loam, and with the character of the surface, which is moderately rolling, seems to conduce to a very high evaporation or a very large absorption by plant roots, and subsequent evaporation so that the run-off from the Ohio streams, both those which flow into Lake Erie, and those which flow into the Ohio river is considerably less than is the run-off of those streams that flow into Lake Michigan and Huron, or into Lake Ontario."

A. The question was do I agree with that?

Q. Yes?

A. I have no information as to the Ohio streams, and many others. With regard to the precipitous character of the ground causing a larger run-off during the months from June to November, I think that is very doubtful in view of the measurements of the three streams that come from the Catskill Mountains. I recognize that the flow of those streams is very much larger than the flow of streams coming from low ground, because there is a higher rainfall upon the mountains, much higher than upon the lower ground; but the percentage of run-off as shown by this table which I have presented does not show a larger per cent. of collection. That is it is not because the water runs off more freely that more comes from the mountain stream, but because the elevation causes a greater rainfall and in the drainage area of Ontario there are no high elevations, until one gets to the Eastern part near the Adirondacks. There the conditions should be similar to the conditions in the Catskill Mountains, except that it is further inland, so that the rainfall presumably is less.

Q. I think you said you had not made any study of the volume of the rivers that emptied into Lake Ontario?

A. No.

Q. So that it is a fact is it not that generally speaking your testimony in this case is speculation based upon experiments in New England, New York and Pennsylvania rather than upon a study of the physical condition of the two basins in question?

A. It is not regarded by me as a speculation. It is the application of well defined laws to these basins; and some of the streams from which those laws were deduced are streams

that are just south of Lake Erie, which empty into the tributaries of the Ohio river and finally into the Ohio.

Q. But it is the application of laws deduced from a study of basins which the rivers in the Erie and Ontario basins themselves show are not applicable to those two basins, is it not?

A. I don't know whether they show that or not, without having the information. I did not expect that these various streams like those in the Catskill Mountains would come into line with the general law, but they did.

Q. Your attention has not been directed to this study of the rivers in the Erie and Ontario basin, already in the case, your attention was not directed to it before you prepared, Mr. Stearns

A. I had seen some of the figures and knew while I was making those studies that the run-off from streams as computed by Mr. Williams into Lake Erie was much smaller than the run-off into Lake Ontario. But notwithstanding that knowledge, I did not credit that as being the correct record of the whole of the drainage areas of those lakes.

Q. Do you not think, if we wanted to get real accurate information as to how much water there was running into Lake Erie and Lake Ontario, the place to go to get it would be the records of the rivers that empty into Lake Erie and Ontario themselves, wouldn't that be the best way to do it?

A. That would be valuable for a part of the drainage area. Due allowance should be made for those sections of the drainage area where there were no measurements, and due allowance should be made for the inaccuracies of such measurements.

Q. Now I direct your attention to your Exhibit 1, Table E. I understand in your testimony you have expressed the opinion that during the period from 1889 to '90, the discharging capacity of the St. Clair river was increased by some 24,000 cubic feet per second. If that is true, why shouldn't the figures in column 5 of Table E down to the year 1890 be reduced by 24,000 for each year?

A. I don't find any such statement in Table E.

Q. I am speaking of your general testimony in the case, which I understood you to say has the effect of certain things which change the regimen of the St. Clair river, you were of the opinion that during that period 1889 to 1890 there was such a change in the regimen of the St. Clair river that there

was an increase in its discharging capacity of about 24,000 cubic feet per second?

A. I don't think that is the case. I don't recall such testimony.

Q. I direct your attention to your testimony, page 1307 "Q. Assuming that as stated in your answer to the preceding question, Huron has fluctuated 14 per cent. more in the earlier period, that is from 1860 to 1889, inclusive, than it did from 1891 to 1910, inclusive, what do you say as to whether the discharging capacity of the St. Clair and Detroit rivers was greater or less in the former or in the later period" (that is from 1860 to 1889 and from 1891 to 1910). "A. It was greater. Q. Assuming that the discharge of the St. Clair river was 197,600 cubic feet per second at certain stage of lake during the latter period (that is 1891 to 1910) that is stage of Huron, what would have been the discharge of the St. Clair river at the same stage during the earlier period?

A. I cannot give a definite amount, but on the basis that the discharge at a given stage increases at least as rapidly as the increment increases, and since the increment varies inversely as the fluctuations, it would not have been more than 87½ per cent. of 197,600 cubic feet per second, equal to 172,900 cubic feet per second.

Q. What would then be the difference between that and the discharge in the former years?

A. Not less than 24,700 cubic feet per second."

Q. Assume that is true, why shouldn't those figures in column 6 prior to the year 1891 be reduced by 24,700?

A. That is column 6 of Table E?

Q. Table E. I mean column 5 or 6?

A. This was an attempt to make a comparison between a deduced St. Clair discharge, and the discharge determined by the Complainant's equation.

Q. But the complainant's equation was derived from observations all made after 1891, was it not?

A. Yes. But notwithstanding that fact, if the channel had not changed its size or flowing capacity, then the complainant's equation would have applied to the year 1883; for instance the first one in the table.

Q. Yes.

A. But the fact that it did not apply shows that the channel has increased in size.

Q. That is true, but here you are comparing the St. Clair river discharges as deduced from the Niagara river with the

computed discharge. Now for the purpose of showing that the Niagara readings are out of line with the St. Clair readings, you have a St. Clair discharge which is deduced by the Government's equation, made from observations after the change of regimen occurred in 1890 or 1891. Now, is it not obvious that if you apply that equation to the years before the change in regimen occurred, you must correct the St. Clair discharge by the amount of increase of flow in the St. Clair after the years 1889 and '90?

A. The statement does not apply to all of the years; but rather to the total increase in the size of the channel from the earlier period, that is away back to 1883 or before. There was, in all probability, a progressive increase in the size of the channel and its carrying capacity, but if that amount was 24,000, then if one were to deduce the Niagara from the St. Clair discharge, that 24,000, if that is the amount, should be deducted, but I believe the 24,700, as given in the answer to this question, was that the amount was not less than 24,700, and it was afterwards stated that that method was not as precise as another method of obtaining the amount of the enlargement of the channel.

Q. I thought you said the two methods checked?

A. They do.

Q. But it is obvious that there should be some allowance there for that change in regimen, if the change in regimen in fact occurred?

A. There should be, if one were going to try and use those years to deduce the discharge of the Niagara, but that makes one added complication, so that naturally one would not select such years.

Q. Of course the effect of the use of these very high figures in column 5, for the years 1883 to 1890 has been to show that Niagara is very much out of line, whereas if the smaller figures were used, the discrepancy would not have been so great, isn't it?

A. No, I think you are mistaken. It has not been so used, as you will see by reference to other tables and other testimony. For instance in the charts put in today, no years have been used before 1895.

Q. I have not studied these charts put in today; we will have to study them to-night, but I am speaking of Table E, put in in connection with your examination in New York, and from which I understood the conclusion was reached that Niagara was out of line with the St. Clair by—

A. It may clear the matter up if I state that if you look at Table F, the next table, you will note that it is the years 1897 to 1906 that give a difference of 20,700, and as I remember the testimony that was the figures used in deducing the accuracy or inaccuracy of Niagara.

Q. But there was no table prepared in which the entire series of years was used, and in which the years from 1883 to 1890 were corrected by the change in the discharging capacity due to the alleged change in the regimen of the St. Clair?

A. No, because there was no occasion to, those years not being used; those years not being used in deducing the Niagara discharge.

Q. What use did you intend we should make of this Table E?

Mr. Adcock: I think that was explained in the direct testimony.

A. It was not thought that any use should be made of it except this: That Table F, which is supposed to be a more accurate table because it uses the St. Clair discharge by the defendant's equation, was presented as the table which showed the most accurate results, and so that the Government might see what the effect would be of using the St. Clair discharge by the complainant's equation, Table E was introduced. The defendant's equation was considered to be much better because it took into account the rise and fall of Lake St. Clair as well as the rise and fall of Lake Huron.

Mr. Wilkerson: Q. And also because in grouping the observations, there had been a period of a day before included, which was averaged up, or 12 hours included which was averaged up in determining the lake level to which discharge observations were referred. You regarded that as another reason why that was more accurate?

A. These are yearly observations, and there was nothing about a half day or a day in the discharge.

Q. No, I am speaking about the defendant's equation, the St. Clair discharge deduced from the defendant's equation; and the defendant's equation was deduced in the manner testified to in this case, by grouping the observations and weighting them, wasn't it?

A. Not to my knowledge, I believe it was not.

Mr. Williams: The increment used is derived from the group observations.

Mr. Wilkerson: Q. The observations were grouped and

weighted, and they referred to a gauge reading in which they were dated 12 hours back.

A. I will say that I did not recall that, or know it. The defendant's equation, I knew, introduced the element of the height of Lake St. Clair, and it was thought to be better by me on that account.

Q. That was recognized in the complainant's equation too, was it not, by a correction that was made when it was deduced?

A As I remember the Complainant's equation, it was assumed that Lake St. Clair would vary in a definite proportion with Lake Huron; that is no account was taken of the variations of Lake St. Clair from that assumed uniform variation. I am stating this from memory.

Q. Now have you any very definite idea in your mind Mr. Stearns of just why the discharge method that was used by Mr. Williams always got a larger increment than the method used by the Government Engineers from the very beginning in these computations? Did you ever try to figure that out?

A. I have examined the tables that he made and there were various methods, first, as I recall, in regard to the St. Clair increment, it was using mathematical results instead of stretching a thread through the points, and assuming the different observations to have equal weight. That is the most correct way to do it. Then there were other methods tried which seemed to me reasonable and proper, which gave higher results.

Q. You did not study however the manner in which the observations have been grouped?

A. I looked at some of the groups but I did not study the list of observations to see how they had been selected.

Q. You did not study to see whether there had been any method used in grouping?

A. No, except to a limited extent.

Q. As a matter of fact, the difference between this so-called three point method and the stretching of a string, did not make any particular difference, did it? It was slight?

A. It was only three or four per cent.

Q. Very slight. And the fact that the observations were weighted did not make very much difference, did it?

A. I don't recall.

Q. Isn't it a fact that the thing that made the difference was the peculiar way in which the observations had been grouped, and the inclusion of this 12 hour period in deter-

mining the gage reading to which the discharge measurements were referred?

A. I did not recall the 12 hour period and I do not know now whether that is the best one or not for the St. Clair River.

Q. Did you know that in the study which was made of the Niagara River measurements that 65 per cent. of the observations had been rejected or neglected?

A. I do not recall whether I knew it or not.

Q. Now in this Table F, your Exhibit Number 1, I observe in column 2 you have the Niagara discharge as figured by the International Waterways Commission formula?

A. Yes.

Q. That was a formula in which no consideration was given to the observations of 1907 and 1908, was it not?

A. I don't know. I do know, however, that it gives substantially the same results as the equations of the Complainant, as shown on the charts submitted here this afternoon.

Q. And in Table E, you have the St. Clair discharge Complainant's equation. The International Waterways Commission had a figure for the St. Clair discharge too, didn't they?

A. No.

Q. Did it not?

A. No, they used the Detroit River, except on some occasions when there was ice in the stream, and they resorted to the St. Clair. I might have made a mistake in my statement.

Q. I was just directing your attention for the purpose of refreshing your recollection to Table number 23 which appears in the Report of the International Waterways Commission for 1910, page 53, in which there is an increment stated for the St. Clair River at five different elevations.

A. I also note that there is a very elaborate equation for the St. Clair River discharge on page 46, and another for the Detroit River discharge on page 47. When I have referred to the International Waterways Commission's discharge equations, I have referred more directly to their tables as deduced from those discharge equations; and the tables giving the discharge, as I recall it of the Detroit River, and not of the St. Clair, except on rare occasions.

For instance, if you will refer to Table 26, which begins on page 131, you will see at the head of one of the columns there is the inflow from the Detroit River. On page 102, the discharge from Lakes Michigan-Huron is given as the outflow from Michigan-Huron through Detroit River, and at the bot-

tom there is a foot note indicating that discharges marked with a small a, are cases where the St. Clair River discharge was used.

Q. Why didn't they use the St. Clair, the Deep Waterways Commission, if you know?

A. Why didn't the International Waterways Commission use the St. Clair?

Q. Yes?

A. I presume it was because they thought that the other was better, but I don't know.

Adjourned to Thursday, October 16, 1913, 11:00 A. M.

Thursday October 16, 1913, 11:00 A. M.

FREDERIC P. STEARNS, resumed:

Mr. Wilkerson: Q. Do you understand Mr. Stearns that it is a generally recognized principle in making deductions from rainfall and run-off that in times of large rainfall, the percentage of run-off is greater in proportion than it is in times of low rainfall?

A. I think that is true.

Q. That is to say we have a season when there is a very heavy rainfall, and the ground becomes saturated, there will be more water in proportion of run-off than in a dry season when most of the water is absorbed in the ground and very little runs off?

A. Yes.

Q. So that in a year when you have a very heavy rainfall, the percentage of that which would go into the lake would be higher than the percentage of the small rainfall which would go into the lake?

A. That is so as a rule, as shown by the examinations which I have made.

Q. And in this discussion of the relation of rainfall to run-off, by Mr. George W. Rafter of the United States Geological Survey, which I read to you yesterday—

Mr. Adcock: Just a moment, is that an official report?

Mr. Wilkerson: Department of the Interior, United States Geological Survey, is what appears on it. I am not offering it. I am simply asking Mr. Stearns whether he agrees with it.

Mr. Adcock: I don't think you have a right to refer to it

unless it is a report made by an official, in accordance with some duty.

Mr. Wilkerson: Q. I direct your attention to the fact, Mr. Stearns, that Mr. Rafter—who is I assume an expert on this subject, is he not?

A. He was.

Q. Or was at the time. He states with reference to rainfall and run-off:

"Safe deductions cannot be made from an average run-off. What is wanted is a clear statement of the minimum together with the longest period which it may be expected to occupy. There is very serious danger in using percentage. The influence of the May rainfall is such that when above the normal, the stream flow is likely to be maintained during the summer." That is in accordance with your observations, is it?

A. The question was do I agree with that?

Q. Yes?

A. Yes.

Q. And it is also true, is it not, that in years of small rainfall, or at any rate in years when there is a small rainfall from June to November, the evaporation on the lake surface is likely to be higher than in years of large rainfall?

A. I do not think there is a material difference in the amount of evaporation. That is shown by taking experiments which have covered a series of years, and they do not vary much with the amount of rainfall. That is the rain period occupies so small a part of the time that there is still remaining a long period when evaporation takes place.

Q. What I had in mind was in a long hot dry season the evaporation was likely to be more than it would be—

A. In a hot season, the evaporation is more than in a cold season because the temperature of the water is greater, but the question of its being dry or wet is not very material; and I state that as the result of comparisons with the actual amount of evaporation in different years. It is affected somewhat by the amount of rainfall.

Mr. Adcock: You haven't any objection to the record showing that this report was published in 1903?

Mr. Wilkerson: Not the slightest. The report from which I read was published in 1903.

Mr. Adcock: It appears from the report that the tables were made up in 1899, that is the last table that appears, in 1899.

Mr. Wilkerson: I assume it does not make any difference because he said he agreed with what Mr. Rafter said.

Mr. Adcock: There were some other things you read from Mr. Rafter.

Mr. Wilkerson: That was yesterday.

Mr. Adcock: Yes.

Mr. Wilkerson: Q. Now, what is it makes the lake higher one time than another, as you understand it, Mr. Stearns? For instance on your chart number 1, we have lake elevations plotted here for 570 to 574½ feet.

A. I presume you refer to Lake Erie.

Q. Lake Erie, yes.

A. The cause of its being higher in one year than in another is due primarily to the run-off of its drainage area, including in that term the whole drainage area away up to the drainage area of Lake Superior. But it may be affected at times by the storing or withdrawal from storage of the water of the Great Lakes above it.

Q. So that a period of large run-off would indicate a period of high rainfall on the drainage basin?

A. Not necessarily. A high run-off into Lake Erie, because of the time required for the water to come from Lake Superior and Lakes Michigan and Huron into Lake Erie, it would be the effect of high run-off for years preceding the date in question.

Q. Now then in Chart number 1, Stearns' Exhibit number 2, I understand you have plotted the Niagara discharge as you have deduced it from the International Waterways Commission figures as to the St. Lawrence discharge. That is to say you have taken the St. Lawrence discharge for the particular year, and you have applied to that a correction which is obtained by taking into consideration the run-off of the Ontario basin, and by making an allowance for evaporation; and also by taking into consideration the storage?

A. Yes.

Q. Let me direct your attention to the year 1883, which is plotted on this chart. That shows, as I understand it, a mean lake elevation of 573.8. It shows a mean discharge of 277,400 cubic feet for Niagara. That is to say the discharge which corresponds to lake elevation of 573.8 is 277,400 cubic feet per second. Now then if as a matter of fact your tables are in error, in that you have not made a sufficient allowance for the quantity of water which runs into Lake Ontario from the Lake Ontario Drainage basin, you would have to subtract

from your St. Lawrence figure a larger sum than the one which you have subtracted, and the result of that would be that the circle which is plotted under the date 1883 would be shoved over nearer the left-hand side of the chart, would it not?

A. That would be the effect of it, to shove it towards the left hand, and the amount it would shove it on a given assumption, I can tell you.

Q. I want to get the general effect first, that is the effect of making too small an allowance for that one thing would be, if it were plotted correctly, it would be shoved over towards the left?

A. Yes.

Q. And that same thing applies to the other years?

A. Yes.

Q. Now if as a matter of fact for a very low elevation, as for instance where the elevation is 571; take the year 1895 where the elevation is 571.32, if as a matter of fact in making the correction by which you have gone from the St. Lawrence International Waterways Measurement to the Niagara measurements, you have allowed an amount for the run-off into Lake Ontario from the Lake Ontario basin which is more than you should have allowed, the result would be that you would have subtracted from the St. Lawrence figures an amount which is too large, and the effect of that would be that the circle for 1895 on that assumption would be shoved to the right of the chart by an amount which you could determine, referring to your tables, if you knew the amount of the mistake?

Q. If there were a mistake.

Q. Yes, and it were in that direction.

A. And I knew the amount of the mistake, and it was in the direction you have stated, it could be determined.

Mr. Wilkerson: In view of the laugh of the expert on the otherside, I will say it appears from his own figures that there has been a mistake. It appears conclusively from Mr. Williams' statements that there has been a mistake.

Q. Now then you have used, in making the deductions for the Niagara discharge from the St. Lawrence discharge a constant percentage , have you not?

A. Yes.

Q. Of the relation of run-off to rainfall?

A. Yes.

Q. And you have not taken into consideration the fact that

the percentage of run-off where there is a large rainfall is greater than it is where there is a small rainfall?

A. I have not gone into that refinement.

Q. You did not go into that refinement in any of the charts which you have drawn?

A. No. I went into the refinement of determining the percentage for the average conditions at Ontario and for the average conditions at Erie; but I did not think it worth while to consider the differences of different years, but can do so.

Q. I direct your attention to the fact that the discharge measurements for the Niagara river which were introduced in evidence in this case show the following facts with reference to discharge as related to lake elevations:

Take Observation number 84, December 7, 1898, of Lake Erie, level 573.69, the observed discharge 234,500. Now let us take your chart and see what discharge your curve gives for a reading of 573.69.

A. Which chart do you wish?

Q. This one, Chart number 1. I mean your line, your increment.

A. 264,000. That is by the main increment shown on the chart.

Q. It is by the increment which you have deduced from the St. Lawrence discharge?

A. Yes.

Q. Now let us take December 10, Lake elevation 573.92; the observed discharge 240,900. What is the discharge as derived from your increment?

A. 272,000.

Q. Now take September 24, 1898. I am picking these out at random. Lake elevation 572.24; the observed discharge is put down in the Government tables at 206,600. What is it according to your increment?

A. 212,000.

Q. Take October 4, 1898, 571.65; the observed discharge 188,700.

A. 191,000.

Q. 570.64?

A. The date?

Q. The date is October 17, 1898, 169,200. What is yours?

A. 154,500.

Q. 570.03; the observed discharge 154,500. What is it according to your curve?

A. 132,500.

Q. Now Mr. Stearns I ask you to give consideration to the figures which have been put down here, and which have been taken at random from the Niagara measurements, to get the fact that for an elevation of 573.69, which is a comparatively high elevation, your computed discharge is almost 30,000 cubic feet per second in excess of the observed discharge; that for an elevation of 571.65 it is practically on the line where the line of your increment crosses the line of the Government's increment, the difference is 2,300 cubic feet per second, your deduced discharge measurement being greater by that amount than the Government's discharge measurement. For an elevation of 570.3, your deduced discharge measurement is 22,000 cubic feet per second less than the Government's observed discharge measurement. I ask you what in your opinion there is in the construction of the current meter which would cause it to register 30,000 cubic feet less, which would cause it to under-register 30,000 cubic feet in the one instance, to register pretty nearly accurately in the other, and to over-register 20,000 cubic feet in another?

A. In regard to the last statement about 20,000 feet, the point is far beyond the limits of the data on which the comparisons have been made. But aside from that, I do not know of any reason why the current meter should register such differences.

Q. That would not indicate to your mind that in these sections which were measured by the Government Engineers this current meter was uniformly under-registering?

A. No.

Q. Because it is obvious that it was under-registering in one case and over-registering in another, assuming your equation is correct?

A. I do not think it is obvious. There are many elements that enter into the measurement of discharge, in addition to the revolutions of the current meter.

Q. Well, anything that would have a constant effect, and with reference to which the errors would not be largely compensating?

A. I don't know as to that. I could not grasp all of the features that entered into those measurements.

Q. What I want to do is this: We are trying to get the truth in this case. You have drawn a curve here, in which you have deduced a figure of 35,600 cubic feet per second from the Niagara river; and you have done that, not by taking observations at Niagara, but by taking the observations at the

St. Lawrence and reducing those according to your process; so that you have got your Niagara measurements from the measurements of the St. Lawrence?

A. Yes.

Q. It appears now that the discharge measurements which you have deduced are at one lake stage very much higher than those recorded by the Government engineers, while at another lake stage they are very much under those. Would it not seem to you that there was more probability that you have made a mistake in not handling this run-off in a proper way either in getting the percentage of run-off, or in not judging the percentage of run-off to rainfall than it is that these current meter Government measurements should be that much off?

A. To take the whole situation, there is a dilemma, in that there are measurements at Niagara that are consistent in themselves and seem to give, as one observes them, good results. There are measurements at St. Lawrence and at the St. Clair river, which are also consistent and seem to give good results.

If one were taking measurements at two points on the St. Lawrence river, or were taking measurements on the St. Clair and Detroit rivers, they would know that a large discrepancy could not be accounted for by the rainfall and run-off between the two. It would obviously be a difference in results, as for instance, at two points on the Niagara river.

Now in the method that has been followed in deducing the Niagara discharge from the St. Lawrence and St. Clair discharges, there are comparatively small quantities of run-off and evaporation; that is they are comparatively small in relation to the whole flow of the river. And it has been found by examination that any allowance for evaporation and run-off which is at all reasonable will still show that the Niagara discharges are in error in the manner shown by the diagrams.

To take the two years referred to in the earlier questions about the observations of 1883 and 1895, the correction applied for the evaporation and the run-off into Lake Ontario amounted to 12,110 cubic feet per second; the run-off itself amounting to 15,100 cubic feet per second. If the run-off had been twice as great as estimated, which I believe to be an entirely impossible condition, the difference would have been reduced by 15,000 cubic feet per second still leaving an error of 22,600 cubic feet per second. This is the year when the rainfall was 1 inch less than the average on Lake Ontario, and if I had taken into account the smaller run-off due to the lower rainfall, the run-off would have been less than 15,100 cubic feet per second, which would make the differ-

ence still greater than the 37,700 shown by the table and diagram. If there is an error in making the run-off too large, it obviously would increase the discrepancy.

If we take the other year mentioned, 1895, the correction for the evaporation and run-off is 6,410 cubic feet per second. The correction for run-off is 12,680. If this had been doubled, the deduced discharge would have been reduced by 12,680, giving as a result 156,620, cubic feet per second as the deduced discharge of Niagara. This would have shown, I believe, without computing, practically the same increment as if these changes had not been made.

Q. How about the rainfall in 1895?

A. I was going to call attention to that. The rainfall in 1895 was only 15.93 inches. It was one of the lowest years in the tables, which cover 24 years. And the actual run-off with such a low rainfall would, if I had gone into refinements, have been shown to be much less than the 12,680; so it is inconceivable, I believe that with that low rainfall, the percentage of run-off could have been greater than shown in these tables. The corresponding deductions from St. Clair agree very closely as to the increment, and I think also as to the quantity, with the deduction from the St. Lawrence.

Mr. Wilkerson: I move to strike that out. That is not a competent answer to the question.

Q. Did you, in deducing the Niagara discharge from the St. Lawrence measurements take into consideration any change of regimen in the St. Lawrence river?

A. Yes.

Q. What ones did you consider?

A. The change due to the building of the Gut Dam. In chart number 1, I assumed that that being a matter of knowledge to the International Waterways Commission, they had taken that into account in their printed figures, it being such an important factor. And in chart number 2, where the United States Lake Survey equations of 1912, were used, a different equation was used for the years from 1904 to 1906, inclusive, from that used in previous years.

Q. You prepared no diagram which shows the difference between your increment and that of the Government engineers, based upon the United States Lake Survey Report for 1912, as to the St. Lawrence river outflow, did you?

A. No, I used the Government's equation which included their increment, but made no comparison with it. Possibly I don't understand the question.

Q. On this chart 1 of yours, Mr. Stearns, let us take the

year 1890, for instance, and see what the effect would be there if there had been an insufficient allowance for run-off.

A. The run-off in that year was 20,900 cubic feet per second, and any addition to that amount would decrease the deduced discharge at Niagara by the amount of the addition.

Q. How, much of a correction would there be for that on the same basis that you spoke about the year 1883?

A. If the amount of run-off were twice as great as is shown, it would reduce the deduced discharge from 249,000 to 228,600.

Q. Which is substantially what it was by the International Waterways Commission?

A. Yes, only 3,000 cubic feet per second more.

Q. Now, let us take the year 1892 and see what the effect of that would be, making a correction.

A. The correction for run-off in that year was 18,450 seconds feet; an error of 100 per cent., doubling the per cent. of run-off, would diminish the deduced discharge from 222,400 to 203,950 cubic feet per second.

Q. That would put it away over to the left of the Government's line?

A. Yes. It may be well to say as applying to all of the four years that have been referred to that in any given year the amount of run-off due to a given amount of rainfall in six months depends to a considerable extent upon the way in which the rain comes. If it comes in heavy rains, more will run off and less will be evaporated than if it comes from time to time in small showers through a month, giving the same total but the averages of a series of years show a large degree of uniformity.

Q. But the point that I think now is obvious, is it not, is that if the allowances which are made for run-off in this computation be changed, that is, if the percentage be changed, the corresponding discharge measurements will be changed, and the whole line will necessarily be changed?

A. It will be set back, but not necessarily changing the increment.

Q. It might not necessarily change the increment and it might?

A. Presumably it would not, because the conditions of run-off and evaporation vary with rainfall and not with the elevation of the lake, and the differences there clearly vary with the elevation of the lake.

Q. As a rule, doesn't the elevation of the lake follow the rainfall, over a series of years?

A. No. As showing that, I plotted the local supply of lakes St. Cair and Erie, that is combining the run-off and the rainfall in connection with the elevation of the lake, and there is no indication that the rainfall is more when the lake is high than when it is low. The results are quite variable, as might be expected.

Q. Where does the water come from if over a series of years you have high lake levels, doesn't it necessarily mean a high rainfall?

A. It means that there is high rainfall preceding on all of the lakes, or some part of the lakes from Ontario to Superior. A high lake level is the result of that rainfall in previous years.

Q. It may be because of my stupidity, but I still cannot see why if following this method that you have followed here, if you take the run-off to be just twice what you have assumed it to be right through, if some years when you have a low run-off you multiply that low figure by two, and some years when you have a very high run-off you multiply that figure by two, and you combine those with other discharge figures, I cannot see why the effect of that is not to change the whole line, without regard to whether it makes it greater or less, I can't see why the introduction of a change of that kind would not change the increment. I don't undertake to say where it would throw it; it seems to me it would change the line.

A. It changes the location of the line, but not the increment. But it must be remembered all these changes of 100 per cent. are wholly hypothetical and assumptions entirely out of accordance with the facts as shown by a multitude of observations.

Q. Just as the one which you applied, as we think, compared with Mr. Williams' figures. You have had some experience in stream measurement, have you Mr. Stearns?

A. Yes.

Q. What kind of streams?

A. Small ones generally.

Q. You used the current meter?

A. Yes.

Q. And got accurate results as you regarded it?

A. Yes.

Q. What was the discharge of the largest stream in the measurement of which you took part, at the time of the measurement?

A. I can explain in one way: It has always been so small that I could use a current meter on the end of a rod, so that

I could hold it in its position that way; that is, the streams were three or four or five feet deep generally.

Q. Do you remember the discharge approximately in cubic feet per second?

A. Why, the average discharge of the Sudbury river, which is one of the streams I have in mind, was about 120 cubic feet per second.

I remember once measuring a larger stream in Michigan, but that was only for a day or two and was still within the depths where I could use a current meter on a rod.

Q. You have had your attention directed have you not, Mr. Stearns to the third section which was measured on the Niagara river?

A. Yes.

Q. Have you given any consideration to that at all?

A. No, I saw a chart showing the lines, and a blueprint, with typewriting matter.

Q. You are not prepared to say whether or not a consideration of that might lead you to modify some of the facts which you have expressed with reference to the correctness of those Niagara discharge measurements?

A. I am not.

Q. Would the fact that the measurements in that section checked very closely with the measurements in the two sections which have already been referred to in evidence be an indication to your mind that there was a stronger reason than there had been to believe that the Niagara measurements were correct?

A. It would have some weight because it would give some further evidence that the incorrectness was in the gagings of the St. Clair and St. Lawrence. But there is an absolute inconsistency which cannot be reconciled in any reasonable way in the Niagara gagings and those of the St. Lawrence and St. Clair. It would have some weight though, I think, if they were sufficiently extended and proved to be right as far as could be judged, in saying which were correct.

Q. When you say "inconsistency," you mean inconsistency on the basis of the run-off as you have computed it, and other factors that you have indicated?

A. Yes, as I have indicated and as I conceive that it could be. I cannot conceive that the run-off, for instance, at high levels of the lake with the same rainfall is going to vary from the run-off at low levels of the lake with the same rainfall, and applying any amount of run-off, assuming it to be in propor-

tion to the rainfall, will still give that inconsistency in increment for the Niagara discharge.

Q. But you saw the table prepared here for certain years, in which the Niagara and St. Lawrence checked very closely, did you not? I think that was our Exhibit N.

A. As to the actual quantity by the computations which have been made, they do agree in some years, but the increment does not.

Mr. Wilkerson: That is all.

Adjourned subject to notice.

VOL. 3

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS, } ss.
EASTERN DIVISION.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,019, and Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

MR. JAMES H. WILKERSON,
United States Attorney, and
MR. ALBERT L. HOPKINS,
Assistant United States Attorney,
For Complainant.
MR. EDMUND D. ADCOCK and
MR. ALFRED S. AUSTRIAN,
For Respondent.

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UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS,
EASTERN DIVISION. } ss.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* *vs.* **THE SANITARY DISTRICT OF CHICAGO,** *Defendant,*	**C. C. No. 29,019.**

The deposition of JOHN R. FREEMAN, taken pursuant to notice, before Samuel M. Morgan, Commissioner, on the 4th day of April, A. D. 1913, at the offices of Messrs. Mayer, Meyer, Austrian & Platt, Chicago, Illinois.

Present:

Mr. James H. Wilkerson, on behalf of the Government;
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian, on behalf of the Sanitary District.

Mr. Wilkerson: I assume that the testimony of this witness may be taken under the same arrangement as to objections and motions to strike as was made with regard to the other witnesses.

Mr. Adcock: Yes.

Mr. Wilkerson: I will reserve those objections and motions then, so as not to interrupt.

JOHN R. FREEMAN, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your full name?
A. John R. Freeman.
Q. What is your residence?
A. Providence, Rhode Island.
Q. What business are you in?
A. Civil engineer, making a specialty of hydraulic work.
Q. And your office is at Providence, Rhode Island?
A. Providence, Rhode Island; also New York City; and have a Boston office also.
Q. Will you state your early training, your experience, and what official positions, of honor or otherwise, as civil engineer, you have held?
A. I graduated in the civil engineering course at the Massachusetts Institute of Technology thirty-seven years ago. Since that time I have been continuously in the practice of civil engineering, making a specialty of hydraulic work, such as water power development and municipal water supply. For ten years, from 1876 to 1886, was principal assistant engineer of the Water Power Company controlling the Merrimac river at Lawrence, Massachusetts, where a large part of my duties were connected with measuring the quantity of water used from day to day by the various factories, and in measuring the flow of the Merrimac river.

During this time I also acted as principal assistant to Mr. Hiram F. Mills, in consulting engineering, which embraced water power work on various rivers; and I had charge of measuring the water used by the factories at Manchester, New Hampshire; also had charge of investigations for water power development at Concord, New Hampshire, which involved studying the flow of the river and making gagings of it. During this period I had supervision in detail of many experiments in hydraulics made by Mr. Mills, which involved the devising of methods for the accurate measurement of flowing water, and studies of the yield of the watersheds of rivers, and studies of evaporation.

I was a member of the Metropolitan Water Board of Massachusetts, which Board was appointed in 1895 to plan and

build the water works for the supply of about fifteen municipalities, of which Boston is the center and chief city.

For two years, about five years ago, I was principal consulting engineer to the New York State Water Supply Commission.

For twelve years, I have been almost continuously engaged as consulting engineer to the City of New York, in connection with the improvement and enlargement of its water supply. This work has involved estimating the yield from many watersheds, and studying the evaporation from great reservoirs.

I was for several years consulting engineer to the water works at Nashua, New Hampshire; and have been consulting engineer to various other municipalities, relative to their water supply. Among these was the city of Los Angeles, California, with reference to its new supply from the Owens river; and the City of Baltimore on the extension of its water works. And for three years past, and at present am consulting engineer to the City of San Francisco in the development of additional water supply, which involved the study of the yield of watersheds, and the evaporation from reservoirs.

Have been consulting engineer to the Mexican Government on the extension of the water supply of the City of Mexico. And for three years past, and at present am consulting engineer to the Canadian Government on matters of water power development on various rivers in Western Canada.

Have made extended studies of the obstructions to flow of rivers caused by ice, principally on the St. Lawrence river, and with reference to water power development at Massena, New York; and in reference to the proposed Long Soo Water Power development on the St. Lawrence.

Have been consulting engineer to water power companies at Niagara Falls. For several years past, consulting engineer to the Mississippi River Power Company on various matters connected with the development of water power on the Mississippi river at Keokuk, Iowa; and have made special study of the ice obstruction to the flow of the Mississippi river at Keokuk.

Was a member of two Boards of Engineers appointed by the President to investigate matters connected with the building of the Panama Canal.

Planned water power developments of the Great Western Power Company on the Feather river, in California, which included a storage reservoir of forty square miles in area, re-

quiring extended studies of evaporation and yield of watersheds.

Have acted as consulting engineer to the United States Reclamation Service, in building the dam on the Boise river. Was consulting engineer to extensive irrigation works in Texas. Have made many experiments, personally, upon the flow of water; and am familiar with the methods of water measurements by current meters and various other devices. And have had practical experience with most of the devices in ordinary use for measuring the flow of rivers.

Q. Have you studied the reports of the Chief of Engineers of the United States Army from 1900 to 1912 inclusive, and the records of discharge measurements of the St. Clair, Niaraga and St. Lawrence rivers; and the statements made in the reports of the Chief of Engineers as to the amount by which the Great Lakes would be lowered by a diversion of 2, 4, 10, or 14,000 second feet through the Chicago Drainage Canal?

A. I have studied these reports in great detail.

Q. Have you studied the testimony of Mr. F. C. Shenehon, a witness for the complainant, and his statement that with 10,000 second feet diverted through the Chicago Drainage Canal these lakes would be lowered substantially as follows: Michigan-Huron, 5 inches; Erie, 5½ inches; Ontario, 4⅛ inches?

A. I have.

Q. Have you studied the testimony of Mr. Gardner S. Williams, a witness for the defendant or respondent in this case, and his methods of computing from the data described as given in the report of the Chief of Engineers, and the various exhibits in this case, from which he concludes that the lowering of the several lakes, assuming that the measurements of the St. Clair, Niagara and St. Lawrence were correct, will be substantially as follows: Huron, 4 1/6 inches; Erie, 3 2/3 inches; Ontario, 3.95 inches?

A. I have studied these carefully.

Q. Have you compared the data, and the selected methods used by Mr. Shenehon and Mr. Williams sufficiently to reach conclusions of your own as to which estimate is most nearly correct, assuming the records of the observations made by the Government on the St. Clair, Niagara and St. Lawrence rivers are correct?

A. I have made careful studies of the computations of both, and I find that both engineers start from substantially the same data; that Mr. Williams' results average about one-

fourth part smaller than Mr. Shenehon's, and that the difference in this result comes from differences of precision in the methods of computation.

The chief differences in these methods are, first, that in preparing the curve of discharge, consisting of a line upon a diagram for showing the increment or the rate of increase in discharge corresponding to one foot increase in height at the respective gaging stations, that apparently Mr. Shenehon, and the Government Engineers, have determined the relation of discharge to height by some such mechanical means of averaging the separate observations as by drawing a thread through the observations, or by making an approximate average by some such means of trial and error as drawing a random line and then measuring the distances of the several observations from this line, seeking to make the sum of the distances on the two sides of the line, for observations at about the same height, equal; which method is one commonly used by engineers for approximations.

On the other hand, I find that Mr. Williams for deducing his discharge curve and increment from the same observations has made use of a method of greater mathematical accuracy, which method I notice has been recently used under the name of the Three Point Method, by the Government Engineers, in certain of their more recent determinations of this same kind.

Second: I find that Mr. Shenehon and his associates, in the preparation of their discharge curve and increment in evidence in this case for determining the effect of the Chicago diversion upon the lake levels have, in the case of the St. Clair river, based their increment solely upon elevations observed in the St. Clair river near the outlet of Lake Huron, and have made no allowance for the effect upon the discharge of the varying elevation of Lake St. Clair.

On the other hand, I find that Mr. Williams, in his similar computations, has carefully made an allowance for the influence of the elevation of Lake St. Clair upon the discharge.

Third: I find that Mr. Shenehon and his associates, in preparing their discharge curve and increment presented in the testimony in this case, have, for the purpose of establishing their average values, included substantially all of the measurements of discharge that have been made, without discarding those in which the lake and the river were in such a changing and unstable condition that the regimen of flow was probably not well established.

On the other hand, I find that Mr. Williams has selected

out from the great number of discharge measurements those in which the lake and river had a nearly constant elevation for a sufficient time prior to the measurements, and during the measurements, so that a stable condition of flow was apparently secured.

To sum up the comparisons between the methods of Mr. Shenehon and his associates, in evidence in this case for establishing the relation of river discharge to height of lake, I find that the methods followed by Mr. Williams lead to a higher degree of accuracy, granting that the data from which both had started is correct. I have not myself attempted to check over all of the arithmetical computations of either party, nor have I personally replotted their diagrams; having assumed this work of arithmetic and drafting was correctly done in both cases; and having found, as I believe, a sufficient explanation for the difference of about five-sixths of an inch, in the case of Huron; about 1 3/4 inches in the case of Erie; and one-fourth of an inch in the case of Ontario, to be sufficiently explained by the difference in the precision of methods followed in the computation which I have described above.

Q. Assuming, as it is claimed by the Government witnesses, that the diversion of 10,000 second feet at Chicago would lower the lakes to an amount of 5 to 4 inches in each case, and that the average diversion through the Chicago Sanitary and Ship Canal during the past ten years has been approximately one-half of this amount, from which it might be inferred on the theory of the Government's witnesses that this actual diversion would have lowered these lakes from 2½ to 2 inches, respectively, have you studied the record of changes of lake levels with a view to determining the possibility of detecting the evidence of any such effect of lowering?

A. I have studied these records; and I find it plain that it would be utterly impossible to detect by direct measurement a lowering of this small magnitude, because of it being disturbed by the continual fluctuations in level of the lakes, which come from natural causes and which are of far greater magnitude.

Moreover, a lowering of this small magnitude would be obscured by the effects of far greater magnitude in lowering the lake levels resulting from the dredging by the Government in the improvement of navigation in the river channels.

I may add that this quantity of 5,000 second feet, which has been diverted, is only about 2½ per cent. of the average flow

at the points where the discharges of the lakes have been measured, which amount is smaller than the precision that can be attained in the most careful measurements of the discharge.

Q. Describe what these fluctuations are which render it, as you say, impossible to measure the effects of the magnitude claimed due to the diversion at Chicago?

A. In order to illustrate these more clearly, I have prepared a diagram, "J. R. F. Exhibit No. 1," extended to 1912 from the data shown upon Williams' Exhibit 26, which I submit to the Commissioner to be marked "John R. Freeman Exhibit 1."

Whereupon the diagram described by the witness was marked by the Commissioner "John R. Freeman Exhibit 1."

Q. Will you describe the exhibit which has just been identified and marked?

A. This bears the title: "Studies relative to Chicago Drainage Canal by John R. Freeman, March 17, 1913." At the top of the diagram I have traced curves showing the elevation of the Great Lakes month by month, throughout the entire period from 1860 to 1912; these curves being an exact copy of Plate No. 1 in the Report of the International Waterways Commission for the Regulation of Lake Erie for 1910. To the right of this diagram I have drawn parallel lines separated by a distance measured upon the same scale as the diagram just referred to, which show the computed effect of the diversion by the Drainage Canal in lowering the lakes, based on the defendant's reduction of the complainant's observations; this lowering being estimated without regard to any compensation works. By comparing the dimensions corresponding to diversions of 4,000, 10,000 and 14,000 second feet with the range of fluctuation in the lake surfaces, from month to month and from year to year, it will be seen that the great fluctuation of the lake surface from natural causes obscures any lowering of the magnitude computed as due to the withdrawal of water through the Chicago Drainage Canal.

There are about six different kinds of oscillations or change in the lake levels, each of which is of far greater magnitude than that estimated to be caused by the diversion of the several quantities through the canal.

For example, we have first, the change of lake level which is dependent upon the varying quantity of rainfall from year to year.

A second kind of fluctuation in lake level is that resulting from the clogging of the outlets of the several lakes by ice, during the winter. This effect is particularly large in the case of Lakes Huron and Michigan; and results from ice cover in the St. Clair river, and occasionally is increased by ice gorges near the head of the St. Clair river. Both the ordinary ice cover and the ice gorge hold back the discharge from Lake Huron, and this causes the level of Lake Huren to rise, while at the same time causing the level of Lake Erie to fall. The magnitude of the change in level caused by ice varies greatly from year to year, in an extremely capricious manner, and to an extent which at present cannot be measured, throughout almost the entire period for which we have accurate lake levels.

This obstruction is extremely variable from year to year, and even from day to day, depending upon many causes con-

nected with wind and weather. The magnitude of the obstruction depends primarily upon the intensity of the cold weather and the duration of the period of extreme cold; and secondarily it is dependent upon the effect of wind in breaking off shore ice from near the outlet of the lake, which floating down through the narrow part of the St. Clair river where the water is open becomes crowded against and lodged beneath the ice covering the river, where it broadens out.

These ice effects were observed with considerable care by the United States engineers only in the year 1901, and at that time periods were found when the flow of the St. Clair river was cut down about one-half by ice. A reference to this may be found in the report of the Chief of Engineers for 1902, on pages 2835 and 2836.

On the other hand, in winters like that which we have just passed through, there would be little or no clogging of this kind. Obviously when the St. Clair River is thus clogged Lakes Huron and Michigan must rise, and Lake St. Clair and Erie must fall, because of the cutting off of their most important source of water supply. Lake Erie doubtless also suffers some impediment to its discharge, because of ice in the Niagara River. But the records indicate that the extent of this clogging is far less than in the St. Clair River.

Perhaps this is as good a place as any to go into this question of ice obstruction, in some detail. I regard this matter as extremely important, because I am led to believe that failure to appreciate its influence has led to serious error in the studies of the levels of the Great Lakes by the Government Engineers; and to the best of my judgment and belief, sufficient compensation for its effect has not been made in their computations and estimates of the yearly discharge of the several lakes, and in the relation of their levels.

From the following observations hereinafter stated, I am led to believe that the effect of ice obstruction, particularly in the case of Huron and Michigan, may be at times far greater than any possible change of level due to the diversion through the Chicago Drainage Canal. I have had occasion to make extended studies of the influence of both ice cover and ice gorges in lessening the discharge of rivers. By "ice cover," I mean the smooth covering of ice remaining in the place where it was formed, presenting a smooth surface to the flowing water on its under side. By an "ice gorge" is meant the condition that results from the ice on the shores of lake or river becoming broken off by wind or wave or change of level, and floating down the stream, and being drawn against

and beneath an ice cover further down the stream, at a point where freezing has occurred by reason of the velocity being less. Conditions of this character are presented in the St. Clair River within a few miles from the outlet of Lake Huron. They are also presented in the St. Lawrence River, particularly in the vicinity of Ogdensburg and in the vicinity of the Long Soo Rapids. To a less extent they are present in severe weather in the Niagara River.

I have had occasion to study these ice conditions in the St. Lawrence River very carefully in connection with the water power developments from the St. Lawrence near Massena, New York; and during the past winter have had occasion to study them on the Mississippi River in the vicinity of Keokuk, with particular relation to the water power now being developed by the dam across the Mississippi River at that point.

To a less degree, I have had occasion to study them in the Niagara River, and during some of the most extremely cold weather of the past winter have had occasion, in connection with my engineering work for one of the water power companies at Niagara, to personally observe the condition of ice formation in the Niagara River between Chippewa and the Falls.

Some of the data from which the conclusions stated above is reached are presented in the report of the Chief of Engineers for the year ending June 30, 1901, on pages 3765, et seq., wherein are described the discharge observations during the very severe ice conditions in the winter of 1900-1901. This states that, "The temperature conditions of the early winter were such that by January 20 Lake St. Clair and the St. Clair River were frozen over from its mouth to a point above Stag Island. The foot of Lake Huron had also frozen over, and what is known as the Ice Bridge had formed at Fort Gratiot. This left open water from a point just below Fort Gratiot to a point some little distance above Stag Island." (p. 3771—Report 1901.)

This section of open river permitted them to continue discharge measurements as usual, and it was found that almost immediately after the closing of the river in January, the discharge fell off approximately fifty per cent., and did not resume normal conditions of flow until the river became free of ice, about the middle of May.

During the general breaking up of the ice, immense masses of it were forced into the river by northerly winds and so choked the flow that for a time but very little water could have found its way through. For same days Lake St. Clair

was but a few inches above the level of Lake Erie. This condition of restricted flow has made itself manifest in the relative elevation of Lakes Huron and Erie, and we find that for the month just closed Lake Huron was 0.55 of a foot higher, while Lake Erie was 0.75 of a foot lower than during June, 1900. These fluctuations, it will be noted, are greater than those estimated to occur because of the present or prospective diversion through the drainage canal.

While the conditions in this year were doubtless uncommonly severe the record of temperatures indicates that something of this kind may frequently occur. And from my study of the levels of the Mississippi River during the ice season, for the past thirty years and more, and my studies of all records that I could find on the St. Lawrence near Massena, and from diligent search for information from the old inhabitants made by my assistants, I am led to believe that the obstruction due to ice upon the St. Lawrence, the Niagara, and particularly the St. Clair, is greater than I find allowed for in the yearly computations of flow reported in the annual report of the Chief of Engineers.

Q. Will you state the conditions which you have observed with reference to ice, upon the Mississippi, St. Lawrence, Niagara and St. Clair Rivers, with which you have personally been connected, and upon which you base the conclusion which you have just stated?

A. I have not my notes of field observations or of records of gage heights with me at the present time, and have trusted to my memory as to what I have seen of ice conditions and as to its effect upon the discharge of the rivers. But my recollections are very clear as to the immediate effect upon discharge produced by ice obstructions having been substantially as stated above.

Q. Will you describe the ice conditions which you have personally observed in these rivers that you have mentioned, the Mississippi, St. Lawrence and Niagara?

A. I have personally made more observations upon the St. Lawrence than on the other rivers; and have noted three or four different kinds of ice formation causing interference with the flow of the river.

The first of these is the ordinary smooth ice cover, which cuts off the section of water way at the top by a depth nearly equal to the thickness of the ice, and which causes a slightly increased friction upon the upper surface of the water, and thereby lessens the flow corresponding to a given gage height

in two ways: First, by the smaller cross section; and, second, by the greater friction against the water.

Q. Where did you observe this ice cover condition which you have mentioned?

A. I have observed this in a great many rivers, in the St. Lawrence, the Merrimac, the Mississippi and other rivers.

Q. And when?

A. From time to time during the past twenty years.

Q. How do you reach the conclusion that you have stated there, that there is an impediment to the flow caused by ice conditions?

A. This kind of obstruction is well recognized by all hydraulic engineers familiar with river flow, and is the simplest kind of obstruction from ice.

The second kind of troublesome ice, found more particularly on northern rivers, is the broken ice consisting of cakes which become detached from the ice cover at a point upstream, from a section of swiftly flowing water, and being carried by the current against the edge of an ice cover formed in the more quiet water at some section of broader area lying down stream from the open channel, are drawn beneath the surface of this ice in a way to gradually roughen the under surface of the ice and further increase the friction, as well as cut off an additional amount from the area of cross section of the waterway. The magnitude of this kind of obstruction is extremely capricious and uncertain, changing rapidly from day to day.

Q. Have you observed these conditions upon the St. Lawrence, Niagara and Mississippi Rivers?

A. I have, and on the Merrimack River also.

Q. During what period did they occur?

A. I may complete my previous answer by stating: As illustrating this rapidly changing condition, I would call attention to the measurements made upon the St. Clair River in January, 1901, reported on page 2835 of the report of Chief of Engineers for the year 1902, in which it will be noted that the discharge measured on January 15, was 181,200 second feet, while that measured on January 30, was only 97,000 second feet. On March 29, the measured discharge was 197,200 second feet; on April 2nd, 159,200 second feet. On April 5, this was found cut down to 108,500 second feet; and on April 10, to 74,000 second feet, which it will be noted was only about one-third of the quantity which was measured flowing on April 1st.

On April 12, the measured discharge was 86,900 second feet, and on the next day, April 13, was 128,700 second feet.

Again on April 16, the measured discharge was 178,300 second feet and on the 19th this was found cut down to 76,000 second feet, or but little more than one-third of the quantity measured three days previously.

In no other winter do I find that discharge measurements have been maintained during the ice season upon the St. Clair River or upon any of the other rivers which form the outlets of the Great Lakes, save a few on the St. Lawrence, which are given in much less detail.

On the St. Lawrence River, I now recall that my investigations showed that the outlet of Lake Ontario became frozen over with an ice cover that presumably was fairly smooth, but down the river at Ogdensburg, the ice cover was broken up for the purpose of maintaining communication between the railroads at Ogdensburg, on the American side, and Prescott, on the Canadian side; and the broken ice drifted down against the ice cover on the river below, under conditions which, from my experience elsewhere, I was led to believe might cause variable obstructions from gorging.

Further down stream on the St. Lawrence, before the Long Soo is reached ice troubles of a third kind begin. This third kind of troublesome ice is that sometimes called "anchor ice," but on these northern rivers near the Canadian border is called "frazil" ice. I have studied this ice during my efforts to keep the canal of the St. Lawrence Water Power Company in operation during the winter, and it has been studied in great detail by certain of the Canadian Government Engineers in relation to ice floods upon the St. Lawrence, which sometimes threaten various of the cities along the river, and result from the sudden clogging of the river by accumulations of this "frazil" ice, in combination with the broken cake ice, described as the second kind of troublesome ice above.

This frazil ice has also been carefully studied by Prof. Howard T. Barnes, of McGill University, Montreal, who has published a book entitled "Ice Formation," which in part deals with this matter.

A report of the Canadian Government investigations was published by Mr. Thomas C. Kieffer, Civil Engineer.

In my studies of the St. Lawrence conditions, I have had occasion to confer both with Mr. Kieffer and with Prof. Barnes; and Prof. Barnes has joined me personally in studying the conditions in the St. Lawrence near Massena.

This frazil ice chiefly forms on the bottom of the river, in the form of masses of needle-like crystals, which cohere in a mass so long as the temperature of the river water is a few thou-

sandths of a degree below 32 degrees Fahrenheit. This frazil ice forms on the bottom chiefly during the night, and becomes detached from the bottom during the slightly warmer temperature of the following day in great masses, which float down stream and gather beneath the ice cover and form hanging dams which greatly obstruct the flow.

During the past winter I have observed this frazil ice floating in the Niagara River between Chippewa and the intake of the Ontario Power Company, and coming down in such masses as to seriously obstruct the ice fender and in-take connected with the Water Power Works; and I have personally observed the men breaking this out from the openings by exploding dynamite, so as to admit a proper supply of water for the turbines.

From thus observing the frazil ice floating at Niagara, I am convinced from my studies elsewhere that this ice must have been formed upon the bottom of the river at some point in the rapids upstream; and I have no doubt that this formation upon the bottom of the river tends to cut off and reduce the flow over Niagara Falls, and therefore, to some extent, the magnitude of which I am unable to determine, holds back the outflow from Lake Erie and thus influences the height of the lake.

I note also on page 5360 of the Report of the Chief of Engineers for the year 1900, it is stated, with reference to the Niagara flow that: "In January, February and March, the decreased slope is doubtless due to the lodgment of ice in the lower river shallows above the rapids leading to the falls."

I have observed the formation of this anchor ice in rapids in the Merrimac River, and have pried large masses of it loose, while I have been making soundings for the building of a dam.

A fourth kind of troublesome ice is the so-called "slush" ice, which results from the drifting of snow into water, chilled to the freezing point so that it does not become melted, but partakes largely of the characteristics of frazil ice.

From carefully studying the reports of the Chief of Engineers for the past 12 years, in the light of my own investigations as to the obstruction of ice as above described, and from the general lack of reports concerning ice conditions, save during 1901 on the St. Clair, and a few observations on the St. Lawrence, I am led to believe that sufficient allowance for the retarding effect of ice upon the outflow from the Great Lakes

has not been made in the estimates by the Government Engineers.

Mr. Wilkerson: I submit that the statement of the witness does not disclose the basis for the opinion that the Government Engineers have not made sufficient allowance for ice obstruction, or for the conclusion as to the relative effect of the ice obstructions and the diversion of the water at Chicago.

Mr. Adcock: Q. Did you wish to say aynthing further upon the effect of ice conditions?

A. I desire to again call attention to "John R. Freeman Exhibit No. 1," to the diagrams plotted a little below the middle of the sheet and opposite the legend "Average monthly difference in elevations between Lakes Mich.-Huron and St. Clair," and also opposite the legend, "Average monthly difference in elevation between Lakes St. Clair and Erie."

These two diagrams were prepared from the diagram at the top of the sheet, by taking the differences month by month between the curves of the upper diagram lines for Huron and St. Clair, and these between St. Clair and Erie; and transferring these directly to the diagram below, thus mechanically performing the operation of subtraction.

The matter to which I would now call attention, in relation to the obstruction of flow of the St. Clair River by ice is, that not only in the year 1901, during the months of February, March and April is there an extreme difference of levels between the lakes, shown by a sharp peak extending upward on the Huron-St. Clair curve, and a sharp peak extending downward upon the St. Clair-Huron curve, which results from the obstruction by ice as described in the quotations and citations made above from the Report of the Chief of Engineers, but similar sharp peaks and depressions are found in many other years, notably in 1855, 1871, 1874, 1877, 1896, and many other years; and in some cases, notably in 1877, the disturbance of level is even greater than that found during the year 1901.

On the other hand, the diagrams now under examination show another class of ice effect in the year 1895, and 1909-10, in which the fall from St. Clair to Erie is about one foot greater than normal, and the fall from Huron to St. Clair about one foot less than normal; this indicating that the ice gorge at that time was in the Detroit River rather than in the St. Clair River.

Q. Are there any other fluctuations than those that you have heretofore described?

A. I have so far described only two kinds. There are at least four other kinds of fluctuation of lake level which tend to obscure the effect of the Chicago diversion, and make it impossible of direct measurement.

The third of these is the so-called seasonal rise, which results each year from the melting snows and spring floods, bringing an excess of inflow, which raises the level and gradually wastes away. It will be noted by an examination of the diagram, at the top of "J. R. F. Exhibit 1," that the lakes each commonly stand about one foot or more higher in the month of June than they do earlier in the year, or than they stand at the close of the season of drouth, towards the end of the year.

A fourth kind of oscillation is that which occurs from day to day, due to barometric changes, the effect of which appears to be very rapidly transmitted through the deeper of the Great Lakes.

A fifth disturbance or oscillation in the level of the lakes, some times greater in magnitude than any of the others, is that produced by long continued, strong winds blowing lengthwise of the lake. The observations of the government engineers show that the outlet of Huron is sometimes raised about two feet above its normal level because of such winds, and they also show that the easterly end of Lake Erie is some times tilted up six, or possibly eight feet above the western end after long continued strong winds.

And on page 24 of his report upon the Preservation of Niagara Falls (62nd Congress Senate Document 105), Mr. Shenehon states: "At Buffalo, in westerly gales, the water sometimes rises eight feet, and in easterly gales sometimes falls six feet, giving a range of fourteen feet." Also he states on the same page that there are three kinds of variations in surface level of Lake Erie at Buffalo: First, periodic variations in the lake stage, due to an accumulation of water from successive wet seasons, or the reverse due to a series of dry years. Thus, in 1895, the lake had a depth of 2½ feet less than it had in 1876. Second, seasonal variations due to greater water supply in the spring rains and freshets, resulting in the presence of more water in the lake in June than in November, by a foot or more. And third, the rise or fall at Buffalo," as just described.

He says also: "All three forms of variations may be superimposed, as for instance in the westerly blow in June, 1896."

The sixth kind of oscillation in lake level, which tends to

obscure precise measurement of such small changes as that due to the Chicago diversion, is the wave effect prevalent during high winds; these waves often rising and falling from three to five feet, or even more, at intervals of a few seconds. These rapidly changing oscillations may very seriously impair the accuracy of a gage reading from which the mean height is determined, if it is attempted to read directly from a graduated staff, or even with the standard type of floating gage used by the government, when the stilling device for this happens to be unskilfully applied.

I can find in the reports of the Chief of Engineers relative to the construction of these gages no proof that the precautions to secure accuracy during violent wave motion received proper attention.

Sources of error may come from the small inlet through which the pressure is transmitted happening to be so shaped that it is easier for water to flow inward than to flow outward, or vice versa. In my experience in water measurement, I have found this a common cause for lack of precision of measurement.

Another source of error in a floating gage enclosed within a "still box" may come from the orifice being placed in such relation to the current floating past that there is an addition or deduction from the true elevation caused inside the box, either by the impact or the suction of the current past the gage.

I find in some of the recent reports of the United States Engineers, notably that by Junior Engineer W. S. Richmond, dated June 15, 1912, relative to Hydraulics of the St. Lawrence River, which will be submitted in evidence and which has been furnished to defendant by complainant from the United States Lake Survey Office, statements that errors of this kind in gage heights near the head of the St. Clair River, which were used in the determination of the complainant's equation and increment of discharge, have recently been discovered.

The occasional violent and disturbing effects of these various kinds of oscillation are hidden in the tabulations presented in the Reports of the Chief of Engineers relative to lake levels, by reason of the fact that in substantially all cases the elevations therein recorded are averages of a great number of observations, and this process of averaging tends to smooth out and conceal the violence of the fluctuation of individual

readings of the gage. Thus, for example, the mean monthly heights appearing in the diagrams of lake levels published from year to year in the Report of the Chief of Engineers are each the average of from thirty to perhaps one hundred more or less discordant observations, in which the discrepancies tend to offset one another.

To illustrate the magnitude of the oscillations in lake level, and the rapid change of conditions affecting flow, which sometimes occur, I would call particular attention to Plate No. 1 in the Report of the Chief of Engineers for 1900, following page 5365, a photographic copy of which is submitted, and marked "J. R. F. Exhibit No. 2."

(Photographic copy of plate referred to was here marked "John R. Freeman Exhibit No. 2.")

From this diagram it will be noted that during a period of only about an hour and a quarter, from half past six A. M. to 7:45 A. M. on May 17, 1899, the government gage at the head of the St. Clair River showed a change in elevation of more than 2½ feet, or about ten times as great a change as that which it has been estimated would result from the diversion of 5,000 second feet at Chicago.

It will further be noted that the change in the discharge of the St. Clair River corresponding to the discharge curve used by Mr. Shenehon in computing the effect of the Chicago diversion, would vary from about 236,800 second feet to about 172,500 second feet, in the course of this period of about an hour and a quarter; which difference of 64,300 second feet is six times as great as the proposed 10,000 second feet diversion at Chicago.

It is not stated that oscillations so extreme as this occurred during the process of current meter measurement in the St. Clair River; but other diagrams and statements given in the published description of these gagings may be referred to as showing that during many of the measurements relied on for establishing the complainant's increment of discharge, there were oscillations of such magnitude as to seriously affect the precision of measurement of the discharge; particularly so when it is considered that the measurement of lake level used in the computations of discharge of Huron was made some sixty miles distant from the gage that was used during the current meter measurements for determining the elevation of the water surface.

Q. Would the probable error, which you mentioned there, be true in a computation of an increment derived from such observations, made under the conditions which you have mentioned?

A. There would be a lack of certainty, or lack of precision in an increment computed from observations during these changing conditions; and the fact that Mr. Williams in his computation of the increment excluded those observations during which there was evidence of a fluctuating condition in the lake is one of the reasons which leads me to regard his estimate of the effect of the Chicago diversion upon the lake level as being the more accurate.

Recess to 1:30 P. M.

After recess—1:30 P. M.

JOHN R. FREEMAN resumed the stand and testified further as follows:

Mr. Adcock: Q. Is there anything further you would like to say concerning ice effects, Mr. Freeman?

A. Only to make it plain that these ice effects have to do with the level of the lakes rather than with the determining of the increment or rate at which the discharge changes for one foot difference in elevation of surface, in the river or lake.

Q. You mentioned in answer to a previous question a change in the condition of the lake outlets due to scouring as among the reasons which prevented an accurate physical measurement of the effect of the diversion at Chicago. What can you say as to the magnitude of these changes, on account of scouring?

A. The record of the lake levels presented in the Annual Report of the Chief of Engineers indicates that a far greater change in the level of Lakes Huron and Michigan has been produced by other causes than that which it has been estimated would be produced by the diversion of 10,000 second feet at Chicago. And the most reasonable explanation which I am able to find for this change in lake levels is a deepening of the outlet of Lake Huron. That this deepening is a fact, and that it has been in part produced by natural scour and in part by the work of dredging a channel for the improvement of navigation, is indicated by various facts presented in the reports of the Chief of Engineers, and particularly in the report of the International Waterways Commission made in the year 1910, concerning the regulation of Lake Erie. Facts bearing on this condition are also stated in the report of the engineers on deep waterways, page 280, which states:

"Previous to 1886 the average fall from Lake Huron to Lake Erie was 9.2 feet, after which date the slope gradually diminished until 1890, since which time it has had an average of 8.3 feet. This decrease of slope was caused by the deepening of the river channels at the St. Clair Flats and at the Lime Kiln Crossing, by the Government; and by the great increase, from natural causes, in depth and cross section of the St. Clair River, through the rapids at the outlet of Lake Huron."

This report further states that:

"A survey made at the request of this Board in December, 1898, by a party under the direction of Lieut. Col. G. J. Leydecker, Corps of Engineers, U. S. A., shows that the gorge at the head of the river now has a central depth of 66 feet, and a cross section of 36,000 square feet; whereas, it had, at the date of the previous survey in 1867, a central depth of only 48 feet and a cross section of 30,000 square feet.

"While there are no records to show when the deepening of channels through the rapids occurred, a study of the water levels and the slope curves shown on Plate 83 indicates that erosion was probably started in the spring of 1886 by the abnormal fall (7.5 feet) of the St. Clair River, at that time."

"It is probable that the decrease of 0.7 feet of the slope is due to changes in cross section through the rapids at the head of the river. And that the 0.2 feet change of slope in the Detroit River and St. Clair Flats is due to the increased depths of channels from Government improvements."

Plate No. 83 of the report quoted, of which a photographic copy "J. R. F. Exhibit No. 3" is presented herewith to be marked "John R. Freeman Exhibit 3," shows this condition in a striking manner.

(Photographic copy of Plate 83 was marked "John R. Freeman Exhibit No. 3.")

(Note: A more distinct copy of this diagram will be submitted in duplicate, to be substituted for the paper marked.)

I have not failed to note that this matter of scouring is also discussed upon page 5323 of the Report of the Chief of Engineers for the year 1900; and that reference is made to the preceding survey of 1859, which tended to dispute the correctness of the statement above quoted relative to the comparative measurement of cross section; but this does not dispute the remarkable change which has plainly occurred in the relative levels of Lake Huron and Lake Michigan with reference to Lake Erie. And it does not appear that the level of the bed of the river at the outlet of Lake Erie is equally susceptible to change, because the outlet of Erie is largely over limestone ledge, while that of Huron is over clay, and therefore susceptible to erosion.

I note also that this matter of scour is treated upon page 4115 of the Report of the Chief of Engineers for the year ending June 30, 1904; and in that report I find evidence that the engineers in charge appreciated the possibility of the change of levels being due to scouring at the outlet of Lake Huron, and in the St. Clair River.

It is of interest to note, while considering this matter of scour as a possible cause of the change in the relative levels of Huron and Erie, that there has apparently been a progressive decrease in the difference of level since the earliest records.

Table XII, page 4094, Report of Chief of Engineers for 1904 presents these data, and from these records it appears that the difference of level at times of earliest observations was about three feet greater than at present. In making these comparisons, I have selected those periods between June and November when the river must have been free from ice.

Some statements of great interest bearing on this matter are found in the Report of the Chief of Engineers for 1904, page 4115, et seq., wherein an extended comparison is made of the lake levels back to the earliest observation, and in course of which large discrepancies are noted between the discharge as computed from heights observed at the head of the St. Clair River, and those computed from the heights observed at the head of the Detroit River, which discharges must actually have been substantially the same; and the suggestion is made by the Government engineers: "In the discharge formula, an error may occur in two ways; either by the co-efficient, or in the datum of discharge."

"That there may have been such a change in the river is

possible, for the beds of the rivers are continually wearing away by erosion."

"The swift current in the narrow rapids from Fort Gratiot Lighthouse to the G. T. R. Gage is an especially favorable place for this kind of action."

"The bottom of the St. Clair River is subject to very great changes during ice blockades; the grounded ice plowing up the bottoms, and the concentrated currents at constricted places cutting away soft material very rapidly. When the ice blockade is lifted, it causes temporary steep slopes along the lower stretches of the river, with velocities of great cutting effect. After the great ice blockage of 1901, the swift current through the St. Clair Flats Canal caused a deepening of several feet at places in the lower end of the canal.

"The cutting of the river in the upper part where the current is strong tends to deepen it and increase the discharge. This is, in a measure, counteracted by the deposition of material in the slack currents of the channel and the shoal part of the flats, which tends to raise the bottom and diminish the discharge."

"In the shallow stretches of the river, the propeller wheels of steamers stir up the material of the bottom, which tends to deepen the channel and increase the discharge. From the head of Russell Island to the St. Clair Flats, a distance of 10½ miles, the depth of channel only exceeds by a few feet the draft of the largest steamers passing. In the last ten years, the draft of vessels passing has increased a good deal. The number of vessels, moreover, now passing, is greater than formerly. In the season of navigation, there are 33,000 vessel passages through Detroit and St. Clair Rivers. This may have had some effect in making the present discharge of river greater than it was in former years."

"The changes in the Detroit River are very likely to be in the same direction as in the St. Clair, but much less in amount."

Q. Omitting the consideration of the effect of natural scour, what would be the effect upon the levels of Lakes Huron and Michigan of the Government work in deepening the channel across the bar at the outlet of Lake Huron?

A. It is certain, beyond the shadow of a doubt, that this deepening of the channel by the government must have produced a lowering of Lakes Huron and Michigan. The earliest charts which I have examined, namely, that based on the survey of 1867, Plate VII of Williams' Exhibit 34, shows at that

time a bar obstructing the outlet of Lake Huron, across which the ship channel was only about 12 feet in depth. Since that time, particularly during the year 1894, 1895, 1896 and 1897, the government has increased the depth of the navigation channel at the outlet of Lake Huron to a depth no where less than about twenty feet.

I have represented graphically upon the diagram, "John R. Freeman Exhibit 1," the time and magnitude of the dredging in each of these years. This is shown near the center of the chart opposite the legend "Total annual dredging between Lakes Michigan and Huron and St. Clair except bar at head of St. Clair River."

The quantity of dredging in the several years is also stated in a table submitted by Mr. Williams, being Table LIII of Williams' Exhibit 34, which shows that the principal dredging at the outlet of the lake was during the three years 1894, 1895 and 1896.

Referring again to the diagram, "John R. Freeman Exhibit 1," and to the line plotted immediately beneath that showing the amount of dredging in the St. Clair River, under the heading, "Average monthly difference in elevation between Lakes Michigan, Huron and St. Clair," it will be seen by a careful comparison of that portion of the curve subsequent to 1896 with the preceding portion of the curve that there has been a very great lowering of the difference between Lake Huron and Lake St. Clair.

It is a matter of plain common sense, as well as of engineering experience, and certain beyond all doubt or question, that when a deep channel is thus dredged at the outlet of a lake into a steeply sloping river, that this providing of a deeper and larger gap in the rim of the basin through which the water can flow out, will, in the absence of building compensatory jetties or submerged dams along the outlet, have some effect upon lowering the average elevation of the lake, if conditions of rainfall and evaporation and inflow remain the same as before. And however difficult it may be to measure such a change in the level, amid the large and frequent fluctuations of the lake surface, it is certain that the providing of the deeper notch in the rim of the basin must result in lowering the elevation of the water in the basin, in some degree.

From examining the charts showing the depths of water at the outlet of Lake Huron, I find evidence that no compensation works have been built at this point which would block up the waterway to any degree sufficient to compensate for the

lowering caused by the dredging and deepening of the channel across the bar at the outlet of the lake. And considering the record of heights before and after this dredging, and considering also the area of the channel dredged, I have, as a matter of judgment and engineering experience, no doubt that the lake has been lowered as a result of this dredging to a greater extent than it has been lowered by the diversion through the Chicago Drainage Canal during the past ten years; or than it would be lowered by the proposed diversion of from 10,000 to 14,000 second feet.

Q. Suppose that the diversion of two, four, ten or 14,000 second feet at Chicago were to produce a lowering of the magnitude stated, namely, about five inches in the case of the 10,000 feet diversion of the Great Lakes, and in the same proportion as to the other amounts stated, could this be prevented? If so. how?

A. This could surely be prevented by building a series of jetties or wing dams at the outlet of each lake, or by one or more submerged dams (which might be composed of sunken cribs) sunk to a depth safely below the bottom of the boat of greatest draft; or being placed in such position as not to interfere with navigation. Such a remedy would in my judgment be complete, and would be comparatively inexpensive; and would prevent all of the injury that it is claimed would follow the diversion proposed at Chicago, by reason of shoaling of channels and harbors along the lakes and rivers connecting the same.

Q. Has this remedy of compensation at the outlet of lakes been tried out in any manner?

A. It has, in several cases, along the Great Lakes.

Q. How?

A. It has been tried and its sufficiency proved at the outlet of Lake Ontario by the Dominion Government, in building a dam across the Gut Channel, which formed a part of the waterway near the site of the Galops Rapids. These compensating works are known as the "Gut Dam." The probable effect of this dam was carefully considered by the United States Army Engineers prior to building. and the amount by which it would raise the water in the Galops Channel, and above, was computed, and it was afterwards found to be substantially correct; and statements to this effect are contained in the reports of the Chief of Engineers already cited. This

is referred to particularly by Mr. Shenehon, at page 479 of the record.

Q. Did this compensation, known as the Gut Dam, have any tendency to raise, or did it raise the level of Ontario?

A. It did raise the level of Ontario, and to an amount somewhat greater than that which it has been estimated Ontario would be lowered by the greatest proposed diversion at the Chicago Canal.

Q. Continuing your answer, do you wish to say anything further in answer to the previous question?

A. Yes. Another example of restoring, or rather raising the level of one of the Great Lakes by an obstruction built purposely at its outlet, is found in the outlet of Lake Superior, where, in order to increase the head for the Chandler-Dunbar Water Power Development, the head works appurtenant were extended between the piers of the International Bridge, so as to form a sort of wing dam, and diminish the natural outlet of Lake Superior. The effect of this obstruction can be seen in the diagram in John R. Freeman Exhibit 1 at the top of the sheet, in the increased level of Lake Superior in later years, as compared with the level of Lake Michigan. Its general effect was to raise the level of Lake Superior about six inches.

Another example of compensation works can be found at the outlet of Lake Erie, although these were designed more particularly for harbor improvement; and consist in part of the breakwater and other works built near Black Rock.

The fact of these works having had some effect on raising the level of the lake is referred to in the Report of the Chief of Engineers already stated.

A still more radical means for raising the level of Lake Erie, by means of an extended dam at its outlet, was presented in the report of the Board of Engineers on Deep-Waterways.

Mr. Alfred Noble, a witness in this case and a Member of the Board of Engineers on Deep Waterways, testified on page 31 of the record that the cost of such a dam was estimated at $796,923; but this was a far more elaborate structure than any that would be required to offset the diversion proposed through the Chicago Drainage Canal.

Q. Would such wing dams as you have mentioned, installed at the outlet of Lake Huron, interfere with navigation through the St. Clair and Detroit Rivers?

A. Not if they were properly designed, although it is pos-

sible that a single wing dam, or pair of wing dams from opposite shores built close to the outlet of the lake, might increase the abruptness of the fall at this point to an objectionable degree, this fall being already particularly steep and the current swift.

There is no necessity of doing the work in that manner, or in such a manner as to interfere with navigation.

On the other hand, this high slope immediately below the outlet of Huron could be lessened and all injurious currents avoided, by means of a series of wing dams, one pair being located down stream from another, so as to subdivide and distribute the fall over a considerable stretch of river, and reduce it to within limits such that the velocity would not be objectionable.

Q. Where would you place these jetties or wing dams that you mentioned?

A. At intervals within a mile or two down stream from the narrow outlet of the lake. It would require surveys and study on the ground as to the direction of present currents, and also of the depth and character of bottom before these could be located to the greatest possible advantage; but I have no doubt they could be so disposed as to thoroughly compensate for the small lowering of about five inches, which it is estimated would result from the maximum diversion at Chicago; and that they could be so placed as to make conditions of velocity and direction of current no worse than they are today. And on the other hand, I think it probable that an improvement might be effected by jetties or obstructions or compensatory works of this kind properly arranged.

Q. It has been suggested that the measure of damage to the navigation interests, that would be caused by the diversion of two, four, ten or 14,000 second feet through the Chicago Sanitary and Ship Canal, should be measured by the cost of deepening about six inches certain lake harbors and certain channels known as critical points of navigation. Do you consider that that would be a reasonable method of offsetting the effect of this diversion, or the reasonable measure of such damage?

Mr. Wilkerson: I suggest that is clearly a question of law.

A. As a matter of engineering, it is plain that compensation works could be built which would restore the lake levels to their condition prior to the Chicago diversion, or such as they would have in the absence of the Chicago diversion, at

only a fraction of the cost of deepening the harbors and channels to the extent of five or six inches.

Q. What would such works cost, Mr. Freeman?

A. I have not had time to visit the sites or to make the necessary surveys, or to prepare estimates, but plainly, as a matter of common sense as well as of engineering judgment, they would be very inexpensive. I can hardly imagine that works sufficient to restore the level, not only of Huron and Michigan, but also of Erie and Ontario, would altogether cost more than, say, one million dollars.

It would be a very simple matter to make the surveys and to estimate the cost of such works with precision. A structure of the kind needed, for compensation in levels sufficient to offset the estimated lowering of from four to six inches due to the Chicago diversion is of a very simple character, and may be of a class of work which costs comparatively little per cubic yard. No elaborate sluices or sluice gates are necessary for this purpose, and no operative mechanism, and no maintenance of a crew to supervise the working of mechanism or to maintain the works. Nothing is needed anything like so elaborate as the dam planned by the Deep Waterways Board of Engineers for the outlet of Lake Erie, which it is estimated would cost a little less than $800,000.

Q. The question of injury by reason of lowering the lake, say six inches and from drawing two, four, ten to 14,000 second feet through the Chicago Sanitary and Ship Canal has been raised. What can you say as to the certainty that any injury would follow such lowering of the lakes?

A. From my knowledge of conditions around the lakes, I believe it very far from certain that the net result would be injurious. On the contrary, there are many reasons for believing that such a lowering would be beneficial, in the sense that the benefits would much more than offset any possible injury, and would also be helpful to a much larger number of people.

I believe it highly probable that were the lakes in course of time thus lowered from four to six inches, there would be found no more real necessity or demand for restoring this level than has been thus far found for restoring, or compensating for the lowering which has already resulted from the channel improvements of the government by dredging through the bar at the outlet of Lake Huron; and the additional lowering that has followed natural scour at this place.

Q. What benefits do you refer to as coming from perma-

nent lowering of the lake levels of the amount that has been suggested?

A. When the Great Lakes, particularly Lakes Michigan and Huron, are at their high stage, such as they attain periodically at intervals of a few years, there is much difficulty in obtaining proper drainage of low lying lands near cities bordering the lakes, and difficulty in obtaining proper slope for drains and sewers, for discharging flood waters following heavy rains, into the lake.

This is particularly true south of Chicago; and I have a very distinct recollection of years ago seeing vast areas of ground near South Chicago practically awash at a time when the lakes were at one of their high stages.

A lowering of the high stage of the lakes by no more than six inches is of material advantage in giving a greater slope for the drainage of such lands.

Q. In your studies of the reports of the Engineers of the United States Army, or in your contact with the engineers engaged in the maintenance and improvement of navigation on the Great Lakes, have you seen or heard any suggestion of building compensation works at the outlet of Lake Huron to restore it to its proper level, or the level that it would have were it not for the cutting of the deeper outlet, as was done by the Government in order to improve navigation?

A. I have neither seen or heard it suggested to build works here to compensate for the lowering which has certainly been produced as a result of this excavation, supplemented by natural scour.

Q. From your examination of the Chicago Drainage Channel, known as the Chicago Sanitary and Ship Canal, connecting the Chicago River with the Desplaines River, what can you say as to whether the greater part of the cost of building this channel was incurred for purely Sanitary purposes, or for purposes of fitting it to become, at some future time, useful for navigation?

A. It is certain beyond all doubt or serious question that a channel over substantially the same route could have been built of sufficient capacity to carry 10,000 second feet or 14,000 second feet, which is the utmost that it is proposed to ever divert through this canal, for only a fraction of the cost that was necessitated in building a channel of the present dimensions, in order to fit it for navigation. Had the channel been built solely for sanitary purposes, that is, solely so as to give it a capacity to convey from 5,000 to 10,000 or 14,000 second

feet of water at the lowest levels of Lake Michigan, a cut probably less than 1/4 part of the width of the present cut would have served every purpose, for carrying 5,000 second feet considering that the slope of this channel from the Chicago River to Lockport could have been made at the steep rate of more than 1 foot per mile, and thus give a high velocity to the current.

It is certain that a much narrower channel than the present would have easily carried from 10,000 to 14,000 cubic feet of water per second, and that the amount of excavation would have been correspondingly reduced.

Although I have not had time to design such a channel, and compute its cost, it is my belief from general experience in the construction of large aqueducts and canals, that careful estimates would show that more than fifteen million dollars of the expenditure actually made upon the Chicago Sanitary and Ship Canal was distinctly for the benefit of navigation at some future time. And it is my belief that at some future time, whenever the contemplated works are completed through to the Mississippi River, this extra width and capacity obtained as a result of this expenditure will far outweigh any possible injury to navigation arising upon the Great Lakes or through connecting channels, from the lowering of their levels to the extent which has been estimated.

Q. You have stated that the estimates of the amount by which the various lakes might be lowered, as a result of diverting two, four, ten or 14,000 second feet at Chicago, are based upon certain gagings made at the outlets of the lakes, particularly Huron, Erie and Ontario, by the United States Army Engineers. Have you investigated these gaging records sufficiently to form some idea of their accuracy, and their stability as a basis for estimating the effect of the diversion of the number of feet indicated?

A. I have investigated these gagings from the very full description given in the various reports of the Chief of Engineers, and that given in the report upon the Preservation of Niagara Falls, and in the records previously submitted in this case.

Q. That is the exhibits?

A. The exhibits previously submitted in this case. These records are sufficiently complete to enable an engineer familiar with methods of river gaging and water measurements to readily comprehend the methods followed, and the precautions taken to insure accuracy.

Q. What are the results of those investigations that you have made?

A. I find that these gagings are on a larger scale, and made under greater natural difficulties than any previous river gagings of which I have knowledge, made anywhere in the world. And I find that the precautions taken to insure accuracy were most elaborate and painstaking.

I find that at first view, and so long as one studies the several gagings at one locality alone, and compares the agreement of the several observations made at this locality among themselves, they appear to be remarkably accurate, and their degree of precision and interagreement most excellent, considering the natural conditions. But when one goes further and compares the general result of the gagings made at Niagara with the general result of the gagings made at the outlet of Ontario, and the general results of the gagings made at the outlet of Lake Huron, and considers the quantity of water that must have come in from the tributary drainage area between these points of gaging; and also considers the limits of the evaporation which could have taken place from the area of these lakes in its relation to the rainfall upon the surface of the lake, the gagings at Niagara are strangely out of harmony and agreement with those on the St. Clair River and those upon the St. Lawrence River.

I find, moreover, from recent reports of United States Engineers connected with Lake Survey work that apparently in recent years serious questions have arisen as to the accuracy of these gagings by reason of comparisons of the nature of those that I have made between the outflow of Niagara, St. Clair and St. Lawrence rivers.

I refer particularly to the statements presented on page 4116 of the Report of the Chief of Engineers for the year ending June 30th, 1904, which states:

"A comparison of the outflow from Lake Erie through the Niagara River with the discharge of the St. Clair River for the ten years 1883 to 1892, June to November, shows that the computed discharge of the St. Clair River for that time is probably too large."

With reference to this discrepancy, my own investigations and comparisons would indicate that while the discrepancy is about as noted, it appears more probable that the error exists at the Niagara River than at the St. Clair.

On pages 4116 and 4117, a comparison of the discharge at Niagara with that through the St. Clair River is made, con-

fining the comparison to those months in which the rivers were certainly free from ice, namely, from June to November inclusive, and during the ten years from 1883 to 1892. This comparison leads to the strange result of showing that the discharge measurements give less water passing out of Lake Erie at Niagara than entered it at the upper end of the lake through the Detroit River, as shown by the St. Clair measurements plus a reasonable allowance for the drainage tributary to Lake St. Clair. And when further allowance is made in this comparison, to compensate for the effect of the lakes having averaged at a lower level at the end of each term than at its beginning, the comparison becomes still more strange in showing, if these discharge measurements at Niagara and St. Clair are to be trusted as accurate, that 18,000 cubic feet per second less water flowed out of Lake Erie all through this period than the amount that was measured into it through the St. Clair and Detroit Rivers.

It is obvious, and certain beyond serious question, from general engineering experience in the yield of watersheds, and from many experiments upon the evaporation of water surfaces that, on the contrary, there must have been a distinct increase in the quantity of water flowing out at Niagara over that flowing in through the Detroit River, due to the contribution of the watershed directly tributary to Lake Erie during these months from June 1st to November 30th.

The land drainage directly tributary to Lake Erie, apart from the lake surface, is about 25,000 square miles; and the net yield from this during these months from June 1st to November 30th, if proportional to that of the entire drainage area of the Great Lakes, would be not far from 30,000 cubic feet per second.

From a computation of this kind, Assistant Engineer Thomas Russell estimates (see page 4117 Report of Chief of Engineers for 1904), that to grant the accuracy of the discharge measurements at both Niagara and the St. Clair Rivers involves the supposition of an evaporation from the surface of Lake Erie averaging about 48,000 cubic feet per second for the six months, or 32 inches in depth, which, he says is "an amount which seems too great."

In my opinion this amount is so absurdly large, and so contrary to all engineering experience upon the run-off of watersheds in this region, and the evaporation from water surfaces under similar conditions as to prove that one or the other of these sets of gagings, either those on the St.

Clair River or those on the Niagara River, involve some serious and as yet undiscovered constant source of error.

Although doubtless there is much evaporation from the broad surface of the lake itself, it must be remembered that the lake also receives the full depth of rainfall, from June 1st to December 1st, by way of compensation for evaporation. And that the most accurate measures of evaporation and run-off of water which we possess would lead us to expect that this rainfall upon the lake surface during these months would pretty nearly balance the evaporation, when one takes account of the result of such observations as those made in connection with the Salton Sea in southern California, which showed that evaporation from a broad lake surface far from the shore is materially smaller than that from a small tank on the margin of the lake.

Some experiments made by the Water Department of the City of Rochester, within about ten miles of the margin of Lake Ontario, and covering a period of twenty years, which are being copied preparatory to introduction as an exhibit in this case, show a decidedly less quantity of evaporation from a tank in the midst of the reservoir than from a similar tank upon the shore.

My reason for thinking that this error more probably exists in the Niagara discharge measurements than in those on the St. Clair River is that upon making a similar comparison between the Niagara discharge measurements and the discharge measurements on the St. Lawrence River, both made principally by Mr. Shenehon, there is a similar discrepancy, but in the opposite direction, when one takes account of the probable run-off from the watershed tributary to Lake Ontario and the probable evaporation from its surface.

In other words, the St. Clair gagings and the St. Lawrence gagings are found to agree as well as one could expect, when taking account of the probable inflow from the watershed between these lakes, and the amount of evaporation from the lake surfaces, while the measurements on the Niagara River are, roughly speaking, some 30,000 second feet smaller than we should expect to find them, from a comparison with either the St. Clair gagings or the St. Lawrence gaging.

Q. Where do the Salton Sea observations appear, Mr. Freeman?

A. I have personally seen their apparatus, when I have been travelling through the region; and I think the experiments have been reported in some of the current engineering

publications; but they are given in abstract in one of the latest and most popular engineering handbooks, the "American Civil Engineer's Pocket Book," which shows in general, as I remember it, that the evaporation over an extended water surface will be not over from two-thirds to three-fourths that from a small tank on the shore.

Q. Over what period of time did these observations extend, if you know?

A. During only a few years past, possibly four years; but the observations on the tank at Rochester, in comparison with a similar evaporation tank on the shore of the reservoir have extended over some twenty years; and that has the advantage of being in proximity to one of the Great Lakes.

Q. Do you know anything about the care with which those observations were made?

A. I do not personally, except I have every reason to believe they were made with a very high degree of accuracy. They were made under government supervision and for a distinct purpose of estimating the length of time that it would probably take to restore the original condition from the evaporation of the water that came into the Salton Sea through the break in the Colorado River.

Q. Those observations are considered as authentic by the engineering profession?

A. I believe they are. Yes, they have been so accepted.

Q. And with reference to the observations made by the Water Department of the City of Rochester, do you know anything about the care with which those were made?

A. I am personally acquainted with the former city engineer of Rochester, under whose care they were begun, and with the present city engineer of Rochester, under whose supervision they are maintained. I know that both are engineers of very high standing and any of their data are entitled to the highest degree of confidence.

Q. In your experience in measuring flowing water by means of current meters, have you found any difficulties that might lead to error of the kind that you have mentioned? If so, will you state what the difficulties are?

A. I had an experience about seven years ago, in making measurements in connection with a turbine test in some of the tail races of the water power plant of the St. Lawrence River Power Company, at Massena, New York, in which I found, to my great surprise, difficulties of a kind which I think offer the most probable explanation of the discrepancy in the meas-

urements at Niagara, as compared with those at St. Clair and St. Lawrence.

In the case of these gagings at Massena, I had, in the effort to obtain accurate measurements, had so-called "stilling racks" inserted at the head of the race-way, in order to quiet the eddies and general turmoil in the currents of water approaching the current meter; and the water was apparently satisfactorily quiet upon the surface, and suitable for presenting an opportunity for accurate measurement. But my suspicions were aroused because the results, in relation to the efficiency of the turbine, did not appear reasonable, and also they did not agree with some other measurements by current meter which I had made in the relatively quiet water of the canal, up stream from the power house. And this led to a very careful investigation of the conditions at the bottom of the tail race, which was some 12 or 15 feet in depth; and by devising a sort of inverted weather vane consisting of a rudder firmly attached to a long pole, which I could immerse to the bottom of the race-way, while the upper part was held in my hands or the hands of my assistant, I was able to detect a condition of far more violent agitation and eddying at the bottom of the race-way than that which appeared on the surface. And thereupon I introduced additional stilling racks at the head of the race-way, until I had gotten the currents into a substantially parallel condition from top to bottom, as judged by the feeling and tests with my inverted weather vane or rudder; and after that we obtained measurements with a current meter which did appear reasonable and satisfactory, and which I gave full credence to.

This matter of the impairment of the accuracy of current meter gagings by disturbed conditions of the current has been one that did not receive particular attention among engineers until quite recently. But it has been somewhat investigated of late by several engineers, though by no means as completely as I believe its importance deserves.

The most recent observations on this subject with which I am familiar are those made also at Massena in connection with some other turbine tests by Mr. B. F. Groat, who was formerly one of my assistants, and who had reported his experiences in the Transactions of the American Society of Civil Engineers for December, 1912.

Mr. Groat finds as a result of his experiments, which I believe are by no means so complete as desirable, that the Haskell meter, which was the type used in all of the gagings at

the outlets of the Great Lakes was affected by disturbed currents very much less than the Price meter, which was the type that I had used at Massena. But nevertheless, he concludes that the Haskell meter under extreme conditions of disturbed currents "will under register by not more than three or four per cent." (See pages 60, 63, Proceedings Am. Soc. C. E. Dec. 1912.)

Mr. Adcock: I submit the report referred to for identification, to be marked "John R. Freeman's Exhibit 4"; to be identified, and such parts to be used as required.

(Report referred to was marked "John R. Freeman's Exhibit 4.")

Mr. Wilkerson: I reserve the right to object to the testimony with reference to the contents of this report of Mr. Groat until I have examined the document. It may be that he should be called, and it may be we will not deem it necessary. We will leave that point open until we have examined the report.

Mr. Adcock: Q. I will ask you if you know Mr. Groat, and if you know anything about the care with which he carried on the experiments which have been made?

A. Mr. Groat was formerly an assistant professor of the University of Minnesota, and I found him a very painstaking, careful observer. I should say that I do not consider that in this particular study he goes thoroughly to the bottom of this question, or that he experimented on conditions which were so extreme as may possibly exist in the Niagara River, at the point where gaged by Mr. Shenehon. But I submit this has shown the discrepancies or errors liable to be introduced in current meter work, where the meters are rated solely in still water, as they were in the case of the work on all of these discharge measurements for the Great Lakes.

I would also call attention to the fact that so far as Mr. Groat's observations go, they are favorable to the superior accuracy of the type of meter used in these gagings, as compared with other popular types of meters.

I am somewhat familiar with the Niagara River, and have noted the appearance of its surface as seen from the shore at many points between Lake Erie and the head of the falls. And it is my belief from what I have seen and can remember relative to conditions down stream from the International Bridge; and also from the statements and descriptions presented in Mr. Shenehon's report of his work, that the discrepancy above noted in the Niagara gagings most probably re-

sults from a condition of violent agitation in the flow of water, at the depth of 20, 30 or 40 feet beneath the surface, and which may be vastly more violent than indicated by the appearances of the surface.

Mr. Shenehon describes the conditions on page 5328 of the report for 1900 of the Chief of Engineers U. S. A. as follows:

"The Niagara River as it breaks out of Lake Erie flows almost due north. It narrows rapidly, and passes swiftly through a choked section of limestone where the speed at midriver must approximate 8 miles an hour. On emerging from this, the river grows wider and deeper and slows up to about 5 miles an hour as it approaches the International Railway Bridge 12,000 feet below the head of the river. In this distance, the fall is about 5 feet at mean lake stage."

This fall of 5 feet in a distance of about two miles and a half is an extremely rapid fall, and indicates that the energy and velocity naturally appurtenant to so great a fall in so short a distance must have been expended chiefly in the violent internal friction of the eddying current.

From observations which I have made at the outlet of other lakes, and from photographs which I have seen of the bed of the Niagara River upstream from the falls, exhibiting the roughness of the bottom as revealed at the time it was unwatered, I think it highly probable that the bed of the river at this point may have been roughened and made ragged by boulders and fragments of ledge that have been dropped by the ice.

Mr. Shenehon refers to these conditions in the following words: at the section where the first season's gagings were made, namely, directly beneath the International Bridge, he says, "The piers rest in timber caissons, and are provided with cut-waters. Protective masses of large stone are dumped about the piers, making a somewhat ragged profile and a bottom dangerous to instruments."

It is also of interest to note from the drawings of the cross section presented that at one point it is still further roughened and obstructed by a large sunken crib. These conditions are shown on Plate VI following page 5360, Report of Chief of Engineers for the year 1900. Mr. Shenehon says on page 5342 of the Report of Chief of Engineers for 1900:

"In such a section as that of the International Bridge, the proper derivation of the velocity coefficients is the most difficult part of the river gaging. To obtain it, the writhing mass

of water streaming through the bridge openings and eddying about the piers, spurting and lagging in minor pulsations, speeding faster as the lake rises, and flowing leisurely in the low stages, must be congealed to a solid by some instantaneous method of survey and its dimensions taken."

It is my belief that because of this writhing and eddying of the liquid filaments deeply beneath the bed of the river that conditions were introduced to which even a meter of the excellent Haskell type did not properly respond. And I know of no experiments made anywhere which would indicate the error introduced by such conditions. The work of Messrs. Haskell and Shenehon in gaging the Niagara River under these exceptionally difficult conditions was pioneer work, and I know of no previous experiences that would have led one to expect that so great an error could exist as that which is made evident by comparison with the gagings in the more quiet waters of the St. Clair and St. Lawrence.

On general principles, one would expect the mechanism of a current meter of the Haskell type to under register rather than over register, under conditions of violent agitation and twisting of the fluid filaments. These conditions as I conceive they may exist at the bottom of the Niagara River are very different from those presented by an ordinary eddy where a great body of water moves more or less in a circle, and with comparative quiet and uniformity of direction among the neighboring filaments. And from my experiments in water measurement, I consider it quite possible that the conditions found within such turbulent and violently agitated currents as may exist near the bottom of the Niagara River may produce very different effects upon a current meter from those that are artificially produced in tests when the meter is suspended excentrically from a moving boat and the boat rocked in order to give a changing direction to the meter in its progress through the water.

It is stated in one of the reports of the Government engineers that the still water rating of these Haskell meters had been confirmed by direct observation of the velocity of the water in the river, by timing a ball of colored water over a measured course. These tests are already in evidence in this case.

While I accept the accuracy of this particular test, I do not think it represents any such conditions of agitation or twisting of the fluid filaments as those likely to prevail at great

depths when a river bed is strewn with large fragments of rock or with boulders that have been dropped by the ice.

Q. What have you noticed in general as to the disturbed conditions of flow near the bottom of the outlets of the lakes mentioned?

A. My observations, so far as the outlets of the Great Lakes system is concerned, are confined to the St. Lawrence River, and more particularly the portion of this up stream and down stream from the Long Soo. Here I have personally noted, when making soundings in the river, the presence very generally of a boulder strewn bottom, which I judged to have been largely caused by the transportation of boulders imbedded in the ice, and which were dropped along the river when the ice lost its grip upon the stones.

I have observed similar conditions elsewhere, for example near the outlets of certain lakes in Maine; and I am inclined to believe it a common condition along the outlets of lakes and along the shores of large rivers in a glacial formation, where boulders prevail. Therefore I think it highly probable that near the outlet of Ontario, and also at some of these other gaging stations, the bottom may be so strewn with boulders and cobble stones as to lead to an exceptionally large disturbance of the currents, and one which may seriously interfere with accurate measurement by a meter whose rating depends upon a test in still water.

The "boils" which one often sees in deep and swiftly flowing channels, where there is a fairly smooth surface, are probably each the result of the deflection of the current by a boulder on the bed of the river at some little distance up stream. Here at the site of the Niagara measurements, particularly at the section at the International Bridge, and also in the open section about 1800 feet down stream therefrom are I believe more likely to present particularly rough bottoms than are the sections at St. Clair and along the St. Lawrence.

I have judged this from the statement as to the river flowing over a broken limestone ledge a short distance upstream, and from the extremely rough and disturbed condition of the bed of the river upstream from the Canadian Falls, which was revealed when a large area was unwatered in connection with building the intake to the power works.

As to other sources of error, commonly found in current meter gagings, some relatively small errors may have, I think, been introduced by the variable condition of slope and by the pulsations of height of lake which occur near its outlet, but

these among so many independent discharge measurements would tend to balance and offset one another; and in explaining the discrepancy of the Niagara gagings as a whole, one must seek for one or more sources of constant error of far greater magnitude than the errors found between these individual observations.

Q. In that last statement you referred to the gagings on the Niagara, did you not?

A. Yes, to the gagings on the Niagara.

Q. How great do you find the divergences between separate discharge measurements, in comparison with the quantity of water now diverted and proposed to be diverted through the Chicago Sanitary and Ship Canal?

A. All through the many individual measurements at Niagara and St. Clair and upon the St. Lawrence, there are differences between successive measurements at the same stage of water, which are greater than the quantity now diverted through the Chicago Drainage Canal; and the greatest quantity which it is proposed to divert at Chicago will be smaller than the range of error or discrepancy between observations taken at the same mean depth at each of these gaging stations.

For example, at the two Niagara gaging stations, successive measurements on the same day when the quantity flowing must actually have been nearly the same, showed differences, on October 11, 1899, of 15,650 second feet; upon November 1st, of 11,320 second feet; upon November 26th, of 8,420 second feet; upon November 7th, of 11,900 second feet; on December 10, of 9,640 second feet, the above measurements all having been made at the Bridge Section in the year 1898.

At the Open Niagara Station, which was considered more favorable, being less subject to the disturbance of the bridge piers, I note among the series of measurements made in the year 1899 there were similar discrepancies between successive measurements upon the same day. For example, on October 7, the two measurements differed by 8,700 second feet; on October 12, the two measurements differed by 8,810 second feet; on October 28, the second measurement differed from the first by 14,130 second feet; on October 31, the difference between the two was 10,320 second feet; on November 3rd, the difference between the two was 10,520 second feet; on November 11, the difference was 7,280 second feet, and on December 6 the difference of the second measurement from the first was 9,400 second feet. These discrepancies, although many of them are larger than the proposed 10,000 second feet

diversion at Chicago, are not particularly large as such measurements commonly result in hydraulic experience upon quantities of this magnitude. But they serve to illustrate and justify my answer to your earlier question that it would be impossible to directly measure the amount of the Chicago diversion by any direct physical measurement.

Q. How does the quantity which it is proposed to divert at Chicago compare with the probable error in the best measurements that have yet been made at Niagara?

A. A diversion of 10,000 second feet would be only about 5 per cent. of the apparent flow at Niagara, St. Clair or the St. Lawrence. but judging by the long series of gagings upon the St. Clair and those upon the St. Lawrence, these Niagara measurements as a whole are probably some 20,000 to 30,000 second feet too small, or probably the final error resulting from the average of all of these very elaborate measurements at Niagara extending over several years is more than twice as large as the magnitude of the proposed diversion at Chicago.

Q. Passing now, Mr. Freeman, from the question of error in the measurements at Niagara to that of possible errors incident to the method followed on the St. Clair River for determining the delivery from Lake Huron by means of the daily records kept for many years at Harbor Beach, are there possibilities of constant errors in these gagings?

A. There are.

Q. State just what your conclusions are?

A. In the first place, no simultaneous, frequent observations of the gage height at Harbor Beach were used in a direct comparison with the discharge measurements in the St. Clair River; but these two separate pieces of data were brought together subsequently by means of an independent series of comparisons of the gage of Harbor Beach with the gage at the section where the discharge was measured; and the later investigations by the government engineers, as set forth in the report of Junior Engineer Richmond made in June, 1910, already referred to, appear to have established that some serious errors were made originally when working out this relation. Granting this relation to have been established with accuracy, there are uncertainties due to the changing slope of the river past the gaging station, which changing slope is induced by the changing elevation of Lake Huron under the influence of wind, which has already been illustrated by the diagram introduced, John R. Freeman Exhibit 2.

The character of these changes, and their magnitude, is

shown by the following diagrams which are photographic copies of Plates VI, VII, VIII, IX and X, which show the result of observations made in course of the careful study of conditions of changing slope and velocity made by the engineers in charge of the measurements of the St. Clair River.

Mr. Adcock: I submit for identification the Plates above mentioned and ask that they be marked "John R. Freeman Exhibit 5 to 9" inclusive, in the order in which they were described by Mr. Freeman. They appear in the Report of the Chief of Engineers for 1900 following page 5400, being indicated there in the manner in which Mr. Freeman has stated in describing them.

I consider that the care taken to record these conditions and to prepare these diagrams tends to prove that these measurements were of the most painstaking character, and, as already stated I believe they are superior in care and precautions to obtain accuracy to any river gagings that have ever yet been made elsewhere. Nevertheless, the discrepancies between individual observations that occurred in spite of all these precautions serve to illustrate the difficulty of measuring or detecting quantities of 2½ per cent. or 5½ per cent. in volume flowing, which correspond to the diversion present and prospective through the Chicago Drainage Canal.

While these pulsations tend to offset one another in the course of the great number of observations made on the St. Clair, the Niagara and the St. Lawrence, and thus become smoothed out, not only in the final result but also in the individual discharge measurements, there are possibilities of other errors of a constant nature such as that of a changing position of the thread of the current under varying slopes, and stages of the river, and I do not find that this particular matter was investigated so thoroughly as would appear desirable.

Q. You have had experience, I believe you stated a little while ago, Mr. Freeman, in connection with providing water supply for cities in the United States?

A. I have, for Boston, New York, Baltimore, Los Angeles, San Francisco and elsewhere.

Q. Do you consider it necessary to keep that water supply free from the contamination by raw sewage or any effluent that might be discharged there after a purification?

A. It is in the highest degree important to do so. It is a condition almost paramount to all other conditions as affecting the health and prosperity of the commodity.

Direct examination closed.

Adjourned subject to notice.

October 13, 1913, 2:00 P. M.

Met pursuant to adjournment.

Present same as before.

JOHN R. FREEMAN, resumed the stand and testified further as follows:

Cross-Examination by Mr. Wilkerson.

Q. In comparing the two methods which were used by Mr. Williams and by the Government Engineers, in dealing with the discharge measurements in this case, you pointed out as a difference that Mr. Williams had used a method which was known as the three point method; and you gave that as one of the reasons why the results obtained by Mr. Williams were more accurate than those of the Government Engineers. At the time you made that comparison did you know as a matter of fact that the formula which had been presented by the Government had been checked by the method of least squares?

A. I did not.

Q. As an engineer, what do you say as to the relative value of the method of least squares and the three point method, in dealing with observations of this character?

A. As a matter of practice, I have very seldom used the method of least squares. I have commonly found it sufficiently accurate to stretch a string and get my mean in that way, just as I assume the curve presented by the Government Engineers has been derived.

As between the least square method and the three point method, my present impression is this: That the three point method is simpler of application. As to the bearing of the theory of probabilities on the two methods, the three point

method and the least squares method, I would not be ready to express an opinion at the present time. I regard the three point method as a more ready method of application, and sufficiently good.

Q. But as to which one would give the more accurate results, you would not be prepared to express an opinion without further study?

A. No, it is largely hypothetical.

Q. Well how much difference did you think resulted, growing out of the fact that a string had been stretched rather than the figures handled according to the three point method?

A. That was shown on the diagrams presented by Mr. Williams. The difference was not large. I could not attempt now to say just what that difference was.

Q. The error, if any, which would come from the simpler method of drawing a string would be just as likely to fall on one side as on the other, would it not?

A. My recollection is that in this case it was plainly seen that as they had drawn the tread, or as they had drawn the line, it tended to magnify the effect of any diversion in lowering the lakes.

Q. That is that one thing alone did that?

A. Its tendency was in that direction.

Q. Why would its tendency be in that direction rather than in any other direction?

A. I would say I am trusting now to the memory of curves I have not looked at for six months, and I think it would be safer for me to turn back to those particular diagrams.

Mr. Adcock: We can get those to refresh his recollection.

Mr. Wilkerson: I can simplify this.

Q. Did you see this chart which was presented to Mr. Williams in New York?

A. I did; I examined it carefully.

Q. In which the observations of the Niagara discharge were plotted?

A. I did.

Q. And the line was drawn through those observations by him?

A. I did see it.

Mr. Williams: It is a chart that Mr. Freeman has not seen. I have a copy of that in my files, and Mr. Freeman has not seen it. He has in mind now other charts, Exhibits 1, 2, 3 and 4.

Mr. Wilkerson: Q. I am referring to a chart which I sub-

mitted to Mr. Williams, in connection with his cross-examination in New York.

A. No, I have not seen that.

Q. I will show that to you.

A. I was trying to recall my recollections of a chart which Mr. Williams did give me in which he had drawn observations, and to which I had applied the two methods.

Q. As a matter of fact, when did you first come in contact with this three point method of handling the observations?

A. My impression is I have known of it in a general way for quite a long time, but that I have not used it practically.

Q. Have you ever come in contact with a piece of work in which it has been used until this case?

A. I can't say positively. I think so.

Q. Do you remember any specific piece of work?

A. I do not.

Q. You have come in contact, have you not, with discussions of observations in which the method of least squares was used?

A. I have, frequently.

Q. Frequently. And you have used that yourself?

A. Very rarely.

Q. But when you wanted a result deduced by a more accurate method than the mere drawing of the thread, you have used the method of least squares, isn't that true?

A. Very rarely, but I will say that I have generally been content with drawing a thread.

Q. When you have used anything else, it has been the method of least squares?

A. Not always. I think I have used a method of moments, somewhat similar to this three point method, but very rarely.

Q. How does the method of moments which you have used differ from the method Mr. Williams used?

A. I can't recall now that it differs at all. I have used either the three point method or the method of least squares very rarely, hardly once in a dozen years I may say.

Q. Isn't it a fact that those who have to do with a series of observations, and who wish to deduce very accurate results from them have as a general rule used the method of least squares?

A. I believe they have. And I will say that the method of least squares—that the superior accuracy of the method of least squares is mainly a very abstruse theoretical matter, so much so that it is seldom used outside of astronomical observations, or outside of some of the refinements of the United

States Engineers, as for example in reducing geodetic determinations. I think it is very rarely used in practical hydraulics.

Q. You know as a matter of fact that it was used by the Government Engineers in connection with some of these very computations, do you not?

A. I have an impression it was. I think I have seen pages of their deductions, in some of their reports.

Q. Now you said the first reason for giving a greater degree of inaccuracy to the Government Engineers than to Mr. Williams was the failure of the Government Engineers to use the three point method. Another reason which you assigned was, as I recall your testimony, that the Government Engineers in preparing their discharge curve had used all of the measurements of discharge, while Mr. Williams in his studies of these observations had selected out of the great number of discharge measurements certain discharge measurements, and had reached his conclusion from these selected observations. Did you make a study of the entire series of observations, and of the observation which Mr. Williams had selected, for the purpose of determining the plan which Mr. Williams had followed in his selection of observations?

A. I reviewed the entire series as published to an extent which I believe justified me in drawing that conclusion that there were observations which plainly were less accurate than some other observations taken at periods of disturbance when the flow was not constant. And I satisfied myself that Mr. Williams had excluded a large number of those observations taken under the least favorable conditions. I cannot say that he had excluded every one.

Q. Do you remember what percentage of the observations taken on the St. Clair River he discarded?

A. I do not. My impression is it was quite a considerable proportion.

Q. Was it more than half of them?

A. At present I should not think it was.

Q. Do you remember how many of the observations on the Niagara were discarded?

A. No, I do not recollect the proportion. Six months ago I could have told you.

Q. Did you know that he had included observations made during the winter season, during February, in the study which he had made of the Niagara observations?

A. No, I do not recall that. In a warm February, he might

be justified possibly in including such observations, if the conditions were steady.

Q. You know as a matter of fact there were observations used in February, when there was ice?

A. No, I did not know that.

Q. Did you know that he had omitted entirely 118 of the Niagara observations for the years 1907 and 1908?

A. No. If I ever knew it, I have forgotten it. I have no present recollection of it.

Q. All I am trying to get at is, when you made your study of Mr. Williams' computations, did you detect those facts to which I have directed your attention?

A. No, I presumed that he had used everything available.

Q. You did not check them against the original series of observations?

A. No, I stated so in my testimony.

Q. Now how did you understand he had treated these observations, with reference to referring a group of observations or the average of the group to a particular gage reading; that is to say, to make myself clear, did you understand that he had gone back to a gage reading which was prior, in point of time, to the discharge measurement?

A. I did understand that, yes.

Q. How did you understand he treated that?

A. I understood that he had gone back to an amount sufficient to allow for the period of transmission of the condition from the point above down to the place where the measurement was taken.

Q. How long a period did you understand that was, how many hours?

A. I don't recall at present, but several hours as I remember it.

Q. Was it 24 hours or 12 hours?

A. My impression is that as an average it could not have been more than 12 hours. I know there was an allowance of that kind.

Q. Now suppose, Mr. Freeman, in comparing two sets of observations for the purpose of deriving an increment, the observations were so selected, and this antedating of the reading of the gage was so manipulated that for very high discharge measurements, the effect of that method would be to refer them to a low gage reading; that is to say the lake rising, while for very low discharge measurements the effect of that would be to refer them to a high gage reading, the lake falling, so that there would be a smaller difference in gage reading

corresponding to a greater difference in gage reading. The effect of that would be to give a larger increment than would be derived if the observations were combined in the ordinary method, would it not?

A. If there had been many cases of that extreme character, but naturally one condition would offset another so that there would be a compensating effect.

Q. Naturally you would expect the groups to fall, so that the difference in one case would be offset by a corresponding difference the other way, in another case. But it would be possible to select the groups in such a way as to get a larger increment by that method?

A. That might be done.

Q. And that illustrates, does it not, the danger of deducing a conclusion from selected observations rather than from—

A. Not necessarily, if one is honestly seeking the truth.

Q. But if one is earnestly seeking to establish a large increment, the fact that the lake is rising and falling, and that groups of observations can be referred to gage readings in that way would furnish a method whereby a larger increment could be derived, if one wanted to do it, wouldn't it?

A. That is conceivable in a general case, but not in this particular case.

Q. You say it is conceivable, in a general case?

A. Yes.

Q. But not in this particular case?

A. I believe it is not.

Q. By that do I understand you to say you have studied these groups of observations?

A. I did in a limited way, yes; spent several hours going over them.

Q. To show you what I mean by that, I direct your attention to Exhibit L for Identification October 8, 1913, Sheet number 3 (handing same to witness), and also to Table XLVa, group 12. On this chart here, the observations 91, 92, 93, 94, 95, 96, are plotted there?

A. Yes.

Q. And the group is averaged?

A. Yes.

Q. That would give the average observation which is used for that particular group. Now, that is referred to a particular gage reading. As I understand, instead of referring it to the actual gage reading, the gage reading is shoved back so as to include the day before. If you took that group for

example, the effect of that would be to refer the average of the discharge observations to a lower average gage reading than would have been the case if the observations had been referred to the gage readings corresponding to the time of the observation, would it not?

A. After studying the diagram, and without attempting to follow through all of the successive steps, I can see that in this particular case by including the mean of the entire preceding day, the result was over-corrected; that is the attempt to compensate for the period required for the condition prevailing at the lake to pass down to the gaging station was over-compensated, and since the preceding day happened to be a day of lower height than the average of the whole period, the effect was to introduce a small error.

Q. That is the effect was to refer the average of the discharge measurements to an average gage reading which was lower than it would have been if that day had not been included?

A. To a very small extent, yes.

Q. And of course it appears in this particular case that the observations were selected in that way, grouped in that way?

A. As I understand it, the same method was followed in every case. And I think that in the absence of fuller information, the attempted correction was in the right direction. It may have been somewhat overdone, but I think taking a long series of many observations you would probably find just as many days when the preceding day was a little higher than the average as you would days when it was lower than the average, as in this particular case.

Q. That would depend entirely, however, on how the observations had been grouped?

A. No, because the same rule was applied all the way through of including the day previous as a means of compensating for the time taken for an effect to pass down the stream from the lake into the channel at the gaging station.

Q. You notice there do you not, Mr. Freeman that in this particular group of observations on the 29th of June, while there is an apparently wide fluctuation in lake elevation, the discharge measurements as plotted appear to be substantially on the line corresponding to the lake elevation, do they not?

A. I find they appear so in that case.

Q. And that is true in a large number of cases is it not?

A. I find that in general the observations follow the line of height very well indeed; that there are occasional divergencies of 5,000 or 7,000 cubic feet per second, but in general they follow the line very closely.

Q. Now, in the light of that, are you prepared to say that observations are to be rejected, because there happens to be on a particular day a greater fluctuation of lake elevation than the ordinary?

A. This is the first time I have had an opportunity to examine these (Referring to charts produced by Government's counsel).

Q. They have all been marked for identification, and they were before Mr. Williams in connection with his cross-examination?

A. I would say that from examining these curves, I do not find that the periods of rapid change in elevation of the lake are those in which there is any particularly large divergence of the observation from the continuous hourly curve. But at the time I was considering this matter six months ago, I did not have before me any hourly curve of heights in the lake; but it is a general rule of hydraulic work that one obtains greater accuracy by excluding those observations taken during the periods of rapid change in the elevation of the stream which one is gaging. So, while from these curves I do not find the evidence that rapid change of height from hour to hour is a sufficient criterion alone for rejecting the observations, it is a general rule of experimental hydraulics that one gets more accurate, more reliable results by deriving his curves or equations from observations taken at times when the flow is substantially uniform.

Q. It is also a rule of hydraulics, is it not, that in measuring a stream, you want to take its natural, normal condition?

A. Surely, yes.

Q. And if the body of water which you are measuring is one whose surface is fluctuating in different portions of time, you would rather want to measure it in that condition rather than in the stationary condition?

A. No, I should still select periods when the height was not changing rapidly, and expect to get more accurate results.

Q. Although those curves do not indicate that has been done in this case?

A. The observations in most cases fall remarkably well

on the curves. To a certain extent though, this is reasoning in a circle because the equation was derived by averaging these same observations which are plotted here.

Q. Still, though, there is that inherent consistency in the whole work which points to its accuracy?

A. In most cases. I find in some of the other sheets a good many observations where there is a divergence of 5,000 to 7,000 seconds feet from the curve. I find no explanation of that in the curves themselves. I find that for example on September 19, 1899, and September 16, 1899.

Q. How much is that last one off the line?

A. All three observations on that day are about 4,000 seconds feet lower than the continuous curve.

Q. That is about two per cent.?

A. A small fraction over two per cent., nearly two per cent.

Q. Those are errors of observation that are inherent in all observations, are they not?

A. Yes, it is remarkably close; I consider it remarkably close.

Q. As throwing light upon the reduction of any of these observations, I show you a chart on which the discharge measurements of the Niagara River have been plotted in line (handing witness Exhibit .....). Assume that those are accurately plotted, and that it is a copy of the exhibit which is already in the record, doesn't that indicate to you that all the observations fall in pretty narrow range?

A. Within about three per cent. I should say, looking at it now and taking it by the eye rather than by scale.

Q. And you think it would be possible to draw a line through there that would be within one per cent. of the correct line, do you not?

A. Well, within two per cent.

Q. Anyway?

A. Yes.

Q. You would not be surprised if you learned that Mr. Williams had actually drawn a line within one per cent. of the correct line?

A. I should think it were quite possible. I would not be surprised if two independent observers, each trying to work it out as correctly as possible came within one per cent. of each other, in determining an increment from that curve.

Q. And so far as the use made of it in determining the

lowering of Lake Erie is concerned, that would be substantially accurate, would it not?

A. Not necessarily. I said that they might come within one per cent. of each other, but that does not yet say that would be within one per cent. of the truth.

Q. I am assuming that one of them is right.

A. No, assuming the observations are right, they can be averaged by any of the well known methods and get results that are dependable within one per cent. on the discharge. I think one per cent. on the discharge is a little finer than is warranted; but I would think one could get within two per cent., assuming the observations were correct; there was no constant error.

I would like to strike out my preceding answer and say that while the quantity corresponding to any given height can be taken off within two per cent., the increment or variation in discharge corresponding to one foot difference in depth, different observers might vary four or five per cent. within the most ordinary range of heights.

Q. By that you mean that the increment which different observers would deduce would vary four or five per cent.?

A. There is room for very much more variation of increment expressed as percentage than there is for deviation of quantity discharged for any given height.

Q. That is because the difference would be per cent. of a smaller quantity in one case than in the other?

A. That is the idea. Five per cent. I would say was a reasonable divergence on determining the increment.

Q. Do these charts which you have just been examining indicate to you by reason of the consistency of these observations anything as to the accuracy of the observations themselves?

A. No, because there may be some constant error.

Q. Assuming there is no source of constant error.

A. They are a remarkably concordant set of observations.

Q. And the source of constant error which you suggested in your direct testimony, I believe, Mr. Freeman, was under registration of the current meter?

A. Yes.

Q. That was the only material source of constant error as affecting a particular observation, which you laid stress on, as I recall, in the testimony?

A. That was the one I laid stress upon. There might be other sources of error.

Q. But they would be small compared with that, in your opinion?

A. I believe the great source—and I do believe that these observations are erroneous to the extent of possibly 10 per cent—I believe the great source of error is in the disturbed condition of the water in the lower portion of the river, and in the lack of correct registration of the current meter under those disturbed conditions.

Q. It is your understanding that the type of current meter that was used in making these observations under registered in turbulent water?

A. It does sometimes; whether it always does, that I don't know.

Q. Suppose, Mr. Freeman, another section of the Niagara River were measured, where the water was not turbulent, the measurement being made by the same type of meter and under conditions favorable to good work of that kind; and it were found that the measurements as determined from that section of the river checked very closely with those at the International Bridge Section and the open section, which have thus far been considered, what conclusion would you draw from that as to whether or not there was a constant source of error due to the under registration of the current meter?

A. I would not think such a series of observations as you have described conclusive, because being somewhat familiar with the Niagara River, I am by no means certain that there is any place anywhere in that vicinity where one can be certain of the condition of the bottom of the river, or that it is free from more or less boils and eddies. That is I think there are other facts entirely outside of those, which might be mentioned, which prove in the most positive way that there must be some error in these observations.

Q. You say you do not think it is possible to find in the Niagara River any section where the water is comparatively quiet?

A. I would not say that positively without making a more complete personal examination.

I can come right to the point this way by saying that it is much easier for me to believe that there is some error in these current meter observations at Niagara than it is to believe that there is no material yield of water from the drainage area tributary to Lake Erie and Lake St. Clair, during the summer months. And one is forced irresistibly by the facts of record in this case to admit that either the Niagara

gagings are wrong, or that the St. Clair and St. Lawrence gagings are wrong, because subtracting the St. Clair observations from the Niagara observations would show no yield whatever, a part of the time, a part of the year, or no yield of reasonable magnitude from the large drainage area tributary between the Niagara gaging station and the St. Clair gaging station.

Now the fact that when one studies the St. Lawrence observations in their relation to the Niagara observations there is a similar discordance makes it to my mind most easy to accept the solution that the Niagara gagings are those which are in error.

Q. You have read the testimony of Mr. Stearns in this case, a witness for the defendant, have you not?

A. I do not recall. I was present during a part of his testimony I think, but only a part of it, and I have not read the record.

Q. He gave some very specific testimony on the rainfall, run-off, evaporation in the basins of these different lakes?

A. Yes.

Q. Suppose this were the situation: Suppose we took the St. Lawrence discharge measurements, and applying the data furnished by Mr. Stearns as to rainfall, evaporation and run-off, we got a measurement for the Niagara River within less than 5,000 cubic feet of the observed discharge, running over a period of say 16 years, and suppose that when we undertook to go back from the Niagara observations to the St. Clair observations, in the same way, we found a wider divergence, wouldn't the fact that the Niagara and the St. Lawrence checked so nearly indicate to you that what was wrong if anything was that the discharge as stated for the Niagara was nearly correct, while that of the St. Clair had been put down at too large a figure?

A. No, I don't think so.

Q. Why not?

A. I have not all the elements in the problem. I don't know how you work that out; whether you work for the whole year, including the periods when all observations are rendered uncertain by the presence of ice, or whether you are taking only the ice free month. I should want to follow the computation step by step, in order that it would have any weight in my mind.

Q. It is your opinion is it not Mr. Freeman that any study of the physical condition of the lakes as determining the effect

of rainfall and evaporation and run-off is worthless, unless effect is given to the ice condition in the winter?

A. That statement I think is too sweeping. One can discern certain facts, but cannot say broadly that no facts of value can be determined.

Q. That is if you undertook to check the outflow through the river, you would want—

A. If one is attempting to check the mean annual outflow through either of those rivers, one certainly must take account of the ice conditions very carefully; and I believe from my studies of these observations reported in the printed reports of the Chief of Engineers, and such facts as have come before me in this hearing, that one of the greatest sources of error has been the failure to take proper account of ice conditions and of the clogging of the outlets of some of these lakes by ice, during the extremely cold weather.

Q. If you were considering, however, the consistency of the Niagara River with the St. Lawrence, you would take the open season?

A. I would take the open season.

Q. I show you a tabulation which has been prepared, Mr. Freeman, which I ask to have marked Government's Exhibit L, October 13, 1913. (Paper so marked.) In the first column appears the year, June to November; in the second column discharge of the St. Lawrence River per second, as stated in the United States Lake Survey Report 1912, from final study of the observations as to that river. In the next column is the local supply and the storage on Ontario, cubic feet per second. In the next column, number 4, is the deduced Niagara discharge according to the formulae which have been applied by the Government in this case. In the next column the actual Niagara discharge according to the figures which have been presented by the Government in this case.

Now assume that the mathematics of this thing is correct, in addition, subtraction and multiplication, and that we have used the supply and storage as given to us by Mr. Stearns in the testimony for the defendant in this case. And assume that the result of that is that the average actual discharge of the river is about 4600 cubic feet less than the Niagara discharge, as deduced from the formula, and from Mr. Stearns' data.

Now assume if the same method were followed in going back from the Niagara discharge to the St. Clair discharge, and there was a much wider divergence, wouldn't the fact that

the Niagara and the St. Lawrence checked so nearly indicate that it was the St. Clair that was out of line rather than the Niagara being out of line with the other two rivers?

A. Not necessarily, because as I understand this table it is the mean annual flow including the ice period, and I believe—

Q. No, assume that it does not include the ice period; that it is June to November only.

A. I see, now.

Q. (Question read as follows: "Assume that the mathematics of this thing is correct addition, subtraction and multiplication, etc.")

A. If we had no other means of weighing the probable accuracy, that might be true, but I consider that there are inherent difficulties in making an accurate gaging at the Niagara station greater than those at either of the other stations. That is, the conditions immediately upstream from the Niagara gaging station, because of the presence of the bridge, and because of the rapid fall in the river approaching the gaging station, and the disturbed condition of the water, lead one, apart from all other considerations, to have more suspicions about the accuracy of the gagings at that point.

Q. Now suppose Mr. Freeman as a matter of fact that they went down the river to the points which have been marked on the map which I now show you, which is already in evidence in this case, the same being the Survey of the Northern and Northwestern Lakes, War Department, Engineering Corps, suppose, I say they went down the river and measured the Niagara at the section called Section Wickwire and Section Oakfield, that far down (indicating on the map); and the measurements there made checked with those which had been made higher up by one-half of one per cent., would you not say that was a fact to be given considerable weight in determining whether any conclusion was to be reached that the Niagara observations were the ones which were wrong?

A. It should be given weight, but would not alone be conclusive because I notice that at both these stations which you have just mentioned, particularly the section Wickwire, that the river is making a comparatively sharp curve, and that tends to cause disturbances which make it difficult, if not impossible, to measure the flow with great accuracy.

In the first place, that disturbed condition due to the curve causes a tendency to eddying, which may not be apparent at the surface as a distinct eddy, but it gives an instability to the

threads of the current past that section; and it also tends to make the river stand higher on one side than on the other due to the centrifugal force and the deflection of the current by the curve at Section Wickwire, so that this does not appeal to me as a particularly good gaging station.

With regard to the one on the other branch, Section Oakfield, I find also that is not a condition which from the map one would judge to be favorable for accurate measurement. The river also is in a curve at that point, and there are shallows and disturbances a relatively short distance upstream. And then we have no knowledge, so far as I know, as to the condition of the bottom of the river at this point, or how free it may be from boulders.

Q. Wouldn't it strike you as rather peculiar that if the discharge measurements of the Niagara are uniformly about 10 per cent. too small, that in all three of the sections which have been measured, the errors should have been so nearly the same?

A. It is peculiar.

Q. And that this last section should have checked within a half of one per cent. with the sections previously measured?

A. It is remarkable but not convincing, because very likely there is the same boulder strewn condition of the bed of the river at these newer gaging stations as that which probably exists at the previous gaging stations, and in all of those stations there is to my mind, beyond all doubt or question, a seriously disturbed condition of the water at considerable depth below the surface.

Q. Well now to get back to the original question that we had under consideration here: I am assuming that this table in which reference is made to Mr. Stearns' rainfall and evaporation data is correct mathematically; we find when we come to compute it, we start back with the St. Lawrence, go up to the Niagara, and we get within 4600 cubic feet of the observed discharge through the Niagara. Now, assume that you go back from the Niagara to the St. Clair; we find a much wider divergence, having these three sections measured in this way in the Niagara. Does it still appear to you that the mistake is in the Niagara rather than in the St. Clair; or to put it another way, that the entire mistake is in the Niagara and that part of it may not be in the St. Clair?

A. It is probable that part of the mistake is in each of the stations. From studying the descriptions of the several

gagings as given in the reports of the Chief of Engineers, it seemed to me that the conditions for an accurate measurement at the St. Clair were superior decidedly to those at the St. Lawrence, and I cannot get that fact out of my mind and forget it, and assume it to have no weight in the question that you have now asked.

Q. Considering your own statement as to the effect of Lake St. Clair upon the discharge of the St. Clair River, you still think that the conditions for accurate measurement would be more favorable in the St. Clair than in the Niagara?

A. That is my impression.

Q. Now you discussed in your direct testimony, Mr. Freeman, the excavations which had been made in the St. Clair and Detroit Rivers. You spoke of the work at the Lime Kiln Crossing. Just what was the net gain to navigation which was produced by the excavation at the Lime Kiln?

A. I did not put my emphasis on the Lime Kiln Crossing; it was more the excavation at the outlet of Lake Huron, which I considered had affected the situation.

Q. The excavation at the outlet of Lake Huron?

A. Yes. I consider that the excavation at the Lime Kiln Crossing is of minor effect, in comparison with that at the outlet of Lake Huron.

Q. I show you a chart, a part of Exhibit Number 34 in this case, Plate Number 10. (Handing witness same.) You had that before you did you, in reaching your conclusion?

A. Not that particular diagram.

Q. Did you have anything like it?

A. I do not recall it at the present time. I had some other charts. I had several charts, which I have no doubt contain substantially the same information, in another form; but not this particular blue print.

Q. I direct your attention to this portion of your direct testimony:

"It is a matter of plain common sense, as well as of engineering experience that certainly beyond all doubt or question, when a deep channel is thus dredged at the outlet of a lake into a steeply sloping river, that this providing of a deeper and larger gap in the rim of the basin through which the water can flow out will, in the absence of building compensatory jetties or submerged dams along the outlet, have some effect upon lowering the average elevation of the lake, if conditions of rainfall and evaporation and inflow remain the same as before."

A. That is still my opinion.

Q. What did you have in mind there as the "rim"?

A. The portion on Plate 10, which you now show me lying about a mile upstream from the zero of the scale of miles.

Q. What was the extent of the dredging there?

A. As I now recall, without going back over my notes, it had been deepened so that boats of 20 foot draft could now pass where many years ago boats of hardly more than 10 or 12 feet could pass, possibly even less draft in the earlier days.

Q. What was the width of the waterway there which was opened up, as you understand it?

A. I can't say what width. I had before me at that time one of the latest charts of the outlet of Lake Huron, and also the earliest chart that I could find, but I do not now find a copy of that early chart.

My recollection is that originally there was a broad bar at the outlet nearly opposite the Ft. Gratiot Lighthouse, and I am quite certain that I found notes of a channel having been dredged through that bar, and that the latest charts show ample water there for a boat drawing upwards of 20 feet to go through.

Q. Have you your notes with you Mr. Freeman on that subject?

A. Only a part of them. I find a copy of one map but not of the earlier one.

Q. I wish you would look through them between now and to-morrow morning, so that you can state in the morning when we come back just what you had in mind there, when you spoke of opening up the rim. I want to know just what you had in mind.

A. I can state that very clearly now. I had in mind not only the work that had been done by the Government in dredging, but also the work that has been going on by natural process of scour by the ice jams there. That I am informed is a hard pan bottom and that that has been scouring, by the force of the current, within the historic period; and I included in the effect the natural scour, and the dredging for the improvement of navigation.

Q. Now we have here the map of Lake Huron. Just where do you understand that that particular work was done, referring to Lake Survey Map of the St. Clair River?

A. Isn't there an earlier chart? I do not find a copy of it. I recall having another chart from the one now

shown me, a much earlier one, which indicated a bar about opposite the Ft. Gratiot Lighthouse. (Counsel hands witness a second chart.) It is Plate 7 of Williams' Exhibit 34.

Now, from comparing Plate 7, Williams' Exhibit 34 with Plate 8,—and I recall particularly that I also referred to one of the latest charts, I was convinced that there had been a very material deepening at the outlet, precisely at the outlet of Lake Huron.

Q. It is the dredging you are referring to?

A. Dredging and natural scour. I have no doubt that in every winter when there is an ice jam, that there is a noteworthy scour takes place, tending to increase the waterway, and also to a lowering of the level of Lake Huron.

Q. I show you your Exhibit, J. R. F. Exhibit Number 1, on which appears a bar dredged at the head of the St. Clair River?

A. Yes.

Q. In 1895. Is what you had in mind there the same thing that is marked on Plate 10, Williams' Exhibit 34?

A. I presume so.

Q. As excavated material? Just where do you understand that to be?

A. Well, from the scale, that appears to be further up into the lake.

Q. That would be away up here wouldn't it? (Indicating.)

A. Yes.

Q. At that point, the lake would be three or four miles across?

A. That particular dredging, a mile or more up the lake, would have no particular effect on what I was considering. But the natural scour at the outlet of the lake would; and also the difference shown by the Chart Plate 7, Williams' Exhibit 34, as compared with the more recent charts.

Q. Then on this J. R. F. Exhibit Number 1, these broad lines are drawn very high in the years 1895, 1896 and 1897, in the second line down Lake Huron?

A. Yes.

Q. They would not have any very appreciable effect—

A. No, not at that distance, they would not have any appreciable effect.

Q. I call your attention to this Plate 10 of Williams' Exhibit Number 34 and ask you to look at the map and see where the excavation that is marked here "Lake St. Clair, excavated material, U. S. Ship Canal," two places at both ends of Lake

St. Clair, where that was and see whether that had any appreciable effect or not. There are three channels of the river as they come out there, are there not?

A. Yes.

Q. And through this particular channel, there is 30 per cent. of the water flows, does it not, from your understanding of it?

A. That would not appear to be unreasonable, judging by the soundings and the length and width, as shown on the chart.

Q. Having in mind the place where that excavation was made, in your opinion would that have any appreciable effect, when you take into consideration the width of that lake?

A. Some slight effect, but not much.

Q. Let us take the one at the lower end of the lake. Would that have any very great effect?

A. No important effect, no, because of the great width.

Q. Now let us take this plate number 10, Exhibit Number 34, with the portion marked "Excavated Material" at the mouth of the Detroit River. Bar Point Light is the one, and the other is Ballard's Reef.

A. The excavation down stream from Bar Point, I should not expect to have any material effect; that is the excavation opposite Bar Point.

Q. Now do you find anything in this dredging shown on this Plate 10 of Exhibit 34 that appears to have had any appreciable effect upon the discharge of these rivers?

A. I would not expect the excavations shown there to have any important effect.

Q. How about your Exhibit J. R. F. Exhibit 1, then?

A. I was under a misapprehension. I supposed that that particular excavation (indicating) was nearer the head of the river.

Q. You mean the one "Bar dredged at head of St. Clair River"?

A. Yes.

Q. If as a matter of fact it was out in the lake some distance, that would not have any very appreciable effect?

A. No.

Q. And there is nothing else either that would have any great effect?

A. No, we have then left the natural scour.

Q. Had your attention been called to the fact, in the preparation of these tables, that of the material which had been

taken from the St. Clair River, all of the material, with the exception of 7,167 cubic yards, was deposited in the St. Clair River in the vicinity of the work, and that 7,167 cubic yards was dumped in Lake St. Clair?

A. I think that fact was within my knowledge, yes.

Q. And did you also know that the material which had been removed from Pine River, and from Bell River, was deposited in the St. Clair River?

A. I am not so clear about that, but if it had been, it naturally would be deposited in some deep portion, where it would not materially retard the flow.

Adjourned to Tuesday, October 14, 10:30 A. M.

October 14, 1913, 10:30 A. M.

Met pursuant to adjournment.

Mr. Austrian: With regard to Government's Exhibit M, that you (Mr. Wilkerson) identified yesterday, on the cross-examination of Mr. Freeman, I want to save the record.

This Exhibit M, as I understand it from the Government's counsel, was marked for identification and used upon the cross-examination of Mr. Freeman. Yesterday afternoon, upon the examination of Mr. Freeman, was the first time that this table had been submitted to any witness for the Defendant or any counsel representing the Defendant. During the recess from yesterday until today, we have examined this table and we find it to be, in our opinion, inaccurate, not based upon facts; the conclusions therein expressed not warranted by facts. And so as to preserve the record, we move that the cross-examination of Mr. Freeman, in so far as it is based upon said table, or anything pertaining to said table, be stricken out.

We take it, of course, the Government intends to prove the correctness of that table; but we do not want to be in the position of having waived this objection, upon the conclusion of the cross-examination of this witness.

Mr. Wilkerson: Of course the table is offered merely for identification; and the witness was interrogated upon the subjects therein referred to, upon the theory that the computations were accurately made. The motion may stand and be disposed of, after the table has been introduced in evidence in the ordinary way. Of course if the table is not introduced in

evidence, the cross-examination of the witness on the table will go out. If it does go in evidence, counsel for the Defendant will have their opportunity to show the particulars in which the table is inaccurate.

Mr. Austrian: I concede the questions were put to the witness on the theory that the table was accurately computed, but I believe some questions might not have contained that hypothesis.

Mr. Wilkerson: I intended in any question which I put to the witness—and I assumed that that element was carried forward in the questions—I assumed the accuracy of the computation of the tables. It might be, if there is anything in the record that should be modified, if pointed out in what particulars it is claimed the table is inaccurate, that might save time.

Mr. Austrian: We have absolutely no objection to pointing it out, so far as we have been able to ascertain it upon a very hasty examination. You want those in the record, those suggestions?

Mr. Wilkerson: Yes. If there is any portion of the testimony of the witness, which would be modified in any way—

Mr. Austrian: Mr. Freeman has not examined the table, but Mr. Williams and Mr. Stearns have.

Mr. Adcock: I think Mr. Freeman has examined it.

Mr. Austrian: No, he has not examined it. I understand from Mr. Williams and Mr. Stearns that there are inaccuracies in this table. I would like to have Mr. Williams point them out to counsel, because he has them in mind, and I have not.

Mr. Wilkerson: You want this in the record?

Mr. Austrian: Just as you like.

Mr. Wilkerson: Let it go in.

Mr. Austrian: No objection.

Mr. Wilkerson: The table really explains itself. We can have somebody swear, who made the computation.

Mr. Adcock: Here is the proposition: Ordinarily it would not be necessary to prove these tables, because we could check them up, without any trouble—

Mr. Wilkerson: I am perfectly willing to have him call attention to the points in which you claim either the theory upon which the table is made is incorrect, or the mathematical work is inaccurate.

Mr. Austrian: Point it out Mr. Williams, please, just the inaccuracies.

Mr. Williams: We find on checking this table, from the year 1891 to 1898 inclusive, the discharge through the Welland and Erie Canals has been introduced into the table twice, thereby increasing the discharge of the Niagara River, and reducing the difference between the derived Niagara and the actual Niagara.

We find furthermore that the discharge of the St. Lawrence purports to be derived from an equation contained in the 1912 report. We find upon examination that the equation there only represents the years from 1904 to 1906, and that there is no equation there which represents the discharges of 1891 to 1903, unless there is something there that we have not been able to find.

Mr. Wilkerson: Mr. Shenehon, will you explain how the table was made.

Mr. Austrian: Have you any other explanation Mr. Williams?

Mr. Williams: No, that is enough.

Mr. Shenehon: Column 2, St. Lawrence River outflow, by U. S. Lake Survey 1912 Report, does not refer to the annual report of the Chief of Engineers, but to a report by Sherman Moore. I have a blue print of the curves of the chart of the Niagara River for the period prior to 1904, and for the period after 1904.

Mr. Williams: You said "Niagara"; you mean St. Lawrence.

Mr. Shenehon: I mean St. Lawrence. That was submitted by me to Defendant's witness, Mr. Frederic P. Stearns, last night. Both the curves for the condition prior to the building of the Gut Dam and the condition after the building of the Gut Dam are shown on this sheet, and were used in preparing this table. The error of Mr. Williams was in assuming the report was the annual report of the Chief of Engineers.

The equation given in that has to do with the condition after the building of the Gut Dam only. As to the inclusion of the 2300 cubic seconds feet twice in the period from 1891 to 1898 inclusive, that is a matter I will need to check up to see whether or not such an error did come in.

Mr. Wilkerson: How much difference would that make in the result, assuming it had been done?

A. Not to exceed 1,000 cubic feet per second, roundly.

Mr. Adcock: What do you say about that Mr. Williams?

Mr. Williams: Something over 1,000 cubic feet, between 1,000 and 1,500 on the average.

Mr. Wilkerson: It will not be more than 1,500.
Mr. Shenehon: It is really half of 2,300.
Mr. Williams: Pretty nearly.
Mr. Shenehon: It is half of the period, provided that error was made.

JOHN R. FREEMAN, resumed the stand and testified further as follows:

Cross-Examination Resumed.

Mr. Wilkerson: Q. Mr. Freeman, I asked you some questions on yesterday with reference to a number of observations on the Niagara River which had been rejected by Mr. Williams in his study of this case. Did you observe when you went over his figures that out of 219 observations at the International Bridge, and 121 at the Open Section, making a total of 340 observations in the original computation, only 129 in all were used, and ten of those were afterwards eliminated, for the reason they were winter observations, making a total of 119 observations which were used. That is to say that of a total number of available observations on the Niagara River, 65 per cent. were rejected. Did you have that fact in mind?

A. I recall that a large number were rejected, but I do not remember the precise proportion.

Q. Now let me direct your attention to Sheet 1 of Table XLV A, of Williams' Exhibit 34.

A. I have it before me.

Q. Now I direct your attention to Group 3 of that Table. Having in mind what you have said with reference to taking the lake at a quiescent time, what range of lake level do you find there between the 15th of the month, October, and the 17th, in column 4?

A. .89 of a foot in elevation.

Q. 572.03 is it not and 570.64?

A. Strike out my answer. I had not followed down to the lowest on the 17th. I find a range from the one observation given on the 15th, at which time the elevation of the lake was 572.03, and the latest observation on the 17th, at which time the elevation was 570.64.

Q. There were two observations on the 15th, were there not?

A. The second observation on the 15th I should say to the fourth observation on the 17th, at which time the elevation was 570.64, a range of 1.39 feet.

Q. Now I direct your attention to Column 6. You find included there in determining the mean of the daily rate elevation at Buffalo, to which discharge observations were referred, reading at the top, 572.15, do you not?

A. I do.

Q. And you observe that the average daily mean elevation of the lake at Buffalo to which these discharge measurements was referred is 571.89?

A. I do.

Q. And you observe that the average of the observed elevations, at the time of the particular observation was 571.36?

A. I do.

Q. That there is a difference between the actual average of the elevations, and the mean to which the observations are referred of .53 of a foot?

A. I do.

Q. That is to say the effect there is to refer the discharge measurement, after it is weighted, 184,471, to a lake elevation which is .53 of a foot higher than the average of the actual lake elevations at the time of the observation?

A. That appears to be the fact.

Q. That would make a difference of about 11,000 cubic feet per second in the figure of discharge, wouldn't it, assuming an increment of 22,000 cubic feet per second?

A. Approximately, yes.

Q. Now what do you think Mr. Freeman of including, in determining the increment for this river, a group of observations in which there is that difference between the lake elevations to which the observations were referred and the average of the actual observations, and in which there is a range of 1.39 feet in the way in which it appears in that group?

A. I have no doubt that some correction should be made to allow for the progress of change of stage from the foot of the lake down to the gaging station, because not only must one allow for the wave to pass down, but there must also be time for a more or less filling or depletion of the basin in the vicinity of the gaging station.

Now just how much that correction should be, I had no means of determining last spring, but since you showed me a curve on which the hourly observations were plotted yesterday, one could from that make a somewhat closer approximation

for the purpose of learning just what correction should be applied.

Q. I wish you would direct your attention now to these curves that were shown to you yesterday, and give us your view on that subject at the present time?

A. (Witness refers to same.)

Q. In the chart to which you are referring now there are three curves, one of which indicates the Lake Erie elevation, another the volume of discharge, and another the Niagara River elevation at the Gorge Pool of the Niagara River, at Suspension Bridge. These sheets are marked Exhibits F, G, H and I.

A. I do not find one of these sheets, the one that covers the period referred to on October 12.

Mr. Wilkerson: I do not think that is plotted.

Mr. Shenehon: We did not have a self registering gage at that time, so that is not included in this series.

Mr. Wilkerson: Q. From those curves there, it appears it takes the effect of the river about how long to travel down to the Gorge Pool?

A. The time of travel from the lake down to the Gorge is variable, but appears to be in general about four hours I should say, from a hasty examination.

Q. Between three and four hours probably?

A. Something like that, yes.

Q. If it takes it that long to travel down to the Gorge Pool, how long will it take it to travel down to the—what I am trying to get at is how much of an allowance ought to be made in correcting these observations, so as to make allowance for that time to travel the distance?

A. Looking at the map now, in the light of these curves, for the first time, I should say somewhere about an hour or two.

Q. Not more than two hours?

A. No.

Q. By that you mean the time it takes the river to fill up as far as Chippewa?

A. Well, the time for the effect of a change in lake level to fully affect the regimen of the stream at the gaging station.

Q. Well, the effect of that, while the river is going up is one way, and while it is going down it is another way. In a certain sense that is compensating?

A. I could not say as to that without more time to investigate it. One must consider the filling or depletion of the basin

all the way between the outlet of Lake Erie and the brink of the falls, or of the rapids at Chippewa, which is a distance of something like 20 miles more or less; and from the fact that apparently the peak of a wave takes approximately four hours to travel from Lake Erie to the Pool below the Falls, I should say approximately that it would take somewhere about two hours for that effect to become established at the gaging station; that is for the pool to come to a corresponding stage with the elevation at the outlet of the lake.

I think the wave itself, the peak of a wave, would be transmitted more rapidly than that.

Q. What I am trying to get from you is an expression of your views as an Engineer as to the propriety of including in these computations in that column 6 that mean daily elevation for the entire day prior to the period covered by the observations?

A. Well, at that time, in the absence of hourly gages like that, that seemed a reasonable first approximation. Now we have data for a closer approximation.

Q. Would you say that in this group 3, to which I have directed your attention, the stage which had been selected was a quiescent stage of the lake?

A. This period is not covered in the four sheets of diagrams which you have shown me, but Mr. Williams shows me another plotting on a smaller scale, which I presume is an exhibit in the case, Chart 4 Sheet number 1, Williams' Exhibit 35, giving the elevations of Lake Erie at Buffalo for September and October 1898; and that diagram indicates that Lake Erie was then in about as stable condition as it is ever found.

Q. I was referring to those observed elevations which indicate a change of 1.39 of a foot in a period of two days. That shows on this Chart 4 Sheet 1, on the 17th day of October, in the form of a sharp depression, does it not?

A. It does, yes.

Q. It is the sharpest depression that you find within a month, is it not, prior to that time?

A. It is sharper than any during the preceding month.

Q. Now I direct your attention to Table number 45 of Williams' Exhibit number 34.

A. I have it before me.

Q. Which is a summary of the computations relating to the Niagara River, and I will ask you whether or not you do

not find that the range of elevation which is considered in this computation is 1.21 of a foot; 572.62 and 571.41?

A. I do.

Q. In the computations which were made by the Government Engineers, there was a range of lake elevation taken into consideration of 3.9 feet, approximately?

A. Something like that, as I remember it from the diagram you showed me yesterday.

Q. Now is it not a fact that where you have a small range of elevation, there is difficulty in getting an accurate measurement of the increment?

A. That is true. It is better to have the greater range.

Q. I also want to direct your attention to another one of these tables in Williams' Exhibit 34. I refer to table number 25 of Williams' Exhibit 34, in which a series of increments for the St. Clair River are derived by comparing the discharge measurements where there is a very small range in elevation.

Take the first column there, the number of observations in the period 3. And then we come to column 5, the one which is the center of gravity at 580.35; and column 7, where we have the center of gravity at 580.32, a difference of .03 of a foot, from which an attempt is made to deduce the increment from the difference in the discharge measurements.

Now, isn't the effect, the evident effect of comparing elevations where you have a very small range that the fact you have such a small divisor, that is such a small decimal for a divisor, multiplies and exaggerates any error of observation which there may be in the observations as to discharge measurements?

A. It has that tendency.

Q. So where you come to compare elevations of very small range, you could group observations in such a way that by reason of the small divisor which you would have, errors of observations would be greatly magnified. Take the third line there, for instance, where you have a range of only .04 of a foot; an attempt is made to deduce an increment from such a small range as that, 580.37 and 580.33.

A. Those two observations give a small base for deriving an increment, if taken alone.

Q. There are others that have a larger base. But now, take the fifth line where you have a difference of .13 of a foot, and in the sixth line you have .11. The point that I am trying to get at and make clear is where you do have

a small range of observations the effect of that is to magnify errors of observation?

A. That is true. It is not a good condition for determining an increment.

Q. So that in that respect, so far as the elimination of errors of observation are concerned, the method which would give you a wider range would be the more desirable, would it not?

A. Yes, but in that same table there are cases which give a much wider range.

Q. Yes, but in getting at the total result, they have been combined with figures where an error of observation may have been magnified by a very small divisor. That is true, isn't it?

A. Yes.

Q. Dean Shenehon directs my attention here to Sheet number 2 of this one curve series, Exhibit K, October 8, 1913. On this point of accurate observations when the lake is in a fluctuating condition, I direct your attention to a period, November 3rd, 4th and 5th, 1899. You observe there do you not a very wide fluctuation?

A. I do, yes.

Q. In the lake, and yet the observations, the actual observations appear to be plotted almost exactly on the line.

A. Well, the curve was in part determined from those same observations.

Q. That is true.

A. They do follow the line.

Q. But they are consistent with each other at least.

A. They are, yes, remarkably so.

Q. Well, that would be the proper way would it not of deriving a curve; you would take all the observations, and then the curve being derived from all the observations, if there was any one particular observation that fell into its proper place when plotted, that would indicate that the curve was a substantially accurate one, would it not, to an engineer?

A. Yes.

Q. You understand the method of weighting these observations, which was used by Mr. Williams in this case, do you, Mr. Freeman?

A. I have forgotten just now. I went over with him his

method of weighting, at the time, six months ago, when I was studying his observations, or computations.

Q. The effect of it, as you understand it, is that if you have a single observation made on one day, and four or five observations made on another day, that the single observation has given to it the same weight as the average of all the observations on the day on which there were four or five?

A. I don't recall. I think they were given different weights. I could tell by referring back.

Q. Well, they were weighted by time intervals. Just why shouldn't all observations be given equal weight in reaching a result of this kind? In other words why isn't one observation just as good as another, without regard to the time when it was made? For instance take this November 3, 4 and 5, 1899, which we have here. Now we have two observations which were made on the 4th of November, and we have two observations which were made on the 3rd of November and two on the 2nd and we have one on the 1st.

Mr. Williams: The 30th and 31st were also included in that, for the preceding month.

Mr. Wilkerson: Q. Take the 30th and the 31st. I find on the 1st of November there we have one observation. The effect of this method, as I understand it, is to give to that particular observation a greater weight than any other one observation which is made, is it not?

A. As I recall, yes; as I recall Mr. Williams' computations.

Q. What I am trying to get at is why one observation is not worth just as much as another, the same as an astronomical observation?

A. Well, in one case there were two observations taken on the same day, one as soon as possible after the other. And in that case (indicating) there was only one taken for a period of several days, and whether the two observations were grouped together for giving the result of a day's determination, and the whole were averaged by days rather than by individual observations would depend somewhat on other conditions, as to wind, or disturbed conditions.

I see now from looking at this curve of hourly heights no reason why one is not as good as another, except that on November 4, the first observation of that day appears to be at a time immediately following an extremely rapid rise of the lake; and it is a general rule of engineering investigation to exclude observations taken when the conditions are vio-

lently and rapidly changing, with the idea that the regimen of flow at the gaging station may not have been brought into entire harmony with the height at the outlet of the lake, which produced that condition.

Q. Can you see any reason as an engineer why in treating these observations you should,—rejecting, if you please, observations taken under abnormal circumstances—but so far as observations which were taken under what you conceive to be normal circumstances, can you see any reason why one observation should not have just as much weight as another, without regard to whether it was taken on one day, or whether two happened to be taken on another day?

A. I see no good reason at the present time.

Q. There is another rule—I suppose we call it a rule—that those who have to do with generalizing from observations follow, engineers, astronomers, and that rule is this is it not Mr. Freeman, that the selection of observations or the rejecting of particular observations is a thing which is to be indulged in with the very greatest care?

A. That is true.

Q. For the reason that if you once commence to select, or commence to reject, the computer may make his selection or rejection having in mind an ultimate result, and that it is a thing which should not be done unless it is perfectly clear that there is some extraordinary circumstances which makes the rejection absolutely necessary?

A. That is a general rule of reducing observations.

Mr. Wilkerson: Here is a chart that we have not had identified before. This is Complainant's Exhibit N, for identification.

(Whereupon chart produced by Government's counsel was marked Complainant's Exhibit N, for Identification.)

Q. This chart purports to show—and for the purpose of all the questions which I shall put to you based upon it, I shall ask you to assume that it correctly represents the level of Lake Ontario with respect to Lake Erie before and after the change in regimen of the St. Lawrence river due to the construction of the Gut Dam, and indicates correctly that in the period following the construction of the dam, Ontario appears to be fluctuating in about 6¾ inches higher elevation as compared with Erie in the earlier period. Now what I wish to ask you is this: Whether or not in case there was a change in the regimen of the river such as that caused by the construction of the Gut Dam, and you were to plot

the observations for the two periods, you would expect to find the change in the regimen indicated by a change in the line such as is shown on this chart?

A. Other things being equal, I would expect to find some such difference; but I think that would be an extremely doubtful and uncertain method for measuring the effect of a change like that of building the Gut Dam, because many other circumstances which would affect the level to a greater magnitude may have come in to obscure that result. That is the ice conditions may have been different in different years, or the rainfall conditions in the two regions might conceivably have been somewhat different. The cause to which I should attach the most importance as a possible disturbing element would be a variation in the ice condition as affecting the outflow of either one or the other of the two lakes, and I think that might entirely obscure any such effect as that of building the Gut Dam.

Q. But if you had two periods long enough so that there was an opportunity for this difference due to ice conditions to compensate each other, you would expect running over that period to find the force which was continuously operating to be indicated by a change in the line as drawn on the chart, would you not?

A. Yes; the effect must be there, but it may be obscured by other disturbing causes.

Q. Of course if you only had two or three years, that would be one thing, but if you had 44 years in one case and 9 years in the other, there is a very fair opportunity for those other disturbing forces to compensate each other, is there not?

A. No, I do not think there is because there are many things that may have occurred. That is it occurs to me at the present moment that there has been a changing condition in keeping the river open at Ogdensburg, between Ogdensburg and Prescott for a ferry; that is in the running of an ice ferry there which might affect the winter height. It is entirely conceivable that the development of water power in the past ten years at Niagara; their building of ice booms and taking various precautions to reduce their ice troubles may have in some way affected conditions. And I think that a nine year period since the building of the Gut Dam is entirely too short to average up the seasonal effects of much greater ice obstruction in one river than the other.

Q. The other factors remaining the same, that one continuous factor would be apparent as drawn?

A. Yes.

Q. You were speaking yesterday of this change of regimen in the St. Clair river. I show you another chart, which has been offered here for identification, on which the relative fluctuations of water surfaces of Lakes Huron and St. Clair, means of six months period, June to November inclusive, have been plotted; the equation used being the United States Lake Survey equation from all data in the Report of 1912, page 3546. Do you see in that chart any indication of a radical change in regimen of the St. Clair river during the years 1889 and 1890. I call you attention to the fact that was the open season, so that there could be no question about ice. For the record, those since 1889 and '90 are in red; those prior to the period are in white. (Handing witness Defendant's Exhibit B for identification October 13, 1913.)

A. The number of observations is too few to make them conclusive; and they also disagree very widely among themselves, but so far as one can deduce anything from them, they indicate that there has been a change and that for the same elevation of Lake St. Clair at the Flats, Lake Huron formerly stood something like .3 of a foot higher than at the present time.

Q. You do not see anything there that indicates a change of from six inches to a foot, do you?

A. The observations are too few and too inconsistent to be conclusive as to how much the change has been. But so far as any deduction can be drawn from that, it should be drawn by two curves, one for each of the two periods shown; two lines on there, one line for each of the two periods shown. And those lines would not coincide, but one would come decidedly above the other, enough to show that there has been some change.

Q. What in your opinion is the cause of that difference between the two periods, about which you have just testified?

A. I think the most reasonable explanation that I could offer for that is the dredging that has been going on, and also the natural scour at the outlet of Lake Huron.

Q. How about difference in ice conditions?

A. The scour caused by ice conditions; and then the storage because of ice conditions, the holding back of the water by an ice jam may affect this. I think the observations are too few of themselves to establish the fact of the amount

of change, clearly. They do indicate that there has been a change, and they are not of themselves competent to show what has been the cause of that change.

Q. You testified to some extent on the subject of run-off from these different drainage basins, as I remember your testimony, Mr. Freeman?

A. I did study into that, yes.

Q. Did you study the run-off conditions in the basin of Lake Erie as compared with that of Lake Ontario?

A. Why in a general way, yes; but not in very great detail.

Q. You examined the computations which Mr. Williams made on that subject, all the tables that he prepared?

A. Yes, and I also examined some that Mr. Stearns had made; and I also examined some computations given in an Appendix to the Report of the Chief of Engineers, by one of the Assistant Engineers.

Q. I wish you would look at the table 59 A in Exhibit 34 of Williams' discussion of this case. Did you give consideration to that table?

A. I cannot now recall particularly. I saw a number of computations of Mr. Williams, but it was six months ago; and I do not at the present moment recall this particular table.

Q. It is a fact is it not that the run-off conditions in the basins of Lake Erie and Ontario are very materially different, as you understand it, Mr. Freeman?

A. I should want to look that up. I should want to go back to the observations before answering specifically.

Q. Well, you know in a general way, do you not Mr. Freeman, that around Lake Erie it is very level country, is it not?

A. Yes.

Q. And cultivated?

A. Largely so, yes.

Q. The whole situation is one where you would expect to find, comparatively speaking, a very small run-off, would you not?

A. I would say small rather than large, but I am not prepared to say just how much smaller than average conditions.

Q. Did you read Mr. Williams' testimony on this subject?

A. I do not think I did.

Q. The streams were measured, gaged, and from that the conclusion was reached as to the run-off of these dif-

ferent drainage basins; and the point to which I am directing your attention is the small run-off of Lake Erie as compared to the other two lakes. Of course we all understand that observations of this kind, so far as accurate results are determined, they are exteremely indefinite, but so far as comparisons are concerned, we might be able to get some help from a study of this kind?

A. Well, I may say that in general from a flat, a highly cultivated territory, one expects a somewhat smaller percentage of run-off than from a steep and forested territory. I think to a large extent around both of the lakes, certainly as regard the extreme eastern end of Ontario, that also is a cultivated country.

Speaking in a general way, I may go further and say that from a flat, cultivated area we do sometimes have exceedingly heavy run-offs, as for example the great floods in Ohio during the past year; and that the total annual run-off comes largely in a season of the year when the ground is frozen and not receptive of the water, so that the cultivation does not have as much influence then as on the summer flow. I would not want to be specific without taking a good deal of time to study all the available data.

Q. I was speaking particularly of Mr. Williams' conclusions there as shown in Table 59 A for the months June to November, the last line.

A. I have not examined that sufficiently to have any opinion of my own upon it.

Q. In determining the effect of the run-off from the drainage basin upon a lake, if you were trying to get at the effect for the period of navigation, say from June to November, would you take into consideration the figures for the full year, or for just that portion of the year during which you were trying to get at the effect?

A. I should want to consider both, because the winter rainfall largely sinks into the ground and comes out and feeds the streams as ground water during the summer; but in considering the effect of lake levels during the open season, I should of course give the principal attention to the summer run-off, or the run-off between April and November, or rather from June to November after the ice is out of the lakes.

Q. Have you any reason to question, as an engineer, the conclusions which Mr. Williams has reached that comparing Lake Erie and Ontario, whether you take the full year or

any part of the year, the run-off for the Erie basin is considerably less than ½ that of the Ontario basin?

A. It looks reasonable to me because Ontario at its western end receives the Oswego river from the Adirondacks, from a forested area; and Huron and Michigan receive a good deal of water from forested areas, so from those facts I should think it reasonable to expect that the run-off of the area, the drainage basin, which has a larger proportion of cultivated land would be relatively smaller.

Q. Now, I understand Mr. Freeman that in its last analysis, your criticism of this Niagara discharge measurements reduces itself to the belief that they must be in error for the reason that if they were accepted as accurate, there was no showing of a sufficient contribution from Lake Erie?

A. That was the principal reason.

Q. When you reached that conclusion, did you have clearly in your mind this very great difference between the run-off in the Erie basin and the Ontario basin?

A. I did have in mind that there was probably some difference, but I am not yet ready to admit that it could be so great as to explain that discrepancy between the Niagara gagings and the gagings at the head of the St. Lawrence and at the outlet of Lake Huron.

Q. It might be big enough to account for part of it, if there was a wide difference?

A. It might account for part of it, but it is inconceivable to me that it could account for the whole of it.

Q. What was your understanding of the extent of the difference between what Niagara ought to show as the discharge observations and what it did actually show?

A. In round numbers 20,000 second feet.

Q. I do not know whether you heard Mr. Stearns testify or not. I think he puts the figure at 16,000.

A. I did not hear him testify. My own recollection is more than 20,000 rather than less, as I viewed it and figured it out.

Q. But without having your attention directed to the great difference in the run-off of the two basins?

A. There are other differences too, in the relative areas of water surface of Erie as compared to its drainage area, its land surface, and that of the other lakes. I tried to consider and properly weigh various elements, not only the fact that the Erie drainage area was flat, but I also tried to

give proper weight to the relation of the land area to the water area.

Q. You reached the conclusion, as I understand, that on the lake surface the evaporation is greater than the precipitation?

A. Probably a little, yes.

Q. That would be true of Lake Erie?

A. Even that is somewhat uncertain because we have no very good observations on the actual evaporation from very broad surfaces such as Lake Erie. All the data that we have indicates that it is proportionally less on a very broad area than it is on the area of an ordinary water works reservoir, or particularly on the area of an experimental evaporating basin.

Q. I thought your conclusion was that the evaporation was probably greater than the rainfall on the surface of the lake; it may be Mr. Stearns' conclusion not yours?

A. Yes.

Q. I thought you both reached that conclusion?

A. I think it was somewhere nearly that, probably a little greater, but my own ideas as to the evaporation from broad lake surfaces are that it is only about say two-thirds as great as one would derive from experiments on a small evaporating basin.

Q. And the basin of Lake Erie compared with the surface of the lake is smaller than Lake Ontario, is it not; the drainage area as compared with the water surface of Erie is smaller than that of Ontario?

A. The ratio in the case of Lake Erie is that the water surface compared with the total drainage area is as one to 3.47, while in the case of Ontario it is as 1 to 4.55; and in the case of Superior it is as 1 to 2.37; and in the case of Michigan 1 to 2.95; and in the case of Huron 1 to .313. So that taking the lakes as a whole, all of the Great Lakes have a ratio of water to total drainage area of 1 to 3.02, while Erie has a ratio of 1 to 3.47; that is the ratio of water to the entire drainage is less for Erie than it is for the Great Lakes system as a whole.

Q. I was speaking however of this difference between Erie and Ontario, and of the apparent discrepancy between these discharge observations for the St. Lawrence and the Niagara. What I wanted to ask you was this: Whether in your opinion in comparing the Niagara with the St. Lawrence you had given enough weight to the fact that the drainage area of Ontario is as one to 4.55, while that of Erie is 1 to 3.47; and that

the run-off as shown by the tables of Mr. Williams of the Erie Drainage Basin is considerably less than ½ of that of Ontario, when you look at it for the entire year, or for the season from June to November; and if you look at it from June to November it is really about ⅓, less than ½ for Ontario?

A. I believe that I did give proper weight to that.

Q. So far as you are familiar with the physical conditions of the country, they all tend to show that that conclusion which Mr. Williams has stated in his table about the wide difference in run-off is in accordance with what you would expect from the physical conditions

A. I should expect the difference to be in that direction.

Q. I am not speaking of the accuracy of the particular figures themselves, but I am speaking of the relative condition as shown by the tables.

A. Yes, as I have already stated.

Q. You spoke also about the difficulty of measurement of the Niagara river. We are not to understand from any criticism you have made about the Niagara river, we are not to understand you have ever actually done any work on the Niagara river in the neighborhood of these gaging stations?

A. I have done no water gaging work. I have done more or less engineering work on the Niagara river.

Q. Have you made any soundings?

A. No.

Q. So that what you have said about the condition of the bottom, and these other things, is your understanding based upon what you have heard and read?

A. What I have heard and read, and photographs that I have seen. And then I have had occasion to go along the river very frequently, and cross it at one point and another many times.

Q. You were never down at the river at these new sections that have been measured?

A. No, I have never been there when they were gaging.

Q. You have observed the International Bridge Section, have you?

A. In a general way, yes.

Q. Well that brings us back to the subject we were discussing here yesterday; that is if the error in these discharge measurements in the Niagara is due to the fact that the water is in a disturbed condition, you would expect to find a variation which would be in proportion to the extent of the perturbation, so that if you found that these three sections checked,

it would indicate that the river could be measured pretty accurately. I just want your view on that.

A. The tendency of these later gagings is plainly to confirm the other gagings, but still both combined tell a story that to me is wholly inconsistent with the story told by the gagings at the St. Lawrence and the gagings at the St. Clair and the obvious facts about the run-off from Lake Erie. It is like the case where one has discordant witnesses testifying as to a fact, and you have the question as to which witness you shall believe when it is physically impossible that all of the witnesses can be telling the truth.

It is much easier for me to believe that the disturbed condition has caused constant errors in the measurements at both of the Niagara stations than it is for me to believe that the drainage area of Lake Erie contributes nothing whatever to the flow of the Niagara river during the open months. And then in studying the Niagara gagings, those that I had the opportunity to study in the record at the section at International Bridge, and the other immediately below it, with a view to seeing whether I should believe the gagings at the St. Lawrence combined with the gagings at the St. Clair, in preference to the Niagara gagings, it seemed to me in that case we had two independent witnesses, both of whom were perhaps better qualified than this very much disturbed witness at the Niagara.

Q. That is when you had only the two sections?

A. I made those considerations, of course, from the two sections. Now that this third section has been introduced, I see possibilities for error in the statements of that witness; that is because of the curved condition of the river at that point. It is a very puzzling state of affairs. And the different sets of gagings are discordant when compared with one another, although all of them remarkably concordant among themselves.

Now if we had nothing to go by but these gagings at the Niagara, and were studying their consistency among themselves, I would be lost in admiration of their remarkable agreement with one another. But I have had cases like that in my own practice. I think I referred to one where I made some water gagings in testing a turbine under disturbed conditions, and I saw no reason at first to think that these current meter gagings were in error, but I found they were inconsistent with other gagings; and then sought for the error and finally found it.

Q. Well, what would you say Mr. Freeman suppose it appeared that so far as the run-off of the Erie basin was concerned, we would accept what Mr. Williams stated here as the correct result for that, and applying the method which has been used by you and Mr. Stearns here, and by making the allowance for the smaller run-off of Lake Erie as shown in Mr. Williams' tables, we would find that the St. Clair and the Niagara checked within five or six thousand cubic feet?

A. That would be a result inconsistent with the result that I found when making the computations; and I should want to look into the newer computations, step by step. I should still be in a puzzled state of mind to know where the truth lay.

Q. That is to say accepting our increment, when you said Erie did not contribute anything at all, you mean it did not contribute as much as you thought it should contribute, wasn't that it? You did not mean there was no contribution at all?

A. My recollection is that comparing the gagings during the summer season—

Q. About 7,000 cubic feet, wasn't it?

A. It is very small. It is almost no flow at all from Erie, and I cannot believe that.

Q. That is assuming of course that the St. Clair increment is correct?

A. Yes, but so far as—

Q. The St. Clair volume of discharge I mean?

A. So far as I could judge from reading the description of the methods, it seemed to me that they had better conditions for accurate measurement at St. Clair and probably also at the St. Lawrence than they had at the Niagara. That is it is entirely beyond a possibility to find out just how much disturbed conditions are there at the Bridge Station, and at the station 1,200 feet below the bridge, except we know they must be very much disturbed.

Q. You have made no attempt have you in this case to derive an increment for the St. Clair river, using all of the observations except those which in your opinion show some abnormal condition, and would be rejected by students on that ground, and giving to each observation the same weight, and not referring the observation to a gage reading in which there is included the element of this day preceding a group of observations?

A. No, I have not gone into that.

Q. I wanted to know whether you had made any independ-

ent study of the St. Clair measurements, with a view to deriving an increment from those observations, on the theory that that was the river which had been measured the more accurately?

A. No, not by plotting the observations, and attempting to deduce an increment.

Q. Or by making any independent study other than for the purpose of determining what observations in your judgment should be rejected?

A. No independent study. I reviewed Mr. Williams' computations.

Q. But you did not take up each particular observation which had been discarded or the groups that had been arranged?

A. No, only in a general way.

Q. With a view to determining whether they had been done properly or not?

A. No, not in detail.

Q. Now in this study of the relation of the lakes, so to speak, to each other—I think you know what I mean—in the equation which is used as expressing the relation between Lakes Michigan, Huron and Lake Erie, in view of this change of regimen which you say took place along about 1890, would it be proper to include the observations which had been made prior to 1890; I mean when you check, when you are trying to check Niagara with the St. Clair, should you include the observations prior to 1890, on the St. Clair?

A. I think it would be proper to consider it. I do not know without further study just how much weight I would give to it.

Q. If, as a matter of fact there was a change of regimen in the St. Clair river from 20 to 24,000 cubic feet per second, which occurred along about 1889 to 1890, and you were making a study of the discharges of the rivers and conditions in the lakes for the purpose of determining whether your St. Clair observations checked with your Niagara observations, you would not want to take into consideration any measurements that had been made in the St. Clair prior to that period of 1889, 1890, would you, any discharge observations made prior to that time?

A. It is proper to take them into consideration, but one should not use an equation for computing flow prior to the change which was derived from current meter measurements made after the change, if that is what you mean.

Q. That is what I have in mind?
A. Yes.
Q. And any consideration which was given to any one of those observations, if the comparison was to be made with conditions after 1889 and '90 would have to be corrected by the amount of the assumed change?
A. It should be corrected, yes.

Recess to 3:00 P. M.

After recess 3:00 P. M.

JOHN R. FREEMAN, resumed:

Mr. Wilkerson: Mr. Shenehon has a statement to make about that table that we were discussing here this morning. Of course both Mr. Shenehon and Mr. Williams are witnesses in this case, and what they say about this case is in the record as their testimony.

I wish Mr. Shenehon you would take this Exhibit N, for identification, shown to Mr. Freeman this morning, and as to which some question was made by Mr. Williams with reference to the double inclusion of the discharge through the Erie and Welland canals. That was something suggested by Mr. Williams. Have you any statement to make about that, Mr. Shenehon?

Mr. Shenehon: I have checked up the table Exhibit N, and find that the correction for additional flow for the Erie and Welland canals was not duplicated in the years prior to 1898, as suggested. The discrepancy between the discharge of the Niagara river as derived by Mr. Stearns and myself is due to the fact that he referred his discharges to the elevations of Lake Erie as given in the 1910 Report of the International Waterways Commission, while I referred mine directly to the records of the United States Lake Survey. I may add that the International Waterways Commission took the data from the same source, and evidently applied a correction of .1 to it; that is added .1 to it.

Mr. Williams: I think it would be proper to read into the record the statement at the end of the table in the International Waterways Report; also the statement you just read from the foot of your table.

Mr. Shenehon: I read from page 94 Table 2 of the Report of the International Waterways Commission on the regulation of Lake Erie, 1910, note B, B, referring to the observa-

tions from 1888 to 1898, inclusive. The note is as follows: "Derived from U. S. Lake Survey Tables by subtracting .1 foot from records there given."

I refer now to a blueprint giving the monthly mean elevations of Lake Erie at Buffalo, New York, this being one of the records of United States Lake Survey.

Mr. Adcock: Has that been offered in evidence?

Mr. Williams: No, it is not in evidence. It was supposed by Mr. Shenehon to have been offered, but I think he is satisfied now that it was not. I have not seen it.

Mr. Shenehon: The note at the bottom of that table reading:

"The water level records for Buffalo gage previous to March, 1887, were destroyed by fire. From March, 1887, to February, 1899, inclusive, are reduced from tri-daily station gage readings taken at Erie basin. The relation of the elevations of the gage and reference bench marks is not definitely known during this period, and the water levels may be in error in consequence; but probably not to exceed .2 foot.

From March 1899 to date, the monthly means are reduced from the records of the self registering gage located on the Buffalo breakwater. This has been kept carefully referenced to the bench marks." Is that sufficient, Mr. Williams?

Mr. Williams: Yes.

Mr. Adcock: Have we a copy of the document you read from?

Mr. Shenehon: We will furnish you one.

Mr. Wilkerson: Have enough copies made and have it marked Government's Exhibit HH October 14, 1913. Enough copies will be prepared for the record and for counsel.

Re-direct Examination by Mr. Adcock.

Q. Are you aware that Mr. Williams corrected the tables appearing in Williams' Exhibit 34 so as to eliminate the observations made while the Niagara river was affected with ice, that is certain eight or ten observations; and that he also made corrections so as to include in his computation of 1907 and 1908, observations on the Niagara river, and that the elimination of the observations mentioned during the ice period, and the use of the 1907 and 1908 observations did not make any material difference in the result, were you aware of that during the cross-examination?

A. No, I think not. Mr. Williams has told me, I think it was since the cross-examination, that he had.

Q. Mr. Wilkerson asked you as to the effect of certain dredgings at certain points in the St. Clair river, and of Lake St. Clair and the Detroit river. There are certain other points where dredging was done that he did not mention. Did those other points have any effect, in your opinion, in increasing the discharge capacity of that outlet?

A. I think they did; that they would have more material effect than those which we discussed on examination of the charts; particularly in the vicinity of Ballard's Reef, as I remember it.

Q. And that would have a tendency, in your opinion, to change the relation of the levels of Huron to those of Erie?

A. I believe that it would.

Q. So as to lower Huron as compared with Erie?

A. Yes.

Mr. Adcock: I think that is all.

Re-cross Examination by Mr. Wilkerson.

Q. Did I understand you to say that you had seen computations made by Mr. Williams in which the 1907 and 1908 Niagara observations were included?

A. No, I have not seen them.

Q. You saw the computation in which the winter observations had been crossed out?

A. That is my recollection.

Q. And that was the computation which you had in mind when you said you understood that the crossing out of those winter observations made no material difference?

A. Yes.

Q. You are not to be understood as having said that the computation included the 1907 and 1908 observations?

A. Not the original one which I saw.

Q. Where around Ballard's Reef was this dredging which you think had considerable to do with changing the discharge of the river

A. Well all along in that vicinity. It would include the excavation made near the Lime Kiln Crossing, too. But as I recall, it was more particularly above the Lime Kiln.

Q. I rather gathered from what you said yesterday that

you did not think that the dredging at the Lime Kiln Crossing had much to do with the changing of the regimen?

A. Not so much as the natural scour, but I think that all that dredging has had some effect.

Q. In what year do you understand was the dredging around Ballard's Reef which produced this effect?

A. The table showing the dredging done in different years, which I understand is already in evidence in this case, and of which I had a copy at the time I was preparing my report, shows that the excavation directly at Ballard's Reef began in the year 1895, and continued until the year 1903; and that the dredging immediately down stream from that, in the first opening of the Lime Kiln Cut, began in a small way as far back as 1877, and continued irregularly for nearly ten years until 1891, and then was resumed again actively in 1900 and progressed from that time steadily until 1908.

Now there was other dredging done along at different times, which may have affected the outflow to some amount, at the outlet of the Black river. That was done at various times; a little done in 1873 to 1877; then again in 1889 to 1892; then a little in 1898; then a little in 1903.

I did not consider that that Black river dredging had produced any important permanent effect, but it may have in some small degree contributed to the general effect. That is, from what information I could get, I believe that the natural scour which was induced, probably mainly in the great ice gorge which I think occurred in 1901 and in other ice gorges in other years, that that has produced more effect on the lowering of the level of Huron than that which has been produced by the dredging. But I think that both have contributed and that the dredging has without doubt been one cause of the lowering. Just how it should be divided between the two, how the lowering should be divided between the effect of natural scour and the effect of dredging, I would not attempt to estimate.

Q. Are you prepared to say as the result of your examination of this subject that the extent of that lowering has been more than four or five inches?

A. Yes, the total of the lowering I believe to have been decidedly more than that; somewhere between six inches and a foot. Now as to how much of it came from the dredging I don't know; only a part, and probably less than half, I would say.

Q. I thought I got the figure this morning .3 of a foot?

A. No, that was from the diagram which you showed me. I said that taking that diagram which you put before me and attempting to deduce it by those very incomplete observations would indicate that there had been a lowering of about .3 of a foot. But I have just been speaking of my own conclusions resulting from studying this matter last February and March.

Q. I forgot to show you an exhibit this morning, being the exhibit in which the Niagara observations are all plotted, and in which the increment of 21,900 and the increment of 34,000 are drawn with reference to those observations. Assuming that those lines are drawn accurately, as a student of observations of this character, would you not say that the line 21,900 agrees, or accords more nearly with the trend of those observations than the line 34,000?

A. It so appears from this diagram.

Q. I am assuming that they are accurately plotted, and that the lines are accurately drawn?

A. And that the observations are entitled to equal weight.

Q. Yes. And I think that is your view about the weight of the observations, unless you find an observation that was taken under abnormal circumstances?

A. Yes, other things being equal, I would give them equal weight.

Further Re-direct Examination by Mr. Adcock.

Q. Referring to that diagram Mr. Freeman that has just been shown you, as I understand it you disregard the Niagara gagings or observations there do you not, entirely, for the reasons that you stated this morning; that is they are out of harmony with the other physical conditions; that you do not consider that they harmonize with the gagings in the other rivers.

A. They are not in complete harmony, but still they are not to be disregarded by any means, and so far as I know they give the best means—the only means that we have of determining the increment in a discharge equation at the outlet of Lake Erie.

Depositions in the above entitled cause taken pursuant to stipulation of counsel for respective parties, before the Commissioner, statutory notice being duly waived, at Ann Arbor, Michigan, on July 15, 1913.

Appearances:

Mr. James H. Wilkerson, representing the Government.
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian, representing the Sanitary Dis-District.

All objections to questions, answers and exhibits shall be considered as having been made, except as to questions involving form, and secondary evidence.

HERBERT CHARLES SADLER, a witness called on behalf of the Sanitary District was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your full name, residence and place of business?

A. My name is Herbert Charles Sadler, place of residence Ann Arbor, Michigan; place of business same.

Q. What is your business?

A. I am Professor of Naval Architecture and Marine Engineering, at the University of Michigan.

Q. How long have you been connected with the University of Michigan?

A. Since 1900.

Q. Will you state your early training and experience, practice as a Naval Architect?

A. I was educated at Dulwich College, England, and at Glasgow University, Scotland. I graduated from Glasgow University with a degree of Bachelor of Science and Engineering, in 1893.

I received the degree of Doctor of Science from the same University in 1902.

From 1890 to 1896, I was engaged in practical ship building on the Clyde, and served an apprenticeship at all branches of the business.

From 1896 to 1900, I was Assistant Professor of Naval

Architecture and Marine Engineering at Glasgow University, and during that time was associated with Professor Biles in a large and varied consulting practice.

From 1900 to date, I have been Professor of Naval Architecture at the University of Michigan.

In 1901 and again in 1904, I was appraiser for the vessel properties in connection with the Michigan Railroad appraisal. I also appraised the vessels owned by the Duluth, South Shore & Atlantic, in 1912. I was one of the consulting naval architects for the City of New York in connection with the municipal ferries.

I have acted as consulting naval architect to the Great Lakes Engineering Works, in connection with the designing and construction of lake vessels. The Great Lakes Engineering Works have one of the largest yards on the Great Lakes. My connection with this firm extends over a period of 10 years, and has covered work in connection with the large type of lake freighers, and also with the Welland canal type.

Among the larger vessels, were such vessels as the Cole, and Shenango. I have also conducted experiments in connection with the tunnel under the Detroit river for the Michigan Central Railroad Company.

For the last two years have acted as Consulting Naval Expert to the Tow Boat Board of United States Army Engineers Corps; in connection with the development of river vessels and barges. The above board consists of Lieutenant Colonel Lansing H. Beach, Major Charles Keller, Colonel Charles Potter and Colonel Newcomber.

I also acted as Consulting Naval Architect for the White Star Line of Detroit, which is engaged in passenger business on the Great Lakes; for the Detroit and Cleveland Navigation Company, and for the Hudson River Day Line, New York.

While you were connected with Professor Biles from 1896 to 1900, what particular work did you perform or were you connected with, in this practice?

A. The practice included the preparation of designs for all classes of vessels; principally those of the London Southwestern Railway, and the American & Red Star Line.

Q. What business were they engaged in?

A. In the cross channel business, and the American Red Star Line in the Trans-Atlantic business.

Q. Since you have been connected with the University of Michigan, what has your work covered?

A. My work has been, first, in connection with the courses

of naval architecture and marine engineering, in which the theory of practice of ship and engine designing is involved.

I have also designed and installed the apparatus for the experimental tank, which is one of the two in the country, and in this connection have been engaged in general research work with ship's forms.

Q. Will you just describe in a general way the tank and its purposes?

A. The naval tank is a large tank 300 feet long, 22 feet wide and 10 feet deep. Its purpose is to enable us to test the resistence and other qualities of vessel's forms. In connection with the tank, there is suitable machinery for making ship models, and cutting them accurately to drawings. After the model is prepared it is placed in the water and attached to a suitable dynamometer, which is mounted on a traveling car. This car may be dragged at any desired speed, and the resistence of the model recorded at any speed.

Q. Electrically operated is it?

A. Electrically operated. In this way we can determine the resistence of the model for any speed, and from that calculate the power required to drive a full sized vessel at corresponding speed.

Q. Is the naval tank that you have just described used only in connection with the University of Michigan work there?

A. It is also available for the solution of actual problems occurring in practice. And we have developed and carried out a series of investigations in the Great Lakes Engineering Works, in connection with the most economical design of vessel for the large freighter type, and also for the Welland canal size.

Q. What is the business of the Great Lakes Engineering Company?

A. They are ship builders, engineers.

Q. When you speak of freighters, you refer to the large freighters used on the Great Lakes?

A. On the Great Lakes.

Q. And designed to be used there?

A. Yes.

Q. You have spoken of the Welland canal type of boat. Can you describe that type?

A. That type of vessel is limited by the size of the Welland canal locks, and in general they run about 250 feet long and 42 feet wide.

Q. And what is the depth of draft of the boat?

A. About 14 feet.

Q. Are you familiar with the design and draft of boats used on Lake Ontario?

A. Not particularly.

Q. Have you been engaged as consulting naval architect since your connection with the University of Michigan, outside of your regular work there?

A. Practically since 1900.

Q. Are you familiar with the classes of boats that are in passenger and the various freight carrying trades on the Great Lakes?

A. Yes, sir.

Q. Do you know about how large the tonnage is of freight per year, of all kinds on the Great Lakes, exclusive of package freight? I am referring to Lake Superior, Huron, Michigan, Erie freight that is carried through the St. Mary's Falls Ship canal and the St. Clair and Detroit rivers.

Mr. Wilkerson: This answer, I assume, is based on some report?

Mr. Adcock: Yes.

Mr. Wilkerson: Not on his own knowledge.

Mr. Adcock: No.

Mr. Wilkerson: If you are referring to some report, specify the report to which you refer and point out such portions as you deem pertinent from your standpoint, and we will call attention to such other portions as we deem necessary.

A. Referring to the St. Mary's Falls canal, Michigan, Statistical Report for 1912, the total traffic is given at 72,472,676.

Q. What is the ore tonnage?

A. The ore tonnage as far as I remember was last year between forty and fifty million tons.

Mr. Wilkerson: Is that for the year 1912, that is from January to January; January 1, 1912, to January 1, 1913?

A. Yes, the season.

Mr. Adcock: I presume it is the season of navigation.

Q. What is the tonnage of coal and wheat?

A. The coal tonnage is about 14,900,000; and the wheat about 5,220,000.

Q. What are the sizes and dimensions of different classes of boats that are engaged in the heavy freight business, ore and coal and wheat trade?

A. They run from in the neighborhood of 400 feet to 600 and over, slightly over in length.

Q. Are they divided, those you have mentioned there, divided into three classes, approximately those 440 feet in length, and about 550 feet and 600 feet and over?

A. Yes.

Q. What is the beam and draft of the different classes that you have mentioned, the dimensions of them?

A. The dimensions would be about 440 by 52 by 28 feet in depth. The 550 would class 550 by 56 by 31, and 605 by 58 by 32.

Q. How many boats are there of those different classes in service now, or were in service last year on the lakes?

A. This is quoting: Of the smaller ones 151; the 500-foot class, 93; and the 600-foot class, 73.

Q. You are familiar with the design of these different boats as a class, are you?

A. Yes.

Q. Do you know what depth the 440-foot class are designed to be loaded to?

A. 19 feet.

Q. And the 550-foot class?

A. 19 feet in general.

Q. And the 600

A. 19 feet in general also.

Q. May those be loaded deeper?

A. It might be possible to load the larger types, the 550 and the 600-foot classes somewhat deeper.

Q. Have you considered the question as to whether the vessels that were of the 550 and 605-foot class could be designed so as to offset a decrease in the depth of water of say 1, 2, 3, 4, 5 or 6 inches, so as not to detract from their efficiency materially?

A. I have.

Q. And would they carry approximately the same amount of tonnage, same material, the design that you have spoken of?

A. Yes.

Q. Will you state what investigations you have made and what conclusions you have reached in regard to that, in regard to the subject matter of the last question and answer?

A. I have made calculations showing the effect of the loss of draft of 1, 2, 3, 4 inches, etc., for the following types of vessels:

1st. A vessel 440 by 52 by 28.

2nd. 550 by 56 by 31, and

3rd. 605 by 58 by 32.

Taking the smallest class first, the loss in capacity for one inch draft would be about 55 tons. In order to compensate for this loss, the vessel would have to be increased in length about 2.1 feet. The increased cost of the vessel would be about $1,000, and the interest and depreciation $100. For two inches loss of draft and three inches loss of draft the figures would be in the same proportion, or a loss in capacity for three inches would be 165 tons; the increase in length to enable the vessel to carry the same cargo as before 6.3 feet; the increased cost of the vessel about $3,000, and the interest and depreciation about $300.

Mr. Wilkerson: Q. That figure of $3,000, is that the difference between the cost of constructing two new boats, one of one type and one of the other, or the cost of making an old boat over?

A. That would be additional cost due to adding 6.3 feet to the original boat.

Q. That is if you constructed a new boat?

A. A new boat.

Q. A new boat of the kind which you described as being designed to offset the effect?

A. Yes.

Q. Of the loss in capacity?

A. Yes.

Mr. Adcock: Now if you will, proceed with the answer to the question before you were interrupted.

A. For the 550-foot class, the loss in capacity for one inch would be 70 tons, the increase in length required to equal this loss 2.9 feet; the increase in cost of the vessel $1,700; the interest and depreciation $170. The figures would be proportional for 2, 3 or 4 inches. And for 3 inches loss of draft, the loss in capacity would be 210 tons, the increased length necessary to compensate for this 8.7 feet; the increase in cost of vessel, $5,100; the interest and depreciation $510.

For the 605-foot class, the loss in capacity for one inch would be 81 tons; increase in length to equal this loss 3.1 feet; increased cost of vessel about $1,800; the interest and depreciation $180.

The figures would be proportional for 2, 3 and 4 inches loss of draft. And for three inches, the loss of capacity is 243 tons; the increase in length 9.3 feet; the increase in cost of vessel $5,400; the interest and depreciation $540.

Q. Now you have spoken of these three classes. Do those

classes of vessels carry practically all of the coal and wheat and ore on the Great Lakes?

A. They carry about 70 per cent. of the total.

Q. What proportion of the ore, wheat and coal is carried by the 440-foot class or vessels smaller?

A. About 48 per cent.

Q. You have stated I believe the proportion that was carried by the 550-foot class and the 600-foot class I believe, haven't you? If you have not will you state it?

A. The 550-foot class carry about 26 per cent. of the total, and the 600-foot class about the same, 26 per cent.

Q. About how many tons is that all together?

A. About 18,800,000 for each two larger classes.

Q. About 37,000,000 all together?

A. Yes, sir.

Q. Are carried by those two classes per year?

A. Yes.

Q. A boat designed as you have suggested to offset for loss of draft of 1 inch, 2 inches, 3 inches, 4 inches 5 inches and so forth, would it cost any more to operate that boat than a boat designed to carry the same tonnage with the deeper draft?

A. No.

Q. Now you have spoken of the increase in cost of different designs of vessels there, those three classes that you have mentioned, and you have spoken also of the increase in cost for one inch and for three inches. Would that be in the same proportion up to 6 or 7 or 8 inches?

A. Yes.

Q. You have spoken of the draft of a boat and the depth, and also the registered tonnage and dead weight tonnage and so forth. Will you explain those different terms?

A. The depth of a boat is the distance from the keel to the deck. The registered tonnage of a vessel is the figure obtained by calculating the internal capacity of the vessel in cubic feet and dividing by 100. In other words the unit for registered tonnage is 100 cubic feet of internal capacity.

The dead weight tonnage is the actual number of tons of cargo that the vessel would carry at a given draft.

Q. Then you have spoken of the draft of a boat also? What do you mean by that term?

A. The draft is the actual amount of water that the vessel draws measured from the bottom of the keel. I might add

that if a vessel is out of trim, by the term draft in connection with dead weight, we generally mean the mean draft.

Q. What do you mean by the term "free board?"

A. Free board is the amount of side of a vessel from the water line to the deck.

Q. What is that in a boat of these given classes that you speak of?

A. That is about nine feet in the 440-foot class.

Mr. Wilkerson: Q. It is the difference between 19 and those figures?

A. Yes; and about 13 feet in the larger classes.

Mr. Adcock: Q. Do you know how many boats of the three different classes you have spoken of have been added in the last year to the service on the lakes?

A. 20 of the 400-foot class and 6 of the 500-foot class and 14 of the larger type.

Q. When you say 400-foot class, you mean boats of those lengths, 400 and 500 and over and 600?

A. Between five and six hundred.

Q. That is over to the next class?

A. Yes. That was in the last year?

Q. Yes.

A. Yes.

Q. Do you know how many of the 400-foot class have been built and put in service in the last 13 years or so, since 1899?

A. All except 41.

Q. All except 41. That would be 110?

A. 110.

Q. How many of the 500-foot class and 600-foot class have been built and put in service since 1899, or the last 13 years?

A. Practically all of them.

Q. Were there any in service prior to 1900 of those two classes, 500 and 600 feet?

A. Referring to the St. Mary's Falls Canal Report for 1899, I find that there were no vessels over 500 feet in service.

Referring to the 1903 report, the maximum length given is 498 feet.

Q. You have calculated the cost of building a boat to take care of three inches less in depth of water, and stated it to be I believe $5,100, and that the interest and depreciation would be about $510. Have you made any calculations for the purpose of capitalizing the $510 interest and depreciation?

A. Yes.

Q. What is that?

A. At 5 per cent. capitalization this would be about $10,000.

Q. So that the total loss then would be $15,100?

A. Yes.

Q. Including the $5,100 actual cost of building. Then, have you made any calculation as to the total loss on that class of boat, being 93 in all, for the three inches loss in depth?

A. Yes.

Q. State what that is?

A. For the different classes?

Q. No, for the 500-foot class and over, up to 600?

A. For 93 vessels, this would be $1,404,300.

Q. Have you made the same calculations in this respect with reference to the 600-foot class?

A. Yes.

Q. Will you state what the results are?

A. The interest and depreciation capitalized at 5 per cent. would amount to about $11,000, or for the 73 vessels in this class $1,197,200.

Q. And that would be in the same proportion as to four or five or six inches, or one or two inches?

A. Yes, sir.

Mr. Wilkerson: All your capitalization figures are on the basis of three inches loss?

A. Three inches.

Mr. Adcock: Q. The two classes that you have mentioned, the 500-foot and the 600-foot class are the largest draft boats in the trade on the lakes, are they not?

A. Yes.

Q. And they are the only ones that may be capable of being loaded, that is are designed to be loaded more than 19 feet?

A. Yes.

Q. Have you made any calculation, leaving out any question of design of the boats, or change of design, have you made any calculation as to the loss per year to the lake commerce of the loss in depth of water of 1, 2, 3, 4, 5 and 6 inches, as to the two classes of boats, 500 and 600-foot class?

A. Yes, I have.

Q. Have you read the record showing the testimony of Mr. Coulby and Mr. Livingstone, who were witnesses for the complainant in this case?

A. I have.

Q. From that testimony and the facts presented by them and from your experience in calculations made, will you state your conclusions as to the losses to lake commerce from the loss of depth of water of 1, 2, 3, 4, 5, 6 inches and so forth, and the method that you have pursued in arriving at the results?

A. The following figures were based upon the steamers Rogers and Corey.

Q. They represent what classes of boats?

A. They represent about the 600 and 550-foot classes.

Q. Respectively?

A. Respectively.

Q. You may proceed with the answer to the previous question.

A. As a basis for the calculations, a change of draft of two feet was chosen. Considering the Steamer Rogers, first, as representing the larger class, the displacement, on a draft of 19 feet, is 15,800 tons. The tons per inch, 81; the cargo carried per annum 323,000; the number of trips, 29; operating expenses $127,000.

Q. That is those figures were obtained I believe from Mr. Coulby's testimony and Mr. Livingstone's?

A. Mr. Coulby's testimony.

Q. Mr. Coulby's testimony.

A. If loaded to two feet deeper, the increase in cargo carried would be 1,944 tons per trip; therefore for 29 trips, it would be 56,400 tons. Owing to the extra draft, the vessel would require about 150 horse power more than at present for the same speed. This would involve an expenditure of about $870 per annum. The increase in expenses, due to unloading the extra amount of cargo due to the two feet extra draft, at 20 cents a ton, is equal to $11,280. The total increase in expenses is therefore $12,150.

From the original figures as given by Mr. Coulby, the cost per ton works out at 39.4 cents. With the draft increased two feet, the cost per ton would be from the above figures 36.7 cents.

Dealing now with the Steamer Corey, as representing the 550-foot class, the displacement at 19 feet is 14,300 tons; the tons per inch 73; the amount of cargo carried per annum 295,802 tons; the number of trips 29; the operating expenses $123,404. When loaded to 2 feet deeper draft, the increase in cargo would be 1,750 tons per trip, or the increase in cargo

per annum for 29 trips 50,700 tons. The increase in cost of coal would be approximately the same as for the Rogers, or $870. The increased expenses for unloading, $10,140 or a total of $11,010.

For the figures as originally given, the cost per ton works out at 41.7 cents.

Q. That is according to the complainant's testimony?

A. Yes. With the draft increased 2 feet, the cost per ton is 38.8 cents. The difference due to 2 feet extra draft in the case of the Rogers was 2.7 cents per ton, and 2.9 cents in the case of the Corey; or an average of say 2.8 cents per ton for this class of vessel. This saving in cost would be proportional for each inch of draft, or say .116 cent per ton per inch.

For a vessel of the size of the Rogers, with an average of 11,100 tons per trip, the cargo carried and the effect upon the cost have been estimated for 15, 20 and 25 trips per annum, corresponding to an increase in draft of 1, 2, 3, 4 inches and so forth.

For an increase in draft of one inch, the increase in cargo would be 81 tons per trip, and therefore for 15 trips would be 1,215 tons, for 20 trips 1,620, and for 25 trips 2,025 tons. The total cargo carried for 15 trips would be 167,715; for 20 trips 223,620 tons, for 25 trips 279,525 tons.

For a loss of draft of one inch, the increased cost would be .116 cent per ton, or an increased cost of $194 for 15 trips, $259 for 20 trips and $324 for 25 trips. For 2, 3, 4 inches, etc., the figures would be in the same proportion, or for 3 inches difference of draft, the increase in cost per annum would be $588 for 15 trips, $790 for 20 trips and $987 for 25 trips.

In the case of the Corey, the increase in cargo for one inch for 15 trips would be 1,095 tons; for 20 trips 1,460 and for 25 trips 1,825 tons.

The total cargo carried per annum, for 15 trips would be 154,095 tons; for 20 trips 205,460; for 25 trips 256,825 tons.

Q. That is with the increase of one inch?

A. Increase of one inch. The increased cost for one inch decrease in draft for 15 trips would be $179; for 20 trips $238 and for 25 trips $297. For 3 inches, the figures would be $537 for 15 trips; $714 for 20 trips, and $891 for 25 trips.

For the 73 vessels of the Rogers type, the increased cost per annum for one inch draft—

Q. Loss?

A. Loss would be $14,160 for 15 trips; $18,900 for 20 trips and $23,650 for 25 trips. For three inches loss of draft, the

figures would be $42,480 for 15 trips; $56,700 for 20 trips and $70,950 for 25 trips.

For the 93 vessels of the Corey type, the figures would be, for 15 trips, $16,650; for 20 trips, $22,130; for 25 trips, $27,620. For three inches decreased draft, the increased cost would be for 15 trips $49,950; for 20 trips, $66,390; for 25 trips, $82,860.

Capitalizing the above sums for the three inch difference of draft and for the 166 vessels of the two classes, the figures are as follows:

For 15 trips, $1,848,600; for 20 trips, $2,461,800; for 25 trips, $3,076,200.

Q. On the basis of the amount of tonnage actually carried per year by these 166 vessels, have you made any calculations as to the loss, possible loss?

A. For the 37,000,000 tons—

Q. Your answer is yes?

A. Yes.

Q. I will ask you to state the result, what your calculations were and the results?

A. For the 37,000,000 tons approximately carried by these two classes, at .116 cent for one inch the loss would be $42,920.

Q. And for three inches would be how much?

A. And for three inches would be three times that or $128,760.

Q. Capitalized at 5 per cent. what does that equal?

A. $2,575,200.

Q. Now the unloading charge and the other figures that you have used there, where did you obtain them?

A. From Mr. Livingstone's testimony.

Q. How deep could you load the boats of the 600 and 500 foot class? Take the 600 foot first. How deep may you load, with due regard to the safety of operation and so forth?

A. So far as free board is concerned, the vessels could probably load to 23 feet.

Q. That is the 600 foot class?

A. The 600 foot class, and retain the same free board as the 400 foot boats. So far as strength is concerned, it might be possible to increase the present stresses about 10 per cent., which would mean that the vessels could load to 21 feet.

Q. That is the maximum load?

A. Yes.
Q. Maximum depth that they should load?
A. Yes.
Q. That is of the 600 foot class?
A. Yes.
Q. With reference to the 500 foot class what would you say?
A. The figure would be approximately the same.
Q. Did you have anything to do with the design and construction of the Cole and Shenango which are boats, I believe you stated, in the larger freighter class here?
A. Yes, I carried out a series of experiments upon those vessels to determine their best shape.
Q. You are familiar with the cross section designs of those boats I believe?
A. Yes.
Q. And the dimensions and the strength?
A. Mid-ship section.
Q. Mid-ship section?
A. Yes.
Q. Do you know anything about what those boats have done, either one of them in the service in the last year or so?
A. I understand the Shenango carried the largest cargo on the lakes, largest ton mileage on the lakes.
Q. When you say you understand, you refer to the report of St. Marys Falls Ship Canal of 1912?
A. Yes.
Q. And that boat is of the 600 foot class, as I understand it?
A. Yes.
Q. You stated that these boats of the 500 and 600 foot class were designed to be loaded to a depth or draft of 19 feet, and you also stated that by increasing the stress say ten per cent, on the larger boats, the boats of larger class, they might be loaded 21 feet. In your opinion what would be the greatest depth of draft, of loading the vessels of the two classes consistent with safety of operation and good practice?
A. I feel that I would not like to advise anyone to increase the stresses more than 10 per cent. over those at present; and therefore not to load deeper than 21 feet.
Mr. Adcock: That is all.

Recess to 1:30 P. M.

After Recess 1: 30 P. M.

HERBERT CHARLES SADLER, resumed the stand and testified further as follows:

Cross-Examination by Mr. Wilkerson.

Q. You have grouped these vessels into three classes, Professor; the vessels with dimensions 550 by 56 by 30 and 605 by 58 by 32. How long did I understand you to say it was since the first one of the 550 foot vessels was constructed?

A. It was 500 feet I think.

Q. Have you anything before you that shows just the facts as to the time when those larger vessels came into use on the lakes?

A. In 1903 the maximum length was 498 feet.

Q. That is to say in 1903, there was no vessel in use on the lakes, the length of which was more than 500 feet?

A. No.

Q. Is that right?

A. That is right, yes.

Q. Now have you tables before you from which you can state, or if you haven't the tables can you state from recollection approximately the facts as to the number of vessels of these classes I have referred to, which have come into use during each of the years since 1893?

A. There was one vessel of 560 feet in 1904, so practically all of them have come in since 1903. And according to the 1912 report, there were 93 vessels of about the 550 foot class and 68 of the vessels about 605; five over 600.

Q. When did the first one of those of the length of more than 600 feet come into use?

A. In 1907 there were two of them.

Q. That is to say in 1907 there were two vessels longer than 600 feet each?

A. Yes, 605.

Q. Have you anything there before you which shows how many of them were built in 1908, 1909, 1910 and 1911?

A. There were two in 1908, three in 1909, three in 1910, and four in 1911.

Q. And the remainder in 1912?

A. Five in 1912.

Q. That does not account for all of the 73?

A. That is from 550 to 600.

Q. As I recall your classification, you had 73 of one type. What was that type in which there were 73?

A. Of the roughly the 600 foot type.

Q. That is the type I am speaking of?

A. Yes.

Q. You had 93, roughly, of the 550 foot type?

A. Yes.

Q. I suppose we can get the exact figures?

A. Yes.

Q. What I understand the fact to be—I want to know if I am in error about it—is that most of those have been put into service within the last few years?

A. Yes.

Q. Those two types?

A. Those two types, yes.

Q. And those have been coming into use, have been increasing each year?

A. Yes.

Q. That is more in 1912 than 1911?

A. Yes.

Q More in 1911 than in 1910?

A. Yes.

Q. Now in forming your opinion of the injury to navigation in this case, which would be produced by diminishing the depth of the channels at the critical points, did you make any study of these figures for the purpose of arriving at a conclusion as to how many of the vessels of these two types, having in mind the number that have come into use already, and the probabilities of the case according to the law that you might arrive at, how many of the vessels of those two types would be in use within the next ten years? Did you give any weight to that?

A. No, I didn't make any estimate of that at all.

Q. Didn't make any estimate of that kind at all. But you have no doubt but that the tendency is towards the use of the vessels of the larger type, and that within the next period of ten years or twenty years, there will be very many more vessels of those two types in use than are in use now, have you?

A. Yes, from the 550 to the 600 foot class, will probably be the—

Q. That would be your judgment based upon your knowledge of the lake commerce?

A. Yes.

Q. And your experience?

A. Yes.

Q. Having come in contact with it and looking at the tendency in the building of vessels to-day?

A. Yes.

Q. That there will be a great many more of those large vessels in use?

A. Probably, yes.

Q. So that your figures which you have given us based upon the number of vessels in use in 1912, in order to get at the future damage, would have to be increased so as to correspond with the number of the vessels of the larger type which were actually in use at the particular time, wouldn't it?

A. Yes, certainly.

Q. So that if there were two or three times as many vessels of those types in use four or five years from now, your figures would have to be multiplied by 2 or 3 or 4 as the case might be?

A. Certainly.

Q. Now you spoke about the vessels of the Welland Canal type, and those are vessels which have a draft of 14 feet maximum. That is due to the fact that you cannot get a vessel of a larger draft through the canal?

A. Yes.

Q. Now with respect to vessels which are used in that kind of commerce, the tendency in vessel building has been to build right up to the limit of the canal, has it not?

A. Yes.

Q. That is they will build vessels as large as the capacity of the canal will permit to be used?

A. Certainly.

Q. That has been true of the other locks, has it not to the extent that the size of those vessels is limited by the locks at the Soo, is that the point?

A. Somewhat; the draft—

Q. The draft at the Soo fixes the limit for the size of vessels which are engaged in the commerce on Superior, Huron and Michigan?

A. Not necessarily.

Mr. Austrian: I do not think you mean the size?

A. You mean length.

Mr. Wilkerson: Q. The draft of the vessels.

A. The loaded draft is fixed by the Soo, as one of the fixed points.

Q. What is that now?

A. About 19 feet.

Q. That is the reason why you say the vessels of too large a type, they may be loaded to a depth of 19 feet only, because of the fact that is the limit?

A. Yes, that is their designed draft.

Q. Now it is in contemplation is it not that the depth there is to be increased?

A. I believe so.

Q. To 24 feet?

A. I don't know the actual figures.

Q. If it were to be increased to 24 feet, that would make possible the use in commerce of the types of vessels which are considerably larger even than those now in use, wouldn't it?

A. Yes, if the rest of the conditions kept pace with it, I mean the harbors.

Q. I mean other conditions being adjusted so as to correspond, you could use in the commerce of the lakes vessels with a draft of 24 feet?

A. Yes.

Q. That would mean that they would be longer, and they would have a great deal larger capacity?

A. Not necessarily longer. They could load them deeper.

Q. They could load them deeper, and they might be longer?

A. That would depend on the conditions of handling and so forth. The length is more dependent on that than on the draft.

Q. With those larger vessels, the effect of a loss of 1 or 2 or 3 inches would be greater proportionately would it not than in the case of smaller vessels?

A. That is vessels, do I understand you ,vessels loaded to a deeper draft?

Q. Yes.

A. No, the effect of one inch, if you kept the other dimensions the same, would be the same.

Q. But if you had a vessel of the larger draft, if you built the way vessels are constructed now, the other dimensions would be increased, would they not?

A. Not necessarily.

Q. Well, not necessarily?

A. No.

Q. But probably; that is to say if you were designing a vessel with a draft of 24 feet, if you followed the ordinary rules, it would be a longer vessel than one with a draft of 21 feet?

A. No, not necessarily.

Q. Of course not necessarily, but as a matter of fact generally speaking, would't you have a longer vessel. You find the vessels of greater draft the longer they are?

A. Not in connection with the lake types, because you gain so much more by increasing the draft than length. It is much less expensive a thing to do. You can put the whole vessel down one inch.

Q. That is why it is very important that you have conditions so that you can have as great a draft as possible?

A. Yes.

Q. In building vessels for the lake trade?

A. Yes.

Q. It is regarded as a matter of considerable importance is it not?

A. Yes.

Q. Now in this first table which you have prepared and about which you have testified, you have given certain figures which indicate the amount which it would be necessary to increase the length of the vessel in order to compensate for the loss in capacity due to the loss of draft. And I notice the first figures have a loss of draft of one inch, you have capacity in tons for vessels of the first class, 55 tons, and an increase in length to equal that loss of 2 feet 1 inch, 2.1 feet?

A. Yes.

Q. Is that computed according to some formula which you have?

A. That was obtained by taking into account the extra weight of structure and the extra displacement needed to be equivalent to that change of 1 inch of draft.

Q. Just how did you do that? Tell me how you got that 2.1 feet there?

A. I estimated the weight per foot of length of each particular size of vessel, and that added to the weight lost due to 1 inch would finally give me a means to find the extra displacement for the total extra weight carried.

Q. What I am trying to get at is, have you the data of your computation here, so that I can follow the figures through

by which you go from the loss of 1 inch of draft to the increase in length of 2.1 feet?

A. No, I haven't those figures here.

Q. Just describe the process as nearly as you can. I want the mathematical process so that if I wanted to check your figures, I would know how.

A. Well, the area of the mid-ship section multiplied by one foot of length would give the extra displacement in cubic feet for 1 foot added length. Now when you add one foot of length, you add one foot of extra structure, so that you do not gain all that displacement due to that extra foot of added length. Now in the case of the vessel cited—what is that table?

Q. These dimensions are 440 by 52 by 28, in your first column.

A. Finally we have to carry 55 tons more in the vessel, and by a process of trial and error, we can determine the exact length that must be added, so that the added displacement will be equal to the 55 tons plus the weight of the structure, so that the net gain in this case due to 2.1 feet is equal to 55 tons.

Q. You have made an estimate of the increase in the cost of the vessel. You have computed, I suppose, the amount of material?

A. Yes.

Q. And computed the value of the material, on what basis?

A. That material would all be put in mid-ships and would be structural steel work, and on a basis of about 3¼ cents a pound, finished material.

Q. On the basis of about 3¼ cents a pound?

A. Yes.

Q. Take vessels of the two types, of the same carrying capacity, but the one with the greater length and the other with the greater draft, what about the resistance in going through the water, which one goes through the more easily?

A. It would be about the same.

Q. No different?

A. No, practically the horse power would be the same for those two vessels.

Q. Within the limits of a foot?

A. Yes.

Q. Two feet? I have an idea you have a little more space on the vessel moving through the water where you have greater length than a vessel of the other type?

A. No.

Q. Certainly under certain limits?

A. A large part of the resistance of vessels of this type at the speed with which they move is surface friction, and the amount of horse power required to overcome that provided great change in length was not made would vary just about as the surface—

Q. I understood you to say a little while ago that the draft was the thing that you would look after; that is draft was preferable to length; it was better to have vessels of greater draft than a long vessel. Just why is that?

A. It is cheaper.

Q. Cheaper to build it?

A. Yes.

Q. And easier to operate? It sits deeper in the water doesn't it, is more stable?

A. Not necessarily, no.

Q. It is deeper in the water?

A. That does not necessarily act as stability.

Q. Generally does, doesn't it?

A. No, sometimes the other way.

Q. Sometimes the other way?

A. Yes.

Q. So it is a matter of cost of construction that makes that difference?

A. To carry a given amount.

Q. In your computation with reference to the Steamer Rogers, a vessel of dimensions 580 by 58 by 32, I notice an item "Increase in expense of unloading at 20 cents." On what basis did you reach that figure, 20 cents?

A. From the figure given by Mr. Livingstone in his testimony.

Q. That is to say that the average expense of unloading a ton of freight is 20 cents?

A. I understand so from—

Q. And this table was made on the assumption that starting out with a given vessel, an annual cargo of 323,000 tons, that if you increased that to 379,400 tons it would cost 20 cents a ton more to handle that freight?

A. To handle the difference.

Q. To handle the difference, yes.

A. It would cost 20 cents a ton to handle—

Q. The difference. It is based on that?

A. Yes.

Q. It is based on that assumption. Take a vessel that has a cargo increased 1944 tons at one trip, you would probably have the same crew, would't you?

A. Yes.

Q. And as a matter of fact having in mind the way in which vessels are operated, it probably would not cost 20 cents a ton more to increase a cargo to 1944 tons, would it?

A. Yes, that is the unloading charge, I understand, charged the ship by the docks for unloading the cargo.

Q. You understand that is a charge made to the ship by the docks?

A. Yes for unloading.

Q. That is a fixed charge, of so much per ton?

A. Yes.

Q. Without any reference at all to the size of the cargo?

A. Yes, I understand so.

Q. And the computation is made on that basis?

A. Yes.

Q. I just wanted to get clearly in mind the basis on which the computation was made?

A. Yes, that is it.

Mr. Adcock: That was the deduction you drew from Mr. Livingstone's testimony wasn't it, and Mr. Coulby's?

Mr. Wilkerson: I wanted to make clear just why that item of 20 cents was put in there?

A. It might be Coulby.

Mr. Wilkerson: I shall be very glad in this connection to have you refer to the portion of the testimony you indicate.

Mr. Williams: I will look it up for you; you can go on.

Mr. Wilkerson: Q. In these computations as to the saving of expense due to the use of boats of larger draft, you had in mind that you had a given quanitiy of freight which was to be moved, and that it would cost a certain amount more to move it in boats of the one class than in boats of the other. That I understand is what you had in mind in preparing those tables, is it not?

A. Not exactly. I took the boat, the Rogers, and the other, and those figures were based on the added amount that that particular vessel could carry, if she could load to a deeper draft.

Q. On the Great Lakes there is a season of navigation isn't there?

A. Yes.

Q. If you have a certain number of boats that are available for use and the amount of cargo that is moved is dependent upon the number of boats which are available, your loss to commerce would be not merely this difference, but it would be the fact that that ore or grain or whatever it is is not moved at all, wouldn't it be?

Mr. Austrian: You must put in another condition there, that you have not sufficient boats to move your commodity that is desired to be moved. You haven't got that in.

Mr. Wilkerson: Now let us just take the case of iron ore.

A. Yes.

Q. You are transporting iron ore from points on Lake Superior to Cleveland, and you have here a vast quantity of ore which may be moved from one place to the other. You have a certain number of boats in the service that are available for use. Now you can load only to a certain depth. If you could load three inches more, you could put in so many tons more of the ore, so that if you are going to figure the real loss under a situation of that kind, you would have to take into account the fact that you have so much ore which might have been moved if you had had the boats, but which was not in fact moved.

Mr. Austrian: You cannot do that—I will put it in the form of an objection if you want—you cannot take that point of view unless you eradicate airships, which may provide a further means of transportation.

A. The point is in the history of transportation that the tonnage has usually kept pace with the demand for it; if anything a little above.

Mr. Wilkerson: Q. Of course they build boats as they are required.

A. As they are required.

Q. Is was just trying to get clearly what your theory has been of this relation of tonnage to navigation. With reference to this transportation, is it a fact that these cargoes are transported as late as December after the insurance has expired; that is that the demand for service of that kind is such that they actually take the risk of engaging in transportation during a month when they cannot get insurance?

A. I understand so. They run. I would rather the ship owners gave evidence on that point.

Q. But that is your understanding?

A. That is my understanding.

Q. Wouldn't that indicate to you that the real loss which

is suffered is the complete loss which results from the fact that so much ore is not transported which otherwise might be transported?

A. Well, there is no doubt that if the lakes were open to navigation all the year around, there would be transportation all the year around.

Q. There would be more transportation?

A. Of course.

Q. They would bring that ore down more rapidly?

A. They would bring it down at the same rate, but if we had the lakes open all the year around, there would certainly be transportation of ore all the year around.

Q. Has the commerce on the lakes increased any definite ratio, or percentage of increase Do you know what the facts are; have you studied that?

A. There has been more or less steady increase.

Q. Has it been rather a fixed increase?

A. It fluctuates from year to year.

Q. Of course, but I mean the general line is upward?

A. The tendency is upward.

Q. Has relation does it to the increase in population?

A. I have not studied that particularly.

Q. You haven't studied that?

A. No.

Q. But in this question of damage to navigation, that is an element that would necessarily have to be taken into consideration to reach any conclusion as to the full damage in the future, isn't it?

A. Probably.

Q. If you were trying to arrive in your own mind at something which would state the full damage, the probable damage to navigation in the future, you would have to give consideration to this study of increase in commerce on the Great Lakes?

A. Well I suppose so, but I have not studied that question at all.

Q. You just simply made an estimate on the basis of the year 1912?

A. Yes.

Q. When you speak of 29 trips, does that mean round trips?

A. Yes, that is according to—

Q. 29 round trips, there would be a cargo each way; those

large boats take ore going down and coal going back usually?

A. Not always, no.

Q. Sometimes?

A. Depends on the state of the trade. If the ore trade is busy, the vessels are very often sent up light.

Q. There would be some loss on the back trips, if the trade was such that the boat could be loaded fuller, which is to be taken into consideration to get the full figure?

A. Yes.

Q. Returning for a minute to the question of the building of vessels, there have been, in connection with the ocean commerce, the tendency has been right along towards the use of larger vessels?

A. Yes.

Q. And so far as the commerce on the lakes is concerned, if there should be ultimately deep waterway navigation, if that plan should be worked out there would be a tendency towards the use on the lakes of vessels very much larger in size than are used now? I am speaking of the general trend of vessel building.

A. Well, I feel personally that vessels much over 600 feet would be rather unwieldly in narrow channels, and for general handling purposes.

Q. But with the larger draft, if the time came when the ocean-going vessels, through the deep waterway project, were brought into the lakes, the movement would be to get as much draft as possible, wouldn't it, to increase the depth of the channels and build vessels of larger draft?

A. To accommodate ocean vessels?

Q. Yes.

A. Yes.

Mr. Austrian: Q. And also widen the channels too, wouldn't it?

A. Yes.

Mr. Wilkerson: With reference to the vessels longer than 600 feet being unwieldy, is that because of the light draft?

A. No, it is due more to the length.

Q. Does the smallness of the draft have anything to do with it; is that a factor?

A. It might even accentuate it in certain places, if the draft were increased, in currents, where there are currents?

Q. You gave us some figures this morning, I think a figure of about two and a half millions of dollars, on a basis of a

certain tonnage, and on the basis of a loss of draft of three inches. For a loss of draft of six inches, that would double, be $5,000,000?

A. Yes, sir.

Q. And for a loss of 10 inches that would be about $8,000,000; 3⅓ times 2½?

A. Yes, sir.

Mr. Austrian: It would be in the ratio?

A. In the same ratio.

Mr. Wilkerson: Your figures were $2,575,200, loss of draft of 3 inches; 6 inches would be $5,150,400; and that was merely on the two classes of vessels, the vessels in the second and third class as you have them classified?

A. Yes.

Q. And on the basis of the number in use in 1912?

A. Yes.

Mr. Austrian: And that loss was capitalized; the amounts you have given?

Mr. Wilkerson: Q. On the basis of 25 trips a season, 20 trips was it?

A. It was not—

Mr. Adcock: We took arbitrarily 15, 20 and 25 trips.

Mr. Wilkerson: Q. On the 25 trips you had a figure of $3,000,000, a little over?

A. Yes, sir.

Mr. Austrian: Q. As I understand it that is the loss capitalized?

Mr. Wilkerson: Yes.

Q. As I understood you to say a moment ago, that did not include the up-cargoes?

A. That is for that amount of cargo moved.

Q. For that amount of cargo moved?

A. Whether it was up or down, those figures would be correct.

Mr. Wilkerson: I think in this connection, we would better have in the record in this case the full report, statistical report, of lake commerce passing through the canal at Sault St. Marie, through Michigan and Ontario, during the season of 1911. That I understand is the document from which you—

Mr. Adcock: No, that is 1912.

The Witness: 1912.

Mr. Austrian: Let us have a further stipulation that all these reports from 1899 to 1912 may be considered in evidence; need not be attached but may be referred to by either

side, with the same force and effect as if incorporated in the record.

Mr. Wilkerson: I think myself it is a document that the court will take judicial notice of, and will take judicial notice of the facts stated. I am perfectly willing that the court should do that.

Mr. Austrian: Take judicial notice of the figures in these reports 1899 to 1912; and everybody may refer to them with the same force and effect as if incorporated in this record.

Mr. Wilkerson: We will stipulate the court may take notice judicially of the figures.

Mr. Austrian: Or any facts or statements therein contained.

Mr. Wilkerson: Q. There is more tonnage through the Detroit river than the Soo, is there not? Look at the report. In the case of the Soo, it is 72,000,000; at the Detroit river it is 78,000,000, as Mr. Shenehon advises me.

A. There is more tonnage through the Detroit river than the Soo.

Q. What is the fact about it?

A. You want the actual figures? There is 72,472,676 tons through the Soo, and 78,671,208 tons passing through the Detroit river.

Mr. Adcock: What does that cover what kind of freight?

A. That is all kinds.

Mr. Austrian: Mr. Wilkerson, I think in view of the fact that you want to get a concrete statement into this record as to the comparative tonnage at the Soo and Detroit river, you ought to also put in the fact, as appears from the St. Marys Fall Canal, Michigan Statistical Report, etc., from which the witness got these figures, that the tonnage at the Detroit river is estimated, and includes a large amount of railroad ferry tonnage, which really is railroad tonnage; and that appears on page 27 of the report in question.

Mr. Wilkerson: Of course whatever appears in this report may go in.

Mr. Austrian: The Soo is accurately computed. The Detroit river is simply estimated, and also as appears on page 27 includes this railroad ferry tonnage, which is simply a convenient means of transporting the cars and the tonnage in the cars on very shallow draft boats used only for that purpose, and really is part of railroad transportation.

Mr. Wilkerson: Q. Have you made any examination of these official tables with a view to ascertaining what the fact

is as to what proportion of the whole commerce of the lakes goes through the Detroit river?

A. No, I have not.

Q. I understand that it appears from the report of the Department of Commerce, that that proportion is 84 per cent. You are not prepared to make any statement about that. Are you familiar with that report?

A. Yes, but I don't recall that particular figure.

Q. And you haven't it here?

A. No.

Mr. Wilkerson: We will furnish a copy of that report. That is our recollection of that percentage. Mr. Shenehon says it is 84 per cent. of all the commerce of the lake at the Detroit river; so that in order to get the whole commerce on the lakes you have to divide the tonnage on the Detroit river by 84 per cent., if that is the correct figure.

Q. Where a vessel is loaded so that it runs very close to the bottom, is there any element of difficulty or danger that is not present if the vessel is operated in water where it does not run close to the bottom?

A. Yes, it is harder to propel.

Q. It takes more coal?

A. It takes more coal.

Q. Danger of collision is greater?

Mr. Austrian: That is collision with the bottom?

Mr. Wilkerson: Q. They have a term they call "Taking a sheer" whatever that is.

A. In constricted waters, in narrow waters the danger would be increased.

Q. Just explain that a little more fully.

A. Two vessels passing fairly close together in narrow channels, and both of them near the bottom, the suction would be greater probably than if there were more water.

Q. Did I understand you to say that your experience had extended to designing vessels?

A. Yes.

Q. To what extent have you designed vessels?

A. Before I came here, I prepared the plans for the Vaaterland, Zieland, of the American Line; for a number of vessels of the London & Southwestern Railway; the White Star Line in Detroit and have vised plans for a number of other vessels.

Q. What do you mean by that?

A. That is some draftsman has made the plans, but they have met with my approval.

Q. You spoke of some positions which you had held before you came to this country. Just what were those positions?

A. Before coming to this country?

Q. Yes.

A. I engaged in practical ship building.

Q. With whom?

A. On the Clyde, the firm of A. & J. Inglis.

Q. Did you design vessels there?

A. In the drawing office.

Q. You were in the drawing office?

A. Yes.

Q. How long were you there?

A. From 1890 to 1896.

Q. How many others were associated with you in the work in the office, in the drawing office; how many were there there?

A. Oh about 10 I think, 8 to 10; 10 maybe.

Q. Did you have a head draftsman? What I am trying to get at is just the organization.

A. Yes.

Q. Were you the head draftsman?

A. No, I was not the head.

Q. Who was the head?

A. A man named Blair I think.

Q. With these others, you did the work under his direction?

A. Yes.

Q. Now since you have been here, you have acted as a consulting engineer, and you spoke about the use of this tank you have out here.

A. Yes.

Q. Just what kind of work do you do as consulting engineer, and in connection with that tank?

A. In developing the right shape to make vessels.

Q. That is to say you have submitted to you plans for a vessel, and then you make experiments to—

A. To determine the best shape, best form.

Q. That is to say you want to get as little resistance as possible, is that the idea?

A. Yes.

Q. Do you make a model?

A. Yes.

Q. Draw it through the water?

A. Yes.

Q. And have some apparatus which measures the resistance?

A. Yes, sir.

Q. And you have had plans submitted to you and from those plans you have done that measuring of resistance and made your report on it?

A. Yes.

Q. That has been your work in the main has it?

A. No, not necessarily. I have been in New York, in connection with the municipal ferries there. We have had the whole—

Q. What was your work there?

A. With Colonel Stevens; I was with the consulting engineers.

Q. You were constructing boats?

A. We had to pass upon all the plans and general scheme for those vessels.

Q. You examined the plans for the vessels and gave your opinion?

A. Made suggestions as the plans were being prepared, etc.

Q. This statement of Mr. Livingstone, about which I asked you and which you refer to, is one in which he says as follows: (Continuous paging 348) "I am trying to explain it is based on the present rate of freight, 65 cents a ton at the head of the lake. Out of that freight rate is paid about 20 cents a ton for unloading." That is the statement you had in mind is it?

A. Yes.

Q. I notice that Mr. Livingstone there says 65 cents a ton from the head of the lake. That is from Duluth to Cleveland?

A. Yes.

Q. The figures which you have taken here with reference to these two vessels about which you testified specifically are smaller than 65 cents?

A. That 65 cents is what the vessel is paid.

Q. What the vessel is paid?

A. For carrying that ore.

Q. It is paid 65 cents for carrying that ore, and it costs it less than that to carry it?

A. Naturally.

Q. Mr. Livingstone there speaks of a freight rate of 65 cents. That is the rate that is paid to the carrier?

A. To the carrier.

Q. For the service?

A. For the services, yes.

Q. You have some figures which are considerably lower than that. Your figures are the actual cost of service to the carrier?

A. Yes.

Q. And not the charge which is received by the carrier for the service?

A. No.

Q. I just wanted to have the record show that. Where did you get your figures?

A. From Mr. Coulby's testimony.

Q. I assume you have quoted him accurately?

A. Yes.

Q. If you say it is from his testimony?

A. From his testimony.

Re-direct Examination by Mr. Adcock.

Q. Your figures are on the basis of the carrier carrying that amount of freight, that is the cost to the carrier of carrying the same amount of freight, wheat, ore or coal, whatever it may be, in boats with less draft, or less depth of water, the same style of boats as these. That is what your figures are based on, isn't it?

A. Yes.

Q. You didn't calculate any speculative profits, or things like that, in connection with this?

A. No, it is simply the difference due to the difference of draft.

Q. You were connected were you not with the University of Glasgow before you came here?

A. Yes.

Q. And from 1896 to 1900, you were connected with Professor Biles, as consulting engineer?

A. Engineer, yes.

Q. You were in practice with him?

A. Yes.

Mr. Wilkerson: Q. In partnership?

A. No, not actual partnership but I had charge of the designing, in connection with our work there.

Mr. Adcock: Q. That is for that firm?

A. Yes.

Q. Since you have been here, your experience has carried you over a large field of different classes of boats and their design and efficiency, etc.?

A. Yes.

Q. I believe, if I remember correctly you stated that you were the Consulting Naval Architect in connection with the design and building of the steamers Shenango and Cole, being the two large classes of freighters on the Great Lakes?

A. That is not quite correct. I was called in to develop their particular forms, and incidentally, of course, took into account the general structural arrangements and everything else.

Q. But you passed upon the design and form of boat?

A. More particularly the form of the boat.

Q. The form of the boat?

A. Yes.

Q. That is the dimensions, length over-all and beam and depth?

A. And shape.

Q. And shape. Referring to Mr. Coulby's testimony, record page 715, you find the statement that: "The Cole is the largest; she is 605 feet long." Do you not?

A. Yes.

Q. And that is one of the boats that you have just mentioned, whose plans you supervised?

A. Well, my work, as I say, was more in connection with the development of the form of those particular boats.

Q. But that was one of the boats?

A. Yes, that was one of the boats.

Q. And the Shenango, whose experience in carrying freight, etc., on the lakes you have mentioned heretofore in your testimony?

A. Yes.

Q. Now in the investigations which you have made, did you consider the cost of carrying ore in the 440 foot class of boats, as compared with the cost in the two larger classes, the 550 and the 600 foot class? Didn't you find it to be about the same?

A. No.

Q. Referring to the last table there (indicating)?

A. No; it was only on Coulby's figures.
Q. And he only took two boats?
A. Yes, he didn't give any for the smaller ones.
Q. They are building boats now of the different classes, are they not?
A. Yes.
Q. I believe you stated that last year there were 20 new boats of the 440 foot class put in service?
A. Yes.
Q. At the present time isn't it a fact that the boats that are ordinarily carrying ore are out of service and seeking cargoes of different kinds, different from ore?
A. At the present time?
Q. Yes.
A. I understand so.
Mr. Wilkerson: That is they are probably seeking cargoes when business is dull?
Mr. Adcock: They have not got the ore to carry.
The Witness: The ore supply is short just now.
Mr. Wilkerson: Q. The ore supply is short?
A. Yes.
Mr. Austrian: There is just as much ore as there ever was; it is not as profitable.
Mr. Austrian: Q. Professor Sadler, you took into consideration, and only took into consideration in giving the increased cost by diminishing the draft of the vessels the items concerning which you testified on your direct examination?
A. Yes.
Q. You did not endeavor to speculate how that cost might be increased or diminished by things that might happen in the future, did you?
A. No.
Q. If the demand for the raw product, the ore, on Lake Erie and other lakes south of Lake Superior should diminish, naturally the demand for deep draft vessels would probably diminish in the same proportion, would it not?
A. Yes.
Mr. Wilkerson: That is not only for ore, but all other products, you mean?
Mr. Austrian: I will supplement that. Q. The type of vessels concerning which you have testified as the 600 foot and over class are vessels which are known as ore carrying vessels are they not?
A. Ore and coal.

Q. And coal. The coal is carried from the south to the north, and not from the north to the south, isn't it?

A. Yes.

Q. But primarily the vessels are constructed for the purpose of carrying ore from the north to the south on the Great Lakes, the large type of vessels?

A. Yes.

Q. And if the demand for the raw product of ore should be diminished from the ore fields of the north to the smelters of the south on the Great Lakes, in your opinion would that diminish the demand for this large class, the large type of vessels known as ore vessels?

A. Yes, I imagine it would.

Q. If it should appear that the steel industry, located for instance at Gary and at other points on the Great Lakes south of Lake Superior should be moved into Canada, so that the raw product would be diverted from those sections of the Great Lakes at which it is now consumed to Canada, wouldn't that diminish in part the demand for the large type or class of ore vessels of the deep draft concerning which you have testified, in your opinion?

A. Which part of Canada?

Q. Canada to the east of Lake Superior; not south but to the east of Lake Superior above the Soo.

A. Yes, it probably would.

Q. Mr. Wilkerson drew your attention to the fact that a number of vessels are operated after what is known technically as the season of navigation has closed. That fact alone did not create the impression in your mind that there was a shortage of bottomry to carry ore and coal and other kindred products, did it?

A. No, I can't say as it did.

Q. Don't you know as a matter of fact that these large steel industries that cause this ore to be shipped, or who directly ship it, ship only through and by their own vessels, or vessels owned by their constituent companies? Isn't that your understanding of it?

Mr. Wilkerson: Do you know anything about that?

Mr. Austrian: You took him in the line of speculation. I thought I would like to travel in the same field.

Mr. Wilkerson: No, this is hardly speculation.

A. I can't answer that question.

Mr. Austrian: Q. You don't know then?

A. I don't know definitely.

Q. Professor Sadler, do you know of any reason why ore cannot be shipped by vessels or on vessels of the smaller type as well as upon vessels of the larger type, that is the 440 foot type?

A. It can be shipped and is shipped that way.

Q. You know in the Detroit river as well as other points in the Great Lakes, to-wit at Chicago, vessels are operated for the purpose of carrying package freight long after the season of navigation closes, and after insurance is terminated by the various naval insurance companies, isn't that a fact?

A. Yes.

Q. If a vessel is a smaller type of vessel, and it runs north empty, or light as it is called, the cost of operation is less than if it were a larger vessel and went north light. Is that correct? The smaller the vessel if it runs north light, the smaller the cost of operation, isn't it, other things being equal, the same type and same general structure?

A. Yes, a small vessel, yes.

Q. A 400 foot vessel can be taken up north light much cheaper than a 600 foot vessel can be taken up north light, other things being equal?

A. Yes.

Q. Mr. Wilkerson drew your attention to the fact that it was contemplated to increase the depth at the Soo to 24 feet. I believe that was the measurement you used.

Mr. Wilkerson: I think that is the correct figure.

Mr. Austrian: Q. You stated that was your understanding?

A. Yes.

Q. Mr. Wilkerson then went along and said if that was deepened to 24 feet as against 20 feet, 21 feet as it is now, or 19 feet, that would have a tendency to cause vessels to be built to a greater depth and of greater carrying capacity?

A. Yes.

Q. If they should make it 44 feet deep instead of 24 feet deep, that is no reason why you could float the Imperator or the Mauretania through those locks, and do business in carrying freight to the navigable points on the Great Lakes?

A. No.

Q. You would have to adjust all the critical points, the wharfage and bays and means of transportation and handling of these vessels throughout the Great Lakes?

A. Yes.

Q. And widen the channels; and the same holds true, if

we have a deep waterway; the same premises hold true do they not?

A. It would have to be made to suit those vessels.

Q. You would have to readjust the intakes, the bays, the wharfs and everything else to accommodate that draft of boat?

A. Yes.

Q. In other words the mere fact that they should deepen the Soo to 21 feet would not permit you necessarily to increase the draft of vessels, in the same ratio or the same proportion?

A. No.

Q. About the use of these small vessels and the large vessels, it is a fact is it not that since the large vessels came into use freight rates have decreased?

A. Yes.

Q. There isn't any doubt but what the effect of the use of the larger vessels is to result in cheaper transportation and lower freight rates; that is a well recognized principle isn't it?

A. Yes.

Q. Now let me direct your attention to page 9 of this Statistical Report of Lake Commerce passing through the canals at the Soo 1912, the table there at the bottom showing the total freight from the year 1888 to the year 1912?

A. Yes, I have a copy here.

Q. That shows a gradual increase in tonnage right along doesn't it, with the exception of two or three years where business conditions were such that they might be called "off years"?

A. Yes.

Q. The years of the panic 1903 and 1904. I wish you would do a little figuring for me, in view of the questions Mr. Austrian has just put to you.

Suppose during the next 24 years, the business of the lakes should increase the same ratio it has increased during the last 24 years, what would be your capitalized estimate of the damage to navigation 24 years from now, the way you figured it this morning assuming that it increased at the same rate it has the last 24 years. I want you to assume that business on the lakes is going to increase at the same rate during the next 24 years that it has during the past 24 years, and on that basis, with that amount of commerce, I want you to give us

your figures for the damage done by the loss of three inches draft.

A. It would be about $30,000,000.

Re-direct Examination by Mr. Austrian.

Q. Professor Sadler, Mr. Wilkerson has drawn your attention to the fact that the records disclosed that the freight rates have diminished in the last ten years, I think you said?

Mr. Wilkerson: I assumed that to be true.

Mr. Austrian: Q. Since the large boats came in. Does that tend to demonstrate to a certainty in your mind that there is no shortage of bottomry to carry all of the freight necessary to be carried? Under the law of supply and demand, there would be a natural reduction, would there not?

A. That is if there was no shortage.

Q. No shortage? The freight rates have decreased because there has been an enlargement of the carrying capacity. Wouldn't you draw that deduction?

A. Yes.

Q. And so commerce has been accommodated by the amount of carrying capacity that has been put on the fresh water to the extent that there has been no shortage, and therefore a surplus, and therefore the lakes have been diminished or decreased. Isn't that correct in your opinion?

A. That is one of the causes.

Q. One of the causes. Now you have just given a figure of $30,000,000 as a mental calculation of a speculative loss in the next 24 years. That depends on a great many elements doesn't it?

A. Certainly.

Q. For instance, I do not know whether you are acquainted with the ore conditions in the northern part of the lake region; are you acquainted with them?

A. Somewhat.

Q. You know that experts have calculated that the ore fields of the Lake Superior region will be nearly exhausted in from 25 to 40 years; have you ever heard such calculation made; that is at the present rate of consumption of the raw product?

A. I do not recall having seen those actual figures.

Q. If that is a fact, that would be an element to be taken

into consideration in computing this future loss, would it not?

A. Certainly.

Mr. Wilkerson: That is if there was nothing else to take its place.

Mr. Austrian: We will come to that.

Q. Do you know as a matter of fact the timber fields—and lumber is a large item in this freight carryng computation you have referred to—will be inside of the next ten years practically exhausted? If my statement is correct, that will be another element to take into consideration?

A. Yes, certainly.

Q. Of course as the mining of ore and the removal of timber is diminished in the north, the demand for coal to be shipped, for the purpose of mining the ore and moving the timber will likewise be diminished?

A. Yes.

Q. And that will be another element to be taken into consideration. There are a great many elements that are more or less speculative that you would want to take into consideration?

A. Yes.

Q. Before arriving at any figure of $30,000,000 of loss by reason of the lessening of the draft of vessels, 1, 2, 3, 4 or 5 inches in the next 24 years. Isn't that correct?

A. Yes.

Q. You don't want to have it understood that is your computation, that will be the loss by the lessening the draft 1, 2, 3, 4, 5 or 6 inches in the next 24 years?

A. Only if the figure is the same as it has been during the last—

Q. That is the increase in the carrying capacity?

A. Yes.

Q. And the conditions upon which you based your original answer remain the same?

A. Remain the same.

Q. As included in your original answer?

A. Yes.

Q. Another question Professor: Rail shipments are considered much more advantageous than boat shipments, other things being equal, that is cost, cartage being equal, because the transportation is in nine cases out of ten more speedy; the delivery is better and the terminals are better and the terminal facilities are better?

You understand that to be a fact do you not?

A. I don't know; I am not much in the transportation business.

Q. You don't know anything about it, but your general knowledge has taught you hasn't it, that rail transportation is to be preferred to lake transportation or water transportation, other things being equal?

A. Provided the rate is the same.

Q. Other things being equal, cost of cartage and so forth being equal. If within the next 24 years it should become cheaper to ship by rail, or equally cheap to ship by rail as by water these various high priced commodities such as ore, coal and so forth, that would be an element to be taken into consideration in ascertaining these capitalized losses, by the diminishing of 4 or 5 or 6 inches of draft of vessels?

A. Yes.

Adjourned to Thursday, July 17, 1913, the Plaza, New York City, New York.

Thursday, July 24, 1913, 10:00 A. M.

JOSEPH RIPLEY, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name, Mr. Ripley?

A. Joseph Ripley.

Q. Where do you reside?

A. Albany, New York.

Q. What is your business and place of business?

A. Civil engineer, place of business is Albany.

Q. Are you connected now with any public works?

A. Consulting engineer to the State Engineer on the Barge Canal construction.

Q. Did you receive an academic training, a course in any college?

A. Yes, sir.

Q. State where?

A. I took the full civil engineering course University of Michigan, graduated in 1876.

Q. In the engineering department?

A. At that time the engineering department was part of

the literary department. I received the degree of civil engineer at that time.

Q. Are you a member of any society of civil engineers, or societies of civil engineers?

A. Yes, sir, the American Society of Civil Engineers; the Western Society, and several other engineering societies.

Q. Have you been connected with any public work since you received your degree?

A. Yes, sir.

Q. Will you state what boards, or work you have been connected with?

A. In 1877 I was employed on the canal work at Sault Ste. Marie, Michigan, particularly the Weitzel Lock constructed by the Government. Alfred Noble was the civilian engineer in charge.

Q. How long were you connected with that work?

A. I was connected with that work until midsummer of 1906.

Q. Will you state what your duties were, and what particular work you had in charge while you were in the Government service at Sault Ste. Marie?

A. For the first two years I was on the masonry construction of the Weitzel Lock, and then I was on the river work, which included a survey of the St. Mary's river in 1879; and then on dredging and other operations for deepening the channels of that river, and that work extended over a period, while I was there, to 1906. I was in charge of the river work from 1882 on, as assistant engineer, and then in 1897 I became general superintendent.

Q. What was your title Mr. Ripley?

A. At that time?

Q. Yes.

A. In 1898 my title was general superintendent. The general superintendent had charge, local charge of all the river and canal improvements, and the operation and care of the canal.

Q. When you say river and canal improvements, what did that cover geographically?

A. It covered the St. Mary's river from the Iroquois Point, mouth of Lake Superior to Detour, the head of Lake Huron.

Q. Before you became general superintendent, what position did you hold in that service?

A. I was assistant United States engineer.

Q. Now during this period from 1876 to 1906, what par-

ticular river or canal improvements were initiated and completed, with which you were connected and had charge?

A. The masonry work of the Weitzel Lock was started in 1876, and the work of building that lock and completing it was done during that period. The canal was deepened and widened, first, from a depth of 12 feet, a general width of about 100 feet, to a depth of 16 feet and varying widths up to 100 and 200 feet. And then finally to a depth of 25 or 26 feet and widths of 100 to 500 feet.

Q. Was the Poe Lock constructed during that period?

A. Yes, sir.

Q. And put in operation?

A. Yes, sir.

Q. The various channels of the St. Mary's river, the Hay Lake channel, the Neebish channels, Little and West Neebish and the Middle Neebish, were they deepened and widened?

A. Yes, sir, the improvement of St. Mary's river was begun in 1853 by the building of the old State canal at the Soo; and that canal had two tandem locks each 350 feet long, 80 feet wide, with a depth of 12 feet on the sills.

The canal was opened for navigation in July, 1855, and boats drawing 8 feet of water were able to pass through the St. Mary's river. The deepening of the river above the canal and one or two shoals and the dredging and making a new channel in Lake George and the East Neebish, and in the vicinity of the Sailors' Encampment was done in the years 1856 to 1859. During the period from 1859 to 1870, there were some boulders removed from the channel of the river.

With the completion of the Weitzel lock in 1881, the river channels were deepened and widened to correspond to that improvement, and the channel by the way of Lake George was made in general 300 feet wide and 17 feet deep from below the locks to the flats in Lake George.

The channel through Lake George was made 250 feet wide and 17 feet deep and the channel at the East Neebish was made on the American side. The channel which had been used up to 1883 was on the Canadian side of the river at the East Neebish. The channel was 150 feet wide and 17 feet deep on the American side of the East Neebish.

Then the channel was improved through Little Mud Lake and on the limestone rock at Sailors' Encampment. Excavation was made for a channel on the Canadian side of the river 300 feet wide and 17 feet deep.

In 1884 the improvement of the Hay Lake channel by the way

of the Little Rapids and Middle Neebish was started; and that channel was finally completed for a least width of 300 feet, and 20 feet deep with reference to certain grade plane; and opened to navigation in 1894.

The channel through Little Mud Lake was excavated to a depth of 20 feet and a width of 300 feet; widening at the angles, between the years 1892 and 1894. And a new channel on the American side at Sailors' Encampment was made through the Limestone Shoal at that place, for a width of 300 feet and a depth of 21 feet; and opened to navigation in July, 1897.

Under the project known as the 1903 project, the channel through Hay Lake was improved by widening at Little Rapids to 600 feet and deepening to 21 feet, with the grade planes lowered from 4 feet at the locks and 2.7 feet in Mud Lake.

The channel was excavated through the West Neebish Rapids for a width of 300 feet and a depth of 21 feet, deepening to 22 feet in the rock section.

In 1908 to 1912, the middle Neebish route was deepened to 22 feet in the rock sections and 21 feet in the earth sections, with reference to the grade plane described for the West Neebish. Above the locks the channels had been deepened through three principal shoals securing a least width of 1,000 feet, and a depth of 21 feet.

Q. You were engaged in and about this construction work that you have described, the deepening of the channels and the improvement of navigation there?

A. Yes, sir.

Q. You have described the construction work in the St. Mary's river and so forth, under what you call the 1903 project, have you not?

A. Yes.

Q. And that was completed along in 1907, was it not?

A. The West Neebish route was completed in 1907. The deepening of the Middle Neebish was completed in either 1911 or 1912.

Q. You have been engaged in the character of work which you have described there since about 1876, until the present time as I understand it?

A. Yes, sir.

Q. You were familiar with the cost of doing that character of work?

A. Yes, sir.

Q. You are also familiar with the present cost of doing

that character of work, in the construction of channels and so forth, as you have mentioned?

A. I am.

Q. Are you familiar with the various channels and routes of travel for boats on the Great Lakes, and navigation generally?

A. I am.

Q. Will you state what experience you have had in that, and your familiarity with navigation on the Great Lakes?

A. In connection with the improving of the St. Mary's river, I made a careful study of the requirements of the boats for navigating that river, and observed them in running channels and maneuvering in the river under all conditions, and have handled tugs and small steamers and have piloted large steamers through the river and also through Lake Huron.

Q. Are you familiar with the construction work that was done in the St. Clair river, Lake St. Clair, Detroit river and the various harbors of the Great Lakes?

A. The improvement of the Detroit river, I kept posted as to that work while it was in progress, and especially after my assistant, C. Y. Dixon, was assigned to that work, along about 1896, I think it was.

Q. What familiarity have you with the determining of lake levels and the operation of the gages showing the elevation of the lake at various points?

A. Why, I kept posted with reference to lake levels, and especially with reference to Lake Superior and Lake Huron and St. Mary's river, and established of course numerous gages along the river and had observations taken with reference to the fluctuations of the water surface; and then also checked up the bench marks and the zero of the gages at the head and foot of the canal, quite a number—well numerous times.

Q. During these entire 36 years that you have mentioned, since you have been familiar with and actively engaged in work having to do with the navigation of the Great Lakes, have you made a study of the subjects concerning which you have testified, and the lake levels, and the method of determining the stages of the lake by the United States Government?

A. I have given considerable study and consideration to those subjects.

Mr. Austrian: Q. During that course of years?

A. Yes, sir.

Mr. Adcock: Q. In the construction of the Panama Canal, did you have anything to do with that?

A. Yes, sir.

Q. Will you state what positions you have held and what work you have done in connection with that project?

A. I was appointed a member of the Board of Consulting Engineers, in August, 1905; and that board studied and reported as to the type of canal to be built at Panama.

Q. By whom were you appointed?

A. By President Roosevelt.

Q. That was in 1905?

A. Yes, sir. And that board was in session from the 1st of September, 1905, to early in February, 1906.

Q. Who composed the board?

A. General George Davis was chairman; Alfred Noble, William Bartley Parsons, William H. Burr, General Abbott, Frederic P. Stearns, Isham Randolph and myself, were the American members of the board.

There was William Henry Hunter, and Messrs. Geurard, Quellenec, Tincauser and Welcher, representing England, France, Germany and the Netherlands.

Q. How many American members were there?

A. Eight, and five foreign.

Q. What was the purpose of the Board of Consulting Engineers you have described?

A. To recommend the type of canal to be built at Panama.

Q. What recommendations were made?

A. There was a majority and a minority report submitted. The majority report, which was made by the five foreign engineers and three American engineers was in favor of a sea level canal, and the minority report made by five of the American engineers recommended a lock canal with summit level at 85 feet above the ocean.

Q. Were you with the majority or the minority?

A. I was of the minority.

Mr. Wilkerson: Who were the other four?

A. Alfred Noble, Frederic P. Stearns, Isham Randolph and General Abbott.

Mr. Adcock: Q. Is that the type of canal that has been constructed or is being constructed?

A. The type of canal being built is the one recommended by the minority members.

Mr. Wilkerson: Q. That was a majority of the American membership?

A. Yes.

Mr. Adcock: Q. Were you at any time principal assistant engineer in charge of preparation of plans for construction of the locks and regulating works in connection with the Panama Canal?

A. Yes, sir; after Congress approved of the lock type of canal, I was appointed principal assistant engineer, and my duties were the designing and constructing of the locks, dams and regulating works of the Panama Canal.

Q. You had charge of that work, as I understand it?

A. Yes, sir; I assumed the duties of that position on August 1, 1906, and proceeded to organize a force of expert designing engineers and a force of draftsmen to prepare the plans for the locks, dams and regulating works of the Panama Canal; and with that force of about six designing engineers and four draftsmen I had the plans for the locks and dams prepared in less than a year's time.

Q. The plans that you prepared as you have mentioned, are they the plans that have been followed in the construction of the locks, dams and regulating works?

A. So far as the dams and regulating works are concerned, they are practically the same; of course with modification of details in some particulars.

Q. Which arises as the work progresses?

A. But as far as the locks are concerned, we made our studies for locks 100 feet wide and after I had resigned, the change was made to a width of 110 feet. But the general design of the locks and the gates and so on followed what we had prepared, only changed to suit the wider locks.

Mr. Austrian: Q. When did you resign that position?

A. After having served as principal assistant engineer for about six months I was appointed assistant chief engineer, and that became effective I believe the 1st of February, 1907, and I resigned in July, 1907.

Mr. Adcock: Were you connected in any other capacity with the construction of the Panama Canal?

A. Yes, sir; I made a careful study in January, 1907, and April, 1907, of the entire workings of the canal. the construction work and the different departments of organization there relating to commissary, schools, courts, police regulation, but particularly with reference to the construction work along the Culebra divide; the chief engineer, John F. Stevens, having decided to resign; and had notified me that he would recommend me as his successor, which he did when he resigned in April, 1907.

I was also appointed by Mr. Stevens a member of the

Commission of which he was chairman, with the authority to appoint two assistants to represent the Government, and the contractor was to appoint two engineers to represent his side, at the time that the Government was considering the bids received for letting the Panama Canal work by contract. That commission was to determine the cost of the entire work, determine the quantities and fix the unit prices, and the contract was to be awarded at that cost price which we determined upon, plus a commission, a bid commission, a percentage of the total cost.

Mr. Austrian: Q. Plus a bid commission?

A. A bid commission. That is the bid was, as I remember it, about six per cent.

Q. Of the cost?

A. Of the cost.

Mr. Adcock: Q. After 1907, when you resigned as assistant chief engineer of the department of construction and engineering of the Panama Canal, what did you do?

A. I accepted a position of advisory engineer to the state superintendent of Public Works of New York State.

Q. And have you occupied that position since that time?

A. I have occupied that position for about 2½ years. That had to do with the new barge canal construction, the maintenance of the other canals of the state, and new construction in the way of river and harbor improvements, bridges crossing the canals or streams under state control, and building of light houses and so on, of that character.

And then I was appointed a member of the advisory board of consulting engineers, for the state canals, and served in that position about a year and three-quarters when the board was abolished; and then I was appointed consulting engineer to the state engineer for the barge canal construction of New York State.

Q. And that is the position which you now hold?

A. And that is the position which I now hold.

Q. Did you have anything to do with the improvements of the Warrior river, Alabama? If you did, state what connection you had with that improvement, and your duties; the position you held?

A. In August, 1897, I was detailed to make a survey, and plans and estimates for a canal connecting Birmingham, Alabama, with the Black Warrior river.

Q. When you said "detailed," you meant detailed by the United States Government?

A. By the United States Chief of Engineers.

Q. Chief of Engineers, U. S. A.?

A. Yes. I organized a party and made the survey, which covered a distance of 63 miles, and had the plans and estimates prepared, and submitted a report on that project. The work occupied a period of six months. In connection with that work, I had a line of precise levels run connecting Birmingham with the line of precise levels which had been run from Beloxi up to Jackson, Mississippi. The length of that line was something over 200 miles.

Q. Did you lay out the plans for the improvement?

A. Yes, sir.

Q. And had charge of the work?

A. I had charge of all that work.

Q. In connection with the various improvements which you have mentioned in the St. Mary's river and the Panama Canal, have you had anything to do with the determination of the cost of making such improvement, or did you have?

A. Yes, sir; in connection with the river improvement and the canal improvement, where work was to be let by contract I made the estimates of cost.

Q. Mr. Ripley, I understand that you were in the Government service for the year indicated, and that while in the Government service a large part of your time, or some considerable portion of your time, was occupied in making estimates for the United States Government on improvements contemplated, and actually carried out?

A. Yes, sir.

Q. And those estimates that you made followed the usual channels, and were the basis upon which the Government acted in the contemplated improvements?

A. Yes, sir.

Mr. Wilkerson: And I assume are matters of record, aren't they?

Mr. Adcock: Q. And whenever proper they become matters of record?

A. Yes, sir.

Q. Under the usual practices adopted by the Government with reference to estimates. Mr. Ripley, ever since you started in the pursuit of the profession of civil engineering, which I understood you to say was in 1877?

A. 1876.

Q. 1876, what proportion of the entire experience that you have had in that profession has been devoted to the service of the United States Government, just approximately?

A. Why, I was in the service of the United States Government from June, 1877, to July, 1907.

Q. Some 30 or 31 years?

A. Yes, sir.

Q. And since that time, you have been acting in an advisory capacity to the State of New York?

A. The State of New York.

Q. And in that experience that you had, and in the pursuit of the duties concerning which you have testified, a considerable part of that work was done under your direct supervision, and a great portion or some portion of it was by force account instead of contract letting. Is that correct?

A. Yes, sir; and even where the work was by contract, a force account was also kept.

Q. Will you state what you mean by the expression "force account," or what is generally accepted and understood by the expression force account?

A. It is an account kept of the actual force employed and the money spent in wages for employes, and in the purchase of material; and cost of repair work and equipment, so that the entire cost of the work to the Government, or to the contractor, is put down.

Q. And supervised and carefully audited and so forth, and determined?

A. And determined?

Q. Mr. Ripley you stated, at least I so understood you to state, that you devoted a great many years to operations and work in the St. Mary's river, and in and about the locks of the St. Mary's river, is that correct?

A. Yes, sir.

Q. That covered a number of years, did it not?

A. Practically 30 years, with the exception of six months in Alabama and five months on the International Board, and then a year on the Panama Canal work.

Q. The operations which you conducted, and observations which you made and supervisions which you pursued in your work and employment in and about the St. Mary's river brought you in close touch with the conditions existing on the entire basin of the Great Lakes and tributaries, did it not?

A. To a certain extent; yes, sir.

Q. And by reason of that, and by reason of other experiences, you became familiar with the conditions existing in that basin of the Great Lakes?

A. Yes, sir.

Q. Both with reference to navigation, commerce, construction and water conditions I mean?

A. That is it.

Q. And in further connection with your duties in that respect, in and about these various streams, lakes and tributaries, you became familiar with the harbors and canals and basins of the Great Lakes, so far as they were tributary to and immediately adjacent to Canada, did you not?

A. Why, I, of course, was familiar with the entire work on the St. Mary's river, and visited at different times various harbors of the Great Lakes, and the work on the St. Clair river and the Detroit river, and in Lake St. Clair. And in 1903, I made an inspection, personal inspection of the Canadian Canal along the St. Lawrence river, and the Trent Valley Canal, in Canada.

Q. That was in connection with your duties for the United States Government?

A. That inspection trip was simply one that I made on invitation of the Deputy Minister of Marine, Canada.

Q. But your inspection of the work on the Detroit and St. Clair river, that was made at the suggestion of the engineer in charge?

A. No, that was incidental to my work. Whenever I was down at Detroit, I talked over the work with Mr. Dixon, the work that he was doing on that river, and with Mr. Kent, what he was doing on the St. Clair river and Lake St. Clair.

Q. How long were you connected with Mr. Alfred Noble?

A. I was an assistant to Mr. Noble at Sault St. Marie on the canal and river work for six years.

Q. During what period?

A. From June, 1877, to July 1883, I think; 1882 or 1883. And then again was associated with him on the International Board of Consulting Engineers for the Panama Canal.

Q. What was Mr. Noble's position at the Soo?

A. He was general superintendent, in local charge of the canal and river improvements, and the operation of the canal.

Q. That is the Mr. Noble, I believe, that has testified in this case?

A. Yes, sir.

Q. Alfred Noble? Were you connected with Mr. Eben S. Wheeler?

A. Yes, sir.

Q. Who testified for the complainant in this case?

A. He succeeded Mr. Noble as general superintendent at

the Sault Ste. Marie, and filled that position from the time of Mr. Noble's resignation until December, 1897.

Q. When did Mr. Noble resign, about 1883?

A. I think it was in 1882, July, 1882.

Q. And when Mr. Wheeler resigned, you then became general superintendent?

A. I became general superintendent in March, 1898.

Q. And you were assistant superintendent from—

A. I was assistant engineer.

Q. Assistant engineer during the period preceding?

A. During all the time I was there at the Soo, practically.

Q. Who were the engineer officers in charge at Detroit of that district, during that period you have mentioned from 1877 to 1906?

A. General Godfrey Weitzel was the engineer officer in charge of the district, at the time I went to the Soo, which was in 1876, until 1882. He was succeeded by Major F. W. Farquardt, and he was succeeded by General Owen Poe. Major Farquardt was in charge there from 1883 I think to 1885; and then General Poe was in charge from 1885 to the time of his death in 1894, or 1895. And then he was succeeded by Colonel G. J. Lydecker, who had charge until about 1900 or 1901, and he was succeeded by Major W. H. Bixby, present Chief of Engineers, and he was succeeded by Colonel Davis, Colonel Charles E. L. B. Davis.

Q. That was about in 1904, was it?

A. Yes, about 1903; and he was in charge when I resigned in 1906.

Q. Where is the office of the engineer officer, in charge of that district?

A. In Detroit, Michigan.

Q. What does the district cover?

A. The river and harbor improvements, from the mouth of the Detroit river up to Sault Ste. Marie in Michigan, along the Detroit river, Lake St. Clair, St. Clair river and Lake Huron, and possibly the Lake Michigan ports now; and St. Mary's river, up to Lake Superior.

Q. Is that called the Detroit river district?

A. The Detroit district.

Q. While you were engaged at the Soo, what did you have to do with the establishment of gages to determine the elevation of the lakes or lake stages, and the operation of reading and recording the elevation at various times?

A. I checked up the zero of the gage, by running a line of levels from a fixed bench mark at the canal lock.

Q. Where was that gage located, or the gages located that you established?

A. The gage at the head of the canal was located at the outer end of the southwest pier, and the gage below the canal was located near the end of the northeast pier, and the bench mark was on the coping of the old state lock for a while; and then it was transferred to the coping of the Weitzel lock.

We had some bench marks at the movable dam, and then also on the southwest pier.

Q. Did you have to do with any gage located near Lake Huron, to determine the level there at the mouth of the St. Mary's river?

A. There was a gage established at Detour, of a self-recording type, about the year 1904, I think. I am not positive as to the year.

Q. Was there a recording gage established by Mr. Noble in 1877, at the southwest pier, do you remember?

A. There was a gage established by Mr. Noble about the year 1871 at the head of the southwest pier.

Q. What kind of a gage was that?

A. Self-recording gage. But it was of a type that required a great deal of attention, and in the cold winter weather it used to stop running quite frequently. The records of that gage were sent every month to the officer in charge of the district at Detroit, Michigan. That gage was kept in operation until about 1879 or '80.

Q. In connection with your establishment of gages that you have mentioned there, and their operation, did you have any occasion to make a study of the best position to place gages, to determine the elevation of the Great Lakes, or any one of them?

A. The zero of the staff gage at the head of the southwest pier was located in a position that would give the best protection from wave action; but at times, with certain winds, the gage will be exposed to wave action. And the gage located at the head of the northeast pier was on the north side of the pier, and the water was swift and turbulent there, and for a number of years we had the gage in a box, the box open at the bottom, serving as a protection against wave action.

The selection of the best location for the Haskell self-recording gages was given careful consideration. One was established at the head of the southwest pier, and another one on the northeast pier. The floats of those gages are placed in

an iron pipe, the pipe having a small hole near the bottom to allow water to enter, and yet of such a size that the water surface cannot be made turbulent. And then the zero of those gages was checked by staff readings, and of course also by checking up the zero of the gage with reference to a fixed bench mark.

Q. Take for instance a lake like Huron, Michigan, Superior or Erie, I will ask you how many gages you would consider it necessary to place on the lake, and where, not speaking of local conditions, but with reference to the general contour of the lake, to best determine the mean average elevation of the lake?

A. In my judgment, in order to determine the average elevation of the lake, gages should be established near the ends of the central axes. That would require four gages, one at each end of the lake and one at each side opposite the middle of the lake. And I am led to that view, on account of the wind effects and possible tidal action.

At Panama, a line of precise levels was run across the Isthmus connecting gages on the Atlantic side with the gages on the Pacific side of the Isthmus, and recent readings of the water surface on Lake Gatun, between Gatun and Bohio, a distance of 22 miles apart between those gages, with a steady breeze of about 20 miles an hour blowing from Gatun towards Bohio each day, it has been observed that the water surface at Bohio is from 1/10 to 2/10 higher, on account of the wind, and about half that amount lower at Gatun.

Q. You mean 1/10 to 2/10 of a foot?

A. Yes, sir.

Mr. Wilkerson: Are these measurements measurements that you made yourself?

A. No, sir; not on Lake Gatun.

Q. Are they measurements that were made by Government engineers?

A. Yes, sir.

Q. And officially reported?

A. Yes.

Q. Where are the official reports?

A. It is officially reported in the Canal Record, which is a publication made by the Corps of Engineers, in charge of the Panama work.

Q. And for the purpose of your answer, you have taken those reports of the Government engineers, and have given credit to the accuracy of the reports?

A. Yes.

Q. You have assumed that their work has been done accurately?

A. Yes, sir.

Mr. Adcock: Q. Have you reached that conclusion wholly upon the Gatun conditions, or have you taken into consideration your experience in connection with the operation of gages, readings and so forth upon the lakes themselves?

A. I had that opinion long before I saw the reference to the Gatun condition. The results given from the observations there simply confirm my previous opinion.

My opinion has been based upon observations taken along St. Mary's river, and especially on the widened sections that are designated as lakes.

Q. Would the mean elevation derived from the four gages located as you have suggested show a greater or less change of level between its monthly means than would be shown by any one of the gages?

Mr. Wilkerson: I would like to know whether the witness is asked to state a fact which is based upon observations and computations made by himself?

Mr. Adcock: In your opinion, for any lake?

A. In my opinion, the elevation of the lake surface as determined from the mean of the readings of the four gages would be greater or less than the elevation determined from reading the one gage, although at times it would probably be the same.

Q. In other words is it your opinion that the readings of one gage would vary to a certain extent from the true elevation determined by the four gages?

A. I think it would.

Mr. Wilkerson: At the same instant?

Mr. Adcock: At the same period of time for similar conditions?

A. Yes.

Q. At the same period of time. You have stated the location of certain gages at the Soo. Do you know how that location compares with other gages on the Great Lakes, with reference to the ease with which they may be inspected and the observations taken; having in mind the location of the officer, in whose charge they may be?

A. The gages at the Soo have undoubtedly received closer inspection than the gages located elsewhere along the Great Lakes. They may not at the present time be receiving any closer attention than some of our particular gages along the

lakes, but in the past I believe they have received closer attention.

Q. By reason of what fact?

A. By reason of the fact that they were directly looked after by an engineer.

Q. Who was stationed at that point?

A. Who was stationed at the Soo, and had charge of the work there?

Mr. Wilkerson: And from that fact you reach the conclusion that they have been looked after more carefully?

A. Yes, sir.

Q. You are not testifying to any fact based on your own observation?

A. Why, I have had instances related to me by those who claim to know the facts with reference to some of the other gages?

Q. Are you speaking about Lake survey gages?

A. The gages, for instance one at Marquette, in earlier days I have heard—

Q. That is prior to the Lake survey?

A. Yes.

Q. They are all as a matter of fact now under the supervision of the Lake Survey?

A. Yes, I know. Since the Lake Survey has taken care of them, I would not attempt to make any discrimination between the leading gages.

Mr. Adcock: Q. Have you any experience with the inaccuracies of the reading of gages at any point?

A. Yes, sir; at the Soo, the southwest pier is located on a sand foundation, and there is more or less settlement taking place continually, but—

Q. State what the facts were in connection with the piers.

A. The zero of the gage has not always been checked up as frequently as it should have been, and I remember on one occasion that a settlement of about 2/10 of a foot had taken place during the period from a previous checking to the time of that checking of the zero of the gage, by levels.

Q. How long a period?

A. As I remember it, it was a period of nearly two years.

Q. Do you remember the years, Mr. Ripley?

A. I do not, the exact years, but it was around the late eighties or early nineties.

Q. Do you know what kind of gages they had around the lakes, up to say 1903, as to whether they were self-recording?

A. They were mostly what we designate as the staff reading gages.

Q. In other words, a man would have to be there?

A. You have to measure down from the zero of the gage to the water surface, or from the water surface down to the zero of the gage.

Q. Some one would have to be there at a particular time and take the reading?

A. Yes, sir.

Q. And record it?

A. Yes, sir.

Q. Will you state what experience you had in establishing the zero of the recording gage below the locks, and in checking?

A. The staff reading checked from the zero of the gage down to the water surface has not always been made with very great accuracy, with reference to that particular gage. The water is turbulent where the staff reading is taken, and so much so that you cannot tell within possibly three or four inches of where the actual water surface would be, the mean water surface, and a glass tube is used to take the reading; and at the end of that glass tube is a cork, and a hole in that cork and a string passed through the hole, which is knotted on the end, the intention being to pull the knot away from the cork and let the water rise in the tube to what would be the mean height of the water surface outside; but the observer has pulled out the cork and then let the water into the tube, and then pulled the cork up into it, and he might catch it at the high stage or the low stage.

Q. When was this gage established that you have just been describing?

A. In the late nineties.

Q. You have mentioned various improvements in the channels of the St. Mary's river, and the time when the improvements were made. Will you state what the improvements have been in the Detroit river, Lake St. Clair and the St. Clair river, and the depths reached by the particular improvement mentioned, and when the improvement was completed.

Mr. Wilkerson: I do not object to the question, but it occurs to me that with reference to the nature and extent of these improvements, they have all been the subject of such accurate official reports, and the data are so easily obtained, that that is far preferable to the mere recollection of the witness about the facts. I do not undertake to confrol the di-

rect examination of the witness at all, but I suggest that fact; that these reports will all be in this case as a part of the record, before we are through.

Mr. Adcock: That is true, but he has made an examination of those records, and I think we can get it in.

Mr. Wilkerson: Your idea is, is it not, to take the place of the better evidence on the subject, but it is a summary of the evidence which he has borrowed his conclusion from.

Mr. Adcock: And from his own recollection.

A. For the Detroit river, the first improvement was made at the Lime Kiln Crossing, in the seventies. The channel was made 300 feet wide, finished in 1877; widened to 400 feet in 1886 and 440 feet in 1890, and 600 feet in 1892.

Q. What was the depth prior to the time you have described?

A. The depth from 1877 to 1890 was for 20 feet, with the reference to the datum of 578.01, 1903 elevations, Lake Erie. Then Bar Point Shoal was made 800 feet wide in 1892, and the Hackett Range 600 feet wide in 1892, and the Amherstburg Beach 500 feet in 1901, and the Livingstone channel 300 feet in 1902, and widened to 450 feet inside the cofferdam in 1911; and the Ballard's Reef, 600 feet 1893, I think, and the depth of those channels to which they were improved between 1890 and 1900, was 21 feet, reference being to reference plane 572.80; and 1900 to 1902, the depth of 21 feet with reference to plane 571.5; 1904 to 1908, 21 feet with reference to plane 571.0. And 1907 to 1912, 22 feet, and 23 feet inside of the cofferdam of the Livingstone channel and 1909 to 1910 21 feet at the Bar Point Shoal; and then that was deepened later on to 22 feet; and from 1910 to 1913 22 feet for the Ballard's Reef. All those since 1904 was with reference to plane 571.0. Those are the clear depths obtained, but payment has been made—

Q. Will you describe how the improvements have been made in the channels and the actual depths of the excavation or dredging.

A. The clear depths secured were those stated, but payment was made at full rate to 23 feet for the work outside of the cofferdam, and inside the cofferdam the full rate has been paid to 24 feet. But they are not required to clean up between those depths. For this 22 feet depth, they are paid full price of 22 feet, and for what they actually take out between 22 and the lower grade, 23 or 24, they are not paid for at full rate.

Q. Why is that done, Mr. Ripley? State your experience and how that custom arose?

A. That was started on my recommendation altogether. In the latter part of 1879, we employed a dredge with a working hour in the deepening of the shoals in St. Mary's river, and another dredge was employed the following years. And we experimented as to the cost of working over a shoal, when the excavation was made close to the required grade, and then for dredging certain depths below that grade, and we varied those depths from half a foot to upwards of three feet. And we found that in sand and clay shoals, it was possible to go at least a foot and a half and preferably two feet or more below the required grade plane for cheapening the cleaning up process, and for the boulder shoals and for rock work to work at least two feet, and preferably upwards of three feet below the required grade plane.

Now, the contractors on the St. Mary's river, where the work was done by the cubic yard, and payment made for bank measurement above a specified grade plane, objected to being paid simply to the grade plane when they were taking out material below that grade plane, and then having the work re-let for deepening in a short period after they had done the work; and of course the bank measurements would be based then on the conditions existing at the time the new work would be let.

Q. As the actual condition of the bottom?

A. Yes, and they were claiming they were taking out material they were not getting any pay for, and so I recommended that a half rate, half the contract price per hour be allowed them for every yard that they removed for a foot below the required grade in soft digging, and in places in the boulder shoals and rock shoals, half price for two feet below.

On the Detroit river, they extended that system somewhat further and they paid full rate prices for two feet below the required grade.

Q. And upon your recommendation that system was followed?

A. Yes, sir.

Q. In connection with the improvements in the St. Mary's river and also in the Detroit?

A. And St. Clair river.

Q. And St. Clair river?

A. Yes, sir.

Q. Is that true also of the improvements, dredging improvements in the harbors?

A. I can't state positively as to that, but I presume it is.

Q. Now, you stated it was found to be better. Will you state why it was so found, after the experiments you had made?

A. It was cheaper for the contractors to work a certain depth according to the character of the material below the required grade plane, and that was fully demonstrated, on a section that we had on the rock work in the Middle Neebish, where the contractor drilled the holes for blasting just to the grade plane, and after removing the blasted rock with the ordinary dipper,—he had a special dipper made with a flat lip, the dipper being about eight feet wide—and he worked over that section eight times, taking only cuts half the width of the dredge, and then had to do a lot of work with a diver in order to clean up to the required grade, because he didn't have more than half an inch up to 4 or 5 inches of water below the required grade.

Q. Now, you have spoken of grade plane, Mr. Ripley?

A. Yes, sir.

Q. And reference plane?

A. Yes.

Q. Will you explain what you mean by those terms?

A. The grade plane is the required elevation of the bottom of the channel. The water surface grade plane would be the grade plane for that stage of water to which the water was referenced to for the improvement.

Q. Do I understand that there is an elevation plane established for an improvement, like for instance the 1903 project, which will run through the St. Clair, Lake St. Clair and Detroit river?

A. Yes, sir.

Q. And the same would be true with reference to the St. Mary's river?

A. Yes, sir.

Q. The improvements in the channels there. Who established that reference plane, in the Government service?

A. The assistant engineer in local charge of the work generally makes the recommendation and it is passed upon by the engineer officer in charge of the district.

Q. Then the grade plane is a certain number of feet below that reference plane, is that it?

A. Yes, it would be a certain number of feet below the water surface plane.

Q. Or the reference plane?

A. Or the reference plane, yes, sir; or the reference plane might be the grade plane, you know.

Recess to 2 P. M.

After recess, 2 o'clock P. M.

JOSEPH RIPLEY, resumed the stand for further direct examination by Mr. Adcock and testified as follows:

Q. You stated in answer to the last question that the grade plane might be the reference plane. Will you state more specifically the distinction, if there is any distinction, or how they might be treated as meaning the same thing. When I say reference plane, I refer to the reference plane of a particular improvement.

A. Yes, sir. The reference plane for channel improvement may be the same as the grade plane, but usually is not. The reference plane for the improvements of the St. Mary's river, for instance, was selected in 1870 by Mr. Noble, and was taken at an elevation which would be below any of the improvement work. That is below the reference plane for any other improvement work?

A. For any improvement work on the river at the canal.

Q. That is prior to that time?

A. No, following the time he selected. And the improvements were made with reference to that plane, and that plane had a certain relation to the mean stage of water, as determined by the gage records up to that time, at the head and foot of the lock. The channel improvements when referenced to that plane also bear a relation to the mean stage of water. Later on, the elevation of that plane with reference to mean tide at New York was determined, and then the sea level was used as a plane of reference.

Q. In other words, for a particular improvement, or any series of improvements that might be carried on, a reference plane was fixed, which was a certain elevation above sea level?

A. Above sea level, yes.

Q. And the reference plane of the improvement was fixed by the engineer officer at Detroit, upon recommendation of the assistant engineer in charge of the improvement?

A. Yes, sir.

Q. Is it your understanding that the reference plane of the particular improvement becomes a matter of record in the department?

A. It does.

Q. Now, when the reference plane was established for an improvement, was the idea in connection with that improvement to obtain a certain depth below that reference plane, or to fix the bottom of the channel at a certain depth below that?

A. Well, the grade plane, or the plane for the bottom of the channel was fixed with reference to the water surface. Of course the water surface being referenced to the reference plane; and as I have already stated, the improvements at the St. Mary's river were started in 1870 with reference to what was the mean stage of water.

Q. Now, is the reference plane fixed at a certain number of feet above sea level for a particular improvement, or is it determined upon?

A. Yes, sir.

Q. Do you know what the reference plane for the 1903 project which you have mentioned for the St. Mary's river improvement was?

A. Prior to 1903, the improvements were referenced to a water surface which was 584.37 above sea level at the foot of the locks, and 581.47 at Mud Lake. The 1903 project, the improvements was referenced to a water surface of 580.37 below the locks and 578.77 in Mud Lake; the variation between those points corresponding to the slope in the river.

Q. That is a supposed water surface?

A. Yes.

Q. Or an actual mean elevation or low water stage?

A. Why, the water stage might get down to that and might not.

Q. But it was an arbitrary plane?

A. Yes.

Q. Fixed at 580.37 above sea level?

A. Yes, for the improvement starting at the foot of the lock.

Q. When you say referenced to water surface, that is a supposed water surface; it is not an actual surface of the water?

A. It is when the water surface is above elevation.

Q. It is merely an elevation arbitrarily fixed?

A. Yes, sir.

Q. Above sea level?

A. Yes, sir.

Q. In making the channel improvements, do they provide

for a certain depth of a certain number of feet below that elevation which you have spoken of?

A. They do.

Q. Is the work done, or was the work done in connection with the improvements, the excavation, the dredging by contract?

A. The work was done by contract.

Q. Under the terms of the contract, may the contractor if he so elects clean up to the depth below, or the number of feet below the reference plane which you have spoken of, or go a certain number of feet below that point as he chooses?

Mr. Wilkerson: I am not going unnecessarily to obstruct the taking of this testimony, but I cannot permit his statement of a conclusion to go in, unless you give the reference in the record to the documents and reports from which these facts may be verified.

Mr. Adcock: We will do that.

Q. What is the custom in that regard?

Mr. Wilkerson: I object to the custom.

Mr. Adcock: Q. Is there a custom?

A. Yes, sir.

Mr. Wilkerson: I object to that.

Mr. Adcock: Q. How long has that custom been in vogue if you know? How long has that practice or custom been in vogue?

A. Ever since I first went on the work.

Q. How years ago?

A. That would be over 36 years ago.

Q. And is it a well recognized and well understood custom?

A. Yes, sir.

Q. With reference to the handling of those improvements?

A. It is.

Mr. Wilkerson: I reserve the right to strike that out on the ground there is no custom established, and on the ground it is a matter that cannot be established by custom. No custom can possibly control in a case of that kind.

Mr. Adcock: Q. Do you know how the reference plane of the 1903 project was fixed with reference to the improvement in the channel of the St. Mary's river?

A. Yes, sir.

Q. Will you state the manner in which that was done?

A. When the project was prepared, the depth of the im-

provement of course had to be stated so it would be incorporated in the Act of Congress authorizing the improvement, and as the prior improvements had been referenced to the mean stage, of water as determined in 1870, and the water at times was below that mean stage, it would not provide navigation for the implied depth of the improvement, and as the department had ruled that for appropriations made along the sea coast the depth should be referenced to low tide, I urged Major Bixby to reference the improvements in St. Mary's river to the lowest stage of water we had, or the probable lowest stage that we would have, and with his approval I prepared the grade plane as stated.

Q. Do you know when you made the recommendations to the engineer officer in charge, Major Bixby, with reference to the fixing of the reference plane of the 1903 project?

A. It was some time during 1902.

Q. Who was Major Bixby at that time?

A. He was the engineer officer, in charge of the Detroit office.

Q. In making the recommendations which you have stated with reference to the fixing of the reference plane of the 1903 project, as stated, did you take into consideration the report of the gagings of the St. Clair river, with reference to the possible lowering of the lake levels by the diversion at Chicago?

Mr. Wilkerson: I object to that as absolutely incompetent in this case for any purpose.

There is the further objection, whether that was taken into consideration or not, if it is competent, is a matter which can be shown only by official records, and not by the frame of mind of the individual. If there are any official records on the subject they should be introduced. If there are no official records, it is absolutely improper for an engineer to say what he had in mind when he did a thing.

A. I gave consideration to the probable lowering of the Lake Huron surface in fixing these grade planes.

Mr. Adcock: Q. As indicated by the reports with reference to the gagings of the St. Clair river made by Mr. Sabin?

A. Yes.

Mr. Wilkerson: I move to strike out of that answer the words "I gave consideration." I submit the witness should tell precisely what he did consider and to what extent he considered it.

Mr. Adcock: I will ask a question incorporating that suggestion of Mr. Wilkerson; that the witness state what he

did particularly consider in connection with fixing the reference plane mentioned.

A. The Chicago canal had been opened at that time, and gagings of the St. Clair river had been made, and some discussion had been had with reference to the amount of the lowering which would be caused by the diversion at the Chicago Drainage Canal.

Mr. Wilkerson: I move to strike out the words "some discussions." I think the witness should state what discussion there was.

The Witness: At that time it was considered that the lowering might amount to as much as eight inches.

Mr. Wilkerson: I submit the words "It was considered" are improper; that he should state by whom, whether by the witness or somebody else.

Mr. Adcock: Q. Mr. Ripley, these considerations which you say prompted you, or which you took into consideration in fixing this reference plane, were those the subject of discussion in the department?

A. I had discussed the matter with Mr. Wheeler at different times.

Q. Who is Mr. Wheeler?

A. E. S. Wheeler, who was formerly general superintendent at the Soo; and also discussed it with my first assistant, who was in charge of the river work at that time, Mr. Benno Rohnert.

Q. Were they recommendations or considerations that were reduced to writing, embodied in a report, either by yourself or your assistants or associates?

A. I discussed the question orally with Major Bixby, and I am under the impression that it was a matter of correspondence as far as a statement in a report to him was made.

Q. At or about that time?

A. At or about that time.

Q. Those discussions, and the fixing of this plane, they were in the course of your official duties at that time?

A. Yes, sir.

Q. And it was work assigned to you, or that came within your jurisdiction?

A. It was work of which I had charge.

Q. And in fixing the plane as indicated by you, you took into consideration all the elements which as an engineer you concluded it was your duty to consider?

A. Yes, sir; I intended that if we had an improvement

for 21 feet that that 21 feet should be available for navigation on all occasions during the navigation season.

Mr. Wilkerson: I submit in this connection—of course this is a subject concerning which the facts have not been called for thus far as I remember—that if this particular matter was the subject of official correspondence, obviously the correspondence is the best evidence; and the testimony of the witness as to what was considered and what was done is improper, and I must therefore reserve the right to strike out the statement of the conclusion of the witness, if it should be found that the matter which he has undertaken to cover is covered by official correspondence.

Mr. Adcock: Q. Mr. Ripley, the grade plane established by you in the manner in which you have just testified was the grade plane adopted in the specifications used in letting the contracts for the various improvements and projects?

Mr. Wilkerson: When you say, in the manner in which he has testified, do you mean taking into consideration the diversion of the water at Chicago, or do you mean simply the figures?

Mr. Adcock: I am just trying to identify the plans.

Q. That is the reference plane adopted in feet?

A. That grade plane was adopted for the improvements between the foot of the lock and the mouth of the river at Detour.

Q. And the specifications for the various improvements on the Hay Lake and Neebish Channel and St. Mary's river—

A. What is known as the Middle Neebish, part of it, those are the specifications.

Q. Issued by the department?

A. Yes, sir.

Q. From the United States Engineer's office in Detroit and based on the grade plane thus established?

A. Yes, sir.

Q. And those specifications of course are official documents?

A. That is an official document.

Q. You say your recommendations to the Engineer officer in charge of the Detroit office were made some time in the year 1902?

A. As I remember it.

Mr. Wilkerson: Q. If I understand it, you recommended a different grade plane from what you would have recom-

mended if there had been no diversion of the water at Chicago?

A. I believe so. I wanted to make sure of having the depth specified in the act available for the shipping interests at all times during the season of navigation.

Q. You thought the diversion of the water at Chicago made it necessary to adopt a different reference plane from what you could have used if there had been no diversion?

A. Yes, sir.

Mr. Adcock: Q. I refer you to plate 18, appearing in Appendix III of the Report of the Chief of Engineers for the year 1900, following page 5400 of that report; the plate being entitled, "Water level of Lake Huron from 1894 to 1900 illustrating effect of withdrawing 10,000 cubic feet per second from Lakes Michigan and Huron," and I will ask you if that is part of the discussion to which you have referred as having taken place with reference to the possible effect of the diversion at Chicago?

A. I don't remember that any reference was made to that plate at that time. There might have been but I don't recall it.

Q. That report was published at the time that you made the recommendations which you speak of?

A. Yes, sir.

Mr. Adcock: It is understood that either side may substitute a copy of the plate 18 referred to, in the record.

Mr. Wilkerson: It is found in the report of the Chief of Engineers for the year 1900.

Mr. Adcock: Q. Under the 1903 project which you have spoken of, were there excavations or dredgings made in the channels of the St. Clair river and Detroit river, at different points?

A. Yes, sir.

Q. Was Lake St. Clair improved at the same time under that project, with reference to navigation?

A. It must have been.

Q. Is that your best recollection?

Mr. Wilkerson: Is this something that he had to do with; did he have to do with the imrpovements in the St. Clair?

The Witness: I had no charge of that work at all, but simply discussed the improvements with the engineers who did have charge of it from time to time, as I happened to meet them.

Mr. Adcock: Q. And you were in that locality every year were you not?

A. Yes, sir.

Q. And saw the improvements as they were going on?

A. I did not pass through Lake St. Clair every year. I was down to Detroit every year, and some years I went down by boat or returned by boat, but not always.

Q. Have you a reference to an improvement made in the Detroit river in 1901, and can you state what the reference plane of that improvement was? When I say Detroit river, I mean the lower Detroit river.

A. The improvement in 1901 was referenced to a datum of 571.5 above sea level, and that improvement was for 21 feet depth.

Q. Now was there an improvement made in the Detroit river in 1904, that is the next improvement?

A. There was an improvement made in 1904 and the depth was for 21 feet. The datum plane was 571.0.

Q. That was the reference plane of that improvement?

A. Yes, sir.

Mr. Wilkerson: Q. Do you recall where the reference is in the report of the Chief of Engineers, so that we can get the full details about that?

A. I made an investigation through the reports of the Chief of Engineers, and have a tabulation of the various improvements there in the Detroit river.

Mr. Wilkerson: Of course as to the work done under the personal direction of the witness, where he knows the thing of his own knowledge, we are entitled to the source of the information and the reference to the official report in which it is found.

Mr. Adcock: Q. There has been considerable said about the mitre sill of the Poe lock at the Soo. Will you state how that is constructed, and when that became the critical point in the navigation of the St. Mary's river?

A. The elevation of the floor of the Poe Lock is 562.37. The mitre sill, the lower mitre sill is located opposite the gate recesses of the lower gate and the intermediate gates. The floor of those recesses is a foot and a half lower than the general floor of the lock. The mitre sill is either 14 or 16 inches in height. Below the mitre sills for the intermediate gates and also for the lower lock gates, are platforms built of 12 by 12 timbers; the platforms being, as I remember it, some 30 feet along the axis of the lock.

Below the lower guard gates, a platform was built which is .33 of a foot, or about 4 inches higher than the floor of the lock. The Poe Lock was opened for navigation in August, 1896, but the depth over the mitre sills was not available to navigation purposes until the spring of 1898 as the sill and platform for the movable dam located across the canal about 3,000 west of the Poe Lock was left in place until that time, and on that guard gate sill, the depth was only 17 feet.

The opening of the West Neebish Channel in 1907 made the Poe Lock the critical place as to the depth of water for navigation purposes in the St. Mary's river.

Q. And that has remained so to the present time?

A. And that has been the case since that time.

Q. Now is it the mitre sill of the Poe Lock, or this platform that you speak of which is 4 inches above?

A. The platform is the critical place, the platform below the guard gates.

Q. Does the platform below the guard gates that you have mentioned serve any purpose in connection with the operation of the lock, or the passage of boats through there?

A. It was put in for the purpose of protecting the lower mitre sill of the lock.

Q. In your opinion, is it necessary for that purpose?

A. It is not, because the platform directly below the sill could be utilized for that purpose, and that would not necessarily be any higher than the general floor of the lock.

Q. And the mitre sill would be protected for all purposes by that?

A. Would be below that.

Q. Have you made any estimate of the cost of removal of that platform below the guard gate that you have mentioned?

A. I have.

Q. Which is four inches above the floor of the lock?

A. I believe that a cofferdam can be built and the platform removed to correspond with the elevation of the floor of the lock for a cost of about $6,000, and certainly for a cost not exceeding $10,000.

Q. And that could be removed in the winter time without any interference with navigation?

A. During the winter season, without interfering with navigation.

Q. Do you know what the depth provided for in the lock that is being constructed there now is?

A. For about 24½ feet with reference to the grade planes established for the 1903 project.

Q. What is that lock called or what is it to be called?

A. The first one I believe is to be called the Davis Lock.

Q. Is there a second lock?

A. There is another one that has been authorized, and that will probably be called the Townsend Lock.

Q. What is the depth for that lock?

A. At the present time there has been no change in the plans for increasing the depth of the Townsend Lock over that of the Davis Lock, although the General Superintendent has given consideration to that and may possibly recommend an increase of a foot or so.

Q. Have you made any estimate of the cost of increasing the depth of water, the available depth of the channels of the St. Mary's river, St. Clair river, the channel in Lake St. Clair and those of the Detroit river to 4 inches or 8 inches, or intermediate inches between those?

A. I have.

Q. State what estimates you have made and your conclusions.

A. I have prepared estimates for increasing the clear depth an additional 4 inches, and also an estimate for increasing the clear depth an additional 8 inches through the channels mentioned, and through the shoal at the foot of Lake Huron.

Q. State what the costs are.

A. The cost for deepening an additional 4 inches through those channels totals $159,538. And for maintenance on account of deepening the channel, which will disturb the streams entering into the rivers and require an annual maintenance for a while brings the total up to $163,990. And the estimate for 8 inches is $403,854.

Q. Would the cost for 5 inches or 6 inches be proportional, practically?

A. Practically so.

Q. And for 3 inches or 2 inches?

A. It would be less than for the proportional amount of either the 4 or the 8.

Q. Have you given consideration to the cost of the improving of the harbors on the Great Lakes?

A. Yes, sir.

Q. Will you give your estimates of the cost for 4 inches and 8 inches?

A. Yes, sir. For 40 harbors on Lake Michigan, 5 on Lake Huron, for the docks along the St. Clair river and along the shores of Lake St. Clair, Detroit river; for 13 harbors on Lake Erie, and for the Niagara river and 7 harbors on Lake Ontario, the estimate for four inches additional deepening is $1,373,207; and the maintenance on account of stream adjustment amounts to $661,626. For the same harbors and docks, the estimate for 8 inches would be, for deepening, $2,746,414, and for maintenance $992,440. And for the harbors in Canadian waters 34 in Lake Huron, the docks along the St. Clair river and Lake St. Clair and Detroit river; the 12 harbors in Lake Erie and 23 in Lake Ontario, the estimate for 4 inches of deepening is $630,709, and for maintenance $62,432. And for the 8 inches deepening, the estimate is $1,261,418 and for maintenance $93,648. Or a total for the channels, United States harbors and Canadian harbors for 4 inches deepening is $2,163,454; maintenance $728,510; and for the 8 inches deepening is $4,405,008; maintenance $1,092,766.

Q. And the cost of the deepening of 4 inches or 5 inches or any intermediate figure between 4 and 8 would be proportional with reference to the harbors, would it?

A. Practically so, yes, sir.

Mr. Wilkerson: Q. By practically you mean it increases some as you get deeper?

A. No, for the harbors, it would be directly proportional; for the channels it would not be exactly proportional.

Mr. Adcock: Q. And as to any lesser depth than 4 inches, would it be proportional?

A. Yes, sir.

Q. Have you given any consideration to the cost in connection with the canals; that is to provide for 4 inches, 6 inches greater depth?

A. For canals?

Q. Yes, for the canals that are in existence?

A. Yes, sir, for the canals which would be affected by a lowering of the surface of the lakes, on account of the diversion at Chicago?

Q. Well, on account of any lowering of the lakes, without reference to any diversion?

A. For a lowering of 4 inches and 8 inches?

Q. Yes, what is the cost?

A. It would be about one and a half million dollars.

Q. For 4 inches or 8 inches?

A. It would not make much difference, and I did not try to make a distinction between the two.

Q. Why wouldn't it make much difference?

A. Yes, I did too; I did make a difference. There would be some difference on the excavation for the lock, at the approaches to the locks, but the actual changes at the locks, there would not be a great deal of difference.

Q. That is, for practical purposes it would be about the same?

A. Yes.

Q. Will you state why, more particularly?

A. The changes which would have to be made at the locks would be the lowering of the mitre walls, mitre sills; the deepening for the greater height of the gates.

Q. You would have to change the gates anyway?

A. Would have to put the bottom of the gate lower by the amount that you were deepening. For that purpose, you would have to excavate across the site of the gate between the gate recesses.

Q. Have you examined the work of the International Waterways Commission with reference to the regulation of Lake Erie, and the discussion of the effect of the diversion at Chicago, in the 1912 progress report?

A. I have.

Q. Have you considered the estimates made there with reference to cost?

A. I have read the statements made with reference to the estimates of cost.

Q. Have you any opinion as to the correctness of the estimates made?

A. I don't think the estimates are correct, based on the method which they used. For instance they state that about $20,000,000—

Mr. Wilkerson: Q Referring now to what page of the report?

A. Page 72 of the 1912 Progress Report.

Q. By whom is the report signed?

A. Signed by the Commission.

Q. The entire Commission?

A. Yes, sir.

Q. Signed by both the Canadian and American members?

A. Yes, sir. (Last answer read as follows: "I do not think the estimates are correct based on the method they used. For instance, they state that about $20,000,000)—of

which ¼ was for maintenance has been expended on 35 harbors on Lakes Michigan, Huron and Erie. The average increase of depth is 10 feet, and the cost per foot of increase was therefore about one and a half million dollars; but as the cost of a small increase would be much greater per foot than an increase of 10 feet, and as several harbors on Lake Ontario are to be added, the cost per foot in this case would probably be not less than $2,000,000 for harbors in the United States.

The expenditure of $15,000,000 on those harbors included piers, break water construction, and for a deepening of 4 or 8 inches, the piers nor the break waters would have to be added to.

The cost also included the high prices paid in earlier days for excavation. For instance, on the Detroit river, as high at $7.50 a yard for rock excavation was paid, whereas the same class of work is being done in the Detroit river at the present time, or has been in the past 2 or 3 years, at a cost of less than $2 a yard for rock excavation. In the same way, the price for earth excavation was much higher at times for that earlier work than the prices now paid for similar excavation.

The estimate also includes an amount of $4,115,430 for deepening the Detroit river 1 foot; and an amount of $1,080,720 for deepening the channel in the St. Clair river, and at the foot of Lake Huron. The estimate also includes three million dollars for the deepening of the Canadian harbors and two and a half million dollars for deepening the approaches, and making the changes in the end locks of the Canadian canals.

Mr. Adcock: Q. There is an estimate there, or some statement, with reference to the depth in Lake St. Clair. What have you to say concerning that statement?

A. Quoting from the report, page 72:

"In Lake St. Clair, the full depth of the lake is now utilized, and any lowering of its surface involves the excavation of an artificial chanel entirely across the lake, a distance of 18 miles, of which it has been necessary heretofore to artificially deepen only one third. To deepen the channel here, and at certain shoal places in the St. Clair river and at the foot of Lake Huron is estimated to cost $1,080,720. It results in replacing open lake navigation by canal navigation for a distance of 12 miles in Lake St. Clair, a decided disadvantage."

Q. What are the facts concerning that?

A. The facts of the case with reference to Lake St. Clair are that under the 20-21 foot ship channel project of 1892 or 1893, the channel across Lake St. Clair was dredged for a width of 800 feet for the entire distance from the foot of the St. Clair Flats Canal to Grosse Point, with the exception of a distance of about 1⅛ miles and that at the present time, on account of the movement of the material from the bed of the lake along the line of the channel, over 2,000,000 yards which have been stirred up by passing boats has been carried off to one side of the channel; and at the present time the channel across Lake St. Clair, with the exception of a short distance below the St. Clair Flats Canal, and for a distance of about 1⅛ miles on the Grosse Point Shore, is from 16 to 1800 feet wide, and from 24 to 25 feet deep.

Q. How has that effect which you mention been accomplished?

A. By the passing boats and the action of the wind and current on the waters of the lake.

Q. In connection with the making of your estimates on cost of the deepening which you mentioned, did you obtain the soundings made by the Government with reference to the depth in the channels which you have mentioned, and also in the harbors, and used those as a basis for making such estimates?

A. The final estimate soundings for the improvements in St. Mary's river below the locks, St. Clair Flats Canal, Lake St. Clair and Detroit river, have been furnished me through Professor Williams; those soundings being the soundings taken by the Government Engineers.

Q. Have you given any consideration to the cost of the construction of compensation and regulating works to raise the levels of the various lakes mentioned?

A. Yes, sir.

Q. That is Huron-Michigan, and Erie and Ontario and St. Clair, and the tributaries or connecting waters?

A. Yes, sir I have.

Q. Will you state where you would place such compensation and regulating works and the cost; and the effect with reference to the raising of the levels of the lakes?

A. The site for which I estimated for the location of a dam on the St. Clair river is situated about 1300 feet upstream on Bunce creek, which is a short ways above Stag Island.

Q. Is that what is called a regulating work? Just state the distinction between compensation works and regulating works.

A. The distinction as made by the International Waterways Commission is that the compensating works are fixed weirs, and the regulating works are a combination of fixed weirs and movable dams.

Q. Is that for the purpose of keeping the levels at a certain range?

A. Keep them within a certain range of fluctuation.

Q. Of what advantage are the regulating works to navigation generally?

A. If the lakes and connecting rivers were regulated within the possible limits of fluctuation, the navigation would be greatly improved.

Q. Would that be in addition to the additional depth of water that they might obtain?

A. Well, it would be additional depth, and the surety of always having that depth.

Q. That is the vessels could load to a certain depth?

A. And navigate different lakes.

Q. And be sure of obtaining that depth?

A. Yes, sir, under the present conditions.

Q. In other words it would be an aid, a convenience to navigation?

A. Yes, sir.

Q. And helpful in the design of vessels too?

A. Yes.

Q. Will you describe the regulating works that you mentioned?

A. A dam could be built at the location I mentioned in the St. Clair river for regulating the levels of Lake Huron and Lake Michigan, and that part of the St. Clair river up-stream of the dam. Another dam located in the Detroit river on the Stony Island Section, and closing the gap between the stone now piled in the river along side the Livingstone Channel to Bois Blanc Island would provide the regulation for the upper Detroit river, and Lake St. Clair and also St. Clair river.

A dam placed in the Niagara river, either near the upper end of the river or down below Tonawanda would provide for the regulation of Lake Erie. But if the dam was located below Tonawanda, it would probably be simply a compensating dam, and not a dam for regulation.

Q. Now those regulating and compensatory works you

have spoken of would not interfere, in your opinion, with navigation, would they?

A. They would be a benefit to navigation. If you put in compensating works, for instance, at the lower part of the Niagara river below Tonawanda, you would raise the mean stage of Lake Erie by the amount you desired within small limits that is within the limits of the lowering which would be caused by the diversion at Chicago.

Q. Have you figured out the cost of those works?

A. I made an estimate of cost.

Q. Will you give them, in the order in which you mentioned them?

A. For the St. Clair river, the estimate, depending on the type of dam to be built, would range from $500,000 to $1,300,000; for the Detroit river, between $40,000 and $150,000; the Niagara river $850,000 to $2,500,000.

Q. From one to the other?

A. Yes, $850,000 the lowest and $2,500,000 the highest.

Q. Depending upon what?

A. Depending upon the type of dam and the extent of the regulating feature. And the St. Lawrence river, from $200,000 to $1,000,000.

Q. Dependent upon the same thing?

A. Yes, sir.

Q. What increase of levels did you contemplate in the estimate?

A. Why by those dams you could provide an increase anywhere from 4 inches to a foot; possibly more than that if it was desirable.

Q. In your opinion as an expert, and based upon your experience, you haven't any doubt that such increase of levels could be made by the compensatory and regulatory works that you have mentioned?

A. I have no doubt as to securing that object.

Q. And if you desired to increase the height of lake levels above the figure that you have mentioned, 4 inches to a foot, would such increase multiply the cost in the same ratio?

A. No, sir, it would add a very small amount to that cost.

Q. How would the regulating works affect the currents in the St. Clair river?

A. With the dam located at the site I have mentioned, the current at Fort Gratiot should be lessened, and that is the place of the swiftest current in the St. Clair river.

Q. And the lessening of that current would improve navigation?

A. Would be a benefit to navigation.

Q. Have you considered the sailing courses of vessels in the freight carrying trade upon the Great Lakes?

A. I have, as chartered on the Lake Survey charts.

Q. There has been some mention of critical areas opposite or off Thunder Bay Island, Sleeping Bear Point, and Poe Reef. What are the conditions of navigation there at the present time?

A. On the course laid out from Pointe Aux Barques, up past Thunder Bay and Thunder Bay Point, there is a shoal in which the depth is about 25 or 26 feet; and of course that would be dangerous to navigate in a heavy storm, but by changing the course so as to clear the point by about 10 miles, a depth of at least 14 fathoms would be secured, and the distance from Pointe Aux Barques to Detour would be increased by about a mile. It would only be necessary to navigate on that course during stormy weather. The inside course could be used in ordinary weather.

Q. And lowering the levels full 5 or 6 inches would not affect the navigation there in calm weather?

A. No.

Q. What has been the custom with reference to following the inner course that you have mentioned, or the shorter course, in stormy weather, prior to 1900?

A. Without the storm comes up when they are sailing along that course in that vicinity, the boats would keep on the outside course. At Poe Reef, the water is only about 4 fathoms deep on the sailing course that is laid down on the charts, but by going to the northward and lengthening the course there about a quarter of a mile, you can get better water, safe navigation.

Q. To what depth?

A. Well, about 6 fathoms.

Q. That is about 36 feet?

A. Yes, sir; and on Sleeping Bear Point, the course passes over a shoal on which there is about 4 fathoms, but by keeping out further and lengthening the sailing distance about 1¼ miles, upwards of 6 fathoms of water can be obtained. At the foot of Lake Huron, the shoal there extends out 5 or 6 miles, but under present conditions it is necessary to deepen that shoal anyway.

Q. I understand you have been familiar right along every

year with the amount of freight carried and the bottoms necessary to carry freight and so forth. Do you know whether in the wheat, coal and ore carrying trades there have been vessels idle each year, or not?

A. While I was at the Soo, I gave particular attention to the navigation part, lake carrying traffic, and without exception every year that I was there, there were some boats idle during part of the year; boats which were classified as freight boats.

Q. It was part of your duties, or in the course of the conduct of your duties and affairs up there, to observe the conditions of freight traffic and the handling of freight through the Soo?

A. Yes, sir.

Q. And did you observe that the carrying capacity was sufficient to meet the requirements of the business?

Mr. Wilkerson: What business?

Mr. Adcock: The freight business.

Mr. Wilkerson: Business to and from the Soo?

Mr. Adcock: The lake traffic.

Mr. Wilkerson: It requires a pretty comprehensive knowledge on the part of a man to know about the ore mines and the wheat fields.

Mr. Adcock: Go ahead.

A. The amount of freight to and from Lake Superior by boat was taken care of each year by the boats. Of course there were some cargoes of grain possibly, or iron ore downbound, and some cargoes of coal upbound, which might have been carried if the navigation season had been a little longer. But under the conditions that prevailed, all the freight that had to be moved, or was desired to be moved could have been moved during each season of navigation, if all the boats had been utilized all the season.

Q. And some seasons would not require the use of all the boats?

A. Possibly not.

Q. Mr. Ripley, I show you a pamphlet purporting upon its face to be a special report of lake commerce passing through the canals at Sault St. Marie, Michigan and Ontario, during the season of 1912?

A. Yes.

Q. Will you just state what that is (handing same to witness).

A. That is a statement of the traffic passing through the Soo canal, the American and the Canadian canals.

Q. For how many years has such a publication been issued?

A. When I was appointed general superintendent there in the spring of 1898, and for two or three years after that, the record of the freight passing through the canal was kept in certain record books, and the publication of the traffic was made by some of the local papers for certain particulars of the traffic. I had the record books changed and some new ones added whereby the records were kept up to date, and then I had the data published in this form, working out the headings for the different tables, and deciding on what tables to insert.

Q. That appears to be issued and prepared under the direction of Lieutenant Colonel Mason M. Patrick, Corps of Engineers United States Army. The ones that were issued during your incumbency up there covered what years?

A. Well, for a year or two after I was there the data was published in newspaper form.

Q. After you started the compilation?

A. No, just in the local papers there. I think this form was gotten up about 1900.

Q. They were published annually in the years indicated by you, under your supervision and direction?

A. The statement is the same as it is here, only giving the name of the engineer officer in charge, and then in the text the statement was made the same as it is here with reference to the general superintendent.

Q. And you were the general superintendent?

A. Yes, sir.

Q. Whose name was mentioned?

A. Yes, sir.

Q. Included in this pamphlet which appears to be issued under the personal supervision and direction of Lieutenant Colonel Mason M. Patrick, impressario, it shows the steamers, the freight, total freight as to valuation, freight charges, average hauling distance freight was carried, freight per ton per mile; shows the carrying capacity of steamers, the largest single cargo, greatest number of mile tons, and everything or practically everything pertaining to the freight carrying business for the year in question, 1912?

A. Yes, sir.

Q. Likewise the character of the freight hauled, coal, lumber and building materials and so forth?

A. Yes.

Q. And it is the most comprehensive document that you know of covering that subject is it not?

A. Yes, sir.

Q. And you inaugurated the style of the pamphlet, and was the first one to collect the data upon which the pamphlet was subsequently published?

A. I originated the form of the pamphlet, but the collection of the data was made from 1881.

Q. After you took charge you revised the method?

A. Yes, sir.

Q. It is by reason of that fact, among other facts concerning which you have testified, that you claim to have familiarity with the freight carrying capacity and so forth as incorporated in the question put to you a few moments ago?

A. Yes, sir.

Q. What percentage of the freight carrying capacity on the Great Lakes passes through the Soo?

A. About 80 per cent.

Q. In your estimates for the cost of deepening the harbors that you have mentioned, did you take into consideration more or less harbors than are mentioned in the report of the International Waterways Commission referred to?

A. More harbors, both United States harbors and Canadian harbors.

Q. They took in something like 35 and you took in 60?

A. I gave the numbers in my answer, and the numbers are stated here in this report as to what the Commission used.

Mr. Adcock: That closes our direct examination, unless we think of some question we have omitted.

Cross-Examination by Mr. Wilkerson.

Q. How long did you say you were engaged in work in connection with the Panama Canal?

A. The work of the International Board of Consulting Engineers extended over a period of a little over five months and then I was employed on the work as principal assistant engineer, or assistant chief engineer for a period of practically one year.

Q. You testified as to the making of certain plans, some

of which I think you said were utilized, and some of which were superseded by other plans. Just which ones of your plans were used and which were not used?

A. The plans for the locks had to be changed on account of widening the locks from 100 feet to 110 feet. That included the lock walls, the culvert construction layout, the gates, and such particulars as those along that line.

Q. Who was in charge of the work on the Panama Canal, while you were there?

A. John F. Stevens, was the chief engineer until April 1, 1907, and on that date Col. George W. Goethals, lieutenant colonel of engineers at that time assumed that position.

Q. Your connection with the work terminated in July?

A. In July.

Q. In the July after the appointment of Colonel Goethals?

A. Yes, sir.

Q. Why were the locks widened there?

A. The officials in the Naval Department were insistent that the locks should be made wide enough so as to give a clearance of at least 12 feet for the passage of their battleships through the locks.

Q. Was it to comply with the growing necessities of commerce, the trend in vessel building being towards the use of larger vessels, is it not?

A. The instructions to the Board of Consulting Engineers was to consider the largest available ships then built, and those probably to be built within a reasonable future time, and we did consider that; and the recommendation by the minority members was for a lock 95 feet wide, by the majority members for a lock 100 feet wide; the majority members recommending a type of lock canal on which to make a comparison with the sea level canal, and then also the sea level canal plan had tidal locks on the Pacific side.

Q. Well, give us the facts about the depths and the other measurement?

A. The depths of the canal?

Q. Yes?

A. The depth recommended by the majority and minority members both was 40 feet sea water or 40½ feet, practically, fresh water. And that was the depth over the mitre sills of the locks and the least depth in any of the channels, any of the channel construction along the line of the canal.

Q. Why were those plans about the size of the locks changed, who did that, who made it 110 feet instead of 100?

A. The change was ordered by the President of the United States on recommendation of the Canal Commission.

Q. When was that done?

A. That was done shortly after I resigned, or about that time.

Q. That is to say they wanted to provide for larger vessels, that was the gist of the matter was it not?

A. They wanted to provide greater clearance than we thought necessary, for the naval boats.

Q. Do you know the history of the growth of vessels in size and draft on the ocean, not for purposes of war alone, but for commercial purposes?

A. In connection with the study that we made for the Panama Canal, we gave consideration to that subject.

Q. And isn't it a fact that the tendency has been towards using vessels of larger size right along, for commercial purposes?

Mr. Adcock: Where, on the ocean?

Mr. Wilkerson: I am speaking of the ocean.

A. The dimensions of ocean boats have been increasing.

Q. Right along?

A. Yes, sir.

Q. That is the general commercial tendency wherever there is navigation, isn't it?

A. Yes, sir.

Q. And any place in the world?

A. (No response.)

Q. You have had a long experience in connection with the lakes, and have been observing them from almost the very beginning of navigation. What has been the tendency on the lakes as to the increase in size of vessels?

A. The tendency has been to materially increase the size of the vessels on the lakes.

Q. Has it not been to build right up to the limits of the critical points of navigation; to make boats just as large as could possibly be used within those limitations?

A. Yes, sir.

Q. And even to crowd those limitations?

A. Generally they have crowded the capacity of the channels.

Q. And whenever in these critical points which place the limit upon the size of the vessel that can be used, there is a change made which makes it possible to build larger vessels, those appear in the commerec on the lakes, do they not?

A. Yes.

Q. Almost immediately, isn't that a fact?

A. The growth has been very rapid, the increase in size of vessels.

Q. What will be the effect when the 24 foot lock is available at the Soo, upon the size of vessels?

Mr. Austrian: That is in your opinion?

Mr. Wilkerson: Certainly.

A. The vessel interests will demand an increased depth in the channels to correspond to that available depth in the lock.

Q. In order that larger boats may be built?

A. Yes, sir.

Q. And the same thing will be true when the 25 and a half foot lock, number 5 is ready for use, in your opinion?

A. Yes, sir.

Q. In connection with the work which you did on the Panama Canal you had something to do with some observations in the reading of water gages; you mentioned that?

A. Why they had a hydrographic department there, in which gages were read, and I have given some consideration to that work.

Q. You stated in your opinion, as I recall your testimony, you would get better results as to the average stage of the lake if you would read 4 gages and combine the observations?

A. Those gages being located near the ends of the central axes of the lake.

Q. You made a study of the results of these readings on the gages on the Panama Canal; that is you saw the reports?

A. I saw the reports in the Canal Record.

Q. Have you made any examination of any of the gages, readings of which have been referred to in the testimony in this case?

A. Excuse me, what gages are you referring to, down there at Panama or up here?

Q. Up here, on the lakes. What I mean is have any of these readings been submitted to you for any critical study in this case.

Mr. Austrian: Is that cross-examination?

Mr. Wilkerson: Yes.

Mr. Adcock: We haven't mentioned any readings.

Mr. Wilkerson: Of course it is cross-examination. He has made some observations here, or insinuations at least, that in some way more or less mysterious these observations which

we have used are not entitled to full credit. I want to know whether he has made any study of them?

Mr. Austrian: We do not object as far as any question put to him. He does not know how you made the gage readings. We just asked him how in his opinion gage readings should be made, that is all. We have not directed his attention towards your gage readings or our gage readings.

A. What is the question?

Mr. Wilkerson: Q. Was your attention called to any of the gage readings in this case, used in evidence in this case? I direct your attention specifically to the gage readings at Cleveland in Lake Erie?

A. I have seen published records of the Cleveland gages and other gages in this matter, but I have not given careful study to the subject of those gages, for the purpose of working out any of the problems in this case.

Q. Prior to the time you formed your opinion as to the method which should be pursued in order to get the most accurate results from gage readings, did you make any comparison of the gage readings at Cleveland and Buffalo for the purpose of seeing how nearly they agreed?

A. I did not.

Q. Nor have you compared the gage readings at Milwaukee and Harbor Beach?

A. I have in years past compared the readings of Milwaukee and Harbor Beach.

Q. How long ago?

A. That was when I was up at the Soo along in the eighties I think.

Q. But not in recent years?

A. Not in connection with this case.

Q. Not any observations for the period from 1890 to 1910?

A. No, sir, I think not; if I have, it has only been casually.

Q. You have presented here certain figures upon the subject, first, of your estimate of what it would cost to deepen the channels and harbors of the lakes, and the rivers connecting them; and you have given us here a general statement of your conclusion as to what the cost would be of making certain deepenings. I will ask you whether you have here available a statement which indicates in detail the work which in your opinion it will be necessary to do to procure a deepening of those harbors and channels to the extent which you have indicated?

A. I have.

Q. That is to say you have a statement in which you have set down the amount of the excavation which you think will have to be made?

A. Not always in terms of excavation.

Q. Or dredging?

A. For the river channels I have based my estimate on the experience obtained in connection with the improvement work of St. Mary's river and with the improvement of the New York State canals, and the soundings shown on the final estimate sheets, or the final estimate soundings as furnished by the engineer department, of those shoals and channels, and I have estimated the number of hours' or days' work for different kinds of plant; for instance the raft with the bars, in order to swing over the channels and determine the location of the points projecting above the proposed deepening; and then for the employment of dredges and of drill boats, and of diving outfits.

Q. You have reached the conclusion, as I understand you, that the figures which are put down in the report of the International Waterways Commission are too high?

A. Yes, sir.

Q. And have you studied the work which, in the opinion of the International Waterways Commission, it is necessary to do to get this deepening, with a view to finding out whether the difference between yourself and the International Waterways Commission grows out of the fact that they think more work is necessary than you do, or whether it is based upon a difference of view as to the cost of the work?

A. I am under the opinion that I have based my estimates on a larger amount of work than they do theirs.

Q. But you think it will not cost as much to do it as they do?

A. Yes, sir. For instance, for the harbors I had a harbor chart for each of the harbors, and then I took the latest Bulletin, number 22, issued by the Lake Survey, and the chief engineer's report for 1912. And from the charts I determined the area which would have to be deepened, and from the chief engineer's reports I got the cost price of doing the work at that harbor in recent years and I added to that cost in every case a considerable amount; and then also the description from the bulletin of what information that gave, I used; and in that way I made up the estimate of cost for each harbor, for all the streams that had been improved and would be affected by this lowering, such as Grand river, and the streams

off of Green bay, and the Rouge river and Black river and so on. And I added in those estimates generally 15 per cent. for engineering contingencies.

Mr. Wilkerson: I think I could proceed along here almost indefinitely and perhaps cover a great deal of space that I would not require, if we examined the tables and the figures.

Mr. Austrian: We will give you the tables.

Mr. Wilkerson: Q. What did you figure for the Galops Rapids of the St. Lawrence river?

A. The St. Lawrence canals, my information was based on an inspection I made along there in 1903, and from a couple of maps, one a profile map and the other a contour map, soundings, and made simply an approximation in the case of that work for those canals; but I had in mind this consideration: The Canadian Government is about—is advertising for bids for enlarging or for rebuilding the Welland canal for, as I understand, a depth of 25 feet on the mitre sills of their locks, and then they will proceed to improve all the St. Lawrence canals along the north side of the river, and while they are making those improvements it will add but very little more to the cost to provide for an additional deepening of 4 inches or 8 inches; whereas if you take the conditions that you have now and are compelled to make over the present locks and approaches to the present canals, the cost will be materially larger.

Q. Did you consider the canal, or did you consider the river itself at the Galops Rapids?

A. From the map that I had, it shows very little work to be done in the river section for the approach of the canal.

Q. It is in the rapids itself, not the approach to the rapids?

A. For the boats going down the stream. As a matter of fact, I did not give much weight to that part of the navigation.

Q. Do you know the purpose for which the Gut dam was constructed by the Canadian Government?

A. I have been under the impression that that work was done for water power development mainly.

Q. Do you know that they have been working in the Galop Rapids for years there to create a channel for down-bound vessels?

A. They were working in some of those channels, at the time I made the inspection.

Q. You didn't figure any—

A. Not for that particular.

Q. Any expense for that?
A. No.
Q. And so far as the Canadian canals are concerned, you figure that they are about to reconstruct a good many of their canals, and that they could take into consideration this diversion at Chicago and do it more cheaply now than they could in the future.
A. Yes, sir.
Q. But if acting upon the situation it is, in view of the situation with respect to that which exists between Canada and this country, it would be necessary for this work to be done at some time in the future, after this contemplated work is already accomplished; that is to say if they refused to do it now, the expense would be a great deal greater than if they did it at the present time, wouldn't it?
A. It would but then they are placing their improvements for such a draft that it will be a long time before the United States Government meets that with an equal draft in their channels and locks and canals on this side. The Canadian canals are not uniform at all as to possible draft.

Adjourned to Friday, July 25th, at 10:00 o'clock A. M.

Friday, July 25, 1913, 10:00 A. M.

JOSEPH RIPLEY, resumed the stand for further examination and testified as follows:

By Mr. Austrian: Q. Mr. Ripley, since the adjournment on yesterday did you go over your estimates that you referred to in the course of that examination with reference to the improvements, or allowances for improvements in the St. Lawrence river?
A. I have.
Q. You wish to correct the answer that you made to a question put to you on cross-examination with reference to having included any amount in that estimate for contemplated improvements in the St. Lawrence river?
A. The estimates for damages to the St. Lawrence—or to the Canadian canals, which includes the St. Lawrence and the Welland, I estimated a lump sum of $200,000 for the river improvement in the rapids, and in the isolated places.
Q. And that amount was included in the statement which you furnished yesterday, was it?

A. The one and a half million dollars.

Q. Directing your attention to the report of the International Waterways Commission, with reference to the time and difficulties to be encountered in changing, deepening and making improvements upon these various waters referred to, will you kindly give us any views that you may have with reference to the statements therein contained.

A. The work necessary to be done to obtain an additional clear depth of 4 inches through the St. Mary's river, the foot of Lake Huron, the St. Clair river, Lake St. Clair and the Detroit river would take one year and would not necessarily interfere with navigation to any serious extent; and for the eight inches' deepening, the time would be practically the same. For the deepening of harbors, the period of time necessary in order not to materially interfere with navigation would be from one to three years. Some harbors could be finished in one year; others would require two years and a few of them three years.

Q. The report of the Commission, I believe, contains these statements that it would take many years to make these improvements, and that they would in the course of construction seriously interfere with navigation?

A. That meaning is implied in their report.

Q. And to the extent indicated by you in your previous answer, your views differ from those of the Commission?

A. Yes, sir.

Cross-Examination Resumed by Mr. Wilkerson.

Q. Speaking of the construction of canal locks again, Mr. Ripley, where in the case of the Panama canal is there the least depth, is it at the floor of the lock?

A. The mitre sills of the lock.

Q. Is there a structure there corresponding to the breast wall or platform below the mitre sill, in the case of the Panama Canal?

A. I can't say as to what the construction has actually been as to that particular.

Q. How about the other lock at the Soo?

A. The lock at the Soo?

Q. The others besides the Poe Lock?

A. The Weitzel Lock, as originally constructed, had a breast wall of about 5 inches, 5 or 6 inches, built upstream

of the upper gates to protect the upper mitre sill of the lock, and there was no construction in the lock for protecting the lower mitre sill, and a ledge of sandstone rock was left at the lower entrance, which was a foot higher than the sill.

Q. Who designed that lock?

A. Alfred Noble.

Q. In the plans that you prepared for the locks at the Panama Canal, was the structure corresponding to this breast work contemplated, did your plans show it?

A. We probably would have provided some protection for the mitre sill.

Q. What is the fact about your plans?

A. Some of those minor details we had not taken up and worked out at the time that I left. It was the main features of the lock walls, and the culverts and the gates that we had finished.

Q. But you probably would have put in a structure of that kind?

A. Yes, sir.

Q. Was that ledge of rock, in the case of the Weitzel Lock to which you have referred left there specifically for the same purpose that the breast wall in the case of the Poe Lock was constructed?

A. It was intended to serve that purpose, but beyond that the depth which had been made in the canal above the lock was 16 feet, and the same on the approach below the lock, it was 16 feet; the depth on the sill being 17 feet.

Q. That is a customary method of construction locks is it not, to provide a breast wall, platform, such as the one you referred to in the construction of the Poe Lock, with the depth a little less than that on the floor of the lock?

A. In the New York State Barge Canal construction, the top of the mitre sill is the same height as the top of the mitre wall for the upper gates, and we have no protection for the lower sill.

Q. Those are for small boats, are they not?

A. The width of the lock is 45 feet, and the depth on the sill is 12 feet.

Q. Where you are dealing with large boats, on the lakes, or with ocean vessels, there is an element of danger to the floor of the lock which must be looked out for in some way?

A. You mean the floor of the lock? There is no protection to the floor of the lock, for instance of the Poe Lock, or the Canadian Lock at the Soo, excepting at the lower platform at

the lower end of the Poe Lock, and none at the Canadian Lock. Upstream, the depth over the mitre wall of the Poe Lock would be the same as the depth on the floor of the lock.

Q. The point of it is: This whole matter about construction of the lock and the way in which the floor of the lock is protected, is a matter of engineering question?

A. The protection of the mitre sill is important, but in the Poe Lock the upper sill is protected by a breast wall, which is some 6 inches higher than the sill; and then there is the mitre wall, which is the same height as the mitre sill practically, and then for the lower sills, the platforms that reinforce and back up the sill could be made as high as the sill, or a little higher, and the top of that sill anyway is either 2 or 4 inches below the elevation of the lock floor, so that the lower sill of the Poe Lock is amply protected without that outer platform.

Q. Is there anything you wish to add to the answer to the question with reference to the purpose of this breast wall in the Soo Lock? I would like to have you state fully your idea as to the purpose of that.

A. For the Poe Lock, with the down bound traffic, being the loaded traffic to the full depth to which the boats can load, and the up bound traffic being most of it light, the up bound traffic only being about one-third of what the down bound traffic is, I do not believe that that lower platform below the lower guard gates of the Poe Lock is necessary for a protection to the lower mitre sill of the lock or the floor of the lock.

Q. I beg your pardon, but that does not answer my question. What do you think the men who put it there had in mind when they put it there? What was their object in having it there?

Mr. Austrian: I object to that.

Mr. Wilkerson: I ask your opinion as an engineer what the men had in mind when they put it there?

Mr. Austrian: I object to that as calling for the mental operation of someone else.

Mr. Wilkerson: The very thing you did all day yesterday.

Mr. Austrian: We were asking for his mental operation, not someone else's.

Mr. Wilkerson: All right, if he can answer it.

A. When the Poe Lock was first built, the platform below the mitre sill was not a part of the original construction and this lower, this outer platform which is higher than the lock

floor by about 4 inches was placed there as a protection to the lower mitre sill, I take it; but afterwards it was found that that sill could be better protected, and it was necessary to protect it by building the platforms which I have mentioned in my former testimony, platforms which were about 30 feet long on the axis of the lock.

Q. When that was constructed, as a matter of fact wasn't the mitre sill below the level of the lock floor?

A. The lock floor on which the mitre sill rests, and covers the area between the gates—

Q. The main lock floor?

A. It is the main floor of the lock at that end of the lock, between the intermediate and the lower lock gates. The elevation of that floor is 18 inches lower than the floor of the lock from the upper end of the recess of the intermediate gates to the upper mitre wall.

Q. As a matter of fact, isn't the mitre sill protected fully by the manner in which the lock is constructed, without this breast wall?

A. In my opinion it is.

Q. By reason of its position with relation to the other parts of the floor of the lock?

A. Yes, sir.

Q. And therefore it is not the purpose of the breast wall to protect the whole lock floor; that is the thing we have before us here. If the mitre sill is protected some other way—

A. I do not believe that platform is necessary for protection to the floor or mitre sill of the Poe Lock.

Q. The result of it is you do not think it is necessary, and you think whoever put it in there did something that was wholly useless?

A. Yes, sir.

Q. That is your opinion about it?

A. Yes, sir.

Q Do you know who was responsible for putting this unnecessary thing in there?

A. That was built under the direction of General Superintendent E. S. Wheeler.

Q. And General Poe?

A. General Owen Poe.

Q. And the plans, as you understand it, were approved by the Chief of Engineers of the United States?

A. Yes, sir.

Q. And so with respect to the necessity for that breast wall,

your opinion simply differs from theirs, that is the net result, isn't it?

Mr. Austrian: Wait a moment: He does not know what their opinion was.

Mr. Wilkerson: Q. Your opinion differs from what they did?

A. Yes, sir.

Q. From their opinion as evidenced by their acts?

Mr. Austrian: I object to "their opinion as evidence by their acts." Acts do not necessarily construe an opinion.

Q. Your experience as I understood you yesterday has been largely at the Soo.

A. I put in about 30 years there.

Q. What work in the St. Clair river have you had to do with personally?

A. None of the work in the St. Clair river has been done under my direction.

Q. Or the Detroit river?

A. Or the Detroit river.

Q. Have you ever had anything to do with any improvements in Lake Erie?

A. Only in connection with the Barge canal work, the east end of the lake.

Q. I am speaking of United States work?

A. United States work, no, sir.

Q. How about Lake Ontario?

A. Only as far as the Barge canal work at Oswego is concerned.

Q. How about the St. Lawrence river?

A. Nothing of that work.

Q. You have gone up and down the St. Lawrence river have you with considerable care?

A. I made an inspection trip with Superintendent Boyd of the Canadian canal at the Soo, and the Superintendents of the Canadian canals on the St. Lawrence river in 1903.

Q. Just what kind of an inspection?

A. Why we visited the different canals along the St. Iawrence river and the Trent Valley canal, and made an inspection of the construction which was under way or had been done on the canal prism, and the locks and regulating works.

Q. Did you ever make any study of the effect of the Gut dam?

A. No, sir, I have not excepting as I have read in the re-

ports as to the effect of that dam raising Lake Ontario about 4½ inches.

Q. Your association with Mr. Noble lasted how many years?

A. I was his assistant for six years at Sault St. Marie, and then have been associated with him on that International Board for the Panama Canal.

Q. He is an Engineer of eminence, is he not?

A. He is the leading engineer of the United States, possibly of the world.

Q. A man whose opinion upon engineering propositions is entitled to great weight among engineers?

A. It certainly is.

Q. I am still left just a little in doubt as to exactly what you had in mind in your testimony about the reading of the water gages. Just what did you intend we should conclude from what you said as to the accuracy of the work of the Lake Survey?

A. With reference to water gages?

Q. Yes?

A. Why that for particular readings of the staff gages and of short periods of the self recording gages, that entire confidence as to their accuracy within one or two-tenths of a foot could not be placed.

Q. That is as to particular readings?

A. Yes, sir.

Q. And for short periods?

A. And for short periods.

Q. You do not—

A. For short periods; the case I cited with reference to the bench mark at Sault St. Marie, as I remember it, covered a period of nearly two years.

Q. That was a long while ago?

A. In which there was a settlement of the bench mark on the pier to which this gage was referenced, which took place during that period.

Q. That was before you went to the Soo wasnt' it?

A. Oh no, that was while I was there.

Q. In what year was it?

A. It was along in the eighties as I remember.

Q. You found this condition?

A. Yes, sir.

Q. After that there was nothing like that happened while you were there, was there?

A. We used to find some settlement in that gage on the Southwest Pier nearly every time we checked it up, a slight settlement.

Q. But you looked after it a good deal more carefully after you went there?

A. Well no, I was there from 1877 in that work and that gage was not checked up as often as it ought to have been.

Q. Isn't it true that there is a great deal more care taken in a matter of that kind than 30 or 35 years ago?

A. Yes, sir, the importance of it is more fully recognized.

Q. As navigation has increased, and vessels have increased in size, it has become more and more important that these readings be taken accurately, hasn't it?

A. Yes.

Q. As a matter of fact the Lake Survey has appreciated that necessity and has kept up with it, has it not?

A. Why it tries to, yes, sir.

Q. You say you think so far as particular readings are concerned, it might make a difference of as much as 1/10 of a foot or 2/10 of a foot?

A. More than that in particular readings.

Q. In particular readings. Uses made of these gage readings in drawing deductions by the engineers of the Government Service. Take for instance in determining the effect of the diversion at Chicago, they made use of these observations.

A. Yes.

Q. Taking the average level of the lake over a long period?

A. Yes.

Q. You had occasion, at one time or another, to study their reports on that subject?

A. Yes, sir.

Q. It never occurred to you that having in mind the periods with which they were dealing, the long length of time over which the observations were taken, there was anything in the possible mistake as to a particular reading, or the condition as to a short period that would in any way materially affect the conclusions that they drew from their observations, did you?

A. It depends on how much weight you put on the word "material."

Q. I mean it would not as to that make a difference of 2/10 of a foot, would it?

A. For instance, the staff gage at the head of the South-

west Pier is located about a mile from the canal office; and the daily noon reading has been taken on that gage ever since it was established in 1870, and during the winter season, it is a long cold trip up there and I have known the observor, instead of going up to the head of the pier, to go part way up and simply make a guess what the reading was.

At other times I have seen when there was a storm, the zero of the gage would be covered with water, and the observor would have gotten wet if he had tried to take a measurement, and he simply guessed how deep the water was over the zero of the gage. He might have guessed within two inches or six inches of what was right.

Q. Those are particular observations?

A. Yes, sir. But this was at the Soo where the conditions are a great deal more favorable for getting close accurate results than they were at the other stations. I have been told by parties who presumably knew the facts of the case, that at Marquette in those years of the seventies and eighties, the zero of the gage was very seldom checked up by level readings from the bench mark.

Q. Were you ever told about anything that happened at Marquette after the year 1890?

A. No, sir.

Q. Ever told about anything that happened at the Soo after 1890 of the kind that you have—

A. I was familiar with what was going on at the Soo until 1906.

Q. Now suppose for the same lake, you had two gages that had been read over a long period of time, and the average lake level was, for all engineering purposes, precisely the same. That would indicate to you that any errors of observation in isolated cases with reference to a particular gage would be balanced by other errors of the same kind in such a way as to be practically eliminated, as a practical proposition?

A. They might be balanced or might not, and the error in one or several of the individual readings might not affect the general mean of all the readings for a period. And again it might be that the readings would be affected as to the general mean to some appraciable extent.

Q. Are you familiar with the Haskell self-registering water gages used by the Lake Survey?

A. Yes, sir. Two were established at the Soo while I was there.

Q. Have you had occasion to observe the results of the use of those gages?

A. Yes, sir.

Q. When were they installed there?

A. Well, sometime in the late nineties.

Q. A self-registering gage of that kind would rather eliminate this element that you mentioned, in going up to read the gage, wouldn't it?

A. They keep up the practice at the Soo of reading both the gage at the head of the Southwest Pier and the gage on the Northeast Pier below the locks daily, the noon reading, as it is necessary to see that these self-registering gages are in working order and are running each day.

Q. Is it not a fact that there are gages upon the masonry of the Poe Lock, both above and below the lock.

A. We had a gage painted on the Poe Lock and on the Weitzel Lock masonry above and below, to indicate the depth on the sills.

Q. With reference to the use of the four gages in reaching a conclusion as to the mean elevation of the lock, as distinguished from determining the mean elevation of the lock from the observations of a single gage, assuming the same degree of care on the part of the gage reader in both cases, how much of a difference in your opinion would it make in determining the mean elevation for a given year whether you had four gages or one?

A. Possibly it might make a difference on a lake like Michigan or Huron or Erie or Ontario of 1/10 of a foot.

Q. You say possibly it might?

A. Yes, sir.

Q. You have never made any study of the gage readings where there has been more than one gage on a given lake and where the readings have been taken for a year for the purpose of seeing whether there has been anything like a difference of 1/10 of a foot, have you?

A. I have never had a practical demonstration of the gages being established on a lake in that way and the readings taken, and then the mean of the four compared with any one of the four.

Q. It would be a pretty fair check, if you had two gages on the same lake and you took the mean level for a given year and found that they tallied exactly; that would show you could get it very nearly from a single gage, wouldn't it?

A. Not necessarily.

Q. It would show that if there was anything wrong with one gage, the same thing was wrong to precisely the same extent with the other gage, which would be rather an exceptional situation.

A. The elevation of those gages, to my mind, should be accurately determined by lines of precise levels, and not depend upon the determination of the elevation of one gage from another by transferring the water surface readings. Otherwise, if the determination is made by transferring to water surface readings, you would not get any difference probably between the readings between two gages.

Q. Is it your opinion that a line of precise levels from Whitefish Bay to Duluth, for example, would give a higher precision for the level at Duluth than if you were simply to treat the surface of the lake as level?

A. I think it would; yes, sir.

Q. If Lake Superior should give one result extending over a period of a number of years, and the line of precise levels were to give another, which one, as an engineer, would you regard as entitled to the greater weight?

A. The one that was referenced to the precise level determination.

Q. Where in the work of the Government has the necessity for such lines been recognized?

A. It has not been recognized in the past. There is no reason why it should not be in the future, if that is the proper way to treat the question.

Q. My proposition is, or my question is, in all the vast work of the Government engineering service, you know of no instance in which the necessity of that has ever been specifically recognized?

A. It has not been, where the work has simply been improvement work, deepening the channels and so forth like that, but when you come to make a scientific study of a problem, I believe that you should try to secure the greatest accuracy.

Q. How about the coast and geodic survey, do they recognize it?

A. I don't know whether they have followed that plan in that particular or not. I doubt if they have.

Q. Where it has been regarded as important by the Government engineers to take readings of two gages for the purpose of determining lake elevation, hasn't that been in connection with the study of storm conditions?

A. I don't know the reasons which have prompted the

officials on the Panama Canal work to have a series of readings taken around Lake Gatun, but they are having such readings taken there.

Q. Are you familiar with the studies made by Mr. Blunt of Toledo concerning storm conditions of Lake Erie?

A. I have read a number of scientific papers relating to the problems pertaining to the lakes, lake levels, but I do not recall whether I read that gentleman's articles or not.

Q. I assume that as a matter of course you have made no detailed study of the problem of determining the effect upon the lake levels of the diversion of the water from the lakes at any particular point?

A. No, I have been just interested in the problem in a general way.

Q. You have made no detailed study and have no information as to the extent to which these isolated and fragmentary errors of observations of gage readings would modify the results which have been reached and certified to by the Government engineers in that respect?

A. No, sir; I have not.

Q. Now, you spoke of the change in the reference plane. I think you said that was made in 1903, wasn't it?

A. It was made for the project of 1903, but made previous to that.

Q. Now, it appears of course from the Government records, but I wish you would state it again so we may have it here in a convenient place, just what the project of 1903 was?

A. The project of 1903 was for the improvement of the rivers and lake channels between Duluth and Buffalo, and Chicago and Buffalo, for the purpose of securing channel depths of 21 feet in ordinary material, soft material, and 22 feet on boulder and rock shoals.

Q. There was a preliminary report of the Chief of Engineers?

A. Yes, sir; the project had to be submitted to the Chief of Engineers.

Q. That is to say, I understand this was the course followed there as is the case for any improvements, in these projects, is it not?

A. Yes, sir.

Q. First there is an Act of Congress?

A. Authorizing a survey by us.

Q. Authorizing a survey by you, and requiring the Chief of Engineers to submit a report?

A. A report, yes.

Q. That report is transmitted by the Secretary of War to the President and he transmits it to Congress, and Congress then appropriates for the work?

A. I don't know as it is transmitted to the President by the Secretary of War; maybe it is transmitted directly to Congress. That is a minor detail.

Q. Did you prepare the estimates upon which some of these improvements were authorized?

A. The surveys were made by my assistant, Mr. Rohert, and the computations were made by his force and himself for the quantities, and he fixed upon the unit prices for the different classes of work and submitted a report to me. And then I revised the unit prices to a certain extent and transmitted the report as mine to the engineer officer, with such recommendations as I saw fit to make.

Q. Just how were those computations made?

A. The surveys were made on a rectangular system. For soft material, the soundings are taken 10 feet apart, with the cross sections generally 100 feet apart, sometimes 25 and sometimes 50. On the rock sections, the soundings are taken 10 feet apart, both on the cross sections, and the cross sections being 10 feet apart. And then the computations are made with reference to the surveys developed by those soundings, the levels and the grade planes and side slopes fixed upon for that particular location.

Q. How much time did it take you and him to prepare these estimates for that work? I mean the surveys and estimates for the work.

A. The surveys for these estimates were made in connection with the regular routine work of the river party, river survey party, and as I remember, the surveys extended over a period of about a year; some of them taken in the summer-time, most of them in the winter-time.

Q. And in doing the computation necessary to make the estimates, how much time was consumed?

A. Well, they were practically worked up so that when the survey, the field work was finished, it was only a very few days after that when the office work was completed.

Q. Occupied all the time during a year?

A. Practically so.

Q. In order to get the accurate results which were necessary for an estimate of this kind, you regarded the method that was used there as necessary?

A. Yes, sir.

Q. How much did that work cost all together?

A. As I remember the project, it was for the St. Mary's river in the neighborhood of five or six million dollars; but that is simply stating from memory.

Q. How long did it take to do it?

A. The contract for the West Neebish work was awarded in the spring of 1904 and the channel was opened in the latter part of July or early in August, 1907. The Middle Neebish work, or the work on the Middle Neebish route was awarded in 1908, spring of 1908 and it was finished either in 1911 or 1912.

Q. Speaking of the Middle Neebish, in the St. Marys River, there is a wing dam constructed there. wasn't there?

A. There was a dam built—cast up by the dredge making a cut from the head of the dyke, the dyke running parallel practically to the improved channel through the Middle Neebish Rapids, on the north side of the channel; and this dredged cut extended from the head of the dyke over to the foot of Sugar Island.

Q. Was there a wing dam running from the dyke to the island, shutting off the flow in the rapids?

A. It was intended for that purpose but it didn't accomplish it. The dyke washed away in places very soon after it was constructed and in two or three years none of the dyke could be seen above the water surface.

Q. By whom was it designed?

A. By Mr. Wheeler.

Q. And who built it?

A. A dredge was employed by the working hour, and the expense, as I remember it was about $14,000 for that particular dyke.

Q. It was built under your supervision of course?

A. Yes, sir, I had charge of the river work at that time.

Q. I want you to state just a little more in detail what it was that was thought the construction of that dam would accomplish?

A. The object of that dam and of similar dams at the Little Rapids was for the purpose of maintaining the pool level of Hay Lake, and the pool level of the point between the head of the Little Rapids and the foot of the lake.

Q. It was a compensating work then?

A. It was intended for a compensating work.

Q. You were familiar with the plans for this improvement?

A. I was, yes, sir.

Q. You understood the purpose for which it was intended to construct the dam?

A. I understood the purpose but I did not approve of the method.

Q. That is you thought that the compensation could not be made in this way?

A. I didn't think it desirable to make it.

Q. Why didn't you think it was desirable?

A. On account of maintaining the swift current in the channel at the Little Rapids at the Neebish and at Sailors Encampment. Of course that particular dyke would not have affected Sailors Encampment particularly.

Q. That is one of the effects of all works of that kind, is it not?

A. Yes, sir.

Q. To diminish the cross section of the river and therefore increase the current?

A. Yes, sir.

Q. So that that always has to be taken into consideration in work of that kind as to whether in compensating, as far as level is concerned, you do not get a bad condition as far as the velocity is concerned?

A. Yes.

Q. Wouldn't there be the same result as to effect upon the current in your proposed plan for the St. Clair River?

A. No, sir, in that case the current would be lessened at Fort Gratiot, where it is now the swiftest in the river.

Q. How about Stag Island?

A. That would not be materially changed, not necessary to materially change it. I do not believe in simply putting in one dam for one of the lakes. If you are going to put in compensating or regulating dams, they should be for all the lakes.

Q. The fact of it is that in connection with this 1903 project, there was a dam constructed which some of the Government Engineers—

A. No, not in the 1903 project. That was in the earlier project. These dykes were built at the Little Rapids and the encampment under earlier projects.

Q. There was one dam?

A. Yes, sir.

Q. There was a wing dam built in the Middle Neebish

which it was thought by some of the engineers at that time would compensate?

A. Yes.

Q. But which as a matter of fact failed to accomplish its purpose?

A. Yes, sir.

Q. That is a fact, isn't it?

A. Yes, sir.

Q. And the fact is that it was opposed by you because it would increase the velocity of the current?

A. Increase or maintain the original velocities before the improvements were undertaken.

Q. So this matter of compensation is, after all, is it not a pretty complicated engineering problem, in which you do have to take into consideration, not merely whether you are going to maintain your level or get your higher level, but also the effect which you are going to have on the current?

A. It is a very complicated problem, but it can be solved in my opinion for the lakes and connecting rivers.

Q. That is to say you think you have reached a solution of it, that is your best judgment about it?

A. Yes, sir.

Q. At a total cost of how much now for compensation, for all the lakes?

A. The cost would be somewhere between the range of One and a half Million and Five Million Dollars.

Q. And in your opinion as an engineer would the cost when the work was completed, I mean the money paid out by the Government, be nearer a Million and a half, or nearer Five Million Dollars?

A. I believe it would exceed $3,000,000.

Q. You believe it would exceed $3,000,000?

A. Yes, sir.

Q. And in this do you include compensation down the full length of the St. Lawrence River?

A. I do.

Q. Allowing how much for compensating works along the St. Lawrence?

A. The estimate for the St. Lawrence River ranges between $200,000 and $1,000,000.

Q. And in your opinion the amount that would be actually paid out by the Government before the work was done would be not less than how much?

A. It depends on how much the work would benefit water

power development, and what share of the work would be paid by the water power companies.

Q. Not for that purpose, but I mean just the expense to the Government?

A. It would probably be nearer the Million Dollars.

Mr. Austrian: Than the $200,000?

A. Yes, sir, than the $200,000.

Mr. Wilkerson: My question is this: Of course you have in mind the practical experience in matters of this kind, based upon observing appropriations over a long period of time. What I wanted to get at is your best judgment as to how much money Congress would have to appropriate for that work before they got through. You think not less than a Million Dollars, as far as the St. Lawrence is concerned?

A. Nearer the Million than the $200,000.

Q. Would it in your opinion be less than $750,000?

A. Probably not.

Q. That is you would not want to go on record, if you were called upon to estimate to a committee of Congress, as to how much it would cost to do that work so that they might make an appropriation, you would not want to say they would have to appropriate in the end less than $750,000 for that, and stake your reputation as an engineer on that proposition?

A. For the St. Lawrence River I have no figures made itemizing the cost for each locality where a dam would be necessary; but I believe my total estimate for all the rivers would build all the dams necessary. For a recommendation to the Government to make an appropriation on, the problem would have to be studied out with great care as to what amount you were going to raise the mean elevation of the lakes, whether it was 4 inches or 8 inches or a foot or whatever the amount would be; and then consider the best type of dam to be built at each locality, and the cost of building such a dam at that locality.

Q. Just how detailed has been your study of the St. Lawrence?

A. The St. Lawrence, the least of any of the streams.

Q. Have you made such a study of the conditions on the St. Lawrence that if you were called upon by a committee of Congress to make an estimate of the cost of doing this work, upon which it could act officially in making its appropriations for an improvement of that kind, you would feel that

you could give to the committee the detailed information which it ought to have to act on your recommendation?

A. If the stenographer will read my last answer, I think that answers your last question.

(Answer of the witness read.)

Q. That is to say you do not feel that you have made that detailed study necessary for a purpose of that kind?

A. No, sir, I have not.

Q. What consideration if any did you give to the situation at Farrans Point?

A. Nothing more than the general detail as to the other locations at the head of rapids along the St. Lawrence River.

Q. What excavation did you estimate as necessary in the river at that point, paralleling the canal?

A. As a matter of fact I do not think that any excavation would be necessary at that point.

Q. Why not?

A. Because you are diverting a certain number of cubic feet per second flow from the St. Lawrence River by the canal at Chicago. Now you want to maintain the level of your pool above the rapids for that location; and the chances are that it would be a dam that would reduce the cross section, but having a movable dam that you could practically have the same cross section that you have now, if it was necessary.

Q. Not the pool though above the rapids, but in the rapids themselves.

A. These dams in my opinion would be located near the head of the rapids all the way along the river.

Q. What fall does the river take at Farrans Point?

A. That is a detail; I have a map which will show it, but I do not recall it offhand.

Q. You may refer to the maps; we want the fact at this point, that is all.

A. It is a small amount as I recall it. (Referring to map.)

Q. (Question read as follows: "What fall does the river take at Farrans Point?")

A. 3 to 5 feet.

Q. Do you know how much money has been expended by the Canadian Government on the St. Lawrence?

A. I read the reports of the department as to the expenditures of the Canadian Government on the Canadian canals and on the St. Lawrence River, but I could not recall.

Q. That has been a very large sum hasn't it?

A. Rather large.

Q. This whole problem of navigation on the St. Lawrence has been a very complicated problem, has it not?

A. It has probably been made so, maybe unnecessarily.

Q. You mean by the Canadian Government?

A. By the engineering and the government method of proceedure.

Q. Now I want your full view on that, because that involves a criticism of the engineers of both this Government and Canada, and I want your full view on it. In what respect do you think they have made a complicated problem of it when as a matter of fact it was a simple problem.

Mr. Austrian: You are incorporating in your question something he did not say. He did not say it was a simple question; he said perhaps they made it more complicated.

Mr. Wilkerson: I will accept your modification.

A. It is simply like this: At the time when I made that inspection in 1903, I received certain impressions about this or that particular feature of the work. Now I can't recall what those impressions were today. That was made 10 years ago. But I can recall what my final judgment and conclusion was with reference to it.

Q. So that you are not prepared to state a conclusion which is based upon facts and data that you are able to present in connection with your conclusions?

A. With reference to that particular question I am not.

Q. Is that same thing true about some other impressions which you had about things that happened 10 or 15 years ago?

A. Not necessarily so.

Q. But it is about the St. Lawrence River?

A. It is for that feature of it, of the St. Lawrence River improvement.

Q. If the same degree of care were given to the preliminary study with reference to these contemplated improvements about which you have testified, which you gave in connection with the estimates submitted for the St. Marys River, how long would it take to present a detailed plan for these proposed improvements, upon which the action of Congress could be predicated.

A. For St. Marys River, my estimate is based on an amount of work to be done by different plant, and not upon yardage, and it would be impossible to present by drawings any such project as an amount of work and the exact work to be done. But you can take the final estimate soundings of those chan-

nels and estimate and locate from the soundings the probable places where improvement work would be done rather than at other places. The exact amount of work to be done would have to be determined by sweeping the channel with raft bars. If you were to look at the soundings for instance of any of the channels of the St. Marys River that I have here—I didn't bring them all but I have a section, for instance, of the Middle Neebish and of the West Neebish and of Sailors Encampment on the rock sections.

Q. You have produced here one of the sheets which illustrates the manner in which you have made some of these estimates. Just explain, so that we will understand what you have done.

A. This is on the rock section at Middle Neebish, and the improvement was for a depth of 22 feet.

Q. This is one of the—

A. This is the final estimate soundings for that work, final estimate 1910.

Q. This is one submitted when you were with the Government?

A. No, sir, this has been submitted at the request of Mr. Adcock.

You take the soundings: The decimal shows the point between the tens and the feet; that is 24.4, 24.8, 24.6. You look along here, and you do not find much of anything below 24. There (indicating) is 25.6, 25.6, 25.9, 25.7, 25.2. You don't find any of them much below 24. Some are over 27 in that section.

Mr. Austrain: That means the depth?

A. The depth from that water plane.

Mr. Adcock: From the reference plane?

A. From the reference plane of the improvement down to the bottom of the bed of the river. They wanted 22 feet in the clear, and here you see they are getting from 24 to 25 feet, 2 or 3 feet, some cases 4 feet below the required grade. The chances are if you wanted to deepen 4 inches or 8 inches along over that section, you would have very little work to do.

Q. That is the reference plane which you mentioned yesterday, in connection with the 1903 project of the St. Marys River?

A. The grade plane mentioned.

Mr. Austrain: Q. All these plats, these reference plats that are technically described here, they are in the Government Survey Office?

A. For the St. Marys River channel, the Detroit River.

Q. For all the navigable rivers?

A. Where they have to do work under that 1903 project. As a matter of fact, in that Middle Neebish work and the Encampment work, the Encapment work was in limestone, and Mr. Sabin told me that the contractors build 3, 4 and 5 feet below the required grade plane to be secured, and put in heavy charges of dynamite so that they virtually pulverized the material. In the Middle Neebish the material came out as sand instead of rock.

Mr. Wilkerson: Q. How much time have you spent in preparing your estimates?

A. Between 20 and 30 days.

Q. What do you mean by raft sweeping

A. The raft we used on the St. Marys River work was built of timber, 12 by 12 inch timbers with board platform. It was 130 feet in length, 20 feet in width, and from that raft along the center line of it was suspended eight bars, the bars being about 22 feet long each; they overlapping at the ends; and then we would run out a head line, a kedge to hold the raft in position as to up and down-stream, and then put out two kedges on each side, one from either end, and then could pull it across the stream by windlasses on the raft, or we could push it with a tug, depending on the location.

The bars were suspended by chains from windlasses. Each bar had a chain at each end of the bar and we could lower those bars to any depth that we wished, and then by swinging the raft slowly across the stream in this position (illustrating), if the stream was coming down this way (indicating), we would locate the material that was above the grade plane.

Q. How much above the grade plane?

A. Well on the Middle Neebish work, on one contract we had a strike, and sent the diver down, and he brought up a little tin can, and the contractor said he kicked on that.

Q. Was the work accepted if a point of rock projected up as much as an inch?

A. I required one of the contractors to tow a drill boat from the Soo down to the Middle Neebish, to remove a piece of solid rock that was a quarter of an inch above grade.

Q. The contractors thought you were pretty hard, didn't they, sometimes?

A. Sometimes, but they all wished me well.

Q. But you were going to make sure that you had all the water in those channels that you were trying to get?

A. Yes, sir.

Q. And even to within less than an inch, the contractor would take out what he had agreed to do?

A. The contractor was required to remove all material above the grade plane so that the raft bars would swing clear without striking.

Q. You have spoken about a contractor, either through some provision in his contract or through some custom, the exact facts about which you seemed to be a little in doubt, was allowed to excavate below the grade plane?

A. They were permitted to excavate to whatever depth they preferred below the grade plane.

Q. Now having in mind that those channels might, at some future time, be further deepened, would it be to the advantage or the disadvantage of the Government to let the contractor do that?

Mr. Austrain: I object; that is a matter of argument. That is a policy that the Government has evidently adopted, and it is not for the witness to pass on.

A. It would be to the advantage of the Government to have them work as much as they would below the paid grade plane.

Mr. Wilkerson: Q. Where there was stone, the broken stone would be more easily taken out than solid stone.

A. Yes.

Mr. Austrain: Q. They are getting extra pay for that work below the grade plane?

A. Yes.

Mr. Wilkerson: Q. I refer to this report of the International Waterways Commission, page 72 of that report, which is Appendix 1, and is the report upon the Chicago Drainage Canal by the Commission January 4, 1907. In paragraph 25 of this report, I direct your attention to the statements: "Careful estimates have been made of the cost of deepening the channels between the lakes 1 foot;" in the preparation of your testimony have you examined those estimates there referred to?

A. No, sir, I have not been able to see their estimates in detail.

Q. I notice the next statement: "To deepen the Detroit River is estimated to cost $4,115,430." Are you able to state the fundamental difference between the estimates made by the International Waterways Commission and the estimates which you have made?

A. I imagine that they based their estimate on the cost of excavating the material 1 foot in depth over the area of all the shoals which have been improved for the channels in the Detroit River.

Q. You made no allowance then for the shoals?

A. I certainly did, but I took the conditions as they are now in those channels, the depth of water as left by the contractors under the last contracts and then made my estimate of the cost of securing an additional 4 inches and an additional 8 inches by using the raft to locate the material that is above the grades for those depths; and then removing the material by a diving outfit, or with dredges, or where necessary to use a drill boat, and drill and blast the rock that would be solid.

Q. That is what they call a cleaning up?

A. Call it a cleaning up, yes, sir.

Q. Is there as much clear water under a vessel after this cleaning up process as there would be if the work was done clean?

A. The vessel could not strike with that additional clear depth any more than they do now, but there would not be the amount of water below the keel of the vessel that there is for the present conditions.

Mr. Adcock: That is for certain places.

A. Any of the places in the channel there; but that additional clear water has been secured without expense to the Government.

Mr. Wilkerson: Of course that additional clear water is helpful to navigation?

A. It is helpful to navigation in a way. They might run a little faster by having it, but still it is uncertain just where it is, so that as a matter of fact for practical navigation it cannot be utilized.

Q. Let me put this question to you: Suppose that the conditions were created where it was necessary to deepen these channels 2 or 3 feet. By that I mean suppose other people along the lake were allowed to take the water, or were to take the water as they are doing at Chicago; and not only Chicago taking it, but they commence to take it in Indiana and Cleveland and Buffalo and all places along there, so that it would be necessary to deepen those channels two or three feet. The expense of doing that could not be determined from your figurs by merely a process of multiplication, could it?

A. It could. One way of estimating the cost would be to

say if the levels of the lakes have been lowered a certain amount, say 1 foot, why then in order to secure a 25 foot grade or 24 foot grade in the future then there would be that additional foot of material to be removed and the cost of that would be a certain amount. And you could also treat the conditions just as the conditions are treated by me at the present time; that is you consider that the improvement was made, instead of 24 feet to 23 feet, and there would be no added cost then; and then go to work and secure the additional foot by this cleaning up process, which would be much cheaper in cost than it would to take out a foot of solid material.

Q. What is your estimate of the expense of deepening the Detroit River a foot?

A. I did not make an estimate for a foot.

Q. What is your estimate for four inches?

A. For deepening four inches, $30,300.

Q. How much?

A. $30,300 practically.

Q. To deepen the Detroit River four inches?

A. Yes, sir.

Q. How much to deepen it eight inches?

A. $103,200.

Q. Have you any views based upon your examination of this as to what would be the expense of deepening it a foot?

A. I have not. The cost would increase quite rapidly from the eight inches to the foot.

Q. Well, about how much, what is your best judgment now as an engineer as to the expense of deepening it a foot?

A. I believe that it would exceed $300,000.

Q. Why in your judgment should there be such a wide difference between your figures and that of the Waterways Commission as to the expense of deepening the Detroit River a foot?

A. Because they are basing their estimate on a foot of material being removed over the entire area of those shoals.

Q. Why wouldn't that be necessary?

A. Because they have got more than that foot of depth, from one to three feet below the grade plane now, and it is a cleaning up process.

Q. If the level of the lake was lowered a foot and you wanted to make the conditions at the bottom of the river precisely what they are now, it would be necessary to take out a solid foot, wouldn't it?

A. It would, but it would not be necessary to do it for pur-

poses of navigation in securing the additional foot clear draft.

Mr. Austrain: If you wanted to make that exactly as it is now, you would have to take a photograph of the bottom.

Mr. Wilkerson: My point is how much it would cost to make the bottom of the river, to leave the bottom of the river in precisely the same condition as it is, with the level of the lake reduced a foot.

Q. And you think their figures would probably be substantially correct for that, do you?

A. I don't know what unit prices they have used.

Q. Assuming their unit prices and yours are about the same, it would cost $4,000,000 to do that?

A. I have not made any estimate along those lines, but I presume that it would approximate the $4,000,000.

Q. You have no doubt that their estimates, on the theory on which they were made—

A. Were honestly made.

Q. So that as you understand it, the difference between yourself and the Government Engineers in the figures stated for the Detroit River grows out of the fact that you have made an estimate of merely the expense of shaving off, so to speak—

A. The high points.

Q. Shaving off the high points, whereas the Government Engineers have made their estimate upon the theory, right or wrong, that in view of what the Government itself may see fit to do with these waters in the future, the damage which results to the Government is the cost of taking out four solid inches.

Mr. Adcock: I do not think it appears in the record anywhere that there are any Government Engineers who have made any estimate on this case. I object to the question for that reason.

Mr. Wilkerson: I will change my question.

Q. As I understand it, the fundamental difference between yourself and the report of the International Waterways Commission is that you have made an estimate which involves shaving off the high points, whereas as you think their estimate is based upon the expense of removing 1 foot of material; that is the difference?

A. Yes, sir.

Q. Now, you spoke of the comparative expense of deepening 8 inches and deepening a foot. The cost would increase rapidly as the extent to which you deepen increases?

A. Yes, sir.

Q. Would that same thing apply between 1 foot and 2 feet?

A. Yes, sir, only more markedly.

Q. And from 2 feet to 3 feet there would be a still further ratio of increase?

A. Yes, sir.

Q. So that when you got up to a deepening of 2 or 3 feet, you would get to a very large figure?

A. You are getting to the solid material to be taken out, entirely.

Q. Now the next one of these rivers, or rather the next body of water in which the International Waterways Commission report says that it will be necessary to do something is Lake St. Clair and the statement is: "In Lake St. Clair, the full depth of the lake is now utilized, and any lowering of its surface involves the excavation of an artificial channel entirely across the lake, a distance of 18 miles, of which it has been necessary heretofore to artificially deepen only one-third."

I understand it to be your contention that that statement of fact is inaccurate?

A. Yes, sir.

Q. And upon what do you base your conclusions as to the correct facts there?

A. Upon the fact that the deepening of Lake St. Clair under the 20-21 foot channel project of 1892 or 1893 to be a channel 800 feet wide, dredged entirely across the lake with the exception of about a distance of a mile and one-eighth; and upon the further fact that since that channel has been improved, the passage of boats has stirred up the soft clay silt in the bed of the channel, and the currents and cross winds have carried that material and deposited it on the bed of the lake to the westward of the channel, so that at the present time the channel is from 1600 to 1800 feet wide and about 24 feet deep.

Q. I call your attention to the estimate made in the report of the International Waterways Commission of $1,080,720, as representing the expense of deepening the channel through certain places in Lake St. Clair?

A. And St. Clair River.

Q. And St. Clair River. I ask you whether or not in your judgment that figure is unreasonable upon the assumption that what it is contemplated to do is to take out a foot of material in those places, and without regard to whether that is neces-

sary for the particular purpose which we are considering here?

A. I have not checked that through as to the quantity or as to the unit price used.

Q. Assuming that the unit price—

A. And the quantity was a fair one.

Q. Yes.

A. And the computed quantities were correct.

Q. Yes.

A. I should say that that estimate was all right.

Q. You have made no estimate however yourself?

A. No, sir, because there was no material to take out excepting a little just below the St. Clair Flats Canal where it silted up and the shoal for about a mile and an eighth along at the opposite end of the lake at Grosse Point.

Q. That is in the shaving up process?

A. No, that means dredging for the boats that are moving there now. That channel has got to be deepened. They ought to deepen it two feet. You could make it two feet four inches at a very little more expense.

Mr. Adcock: You mean 4 inches, 4 or 5 or 6 inches?

A. 4 to 8 inches.

Mr. Wilkerson: Q. Now your estimate for the deepening of Lake Erie was made upon the same assumption as the estimate—

A. The estimate for Lake Erie is included in the Detroit River work. The channels would have to be lengthened for possibly a half a mile at the lower end of the Detroit River, on account of deepening an additional 8 inches.

Q. Did you include the approach to Toledo?

A. The approach to Toledo was included in the improvement, or the deepening for the Toledo estimate.

Q. Did you include the South Passage?

A. I did not include the deepening of the channels in Lake Erie.

Mr. Austrian: Why not?

A. The depth is greater than is being secured in the improved river channels already, or greater than with the present improved channels deepened an additional 8 inches. This is true for all the channels on the west end of Lake Erie.

Mr. Wilkerson: The report of the International Waterways Commission as to the deepening of the harbors in the United States is $2,000,000. What is your figure for that?

A. That was for a foot, you understand.

Q. Yes.

A. My estimate for the harbors of the United States for eight inches was $2,750,000 practically, but I included more harbors than they have.

Q. In that particular respect your figures are larger than those of the International Waterways Commission?

A. Yes.

Q. For a greater number of harbors?

A. Yes.

Q. What was your figure for the Canadian harbors?

A. For eight inches, $1,260,000.

Q. You made no computation for a foot?

A. No, sir.

Q. But it would be practically 50 per cent. more for a foot, or would it be more than 50 per cent. more?

A. Probably more than that.

Q. Probably more than 50 per cent. in excess of one million, what is it?

A. $260,000.

Q. That would be, for a foot it would be between two and three million dollars according to your figures?

A. Yes.

Q. I show you the map of Lake Erie, Williams' Exhibit 11, March 18, 1913, showing the South Passage from Toledo to Cleveland and ask you to examine that; and in the light of that examination to say whether you care to make any amendment to your statement of the depths and therefore the consequent necessity of deepening, even on your own theory?

A. The map or chart shows the soundings referenced to standard low water datum, which is 570.0. The improvements of the lower Detroit River for the Lake Erie elevation are referenced to datum 571.0. So that 1 foot should be added to these soundings to make them comparable with the soundings for the improved lower river channels of the Detroit River.

Q. Doesn't the chart show 18 feet or less at that stage?

A. 21 feet at the contours, so that it shows it is less than 21 feet. It may be more than 21 feet of the improved river depths.

Q. You had that in mind in stating it would not be necessary to deepen that passage?

A. I do not say it is not necessary to deepen that passage. It should be deepened for the present navigation, in order to make it safe in stormy weather; but if you are going to deepen it, the additional cost for securing 4 inches or 8 inches would

be less than one-fifth of the amount of money that should be expended on that shoal.

Mr. Austrian: You think it ought to be deepened two feet?

A. It should be deepened at least three feet if they are expecting a probable or about two feet deepening.

Mr. Wilkerson: Q. It is a fact that the deep draft vessels have to go around by the other passage now, do they not?

A. I understand so.

Q. When you made the estimate for Lake St. Clair, did you have in mind the points upon the lake in which there is some navigation?

A. Yes, sir.

Q. Wouldn't that make it necessary to do considerable work in Lake St. Clair then?

A. I estimated that under harbors.

Q. Under harbors?

A. Yes.

Q. In going through the Thames River wouldn't it be necessary to deepen the whole lake, that is to restore the equivalent conditions?

A. I included in my estimate what I consider the necessary deepening in the lake and at the docks around the shores of the lakes under the estimate for harbors, both in taking those for the Canadian side and for the Canadian harbors, and the American side for the American harbors; also for the Clinton River deepening, and up to Mt. Clements.

Q. Does the deepening of the harbor have any effect upon the piers in the harbor?

A. If you deepen to a large enough extent it would.

Q. Did you take that into consideration as an element in your estimate?

A. I consider a deepening of 4 inches or of 8 inches would not require any change in the piers or breakwaters of any of the harbors.

Q. Even when taken in connection with the deepening which has already been made the deepening which the Government may see fit to make in the future?

A. Taken with reference to what deepening has been made in the past by the Government, but without any reference to deepening which the Government may make in the future.

Q. But if, we will say, the Government were to deepen several feet in the future, and this 4 or 8 inches were a part of that several feet, it would be a part of the deepening which

would have an effect upon the piers and breakwaters, wouldn't it?

A. I do not believe that a deepening of 4 or 8 inches should be charged up for any of the cost of any changes in piers or breakwaters for a greater deepening that the Government may do in any of the harbors of the Great Lakes.

Q. And I, of course, understand that you did not take into consideration as an element in your estimate of damage the fact that future commerce may require the extension of existing harbors, or that there may be new harbors necessary.

Mr. Adcock: I object to that "estimate of damage." There is no question of that kind raised or involved here. It is a question of the cost of deepening a certain amount.

Mr. Wilkerson: On what theory is this evidence introduced, except upon the theory that you are trying to show how much you damage the Government if you take the water? I supposed that was admissible for no other purpose except that.

Mr. Adcock: The question assumes a conclusion which is not the case.

Mr. Wilkerson: I am perfectly willing to modify my question.

The Witness: I have estimated for the cost of deepening the channels now in use, the harbors now in use or any isolated docks in use along the Lake Shores and River Shores.

Re-direct Examination by Mr. Adcock.

Q. During the time that Mr. John S. Stevens was Chief Engineer of the Panama Canal, if that is the term you use, was the plan of the canal and the method of construction laid out by him, or under his direction?

A. Yes, sir, and the methods of doing the work and the kind of plant to be used and the organization of the forces necessary for all the department was made and under way, and he is, in my opinion entitled to the credit of making the Panama Canal construction a possibility of success.

Q. He is an engineer of national reputation?

A. He is.

Q. Have you examined the plans of construction of the new lock at the Soo called the Davis Lock?

A. I have.

Q. Is there any such platform provided for as the one that

has been built and in existence at the Poe Lock, that has been mentioned as a breast work 4 inches above the lock floor?

A. A platform is shown on the plans for the Davis Lock, located below the lower mitre gates with its top elevation the same as the elevation of the floor of the lock, the main floor of the lock.

Q. As I understand it, from the time the Poe Lock was built or placed in operation until about 1907, it was not the critical point of navigation in the St. Marys River?

A. I think that is true.

Q. You spoke of the cost of deepening the harbors from 4 to 8 inches and from 8 to 12 inches, and I understood you to say that would cost more in proportion for 8 inches than 4, or 12 than 8?

A. I had in mind the estimate for channels which I had prepared. For the harbors, the estimate was on the yardage basis and for 8 inches would be double of that for 4 inches and for 12 inches three times that of 4 inches, in direct proportion.

The further taking of evidence before the Commissioner in this case is adjourned until such time as may be fixed either by stipulation, or upon the notice of the counsel for the Defendant.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Thursday, September 25th, 1913.

Appearances:
Mr. James H. Wilkerson, and
Mr. Albert L. Hopkins,
Representing the Government;
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

HENRY C. ADAMS, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your name, Mr. Adams?
A. Henry C. Adams.
Q. Where do you reside?
A. Ann Arbor.
Q. What is your business?
A. I am Professor of Political Economy and Finance, in the University of Michigan.
Q. How long have you been connected with the University of Michigan in that capacity?
A. As a Professor, since 1887.
Q. And prior to that time?
A. Prior to that time I was a student, and was lecturing in the three universities, Cornell University, Johns Hopkins University, and Michigan. I took the professorship and remained all the year in Michigan in 1887.
Q. Have you been connected with any other institution since that time, or engaged in any other work?
A. I have not been connected with any other institutions, except as now and then I would lecture in other institutions. I have lectured at the Johns Hopkins University off and on for a good many years. And in 1888 I became Statistician to the Interstate Commerce Commission, and held that position until 1907, when I became director, for the Interstate Commerce Commission, of their division of Statistics and Accounts. It was at that time they undertook the development

of a uniform accounting system for the railways of the country.

Q. Did you have anything to do with the development of that accounting system?

A. Yes, sir.

Q. State what you did in that connection.

A. The development of that system was under my immediate direction, and everything was prepared under my direction until it was submitted to the Commission for approval or disapproval, and then promulgated by way of the Commission.

Q. Will you state what your duties were as Statistician to the Interstate Commerce Commission?

A. The usual duties of statistician, having direction of the forms of annual and monthly reports that the railroads submitted; and the direction of all special investigations that the Commission might desire to have made, of a statistical character.

Q. Did you have anything to do with the valuation of railroad property, at any time?

A. Yes, sir, in 1910, I had charge of what is known as the "Determination of the Intangible Values of the Michigan Valuation of Railroads"; and I continued in that advisory capacity to the State of Michigan until after 1905.

Q. Are you about to enter upon any work in connection with the valuation of railroads abroad; if so, state what.

A. Yes, sir, I am going to China as the advisor to the Chinese government on the standardization of Chinese railway accounts.

I might add, also, as bearing upon this point, that in the census of 1890 I had charge of the Department of Transportation, including the Railways, Steam Lines, Express Companies; and I was also employed by the Commission on Railway Mail Pay, of which Senator Wolcott was chairman and made a statistical investigation upon that point for that Commission, which was a Commission composed of both the House and Senate.

Q. Have you made any examination of the records of the City of Chicago as to death rates from various diseases in the last 26 years, say?

A. Yes, sir.

Q. Just state what data you secured, and what has been the nature of your investigation, and the sources from which you secured the information?

A. The information that I studied was secured from the Department of Health of the City of Chicago. That was supported by a study of volumes on Vital Statistics of the Census Office, the Federal Census Office, and by reading excerpts and treaties upon the general subject of health statistics. But the data that I have is supplied by the Department of Health of the City of Chicago.

Q. Is that incorporated in any volume?

A. Not all of it. The volume that I have here, and which was made use of for many of the years covered, is the Report of the Department of Health of the City of Chicago for the years 1907 to 1910. The Department itself furnished me the data covering 1911 and 1912.

Q. Have you made any comparison of the death rates from water-borne diseases between the two periods say 13 years preceding 1900 and 13 years subsequently, as shown by the statistics which you have; and if so, will you state what your conclusions are with reference to that?

Mr. Wilkerson: We are not going to interpose any unnecessarily technical objections to this line of proof. Of course, all this testimony is taken subject to the right to object at the hearing?

Mr. Adcock: Yes.

Mr. Wilkerson: And all that I shall insist on, so far as the figures you use, will be that you indicate to us the document from which they are taken, so that we may have an opportunity to consider either of two things, first: Whether that document is competent evidence; and second, whether the figures are accurate.

Mr. Austrian: For instance, this document that the Professor has described, might not be competent evidence in itself, without calling a witness to identify it.

Mr. Wilkerson: I can conceive of a document of that kind wherein some parts might be competent and some not; some statements might be competent.

Mr. Austrian: We are not going into these statements. All we are using this for is to get figures.

Mr. Wilkerson: I suggest you go ahead with your testimony, and we will reserve the right so far as these documents you use are concerned, to make such objection as we see fit.

Mr. Austrian: That objection is to be made prior to the hearing, and giving us an opportunity to supplement the proof.

Mr. Wilkerson: Even if made at the hearing, you will be given an opportunity to obviate it.

Mr. Austrian: Or qualify it.

Mr. Wilkerson: It may be it will come up before the hearing I think that is the understanding on which this case is to be tried.

Mr. Adcock: Yes.

Mr. Wilkerson: I make that suggestion so that the Professor may go ahead without any interruption, and so that the Government will not be put in the position of waiving any of its rights.

Mr. Adcock: Certainly. I presume Professor Adams can state in the record now the place from which he obtained the data, if he has not already done so.

Mr. Wilkerson: I understood that he got part of it, down to a certain time, from the Report of the Health Department. I understand he has used in this comparison, some figures which he got from some other source. It might be well to indicate from where he got it, where we could find it.

The Witness: They are taken from the records of the Health Office.

Mr. Adcock: Q. Of the City of Chicago?

A. Of the City of Chicago.

Q. Will you state just what those records are, that is perhaps not in detail but in a general way; how they are compiled by the City officials.

A. I am not familiar with the process of compilation by the City officials.

Mr. Austrian: Q. But they are records kept in the office of the City of Chicago Health Department?

A. Yes. And the records are kept in such a way that the tabular statements in this volume are added to from year to year.

Mr. Wilkerson: I suppose they summarize the death certificates, do they not?

Mr. Austrian: That is it.

Mr. Wilkerson: And give the figures as to the number of deaths from different diseases.

Mr. Adcock: The doctor makes a report of the cause of death, and so on.

Mr. Wilkerson: I assume they are statistics compiled from the death certificates.

Mr. Austrian: And the reports are made to the Council, on the proceedings, and in the State courts would be competent without oral proof; might not be in the Federal courts.

Mr. Wilkerson: So far as what they show is concerned,

depends entirely on the statement of the doctors as to the cause of death.

Mr. Adcock: There may be some percentage of error.

Q. Answer the question now.

Have you those documents before you?

A. Yes.

Q. With those before you, kindly state the figures making up the compilations, and the summaries and deductions and conclusions that you make therefrom.

A. The basal statement we find is a statement that shows the death rate per 100,000 population of the City of Chicago for the years 1887 to 1912 inclusive. This statement is divided into periods of 13 years, being 13 years prior to and 13 years subsequent to the opening of the Drainage Canal. This basal statement gives, first, the deaths per 100,000 of population from all causes by years.

Q. That is in the first column?

A. That is in the first column.

Q. The second column gives what?

A. It then gives the deaths from typhoid fever. Third, the deaths from diarrheal diseases. Do you desire these to be mentioned?

Q. Yes.

A. The deaths from tuberculosis, the deaths from pneumonia, the deaths from bronchitis, the deaths from influenza, the deaths from diphtheria and croup, deaths from scarlet fever, deaths from tuberculosis of the lungs, deaths from measles, deaths from whooping cough, deaths from smallpox, deaths from Bright's disease, deaths from heart disease, deaths from cancer, deaths from violence, and deaths from tuberculosis other than pulmonary. And to this is another column added, deaths from all causes in children under five years.

Q. Have you an extra table there of the ones just read?

A. Yes, except that the heads of diseases are not indicated on that second sheet.

Mr. Adcock: Perhaps we had better just offer this in evidence and I will furnish you with a copy of it.

Q. As I understand it, those are tabulations which you have made from the records of the Health Department of the City of Chicago?

A. Yes, sir, they are copies; I could give you the pages of the report they are taken from, if desired.

Q. Of those different diseases which you have mentioned,

what are ordinarily called water-borne diseases and what are air-borne diseases?

Mr. Wilkerson: As bearing upon the competency of this testimony—of course this is a question we will have to argue at the hearing,—I do not know what the purpose of this may be; I do not know what importance may be attached to it at the hearing. If the purpose of this line of testimony is to demonstrate the duty of a city to furnish a pure water supply, the Government concedes that. The Government will concede, claiming, however, if a method is adopted which interferes with navigation, the local authorities can adopt that method only with the concurrence of the Federal authorities. If that is all there is to it, to demonstrate the necessity of a pure water supply, we have no issue.

Mr. Austrian: Will you make the further concession that by adopting this method the City of Chicago has given to its population a pure water supply.

Mr. Adcock: And by the only way it could.

Mr. Wilkerson: We will contend they adopted a method they had no right to adopt, until they had the concurrence of the Federal authority. And we have the evidence in the case, produced by the defendant, which we think amply demonstrates that the water supply could have been purified in a way in which commerce would not be interfered with.

Mr. Austrian: I do not believe you are making any point that those figures are not accurate.

Mr. Wilkerson: I am not making any point one way or another on that, until we have a chance to look them over.

Mr. Austrian: You are not making any objection to the method of introducing these tabulations, instead of introducing the original figures.

Mr. Wilkerson: No, we will check your compilations.

Mr. Adcock: This may be marked "Adams' Exhibit 1."

(Document identified by the witness and offered in evidence was marked Adams Exhibit 1, and here follows:)

ADAMS EXHIBIT ONE.

2—CHICAGO.

Death rates per 100,000 of population.

Years.	All Causes.	Typhoid Fever.	Diarrheal Diseases.	Tuberculosis.	Pneumonia.	Bronchitis.	Influenza.	Diphtheria and Croup.	Scarlet Fever.	Tuberculosis of the Lungs.	Measles.	Whooping Cough.	Small-pox.	Bright's Disease.	Heart Disease.	Cancer.	Violence.	Tuberculosis other than Pulmonary.	Children under 5 years.
1887	2027	50.3	477.6	202.6	132.6	99.2	.....	184.9	25.0	180.7	44.9	13.9	.3	42.1	72.2	39.6	126.8	22.0	996
1888	1965	46.7	487.2	201.3	137.7	102.5	.....	161.6	22.9	182.1	18.8	22.8	.....	41.1	77.1	45.0	110.5	19.2	939
1889	1812	48.4	465.6	181.0	125.0	87.3	0.1	161.4	19.8	164.9	21.8	10.3	.2	39.9	71.0	40.5	104.4	16.0	878
1890	1987	91.6	471.5	201.9	188.5	108.1	10.2	114.7	17.5	182.8	6.1	18.3	.....	46.3	74.2	41.9	130.4	19.2	899
1891	2416	173.8	585.3	208.9	251.8	130.1	1.7	118.2	43.4	184.5	23.1	16.9	.....	51.7	80.9	47.4	128.8	24.4	1097
1892	2185	124.1	508.6	198.6	199.8	108.6	8.6	129.0	31.8	182.3	15.4	13.7	.2	50.8	88.2	44.9	138.4	16.3	972
1893	2161	53.5	512.6	211.2	196.1	111.4	7.0	117.1	26.3	188.5	18.7	16.8	1.8	60.1	88.3	48.6	151.7	22.7	986
1894	1826	37.5	445.5	191.0	116.1	90.5	3.9	106.4	14.5	167.4	13.9	16.0	78.9	52.0	79.3	48.8	118.4	23.5	842
1895	1772	37.9	372.7	180.2	172.6	82.9	12.1	120.1	5.6	159.1	11.4	8.9	11.5	51.3	99.8	49.9	108.3	21.1	765
1896	1629	52.6	337.2	186.8	150.0	81.6	1.2	76.2	3.8	162.4	5.1	13.1	.....	57.3	90.3	51.4	108.7	24.4	680
1897	1463	29.3	278.2	172.6	144.3	68.8	1.0	51.9	5.4	146.4	9.3	10.7	.1	62.8	91.6	49.8	99.7	26.3	574
1898	1464	40.8	241.5	181.7	159.1	63.9	18.0	43.7	4.3	155.2	3.5	13.4	.....	67.5	89.8	50.8	97.4	26.5	523
1899	1568	27.2	253.5	178.9	211.4	62.3	19.1	56.4	32.8	154.7	10.3	4.7	.1	72.6	91.7	54.7	97.5	24.2	546
1900	1468	19.8	216.2	173.9	199.5	65.1	9.4	49.5	13.3	153.0	11.4	16.8	.1	65.7	111.4	56.2	97.3	20.8	487
1901	1397	29.1	211.3	164.0	178.5	49.4	11.5	29.4	9.4	142.4	9.0	11.8	.2	57.9	111.1	57.2	99.9	21.6	428
1902	1473	44.5	201.0	165.4	190.6	54.3	6.6	34.8	24.7	141.9	6.8	14.8	.3	69.8	116.5	59.6	104.9	23.5	446
1903	1562	31.8	194.6	182.5	250.1	54.3	9.0	34.4	16.0	155.0	14.9	14.6	2.5	81.9	113.0	57.4	139.9	27.5	447
1904	1410	19.6	177.7	186.5	217.8	44.0	6.0	21.5	7.5	164.8	2.5	5.9	1.5	97.3	107.5	59.2	106.0	21.7	371
1905	1413	16.9	192.5	188.8	184.1	43.5	7.9	22.2	4.1	164.6	11.9	18.4	3.1	103.5	108.3	61.1	108.3	24.2	438
1906	1453	18.5	197.0	192.0	202.5	36.3	6.0	27.7	24.7	161.3	6.4	8.4	.....	106.5	109.8	66.5	111.6	30.7	440
1907	1572	18.2	195.4	197.2	232.1	38.4	11.6	27.1	35.1	171.5	12.8	12.0	.05	121.9	113.2	75.1	121.6	25.7	492
1908	1449	15.8	202.3	186.7	167.4	37.6	15.9	26.5	19.6	163.0	8.1	6.4	.....	102.0	128.1	74.9	118.1	23.7	459
1909	1458	12.6	171.1	181.0	219.6	6.8	8.7	31.7	17.2	155.9	7.7	6.5	.....	105.9	147.4	76.7	126.5	25.1	436
1910	1514	13.7	177.2	178.0	240.8	7.8	6.6	37.4	18.4	153.3	8.7	7.9	.05	113.9	151.4	82.3	116.2	24.7	461
1911	1455	10.9	147.0	166.0	219.6	4.0	5.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	409
1912	1482	7.5	149.7	163.5	220.4	4.7	2.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	436

Mr. Adcock: Q. I asked you which of these were commonly known as water-borne diseases and which were impure air diseases?

A. The water-borne diseases are the typhoid fever and the diarrheal diseases, intestinal diseases in general. The impure air diseases are tuberculosis, pneumonia, bronchitis, influenza, grippe, and things of that kind.

Q. What is the difference in the death rate from typhoid fever during the latter period as compared with the earlier period; and by the latter period I mean from 1900 to 1912, and by the former period I mean from 1887 to 1899, both years inclusive, as appears in that compilation.

A. The average death rate per 100,000 population in the period prior to the opening of the Drainage Canal.

Mr. Wilkerson: When was your canal opened?

Mr. Adcock: January, 1899.

Mr. Wilkerson: I object to this on the ground that is not a proper basis of comparison.

The Witness: The average was 62.7. The average for the period subsequent to the opening of the canal was 19.9, showing a reduction in the death rate per 100,000 population of 41.8.

Q. And that is the reduction in the death rate from typhoid fever?

A. Yes.

Q. Between the two periods?

A. Per 100,000.

Q. Per 100,000 of inhabitants?

A. Yes. I might say in the subsequent computations, I used that figure 20 instead of 19.9, just to get rid of the fraction.

Q. And compared the death rate in other diseases, water-borne diseases?

A. With the air-borne diseases.

Q. Before and after the opening of the canal, other water-borne diseases?

A. I should have to furnish that to you. It requires adding. That can be done from the figures here given. I have not worked that out.

Q. Has there been a reduction or an increase in the death rate of water-borne diseases since the opening of the Canal as compared with the period of time which you have mentioned prior to the opening of the Canal?

Mr. Wilkerson: Which particular diseases?

Mr. Adcock: Water-borne diseases.

A. There has been a marked decrease in the death rate in water-borne diseases.

Q. Varying from 25 to as high as 45 per cent., in round figures?

A. Yes, sir.

Q Per 100,000 of population?

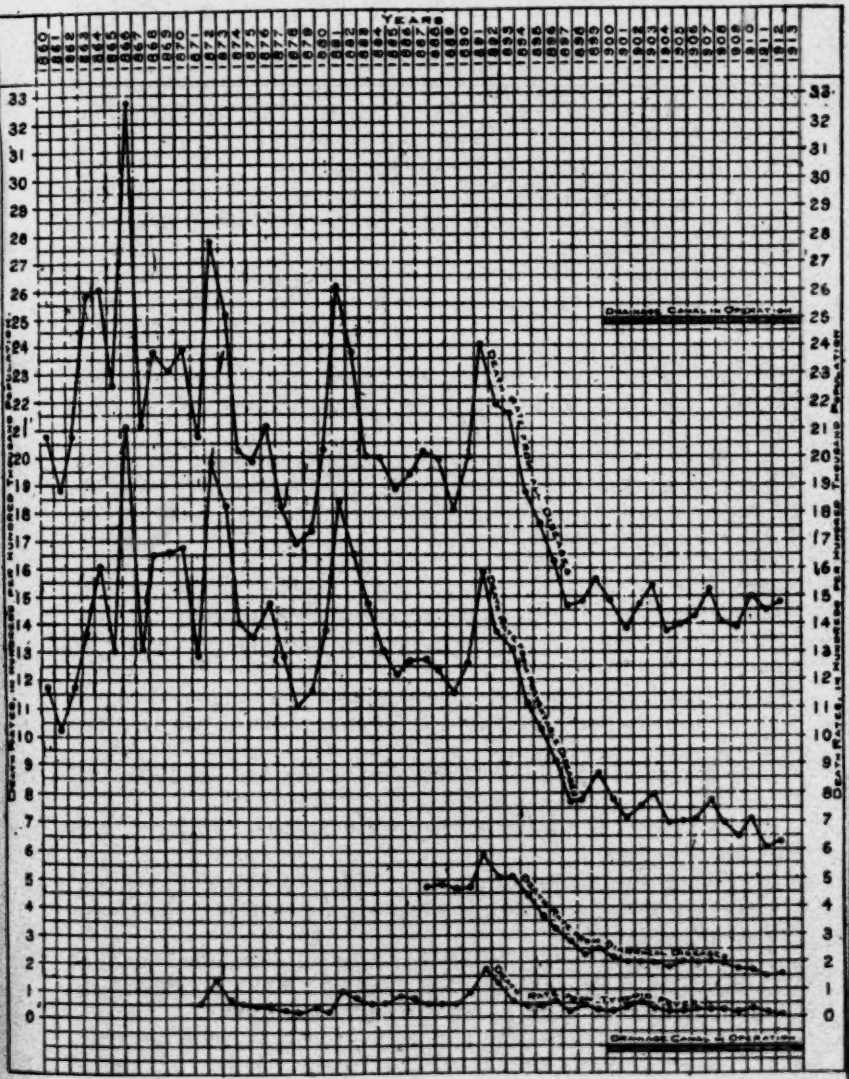
A. And the comparison of that with the air-borne diseases shows that there has been very slight decrease in the air-borne diseases during the same period.

Q. About 6 per cent.?

A. The decrease in the water-borne diseases is 56.9 per cent. and the decrease in the air-borne diseases, computed in the same way, is 6.1 per cent.

Mr. Adcock: I ask that the paper which is presented to the Commissioner be marked "Adams' Exhibit 2."

(Document referred to was marked "Adams' Exhibit 2," and here follows:)



ADAM'S EXHIBIT 2.

Q. Will you explain that exhibit and its compilation?

A. This table presents the death rate in the City of Chicago in a diagrammatic way, the usual curves being adopted; and the table covers from 1860 down to 1912, 1913. The lines represent the death rate from all causes; that is the top line on the diagram. The second line represents the death rate from what is termed "preventable diseases."

The third line is the death rate, the curve from the diarrheal diseases. And the fourth line is the death rate from typhoid fever.

The readings from the table, or the significance of the table is that Chicago, prior to the opening of the Drainage Canal, has always been subject to epidemics. Thus, the curves rise for all diseases to 1866, 1872, 1881, 1891; and fall after the epidemic of 1891; and instead of a recurrence of an epidemic in 1901, the curve shows that the diseases have been brought under some degree of control.

It should be said in explanation of the curve subsequent to 1891, that at that time, shortly after that epidemic, the intake of water was extended in the lakes by putting the cribs out, I believe about four miles.

Mr. Wilkerson: What year was that?

Mr. Austrian: After 1891.

The Witness: It was after that epidemic of 1891.

Mr. Wilkerson: Is this a fact you want to prove in this case?

Mr. Austrian: No, that is so you may not be misled in any way by his answer. In fairness to you, he tells you that the intakes were moved.

The Witness: But the Drainage Canal came in 1901, and since then the curves have been fairly constant.

Mr. Adcock: Q. That is, they have followed straight lines to a large extent?

A. With slight variations they follow a straight line, but the curve for the preventable diseases is constantly declining, dropping, since 1901.

Mr. Wilkerson: Q. What diseases are included in that classification, "Preventable Diseases"? That is, where do we get the figures from which the curve is drawn?

A. I take my authority for answering that question from the Report of the Department of Health, page 109, where the list is as follows: Asiatic cholera, diphtheria and croup, diarrheal disease, measles, pneumonia, bronchitis, puerperal fever, typhoid fever, typhus fever, whooping cough, erysipe-

las, influenza, malarial fever, scarlet fever, smallpox, tuberculosis.

Mr. Adcock: Q. Is there a curve there for typhoid fever? Will you state the conditions of that curve?

A. Yes, there is a curve for typhoid fever in this diagram, but the diagram is drawn to so large a scale that hardly appears as a curve. The figures themselves in the second column of Exhibit 1 will give you a better indication of the movement of the death rate in typhoid fever.

Mr. Adcock: Q. I will have a blueprint made, which the Commissioner can mark, in lieu of the paper that has already been marked as Adams' Exhibit 2.

I ask that the paper which I now hand the Commissioner be marked "Adams' Exhibit 3."

Paper referred to by counsel was marked Adams' Exhibit 3, and here follows:

ADAMS' EXHIBIT 3

6.

COURSE OF THE DEATH RATES
FROM IMPURE WATER DISEASES AND IMPURE AIR DISEASES:
CHICAGO, 1887-1912.

COMPARISON OF TWO THIRTEEN-YEAR PERIODS.

Death-Rates per 100,000 Population.

Year	IMPURE AIR DISEASES (Tuberculosis. Influenza. Pneumonia. Bronchitis.) Total	IMPURE WATER DISEASES. Typhoid and Diarrheal Diseases.
1887	434.5	527.6
1888	441.5	533.9
1889	393.4	514.0
1890	508.7	563.1
1891	593.1	758.1
1892	515.6	623.7
1893	525.7	566.1
1894	401.5	483.0
1895	447.8	410.6
1896	419.6	389.8
1897	386.8	307.5
1898	422.7	282.3
1899	471.8	280.7
1900	447.8	236.0
1901	403.4	240.4
1902	416.8	245.5
1903	495.9	226.4
1904	454.3	197.3
1905	424.3	209.4
1906	436.8	215.5
1907	479.4	213.6
1908	407.6	218.1
1909	416.1	183.7
1910	433.2	190.9
1911	394.8	157.9
1912	391.4	157.2
Average Rate.		Average Rate.
1887-1899	458.7	480.7
1900-1912	430.9	207.1
Decrease	27.8	237.6
Per Cent Decrease	6.1%	56.9%

Q. Will you state what that exhibit is and explain its significance?

A. This Exhibit 3 is a comparison for the two periods already described of the death rate per 100,000 population from impure air diseases and the impure water diseases. The percentage result of that comparison has already been given. The average decrease in the death rate for impure air diseases is but 27.8 per 100,000 population, whereas, for the impure water diseases, the decrease on a comparison of the average for the two periods, is 237.6, showing a decrease of 6.1 per cent. in the impure air diseases and 56.9 per cent. in the impure water diseases.

Q. Does the death rate from typhoid fever bear any relation to the death rate from other diseases; if so, will you state what the relation is, and what other diseases may be considered in that relation?

A. It is a well established fact, as shown by the statistics of cities before and after the introduction of the improvement of water supply, that the decrease in the death rate of the particular diseases held in mind, and usually this is typhoid fever, is accompanied by a corresponding decrease in the death rate of other diseases. And typhoid fever is commonly accepted as the basis from which to measure the general effects of the improvement of the water supply.

This relationship is what is known as Hazen's Theorem or Hazen's Law. It is universally conceded that the improvement that is reflected in typhoid conditions must be multiplied by some figure in order to get the general improvement in the health conditions of the community.

Q. That is, that the same causes which might effect an improvement in typhoid fever conditions would effect an improvement in other diseases and cause a less death rate in a certain proportion, is that it, a certain ratio?

A. Yes, sir. Here is a statement of Hazen's Theorem as given by himself, he says: "Where one death from typhoid fever has been avoided by the use of pure water, a certain number of deaths, probably two or three, from other causes have been avoided."

Q. Where is that to be found?

A. All my information on this point is taken from an article by W. T. Sedgwick, who is Professor of Biology at the Massachusetts Institute of Technology, and J. Scott McNutt, Health Officer, New Orange, New Jersey, published in the Journal of Infectious Diseases, 1910.

Q. Are they considered recognized authors on that subject?

A. I think Professor Sedgwick is a recognized authority upon this matter in the United States. It was for the purpose of testing the accuracy of Hazen's Law that Sedgwick and McNutt undertook this investigation in American cities.

Q. And how long has Hazen's Theorem, that you have referred to, been recognized as such?

A. I am not sure that I can answer that correctly. My remembrance is that he promulgated this theorem in a paper he read at the time of the St. Louis Exposition, before The International Congress of Learned Societies.

Mr. Wilkerson: Who is Mr. Hazen, what are his initials?

A. He is the Sanitary expert or engineer in New York City.

Mr. Adcock: I ask that the paper I hand the Commissioner be marked "Adams' Exhibit 4."

(Paper referred to by counsel was marked "Adams' Exhibit 4" and here follows:)

ADAMS' EXHIBIT 4

Distribution of Deaths from Typhoid Fever, by sex and age.
Chicago, 1912.

Age	Males	Per Cent of all Deaths of Males	Females	Per Cent of all Deaths of Females	Both Males and Females	Per Cent of all Deaths
1- 5	5	4.27%	4	6.8	9	5.1
5-10	5	4.27	7	11.9	12	6.8
10-20	18	15.4	13	22.0	31	17.6
20-30	42	35.9	20	33.9	62	35.2
30-40	22	18.8	10	16.9	32	18.2
40-50	18	15.4	2	3.4	20	11.4
50-60	5	4.27	1	1.7	6	3.4
60-70	2	1.7	1	1.7	3	1.7
70-80			1	1.7	1	.6
All ages	117	100.0	59	100.0	176	100.0

Males constitute 66.5% of all deaths, females 33.5%.

(Data taken from the records of the Chicago Department of Health.)

Mr. Adcock: Q. Will you explain that exhibit and state what it shows?

A. Which exhibit is that?

Q. Exhibit 4, the Distribution of Deaths from Typhoid Fever, by sex and age?

A. This exhibit shows the distribution of deaths from typhoid fever by sex and by age. The sex classes are under

5, from 5 to 10, from 10 to 20, from 20 to 30, from 30 to 40, from 40 to 50, from 50 to 60, from 60 to 70, from 70 to 80.

The third column of the exhibit shows the percentage of the total diseases borne by males at the various ages named. The significance, or the bearing of the table upon the question of the loss that might be suffered by a city in the absence of proper preventive causes for typhoid fever is that a large percentage of diseases from typhoid fever is suffered by males than females; and that the age when typhoid fever is likely to result fatally for males is between the age, as shown here, between the age of 10 and of 60. Closer figures will show that between the age of 17 and 18 and 55 60-5/10 per cent. of all deaths are male and 33.5 female. The figures here are taken from the records of the Chicago Department of Health.

Q. That is, you mean the figures upon which you base your arithmetical conclusion?

A. The figures that appear in the exhibit.

I would add that the figures in this exhibit influenced me in choosing the multiplier in the application of Hazen's Law.

Mr. Adcock: Q. I ask that the paper which I now hand the Commissioner be marked "Adams' Exhibit 5."

(Document referred to was marked "Adams' Exhibit 5," and here follows:)

ADAMS' EXHIBIT 5.

II.

DECREASE IN VARIOUS DEATH-RATES SINCE THE DRAINAGE CANAL WENT INTO OPERATION.

Comparison of Two Thirteen Year Periods: (1887–1899) and (1900–1912) Death-rates per 100,000 Population.

CAUSE	Decrease in Death-rate (1887–1899) (1900–1912)	Per Cent Decrease (1887–1899) (1900–1912)	Number of Deaths Prevented from cause named for every death Prevented from Typhoid
All Causes.....	398	21.3	9.3
Preventable Diseases.....	418	36.9	9.8
Impure Water Diseases (as recognised by Chicago Dept. of Health).....	274	56.9	6.4
Impure Water Diseases (as recognised by Sedgwick and MacNutt).....	‡290	31.8	6.8
Diarrheal Diseases.....	231	55.2	5.4
Typhoid Fever.....	42.7	68.2	....

‡1887–1899 compared with 1900–1912.

Mr. Adcock: Q. Will you explain that exhibit?

A. This exhibit is one designed to show the decrease in the various death rates since the Drainage Canal went into operation; first, from all causes; second, from the Preventable Diseases, and third, from the impure water diseases, as recognized by the Chicago Department of Health. Fourth, from the impure water diseases as recognized in the work of Sedgwick and MacNutt. Fifth, the diarrheal diseases. Sixth, the typhoid fever.

In the last column in that exhibit will be found the ratio between the decrease in the deaths from typhoid fever and the various other diseases.

It is introduced also as having a bearing upon the choice of the multiplier in the application of Hazen's Law to Chicago.

Q. Will you state what territory, and the population, that will necessarily be affected by good health or bad health conditions in Chicago, that is, from an economic standpoint.

A. I recognize in the application of the foregoing facts to Chicago at least three territories with distinct population. The first is the municipality of the City of Chicago. This is the narrowest possible conception of Chicago as a center of population. This is the unit that has bonded itself for part of the investment of the Drainage Canal and I have accepted as the population—part of this of course must be estimated for the last two or three years—present population 2,300,000.

Q. Is that the City of Chicago or the Sanitary District?

A. That is the City of Chicago, the political unit. That is the people here that eat, sleep and work in the city.

The second territory is that which I call the outlying districts; the people who have business in the City of Chicago, but who go out at night to the suburban districts, and for whom health conditions in the City of Chicago are of perhaps as vital importance as to the people who live in the city. There was some difficulty in arriving exactly at the territory to be covered by this second district, but I accepted what is called by the Chicago Association of Commerce, the Manufacturing Zone of Chicago. I have here a map of that zone.

Mr. Adcock: Let it be marked "Adams' Exhibit 6."

(Paper referred to by witness was marked "Adams' Exhibit 6," and here follows:)

More than $60,000,000 is being annually expended in industrial enterprises within this manufacturing district.

The death rate of Chicago is lower than any American city having 200,000 or more inhabitants.

Being the center of the food supply of the country, the cost of living is correspondingly low.

No hills to make the transference of freight unusually burdensome.

Unlimited water and electric power at exceptionally low rates.

Longest electric subway freight railway in the world.

Rate of taxation far below the average of American cities.

Sidetrack facilities are easily and economically secured.

The manufacturing zone is large and sites are abundant.

Street car facilities are unequaled by any city of the United States.

Commercial banking resources are larger, in proportion to population, than in any other city of the country.

Best transportation facilities of any city in the world; 40 freight handling railroads, river and canals.

Nearer to every variety of raw material than any other city in the United States.

No extremes of temperature ever cause a temporary suspension of indoor labor.

Annual value of manufactured products, $1,250,000,000.

Center of population of the United States.

Labor abundant and conditions stable.

No floods.

The Witness: (Continuing) This is the territory for which the Chicago Association of Commerce assumes some definite responsibility, and the manufacturing interests within this district are cared for by the association in the same way as the manufacturing interests within the political unit known as Chicago. I have accepted that as evidence of the interdependence of life and commercial interests, their mutuality, in this district.

In the third, there is a large population lying outside even of this district, which is indirectly affected at least because of Chicago's position as a primal market; that is, there is a well recognized territory over which the commercial interests of Chicago have a more or less defined influence. The difficulty arises, of course, in defining strictly this territory, and I have not attempted to do it. For the meat industry, the territory would be defined in one way; for the wheat industry, another; for the jobbing trade, still another; and then for various classes of jobbing and so on. It became so complicated in trying to do that, that I abandoned the attempt; and I may say that I made no use of the population lying in this district, outside of the manufacturing zone of the City of Chicago. But I venture to suggest that any estimate of the loss through the impairment of water supply would be greater than the estimate confined to the municipality or the manufacturing zone, although it is not perhaps capable of absolute measurement.

Q. Professor Adams, have you examined the testimony of Mr. Livingstone, given on behalf of the complainant in this case?

A. Yes, sir.

Q Directing your attention to his estimate of loss to the lake navigation by the opening of the Drainage Canal, and assuming that it is 6 inches in water level loss, have you any comment that you desire to make with reference to his computation?

A. Yes, sir, I have two comments.

Q. Will you make them.

A. In the first place, I doubt if his theory of computing the loss is a satisfactory theory.

Q. By satisfactory you mean a sound theory?

A. A sound theory.

Q. He computed the annual loss at $4,387,500, assuming a depression of the normal lake level of 6 inches. Is that correct?

A. Yes, sir.

Q. Will you state wherein you think his computation or conclusion is inaccurate, and not based upon a sound theory?

A. You have reference now to the theory of the computation?

Q. Of the computation.

A. I understand from the testimony of Mr. Livingstone, that having determined the amount of load that could not be carried because of the level of the water, that he multiplied that loss of load by the rate for carrying the ore—and this is confined to ore—and claimed that that was their loss, without taking into consideration the increased expense incident to that increased freight carried. And I cannot conceive that you could put in a large amount of tonnage into a boat, without increasing in some degree at least the cost of carriage.

Q. What is the second comment.

A. My second comment is that some of the assumptions of Mr. Livingstone, even in applying his theory, are assumptions that do not seem to hold upon an investigation of the transportation on the lakes.

Q. To what do you refer generally, without going into detail?

A. I think I should agree with Mr. Livingstone in confining this loss to ore. I think the analysis of lake traffic will support that proposition.

Q. That is, when you say confining it to ore, deep draught vessels that he refers to in his testimony are ore-carrying vessels?

A. They are ore-carrying vessels, and the conditions of carrying other commodities, with the possible exception of grain—and I should hardly except that—is such that the change in the lake level would not materially affect the situation. But I should disagree with the testimony in the assumption of the average number of trips per vessel. In Mr. Livingstone's estimate, he claimed that every vessel made on an average 20 trips in a season. In Mr. Coulby's testimony, as I remember it, although he did not estimate the loss, he claimed for the Pittsburg Steamship Company 25 trips a season.

Now, my investigation of the trips of the vessels covered by what is known by the "Red Book," the vessels represented by the Lake Carriers Association shows that the average number of trips for all those vessels is but 11.6.

Q. And from what source did you obtain the statistics upon which you arrived at the figures 11.6?

A. Before answering that might I add, so as not to be confused, that in the Pittsburg Steamship Company it is higher, and also in quite a number of the fleets other than the Pittsburg Steamship Company the average would be higher than 11.6.

Q. But that is the entire average of all vessels included in the "Red Book"?

A. Yes.

Q. The Red Book constituting all vessels belonging to the Lake Carriers Association the average is 11.6?

A. Yes.

Q. Do the records show the average number of trips of each vessel; that is, you have calculated the average number of trips from the records at the Soo. Is that correct, Professor?

A. Yes, sir, I took an account of every boat that went through the St. Mary's Canal for the year 1912.

Mr. Wilkerson: Q. Without regard to whether its draught was so large it would be affected by this change of 6 inches, or not?

A. I excluded from the compilation, in order to arrive at the averages that I have stated, such things as towboats and lighters and all that class of boats. The boats covered by the averages stated are boats carrying freight.

Mr. Austrian: And are the same boats included in the list of boats upon which Mr. Livingstone arrived at his figure of 20 average trips.

Mr. Wilkerson: It may be or may not.

Mr. Adcock: Q. Mr. Adams, there was a federal statute passed February 21, 1891, which required the compilation of this data, was there not?

A. Yes, sir.

Q. And a form prepared by the federal department for the purpose of recording and making note of the data?

A. Yes, sir.

Q. You have one of those forms here present, or several of them?

A. Yes, I have one for the up trips and one for the down trips.

Q. Those are the two documents which I now show you, are they not?

A. Yes, sir.

Mr. Adcock: We will offer these in evidence as Adams' Exhibit 7 and 8.

(Papers identified by the witness were marked Adams' Exhibit 7 and 8, and here follow:)

E31(a)

ADAMS' EXHIBIT 7.

(Public—No. 92.)

An act to facilitate the collection of commercial statistics required by section 2 of the river and harbor appropriation acts of eighteen hundred and sixty-six and eighteen hundred and sixty-seven.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That owners, agents, masters and clerks of vessels arriving and departing from localities where works of river and harbor improvement are carried on shall furnish, on application of the persons in local charge of the works, a comprehensive statement of vessels, passengers, freight and tonnage.

Sec. 2. That every person or persons offending against the provisions of this act shall, for each and every offense, be liable to a fine of one hundred dollars, or imprisonment not exceeding two months, to be enforced in any district court in the United States within whose territorial jurisdiction such offense may have been committed.

Approved February 21st, 1891.

Trip No. _____

Statement of Traffic
Passing Through
St. Mary's Falls Canal

_____ 190____

From _____ _____

To _____ _____

Bound Down
(East)

Name and Class of Vessel _____

Draft of Water _____ feet _____ inches

Copper, tons _____

Grain, bushels (Corn, Oats, Rye, Barley, Flax Seed)_____

_____

Building Stone, tons _____

Flour bbls. _____

Iron Ore, tons _____

Iron, Pigs, tons _____
Lumber, M ft. _____
Silver Ore, tons _____
Wheat, bushels _____
Unclassified Freight, tons _____
Total Cargo, tons _____
Passengers, number _____

Clerk Master

N. B.—(All tons are "net" tons of 2,000 pounds except where otherwise specified.) Detroit March, 1905—30,000.

E31(b)

ADAMS' EXHIBIT 8.

(Public—No. 92.)

An act to facilitate the collection of commercial statistics required by section 2 of the river and harbor appropriation acts of eighteen hundred and sixty-six and eighteen hundred and sixty-seven.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That owners, agents, masters and clerks of vessels arriving and departing from localities where works of river and harbor improvement are carried on shall furnish, on application of the persons in local charge of the works, a comprehensive statement of vessels, passengers, freight and tonnage.

Sec. 2. That every person or persons offending against the provisions of this act shall, for each and every offense, be liable to a fine of one hundred dollars, or imprisonment not exceeding two months, to be enforced in any district court in the United States within whose territorial jurisdiction such offense may have been committed.

Approved February 21st, 1891.

Trip No. _____

Statement of Traffic
Passing Through
St. Mary's Falls Canal

_____ 191____

From _____ _____
To _____ _____

Bound Up
(West)

Name and Class of Vessel _____
Draft of Water _____ feet _____ inches
Coal, tons Soft _____ Hard _____
Grain, bushels (Corn, Oats, Seeds, Cut Feed) _____
Flour, bbls. _____
Manufactured Iron, tons _____
Salt, bbls. _____
Unclassified Freight, tons _____
Total Cargo, tons _____
Passengers, number _____

_____
Clerk Master

N. B.—All tons are "net" tons of 2,000 pounds, except where otherwise specified.

Detroit, April 12, 20,000.

Mr. Adcock: Q. And those documents when made out are recorded and filed at the Soo?

A. Yes.

Q. And it was those documents which you examined?

A. Yes, sir.

Q. And those are the documents which you referred to as having been the documents from which you made the compilation, additions, deductions and averages concerning which you have just testified?

A. That is true.

Q. You had finished that answer of yours, had you not, Professor?

A. No, sir. There is one point I should like to state as modifying somewhat my previous statement that the average was 11.6, the average number of trips. I separated these trips and vessels according as the report of the captain relative to draughts was less than 18 feet 10 or above 18 feet 10. If we confine the statement of the average trips to the boats which drew, on their down trip, those are the trips carrying

ore, 18 feet 10 or above, the average number of down trips for all vessels of this class is 14.12.

Q. That is, if you separate them?

A. And that is the figure which it seems to me should be placed in comparison with the assumption of Mr. Livingstone that the average number of trips per vessel is 20.

Q. What further comment, if any, have you to make upon Mr. Livingstone's method of ascertaining the loss?

A. Mr. Livingstone claims, as I understand him, that the Lake Carriers' Association, for which he speaks, covers about 7/8 of the vessels that would be affected by the reduction of the level, and adds, therefore, to his computation 1/8 for other vessels not in his Association.

Now, I do not find from the records of vessels passing through the St. Mary's Canal that there were more than 12 vessels carrying ore, and but six loads of wheat over 18 feet 10. Therefore it seems to me that ought not to be added, with this possible exception, that my figures do not take into consideration the transportation from port to port below St. Mary's Canal, as for example ore from Escanaba; but that is a relatively small amount.

Q. Professor, have you examined the testimony of Mr. Sadler, bearing upon this point?

A. Yes, sir.

Q. Do you concur in the view that he adopted?

A. I think the principle underlying his estimate is correct.

Q. State what that principle is?

A. That principle is that in estimating the loss due to decreased freight—

Q. Decreased carrying capacity?

A. Decreased carrying capacity, you must take into consideration operating expenses as well as the revenue. That is, if for any reason you increase the amount of freight carried, the gain is only the net gain, and not the gross gain.

Q. Professor, do any class of vessels benefit by the fact that these so-called deep draught boats do not carry at times, as they claim, full capacity?

A. I think so, yes, sir.

Q. What do you base that conclusion on?

A. I base that conclusion upon a comparative study of the various fleets, upon the fact that there seems to be classes of carrying capacity on the Great Lakes, and that there are

certain fleets that when things are slack take the freight and leave the other boats to do nothing.

Q. What class of vessels do you refer to?

A. Especially the Pittsburg Steamship Company's vessels.

Q. Do you know by whom they are owned?

A. They are owned by the Steel Corporation.

Mr. Wilkerson: Do you know that? I move to strike out the answer.

Mr. Adcock: Q. Upon what do you base that statement?

A. I base that statement on the report of the Commissioner of Corporations, on the Steel Industry; that being a Report issued under the authority of the Department of Commerce and Labor.

Q. What volume is it?

A. I don't know; I have got both volumes here.

Mr. Wilkerson: With great respect for the Government Reports, I still insist on my motion, because you cannot prove that fact even that way. I would not object if it had the slightest bearing upon any possible issue in this case. It has not the slightest bearing on any question involved in this case. There is no use putting it in the record.

Mr. Adcock: Inasmuch as the Government counsel has raised the question as to the competency of your testimony, I draw your attention to the testimony of Mr. Coulby, who is the President of the Pittsburg Steamship Company, to be found upon page 721 of the record in this case, in which he says that the "Pittsburg Steamship Company is a corporation organized under the laws of, I think the State of West Virginia. The United States Steel Corporation owns the stock." That was one of the elements that you took in consideration in arriving at your answer that it was owned by the Steel Corporation, is that correct?

Mr. Wilkerson: If the fact is proven in the record by competent evidence, what is the use of having somebody swear to it who is incompetent.

Mr. Adcock: Q. Professor, from a scientific view point, is there any method which you can adopt for the purpose of ascertaining the saving to a community annually by the reduction in the death rate and maintenance of the health of those constituting that community?

A. Yes, sir.

Q. Have you computed the saving to this community, and by this community I mean the community to which you have heretofore referred, by the reduction of the death rate and

diminished illness due, as you have testified, to the betterment of conditions surrounding the water in this Sanitary District?

Mr. Wilkerson: In addition to the general objection which we urge against that, we urge the specific objection that the matters embraced within the scope of that question are beyond the scope of that which the witness has qualified himself to speak with reference to, as an expert witness. It embraces elements that must necessarily be taken into consideration, that are outside the subject which he has stated he is competent to testify in regard to.

Q. (Last question read.)

A. Yes, sir.

Q. Is that a statistical question, or a question for a statistician or political economist, or a combination of both?

A. It seems to me to rest entirely upon statistical rules and principles, and upon ecomonic analysis.

Q. And are you familiar with those?

A. Yes, sir.

Q. Have you devoted years of study to them, taught them, lectured upon them, read upon them?

A. Yes, sir.

Q. Have you computed what that saving to this community is, Professor?

A. Yes, sir.

Q. Annually, I mean?

A. I computed the annual saving.

Q. Will you state how much that is?

Mr. Wilkerson: Are we to have the benefit of his methods?

Mr. Adcock: You can cross examine.

Mr. Wilkerson: Then I object to the question as incompetent, irrelevant and immaterial, and as calling for an improper conclusion of the witness.

A. I have expressed the figures that I have here in the language of loss rather than gain. But what I have to say is—

Q. Answer it in your own way.

A. As I have computed the loss that would be sustained by the City of Chicago and dependent population, were the present facilities for obtaining an adequate supply of pure water impaired or destroyed, based upon a comparative study of health statistics of the City for thirteen years before and thirteen years after the opening of the Chicago Drainage Canal, for the City of Chicago as a municipality.

Q. Upon the theory that it was 2,300,000 inhabitants, I take it?

A. Upon the assumption it has 2,300,000 inhabitants I computed it to be $17,899,000 a year.

Q. And on the theory that it had 2,100,000 inhabitants?

A. It would be proportional.

Q. The same proportion?

A. That is, this analysis is first made per 100,000 of population as a unit, and then for any population for any district, if can be computed.

Q. Will you give us the unit figure on 100,000?

A. The unit figure on 100,000 is $778,246. Now the Sanitary District, having a population larger than the City of Chicago will suffer an annual loss of $19,237,000. That is upon the assumption of a population of 2,472,000 for the Sanitary District.

Q. But whatever the population is, it would be a multiple of the unit you have given of 778,000 and some odd hundred dollars?

A. Yes, sir.

Q. This increased cost that Mr. Livingstone spoke of to the Pittsburg Steamship Company by reason of the claim of the lowering of the lake levels by the opening of the Sanitary District Canal, have you made any investigations for the purpose of ascertaining whether if that increased cost were removed, the consumer of the steel products would obtain the benefit thereof?

A. Yes, sir.

Q. What investigations, if any, have you made?

A. I have studied the position of the United States Steel Corporation in the general conditions for the manufacturing of steel products, and come to the conclusion that they held rather a dominating influence; and further have compared the courses of prices of steel products before the organization of the Steel Corporation and after the organization of the Steel Corporation, and find that in my judgment they have been pretty steady, or that they have not been subject to competitive influences, and that the prices have not been reduced to the consumer.

Mr. Wilkerson: I move to strike out the conclusion and finding of the witness for every reason that can possibly be assigned as objection to an answer. I know of no rule that is not violated by that answer.

Mr. Adcock: Q. Have you any diagrams or data which

have been prepared which will show the prices before and after the organization of the Steel Corporation?

Mr. Wilkerson: I object to this entire line of testimony, not only as incompetent, but also as to the manner in which it is attempted to prove these facts.

A. The diagrams that I have are taken from the transcript of the record in the District Court of the United States for the District of New Jersey, United States of America vs. The United States Steel Corporation and others.

Q. And those appear in the testimony of Mr. Walker who made those—

A. Who was the Government's witness in this case, and Mr. Walker is the—

Q. Is the statistician who prepared those charts?

A. I think he is the deputy commissioner of corporations at the present time, of the Bureau of Corporations.

Q. Will you refer to the different charts there which you have in mind, and the page of the record on which they appear?

A. Yes, sir.

Q. And state what those charts and diagrams show?

A. The first chart that I selected was chart numbered 1652 in the record. It shows the average monthly prices of Bessemer pig iron and Bessemer billets at Pittsburg, and heavy Bessemer rails at mills in Pennsylvania. It is a chart made upon the tables appearing in this record, 5, 6 and 7.

Q. And it is Walker Government Exhibit No. 245, date November 19, 1912?

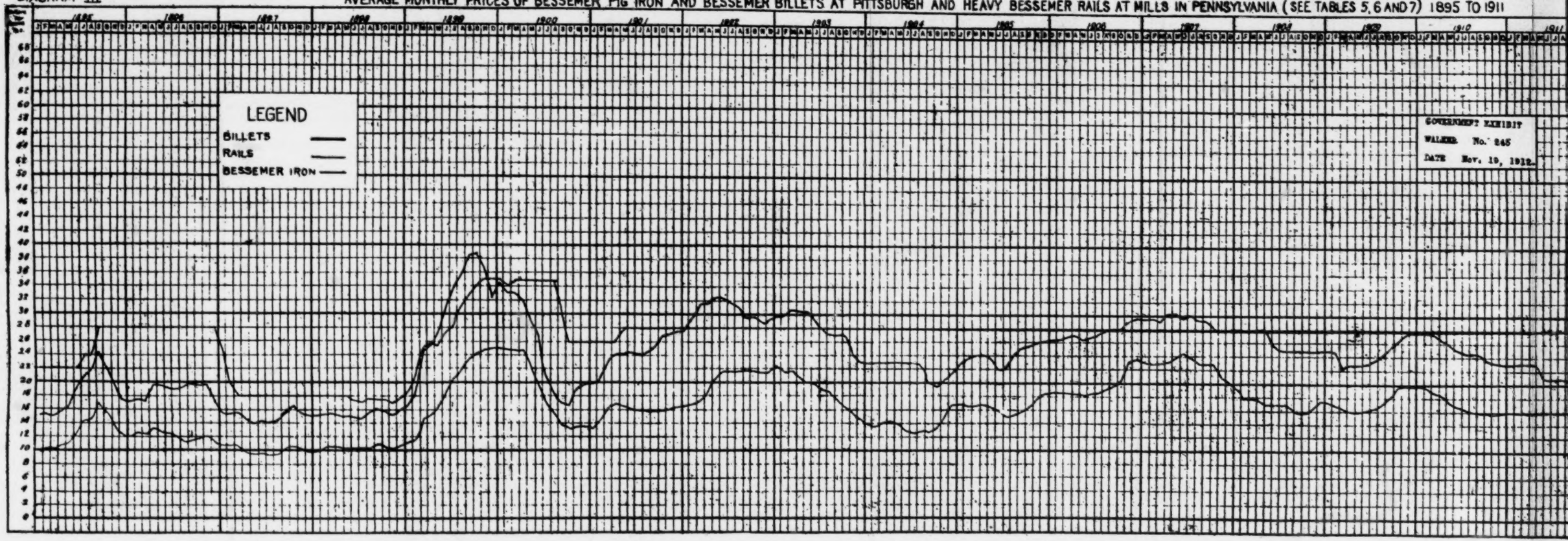
A. Yes.

Mr. Adcock: This will be Adams Exhibit No. 9 in this case.

(Document identified by the witness is marked Adams Exhibit No. 9 and here follows:)

DIAGRAM III

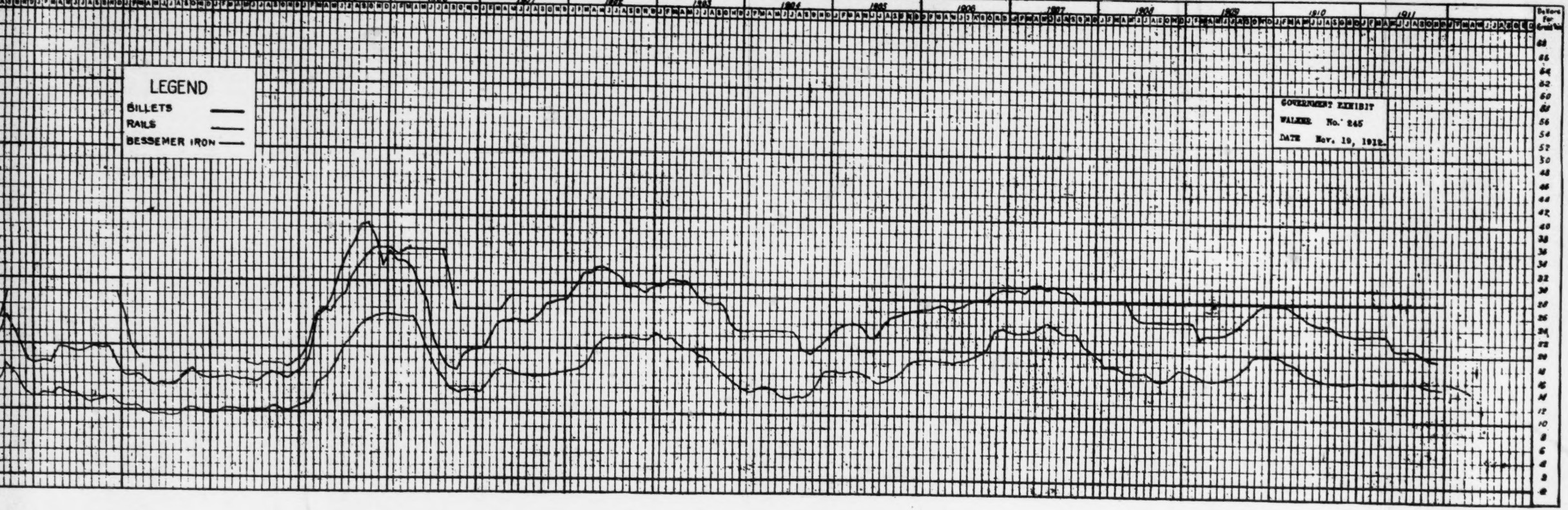
AVERAGE MONTHLY PRICES OF BESSEMER PIG IRON AND BESSEMER BILLETS AT PITTSBURGH AND HEAVY BESSEMER RAILS AT MILLS IN PENNSYLVANIA (SEE TABLES 5, 6 AND 7) 1895 TO 1911



III

AVERAGE MONTHLY PRICES OF BESSEMER PIG IRON AND BESSEMER BILLETS AT PITTSBURGH AND HEAVY BESSEMER RAILS AT MILLS IN PENNSYLVANIA (SEE TABLES 5, 6 AND 7) 1895 TO 1911

Adams' Exhibit 9



Mr. Wilkerson: This is all subject to objection, exhibit and all.

Mr. Austrian: I understand if the evidence is material, that you do not object on the ground we are introducing it without producing Mr. Walker.

Mr. Adcock: If you want us to produce Mr. Walker—

Mr. Wilkerson: No, I am perfectly willing that the chart may be treated as if Mr. Walker said here what he said in that case about having made it. I do not insist on your bringing him here; but I insist that from any standpoint it has no bearing whatever upon any issue presented in this case. It is perfectly inconceivable that the question of interference with navigation should be even remotely connected with the increase in the price of steel.

Mr. Austrian: The reason why we are offering this testimony, and I state it in the record, is because in the Government's case they undertook to prove that by reason of the alleged lowering of lake levels the cost to the consumer of the product so carried was increased; and the main product referred to was ore and steel.

The Witness: This diagram shows that for steel rails the curve is a straight line from March, 1901.

Mr. Adcock: Q. Up to and including 1912?

A. Up to and including December, 1911.

Q. That is, they were $28 a ton?

A. The rails were $28 a ton.

Q. Every day and every month in the year of each year?

A. Yes, sir; that the other commodities named fluctuated, but they do not fluctuate as violently as they did prior to 1901, the date of the organization of the Steel Corporation.

Q. Will you indicate in the record what those fluctuations disclose as to higher or lower cost of the products referred to?

A. The diagram indicates that the fluctuation in billets and Bessemer iron was subject to about the same influences, whatever those influences may be; but that in neither case is the fluctuation as violent as prior to the formation of the Steel Trust, and they are on the average above the level prior to the formation of the Steel Trust.

The Table No. 1675—

Mr. Adcock: Appearing at page 1675 and being Government's Exhibit Walker No. 268, date November 20, 1912, in the case referred to.

A. That gives the price of steel rails in the United States and in England from 1895 down to and through 1911.

Mr. Adcock: That may be treated as Adams Exhibit No. 10. I will substitute a copy.

Mr. Austrain: Under the same stipulation.

Mr. Wilkerson: Yes.

(Table identified by the witness was marked Adams Exhibit 10, and here follows:)

ADAMS' EXHIBIT 10.

1675
Government Exhibit Walker No. 268
Date, Nov. 20, 1912

TABLE 52. Average Price of Heavy Steel Rails in England and in the United States, 1895 to 1911, by months (Dollars per Gross Ton).

	1895		1896		1897		1898		1899		1900	
	England	United States	England	United States	England	United States	England	United States	England	United States	England	United States
January.....	17.18	22.00	23.11	28.00	22.38	25.00	21.90	18.00	22.96	18.50	34.06	35.00
February...	17.03	22.00	23.11	28.00	22.50	20.00	21.90	18.00	23.11	20.25	34.37	34.20
March.....	17.27	22.00	23.11	28.00	22.05	18.00	21.90	18.00	23.23	24.80	36.01	35.00
April.....	17.64	22.00	22.50	28.00	21.90	18.00	21.90	18.00	24.48	25.75	37.40	35.00
May.....	17.64	22.00	22.14	28.00	21.90	18.00	21.90	18.00	24.94	25.20	37.71	35.00
June.....	17.64	22.00	21.90	28.00	21.90	18.00	21.90	17.50	25.30	27.25	37.10	35.00
July.....	17.64	24.00	21.90	28.00	21.90	18.00	22.14	17.00	30.26	28.25	36.50	35.00
August.....	18.25	24.00	21.90	28.00	21.90	18.00	22.50	17.50	30.41	31.00	35.16	35.00
September..	19.31	28.00	21.90	28.00	21.90	18.00	22.50	17.50	32.36	32.50	34.06	30.25
October....	21.13	28.00	21.90	28.00	21.90	18.00	22.50	17.50	32.85	34.00	34.06	26.00
November..	22.87	28.00	21.90	28.00	21.90	18.00	22.50	17.50	33.76	35.00	30.66	26.00
December...	23.11	28.00	21.90	28.00	21.90	18.00	22.50	17.50	34.06	35.00	28.89	26.00
Average..	18.89	24.33	22.27	28.00	22.00	18.75	22.17	17.63	28.14	28.13	34.67	32.29

	1901		1902		1903		1904		1905		1906	
	England	United States	England	United States	England	United States	England	United States	England	United States	England	United States
January.....	28.59	26.00	26.28	28.00	26.76	28.00	22.87	28.00	21.90	28.00	29.35	28.00
February...	27.67	26.00	24.63	28.00	26.76	28.00	21.90	28.00	23.72	28.00	30.11	28.00
March.....	25.79	26.00	25.70	28.00	26.76	28.00	21.90	28.00	24.45	28.00	30.41	28.00
April.....	25.55	26.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	30.41	28.00
May.....	25.06	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	30.87	28.00
June.....	25.24	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	31.02	28.00
July.....	26.76	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	31.02	28.00
August.....	26.76	28.00	26.76	28.00	25.55	28.00	21.90	28.00	25.55	28.00	31.02	28.00
September..	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	25.55	28.00	30.72	28.00
October....	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	25.55	28.00	30.41	28.00
November..	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	28.13	28.00	30.53	28.00
December...	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	28.95	28.00	31.63	28.00
Average..	26.54	27.33	26.45	28.00	25.85	28.00	21.98	28.00	25.50	28.00	30.63	28.00

	1907		1908		1909		1910		1911	
	England	United States	England	United States	England	United States	England	United States	England	United States
January.....	32.08	28.00	29.80	28.00	26.15	28.00	25.55	28.00	27.52	28.00
February...	32.69	28.00	29.20	28.00	25.55	28.00	26.00	28.00	27.98	28.00
March.....	32.85	28.00	29.20	28.00	25.55	28.00	26.15	28.00	27.86	28.00
April.....	32.85	28.00	28.59	28.00	25.55	28.00	26.28	28.00	27.37	28.00
May.....	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
June.....	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
July.....	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
August.....	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
September..	32.08	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
October....	31.63	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
November..	30.66	28.00	27.67	28.00	25.55	28.00	26.76	28.00	27.37	28.00
December...	30.41	28.00	26.76	28.00	25.55	28.00	26.76	28.00	27.37	28.00
Average..	32.22	28.00	28.26	28.00	25.60	28.00	26.51	28.00	27.47	28.00

The Witness: This exhibit in general indicates where there has been a perfectly uniform price for steel rails subsequent to the organization of the Steel Corporation, that the price of steel rails in England has been subject to fluctuations; part of the time the price in this country being above and part of the time below in England.

On page 1657, there is a diagram being Walker Exhibit No. 250, date November 19, 1912, which shows a simple average price of steel products from 1895 to 1911, inclusive. These products are light steel bars, light steel, steel bars, black sheets, A wire, and wire nails covered by one line; and heavy steel billets, standard rails, beams and plates by the other.

Q. The former being a black line and the latter a red line?

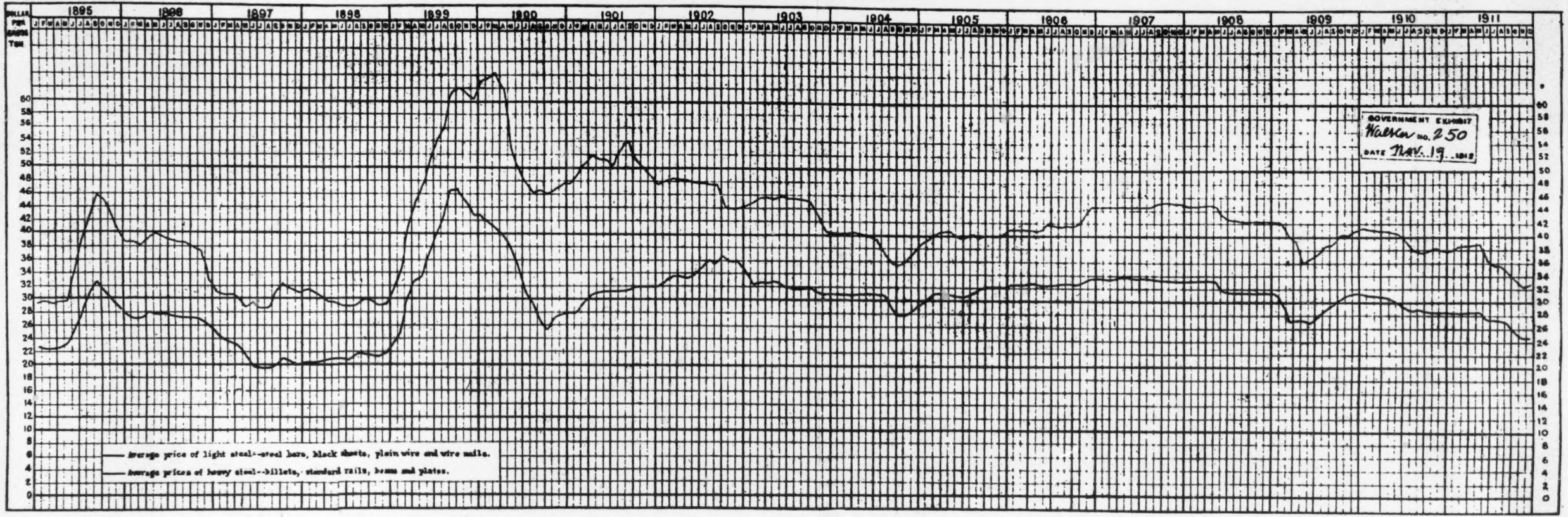
A. The latter a red line, yes, sir. This table shows the same general trend of prices as before, the extreme fluctuations prior to the formation of the Steel Corporation, and relatively steady prices subsequent to that time, and prices that for considerable periods do not vary greatly.

Mr. Adcock: That last table will be marked Adams Exhibit 11.

(Table Walker Exhibit 250, was marked Adams Exhibit 11 and here follows):

DIAGRAM VIII

SIMPLE AVERAGE PRICES OF STEEL PRODUCTS---JANUARY, 1895-DECEMBER 1911.



The Witness: I refer next to page 1656 being Walker Exhibit 249, date November 19, 1912, which is a diagram showing the simple average price of Bessemer pig iron, foundry pig iron, Bessemer billets, steel rails, beams, tank plates, steel bars, black sheets, plain smooth wire and wire nails, from January 1895 to December, 1911, inclusive.

The line representing the averages here shows the same general trend as the other tables, but this diagram gives an average price for all these commodities for the years January 1st, 1895, to March 31, 1901, and compared with it an average price from April 1st, 1901, to February 8th, 1909; the latter being higher than the former.

This diagram also shows the basis upon which these quotations rest, being taken from the Iron Age, except for standard rails which are taken from the reports of the American Iron & Steel Association. And with regard to the authority for these prices, that will be found fully described in the testimony by Mr. Walker, which is in volume 7 of the same report.

(Table Walker Exhibit No. 249, was marked Adams Exhibit 12, and here follows):

Mr. Wilkerson: I want to say about this whole line of testimony that I propose to move the court before we close our testimony in rebuttal, to strike all this evidence from the record, on the ground it has no bearing on this case whatsoever. I am at a little disadvantage in connection with the completion of the cross examination of this witness on these points. He has gone into an issue here which is in controversy in the other lawsuit which involves, as I understand it, the question whether there was a combination to control the price of steel, a matter in litigation in the federal courts. And if the court should hold this would have any possible bearing on this case, I would have to pick out offhand what other portions of the record I want to direct the attention of the witness to.

Mr. Austrain: We are not introducing any testimony given in another case. We are simply taking charts that were prepared showing the prices, over which there can be no dispute, prepared by the Government's own expert witness, as to steel and ore products.

Mr. Wilkerson: You are using them as a foundation for certain conclusions that you ask this witness to draw. It may be there are other things which ought to be directed to his attention.

Mr. Austrain: He is not drawing any conclusion except from these diagrams.

Mr. Wilkerson: Go ahead.

Mr. Austrain: He takes the exhibits prepared by your own Government expert as correct. If they are not correct, that is easily ascertained, because it is a matter of public record.

Mr. Adcock: That is all.

Cross Examination by Mr. Wilkerson.

Q. Professor, you gave some figures here which you stated represented in your opinion, the loss which would have resulted if the death rate during the period of 15 years prior to the opening of the Canal for typhoid fever had remained the same during the 13 years following the opening of the Canal, as I understand you?

A. Yes, sir.

Q. In that, you assumed that there would have been more people who would have died during the second period than the first?

A. If it had not been for the improvement in the sanitary conditions, yes, sir.

Q. And that none of those might not have died from other causes?

A. That is the assumption, because the comparison is made with the expectation of life, including all diseases.

Q. And you have undertaken to give your opinion in dollars and cents of the loss which would have resulted to the community if a certain number of people had died and had become sick. Is that what you attempted to do?

A. Yes, sir.

Q. You have presented a table here in which wou have shown the death rate per 100,000 in the City of Chicago during the years running from 1897 to 1912. Have you had occasion to make any study of the death rate of any other American cities during the same period?

A. Not as careful a study as that of Chicago; but I have always been interested in that study and have made something of a comparison between the result here and other cities.

Q. I mean, in connection with this specific investigation?

A. Yes.

Q. You have limited yourself to the City of Chicago?

A. Yes, in that case I have.

Q. Have you given any consideratior to the change of death rate throughout the entire nation?

A. Yes, sir, except the statistics don't exist for the entire nation. It is not possible to go beyond, in that study, what is called the registration districts, which covers the states that have laws regarding uniform registration of death and illness.

Q. Have you given any consideration to the diminution, the comparative diminution of the death rate in cities where during a particular period there has been a large movement into the city of persons between certain ages, say between 20 and 40 years old, and as to whether or not that would tend very materially to diminish the death rate?

A. I have not asked whether the increase of population through immigration was greater or less in Chicago as compared with other cities.

Q. Have you in the conclusions which you have drawn with reference to the diminution of the death rate in Chicago given any consideration whatever to the immigration during the respective years into the City of Chicago, and to the ages of the immigrant?

A. No, I have not.

Q. Are you aware of the fact that in small towns and

cities, where there is no immigration of adult persons of an age where the death rate is comparatively low, in small towns and cities the death rate appears to be high compared with other towns and cities into which there is that immigration?

A. I do not know that is so.

Q. You have never given it any consideration?

A. I do not know that that is true.

Q. It would naturally have a very great effect upon the death rate, would it not, if you bring into a community each year a large percentage of immigrants between the age of 20 and 40 years?

A. I think you ought to have a medical expert to answer the question, but my impression is that outside of the tubercular diseases, the germs do not live long enough, so that it is the local condition rather than the condition of the immigrant that effects the death rate.

Q. My point is this: If you have a thousand persons between the age of 20 and 40 years, there would be fewer of that thousand die than of a thousand whose age is over 50, would there not?

A. Yes, but not of typhoid fever.

Q. No, I am speaking of the whole death rate, the total death rate.

A. Of the total death rate, it is a universal truth that the older the age of the group the less expectation of life will that group have. If you mean that, yes.

Q. And the same thing is true with reference to young people; that is, the death rate is very high in young children?

A. Yes, in certain diseases.

Q. So that if you reduce in the community the percentage of small children and of old people, you will have a lower death, would you not?

A. Yes.

Mr. Austrian: Other things being equal.

Mr. Wilkerson: Other things being equal.

Q. Now, I notice in this table that you have presented that, take the year 1897, for instance, which was before the opening of the Canal, the death rate per 100,000 from typhoid fever was 29.3, while in 1902, which was three years after the opening of the Canal, the death rate from the same source was 44.5 per 100,000. You noticed that fact, did you?

A. Yes, sir.

Q. Which would indicate, would it not, that the prevalence of typhoid fever, while it might have been to some ex-

tent influenced by the opening of the Drainage Canal, was determined by other factors than that alone?

A. I can't answer that "Yes" because that brings in yet another point, on which you ought to have a medical expert; but I can tell you what the medical expert would say upon that, because I have asked him and he has told me.

Mr. Wilkerson: I have no objection to the Professor giving us any light he can.

The Witness: My understanding about this is bound up with these epidemic years. I first got this explanation from Dr. Young, who is your health officer here in Chicago; and also from talking with physicians who are expert in this matter. That is all I know about it. And from these conversations I understand it to be the opinion of the medical experts that naturally, other things remaining the same, any congested community will have epidemics about once in ten years; that the fact of an epidemic itself is a sort of vaccination against the recurrence of these diseases; and this figure here, 29 and 44 are the years when had there not been a control you would have had an epidemic here in Chicago.

Q. So that this high average for the period before the opening of the Canal grows out of the fact that included in that period are two or three years in which there was an epidemic of typhoid fever in Chicago?

A. Yes.

Q. That is, 1890, 1891, 1892. We are all familiar with that period.

A. And of course might I add this: That as a statistician I should dislike to undertake to explain one year against another year. It is always necessary to cover a sufficiently broad basis of figures, and data over a sufficiently extended period, so that these local factors are eliminated.

Q. Why was it necessary to take a period of 13 years? Why was it necessary to go back far enough to include that epidemic period?

Mr. Austrian: That is because it is 13 years since the opening of the Canal.

The Witness: If it had been five years from this time, I should have gone 18 years instead of 13. Thirteen is all the years we have since the opening of the Canal.

Mr. Wilkerson: With reference to the statements of the witness as to opinions concerning loss which would have accrued to the City of Chicago had the death rate during the one period to which he has referred remained the same dur-

ing the second period covered, I move to strike out each and every statement of the witness on that subject, on the ground that it is the mere expression of an imaginary opinion; that there is no statement in the evidence of the alleged loss or damage; no basis whatsoever for determining the principle upon which the conclusion of the witness is based. That is all.

Mr. Austrian: The witness is here, and if the Government's attorney wants to know how he arrived at the computation, what elements entered into it, he is here ready to be cross-examined.

Mr. Wilkerson: If the counsel for the defendant do not see fit to bring out in the record the elements of the alleged loss or damage, I do not conceive it is part of the duty of the counsel for the Government to bring out evidence on that subject.

Re-direct Examination by Mr. Austrian.

Q. So that there may be no quibble about it, or question about it, we will ask the witness as a part of our direct examination to state to the Government attorney what elements entered into that computation; not recognizing however the correctness of the rule that he lays down. We do not desire to speculate with so important an element in this case.

A. You ask for the methods followed in computing the loss to which I testified?

Q. Yes.

Mr. Wilkerson: I think what you wanted more particularly was a statement of the elements of the loss.

Mr. Austrian: Yes, the methods that he employed in arriving at the loss and the reasons; and how he reached the figures testified to.

The Witness: The factors employed in computing the community loss on account of premature death as working citizens are, first: the number of working years annihilated by premature death. For any given person this is measured by the difference between the age at which death occurs and the normal expectation of life for that age. For the community, the average at which death occurs is the point from which the measurement is taken.

The second factor is the worth or value to be imputed to a working year. By the first, it is evident that we learn the number of working years for each year annihilated by a premature death. If now we know the value to the community

of a working year, the multiplication of the one into the other gives the desired result.

Q. You arrived at the value for a working year?

A. Yes, sir, but might it not be well to state how the other is arrived at first. That is well established by actuarial methods. And in the case of typhoid fever, which is made the basis of this computation, the loss, the average age of those who died of typhoid fever is 29 and a fraction years. Now, the average expectation of life for that age, 29, is 66 years. If now we take 65 as the limit of working years, there is by a death of typhoid fever annihilated the difference. At that age there is an expectation of 36 working years for each person that dies. Therefore, the deaths multiplied by 36 years gives the loss to the community in years.

Now, the other element the value of a year is one that the actuaries have always dodged. They have made assumptions, but have never given the matter, in my judgment at least, sufficient analysis, industrial or economic analysis.

I have for the purpose of this case endeavored to analyze the community's interest in premature deaths. And by the community's interest I mean the interest of the community as though the community were a unit, an organization, an industrial corporation, you may say, of perpetual life. And starting from that point, the burden that must be placed upon current industry is the burden first of maintaining the current social asset, the important asset being in the number of workers in existence, so that notwithstanding deaths there will be births, raising children, education of workers, who will come to supply the place of the worker so that what you may call the labor asset of the community will be maintained.

Every time there is a premature death, the community loses in this respect; that is, the fund for the maintenance of its industrial or social aspects is impaired.

It is also a burden or a duty imposed upon current industry to provide for the normal development of industry, the normal growth of society, increase in numbers and increase in grade, quality of labor, greater education; and that I call as distinguished from maintenance of development, the additions and betterments that come to this society, considered as an industrial organization. Those are the two elements that are attempted to be measured; and each of them is impaired by a premature death.

Then, third, there is a dissipation of assets, a dissipation of energy, dissipation of well being, dissipation of work, dissi-

pation of time, on account of sickness and death, and the cost of the sickness being a burden upon the community, a burden eliminated if there were no sickness, and this class is recognized as the third element of loss. Those are the three elements on that side of the equation.

Mr. Wilkerson: You still have made no statement of the value assigned to each of those elements.

The Witness: The problem as it has been worked out by that explanation and analysis is given on this page submitted.

(Handing paper to counsel for the Government.)

(Paper referred to was marked Adams Exhibit 13, and here follows:)

ADAMS' EXHIBIT 13.

19

Loss that would be sustained by the City of Chicago and dependent populations were the present facilities for obtaining an adequate supply of pure water impaired or destroyed, based upon a comparative study of health statistics of the city for 13 years before and 13 years after the opening of the Chicago Drainage Canal.

Per Annum.

Per 100,000 of the Population.

Kinds of Loss.	From Increase in Typhoid Fever	From Increase in Other Diseases
I. By Loss of Contributions to Maintenance:		
a. Through premature death of male workers, 83% of 28.39x36x300.....	$254,488	$636,220
b. Through sickness, 83% of (483x10) + (28.39x2) + 52x300.....	23,400	23,400
II. By Decrease in Capital Building:		
a. Through premature death, 42.7x 36x40.....	28,256	70,640
b. Through sickness (726x10) + 52x40	5,581	5,581
III. By Unnecessary Dissipation of Resources: 483x58.41.....	42,405	42,405
	$354,130	$778,246

$354,130x23=$8,144,900.
$778,246x23 = $17,899,658, which is the annual loss to the City of Chicago.

Mr. Austrian: Q. Will you explain that table which is marked Adams Exhibit 13?

A. A full explanation of that table would require a detailed explanation of each of the items in the equations used in arriving at the result.

Mr. Wilkerson: May I ask you this question: Your table here is prepared on the assumption that if a member of the community dies prematurely, the community necessarily sus-

tains a money loss even though somebody else moves into the community the same day and takes his place?

A. Yes, sir; in the same way and for the same reason that a corporation sustains a loss, a railway corporation sustains a loss in case its locomotive is wrecked ten years before its life has expired. It also must use its resources to supply the place of that locomotive. But the resources used to supply the place of the locomotive that is prematurely retired cannot be used in any other way. I think the analogy between a corporation maintaining its property and improving its property and a community maintaining its labor force and extending its labor force is very close.

Mr. Austrian: If you desire, we will have Mr. Adams explain each item and how he arrives at it.

Mr. Wilkerson: Just as you please about it.

Mr. Austrian: If you are going to make the objection—

Mr. Wilkerson: Yes, I think this whole thing, to be perfectly frank, is so much in the realm of speculation it cannot even be included in the evidence.

Mr. Austrian: Expectancy of life is within the realm of speculation.

Mr. Wilkerson: You are assuming that for every man who drops out of a community prematurely, the community has suffered that loss, notwithstanding the fact his place might be filled.

Mr. Austrian: Don't you admit that for every one of the community who drops out prematurely the community suffers a loss?

Mr. Wilkerson: It may be a financial gain to the community.

Mr. Austrian: Will you explain those various items making up the aggregate figure, concerning which you have testified on Adams Exhibit 13.

Recess to 2:15 P. M.

HENRY C. ADAMS, resumed the stand and testified further as follows:

The Witness: Under the first item mentioned in the table, namely, "By loss of contributions to maintenance," there are two sub-items, a: "Through premature death of male workers" and b: "Through sickness." The formula for computing the loss through premature death of male workers is as follows: 83 per cent. of 28.39 multiplied by 36 multiplied

by 300. The 83 per cent. of what will be the result of the computation following that figure in the formula is arrived at in this way: this computation rests upon the loss incident to the premature death of active workers, and it would therefore be improper to include all of the deaths as the computation should confine itself to the deaths from typhoid fever that occur during the working period.

Now, about 83 per cent. of the deaths from typhoid fever occur within the working years, and for that reason only 83 per cent. of the 100 per cent. of computed loss is permitted to enter into the present computation.

The table upon which that percentage rests has already been submitted as Exhibit 4.

The figure 28.39 is derived as follows: as already explained, the decrease in the number of deaths from typhoid fever per 100,000 population since the introduction of the Chicago Drainage Canal is 42.7; this decrease being arrived at by a comparison of the average number of deaths per 100,000 population for the 13 years prior to the opening of the Drainage Canal with the corresponding figure for the 13 years subsequent to that event.

Now, the table of distribution of deaths from typhoid fever shows that males constitute 66.5 per cent. of all deaths. The decrease in the number of males dying from typhoid fever, therefore, is 28.39 per 100,000 of population. That means in effect that the deaths of females are thrown out in this computation, although there are some reasons why females should be included in the productive population, as well as males. But here, as everywhere throughout the computation, I have taken the lowest of the figures that can be used.

The figure 36 is the computed expectation of working life at the average age of death from typhoid fever. This average age for the City of Chicago including all deaths at all ages, is 29.04 years. The average expectation of life for that age is 37 years. If now 65 years be accepted as the average limit of the normal working period, it follows that the number of years lost to a community, of working years, resulting from a death caused by typhoid fever is the difference between 29 and 65 or 36 years.

The next item in the formula is 300. This figure covers that portion of current earnings, the expectancy of which is for a communal or community purpose described in the foregoing analysis. That rests upon the assumption that the general average income representing the productive capacity of workers is some $700 a year. We are concerned here not

simply with workers, men who get wages, men on payrolls of factories, but it is all members of the community, and really you should take into account men who earn from a dollar a day up to men of very high income, all of whom are subject to death from typhoid fever.

The amount that is required for the support of the worker, what you may call the personal expenditure of the worker is deducted from what is called the average productive capacity of individual citizens, and the remainder is accepted as the community loss on account of premature death. That is, the remainder measures the amount that is contributed from the income of the worker to the maintenance of the working fund, and the expense, the personal expense, the demand for or the occasion of that expense dies with the man, but to the extent that while a man is living he contributes to what is the community need, namely, the maintenance of the number of workers, the education and rearing of working men so that they can take the place of workers when retired on account of age that is the community contribution of the individual, and that community contribution of the individual is what is destroyed by a premature death.

I have put it here at the low figure of $300, on the basis of a $700 income. There has been a great deal of analysis and work by economists in arriving at those figures. I do not care to go any further into that unless it is desired that I should do so.

Mr. Austrian: There are a great many authorities on that subject that he can cite to you, if you want them. I think you had better give us those.

Mr. Wilkerson: Do I understand that what the witness has in mind is that there are a number of treatises?

Mr. Austrian: Yes.

Mr. Wilkerson: On that subject?

Mr. Austrian: Yes.

Mr. Wilkerson: Scientific books to which reference is made on this subject.

Mr. Austrian: To which reference can be made.

Mr. Wilkerson: I mean to which he has made reference.

The Witness: No, I have made reference to none as yet. I merely gave my own conclusions from the study of this matter.

Mr. Wilkerson: I thought what was in mind was there were certain kind of treatises to which we can be referred as showing the propriety of the adoption of the $300 figure.

Mr. Austrian: I will not say that figure, but on that comparison.

Mr. Wilkerson: I think we might as well for convenience have here the names of the different gentlemen who have written on this subject. Or if the Professor himself has written anything, if he can refer us to that.

The Witness: From the actuarial point I suppose that Dr. Glover, Professor of Mathematics and Insurance in the University of Michigan, has done as much work as anyone.

Another treatise upon this general subject—

Mr. Wilkerson: What is the title of his book?

A. The title of the pamphlet I have here is, "The Cost of Infectious diseases." But he has a more extended presentation of his theory, which was read before the International Hygienic Congress at Washington, some years ago on the Cost of Tuberculosis in the United States.

There is another article reprinted from the quarterly publication of the American Statistical Association, by William O. Mendenhall, Professor of Mathematics of Earlham College, and Earl W. Castle, of the University of Michigan. This has to do with the monetary losses in the United States due to typhoid fever.

Another recognized authority which summarizes almost everything that has been done on these lines is the Bulletin of the Committee of One Hundred on National Health, being a report on national vitality, its wastes and conservation by Professor Irving Fisher, of Yale University, and of the Commission.

There is another authority upon this matter, Frederick L. Hoffman, statistician of the Prudential Insurance Company of New York. He has published quite a number of articles; and along this line there are a good many contributions made recently for the various life insurance companies, the purpose of which is to justify the expenditure of money in making conservation of health for the companies themselves. I have not a record of all of them, but there are a good many of them.

On the particular question, namely, the estimate of productive ability, perhaps the best authority is Dilfredo Tatreto. He has made a study of the distribution of incomes, and has established what some regard as a law of the distribution of incomes, so that if it is known, according to his law, if it is known what the daily unskilled wage is, he can arrive at the average of the incomes from $300 up to $30,000.

Men like Hoffman usually take $600 as the earning capacity,

and merely say that the earning capacity is equal to the productive ability of the worker; but that includes only the day workers, the unskilled and the low paid workers. And that rests upon the statistics of wages which are very voluminous and very carefully worked out. This law arrives at an income, not only for day workers, wage workers, but for others who create their own wages, pay themselves their own wages, and there the average would be according to this law for a dollar a day something like $700 or $800. I took the lower figure and estimated the amount of personal expenditure, and the difference is recognized as the loss suffered by the community on the occasion of the premature death of any citizen.

The second formula presents the loss on account of cases of typhoid fever which did not result fatally. The 83 per cent. is arrived at in the same way as in the first formula described. The figure 483 represents the number of male cases of typhoid fever which occur annually in the City of Chicago, but which do not result fatally. It is arrived at by the multiplication of the number of deaths, 28.39 by the figure 17, which is the figure accepted as representing the number of cases of typhoid fever for every death from typhoid fever. My authority for that figure is the Pittsburg Survey, and Whipple on Typhoid Fever.

The figure 10 is the number of weeks that each case that recovers is out of work. That assumes that the sickness and convalescence in every case covers at least 10 weeks; I mean that is the average of the cases.

The 28.39 in this formula has already been explained, this being the number of deaths, and the 2 is the number of weeks on the average prior to the time that the death occurs, which is a burden for the community in the same way that the weeks of sickness of those that do recover. This is divided by 52 to reduce it to years and multiplied by 300, which is the figure in the formula already described.

The second kind of loss is expressed in the table as a loss by decrease in capital building. That is, every worker, every member of an industrial community, during his active life, not only contributes to his own maintenance but contributes something to the fund of which he is a part and to take his place when he dies; he not only does that but he contributes something toward the increase of the working fund and towards the higher education, which is equivalent to the raising of the labor, quality of labor. This is the same thing as additions and betterments in the case of an industrial corporation.

This also is submitted under two heads: a, loss through premature death, and b, loss through sickness. 42.7 in the first formula has already been explained. I ought to say before explaining these figures that in this case it is population as such that is taken into consideration, because we only know the increase in wealth and capital on the per capita basis, and therefore it is not the deaths of workers, the working age, but the total deaths from typhoid fever that must be considered.

Now the 42.7 in the equation under A is the average decrease in the death rate from typhoid fever during the 13 years subsequent to the introduction of the Drainage Canal as compared with the 13 years prior thereto. This is multiplied by 36, because this loss continues for 36 years. And the loss per year is computed at $40 on the authority of the United States Census that the increase in capital or valuation from year to year is about $40.

There is also added here a loss because of the decrease in capital building through sickness, which is 726 multiplied by 10 divided by 52 multiplied by 40, all of which figures explain themselves.

The third point in the formula is losses by unnecessary dissipation of resources. That is what is commonly called the sick loss. And I have taken 483 cases of typhoid fever that do not result fatally, and I have taken the result of the Pittsburg Survey, giving 58.41 per case. That seems to me to be unusually low, and so far as I know it is the lowest figure that has ever been arrived at, and I think is too low, for the reason that this Survey in Pittsburg had to do with the poorer people in the poorer districts, whereas, the question we are now interested in covers all citizens of Chicago, of all classes.

The figure 90 has been suggested but the figure 58.41 is the one that is used in this computation.

I think that explains everything in the table, except the question of multipliers. The character and need of Hazen's Law has already been explained, and this table accepts 2½ as the multiplier; that is, it accepts the Hazen Law, as originally stated, and not as modified in figures by Sedgwick and MacNutt and others, who place a higher figure.

In Exhibit 5 there are certain figures that show what the relation is between decrease in deaths from typhoid fever and decrease in deaths from other causes subsequent to the introduction of the Drainage Canal, and the ratio so far as impure water diseases is concerned, as submitted by the Chicago

Department of Health, would suggest that 6.4 ought to be the multiplier. Now, I hesitate to accept that figure, however, for this reason: That these impure water diseases cover diarrheal diseases, and most of the deaths, a very large percentage of the deaths from these diarrheal diseases are deaths of children in early years and this computation has omitted the consideration of any deaths except the deaths for workers.

Mr. Austrian: That is your computation?

A. My computation. Undoubtedly the community does suffer from the death of people who are in the process of education, children, young people who are destined if they live to take the place of workers who are superannuated. This is one point, however, where I omitted an item that ought to be included and shows that the result of my table is below the result that might very properly be claimed as the loss to the City of Chicago should it be deprived of pure water. If 2½ is considered too low of course it can be raised and the conclusions modified accordingly.

Mr. Austrian: Q. These authorities whom you have mentioned, Whipple Tatreto, Hoffman, Sedgwick, MacNutt and a number of others, those are recognized authors upon the subject and recognized authorities upon the subject upon which they have written?

A. Yes, sir, they are recognized by members of their own craft as being specialists in these particular lines.

Mr. Austrian: That is all.

Mr. Wilkerson: That is all.

Adjourned sine die.

Depositions in the above entitled cause taken pursuant to stipulation of counsel for respective parties, before the Commissioner, at the offices of The Sanitary District, Chicago, November 17, 1913.

Appearances:
Mr. Albert L. Hopkins,
Appearing on behalf of the Government
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
Appearing on behalf of the Sanitary District.

Mr. Hopkins: This agreement about the reservation of objections prevails here as in all the other testimony.

Mr. Adcock: Yes. You mean with reference to taking them up at the hearing.

Mr. Hopkins: Yes.

GEORGE W. FULLER, a witness called on behalf of the defendant, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?
A. George W. Fuller.
Q. Where do you reside?
A. Summit, New Jersey.
Q. Where is your place of business?
A. New York City.
Q. What is your business?
A. I am a hydraulic engineer and sanitary expert, making a specialty of matters of water supply, water purification, sewerage and sewage disposal.
Q. Will you state your education, early training and experience as hydraulic engineer and sanitary expert?
A. I am a graduate of the Massachusetts Institute of Technology. I have made a specialty, since 1888, of sanitary matters relating to water supply and sewerage questions.

I studied in Berlin at the Hygienic Institute, and took a number of special courses relating to the practical art of water filtration, in 1890, in the office of Piefke, the engineer of the Berlin Filters. I then spent some four and a half years

on the technical staff of the Massachusetts State Board of Health.

I was at Lawrence from the spring of 1891 until the autumn of 1895. That station at Lawrence was conducted by the Massachusetts State Board of Health with a view to ascertaining the best means of purifying water and sewage under local conditions in Massachusetts. The tests were conducted to develop the necessary information relating to the laws of purification from an engineering, chemical and bacteriological standpoint. I had charge of the testing station for more than half of the time that I was at Lawrence, having succeeded Mr. Allen Hazen in March 1893, as the man in charge.

I then spent some four years at Louisville, Kentucky and Cincinnati, Ohio, in ascertaining the best means in point of efficiency and economy of purifying the muddy polluted Ohio River water. All these investigations at Lawrence, Louisville and Cincinnati, were reported upon at length, and the reports were published.

Since the summer of 1899, I have been in practice in New York City, and from 1901 to 1911, I was in partnership with Rudolph Hering in the line of hydraulic and sanitary work that I have spoken of above.

During the past fourteen years, I have been connected with upwards of 100 different sewerage and sewage disposal projects, and, roughly, an equal number of water supply and water purification projects. Among the more important sewerage projects with which I have been connected, I can mention the work at New Orleans, where for nine years I was a member of the Board of Advisory Engineers having to deal with the expenditure of some $20,000,000 on drainage, sewerage and water supply projects.

I was also connected with the Passaic Valley Trunk Sewer project in New Jersey, both with regard to getting out the preliminary estimates of cost of that project, to serve about One Million Six Hundred Thousand people, and also have been connected with the litigation before the United States Supreme Court in the matter of the pollution of the New York Harbor waters by that trunk sewer flow.

I have had considerable to do with the Baltimore sewerage and sewage disposal projects; and went abroad in 1906 to collect information as to experiences there bearing upon the local matter.

I have had a good deal to do with intercepting sewers in

a number of large cities, Memphis, Kansas City, Columbus, Schenectady, New York, and elsewhere.

I was connected with the design of the sewage treatment works at Columbus, Ohio, serving also as consulting engineer during their construction, and the first year or two of their operation. I served similarly at Reading, having operated that plant for some two or three years.

I have been connected with sewage disposal designs in perhaps 30 or 40 different instances, the more recent ones being at Atlanta, Georgia, Schenectady, New York, Altoona, Pennsylvania, Norristown Pennsylvania; and a group of cities in New Jersey in what is known as the Plainfield District, and many others.

On water supply matters, I was a member of the committee appointed in 1901 by the United States Senate to consider water supply matters in point of purification of the city of Washington. I served in New York City as consulting engineer, both to the Catskill project and the existing Croton Water Supply.

I have been connected with numerous water supply and water improvement matters for various large cities in this country, including St. Louis, New Orleans, Louisville, Cincinnati, Columbus, Ohio, Minneapolis, Grand Rapids, Montreal, etc.

I have had a good deal to do in connection with appraisal of water works at sewerage projects, having been connected perhaps with 25 water works appraisals, and recently I have been connected with a number of sewerage appraisals; three during the present year.

I have had considerable opportunity to study the art of water and sewage treatment, particularly in connection with appearances as a patent expert in a number of the leading patent suits bearing upon treatment methods. I have followed the development of the art of sanitary engineering in Europe; and have made quite a number of visits to Europe for that purpose. This has been particularly true during the last few years when I have been engaged in getting material for a book upon sewage disposal, which was published in 1912.

Q. Have you had any opportunity to study the conditions relating to the water supply and the sewage disposal problems here in Chicago?

A. Yes.

Q. State what studies you have made and what your op-

portunities have been to become familiar with the conditions?

A. My first opportunity to study sanitary matters in Chicago was in 1893. During the World's Fair, I spent a number of weeks in Chicago, and had charge for a time of the exhibit of the Massachusetts State Board of Health. On that occasion I took advantage of the opportunity to look into water supply and sewage disposal matters, as the various officials here in Chicago were then studying them.

In 1901, I was called in as an expert by the St. Louis Water Department with reference to treatment of the then existing water supply of St. Louis, and that gave me occasion again to review the conditions at Chicago.

In 1903, I was one of the experts in the Drainage Canal litigation, Missouri versus Illinois.

In 1906, I looked into matters here in Chicago with some care in connection with an investigation and report which was made by my former partner, Mr. Rudolph Hering, and myself, to the International Waterways Commission.

In 1909, I had quite a little to do with the testing of a filter plant out in the Stockyards district, and later appeared as a witness in a suit brought by the City of Chicago to restrain the use of the output of that plant for certain purposes in that district.

In 1911 and '12, I made quite a study of the various published documents relating to the Chicago water supply and sewage products, including the report by Mr. Wisner, made in October, 1911; all with a view to embodying the essence of that information in my book.

During the current year, since February, I have had an opportunity to look into this matter in considerable detail as related to the protection of the Chicago water supply and various means of treating the sewage. I have in that connection had opportunity to study up local prices and conditions relating to construction work, and have had experience in that connection through an independent line of work; and that relates to the design and construction of a water filter plant at Evanston.

Q. Your work in 1913, has been in connection with this suit of the Government versus The Sanitary District, has it not?

A. Yes, since February, 1913, I have had occasion to study this problem from various angles, with much thoroughness.

Q. Were you familiar with the conditions which existed here at Chicago in 1889 and prior thereto, in regard to the

opening of the Drainage Canal in 1900, with reference to the disposal of sewage and the water supply conditions here in Chicago?

A. Yes.

Q. I show you a map which is entitled the Sanitary District of Chicago, the map showing the Sanitary District boundaries and corporate limits of Chicago; and ask that it be marked Fuller's Exhibit 1, November 17, 1913. With this map before you, Mr. Fuller, will you explain the conditions which existed here at Chicago in 1889 and prior to 1900, with reference to the sewage conditions and its disposal, and the water supply conditions, for the inhabitants of Chicago and vicinity?

Mr. Adcock: I offer the map in evidence.

A. Briefly stated, in 1889, the sewage of the residents of this community adjoining the lake front, and for some distance back from the lake front, discharged into the lake. The water supply was then taken from a number of cribs connected by a tunnel, and located in Lake Michigan at comparatively short distances from the shore. I speak of distances to emphasize the point that the tunnels were then not so far out into the lake as at present. The sewage from portions of this district removed from the lake shore discharged into the Chicago River and its various tributaries.

There was at Bridgeport an old pumping station of a capacity of something like 1,000 seconds feet; and the purpose of that station was to lift the sewage polluted waters of the Chicago River, and send them through the old Illinois and Michigan Canal down into the Valley of the Des Plaines River in the vicinity of Lockport. The water supply conditions in point of pollution with sewage were notoriously bad, as shown by the records of death rate from typhoid fever and other water borne diseases. The pollution of the lake water at the intake-cribs, where the water was drawn for the public supply of this district was brought about, with substantial regularity, by the flow of sewers discharging directly into the lake. The conditions at certain times were much worse than this, and then the accumulations of sludge in the Chicago River and its tributaries, at times of very heavy rainfall, were flushed out into the lake and unquestionably had a very deleterious influence upon the hygienic quality of the water supply at the intake cribs, and as sent to the water consumers of this general district.

I think that outlines the conditions in 1889, so far as the main features are concerned.

Q. Were you familiar with the conditions of the Chicago River as to whether there was an active nuisance there or not, during that period?

A. Yes, I am familiar with the conditions as existing in 1893, from personal observation, and I have made considerable study of the reports and records and other official communications recording the influence of sewage upon various waterways.

It is a fact that along the lake shore, there were very decided evidences of sewage pollution, and the stranding of sewage solids in putrifying conditions at various points in the vicinity of sewer outlets, along the lake shore. In the Chicago River itself, there was a notoriously bad set of conditions, in point of accumulation of solid matters, of sewage origin. These accumulations of sewage sludge were undergoing putrifaction, and produced what was literally a septic tank.

The so-called Bubbly Creek, for instance, derived its name from the ebullition of gas resulting from the putrifaction of the organic wastes in that branch of the Chicago River. That bubbling action due to the putrifaction of sewage and sludge, or solid matters, caused these solid matters to rise to the surface and form a scum, which the records showed was strong enough to allow men to walk upon it.

In brief, in point of sewage nuisance, the conditions in various waterways in this district were notoriously bad.

Q. I understand you to say that in the time of heavy rains when the run-off exceeded the 1,000 or 1,500 seconds feet of water that was caused to flow into the Illinois and Michigan Canal at Bridgeport, all this sludge, etc., that you have mentioned was washed out into the lake?

A. Large portions of the sludge were so washed out into the lake at times of heavy downpour, and when the flow in the river exceeded the quantity which could be diverted by the pumps at Bridgeport into the old I. & M. Canal.

Q. Do you know whether there were any sewers at that time that were discharged into the lake?

A. Yes, I think there were quite a number of sewers, both on the South side and on the North side.

Q. Were there any of the water intakes that you have mentioned placed further out into the lake, subsequently to that

period; and if you know when they were so placed will you so state?

A. All four of the main intake tunnels have been extended since 1889. My memoranda show that the four mile crib, so called, was completed in 1892. During that same year, the Lake View intake was extended to some 6,000 feet off shore; and in 1896, the Lake View Intake Crib had been extended to about two miles off shore.

In 1892, the 69th street intake had been extended. Another extension there was made in 1894. And in 1910, the Dunne intake crib off 68th street was completed and joined by a bridge with the so-called 68th Street Crib which had been completed in 1894, at a distance of some two miles from shore.

In 1899, the Carter Harrison Crib was completed at a distance of, roughly, four miles from shore.

Q. Do you know what portions of the City of Chicago were served by these various cribs that you have mentioned, with their drinking water supply?

A. Substantially all of the city of Chicago was served by them; the exceptions being very small in significance. For instance, at Rogers Park, there was in earlier years a small intake crib extending some 3,200 feet off shore. I understand that after that Suburb was annexed, it was abandoned as a part of the water supply.

Q. The water is pumped through these tunnels and cribs to the various mains and so forth, from which the people get their water for drinking purposes, is that it?

A. Yes, that is so. From the pumping stations, the water is pumped through the different water pipes in the street. I should explain that some of these tunnels extend under land, and the pumping stations are not in all instances connected at the lake shore. There are a good many land tunnels here in Chicago, but broadly speaking the water from the Lake View, Chicago Avenue, Carter Harrison Intake Crib, the Four Mile Crib, from the two cribs opposite 68th street, the water from those four groups of intakes supplies the water for practically the entire city. I understand that with little exception, in the City of Chicago, there is water taken from no other intake cribs at the present time.

Q. Prior to 1900, did the water that was obtained from these cribs that were built further out in the lake, was it still polluted to any extent by the sewage which discharged into the lake and the Chicago River?

A. Yes, it was.

Q. Now referring to that map, will you explain what works the Sanitary District of Chicago has constructed in the shape of channels, adjuncts, additions to that channel, and intercepting sewers and pumping stations, etc., relating to the disposal of sewage and the protection of the water supply; and if you can state when the different works were completed and what their purpose was.

A. The present main drainage channel was built from 1892 to 1900, and placed in service in January, 1900. It was a waterway starting in the City of Chicago in the vicinity of Robey street, and extended to the vicinity of Lockport, a distance of, roughly, 30 miles. That channel has a capacity nominally to carry some 10,000 seconds feet; and in portions its capacity is 14,000 seconds feet.

At the head of this channel, connections are made with the Chicago River for diverting a flow of lake water entering the mouth of the Chicago River, and with it the sewage which enters the Chicago River and its tributaries.

Prior to the opening of the main drainage channel, there was a reconstruction of some of the main sewers of the city, so that they would divert the sewage from the lake into the Chicago River, or its branches. In 1898, for instance the main sewers on 12th street and 22nd street, were reconstructed and reversed in their slope; that is they flowed into the Chicago River, and no more into the lake.

In 1906, there was practically completed an intercepting sewer on the south side, which took all of the sewage previously entering the lake from the 22nd street district, as far south as 73rd street; and at 39th street, there was erected a pumping station, whereby the flow of sewage from the entire south side was sent through a conduit to the head of the so-called Bubbly Creek. In 1910, this main south side interceptor was extended southward so as to eliminate all lake shore pollution as far south as 87th street. There was a north side interceptor built and practically completed by 1908, for diverting from the lake the flow of all sewers from the northern city limits to Lincoln Park, with the pumping station at Lawrence avenue.

In 1911, the North Shore Channel was practically completed, to allow the diversion from the lake of the sewage from a limited portion of the north shore towns, especially Wilmette.

There was also erected at 95th street a pumping station,

which deals with the sewage flow of a certain area in that general vicinity.

This drainage channel, beginning in its operation in January, 1900, has for its purpose the diversion of the flow of the water of the Chicago River and its tributaries, and the sewage contained in it, so that there would be secured a reversal of flow of the polluted waters away from the lake down the main channel, and into the valley of the Des Plaines River.

Q. Have you been familiar with the conditions that have existed since the opening of the drainage channel?

A. Yes.

Q. With reference to water supply and sewage disposal?

A. Yes.

Q. What conditions have existed with reference to those matters since that time, as compared with conditions that existed before 1900?

A. The conditions have been very materially improved. In regard to the water supply, the building of these lake shore interceptors, and the reversal of some of the sewers at 22nd street and at 12th street, for instance, have resulted in eliminating the effect of sewage pollution in the water supply, and have resulted in the quality of that water being very favorable in its hygienic character, and comparable with the best water supplies obtained elsewhere. In fact, as measured by the typhoid fever death rate, the Chicago water supply is in the very foremost rank in point of purity as compared with any of the large cities in this country, or elsewhere.

In regard to sewage disposal, the present project, which you name in the question, has been completely successful in eliminating pollution and sewage nuisances along the Lake Shore. In the Chicago River and its various branches, the Drainage Canal project has eliminated nuisances to a satisfactory degree and compares most favorably with the success which is found in large cities elsewhere in sewage disposal projects.

Q. I call your attention to the channel known as the Calumet Sag Channel, which is now being constructed, with a capacity of 4,000 cubic feet of water per second. What effect will that have upon the conditions, when completed?

A. The Calumet Sag Channel when completed, and of a capacity of 4,000 seconds feet, will reverse the flow of the Calumet River for a very large portion of the time, perhaps 350 or 355 days in the average year, and in that way will allow a thoroughly satisfactory disposal of the sewage of the Calu-

m.t District, and will also prevent pollution reaching the lake through the Calumet River.

Q. What will be the uses of the 4,000 feet of water that may be caused to flow through that channel when completed, for the purpose of protection of the water supply and disposal of sewage of that district and the City of Chicago and vicinity?

A. The first use will be to reverse the flow for nearly all but not quite all of the time with respect to the Calumet River. In other words, there will be a very substantial elimination of pollution in the lake water, which has practical significance with reference to the supply drawn from the 68th street crib, and which now has an element of some significance on account of the pollution which the Calumet River carries to the lake from the Calumet District in Illinois, and also in Indiana. That would be of very substantial benefit as regards the water supply drawn from 68th street intake; and it will also serve in eliminating any sewage nuisances in the Calumet District by the diversion of the sewage from those various centers of population.

It will also serve a very distinct and important use, in that it will bring into the lower portion of the main drainage canal a well oxygenated water, which will be a very substantial benefit in oxidizing the organic wastes coming from the main central portion of the Sanitary District into the Chicago River, and floating down the main channel.

In other words, to state it briefly, water sent down the Calumet Sag Channel with a relatively small amount of sewage entering that water, will be available for oxidizing and satisfactorily treating and putting in an inoffensive condition the sewage originating in the central and northern portions of the Sanitary District.

Q. If interceptors are constructed so as to discharge the sewage of the population in what is called the Calumet District into the main channel at such a point that it will not flow into the Calumet River at high water times or at such times when the run-off is in excess of 4,000 seconds feet, will there be any material pollution of the lake water from that source?

A. No, if the sewage is intercepted and sent beyond regulating works. That is true, of course, of the sewage in this district.

Q. What was the attitude of sanitary experts or sanitary engineers in 1889, as to public water supplies being polluted by sewage?

A. The up-to-date sanitarians were very nearly all of the opinion that sewage should not be allowed to reach public water supplies, as they fully realized that such sewage pollution and infection and the transmission of germ diseases such as typhoid fever were possible and thereby there would be brought about a very grave menace to the public health of the community drinking such sewage polluted water.

I might say in this connection that in 1889, there was being brought to a close a transitional period between what was known as the filth theory of disease and the germ theory of disease. Up to the early eighties, sanitarians knew that water supplies which received sewage and other filth were prejudicial to the public health. They did not know just how that was brought about. During the eighties, the medical men interested in scientific sanitary matters developed the theory of the causation of disease through the bacteria or specific germs for the respective diseases. There were a few of the leading medical men, and a few of the most prominent of the sanitary engineers, who in 1889, were of the opinion that sewage pollution gave opportunity for the transmission of intestinal diseases, to the consumers of water which had been so polluted with sewage; but it was several years after 1889 before there was a general recognition of the germ theory of disease by the medical profession and by the more intelligent laymen and by the engineers as a group of professional men.

Q. They have that same idea at the present time, haven't they?

A. They have yes, and with a wide range of actual observation and fact to support the proposition that water supplies are not safe when they receive sewage pollution.

It was a few years after 1889, when the severe epidemics of typhoid fever in the Merrimack River Valley in Massachusetts and elsewhere, and when the cholera epidemic in Hamberg showed most conclusively that it was a grave menace to public health for a community to be supplied with drinking water, sewage polluted, and containing the germs of disease.

Q. What was the state of the art of water purification, protection of water supplies from sewage pollution in 1889?

A. As regards the protection of water supply, the larger cities having the foremost sanitary advisors, recognized the importance of keeping sewage out of water supplies. That was about the date when the early beginnings were made of separating sewage from water supply. In some instances, efforts were being made to locate new intakes for cities situated

on rivers, so that the water would be taken from above the discharge of sewage. It was recognized that where this was not feasible, intercepting sewers should be built for river cities, so that the sewage would enter the stream below and not above the river intakes.

There was at that time nothing known at all about the sterilization of public water supplies. In this country, there were practically no water filters in towns of any considerable size. For 20 years the art of water purification had been dormant.

In the late sixties, Mr. Kirkwood, one of the leading American engineers, studied water filters as practiced in Europe, and had made an extensive report in the interests of the City of St. Louis. It was not thought wise, however, to build filters from information then available.

There were one or two filters built in the Hudson River Valley at Poughkeepsie and Hudson, New York, but with that exception, there were no sand filters in existence in this country.

Mechanical filters, as now known, were practically unheard of and were then merely crude straining arrangements in use in mills and other industrial establishments, with a few scattered plants that were just beginning to be installed for some municipal supplies. In those days, the germ theory of disease, as I have already explained, was not generally recognized; and while there were sand filters in Europe, they were essentially clarifying devices, and the benefit to the hygienic quality of the water appeared to be a mere incident. In other words, there was practically nothing known in the art of filter filtration which had associated with it well defined laws which would allow hygienic accomplishments to be reliably secured. American engineers were afraid of water filters in those days, owing to the wide differences in climatic conditions as compared with European facts and conditions; and furthermore they had nothing to serve as a practical guide as to how they should build the filters to secure effective accomplishments at all times, under the wide range of local factors, climatic, and relating to the water itself.

I can best illustrate the negligible working art of water supply in 1889 by saying that I was at that time connected with the Massachusetts State Board of Health, and even a little later on their attitude was one of not knowing how to advise the City of Lawrence to filter a grossly polluted water supply, at a time when severe epidemics of typhoid fever were raging.

In fact it was not until 1892 that experiments even were

made at the Lawrence Experiment Station to work out what might be called the laws of filtration, which are the basis of water filtration of subsequent years.

Q. What is your opinion as to the hygienic improvement in the Chicago water supply due to the drainage canal and its appurtenances, in comparison with what may reasonably have been secured with water filters and other means of improving the local water supply, as known to the art of 1889?

A. The hygienic improvement in the Chicago water supply due to the Drainage Canal is decidedly greater and better than could have been obtained by improving the water supply in other ways as known to the art of 1889. In other words, the diversion of the sewage from the lake and from the Chicago water supply was far better than to have attempted to try any other means for getting a pure water supply, as those means were known in those days.

Q. What methods of sewage disposal were available to cities at that time?

A. There were three methods that were studied for large cities. There was the dilution method, which was by far the most prevalent method, and there were available two other methods which had been tried somewhat in certain of the European countries where large centers of population had sprung up upon very small water sheds. Those methods other than the dilution method were known as chemical precipitation and land treatment. In explaining those two latter terms, I will say that land treatment grew out of an effort to apply sewage to farm lands, in order to take advantage of the manurial properties of sewage.

It had been tried, for instance, here in the Chicago district, at Pullman, and it was found that the land was not suitable for such purposes.

In regard to chemical precipitation, that was a method of applying certain chemicals like lime, alum and iron sulphates to sewage, allowing the treated sewage to pass through tanks holding several hours' flow; and in the tanks there would be deposited the course sewage filth. Those chemical precipitation works in England that were then in existence, had their origin also in efforts made commercially to secure the manurial properties of the solid sewage substances. They were not a success commercially, as to the securing of fertilizing properties at a cost which would be at all warranted on a large scale. They were essentially clarifying arrangements, and were then in considerable vogue, owing to the efforts made in

London to clear up the lower Thames, which had very foul decomposing banks of sewage sludge in its lower reaches.

I might say that there were some little contrivances, called clarifying or straining arrangements, which were practiced at places like Atlantic City and Long Branch, in order to keep the sewage solids away from the more prominent sea shore bathing beaches, but they were very short lived and are not worthy of any serious consideration in a project such as then existed at Chicago.

Q. Was the chemical precipitation method of any use in rendering the sewage inocuous, or less dangerous to water supply?

A. It tended of course in that direction, but it did not produce a treated product so that you could safely discharge that treated sewage, clarified sewage into a stream or into a lake and have a safe water supply. It was a clarifying process and not one for removing completely disease germs. In fact it was applied, not with a view of protecting water supplies but solely to eliminate sewage sludge, prevent these foul decomposing masses of sludge, and that alone was its true function. It was not a means of protecting a source of water supply.

Q. What has become of the sewage farming method in this country, how has it been used if at all?

A. It has never been used with any success commercially. In fact, the method, even in our arid western states has had a very limited and merely nominal scope of usefulness. The reason of that is that it costs more to get the sewage to farm lands surrounding a large city than is the worth of that sewage for fertilizing purposes, or for irrigating purposes, or for the two combined. That is very well demonstrated by the experiences of Los Angeles, for instance.

Twenty years ago, the sewage from the outfall sewer at Los Angeles was used in sewage farming, but the resentment of the public to having garden truck come in from districts where it was known that sewage was used on the farm lands, the odors which arose from the pooling of the sewage on the farms, and the interference with land development projects even miles away from sewage farms, all led that city, with a rainfall of only ten or twelve inches per year, to abandon sewage farming and build a new outfall sewer to the Pacific Ocean.

What I have said with regard to Los Angeles applies, I think, to every other sizable city in our arid districts. It is not difficult to find references in official publications to some

nominal use of sewage for sewage farming in the western states, but a careful examination such as I have given to these subjects, shows that the sewage has been used simply for its irrigating purposes, at times when it would be of benefit to the farmer, and that on other occasions it has been diverted to the nearest water course.

In our eastern states, the matter stands in quite a different attitude, because the rainfall is generally sufficient for farming purposes, and when there is ample rainfall the farmers are in all cases disposed to divert the sewage to some water course, or to allow it to build up on certain portions of the farm lands where it putrifies and produces nuisances.

Briefly stated, the attitude and experience in this country with regard to sewage farming, I would say that the method has never become well established, even for small cities, and it is entitled to no established footing or standing for the problems of large cities. That is true in the west, and still more so in our eastern states.

Q. Will you describe briefly the state of the art, the development of the art of sewage disposal, if there has been any development from 1889 to the present time?

A. In 1889, I take it all sewage was disposed of by dilution. There are some instances where sizable towns have grown up on very small streams, where treatments works of some kind or another have come up for consideration, but to-day it is safe to say that somewhere from 93 to 96 per cent. of the sewage of all towns and cities is disposed of by dilution. Where it is not so disposed of, the dilution method is not a candidate for consideration, because of the small volume of water available for diluting purposes.

There are a few other exceptions along harbor towns, for instance, where shell fish pollution has been a factor.

Broadly speaking then, the dilution method which was practically in universal use in 1889, has continued to be the prevailing one. In fact it is always applied to-day where the conditions allow of its being applied under reasonable conditions.

The sewage farming method that I have spoken of already is on the wane decidedly, in Europe. The largest sewage farm in England, at Birmingham, has been practically abandoned. In Paris, it is being gradually given up, and, beginning a couple of years ago, they are installing sprinkling filters to take the place of sewage farms now located in part in the growing suburbs of the district.

In Berlin, the sewage farms are still used, where the conditions are very favorable as regards light, sandy, porous soil, on lands that were purchased many years ago at a very low price, and where the rainfall conditions allow the irrigating value of sewage to be taken advantage of, in a way that does not exist in our eastern or central states. The increment of land value alone at Berlin seems to justify a continuance of a method which is expensive at best.

Q. Does the consumption of water per capita in Berlin, as compared with that in the cities of the United States, have anything to do with that problem?

A. Yes, it has quite a little to do with it. The amount of water consumed in Berlin is only about 30 gallons per capita as compared with 200 gallons and more found in many of our American cities. That has a good deal to do with the cost of intercepting sewers, pumping stations, and works for delivering the sewage to the farms. And it requires a much smaller area per capita in European cities than would be required in our American cities.

Chemical precipitation works in 1889, had been recommended for adoption in Providence, and those works were built after an interval of some 14 years, put in service in 1901, following the recommendation for adoption in 1887. Their purpose was to eliminate sewage mud from the Providence Harbor, and to prevent the foul decomposing conditions there found.

That method of chemical precipitation at Providence, was continued until a year or two ago, when it was superseded by plain sedimentation and sterilization of the sewage, for the purpose of protecting the shell fish layings in the Providence River below the outfall from the treatment works in the deep water at Feild's Point.

At Worcester, under orders of the court as the result of litigation on the part of the riparian owners in the lower Blackstone River, the City of Worcester about 1889 started to build chemical precipitation works, which were completed in 1891. Those works were enlarged a few years later, and are in service today to treat some of the sewage, which, for the most part however is now being treated in works of more modern, economical and efficient design. The few little chemical precipitation plants around Coney Island, and some of the beaches of greater New York, at Canton Ohio, East Orange, New Jersey, and a little plant in the Mystic Valley just outside of Boston, have all been abandoned.

It is a fair general statement to say that the chemical pre-

cipitation method has no standing today in this country for disposing of sewage as regards elimination of sewage nuisances, except perhaps for some small problems where there are complicated trade wastes. Its day has come and gone, and I think that statement applies also to the large European cities generally speaking. It is certainly true of London, where this method of chemical precipitation received its greatest impetus in the late eighties.

Since the days of 1889, there has been quite a substantial advance made in treatment works for sewage, that has come in as the result of the pressing needs of some communities located on small streams, where the dilution method could not be satisfactorily applied.

Q. In order to remove a nuisance in those streams?

A. Yes, in order to remove a nuisance in the streams.

Continuing the developments of the art since 1890, I will say that various methods have come up for the consideration of the solution of sewage treatment problems. From about 1895 to 1900, the so-called single story septic tanks were in vogue. Their purpose was to remove the solid sewage filth, and allow it to become septicised, and in early days it was assumed all solid sewage filth could be liquified, and gasified by bacteria. Practical developments have shown that this was not feasible.

More than that, the practice with large cities has shown that very severe complications in point of nuisance have been brought about, as the odors from septic tanks have arisen.

Recently, septic tanks of the single story type, built so frequently a dozen years ago or so, have been practically abandoned for all large municipal projects. Within the last year, there has been put in service at Atlanta a two story tank, a settling and septic tank, which has proved to be of much practical benefit, according to the data now available. This is the method of clarifying sewage that has superseded both the chemical precipitation of 20 years ago and the single story septic tanks of a dozen years ago.

In regard to methods of oxidizing those portions of sewage which are either in solution or will not settle in settling tanks, there has been a radical change in the art from 1889, when sewage farms were almost exclusively used.

First there was developed in Massachusetts the intermittent sand filter, where sewage was applied to large areas of porous sand found in place in sections where glacial drift formation was noted. In the central, western and southern states, that method had no footing because the porous sandy

deposits did not exist in place, and the method was found to be too expensive when sand beds had to be built artificially.

Next, there came about 1900, the so-called contact bed in which beds of stone were filled with sewage, and allowed to have the pores stand full of sewage, for a few hours when the bed was drained and allowed to have its pores filled with air. That method was found to be prohibitively expensive for large projects, and its use today is confined to small communities in residential districts, where the effort is to minimize the odor question.

In places where water cannot be made available for oxidizing clarified sewage, so as to prevent sewage nuisances, it is found that the so-called sprinkling filters are the best means of making sewage stable or non-putrescible. By that I mean the treatment of sewage, so that it will no longer putrify after treatment, and after standing for an indefinite period. These devices are large beds of stone, perhaps one to three inches in diameter, and six feet or more deep, and on to which the sewage is thrown in the form of a spray from numerous spray jets, spaced perhaps ten feet apart, over the surface of the bed. The practice has shown that these devices will produce a non-putrescible effluent; but it has also been found, at Columbus and elsewhere, that unusual care must be taken for large projects, to keep the sewage in a fairly fresh condition, so that very serious odors will not arise in the neighborhood of the sprinkling filters. These odor factors have not been encountered in the smaller plants, and in a large scale, the art now shows means of guarding against the odors by keeping the sewage well aerated, and thus arresting putrifaction of the liquid before it meets the sprinkling filter beds.

In the general developments of the art of sewage treatment works, practice has shown that it is much more expensive to build and operate these works on a satisfactory basis than was anticipated a few years ago. In fact, the experiences of the past year or two indicate clearly that projects now in service involve considerably larger sums of money than the earlier estimates indicated.

One other factor I should mention in the art of sewage treatment works, and that is the sterilization of sewage to attempt to destroy disease germs.

Nothing was known of sewage sterilization on a practical scale until about 1906. It was then tried at Red Bank, New Jersey, to apply hypochlorite of lime in settling tanks to sewage with a view to reducing the number of disease germs in

the liquids that were sent out in tide water, in the vicinity of shell fish layings. There have been a number of projects recommended for the sterilization of sewage, but so far as I know there is no instance where large cities have made public any records as to experiences in the systematic sterilization of sewage. The nearest approach to it is at Providence, that I have already spoken of, and where they have abandoned chemical precipitation and started out on a tentative scheme of using their tanks to settle the sewage and to apply sterilizing processes in the interests of shell fish layings in Narragansett Bay.

I have been told also that recently the City of Toronto is attempting to sterilize its settled sewage before discharging it into Lake Ontario.

With regard to the dilution method, the greater attention given to sanitary matters in various parts of the country have shown that it was applied in earlier years with many shortcomings. By that I mean that sewer outlets were built into water courses to a very unsatisfactory degree. There are many American rivers and lakes where sewers reach only to within 100 feet or so of the waters edge, and show a pollution which has given rise to offensive conditions that do not exist or would not exist if the sewage had been well mixed with available water for dilution.

It is also found in some places that sewage has built up sewage banks or sludge deposits, which could be remedied with a little care.

So in brief, the dilution method in my opinion, as the result of careful study of the various engineers, now applying it on a more rational basis than in earlier years, is now on a firmer basis than ever before.

It is true however that it is suffering, in the public mind at least, from the poor reputation it got in earlier years, when it was applied in a very inadequate and haphazard fashion in a great many cities, with attending nuisances as to odor. Today I believe it is entitled to far more consideration than ever before, and I think that engineers in approaching these problems will give it in many cases more careful consideration than they would have done a short time ago, when it was not so clearly appreciated as to what the conditions were under which it could be used, and take advantage of its economy and allow local nuisances not only to be eliminated, but to allow them to be eliminated in a way that they would not be transferred to other neighborhoods.

Q. Have you considered the adequacy of the minimum

ratio of dilution, that is to say 3.33 cubic feet per second per thousand population, that is prescribed by the act under which the Sanitary District of Chicago is organized; and if so will you state your views upon that problem?

A. Yes, I have considered this ratio; and in my opinion it is as low a ratio as it is feasible to employ, when consideration is given to the domestic sewage of a community.

If I were to consider any change in this ratio, I should be disposed to increase it. That ratio makes no provision for trade wastes; and if trade wastes were to be considered as well as the domestic sewage, I believe this ratio should be increased.

I have looked into this matter with considerable care; have been down the length of the Drainage Canal, studied the records on many occasions. I am making this statement now with respect to conditions as applied to the Chicago Drainage Canal.

Q. To what extent have you taken trade wastes into account in your study of Chicago problems, and what are the reasons for your position, and in this connection will you describe what you mean by the term "trade wastes"?

A. I take trade wastes to mean those products which arise in large industrial establishments, for instance tanneries, packing houses and slaughter houses, where the wastes are removed by water carriage, are substantial in quantity, and are entirely different from what you would get in sewers, which drain the ordinary residential community, with the wastes that would come from business blocks, commercial enterprises and small manufacturing establishments where the wastes that went into the sewers were merely nominal in amount. As applied here particularly to the Chicago problem, it relates essentially to the waste coming from the Stockyards district and to the tanneries and to the other establishments along the North branch.

Now, in this problem, I have given no consideration to the trade wastes item. The reason for that position is that the disposal of trade wastes is a matter which applies with equal force, whether on the one hand you are considering the dilution method for the local problem, or whether there are considered treatment devices for disposing of the sewage other than by dilution methods.

In other words, it is an item which appears on both sides of the equation in these dilution projects which I have studied; and being the same item on each side of the equation, it properly drops out of consideration.

I might further say that it is my understanding that the Drainage Canal here was projected on the basis that trade wastes were not to be a factor ultimately in dilution ratios, or in other aspects as regards sewage disposal. It is a fact, however, that trade wastes have gone down the Drainage Canal, as an incident to the period during which the volume of domestic wastes has not required the amount of diluting water equaling the capacity of the channel.

I understand further that in the Department of Engineering of the District, there has been established a division, the purpose of which is to study various methods for treating trade wastes, without, however, any consideration, so far as I know, of the financial arrangements under which such treatment methods would be applied.

Q. Taking into account all the facts and conditions that you have mentioned relating to the Chicago Drainage Canal, referring to the protecting of the water supply and preventing sewage nuisance, what is your opinion as to the standing to which the Drainage Canal project is entitled, when viewed in the light of the art of 1889, and also today?

A. In my opinion, the protection of the Chicago water supply is secured in a more simple, effective, economical and therefore better way, than could be secured by any other means of treating the sewage than by the present method; and that applies to the art of 1889, and also to the art as known today, in the matter of sewage diversion and sewage treatment.

Q. Assuming that the flow of water from Lake Michigan through the Drainage Channel, or its adjuncts, were restricted to 4,167 cubic feet per second, what would be in your opinion the consequences with reference to the water supply and sewage disposal problems of Chicago?

A. Such a reduction in the flow of lake water through the main channel and its adjuncts would create a profound and unfavorable disturbance in the fundamental principles upon which this project was designed and built. They would relate to several factors, which I will speak of in turn.

First, a flow of water from the lake of 4,167 seconds feet would defeat the main purpose of the channel, which is to secure at all times a reversal of flow of the Chicago River, in order to protect the water at the intake cribs of the Chicago water supply.

In other words, at times of very heavy rainfall, there would be a reversal of flow of the Chicago River carrying the river water and considerable sewage out into the lake, such as was

the condition of affairs prior to 1900. That reversal would occur on a good many days in the course of a year; at least ten in the ordinary year, and a much greater number than that during years of abnormally high rainfall, or having periods of unusually high rainfall.

Q. What would be the conditions with reference to the reversal of the flow of the Calumet River, with the flow limited to 4,167 seconds feet, and assuming that the Calumet Sag Channel were completed?

A. That of course depends somewhat upon the relative volumes of water that would be sent down the main channel from Robey street as compared with what went down through the Calumet; but it is reasonable to assume that under ordinary conditions of operation there would be substantially no reversal of flow in the Calumet River.

Proceeding now with my answer to the next to the last question, I wish to point out that even on the assumption that at times of heavy rainfall the flow down the channel would not be limited to 4,167 seconds feet, that, in a practical working way, this does not modify my statement above as to inability to secure a reversal of flow of the Chicago river such as is necessary in order to protect the Chicago water supply. The reason for that is that it takes a good many hours, half a day or so, in order to change the regulating works at Lockport so as to increase the volume of flow in the vicinity of the Chicago river down into the main channel and into the Desplaines river. It is this lag of half a day or so, which in my opinion would prevent the practical operation of the Drainage Canal in times of storm flows, so as to secure the protection that now comes from the present method of operation with respect to preventing sewage getting to the intake cribs.

A third aspect of the proposition, assuming 4,167 seconds feet diversion from Lake Michigan water through the main channel and its adjuncts, would force to consideration other means of treating the sewage, whih now is disposed of by the dilution method. That flow corresponds to the legal minimum ratio of dilution for about 1,250,000 people. Obviously the domestic sewage from a population in excess of that figure would require treatment works, or other means of eliminating sewage. This last proposition involves two aspects: One is the feature of the dilution of sewage, so as to prevent putrification of the flowing sewage; and in the second place, with this assumed reduction in the flow of Lake Michigan water, the velocities in the waterways of the channels, main channel,

Chicago River and the various appurtenances would be reduced so that the solid sewage matters would become stranded to an extent where sewage mud banks would arise, putrify and produce seriously offensive odors.

To my thought, it means that with this reduced flow of lake water it would be necessary to settle all of the sewage so as to keep the sludge out of the waterways, as well as to provide means of protecting the water supply through the sterilization of all sewage. And it would further mean the use of sprinkling filters, or other devices, for rendering stable and non-putrifactive the flow of sewage in excess of that which could be properly diluted with this 4,167 seconds feet of lake water.

Q. What are the remedial measures that could be taken to protect the water supply of Chicago, in the event that the flow of lake water were reduced, or limited to 4,167 cubic feet per second?

A. There are two styles of procedure, or two projects which could be adopted for protecting the water supply of Chicago and eliminating sewage nuisances.

The first of these (which I will call A) would involve the collection of the dry weather sewage flow and the first flushings of storm flows, after they pass through settling tanks and apply them to sprinkling filters, so as to render the sewage non-putrescible.

The sprinkling filters should be built to take care of the sewage flow from such portion of the population as could not allow its settled sewage to be adequately diluted by the 4,167 seconds feet of lake water. It would be necessary in protecting the water supply to sterilize this flow of sewage after its treatment by settling or sprinkling filters, or both; and it also would be necessary to sterilize the storm overflows at times of very heavy rainfall. The reason for this sterilization would be that if it were not sterilized some of this treated sewage or storm overflow, or both, being present in the Chicago River and its tributaries at the beginning of heavy downpours, would be sent out into the lake at times. Therefore, to be on the safe side and reasonably to protect the water supply, it would be not only necessary to settle or filter the sewage to guard against nuisance day by day, but it would also be necessary to sterilize these liquids to protect the water of the lake at the intake cribs.

There is a second method of procedure (which I will call B) which would be a project involving, in the first place a sys-

tem of separate sewers throughout the district for collecting the household wastes. That would mean a new set of sewers on all the streets where sewers now exist. It would mean that the rain water falling on the streets and roofs and various areas, yards, vacant land and parks, would reach the water courses through the present system of sewers; and that all house connections for all the properties of this district would be disconnected from the present system of combined sewers and shifted over to the proposed system of separate or sanitary sewers. The flow of such a proposed system of separate or sanitary sewers would then be treated by sedimentation and filtration to secure a product which would not produce putrificative conditions in the channel, and this flow would also be sterilized.

Under this arrangement, the storm water which would reach the water courses through the existing system of sewers would go there without any treatment of any kind.

Q. Describe the different types of works that you have mentioned in connection with the two projects?

A. As these two projects have been developed, it is necessary, first, to state how the sewage would be brought to various places for treatment.

I will speak first of project A, in which the flow of sanitary sewers would be through the existing present combined sewers. Speaking generally, there would be intercepting sewers, which would run along the margin of the Chicago River, and at some other points, picking up the sewage from the lake front. These intercepting sewers would receive the settled sewage which would flow from the sewers as they exist today. By that I mean that the sewage flow would be led into settling tanks before it discharges into the water courses. This ordinary dry weather flow and the first flushings of storm water would then pass from the tanks to intercepting sewers. These intercepting sewers would lead to sprinkling filter sites in most cases, where the sewage, with some intermediate pumping, would all be lifted at the end of the intercepting sewers on to sprinkling filters, where it would be applied to beds of stone through various spray jets.

Speaking generally now of locations—I am looking at the map marked Fuller Exhibit 1, November 17, 1913—I will call attention to the fact that along the north branch, for instance, intercepting sewers would be built from Kinzie street on either side of the north branch to a point above Fullerton avenue, where the conditions would allow sedimentation tanks to be

built. There are some sixteen sedimentation tanks which would be required along the north branch north of Fullerton avenue. The flow of sewage from these settling tanks would be into interceptors, which would lead on either side of the river to about Lawrence avenue. Thence they would unite in a single interceptor built, leading to a proposed sprinkling filter area, just north of the city limits between Devon street on the south and Tuohy avenue on the north. This area lies immediately west of the present north shore channel.

These intercepting sewers would be built of a capacity of about 900 gallons per capita, with a population estimated as of 1930 for the various areas tributary to these respective sewers.

There are, besides this so-called Lawrence avenue project, for treating the sewage north of the Chicago river, three other projects. The second one, spoken of as the West Side project would involve the collection of sewage from the Loop District, and an intercepting sewer which would run along the west bank, or near the west bank of the Chicago River, to the vicinity of Western avenue. There the settled sewage, which at various outlet sewers would pass through settling tanks and into this interceptor would be lifted from the interceptor to settling tanks located between Western avenue and Kinzie avenue beyond the Bridewell; and thence the sewage from the western portion of the city in the sewers now existing and located north of the main channel would likewise return to this main settling tank.

Sprinkling filters, so fas as required would treat the settled sewage from this main west side plant at an area located north of the main channel, south of 39th street, and between South 64th and South Harlem avenues. These sprinkling filter sites in all instances are colored brown on this map.

The third main project, spoken of here as the 39th Street Project, would receive the sewage from the various sewers tributary to the present 39th Street Pumping Station. There on the lake front, settling tanks would be located, the flow of which would be pumped through a conduit which should receive also settled sewage from various main sewers in this area lying south of the Chicago river, excepting the Loop District, and south of the main channel. This settled sewage would be delivered for treatment in sprinkling filters to an area immediately south of that which I have previously described, that is south of the main channel, and lying between South 64th avenue and Harlem avenue.

There would be needed in this instance several pumping stations and settling tanks for the Stockyards District and for the various sewer outlets now discharging into the river or channel, and not tributary to the main pumping station at 39th street.

The fourth project, spoken of here as the Calumet Project, would involve an intercepting sewer starting in the vicinity of the 95th Street Pumping Station, taking the flow from the various centers of population in the Calumet District and leading to springling filters lying just north of the Calumet river, south of 130th street, and lying immediately west of Cottage Grove avenue extended south. On this system of intercepting sewers, there would be settling tanks at the outlets of the various sewers and a number of pumping stations, all of which will be detailed in the estimates which I will consider later on.

On this map, the intercepting sewers are marked in red showing their location, and also with an arrow indicating the direction of flow.

The sewage pumping stations, at points where it is necessary to lift the sewage flow along the line of the interceptors, are shown with black circles, and the same black circles are used to indicate the pumping stations needed for lifting the sewage at each of the respective sprinkling filter sites. The sedimentation and disinfecting plants are shown in yellow with a heavy black margin around the area, and as I have already stated, the sprinkling filter areas are shown in brown.

I should explain that at all of these settling tanks, the flow of the sewers in excess of 900 gallons per capita for the 1930 population would have disinfection or sterilization plants where such excess storm flow would be thoroughly disinfected.

Now, proceeding to what I have called the other project, Project B, the various treatment works would be located at the same areas as I have just described for Project A. The intercepting sewers, however, would be smaller because they would deal only with the domestic wastes and not receive storm flows. They would be, roughly, half of the capacity of the interceptors of Project A. The pumping stations would also be smaller in size, on account of having no storm water to deal with.

I have assumed that the settling tanks, sprinkling filters and the interceptors, in point of location, would all be located precisely as in Project A.

By Project B, there would drop out of consideration, how-

ever, the disinfecting plants as regards storm water flows; but the treated sewage would in all cases be subjetced to sterilization.

One further word about the sterilization should be added, and that is that where the sewage is subjected to treatment in sprinkling filters, the sterilization plant would deal with the filtered sewage after it had been subjected to a secondary sedimentation.

In those cases where the sewage is not passed through sprinkling filters, the disinfection would take place at the primary settling tanks, and adjoin the works for sterilizing storm overflows in Project A.

Recess to 2:00 P. M.

After recess, 2:00 P. M.

GEORGE W. FULLER, resumed the stand and testified further as follows:

The Witness: (Answer continued.) This map marked Fuller Exhibit 1, shows also a small project marked here the "North Shore Project," wherein is shown a system of intercepting sewers beginning in Glencoe near the northern district boundary line, coming through Winnetka, Kenilworth, down to Wilmette; there showing a pumping station and small treatment works for a population of 55,000 people estimated as of 1920.

In regard to the collection of the sewage flow from the present sewers discharging into the various water courses, I should state that in these intercepting sewers and appurtenances arrangement is made for aerating the sewage. The purpose of that aeration is to prevent putrification taking place such as is found in a great many outfall sewers of large cities, owing to the age of the sewage. Now, to prevent and offset the putrification, which is due to bacterial processes taking place as the liquid flows in the sewer, provision is made in these projects for pumping in air so as to keep the decomposition on an oxidizing and not on a putrifying basis.

With respect to the population, it will perhaps be more explicit to repeat a word or two, and say that these intercepting sewers for delivering the sewage flow to settling basins, sprinklers and treatment works, the design has been based on the assumed populations of 1930, namely 3,500,000 people. With respect to the treatment works, this is including the filters,

settling basins and sterilizing arrangements, the population has been assumed as of the date 1920. On that date, the estimates of population show for the city a population of 2,900,000. In fitting these different projects to a population basis, there has been some little latitude used and there has been included the population of the Calumet District on the south and the North Shore district on the north.

The population provided for in my estimates is: Within the city, 2,900,000 population; outside of the city limits, in District 14 on the west side, 133,000; 21,000 outside the city limits in the Calumet District, and in the North Shore District 55,950. The latter figure includes Evanston.

Now, the summation of all of these different populations assumed to be provided for in the respective treatment works amounts to roughly 3,000,000. I have assumed in my estimate that that would be equivalent to what would be served by 10,000 seconds feet flow in the main drainage canal, equal to 3,000,000 people.

I am aware that in making estimates of future growths of population in different districts there are bound to be some discrepancies, and these aggregate figures are rather more liberal than should be made for the respective individual treatment plants.

I think next I will outline briefly the particular devices which it is proposed here to use in settling and filtering the sewage, and in sterilizing it; and refer roughly to what in practice elsewhere these particular devices have accomplished in the nature of improving the hygenic character of the sewage, and with regard to the bearing which the works would have upon the elimination of sewage nuisances.

The settling tanks would be built of the two story Imhoff type. By that I mean that there would be large settling tanks built with their flow line roughly corresponding to the flow line in the existing sewers. They would have a depth of some 25 feet, say, and be in two stories. In the upper compartment, the sewage would flow through the tanks for a period on an average of two hours. The increase in the cross-section of that settling compartment with respect to the size of the sewer so checks the velocity down to half an inch per second or so, with the result that there are deposited the coarse matters in the sewage.

In the bottom of this campartment is a slot or opening, through which the solid matters would pass to a large chamber beneath. This lower chamber is called a digestion cham-

ber, and in it the solid matters would be allowed to accumulate for perhaps six months or so. During this interval bacterial decomposition would intentionally be directed and encouraged, so that it would gasify, putrify and allow the bacteria to eat up all of the unstable organic matters. Much of this solid matter would be changed to liquid and gaseous substances. The result of this is that the sewage sludge would become septicised or eaten over by the bacterial life, so that it would be taken out in a substantially inodorous condition.

This wet sludge from the lower compartment would be removed at intervals through a pipe, and applied to little thin beds of sand and gravel; and it so happens that the sludge as removed contains much gas. This is of importance, because when it is removed and applied to these straining beds or sludge beds, the gas seems to lift the solid matter to the surface, and it allows the liquid from the bottom to pass down through the sand and gravel of the bed to which it is applied. In the course of a week or so this septicised sludge has been so freed of water that it is spadeable, and can be shoveled into containers for its removal to any convenient place to be used for filling, or to be stored in a spoil bank.

At these settling tanks along the various sewer outlets going into the water courses, arrangements would be made whereby the sewage flow passing through the tanks would be limited to three times the dry weather flow, or to 900 gallons per capita daily. The storm flow in excess of that quantity would not pass through the regular settling tanks, but would be subject to sterilization. By sterilization, I mean that there would be added to the storm flows liquid chlorine sufficient to kill the disease germs in the liquid and upon the exterior of particles of suspended matter. Sterilization is, of course, not effective in killing the germs in the interior of particles of suspended matter.

These tanks for purposes of sedimentation would allow the removal of some 90 per cent. or so of the particles which are capable of settling. They do not of course affect at all those soluble matters in the sewage, such as urine, nor the fine particles of fecal matter, or substances of other origin which are so fine that they will not subside. That is the non-settling solids and the soluble matters in the sewage pass through the settling tank and on into the intercepting sewers.

In the course of six or eight hours or so, sewage will become, under ordinary conditions in large cities, putrifying, and productive of foul odors to an objectionable degree. These

intercepting sewers are supposed to carry sewage which has its content of oxygen not depleted; and the oxygen supply is assumed to be replenished by pumping air at intervals into the flowing liquid in the intercepting sewers. The quantity is, in accordance with various tests at New York, roughly, one-tenth of a cubic foot of air to one gallon of sewage.

In those cases where the settled sewage must be filtered, that is for all projects other than the West Side Project, the settled sewage will flow in these intercepting sewers and be pumped at the respective filter sites on to the sprinkling filters. I should say that for the West Side, I have assumed that the settled sewage from the central west side area, from the Loop District and the floating population in the Loop District of some 300,000 people, that that settled sewage could be adequately diluted by 4,167 seconds feet flow of lake water, so that it would not be necessary to filter it.

The removal of organic matter by sedimentation is taken to be roughly 25 per cent. on an average, as compared with the organic matter in the raw material. To reduce the organic matter of the settled sewage to a point where it will not putrify in the water courses, it is estimated that there would be required one acre of sprinkling filters for 12,500 population.

These sprinkling filters, as I have already stated, would be large beds of stone, of a size ranging from one to three inches in diameter, about six feet deep. To these filters, the settled sewage would be applied from a series of sprinkler nozzles, spaced roughly ten feet apart. The sewage would then be thrown as a form of spray such as from a lawn sprinkler over the surface of the bed of stone. These sprinkler filters operated at this rate will produce an effluent which will not putrify after there has been removed from it some suspended matters which are released from the bed in an irregular way.

To clarify this filtered sewage, these projects provide for secondary settling tanks holding about one hour's flow, and of about the same size structure as the primary settling tanks, but of one-half size for a given sewage volume.

This sewage sludge would be similarly strained on sludge beds to remove the water, so as to get it in a spadeable condition for removal to a sludge bank, or any other convenient way of disposal. The sludge has somewhat limited value for fertilizing purposes, and in some cases in Europe it is taken away free of charge by the farmers of the neighborhood.

I have assumed that it would cost some 50 cents a yard

to get rid of this sludge, and that it would not be feasible to dispose of it to farmers.

Wherever the dry weather flow of sewage is subjected to filtration the sterilization process would be applied to the effluent after it leaves the filters, and not to the settled sewage before it reaches the filters. In the West Side Project where filters would not be needed with the present assumed volume of lake flow, the sterilization process would be applied of course to the flow from the primary settling tanks.

In the matter of sufficiency of sprinklers, I would say that they will reduce the organic matter in the sewage some 70 per cent. or more, and in connection with the oxygen present in the filtered sewage, they will produce a stable liquid which will not putrify upon exposure to sunlight and the air, for a long term. There are times when these beds unload their solid matter, when perhaps that would not be literally true; but generally speaking these beds, in practice at the rate here indicated would produce a liquid which would not give trouble from putrifaction.

The removal of bacteria by the sprinkling filters would probably range from 80 to 90 per cent. The liquid would be substantially free of suspended matter. The sterilization of the filtered sewage would have for its purpose, of course, the destruction of disease germs to the extent of the 10 or 20 per cent remaining in the filtered sewage as compored with that appearing in the raw sewage.

As to storm water flows, the liquid coming from the streets contains a good deal of organic matter, and would probably call for as much as 70 pounds of liquid chlorine to the million gallons. For the ordinary settled sewage coming from the primary tanks, I assume it would take some 50 pounds of liquid chlorine to a million gallons. For the filtered and settled sewage I have assumed that about 10 pounds per million gallons would be sufficient.

As to what sterilization will accomplish in point of removal of disease germs, I should say that the removal would amount to 95 to 99 per cent., depending upon the success with which the applied quantity of liquid chlorine was adjusted to the particular organic content of the liquids flowing, and recognizing the variation in such flow, and in their strength from time to time.

In the matter of pumping stations, these projects for the treatment of the sewage would involve the operation of the present pumping stations for sewage flows at 39th street,

Lawrence avenue, 95th street and elsewhere. They would also require some intermediate pumping along the line of the interceptors, at settling basins and at each of the respective filter plants it would be necessary to lift all the flow, in order to produce a head sufficient to distribute the sewage to these various sprinklers scattered over the surface of the filter bed. There would have to be a head at the nozzle of some six to eight feet, as well as to lift the sewage up to the elevation of the nozzle itself.

In regard to the question of odors and nuisances, I have already spoken of the great importance of preventing such conditions as have arisen at Columbus and Baltimore, where the sewage has become highly putrifactive before it reached the treatment works. That would be accomplished by the aeration that I have described.

In regard to the sprinkling filter sites, I have outlined certain locations which have been used as the basis of these studies. It is not necessary to treat them precisely at the areas indicated on this map marked Fuller Exhibit 1, but those approximate areas, however, are convenient and suitable; and in these instances are entirely reliable for the purposes at hand. These different filtering site areas cannot be limited to the immediate ground which would be occupied by the structures. It is found that in these beds there will grow flies and various forms of animal life, and it is necessary for that reason to purchase land which would keep other property owners from living immediately adjacent to the beds.

There is also the item of odor, which is not very serious if the sewage is kept in this fresh condition that I have spoken about with respect to aeration.

For instance at Reading, Pennsylvania, where the sewage is fresh, it is a mountainous town and high velocities obtained in all cases, the odors are rarely if ever noticed more than 300 feet away. Most sprinkling filters, however, are apt to develop an odor, in the case of large plants for a quarter of a mile; occasionally in some plants it is extended much further than this.

In these estimates made in developing this project, allowance is made for the purchase of land one-quarter of a mile in extent around the entire outer periphery or building line of the proposed works.

In regard to the question of odor around the settling basins, I do not believe that there would be anything serious encountered there, nor would the flow of storm water treated with liquid chlorine be objectionable in the water courses. It is

conceivable, however, that lack of care might produce an excessive application that might not be present except for a very short time.

That, I believe, covers in outline the main features of the best methods now available for building treatment works to clarify sewage, to eliminate the stranding of sewage solids, and putrifaction of mud banks, to take the sewage after settlement and where there would not be water available for oxidizing it by dilution, then subjecting it to the oxidization in sprinkling filters and finally in sterilizing all of these flows so as to destroy objectionable bacteria to the extent of say 95 to 99 per cent. of those contained in the original sewage.

This residual small percentage, as I have already explained, cannot be reached by sterilization or any other process, on account of some of those germs being located within the interior of tiny little particles of fecal matter, where the chemicals will not have access. These treatment works are the best than can be applied to problems of this kind, as the art of sewage treatment is known to-day, both in point of theory and practice.

In regard to the pumping stations, I might add a word and say that they are all assumed to be centrifugal pumps, steam driven, and are assumed in the estimates to be strictly in line with the installations of sewage pumping machinery in the district here in Chicago, and in other large cities. The equipment, as I have said, provides for handling the sewage at a number of points along these interceptors, and in pumping all of the sewage going onto the sprinklers.

Q. Why do you assume a population that would exist in 1920, for the Sanitary District of Chicago in making your calculations and in solving the problems?

A. That approximate figure in 1920, has shaped itself in these estimates by virtue of the fact that the population then existing in the city and in the outlying areas within the Sanitary District would roughly equal the diluting capacity of a 10,000 seconds feet flow of lake water down the main channel. It also represents the best judgment of those familiar with the details, according to my information, of the past growth and the increments in growth leading to proper and reasonable conclusions as to what the 1920 population may be.

My own purpose was largely in getting at a figure as to scope of project which would allow a comparison to be made of the treatment works for a 3,000,000 populatlon which has come into this project, and my reflections in connection with the 10,000 seconds foot flow, when treating the population

at the legal minimum dilution ratio of 3.33 seconds feet per thousand.

Q. Then, as I understand, Mr. Fuller, you have used this figure or calculation of 1920 as a basis on which you calculate the estimates for the solution of this problem?

A. Yes.

Q. Taking into consideration the efficiency of these methods, and then putting them into operation, and taking the water supply of Chicago, how would they compare with the efficiency of the present method that is in use, in the protection of the water supply?

A. They would not protect the water supply so reliably or completely as would the diversion of the sewage of the district down the main channel.

Q. Have you made any estimates of the cost of installing and operating each of these two projects A and B, which you have mentioned?

A. Yes.

Q. Will you state how you have arrived at the cost, and what your estimates are of such cost?

A. You mean construction cost now, or the operating, or both?

Q. Both cost of installing and cost of operation.

A. I have estimated that it would cost for construction purposes to build project A, $71,365,866. The annual operating expense and depreciation I estimated at $5,116,057. I have capitalized this annual charge for operation, maintenance and depreciation at 4.25 per cent., and have added it to the investment cost. This makes a sum of $191,742,866. That is the sum which it would cost this district to take care of the sewage by project A, for the population estimated to exist in 1920, roughly 3,000,000 of people.

For project B, the investment cost I place at $131,229,707. The annual cost of operation, maintenance and depreciation, I place at $4,524,952. Capitalizing the latter sum at 4.25 per cent., and adding it to the investment cost, there is obtained $226,970,647, as representing the cost to the district of treatment works for 3,000,000 people by project B.

Q. Have you made any estimate of the cost of these same works if applied to a population which would be served by the works of the Sanitary District, in the event 12,000 cubic feet and 14,000 cubic feet of water per second passed through the channel?

A. I have assumed that the same per capita cost would

obtain, and I have pro rated the expense to get at figures for the 12,000 and 14,000 feet respectively.

Q. Will you state what the cost would be under those two projects?

A. You mean the aggregate cost?

Q. Yes, cost of installing and cost of operation.

A. Under project A, to provide treatment works corresponding to a population which would be taken care of by a lake flow of 12,000 seconds feet, the investment cost would be $85,000,000. The annual operating maintenance and depreciation cost would be $6,102,000. Capitalizing the annual cost and adding it to the investment, there would be obtained $230,000,000. The corresponding figures for treatment works of a capacity equal to that which would be taken care of by 14,000 seconds feet flow of lake water would mean, by project A, an investment cost of $100,000,000, an annual operation, maintenance and depreciation item of $7,260,000. The sum of the investment and capitalized operating expense would be $268,000,000.

I should state that these figures which I am reading are round figures, obtained with a slide rule. They are not figured to individual dollars and cents.

By project B, the investment cost of treatment works, with separate sewers to provide for a population equal to that which would be taken care of by 12,000 seconds feet flow of lake water would be $157,000,000. The annual cost would be $5,400,000. Capitalizing the operating expense and adding it to investment, the total cost becomes $270,000,000.

The corresponding figures by project B, for treatment works equivalent in population served to that for 14,000 seconds feet flow of lake water becomes for investment cost $183,000,000; the annual cost would be $6,300,000. The sum of the investment plus capitalized annual charges would become $316,000,000.

I should perhaps state with regard to project B, one or two points that I think I briefly touched upon in my preceding answer; and that is this project B deals with no storm water sewage at all, no street wash, but assumes a complete new system of sanitary sewers which would deliver to settling basins the sanitary wastes of the community. That settled sewage would pass through interceptors with aerating arrangements onto sprinkling filters, all in substantially the same way as in connection with project A. The intercepting sewers, however, would be of about half size. The pumping stations would be somewhat smaller. There would be no steril-

ization of storm flows; it would go directly into the river without treatment through the existing sewers. The settled sewage, filtered sewage, would be sterilized.

Q. When you speak of the sanitary sewers, what sewage would they collect, would that be just the domestic sewage coming from the houses and buildings?

A. And office buildings and industrial establishments, but not to any extent have I dealt with the large element of trade wastes of this community, as found in the stockyards district and along the industrial establishments on either side of the north branch. It is domestic sewage and sewage of the loop district, that is the typical sewage, which they would treat.

Q. How long would it take to install these different works that you have mentioned under projects A and B?

A. I should say that eight years would be a fair estimate for the period of active construction. I have placed the time at ten years, assuming that conditions would be favorable in all respects with regard to securing funds with which to build these works, and to get the necessary legislation, enabling acts, and condemnations of lands and rights of way.

Q. You refer to the condemnation of land, you mean for the sites where these works would be placed in the city?

A. Yes. In this period of two years, that is the difference between the eight years and the ten years, there would of course be a large amount of work involved in the matter of preparing plans and specifications for these various works to be placed under contract.

I have assumed that the amount of engineering required would always be provided without delay, and not recognizing the limitations of any staff, which usually has to be adjusted to certain regulations. That is I have assumed that any one of these projects would have a certain designing period, and that there would be as many multiples of designing forces as needed, in order to design the works in the aggregate.

In this general connection, I might state that experience shows that the minimum periods of designing and building sewage treatment works do not aggregate by any means the periods which experience has shown to have been needed in solving large problems of this sort elsewhere.

I could point out for instance that at Providence it was determined in 1887, to build chemical precipitation works, but they were not put in service until 1901. That period in the

interim was required for financing and building the necessary intercepting sewers and treatment works and in adjusting delivery of sewage to those new structures.

In Boston, the original main drainage works were recommended in 1875 for collecting the sewage of the old city of Boston and delivering it to Moon Island for discharge on the outgoing tide. Those works went into service in about 1884.

The Washington works for intercepting the sewage of Washington City and pumping it after some screening into the Potomac River below Washington were recommended by the Commission appointed by President Harrison in 1889. Those recommendations by the Commission were made in the early part of 1890. I think it was 1908 before those works were completed and put in service.

In the Passaic Valley project, in New Jersey, opposite New York City, the first recommendations there were made in 1897. The matter was reviewed by a State Sewage Commission again in 1901. There was an enabling act passed in 1903. It was in litigation in point of constitutionality until 1907, and the project in its present form was outlined by Hering & Fuller, in 1908, and the construction work was started in 1912, about a year ago, and it is still subject to injunction suits and various vicissitudes of litigation, and including an injunction suit brought in the United States Supreme Court by the State of New York with respect to discharging this sewage into the upper New York Bay.

The Charles River Dam project in Boston was active in my days there in 1891. That relates to building a dam across the Charles River near the old Cragie bridge, and preventing the exposure of the tidal flats on the Boston and Cambridge sides of the river, and in building intercepting sewers along the water front on each side to send the sewage down to points beyond or outside of Boston Harbor.

Those works were the subject of many legislative investigations, particularly a very exhaustive one made by Mr. John R. Freeman in 1903. The works have been in service I should say about three or four years, so that I think experience very abundantly shows that actual periods required for getting legislation and in getting financial programs adjusted, getting works that will not be made the subject of too many legislative inquiries and investigations by Citizens' Committees, I think all of those things taken into account make the period very much longer than the actual designing and construction calls for.

Q. How do those projects that you have mentioned compare in size with these projects here that you have outlined, A and B?

A. They are all very much smaller. I doubt whether any of them exceeds $15,000,000 in investment as compared with $70,000,000 here for project A, and $130,000,000 for project B.

Mr. Hopkins: I move that all this testimony about other peoples' difficulties be stricken out.

Mr. Adcock: Q. Will you continue your answer to the next to the last question?

A. In regard to getting sites for sewage treatment works, I have had considerable experience with a good many fairly sizable undertakings, and I know that there are a great many delays incident to taking title to lands for sewage treatment works.

I have been engaged for some seven years in what is known as the Plainfield district of New Jersey.

Mr. Hopkins: I object to the witness testifying to these matters, as he is not qualified to speak with reference to the condemnation laws of the various states.

The Witness (continuing): I think that I have designed for those communities three or four different sewage treatment works fitted to as many different sites. The project is not yet under construction, and what its future interruptions and delays may be, I do not know. I know that in the majority of instances, unless sewage treatment works are located in areas far removed from built-up areas that there is a decided objection on the part of property owners to having works so located.

I recently encountered that, in connection with a large trunk sewer project immediately north of New York City, discharging the sewage of the Bronx Valley into the Hudson River, just north of New York City line. Those injunction suits seem to be a factor which has to be reckoned with most carefully. No one can foretell what their exact significance may be in making a program in point of dates for carrying out these large sewage treatment projects.

Q. The projects that you have described, A and B, do they involve the tearing up of the streets of the city in any particular, or to any extent?

A. Project A, would involve tearing up streets along the lines shown here in red ink on this map marked Fuller Exhibit 1. It would cover a good many miles of streets in the vicinity of the water courses of the north branch, the main

Chicago River from 39th street over beyond the stockyards district, to a point where 39th street meets the Drainage Canal; also down through the Calumet district as shown in this plan.

In project B, there would be involved the tearing up of every street throughout the district, in order to build the sanitary sewers in it to parallel the existing sewers. It would not only mean tearing up every street that is now paved, but it would also mean lateral house branches from the street sewer out to the curb line under the sidewalk to the property to the building line.

It would encounter, of course, a good many underground obstructions, in the nature of interference by existing utilities, water mains, gas mains, electric light conduits and telephone conduits, etc.; also make a decided impression on street pavements; involve considerable care in maintaining trolley lines in service during construction periods.

Q. Now, Mr. Fuller, you have stated what you consider to be the cost of installing projects A and B, and also the annual cost of operation of projects A and B, each respectively. Will you state how you have arrived at the cost of installation, the cost of operation and the elements which you have taken into consideration in arriving at such costs?

A. Taking up first project A, the intercepting sewers are assumed to be of a capacity of 900 gallons per capita for the 1930 population. These intercepting sewers are built of concrete, in open cut to a depth of some 30 feet.

These intercepting sewers are assumed to have a velocity of not less than 2.5 feet per second; and where the conditions permit, a velocity as high as four feet per second.

The construction cost per running foot of the sewers of the sizes required are taken from the records of the district, showing their actual experiences in construction cost of sewers of the respective sizes, adjusted to the prices of current date for labor and materials.

The sewers are predicated upon excavation being made by machine in all streets that are sufficiently unobstructed by the utilities of other than a sewerage nature. On the streets that are congested with various underground obstructions, the excavation is assumed to be made by hand.

In regard to the pumping stations, they are all assumed to be steam driven pumps and the unit price is uniformly taken at $500, per water horse power for the lifts involved.

The aerating devices are assumed to cost $1,500 per mill on gallons of sewage to be aerated.

The cost of sedimentation tanks with their various appurtenances is taken at $2.40 per capita for the population connected with the sewers leading to these settling tanks. This item of $2.40 per capita is sub-divided into the following:

Venturi meter, four cents.

Grit chambers in which to remove the heavy matters coming from the street wash, 15 cents.

Sedimentation tanks of one story Imhoff type, $1.93.

Sludge beds, 18 cents.

Laboratory and miscellaneous appurtenances, 10 cents.

Total, $2.40 per capita.

The sprinkling filters are assumed to cost, with their final settling tanks and appurtenances, $5.20 per capita. This item is divided as follows:

Dosing tank and piping for applying the sewage to the filters, 20 cents.

Sprinkling filters, $3.80.

Final tank for settling, $1.00.

Sludge beds for final tanks, 10 cents.

Laboratory and miscellaneous items, 10 cents.

The sterilization devices dealing with the storm flows are estimated at a cost of $8,400 for each square mile of area tributary to the treatment plant. This is on the basis of $210 per million gallons, with an assumed maximum run-off of 40,000,000 gallons per day per square mile. Under these conditions, there would be a storage tank in which the storm flows would be retained under conditions of maximum flow for about 10 minutes.

I have applied in every instance to the sums obtained by multiplying the unit prices above given by the number of population as the case may be tributary to each plant, certain allowances for overhead, and for interest during construction.

To the figures for unit prices above given, I have added to the resulting sums an item of 25 per cent. to cover overhead cost, including engineering, legal expenses, administration, clerical work, omissions and contingencies such as are bound to arise in preliminary estimates of projects of this nature. I have also added interest during construction. By that I mean that where it would take eight years to build plants for the treatment works of this district, I have assumed, as is quite generally the rule in appraisement matters, in getting at the value of completed structures, interest at the ordinary rate, here taken at 4.25 per cent. on the full amount of construction work for one-half of the period estimated to

be required for construction. In the case of land, I have taken figures from the officials of the district who have looked into these matters in detail.

I believe I have already stated that in connection with sprinkling filters, an area is taken equal to a quarter of a mile in width around all sides of the treatment works. That would mean, for instance, the Lawrence avenue project about 630 acres; the West Side project, 720 acres; the 39th street project, 650 acres; the main project in the Calumet District, 364 acres.

I have personally visited the areas considered as sites for the filtering projects and have been in general over the loca tion of the various structures involved in these treatment works. I think the sites are proper ones and as good as can be selected.

The estimated cost of this land, as I have already stated, is a matter concerning which I am not personally informed, but have taken that from the officials of the district. In regard to the treatment works themselves, I should state that the pumping stations, settling basins, filters, sterilizing devices are all estimated by me upon individual studies predicated upon quantities of the different structural work involved and based upon my personal experience at various places in this country, such as Reading, Columbus, Atlanta, Schenectady, where sprinkling works now exist, and upon the most modern settling basins of the two-story Imhoff type, such as built at Atlanta and elsewhere. These studies are predicated further upon drawings which I have prepared, endeavoring for these large projects to make the structures as economical as possible.

In my judgment, these various treatment works are predicated upon unit prices for excavation, concrete and other work as low as is consistent with the local market conditions for labor and materials, and upon structures as economically laid out as is feasible.

The pumping stations, as I have already said, are estimated to have cost $500 per water horse power, and that estimate is predicated upon a personal study of the actual cost of similar sewage pumping stations in this district, and other large American cities.

The interceptors and the aerators have been discussed fully by me with the officials of the district, and I believe that as the result of those conferences the unit prices and the structures involved are thoroughly fair and reasonable for the work which they would do, and which work is as small an amount

as is consistent with the nature and the scope of the problem.

To the estimate which I have prepared for project A, I have added, as already stated, 25 per cent. overhead and an interest charge of 34 per cent. on the land for the period of eight years, that is, 34 per cent. interest. On all construction work, I have added an interest item of 17 per cent., equal to the interest for four years on the whole construction work, or one-half of the estimated period of construction.

The different portions of these treatment plants under project A, with their respective amounts, including overhead and interest are as follows:

Interceptors, $16,669,974.
Aerators, $2,014,593.
Pumping stations, $12,383,718.
Settling basins, $10,895,157.
Sprinkling filters and appurtenances, $16,233,138.
Sterlizing devices, $2,393,073.
Land, $5,190,322.

Utilities, meaning by that the various pipes, conduits and underground obstructions for other public service, $5,585,-891.

That gives the total of $71,365,866.

I should state with regard to the allowance for public utilities, in the nature of what it would cost to move water mains, gas pipes, telephone conduits, electric light conduits and the like, that I have examined carefully the figures which have been obtained by the officers of the district, in conference with the various people in charge of those utilities. I have looked them over, and made comparison with what my experience has been in connection with similar work elsewhere, and I consider those allowances, those estimates fair and reasonable.

Now, with respect to the annual cost of operation, maintenance and depreciation for project A, first, as to depreciation I have made allowances as follows:

Interceptors, .5 per cent. per annum, that is depreciation.
Aeration devices, 3 per cent.
Pumping stations and equipment, 3 per cent.
Settling basins, 1 per cent.
Filters and appurtenances, 1 per cent.
Sterlizing devices, 3 per cent.
Land, nothing.
Utilities going with the interceptors, .5 per cent.

That makes an annual sum for depreciation or obsolescence of $886,297.

The pumping station operation, maintenance, repairs and

renewals I have estimated at $350 per water horse power per year, equal to four cents per water horse power hour, or 16 cents per million gallons lifted one foot high. That is based upon a careful study of the operation of sewage pumping stations in this district, and in the case of other large sewage pumping stations in other American cities.

That gives an allowance per year for pumping stations of 6,544 water horse power, $2,325,400.

The cost of operating the aerators is taken at eight cents per capita based upon the one-tenth cubic foot of air pumped into each gallon of sewage, as I have previously explained, and that amounts to $166,280 per annum.

In regard to the settling basins, I have estimated the cost of handling the settling basins with the grit chambers, which would precede the settling basins and take out some of the coarse street wash at 18 cents per capita. That sum allows, as I have previously stated, an estimate of 50 cents per cubic yard for removing and disposing of the spadeable sludge. I should make it plain that in my judgment there is no likelihood at all of any substantial quantity of this sludge being used for farming purposes such as I have mentioned before as being experienced to a limited extent in some of the small German cities.

For these large projects, I am convinced it would be necessary to dispose of the sludge in other ways than relying upon the efforts of farmers to take it away.

This operation of settling basins, in point of attendants, supervision, is predicated upon actual experience in operating plants of this sort elsewhere. The cost of operating the settling basins per year amounts to $558,720. Filter operation is estimated at 12 cents per capita per annum, giving the aggregate figure of $256,140. These estimates are made on the assumption that they would include a reasonable average allowance for repairs and renewals, to keep them working in good shape.

In regard to the filters, I should make it plain that I have not in this project A assumed that there would be such filters built for the West Side district, on the assumption that the sewage of the loop district and the West Side district, after sedimentation, would be sent into the channel and the lake water flow of 4,167 seconds feet would oxygenate that settled sewage so as to do away with the need for filtration.

To make that point clearer, I should state that the settling basins estimate of cost for maintenance applied to the 3,104,000 people, and the filter cost applied to 2,134,500.

As I have explained previously, this loop district and the West Side district are assumed also to carry on the sewage end the flow of a floating population that is not resident here of 300,000 people on an average.

Coming now to sterilization, I have assumed from my experience elsewhere that for the final filtered sewage it would require ten pounds of liquid chlorine per million gallons; for plain, settled but unfiltered sewage, 50 pounds per million gallons; of storm water overflow 70 pounds per million gallons. The cost of this liquid chlorine I have taken at a current market price of ten cents per pound. This would give an aggregate annual cost for sterilization of $885,820.

I further assume that there would be four superintendents in charge of the four main sewage treatment projects; that their annual salary, $3,600, gives $14,400 for general superintendence.

There was an item also of maintenance of intercepting sewers, taken roughly at $500 per mile of interceptors per annum, including the general outside management expenses, and predicated upon experiences on similar work elsewhere, amounting to $23,000 per annum.

That gives a total annual cost of operating of treatment works by project A of $5,116,057, the figure which I previously stated.

Q. Those figures are based upon an estimated population of approximately 3,000,000 people?

A. Yes, in round numbers.

Now, I will go to project B. Taking up now project B, which involves duplicating the present sewer system or paralleling it with a new system of sanitary sewers, which would take household wastes only, I find that the records of the City of Chicago show that there are now in existence 2,037 miles of sewers. The cost is given as $31,867,268. These are the sewers exclusive of the large interceptors along the lake shore. This figure gives roughly a cost of $15,800 per mile.

As I have stated already, these present sewers, with the exception of here and there some limited areas that have recently been annexed, are all built upon the combined plan of receiving household wastes and also the storm water. They were built at a time when the public utility item of underground obstructions and pavements was very much less of a factor than at the present time. The new system of sanitary sewers involved by project B, would be smaller in size, but they would involve cutting the pavements, replacing the pave-

ments and taking care of the public utility underground obstructions, so that I am inclined to be lieve that their cost would equal that of building the old sewers under the conditions which existed at the time when they were actually constructed. I have looked into this matter in connection with two or three sewerage system appraisals that I have been on during the past year, and I find that $15,000 per mile of sewers on an average, taking into account the pavement and public utility obstructions underground is a reasonable price. In fact it has been exceeded in a number of cities elsewhere, for instance at New Orleans, where I have been connected with the complete new system built for that city within the past ten years. The construction of the sanitary sewers in the streets, estimated by me to cost $30,000,000, in round numbers will not tell the whole story by any means. There would still be required connections between the street sewers and the 300,000 properties, by that meaning houses, business blocks, etc. Not only would there have to be built the house connection for each of these 300,000 properties from the building to the street sewer, but there also would have to be rearranged the plumbing facilities within the house, disconnecting them from the present storm water sewers and reconnecting them to a new house lateral. Storm water coming from roofs would also require separation so that it would go to the old and not to the new sewers. Taking into account experiences elsewhere, in connection with the resewering of a city, I estimate that it would cost on an average $100 per connection for each of these properties, making for the entire district $30,000,000, which added to the cost of the new street sewers makes a total of $60,000,000. In arriving at the total investment because of project B, $131,229,707, I started out with the investment cost of project A, of $71,365,866. To that I have added the $60,000,000 for separate street sewers and the house connections and plumbing rearrangements. I have also added the cost of building sterilizing devices for the flow of these separate sewers alone. That amounts to $136,159, the sum of which three items is the aggregate figure of $131,229,707 above stated.

From this I have deducted the cost of building storm water sterilizing devices as outlined in Project A, that sum being $2,393,073. I have also estimated that the cost of interceptors and pumping stations would be less by Project B, than by Project A. I have considered these two items, and taken the cost of the interceptors at one-half of what it would be in

Project A, or $8,334,987, as an item to be deducted. Adding together these two items for deduction, storm water sterilization and reduced size of interceptors, with allowance for pumping station reduction, there is obtained $120,501,647, as the investment cost for Project B.

The net cost of operating Project B, amounts to $4,524,952 per annum. That is made up in my estimates of the operating cost of Project A, namely $5,160,057. To that I have added a depreciation of ½ of 1 per cent. per annum on the $60,000,000 investment for the separate system of sewers, namely $300,000. I have also added the cost of maintaining the sanitary sewers estimated from my experience elsewhere at $40 per annum for 2,000 miles, or $80,000. The sterilization of the sewage flow I have taken at $679,500. That gives a total of $6,175,557. From this sum I have deducted certain items which would not be involved by this Project B, which were taken into account by Project A. These involved the depreciation on the sterilization for storm flow devices for the interceptors of a total expense as compared with those for Project B, and the actual cost of sterilization of storm water flows.

I have also assumed that the pumping station cost would be 4/5ths of that involved by Project A.

I have also assumed that the volume of sludge to be removed would be less. This is on account of Project B, not involving the street wash. In this item of sludge removal for Project B, I have assumed to cost 6 cents per capita per annum less than for Project A. This gives credits to Project B, of $1,650,605; the individual items amounting as follows:

Depreciation on sterilization devices, $71,790.

Depreciation on one-half cost of interceptors, $41,675.

Sterilization cost, $885,820.

Credit of one-fifth pumping station operating expense $465,080.

Reduced item of sludge disposal $186,240.

Subtracting these credits from the above summation of the operating expense for Project A, and the new items involved by Project B, there is obtained the net sum above stated, namely $4,524,952.

Q. This unit prices that you have mentioned in connection with the operation and installation, on what are they based?

A. So far as the treatment works are concerned, they are based upon my individual study of the experiences ob-

tained in building and operating sewage disposal devices in various places in this country and in Europe, where I have made an individual study of these matters. They were produced in my office in connection with quite thorough studies of the amount of construction work involved, keeping the size and design of these tanks and filters at a minimum of expense for accomplishing the work which I have described them to be able to accomplish.

Q. Is that true also of the items which you have mentioned there as making up the sum of the cost of operation?

A. The operating expenses for the treatment works themselves are also the result of my individual study of these matters, based upon my experience at various places in this country and elsewhere. In regard to pumping stations, I should say also that the cost, both for construction and operation represent my individual experience in studying these matters as actually has been encountered in handling problems of this type, in various places in this country and abroad.

Q. You have mentioned an item there that you assumed as the overhead, cost of legal expense, contingencies, engineering and so forth. Upon what was that estimate based?

A. That is based upon my general experience in connection with projects of this kind of a very diversified nature, complex type of structures, the uncertainty under which they are found in all preliminary stages. It is based upon the practice in New York in connection with handling large projects even of a similar nature with this. There are always things that cannot be foreseen. The contingent item is a large factor in projects of this magnitude even where in disjointed studies they have received very careful consideration; and experience in handling these large enterprises shows that the amount of money paid to a contractor for building certain projects, plus the cost of engineering expense, plus the ordinary legal and administration expense, still falls short of the aggregate cost to the community. And I think experience in large enterprises elsewhere clearly shows this is correct, that the overhead allowance of 25 per cent. is fair and reasonable.

Adjourned to Tuesday, November 18, 1913, 10:00 A. M.

Tuesday, November 18, 10:00 A. M.

Met pursuant to adjournment.
Present same as before.

GEORGE W. FULLER resumed the stand and testified further as follows:

Mr. Adcock: Q. You have spoken of sprinkling filters and you provided in your Projects A and B, for the construction of sprinkling filters, Will you state why you have used sprinkling filters in the plans for these two projects?

A. These two projects for remedial measures, where there would be an insufficient volume of lake water for oxidizing the sewage, provide for sprinkling filters to make the sewage non-putrescible by oxidation, which would take place in those beds. These sprinkling filters for large projects are uniformly used, because they are the most efficient and economical means available. There is for some small suburban communities a different type of filter called contact beds, found in some instances. Those contact beds are so much more expensive that they are not used at all for large projects.

Sand filters of the intermittent type are clearly more expensive and not available here, because porous sand is not to be found.

Now returning to the sprinkling filter question I should say very clearly that that is the type of artificial oxidizing means taken at Columbus, Atlanta, Reading, Baltimore, and in all of the large projects figured upon in the last six or eight years in America for oxidizing sewage where the dilution method is not available.

Sprinkling filters are also found in nearly all of the large filter plants in Europe where oxidation of the sewage must be secured.

It is important to note that at Birmingham, England, this is the type of filter which has succeeded the use of sewage farms.

At Paris this is the type of filter adopted for the various suburban communities lying south of the city, and the city of Paris itself began some two years ago to install filters of this type to take the place of the sewage farms now becoming inadequate.

At Berlin, at Wilmersdorf, the sewage of the various south-

ern suburbs of Berlin is treated on a sprinkling filter plant, designed ultimately to serve about 1,000,000 population.

Without any doubt at all the sprinkling filter is the best means of oxidizing sewage in works of artificial construction where the dilution method is not available.

I think I have made it plain that these sprinkling filters would have applied to the sewage after it had been passed through settling tanks, in order to remove the relatively coarse solid matters. That is quite important, in order to be able to distribute the sewage over the surface of the sprinkling filters through the series of nozzles which have to be of a diameter of perhaps half an inch or less, in order to throw the sewage as a spray over the filter surface. If the solid matters in sewage were not removed, it would involve an enormous expense in attempts to keep these sprinkler nozzles free from clogging, and in fact it would be impossible to make the filters work well, even with an indefinite or theoretically unlimited amount of operators, the uniform distribution of the sewage over the sprinkling filters being one of the fundamental features to be secured at all times, in order to obtain the results that I have spoken of, namely a nonputrescible effluent.

And furthermore, in connection with these sprinkling filters, the solid matters which seem to accumulate on the surface of the stone have to be removed before the filtered liquid reaches the stream, and this is the reason why a secondary settling tank has to be used in connection with the sprinkling filters.

Q. In the cost of operation of these works which are embraced in Projects A and B, did you include the cost of operation of the other works of the Sanitary District, those that are already constructed?

A. No, I did not. I made no allowance for those items which would be involved by the use of the dilution method through works now existing. That statement applies to the pumping stations, for instance, that are owned and operated by the city as well as the pumping stations that are operated by the District at 39th street, Lawrence avenue, Wilmette, etc.

Q. Then as I understand it the cost of the operation which you mentioned for the works embraced in Projects A and B would be in addition to the cost of operating the other works of the Sanitary District in the flow of 4,167 cubic feet per second.

A. Yes.

Q. And the same answer would apply to the cost of installation. That would be in addition to the cost that the Sanitary District has already expended?

A. Yes.

Q. Do you know what the cost of installation or construction has been for the works of the Sanitary District, or that would be necessary to divert 10,000 cubic feet of water per second, 12,000 and 14,000 cubic feet through the main drainage channel.

Mr. Adcock: I will say, in connection with this question that the figures which the witness will give are figures which have been given to him by the District; and I simply wish to have it appear in the record at this time for the purpose of answering subsequent questions. We will show by further testimony the actual cost. If we do not it may be stricken out.

Mr. Hopkins: It is a case of assuming they are correct.

Mr. Adcock: Assuming they are correct for the purpose of the examination of this witness.

A. Yes, I have been informed by the officers of the District what these costs would be.

Q. Will you state what those costs are?

A. This investment cost?

Q. Investment, and you may include in that the cost of operation.

A. The figures furnished me by the officers of the District are shown in the following table:

Flow C.F.P.S.	Investment.	Annual Oprg. and Depr.	Capitalized Gross.	Electrical Credit Capitalized.	Net Capitalized.
10,000	$64,095,082	$508,832	$76,067,600	$13,242,000	$62,825,600
12,000	78,385,182	728,105	95,517,070	17,790,000	77,720,070
14,000	84,020,182	786,238	102,519,910	22,306,000	80,213,900

Q. In your consideration of sewage treatment works through the Calumet area other than by dilution, how do your estimates and proposed procedures at the present time compare with those that you reported upon in 1906 to the International Waterways Commission, and if any difference exists state briefly the reasons for the same?

A. In 1906 I prepared a report for the International Waterways Commission, in conjunction with my former partner Mr. Hering. In that report there are quite a number of

conditions assumed that are of a considerable influence in showing differences between estimates of that report and that which I have testified to in this suit.

In the first place, in 1906, we were figuring upon a population of 1,200,000 people for the Calumet District. That figure came in as a result of getting for treatment works an amount of work done equal to that which should be secured with a flow of 4,000 seconds feet, as then discussed and proposed for the Calumet Sag Channel, and on the basis of the legal minimum rate of dilution.

The figures of 1906 were also made upon the assumption that that area, with its relatively sparse population, could be best sewered by building sewers on a separate system. By that I mean that it was assumed in 1906 that the comparatively few sewers in that area could be best devoted to handling storm water, and all household and ordinary wastes, from office and business buildings and some minor industrial wastes, would go through an entirely new system of separate sewers. Those separate sewers, however, were not dealt with at all in the estimates presented to the International Waterways Commission. Those estimates started out on the assumption of intercepting sewers dealing with sanitary wastes only, and equal to 150 gallons per capita daily.

The 1913 estimates deal with 300 gallons per capita for dry weather flow, or flow at times other than excessive rainfall. The amount of storm flow would add about 10 per cent. to the average volume of liquid treated per capita. This made a marked difference in the cost of intercepting sewers, dealing in 1907, with 150 gallons for 1,200,000, and at the rate of 900 gallons per capita for a population in 1930, which would be for this district 301,000. In consequence of these differences in assumption as to population, type of sewerage system, capacity of interceptors, the investment estimated in 1906 was $3,795,000 for a population estimated at 1,200,000. The figures in 1913 became $2,557,240, for a population of 301,000. These latter figures, I should state, include, however, not only the intercepting sewers but the pumping stations.

In 1906, no provision was made for the aeration of the sewage as it flowed along the interceptors. That is included in 1913, owing to the fact that experience at numerous places elsewhere has shown the urgent importance of keeping the sewage applied to treatment works from getting into a putrifying condition before applied to sprinkling filters.

As regards land, there was no direct allowance made in 1906, but in 1913, the allowance is $697,750.

Coming to the treatment works themselves, the preliminary settling tanks are on a distinctly different type. In 1906, it was figured that they would install so-called single story septic tanks which on account of their objectionable odors for sizable projects are no longer in vogue. Their cost for building simple storage tanks holding eight hours' flow would have amounted to about 91 cents per capita for the assumed population of 1,250,000.

In 1913, estimates had been made on the basis of two story tanks of the Imhoff type, with arrangements for septicizing the sludge in a compartment entirely and distinctly separated from the upper or settling compartment. The relative sizes are of course increased by virtue of the fact that the 1906 estimates provided only for 150 gallons per capita, whereas in 1913, the corresponding figure is 900 gallons. The investment cost per capita in the 1913 estimates is $3, as compared with 91 cents in the estimates of seven years ago.

Those differences are clearly explained by the advances in the art of sewage treatment, as I have previously explained at some length.

In regard to sprinkling filters on the final settling tanks, the investment is markedly increased. In the 1913 estimates it is $6.50 per capita as compared with $3.64 in 1906. The increase is explained partly by there being now assumed a load of 12,500 people per acre of sprinkling filters as compared with 15,000 people in 1906. The main difference, however, is explained by more complete and adequate structures, arranged first to distribute the sewage more effectively over the surface of the sprinkling beds, and secondly in providing settling tanks of the two story type so as to guard against at intervals the belching forth of sludge into the waterways, as takes place at numerous places elsewhere, where single story settling tanks are used.

There is also in the 1913 estimates an allowance of some $399,000 estimated to be required for treating by sterilizing processes all of the sewage which goes through the settling tanks and sprinkling filters up to a volume equal to 900 gallons per capita. Aud furthermore the excess storm flows are likewise estimated now to be subjected to efficient sterilization. This adds on the investment basis an item of about $1.93 per capita for structures not considered in 1906, as they had not yet appeared in the art of sewage treatment.

Those are the principal items on the investment in the Calumet District with respect to variations in the estimates of today and of seven years ago.

I should furthermore point out that in 1906 no allowance was made for interest during construction, and the overhead percentage was taken as 15 per cent. rather than 25 per cent. Experience during intervening years has clearly shown the wisdom of the allowances made in this current estimate.

The aggregate estimates in 1906 for a population of 1,200,000 people was $9,257,500. The current estimate is $5,551,470, on the basis of the 301,000 population assumed to be that of the year 1930, as regards intercepting sewers and pumping stations, and for sewage treatment works for a population of 207,000 estimated as of 1920.

In further explanation of the relative increases in cost of sewage treatment works of today as compared with estimates of 1906, I should make reference to the increased price of labor. That I have had occasion to ascertain personally from construction work in this district, and know it to be a very substantial factor, without trying to make any analysis to show precise relative figures. To some extent that also applies to materials used in construction.

With respect to the cost of operation of sewage treatment works, the estimates of 1906 show for a population of 1,200,000 an annual sum of $419,000. The corresponding annual cost of works in 1913, to serve a population of 207,000, is $416,000. This difference is made up chiefly of two items, one of which is the pumping of a volume of flow estimated at 330 gallons per capita in 1920 population for the current estimates as against 150 gallons per capita in 1906.

In the estimates of seven years ago, no allowance was made for sterilization, and the current estimates show $38,420.

A third item of difference is the aeration, which was not figured upon at all in 1906, but which is now found to be necessary to eliminate odors, and is taken per year at $16,560.

The discrepancies are not great in regard to the other items, except that I should point out clearly that in 1906 no allowance was made for depreciation, except in the case of the sprinkling filters, whereas in the current estimates there is an allowance taken at what I have already described for the various remedial projects, namely 5/10ths of 1 per cent. per annum, for intercepting sewers, 1 per cent. for settling tanks and sprinkling filters and 3 per cent. for pumping stations, aerating devices and sterilizing equipment. The net differ-

ence of all of these items is most clearly stated by pointing out that in 1906 the annual cost was taken at 35 cents per capita per year, whereas the corresponding figure in the current estimates is $2 per capita per year. These figures take into account pumping aeration, operation of intercepting sewers, settling tanks, filters and sterilizing devices.

Q. In your estimates of 1906, where was the 1,200,000 population assumed to be?

A. In the Calumet District.

Mr. Adcock: I think that is all.

Adjourned subject to notice.

Depositions taken pursuant to stipulation of counsel for respective parties, statutory notice being duly waived, at the Belmont Hotel, New York City, on November 26, 1913, and on subsequent days.

Appearances:

Mr. James H. Wilkerson, representing the Government.
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian, representing the Sanitary District.

GEORGE W. FULLER resumed the stand and testified further as follows:

Cross-Examination by Mr. Wilkerson.

Q. You were in partnership with Mr. Rudolph Hering, in 1906, were you, Mr. Fuller?

A. Yes.

Q. You are one of those who signed a report dated December 18, 1906, to the International Waterways Commission?

A. Yes.

Q. That is the report which was printed in the abstract of the evidence in this case, prepared by the counsel for the defendant, beginning on page 2882, and on page 313 of the abstract, is it not?

A. Yes.

Q. And it was printed as Appendix F, to the report of the International Waterways Commission dated January 4, 1907; that report having been published as War Department document number 293. Am I correct in that statement?

A. Yes.

Q. Did you prepare at any time any other report covering this subject for the International Waterways Commission?

A. No.

Q. Did you prepare at any time any report dealing with this subject for any other department of the Federal Government?

A. No.

Q. Were you examined as a witness at any hearing before the Secretary of War relating to the questions covered by the report of 1906?

A. No.

Q. Or similar questions?

A. No.

Q. Were you ever called upon to prepare any data to be submitted to the Secretary of War subsequent to the report which you made in 1906?

A. No.

Q. The first attention then which you had given to the subject since the report in which you joined with Mr. Hering in 1906 was when you commenced to prepare for your testimony in this case, during the spring of the present year?

A. Yes, that is to say February of this year I commenced my preparations for my testimony in this suit.

Q. So that, so far as you know, the only document prepared by you which has ever been submitted to the Department of War, or any other department of the Government, or any other Commission of the Government for consideration was this report of December 18, 1906?

A. Yes, that is so.

Q. What I am getting at is, that is the only thing from you which the executive officers of the Government have ever had before them for consideration in any action which they might have taken with reference to this matter?

A. Yes, that is so. That is the only report that I joined in the preparation of, or prepared myself, prior to my preparation for testifying in this suit at the present time.

Q. And none of these figures, except as you may have present original figures relating to the Calumet project, none of the figures which you have submitted in your testimony here have ever been submitted, either to the Secretary of War, or anybody connected with the War Department, or the Chief of Engineers, or any Government commission?

A. No, they have not.

Q. Were you in partnership with Mr. Hering in 1907?

A. Yes.

Q. Do you recall a report which he made for the president of the Sanitary District of Chicago, dated October 15, 1907?

A. Yes, I recall such a report, but I had nothing whatever to do with its preparation.

Q. You did not read that before it was submitted?

A. No, I did not.

Q. When was the first time your attention was directed to that report; or rather, when was the first time you ever gave it any consideration?

A. Well, I presume I might have glanced over it shortly after Mr. Hering's return from Chicago. This report, I recall distinctly, was prepared in Chicago; and it is so dated, I notice. Now, to what extent I looked it over in the Autumn of that year, shortly after its presentation, I don't recall.

Q. Did you study it in connection with the preparation of your testimony in this case, which commenced in February of this year?

A. Yes, I read it over among other papers, as one of the first things which I did in my preparation.

Q. What was the nature of the work which you did at New Orleans?

A. I was a member of a Board of Advisory Engineers, which was appointed in the spring of 1900, and continued until about 1909. That board of which I was a member had to do with the consideration of the best general methods available under local conditions for the design of a sewerage system, and also a new water supply for that city. And there were meetings from time to time of the board which passed upon the methods and designs, the details of which were prepared in the office of the Local Engineer in charge of those works. The drainage project, during the latter portion of that term of years, was also taken over by this Board of Sewerage and Water; that is it succeeded to the duties and functions of an earlier appointed Drainage Board.

Q. Has that work been completed yet?

A. Not entirely so, but the major portion of the city has been provided with a water supply from a new plant, and it is also provided with sewerage works to take care of the domestic wastes. The drainage works have been in operation, as a partially completed plant, since about 1900.

There is still under consideration and under construction extensions, I think, to all three of those municipal pro-

jects, but particularly as regards the sewerage and storm water drainage.

Q. The water supply plant has been completed, has it?

A. That is the supply end of the new water works has been completed, so far as required for quite a number of years.

Q. How much was spent on that if you know?

A. The total expenditure was roughly $20,000,000.

Q. On the water supply?

A. No.

Q. That is on both the water supply and sewerage?

A. The memoranda which I have at hand show an investment in the water supply and distribution works of, roughly, $8,800,000. The memorandum here as to sewerage takes into account both the separate system for the sanitary sewage as well as the drainage works to remove storm water.

The aggregate of drainage and sewerage works is roughly given here in this memorandum as $14,600,000; and of that sum, speaking from memory, there was spent prior to 1900, about $5,000,000 for drainage; that is for removal of storm water, independently of sanitary sewers. That last figure for drainage has been probably increased somewhat, between 1900 and the present time.

Q. But that work has not yet been completed, that is the sewage disposal works?

A. The sewage disposal is completed, but there are still being built street sewers out into the less thickly occupied areas of the city; and in particular there are being built the house connections from the street sewers to the properties.

Q. All this work which you have been describing is part of the one problem of getting and keeping a supply of pure water for the people of New Orleans. Is that the purpose

A. No, the drainage and sewerage matters are not so directly related to the water supply as in many cases. They are independent sanitary propositions.

Q. What is the chief end accomplished by the drainage and sewage part of the plant?

A. Well, it is an important part of municipal sanitation. The city is almost entirely flat, after you get away from the levees adjoining the Mississippi River, and the heavy rains in earlier years caused the water to stand for a depth of several feet for many, many hours.

The drainage works have for their purpose the removal through artificial canals of that water out into Lake Pontchar-

train. There probably is a somewhat unusual connection between those drainage works and the sanitation of the city, owing to the influence of flies in transmitting disease; but it is not connected with the water supply end of the project. The sewerage is intended to remove household wastes, fecal matters, and eliminate the use of privies in a country where the ground water level originally stood only two or three feet below the level of the surface of the ground.

Q. So both the water supply and the sewage disposal projects cost more than $20,000,000, that is the only parts that you had to do with?

A. The water supply and sewerage cost roughly $15,000,000 I should say, and my relation to the drainage works was incidental only, as regards certain extensions and changes in the system that had been put in service prior to my appointment on this Advisory Board of Engineers.

Q. I was just getting at the total cost. The total here is $23,400,000 for water supply, sewerage and drainage. Does that represent the total cost of all the works of that kind that are now in use at New Orleans?

A. I think that is substantially correct, yes.

Q. What is the population of New Orleans, if you know?

A. In 1910, the federal census showed 339,075.

Q. You have also had some connection with the Passaic Valley Trunk Sewer Project in New Jersey. Just what is that project?

A. Well, that project refers to means for eliminating sewage nuisances arising in the lower stretch of the Passaic River. This river enters Newark Bay, and in that way into upper New York Bay, and drains an area of perhaps 1,200 or 1,300 square miles. It is the river on which the Cities of Patterson and Passaic, large mill towns, are located; and below Patterson and Passaic, for the last 15 years and more, the sewage pollution has reached an excessive degree; offensive odors arose, and the stream for many months is foul smelling, black, discolored. The Passaic Valley Project involves an intercepting sewer; the trunk sewer starting in Patterson, some 20 miles or so west of New York, and in this trunk sewer it is proposed to collect the sewage of Patterson and Passaic, Newark and various suburban residential communities, and pump it from the terminus of that sewer in the Newark meadows through a channel out into the Upper New York Bay.

Q. Has that work been completed?

A. No, it was started in point of actual construction only about a year ago.

Q. What was the preliminary estimate of the cost of the project?

A. Some 12 or $13,000,000.

Q. Where do those towns get their water supply, the towns that are served by that sewage project?

A. Patterson and Passaic bring their water supply from this same river at Little Falls, a point on the Passaic about five or six miles above the City of Patterson. The City of Newark formerly obtained its water supply from the lower Passaic River, opposite the present City of Belleville, but some 20 years ago changed its source of supply to one from upland sources, whereby a gravity flow was obtained from various reservoirs built upon a tributary of the Passaic River.

Most of the residential towns obtain their supply from the same private company that takes their water from Little Falls, and supplies Patterson and Passaic, as I have previously stated.

Q. You spoke of some litigation before the Supreme Court of the United States in that project. What litigation do you refer to specifically?

A. That is an injunction suit still pending brought by the State of New York, in an effort to restrain the State of New Jersey and the Passaic Valley Sewerage Commission from discharging the sewage from this Passaic Valley sewerage district into the upper New York Bay, in the vicinity of Robbins Reef Light. That light is about three-quarters of a mile or so north of Staten Island the landing place of the Staten Island ferryboats.

Q. Your employment is by the State of New York?

A. No, I have not been employed actively in that litigation. I was employed on a number of occasions by the Attorney General's office of the State of New Jersey, in conferences, and particularly in connection with a stipulation whereby the United States Government, which had come in as an intervener, withdrew as an intervener on making certain contractual stipulations with New Jersey in point of arrangement of these drainage, sewerage works; and particularly with regard to certain clarification appliances which the Passaic Valley Commission agreed to install.

Q. You were a member of the Commission appointed by the United States Senate to consider water supply matters

in connection with the City of Washington. Have you followed that up to the extent that you have any knowledge as to the cost of works constructed in Washington, in connection with their water supply and sewage disposal?

A. I have general information about the Washington cost for water supply.

Q. How much did the water supply works there cost?

A. My memorandum shows that at Washington the water supply investment, that is for the supply works, aqueducts, filtration works, distributing system was roughly $19,500,000.

Q. And the sewage disposal works cost how much?

A. That is $15,700,000 roughly. That is the total cost for the sewerage system and intercepting sewers and disposal works.

Q. Amounting in the aggregate for water supply and sewage disposal to how much?

A. Roughly $35,300,000.

Q. And what is the population at Washington?

A. The federal census of 1910 showed 331,069.

Q. That would be about how much per capita for the combination?

A. Roughly $104 per capita.

Q. You stated that you served as Consulting Engineer to New York City, both as to the Catskill Project and the Croton water supply. Do you know what the total cost of the Croton water supply has been to the people of New York City?

A. I have no memorandum of it.

Q. I do not care for the precise figures but if you have any information on the subject which will enable you to make a general statement, I would be glad to have you do so, subject to any correction that you see fit to make.

A. Starting with the Croton Works that began to deliver water to New York City in 1842, and with the various extensions that were made up to within the last few years, I should say that roughly $50,000,000 had been spent on the present water supply of the old City of New York; that is Manhattan Island and the Bronx.

Q. What about this Catskill Project, have you any idea as to how much that is to cost?

A. The works, either built or building, that is the first installation was estimated, as I recall, at one hundred and sixty-one millions for an investment cost. That was not for the old City of New York alone, but that was for Greater New

York, and included arrangements for distributing water to Brooklyn and Staten Island and other points than Manhattan Island.

Q. But not designed to serve the entire population of greater New York, was it?

A. Not to supplant or displace the Croton supply, but it was intended to be available for displacing certain ground water supplies that were pumped at great expense over on Long Island, and serving as a part of the Brooklyn supply.

Q. The figure which you gave was for the cost of construction; did not include anything for capitalization or operating expenses?

A. No.

Mr. Austrian: Q. That is purely a water supply proposition?

A. Yes.

Q. How many miles does that carry the water?

A. Oh, roughly 90 miles to the city, without the distributing tunnels within the city.

Mr. Wilkerson: Q. You say you have had opportunity to study the art of water and sewage treatment, particularly in connection with certain patent suits bearing upon treatment methods. Let me direct your attention to the matter of treating a water supply. What study have you given to that?

A. You mean from the standpoint of patent litigation and the study of the art?

Q. The study of the art, yes.

A. Well, I have given a good deal of study to water supply and water purification matters, beginning in my student days at Berlin, and including quite a number of rather exhaustive tests as to different means of purifying muddy and polluted waters, and I have been connected with a good many purification projects, that is water filtration plants, from the standpoint of selecting methods and places for building purification works; also their design, supervision of construction and operation.

I have been connected with four or five different patent suits, in which the development of the art of water purification has been of importance; and I have been a witness in several of these suits; what is known as a Practical Art Expert, to testify as to the progress in water purification matters and devices through a term of years that came within the range of my personal observation and knowledge.

Q. During the last few weeks, we have had some bad

storms on Lake Michigan, as a result of which the water in our lake out there is very muddy, and health officers and doctors are telling us we ought to boil it before drinking it. According to the state of the art as it exists now, how ought that water to be treated so as to make it fit to drink?

A. To make it fit to drink, it is important to keep sewage out of that water.

Q. Well, I understand the sewage is kept out of it now. It is stirred up from the bottom.

A. With the sewage kept out of the water, still there is left, of course, the aesthetic side which is receiving more and more attention; and I presume that you have in mind the mud or silt that is stirred up by wind action from the bottom of the lake.

Q. I had in mind the statement of these doctors and health officers, who tell us we ought not to drink the water.

A. Those are not my statements; those are doctors' statements.

Q. You do not think there is any danger in drinking the water. You think they are wrong about that, if they have any such opinion as that?

A. That is a pretty broad proposition to deal with. I think if it could be shown that sewage entered the water, that is one aspect; if there is no question of sewage entering the water that gets roily a few days in the year, that is a different matter.

Q. Of course around Chicago, there is a good deal of commerce carried on; a good many ships going and coming; and naturally there is some pollution of water from that, is there not?

A. Theoretically that is so, and practically I believe to some extent that is a factor to be reckoned with.

Q. Then if that is a factor and there is enough of that so that in the course of time it does accumulate on the bottom of the lake and when there is a storm it is stirred up and makes the water unsafe, according to the state of the art as it is today ought that water to be filtered?

A. Filtered or sterilized, in the event that there is a substantial amount of sewage matter reaching the supply.

Q. How would it be sterilized, assuming it is necessary to sterilize. Let us go that far, assume it should be sterilized, what is the method of treating it according to the art as you understand it today?

A. Well, speaking generally, the art of sterilization of

water involves the application of some oxidizing chemical, either liquid chlorine, or hypochlorite of lime. There is accomplished in that way quite a material reduction in the numbers of bacteria.

There are some cases where it is difficult to apply that method with anything like the success that attends its use in general. And I believe that along the Great Lakes there is difficulty encountered of a serious practical nature in applying these sterilizing chemicals. That arises from this state of affairs: That the amount of organic matter in the water of the Great Lakes is relatively small. That means that oxydizing chemicals can be put in only in relatively small amounts. There is not any laboratory way or method by which with a sudden increase in organic matter or bacteria, such as storms might bring about, there isn't any method which reliably would show an operator how much to increase the dose of these chemicals. The result of that has been that a dilemma arises,—is the operator to put in enough of these chemicals so as to produce objectionable tastes or odors in the water as delivered to the consumers, or are the bacteria insufficiently treated with chemicals to bring about their destruction.

In a word, I mean to say that the art of sterilizing water supplies about five or six years ago met with quite a little success, quite substantial success in treating certain unfiltered waters, but in recent years, the last two or three years, it has been applied more particularly to filtered waters where the opportunity for variation in conditions of application was very small and these arrangements of work to be done are restricted to much less than they would be in the case of the waters of the Great Lakes.

Q. What about filtration as a method of handling the water supply of cities?

A. Where it is not feasible to get a water supply that is free from sewage or infectious diseases, the present state of the art of water filtration shows that very substantial improvement can be obtained as to the quality of the water initially infected and polluted; and it shows that the opportunity or likelihood of any danger coming to the users of the filtered water supply is comparatively small if the filter plant is well built, and at all times carefully operated.

Q. Have you given any consideration to the water supply and sewage problem of Cleveland, Ohio?

A. Not professionally. I have visited Cleveland and know in a general way as to the situation.

Q. What do you understand to be the method used there?

A. On the sewerage end of the proposition, I understand that some 50 per cent. of the sewage of that city still goes into the Cuyahoga River, which discharges into Lake Erie approximately at the center of the city. There is roughly 40 per cent. of the sewage that is collected in an intercepting sewer which extends for some eight or nine miles to the eastern limits of the city, and there is discharged through an outlet pipe some 2,500 or 3,000 feet off shore, in a depth of about 30 feet of water.

There is a remaining about of 10 per cent. of the sewage from the extreme western portion of the city that goes into the lake through, perhaps, one outfall sewer, possibly more than one. The water supply is obtained from the lake through an intake tunnel, the outer end of which is perhaps four miles or so off shore. The water supply has been subjected to sterilization without great success, and illustrates very clearly what I had in mind in answering one of your preceding questions. That is, in order to move to a substantial degree at all times the objectionable bacteria in the lake water, it has been found necessary by the Health Department to apply quantities of hypochlorite of lime, that resulted in quite seriously objectionable tastes and odors in the water as it reached the consumers. I believe at the present time the authorities are considering means of still further improving the conditions, in point of both sewage disposal and water supply.

Q. They will be obliged there either to filter the water, or to construct plants for the disposal of the sewage, or both, will they not?

A. They have all of those matters under advisement. I am not informed as to any official decision in the matter at the present time. They have studies under way, I believe, on both water and sewage, in point of improvement.

Q. They have no way of diluting their sewage there, except to let it go out into the lake?

A. There is no way by which they can divert it from the lake at anything within hailing distance, in point of cost.

Q. Have you studied the situation in Milwaukee?

A. I have been in Milwaukee in connection with other matters, a garbage incinerator plant, and have become familiar with some of the general features of their water supply and

sewerage problems. I am not officially or professionally informed as to their details of procedure.

Q. Have you any idea what it will cost Cleveland to take care of its sewage, according to the method which you have outlined here for Chicago, when it gets a population of 2,000,000?

A. I have not given the matter any thought.

Q. Now have you given any thought to what it will cost Milwaukee to take care of its sewage; what it would cost to take care of its sewage according to the method which you have outlined in your testimony, when Milwaukee has a population of say a million and a half?

A. No, I have not sudied that proposition.

Q. You were an expert in the Drainage Canal litigation, Missouri versus Illinois?

A. Yes.

Q. On which side of that proposition?

A. Missouri.

Q. Your own book on this subject was published in 1912?

A. Yes.

Q. You state that in connection with the preparation which you made for your testimony in this case, you have studied a number of public documents, including a report by Mr. Wisner, made in October, 1911. The report which you referred to, I will ask to have marked as an exhibit for identification, "Number 1, cross-examination of Mr. Fuller," and ask you whether that is the document to which you referred?

(The report of George M. Wisner, Chief Engineer, Sanitary District, dated October, 1911, was here marked "Number 1, Cross-Examination of Mr. Fuller.")

A. Yes.

Q. In this case of Missouri versus Illinois, on what phase of the case were you an expert?

A. In respect to the sanitary aspects, and with particular reference to the proposition of whether or not disease germs originating in the Chicago sewage might travel down the Desplaines, Illinois and Mississippi Rivers to the shores of Missouri, and particularly the intake of the St. Louis Water Works.

Q. You were on the same side of the case as Mr. Gardner S. Williams?

A. Yes.

Q. And you and he had substantially the same views on the questions that were involved?

A. Oh I would not say that. I don't remember.

Q. You both had, as nearly as you can remember now,—you were both called by the same party to the litigation, and both had the same conclusions—I will put it that way—as to the sanitary questions which were involved in the case?

A. Well, speaking for myself, I would say that my recollection is that we gave no consideration, or none of much if any consequence, to the question of nuisances in the Mississippi River, so far as Chicago sewage was related to the people living along the shores in the State of Missouri. But our viewpoint was directed in particular to the question of whether or no the Chicago sewage might not carry with it some disease germs which would reach the St. Louis intake of the public water supply, and be a material factor in explaining certain increases in typhoid fever statistics which the records of the city Health Department of St. Louis showed to have actually been experienced at that time, when I was studying the matters.

Q. Your opinion was that the discharge of the sewage down the Desplaines River and the Illinois into the Mississippi did endanger the health of the people of St. Louis in that respect?

A. That was the opinion which I held at that time, and it was predicated upon vital statistics that I believe did not hold water in point of rebuttal testimony, as to the correctness of diagnosis.

Q. That was a case where it was the statistician who was wrong, and not the sanitary expert?

A. I would not say the statistician. I believe it went back further than that. It was a question of whether or no typhoid fever, malarial typhoid fever and typhoid pneumonia all related to the same thing, and there was a difference in the classification of deaths occurring not far from the time this Drainage Canal was opened, so that the statistics did not hold water in the way in which I was led to expect they would.

Q. You have not examined the statistics on the same subject in this case, to see whether they are open to the same objection or not?

A. I have looked at them sir.

Q. Do you know, as the result of your studies of this subject in Chicago, how long after the completion of the Drainage Canal sewage continued to be discharged into Lake Michigan from Chicago?

A. Why I have stated in my direct examination what the

main facts are in point of dates as to the construction and operation of both the South Shore and North Shore interceptors, and also the date when the 12th street and 22nd street sewers were reversed in their flow. I will look them up if you like.

Q. I would like to get that date fixed, if I may, in the record, how long after this canal was opened they continued to discharge sewage into Lake Michigan. I am not speaking of the Calumet Project, but I mean the original drainage district, how long after they completed the canal did they continue to discharge sewage into Lake Michigan?

A. My knowledge of the records indicates that it was practically 1910 before the Lake Shore interceptors were completed, and that it was 1911, before the North Shore Channel was completed, to remove the sewage from a limited portion of the North Shore towns. There is still going into the lake, as I understand it, sewage from the City of Evanston.

Q. Have you any idea how much sewage was discharged into the lake, say in the year 1905?

A. No, I have not, precisely. I know the status of these diversion works, though, at that time.

Mr. Austrian: I think your question is just a little bit misleading. Of course a lot of works are not completed yet.

Mr. Wilkerson: I understand that. What I am trying to get at, as preliminary to another question which I am going to put to the witness, I understand this to be the fact, and I want to know if the witness understands this to be the fact also, that for a considerable period after the opening of the Drainage Canal, running down to 1906, anyway, there was a very considerable quantity of sewage that was discharged into the lake.

The Witness: Yes, I think there was. Just how much, I don't know.

Mr. Austrian: Let us put it around the other way: Isn't it your understanding also after the Sanitary District Channel was opened in January, 1900, a great part of the sewage that theretofore was dumped into the lake was dumped into the channel.

Mr. Wilkerson: There also continued to be a part of it discharged into the lake.

Mr. Austrian: Well, put it all in.

Mr. Wilkerson: Q. Have you any idea as to how much that amounted to in the aggregate?

A. That is the amount of sewage going into the lake?

Q. Yes, in 1905, every day, how much went into the lake?

A. I haven't a very accurate idea. I know that that was prior to the putting in service of the Lake Shore interceptor connecting with the pumping station at 39th street, for instance.

Q. Now, what do you understand to be the average, the mean outflow of water from the Chicago River into Lake Michigan? Do I make myself clear?

A. Flow of the river?

Q. Flow of the river, or to put it another way, how much on the average has to be taken out of Lake Michigan into the Chicago River to reverse the flow of the river? I am speaking about the mean now; not in times of storm, but the average?

A. I have not considered the question of the mean or average flow, but it would be very much less than the maximum of 10,000 second feet that I have been considering in its relation to the sanitary aspects of the Chicago problem.

Q. Do you understand that there is ever a time when the flow of the river is as much as 10,000 cubic feet a second?

A. Yes, I understand that that was so, and in fact that is the very essence of the design in the late eighties when the size of the canal was determined upon, but now that is not a figure of flow which would be attained every year. It is a maximum run-off, as I understand the conditions that were set forth in connection with the determination of the original size, and when that was reconsidered in point of design with the construction as actually built.

Q. Have you ever given any consideration to the determination of the number of days in the year when the flow of the river was more than 8,000 cubic feet a second?

A. No, I have not.

Q. Or when it was more than 6,000 cubic feet a second?

A. No, I have not.

Q. And do you know how small the flow becomes in times of low water?

A. Oh yes, I am aware that it would be a very small flow. I think that I have stated in my direct examination that in a rough way the flow of the Chicago River would exceed a volume of 4,000 cubic feet per second for about ten days; that is during a year of average rainfall. That is a rough, approximate figure.

Q. That is at the present time, is it?

A. Yes.

Q. About ten days in the year when it is more than 4,000 cubic feet per second is your understanding?

A. That is my understanding of it.

Q. So that with a diversion from Lake Michigan of 4,000 cubic feet per second, there would be ten days in the year when the water would flow from the river out into the lake?

A. Yes, that would be so on the premises involving rainfall alone. There would also have to be reckoned with the question of reversal of slope and the flow of river water out into the lake, due to the effect of wind action suddenly lowering the lake level, as the facts show would occur very suddenly, and to an extent at times of as much as three feet in a single hour.

Q. From which branch of the Chicago River does the most of the water come in time of storms?

A. I should say from the North Branch.

Q. What proportion of it comes from the North Branch?

A. I haven't the relative areas in mind. Do you want me to look them up?

Q. No, except in a general way; it is very much the largest part that comes through the North Branch, so that if the water of the North Branch, in whole or in part, did not go into the Chicago River in time of storm, there would not be very much water flowing through it, would there?

A. Why, any diversion of the North Branch would make an equivalent reduction in the flow of the Chicago River, as a whole.

Q. And that would be true with reference to the South Branch also?

A. Yes, whatever the facts might show.

Q. Now during the years 1904, '05 and '06, there was a very considerable amount of sewage discharged into Lake Michigan. I understand that prior to that time the cribs were moved out so that the water supply was taken from a point further out in the lake. Have you made any study of the effect of the discharge of the sewage into the lake upon the water supply of Chicago during those years?

A. Why I have considered the matter. In fact I did look into it with some care in 1906, and found that there were signs of the water being polluted on certain occasions, with an amount of pollution sufficient to cause the Health Department to advise the water users to boil the water.

Q. That was at certain cribs?

A. Probably that is so. My recollection is not clear.

Q. Do you know which cribs were the ones which were affected?

A. No, I was really under the impression that that warning from the Health Department applied to all cribs, but I may be in error. That is my recollection that it applied to all cribs.

Q. You have spoken in your testimony of the lag of the river, that is to say the time, as I understand you, when the result of opening the gates so as to let more water through would be effective at the mouth of the river. Did I understand you to say there was some difficulty in getting those gates open?

A. No, I was speaking in my direct examination of the time necessary after the gates are opened, to create a slope which would bring the water from the upper end of the canal down towards Lockport, at a rate that was intended—that is the mere opening or lowering of the Bear Trap Dam at Lockport would not necessarily effect for some hours a substantial increase in the rate of flow of water at Robey street or Western avenue.

I think that in my direct examination I was speaking of the lag solely from that angle. Of course there is also to be taken into account practically another element, and that is the lowering of the lake levels at times, due to wind action. This lowering of as much as three feet in a single hour sometimes occurs, so that the regulating works in point of fact might on many occasions through a term of years have to overcome not only the lag or time delay incident to creating the slope to pull the water from the eastern end of the canal but would also meet with complications incident to a lowering of the lake level at the same time.

Q. There would be some time elapsed between the rainfall and the time when the water would get to the river, would there not, so that if the works were opened as soon as a heavy rain commenced to fall, the effect would travel down to the mouth, by the time the water got to the river, wouldn't it?

A. There is a good deal in that thought, but it strikes me it would lead to lowering the Bear Trap Dam or the gates there whenever there is a substantial rainfall, because there is no way of telling—

Q. Why wouldn't that be practicable?

A. It would, if it would succeed, but in my opinion it would not succeed.

Q. Why wouldn't it, if whenever there was a heavy rain

it was opened so as to let a little more water through; had a man there in charge of it to close it when the water got down, why wouldn't that work all right?

A. I certainly would not want the responsibility. On paper it sounds all right, but practically I don't think it would work. I think you would have to open the gates before the rain began.

Q. Of course this back flow is a subject which has been studied a good deal by engineers, in connection with problems of various kinds, has it not?

A. Yes.

Q. Have you made any particular study of this situation for the purpose of determining just how long it takes that effect to travel up the Chicago River, or is the figure which you gave a rough estimate?

A. Well, it is not a close estimate. It is a thing that I did consider with considerable care in 1906, when I found that it was a factor that required considerable careful attention. I do not pretend to be able to state whether that lag is a 16 hour interval or 6 hour, but it is more likely to be half way between. If you are trying to get precise periods of lag, either with or without the complication of a lowering lake level due to wind action, I can't answer the question. I am giving it just approximately.

Q. The effect of that situation is this: That with 4,000 cubic feet of water going from the lake into the Chicago River, the flow of the river will be reversed as long as the amount of water in the river flowing out is less than 4,000 cubic feet per second?

A. Yes, as a general proposition that is true.

Q. If there is more water flowing into the river, and the amount that is taken from the lake is increased so as to equal or exceed that amount, the water will continue to flow away from the lake?

Mr. Adcock: I presume you are sueaking of 4,167 feet?

Mr. Wilkerson: I was speaking of any figure, for illustration; as an abstract proposition.

Q. So that water would only flow out into the lake in any event for the length of time that the amount of water flowing out of the river exceeded the amount of the diversion?

A. Yes, sir, that is obviously so.

Q. And on the basis of 4,000 cubic feet per second diversion, you think that would be about ten days in the year?

A. Well, I tried to make it plain that was an approximate statement, predicated on the rainfall aspect only.

Mr. Adcock: Are you speaking of 4,000 cubic feet or 4,167 cubic feet, when you say ten days?

Mr. Wilkerson: The ten days' statement is on the basis of the diversion of 4,167 cubic feet per second.

The witness: Yes. Let me finish my other answer there. (Previons answer read as follows: "Well, I tried to make it plain that was an approximate statement predicated on the rainfall aspect only,—")—and not taking into account the influence of wind action in suddenly lowering the lake level as much as three feet in an hour, and creating a slope lakeward in that way. I do not know what the number of days would be when a reversal into the lake might result from the lowering of lake levels by wind action.

Q. How would the total amount of sewage that was sent out into the lake as the result of that occasional change in the direction of the flow of the river compare with the amount of sewage sent into the lake where it was sent continuously from a population of 300 or 400,000 people? It would not be nearly so much would it, the total amount, of course, in a year?

A. The total amount might not be so much, but I should be inclined to think that under the influence of flood flows, it might be driven very much further away from the shore in the direction of the intake cribs, and do very much more harm to the water supply.

Q. It would be driven straight out, wouldn't it. It would not be driven to the crib at Hyde Park or the North Side. The cribs could be so located as to get them out of the zone, could they not?

A. That would depend upon the effect of wind. As I recall, the distance is not so very great from the mouth of the river, in an east and west direction, to the four mile crib and the Carter Harrison Crib.

Q. Suppose there were a diversion of 10,000 cubic feet per second, and the lake were to drop three feet, as indicated in one of your answers a few minutes ago, what would be the effect of that?

A. I have made some inquiries along that line, and it is my information that while five or six years ago, or rather in 1906, there was to be found at intervals a flow out into the lake, in recent years that has not taken place.

Q. Do you understand they are taking 10,000 cubic feet a second through the river now?

A. No, I am just using that as a basis of reasoning, in answering your question.

Q. Do you know how much they are taking now?

A. I should say roughly 7,500 cubic feet per second. I don't know exactly.

Q. How long has it been since the water flowed out into the lake, as far as you understand?

A. I have no knowledge of any flowing out into the lake since my investigations in Chicago in the Autumn of 1906.

Q. So that for the period of seven years, a diversion of 7,500 cubic feet per second appears to have been sufficient to keep the flow of the river continuously reversed?

A. So far as my knowledge goes, but I may not be fully or correctly informed.

Recess to 2:00 P. M.

After recess, 2:00 P. M.

GEORGE W. FULLER, resumed the stand and testified further as follows:

Mr. Wilkerson: Q. In the report made by yourself and Mr. Hering in 1906, estimates were given with reference to the cost of constructing sewage disposal plants for what is known in this lawsuit as the Calumet Region; and there was a comparison between the cost of constructing a sand filter plant and a contact filter plant and sprinkling filter plants; and those figures were on the basis of a population of 1,200,000 for that district, were they not?

A. Yes.

Q. And in that report there was an estimated cost of the construction of a branch of the Drainage Canal. Did you make any estimate of the cost of construction of that branch of the Drainage Canal, the Calumet Sag Channel?

A. No, I did not.

Q. The figure which you state there when you say, "The estimated cost of this proposed canal is $12,000,000," was a figure which you obtained from the engineers of the district?

A. Yes.

Q. In the figures which you gave in your testimony in this case for dealing with this Calumet region, you made an esti-

mate, I think, based upon the assumed population of the district in the year 1930, or 1920?

A. 1920, so far as treatment works are concerned and 1930 so far as intercepting sewers are concerned.

Q. What was the estimated cost of the sewers and plants for the assumed population of that district in the year which you have just mentioned? I want to get that figure in the record at this point.

A. That is sewers only, or treatment works?

Q. And treatment works, the entire plant?

A. The current estimate given in my direct examination shows $5,551,470.

Q. For which project is that?

A. That is the Calumet Project, with the intercepting sewers and pumping stations adjusted to the estimated population of 1930, and with sewage treatment works adjusted to the estimated population of 1920.

Q. And with the use of sprinkling filters?

A. Yes.

Q. How does the plant which you have suggested in your testimony in this case differ from the sprinkling filter plant which was discussed by you in your report of 1906?

A. Well, the sprinkling filters themselves would be quite generally similar. The loading, that is the sewage from a somewhat smaller population would be applied to one acre of surface. In 1913, I have estimated that the load or amount of sewage per acre would be that coming from 12,500 population. In 1906, it was a load of 15,000 people per acre. That was assumed to be the average rate. It is not the sprinkling filters themselves that account for a substantial difference between the current project and that of seven years ago. It is the appurtenances, the other works of the treatment plants that explain the differences that I described at some length in my direct examination.

Q. Yes, I read that, and there were two or three points of distinction not entirely clear to me,—probably my fault,—your figure for the use of sprinkling filters for an assumed population of 1,200,000, was $17,637,500. Now what is your assumed population in 1930?

A. 301,000.

Q. 301,000, and the sprinklers were for 1920, and what was the population in 1920?

A. 207,000.

Q. In your report for 1906, the estimated cost of construc-

tion with a sprinkling filter plant was $9,257,500, for an assumed population of 1,200,000. In your 1913 project, you have an estimated cost of five and one-half millions, which is to take care of a population of 207,000 in 1920, so far as the filters are concerned, and 301,000 in 1930, so far as the sewers are concerned, as I understand it. I want to know what there is in the 1913 project that makes the estimate so much larger per capita, so to speak, than it was in 1906?

A. I explained this at some length in my direct examination, but to recapitulate, I would state at the beginning that the current estimate is made on the basis of treating the flow of the combined sewers. In 1906, the estimate was based upon a separate system of sewers that dealt with the sanitary sewage, that is domestic wastes, and not at all with storm flows. I find that the combined system during this interval of seven years has been extended and the local authorities have not acted at all in line with the suggestion or assumption of 1906, of dealing with separate sewers.

Now, that makes a good deal of difference with regard to the size of sewers and the volume of liquid to be handled. We figured in 1906, Mr. Hering and I, that there would be a volume of sewage per capita of 150 gallons daily. Under the current estimates that figure is double that, or 300 gallons. That makes a difference in itself as regards the size of the intercepting sewers, and furthermore the current intercepting sewers now being considered, or being considered during 1913, for an estimated population of 1930, are figured upon a capacity of 900 gallons per capita; that is three times the daily dry weather flow. The reason of that is to allow the sewage to be settled and sterilized before coming to deal with the question of sterilization of storm flows.

In 1906, storm flows were not considered at all. They were assumed to go through sewers which did not receive any sanitary wastes. That is the first point.

The second point is that the pumping stations would be required, under the conditions of the 1913 estimate, to deal with much larger volumes of flow, for the reason that I have just explained. That explains the difference in point of size of the pumping stations.

The third item deals with a factor which was not considered at all in 1906, and that is aerating devices by which air would be applied to the flowing sewage, so as to prevent putrification, and to prevent bad odors arising from the vicinity of the sprinkling filters.

The next item deals with the type of settling tanks. In 1906, the estimates showed an allowance for a so-called single story septic tank; whereas the 1913 estimates deal with a two story tank of Imhoff type, with the settling compartment distinct from the sludge digestion compartment. That makes a difference of a considerable amount in the per capita cost. The sprinkling filters themselves are rated at a somewhat lower population, contributing sewage to each acre of sprinkling filters. I have just explained the difference between the loading of 15,000 people per acre and 12,500.

There is an item of sterilization taken into account in 1913, which was not considered at all in 1906. There is also taken into account differences per unit of construction work based on the experience which I obtained during the past seven years, which is considerable of a factor as I stated in my direct examination.

There is also the allowance of 25 per cent. for contingencies, engineering, administration, etc., in the 1913 estimates as compared with the allowance of 15 per cent. in 1906.

The last of these principal items is the interest during construction which I have allowed for in the current estimates, equal to the interest on the entire construction work for one-half of the period estimated by me to be required for construction. In 1906 no allowance was made at all for interest during construction.

I think the last item of difference is that of land, which was included in 1906 in the percentage addition for overhead, that is contingencies and supervision, but which in 1913 was taken separately and based on figures which were furnished me by the officers of the district, and predicated as I understand it upon a detailed examination of the facts and factors relating to land values.

Q. Not made by yourself however?

A. No, not the land values, land figures.

Q. If you had prepared figures in accordance with your project as it was in 1906, the purpose being to take care of a population as estimated in 1920, so far as the filters were concerned and 1930 so far as the sewers were concerned, what would have been the amount required for the construction of the plant, in your opinion?

A. It would have been materially less, but I don't know how much less, being a matter of estimating the significance of these factors, which I have just recited.

Q. It would have been less than five and a half million dollars in your opinion?

A. Yes.

Q. The estimate for the population of 1,200,000 in 1906, was $9,257,500, and you state there "the present population of the Calumet area of the Sanitary District being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expended at the outset." If in 1906, it was intended to take care of a population of up to 1920 so far as filters were concerned and up to 1930 so far as sewers were concerned, what portion of the estimated cost of $9,257,500 would it have been necessary to expend, in your opinion?

A. It is impossible to state that accurately. Presumably the intercepting sewers, and a large portion of the pumping station structures would be built of full size, with the tanks and filters reduced on a per capita basis, and account taken of the fact that for small plants the per capita cost is liable to be materially more than for large plants. Just what the influence would be of all these factors, I cannot state offhand.

Q. Assume for the purpose of answering this question that the Sanitary District is limited to 10,000 cubic feet of water per second; that is to say that it is limited to taking from Lake Michigan the 10,000 cubic feet that may go through the main channel. What reason would there be for disposing of the sewage of the Calumet region by the dilution method instead of this other method you have outlined, unless additional water is to be put into the canal at a point further away from the lake?

A. Well, that is a question that I have not considered at great length, and would be open to the discussions and deliberations by those who managed works having a main channel and a branch channel going up into the Calumet District. The purpose of the Calumet channel primarily is to take the flow of the Calumet River to secure under the ordinary conditions its reversal, and to protect the waters of Lake Michigan from being polluted by the flow of the Calumet River.

Q. But you have suggested now for the disposal of the sewage of the Calumet region a plan by which that can be handled by an expenditure of five and a half million dollars?

A. Yes.

Q. The estimated cost of this channel was $12,000,000 in 1906. I assume that that estimated cost would be subject to increase on account of the cost of labor, the same as your

figures have been increased on account of the cost of labor; so that what I am trying to direct your attention to is the reason for the adoption of that dilution method in dealing with the Calumet region, if the district is limited in the quantity of water which it takes from Lake Michigan to that which it can handle through the main channel?

A. I have not reflected upon or considered that aspect of the case; that is I have taken into account the Calumet area as providing a certain portion of the population of the district as a whole. I have recognized clearly that the facts as I know them show that water taken through the Calumet Sag Channel would be available for diluting the sewage which would enter the Chicago River and flow down the entire length of the main channel. Those are matters of policy, matters of administration, that I have not considered at length.

Q. If the district were not permitted to take from the lake any more water than could be handled through the main channel, it would appear that there is no reason for building a channel for the purpose merely of dividing the amount of water taken from the lake, if the sewage of the Calumet region can be handled, some other way at a less expense, even from their own standopint, would there?

A. There is something to be said in support of that proposition, but in its final analysis it should take into account the benefits of reversing the flow of the Calumet River, which is a desirable thing. And I understand it also involves business considerations as to the expense of getting water to the head of the main channel. For instance, the relative cost would come up for consideration, I should say, as between the cost of the Calumet Sag Channel and enlargement, we will say, of the Chicago River. These are all matters, though, that I have not taken into account with a great deal of care, and only in a very incidental way in my deliberations on these matters.

Q. What is the outflow of the Calumet River?

A. Oh, it varies very widely.

Q. What is its maximum outflow?

A. Something in the vicinity of 15,000 second feet.

Q. How many days in the year does it get up to 15,000 second feet?

A. I do not think it would get up there every year for even a single day.

Q. How many days in the year is the maximum outflow of the Calumet River more than 10,000 second feet?

A. I do not think it reaches 10,000 second feet for any day every year.

Q. Does it reach 8,000?

A. Perhaps it does. I am not informed in detail about those figures.

Q. Isn't it a fact that there are many days on which the outflow from the Calumet River—there are many more days on which the outflow through that river exceeds 4,000 cubic feet than there are days when the outflow through the Chicago river exceeds 4,000 cubic feet per second?

A. Yes, I should think that would be so.

Q. Isn't it a fact that in order to secure with reference to the Calumet River the condition which is sought to be secured with reference to the Chicago River, namely a condition so that the river never flows into the lake, it would be necessary to divert more water through the Calumet River than through the Chicago River?

A. Yes, I think that is so.

Q. So that in order to procure a permanent condition, with the Calumet River reversed all the time and the Chicago River reversed all the time, it would be necessary to divert more than 20,000 cubic feet per second from Lake Michigan, as you understand the situation?

A. I should thing that that would be so if periods of extreme rainfall should be identical or coincident on the two water sheds. I can't say precisely whether that is the aggregate figure necessary or not, but it is in a rough way, I should think; it is not far in excess from the truth as I know it.

Q. What is the use of devising an expensive system of works for the purpose of procuring a condition which is equally as good so far as as purification of the sewage is concerned as if the Chicago River never flowed into the lake, when you have a situation whereby with any amount that has been suggested, even up to 4,000 cubic feet per second, there would be some sewage going into the lake from the Calumet River?

A. Well, the basis of that is to minimize the element of danger. The reversal of flow in the Chicago River, receiving the sewage of 2 to 3,000,000 of people, is quite a different proposition from the reversal of flow of the Calumet River, where the population is sparse and where, as I understand it, it is reasonable to assume that the population in Indiana will take care of its sewage, at least from a sanitary standpoint I have assumed that that would be the case.

Q. That is take care of it by letting it go into Lake Michigan?

A. I am not trying to solve their problems for them. I

presume the time will come when the sewage from Indiana's population will be under control, so that it will not constitute a menace to the people of the Sanitary District in Chicago, with respect to the water supply.

Q. If they do not do that, if sewage from the Indiana cities that are rapidly growing up down there goes into the lake, then it would be necessary to treat and filter the water supply of Chicago, and that without regard to the manner in which Chicago handles its own sewage, would it not, in your opinion?

A. My opinion would not justify so broad a statement, by any means. I think that the sewage entering the Calumet River from Indiana towns should be controlled by all means. The sewage of a resident of Indiana and the sewage of a resident of Illinois in the Calumet District, or the area tributary to the Calumet River should not be treated differently. The proposition from a sanitary standpoint is to take care of the sewage from the entire area. Getting to the question of whether the sewage from the Indiana towns would call for the filtration of the water supply of the entire district, that is an entirely different matter. The mouth of the Calumet River is far removed,—removed by a much greater distance from any of the Chicago intakes than is the mouth of the Chicago River.

Q. That is to say while the discharge of sewage into the lake from the Calumet and from these Indiana towns might make it necessary to filter the water from some of the intakes, it probably would not make it necessary to filter it from all of them?

A. I would not say necessary. It would make it—

Q. Advisable?

A. Much more desirable; and in the event that the sewage would not be kept out of the Lake Michigan waters in the vicinity of the intake.

Q. Just as if some sewage for a few days in the year would flow from the Chicago River into the lake, it might be necessary to filter the water from some of the intakes, but not from others that were far away from it?

A. That might be so. It would call for a much closer analysis than I can give offhand of the proposition as you state it.

Q. Have you, in your study of this subject, given any consideration to the proposition that it is only a matter of a few decades when it will be not only advisable, but perhaps neces-

sary for Chicago to filter or otherwise treat its water supply from Lake Michigan?

A. No, I have not so considered it because I believe if the sewage is kept out of Lake Michigan, the hygenic aspects will then be taken care of satisfactorily. There is still left, of course, the matter of the aesthetic side, the occasional turbid water that comes following heavy storms.

Q. Is that purely aesthetic, or is there an element of health that comes from this mud or whatever it is that is stirred up from the bottom of the lake?

A. That would not be so at all, in the event sewage is all diverted from the waters of Lake Michigan, and the influence of shipping with reference to pollution is kept under control, which I understand has been considered very carefully by the authorities at Chicago.

Q. What authorities do you mean?

A. I understand it has been considered both by the health authorities of the city and by the district. Personally I have not made a special study of that fact. I mentioned it to emphasize this proposition that the hygienic needs of filtration do not stand in my mind if all effects of pollution of the lake waters by sewage are cut out, are eliminated.

Q. I think you said you had read the report of Mr. Wisner. I just call your attention to one statement, the statement of a general proposition. He says: "Today standards of sanitary science are much higher, and in consequence the demand is rising for the filtration of all surface supplies. It is thought that in the future filtration of the water supply of Chicago will be urged. Should untreated, or even treated sewage be discharged into the lake in the vicinity of the intakes, the water should be sterilized and finally filtered. Such discharge of sewage is not contemplated in the plan of the Sanitary District." So far as the filtration of the water supply is concerned, where treated sewage is discharged into a lake, do you understand that is the view which is generally taken by sanitary engineers today?

A. Generally speaking I think that is the viewpoint, if it is not readily feasible to keep the sewage out of a water supply.

Q. Now let us look forward, not to 1920 or 1930, but let us look 40 years ahead or 50 years ahead in Chicago, and let us assume we are dealing with a population of 6,000,000 people there. It would be necessary, according to the standard of dilution which you have indicated in this case, with a popula-

tion of 6,000,000 in Chicago, either to take from Lake Michigan 20,000 cubic feet of water per second, or to filter the water supply, wouldn't it?

A. No, I don't think so. There might be the purification of the sewage and the sterilization of the sewage with somewhat less than the volume of water diverted that you speak of, so that the filtration of water is not absolutely a criterion of what the future will bring to that community.

Q. How much less than 20,000 cubic feet of water per second do you think would take care of the sewage of a population of 6,000,000 people, by treating the sewage before it was discharged into the canal?

A. That would depend upon the amount of treatment given to the sewage, of course. The figure which I considered in this case has dealt, so far as the Chicago River is concerned, with an amount to ensure the reversal of flow at all times down the channel, and to prevent the sewage going out into the lake and contaminating the water at the intake cribs.

I have not given any consideration to the proposition of taking more than the 10,000 second feet through the Chicago River, plus 4,000 second feet flow through the Calumet Sag Channel, because those are the figures which I find in my consideration of the project put before me, all of the projects put before me.

Q. It is perfectly obvious, even with a diversion of 14,000 cubic feet per second, after the population of Chicago and vicinity, which is served by this system, increases to more than 4,200,000, one of two things will have to be done, either there will have to be more water taken out of the lake, or there will have to be some system devised of treating the sewage?

A. Yes, that is a fair general proposition.

Q. It is only a matter of a few decades until the same question will be up again in that form?

A. I could see how that might arise.

Q. And the only solution is more water, or some other method of dealing with the sewage?

A. Yes, I think that is true as a general statement. I was commenting, in my early answers, on a proposition dealing with a quantity named by you, that is 20,000 second feet diversion; that is the sewage should be diverted from the lake in order to protect the lake waters. That is the first proposition that my mind insists upon, hygienically, and if there should be diverted in excess of that water which would be available for

dilution of sewage, that takes care of sewage disposal matters. If water is not available in excess of preventing the reversal of flow, and a population springs up so that treatment works are required, why that is a matter which I have not considered at all, the relative aspects of added quantities of water for sewage dilution as against sewage treatment works. I have dealt specifically here with quantities as I find them, and particularly with reference to 4,167 second feet.

Q. Assuming for the purpose of answering this question that a diversion of 4,167 cubic feet per second properly utilized by the Sanitary District will ensure a reversal of the flow of the Chicago River at all times, have you given any consideration to the cost of disposing of the sewage of the city, on the assumption that there would be 4,167 cubic feet of water per second on the average going down the Chicago River with the flow reversed? Have you given any thought to the methods by which the sewage could be partially purified so as to dispose of the sewage through the canal with the 4,167 cubic feet per second?

A. I have studied sewage disposal projects dealing with the assumption that 4,167 second feet were to be the flow which would be diverted down the canal, but I have not considered it on the assumption that that would secure a reversal of flow at all times, and thus protect the water supply at Chicago at the present intakes.

Q. Just what use is made of this 4,167 cubic feet of water per second, which is taken from Lake Michigan, in the projects that you have suggested here?

A. It has been used to oxidize the settled sewage coming from the Loop District and the West Side District and thus save the expense of subjecting that settled sewage to treatment on sprinkling filters.

Q. What becomes of that according to your project when the flow is reversed, where does the sewage go? I want to get in mind the ultimate disposition of the sewage from the different parts of the city according to your project?

A. All treated sewage and all storm water, with a flow of 4,167 second feet would go down the main channel to the lower end of the main channel at Lockport, so long as the storm flow would not bring about a reversal. When the flow of the Chicago River and its tributaries would exceed 4,167 feet, then under the projects which I have described or estimated upon, this treated sewage, filtered sewage, settled sewage, also sterilized sewage would go on out into the lake.

Q. I want to be sure that I understand that. In your project, the sewage from the Loop District and the West Side is discharged into the Chicago River. You have before you now the map which was identified in connection with your direct examination?

A. Yes.

Q. What I am trying to get into my mind is this: According to your projects, what is done in the first instance with the sewage from the Loop District and the West Side, where does it go?

A. That is taken out to settling basins in the vicinity of Kedzie avenue, and if there is available 4,167 second feet of lake water for dilution, then that settled sewage from the West Side District and the Loop District would be sent into the canal, and its oxidation would be taken care of by this diluting lake water and sprinkling filters which are shown on this map; in laying out projects of various natures, the site for sprinkling filters shown here between Harlem avenue and South 64th avenue would not be required.

Q. That is to say there is sewage which is put into the Chicago River from the West Side and the Loop District which in times of storm, when the flow is more than 4,167 cubic feet per second, goes out into the lake before it has been filtered, or after being filtered?

A. It would not be filtered at any time, if that volume of lake water is available for dilution, but that sewage after sedimentation would be sterilized according to the projects which I have described in my direct examination. That sterilization applies to the flow of all districts.

Q. Is it sterilized in big storms?

A. All storm overflows would be sterilized when they exceeded three times the dry weather flow, and there would go through the settling basins the storm flows up to three times the dry weather flow; so that everything would be sterilized, dry weather flow, storm flows, everything would be sterilized coming from the existing sewers by the projects which I have described.

Q. By three times the dry weather flow, do you mean that that is the maximum flow?

A. That is the maximum flow which would go through these settling basins of the two story Imhoff type, and which would go through intercepting sewers leading to sprinkling filters in the instance of those areas where the sewage after sedimentation is subjected to filtration.

Where the sewage flow at times of storm should happen to exceed 900 gallons per capita, or three times the dry weather flow, then there would be applied sterilization processes for that excess flow; what I have spoken of in my direct examination as storm overflows, so that sterilization would be applied to all of the discharge from all of these sewers at all times; either the treated or settled sewage, treated sewage or the excess which I call storm overflow.

Q. Now let us see: Unless this sewage is settled, it cannot be sterilized, can it? I am speaking now about the disposition of this sewage in times of storm. What I am trying to find out is whether according to this project here there will be any time when there will be sewage go out into the lake without being sterilized, settled and sterilized?

A. Well, these storm overflows are what I think you have in mind, and I would say in that regard when the storm flow exceeded three times the dry weather flow, then these excess flows, storm overflows would not go through the regular settling tanks but would go through what I have called contact tanks. That is there would be a detention period of, I think it is ten minutes under the extreme maximum conditions of rainfall, that is 60 cubic feet per second per square mile. And there would be at all times some sedimentation in these contact tanks where the sterilizing agent would be applied; with rainfalls any less than the extreme maximum to give a run-off of 60 cubic feet per second, this ten minute period of detention in the contact tank would of course be correspondingly increased.

Q. But there are times when the sewage would find its way into the lake without having been filtered?

A. Without having been filtered, on the assumption that filters were not necessary for this West Side and Loop District because that settled sewage could be oxidized by this volume of lake water.

Q. When the river flow was reversed?

A. No, at all times, that is the sprinkling filters have for their purpose essentially the oxidation of organic matter to prevent putrifaction. They are not considered by me in these projects as devices for removing the disease germs and making the effluent safe for drinking water. They will remove, perhaps, 80 or 90 per cent. of the bacteria in the liquid applied to them. But to protect the water supply of Chicago at the respective intakes against disease germs coming from the Chicago sewers at times of heavy storms when there would

be no reversal, with an allowed flow down the canal of only 4,167 feet to prevent that pollution of the water supply, I have provided for the sterilization of all liquid which would come from the sewers, whether it is settled or whether it is filtered or whether it is a storm flow that goes into a simple contact tank in order to deposit the coarser solids and give opportunity for the flow of the sewers to come in contact with the sterilizing liquids.

Q. What approximately is the population of that portion of the district as to which the 4,167 cubic feet would be utilized, as you have indicated?

A. That flow of 4,167 second feet of lake water down the canal would be utilized in oxidizing the sewage after sedimentation from the West Side and Loop districts, which would have a resident population in 1920 estimated roughly at 970,000, plus a floating population estimated at 300,000.

Q. About 1,200,000 in all?

A. 1,270,000 in all.

Q. Now the result of this method of handling sewage would be that in times when the flow of the Chicago River was not reversed, the sewage from that population would find its way into Lake Michigan, with no other treatment than the sterilization which you have described. Is that right?

A. That is true, if you consider the sewage as having been subjected to sedimentation as well as sterilization.

Q. What good does the sedimentation do during a storm?

A. It keeps the accumulation of solid fecal matters from building up on the water courses, stream beds, and it also aids in bringing about effective sterilization.

Q. The most difficult conditions under which to sterilize the sewage are the storm conditions, are they not?

A. Yes, that is so with respect to adjusting the amount of sterilizing agents to a fluctuating volume of liquid, and during the first flushings, so called of sewers when heavy rains begin, there are solid matters washed from the walls of a sewer. It is feasible to sterilize the liquid portion of sewage and the exterior surface of particles in suspension. It is not feasible to kill disease germs that are situated, for instance, in the interior of a solid particle of fecal matter. The sedimentation has been considered as a part of this project, in order to deposit solid fecal matters so far as practicable rather than to allow them to get out into the stream bed of the Chicago River and its tributaries.

Q. Well now if it is all right to have that sewage find its

way into the lake with no other treatment than this sterilization under these storm conditions, why the necessity of these sprinkling filter plants; why not sterilize the sewage before it goes into the lake, the other sewage, in the same way?

A. The flow from all these other plants would be sterilized. I have endeavored to make it plain that sprinkling filters for this West Side and Loop District are omitted from my projects solely by virtue of the fact that the oxidation of the organic matter coming from this tributary population could be secured by the flow of the 4,167 second feet. If there should be sufficient flow of lake water, there could be omitted the sprinkling filters from this so-called Lawrence avenue project; but there is not enough lake water under the assumption of 4,167 second feet to prevent putrifaction of settled sewage coming from this northern area; and hence to secure a stable, non-putrifying liquid, sprinkling filters would have to be used at all other locations than this one that I have spoken of, namely the West Side and Loop District.

Q. I still don't understand why if in times of storm it is proper to send that sewage out into the lake, with no other treatment than this sterilization, it is not proper at other times to send the other sewage out into the lake with no other treatment than the sterilization, without filtering it, without the sprinkling filters?

A. The sprinkling filters are figured on to prevent putrifaction of these waters and foul stinks arising to produce nuisances. There is not enough water with 4,167 second feet available for dilution to prevent putrifaction, except for this area that I have just spoken about, shown here as the West Side project.

Q. I think it is Mr. Wisner who in his report speaks of the aeration of sewage for the purpose of preventing stench and other offensive features. Why couldn't you do that, instead of having sprinkling filters?

A. I think you might, but I think it would be too expensive. I think sprinkling filters are a cheaper means of oxidation.

Q. Than the aeration?

A. Than the aeration, to the point of getting a non-putrescible effluent.

Q. You have been utilizing this 4,167 cubic feet per second, used that for the purpose of oxidizing, you say, for a permanent population in 1920 of 970,000 and a floating population of 300,000, making a total of 1,270,000. Now isn't it a fact

that that quantity of water can be made more efficient by some treatment of the sewage, or haven't you treated the sewage in such a way that the 4,167 cubic feet per second can be utilized in handling the sewage of more than that number of people?

A. I should be disposed to say that it might be used to handle the sewage from a somewhat larger population, but whatever that increase might be in excess of the 1,270,000, I have assumed in these estimates as a factor of safety. I have realized that the division of the future population of Chicago into different sewerage districts must of necessity be somewhat arbitrary, and for that reason I have taken this largest district as the one from which to omit sprinkling filters. Theoretically, the point which you mentioned has some measure of support, but I have used it as a factor of safety which a few years would eliminate.

Q. If by settling and sterilization you could add, adopting Mr. Hering's figure, which I think is 33 1/3 per cent. to the efficiency of the water, that would mean this 4,167 cubic feet in the way in which you have utilized it could take care of a population between 1,600,000 and 1,700,000 people, so your factor of safety there adds considerable to the expense of this project, doesn't it?

A. It does, looking at it in that light. And it does in a practical way where a factor of safety must be provided.

Q. As a matter of fact, dealing with factors of safety and things of that kind, it is only a matter of a little time until the 10,000 cubic feet, so far as this dilution method is concerned, would be wholly inadequate, so with a diversion of 10,000 cubic feet from Lake Michigan, there is nothing permanent in that way of handling the sewage?

A. Well, I can see how that might be reasoned out, but on the other hand in the heart of a large busy metropolis, for many hours of the day a factor of safety in point of dilution would have to be dealt with that would not apply to the city as a whole. There is some margin there, I will say that, as I have already explained, but I do not think it is an unreasonable one at all, in view of all the facts and conditions.

Q. And it is also true that there is another factor of safety in the fact that the sewage of a floating population can be taken care of with a smaller quantity of water than the sewage of regular residents?

A. Not if the floating population are resident within this area 24 hours per day, it certainly is not so. If they are resi-

dent there only eight or ten hours, I can see how that would be a factor.

Q. By floating population, you mean those who come into the city and stop at a hotel for a little while and go out?

A. Yes, temporary residents rather than continuous residents of the community. Of course there is also from this district some trade wastes to be dealt with that are not peculiarly or characteristically Chicago trade wastes. By that I mean not the wastes of the stock yards district or packing houses, tanneries on the north branch, and the like. In all business districts there are wastes other than heavy trade wastes.

Q. Let me direct your attention to a matter about which I have asked you one or two questions already, but I want to put it in a little different form so as to make sure that I have your full explanation: In your direct examination you state that with a diversion restricted to 4,167 cubic feet per second, it would be necessary to settle all the sewage as well as to provide sterilization for all the sewage; and also sprinkling filters to render stable and non-putrefactive the flow in excess of that which could be diluted with the 4,167 cubic feet per second. Why, having settled and sterilized all of the sewage from the entire district is it necessary to still further treat it by sprinkling filters? Have you anything to say as to that, in addition to what you have stated already?

A. I have endeavored to make it as plain as I could that if you did not have sprinkling filters for the Lawrence avenue, North Shore, 39th street district, for instance, you would get a putrefaction of the flowing liquid down the canal. It would be a black bubbling stinking nuisance, and it is necessary to keep that on a stable, non-putrifying basis, in order to be able to send that down the valley, send that liquid down the valley of the Des Plaines and Illinois Rivers, and keep a condition in point of nuisance as good, or keep the conditions as free of nuisance as would be the result with this dilution of 3 1/3 cubic feet per second per thousand population.

Q. In these districts outside of the Loop District and the West Side District which we have been considering, what is the course the sewage takes? Let us take the district on the South Side, that sewage goes into the sewers, and where—

A. Take the South Side for instance, the sewage would flow through the existing sewers into the present Lake Shore interceptor, from 87th street we will say to 35th. That portion of the South Side would have its sewage then going

through intercepting sewers to 39th street pumping station. It would be subjected then to sedimentation in settling tanks built at the Lake Shore and adjoining the 39th street pumping station. That settled sewage then would be pumped through conduits on west to this area south of the main channel between Ridgeland and Harlem avenues, and there would be added to this flow in the delivery mains the settled sewage lifted by other pumping stations along the route. All of the sewage then after having been settled is put on to sprinkling filters in the vicinity of Summit, and after having gone through the sprinkling filters, and little small settling tanks following the sprinkling filters, it would flow after sterilization into the main channel.

Q. All of the sewage according to your plan then finds its way ultimately into the canal. None of it goes into the lake?

A. None of it would go into the lake except under conditions where the rainfall produced a flow in excess of the 4,167 second feet. When the flow was less than 4,167 second feet, then the flow would all go down the main channel as at present.

Q. And that is true as to both projects A and B?

A. That is true as to both projects.

Q. In your consideration, Mr. Fuller, of the purifying effect of the 4,167 cubic feet per second of lake water, are you considering as a major factor the oxygen content of that diluting water?

A. Yes, I should say I am, in the sense that that water is used to prevent putrefaction, and therefore serving as a substitute for sprinkling filters which are used under conditions where the dilution method is not available.

Q. In what other way than oxidation would you prevent putrefaction by that water?

A. I don't know of any other way than by oxidation or by keeping sewage matters diluted in a sufficient volume of water, so that if there is no direct oxidation there is the prevention of the negative, that is prevention of putrefaction.

Q. What do you assume the oxygen content of the lake water to be when it enters the canal?

A. Whatever the facts show.

Q. If you don't know what the oxygen content of the water is, how are you able to tell what its effect would be in purifying the sewage?

A. By satisfying myself that 3.33 cubic feet per second per

thousand population is as small a dilution as the oxygen content or any other factors taken with it justify, in point of dilution. I am talking, not only of oxidation with the oxygen content, but everything that goes with it as a mass.

Q. That was for crude or raw sewage was it not?

A. Yes.

Q. And not sewage that had been subjected to treatment. Do you know what the average oxygen content of the water is as it enters the canal?

A. Not from memory. I can easily look it up.

Q. What portion of the oxygen content of the 4,167 cubic feet per second do you assume as available for the purification of organic matter?

A. Theoretically it is all available, with the proviso that there ought not to be allowed to occur an exhaustion of oxygen at any point at any time. There is some difference between theory and practice. So long as you have a plus oxygen content at all times and all places you will not get into trouble with putrefaction from the theoretical standpoint. Practically I believe you should have some margin of safety, and I have considered that with much care. The different factors have to be considered somewhat differently in different places. I believe at the foot of the canal, for instance, at the foot of the Chicago Drainage Canal at Lockport it would be very highly desirable to have an oxygen content, say, of about 1½ parts per million. That is more than is secured for the summer months under the present conditions, and as I stated on my direct examination, I believe this legal minimum ratio of dilution, if it were to be changed at all, should be increased.

Q. What would that represent in per cent. of saturation at ordinary temperatures?

A. It would range from 20 to 30 per cent. during the warmer half of the year, depending on the temperature of the water.

Q. If the water enters with 90 per cent. and leaves with 25 per cent., then you have 65 per cent. available, is that right?

A. That is a correct calculation.

Q. You are familiar with the statement of Mr. Hering in his report of October 15, 1907, page 6, to the Honorable Robert R. McCormick, president of the Sanitary District of Chicago, to the effect that: "As the population sewering into the canal is now estimated at 1,887,472, the ratio is 2.75 cubic feet per second for 1,000 persons, and the results with this ratio are satisfactory, but closely approach the limit."

A. I have noted it, yes.

Q. And have had it in mind in your testimony about this ratio of dilution?

A. Yes, I have considered that.

Q. It is a statement that is entitled to some weight, is it not, in view of the standing of the man who makes it?

A. Yes, it is, but to take it very literally it ought to carry with it a statement of the season of the year.

Q. It is October, 1907?

A. Yes.

Q. When the report was dated. I do not know when the study was made.

A. October is a month in which you do not get the complications you do in winter, where you have ice preventing the oxygen of the atmosphere reaching the sewage as it flows down the canal and rivers below, and you have more oxygen in the water of Lake Michigan than you have during the heated period in summer. I do not find any fault with that statement, and I will take that into account in making the statement which I make in respect to the legal minimum ratio of dilution.

Q. But there is no allowance there made for a floating population apparently, is there?

A. Not that I have noted.

Q. In what fundamental respects do your projects A and B differ from each other?

A. In the first place, Project A takes the flow of sewage from the present sewers, whereas in Project B, an entirely separate system of sewers would be built in which to get the household waste at their point of origin and deliver them to the pumping stations and treatment works.

In the Project A, the storm water, that is the rain water falling upon the streets, roofs, parks and vacant lands would reach the water courses through the existing sewers together with the household wastes.

In Project B, storm water would flow through the existing sewers used exclusively for storm water, and with the household wastes in an entirely new system. The treatment works would be substantially along the same lines in the two projects, the intercepting sewers, pumping stations would be somewhat smaller with Project B because they would not deal with a portion of the storm water.

Q. So far as any of the sewage finding its way ultimately into Lake Michigan is concerned, there would be the same

situation when the flow of the Chicago River was such as to cause the water to flow out into the lake, would there?

A. I should have said in answering your preceding question that in Project A the storm flows would be subject to sterilization, whereas in Project B, keeping the storm water by itself, it would not be subject to sterilization.

Q. How would it be treated before it found its way into the lake, in times of storm and flood?

A. In Project B, there would be no treatment at all of street wash, horse manure and things of that kind.

Q. That would go into the lake after—

A. That would go into the Chicago River and water courses and if the flow of the river should bring about a reversal, then it would go to the lake.

Q. How would the domestic sewage be treated in Project B?

A. That would be subjected to sedimentation and sterilization with sprinkling filters used for areas other than the West Side and Loop districts.

Q. But take the West Side and Loop districts, how would that be treated in times of storm or flood, would that find its way into the lake in Project B?

A. Yes, in Project B if the sterilized and either settled or filtered sewage reaching the canal and mingling with the other waters if the flow of the Chicago River should be outward to the lake, then the treated sewage by Project B also would reach the lake.

Q. Would be treated in the same way in Project B as Project A?

A. Yes, that would be true with the exception I have just spoken of, that the storm flows in Project A would be sterilized. In Project B, they would go through the existing sewers without household wastes, and receive no treatment at all.

Q. In view of the fact that in Project B there would be some water which would find its way into the lake without any treatment, which would be treated in Project A, in view of the fact Project B is the more expensive, what was the purpose of suggesting Project B?

A. The purpose of suggesting Project B was to keep the sewage removed from a really bothersome proposition, and that is dealing with storm overflows. They have been assumed to be sterilized, but I do not believe that in the state of the art of sewage treatment today, a project related to a

water supply would be considered as perfect, or would approach as near perfection, where storm flows enter into the reckoning, as would be the case if separate sewers were to be built and the flow of the household wastes alone were subjected to treatment.

Q. In your Project A, what per cent. in your opinion of the total organic matter would be removed in the primary settling tanks?

A. By Project A?

Q. Yes?

A. I should say that it would be roughly 25 per cent.; that is of the putrescible organic matter.

Q. And what per cent. in the supplementary tanks which follow the sprinkling filters?

A. Well, taking the sprinkling filters and the supplementary tanks, it will bring the total percentage of removal to something like 70 per cent. with the residual so stable that with the oxygen content, coming from the aeration at the sprinkling nozzles, it would be a stable effluent under all ordinary conditions. That is to say it would not putrify upon standing.

Q. Can you divide the percentage which would be removed in the sprinkling filters and the percentage which would be removed in the supplementary tanks?

A. No, I cannot readily. It would vary tremendously. During the spring months, there is a good deal of accumulated material from these sprinkling filters that seem to unload. The stored organic matter for weeks at a time has to be dealt with in figuring upon what the percentage of removal would be by final tanks. I never have attempted to get an average figure in mind, as between the sprinkling filter removal of organic matter and that of the supplementary tanks.

Q. Have you given any consideration to the methods used in Milwaukee for disposing of their sewage?

A. You mean the methods now in vogue there?

Q. Yes?

A. Practically none at all. I know they are not satisfactory.

Q. And the projected methods?

A. No, I have never seen the final report, except as summarized briefly in the technical press.

Q. Assume a diversion of 10,000 cubic feet per second from the lake, which on your statement of the ratio of dilution re-

quired would take care of a population of 3,000,000 people. Now assume that the amount which may be taken from the lake is limited to 10,000 cubic feet per second, and it becomes necessary to provide for the sewage of a larger population than the 3,000,000, would the projects available for taking care of that sewage, after you have utilized to the full extent the water for the purposes of dilution, be the same as the ones which you have indicated here as Project A and B, with the exception of the provision which you have made for sterilizing the water when the river with the smaller amount of diversion from the lake in times of storm flows towards the lake?

A. Well, the project would involve no sterilization, as you say in your question.

Q. Yes?

A. Because then the protection of the Chicago water supply would not be a point at issue.

Q. Aside from that would it be the same substantially?

A. It would involve the consideration whether the best investment would come from settling the sewage from a portion or all of the population, and letting that settled sewage go down the channel, or whether from a certain smaller portion of the district the sewage would be subjected, both to sedimentation and the sprinklers. That is a question I can't answer offhand because it takes into account other factors of course, such as getting the settled sewage to suitable sites for sprinkling filters. The sprinkling filters on the basis of per capita cost will probably cut down the required dilution per capita more than will settling tanks. That is one end of the string, and the other is that settling tanks would be applied at the outlet of existing sewers, and not require pumping stations and long delivery conduits to reach suitable and isolated areas such as are necessary for sprinkling filters, so that I cannot state offhand how those factors would balance and indicate ultimate economy. Which ever was cheapest would be the best, where it is simply a matter of preventing sewage nuisances in the Chicago River and various water courses associated with populations in excess of 3,000,000 people, and with the protection of the Chicago Water Supply out of reckoning because of the reversal at all times of the Chicago River.

Q. After the city has outgrown the dilution system with a diversion of 10,000 cubic feet per second, and it becomes necessary, assuming that the district is not allowed to take

any more water out of the lake, to resort to other methods, other conditions remaining the same, would it cost about as much to provide for the disposition of the sewage of an additional 3,000,000 people at that time as it would now to provide for the sewage of the first 3,000,000, with the exception of this sterilization of the sewage which may find its way into Lake Michigan because of the insufficient diversion of water from the lake to reverse the flow at all times?

A. Well, assuming the unit prices of labor and materials the same?

Q. Yes?

A. I think it would be true as regards settling tanks and sprinkling filters. The question of intercepting sewers is a very complicated one. It depends upon the density of population and the manner in which sewage might be assembled at suitable sites. That I really don't know how it would be. The pumping question would similarly be a thing that I can't forecast upon.

Q. They would be figures which might be said to fall in the same general range?

A. Cutting out sterilization and interceptors and pumping station, I should say that would be generally true; that is, it does apply, labor and materials being the same, to the settling tanks and to the sprinkling filters. I ought to say that with the sterilization eliminated, I think that the intercepting sewers could be somewhat smaller than with project A, but not smaller than project B.

Q. So that if the district is permitted to utilize this 4,167 cubic feet per second, and if at no time it were to be permitted to take more than 10,000 cubic feet per second, if that were a fixed fact, it never could take more than 10,000 cubic feet per second, then what we are dealing with here is the disposition of sewage, which by the dilution method would be taken care of by a diversion of 5,833 cubic feet per second, and that is as I understand the comparison figures which you put into this record.

Mr. Austrian. In other words, he took the 4,000 from the 10,000 and got the figure which you mentioned, is that right?

A. These projects which I have described will dispose of the sewage without nuisance for a population equal to that which would be taken care of by the 5,833 cubic feet per second, and also provide the best method other than by dilution

with a diversion of all sewage down the channel, for the protection of the Chicago water supply.

Adjourned to Friday, November 28, ten o'clock A. M.

Friday, November 28, 10 A. M.

Parties met pursuant to adjournment.

GEORGE W. FULLER, resumed the stand for further cross-examination by Mr. Wilkerson, and testified as follows:

Q. In these projects which you have outlined in your testimony, Mr. Fuller, you have referred to the secondary sedimentation or to the sedimentation after the filters, I think?

A. Yes.

Q. Just what do I understand you have in mind as to the purpose of that particular part of the operation; what value do you attribute to that?

A. The sprinkling filters retain a good deal of the very finely divided particles that are suspended in the sewage, and which pass through the primary sedimentation tanks. They seem to adhere to the stones comprising the bed of the sprinkling filter. At intervals they are released and the effluent coming from the sprinkling filters at times will contain these little detached filaments from the surface of the stone, and some of them will be perhaps as large as the end of your little finger. They vary in size, and at certain seasons of the year, particularly at the end of the winter, when warm weather comes in the spring, there will be a relatively large amount of these particles detached. The purpose of these secondary settling tanks is to remove from the sprinkling filter effluent the suspended matter which comes from the sprinkling filters. These secondary settling tanks would also serve another purpose, in that they would be of aid in allowing sterilization to be made of the sprinkling filter effluent. It is the settling of solid matters, however, which is the main purpose of calling for the secondary settling tanks.

Q. Isn't it your opinion that the particular thing could be accomplished in a less expensive way than in the way you have outlined?

A. No, I think not. It is my regular practice to provide secondary settling tanks for sprinkling filter effluents, and that has been done in every project with which I or my

office has been connected, with possibly one exception, where Mr. Hering, I believe, under unusual conditions at Atlanta in point of a turbid water in the stream where the effluent was discharged, he omitted them, but other than at Atlanta, Ga., I know of no sprinkling filter project in which secondary tanks have not been a part of the design, and actual construction of works has followed.

Q. How about the plant at Batavia, N. Y., are you familiar with that?

A. I do not recall it at the moment. My impression is that they have secondary settling tanks.

Q. You are not sure about that?

A. I would not state positively. I was not personally connected with that plant, although it was designed by Hering & Fuller, but Mr. Hering was the one having immediate oversight of the work.

Q. If Mr. Landreth says as a matter of fact they do not, you would not be surprised if that were true?

A. If that is the fact, I would not be surprised. I do not remember specifically what the facts are.

Q. What I mean is it might be true?

A. It might be.

Q. Now, part of your method of treating this is by aeration of the sewage. I want to ask you a little more about that. What is the purpose of that?

A. The aeration feature of these projects which I have described is embodied in the intercepting portion of the works. The purpose of aeration is to prevent the sewage becoming septicised, so to speak, or becoming decomposed to a point of producing very foul odors. It is found that in a number of places where sewage has reached an advanced stage of decomposition and is applied to sprinkling filters from a series of nozzles a good deal like lawn sprinklers, that very of fensive odors are transmitted a considerable distance away from the plant itself. The purpose of aeration in these projects which I have described is to prevent the sewage becoming black and foul, decomposed, or what is technically an anaerobic condition, that is, decomposition in the absence of atmospheric oxygen.

Q. You have discussed in your book, I think, this matter of aeration, to some extent, have you not?

A. I think I have spoken of it some, yes, from several different angles.

Q. Have you made any study of the subject since your book was published?

A. Yes, I have.

Q. What study have you made? What has been the result of your study since the publication of your book on the subject of aeration of the sewage?

A. The result has been such as to cause me to consider it to be highly desirable, and in fact necessary, where sewage has to be transmitted for long distances, and to prevent this offensive decomposition about which we know more to-day than we did at the time my book was written.

Q. That is, to put it not in technical language, the effect of it is by getting the air in the water, you increase the efficiency of the water in handling the sewage, is that it?

A. There is something in that viewpoint which you speak of, but I think it is hardly a commercial proposition to use atmospheric oxygen for the purification of sewage. I consider aeration applied to the flowing sewage in interceptors more in the nature of what might be called a preservative; that is its purpose is to prevent putrefaction with its attending bad odors. I am not setting forth aeration as a part of the purification project in these various schemes described for the Chicago Sanitary District.

Q. That is one branch of your art in which studies are being made all the time, in which there has been some development in recent years, has there not?

A. It has been studied a good deal, yes, but the practical advance in the art is confined to just these lines I have spoken of, in connection with the Chicago project.

Q. This matter, this whole question of the disposal of sewage is one as to which the art has been undergoing somewhat rapid change?

A. I think that is true so far as the detail is concerned. It is not so true by any means with respect to what might be called the basic principles involved.

Q. It is now in process of development, in the way in which you have spoken?

A. To some extent, I think that is so, as regards details for utilizing the principles, which have been known for some time.

Q. And in this question of taking care of water supply and handling sewage, as our large cities grow, there are two things for which the dilution method is used to be accomplished, are there not: The first is saving the water, that is to say preventing the waste of the water, and the next is to increase the efficiency of the water which is used for the purpose of diluting and taking care of the increased quantity of sewage.

What I mean is it is found that those are the two things that you have to try to accomplish, is it not, in a great many cases?

A. There are cases where it is quite important to make the diluting water go as far as practicable, and if I understand you rightly the amount—do I understand that the amount of sewage is one of the features which you raise?

Q. Preventing the water from being used in an extravagant and wasteful way?

A. It is desirable to keep the volume of water supply per capita on as economical basis as practicable. In this country the use of water is much more lavish, of course, than it is in European cities.

Q. Yes, I had in mind the statement in the report of Mr. Wisner as follows: "The use of water in Chicago to-day, as stated by the Department of Public Works, is extravagant and wasteful. A large volume of water makes the question of sewage disposal more expensive by increasing the size of settling tanks and sewers and pumping works. It is believed if the dry weather flow were lowered, the economical point to intercept would also be lowered. The annual cost of pumping sewage will also be reduced. Metering the water service throughout the city is the only remedy to prevent waste." In your project you have assumed a per capita consumption of 230 gallons, have you?

A. I took a dry weather flow—

Q. Or 300 gallons?

A. I took the dry weather flow of sewage as 300 gallons per capita on an average, and based on actual measurements at Chicago.

Q. That is to say, based on the figures which were given to you by the Sanitary District?

A. Yes, by the official records of the district. That takes in not only the water supply, but also some ground water leakage into the sewers.

Q. And you prepared no estimates based upon an assumption that this wasteful and extravagant use of the water would cease, and the consumption per capita would be brought down to a reasonable basis, did you? You simply took it as the figures were given to you, as you found it in the present wasteful and extravagant way in which the water is used?

A. I took things as I found them, but I also have been informed that there has been within the last few years quite a reduction in the amount of water used per capita, and compared with what was the volume used per capita in earlier

years. The reduction in the volume of water supply is a good deal easier thing to talk about on paper than it is to accomplish in actual practice.

Q. There are a good many cities which have dealt successfully with that problem, are there not?

A. In the case of relatively small cities, there are quite a number. There are some fairly large cities that have met with some substantial success; but I do not believe it is at all feasible to cut the consumption of water in our large American cities, get it reduced to anything like the low figures which one reads of for cities of corresponding size in Europe. That is the habits of the American people are fixed in a way that it is not at all easy to reconstruct them.

Q. When you got 300 gallons per capita, did you consider the floating population, or did you take only the resident population of the city?

A. That is the resident population as I recall.

Q. Only?

A. Only.

Q. But in the figures you have given, you include the floating population of 300,000 with the same value per capita. I think you characterized that as a margin of safety?

A. That applies only to the loop and West Side district, as that was taken into account in the factor of safety as I described it day before yesterday. The rated population obtained by adding the sum of all of these different projects together does not take into account the floating population.

Q. Have you any idea what difference it would make in your figures if you assumed a per capita consumption of 100 gallons instead of 300?

A. No, I have no relative figures in mind. I don't think it would affect the cost of the sprinkling filters appreciably, but it would affect the cost of the settling tanks, of the intercepting sewers and of the pumping stations, and the operation of the pumping stations. It is too big a proposition for me to speak about in comparative figures in an offhand way.

Q. It would be considerable, would it not?

A. It would be quite an amount of money, yes, that would be involved.

Q. A good many millions of dollars?

A. It would be several million. I don't know how many.

Q. In your 1906 report, you were figuring on the basis of 150 gallons per capita, were you not?

A. For the Calumet District, the 1906 report dealt with

the flow of sewage assumed to come from a system of separate or sanitary sewers only; and not dealing in any way with any first flushings or combined sewers, due to rain water. The 150 gallons per capita which you mentioned is the approximate figure, as I recall it, taking into account some allowance for ground water entering the sewers through the joints in the sewers.

Q. Why would the cost of the sprinklers not be reduced if the per capita consumption were cut down from 300 to 100 gallons?

A. Because the facts show, as I understand them, that the rating of sprinkling filters in a point of capacity depends upon the number of units or the quantity of organic matter reaching the sprinkling filters rather than the volume of sewage. That is shown very clearly by comparing the results obtained from operating sprinkling filters in this country as compared with European experiences. In America, with our dilute sewage, sprinkling filters can be operated successfully at rates two or three times as great as is the case in Europe. But when the work of the two plants in America and Europe are compared on a per capita basis, then it is found that the experiences are quite similar, so I do not believe that the reduction in the volume of flow for a given population would have any substantial influence upon the area of sprinkling filters required.

Q. There are other factors that enter into that that might have influence, are there not?

A. There are some other factors, but that does not influence the correctness of this general statement which I have made, namely, that it is the units of organic matter which control rather than the volume of applied sewage as regards rating of sprinkling filters.

Q. Are you prepared to say, as an engineer, Mr. Fuller, that there could not be devised a system of dealing with this question on the basis of a diversion from Lake Michigan of 4,167 cubic feet per second, which, so far as the protection of the water supply of Chicago is concerned, would give as good results as were had in the year 1906 in Chicago, at a much less expense than your project A?

A. I have not given specific study to the 1906 conditions, because those related to the present project carried out only to a partial extent. I believe that these projects which I have described are as economical as can be devised to give safety to the Chicago water supply approximating that which would be obtained with a complete diversion of all Chicago sewage

from Lake Michigan. It is this latter proposition which I have considered rather than an attempt to figure projects against the dilution method as now applied, in its unfinished and partially applied stage.

Q. Your answer to the question would be the same if I asked you with reference to the years 1907 and 1908, would it?

A. Precisely the same.

Re-direct Examination by Mr. Adcock.

Q. Is it your understanding, Mr. Fuller, that the capacity or the dry weather flow was obtained from actual gagings of the sewers; is that the way you arrived at that figure, present experience?

A. Yes, either gagings of the sewage or the volume of water and sewage that is pumped, ground water and sewage that is pumped at 39th street station.

Q. Have you any idea of the cost of metering the water supply for a city like Chicago; would it be expensive or not?

A. Yes, it would run into a good many millions of dollars. I don't know precisely how much.

Mr. Wilkerson: That is on that metering, there would be just the one cost for the installation of the meters in the first instance.

A. And the fittings, cost of reading the meters subsequently at frequent intervals.

Mr. Adcock: Would there be some cost of maintenance of the meters?

A. Yes.

Q. There was some reference made to the Hering & Fuller report of 1906, to the International Waterways Commission, where you discussed the rate of dilution. Have you anything further to say with reference to that statement and also the statement which was made by Mr. Hering in his report to Mr. McCormick of 1907, in connection with any subsequent data that you have obtained?

A. I have looked over all these lines of evidence that would bear on the adequacy of the legal minimum rate of dilution of the Chicago sewage, by the water flowing down the main channel. In the Hering and Fuller report of 1906, printed in 1907 as War Department Document number 293, there is found on page 46 the following paragraph representing a careful study of the conditions found at that time. I will read as follows:

"It is our judgment that for large canals, with the trade wastes eliminated, a dilution of 3.33 cubic feet per second for each 1,000 population connected with the sewers, also re-

ceiving storm water, is as low a figure as it is now possible to state. Local conditions, especially temperature, which affects bacterial activities and the coefficient of absorption of oxygen by water and still other matters bear upon this question, the detailed discussion of which is not now necessary. We feel certain that a dilution of 2½ cubic feet per second would cause offense at times, and probably also a dilution of 3 cubic feet per second."

I might add further that at the time Mr. Hering recorded his single observation in the Autumn of 1907, there had not been obtained an extended series of observations made in fact for days and weeks at a time at 12-hour intervals of the dissolved oxygen content of the mixed lake water and sewage, as it flowed down the main channel.

I have, since preparing my portion of this report in 1906, given very careful study, not only to the dissolved oxygen records of the canal water, but I have also visited the main channel during the warmer season of the year, and studied various records and observations, and feel that the statement made in my direct examination, namely, that 3½ cubic feet of diluting water per thousand population is as low or small a diluting factor as it is reasonable to assume now. In fact, as I then stated on direct examination, if any change were to be made in the legal minimum ratio of dilution, it is my judgment that the volume of diluting water should be increased rather than decreased.

Q. You referred to the oscillations of the lake due to winds affecting the flow in the channel, and danger of reversal of the flow of the Chicago River, that is, towards the lake. Have you anything further to say with reference to that subject?

A. I looked into that matter with considerable care in 1906 and have given it some thought during the current year. I have not recently made a study of the detailed records, but I did look into that matter in earlier years. I find in this same War Department Document Number 293 a statement of what I had in mind while I was being cross-examined on day before yesterday. On page 7, paragraph 22, there is a statement as follows:

"Variation in the level of the lake's surface due to winds and to change of barometric pressure are frequent and irregular, and at times violent. Variations of more than six inches are very common, often occuring hourly for many hours in succession, while variations of two or three feet within an hour are not uncommon."

Q. Some mention was made of possible pollution of the water supply as the result of sewage or waste coming from ships or boats in the vicinity of Chicago? Have you anything to say as to how that pollution might be removed or prevented so as to make it unnecessary to use any other means to purify the water, or filter it or protect the water supply?

A. I have given some consideration to the prevention of the polluting influence of shipping upon the Chicago water supply, under conditions where all local sewage from the land population were diverted from the lake. I think I stated in my cross-examination that federal, state and municipal regulations, if properly applied, could bring about a discontinuance of this element related to the hygienic quality of the Chicago water supply. Whether it should be federal legislation, under federal supervision, or state or municipal control are points upon which I have not come to a final conclusion, but I should suppose that with the interstate factors involved it would be the federal legislation and control that would be of perhaps the greatest assistance. Whether the local laws would allow state or municipal control to be effective is a matter upon which I am not fully informed.

Q. What I had reference to was more in particular the mechanical means that might be adopted, that is the closing of the closets of the ships within a certain distance of Chicago, would that have any effect?

A. Yes, that is what I had in mind and assumed to be the feature that was to be taken care of in answering the last question. It would mean paralleling somewhat the practices of railroad transportation in closing the water closets and keeping them closed on these various vessels until they had passed beyond certain distances removed from the intakes of the Chicago water supply.

Q. Would it be possible for the boats to be provided with receptacles to retain the excreta that might be accumulated at certain times while they were in the Chicago Harbor or within certain distances of the Chicago Harbor, and then to be dumped at points outside of certain zones?

A. Yes, that would be feasible.

Re-cross Examination by Mr. Wilkerson.

Q. Having in mind the condition of the canal as described on page 8 of the report of Mr. George M. Wisner, the chief engineer of the Sanitary District, as follows: "At present there is a large deposit of sludge in the fore bay of the power house, extending from two miles north to the controlling works and into the rock section. This is due to the greater cross-section at that point and the tendency of the controlling works to act as skimming devices holding back the settling or suspended matter. In the rock section there is a little settled matter, slight sludge deposits being found on the sides. In the full size section from Willow Springs to Summit, there is a sludge deposit from which arises at times a very noticeable gas ebullition. This deposit is due to the reduced velocity in the large cross-section. The deposit generally seems to be a fine silt containing a small amount of organic matter similar to the grit that is found in the grit chamber of the 39th street pumping station," is it not your opinion that even though a diversion of say 10,000 cubic feet per second is permitted to be made from Lake Michigan, it is only a matter of a few years, in view of the growth of the population of Chicago, when with that diversion it will be necessary for sedimentation tanks to be constructed and other devices used to treat the sewage, and for aeration, perhaps to be employed to eliminate the offensive conditions that are there described?

A. No, I don't think that that is true so far as elimination of these sludge deposits in the fore bay of the power house or in the main channel is concerned. In fact, as the population grows and the volume of diluting water is increased, it will naturally increase the velocity of flow and lessen the deposit of sludge. The accumulations of sludge do not at the present time seem to produce conditions that are in my mind offensive as sewage disposal projects go. That is to say the amount of fresh sludge in this accumulation perhaps of years is not great enough to give off offensive odors that are noticeable a long distance away. It is true that there is some gas ebullition showing that the actual diluting factors employed are not excessive, and perhaps it may tend to show that they were rather too small under some circumstances. These deposits, however, are a function of velocity of flow essentially.

Now, coming to the question of what might happen in 1920 or later on, I can see where the population might reach

a point where the economic ratio of dilution, the capacity of the channel might become such that some supplementary treatment might ultimately be required. I mean by that treatment of the sewage other than by dilution.

Q. It is your opinion, then, at the present time there is no objection to putting raw sewage direct into the canal?

A. As a general proposition I consider that is true. I believe, however, that with increasing velocities there would be a lessening of these deposits of sludge, but on the other hand with a reduction in the volume of lake water to say 4,167, the accumulation of sludge would clearly become much greater, and offensive conditions would increase very markedly.

Q. Well, there is not much room for increasing velocity, is there, between the amount they are now taking out, if it is 8,000 cubic feet a second and 10,000 cubic feet?

A. Why, I should say there was quite a little in percentages; from 8,000 to 10,000 would be an increase of 25 per cent.

Q. Would not make much difference in the sludge deposit?

Mr. Adcock: You are assuming for the purpose of that question that we are taking 8,000 cubic feet?

Mr. Wilkerson: I understood you to say the other day that you were.

Mr. Adcock: No, I do not think it is that amount.

Mr. Wilkerson: Of course that is a matter for your answer. We haven't got your figures yet, but it has been my understanding to be admitted in this case that you were taking from seven to eight thousand feet.

Mr. Adcock: Whatever we are taking of course we will admit. But I do not understand the figure reaches that point.

Adjourned subject to notice.

Depositions in the above entitled cause, taken pursuant tc notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Friday, December 12th, 1913, 10:30 A. M

Appearsances:
Mr. James H. Wilkerson and
Mr. Albert L. Hopkins,
Representing the Government.
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

ASA E. PHILLIPS, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your name?
A. Asa E. Phillips.
Q. Where do you reside?
A. Washington, D. C.
Q. What is your age?
A. 47.
Q. What is your occupation?
A. Civil engineer.
Q. Will you state what, if any, experience you have had either as civil engineer or in connection with any sewerage disposal plants, and what if any training and education along those lines you have had?
A. I graduated in civil engineering at Lehigh University I have been engaged in sanitary engineering work continuously for more than 20 years. I have made a study particularly of sewerage, and of sewage disposal work in this country; covering experience along the Atlantic seaboard particularly—the large cities.

I have visited the sewerage works of a number of the large European cities, among which are London and Paris, and Birmingham and Manchester in England.

I have had charge of the preparation of the plans, of the construction and of the operation of the sewage disposal system of the District of Columbia, covering a period of more than 14 years past.

I have been, for the past seven years, superintendent of the sewer department of the District of Columbia, having charge of all sewerage works.

I have studied the modern development of sewage treatment, and the appliances that have been developed up to date for artificial disposal of sewage.

I have had some connections with several small projects; and also have been connected, in an advisory way to some extent, with the Passaic Valley work for the sewage disposal project for the drainage in the Passaic Valley.

Q. In other words, you have made a study, in the last 20 odd years, of sewage disposal, both from the scientific and practical viewpoint?

A. Yes.

Q. And what has been your work?

A. That has been my work, the practical construction and the practical operation of the works during that period.

Q. What is your present occupation?

A. Superintendent of the sewer department of the District of Columbia.

Q. How long have you occupied that position?

A. The past seven years.

Q. And prior to that time, what position did you hold?

A. Prior to that time, I was engineer in charge of the plans and construction of the sewage disposal system, for about seven years.

Q. What are your duties as superintendent of sewerage of the City of Washington?

A. In our organization, the superintendent of the sewer department is the engineer for the department; has charge of the preparation of plans for construction, the actual construction work, the maintenance and operation of the works; and the studies, of course, for new works and preparation of estimates for the department of construction.

Q. And what were your duties in the position which you held formerly, that is, prior to the present position?

A. I was engineer in charge of the sewage disposal system.

Q. What did you have to do in that connection?

A. I had the preparation of the detailed plans, the letting of the contracts, the construction work, and the design of the works, the stations and the various works connected with the plan.

Q. How were you appointed to the position, if it was an appointment?

A. I was appointed to the position by the Commissioners of the District of Columbia.

Q. Who are they?

A. The Commissioners of the District of Columbia are

a body of three men appointed by the president and confirmed by the Senate, one of whom must under the law be an officer of the Corps of Engineers of the army, and the other two are civilian commissioners. They must have had a residence prior to appointment within the district.

Q. What are their duties, just in a general way?

A. They fill the office of mayor, council and all the governing bodies of the ordinary city organization.

Q. You have certain works there at Washington for the disposal of sewage, do you Mr. Phillips?

A. Yes, we have what is known as the sewage disposal system of the District of Columbia, which is a separate construction, really an organization apart from the sewerage system itself. It was appropriated for specially, specifically by Congress, and its maintenance is provided for under separate appropriation, although its control and operation are under the same office.

Q. Will you describe those disposal works?

A. The disposal works provide for the collection of the sewage from the various public sewers of the city, and the delivery to a pumping station, required on account of the very flat, low level of the city, in the older part and along the river fronts. It is passed through the ordinary rough treatment preliminary to disposal by dilution at the station and elevated sufficiently by sewage pumps to discharge into the river at submerged outlets below the city in about midchannel of the Potomac River.

Q. Is the method which is used there known as the dilution method of disposal of sewage?

A. It is absolutely the dilution method.

Q. Where is the sewage discharged into the Potomac?

A. It is discharged into the Potomac at the bottom of about midchannel, four miles below the city.

Q. Is the sewage treated in any way to improve it, or purify it?

A. No.

Q. What is the treatment that is given the sewage before it is discharged into the Potomac?

A. Well, it passes through a grit chamber, and through screens, coarse screens; through a skimming tank where the grease is removed.

Q. What is the purpose of that?

A. The purpose of that is to avoid the creation of any nuisance on the river surface at the point of outfall. Owing to the rather restricted territory, to keep our construction

within the District of Columbia it was necessary to locate the outfall almost opposite the City of Alexandria, Virginia; and it was desirable to have the discharge into the river at that point such that it would not be subject to criticism and objection on the part of the people of the City of Alexandria.

Q. Does it improve the sewage so that it requires less water to dilute it, or do those works merely take out the solids so that the sewage when it is discharged will not appear so unsightly?

A. The work that is done on the sewage before the discharge does not affect at all the quantity of water required for dilution. It is merely to avoid unsightly conditions that would be objectionable; and to remove heavy material that might be an element of objection in operation, owing to the fact that we have to discharge from our pumps through inverted castiron siphons laid very deep below the channel of the Anacostia River, rising again on the other side, so as to prevent obstruction in those pipes.

Q. Do you pump all the sewage, including the storm water, through these interceptors?

A. No, we pump only the sewage, and in part the first runoff of storm water. Of course we pump the light rains, but ordinarily the storm water discharges at the various outlets along the city front. I might say in that connection, if I may, that the reason for the arrangement, the reason for selecting the location of the outfall so far below the city is the fact that Washington is at the head of the tide in the Potomac, with two substantially blind channels that have no flow of water normally through them; and it is desirable not to have the sewage discharged where it would back into those slips, such as the Washington channel, for example, and the channel of the Anacostia River, leading to the Navy Yard.

The point was selected with the view that the incoming tide would not carry the sewage from the point of outfall into these blind channels along the water front of the city.

Q. Who laid out the plans or recommended the method of taking care of the sewage, which has been adopted there at Washington?

A. The recommendations were made by a Board of Sanitary Engineers appointed by President Harrison in 1889, consisting of Mr. Rudolph Hering, Mr. Frederic P. Stearns, and Mr. Samuel M. Gray. They made a report the following year outlining a recommended plan for the disposal of the sewage

of the city, which has been carried out substantially, and has been in operation for the past seven years.

Q. How long did it take to install those works there, from the time that the money was provided for by Congress?

A. The report was made in 1890. The first appropriation was made by Congress in 1893; consecutive and continuous appropriations began in 1900 and the works were completed near the beginning of the year 1907.

Q. What did they cost?

A. The total cost of the works was substantially $5,000,000.

Q. What is the water supply for the City of Washington?

A. Washington takes its water supply from the Potomac River at Great Falls, sixteen miles above the city, through a conduit laid in 1858. It passes through one large reservoid untilized as a settling basin; then to a receiving reservoir at the westerly limits of the city; then through a deep tunnel to a reservoir and purification works, at the north end of the city near Howard University, where they have a modern slow sand filtration plant.

Q. When was that filter plant installed?

A. That filter plant was installed about six years ago, possibly about 7 years ago.

Q. Is that a modern plant?

A. That is a modern plant.

Q. How does it compare with other filtering works?

A. It is a slow sand treatment, of probably as high class as any in the country, and very efficiently maintained. The quality of the water is perhaps as high as the water supply for any city in the country, of any considerable size at any rate.

Q. That is, where filters are used?

A. Yes, where filters are used.

Q. Is this water in the Potomac polluted in any way above the intake, by sewage being discharged from other cities?

A. It receives a considerable pollution from towns in Maryland, such as Cumberland, Maryland; also from towns in the Shenandoah Valley in Virginia. All the pollution is at a considerable distance from the city. For example, Cumberland, the largest town in the basin, is 180 miles from Washington.

In addition to the pollution, the Potomac carries a very heavy amount of silt which always rendered the water objectionable for domestic use. It is turbid water.

Q. Do you know to what extent the artificial methods for

the disposal of sewage, so-called, purification of sewage are used in the United States to-day, in the larger cities?

A. In connection with the work at Washington and the development of the sewage disposal system, I have kept in close touch with the feature of treatment works and their development in the country, and attempted to follow the operation of those works, as to the success of operation.

Q. How largely are these treatment works used in cities of the United States, as compared with the dilution method of sewage disposal?

A. In a broad sense, they are not used. In the cities of the first class, something like 18 cities over 300,000 people, the disposal of sewage is entirely by dilution, with the one exception of Baltimore which has recently completed a plant, but has only partly operated same to date.

In the cities of the second class, perhaps 14 cities over 150,000 population and less than 300,000, we have treatment works at Providence, Rhode Island, at Columbus, Ohio, and at Worcester, Massachusetts.

In the third class cities, coming up from 100,000, we have treatment works at Atlanta.

Q. What is the purpose of these purification works as used in these various cities?

A. They have a somewhat varying purpose. Altogether, their object is to prevent nuisance in the streams in which they discharge. The variation from that is in the two cases, one, of the older works at Providence, Rhode Island, were put in with a view of preventing the oyster beds in the Providence River below the point of discharge from being polluted, and in the case of Baltimore, comparatively new works, to protect the oyster beds in the upper Chesapeake Bay from pollution.

Looked at from the point of view of practical results up to date, none of these works have accomplished what would reasonably be supposed to be their complete function. In every case, they discharge either an effluent that does not have a degree of purification such as to prevent the streams from actual and dangerous pollution, or they operate intermittently, and intermittently throw a load of sewage directly into the streams, or discharge the sludge from the treatment works at times into the streams.

In the comparison between what is accomplished at these works and what is accomplished at other works using the method of dilution where reasonably uniform and constant results are obtained, practically unchangeable except due to the

variation of season and of temperature, these artificial treatment works have not been successful. Some qualification ought to be made as to this, in the case of the new works at Baltimore which, while completely contructed, handle only a very small portion of the sewage, and with regard to these works they have developed just as the works at Providence developed, very serious local nuisances, which are involving lawsuits. And at Baltimore, a very great reliance, even by the engineers in planning the works, has been placed in the effectiveness of the purification by dilution, that would be accomplished in the travel through the arm of the Bay in which they discharge, Back River, of some fifteen miles before reaching the oyster beds.

In the case of the other works, having only in view the prevention of the gross pollution of small streams, such as the new works at Atlanta, there is no very serious problem such as the protection of the water supply, involved.

The works at Providence, chemical precipitation works, designed to protect the oyster beds from pollution, have been substantially abandoned, and the works there to-day, with the exception of some sedimentation and some attempt to disinfect the sewage, are substantially, pure and simple, works of dilution.

Q. What can you say as to whether the artificial methods that are suggested for the purification of sewage will be used in the future for any great length of time?

A. In considering that phase of the question, the abandonment of older processes, though comparatively new themselves, and the fact that the present appliances that have been introduced in the design of artificial treatment works are extraordinarily new, and might fairly be considered experimental, it is a reasonable conclusion that with the changes that have been going on in a short space of a little more than 15 years, and most of it in the space of a little more than 5 years, possibly within 10 years, there will be new lines in the treatment of sewage, and new processes that will revolutionize as completely the methods of to-day as those methods were revolutionized only a very few years ago.

Q. In solving the problem or determining the plan of disposal of sewage, what elements are taken into consideration by sanitary engineers, particularly with reference to the adoption of a plan which will be a safe and sure plan for protecting the water supply?

A. The very first consideration in weighing various possible plans in any case would be the protection of the water

supply. The absolute necessity of this exists where a water supply is in reasonable proximity to the works. That is in the discharge, for example, of the effluent of artificial works or of sewage for dilution within a certain range of distance subjects the water supply to pollution and to serious injury. At greater distances, further removed, of course, that becomes less important. In any case, the method should be such and the design of the works such as to absolutely prevent at any time the pollution of the water supply if that is within the range of possibility; that is even the contingency of pollution should be prevented.

Q. That is when you say pollution, do you refer to pollution that may be accomplished by the discharge of raw sewage, or any effluent from these so-called purification works that you have mentioned?

A. I mean both, and it involves both the raw sewage and the effluent because there is no, absolutely no certainty that with the most modern works, most carefully devised and designed, that there will not be periods when raw sewage may be discharged.

And then, on the other hand, is the question of the efficiency of the works themselves in obtaining, if it is possible to obtain such a thing, an effluent that is entirely, at all times, free from dangerous pollution.

Q. Then, as I understand it, Mr. Phillips, you give considerable weight to the danger which may result from the operation, that is, the inefficient operation of these plants, disposal plants, or the efficient operation of filter plants to filter water supply?

A. A very great deal of weight, owing to the absolute uncertainty of continuous, efficient operation in both cases.

Q. Take it in a large city like Chicago, what are the difficulties necessarily to be encountered in the use of artificial methods of sewage disposal?

A. The greatest difficulty is involved in the impracticability of handling the sewage otherwise than on a system of units, owing to the enormous volume of sewage, to the great areas covered, and the long period of time involved for the transit of the sewage to the treatment works. It involves the necessity of the construction of such works substantially within the city close to dwellings; that is in fairly close proximity to dwellings; and all experience on the treatment of sewage to-day, so far as the location of treatment works is concerned, is in favor of their remote removal.

Baltimore, for example, one of the newest, and the largest

city in America to put in treatment works, located the works something like seven or eight miles from the city, selecting a location remote from any dwellings. In addition to that, they felt compelled to buy large tracts of ground to create a neutral zone around their works, and yet, with a very short period of operation, and very low load on their works, only having part of the sewage to handle, they have been confronted with damage suits for the creation of a nuisance, by the owners of property along their holdings. The certainty in a very large community of the sewage reaching the works stale, its creating local nuisances along the line of travel in the interceptors, even with the entire area broken up into districts, is a great problem and a source of danger in a very large community.

The difficulty of handling the resulting materials accumulated, the sludge particularly, from the treatment works, its removal, its necessary storage in preparation for its removal, appears to me to be a most serious problem in considering any treatment works for very large communities.

Q. In the last three years, what has been the death rate in the City of Washington from typhoid fever?

A. In the years 1910, 1911 and 1912, the death rate from typhoid in Washington was 24, 22 and 22, respectively; per 100,000 population.

Q. Have you the death rate in the City of Chicago for those years?

A. Yes, apparently the death rate in the City of Chicago for the years 1910, '11 and '12, was 14, 11 and 8, respectively.

Q. As I understand it, Mr. Phillips, you had to do with the details of building these works at Washington City, that you mentioned?

A. Yes, I had charge of their construction.

Q. And you have had charge of the operation since?

A. I have had charge of the operation continuously, since they were put into service.

Q. If I remember correctly, you stated that you operated pumping works there?

A. Yes.

Q. Now, in your experience in the operation of those pumping works, would you consider that the estimate of $350 made by Mr. Fuller per water horse power per year a reasonable estimate for the cost of operating pumping plants?

Mr. Wilkerson: I will object to that, on the ground the witness is asked to state an improper conclusion; without a proper basis. I do not object to the form of the question, but I object to the statement of the conclusion?

A. After seven years' experience in the operation of the pumping plant at Washington, and a close study of the cost of pumping, considering the elements that necessarily enter into an estimate, covering a period of a number of years, I would consider the estimate of $350 per water horse power per year reasonable.

Cross-Examination by Mr. Wilkerson.

Q. You have had nothing to do, as I understand you, with the construction of the works at Washington relating to the water supply?

A. I have not; no.

Q. You do not know what those works have cost, except by hearsay?

A. Except by seeing the reports that are made each year.

Q. I think it is in the record, but if you know I would like to have you tell us how much the works for filtering the water supply of Washington and furnishing the water supply, cost the city in the aggregate?

Mr. Austrian: You mean the cost of the works themselves?

Mr. Wilkerson: Yes.

A. I cannot give the figure—you mean of the filtration plant alone, or of all the works?

Q. I mean of that part of the plant which is necessary for the filtering of the water; that is of the part of the plant which does the work which would not be done if the water were taken directly from the river?

A. Well, Washington is peculiarly governed, and it is a very complicated proposition, owing to the fact that the works beginning at Great Falls on the Potomac, passing through the conduits to the reservoirs, to the filtration plant, are directly under the Chief of Engineers of the Army; and the pumping station and the distributing works come under an entirely different organization; coming under the District Commissioners,

Q. Have you any idea what the total cost of that plant has been?

A. The total cost of the entire plant?

Q. Yes?

A. I think the total cost of the entire plant has been about $16,000,000, but that involves all costs going back to the construction of the original conduit from Great Falls, various modifications that have been made and changes that have

been made in the works, and represents really the total aggregate capital invested.

Q. Do you know how much has been spent on these sewage works?

A. In the District of Columbia?

Q. Yes?

A. The total cost of the sewerage system, and of the sewage disposal system for the District of Columbia, involving all investments that have been made from the beginning of the city, including all the lateral system of sewers, has been substantially the same amount, about $17,000,000.

Q. The reason why Baltimore does not use the dilution method, or has discontinued the use of the dilution method, as I understand you is to protect the oyster beds?

A. No, primarily the reason for the construction of the Baltimore sewerage system—and it has been frequently stated it did not have a sewerage system before, when as a matter of fact they did; they discharged very large quantities of sewage into the very small harbor there at Baltimore, which was very seriously polluted. Some parts of the city did not have a developed sewerage system. The proposition was to provide a main sewerage system, and to prevent the pollution of the harbor, which was very narrow and small, and had practically no circulation of water. It became a septic tank, really. The odors were very great.

Q. It was at Providence they were protecting the oyster beds?

A. Yes, in both cases the question of protecting the oyster beds was involved immediately; at Baltimore when the study was begun for the sewerage system; and for the removal of the sewage from the harbor by a disposal system, but the matter of the protection of the oyster beds near Baltimore was determined, not so much as an engineering matter pure and simple, but by an absolute act of the state legislature, which required it.

Q. Have you had occasion to make a study of the sewage disposal problem in any cities where the question has been that of increasing the use which may be made of a limited quantity of water, in handling the sewage by the dilution method?

A. I know of no city to which that applies except Chicago.

Q. I say, you know of no city with a river, where the attempt either has been made, or where the matter is under

consideration, or partially purifying the sewage before it is discharged?

A. Oh, yes, that has been under consideration in perhaps most of the larger cities, in one form or another, as an ultimate proposition.

Q. Of the partial purification of the sewage?

A. Yes. That of course is a subject that we consider. We are studying at this time at Washington that question, not as anything immediate, but as possibly a subject that will be of interest when the population has reached a far higher figure than the present.

Q. What is the outflow of the Potomac River?

A. It has a minimum flow of record of 900 second feet.

Q. What is the average flow?

A. That is the minimum of record, about 900 second feet. It has during the fiscal year 1913, ending June 30, 1913, a minimum range of flow, in and around 2,000 second feet. That was about the minimum of that year, which was a very favorable year. We frequently have a minimum as low as 1,200 second feet for one day, or 1,400 second feet. It varies very much, depending on the rainfall and distribution of rainfall. The average flow would always exceed 2,000 second feet; probably covering any period of years the average flow would be very much in excess of that. The minimum might vary, ordinarily we could say, between 2,000 and 2,500 second feet.

Q. A flow of 900 second feet would take care of the sewage of how large a population by the dilution method, as you understand it?

Mr. Austrian: In what sort of a body of water?

Mr. Wilkerson: In the Potomac River.

A. It would take care of a pretty small population. You have to remember that 900 second feet is a question of a day, the flow drops down to that and immediately lifts out of it.

Q. Well, a flow of 2,000 second feet would take care of how much, according to your understanding of this subject, by the dilution method, flow of the Potomac River.

A. Well, probably I could best answer that by the statement of the Board of Engineers reporting on the sewage disposal system, stating that the method was adequate for a population of 500,000 people.

Q. 500,000. And when the population reaches 500,000, you will be confronted with the necessity of a partial purification of the sewage before it is discharged into the river?

A. Well, possibly not at 500,000, but there is a limit there.

We have probably some difference of opinion on that as to exactly what the population would be when that must be considered, but that is of course the pending thing.

Q. What in your opinion will be the population of Washington when it will be necessary to partially purify the sewage before it is discharged into the Potomac?

A. My opinion is that the limit may be reached when the population reaches 750,000 people. It would have to be explained in reference to the amount of water for dilution that the local situation is very peculiar. The sewage is discharged, not into a running stream or into a lake, but is discharged into the upper reach of a tidal river, where we have a very large drainage area and a large storage basin. In our study of the work, we speak of that stretch of the river as the dilution basin and into this the upland water flows.

Now, we have a river discharge up to 250,000 second feet. We have about three billion cubic feet of water in this range of river as a storage. When the flow is running along up to 5,000 second feet every day, and then goes to four and drops down to the low limit, it is generally a quick drop-off and back again. The low limits are longer in period, but the very high limits are short periods constantly recurring so that while they do not increase so markedly the average second foot flow of the river, they do by their piston effect in displacing the entire immense storage of water with comparatively clear pure water from the upland flow, provide additional capacity for dilution.

Q. There are those who think that the limit will be reached at 500,000 people?

A. That was stated in the report of the Board. That should be qualified in another way, that it was stated at a time when the regular and consistent gaging of the river was not carried on, and it was based on such data as was accumulated in connection with the data of the water supply system at Great Falls where the record was kept more consistently of the extreme low flow of the river, instead of a constant daily reading, and a determination of what the real capacity of the river was.

Q. Assume a gradual growth of population of the city of Washington, so that it would have a population of 2,000,000 within 20 or 30 years, what would have to be done with that sewage disposal plant?

A. There would have to be some facilities for the sewage treatment introduced.

Q. That is there would have to be a partial purification of it, before it was discharged into the Potomac River?

A. Yes.

Q. And that is inevitable in Washington when the population passes a point some place between 500,000 and 750,000, in your opinion?

A. Yes, not between 500,000 and 750,000. I would say the point of when consideration should be given to it is at 750,000. I think I stated that, that was my intent, but the commission had stated it would be adequate for 500,000. I suppose they may have dealt rather conservatively with their figures.

The question of that treatment, however, of course would be a matter of development; and that question of development is one that we are, even today, considering. We have a large area geographically, 70 square miles; that is large among the municipalities in the country, about the fourth, I think, largest in the country; and that problem involves the development of the system in detail in advance, in anticipation of the need, by the construction of separate and storm water sewers, the elimination for the further reach of population of combined sewers, and an installation and construction and design of a sewerage system that would be in form to permit the treatment of the sewage of the excess population. And I think beyond all question, merely considering the development of sewage disposal works today that that will be—that is without any idea of the future improvements, and we have had a tremendous lot of changes in a very short time—that that will be the way in which the problem will be worked out.

Q. This art is one in which very rapid progress is being made, is it not?

A. And very sudden changes.

Q. Very sudden changes?

A. Yes, sir. The great works, thought to be great works at Providence, became a back number in such a short time, that they were started in 1900 and today they are so much out of date that they are antiques.

Q. You have given some study to this question of the partial purification of sewage have you not?

A. Yes.

Q. It is done in some cities with success, is it not? I am speaking of the partial purification so as to increase the use which may be made of a limited amount of water?

A. I don't know of a city in which it is being successfully done.

Q. You say you know of no city in which it is being done successfully, or no city in which it is being done at all?

A. I mean a city; I mean for instance in the classification of cities I gave of the first class, over 300,000 people. In a very small community, of a house or two houses, a village or small towns, even a small city, there is a great deal of possibility in that direction, and of course we have some examples.

Q. I should think a place like Indianapolis would have that question to deal with sooner or later. What is the outflow of the river there, do you know?

A. I do not. I do not recall the figures for Indianapolis.

Q. I should think cities on small rivers of that kind would have that problem sooner or later, would they not?

A. Yes, no question about it. And it is a problem that awaits them.

Q. If all the solid substances were screened out of the sewage, by what amount is the quantity of water required for dilution purposes diminished in your judgment?

A. In my judgment the volume of water required for dilution is very little changed.

Q. By screening?

A. By screening, and by the ordinary coarse sedimentation. It is a function of the capacity of the water and of its oxygen content to accomplish the purification. The quantity to be purified is the quantity of organic matter which is not sensibly removed, either by screening or by the ordinary coarse sedimentation such as for instance we have in Washington.

Q. It is increased some by screening and sedimentation, at least that is the view of a great many engineers, is it not?

A. Of course you must define first the screening and then the sedimentation. If you go into treatment works sedimentation, of course you are removing a larger quantity than you are from the grit chamber sedimentation that is ordinarily practiced, such as we have. In screening, if you take the very fine meshed screens, you are removing a portion of the organic matter, but you are not removing a very great proportion, and you are not affecting the purification of the sewage to any great extent. You still have to deal with sewage containing comparatively the same amount of organic matter that will require substantially the same volume of oxygen

from the water of dilution, and therefore substantially the same volume of water for dilution.

Mr. Adcock: You mean the volume of water containing an oxygen content?

A. Yes.

Q. Are you familiar with the views of Mr. Hering on the subject of increasing the use to which the water may be put by the partial purification of sewage?

A. Yes, I have talked to him some about that and read—

Q. You have read what he has written?

A. Read what he has written.

Q. You and he agree on that substantially, do you, or do you think he is wrong?

A. Well, that is a question of judgment as to what can be accomplished.

Q. You are rather conservative on that?

A. I am very conservative on that. On treatment works, I have to be shown; I have not seen them.

Q. You think Mr. Hering is a little radical about the things he thinks can be accomplished by this partial purification?

A. I think he probably is taking a hopeful view of it.

Q. You are rather pessimistic about it?

A. I am inclined to be conservative.

Q. You say that in the problem of sewage disposal, you regard it as of great importance to keep the sewage away from the source of the water supply. I think that was your statement?

A. Yes.

Q. If as a matter of fact the conditions are such that even without the discharge of the sewage into the water it would be necessary to filter the water, that would not be a matter of so much importance would it?

A. I would yet consider it a matter of very great importance.

Q. Even though the conditions were such that they made it necessary to filter the water?

A. Yes. I think that the sound point of view is to prevent the pollution, first of all.

Q. What is the object of preventing the pollution of water that is already polluted? I think you understand my question, do you not?

A. I do not.

Q. I say assuming that the condition of the water is such that it is necessary to filter it before it can be used for drink-

ing purposes, why is it a matter of so much importance to prevent its further pollution, in your opinion?

A. Well, as I stated, all possible pollution should be prevented, first of all. That is the first safeguard of the water supply. If there is some pollution, it would not justify ignoring opportunities to prevent further pollution. That is what I attempted to say.

Q. Well, let us take the case of Lake Michigan for instance. Suppose for example the sewage of half of Chicago is discharged into the lake so that it became necessary to filter the water before it was used for drinking purposes. The impurities in the water would be removed by the filtering process just the same if the sewage of all the city were discharged into it as if the sewage of half the city were discharged into it, would it not?

A. Absolutely not, for the reason that you must furnish a consistent, uniform, invariable quality of water. All the typhoid outbreaks we have had, the epidemics we have had, have not been due to a consistent moderate pollution, but they have been due to the breaks that have come, and those breaks you might encounter in your filter plant itself. Is it an absolute assurance of an unpolluted water supply? I mean after treatment, does the treatment ensure at all times, under all conditions, what is essential for the community?

Q. Yes, I think I understand those general observations; but I still am unable to see—and I do not want to argue with you, but I would like to get your further view on this—I am still unable to see why the filtering process, if it is necessary at all, will not take care of the impurities which would come from discharging all the sewage into a body of water as well as it would if the sewage of only half of the population was discharged into the body of water; that is to say if you must filter the water anyway?

A. Simply because every pollution, every part of the pollution, every increment of pollution rather, is an increased load put upon the purification works; and is an increased opportunity for any break in the absolute efficient operation of those works.

Q. Well, applying that rule then, cities along the banks of rivers should not be allowed to discharge their sewage into the river, because of the effect upon the cities further down?

A. Well, that is not quite a parallel case, because this process of purification by dilution requires a certain space of time and distance. The distance, really, in the case of the

river, is merely an element of time substantially, but it can be reduced into a statement of distance, and so a city putting sewage into a river at a point 200 miles or 300 miles away from where a city further down the river takes its water supply is not in the same relation at all to the case that you were speaking of, of Chicago putting its sewage directly into the lake and immediately taking its water supply from a reasonable proximity out of the lake.

Q. What do you mean by a reasonable proximity?

A. As I say, two cities within two or three hundred miles, even with a larger discharge of sewage, the natural processes of purification have gone on, the bacterial life period has passed, and the danger is remote.

Q. How about a distance of 20 to 50 or 60 miles?

A. In a river, flowing stream?

Q. Yes, or along the shore of a lake?

A. Well, in my judgment it is an element of the time of travel more than anything else.

Q. As a matter of fact, if you are going to be on the safe side, absolutely on the safe side, it is coming to be believed is it not that the supply of drinking water should be filtered in almost every case?

A. That has been very generally accepted because the physical conditions have absolutely required it.

Mr. Wilkerson: That is all.

Adjourned to Saturday, December 13, 1913, at 10:30 A. M.

Saturday, December 13, 1913, 10:30 A. M.

Met pursuant to adjournment.
Present same as before.

ERNEST W. SCHODER, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?
A. Ernest W. Schoder.
Q. Where do you reside?
A. Ithica, New York.
Q. What is your present occupation?

A. I am a teacher, and engineer.

Q. What is your title?

A. I am in charge of the Cornell University Hydraulic Laboratory, College of Civil Engineering.

Q. How long have you occupied that position, Professor?

A. Nine years.

Q. Will you state your education and training in connection with your work as hydraulic engineer?

A. I was graduated at the University of Washington, Seattle, in 1900 and then pursued post graduate work at Cornell.

Q. For how long?

A. For 2½ years.

Q. Was that in engineering?

A. In experimental hydraulics.

Q. Since that time you have occupied the position which you now occupy?

A. Except for one year in general hydraulic engineering.

Q. What did you do during that year?

A. I was engineer on construction, on two pieces of construction work, a pumping station in Ithaca and a filter plant at Cornell University.

Q. Will you describe the laboratory at Cornell University, the hydraulic laboratory?

A. Our laboratory at Cornell is on a stream having a watershed of some 125 square miles; and we have a pond there of some 20 acres and a canal some 450 feet long, 16 feet wide, from 18 to 10 feet deep; various regulating gates; and a laboratory building which contains many pieces of apparatus on a small scale. Those are the main features.

Q. Are you familiar with the use and operation of the Haskell current meter?

A. Yes, sir.

Q. Did you make any experiments at the request of Mr. Gardner S. Williams, during this year, in the laboratory?

A. I did.

Q. With the Haskell current meter?

A. Yes.

Q. Will you state what experiments you made and the results of such experiments?

A. We made nine discharge measurements in the canal with the Haskell meter, checking the flow by means of weir measurements. These measurements were made at various distances down from the upper end of our lower canal. The

water falls from what we call our upper canal into the lower canal and then passes through a set of baffles, and flows on through the lower canal; so by going various distances down from the upper end of the canal we are in various regions of more or less disturbed flow; that is appearing so to the eye. These measurements were made by what is called the "point" method. That is to say with the water flowing and steady conditions prevailing, we held the meter in various parts of the cross-section of the flowing water, at various distances below the surface and at various distances from the walls of the canal, and observed the number of revolutions in any given time, and from those observations we computed the discharge, using for that purpose a rating made of the meter, checked also during the experiments and after the experiments; and the results of those measurements, summarized, I have here.

Q. Have you any photographs of the canal and the water flowing in the canal, which would indicate the conditions existing there?

A. Yes, we have a number of photographs showing the conditions during the tests.

Q. Were those photographs taken at the time the measurements were made?

A. Yes, I made these in person at the time of the measurements.

Q. Who assisted you in making these experiments?

A. Professor K. B. Turner, and several advanced students who had had previous experience with the current meter.

Q. You had general charge of the work did you, in making the experiments?

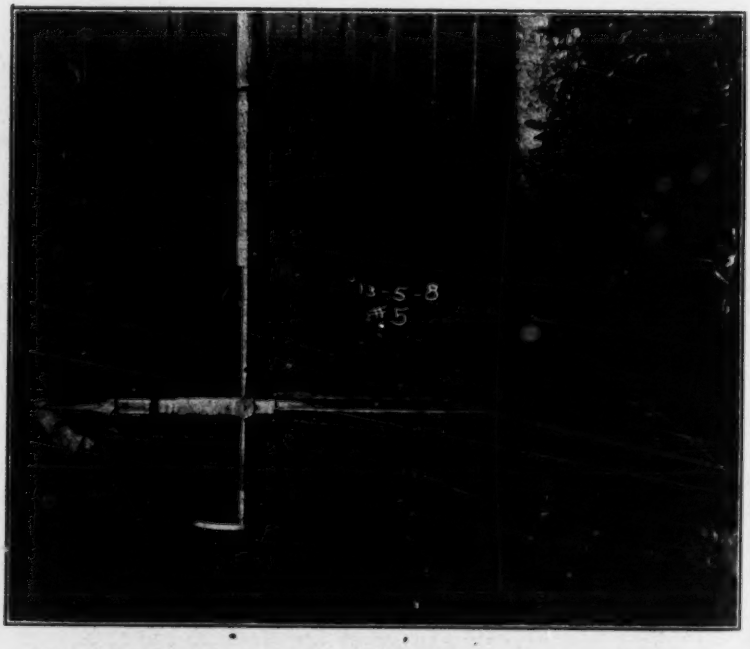
A. General, and also immediate supervision.

Mr. Adcock: I offer in evidence the photograph of the Haskell current meter, to be marked Schoder Exhibit 1, December 13, 1913.

(Photograph so offered in evidence was marked Schoder Exhibit 1, December 13, 1913, and is here inserted.)

SCHODER EXHIBIT 1.

Dec. 13, 1913.

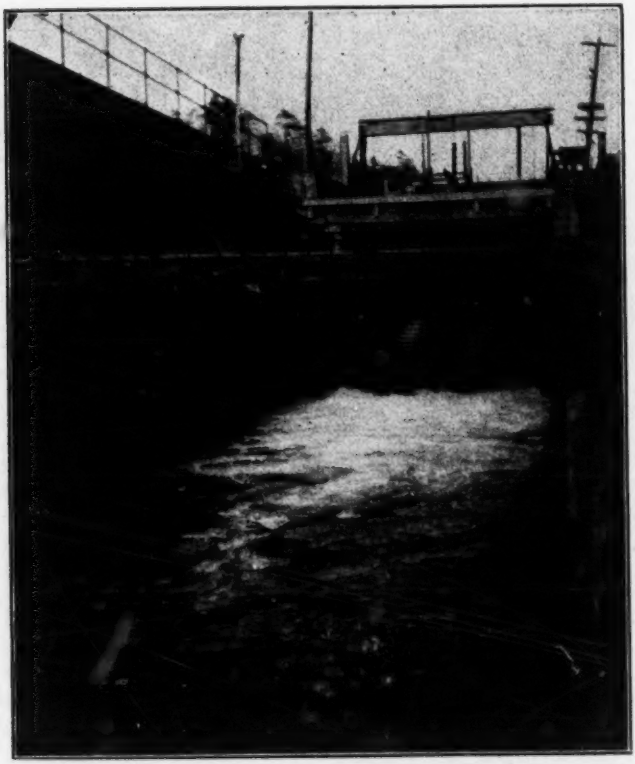


Mr. Adcock: I also offer in evidence eleven other photographs, which appear to show the canal, the water flowing in it, as Mr. Schoder has just described; to be marked Schoder Exhibits 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12, December 13, 1913.

(Photographs so offered in evidence were marked as directed, and here follow):

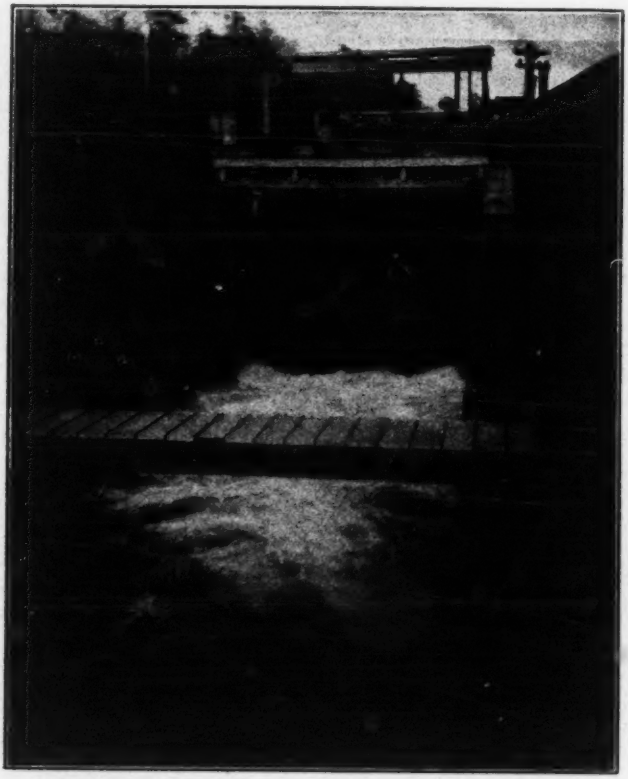
SCHODER EXHIBIT 2.

Dec. 13, 1913.



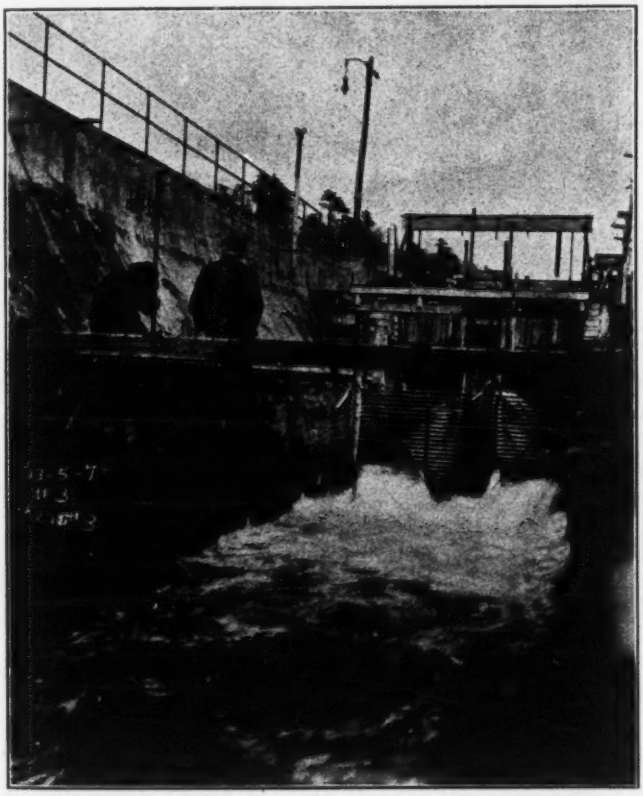
SCHODER EXHIBIT 3.

Dec. 13, 1913.



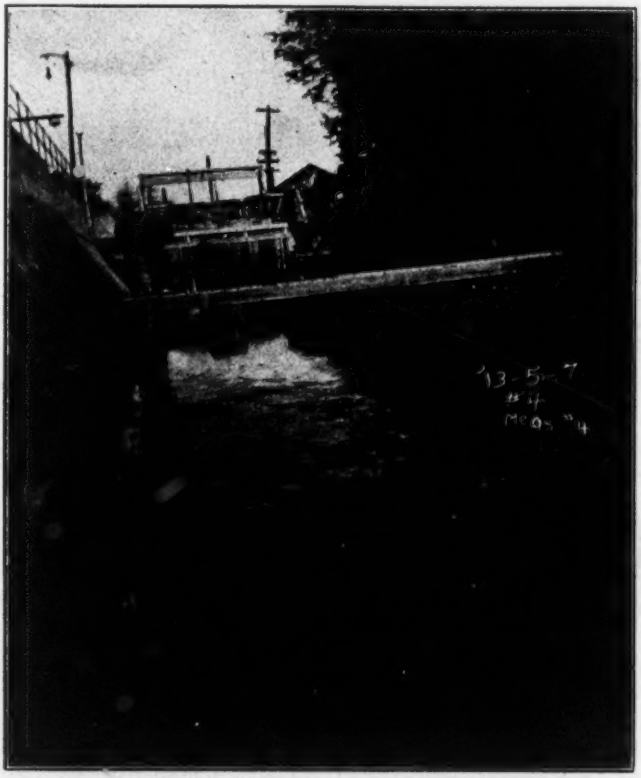
SCHODER EXHIBIT 4.

Dec. 13, 1913.



SCHODER EXHIBIT 5.

Dec. 13, 1913.

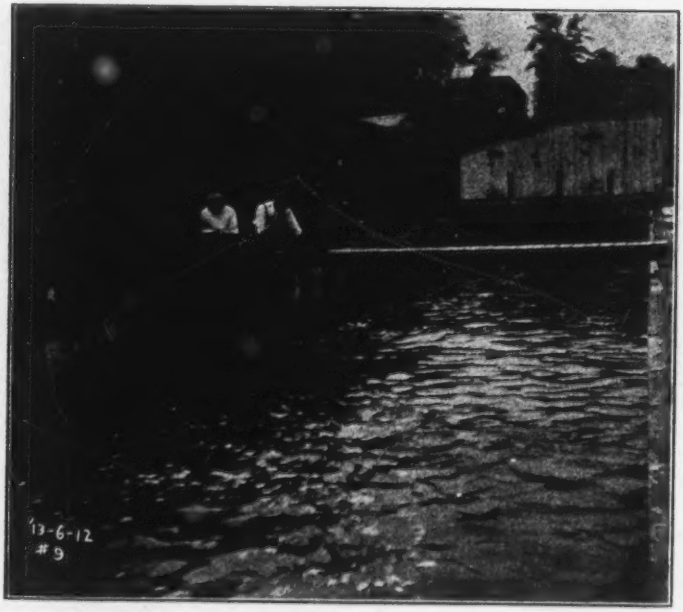


SCHODER EXHIBIT 6.

Dec. 13, 1913.

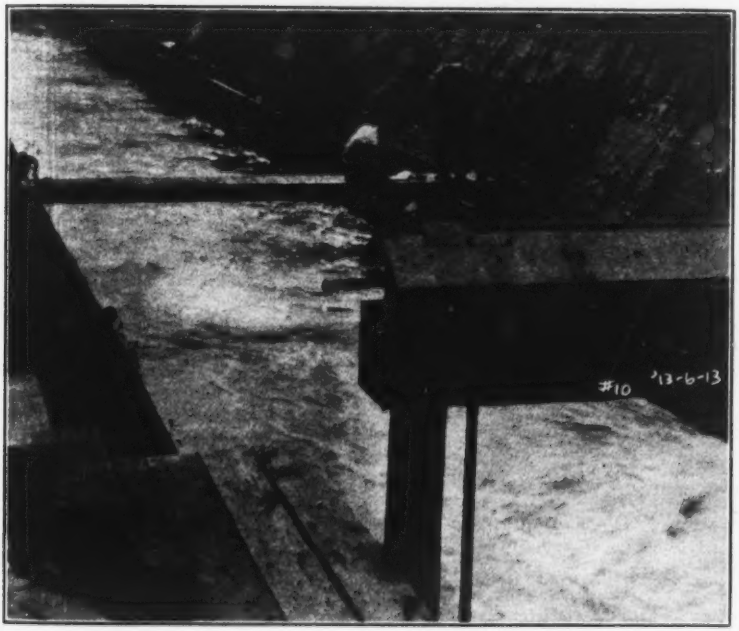
SCHODER EXHIBIT 7.

Dec. 13, 1913.



SCHODER EXHIBIT 8.

Dec. 13, 1913.



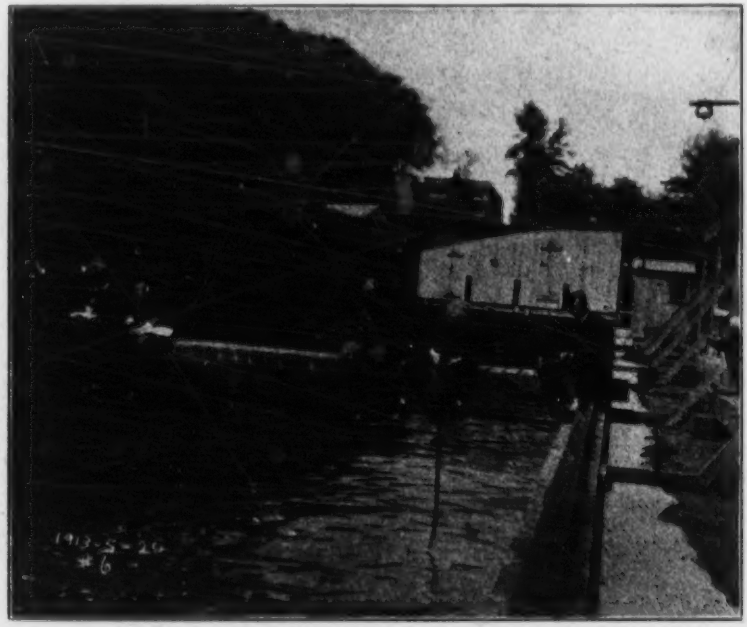
SCHODER EXHIBIT 9.
Dec. 13, 1913.

SCHODER EXHIBIT 10.

Dec. 13, 1913.

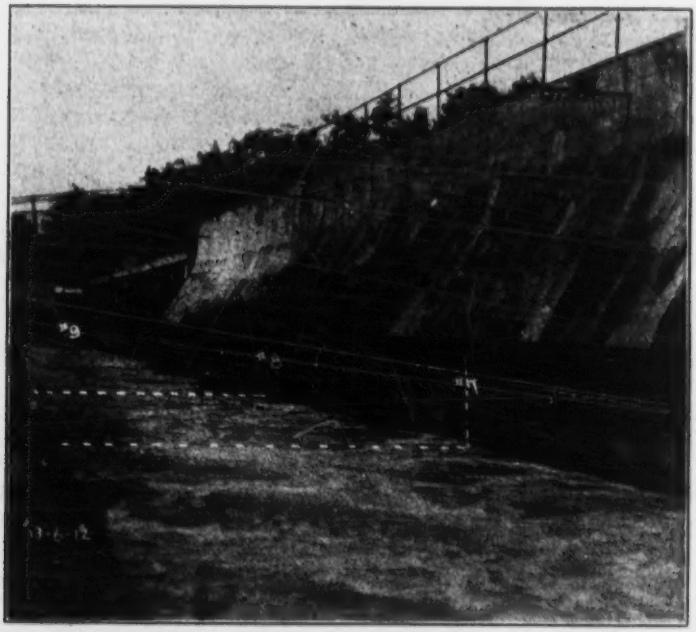
SCHODER EXHIBIT 11.

Dec. 13, 1913.



SCHODER EXHIBIT 12.

Dec. 13, 1913.



Q. Professor Schoder, you have placed some marks and figures in pencil opposite some of these photographs. What do they indicate on these exhibits?

A. They indicate the number of the measurement.

Q. Which you have heretofore described?

A. Yes.

Q. As I understand this water that went through the canal at the time you made these measurements with the Haskell current meter was at the same time measured by means of a weir?

A. Yes, sir.

Q. Will you state now the results of your experiments, continuing your answer to the original question?

A. The sheet I now hand you contains the summarized results of the nine measurements.

(Table referred to by the witness is as follows):

CORNELL UNIVERSITY HYDRAULIC LABORATORY CANAL DISCHARGE MEASUREMENTS BY HASKELL CURRENT METER

No. of Meas.	Distance down stream from Baffles, feet	Mean depth of water in feet	Discharge by meter c. f. s.	Discharge by weir c. f. s.	Deficiency in discharge by meter c. f. s.	%Deficiency of meter meas.
1	51	3.96	159.4	170.6	11.2	6.6
2	260	4.40	161.9	170.6	8.7	5.1
3	51	2.62	164.3	170.6	6.3	3.7
4	88	2.73	161.6	170.6	9.0	5.3
5	208	2.91	165.0	169.6	4.6	2.7
6	41	7.12	166.3	170.5	4.2	2.5
7	67½	7.19	160.3	169.5	9.2	5.4
8	208	7.44	160.4	168.0	7.6	4.5
9	41	7.09	152.3	168.3	16.0	9.5

(Table identified by the witness was marked Schoder Exhibit 13, December 13, 1913, and the original document is inserted here in the transcript of testimony to be submitted to the court.)

Q. Describe what that Exhibit 13 shows?

A. For each of the measurements we have here tabulated the distance down stream from the baffles, in feet.

Q. The first column is the number of the measurement?

A. The number of the measurement.

Q. And the second column is entitled what?

A. The distance down stream from the baffles.

Q. What does that mean?

A. The distance down stream from these boards intended to quiet the flow after falling from the upper weir, and shown in the photographs. That is the distance at which the measurement was made.

Q. Will you refer to the photograph which shows the baffles you speak of?

A. They are shown in this photograph marked Exhibit Number 6.

Q. Also in the photograph marked Exhibit 3?

A. Yes and in Exhibits Number 4 and 5; also Exhibit 10.

Q. Is that the lattice work that we see there?

A. Yes, right there (indicating).

Q. Just above where those men are holding a rod?

A. Yes, it is shown in Exhibits 2 and 3.

Q. What are the baffles for?

A. They were put there in the canal to quiet the disturbed

condition of flow created by the water falling over the upper weir into the lower canal, so that in the lower canal the flow will be much less disturbed than if the baffles were not there. These baffles consist of wooden plank, two by twelve plank, placed one above another with about a two inch space between them from the bottom to the top of the canal, and through those the water must flow, and is guided in a horizontal direction as it flows through.

Q. What does the second column show, entitled "Mean depth of water in feet"?

A. That is the average depth of the water at the point where the meter measurement was made.

Q. That is at 51 feet below the baffles?

A. Yes.

Q. The next column, what does that show?

A. The next column is the discharge by the meter in cubic feet per second.

Q. In that case it is 159.4, is that correct?

A. In number 1.

Q. Number 1 measurement?

A. That is gotten by computations from the point measurements with the meter.

The next column gives the discharge by the weir in cubic feet per second. The next column, the deficiency in discharge by the meter in cubic feet per second.

Q. That is the amount that the meter measurements shows less than what the weir measurements show, is that correct?

A. Yes. The last column shows the percentage deficiency of the meter measurement.

Q. Do you know whether this Haskell meter which you used there is the same type of meter as was used by the United States Lake Survey, in their work?

A. It is.

Q. What does the next column show?

A. That is all.

Q. Did you state what the last column showed?

A. The last column shows the variations in percentage deficiency of the meter measurement from the weir measurement, varying from 2.5 per cent. to 9.5 per cent.

Q. That is in all the nine measurements?

A. Yes. They are all deficiencies.

Q. Those nine measurements were all the measurements which you and Mr. Turner made, were they, at the request of Mr. Williams?

A. Yes.

Q. Do the deficiencies show any apparent law of variation, according to the distance from the baffle or weir?

A. No regular law is apparent, as far as I can see.

Q. Do you know what the velocity of the water was flowing through the canal, at the time you made the measurements?

A. It varied from about 2 to 5 feet per second. I haven't the exact figures in my mind, although they are on the measurement sheets here.

Mr. Adcock: Mr. Schoder has here a number of sheets on which he has made computations. So as not to encumber the record, we will give these to you for the purpose of whatever use you may want them for. It will not be necessary then to put them in evidence.

Q. How long has this weir been used there, Professor Schoder?

A. The measuring weirs have been at the laboratory for 14 or 15 years now.

Q. In your opinion, with what degree of accuracy was the water measured by you as it passed over the weir?

A. Within one per cent. of the truth.

Mr. Adcock: That is all.

Cross-Examination by Mr. Hopkins.

Q. What was the amount of the fall from the reservoir into this canal?

A. About eight feet I should say.

Q. And within what distance did that total eight feet occur?

A. Why right in one place, a single fall.

Q. A sharp drop?

A. Yes.

Q. And how far below the fall are these baffles located?

A. Between 20 and 30 feet I should estimate. I don't recall the exact distance.

Q. Do you know of any meter that is more accurate than the Haskell meter in measuring streams?

A. As a general answer to a general question, yes.

Q. Small or large streams? Go ahead, explain what you mean.

A. I don't understand your question.

Q. Well then confine it to velocities from one to six feet per second, and large streams from 50,000 cubic feet to 250,000 cubic feet per second, do you know of any meter that is more accurate?

A. No, I do not.

Q. Did you ever make any measurements of large streams?

A. Yes.

Q. What one?

A. The Susquehanna River.

Q. What was the flow per second?

A. About 8,000 cubic feet a second.

Q. What did you use there?

A. The Haskell meter and the Price meter.

Q. Did you rely upon the results obtained, as being fairly accurate?

A. With the emphasis on "fairly," yes.

Q. For what purpose was that measurement made?

A. For the usual purpose of obtaining the discharge, where there was no other means of measurement available.

Q. By whom were you employed to do this, if anyone, or was it simply an experiment?

A. It was an experiment.

Q. For your own enlightenment?

A. Yes.

Q. You say the measurements were fairly accurate, with the emphasis on the "fairly." You mean by that that they were not accurate?

A. I mean that they were accurate within 5 to 15 per cent. of the truth.

Q. Where did that 5 to 15 per cent. come?

A. It came in partly in erroneous measurements of depth, partly in performance of the meter difference from the assumed performance, and partly in disturbances in the flow, which could not be observed; partly in direction of the stream when the meter was out of sight; possibly also varying effects of the wind during the measurement; causes of that sort.

Q. Who was with you on this measurement? Were you in charge of it?

A. I was in charge of the measurement. I had a number of different men with me. Professor Turner was with me. Professor Turner and I had general direction of the work.

Q. When was this?

A. There was one measurement a year ago; one two years ago.

Q. And where was that error, on which side do you think, or do you have any way of determining

A. We have no way of determining.

Q. Then how do you know it was in error? Did you make mistakes in the depths, did you find later that you made some mistakes?

A. I think discharge errors are liable to occur in any measurement of a large river.

Q. It is just simply a question of speculation?

A. No.

Q. You don't know that there were any errors in these measurements. Do you know that there were any, or is it simply guess work?

A. I know that no one has ever proved that it is possible to measure a stream more accurately, generally speaking, than I have stated.

Q. That is the accuracy with which you measured the Susquehanna?

A. The limits I have stated.

Q. Within 5 to 15 per cent.?

A. 5 to 15 per cent. It is no proof of the precision of a meter because a meter records in succession the same flow, when the same methods of observation and computation are used.

Q. Those mistakes of 5 to 15 per cent. may be on one side or the other, may they not?

A. Generally speaking, yes. In particular cases one might be able to say whether—

Q. You may find a consistent error, you mean?

Mr. Adcock: Wait until he finishes.

The Witness: In particular cases the errors might be one way and one would have reason to say on which side they would be.

Mr. Hopkins: Q. What would you say as to your measurements on the Susquehanna River, whether they were above or below?

A. On account of the character of the river there, it would be indeterminate in my judgment whether they would be above or below. The bottom was rough.

Q. Are you acquainted with the A meter, the Haskell A meter, and the B meter?

A. Not by those designations.

Q. Do you happen to know just what size the meter was that you used in these experiments at Cornell?

A. The meter was very closely of the size of a meter which I saw in operation about three years ago by Lake Survey men.

Q. Do you happen to know what size it is?

A. I can't say to which of the categories you refer to it belongs.

Q. In inches, and diameter of the wheel.

A. I should say about six inches in diameter; possibly as great as seven.

Q. You think then Mr. Turner was in error when he says about four inches in diameter?

A. I think that this meter that we used in these tests was larger than that, yes.

I may explain that we have a number of smaller Haskell meters in the Laboratory, the size being approximately as stated by Professor Turner; and we have used those quite a bit since these tests were made. This one I am quite certain is larger than that.

Q. In this possible 15 per cent. of error that you think is inherent in measuring streams, what part of that would you say is due to error in measuring the depth of your streams?

A. One cannot give a general answer to a question of that sort, because conditions are so different in different rivers. In some streams, one might make errors of as much as that, as much as the 5 to 15 per cent. in the depth measurement alone. A rough bottom, changeable surface, a very swift stream and a deep stream, all those causes would contribute to errors, considerable errors in measurement of depth.

Q. In a very large stream with a great number of soundings, wouldn't the uneveness of the bottom tend to be eliminated?

A. With a great depth and not too fast velocity, yes.

Q. And where the surface is comparatively smooth, like a river usually is that is half a mile to a mile wide?

A. Yes.

Q. There you would not have much trouble with the surface, would you?

A. Not much trouble with the surface ordinarily.

Q. In a big stream of that size, of not more than 5 feet per second velocity, couldn't you measure the depth of that and get the cross section with a great degree of accuracy?

A. You should be able to do so if the bottom were not too rough, and if the character of the bottom were known.

Q. The soundings would help determine that, wouldn't they?

A. Not necessarily, in a deep river.

Q. What per cent. of your error do you think is due to winds?

A. That would be different depending on the slope of the stream, on the velocity of the stream. It would be small in percentage with very swift streams, and larger with very sluggish streams.

Q. How does it affect it, by moving the surface water faster or slower?

A. Yes.

Q. You measure relatively close to the surface, don't you?

A. Well, measurements are usually made as close to the surface as it is deemed advisable to go without introducing effects due to the presence of the meter near some limiting medium.

Q. And isn't the direction taken care of to a high degree of accuracy by this tail or vane in these meters?

A. Yes, ordinarily.

Q. What percentage of your 15 per cent. would you charge up to the direction?

A. That would be indeterminate in the case of a stream with a rough bottom, as well as at such depths where the meter could not be seen. Ordinarily, the river flowing regularly and away from the influence of the bottom or the sides, or obstructions in the stream of any character, the error would probably be within one or two per cent. in most cases.

Q. You heard me asking Mr. Turner about shallow streams?

A. Yes.

Q. And the indeterminate area that we were speaking of that you could not measure with one of these meters?

A. I did.

Q. You would also agree that if there is a constant error in your computation of this indeterminate area, it would show much more pronounced in the shallow stream than it would in the deep stream?

A. With the same conditions of bottom and sides, yes.

Q. And other things being equal, the measurements of a large stream are likely to be more accurate than a small stream, aren't they?

A. If in the "other things" you mean the condition of the sides and bottom, yes; otherwise, no.

Q. The only difference being in the size of the stream?

A. If the differences were only in the size of the stream, one should be able to measure a large stream more accurately than a small stream, not however with the same number of point measurements.

Q. You think there should be more measurements in the large stream than the small?

A. Yes.

Q. How much time did you put on these measurements in the Susquehanna River?

A. Each measurement occupied three hours, three to four hours.

Q. You mean each cross section?

A. Yes.

Q. How many cross sections did you measure?

A. Each discharge measurement. You mean at how many different places in the river?

Q. Yes?

A. One. I may modify that by saying really at two. We made these observations at a bridge, and some of the observations were made between the piers, and upstream; and others were made between the piers further down stream.

Q. Did your results at those two places check?

A. Within the limits I have mentioned, they did. I have not the exact figures with me.

Mr. Adcock: That is 5 to 15 per cent.

A. That is from 5 to 15 per cent.

Mr. Hopkins: Q. And if they had checked say within two or three per cent., you would think it would be more accurate, wouldn't you?

A. I would think it was an accident.

Q. Suppose you did that several times, and at several different places in the river, and still would get that check, would you still think it was by accident?

A. What do you mean by that?

Q. That every time they check within a degree of precision, is it always an accident?

A. No, I would not think so always, if they always did that. In my experience, no one has ever found by measuring in different places on the same river with different conditions prevailing, that checks have been closer than those limits.

Q. Are you familiar with all the measurements of the Lake Survey?

A. Not all of them, no.

Q. What is the total time you put on the measurements of the Susquehanna?

A. As I say, each cross section occupied about three hours.

Q. How many times did you measure a cross section?

A. I think four times.

Q. About a total of 16 hours?

A. Something of that sort.

Q. Covering about how long, one or two days?

A. Yes, covering two days, with certain preliminary measurements; possibly four days altogether.

Q. When Mr. Williams asked you to make these tests, did he tell you what purpose they were for, and what condition of perturbation there should be and things of that kind that he wanted?

A. No, he merely gave a general description of the tests wanted, with reference to our laboratory conditions.

Q. What was that general description? What was it that he wanted?

A. That he wished to have the matter tested by measuring as nearly as possible, in various degrees of disturbance, the discharge of a flow which was measured also by a weir, measuring exactly the same flow with different degrees of disturbance, as judged by the eye and as judged by distance below whatever was creating the disturbance.

Q. Did you make any then at a steady velocity, uniform velocity, I believe we spoke of? Did you make any in response to this request of Mr. Williams?

A. Yes, these tests that have been mentioned, these nine measurements were made in response to that request.

Q. Yes, but these are all, judging from the photographs, at quite a degree of perturbation, aren't they?

A. Those further than 100 feet below the baffles were in a region of flow which would be called in any river that I have ever seen just the opposite of disturbed,—rather a steady tranquil flow.

Q. Then your conclusion is that this meter that you used in these experiments under registered under practically all conditions?

A. Under all the conditions of these experiments, it certainly did under register.

Q. Do you think there was any other source of error than the current meter?

A. Only the errors mentioned with the limits of the weir and the method of computation.

Q. Does that method of computation cover this area that you have spoken of as an indeterminate area?

A. It does, with the provision that whatever error was made in computing the discharge tended to overestimate the discharge.

Mr. Adcock: That is the current meter discharge?

A. Discharge by current meter.

Mr. Hopkins: Q. At the time you made the measurements, did you think you were making a mistake all the time and giving a higher volume of discharge than you ought to have given?

Mr. Adcock: That is for the current meter discharge.

Mr. Hopkins: Yes.

A. We knew we were.

Q. Then you knew that you were not making an accurate test?

A. Under the conditions just stated, we knew that there was an error of the nature described, an over estimation. We did not try to eliminate that over estimation by bringing other measuring instruments than the current meter into the question. Had we done so, we could have made a more accurate measurement, by bringing other measuring instruments, such as other meters, other current meters of the Pitot Tube into it. We know about what reduction to expect in cases of this kind, and if we were in doubt we could find out by the actual measurement itself, but this was to be a measurement by current meter.

Q. The sides of your canal are rough, and the bottom smooth?

A. In general that describes the condition of affairs. The sides are rougher than the bottom.

Q. Now is there any uniformity about your results, as to whether your degree of error, or whether the degree of error in the current meter measurements from the weir measurements is based upon the degree of perturbation?

A. As judged by the eye, there appears to be none. That is according to the perturbation as judged by the eye there appears to be none, no regularity or law.

Q. Then there is some other thing that causes this error besides the perturbation?

A. I am not prepared to say that. There are perturbations that may have an effect on a current meter that would

not be apparent to the eye; and there is much reason to think that that is the case.

Q. Why is it that there is such a difference between "one" and "nine," both of which are fairly close to the baffles?

A. I don't know, except that "nine" was made with an attempt to get the discharge by meter with the greatest possible accuracy, or with much greater accuracy rather than "one."

Q. Wherein was there an attempt to get greater accuracy in "nine" than "one"?

A. By making measurements at more points.

Q. But the condition of the water there was practically a rapids, a state of rapids, wasn't it, 41 feet from the baffles?

A. Yes, "one" was 51 feet and "nine" was 41 feet. The conditions of depth were different there. Number 9 was made with water over seven feet deep and number 1 with water about four feet deep.

Q. How do you explain the difference in number six and number nine, both made at the same station, 41 feet below the baffles, number 6 giving the error only 2½ per cent. and the other, number 9, 9.5 per cent.?

A. I think one reason is that number 6 was a measurement made taking fewer points of observation, and that on that account an error came in in estimating the discharge, having at hand only the data from the points where we observed.

Q. If this whole discrepancy were due to the under rating of the Haskell Meter, that difference should not appear should it at the same place?

A. The greater number of points taken in measurement number 9 introduces a somewhat different condition of affairs in the two measurements. One measurement from the current meter standpoint is more precise than the other because we cover with greater minuteness the cross-section. Nine was intended to be an exact duplicate of "six" as far as conditions of flow was concerned, and as far as weir measurements could show it was an exact duplicate.

Q. How about number 8 as compared with number 9 as to the number of observations made?

A. Number 9 had approximately double the number of observations that number 8 had.

Q. Is that true of "nine" with relation to all the other eight?

A. It is.

Q. Then there seems to be quite a difference in your result, when you had a greater number of observations?

A. The only index that we have of that is the comparison of number six and number nine. Comparing the other observations, comparing numbers 1 to number 8 inclusive, where the number was about the same, or where the spacing was about the same, the discrepancy in those appears to give a wide variation, without including number 9 at all.

Q. But not so wide as the difference under the same conditions when the number of observations was the only difference?

A. No, because number 6 and number 9 were the only two taken as close to the baffles as 41 feet.

Q. Then wouldn't it have been fairer to have given a list where the observations, number of observations were taken in the same way, all nine like "nine," as the eight without "nine"?

A. We made more measurements. We desired to find out exactly what would happen under these conditions and we made more measurements than I think anyone has ever made before. Our time was limited, and we did the best we could. The results are here.

Q. The point is this: You show a great discrepancy at some place when you double your number of observations. If you had doubled the number of observations all down the line, your results at some of the better places, say where it was over 100 feet below, might have been entirely different from what you have given there?

A. They probably would have been more precise.

Q. And might have registered more than you have there?

A. Might have registered more or might have registered less, yes, sir.

Q. So that in what you call the greater degree of precision, we do not have the measurements all the way down. We only have them at this turbulent place right under the rapids?

A. We do not have an ideal degree of precision anywhere. Measurement number 9 was made to be an exact duplicate of number six, to see what result would be gotten by taking a greater number of measurements, but especially because when the results of number six were carefully scrutinized, it was seen that there was a rapid change of velocity from point to point, and to eliminate the uncertainty coming from that we made measurement number 9. That appeared, I think, in greater degree for number six than any other measurement from number one up to number eight. Referring to number three, 51 feet below the baffles, it appears from this sheet

that you gave me that on one side, half a foot from the side, the velocity is 2.47 feet per second; on the other side, a half a foot from the side, the velocity is 4.05, which indicates there is a very strong cross-current, doesn't it?

A. Indicates that the velocity is higher on one side than the other; indicates of itself nothing as to cross-current.

Q. You are 51 feet from the baffles at that place?

A. Yes, sir.

Q. Is it likely that the water would flow that entire 51 feet with so much difference in velocity on the sides?

A. 51 feet is relatively a short distance in a canal as large as that. It is only three times the width of the stream.

Q. How do you explain how it happened that that is the case?

A. I think the conditions of flow are such that the water can flow a little bit easier on one side than the other; and there would be a great many different conditions that would have to be analyzed to show just why the water flows faster there than elsewhere.

Q. Would you expect that condition to keep up, one side faster than the other, for 30 feet more?

A. I should think that the further down stream you get in a regular canal the more nearly the water would assume a uniform condition of affairs.

Q. How far down would you expect it to get uniform?

A. I think every added width of the canal down would have some effect; and when one went ten times the width of the canal down stream, the condition of flow should become more settled.

Q. Take number 5: On one side you have got a velocity of 2.95; on the other side you have 3.39.

A. Your statement of 3.39 refers to the 13 foot point. You should look at the 2.95 as against 2.81.

Q. In measurement number 4, 88 feet down, they are just the same?

A. 3.12 and 3.12.

Q. Did you make any measurement of the direction of flow in each particular section?

A. We observed very carefully for direction, and found in practically every case the direction of flow was either straight down the canal, or so close that no correction was necessary on account of direction.

Re-direct Examination by Mr. Adcock.

Q. How rough were those sides? Were they rough enough to cause any particular disturbance in the flow of the water?

A. They were rough in comparison with the bottom rather than rough as we speak about a river bottom being rough. The bottom of the canal is what would ordinarily be called smooth cement finish. The sides are rougher due to a disintegration of the surface finish; and show the gravel in places sticking through, and sticking out a little, so that from place to place there are variations in the degree of roughness. Here it would be sand in appearance, and here with some gravel sticking out, but the general degree of roughness is not such as to cause any high degree of disturbance of the water. The flow of the water proceeds through without any high degree of disturbance.

Q. This disintegration has been going on for some time has it not?

A. Yes.

Q. Now these baffles that are used there, how long have they been used in that canal?

A. Baffles of this same sort?

Q. Or a similar description?

A. Baffles of this same sort have been used ever since I have been there, and judging from photographs earlier and descriptions of tests, they have been there since the first experiments made on the canal.

Q. And the purpose of baffles, as I understand it, is to smooth out the disturbed conditions resulting from the fall of the water over this upper weir, isn't it?

A. Yes, sir.

Q. And to produce a condition of flow similar to that which would obtain, or does obtain in streams or rivers.

A. Yes sir, produce a condition of normal flow.

Q. And this is the same canal that Professor Turner spoke about, that is maintained by the Cornell University, and over which Professor Haskell has charge, is that correct?

A. Yes, sir.

Q. Do you recall whether the United States Government has made any tests of measuring devices there, such as current meters, in that canal?

A. There have been a number of measurements made by the United States Government, various departments, bureaus

of the same, with various measuring devices, current meters, weirs, dams.

Q. Did they re-calibrate the weir when they made their measurements, do you know?

Mr. Hopkins: That is objected to as immaterial in this case?

A. The standard formulae for weir flow over weirs of this description have been used by all the Government Departments or Bureaus that have made tests there. I may say that those departments include the United States Geological Survey, the Irrigation Investigations Branch, Department of Agriculture, the Deep Waterways Commission.

Q. The International Waterways Commission, do you know whether they made any measurement?

A. In fact I was thinking of that commission; the International Waterways has also been there. I was thinking of the International Waterways Commission, when I made that statement.

Q. The Board of Engineers on Deep Waterways; that is the same thing as the Deep Waterways?

A. That is the Deep Waterways.

Q. Do you know whether the International Waterways Commission made any tests of the models of a weir which they proposed to use in connection with regulating works in the Niagara River, in that canal?

A. Yes, sir, they did. I acted in an advisory and supervisory capacity for those tests.

Q. As I understand it, Professor, your opinion is that in a number of observations in a large stream by the current meter, the error might be all one way, in each measurement?

A. Yes, sir.

Re-cross Examination by Mr. Hopkins.

Q. They might be anyway might they not, Mr. Schoder?

A. Generally speaking, yes; specifically speaking, there would be many reasons to indicate which way. It would depend entirely on the case in hand, the river in hand.

Q. But it may be, assuming your conditions, either above or below?

A. It would be above in some cases and below in others.

Further Re-direct Examination by Mr. Adcock.

Q. Or it might be all one way, depending on conditions?
A. Under certain conditions, the error undoubtedly would all be one way.
Q. Do I understand you to say that the personally equation might enter into the making of measurements of this kind, such as the determination of the depth of the river and the cross-section and so forth, and the placing of the meters and the determination of verticals, and so on, by the person who makes the measurements?
A. Oh, yes, most emphatically; judgment enters in, very largely.
Mr. Adcock: That is all.

KENNETH B. TURNER, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. Will you state your full name?
A. Kenneth B. Turner.
Q. Where do you reside?
A. Ithaca.
Q. What is your present occupation?
A. I am a teacher and investigator.
Q. In Cornell University?
A. Yes.
Q. How long have you been in that position?
A. About seven years.
Q. Previously what did you do?
A. I was a student at Cornell for five years taking the degrees of C. E. and M. C. E.
Q. What are those degrees?
A. Civil Engineer, and Master of Civil Engineering; and I was with the United States Lake Survey for about 20 months.
Q. When was that?
A. That was the beginning of 1905, January, 1905, to September, 1906.
Q. Was that before you took your position?
A. That was after my training at Cornell.
Q. That was between the time that you—

A. Between the time I finished my education there and when I started teaching.

Q. What work were you connected with while you were with the United States Lake Survey?

A. The first work with which I had anything to do was in connection with some river discharge measurements at Sault Ste. Marie, Michigan, discharge measurements of the St. Mary's River.

Q. Where were those discharge measurements made?

A. They were made at Sault Ste. Marie, about a mile below the rapids at that point.

Q. How many measurements were made there?

A. I can't state exactly, about between 50 and 60.

Q. That was in what year?

A. That was February and March, 1905.

Q. With whom were you connected?

A. Mr. Murray Blanchard.

Q. In making those measurements?

A. Yes.

Q. Who was the Principal Civilian Assistant?

A. Mr. E. E. Haskell at that time.

Q. That is Professor Haskell of Cornell University?

A. Yes.

Q. He is the inventor of the Haskell Meter?

A. Well, he is a co-inventor, I believe. I believe the Ritchie people have interests in common with his.

Q. Were you engaged in any other meter measurements during that time?

A. No, I was not.

Q. What did you do during the rest of the time that you were with the United States Lake Survey?

A. The rest of the time I was occupied reducing these observations, that is making the computations, immediately following the discharge measurements, and after that I was traveling around the lakes collecting data with reference to evaporation, temperature records and so on.

Q. How did you make those measurements?

A. The measurements were made under the ice. Of course the river was frozen over at that time. We laid out a section across the river.

Q. Was the Haskell Current Meter used in that connection?

A. It was.

Q. What other training have you had besides what you have mentioned?

A. While I was a student at Cornell, I was in the New York State Department, for about three months, in connection with road construction. And since being at Cornell, I have been employed along the lines of hydraulic experimentation, having participated in a number of commercial tests there, and in conjunction with Professor Schoder, have carried on some investigations of our own along the line of hydraulic experimentation.

Q. During that time did you have any occasion to use a current meter, Haskell meter?

A. Used the current meter very much. We have used the Haskell meter considerably in connection with class work; also in connection with investigation work on the canal.

Q. You have made various experiments?

A. Yes, we have used it at frequent intervals, during the time I have been there.

Q. Did you, with Professor Schoder, carry on any experiments, make any experiments at the request of Mr. Gardner S. Williams at the laboratory during this year?

A. We did.

Q. When were they made?

A. During the months of May and June of this year.

Q. Will you state what connection you had with those experiments, in the making of them?

A. I was associated with him in the experiments, taking part in the observations and the reduction of data. I participated however, in only five of those nine measurements. In the last four measurements, I was not a participant.

Q. What can you say as to the accuracy with which these current meter measurements were made by Professor Schoder, as compared with the work of the United States Lake Survey that you were on?

A. They certainly were as accurate, and relatively I should say there was greater accuracy in that the conditions we had to work under were more fixed and our observations were of a nature where we could fix them more definitely, to the best of my knowledge.

Q. Did you have anything to do with determining the volume of water, as shown by the weir?

A. I did.

Q. With what degree of accuracy do you consider the weir measurements were made?

A. We considered that the weir that we used is accurate well within one per cent.

Q. Will you describe the experiments which you made at the St. Mary's River, and the results?

A. I will have to rely in part on memory of course, because it has been some time.

Q. If you have any data here that you wish to refer to you can do so.

A. Do you wish me to state the method of observation and the results?

Q. Yes.

A. As I stated, our section was laid out across the river, we having the meter stations at intervals of 100 feet; the stations being holes cut through the ice at that distance apart. And in connection with the discharge measurements we observed velocity distribution in the vertical; that is the variation of velocity in the stream from the surface to the bottom, in these different stations; and during the series, (the entire series of discharge measurements), we observed in those stations a varying number of vertical velocity curves, varying from about 10 to 12 in some stations to about 17 in others.

In those verticals, the method of observation was to take a surface observation. That invariably was taken one foot below the ice. Then we took a bottom observation, which was at a distance above the bottom equal to the distance of the meter axis from the standard or weight which is used. Then the intermediate distance was divided into ten parts and the meter suspended in turn at each of these tenths, using what is known as the proportional method of observations in the vertical, so that that series of observations would give eleven determinations for each observation of the vertical. And all the verticals taken during the season at any one station were summarized, the average result taken, and the relation found between the mean velocity as indicated by that average and the velocity at 5/10ths depth.

The reason for getting this relation between the mean velocity and the 5/10ths was that in the discharge observations themselves, the meter was lowered directly to the 5/10ths depth point, and an observation made at that position. Then the figures on that observation are used in connection with computing the discharge, by taking the result of such observation and modifying it by the index coefficient which was obtained from the average vertical curve, as before stated. So that a discharge measurement consisted in measuring in turn from station to station across the stream the velocity at the 5/10ths point, measurement at each station point being made.

Q. Do you know how the method which you have described compares with the method usually used by the United States Lake Survey in making such measurements?

A. Those measurements are the only ones I have participated in directly, and I can't say as to other measurements absolutely. Those measurements were along the same line as those made back in 1896, at about that same point in the same stream.

Q. Were they made under the direction of Professor Haskell?

A. Under the immediate direction of Mr. Blanchard, who was in charge of the field measurement.

The general scheme was the regular lake survey scheme.

Q. What was the condition of flow there as to velocity or disturbance of the water?

A. The section was laid out at this point primarily to involve all the flow passing down the stream. That meant that we had to lay out our section below the tail race of the Michigan Power Company, and efflux from the power company there, coming into the stream at about right angles to the normal flow of the river gave us an eddy on the American side of our section. That is, apparently the water was flowing upstream at that point for a distance of about six or seven hundred feet from the American shore.

The velocity in the whole section was relatively low. The mean velocity of the whole river, as I recall was low. I am not exactly clear about the observations in a number of places. The maximum was under two feet a second; I should say about 1.8.

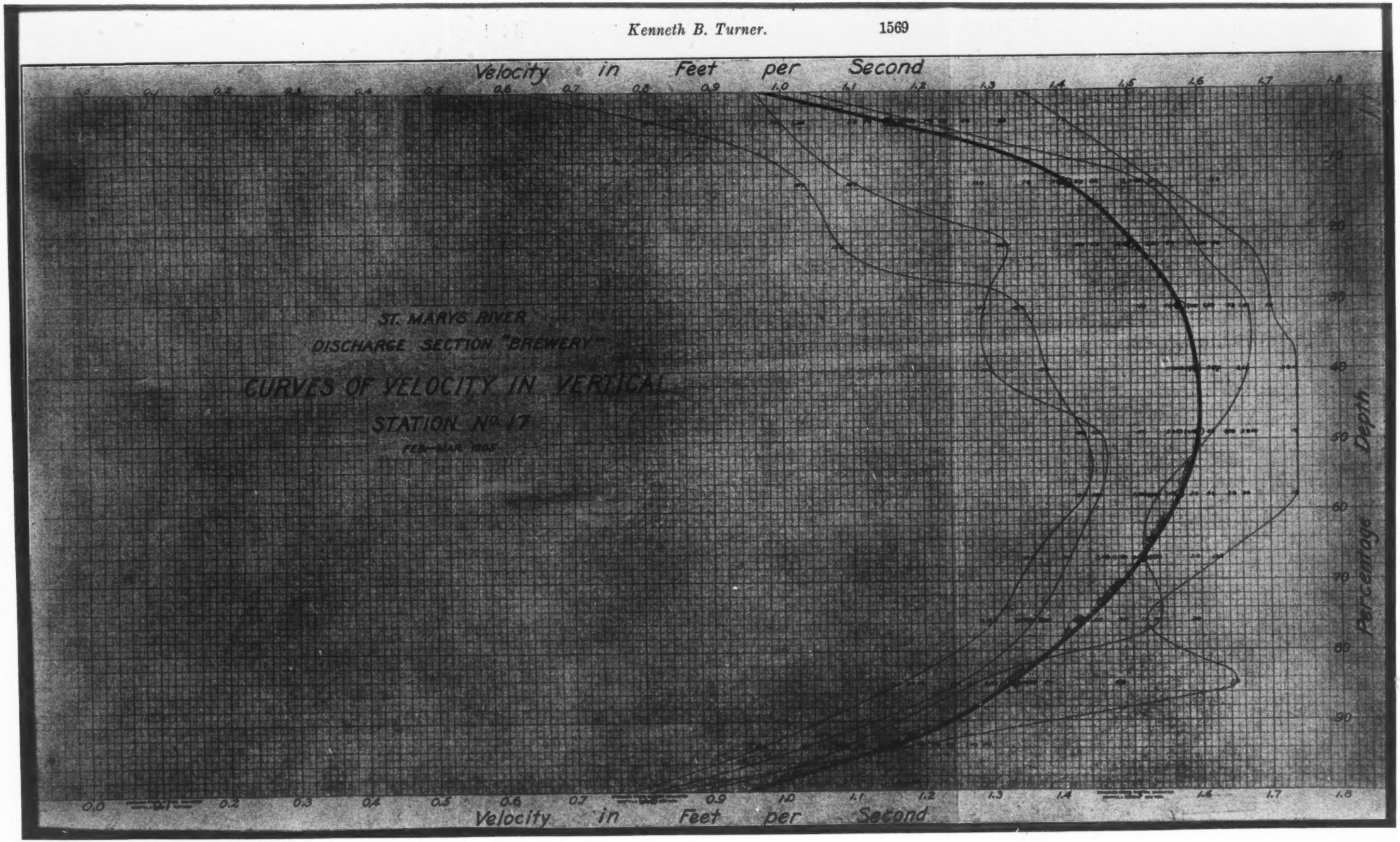
Q. Have you any plottings here of the vertical curves?

A. I have a plotting of the vertical curve observations in one of those places called station number 17, which means 1,700 feet from the American shore, about in the middle of the river.

(Producing plat.)

Mr. Adcock: I offer this paper that Professor Turner has referred to in evidence, and ask that it be marked Turner Exhibit 1 of this date.

(Plotting referred to by the witness, was marked Turner Exhibit 1, December 13, 1913, and here follows):


Velocity in Feet per Second
ST. MARYS RIVER
DISCHARGE SECTION "BREWERY"
CURVES OF VELOCITY IN VERTICAL
STATION No. 17
FEB.-MAR. 1905
Percentage Depth
Velocity in Feet per Second

Q. Will you describe Turner Exhibit 1, which you have referred to, and state what it shows; how it was made and so forth?

A. This exhibit was made on the train last night, I will say by way of explaining the character of the plottings and so on. What is intended to be portrayed is the individual vertical curves and depths of one particular station.

Q. What station was that?

A. Station number 17. This plotting shows how the velocity in the vertical at that station varied between measurements, or from measurement to measurement.

Q. Explain this, so the court will understand giving for instance the top of the curve to the left, how did you get that?

A. The curve begins usually at the top, what we call the surface point. The observation at that point, as above stated, was one foot under the ice and the bottom observation on the curve was made at a point 1-1/2 feet above the river bottom. The intermediate points were made at tenths of depths from the surface to the bottom. That is instead of going down foot by foot, or any even measured distance, the meter was lowered by proportional depths; lowered one-tenth of the whole depth for each position.

Q. What is the heavy red line?

A. The heavy red line in this plotting is the average of these fourteen different curves.

Q. Is that solid line the average, as computed by the lake survey?

A. It is.

Q. Now you have four dotted lines there, irregular dotted lines. What are they?

A. Those dotted lines indicate four of these fourteen verticals before mentioned, which have been traced in in ink. The other ten are not traced, although the points are plotted.

Q. They could be traced?

A. They could be traced.

Q. Do they show substantially the same variation as the four which you have there?

A. These four show rather the extreme.

Q. That is the outside of one, the outside of the other; the extreme?

A. Yes, these four were traced in to show the range.

Q. What do the figures .3, 1.8, mean?

A. Those are the velocities in feet per second.

Q. And down the right hand column, what do those figures indicate?

A. Those are meter positions expressed in percentages of the total depth.

Q. Now if you desire to get the average velocity at any one point, at any particular depth, how would you do it?

A. I don't understand the question.

Q. Professor, what would be the average velocity from all the observations, made at .3 depth, say?

A. The average velocity at .3 depth, taking into account all the observations made at that point, would be the numerical average of all the observations made at that point; and it is shown on this plotting by the full line, the value which the full line indicates at that point.

Q. What is that?

A. That, on this particular plotting, is 1.585 feet per second.

Q. What is the actual velocity shown at .3 depth as shown in curve numbered 14; that is the dotted line?

A. Curve number 14 which refers to the 14th observation for velocity in the vertical shows a velocity at .3 depth of 1.290 feet per second.

Q. What is the velocity at .3 depth of curve number 1, as shown on that exhibit, the dotted line?

A. The velocity shown by curve number 1 at .3 depth, is 1.705.

Q. What is the velocity shown on the mean curve, that is the heavy line, at .5 depth?

A. The velocity shown at .5 depth by the mean curve is 1.610 feet per second.

Q. And by curve number 14 at the same depth, the dotted line?

A. And the velocity at same depth, .5, as shown by curve number 14 is 1.455 feet per second.

Q. And also the same question as to curve number 1, the outside dotted line, the one furthest to the right, same depth?

A. The corresponding velocity as shown by curve number 1 is 1.740 feet per second.

Q. What is the percentage variation in velocity from .3 depth to .5 depth shown on the average curve, the mean curve?

A. Referred to which point?

Q. Refer it to the .5 depth?

A. The percentage difference in velocity between the

velocity at .5 point and that at the .3 point, as shown by the mean curve, using the .5 point as reference, is 1.55 per cent.

Q. Referring to curve number 14, what is the same relation, the variation?

A. The percentage variation in velocity between that at the .3 point and that at the .5 point, as shown by curve number 14, using .5 point as reference, is 11.34 per cent.

Q. Referring now to the curve number 1, what is the variation?

A. The percentage variation between the velocity of .3 depth and that of .5 depth, as shown by curve number 1, using .5 depth as a reference, is 2.01 per cent.

Q. Now will you make the same calculations as to the same curve at .9 and .8 depth?

A. The percentage variation between the velocity at .8 depth and that at .9 depth, as shown by the mean curve, using the .8 point as reference, is 6.30.

Q. Give the same percentage as to each curve that you mentioned?

A. The percentage variation between the velocity at .8 depth and that at .9 depth, as shown by curve number 1, using the .8 point as reference, is minus 7.15 per cent.

Q. What does the minus sign mean?

A. The minus sign means that the velocity at the .9 depth point is greater than that at the .8 depth point, which is contrary to what is shown by the mean curve for those positions.

Q. Make the same comparison as to curve 14?

A. The percentage variation between the velocity at the .8 depth and that the .9 depth, as shown by curve number 14, using the .8 depth as reference, is 8.32 per cent.

Mr. Hopkins: Q. Why were these four curves you have here selected, namely 1, 13, 14, and 6?

A. The idea of course was to trace in all those curves, but time precluded that and only hose showing the extreme range of variation were sketched in.

Q. This entire plat was based upon one station?

A. One station.

Q. What station is that?

A. Number 17, meaning 1700 feet from the American shore.

Q. And about what part of the river is that?

A. Very nearly in the center. The river was about 3350 feet wide at that point.

Q. Why was that particular station selected?

A. Because at that station it was well removed from the eddy part of the stream and at a point where the velocity was about the maximum and it was assumed that the conditions there were as good as anywhere. I mean to say that I simply preserved these sheets from my own desire to have something of the kind to show that I had been connected with the work.

Q. You think that where the velocity is high, that makes conditions more favorable to the measurements?

A. It would be much better than in a station near the eddy where the velocity was lower, ordinarily.

Q. When you say that there was a percentage of variation on a certain curve here, comparing your .3 and your .5 depths, will you tell us again just what you mean?

A. I mean that reading the velocities indicated by any particular curve that may be under discussion at these two points shows that the velocity at one point differs from the other on a percentage basis by the amount stated.

Q. In other words at this station 17, a certain velocity is read at .3 depth?

A. Yes.

Q. Then a reading is made at .5 depth?

A. Not immediately following. Those velocities were observed in water beginning at the surface and going down towards the bottom by tenths of depths.

Q. Then you read .4, then .5?

A. Yes, and so on.

Q. You mean the velocity at this .5 depth is different from that at the .3 depth?

A. That is what the curve shows.

Q. And this percentage you were giving is the percentage of difference?

A. Yes.

Q. Taking one as a reference?

A. Taking one as a reference, yes.

Q. These curves that you have platted here, are based upon how many readings at a particular depth, at this station?

A. Usually one.

Q. One, so that this percentage of variation which you have testified to is based upon one reading at .3 depth and one reading at .5 depth?

A. As a rule.

Q. Now how many meters were you using, at the time you made these readings?

A. One meter.

Q. About how long do you permit the meter to remain at one particular depth?

A. One minute, I believe, was the time.

Q. About how long would it be between the time that you measured or took a reading at the .3 depth and the time that you would take a reading at .5 depth, taking into consideration the time that you were noting this down and changing your depths, and all the things that you did?

A. From the time of beginning a reading at the .3 depth to the time of ending one at .5 depth would be something like 4 minutes I should say. The 13 readings were taken as a rule, in about 11 or 12 minutes, covering the whole vertical within that time. I mean the whole vertical was covered in from 11 to 12 minutes, or something like that.

Q. What was your maximum percentage of variation as you gave it here, do you recall?

A. I will have to refer to the record. I do not recall it. I note one of 11. Possibly there was one greater than that; I cannot recall.

Q. Just what conclusion do you draw from this percentage of variation that you have been putting in from this curve?

A. That the conditions of flow at that point vary from time to time; that the water is surging there, and not only the velocity itself is changing, but the distribution of the velocity in the vertical is changing.

Q. Is there any particular reason that that condition existed at that particular place?

A. That condition exists in all flowing water.

Q. Any special reason for it at that place?

A. Not that I know of in particular.

Q. Isn't there a sand bar above this point?

A. I don't recall.

Q. About the middle of the stream?

A. I can't state about that.

Q. Do you know whether there is one or not?

A. I don't know.

Q. What other stream do you know of where the conditions are changing to that extent between .3 and .5 depth within 4 minutes?

A. No stream of that size that I know of, because I have

not been associated with measurements on any other stream of this size.

Q. How far below the rapids in the St. Mary's River did these measurements take place?

A. I will have to use my recollection of the conditions there.

Q. To the best of your recollection?

A. About a mile I should say, possibly a little more or a little less.

Q. What is the fall in the rapids?

A. That varies, of course, from time to time.

Q. Isn't there about a 20-foot fall there in a short distance?

A. At certain times of the year. Other times it is 18, sometimes less.

Q. How much less?

A. In the case of ice jams in the lower St. Mary's River, at times, it is several feet less than that.

Q. At this particular time, about what would you say was the fall?

A. I can give you the exact figures in a moment; on the average about 17.4 feet.

Q. In what distance was that fall?

A. That is the fall between what is known as gage number 1, which was located at the entrance to the canal above the rapids and gage number 3, which was located at our section.

Q. About three-quarters of a mile?

A. Yes, possibly a mile; more than three-quarters I should say.

Q. What was the total depth of the river at that particular station?

A. At what time? That varied of course with the stage.

Q. At the time this measurement was being made?

A. Which one? There were 14. The average depth? I can give you the average of all of them.

Q. The average depth?

A. 23.1 feet under the ice.

Q. Was there much variation in that?

A. The extreme, covering the range of the curves on that sheet, was about half a foot, between .5 and .6 of a foot.

Q. All this, you say, was under the ice?

A. Under the ice.

Q. At this season of the year, isn't it likely that there was

ice and slush under the surface ice, that might tend to interfere with the flow?

A. Not very likely. During the February measurements, there had been no breaking up whatever of the ice, and the conditions were assumed to be good at that point. We investigated the stations in the immediate vicinity of the holes by reaching under and scraping around, and found no obstructions at the station. We assumed the conditions were good during the discharge measurements, except possibly the last four or five, when the river began to show signs of breaking up.

Q. When there is a slow running stream, the velocity is low as it is here, it is much more likely that there will be at a particular point a change in velocity than when there is a very high velocity in an open river?

A. As a rule, one would look for fixed conditions under normal velocity and a relatively higher velocity as we have here. That is why this station 17 was chosen, because it had the highest velocity of any station in the river.

Q. Which runs from .8 of a foot per second to—

A. About 1.75.

Q. 1.75 feet per second. So that at the highest, that is a relatively low velocity, isn't it?

A. Relatively low, in comparison with other streams; relatively high for the St. Mary's River at that point.

Q. You would not expect as accurate measurements under ice as you would in an open river, would you?

A. I should expect the measurements themselves would be equally accurate in either case. I don't just understand what you mean by the question. You mean the observations themselves?

Q. Any one observation would probably be just as accurate, I understand that is what you mean by your answer?

A. Yes.

Q. But when you are comparing one with the other, aren't the conditions more likely to be changeable under ice than they are in an open river, so that you cannot compare one with another? You would expect this percentage of variation that you speak of to be materially less in a higher velocity, wouldn't you?

A. I would have to know the conditions, of course, under which that higher velocity was obtained, or under which it obtained.

Q. Other conditions being the same?

A. A stream in high velocity tends to keep its regimen a little better than one in low velocity, I should say.

Q. You would suppose that if meters were read simultaneously at the two places that there would be a better check likely, wouldn't you?

A. Two meters you mean at the same point?

Q. Yes?

A. Providing they were not near enough to each other to create any local disturbance.

Q. Where you read them, one at the .3 and one at the .5 point?

A. Yes, I should say that two meters would probably give greater accuracy than one.

Q. Are you acquainted with the method used by the Lake Survey in what is known as the two meter work?

A. No, I don't think I am. I do not recall it.

Q. Then you do not know that on the other rivers all of the coefficient work of the Lake Survey in the measurement of these rivers was done with two meters or more?

A. I know that some of it was not.

Q. Which particultar ones?

A. I recall statements by Mr. Blanchard when he used a battery of 10 or 11 on the St. Clair River.

Q. Two or more was my question?

A. Oh, yes, two or more, I understand.

Q. You say you would expect them to give more accurate results?

A. Judging from the velocity curves there, I would say that one would conclude that way. That is merely a statement of what I believe to be so. I have no data; I have not been associated with conditions of that kind.

Q. Do you think it is a fair comparison to take a low velocity compared to the velocity in the other rivers, the St. Clair, the Detroit and Niagara and take extreme conditions, the curves showing extreme discrepancies, as you have here, and use that as a basis of criticising the measurements on the other streams?

A. I am not criticising the measurements on the other streams.

Q. Again then, what is the conclusion you draw from this, just simply that that particular place and under the conditions that you have described there, there might be a discrepancy such as you have mentioned?

A. These are measurements with which I was directly connected, and are the only data of the kind I have had from actual observation, and these have a bearing on the experiments which we made at Cornell.

Mr. Hopkins: I move that all of the testimony in regard to these measurements on the St. Mary's River be stricken out, because it is shown there is absolutely no connection between them and the conditions at other places, and that the same people made the measurements in any way that they can be used as a basis for criticising or throwing any light upon any of the other measurements involved in this case.

Recess to 2:00 P. M.

After recess 2:00 P. M.

KENNETH B. TURNER resumed the stand and testified further as follows:

Cross-Examination by Mr. Hopkins.

Q. Mr. Turner you say you have been for about six or seven years instructor at Cornell?

A. Instructor for two years, assistant professor for five years.

Q. Who is the head of your department?

A. Professor I. P. Church.

Q. What is Mr. Haskell's position?

A. He is Professor of Experimental Hydraulics and Director of the College.

Q. Just what is your department?

A. My title Assistant Professor of Hydraulics would indicate that I am in the mechanics and hydraulics department of which Professor Church is the head.

Q. And of which Mr. Haskell is the—

A. He has nothing directly to do in that department, except he has general supervision over the whole college. His work does not lie in close connection with that.

Q. What is his title?

A. Director of the College and Professor of experimental hydraulics.

Q. That is E. E. Haskell, is it?

A. E. E. Haskell.

Q. Are you familiar with the St. Clair, the Detroit and the Niagara Rivers?

A. I am familiar with the rivers, in that I have been on them, and up and down them.

Q. Are you familiar with the Niagara River at the International Bridge and above it, the section there?

A. No.

Q. Have you seen the river at the International Bridge?

A. Yes, I have been over the International Bridge.

Q. Have you examined the general surface conditions there?

A. No, I never had any occasion to.

Q. You observed them?

A. Just casually as anybody would, passing over the stream at that point; not having any immediate connection with the conditions there.

Q. The river is rather wide at that point, isn't it?

A. I should say half a mile, maybe more. I do not recall the exact figures.

Q. And flowing straight ahead? There is no obstruction in it that you could observe?

A. Nothing beyond the obstruction that the bridge itself would cause, so far as I know.

Q. About how wide are the spans in that bridge?

A. I haven't any idea.

Q. As compared to that canal at Cornell?

A. I haven't any idea, because I don't know anything about the dimensions of the bridge.

Q. Mr. Haskell is the head of this experimental laboratory isn't he at Cornell?

A. He doesn't do any work in the laboratory and never has. He is Professor of experimental hydraulics, but does not do any immediate work there.

Q. How many meters did you use in these experiments at Cornell?

A. One meter.

Q. What was its size?

A. I can't state exactly. I think it was about four inch diameter wheel, possibly a little larger. It was the harbor meter, so called.

Q. Harbor meter?

A. Harbor meter so called, remodeled for these experiments; that is the direction device was removed and the shaft substituted in place of the direction device.

Q. Did not have this vane on the rear?

A. It did have a tail or direction vane.

Q. How long was that?

A. Just an estimation, I should say between 18 inches and two feet.

Q. Was that the entire meter, or just the vane?

A. The vane or tail part.

Q. It is not what is known as an A or B meter, is it?

A. I can't say. I do not know about that.

Q. Are you acquainted with what is known as the A meter?

A. No.

Q. Or the B meter?

A. No.

Q. As a matter of fact the meter that you were using was entirely designed by Mr. Haskell, wasn't it?

A. I believe it was, to the best of my knowledge.

Q. The only part that Ritchie had anything to do with was some compass, or something of that kind, but nothing of the meter that you were using?

A. I do not have any direct knowledge on that question. I do not really know whether Dean Haskell is involved alone or not; I have no knowledge. It is called the Haskell meter. That is as far as my knowledge goes.

Q. Do you know of any meter in use that gives any more accurate results than this meter?

A. Under certain conditions, yes.

Q. What conditions?

A. Conditions of low velocity primarily.

Q. What would you include within your limits of low velocity?

A. Down below a half a foot a second.

Q. Above a half a foot a second, do you know of any meter that would give any more accurate results than the Haskell meter?

A. No, I don't think there is any that gives more accurate results. I think one is as good as another under those conditions, aside from the standpoint of convenience in use and so on; convenience of recording, and things of that kind that are outside of the meter itself.

Q. Are there any other meters except this cup meter?

A. There is what is known as the Voltman Meter, the old type screw meter, which was really a forerunner to the Haskell Meter. In general today, I believe there are only these two types, the cup meter and the propeller wheel meter that are used to any extent at all.

Q. Does the cup meter adjust itself to varying directions in the current as readily as the Haskell meter?

A. I believe it does, from my own observations and the use of the cup meter.

Q. Just what preliminary test did you make of this meter that was used there?

A. By preliminary test, what do you mean, these tests themselves?

Q. No, to rate the meter and so on, if it was rated.

A. We rated the meter in the way it is usually done on our canal. We have a rating station there. The canal is spanned by a car which is operated electrically and we are able to get velocities from about a half a foot a second to possibly eight or nine feet a second.

Q. What is that, a still water rating?

A. Still water rating, yes.

Q. How long before your test, to which Mr. Schoder has testified, was that rating made?

A. I can't tell without referring to the data. I haven't them here. The tests were made before, during and after these experiments; the rating of the meters.

Q. Was there any change whatever in the condition of the meter at any of those times when you made ratings?

A. No, those ratings all seemed to fit the same general line.

Q. Was that the only test you made as to the accuracy of the meter, the still water rating?

A. That does not test the accuracy, as I see it, the still water rating. That is simply a means of finding something by which to interpret the indications of the meter we actually used in discharge measurements.

Q. Did you make any test to test the accuracy of the meter?

A. Only these tests themselves.

Q. You did not, for instance, test the meter with particles in the water, anything of that kind?

A. No.

Q. I believe you say you used a pole to hold it with?

A. Yes, it was held from the bridge by a rod.

Q. Did you have a lead standard?

A. No, what was known as a foot plate on the meter; no lead weight under it. The photograph of the meter shows the condition in which it was used; shows the condition of the meter, rather, while in use.

Q. How long is the canal from the baffles; how long is your canal from the baffles?

A. I can't state exactly; in the neighborhood of 350 feet, possibly a little less.

Q. What is the condition of the canal, say at the lower end of it?

A. The sides are rough, due to the cement coating being off in places. The bottom is smooth; that is the original cement bottom is the same as when it was first constructed. The sides are rough because of this coating having fallen off.

Q. Is that true pretty well along the canal?

A. Along the sides. The bottom is still smooth.

Q. Your photographs show that, don't they?

A. I believe they do. I can't say for certain.

Q. Is there any difference between the condition of the canal at the lower end and at the middle, say?

A. Not any that the eye would detect, that is any general conditions. There may be little spots here and there where the side is smoother, but in general it is about the same.

Q. Why weren't some of these readings made further down than 250 feet?

A. Well, taking my estimate of the whole distance from baffles to the lower end, 350 feet or thereabouts the water which passes under the weir—(the weir was raised at the lower end of the canal) as it approaches that point, begins to acquire very high velocities, so that if we got down in the region of the actual discharge point itself in the canal, we would get into pretty extreme conditions of velocity.

Q. What would you call very high?

A. Well, I should say anything up in the region of the upper limit of ratings, seven or eight feet a second, eight or nine feet a second. What I am speaking of now refers only to the measurements with which I had anything to do; that is the first five. I was not connected with the last four measurements.

Q. The first five were all made within the extreme limits of distance from the baffles, weren't they, the first one 51 feet?

A. The distances are all stated. I do not recall them.

Q. And the second one was 260 feet?

A. 260.

Q. From the table furnished by Mr. Schoder, there is no velocity at the second measurement, which is 260 feet down, higher than three feet. Does the velocity increase after that?

A. It would down in the region where this water leaves the canal.

Q. Wouldn't the conditions a little further down, where the velocity begins to increase, give a more even flow though, rather smooth out the roughness gotten from the fall above?

A. No, I should say under certain conditions the flow there might be radically different from that, because if the discharge was not flowing freely under this weir that was raised, that is, the weir jutted down into the stream, there would be high disturbance.

Q. What weir are you speaking of now?

A. The bulk head at the lower end of the canal, which was raised during these experiments.

Q. Would that raising it at the lower end tend to retard the flow in the canal or increase the flow?

A. That would depend—it would increase the velocity of course, but diminish the depth. In order to get a fairly high velocity, this lower weir was raised so that the water could flow freely under it.

Q. In that 350 feet, you have a condition where the velocity in the first 50 feet or so, at 50 feet you have a velocity running up nearly six feet a second, and 260 feet it is below three feet a second. And then it gets faster again?

A. I can't recall the figures, but I know originally—

Q. Assuming they are correct? I am taking them from figures furnished by Mr. Schoder.

Q. That might be for a measurement, yes.

Q. Under such conditions as that, what place in the canal would be the best to get accurate measurements?

A. Well, so far as the eye could detect, any reach between that 260 point and 100 or more feet upstream would look equally good.

Q. How about 100 feet further down stream?

A. That would lead you outside the canal itself.

Q. I thought it was 450 feet along?

A. About 350 I think. I might add that the canal is arranged for making observations at the 260 foot point; there are ladders on which bridges can be placed at that station. That was of course one of the reasons why that point was selected.

Q. Professor Haskell did not take any part in any of these tests?

A. I don't think he came over during the measurements at all. I didn't see him.

Q. Did he follow the work?

A. I don't think so. He never said anything to me about it.

Q. Where do you measure this water that went through the canal, by the weir above or below?

A. In these experiments the flow was measured by a weir that was above the baffles.

Q. How was that weir calibrated?

A. That weir is an experimental weir which Professor Schoder and I have been using for some research work for some time past, and the water that flows over that weir in our observations is passed over the weir at the lower end of the canal.

The weir at the lower end of the canal is duplicated inside the laboratory in a smaller canal, as to height, character of crest and so on; and we have a means of getting volumetric measurements of the flow over that weir that is in the laboratory, so that by tying the weir at the lower end of the large canal in with that, and tying that weir at the lower end of the canal with the upper weir, we are able to calculate for flows that do not go beyond the range of head of experiments on the weir in the laboratory.

Q. Then the weirs in the canal are not calibrated at all?

A. In that way that I just stated, not volumetrically absolutely.

Q. By using one of similar shape in your laboratory?

A. One with similar conditions as regards the height of the weir and the character of crest and so on, yes.

Q. You have no absolute measurements then, or actual calibration of these weirs, have you?

A. We have no volumetric measurement of the weir itself; that is the one at the lower end of the canal.

Q. If your method of transferring your observations from one weir to another should happen to be in error to a slight extent, and there was error in your method, that error would usually show on the same side?

A. Oh yes, if there were error in the method, that would prevail, of course.

Q. You said this morning you thought that error was well within one per cent.?

A. Yes.

Q. Might that not be even larger than that?

A. Not to the best of my knowledge.

Q. You have no way of checking it though absolutely, have you?

A. In the way I have stated already, that is all.

Q. Simply by a model?
A. By a model with exact duplication of the conditions.
Q. Different size?
A. Different only from the standpoint of length; otherwise the same.
Q. At each cross section you made measurements at 13 places, didn't you?
Q. That is in the thirteen vertical positions; 13 positions across the stream?
Q. Yes?
A. Yes, something like that.
Q. And the one nearest the bottom was half a foot from the bottom?
A. I don't recall whether they all were, whether all the bottom measurements were at that depth, but I know they were on some of the runs.
Q. And from the sides you began within half a foot?
A. Half a foot from the wall, yes.
Q. How would you explain this difference between the measurements of the current meter and the measurements you had over the weir?
A. Well, one explanation which I believe would apply would be that the meter while in use was vibrating to a considerable extent in a horizontal plane, and in a vertical plane also, and I think that vibration would tend to introduce discrepancies in the observations.
Q. That water was at rather a high state of perturbation, wasn't it?
A. It was in a state which caused the meter to vibrate, as I stated.
Q. Wasn't the water in that canal much more perturbed than an ordinary river, or the rivers that we spoke of, the Niagara and St. Clair?
A. Not at the lower stations, that is so far as the eye can judge. Of course that is merely a relative matter. You have to judge from appearances. Beyond the very first station next to the baffles, that is from there 40 or 50 feet downstream, the eye would not detect much difference in the appearance of the flow. After the foamy part of the first overfall from the upper weir had gotten out, the character of the flow had gotten fairly settled, so far as the eye could see.
Q. Were there any other uncertainties of measurement?
A. I don't know of any.
Mr. Adcock: I object to that question, because it assumes

that there were uncertainties, and it has not been shown that there were.

Mr. Hopkins: Q. There was an uncertainty in the weir itself, wasn't there?

A. As I have stated, there was an uncertainty which I believe was less than one per cent.

Q. There was an uncertainty in the cross section of the place in the canal that you were using, wasn't there?

A. I should say that is under 1/10th of 1 per cent., it was very accurately measured both horizontal and vertical by tape.

Q. Up near the baffles, where it was rough?

A. You mean the cross section of the stream itself?

Q. Yes?

A. Measurements were made across the section every foot by what is known as a point gage, that is a long staff with a point on the end, which was lowered down from the bridge and the average position of the water surface read at each point and the average of all those readings was taken as the average water level for a measurement, for a discharge measurement.

Q. What was the variation in level across the width of the stream, say within 75 feet of the baffles?

A. I can't tell without referring to the record.

Q. Is that in any of these papers that has been handed me here?

A. No, I don't think so. That is you refer to the average level? Of course these reports of levels taken were averages of the position of the water surface.

Q. What would you say would be the extreme between the lowest and the highest?

A. Based on my recollection, I should say maybe two-tenths of a foot, possibly one-tenth. It might be as much as two-tenths, but I should say more likely one-tenth.

Q. Wasn't there a kind of choppy, wave motion all the way through to the crest at the valley there?

A. At the upper section?

Q. That is what I am speaking of.

A. Yes.

Q. So that it made it very difficult to measure the cross section of the stream?

A. No, I don't call it difficult to get the cross section, the average cross section under such conditions.

Q. There is kind of a retardation in the flow of a stream

next to the bottom and at the sides, say, of a canal of this kind, isn't there?

A. There is considerable; not so much as one would find in a rougher stream. This is a smooth bottom, of course, smooth cement bottom.

Q. Just how did you compute your volume from the measurements that you had at any particular cross section?

A. The observations for velocity were first gotten, of course, in the form of revolutions of the meter.

Q. In the form of the readings as you have here?

A. Those are the summary of results.

Q. After you had those?

A. From the readings of the meter the velocities in feet per second where the readings were taken were found from the rating curve, rating table. Then the stream was divided into vertical strips in which the mean velocities in the verticals controlled each its own proportion of the whole area and by the kind of calculations used in stream measurements, the partial discharge for each strip was found; the sum of those giving the discharge for the whole stream.

Q. To what extent did you take into consideration the difference in the velocity next to the walls and next to the bottom?

A. In taking the velocity near the wall, the nearest of course that we could get by virtue of the construction of the meter and its size was half a foot; and we assumed that that observation controlled a one foot strip; that is the first foot of width. And the same way at the bottom, we assumed the observation 5/10ths from the bottom controlled the last foot of depth.

Q. There is quite an area there around the sides and next to the bottom that you could not measure because of the meter, wasn't there?

A. Yes, the nature of the meter was such we could not get nearer than that.

Q. It was to some extent uncertain, and you had to assume the flow in some such way as you have mentioned?

A. Yes. We assumed that the drawing back in the velocity on the bottom was much less in the case of this smooth canal than it would be in a stream, and the best assumption based on data available was that those velocities would control one foot of width and control one foot from the bottom.

Q. You had to use some theories then?

A. Yes, we had to make some assumptions as always is done in such cases.

And there is always a possibility of an error?

There always is, so far as that partial discharge is con-ed. The error is slight, of course, in connection with the e.

In a canal, shallow canal, besides running up straight way (illustrating), the percentage of the total flow that this indeterminate area is much greater than in a big , isn't it?

I should not say it was. I should not say any more is introduced by virtue of conditions that obtained in anal than in the case of a stream, ordinary stream.

Your average of the depth here as shown in these urements is less than four feet?

Those five with which I had to do were less than four yes. I believe that is the figure.

And certainly in a shallow stream, there is a greater ortion of this indeterminate area to the whole volume in a deep stream, isn't there?

Oh yes, there would be.

In fact it would be nearly 25 per cent. of the total me?

Nothing like it, I should say. Four feet, and half a would mean only 1/8th.

Half a foot at the top and half a foot at the bottom?

We can measure within a little less than half a foot e top. You cannot with the Haskell meter; you can with ther types.

That is what you were measuring with here?

Yes.

The point I am trying to bring out is if there is an r in this indeterminate area in the shallow stream, the entage reference to the whole will be greater than in a er stream?

It might be, yes.

Yes, might be. If there is an error, wouldn't it be?

No, I don't think it would, because in this same canal ave run numbers of experiments with smooth flow, that ithout trying to introduce disturbed conditions of any , and have found that our measurements checked the very closely. Now if we made large errors as regards conditions near the bottom and the wall in the one case ere made in the other, we ought to get the same dis-ancy.

If there is an error in your theory—you have a theory, ssuming this that I call the indeterminate theory?

A. Yes.

Q. If there is some constant error in that theory, wouldn't it be greater in volume in a shallow stream than in a deep stream?

A. Yes, you can measure more accurately of course, relatively in a large stream than you can in a small one, providing you use the Haskell Meter.

Q. Your only criticism of this Haskell Meter is that there is an error in the instrument itself due to perturbed condition of the water, and resulting in an under registration?

A. I should say that is what the tests bear out, yes. The under registration of course is helped (lessened) by our assumption as to the velocity at the walls and the bottom, because in an ordinary stream we know the velocity draws back more than we assumed in this case, so that we really gave more flow than we would had the case been that of a natural stream.

Q. That depends on your theory, doesn't it?

A. There is no theory involved.

Q. I believe you said the bottom of this stream was very smooth?

A. Yes.

Q. So that there would be much less retardation there than there would be in an ordinary stream?

A. There probably would be.

Q. From what can you say that you took that into consideration sufficiently in your estimate?

A. By looking at the curves of vertical velocity, which are plotted on one of these sheets.

Q. But the curves might make a radical change within that limited area, as it approaches the bottom or approaches the station?

A. Yes, I think if we could have made Pitot tube or other current meter observations, we would have found a greater drawing back than was used in computing the experiments.

Q. Then your test was not the most accurate, according to your best judgment?

A. The most accurate that we could make under the given conditions.

Q. You think you did not allow sufficiently though for the retardation?

A. I think that whatever doubt is involved is in favor of the meter rather than otherwise.

Q. You say you have measured streams when the con-

ditions were more favorable, smooth or something of that kind?

A. Yes, we have made experiments in the same canal with small flows, the velocity more uniform.

Q. What meter did you use?

A. Both the Haskell and the Price meter.

Q. How did the results check with the weir?

A. Very closely, within one per cent. usually.

Q. With your uniform velocity?

A. Not exactly uniform, but a more uniformly varying velocity from top to bottom; more nearly like normal conditions in a stream.

Q. You say then they checked within one per cent.?

A. I recall numbers of observations which checked that way, yes.

Q. What was the velocity in some of these conditions, where they did check?

A. That I can't say offhand.

Q. Do you have any idea of any limits?

A. It might be from two to four or five feet a second possibly.

Q. So that these tests were made under highly artificial conditions, that is as regards perturbation of water?

A. Highly artificial as regards to the canal; we have not run tests of that character before.

Q. At whose instigation did you start into this testing?

A. Professor E. W. Schoder. Professor Schoder had charge of the tests, and arrangements were made with him.

Q. I believe you said you did not know the condition of flow in the rivers that the Lake Survey have been making measurements in, with the exception of the St. Mary's?

A. Not in the St. Clair or the Niagara, which were mentioned.

Re-direct Examination by Mr. Adcock.

Q. This hydraulic laboratory which is composed of this canal and other apparatus, etc., is used for the purpose of making experiments by various people in the country, is it?

A. Yes, commercial tests are made there very frequently.

Q. United States Government has made tests there?

A. They have made tests.

Q. In connection with their work?

A. I had nothing to do with it at that time. It was before my time.

Q. And this weir, and calibrating the weir, etc., and this laboratory are maintained by the College of Civil Engineering of Cornell University?

A. By Cornell University, of which the Engineering College is only a department.

Q. You say that Professor Haskell—

A. He is director of the College of Civil Engineering.

Mr. Adcock: That is all.

Whereupon an adjournment was taken subject to notice.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Tuesday, January 20th, 1914.

Appearances:

Mr. James H. Wilkerson and
Mr. Albert L. Hopkins,
Representing the Government.
Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

GEORGE M. WISNER, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?

A. George M. Wisner.

Q. Where do you reside Mr. Wisner?

A. Chicago.

Q. What is your business?

A. Civil engineer.

Q. Are you connected with any municipal or commercial concern?

A. Yes, sir.

Q. What are your connections at the present time?

A. Chief Engineer of the Sanitary District of Chicago.

Q. With the defendant in this case?

A. Yes, sir.

Q. How long have you been acting as Chief Engineer of the Sanitary District?

A. I think since 1907.

Q. Prior to that time what was your engagement?

A. Well, I started in, in 1892, as a rodman, I think, and then was made sub-instrument man, instrument man, sub-assistant engineer, assistant engineer, assistant chief engineer, and then chief engineer in 1907.

Q. What are your duties as Chief Engineer of the Sanitary District?

A. I have entire charge of all work coming into the engineering department, which involves the design of all the works carried on by the Sanitary District; and in charge of the construction of works that are in process of being built. I am also in charge of all the original research carried on by our experimental stations. This applies particularly to sewage disposal and water purification.

Q. Will you state your education and experience to qualify you to practice as a hydraulic and sanitary engineer?

A. I had the ordinary school education; graduated from the Detroit High School and entered the University of Michigan in the fall of 1888; and graduated in civil engineering in the spring of 1892. Then went to work, a few days later, for the Sanitary District. My duties there involved a study of sewage disposal and sewage conditions, as well as all sorts of construction work. It also involved, and caused me to study and look up all hydraulic problems, many of which enter into our work here. In the matter of sewage disposal, I have visited the plants at Columbus, Baltimore, Milwaukee, Washington and other American cities. I have visited the plants at Birmingham, Manchester and London in England; Paris, France, and Berlin, Germany; possibly one or two others which I have forgotten.

Of course this has involved the reading of authorities on this subject and the consultation with other engineers engaged in similar lines of work, which has tended to keep me informed as to the progress of the art up to the present time.

Q. Has your connection with the Sanitary District of Chicago enabled you to become familiar with the various works of the District?

A. Absolutely.

Q. All of the works of the Sanitary District have been installed during your service with the defendant?

A. All of them. I was at work on the construction work

at the time of the shovel day; that was when the first spade full was turned on the construction of the main channel.

Q. Are you familiar with the sewerage system of the City of Chicago?

A. Yes, sir.

Q. Will you describe briefly the essentials of the sewerage system of the City of Chicago and the Sanitary District, and point out in particular the location of the present intercepting sewers, which divert sewage from the lake. I show you a map which I offer in evidence, the same showing the limits of the Sanitary District of Chicago, which may be marked Wisner Exhibit 1, January 20, 1914. And in that connection will you also describe the map which I have just shown you?

(Map shown to witness and offered in evidence by counsel for defendant was here marked Wisner Exhibit 1, January 20th, 1914.)

A. The sewerage system of the City of Chicago consists of sewers built for the collection of sewage; the first one being built in 1855, and they have been added to since, piece by piece. They range in size from six inch tile up to brick sewers 20 feet in diameter. The more important sewers are those that are two feet in size and over, as shown on Wisner Exhibit 1.

The sewers originally discharged into the Chicago River, and a part of them, on the north and south sides, directly into Lake Michigan. The sewers are all built on what is known as the combined system; that is they receive both the storm water and the sanitary sewage; all the sewage coming directly from the homes and buildings of the city. They also receive to a large extent the manufacturing wastes.

There have been completed recently two main intercepting sewer systems. These were built by the City of Chicago to prevent the sewers that had previously discharged directly into the Lake from discharging into it; in other words to keep the sewage out of the lake. One is on the North Side, and is shown on Wisner Exhibit 1, starting on the north at Howard avenue and running south to Lawrence avenue, and a part of the same system starting on the south at Diversey boulevard and running north to Lawrence avenue, where the sewage is picked up by pumps and forced through a conduit 16 feet in diameter on Lawrence avenue to the west and into the north branch at that street. This pumping station also pumps diluting water from Lake Michigan, mixing it with the sewage water,

and being utilized for dilution of the sewage and flushing the North Branch.

The other intercepting sewer system is on the South Side, as shown on Wisner Exhibit 1, and extends on the south from 87th street north to 39th street and the lake, and from 31st street south to 39th street, preventing the sewage which had flowed directly into the lake from flowing therein. At 39th street it is picked up by pumps and forced through a 20-foot conduit west to Halsted street, where it discharges into the east arm of the south fork of the south branch of the Chicago River. This is the arm of the river that is commonly known as Bubbly Creek.

The same pumping station pumps fresh diluting water from the lake, diluting the sewage and flushing out the arm of the south fork of the south branch. This combination of fresh water and sewage flows through the south fork to the south branch; then into the west fork of the south branch, and then directly into the Sanitary Canal.

Other sewers north of 31st street and south of the main branch of the river that had discharged into the lake have been reversed, and the sewage now flows directly into the river. The result of all this work has been that no sewage between the south line of Evanston and the Calumet River enters Lake Michigan at this time.

The sewers between the main river and Diversey boulevard prior to the works of the Sanitary District, did not discharge into the lake, but either discharged into the main river or the north branch and required no reversal of the sewage flow to keep the sewage from getting into the lake.

Q. Did not require any intercepting sewers to be built?

A. No.

Q. And those sewers discharge in the same way that they did previously?

A. Yes, sir.

Q. Will you describe the present water supply system of the City of Chicago, and point out the location of cribs, and their position?

A. The water supply system of the City of Chicago has been developed since 1852. The city takes its water supply directly from Lake Michigan by tunnels which extend out beneath the bottom of the lake to cribs or intakes. These tunnels and intakes and the water supply system is maintained by the City of Chicago. The present cribs are from two to four miles off shore, and are shown on Wisner's Exhibit 1.

There are six of these cribs. The first one, known as the Two Mile Crib, was built in 1867, and is opposite Chicago avenue on the North Side. The Four Mile Crib, built in 1892, is, as indicated, approximately four miles off shore and is opposite 14th street.

The Hyde Park Crib was built in 1894, and is practically two miles off shore opposite 68th street.

The Lake View Crib built in 1896, is two miles off shore and opposite Montrose avenue, or boulevard.

The Carter H. Harrison Crib was built in 1899, and is three miles off shore; practically amounts to the extending of the old Two Mile Crib, although I believe at times both are used. It is opposite Chicago avenue.

The Dunne Crib built in 1910, is two miles off shore and opposite 68th street. It is right alongside of what is known as the Hyde Park Crib. It was put in to give additional capacity for this particular part of Chicago that those two cribs serve.

I might say that this water, after passing through these tunnels under the lake is then carried by land tunnels to pumping stations located in different parts of the city, and forced through the mains to consumers.

Q. Will you describe the various works of the defendant built and operated for the purpose of protecting the water supply of the inhabitants within the limits of the Sanitary District?

A. As preliminary to the answer to that question, I would state that I will not re-describe the sewerage system which has already been spoken of in previous answers.

The Sanitary District was organized in 1889, and the construction was started in 1892. The principal feature of its work has been the construction of what is known as the Main Channel. This channel begins at Robey street and the Chicago River, which is about 6 1/3 miles from the mouth of the river. It was originally 28.05 miles long and extended from Robey street the starting point to Lockport, Illinois. Practically the first 14 miles of it was through clay and glacial deposits, and the lower 14 miles was through limestone rock.

The Chicago end of the canal, for about 7 miles, was constructed to about half of the ultimate capacity. It was capable of progressive development as the needs for additional water became necessary to dilute the sewage. This extended to a place known as Summit.

From Summit to Willow Springs, a distance of another 7

miles, the channel was constructed to its full capacity; and from Willow Springs to Lockport, through the rock, it was constructed to its full capacity.

The channel at the upper end was 110 feet wide on the bottom, and had side slopes of one vertical on two horizontals.

The second stretch through the glacial deposit to Willow Springs was 202 feet wide on the bottom, and with the same side slopes. From Willow Springs to Lockport, generally, the channel was 160 feet wide on the bottom, and 162 feet wide on the top, with sides that were practically vertical.

At the end of the channel were controlling works for regulating the amount of water flowed through the Chicago River and the Main Channel.

In 1903, the right was obtained from the Legislature to develop power which had been incidentally created in connection with this work, and the channel was extended to practically the City of Joliet. Prior to this, however, the Sanitary District had done considerable work improving the Des Plaines River below the end of the Main Channel and through the City of Joliet, removing several dams and deepening the stream, building levees and walls. This power development involved the lengthening of the upper reach of the Main Channel for about two miles, at which point was located a power house, dams for regulating the flow and a lock for the passage of vessels from one level to the lower level. It developed an average head of about 34 feet, and the plant is capable of developing about 4,000 kilowatts for every 100,000 cubic feet of water flowed per minute; generally, in round numbers, that is true.

Below the power house, the channel is carried on the same depth, practically the same depth as above the power house, which I neglected to give, it being about 24 feet at normal stages of the lake, to a point near to the upper limits of Joliet, where it is from there through the City of Joliet ten feet or over in depth. This power extension was completed I think in the latter part of 1907 or early in 1908. If it is important I can get the exact date.

Q. It was the later part of 1907.

A. I think that is right.

Q. It was put in operation December 31, 1907?

A. Yes, I believe that is right.

This work involved the construction of transmission lines and distributing systems in the City of Chicago, most of the power being brought to Chicago for the lighting of streets

and pumping of water for the municipality, the excess being sold for commercial purposes. This power was all developed incidental to the sewage disposal, and the District has never flowed more water on account of power developments than it would have flowed if there had been no development there. Prior to this construction this power was simply going to waste, and it simply amounted to the conservation of this wasted energy.

In connection with getting water through the Main Channel, it became necessary, on account of the restrictions placed on the velocity of the current in the South Branch for the Sanitary District to improve the South Branch of the Chicago River by widening and deepening it and by the removal of certain bridges, whose center piers interfered with the free passage of the water through the river.

The Sanitary District has expended approximately $11,500,000, on the improvement of the Chicago River. This money was expended almost entirely under what is known as the 1900 Project. It generally was expended to widen the South Branch from its junction with the North Branch at Lake street to the beginning of the Drainage Canal at Robey street. The river has been widened to a width of at least 200 feet, and it has been deepened so that at the dock lines there is a depth of water of 16 feet, gradually deepening to a point 50 feet out from the docks where it is 26 feet deep for the middle 100 feet of the river. This depth of water is below what was known as the hydraulic grade of the river; that is the water in flowing from the Lake to the Drainage Canal has a slope which at times is two feet lower at Robey street than the Lake level.

This widening of the Chicago River involved the purchase of over 792,000 square feet of property along the Chicago River, and generally, I should say, the river had been widened on an average 50 feet. The widest piece taken off was, as I remember, 110 feet in width, and from that down to nothing.

This involved the excavation of over 5½ million cubic yards of material; the construction of over 19,000 lineal feet of dock, for wherever the Sanitary District widened the river it became necessary to build new docks.

In the improvement of the river, as already stated, the Sanitary District replaced many of the old center pier bridges with bridges of the modern type, known as bascule bridges. It has replaced or rebuilt the following bridges across the Chicago River: State street, Dearborn street, Randolph

street (and it is now engaged upon the construction of a new bridge at Jackson boulevard), Harrison street (Polk street was built by the City of Chicago), Taylor street, Chicago Terminal Transfer Railroad Bridge, now owned and operated by the Baltimore & Ohio Railroad (it has agreed to pay half the cost of rebuilding the 12th street bridge, which has been ordered out by the Secretary of War), 18th street, Canal street, 22nd street, Main street, Throop street and Ashland avenue. One other bridge was removed and reconstructed by the City of Chicago. That is at Washington street.

Widening the river also involved the removal of many buildings, and paying damages to adjacent property owners.

The Sanitary District has also widened and deepened the North Branch of the Chicago River from Belmont avenue to Lawrence avenue, a distance of about two miles. This stream, prior to this straightening and deepening, was practically dry in the summer time, simply being a small creek. The Sanitary District made a stream having a depth of 12 feet and a width of 90; and has also deepened the South Fork of the South Branch to a depth of 20 feet; has done considerable work in the West Fork of the South Branch west of the beginning of the Main Channel, deepening it about three feet.

This, generally, covers the work done by the Sanitary District as far as its main channel and the Chicago River are concerned, with the possible exception of the North Shore Channel which was completed in the latter part of 1910 and early in 1911; and it extends from Wilmette and the Lake to the North Branch of the Chicago River at Lawrence avenue. This was a rather small canal, having about 13 feet of water. It is navigable and was built to take care of the sewage coming from what is known as the North Shore towns, that is the towns from Glencoe south to the Chicago Limit, including Evanston, Wilmette, Winnetka, Kenilworth and Glencoe. It is provided with a pumping plant at Wilmette, which pumps 1,000 cubic feet of water per second through this canal and down into the North Branch, and the water to be used for diluting the sewage and flushing out the North Branch, which otherwise would be stagnant, septic, and become a local nuisance. This water flows then directly into the South Branch and into the Drainage Canal.

Q. What was the depth of the South Branch of the Chicago River before the Sanitary District entered upon the project of deepening and widening?

A. The South Branch had been dredged by the United

States Government to a depth of 17 feet, but it had shoaled up considerably, due to silt coming in from the lake and settlement coming from sewers, so that at the time the District started on the deepening of the South Branch, it did not have available probably over 16 feet.

Q. You spoke of a lock at Joliet, the terminus of the Sanitary District Channel. Is that capable of being enlarged, are facilities provided so that it could be enlarged to accommodate very large vessels?

A. It is not the intention to enlarge that lock, but there was space left, and the work was so designed that a large lock could be installed when the deep waterway is constructed.

Q. What is the depth of the water now through the various branches of the Chicago River and Drainage Channel to the terminus of the Drainage Channel at Joliet?

A. The Chicago River through the main river is 20 feet; through the South Branch and West Fork down to the main channel 26th street. The main channel itself at ordinary stages is at least 24 feet as far as the power plant. Below the power plant it is 20 feet to the north limits of Joliet, and from there on at least 10 feet in depth down to Dam Number 1, which is near the center or heart of the city of Joliet. Below there the Des Plaines River is not navigable. The only means of navigation from there on at the present time to the Illinois River is by way of the old Illinois and Michigan Canal.

Q. Do you know how much the United States has expended in the improvement of the harbor at the mouth of the Chicago River?

A. It has expended approximately $2,390,000. No part of that sum was expended in the improvement of the Chicago River. The Government did not expend any money in connection with the improvement of the Chicago River until 1896.

Q. Since 1896, what has the United States expended, up to say June 30, 1913, in the improvement of the Chicago River itself?

A. Approximately $1,626,000.

Q. Do you know what this money was expended for in the Chicago River?

A. It was expended for dredging the North and the South Branches to a depth of 17 feet on the first project, and later the deepening of the North Branch as far north as Belmont avenue, I think, to a depth of 20 feet.

The Government also bought some land on both branches of the river for the purpose of constructing what is known

as turning basins. These are basins that are large enough so that vessels can turn around and come back down the river bow first. The one on the North Branch is at Diversey boulevard, and the one on the South Branch is at the junction of the West Fork and the South Branch, just east of Ashland avenue. Part of this money on the original project was expended for widening the Chicago River at some of the narrowest and most dangerous places. Part of this money was expended deepening the main branch of the river to a depth of 20 feet from the mouth to the junction of the two branches. Generally this covers the money that was expended by the Government for the improvement of the river.

Q. Do you know how much money the City of Chicago has expended in the improvement of the Chicago River?

A. Approximately $6,275,000.

Q. Do you know what it was expended for; and between what years?

A. I think from about 1861 to the present time, approximately to this time. It was expended for dredging of the Chicago River, both the main river and on all its branches, building of bridges and docks, and general improvements.

Q. Were any of these improvements in the Chicago River done by the United States Government during the time that the Sanitary District was completing its works?

A. Yes. I refer particularly to the South Branch. The deepening of the North Branch has been done in quite recent years; that is deepening the North Branch to 20 feet.

Since the 17 foot project of the United States Government it has done no work on the South Branch, although it has deepened the North Branch to 20 feet. The Sanitary District took up its work and did this dredging. When the Sanitary District started on this project, the Government had, as I recall, not quite completed the dredging to 17 feet. And I know it was widening the river at certain places where it was narrow, that is the South Branch. Some of this work of the Government and the Sanitary District was carried on simultaneously. The widening done by the Government however was at a few places, and did not amount to very much.

Q. The Sanitary District commenced its work on the improvement of the Chicago River along about 1896, did it not?

A. Yes, along about 1896 or '97.

Q. Will you state the conditions of navigation upon the South Branch of the Chicago River prior to the time the Sanitary District widened and deepened it, as you have stated?

A. Boats drawing over 16 feet of water could not have navigated the South Branch, even providing that the tunnels had been removed, for the reason that there was not any more available depth than that, up to the time that the Sanitary District started its dredging. I do not believe that a boat over 400 feet in length could have navigated beyond 22nd street, for the reason that between 22nd and Halsted street the river was very narrow and tortuous, and a boat of that length could not make the turn. Boats having a beam greater than 48 feet would probably not have been able to pass through some of the bridge openings. These bridges have since been removed and replaced by modern bridges giving a wider opening.

Q. What are the conditions of navigation as the result of the Sanitary District improvements in the Chicago River?

A. Well, at this time I think a boat of probably 500 feet could navigate the river, and one drawing 20 feet; the depth being controlled by the depth in the main branch of the river. If certain bridges, which are now either coming out or shortly to come out are removed, a boat of larger length could be taken down the river.

Q. What flow of water will the Chicago River in the South Branch accommodate without injury to navigation?

A. The critical point probably, the critical stretch, is from Lake street to the turning basin at Ashland avenue. This will safely take, in my opinion, 8,000 cubic feet a second. From there on to the Drainage Canal, the river is much wider, and with the same depth would take an additional flow of water without any injury to navigation.

Q. Would the current exceed 1¼ miles an hour through that stretch?

A. No, sir.

Mr. Hopkins: You mean after you pass Ashland?

Mr. Adcock: No, through the stretch.

The Witness: Anywhere.

Q. Have you described all of the works of the Sanitary District, so far?

A. I think I have described the principal ones. The Sanitary District has done some work in improvement on the Illinois River, and some improvement in a sanitary way for some of the smaller towns within the limits of the Sanitary District.

I have assumed that in describing the sewerage system and speaking of the pumping stations which were constructed by

the City of Chicago, that they are part of the works of the Sanitary District. Certainly 39th street Pumping Station is, where the Sanitary District paid quite a percentage of the cost.

Q. I show you Exhibit B to the answer in this case and ask you whether that is a correct representation of the position of the Chicago River and its various branches with reference to the limits of the Sanitary District?

A. Yes, sir, it is; on a very small scale, however.

Mr. Hopkins: That is to the answer in number 114.

Mr. Adcock: Yes.

Q. What is the area of the Sanitary District as it exists to-day?

A. The total area of the Sanitary District is at the present time 386.2 square miles. The original Sanitary District, that was up to 1903, was 185 square miles. The North Shore District of 78.6 miles was added at that time, as was what was known as the Calumet District amounting to 94.5 square miles, and under a recent act of the Legislature 28.1 square miles more have been added to it. This includes all of the City of Chicago, the area of which is a little over 191 square miles. The total is 386.2 square miles.

Q. I show you a map which I offer in evidence and ask that it be marked Wisner's Exhibit 2 of this date. I wish you would explain that map.

(Map offered in evidence by counsel for the Sanitary District was marked Wisner's Exhibit 2, January 20, 1914.)

A. This is a map that was prepared in this office under my direction. It is a map showing the land sections of Cook County, part of DuPage County, a part of Will County; and generally shows and was made to show the areas comprising the Sanitary District with its relation to the Chicago River and the main Drainage Canal. There is a scale upon this map. The part of the map which is tinted green is the original Sanitary District. The part lying to the north of this and tinted a brown is the area that was added to the Sanitary District by the Legislature in 1903; and the part lying to the south of the green tint and tinted brown is what is known as the Calumet Extension to the District, and was added in 1903. The part tinted brown and lying west of the green tint is that which has been added to the District recently. The yellow tint shown upon this map indicates the branches of the Chicago River and the Main Drainage Channel extending to Joliet.

The part tinted red, or red line, and marked Calumet-Sag Channel is the Calumet-Sag Channel which is now being constructed from the Little Calumet River, east of Blue Island to the present main drainage channel at the place marked Sag.

Q. Did you mention in your description of the works of the Sanitary District the Fullerton avenue conduit?

A. That was built by the City of Chicago prior to the Sanitary District work, and is a conduit extending from Lake Michigan to Fullerton avenue and the North Branch; was installed for the purpose of flushing the North Branch.

Q. You mentioned the Sag Canal Project. Will you describe that and state the condition of the work to date; and what relation it bears to the entire project?

A. I overlooked in my former answer a description of the Calumet Sag Channel. It is a channel extending from the Little Calumet River just east of Blue Island to the Main Drainage Channel at the Sag, a distance of approximately 18 miles. It is a channel which is to have water 20 feet in depth, and through the rock sections is 60 feet in width, and through the earth sections generally 36 feet in width on the bottom, with side slopes varying from one vertical to two horizontal, to flatter slopes.

It is to have regulating and controlling works located at its eastern end, which will control the amount of water that can flow through it. Generally it is designed to carry 2,000 cubic feet per second at this time, but it is capable of progressive development so that it can ultimately be enlarged to carry at least 4,000 cubic feet per second. And it has been my intention to enlarge it to that capacity, when it became necessary. It was not done at this time for the reason that it figured cheaper to make this progressive development than to make a large initial investment, which would not be needed for some years to come.

At the present time, this work is under construction, there being nine contract sections awarded by contract averaging about a mile and a quarter long; there are about five more to be let within the next few months.

This canal will be navigable.

Q. What city, villages and towns are located within the limits of the Sanitary District?

A. Chicago, Evanston, Glencoe, Winnetka, Wilmette, Shermerville, Glen View, Morton Grove, Niles, Cicero, Stickney, Evergreen Park, Morgan Park, Blue Island, Riverdale,

Oak Park, Berwyn, Forest Park, River Forest, Maywood, Riverside, Brookfield, Bellwood, Franklin Park, Melrose Park, River Grove, Dolton, Harvey, West Hammond, Worth, Bremen, Calumet, Kenilworth, Burnham.

Q. Will you describe the Chicago drainage area and state the amount of the run-off of that area?

A. The drainage area of the Chicago River basin is about 307 square miles. The run-off of the Chicago River basin in a dry season is practically the city water supply, and some little ground water, but at times of maximum floods it will reach as high as 10,000 cubic feet per second.

Q. Have the inhabitants of the Sanitary District within the boundary of the Sanitary District any available water supply other than Lake Michigan?

A. Generally, no. It would be impossible to supply the entire inhabitants of the Sanitary District with a good supply of water by any other means. There are a few wells in Chicago and the smaller places, which are used for that purpose; but it would be impossible to get sufficient water from a ground supply to supply the entire city.

Q. What was the condition of the Chicago River and Lake Michigan in reference to pollution, etc., prior to the opening of the Drainage Channel?

A. To illustrate what the appearance of the Chicago River was at that time, it is only necessary to say that practically the entire North and South branches were in the same condition as that part of the Chicago River known as Bubbly Creek is at the present time. It was a filthy, dirty sewage polluted water, in a septic condition, with gas bubbles rising; having large cakes of floating sewage mud. This mud was held at the surface by the gas being generated in it. A large percentage of the docks along the river were falling into the stream. The river was littered up with old worn out bridge protections which interfered with the passage of boats, and in fact often proved a menace to the boats, for the reason that the piles were rotted off below the surface of the water. Not only the appearance of the river was objectionable to the eye but the odors coming from it were objectionable to the nostrils; and at times of flood could be smelled for long distances. It was a disgrace to a civilized community at that time.

Q. Which way did the river flow? Did it have any current?

A. At times it flowed in different directions. The current was practically stagnant except in times of floods due to heavy

rains, and the run-off of melting snows. Although the Bridgeport Pumping Works were operating, pumping between forty and 50,000 cubic feet of water per minute out of the South Branch, this was so insufficient that it did not make any perceptible current; and often the current could be observed running towards the lake, due to the sudden drop of the lake level.

When the lake would rise, one might observe a current of water coming in from the lake, but generally the river was stagnant.

In times of heavy rains, this sewage polluted water was driven by the storm run-off into the lake, polluting the water supply. This was traced to several miles from shore, and went even beyond the present location of the Four Mile Crib.

On account of the lake rising and falling as stated above, large quantities of this sewage polluted water found its way into the lake and resulted in not only the river itself being objectionable to the eye and nose, but the lake at the mouth of the river was objectionable. It contained large quantities of sewage pollution for a considerable distance from the mouth of the river.

Q. Was there any change brought about after the opening of the Drainage Channel, in this condition which you have described?

A. It has absolutely remedied this condition, so that at the present time there is no local nuisance in the Chicago River and the sewage does not get into the lake polluting the water supply at any place between the Calumet River and the south line of Evanston.

Q. Do you know what has been the cost of the works built by the Sanitary District of Chicago and the City of Chicago, for the purposes of sanitation up to December 31, 1912, that you have described?

A. I do. Up to December 31, 1912, an amount of $61,845,838 had been expended by the Sanitary District of Chicago and the City of Chicago for the construction of works now in operation. The works of the Sanitary District of Chicago include the Main Channel, North Shore Channel, and the various appurtenances necessitated, including bridges, the enlargement of the Chicago River, the diversion of the Des Plaines River, and the construction of flushing pumps. Those paid for by the City of Chicago include the intercepting sewers on the North and South Sides, the Lawrence avenue sewage pumping station, and also the sewage pumping station at

Fullerton avenue and 39th street. The Sanitary District, as stated before, paid part of the construction of the 39th street station.

Q. Did you state the capacity of the 39th street pumping station and conduit, in taking water away from Lake Michigan?

A. No, I did not. It has a capacity of 2,000 cubic feet per second, or 120,000 cubic feet per minute.

The Lawrence avenue pumping station has a capacity of 40,000 cubic feet per minute.

Q. What is the cost of the works that you have described, built by the Sanitary District and the City of Chicago for the purposes of sanitation for a diversion of approximately 10,000 cubic feet of water per second through the main channel, at a velocity of 1¼ miles per hour or less through the Chicago River?

A. It is the intention to flow 8,000 cubic feet per second through the main river and the south branch to its junction with the South Fork of the South Branch, at which place will come an additional 2,000 feet from the 39th street pumping station, and from this junction of these two branches to the Main Channel, a flow of 10,000 cubic feet.

As stated before, this stretch of the river is wider than the river is east and north of Ashland avenue, and is fully capable of taking the 10,000 feet without creating a velocity of probably over a mile an hour.

The cost of the works built and paid for by the Sanitary District of Chicago and the City of Chicago, for the purposes of sanitation, with a rated capacity of 10,000 cubic feet per second through the Main Channel, and having a velocity in the Chicago River not to exceed a mile and a quarter per hour is $64,095,000.

This cost is made up of the amount expended by the Sanitary District on completed works, which has already been mentioned, and the expenditure by the City of Chicago for works which I have already described, and for the work which has been practically finished during the last year, which is the widening of the eastern end of the present Main Channel, which I have spoken of before as being capable of progressive development; and also includes an estimate of the cost of completing the Chicago River widening to 200 feet. There yet remains four places where it is not quite completed; and certain other minor details, which go to bring this figure up to the amount stated.

These costs have been taken from the books of the District and the City of Chicago. An allowance has been made for the actual interest on the bonds prior to the opening of the Main Channel in 1900, an estimated amount for interest during construction for works built by the District after 1900, and a proportion of the overhead charges of the District pro rated in accordance with the construction and maintenance expenditures. An allowance has also been made for the interest during construction on the city expenditures.

I would in this connection submit a table which gives in some detail the money that has been expended for different purposes and projects.

COST OF WORKS OF THE SANITARY DISTRICT OF CHICAGO AND THE CITY OF CHICAGO.

The Sanitary District of Chicago— To December 31, 1912.	
Right of Way,	$9,703,018.37
Construction of Main Channel and Controlling Works,	19,813,197.96
Bridges (Incl. Chicago R., North Branch and North Shore)	6,633,073.23
North Shore Channel and Wilmette P. Sta.	1,450,985.83
Rivers (Chicago River, River Diversion, and North Branch)	3,666,720.23
Flushing and sewers,	782,150.20
Joliet (Joliet Project, incl. bridges)	1,601,104.30
Administration, Engineering, Legal and Clerical Expenses (Excluding water power eng, and Calumet Sag and prorated M. & O. charge)	6,658,923.05
Miscellaneous (Illinois and Michigan Canal)	167,404.88
Bond interest and Premium Acct. to Dec. 31, 1899, actual,	2,950,618.42
Interest computed on construction carried on from Jan. 1, 1900, to Dec. 31, 1912, allowing equivalent one year at 4¼ per cent.,	737,697.42

Damages, Lands, Marine, personal, ...	276,782.11	$54,441,676.00
Contract Work in 1913 and 1914.		
Estimated Overhead Expense,...	900,000.00	
Estimated Cost of Dredging,....	1,486,085.00	
Interest during construction 1 year at 4½%,.....	63,158.61	$ 2,249,243.61
	(Exhibit Cont.)	
	For	$56,690,919.61
The City of Chicago—		
Intercepting Sewers, Land, etc.,	$5,312,024.74	
Fullerton Ave. Pumping Station,	115,308.75	
Lawrence Ave. Pumping Station,,	452,635.65	
39th Street Pumping Station,...	944,143.98	
Estimated Interest during Construction—half period on four year basis.....	580,049.62	$ 7,404,162.74
		$64,095,082.35

Q. What do you estimate the annual and capitalized cost of the works for the diversion of 10,000 cubic feet per second?

A. The annual cost of the works for a diversion of 10,000 cubic feet per second is $508,832.09, including maintenance and operation, overhead charges and depreciation; and an allowance has been made for the receipts from rental.

This brings the total cost of a 10,000 cubic feet diversion project up to $76,067,582. This sum includes the annual cost capitalized at 4½ per cent., and the original construction investment. The details are as follows:

M. & O. acct. 8,000 c. f. p. s.	$210,036.99
Estimated overhead,	50,032.33
Depreciation:	
Main Channel, etc., as of 8,000 c. f. p. s.	265,030.68
Addit. investment	
½ of 1% on $2,249,243.61	11,246.22
City Acct.	
½ of 1% on 6,414,440.88	32,072.20
5% on 409,672.24	20,483.61
	$588,902.03
Less rentals,	80,069.94
Annual,	508,832.09
Capitalized at 4¼%,	11,972,500.00
Investment,	64,095,082.00
Corrected figures,	$76,067,582.00

Q. In these estimates of cost, have you made any allowance for the expenditures on the Calumet-Sag channel?

A. No.

Q. What amount has been expended up to the present time on account of the Calumet-Sag Channel work, including engineering, but exclusive of overhead charges?

A. To December 31, 1913, about $2,080,000, has been expended on the Calumet-Sag Channel. This includes the construction of the channel, purchase of right-of-way, engineering, legal and real estate expenses; but no allowance for overhead or interest upon the money invested. The additional liability incurred on account of contracts that have been awarded is about $3,300,000. This brings the total amount of the liabilities up to about $5,380,000.

Q. What do you estimate the cost of the Calumet-Sag Channel, for a diversion of say 2,000 cubic feet per second?

A. The estimated cost of the completed project is $14,290,000. This is made up of the items as given in the following table. This includes the construction of the channel for a capacity of 2,000 cubic feet per second, with controlling works, intercepting sewers to bring the sewage to the channel from the principal centers and for the sterilization of certain storm overflows, land, engineering and contingencies.

CALUMET SAG CHANNEL

2000 C. F. P. S.

Canal Proper, incl. Eng. & Con.		$8,140,435.00
Contingencies 10%,		814,043.00
Interest during Constr.—		
Allow for three years at 4¼% on,	$8,954,478,	1,141,695.00
Old Accounts—		
Main Channel Extension,	$458,082.50	
Bridges,	179.08	
Engineering Expense,	32,969.69	491,231.27
Interest on $491,231.27 1 year at 4¼%		20,877.33
		$10,608,282.53
Intercepting Sewer (1930) at 900 gals. P. Cap,	$1,468,045.00	
Pumping Stations (Bldgs. 1930 Eq. 1920,	617,025.00	
Disinfection Plants,	489,054.00	
Sewers account West Hammond, Harvey and Hegewisch,	177,214.00	
Land,	100,850.00	
	$2,852,188.00	
Eng. & Conting. 15%	427,828.00	
	$3,280,016.00	
Inter. during Constr.—		
Allow 3 years at 4¼%	401,802.00	3,681,818.00
Total cost,		$14,290,100.53
Capitalized operating cost of Channel, etc,		1,424,500.00
Capitalized operating cost sewers, etc., as of 1920,		3,734,870.00
Total, Capitalized and Construction,		$19,449,470.00

Q. What is the capitalized operating cost of the Calumet-Sag Project?

A. The capitalized operating cost of the channel is $1,424,500, and of the sewers that are to be constructed in connection with it $3,734,870, bringing the total capitalized cost and construction cost up to $19,450,000 in round numbers.

Q. You spoke awhile ago about the channel as designed for an enlargement to capacity of at least 4,000 cubic feet of

water per second. What will be the cost to bring it up to that figure?

A. The construction cost of the Calumet-Sag Project for a diversion of 4,000 cubic feet per second is estimated to bring the total construction cost of this channel when enlarged to 4,000 cubic feet per second up to $19,925,000. The capitalized operating cost would be, $6,229,000. The total capitalized cost and construction cost will be $25,729,000, in round numbers. The following is an estimate in detail, giving these figures:

CALUMET-SAG CHANNEL.

4000 C. F. P. S.

Cost of 2000 C. F. P. S. project,		$14,290,100.00
Additional to widen channel,		5,000,000.00
Interest during Constr., say 2 years at 4½% ($200,000) (12,500)		425,000.00
Additional to bring equipment Pump Sta., etc., up to 1930.		
Pumping Sta.	$ 75,000.00	
Miscellaneous sewers, etc.	135,000.00	210,000.00
Total Construction Cost,		19,925,100.00
Capitalized Operating Cost (as of 1930)		
Total for sewer,		4,216,800.00
Total for channel,		2,012,740.00
Total Capitalized and Construction cost,		$25,729,640.00

Q. Did you state the capacity of the Main Channel from the terminus of this Calumet-Sag Channel to the controlling works?

A. That is 14,000 cubic feet per second.

Q. What are the summarized construction costs and capitalized costs, gross, for the works required to dispose of the sewage within the boundaries of the Sanitary District, on a dilution basis, for diversions of various amounts, 10,000-12,000 and 14,000 cubic feet per second?

A. The following is a table giving these costs for the different flows asked for in the question:

Flow Cu. Ft. Per Sec.	Investment of of Construction cost	Annual Cost Operating Plus Depreciation.	Capitalized Gross Cost.
10,000	$64,095,082.00	$508,832.00	$76,067,600.00
+2,000	+14,290,100.00	+219,273.00	+19,449,470.00
12,000	78,385,182.00	728,105.00	95,517,070.00
+2,000	+5,635,000.00	+58,133.00	+7,002,840.00
14,000	84,020,182.00	786,238.00	102,519,910.00

Q. What is the cost of the electrical development of the Sanitary District?

A. The cost to December 31, 1912, was $5,349,241.57. This comprises the book account valuation of the electrical development of $5,047,625.57, plus an allowance made to have this cost comparable with the other costs for the purpose of our analysis, the allowance covering interest during construction, taken at 4½% on the cost during construction for ½ the period during which these works were being built.

Q. What are the summarized construction costs for the works required to dispose of the sewage of the inhabitants of the Sanitary District for the diversion of various amounts, say 10,000—12,000 and 14,000 cubic feet per second, on a net basis, making allowance for any income from the hydro-electric power works?

A. I have prepared a table, which is given below, giving these costs. It gives the investment cost on the construction, the annual cost of operation and the gross capitalized and construction cost and the capitalized electrical credit; and this is subtracted in the last column from the gross capitalized cost. The allowance for the income coming from the electrical department are based on the value in the Chicago market for electric energy used for commercial purposes; and is based on what could be developed over that which could be developed with a flow of 4,167 cubic feet per second.

The present electrical plant and equipment is sufficient to generate the energy coming from the flow of 14,000 cubic feet per second, with the possible exception that one electrical and water wheel unit would have to be installed, provision for which has been made.

NET CAPITALIZED COST DILUTION SCHEME.

Flow Cu. Ft. per Sec.	Investment or Construction	Annual Cost Operating Plus Depreciation	Capitalized Gross Cost	Electrical Credit Capitalized	Net Capitalized
10,000	$64,095,082.00	$508,852.00	$76,067,600.00	$13,242,000	$62,825,600
12,000	78,385,182.00	728,105.00	95,517,070.00	17,790,000	77,720,070
14,000	84,020,182.00	786,238.00	102,519,910.00	22,306,000	80,213,900

Q. Will you state the cost of the works built inside the limits of the Sanitary District of Chicago for supplying water to the people inside the corporate limits of the Sanitary District of Chicago? Will you also state the cost within the same corporate limits for the collection of sewage? Summing these up with the amount expended by the Sanitary District for the removal of sewage, also state what is the total expended for the entire scheme for supplying water and collection of sewage and the removal of sewage to date?

A. Since the sewerage system was started to be installed in 1855, the City of Chicago has expended, up to December 31, 1912, $31,867,268.68. This is exclusive of any intercepting sewers. The sewer systems in the outlying villages and towns up to an average period of 1911, had cost $5,246,764.16.

The water supply system of the City of Chicago up to December 31, 1912, had cost $49,948,318.06. The water supply system of the outlying villages and towns within the Sanitary District, so far as the same can be obtained, has cost about $2,000,000 for five towns out of seventeen outside of Chicago, but inside the Sanitary District. No allowance is made for interest during construction in these figures. Adding the expenditures of the Sanitary District as given above, brings the total amount expended for water supply and sewage disposal up to the total sum of $150,908,189.64. If all charges could be obtained and the methods of work known, this figure would be materially increased.

Q. Now, you have described the various works of the Sanitary District. What is the general purpose, exclusive of the electrical development?

A. The purpose of the works of the Sanitary District of Chicago is to provide for the proper and efficient sewage disposal, and to protect the water supply from pollution; and in so doing to so dilute the sewage that local nuisances will be prevented within the corporate limits of the Sanitary District; and to dilute this sewage with a minimum flow of 3½ cubic feet per second for every 1,000 people sewering into the channels of the District, so that nuisances will be prevented

in the Des Plaines and Illinois Rivers below the end of the works of the Sanitary District.

Recess to 2:15 P. M.

After Recess 2:15 P. M.

GEORGE M. WISNER, resumed the stand and testified further as follows:

Mr. Adcock: Q. Mr. Witness, do you consider this minimum legal ratio of dilution, which you referred to in your last answer, adequate for the conditions in the Sanitary District of Chicago?

A. For the disposal of the domestic sewage, I consider that 3½ cubic feet per second per thousand people draining into the channel is sufficient.

Q. What is the effect of the main channel upon the Chicago River, the Des Plaines River from Joliet to the Illinois River, and on the Illinois River?

A. The effect of the flow through the Main Channel is to dilute the sewage coming from the Sanitary District to such an extent that it avoids all local nuisances in the Main Channel itself, and in the Des Plaines and Illinois Rivers. It flushes out the Chicago River, and the Des Plaines River from Joliet to the Illinois River is thoroughly flushed under summer conditions; whereas, formerly there was practically no flow in the Des Plaines River north of the junction of the Kankakee and the Des Plaines. This continued for many months in the year.

In the Illinois River, the effect has been to produce a constant flow, and it has improved the conditions of the water of the Illinois River all the way to the Mississippi River, over what it was under summer conditions.

The effect has also been to improve the navigation in the Des Plaines and the Illinois Rivers, by increasing the dry weather flow and giving greater depths. This also, as stated, has improved the sanitary conditions, by affording increased dilution for the cities and towns sewering into the river below Chicago.

The value of the water powers on the Illinois River has also been increased, by increasing the flow.

The value of the fish and mussel industry in the Illinois River has materially increased since the opening of the Main Channel. In my opinion this improvement is almost wholly

due to the maintenance of a cleaner condition of the river, and the additional food furnished by the products of the self-purification of the stream for supporting fish life.

Q. What has been the improvement in the Illinois River, with reference to the preservation of fish life, since the opening of the Drainage Canal?

A. The fishing industry has gradually increased in value. The figures given in the special report of the United States census for 1908, on the Fisheries of the United States show that the fisheries in the Illinois River have grown as follows:

Year.	Tons.	Value.
1894	3,000	$162,000
1899	7,000	382,000
1908	23,000	860,000

Besides the growth of the fishing industry, there has been a great increase in the mussel industry. The mussel shells are used for making buttons. This is shown by the following table, taken from the special report of the United States census, 1908:

Year.	Tons.	Value.
1894	24	$ 700
1899	2,500	43,000
1908	20,000	184,000

And in that time there was also $170,000 worth of pearls taken from these mussels. From the investigations of the Sanitary District, it appears probable that the amount of fish now caught exceeds the figure given by the census of 1908.

Q. Will you describe briefly the conditions in the Chicago and Illinois Rivers prior to the opening of the Chicago Drainage Canal?

A. I have described the conditions in the Chicago River prior to the opening of the canal in the former answer. The Illinois River was a slow, sluggish stream in the summer time, having a very small discharge, and in times of run-off of melting snows and heavy rains, the discharge was quite voluminous. The condition of the river was that it was a polluted stream, particularly below Peoria where the sewage from Peoria and the wastes coming from the distilleries polluted the water to such an extent that it was practically a nuisance. From a navigation standpoint there was some little navigation maintained by dams, which produced slack water, and it was generally navigable from Utica to the Mississippi.

I would say in this connection about the condition of the Illinois River, that we have since 1909 made regular examinations, both chemical and bacteriological of the waters of the Illinois River, showing the effects of the Drainage Canal upon the Des Plaines and the Illinois Rivers, and it shows that the waters are in good shape from the standpoint of the oxygen content below Marseilles. This we have carried on continuously for the last several years.

Q. You mean this investigation?

A. This investigation.

Q. Will you briefly describe the present condition of the Main Channel from the standpoint of odors and the location of deposit?

A. We have carried on the same investigations in the Main Channel, in regard to the condition of the combined sewage and fresh water, by having the water analyzed regularly. Up to the present time pretty nearly all of the manufacturing wastes from the city have been going into the sewage and channel without any preliminary treatment. There has been some slight treatment by means of removing part of the settling solids from certain industries. The result has been that there has been large accumulations of deposits in certain parts of the channel, where at times in the hot weather local nuisance is present; but the condition is now so much better than it was prior to the opening of the canal, which parallels the old Illinois and Michigan Canal, which prior to 1900 ran its capacity full of septic sewage, water and mud, so that the improvement down the Des Plaines Valley has been considerable, but at the same time there has not been sufficient water to take care of and properly oxidize both the domestic sewage and the manufacturing wastes, coming from the large industries in this city. There are large deposits of sewage mud in the Main Channel from the end of the narrow earth section that I have spoken of to Willow Springs where the rock section starts. There is practically no sludge deposits in the rock section until Lockport is reached, where the Main Channel was widened out for the purpose of making a basin at the controlling works, and in the stretch of the new channel built for the development of water power. In these stretches of the channel, there have been big deposits which in the summer time produce gas and are in a fair way to make a local nuisance. In the vicinity of the controlling works, odors are at times perceptible. This is where the deposits occur principally.

Q. Can you state what the population of the District has been since 1900, up to and including the present time?

A. Yes.

Q. Will you state what the average flows have been in the Main Channel, with reference to the minimum ratio provided by law?

A. In the last few years, it has been practically what is called for by the law, but prior to that it was not up to what was called for by the State law, for the reason that the Chicago River had not been improved and the District was restrained by the Secretary of War from causing a current in the South Branch of the River to exceed a mile and a quarter an hour. For that reason, the flow in the early years of the canal was not what it should have been or what was called for by the state law; that is 20,000 cubic feet per minute for every 100,000 people draining into the channel.

Q. Have you prepared a tabulation showing the population within the limits from year to year between 1900 and 1913, and the average daily flow in cubic feet per second based on the population as provided by the state law?

A. Yes, sir.

Q. Will you kindly give that to the Commissioner?

A. The following is the table:

Year	Population Based on U. S. Census		Average Daily Flow in Cu. Ft. per Second Population Basis	
	Within Corporate Limits S. D. C.	Actually Tributary M. C.	Total	Actual
Original Limits				
1900	1,638,656	1,294,312	5462	4314
1901	1,690,874	1,331,119	5636	4437
1902	1,740,129	1,364,961	5800	4569
1903	1,789,593	1,399,014	5965	4663
Territory Annexed				
1903	1,933,694	1,543,115	6445	5144
1904	1,987,205	1,581,376	6624	5271
1905	2,040,717	1,614,228	6802	5381
1906	2,094,228	1,887,605	6981	6292
1907	2,147,740	1,933,176	7159	6444
1908	2,201,250	1,978,744	7337	6596
1909	2,254,763	2,091,015	7516	6970
1910	2,308,276	2,139,787	7694	7132
1911	2,361,788	2,188,524	7873	7295
1912	2,415,300	2,237,330	8051	7458
1913	2,468,811	2,285,993	8229	7619
Territory Annexed				
1913	2,498,660	2,285,993	8329	7619

Q. Mr. Wisner, the flow of the water through the channel, has that been approximately the figures as indicated in the last column of that table?

A. Yes, sir, subsequent to 1908.

Q. Do you have any comments to make upon the tabulations made with reference to the actual flow further than you have stated?

A. Only to this extent, that in the early part of 1908, the water power plant was installed, and the only way of measuring the water that went through the canal was to use the water wheels as a meter. These wheels had been tested in a flume at Holyoke, by which in an approximate way we could get at their discharge under different gate openings.

I have found out, however, recently that these discharges are somewhat small, and through some investigations that we have been making and are making, I think that the flow as indicated in the last column from 1908 on is somewhat small. This is based upon measurements made by myself, and some that have been submitted to me made by the United States Government.

Q. The amounts shown to have been discharged through the Main Channel of the Sanitary District in the last column, does that include lake water, sewage and storm water and everything?

A. It includes everything that passes through the end of the canal at Lockport.

Q. What in your opinion has been the hygienic improvement in the Chicago water supply, if any, due to the opening and operation of the Main Channel and its appurtenances?

A. The improvement was very marked after all the sewage had been diverted from the lake. The intercepting sewers were not wholly completed until 1910, but were practically completed on the south side in 1906 and on the north side in 1908. Since that time, the reduction has been more marked in the typhoid fever death rate, so that today the water supply from the criterion of typhoid fever death rate compares very favorably with other large cities in the United States and in Europe. The typhoid fever death rate is lower than in many cities having filtered water supplies. In 1912, Chicago's typhoid fever death rate was 7.5 per hundred thousand. From 1909 to 1912, the typhoid fever death rate in Chicago was lower than that of Pittsburg, Philadelphia, Washington and New Orleans, all of which have filtered water supplies. The rate was also lower in Chicago than in other

cities having filters; namely, Albany, Atlanta, Birmingham, Columbus, Grand Rapids, Indianapolis, Louisville, New Haven, Oakland, Providence, Scranton and Toledo.

Q. Have you made any study to show the probable population discharging sewage into Lake Michigan subsequent to the opening of the Main Channel, first with reference to the District as a whole, and secondly the city water front immediately adjacent to the intakes?

A. I have made such a study, using the shore line within the present limits of the Sanitary District as a guide, to show the population discharging into Lake Michigan after the opening of the Main Channel. The results are given in the following table. This table shows the total population located in Chicago, the north shore towns and the Calumet district, which drains its sewage into the lake, on January 17, 1900:

After the opening of the Main Channel, January 17, 1900.

POPULATION DISCHARGING INTO LAKE MICHIGAN INSIDE PRESENT SHORE LINES OF THE SANITARY DISTRICT.

Year	Total	Between 87th Street and South Boundary of Evanston
1900	344,344	223,625
1904	405,829	265,940
1905	426,489	281,708‡
1906	206,623	57,100
1907	214,564	60,300
1908	222,506	63,500†
1909	163,748	0
1910	168,489	0
1912	177,970	0

‡39th Street pumping station district diverted in 1905.

†Lawrence Avenue pumping station district diverted in 1908.

Q. And this lesser number from year to year, as indicated upon this table, of population discharging into the lake and within the present shore lines is due to the fact that intercepting sewers were opened from time to time, and the sewage of the population discharged into the Main channel where it is tributary to the Sanitary District, is that correct?

A. Yes, sir. The third column of the table shows the population between 87th street in Chicago on the south and Evanston on the north, that has drained into the lake since the opening of the channel.

Q. And the second column shows the total?

A. The total including Evanston and the Calumet District.

Q. And prior to 1900, all of the sewage substantially was drained into the lake?

A. Substantially, with the exception of what was pumped through the old Illinois and Michigan Canal.

Q. What is the effect of the sewage from the towns in Lake County, Illinois, on the water supply of Chicago?

A. The effect of the sewage from the towns in Lake County, Illinois, is practically nill on the water supply of Chicago. These towns include Highland Park, Lake Forest and Waukegan. There are no currents in Lake Michigan, other than varying drifts produced by the wind. The sewage discharge in Lake County nearest the Lake View crib is over 16 miles away. The population is small, so that the protection to Chicago by dilution and storage and consequent death of pathogenic bacteria probably suffices for many years to come. The danger is to the water supply of the villages themselves more than to the City of Chicago proper.

Q. What is the effect of the sewage from the towns in Lake County, Indiana, on the water supply of Chicago?

A. The effect of the sewage from the towns in Lake County, Indiana, on the water supply of Chicago, as taken from the 68th Street or the Dunne cribs is largely influenced by the condition of the Calumet River, into which these towns discharge a part of their sewage. Flood discharges will heavily pollute the water of the lake around the crib. In drier weather, pollution may occur with sudden rains. The pollution has been traced eight to ten miles into the lake.

The district is taking steps now to reverse the Calumet River and to keep the sewage coming from the Sanitary District out of it, so that in times of flood the water in the river will not be polluted with sewage. It is also negotiating with the Indiana towns to get them to remove or purify their sewage before it enters the lake or the Calumet River, to such an extent that it will be non-putrescible.

Q. Have you made an examination at or about the present time with reference to the quality of the Chicago water supply?

A. Yes, sir.

Q. What is it?

A. The typhoid fever death rate shows that the quality of the Chicago water supply is excellent from a hygienic standpoint, and is far purer than most of the larger municipal supplies in the United States.

The 68th Street and Dunne cribs on the south, and the

Lake View crib on the north are, however, exposed to possible pollution.

Q. That is in the manner you have just mentioned, is it not?

A. Yes, sir, and on the north on account of Evanston not having diverted its sewage as yet. The effect on the Chicago water of outside pollution from the north of the Cook County line is very remote. Pollution from the Calumet region in Indiana is very intermittent, but may be severe in its effect on the 68th Street and Dunne cribs.

The effect of pollution coming from passenger vessels and other vessels is being minimized by the action of the city in keeping the vessels away from the intakes, and to have the closets locked, or tanks to store the sewage in while the vessels are passing in and out of the harbor. The shipping factor is particularly of moment in the summer months. This chiefly affects the cribs at the mouth of the Chicago River.

In the recent storms, this fall, the water supply of the city has been extremely turbid at times and in consequence the newspapers have quoted the Health Department as advising the boiling of the water. The condition of the water and the attitude of the Health Department was investigated by the Engineering Department. The records of the analysis made by the Health Department laboratory shows practically no difference in the hygienic quality of the water on account of the storms. The turbidity or aesthetic appearance of the water was, however, unsatisfactory. The Health Commissioner, Doctor Young, and his labortory director, Doctor Tonney, both admitted advising the boiling of the water in an informal way to the newspaper men, but stated that this was a precautionary measure only, inasmuch as it is impossible to learn the quality of the water by immediate tests. The bacteriological tests employed do not give results until after 48 hours have elapsed. Their opinion was the same as ours, that only the appearance of the water had been injured by recent storms, and that the hygienic quality of the water was unimpaired, rendering boiling unnecessary.

Q. What has been the improvement, if any, in the typhoid fever death rate in the City of Chicago since the opening of the Drainage Canal, and please also state the reduction of the death rate from diarrhoeal diseases; and whether this reduction in typhoid fever death rate has been as great as the same has been in other cities of the United States, during the same period of time?

Mr. Hopkins: I think the witness ought to be required to state the basis of all this testimony, because he cannot know all that he has testified to here, and we would like to have the source of it.

Mr. Adcock. Q. State the source. The death rate from typhoid fever and diarrhoeal diseases that you have referred to and the conditions pertaining to same are from what statistics?

A. From the records of the Health Department of the City of Chicago.

Q. They were produced upon a previous hearing?

A. That is my recollection.

For 13 years prior to the opening of the Drainage Canal, the average typhoid fever death rate was 52.6 per one hundred thousand. For the 13 years after the opening of the canal, the death rate was 19.9 per one hundred thousand. This reduction is about 68 per cent., and would have been more marked had the sewage been intercepted completely earlier in this period.

Q. That is in the last 13 years?

A. In the last 13 years. The average death rate for the diarrhoeal diseases for the period before the opening of the drainage Canal was 418.2 per one hundred thousand. This was reduced to 187.2, a reduction of 55 per cent.

The typhoid fever death rate in Chicago has been reduced markedly, even compared with the reductions affected in cities where filtration plants have been installed. The rates for 1911 and 1912 were lower than the rates in the cities of Philadelphia, Washington, Pittsburg, and New Orleans, where filtered water is supplied. They are as low as in Boston and lower than San Francisco where the water sheds are carefully watched and pollution is kept out of the reservoirs.

Q. What is the present cost of typhoid fever to this community, and what are the costs which the community would have been called on to bear if the typhoid fever death rates prior to the opening of the Drainage Canal had been maintained.

Mr. Hopkins: Objected to as not within the witness' knowledge and no reliable statistics are obtainable; and it is impossible of determination.

A. This is best shown by Wisner Exhibit 3, January 20th, 1914, on which the various costs to the community are indicated. These costs are made up on the assumption that a life is worth $10,000 as fixed by certain statutes in Illinois, and

with allowances for the cost of nursing, medical attendance, drugs, loss of wages, and funeral expenses in the case of death. The ratio of deaths to cases has been taken at ten per cent.; that is for every death reported there has been assumed at least ten cases. Two curves are plotted for the probable costs if the channel had not been built, one figured on the average rate of typhoid fever deaths for the 13 years prior to the opening of the canal, and other figured on the average of the four worst years from 1890 to 1893 inclusive.

(Chart identified by witness was marked Wisner Exhibit 3, January 20th, 1914.)

Q. The chart which you have referred to and which has been marked Wisner Exhibit 3, that has been made up under your direction, upon the premises which you have just stated?

A. Yes, sir.

Mr. Adcock: It is offered in evidence.

Objected to by counsel for the complainant.

Q. Has the same improvement in typhoid fever death rates been observed in the Calumet region of Indiana, adjoining the Sanitary District of Chicago?

A. No, sir.

Q. Have other cities of size around Lake Michigan shown improvement in their typhoid fever death rate during the last 12 years, as compared with the previous 20 years? Has the improvement in any degree been comparable to that in Chicago?

A. No. In Milwaukee, for instance, the typhoid situation has been practically unchanged for over 30 years, the rate at times being practically as high as 30 years ago. The improvement in Chicago has been very favorable. In Michigan City, a city of 19,000 people in 1910, the typhoid rate has been high, with violent fluctuations, extending over a range of from nothing to 112 deaths per one hundred thousand between 1882 and 1907.

Q. From what source did you get the information?

A. From the reports of Boards of Health and Health Commissioners of the different cities, and published statistics of the United States census, and every available source; some of it from government reports made in the geological survey.

Supplementing my answer to a previous question, I desire to state: The same improvement in typhoid fever death rates in the towns in Indiana, adjoining Illinois, has not been ob-

served. The current typhoid fever death rates are shown on Wisner Exhibit 4, January 20, 1914.

These are for the towns of Hammond, Whiting, East Chicago and Gary, Indiana. Whiting and East Chicago discharge their sewage directly into the lake in the neighborhood of their water supplies, and Hammond and Gary discharge their sewage into the Calumet River, thereby affecting at times their own water supply and that of the City of Chicago taken from the 68th Street Cribs. The conditions in Indiana adjoining the Sanitary District are very unsatisfactory.

Referring to Exhibit Wisner Number 4, you will notice that for Whiting in 1908, they had a death rate of 140 per one hundred thousand, where Chicago had a death rate of about 16 or 17. The effect of keeping the sewage out of the water supply of Chicago is shown very markedly by this exhibit, in that since 1904 there has been no marked epidemic of typhoid, whereas all of these other three towns lying adjacent to Chicago and having practically the same milk supply, same foods, and generally the population being of the same general character as that of Chicago, have had several epidemics as shown by the peaks on these so-called curves, which give the death rates per one hundred thousand of the people living in these towns.

Q. The line on that chart shows that Chicago has had no epidemics, and is gradually going down?

A. Since 1902, Chicago has had nothing that represents an epidemic, and the line from 1904, the solid line on this exhibit, which represents the death rate from typhoid fever in Chicago, has been gradually going down, showing a decrease in the typhoid fever death rate.

(Chart produced and identified by the witness was marked Wisner Exhibit 4, January 20, 1914.)

Q. Assuming that 4,167 cubic feet per second is allowed as the diversion from the lake through the channel, what would be the effect on the water supply and sewage disposal facilities of the District?

A. The effect of a diversion of only 4,167 cubic feet per second would injure the quality of the water supply and seriously disturb the sanitary conditions in the Chicago River, the Desplaines and Illinois Rivers; and the water supply would be subjected to pollution, since the reversal of the flow of the Chicago River could not be prevented. This might occur on periods equivalent to six to 10 days per year.

The immediate effect on the canal would be to cause the line of no oxygen to come close to the city. By that I mean that all of the oxygen in the diluting water would be used up probably before the combined sewage and water got into the canal. Anaerobic conditions would prevail at Lockport, and a nuisance would result in the Desplaines River at Joliet which would be serious. Sludge banks would form along the whole length of the channel. This would increase the odors and cause a nuisance.

The Illinois River would also be affected, since the dilution would not be sufficient to balance half of the oxygen requirements. This would tend to spread anaerobic conditions down the river, and would interfere with the fishing industry, ending fish life until down as far as south of Peoria. Nuisance would occur at Morris, Marseilles, Ottawa, and Peru, and possibly Chillicothe, and there might be nuisances below Peoria.

In my opinion, it would be impossible to construct remedial works of problematical efficiency in less than ten years. If the flow were limited at any time before the completion of these works to 4,167 cubic feet per second, with a constantly increasing population, intolerable conditions would arise in the canal, the Desplaines River, through Joliet and in the Illionis. Conditions in large portions of the Chicago River proper would be a living nusiance.

Q. Sludge would accumulate in the Chicago River?

A. Yes, sir.

Q. What would happen to this in times of high water when the river were reversed as you just mentioned?

A. Then this accumulation of sludge would probably be scoured into the lake, polluting the water supply.

Q. Along with the sewage?

A. With the sewage polluted water of the river itself.

Q. Assuming that the flow is reduced at once to 4,167 cubic feet per second, do you know of any emergency treatment to tide over the nuisances which would accrue until the remedial works described by you could be constructed?

A. I know of no thoroughly satisfactory emergency treatment. If the flow were continued in accordance with the minimum ratio of 3½ cubic feet per second, a double expense would be thrust upon the Sanitary District, as it would have to develop the canal to a capacity of 12,000 cubic feet per second before the other works could be put into service.

The only suggestion would be the use of an excessive amount

of chloride of lime. This would be unsatisfactory, as the sludge would still go into the river and create nuisance, and in addition would be very costly. Time would be required to install emergency works on such a large scale.

Q. Have you made any estimate with reference to the floating population of the City of Chicago, or is there one that you have in mind?

A. Yes, sir; I have had one made. I estimate that the daily floating population by 1920 in Chicago will be 300,000 people. I have found that there is to-day a transient population of 68,000,000 in the course of a year, including through and local travellers from outside the boundaries of the district, who may be assumed to come in contact with conditions in the City of Chicago.

Q. From what sources did you obtain the figures upon which the estimate is made?

A. I am of the opinion that the estimate is small, if anything. I got all the records obtainable from the different railroads coming into Chicago and complied these figures from figures given to us; and also from steamship companies. I had the people counted coming into the stations for a certain length of time to get an estimate of the number of people where the railroad companies had no sufficient data at hand.

Q. Have you computed the probable population of the Sanitary District in the years 1920, 1930 and 1940?

A. I have. This is based on the United States census reports, and upon the probable growth of the city in the future as based upon what it and other large communities have done in the past.

Q. Have you computed the amounts of water required for the population based upon the minimum legal flow for dilution?

A. Yes, sir; I have.

Q. Will you state what that is; and also your compilation with reference to future population?

A. It is as follows:

Year	Population	Flow required in Cu. Ft. per second
1910 Actual	2,308,276	7694
1920	3,110,036	10367
1930	3,866,023	12887
1940	4,466,000	14900

Q. What are the available methods in your opinion for

sewage disposal open to cities of large size, according to modern practice?

A. The available methods for the sewage disposal of large cities comprise dilution, screening of the sewage, sedimentation, which is the removal of the settling suspended matter by settling in various types of tanks, chemical precipitation, broad irrigation or land irrigation, intermittent filtration, contact beds and sprinkling filters. These methods may be used in combination, according to local circumstances or conditions. Sterilization by the use of chloride of lime, or liquid chlorine, may also be used on raw sewage and effluents of treatment works.

Screening is useful principally to remove coarse floating material. Sedimentation may remove most of the settling suspended matter, and improve the stability of the liquid from 15 to 25 per cent. Chemical precipitation will remove somewhat more of the settling suspended matter and some of the colloidal matter. In order to make a stable effluent after the suspended matter has been removed, treatment to oxidize the organic matter is required. This is frequently carried out in bacteria beds or biologic filters. Such broad processes include broad irrigation, intermittent filtration, contact beds and sprinkling filters. These methods, however, are not all equally practicable.

The methods of broad or land irrigation and intermittent filtration require very large areas of land. In the United States, broad irrigation is practically abandoned, save in the arid regions, where it is of value principally for the water rather than for any other purpose. Intermittent filtration is not now installed for large cities, but is considered practicable for small towns under 10,000 population, where sand is cheap and land valuable. Sprinkling filters and contact beds are more practical for large cities as a larger population can be taken care of on smaller areas. Of these two, the sprinkling filter is most economical and efficient, as a rule.

Q. Of these methods, which do you consider best adapted to the conditions existing in the territory comprising the Sanitary District of Chicago, taking into account the protection of the water supply, disposal of sewage, and the removal of local conditions of nuisance?

A. The dilution method, by the use of the main channel and a supply of water from Lake Michigan, is the most economical and efficient, the surest and the most effective, in that it diverts all the sewage from the water supply, and works automatically; is not dependent upon any individual

or individuals for its efficiency; and permits of self-purification of the sewage in the ordinary and natural way.

Q. What methods are available, other than dilution, for handling the sewage of the Sanitary District in case the flow required by the legal ratio is restricted?

A. Settling would be the first step to bring about the removal of settling suspended matter. This could be followed by the use of sprinkling filters to produce a stable effluent, as required. Secondary settling basins would probably have to be used to remove the humus formed in the sprinkling filters. Sterilization by chloride of lime or liquid chlorine might be utilized on storm flows and sewage effluents as required by circumstances.

Q. From your studies and observations of the local situation and the estimates presented in this suit, what allowance have you made for the industrial load, that is for the effect of industrial wastes upon the oxidizing capacity of the canal?

A. No allowance has been made for the industrial load, as it is recognized that whatever happens the industrial sewage would have to be cared for in any case. This means that the cost of handling the industrial sewage would be additional to all of the comparative estimates submitted, in this testimony. This has been recognized by the Board of Trustees, and special studies are now being conducted by the engineering department of the District to determine the methods of treatment for the industrial wastes, principally for those of Packingtown and the Stock Yards, and for the tanneries.

Q. Briefly, what is the average dry weather flow as shown by the gagings of the Sanitary District from typical sewage?

A. The dry weather sewage flows vary from 170 to 600 gallons per capita. An average flow of 300 gallons, about, per capita, has been estimated from a study of the flows actually found on various typical areas by gagings made by the Sanitary District of Chicago. The storm flows vary considerably. Maximum storm flows have been found from 50 to 70 cubic feet per second per square mile on areas of some size, with a maximum of 128 cubic feet per second per square mile on small well built areas. Intercepting sewers planned for a flow equivalent to 900 gallons per capita daily are required to care for the first rush of storm flows, and the minor storms.

Q. Assuming that 4,167 cubic feet per second of water are available from Lake Michigan for dilution, what will be the

cost to the Sanitary District for handling population equivalent to diverted flows amounting to 10,000—12,000 and 14,000 cubic feet per second?

A. The costs to the Sanitary District for these additional works are given in the following table:

COST OF CONSTRUCTION FOR SEWAGE TREATMENT ON ASSUMED DIVERSION OF 4167 C. F. P. S.

Items	Equivalent to Diversion of 10,000 c. f. p. s.	
Population Distribution Treatment		Net Load in Population.
Lawrence Ave,		997,000
West Side,		0
39th Street,		944,000
Calumet,		207,085
Dilution	1,562,500	
Less Floating,	300,000	
	1,262,000	
Less Factor Safety,	362,000	
Net	900,000	900,000
		3,048,085

Costs	
Lawrence Ave,	$17,595,582.00
West Side,	7,170,045.00
39th Street,	17,549,206.00
Calumet,	5,106,957.00
Storm Water Disinfection,	1,545,988.00
Domestic Sewage Disinfection,	600,000.00
Aeration,	1,065,000.00
North Shore,	1,192,280.00
Public Utilities,	3,453,570.00
Paving,	365,843.00
	$55,644,471.00

Forward, ...	$55,644,471.00
Interest during Construction, 21-1/4%.....	12,500,000.00
Legal and Administration, 10%.....	4,740.000.00
	$72,884,471.00

Population equivalent to a diversion of 12,000 c. f. p. s.,.....	3,600,000.
Population Equivalent to a diversion of 14,000 c. f. p. s.....	4,200,000.

Cost Pro-rated from Cost for Equivalent to Diversion of 10,000 C. F. P. S.

Pro-rated for increase of population from 3,000,000 to 3,600,000 equivalent to a diversion of 12,000 c. f. p. s.....	$87,200,000.00
Pro-rated for increase of population 3,600,000 to 4,200,000 equivalent to a diversion of 14,000 c. f. p. s.....	101,900,000.00

Q. Does this table show the expense to which the District would be put if the supplementary works required with the lessened flow of water are built?

A. Yes, sir, it does. No allowance has been made for the cost of the existing works in this table. The total costs of the projected works on the allowance of 4,167 cubic feet per second, added to the existing works, is given in the following table:

COST OF WORKS FOR SEWAGE DISPOSAL COMBINING COST OF NEW TREATMENT WITH EXISTING INVESTMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Construction Cost of New Works	Construction Cost Existing Works	Total Construction Cost
10,000	$72,884,471	$64,095,082	$136,979,553
12,000	87,200,000	64,095,082	151,295,082
14.000	101,900,000	64,095,082	165,995,082

Q. Have you computed the annual cost for sewage treatment on the same basis and assumption.

A. Yes, sir.

Q. Is that annual cost shown on the table which you now hand the Commissioner?

A. Yes, sir, it is.

The table is as follows:

ANNUAL COSTS FOR SEWAGE TREATMENT ON ASSUMED DIVERSION OF 4167 C. F. P. S.

Item	Basis 10,000 C. F. P. S.
1. General Expenses,	$30,000.00
2. Sewers,	23,000.00
3. Pumping Stations, 4910 W. H. P. at $350	1,820,000.00
4. Sedimentation at $0.15 per capita,	456,000.00
5. Sprinkling filters at 0.10 per capita,	214,800.00
6. Aeration at 0.08 per capita,	171,840.00
7. Disinfection,—	
Storm Sewage,	433,800.00
Domestic Sewage,	370,000.00
	3,519,440.00
8. Depreciation,	1,182,157.00
Total,	$4,701,597.00
9. Pro-rated for increase of population from 3,000,000 to 3,600,000 equivalent to a diversion of 12,000 c. f. p. s.	5,650,000.00
10. Pro-rated for increase of population from 3,600,000 to 4,200,000 equivalent to a diversion of 14,000 c. f. p. s.	6,590,000.00

Q. Do you desire to make any explanation of any of the items included in this last table or any of the other tables?

A. No, sir, I think the table speaks for itself as to what is included.

Q. What does this project or scheme that you have just been referring to provide?

A. This scheme contemplates the construction of intercepting sewers based on a dry weather flow of 300 gallons per capita per day, carrying flows up to 900 gallons per capita per day to Central points for treatment. Above this amount, the storm flows would be discharged into the Chicago River or Calumet River, with sterilization; special tanks being provided to give a contact of 10 minutes on flows based on the maximum peak discharges. Coarse screens and grit chambers are contemplated, with facilities for cleaning. Settling basins are also to be built of the double deck type for dry weather

flow, with capacity up to 900 gallons per capita. Sprinkling filters are estimated for the excess population which cannot be cared for by the extended use of settling tanks. The estimates include the sterilization of all the sprinkling filter and settling tanks effluents before being discharged into the Chicago River or the Canal. The double deck tanks would be designed on a basis of two hours retention of 300 gallons per capita daily in the settling chamber, and six months retention of sludge. The sprinkling filters would be designed on a basis of 12,500 people to the acre, the filters being assumed to be 6 feet 4 inches in depth of filtering stone. Secondary settling tanks are to be used for the filters, nominally of half the size of the primary settling tanks.

Q. What is the basis of the construction estimates given in your last answer?

A. The estimates given are based on the current cost of sewer construction in the City of Chicago, due allowance being made for the probable character of the work, the cost of labor and material, and the character of the excavation to be made. The cost of the pumping station is based on $500 per water horsepower, the amount being adjusted slightly to scale down for the larger installations. Such costs are based on the known cost of the existing pumping stations in the city of Chicago. The cost of the settling tanks and appurtenances is based on careful estimates made from detailed drawings for a unit plant designed to care for 40,000 people. The appurtenances include a Venturi Meter, grit chamber, sludge drying beds, office building, laboratory, walkways, roadway, electric lighting, and the general appurtenances required. The cost of land has been estimated from actual cost of land purchased by the District for its right of way for channels, and current sales of real estate in the city of Chicago. In each case, an allowance has been made for the probable increase in future costs.

Q. What is the annual cost for the above scheme to provide treatment equivalent to flows of 10,000 cubic feet per second, 12,000 cubic feet and 14,000 cubic feet, assuming that only 4,167 cubic feet per second is permitted and allowed?

A. That annual cost is given in the table just submitted. The annual cost submitted upon the table last given by me in this case, is entirely independent of any present operating cost of the Sanitary District.

Q. In making up these annual costs, what have you included in your allowances, if anything?

A. The annual cost includes an allowance for labor, repairs and supplies for the operation of the grit chamber, settling basins, sprinkling filters, secondary settling basins, the cost of labor and supplies for the disinfecting plants; the cost of labor, fuel, supplies, and repairs for the pumping stations; depreciation on all structures; interest during construction at 4½ per cent. for the entire construction cost for one-half the period estimated for construction. The allowance however made on land is the interest on the cost for the entire period. In the making of the estimates for sterilization, chloride of lime has been used as a sterilizing agent for the effluent of settling basins and sprinkling filters, whereas liquid chlorine has been estimated for handling the storm flows, in order to have available a large potential supply of chlorine for immediate use on sudden storms.

Q. What is the capitalized cost of the foregoing schemes, including in your capitalization the construction cost, as well as the capitalized cost for maintenance, operation and depreciation?

A. These costs are given in the following table:

CAPITALIZED COSTS OF SEWAGE TREATMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Construction Cost	Capitalized Operating and Depreciation Cost	Gross Capitalized Cost
10,000	$72,884,471	$110,625,800	$183,510,271
12,000	87,200,000	132,941,100	220,141,100
14,000	101,900,000	155,058,800	256,958,800

Q. Are these costs in the table which you have just testified to supplemental to the present expenditures made by the Sanitary District which have been given by you as construction and operating costs?

A. Yes, sir.

Q. What are the combined total costs, covering construction and capitalized annual maintenance and depreciation, combining the existing investment of the District with the investment required to produce with a reduced flow of 4167 cubic feet per second the equivalent of conditions of flow of 10,000—12,000 and 14,000 cubic feet per second?

A. These are given in the following table:

CAPITALIZED COST OF SEWAGE DISPOSAL COMBINING COST OF NEW TREATMENT WITH EXISTING INVESTMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Capitalized Cost New Works	Gross Capitalized Cost of Existing Works to Dec. 31, 1913	Total Gross Capitalized Cost
10,000	$183,510,271	$76,067,600	$259,577,871
12,000	220,141,100	76,067,600	296,208,700
14,000	256,958,800	76,067,600	333,026,400

Q. What do you estimate the gross resources of the Sanitary District of Chicago to be in the period between 1914 and 1925, based on both receipts from taxes and sale of bonds, assuming that all construction work was stopped on December 31, 1913, and that only the necessary operations for maintenance and operation of existing works for sanitation were continued?

A. I have had studies made of receipts from taxes in the past by the Sanitary District, and a study made of the probable increase in the taxable value of property within the Sanitary District, so as to estimate the amount of bonds that can probably be issued by the Sanitary District, and from these have estimated what the highest possible income could be up to 1925, by issuing all of the bonds it is possible to issue, and getting all of the money from general taxation that it is possible to get, and the amount available from 1914 to 1925 inclusive would be $54,729,000 approximately.

Q. What is your estimate of the actual requirements of the Sanitary District aside from any works necessitated by fixing the available diversion, to round out unfinished details in connection with the present works?

A. I have compiled from the books of the District and from estimates the probable investments required in the next ten years to cover extraordinary repairs and to settle obligations on contracts, assuming that all existing contracts for construction are terminated on December 31, 1913. This includes the amounts necessary to complete the North Shore and Evanston intercepting sewers, to improve the Des Plaines River in the territory recently annexed, to adjust the conditions in the North Branch of the Chicago River, to build certain docks in the Main Channel, repair walls at Lockport and Joliet, and to carry a share of the expense of handling the industrial wastes. This amounts to $11,577,000. This would be deducted from the available resources given in my pre-

vious answer, this reducing the net amount available for new works to $43,152,000 approximately.

I am of the opinion that the amount of $11,577,000 would probably be too small.

Q. In your judgment, what time would be required to build the works covered in your estimates, if a diversion of 4167 cubic feet per second were assumed?

A. I should judge that if it could be done at all, ten years would be required, of which probably the first two years would be devoted to overcoming the inertia and making necessary studies in detail, financial and legal arrangements.

Q. Referring to your estimates of the financial resources of the Sanitary District, would you say that the District could finance the scheme which you have outlined in this working period of ten years, assuming that a diversion of 4167 cubic feet per second is allowed?

A. No, I do not believe it would be possible to finance this with the net revenue available. Not only would the construction costs have to be met, but also certain operating costs, as parts of the works were finished and put into service.

Q. Will you identify the report of Mr. G. M. Wisner, made on October 12, 1911, to the Board of Trustees of the Sanitary District; and will you briefly explain the premises on which it was made?

A. I have the report before me and it is a re-print from the original type of the original report published in the proceedings of the Sanitary District in the official issue of October 26, 1911; and that is the report made by me. In accordance with the instructions of the Board of Trustees, this report was prepared and was presented to the Board. The basis upon which the report was developed was the assumption that 10,000 cubic feet per second could be diverted. This was simply an assumption for the purpose of study, and to call the attention of the Board of Trustees to the need of considering carefully the future development of the District, if additional water above 10,000 cubic feet was not available.

This is made clear by conclusion 2 at the bottom of page 76, which states:

"The amount of water available for dilution, if taken at 10,000 cubic feet per second, will be insufficient after 1922, when supplementary methods of sewage disposal will have to be installed."

There is nothing in the report to indicate that an additional flow of 4,000 cubic feet per second would not be ob-

tained, or that this additional flow would not accomplish a better, more scientific and hygienically safer solution.

Mr. Wilkerson: I will move the answer be stricken out, on the ground it is unintelligible unless the report is in evidence.

Mr. Austrian: We offer so much of the report in evidence as the witness testified to.

Mr. Wilkerson: No, he stated the premises on which the report is made and the answer is utterly unintelligible unless the report is in evidence.

Mr. Austrian: We offer so much of the report in evidence, it having been heretofore referred to upon the cross-examination of numerous witnesses by the Government Attorney, we offer so much as embodies conclusion 2, at the bottom of page 76, in evidence.

Mr. Wilkerson: I move to strike out the answer on the ground stated.

Mr. Austrian: If the Government desires to offer the balance, that is up to them.

Mr. Wilkerson: The Government has no desire to offer it in evidence at this time, because it is not putting in its evidence; but the Government does object to any questions or answers relating to the premises upon which the report was prepared, or what the report means, or what the witness had in mind when he wrote the report, unless the entire report is in evidence, and will insist upon its motion to strike out any explanation of that kind, unless the report is first offered as the basis of the question. That is to say the Government does not propose to allow the witness to go into an explanation of this report, and then be forced, in order to get the statements in the report clearly favorable to the Government's contention in this case before the court, be compelled to offer the report itself.

Mr. Adcock: Q. Did you have, at the time when the report was made, any official or any other knowledge, which led you to believe that any agreement could be reached at that time by the District and the Government for a definite diversion; and what if any diversions had theretofore been discussed between the District and the Government?

A. At that time, the International Waterways Commission had recommended that no question be raised as to the right of the Sanitary District of Chicago to divert 10,000 cubic feet per second from Lake Michigan, and in fact no one had questioned the right of the Sanitary District to divert that amount.

At the time the report was made, I had no knowledge that any definite diversion was agreed upon. I based the report wholly upon the assumption that if a diversion of only 10,000 cubic feet per second were permitted, certain developments would be required, other than dilution. I knew that if 14,000 cubic feet per second could be secured that the construction of the developments proposed would be postponed by the extension of the dilution capacity due to the additional flow. I also knew that the extension of the diversion facilities of the District to cover the use of 14,000 cubic feet per second by the construction of the Calumet-Sag Channel and the enlargement of the small sections of the Main Channel was the most economical method of handling the sewage of the District up to the equivalent population.

I did, however, point out in my report, pages 75-76, that: "The extension of the capacity of the Main Channel in the manner indicated is, therefore, both reasonable and economical." This observation is, however, contingent upon a maximum diversion of only 10,000 cubic feet per second. It is however a much more costly procedure for the District than the use of the existing rock section up to its economical and full limit, that is a diversion of 14,000 cubic feet per second.

I purposely omitted all comparisons of cost with the existing methods of dilution, because I was not making a comparison of methods, but was endeavoring to show the need of careful study to solve a then unknown problem—that is, the means available in case a diversion of 10,000 cubic feet per second should be the limit.

Mr. Wilkerson: So that there will be no mistake at the hearing of this case, I still insist on the motion that the trial judge strike out this answer of the witness and fail to consider it unless the defendant shall have introduced the report in full in evidence.

Mr. Adcock: The report that you have been referring to is the document which I now hand you, and which we ask to be marked Wisner's Exhibit 5, for Identification.

A. Yes, sir.

(Whereupon the report of the witness was marked Wisner Exhibit 5, January 20, 1914.)

Q. What were your plans for the future extensions and improvements to the various works of the Sanitary District to take care of the increase in population?

A. It has always been my plan, since becoming Chief Engineer of the District to utilize the capacity of the different sections of the Main Channel to the full limit, and to have at

all times a flow of 10,000 cubic feet per second through the earth sections. The diversion to utilize the full capacity of the rock section was planned to come by the construction of a 2,000 cubic feet per second channel from the Calumet River to the Main Channel at the Sag, which could subsequently be enlarged to 4,000 cubic feet per second. These matters were presented by me from time to time to the Board of Trustees, upon whom I urged the construction of the Calumet-Sag Channel, as now being built.

Q. Will you explain briefly what was the nature of the report of October 12, 1911?

A. The nature of the report was of necessity preliminary, as it was prepared with considerable haste. The data presented on the physical condition of the district were substantially accurate, but it was realized that the estimates presented for the cost of the work would be subject to considerable revision, as the time and assistance available only permitted a very cursory study of the case.

The estimates were made on a conservative low basis, to indicate to the Board of Trustees a figure which would certainly have to be spent and would probably be materially exceeded, as our present figures show.

In the interval of two years, close attention has been paid to the movement of population. It has been found that certain areas are building up fast and that sites considered available two years ago are now out of the question. By sites, I mean locations for sewage disposal works.

My attitude is best indicated by the following from page 3 of the report:

"The sanitary aspect only of the problem is given consideration. Enough cost figures will be given to indicate the relative expense of the remedies suggested." And further: "At best this report is but a skeleton to start detail studies and designs so that the cheapest and most feasible method can be worked out for the handling of the sewage of the Sanitary District after the year 1920."

Q. Have you found in making your revised estimates that further allowances should be made which were originally omitted, and if so, and if so state?

A. In making the estimates of 1913, it was found necessary to increase considerably the cost of the settling plants and appurtenances because detailed study and the preparation of careful plans showed that the cost would be greater than anticipated from any known costs elsewhere where work was carried on on a smaller scale. It was also found that it would

be necessary to obtain much more land than was estimated upon in the report of 1911. Investigation of local conditions showed that construction costs would be somewhat higher, that the excavation required would be deeper than was anticipated originally, and that the appurtenances required for the careful operation of large plants would cost more than was originally supposed.

Further precedent was also available on the cost and design of sprinkling filters, which was taken advantage of in the later estimates.

In addition, more liberal allowance was found desirable from the study of our own costs and elsewhere for large projects, for the overhead charges, and an allowance for interest during construction which was not included in any way in the former estimates.

The costs of operation were also revised in the light of careful studies from such data as could be secured on known plants, and careful investigation of the local conditions of the Sanitary District. In preparing the estimates for the sewer costs, very careful attention has been given to the actual location of the sewers, their sizes and probable cost. Allowances were found to be necessary for the changes in public utilities in an intercepting sewer system to be constructed on such a large scale.

Q. What effect has the change from a diversion of 10,000 cubic feet per second to 4167 cubic feet per second on the estimates and methods?

A. It was known that a diversion of 10,000 cubic feet per second would suffice to prevent flood discharges of the Chicago River into Lake Michigan; therefore, no allowance was made for the disinfection of storm water sewage or the effluents of settling plants or sprinkling filters. With a diversion of 4167 cubic feet per second only, the complexion of the case is entirely altered, since there is a probability of a discharge into the lake for many days each year. It therefore becomes necessary to extend the installation of the equipment to include the sterilization of the storm water, settled sewage and sprinkling filter effluents, and to provide contact tanks for the retention of the storm water, as well as apparatus for sterlization, and the men to operate the sterlization devices. The smaller diversion also necessitates the construction of a very complete intercepting sewer system, with additional pumping stations and a much more extended treatment.

Q. In the interval from 1911 to 1913, has there been any great advance in the art of sewage disposal, if so state what?

A. There has been considerable advance in the knowledge of the conditions attending sewage disposal, and in particular of the precautions to be taken to avoid the production of anaerobic conditions, or nuisance, all of which have also increased the extent of the proposed works, and naturally increases the cost. The difficulties attendant upon the proper treatment of sewage have become more appreciated than they were two years ago or three years ago, whereas the methods of treating have not materially changed except to add to the treatment at that time supposed to be adequate, such as for instance the aeration of sewage and the disinfecting of the effluents coming from disposal works.

Experience in the actual operation of works since 1911, has demonstrated that the problem of sewage treatment is not a simple one. The development of the art points to the need of greater care and attention to works, design and operation, and to the need of conservative loadings and basis of design. The tendency of all this is to increase the cost of works, rather than to reduce it.

Q. What further investigations have you made since 1911, of the dilution ration and the effect of industrial wastes?

A. Immediately after the publication of the report, I arranged to have continuous study made of the condition of the canal at Lockport day and night, so that since that time samples have been taken at intervals of eight hours practically continuously. I have also had preliminary but careful studies made of the effect of industrial wastes, and the burden which they put upon the Drainage Canal. All of these studies have reinforced my judgment in forming a conclusion as to the handling of the sewage of the Sanitary District and the developments needed.

Q. Why is a diversion up to the full capacity of the rock section, viz.: 14,000 cubic feet per second, the most economical way of developing the resources of the Sanitary District for sewage disposal?

A. This is shown by the following table which shows the amounts which would have to be expended by the Sanitary District under the different alternative methods, first of dilution, and second of treatment, to produce approximately the same result in the treatment of the sewage. I do not consider, however, that this scheme for treating the sewage with

a diversion of 4167 cubic feet per second, and the use of the supplemental works, is as effective in protecting the water supply as the diversion of from ten to 14,000 cubic feet per second.

COMPARISON OF CAPITALIZED COST TO SANITARY DISTRICT FOR EQUIVALENT DIVERSIONS OF 10,000, 12,000 AND 14,000 CU. FT. PER SEC.

Existing Works plus Treatment on Basis of Diversion 4167 Cu. Ft. per Sec.	vs.	Extension Dilution from 10,000 to 14,000 Cu. Ft. per Sec.	
Equivalent Diversion of Cu. Ft. per Sec.	Existing Works with 4167 C. F. P. S. Plus Treatment	Extension of Dilution, Gross	Extension of Dilution, Net‡
10,000	$259,577,871	$76,067,600	$62,825,600
12,000	296,208,700	95,517,070	77,720,070
14,000	333,026,400	102,519,910	80,213,900

‡This allows credit for Electrical Dept. earnings.

Q. In basing your opinion on the efficiency of the various methods of sewage treatment, what factors have you taken into consideration, in reaching the conclusions concerning which you have just testified?

A. One factor is that of the known methods in 1887-1890, and even up to 1900. The present method of dilution is the only one available for handling the sewage of cities over 100,000 population, which has survived the test of time. We have definite knowledge of the workings of the Main Channel from 1900 to 1913, with the severe tests which actual continued use imposes. Of the alternate schemes, no one can show a continued use so long, nor an application on so large a scale.

Another factor has been the attitude of sanitary engineers and sanitarians in general. I know of no sanitary engineer or expert qualified to speak authoritatively who does not say that the diversion method installed at Chicago is the best method for that locality. This opinion I have found held not only by American but also by foreign experts.

For many years many engineers and others, particularly laymen, residing in and out of Chicago, had criticised the dilution method of sewage disposal, as exemplified in Chicago. In order to satisfy the Board of Trustees and myself on this point, I recommended the establishment of a testing station and finally was authorized to build one in 1909.

Mr. Wilkerson: I assume our general objection is broad enough to cover this specific point, that the last statement of the witness is purely hearsay and entirely argumentative

except as the statements of the experts appear in the testimony of this case.

Mr. Adcock: Yes; it is leading up to the result, that is the establishment of the testing station.

Mr. Wilkerson: I mention that point specifically because it is so apparent that it is all hearsay except as there may be in the record in this case the statements of the experts.

The Witness: This testing station has been running continuously ever since. The results obtained and the studies made on the canal and the Illinois River have only served to confirm my opinion that the method of diversion and dilution is the best, the safest, and the most economical for the local situation.

I might say that at this sewage experimental station at 39th street, and the second one at the Stock Yards, where the wastes of that industry are being tested, at these places we have tested out every known device that would be applicable to the treatment of sewage in this locality.

Q. You have outlined certain method by which sewage could be treated if the diversion were limited to 4167 cubic feet per second. How do you regard those plans from a practical standpoint?

A. As an engineer, I have had serious doubts concerning the practicability of works for treating sewage on such a large scale. This does not come from fear or ignorance of the correct principles to follow, but is based on conservatism, induced by lack of precedent anywhere for the partial or complete treatment of sewage on such a large scale. There are many novel problems involved. One of the greatest difficulties in the way is the securing of suitable sites. Judging by the opposition developed in Chicago recently in the various wards to the location therein of garbage treatment plants, I would anticiapte serious delay in obtaining the sites desired. Public sentiment, even though wrong, is slow to recognize the necessity of certain locations. Another condition that might work adversely to artificial sewage disposal is the climatic conditions of Chicago, where severe winter weather is encountered. Most of the plants that I have seen in operation do not have the severe winters that Chicago experiences.

Q. What economies have been afforded to the towns lying in the valley of the Des Plaines and Illinois Rivers below Lockport, due to the operation of the Main Channel of the Sanitary District?

A. So far as the towns in the Illinois River Valley, exclu-

sive of Joliet on the Des Plaines, are concerned, ample dilution has been afforded. It is possible that if only the natural flow of the Illinois River were available that the low flow would be insufficient today for the dilution of their sewage alone, provided local nuisances were avoided. Coarse screening and possibly sedimentation might have to be installed. The cost of this I have not studied, other than to note the probable need of additional expenditures over and above those now made for sewer systems. On the Des Plaines River, however, Joliet would have had an absolutely inadequate dilution, which would have necessitated complete treatment of the sewage at a probable cost, pro rated from our estimates for Chicago of about $1,000,000. This has been saved by the flow from the Sanitary District to the City of Joliet.

Q. What has been the elevation of the lakes before and after the opening of the Drainage Channel in January, 1900?

A. I have prepared a diagram which has been brought up to date, month by month, showing the lake levels at Chicago, taken from the publication of the United States Engineer's Office, and the Lake Survey, and corrected to date in accordance with the monthly bulletin issued from the office of the Lake Survey at Detroit. This shows that the average lake level for the 11 years following the opening of the canal was 580.63 elevation referred to mean tide at New York, or 0.22 of a foot higher than the average lake level for the 11 years prior to the opening of the canal, which was 580.41 elevation referred to mean tide at New York.

Q. You have referred to a diagram. I offer the diagram referred to in evidence as Wisner Exhibit 6 of this date. Is this Exhibit 6 the diagram to which you have referred, if so will you just state what it shows?

(Whereupon diagram referred to by witness was marked Wisner Exhibit 6, January 20, 1914.)

A. Yes, sir, it is. It shows the average monthly elevation of Lakes Michigan and Huron from 1899 to 1913 inclusive by the zigzag line tinted blue. The sides of the diagram show the elevations referred to the mean tide at sea level. The straight horizontal black line at the left of the exhibit, below which it is tinted brown, is the mean elevation for the 11 years prior to the opening of the canal, and the straight horizontal line with the reddish tint below it shows the average elevation of the lake from 1900 to 1910 inclusive, the 11 years following the opening of the canal. It shows during this entire period the highest point to which the lake has gotten in any

one month; also the lowest point; the lowest one being in 1905 winter of 1905 and '06.

Q. What effect if any has high lake levels on the cost of construction and operation of sewers in Chicago?

A. High lake levels will increase the cost somewhat of new sewers by reason of the ground water, but the principal influence is in retarding the efficient operation of the sewers by backing up the waters in the sewers to a greater distance from the mouth, and probably permitting thereby the stranding of solid materials which is very undesirable. The engineer in constructing the sewerage system plans to put the sewers at a certain depth below the surface to permit discharges of liquids from cellars and to get grades which will produce safe velocities at low flows. With the flat topography of the City of Chicago and the back water produced by the lake, it is extremely important to produce the best working conditions on the intercepting sewer systems, which necessitates pumping and great increased cost.

Adjourned subject to notice.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the rooms of the Sanitary District, Chicago, Tuesday, January 27th, 1914, at 10:30 A. M.

Appearances:

Mr. James H. Wilkerson, and
Mr. Albert L. Hopkins,
Representing the Government.
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
Representing the Sanitary District.

GEORGE M. WISNER resumed the stand and testified as follows:

Direct Examination (Continued) by Mr. Adcock.

Q. Mr. Wisner, who has assisted you in preparing estimates under the two projects that you mentioned, for works to dispose of sewage?

A. Mr. Langdon Pearse, Division Engineer, and Mr. Samuel A. Greeley, Assistant Engineer, and Doctor Lederer, to

some extent; he is our bacteriologist. And then there has been general work by others in the office.

Q. In general, what has been the scope of the work; the time that has been applied by yourself and others connected with the work?

A. I should say that Mr. Pearse and Mr. Greeley and myself have probably spent nearly two-thirds of our time on it since last February, preparing for this case and studying all sorts of possible schemes to take care of the situation, in case the flow was restricted to 4167 cubic feet per second; preparing estimates and getting up costs and data; finding out the data in regard to the death conditions in other cities; the condition of their water supply; and consulting with engineers and experts along sanitary lines, to see if we could develop a scheme that would approach in efficiency the present one. And we found we could not.

Cross-Examination by Mr. Hopkins.

Q. Who assisted you Mr. Wisner in the preparation of your report of 1911, which is referred to in your testimony and identified as Wisner Exhibit 5, dated October 12, 1911?

A. As I stated on page 3: "This report is largely based upon studies made at the 39th street testing station under the direction of Mr. Langdon Pearse, assistant engineer." He had a number of assistants, and Doctor Lederer there; and this report was the result of the studies that we made there, and my general knowledge of what was being done at other places.

Q. Were the estimates, costs, obtained in part from Mr. Pearse?

A. Yes, in part from Mr. Pearse.

Q. Did he agree with those estimates when they were made?

A. Those estimates at that time were made rather hurriedly. There was some disagreement on the Board as to the advisability of this report being made.

Mr. Hopkins: I object to that.

The Witness: For that reason we did not have as much assistance in the preparation of this report as we should have had.

Mr. Hopkins: I object to that and move it be stricken out as not responsive.

Mr. Austrian: Do you refer to the estimates in the report of October, 1911?

Mr. Hopkins: Yes, sir.

Q. Did Mr. Pearse study those and examine them?

A. Those estimates?

Q. Yes?

A. Yes, sir.

Q. Did he object to any of them that were put in?

A. There was no objection made to them. It was simply that we were trying to arrive at what possibly might be the minimum cost, and it was a little matter of policy to keep the estimates low.

Q. Did Mr. Pearse—

A. Mr. Pearse objected only to this extent, as I remember, that we both thought that we did not have sufficient data to give a detailed estimate that would be accurate. The cost was merely relative and preliminary to a detailed study of the projects outlined in that report.

Q. Then Mr. Pearse agreed with you in that report; you acted together?

A. We acted together. He was working under my direction and we worked together.

Q. There was no disagreement between you as to matters contained in that report?

A. There may have been some. I don't remember now.

Q. But on the whole he—

A. Generally I think we were pretty well agreed as to the policies outlined in that report, the conclusions arrived at.

Q. As a matter of fact you and Mr. Pearse did nearly all of the work in that report?

A. Oh, I think some of Mr. Pearse's assistants did considerable work in getting up tables and drawings.

Q. But if you and he had not approved of it, it would not have gone into that report, would it?

A. Oh no, it would not have gone in if I had not approved of the general policy of it.

Q. You have described in your direct testimony the intercepting sewers from 87th street to the south line of Evanston. When were they completed, to the extent of keeping sewage out of the lake?

A. Practically, on the South Side, in 1906, and on the North Side, in 1908. I believe there was one connection on the South Side that was not put in until 1910.

Q. What provision is made in those intercepting sewers for storm overflows now, if any?

A. We handle all the storm overflows.

Q. All of it?

A. We do not have any storm overflow. We handle the entire storm water.

Q. Then there is no water whatever that goes into the lake?

A. No.

Q. Between 87th street and Evanston?

A. Practically none.

Q. To what extent does any go in?

A. Well, possibly along the lake shore, between the lake shore and the sewers there may be a little water that runs in, but it does not amount to anything.

Q. It is the direct run-off of the land?

A. The direct run-off of the land right along the lake shore; park drainage might go in some, like Jackson Park and Lincoln Park.

Q. You do not collect the park sewage then?

A. Possibly some of it is sewered. I am not sure about that.

Q. In the summertime that would be quite an item, would it not?

A. In the summertime? I should think not.

Q. What was the additional cost of the Sanitary District works necessary to develop the power?

A. I have given that in my direct testimony, the cost of that; if you will refer to that.

Q. That is the item of about $5,345,241.57?

A. That is my recollection of about the amount.

Q. Was that intended to include everything, changes in the canal itself, dams and so on, which would assist in the water power development?

A. It was chargeable to that development.

Q. That is what I am after. Just what did you consider chargeable to the water power development?

A. Well, for instance, the lock that was put in down there was chargeable against the Calumet-Sag Channel. That was not charged against the water power development.

Q. What was the cost of that?

A. I would have to look that up for you. I can have that looked up for you.

Q. Where is that lock located?

A. Right adjoining the power house.

Q. Well, is it necessary for your water power system?

A. No, not at all.

Q. It has nothing to do with it?

A. No.

Q. Then you do not consider it properly chargeable?
A. Against the water power development, no.
Q. Your water power would be just the same without it?
A. Yes, sir.
Q. You need not look it up then?
A. It was not included in that figure, Mr. Hopkins.
Q. Go ahead; just what do you include in that?
A. Well, we included the power house, the electrical machinery, transmission lines sub stations, the excavation made necessary for the power development, construction of walls and embankments and cost of fixed bridges across the channel over this extension; cost for the tail race development. Generally that is it.
Q. Does it include everything which is additional to the necessary disposal of sewage?
A. No, there are certain charges that went in against the Calumet-Sag Channel, that it does not include, that was built at that time.
Q. The Calumet-Sag Channel is for the purpose of disposing of sewage, isn't is?
A. Yes. Under that, I should say it included that.
Q. Along towards night, the flow through the canal is increased, isn't it?
A. Sometimes and sometimes not.
Q. Isn't that rather the usual state of affairs?
A. I should not say it was the usual state of affairs.
Q. Don't you increase the flow, so as to increase your power a little at night?
A. At certain seasons of the year, we diminish the flow during the day time, and increase it at night time. That is only for, I should say possibly December, January and February; but we do not flow during the day an average of more than what is called for under the state law, even at that time of year.
Q. What do you mean, what state law?
A. The state law which prescribes that we shall flow 20,000 cubic feet per second for every 100,000 people draining into the channel.
Q. Do you have a diagram showing the low curve at the power plant?
A. We have one here in the office, I believe.
Q. How much water is necessary in cubic feet per second to develop the power that you are actually disposing of at this time?

A. Well. at certain times Mr. Hopkins, so that you will not go wrong, when our peak load, which is the high load of our power is on, we help out our peak load by running steam plants.

Q. That is you—

A. We develop power by steam, to help out on the peak load.

Q. Where are they located

A. There is one at South Park, Washington Park; there is another, an old city station, called the H. N. May plant; and I believe there are possibly one or two others that we can use.

It is the old city municipal electrical plant that we use, and the Washington Park electric plant, which, after we got to furnishing them electricity they turned over to us for our use.

Q. So that the amount of water you are actually taking through the canal now is not sufficient to develop all the power that you dispose of?

A. Not at times of the peak load.

Q. This Washington Park plant lights the South Parks, doesn't it, Washington and Jackson Park, the Midway?

A. It can be connected up with our system. It only lights it, or helps to light it at the time of year when the peak of our power load is too great for the water flowed to develop.

Q. What part of the year do you run the supplemental station?

A. During the months that I spoke of, December, January and February, and then not all the time.

Q. What part of your power is used in lighting streets, and what power in the pumping stations; what part is sold for commercial purposes?

A. I don't know how much is given to each department.

Q. Do you have it in mind approximately?

A. No, I have not.

Q. Is there any publication of the Sanitary District which shows that?

A. There may be, but I haven't it in mind.

Q. What kind of a record do you keep of that?

A. That I am not very familiar with, Mr. Hopkins. It comes under the electrical department, and I am not an electrical engineer.

Q. Do you know how much power you have at Lockport

for 4,167 cubic feet of water a second; how much you can generate with that supply of water?

A. I could get that for you.

Q. Will you do that?

A. Yes, I will have that figured.

Q. And for 7,500 cubic feet and for 10,000 cubic feet?

A. Under present conditions?

Q. What conditions would make a difference?

A. Well, there might be some improvements made in the Drainage Channel itself that would increase the power without increasing the flow.

Q. Would that change any condition, interfere with the current?

A. Why it might lessen the current.

Q. Whatever conditions you call most favorable to the Sanitary District, I would suggest. In your direct testimony, in speaking of the benefits from the direct Drainage Canal, you spoke of power along the Desplaines and Illinois Rivers?

A. Yes, sir.

Q. Just what power is there now being developed along those rivers?

A. There is one place right at the junction of the Kankakee where they are trying to develop it, but I believe the government is trying to stop them from doing it.

Q. That is the Economy Light and Power Company?

A. Yes, at Dresden Heights. There is power being developed at Marseilles.

Q. How much?

A. I don't know.

Q. Isn't Marseilles below the Kankakee?

A. Yes, sir.

Q. What is the head at that place?

A. I don't know.

Q. Any other power plants along the Desplaines or Illinois?

A. No, but there are places where it is possible to develop power.

Q. Where are the other places?

A. That I would have to look up. There have been several schemes, some of them I think were reported upon, one has been reported upon by Mr. Randolph of the Internal Improvement Commission; another one by Mr. L. E. Cooley; and I believe the government engineers themselves have reported upon a deep waterway and power development.

Q. Do you know about the amount of power that was estimated they can develop along there?

A. I did know, and I can look that up for you, but I haven't the figures in mind now, Mr. Hopkins.

Q. I wish you would look that up.

A. There have been several estimates made.

Q. Do you know to what extent the development of such power plants would interfere with the navigability of the streams?

A. It would not interfere. I think it would tend to be a benefit to the navigability of the streams.

Q. In all cases?

A. I do not see really that they would be of any harm.

Q. In each case they would have to have a dam and locks?

A. Yes, sir, that is true, but in developing these powers they would get greater depth, and improve all the slack water navigation, and would make the river at certain places where now it is practically not navigable, would make it navigable. There is power being developed at Joliet. I neglected to mention that.

Q. On what river?

A. On the Desplaines.

Q. How much?

A. Well, they have got a very inefficient plant. I presume they have got in the neighborhood of 3,000 horse power that is being developed there now.

Mr. Austrian: I think the record ought to show that none of this power that the witness is speaking of is being developed by the Sanitary District.

Mr. Hopkins: Q. Now, you say the Sanitary District has expended approximately eleven and a half million dollars in the improvement of the Chicago River. That includes the North and the South Branch, but is exclusive of any work done on the canal itself

A. Yes, sir.

Q. Just what proportion of that was spent before January 1st, 1900, and what part after January 1st, 1900?

A. I would have to have that looked up; I haven't it in mind, it is so long ago, Mr. Hopkins.

Q. Will you have a table prepared showing in a general way those expenditures by years, and what they were for?

A. I will. It may take some little time to get that up. I think I can get it, though.

Q. You can get without much trouble the amount that was spent each year, can't you?

A. It will mean going through the books by the bookkeeper and picking out the amounts expended on that account.

Q. I think we would like to have it, what was spent by years, at least what part of that $11,500,000 was spent before May 8, 1899?

A. It might be impossible to divide it on that date.

Q. You can give it though, you think, by years?

A. I think I can get it up that way.

Q. Do you know whether there was much spent in the Chicago River between May 8, 1899, and January 1st, 1900?

A. There might have been quite a little expended at that time.

Q. But if we get the annual, we can approximate what was before that time and what was after?

A. I don't know whether you can or not.

Q. Just what will you furnish?

A. I will try to furnish what you ask for, Mr. Hopkins.

Q. Was any of the expense or cost that you have given in regard to the Calumet-Sag Canal spent before May 8, 1899?

A. I doubt it Mr. Hopkins, unless possibly there had been some survey work done that was chargeable against that project, some engineering work; and of that I am not certain.

Q. What part if any of it was spent before March 14, 1907?

A. That I can't tell you unless I look it up or have it looked up.

Q. Will you look that up?

A. I will do the best I can.

Q. As near as you can, if you cannot get it definitely?

A. I will see if I can get anything on it.

Q. Was the cost of that North Shore Channel included in the $11,500,000?

A. Of the North Shore Channel?

Q. Yes?

A. No, sir, the only thing north of the main river that was included in it was the improvement of the Chicago River from Belmont avenue to Lawrence avenue, of which I spoke in my direct testimony. The North Shore Channel was not included in that sum.

Q. Do you know what part of the $6,275,000 spent by the City of Chicago was spent before the opening of the Drainage Canal, and what part afterwards?

A. No, I do not.

Q. That was spent, you say, for dredging the river, including its branches, and for bridges and docks principally?

A. That is my information in regard to the matter. They may have bought some property too.

Q. For the purpose of the harbor for the city, and its navigation, and for crossing the river, all of those expenditures would be made, regardless of whether there was a sanitary canal or not, wouldn't they?

A. I do not know.

Mr. Adcock: You mean by the City of Chicago?

Mr. Hopkins: Yes.

The Witness: I don't know whether they would be or not.

Q. Do you have any reason to think that the diversion of water through the Sanitary Canal made any difference whatever as to the amount spent by the city in improving the river and building bridges?

A. It might have in regard to the building of bridges, Mr. Hopkins.

Q. In what way?

A. Getting wider openings, so that there would be a freer passage of the water in the South Branch.

Q. The city as such was not concerned in that, were they?

A. They were working in harmony with the Sanitary District, as far as that is concerned.

Q. That phase of it was really a Sanitary District matter, wasn't it?

A. Well, the City of Chicago is just as much interested as the Sanitary District.

Q. Except that they turned over the Sanitary feature of the city to the Sanitary District?

A. Yes, but they did build the bridge openings wider, probably on account of the current, wider than they would otherwise.

Q. As far as navigation is concerned, you speak of the stretch from Lake street to Ashland avenue as the critical point?

A. I would not call it a point, but the critical place. Of course there are places on the North Branch that are pretty difficult for navigation, on account of the river being crooked; but before we did any work the South Branch, that stretch, was the critical place.

Q. As far as current is concerned, though, if you were

flowing 8,000 cubic feet a second through the river, that would be the part of the river that would be critical?

A. As far as current is concerned, yes, sir.

Q. When you speak of the current not exceeding a mile and a quarter per hour, you speak of the mean current?

A. Average current, yes, sir.

Q. Do you have any figures of the maximum current in the river?

A. No, I have not.

Q. In mid-stream, that current would be much higher than this mile and a quarter you speak of, in order to get an average?

A. It might not be much higher. I think it was some higher.

Q. It was probably in excess of two miles per hour, wasn't it?

A. I think not.

Q. Just what is the cross section of the river from Lake street to Ashland avenue at its narrowest place?

A. I presume the narrowest place is right opposite Jackson boulevard and the Metropolitan Elevated, where it is, as I recollect, 90 some odd feet in width, and it is dredged, I think to about 26 feet.

Q. 26 or 36?

A. 26 feet, maybe a little deeper in places; and Jackson boulevard bridge is now being taken out. It is to be replaced by a bridge which will give sufficient openings so that the current will not exceed a mile and a quarter an hour. The contract is now let for it; and the Metropolitan Elevated bridge, as I understand, has been ordered out by the Secretary of War.

Q. At present then the width is 90 feet?

A. 90 some odd feet, as I recall.

Q. And with the new bridge in at Jackson boulevard, what will be the width?

A. It will be 168 feet, as I recall it, in the clear, and in addition to that there is a by-pass back of one of the pier abutments.

Q. 168 feet?

A. Yes.

Q. After those bridges are taken out, what will be the narrowest place?

A. Other improvements may be made by that time, and I can't tell you what would be the narrowest place.

Q. Do you know anything about when this Jackson boulevard bridge will be out, then, how long it will be before we will get this?

A. I think the specifications provide that the old bridge shall be out next spring some time.

Q. How about the Metropolitan bridge?

A. That I have no control of. I understand that the Secretary of War, as I stated, has ordered it out. When they will take it out, I don't know.

Q. What is the width of the Metropolitan bridge?

A. Practically the same as at Jackson boulevard. I should say they are only 75 feet apart, or 100 feet.

Q. Will the mere removal of that bridge remedy the condition between Jackson boulevard and the Metropolitan bridge; what is the width?

A. That we have widened and dug out back to the wall of a by-pass that is in back of the abutment of the Metropolitan and back of the center pier of the Jackson boulevard bridge.

Q. Aside from those two, what is the narrowest point in the river?

A. Well, Van Buren street, just below that, that is somewhat wider I believe than these two places.

Q. How much?

A. And it has a by-pass back of the abutment which gives additional available width for the flow of water.

Q. Do you know what that width is?

A. Of the by-pass, you are referring to?

Q. No, the main channel.

A. I am speaking from memory, and my recollection is that the opening of the Van Buren street bridge is about 110 feet and then there is a by-pass of about 50 feet in width.

Q. As a matter of fact, if you had 8,000 cubic feet of water a second flowing through there, there would have to be a great deal of widening to hold the current down to one and a quarter miles per hour?

A. Not very much. There are a few places which would have to be widened, and which we expect to have completed within a year.

Q. What cross section would you consider sufficient to get the result of a mile and a quarter an hour?

A. In square feet?

Q. Yes?

A. I will figure that for you. I haven't it in mind. On a diversion of 8,000 cubic feet per second?

Q. Yes?

A. Approximately an area of 4,360 square feet.

Q. Assuming a depth of 26 feet, then you would need a width of over 160 feet wouldn't you?

A. Yes, that is so, if you didn't have it any deeper than 26 feet.

Q. Is the river any deeper than 26 feet?

A. It is in places, yes, sir.

Q. How much deeper than that?

A. There are places where it is 28 or 29 feet in depth.

Q. That would not reduce the cross section very much, I mean the width?

A. It would not increase the width very much, but it would increase the cross section somewhat.

Q. And that would be on the assumption that the channel is rectangular in shape?

A. That would be on that assumption, yes.

Q. If the bottom sloped to a depth of 26 or even 28 or 29 feet in the middle, and sloped out, you would require much greater width?

A. Require a little greater width, if we had the 26 feet throughout its entire width, 26 feet or deeper.

Q. Do you have in mind any estimate as to how much excavating it would take to make the river all along so that the narrowest point will not be less than this cross section that you have estimated?

A. No, I haven't that figure in mind as to how much it will cost.

Q. Do you have any idea?

A. Not offhand. I think I made an estimate of that kind at one time, but I don't remember it now Mr. Hopkins.

Q. That would be a proper thing to be considered in the expense of the Sanitary District, if it were given the 8,000 cubic feet through that channel, wouldn't it?

A. My recollection is that I included that in the money that would be necessary to be expended.

Q. Where do you include that?

A. No, I think I am mistaken about that. I do not think that was included.

Q. Where does this mile and a quarter to a mile current come from, where is the idea of that, from the Secretary of War?

A. Yes, sir.

Q. Do you know in what permit it is included?

A. I don't remember which one now, but it was one of the early permits. The permits were changed from time to time, and as I recollect it was the—

Q. Do you know what the wording of that was?

A. My understanding was that the mean current should not exceed the mile and a quarter per hour.

Q. Was it the mean current, or that the current should not exceed a mile and a quarter per hour?

A. My impression is it meant the mean current; whether it said the mean, I am not certain at this time.

Q. Your figures have been based upon the idea of a mean current?

A. Yes, sir.

Q. If it were a maximum current of a mile and a quarter an hour, that would make the amount of widening much greater, or the amount of excavating?

A. The project for flowing 8,000 cubic feet on the 200 feet scheme has an area of 4,700 square feet. As I stated in one of my previous answers, to have an average current of only a mile and a quarter an hour requires about 4,360 square feet, so there is some excess on the completed project of a 200-foot channel.

Q. Do you have any idea what the cost of excavation to that extent would be?

A. It has practically all been done Mr. Hopkins except in three or four places; small distances along the river. And I think there are four of them that remain to be completed, negotiations for which are now being carried on, and these obstructions should be removed within the coming year.

Q. The Sanitary District, through contractors, is now actually engaged in digging the Calumet-Sag Canal?

A. Yes, sir.

Q. Along the line of the original survey?

A. To what do you refer as the original survey?

Q. The one that you outlined in your answer to the first bill filed in this case?

A. I should say practically along that line. There may have been some minor changes.

Q. The first addition to the Sanitary District was made in 1903?

A. Yes, sir.

Q. The original area was 196 square miles approximately?

A. I gave it in my direct. I haven't the figures in my

mind now. I can give them to you, right here, if it is of any benefit to you.

Q. No, I think we have them on record here.

A. No, it was 185 square miles, the original.

Q. Did you include what population has been added to the district, from the time that those areas have been added?

A. In the table on page 2072 of the record, it gives the populations.

Q. Well, does that give the population of the district as it originally was, the 185 square miles?

A. If you will notice, it gives two figures for 1902, and on that page it says, "Territory annexed" and then gives 1903 again. The same in 1913.

Q. You speak of the mussel industry of the Illinois River. Do you have any way of knowing that the increase in the mussel industry is due to the Sanitary Canal; or is it simply that you find they are getting more mussels down there?

A. Only from seeing the records and from talking with the people interested in the industry, and general information that I find in regard to that.

Q. That is they have gotten more mussels down there in recent years than they did before?

A. They have, and that is the opinion of men engaged in that industry, that it has increased the supply since the opening of the canal.

Q. Have you compared it with the mussel industry at other places?

A. No, I have not.

Q. As to whether or not there is any greater demand for mussel shells in making buttons nowadays than there used to be, have you taken that into consideration?

A. No, I have simply gone on what I learned from people engaged in that industry.

Q. Just some general hearsay?

A. That I would not say was general hearsay. It was from men that ought to know something about the business they are engaged in.

Q. What do you mean by the figures in that column (record page 2072) "Actually tributary M. C."?

A. That is as near as I could estimate the actual population that is draining into and through the Main Drainage Channel.

Q. That really are draining into it? Or do you mean they are in a position where they can?

A. Where they do drain into it. Some of them may drain into the branches of the Chicago River; but it goes through the Main Drainage Channel, the sewage coming from that population.

Q. Now in your last column you state, "actual flow," is that actual flow or is it only computed?

A. That is the actual flow that would be required under the state law.

Q. Well then, are you flowing that much?

A. For some period back, we are flowing practically that much, yes.

Q. For how long a period back?

A. That I can't tell exactly because, as I stated in my direct testimony, our water wheels acting as meters have not given correct results.

Q. I understand, in your direct testimony you thought they under measured a little?

A. I do think so, as far as the actual flows are concerned.

Q. Don't you know how long you have been taking approximately this amount?

A. During the last year and 1912, and part of 1911, I think we have been taking about the amount as near as I can tell; prior to that, not quite as much.

Q. That would be at least 1912 and 1913, and you think in 1911?

A. 1911 may have been just a little shy, and 1910 possibly.

Q. You have taken at least as much as the figures indicated in this last column?

A. No, I think not except possibly this last year.

Q. 1913?

A. 1913. Before that it might have been somewhat shy.

Q. As a matter of fact you took as high as 10,000 cubic feet at times?

A. For a short time we might have taken as high as 10,000 cubic feet for a short time; I mean a few hours.

Q. That is a few hours in a great many days. You do not mean just two or three hours at one time and that was all?

A. That is what I mean, yes, sir.

Q. Had that simply occurred on one day?

A. Oh no, it has occurred on several days, but only for two or three hours at a time; and on that same day there would be probably times when we would not be flowing over 5,000 cubic feet a second, possibly less.

Mr. Adcock: Q. Would that be in the winter time?

A. In the winter time, as I stated before, when this heavy peak load comes on; but the average for the day has not exceeded—

Mr. Hopkins: Q. That peak load, you mean in reference to the power?

A. In reference to the power, yes, sir.

Mr. Adcock: Q. The daily or yearly average has not exceeded the amount provided for in the state law?

A. No, sir. There might have been times, Mr. Hopkins, when there were heavy floods due to run-offs of the Chicago River basin, when we ran 10,000 feet for a considerable length of time. That was simply to keep the Chicago River from going into Lake Michigan; taking the pollution out into the drinking water.

Q. How do you handle that flood water, keep it out of Lake Michigan?

A. We keep on increasing the flow so as to prevent the river from going into Lake Michigan.

Q. That is gaged at Lockport?

A. It is gaged at Lockport, yes, sir.

Q. In what way is it indicated to the man stationed there how much to open it?

A. We indicate from this office. As a matter of fact, there have been times when it got away from us and did go for short periods into the lake.

Q. Then you do watch the floods, and the rains in general and indicate to the man to increase the flow?

A. We do, if it looks as though there was any danger of the water going into the lake.

Q. With what success is that operation carried on?

A. In the last few years, we have prevented it; but in the earlier days of the Drainage Canal there were several times when it got away from us and got into the lake before we could increase the flow sufficiently.

Mr. Adcock: Q. That was when the flow was low and did not approach the maximum?

A. Yes, sir, and before the Chicago River was improved.

Mr. Hopkins: Q. Do you think the size of the flow makes very much difference as to your ability to take care of floods, if you increase it with your system of opening the gates at Lockport?

A. I really don't quite understand that question.

Q. Would it make any particular difference in taking care

of flood waters whether you were flowing 4,167 cubic feet average, or whether you were flowing eight or nine thousand cubic feet?

A. Yes, indeed.

Q. In what way?

A. In this way: If we would be flowing 8,000 cubic feet, a flood that would only produce that run-off in the Chicago River Basin would not reverse the current in the main river.

Q. You mean that you would have more floods you would have to watch?

A. We would have more floods we would have to watch, and the time it would take to get up a current or a discharge to reach the volume of the run-off would be shorter.

Q. What do you consider is the time required in order to create a current, increase your current from Lockport?

A. Say from 4,000 up to 10,000 cubic feet per second, so that the effect would be felt here in Chicago?

Q. Yes, to that full amount?

A. I speak approximately, but I should say to get the full effect of that would require in the neighborhood of from 7 to 9 hours.

Q. To get most of the effect, not the full effect?

A. Most of the effect, there would not hardly any of the effect be felt inside of four or five hours in the Chicago River around the junction of the North Branch and the South Branch.

Q. What is the capacity of the flow at Lockport?

A. At Lockport?

Q. Yes?

A. 14,000 cubic feet per second.

Q. If you opened up everything wide how long would it take you to get an effect of 10,000 cubic feet, in Chicago?

A. The whole channel hasn't that capacity. Don't misunderstand me: You asked about the channel at Lockport.

Q. Yes.

A. I should say from 7 to 9 hours before we would get 10,000 cubic feet going through the river. I get that Mr. Hopkins from the fact that in the past there have been vessels stuck at different parts of the river, and we would have to shut off the flow at Lockport so they could get out of their predicament; and from observing that condition, we noticed any rising in the water in the Chicago River would be 4 or 5 hours after the works were closed down.

Q. Have you made any tests of the converse?

A. Of the converse?

Q. Yes, opening it up instead of backing it up?

A. Only as I have had them watch it the same way, after we had closed it off, to see when the current would start up perceptibly, and it seems it would be about the same length of time. Of course there are times when the influence of the lake level, the lake rising and falling, has an effect; but as near as I could judge 4 or 5 hours was required to feel the effect of opening or closing the works there in the Chicago River.

Q. If a careful watch were made and reported to Lockport, and an attempt made to keep the water out of Lake Michigan, what percentage of the time do you think there would be any flow into Lake Michigan?

A. With a flow of how much?

Q. 4,167 cubic feet?

A. I should say there would be probably 6 to 10 days a year when it would go into the lake.

Q. Out of those 6 or 10 days, I understand those are days —that is a very liberal estimate of the number of days on which the flow would reach 10,000 cubic feet in the Chicago River?

A. No, it would be the number of days it would exceed 4,167 cubic feet.

Q. Well, then, do you figure that every time it exceeded 4,167, some would get into Lake Michigan; that with your lookouts you could not prevent that most of the time?

A. I am assuming that we have a flow of only 4,167 cubic feet through the regulating works at Lockport?

Q. Assuming in connection with that you are permitted to open them up to a greater capacity at Lockport sufficient to take care of flood water so as to keep the Chicago River reversed?

A. In that case, I would have to open them up every time there was a rainstorm, because one cannot tell at the beginning of a rain whether it is going to cause a run-off of over 4,167 cubic feet per second in this basin, or not. It may not get to that amount; it might exceed it greatly. And you cannot tell until after the rain comes. The rain does not come in two minutes; it lasts over several hours, often.

Q. By so doing, and anticipating it, then what do you think would be your result? Couldn't you at all times in that way keep the water out of Lake Michigan?

A. It might be possible to do that, because we are doing

that now; but it would involve keeping observers all over the District, and it would involve increasing the flow when, as I have already stated, the run-off might not come anywhere near being 4,167 cubic feet per second.

Q. That excess that you would take for a few hours would not be very much would it, in case your rain did not come up to your anticipation?

A. During the course of the year it would amount to considerable.

Mr. Austrian: Q. You would have to anticipate it 5 or 6 or 7 hours in advance, wouldn't you?

A. You would have to anticipate the rainstorm, so that you would get your flow up; otherwise it would get away from you, because, as I stated, to get your flow up it takes 7 to 9 hours.

Mr. Hopkins: Q. How long do you think it will take the water from a rainstorm generally over the District to get into the river?

A. There have been floods around here where it has come in inside of 5 or 6 hours with excessive rains. Some of it comes in quicker than that.

Q. Then you would not have to anticipate it over 2 or 3 hours?

A. Oh, yes, you would; you would have to anticipate it, over and above the rainstorm, and you have to anticipate the rainstorm. You do not know whether you are going to get that kind of a flood or not; so it means you have got to anticipate it nearly nine hours, as I understand your question.

Q. But still it takes 5 hours at the least for the water that falls on the ground to get into the river?

A. That is to get up a big flood in the Chicago River.

Q. That time can be used in getting the flow reversed, so that your margin is only about 4 hours?

A. No, you have to anticipate the rainstorm, too.

Q. By a short time, much shorter than you say?

A. No, I think not.

Q. And with the assistance of the weather bureau, couldn't you anticipate big rainstorms to the extent that there would be a very small proportion, if any, of the water going into Lake Michigan?

A. No, I think not. There is no denying that the Weather Bureau is a help, but they cannot prophesy whether you are

going to have a rainfall of half an inch or two inches or a quarter of an inch. At least I have never seem them do it.

Q. I am assuming that you anticipate the rainstorm, if you consider it necessary to do so?

A. In which case I say we should have to start up our flow about 9 hours ahead of the time that we needed it.

Recess to 2:00 P. M.

After Recess, 2:00 P. M.

GEORGE M. WISNER, resumed the stand for further cross-examination by Mr. Hopkins and testified as follows:

Q. I believe you say that the typhoid fever death rate in Chicago is less even than in those cities that have filtered water?

A. That in many cities with filtered water.

Q. That rather indicates that there is something else that has to do with it besides water, doesn't it?

A. Well, the marked reduction in Chicago has been due to the improvement in the water supply.

Q. How do you know?

A. Because other municipalities situated the same as Chicago have not had the improvement found here.

Q. They have had some improvement haven't they?

A. And the conditions surrounding them are practically the same as in Chicago, with the exception that they are getting an impure water supply.

Q. How about the cities with filtered water, again, your own suggestion?

A. How about them, what?

Q. Why is it that that death rate is higher than in Chicago?

A. I do not know the exact reason for that, unless possibly the filters are not working as well as they should work; and there may be some other causes that bring this about. It may be that the filters are not doing the work they are supposed to do, although they have made improvements over and above the condition before the installation of the filters.

Q. As a general proposition, wouldn't a city that has filtered water have purer water than Chicago?

A. Not necessarily, from a bacteriological standpoint, at times.

Q. You have certainly some contamination of the Chicago water?

A. It may look better at times, when the water here is very turbid, but as far as its safety in drinking is concerned, we cannot discover that it is dangerous or unsafe.

Q. You simply charge the decrease in typhoid fever death rate to the water supply?

A. I think that is the principal cause of the decrease.

Q. You do not give any consideration to advance in medical science in the way of curing?

A. That probably has had something to do with it.

Q. Milk infection?

A. Typhoid fever is simply a disease in which the patient has to be nourished, rather than have any medicines, that one could take; and in cases where the milk supply has been watched, that tends to improve conditions, too.

Q. Vaccination?

A. Vaccination, that has only been done in recent years, and has not been done to any etxent in the City of Chicago.

Q. The crusade against the flies?

A. I do not think the flies have been done away with to any extent in the city.

Q. Did I understand you to say awhile ago that you regarded the water supply of the City of Chicago to be in as good condition bacteriologically as it would be if it were filtered?

A. I would like to have you pursue that assumption a little bit further, as to whether our system is in operation or not.

Q. With the conditions as they are to-day?

A. Would the water be pure if it was filtered, in addition to the Drainage Canal working, and keeping the pollution out of the lake, is that your question?

Q. As far as bacteria are concerned, yes.

Mr. Austrian: Q. Do you mean if the Sanitary District Canal was not in operation, and we filtered the water?

Mr. Hopkins: Just as it is today, would filtering help the conditions today as far as bacteria are concerned?

A. Well, it would certainly tend to reduce the number of bacteria and make the water safer where it is now contaminated, like for instance the 68th Street Crib, where the water supply is contaminated at times from the flood discharges of the Calumet River; and possibly sometimes from the sewage coming from the Indiana towns.

Q. And from vessels?

A. Vessels are being kept pretty well away from the cribs now. The last year or so, we have taken this matter up with the vessel owners, and they are giving instructions to keep the vessels away from the cribs. That is a source of pollution, but it is a thing that can be overcome by regulation, without causing any great burden on the shipping interests.

Q. What percentage of bacteria in water can be taken out by the filtering process?

A. I think that would depend to a large extent on the number you had to start with.

Q. In what way would that affect it?

A. I mean if there were more bacteria in the water, the chances are you would take out a larger percentage than you would if there were a very small number.

Q. Suppose that the sewage were dumped into the lake direct at Chicago, and you had a good filtration plant, what percentage of the bacteria would be taken out?

A. I really don't know. I know it would overburden the filters and would be unsafe, I am afraid.

Q. Suppose you treat it with hypochlorite of lime?

A. Well, that would help, but that is objectionable as it is apt to create a taste that is objectionable to the consumer. They are having a great deal of trouble with that most every place they are using it.

Q. Couldn't you filter your water, or treat it, to an extent that it would be reasonably pure hygienically?

A. I think you could probably do that but there would be times when it might be unsafe. You are depending upon human agency; and I could only judge by what has happened at other cities. They are not having as good results as we are with a few possible exceptions.

Q. Have you got that chart Exhibit 3, whereon you figure out what we are all worth?

A. (Witness produces same.)

Q. Your Exhibit 3, shows graphically, or is supposed to show graphically, certain costs to the community. It is first dependent upon your assumption that a life is worth $10,000?

A. That is one of the assumptions, yes, sir.

Q. What is the basis of that assumption?

A. We took that because that is as I understand it what the statutes provide in case of accidental death.

Q. Who is "we." You said "we took that."

A. I mean this office, in figuring this up, the engineering department here.

Q. That is an engineering figure, that $10,000?
A. I said we got that from the statutes.
Q. What statute?
A. The Illinois death—
Q. Do you know what particular statute you are referring to?
A. I don't know the particular statute, but I think you understand what I mean. It is in case of death by accident that the employer would have to pay to the extent of $10,000 for a death.
Q. You mean the statute of Illinois making the maximum recovery in case of death by wrongful act $10,000?
A. Yes; I don't know whether it is wrongful or not.
Q. Did you have in mind that prior to ten years ago the maximum limit was $5,000?
A. Yes, I knew that.
Q. If you are going to take that assumption, a life over ten years ago was not worth as much as a life today?
A. I am taking what it is worth today, not ten years ago.
Q. Was it called to your attention that under the Workmen's Compensation Act, the maximum amount recoverable for death was $3,600?
A. No, that was not called to my attention.
Q. Now as a matter of fact there is no way of valuing the life of a person at all?
A. I should think that $10,000 was not too much.
Q. Isn't it simply an arbitrary matter founded on the statute?
A. (No response.)
Q. Now in this Exhibit 3, by that top line there you mean to indicate that if you had a very high death rate all the time, as you did between 1890 and 1893, and you valued each life at $10,000, that it would have cost the community—that would have been the loss to the community, the difference between that line and the lower one, on that assumption.
Q. Suppose you assume an epidemic period, and assume that it is not checked but goes on, you could get that kind of a line most any time, couldn't you?
A. Not under our conditions, we could not get an epidemic of that kind.
Q. I was assuming an epidemic period, you could get such a result as this?
A. We do get such a result, right on that chart.
Q. Was it called to your attention that that $10,000 pro-

vision had no reference whatever to a loss to the community, but was simply a loss to certain individuals?

A. Well, that was not called to my attention, but I understood that. There had to be some assumption made, the way I was getting at it, as to the value of human life.

Q. You think it is possible in dollars and cents to value human life to the community?

A. I think it is, yes.

Q. Just what is your basis for that?

A. A basis as to whether you take arbitrarily $10,000 as the value of life, I do not say that necessarily follows, but I think economists—

Q. That is what you said wasn't it?

A. Just a minute—I think economists have figured out that human life is of value to the community, and goes to make up the wealth that a community has.

Q. Doesn't that depend somewhat, very much in fact, upon the demand for population?

A. Well, we are talking about this particular country.

Q. You think you can go on indefinitely increasing people and the value of lives, at so much per head?

A. It depends upon whether there is room for them, I presume and whether they are educated people, such as the American people are.

Mr. Hopkins: Motion to strike out Wisner's Exhibit 3.

Q. How did the state, if you know, arrive at that figure of 3½ cubic feet per thousand inhabitants?

A. Generally it was arrived at, I think, as a kind of compromise.

Q. I mean what was the basis of it?

A. After consultation with experts and getting their views. I think they varied as to the amount that was necessary, from something like 2½ cubic feet per second per thousand people up to over four. And there were some experiments, I believe, made at that time; and they finally arrived, they thought 3½ would be sufficient. And if I remember, the law states that the dilution shall be at least 3½, giving some leeway to go above that, but that was thought to be the minimum that would properly dilute the sewage coming from a thousand people. There was not much reliable data at that time to go on, and it is remarkable, I think, that they guessed as well as they did at that time.

Q. Well, isn't that estimate based in a large part upon experiments and the experience of other cities?

A. There has never been any very careful experiment made, and what they did have was based upon the waters of rivers, which was not as good water for dilution purposes, oft times, as is the water of Lake Michigan.

Q. Then Lake Michigan is exceptionally high in oxygen?

A. It is as compared with a lot of rivers. It is not exceptionally high as compared with the waters of Lake Superior or Lake Huron or Lake Erie, if the temperature is taken into consideration.

Q. The ratio as determined was based in part upon experience from rivers at various places, wasn't it?

A. That I would hardly be qualified to say, as to whether in arriving at that they did not take into consideration the fact that the oxygen content of Lake Michigan water was higher and better; and another thing, that Lake Michigan water is low in organic matter, whereas some of these rivers have considerable organic matter.

Q. What I am trying to get at is whether in coming to a conclusion as to a rate per thousand, experience in other localities was not taken into consideration?

A. Well, I presume they did take it into consideration Mr. Hopkins.

Q. Wasn't that the basis of the whole thing, in the beginning?

A. No, not exactly. It must have been experience at other places, but my recollection is that they carried on some experiments here also.

Q. Do you know just what was done in those experiments? When were they, first?

A. A Doctor J. H. Rauch, concluded, after some studies made by himself, that 180 cubic feet per minute that is 3 cubic feet per second per thousand population, in winter, would be ample. Then there was in 1887 some knowledge of the Blackstone River obtained, and they thought even a smaller dilution than that per second might do.

In Paris, at that time, they knew that 60 cubic feet per thousand people produced inoffensive conditions 14 miles below Paris in the Seine, but they excluded all excrement, fecal matter. But my recollection is that there were some experiments made here, on or about that time, in the old canal, which helped them to arrive at this figure.

Q. How did you compute or estimate this 300,000 floating population?

A. We got such available data as we could from the rail-

roads and the steamship lines, as to the number of passengers, number of people that were brought into Chicago during the course of the year; and as near as we could get at it, there were at this time about 68,000,000. And from that we estimated that by the time 1920 was reached, there would be a floating population pretty close to 300,000 per day. I believe we did count, for a while, passengers coming in at certain stations, to check up on the estimates as near as we could.

Q. Did you make any estimates as to how many were going out?

A. Our total figures showed that at this time there were about 69,800,000 people that came in, through and suburban. The number that left the city, we did not take into consideration, as it was not believed that they amounted to a very large percentage of this number.

Q. Then we would soon have a rather large city here, wouldn't we, if only a very small proportion of those that come in go out?

A. I thought you referred to the people living within the city that went away from here, as an offset to those that come in. Of course the suburban traffic goes in and out practically every day, Sundays excluded.

Q. What was the basis of that sixty-eight or 69,000,000 people?

A. That was the number of people that come into the city on an average, in and out of the city each day; that is 68,000,000 during the year come in, and that 68,000,000 go out at this time, or, to be exact, 69,800,000.

Q. Now did you determine where they came from?

A. No, it is impossible to find that out.

Q. Did you ascertain what part of those people came from within the District?

A. Only as far as we could, but it would only be a matter of estimate, Mr. Hopkins. The error might be in either direction.

Q. You consider, I believe you just said, there is about sixty-eight or 69,000,000 people coming in and sixty-eight or nine million going out?

A. Yes, sir.

Q. Then how did you get the 300,000 here all the time, do you figure that 69,000,000 in a year are in Chicago all the time, and just divide by 365 or 330?

A. The only way we could get at that is they even up. Take the through passengers that come in, they might stay

a day or twelve hours or a week, and as near as we could tell after careful study, we thought the floating population would be 300,000 by 1920.

Q. But you do not take into consideration the people in Chicago that are out of the city?

A. That would be a small percentage of the total.

Q. Nor did you take into consideration, as you say, those that come from somewhere within the District?

A. We could not always separate them. We did it as well as we could.

Q. Isn't it necessarily the case that about as many people are going out as are coming in?

A. That is true that there are as many people going away from a city as are coming in, when you take into consideration the people living in the Suburbs, they go out and they come back, or rather they come in and go back to their homes. The through passengers stop, and go on; but it is not true that as many people go out of a large city and stay away as long as the people that come to a large city.

For instance there are more people that go to New York City and stay there than there are New Yorkers that go out of New York City by a large number.

Q. How did you get this 300,000?

A. That was merely an estimate based on what would be the condition by the year 1920.

Q. I want to get your method of estimation, how you get that result?

A. At the present time, as near as we could tell there are about 69 to 70,000,000 people in a year.

Q. How would you get the day, so many per day?

A. That gave you so many per day for 300 and some odd days a year.

Q. Then you just divide by 300?

A. No, that would not give it, but we estimated on the growth of the city and the growth in the passenger traffic.

Q. I mean today, how would you determine this same figure corresponding to 300,000 for 1920?

A. Divide by about 310.

Q. Divide 69,000,000 by 310?

A. 69,800,000 by 310.

Q. Why do you select 310?

A. That is practically the year without Sundays; that is the only reason, and ordinarily there are more people in a big city on week days than there are on a Sunday.

Q. As a matter of fact, in the year around, there is quite an exodus on Sundays?

A. I suppose so, but it would be safe if you take the week day conditions.

Q. In the summer time, there are a great many people who leave the city?

A. On Sundays, probably, over Sunday.

Q. Every day, a great many people are out of town in the summer time, in the warm weather, aren't they?

A. Yes, there are quite a number out of town; quite a number in the city, too.

Q. A great many people coming in from day to day are people living in the city, who are returning home?

A. Pardon me?

Q. A great many millions of people coming into the city are people who live here and are returning home?

A. If they lived here, they would not be returning home.

Q. Traveling men who may be out, coming in from time to time. You got your records, I understand, from the railroads?

A. There may be a percentage of those that are counted in twice, but that is on the side of safety, rather.

Q. You have not given consideration to those who lived in the city returning home, those who live somewhere else in the District coming to Chicago, nor the people in the city who are away, in computing this figure?

A. As near as we could we deducted those who lived in the Sanitary District, in the suburbs.

Q. You said you had no way of determining that?

A. Accurately, no. It was a matter of judgment.

Q. You gave no consideration to the other items I called your attention to?

A. It would be a very small percentage of the gross total.

Q. That is the people who live in Chicago and are out are a very small proportion of those that come in every day on those trains?

A. On the average, yes.

Q. So small you didn't even consider it?

A. It would be all on the side of safety to get good conditions here, but as near as we could, we got this up as accurately as we knew how.

Q. As a matter of fact, in every city where they have sewage problems, and in which it has been used in whole or in

part, as a basis of getting at this figure of 3½, there is more or less of a floating population?

A. I do not think the floating population was as great 25 years ago as it is today in the large cities; but as far as the figure of 3½ is concerned, our own experiments and experience here show that is about the proper figure, with trade wastes kept out.

Mr. Hopkins: I move the latter part of the answer be stricken out as not responsive.

Q. (Question read to witness.)

The Witness: I answered it.

Mr. Hopkins: You said 25 years ago something happened.

A. It was not as carefully studied, and I do not believe at that time they took it into consideration. I don't know as that was ever done; and I do not think it was ever carefully studied before the Sanitary District got to studying its own conditions; there was not very good available data as to what was needed for dilution purposes.

Mr. Hopkins: I would like to have the question answered.

Q. In nearly all of the centers where there is a sewage problem, there is a floating population, isn't there?

A. Yes, that is true.

Q. And any tests that might be made down the river from some city as to the condition of the water there would include whatever sewage would come from the floating population wouldn't it?

A. I don't know of any place where they have ever made that study except here, Mr. Hopkins.

Q. The Blackstone River, you mentioned a while ago?

A. The Blackstone River.

Q. Mr. Hering made certain statements, did you hear them?

A. That was back in 1889, and that is hardly a large city.

Q. (Question read as follows): And any tests that might be made down the river from some city as to the condition of the water there would include whatever sewage would come from the floating population, wouldn't it?

A. If any such tests were made, it would include the sewage coming from the floating population, but I know of no such test ever having been made.

Q. You have formed your opinion in regard to the amount necessary based upon the conditions in the Chicago Canal that you have studied?

A. Yes, sir. I did not know anything about the conditions in 1889 myself. I was not even here.

Q. You have some kind of an opinion now in regard to the matter?

A. Yes, sir.

Q. It has been formed on that basis?

A. Formed on the basis of our own particular studies here.

Q. And the condition of the water in the canal as you studied it had in it the sewage from whatever floating population there might be in the city of Chicago, didn't it?

A. Yes, sir.

Q. So that in forming your unit per thousand, all the way through, it was based upon the population of a particular district rather than upon individuals actually sewering into the stream at the time?

A. No, it was based upon, as near as I could tell, the number of people sewering into the canal.

Q. On page 2072 of your testimony, do your figures include any floating population?

A. No, those do not include any floating population.

Q. The state law makes no provision for anything more than the population does it?

A. That I suppose would be a matter of argument as to whether it should, whether it would mean the people that are in Chicago or not. We have assumed that we were complying with the state law if we sent down as much as the population exclusive of the floating population would require, but to be safe and have the proper dilution, I think we should have water enough to take care of the floating population as well as the resident population, and at the rate of 3½ cubic feet per thousand people sewering into the canal, whether they be resident or floating.

Q. When did you change your ideas to the extent you thought you had to make an extra allowance for floating population?

A. I don't know as I have changed it.

Q. You said you thought you were doing it properly heretofore, by simply having sufficient water in proportion to the actual population?

A. That was to comply with the state statutes.

Q. And that included trade wastes and everything, didn't it?

A. Yes. Trade wastes have been going in, but the point

remains that we find local nuisances along the canal and the water itself in the canal, the oxygen in the water has been entirely used up before the end of the canal was reached.

Q. Do you have any other basis for your estimate that there will be 300,000 more people in Chicago each day than there are people normally here that are away in 1920, than just some information you have gotten of people coming in on the railroads?

A. Why the only other information I have is such articles as I read; and I read one here a short time ago. As I remember, the estimate compared very closely with the one that I had as to the floating population.

Q. Just what did it purport to give, did it purport to give the population in excess of those that are out of town?

A. As I understood it, yes.

Q. But still your railroad reports show about the same number going out as coming in?

A. Those that come in do go out. They do not come here and stay.

Q. What was this article?

A. I was trying to recollect. It was something I saw recently, and I don't remember where.

Q. Mr. Wisner, what advances in the art of sanitation or disposal of sewage have taken place since October 12, 1911?

A. I think we have found out the difficulties rather than have made any particular advance or change in methods. It has been deemed advisable in certain cases that aeration, for instance, should be used in connection with long sewers to prevent septic conditions in the sewers themselves; and that certain sterilization should be added in connection with plants where the effluent is to go into streams that may get to the source of your water supply. As far as any changes or improvements being made in the way of disposal of the sewage itself, I do not think there has been many; it has been more detail. We have appreciated the care that was necessary to properly handle sewage, to prevent obnoxious conditions arising.

Q. Anything else that you think of that would make the conditions different today from what they were at the time I just mentioned, aside from this matter of aeration and sterilization?

A. There is one other matter that, for instance, was not considered in that report that I made at that time, and that

was the amount of land that it is necessary to have around a sewage disposal station, so that the municipality would control the land and there would not be residences near the sewage disposal station.

At this time, I think there should be at least a quarter of a mile all around a sewage disposal station, and even more than that to avoid future litigation, and local nuisances on property not controlled by the municipality.

Q. You have doubled your estimate on that then?

A. On the amount of land necessary?

Q. On the distance that it would be noticeable?

A. Well, it would depend altogether on the condition of the atmosphere and the wind, as to how far it would be noticeable. I have no doubt that with a foggy saturated atmosphere, and a wind blowing from the Southwest that it might be noticeable two or three miles away at certain times. I know we get odors that far from the stock yards district.

Q. Anything else that you have in mind now that was not considered then?

A. There may be something else. That generally is it, as I remember .

Q. If there are any other matters, are they very important ones?

A. They might be. I do not think of them right now, except there is one other matter, that sites that were available at that time for sewage disposal works are not now available, and the sewage in one particular case would have to be taken a longer distance than we counted upon at that time. The centers of population, or growth of suburbs of the city has changed somewhat from what it was at that time. Districts at that time that were not built up are now building up, and it would make it impossible to locate sewage disposal stations where we thought at that time they could be located.

Q. What has occurred to change your opinion in this: "That it will be impossible to get a continuous flow of 10,000 cubic feet per second through the main channel until the Calumet-Sag Channel is completed"?

A. Well, at that time the Main Drainage Channel had not been widened to its full capacity at this end of the canal; and at the present time that has been pretty near finished.

Q. Was that the impossibility you had in mind?

A. That is the only one I think of now.

Q. You prepared with Mr. Fuller the estimates that he gave, didn't you, in regard to projects of sewage disposal?

A. I went over them with him generally, yes.

Q. The results that you have given in your direct testimony are about the same as his, aren't they?

A. They do not vary so very much. I think there is some variation.

Q. What, generally, is the variation?

A. I do not remember.

Q. Are yours more or less than his?

A. My recollection is they are a little less, slightly less.

Q. You think that one of the principal things to be remedied or prevented, as the case may be, in the canal, is to keep out sewage mud or stale sewage, deposits of that kind?

A. Well, the deposit of fresh sewage mud is objectionable, yes, sir.

Q. Because it would prevent local nuisance?

A. It does, until it has a chance to be what we call worked over or oxidized. After a time it becomes inert and it ceases to give off gases as it does when freshly deposited.

Q. If all the sewage in Chicago were screened and settled, wouldn't most of that be prevented?

A. Most of what?

Q. The sludge deposits?

A. I do not think there are any deposits to speak of at this particular time. I think that with our present flow that there will not be any deposits to speak of. By that I mean that the channel has been so filled up that there is now practically a scouring velocity through it which carries the suspended matter through.

In answer more directly to your question, if all the suspended matter were screened or settled out of the sewage, it would materially lessen the deposits in the channel.

Q. Wouldn't you think with 4,167 cubic feet, this settling would prevent most of the deposits?

A. No, there would be great quantities come in from Lake Michigan every time there was a storm and the water became turbid and muddy, such as we have had here recently. There would be large quantities of sediment that would come into the channel and settle.

Q. That would be dirt and sand?

A. It would be dirt and sand, yes.

Q. That would not be sewage?

A. It would so shoal up the channel that at times, if we wanted, could flow more than 4,167 cubic feet through it,

should desire to do so, it would be impossible to get it through.

Q. That would materially improve conditions over what they would be if you didn't settle it or screen it?

A. As far as nuisances are concerned at the start, yes, sir, but there would come a time when the stream would just take this amount and there would probably be no further settling.

Mr. Adcock: Q. You would reach a scouring velocity?

A. You would reach a velocity such that by the channel filling up there would be no more settling.

Mr. Hopkins: Q. Do you agree with Mr. Hering when he says that by settling the sewage he thinks that 10,000 cubic feet per second would take care of about 4,200,000 people?

A. Just settling it? No, I should say not. In answer to that, I do not agree with him, if he says 4,200,000 people. I think that is too many. As near as we can tell the improvement from screening and sedimentation would only amount to about 25 per cent.

Mr. Adcock: That is the maximum?

A. I think it would be about 25 per cent.

Mr. Hopkins: Q. What percentage of the organic matter would be settled out of the sewage?

A. I think about 25 per cent.

Q. Of the coarser particles?

A. No, I mean of the organic matter in the sewage.

Q. That 25 per cent. would largely be made up of the heavier and coarser particles?

A. It would be made up of that.

Q. As a matter of fact, do not the larger particles require more oxygen to decompose them than the smaller particles?

A. I don't think so. The action is put off longer.

Q. And that would to a great extent remedy the sludge deposits, if that is the part that would probably settle anyway, would settle in those tanks?

A. It would not remedy it, because they are already there, at the present time, in the canal.

Q. That that is already there could be cleaned out?

A. Well then there would be deposits, there would be fresh deposits which to my mind are more harmful than the old deposits which have been partly oxidized.

Q. That is even with this 25 per cent, of the entire organic matter, composed of the larger particles, if that were taken out, still your sewage deposits would be as fast or faster than they were before?

A. Oh, no, I misunderstood you if I said that. What I meant to say was that if we take out the deposits that are in there and then allow the sewage to go in as it is, there would be fresh deposits in the places where we took the old sludge out.

Q. But not so much as there would be without that settling process?

A. If you have the settling tanks in connection with that, there would not be so much.

Q. This was all on the assumption that you had settling tanks for the raw sewage?

A. I misunderstood your question. If you will start in again, I will try and get it right.

Q. Suppose you had grit chambers, settling tanks and screening, wouldn't that decrease very materially sludge deposits in the canal below that?

A. I don't think at the present time that there are any sludge deposits in the canal being freshly made or freshly deposited; I think that the matter is carried through the canal.

Q. Given the same amount of water, if your sewage is treated by grit chambers, settling tanks and screens, wouldn't the sludge deposits be much less than they would without such treatment?

A. Not much, under the present condition of the canal. If, Mr. Hopkins, you remove the sludge deposits that are there now, then the deposits would be much less if they were taken out in tanks and by other methods than they would be if they were not, but the canal now is in such shape that it practically has a carrying velocity throughout its entire length, and the material is not settling in the channel.

Q. As I understand, if you take out the sludge deposits that are now there, there will be a greater tendency to have deposits?

A. Yes, that would make the cross-section larger and the current slower, and it would drop these heavier deposits of suspended matter which are now carried on by the velocity in the channel.

Q. Then it would be better just to leave the sludge deposits as they are?

A. Right at the present time, I think it would be.

Q. And then if you took out this proportion that you speak of by these processes of settling, you would greatly minimize the chance of increasing those sludge deposits?

A. I do not think they will increase under the present conditions.

Q. Suppose your flow of water were reduced to 4,167 cubic feet per second?

A. Then they would increase.

Q. Your sludge would increase?

A. Your sludge deposits would then increase.

Q. Then what effect would settling tanks have?

A. They would tend to decrease it.

Q. By a greater proportion than 25 per cent., too, wouldn't they?

A. They would decrease the sludge deposits by more than 25 per cent.

Q. They would practically eliminate it?

A. There would still be some deposits coming from the sewers and the tanks and also considerable from Lake Michigan water itself.

Q. But that is the only possibly thing to remedy that situation?

A. That would prevent the nuisance in the canal, and tend to purify the sewage.

Q. Now, suppose that trade wastes from tanneries, stockyards and commercial works were kept out, to what extent would that improve the conditions in the canal, or what effect would it have upon the requirements of water?

A. Well, keeping out these manufacturing trade wastes would mean that you would not require as much water to dilute the sewage coming from the city as is required at the present time, when we are not getting sufficient. As stated in my direct examination, I believe that then 3⅓ cubic feet per second would be sufficient to properly dilute the sewage coming from the rest of the city. Of course, a great big city like this, it is almost impossible from a practical standpoint to entirely eliminate all trade wastes.

Q. But you could eliminate a good part of them, couldn't you?

A. You could probably eliminate the worst offenders.

Q. In the estimate as put in by Mr. Fuller, did he include settling of the sewage from the loop district and the West Side?

A. Yes, sir; I think he did.

Q. On the basis of 3⅓ cubic feet of water per second per thousand population, if the sewage were first setled, then 4,167 cubic feet would take care of about 1,600,000 people, wouldn't it?

A. It might take care of 1,562,000, providing that the sewage of the entire population within the district was settled, and that the manufacturing wastes were kept out.

Q. The 3½ feet, as now provided by state law, makes no provision for trade wastes and things of that kind, does it?

A. That I am not sure, Mr. Hopkins, whether that is in the law or whether it is in my own mind as to what people have told me that they had in mind, at the time the law was framed. At that time, it was expected that the trade wastes would to a large extent be kept out.

Q. Do you have any idea as to the amount of the coarser, larger wastes that are being deposited in the canal?

A. At the time I made that other report in 1911, we had some figures upon it that are given in there.

Q. Do you have any more now?

A. We have figures, which I haven't in mind now, as to the amount of settling matter that comes from certain sewage districts and from certain industries, in the form of trade wastes.

Q. If those trade wastes were taken care of in other ways, by the industries themselves, that would increase the power of the water to dilute the sewage very materially, wouldn't it?

A. Well, as I said before, it will require more water to properly dilute the entire sewage coming from the people and from trade wastes than it would if the trade wastes are kept out, but I think it will require 3½, as near as I can tell now, to properly dilute the so-called domestic sewage.

Q. You say that you have been taking for some little time now about 3½ feet per second per thousand inhabitants, and that you consider that the Sanitary District is in very good shape?

A. No, I didn't say in very good shape, Mr. Hopkins. I said there were at times local nuisances along our channel, at times when the oxygen in the combination of diluting water and sewage is practically used up at this end of the canal, and that septic conditions exist in the channel.

Q. That is largely due to sludge deposits, isn't it?

A. I think it was at one time, but at this time I think it is mostly due to the sewage itself and the burden it is carrying.

Q. Trade wastes have been going into that right along, haven't they?

A. Yes, sir; although the last two years it has been pretty well filled up, as far as it will fill.

Q. What has been filled up?

A. The channel itself at the wide places in it, where the velocity originally was slow.

Q. You said that your water supply was very good in Chicago now?

A. Yes, it is.

Q. You are not having any water flowing into Lake Michigan?

A. No sewage?

Q. Yes?

A. Only such as comes in north of the south line of Evanston, and that that comes in through the Calumet River and the Indiana towns and such as comes from passing vessels.

Q. But through the Chicago River you are not getting any?

A. There has not been any flow of the Chicago River into Lake Michigan in the last two years that I recollect.

Q. So that for all practical purposes, your situation now is really good, isn't it?

A. As far as the drinking water is concerned.

Q. As far as the general health of the community, taking care of the sanitation?

A. That is generally true. There are places in the river and in the canal itself and below the end of the canal where the effluent coming from our works is not what it should be.

Q. Now, as a matter of fact, aren't the trade wastes that get in there a very big item; it takes a great deal of the oxygen?

A. Undoubtedly that is so. It is also true that within the the last two years these larger offenders have improved the condition of the effluent coming from their works, and they are not putting in so much of the solids as they did two or three years ago. But at the same time they are putting a big burden upon the diluting water that we use; and to my mind, if this burden was not there, why the canal and the river below the end of the canal would be in just about such shape as it should be.

Q. Do you have any idea how many people could be taken care of by the water and oxygen which is now necessary to dispose of these trade wastes?

A. That is a rather difficult question to answer.

Q. Could you make any outside limits?

A. It would amount to several thousand people.

Q. Could you give us any figure on that?

A. I would not want to hazard any guess on that.

Q. 500,000?

A. I suppose a man could guess 500,000, but I am not going to.

Q. I believe in your report you said that the remedy for overloading of the sludge can be settled at once, by having all the suspended matter settled out?

A. To what page do you refer, Mr. Hopkins?

Q. Page 22, just before you get to the Ogden Ditch?

A. (Referring to same.) Yes, I said that.

Q. And that settling would probably dispose of the floating matter; certainly screening would, wouldn't it and dispose of the parts that are offensive to the eye?

A. It would probably have to be a combination of screening and settling, and possibly some chemical precipitation of some kind. We are at the present time carrying on experiments to see what we can do with the trade wastes coming from Packingtown and the packing industries, and as yet we have not got the solution.

Q. Don't you think that a combination such as you suggest there would really take out more than 25 per cent. of the organic matter?

A. I doubt it; a little less if anything. That is from the results of our experiments.

Q. Have you experimented with the combinations?

A. Yes, we have experimented with the combination of screening and settling and with different kinds of settling tanks, and are now experimenting with chemical precipitation.

Q. This aeration that you speak of, which is new to you, you simply mean the aeration in the sewers proper; you had in mind the aeration of sewage in general, didn't you?

A. Had in mind the aeration of the sewage proper on the way to the treatment works, to keep it from becoming septic, and causing nuisances en route.

Q. At the time this report was written, you had in mind aeration of the canal?

A. That was in connection with increasing the oxygen in the canal itself, and also the possibility of aerating the effluent of settling tanks.

Q. Wouldn't this aeration of the sewage on its way to its place of treatment tend to increase the oxygen in the fluid itself, and help your dilution process in the long run?

A. It would help out the sewage treatment on disposal works and keep the sewage, as we call it, fresh instead of septic.

Q. If it did not go to settling works, it would help the dilution, wouldn't it?

A. I presume it would, some.

Q. Do you have any reason to change the opinion that you expressed in that report very positively two or three times that the drinking water of Chicago should be filtered?

A. I don't remember that I stated that it should be, absolutely positively. I said, as I recall, that from an aesthetic standpoint that it undoubtedly would be at some time.

Q. I do not find the place in the report, but whatever is in there, you have no occasion to change it, whatever you said in regard to filtering?

A. I could tell you what is in there.

Q. It is not only in the recommendation, but there is another place where you had it positive?

A. I think you are mistaken, Mr. Hopkins, if you think that I urged it in this report.

Q. Whatever is in there you have no occasion to change; nothing has occurred to change it?

Mr. Adcock: You mean as to what?

The Witness: As to the filtration of the water supply. You are only referring to the filtration of the water supply?

Mr. Hopkins: Yes.

The Witness: My recollection is that I said that it was thought in time to come, for aesthetic reasons and other reasons that that it would be urged that the water supply be filtered; and I presume that may come.

Q. Now, in your sprinkling filter system as outlined in that report, in your plans for 1920 and 1930, you were going to put through sprinkling filters the sewage from the North Side, the sewage from the Calumet District, the sewage from the South Side, weren't you?

Mr. Adcock: You refer to the 1911 report?

Mr. Hopkins: Yes.

A. It is all in there, what I had in mind at that time. It is some time since I looked it over carefully. I gave estimates at that time on those projects but my recollection is that the sprinklers were not to be installed until after 1930. I may be mistaken about that. Anyway, the report gives it.

Q. You gave estimates for sprinklers to be installed in 1930?

A. In the Calumet region.

Q. I think in all the regions that I have mentioned?

A. I gave estimates for them, but they were not to be installed as I recall before 1930.

Q. But as far as what you were going to do is concerned, it does not make any difference whether it is 1930 or not?

A. It does as a matter of cost.

Q. You think it will cost more then, don't you?

A. More to install them than than now.

Q. Yes?

A. I think the chances are that they may cost more.

Q. You were going to treat by sprinkling filters the sewage from the districts I have named, weren't you, in 1930?

A. I think it was after 1930.

Q. Well, after 1930?

A. That is providing that the district was limited to 10,000 cubic feet per second.

Q. Then your estimates were based upon that?

A. Upon those districts.

Q. Upon treatment by a sprinkling filter?

A. Of the excess population over and above 3,000,000, which was not offset by sedimentation.

Q. Don't you in your report provide for the treatment by sprinkling filters of all the sewage from the districts that I have named?

A. From certain districts; whether that was the districts you have named or not, I do not at this time recall.

Q. Do you have the report referred to before you?

A. Yes, sir.

Q. Will you refer to it and see if you do not include the districts I have named?

A. I gave estimates on several different projects. There were no recommendations as to when they should be built except as to the Calumet District. I did recommend, as I remember, that certain sites be procured so that if in the future it seemed best to treat certain districts, that those sewerage districts could have the sewage treated.

Q. Your estimates, however, were based upon carrying out the sprinkling system process?

A. Wherever used; yes, sir.

Q. Will you refer to page 66 of that report?

A. Yes, sir.

Q. There you give an estimate of treating a certain designated population amounting to about 1,400,000, which includes estimates for both settling and sprinkling, and for the annual cost, doesn't it?

A. Those are three different projects, and it gives the first cost of each of them and the annual cost of each one

of them. It does not anywhere say that they should all be built.

Q. I didn't ask you that. I asked you for the estimate of the cost; if you did not make an estimate of the cost.

A. I said that I made an estimate of the different projects.

Q. The sewage which was to be treated in those estimates is practically the same sewage as is spoken of by Mr. Fuller in his estimate as to what part is going to be treated by sprinkling filters. To refresh your recollection a moment, was not the West Side and the Loop District to be sent down by the dilution process, and the North and South Sides and the Calumet District to be treated by sprinkling filters, in his project?

A. This report was written on the basis that there would be 10,000 cubic feet of water available for dilution; and the Fuller estimate that you speak of is on the basis that there would only be allowed a diversion of 4,167 cubic feet per second.

Mr. Hopkins: I move that the answer be stricken out.

The Witness: And therefore these estimates of Mr. Fuller and those made by myself in 1911, were not on the same basis.

Mr. Hopkins: I move the answer be stricken out as not responsive.

Q. My question is, if the sewage from the population which you estimated the cost of treatment for is not practically the same as the sewage from the population that Fuller had under consideration?

A. No, sir.

Q. Well, you estimated on the treatment of all sewage collected in the Calumet District in that report, didn't you?

A. In the Calumet District it might come near being the same, but the other districts would not.

Q. In that estimate, you had in mind the sewage of all the population which was collected through the intercepting sewers and through the 39th street pumping station, too, didn't you?

A. I had in mind all of the sewage, Mr. Hopkins, but I did not have in mind treating anything except for the excess population over 3,000,000 people.

Q. Isn't this the situation: That you said in that report that with 10,000 cubic feet a second you could take care of 3,000,000 people, but that you thought you ought to have sedimentation anway?

A. In connection with the growing population, I felt that in a city like this, that is growing 50 or 60,000 people per year, that there should always be available surplus works to take care of the people?

Q. Here is my point: That until you exceeded 3,000,000 people, your 10,000 cubic feet would take care of it without sprinkling filters?

A. It would, or without sedimentation tanks; but you cannot build those works in a day and I figured by 1920 that population would be reached, and by the time that we could install works to take care of the excess population after that, in order to take care of the excess population we should start building at once, providing we would be limited to 10,000 cubic feet per second.

Q. I think we can work together better, if you keep in mind that I am not trying to ask you about your recommendations so much as about estimates. You recommended that until the population exceeded 3,000,000 you would not need sprinkling filters?

A. No, you would not need sprinkling filters until it did exceed that.

Q. You made an estimate, however, of what it would cost to run all your sewage of the North Side through settling tanks and through sprinkling filters located in the places mentioned there, didn't you?

A. Not all the sewage, no, sir.

Q. Of the North Side?

A. No, sir; not as I recall it.

Q. You did not say anything about any sewers taking any part of it directly into the Chicago River or the Drainage Canal, did you?

A. There were certain sewers I was not going to touch at all; just let them go on and do as they were doing, and are doing now.

Q. It will not make any difference in the cost of sprinkling filters whether you have 4,167 or 10,000 cubic feet in the river itself, if you put all the sewage through the sprinkling filters, will it?

A. If the same amount of sewage went to the sprinkling filter, I suppose it would cost just the same in either case.

Q. If in fact you did consider in that estimate that all of the sewage of the North Side and of the South Side and of the Calumet District was to be treated by sprinkling filters, has anything occurred to change your estimates, with

the possible exception of this matter of aeration in the sewer proper, and of sterilization?

A. In the first place, I want it distinctly understood that we did not include all of that or have it in mind as being treated. I am perfectly willing to answer your question, which I understand is: Has anything occurred between 1911 and the present time that would tend to make me give higher estimates than I did at that time. That is what you are getting at, isn't it?

Q. Yes?

A. The aeration which you mentioned.

Q. Can you give the amount of that?

A. I think we have got that; I haven't it in mind. I can get that for you; and the sterilization of the effluents, and larger areas are provided for the reason that I have stated, that in this estimate we just gave an estimate of the actual land that is necessary. Since that time I realize that we must control land lying around the filters as there is bound to be some odors come from sprinkling filters.

We have also, since then, prepared detailed plans for a plant of this kind and the figures given in the report of 1911 are lower than they should be. As I stated before, I think at that time I was inclined to give estimates lower than were warranted, by the actual experience that has been had since that time.

Q. Can you tell how much should be added to the estimate by reason of extra land, how much for sterilization, aeration, and then how much in error you were in that estimate generally?

A. I suppose I could by doing a great amount of work to get that out; it would take some time. And as I stated before these two estimates are not comparable. One is based upon a certain flow and the other on an entirely different flow.

There was one thing that I forgot to state, that in the report of 1911, we did not take into account the expense of taking care of the public utilities, which these schemes involve. That is in building big sewers down through the streets of the city, you disturb the water mains, gas mains, electric conduits, telephone conduits, street car tracks, railroad tracks, paving.

Q. Well on project A, as described by Mr. Fuller, the sewage was to be treated under the present combined system of sewers, wasn't it?

A. I have forgotten which project that was. He had one project—

Q. So that in that project you would not have to take up all the streets of the city, would you?

A. Not all of the streets, but you would have to take up the streets along which the intercepting sewer went, Mr. Hopkins?

Q. How many intercepting sewers would be needed for that on project A?

A. Miles of them. I could have the list scaled off of the plans, giving you the distances that they travel through these streets, if it is desirable. I can get that for you. It takes some little time to add up the different lengths.

Q. Did you see what the estimate was in regard to aeration that was to be added?

A. That is given in my direct testimony on page 2095.

Q. Does that include the sterilization there?

A. It also gives the sterilization, it is called disinfection.

Q. Under which head, storm water disinfection or domestic sewage disinfection?

A. Both.

Q. I believe there is included in there the cost of an intercepting sewer in the Calumet District to keep any sewage from going into the Calumet River?

A. That is in there, I think.

Q. Did you say it was included?

A. Yes, that is included in those estimates.

Q. Such intercepting sewers would be necessary in a dilution method, even though you had two or 4,000 cubic feet of water, through the Calumet-Sag Canal, wouldn't they?

A. They might be different in detail, but in our Calumet project that we have estimated the cost of, we have included the cost of those sewers.

Q. In which Calumet project do you estimate that?

A. That is given in my direct testimony as I remember, the cost of the Calumet project.

Mr. Adcock. You mean under the dilution method?

A. Under the dilution method for the Calumet channel.

Mr. Hopkins: Q. So that that expense would be the same under either theory, whether you got the water or not?

A. It would be a little different, but in comparing the estimates they have been included in both cases.

Q. I believe you say the sewer system in the Loop ought to be remodeled throughout, regardless of whether the dilution method is used or not?

A. I think that is true. It has not been included in any of these estimates, however.

Mr. Adcock: Q. That is, it does not make up a part of the cost of any of the different projects?

A. No, sir.

Mr. Hopkins: Q. What is your income or would be your income a year from the sale of power; what is your annual income from the sale of power?

A. Now?

Q. Yes?

A. I don't know what it is now.

Q. Do you know what it would be if you were limited to 4,167 cubic feet per second?

A. It would depend on how it was disposed of.

Q. It would be a credit, whether you used it or sold it, wouldn't it?

A. What I mean by that is that we sell it to the City of Chicago for one price, practically cost. We sell it to commercial consumers at as near the market price as we can get. The people are receiving the benefit in the form of cheaper lighting.

Q. You have no other source of income except taxes, besides the water power?

A. Some leased property, and we have given credit for that.

Q. That is nominal?

A. It is given in the testimony here; I think about $80,000 a year. And of course interest on deposits and things of that kind, merely incidentals.

Q. Your main source of income to take care of operating expenses of any of the projects that you have mentioned would be taxes, wouldn't it?

A. Yes, sir; that is the main source of income.

Q. Annual taxes?

A. Yes, sir.

Q. You are familiar with the applications that have been made to the Secretary of War for permission to divert water from time to time, weren't you?

A. Some of them. I have been somewhat familiar with all of them?

Q. You knew that you were limited, and have been limited for about ten years now, to 250,000 cubic feet?

A. As it affected the navigation of the South Branch; I have always considered that that was the cause of the limitation put upon us.

Q. You knew that an application was made in 1906 in con-

nection with the Calumet-Sag Canal to Secretary of War Taft and denied?

A. For an additional 4,000 from the 10,000.

Q. You knew that?

A. I knew that such an application had been made.

Q. You knew an application was made in 1907 in regard to the diversion of water through the North Shore Canal at Wilmette, that was granted on condition that the total diversion from Lake Michigan should not exceed 250,000 cubic feet a minute, already permitted?

A. That diversion also went through the South Branch, so the current—

Mr. Adcock: You could not increase it.

Mr. Hopkins: You knew about that permit?

A. I don't remember that particular one. I knew there was some permit, Mr. Hopkins.

Q. You knew you were never given permission to take more than that amount in the last ten years, 250,000 cubic feet a minute at any place?

A. I don't know that we ever had any positive permit to take more than 250,000 in the last seven or eight years.

Q. You knew you made application to the Secretary of War in 1910, to dig the Calumet-Sag Canal and got permission on condition that the total diversion should not exceed 250,000 cubic feet a minute?

A. I don't remember whether that was specifically put in, 250,000 cubic feet per minute, or not. I know the sense of the permit was that we could not—we had not a permit to withdraw more through both channels than we would be allowed to draw through the Chicago River.

Q. And that was at that time limited to 250,000 cubic feet a minute?

A. Based upon not creating a current to exceed a mile and a quarter an hour.

Q. Regardless of what it was based upon, that was the amount it was limited to.

Mr. Adcock: I object to that.

A. I don't remember whether it was changed at all.

Mr. Adcock: I object to that; that is a matter of record and the permits themselves show.

Mr. Hopkins: I am asking for his knowledge of the limitations.

Mr. Adcock: I do not see how that is material.

Mr. Hopkins: Q. As a matter of fact you were familiar with all of the permits?

A. I have read them all.

Q. And applications?

A. I have read them all. I could not tell you now what was in all of them. I know that we were limited on account of the small size of the South Branch, so as not to create a current in excess of a mile and a quarter an hour.

Q. As a matter of fact, Mr. Wisner, in the offices of the Sanitary District, you do not use as drinking water the local lake water?

A. No, for the simple reason that all of these buildings store their water in tanks on top and the water becomes unfit to drink. It has to be pumped and put in tanks on top of the building, and soot and dirt get into it.

Q. Then a large part of the drinking water throughout the city is subject to the same condition?

A. In the business district, the water supply would not reach these floors we are on; there is not sufficient pressure. Whether they drink it in the basement or not, I don't know. I presume they do. They serve it in the restaurants and in cafes.

Q. In your Exhibit 6, you have put in a chart showing the levels of the lakes before and after the opening of the canal. Do you think that the higher elevation sometime after the canal was opened compared with 1896, is due to the opening of the Drainage Canal?

A. I don't know what it is due to entirely. I know it exists. That is taken from the record of the U. S. Lake Survey.

Q. You do not mean to intimate anything by that as to the cause of that elevation?

A. I did not say anything about the cause of it.

Mr. Adcock: It is just a fact, a physical condition.

The Witness: It is just a fact.

Mr. Hopkins: I move it be stricken out then.

Q. If you had completed your average down to 1912 or 1913, there would not be as great discrepancies as shown there, would there?

A. Well, we simply took it up to the time this suit was started, and for the same number of years before.

Q. The time this suit was started; it was started in 1908, wasn't it?

A. I thought it was 1910. I know we had the records at that time.

Q. Have you made a computation of lake levels including 13 years after 1900, and the 13 years before?

A. No, for the reason that the 13 years before was when they were, as I recall now, was about the time they were making changes in the Detroit River, which to my mind had some effect upon the levels of Lakes Michigan and Huron.

Q. In other words that would have shown the average was higher before—

A. Before the government made these improvements.

Q. —before 1900 and was lower after 1900, and tended to equalize the levels?

A. I don't know as it would. It might have tended to bring them closer together; I don't know. I have not made that computation.

Q. You can tell it was a good deal lower, the average, in 1912 and 1913?

A. It was lower in 1911, but not as low as it was in 1895.

Re-direct Examination by Mr. Adcock.

Q. You have had some experience, as I understand it, Mr. Wisner, in the operation of this channel?

A. Yes, sir.

Q. You have had occasion to observe the conditions of flow with reference to whether or not the ratio of dilution that is provided for under the state law is approximately the correct ratio, when you take into consideration the condition of the lake water and the sewage here, domestic sewage?

A. I think it is, with the trade wastes removed.

Q. Your experience has run over several years, as I understand it?

A. Yes, sir, and within the last year the experiments that we have made tend to show that on certain days, like Mondays for instance, when there are not such excessive amounts of trade wastes coming from the industries such as the tanneries and the packing houses, that then the dilution is almost sufficient, whereas on week days when there are large quantities of these trade wastes going in, it is not sufficient.

Q. Then you have reached the conclusion from experience, practical operation of the canal and from the experiments which you have made, that the legal ratio of dilution is practically correct for the domestic sewage?

A. That is my opinion at this time, as near as it is possible to tell, that that dilution is sufficient for the domestic sewage.

Q. Now you were asked on cross-examination about lowering the dam at Lockport, the opening, so as to take care of a flood condition, on the assumption that the flow of water through the channel from the lake was limited to 4,167 cubic feet per second. In that connection, I would like to ask you whether or not if the flow were limited to that amount, the channel would after some years of operation tend to fill up, so that it would have a capacity of approximately that amount?

A. It would not only tend to fill up, but it would fill up so that it would in time have a capacity of practically that amount only.

Q. What effect would that condition have upon the opening of the gates, opening of the dam at Lockport, to take care of flood conditions?

A. It would mean that we would be unable to take care of the flood conditions, and practically all water, storm run-off, in excess of 4,167 cubic feet per second, would be discharged into Lake Michigan polluting the water supply.

Q. In the earlier years of the operation of this channel, as I understand you, there was less water flowing through it than there is now, is that correct?

A. Yes, sir.

Q. As a result of that condition, was there a tendency to deposit sludge matter greater than there is at the present time when the flow is approaching more the capacity of the channel?

A. Very much greater, and the deposits did take place.

Q. So that now there has been deposits sufficient to fill up the channel at certain points, so that there is a continuous channel with a scouring velocity, and there are no deposits being made.

A. In my opinion there are practically no deposits being made in the main channel at the present time.

Q. You have been asked about your understanding with reference to the permits. Did you ever have any talks with government officials about the amount of flow of water through the Sanitary District Channel from time to time, during the last period of years?

A. Yes, sir.

Mr. Hopkins: First, I think we ought to know what government officials he has talked with, and whether they were speaking in an official capacity.

Mr. Adcock: Whom did you talk with?

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A. I talked with members of the International Waterways Commission, including my father, Mr. Haskell, General Ernst, who had at one time or another been members of this Commission; also with Mr. Gardner S. Williams.

I talked with General Bixby, while he was engineer officer in charge of the Chicago District; also talked with him when he was in charge of the St. Louis office, just prior to the time that he was made Chief of Engineers, and innumerable times with him while he was Chief of Engineers; also with Colonel Zinn, who was in charge of this District; Major Riche and, there was another officer here just before Colonel Zinn came; I do not recollect his name now. And in Washington I talked with Colonel Taylor, Burr; I don't remember their exact titles, and several others there that I have forgotten the names of. General Marshall, I believe I have talked with him about it too.

Q. As I understand it, the Sanitary District first commenced to improve the Chicago River in 1896 or '97 was it not?

A. That was the dredging, yes, sir.

Q. And as you stated before, the purpose of that improvement was to furnish a greater cross-section, to flow a greater amount of water through the channel?

A. For the purpose of furnishing a larger cross-section and keeping the current down to a mile and a quarter an hour with the increased flow going through the South Branch of the river.

Q. In 1896; that was known as the first project, was it not?

A. Yes, sir.

Q. Then there was another project that was entered upon along in 1900, was there not?

A. Yes, sir.

Q. That contemplated a wider river and a deeper channel than the first project?

A. Yes, sir.

Q. During the time that the channel has been in operation, you have actually flowed more water than 4,167 cubic feet per second, have you not, during the greater portion of the time?

A. During the greater portion of the time, that is true.

Q. In your talks with General Bixby, when he was here, and while he was Chief of Engineers, did you inform him as to the amount of water that the District was flowing?

A. Several times I told him, not only when he was here but when he was in Washington, the amount of water that we were flowing; and also have told the Government Engineers that were stationed here.

Q. The project providing for the improvement of the Chicago River and the South Branch of the Chicago River is practically completed?

A. It is.

Q. Except in some small stretches?

A. Some small stretches.

Q. When the improvement is completed, as provided for, will the river accommodate a flow of at least 8,000 cubic feet of water per second, without injury to navigation?

A. There is no doubt in my mind that it will, for the reason that at times we do flow that through there at the present time, and we have no complaints from the navigation interests in regard to the current. That has been so in the last two years. The only complaint that I remember of in the last several years was one that was caused by the construction of the Pennsylvania bridge across the South Branch at Stewart avenue, where, in putting in the foundations, it became necessary to clog up a part of the river with cofferdams.

Mr. Adcock: That is all.

Re-cross Examination by Mr. Hopkins.

Q. You mean that there has been no complaint made to you?

A. Well, in the old days, I used to get them often, Mr. Hopkins, and lately there have not been any complaints made about this condition.

Q. There were complaints made to the Secretary of War, when you made your last petition, weren't there, your last application?

A. By only one man and he referred particularly to the case that I mentioned, the condition at Stewart avenue during the reconstruction of that bridge.

Q. As a matter of fact, aren't all the navigation interests opposing, and complaining that the rate of flow is interfering with navigation?

A. I have not had any complaints in the last two years.

Q. In talking with all of these men that you have men-

tioned, didn't you know what the government limitation was in cubic feet per second?

A. I knew it was the limitation in regard to the mile and a quarter an hour. I also knew, Mr. Hopkins, that at the time that was made that 250,000 cubic feet per minute was all that could be gotten through the Chicago River at certain places without creating a current greater than a mile and a quarter an hour.

Q. But there had been several applications in recent years, and they were always refused, unless no more water were taken?

A. Only as I understand it in regard to a flow of over 4,000 additional to the 10,000. The one in regard to the North Shore Channel, any diversion that was made through there the water had to pass through the South Branch the same as though it had come in through the main river.

Q. You were familiar with what applications and what permits there were?

A. I have seen them, yes, sir.

Q. Talking about this question of the storm water again, do you mean to say that if you were given permission to increase the flow at Lockport, in order to prevent storm overflows going into the lake, you could not do so to such a degree that the amount that would get into Lake Michigan would be practically unnoticeable?

A. What is that?

Q. If you were given permission to increase the flow at Lockport, to prevent overflows into Lake Michigan, couldn't you do so?

A. I do not think it could be done, Mr. Hopkins, providing that at other times we were held strictly to a flow of only 4,167 cubic feet per second, for the reason as stated that the Main Channel would then on account of the slow velocity of the current deposit material on the bottom of the channel decreasing the cross-section to such an extent that the channel would not carry much in excess of 4,167 cubic feet when you wished to use it. That would not occur immediately, but in the course of time.

Q. How long would it take it to fill up, take the canal to fill up in such a way it would interfere with the flow?

A. Just giving you my best judgment, I imagine inside of three or four years.

Q. That could be dredged out?

A. That could be dredged out at great expense, and there

is no place that I know of where it could be placed without great danger to the water supply, or great expense.

Q. How many cubic yards do you think that would be?

A. Well, I would hate to guess on that. That is a matter of computation which you could have figured out for you. I have not figured it.

Q. What do you think the depth of the fill would be?

A. I do not know. I know that in some parts of the channel there were fills of 12 or 15 feet.

Q. Wouldn't those fills come at certain places rather than tend to scatter out?

A. They would come where the current velocity was such that it would deposit the suspended matter.

Q. So that it would be much easier to dredge it than if scattered out?

A. Oh, no, I think it would be generally scattered throughout the entire length of the channel, with a flow of only that amount.

Q. Where does this sediment come from?

A. It comes from Lake Michigan and also from the sewers and from street washings that flush into the river, snows, and it is impossible to keep the solid material out of the river. Take this last storm for instance, there were large quantities of sediment, of water that we pump through 39th Street Station, through the 39th street conduit, bringing a large quantity of cinders and sand into the South Fork, and we have already had to dredge it out twice, and it was not all sewage mud. It was a large percentage stuff that came through in suspension from the 39th street pumping station; and we are now figuring upon enlarging that so as to avoid that to some degree if we can.

Q. And a large part of it comes from Lake Michigan?

A. A large part of it comes from Lake Michigan.

Q. If the sewage were settled in the way we have discussed before, you would take out a large part coming from the sewage, wouldn't you?

A. You would take out a large part coming from the sewage, that would be true.

Q. If you had 10,000 cubic feet instead of 4,167, you would have a great deal more coming in from Lake Michigan?

A. No, sir, that would go through.

Q. Where would it finally stop?

A. Well, now that is pretty hard to tell. It might be the Gulf of Mexico.

Q. You think the difference in current between 10,000 and the 4,167 would be sufficient to put it to the Gulf of Mexico?

A. That is not the point. It would probably be carried down into the Illinois and Mississippi Rivers, which in times of flood have great scouring velocity, and scour the material on down and it is carried out and that is undoubtedly what is forming deltas at the mouth of the Mississippi River. Of course all of that material does not come from us, but some of it probably does.

Q. With the screening, and authority under emergency conditions to send 10,000 cubic feet through, you could practically keep it cleaned out, couldn't you?

A. I don't think so. It would take some time to scour that out and we would not do it in a short space of time, and by the time we got it scoured out the damage would be done by the Chicago River reversing itself and flowing into Lake Michigan.

Q. How many days in the year does Lake Michigan carry any great proportion of sediment?

A. This last year, I presume in the last 60 days there has not been a day but what it has carried considerable.

Q. Hasn't that been very unusual?

A. I will say it is as bad as I have been it for some time, but there is never a year goes by but there are several days when the water of Lake Michigan is turbid and carries a large amount of suspended matter.

Q. If at such time your rate of flow through the river were increased to meet that emergency situation, you would not get much of a deposit, would you?

A. Well, if we could flow 10,000 cubic feet all the while, I do not think we would.

Q. All the while, for those few days of extraordinary--

A. It is not a few days; it is a great number of days during the year in which the water in Lake Michigan is turbid and carries considerable suspended matter.

Q. Assuming you keep your canal cleaned out in any way you see fit; you say that nine hours is the maximum time for the effect to get back?

A. No, I didn't say maximum; I said as near as I could tell nine hours was about the time that it took for the effect to be felt up here.

Q. You said from six to nine?

A. I was trying to be liberal on that. As near as I can

tell it is from six to nine hours; about seven to nine hours I think I said.

Q. What would you say would be the average time that water falling from rainfall would get into the canal?

A. It would depend on how fast it fell and how close it was to the river and how close along the river it was to the canal.

We had one flood down on Hickory Creek, which is a creek that comes into the Desplaines River at Joliet, in which they had a severe rainstorm one night; I think it started in about eleven or twelve o'clock and the next morning a good share of Joliet was submerged. I do not see any reason why the same kind of a storm could not take place on one of the branches of the Chicago River.

Q. That was an exceptional condition, wasn't it?

A. It is not so exceptional. That was as large a one as I knew of, but those conditions happen every few years around here.

Q. How many miles of sewer does the water have to travel through?

A. To get into the river?

Q. Yes?

A. Oh, from nothing to probably eight or ten miles. A great many of the sewers here are comparatively short, because the city is divided up by the river itself and the different canals we have built, so that a good share of it hasn't long distance to travel.

Q. Out of this 6 to 10 days a year in which the flow of the Chicago River would normally exceed 4,167 cubic feet per second, how many do you think would be so quick, and right at the mouth here that you could not take care of it by properly opening up at Lockport?

A. The only thing that I can say is that when we were flowing these smaller amounts there was usually several times, two or three times during the year when we could not keep the water from getting into Lake Michigan.

Q. Were you trying then, very hard?

A. We were trying, yes.

Q. You were lowering it to the extent of 10,000 or 14,000 feet at Lockport, its full capacity?

A. No, we never had it down to 14,000. We had it down to 10,000.

Q. You think you could reduce that now, with more care, to less than two or three days a year?

A. With a flow of only 4,167 feet initially?

Q. Yes, that is what you said you had it.

A. I doubt it. That is eliminating also the other problem that the canal has not so filled up that it would not flow much in excess of that.

Q. What would be the cost of sterilizing the river water for two or three days when the flow might be reversed, two or three days in a year?

A. I have not figured upon that. I do not consider it practicable to sterilize the river water itself.

Q. Wasn't that included in Mr. Fuller's estimate?

A. No, he sterilized the overflow of the sewers, not the river.

Q. Was he going to sterilize it in the sewers?

A. No, the overflow coming after a certain amount was reached, as I recall it at the sewer outlets, the overflow in contact tanks.

Q. Couldn't you still do that?

A. Oh, that can be done, yes.

Q. In that way avoid any unsterilized water going into Lake Michigan?

A. Except such little as might be in the river itself. The river itself is always bound to be more or less polluted.

Q. The amount then of sewage that could get into Lake Michigan would be reduced to an infinitesimal proportion of the total amount of sewage?

A. No, there would still be sewage get in, organic matter, but it would be probably pretty well sterilized.

Q. Storm conditions on the Calumet, even if you have 4,000 cubic feet, there will be a great many more days in the year when you will have sewage flowing into Lake Michigan than in the Chicago River?

A. As I stated, it is our intention to keep the sewage out of the Calumet River as far as the State of Illinois is concerned; and as soon as we get our own back yard cleaned up, we are planning to get our neighbors in Indiana to take care of their sewage, so that in times of excessive floods in the Calumet, the water will not be in the polluted condition it is at present.

Q. The question was that there would be more days in the year when the Calumet River would flow into Lake Michigan than the Chicago River?

A. That is so, but you injected into your question also

that there would be more days when the sewage of the Calumet River would flow into Lake Michigan.

Q. Whatever there was?

A. The sewage would undoubtedly be kept out of the Calumet River.

Q. That is you would hope to have that condition?

A. That is what we will get.

Adjourned subject to notice.

Depositions taken before the Commissioner, at the offices of the Sanitary District, Chicago, pursuant to notice, beginning on Thursday, March 5th, 1914, at 10 o'clock A. M.

Present:

Mr. Edmund D. Adcock and Mr. Alfred S. Austrian, on behalf of the Sanitary District.

Mr. Albert L. Hopkins, on behalf of the Government.

LYMAN E. COOLEY, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner, and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?

A. Lyman E. Cooley.

Q. Where do you reside?

A. Evanston, Illinois.

Q. What is your present business?

A. Civil engineer.

Q. You are connected with the Sanitary District as consulting engineer, are you?

A. I am at present consulting engineer of the Sanitary District of Chicago.

Q. How long have you been connected with the Sanitary District in such capacity?

A. I have been connected with the District in that capacity since December, 1912.

Q. Will you state your education and experience, qualifications as civil engineer?

A. I was educated, and received the degree of civil engineer at the Rensselaer Polytechnic Institute, Troy, New York, in 1874, and have practiced my profession ever since.

For the first eleven years from 1874 to 1885, I was con-

nected with the Northwestern University; for 3½ years, as professor of engineering and professor of mathematics.

I was also the associate editor of the Engineering News, when it started in Chicago in 1875, and for three years subsequent thereto, and later was the editor of the American Engineer.

For six years of the time, I was assistant engineer to the War Department on the improvement of western rivers, principally the Missouri River.

For the following ten years, after I returned to Chicago in 1884, my work was largely connected with the development of the Chicago Sanitary District enterprise, and in connection with the Sanitary District.

From 1895 to 1905, I was engaged largely in private practice. I was consulting engineer of the district in 1897.

I was on the Intercepting Sewer Commission which designed the system of intercepting sewers on our lake front, for the City of Chicago in 1896 and '97. And I was the working member of the Commission on a comprehensive plan for the Sanitary District in 1901.

I was on the International Deep Waterways Commission in 1905 to 1907; a member of the American Section, which was known as the U. S. Deep Waterways Commission.

I was engaged in the investigation of the expenditure of $9,000,000 for the enlargement of the Erie Canal in 1908. That was for the State of New York.

I acted as engineer to a group of contractors who visited Panama and Nicaragua, in 1897 and 1898, in the interest of a New York financial group that proposed to finance the building of the Nicaragua Canal, in case this group of contractors would mature plans and make propositions. I spent about a year on that proposition.

I was the engineer of the Union Water Company, or the consulting engineer, rather, at Denver, Colorado, from 1899 to 1904, and in that capacity had general oversight over the construction of the Cheesman Dam, 210 feet high, and at that time the highest structure in the world of that character.

I was also the designing engineer for the Keokuk and Hamilton Waterpower Company that worked out the proposition of Keokuk in 1901, '05, when they procured their enabling act from Congress. That enterprise has since been carried out.

I also was engaged in a number of other enterprises. I reported on four Michigan streams in regard to the water power available in them.

Reported upon the Barge Canal and the flood conditions in the Genesee River at Rochester, New York.

I was employed by the City of Omaha to appraise the waterworks for the city of Omaha. And I had a number of other minor engagements.

After 1905, down to the time of my engagement with the Sanitary District as consulting engineer in December, 1912, I was the secretary and later the consulting engineer of the Internal Improvement Commission of Illinois; wrote the report in 1907, which underlies the constitutional amendment adopted by the people of this state in 1908, providing for the expenditure of $20,000,000 in the development of the Deep Waterway between Lockport and Utica.

Since 1909, I have been consulting engineer of the Lakes to the Gulf Deep Waterway Association, which is interested in developing a deep waterway between the lakes and the Gulf of Mexico.

I was also on a Commission to devise plans for new waterworks for the City of Omaha.

I made an appraisement of the waterworks at Racine, Wisconsin.

I also wrote reports on flood conditions, at Grand Rapids, Michigan, and at Saginaw, Michigan.

I was the leading expert in the State case of the State versus the Economy Light & Power Company from 1907 until 1909; also of the Federal case.

Q. By whom were you employed in those two cases?

A. In the State case, I was employed by the Attorney General of the State of Illinois and in the Federal case I was engaged from 1910, until sometime in 1912, employed by the District Attorney at Chicago.

Q. That is you appeared in behalf of the United States Government in that case?

A. Yes, sir. And a number of minor engagements.

Q. You were connected, were you not, with the State Board of Health at one time?

A. Yes, sir. That comes in the second period that I referred to, when I was largely employed on sanitary questions at Chicago. I was employed by various agencies, the City of Chicago, by local committees interested in the matter, and also by the State Board of Health, in connection with the examinations at Chicago and the streams of Illinois, the Illinois River and its tributaries.

Q. As to the sanitary conditions of those streams?

A. Yes, sir. The State Board of Health undertook to co-

opera'e in the investigations that we were making at Chicago between 1885 and the passage of the Sanitary District Act in 1889, and made a very comprehensive series of analyses of samples through one summer and one winter, taken at various points between Lake Michigan and the City of St. Louis, in order to determine the question of the self-purification of sewage introduced by the Illinois & Michigan Canal from the City of Chicago.

Q. You have made studies of the hydraulics of the Great Lakes, have you not, Mr. Cooley?

A. Yes, sir.

Q. Of water levels and changes in oscillations and so forth of the lakes?

A. Yes, sir, I did that as early as 1881, when I was connected with the Government service at St. Louis, when the matter of the reservoirs at the headwaters of the upper Mississippi was under consideration, in the aid of low water navigation.

I then made a study of the possibility of utilizing this great natural reservoir in passing waters by way of the Des Plaines and Illinois Rivers to the Mississippi River; and gave the matter general consideration at that time.

Later, I took up the matter as part of my duty as chief assistant to the Drainage and Water Supply Commission in 1886 and 1887. I followed the matter up, prepared a paper upon the subject matter in 1888, and brought the whole subject matter into final form in a series of papers before the Western Society of Engineers in 1888; printed early in 1889.

I later gave it further consideration, while a member of the International Waterways Commission. The instructions of Congress to that Commission were that we consider in full the water supply in connection with the development of ocean navigation into the lakes from the Atlantic Seaboard. At that time I brought together all the material that had formerly been gathered; and obtained from the United States and Canada and the cities about the Great Lakes all the records that had been made going back to the beginning of the last century, in regard to the fluctuations of the lakes, the elevations of the lakes.

Q. And their oscillations from time to time and hour to hour?

A. Yes, sir. And the Commission at that time did recommend that there should be undertaken a comprehensive series of measurements through a wide range of fluctuations, for the purpose of definitely ascertaining what the relation of out-

flow was to stage of water. And they did further give the opinion that for such navigation as they recommended, 30 feet of water, would require that the levels of all the lakes should be controlled.

The Canadian Government has recently undertaken to carry out the substantial recommendations of the Commission, and has started to construct the St. Lawrence waterways on the basis of 30 feet, and have let contracts on the Welland Canal for that purpose.

Q. Did you have occasion in this time to make a study and examination of the necessities of the navigation interests and the improvement of navigation at Chicago and through the Illinois and Des Plaines Rivers?

A. Yes, sir. That proposition was in view from the inception of the drainage enterprise, and in fact you might say from the time that the Chicago divide was discovered, in 1673; and it was a part of the policy of this State from the beginning to procure the construction of a waterway through the State. And when the Chicago sanitary question came up, and it was determined that the solution would require a large canal across the Chicago divide, the State, through its General Assembly, took the view that it should be constructed so as to lend itself to the development of a deep waterway through the State. And so from the beginning, the effect of this water which was needed for the sanitation of Chicago upon the regimen of the Illinois River and of the Mississippi River; and how it could be utilized in producing a waterway, was a prominent factor and an important factor also in determining the policy of the State in granting the privilege to the City of Chicago of sewage disposal in the manner proposed.

Mr. Hopkins: I move to strike out that entire answer as not responsive to the question, and as incompetent as to what anybody intended with reference to the policy of the State, or what the legislature had in mind; and as incompetent and immaterial.

Mr. Adcock: Q. You are familiar with the action of the State in connection with the matters which you have mentioned, and you attended, did you not, at different times the meetings of the Senate and House of the General Assembly of this State?

A. Yes, sir; I am familiar with the history of the State prior to the time when this matter was taken up. I acted as consulting engineer to a special joint committee of the General Assembly, which framed the Sanitary District law

and was familiar with all the considerations that influenced that law, in Chicago and in the valley.

I was at Springfield during the entire consideration of the matter, and had general charge in the latter part of the session of the bill for the City of Chicago, for the City Council of Chicago and for the several civic organizations of Chicago, and I believe that I know as much about what the policy of the State was at that time, as anybody can know.

I drew some supplemental measures known as the Little Waterway Bill and the joint resolutions of 1889 and also of 1897, which were passed by the General Assembly, declaring the policy of the State.

Mr. Hopkins: I renew my motion and add to it the further ground that it is not the best evidence.

Mr. Adcock: Q. You were familiar also, were you not, Mr. Cooley, with various reports of the Government engineers that were made prior to 1889, referring to the report of 1867?

A. Yes, sir; I had at that time been over all the documentary evidence in relation to the subject matter, reports of various kinds, going back to that of Long in 1816, Major Long; Phillips and Graham, in 1819, and to the report of General Gratiot, in 1834, in which the United States proposed at that time to construct a channel 10 feet deep and 100 feet wide; the land grant to the State of Illinois to aid in the construction of the Illinois and Michigan Canal; the report of the survey and examinations of John B. Preston, in 1857 and '58.

Q. Who was Mr. Preston?

A. John B. Preston, was a civil engineer in the State of Illinois, who made a project for steamboat navigation between Lake Michigan and the Mississippi River, in which the low water navigation of the Illinois River was to be made by aid of a water supply from Lake Michigan.

That proposition was followed up by joint resolution of the General Assembly in 1861, which called upon the canal trustees to examine the subject mater.

In 1862, there was a bill in Congress providing for such a waterway. The Honorable Thad Stevens made a speech, in which he denounced the proposition as a measure to drain Lake Michigan and convert it into a cornfield. So the objection on this lake diversion proposition goes back a long ways.

In 1866, General Wilson was charged with the duty of making a survey, and based his report of 1866 and '67 on the notes and data collected by John B. Preston in 1857-'58.

In 1867, General Wilson by the aid of a special appropria-

tion from Congress made a survey of his own, which was reported upon in December of that year, and there was also a report on the Upper Illinois River by Colonel McComb, 1874 and by Major Benyaurd in 1883; and also upon the enlargement of the Illinois & Michigan Canal in connection with the Hennepin Canal in 1882-4, and by the Comstock Board in 1886 and '87.

All these documents gave a very complete idea of the physical conditions of the Illinois River and its possibilities of development, and were available prior to the passage of the Sanitary District Act.

I omitted to mention in the list, as long as I have gone into it, the fact that Howard Stansbury, United States Engineer, made an examination of the Illinois River in 1838; and that General Joe Johnson, later of Confederate fame, was upon the river engaged in improving the same in 1852 and '54. We had all that material.

Mr. Hopkins: I move that that answer be stricken out for all the reasons assigned in the last objection.

Mr. Austrian: I want to state in this record now that the motion now is in direct violation of stipulations between the District Attorney and ourselves. The District Attorney has agreed with us repeatedly, both in and out of this record, that it was not necessary to produce original documents, as long as we gave the source of the information from which the witness testified; and if upon examination it was found to be correct, no such question would be made or pressed.

Mr. Hopkins: I am not familiar with the stipulations made. If that is so, any stipulation will be lived up to.

Mr. Austrian: It has been made outside the record by the District Attorney and ourselves repeatedly and the Government's evidence has been produced upon that theory. Witnesses have been permitted to testify repeatedly without the introduction of documents, so long as they gave the source from which they testified.

Mr. Adcock: Q. You were the chief engineer of the Sanitary District for a time, were you not?

A. Yes, sir; I was the first chief engineer from January 1890 to December of that year; and a year later, December, 1891, I became a trustee of the Sanitary District and the chairman of its engineering committee until the close of my term in 1895.

Q. Will you describe the physical conditions here at Chicago and the surrounding territory, with reference to the topography of the country?

A. The Chicago River basin, as it originally existed in nature, consisted of the North Branch and its drainage basin, together with the South Branch, an area of about 240 square miles (now about 300 square miles). West of the Chicago River basin, was the Des Plaines River basin, drained by the Des Plaines River which ran parallel to the lake from the headwaters in Wisconsin down to a point about ten miles from Lake Michigan at Lyons; and then leading southwesterly to a junction with the Illinois River, or to the junction with the Kankakee River, which formed the Illinois.

This Des Plaines River, in the vicinity of Lyons, had a low water elevation of about eight feet, and a drainage area of 633 square miles.

The divide between the Des Plaines River and the Chicago River was in the vicinity of the Bridewell, just west of Kedzie avenue, and had an original elevation of about 10½ feet above Lake Michigan, and whenever the Des Plaines River rose from two or three feet above low water, or exceeded a volume of about 1,000 second feet, the flow of the river divided, part of it coming through the South Branch of the Chicago River to Lake Michigan, and in great floods 60 to 70 per cent. of the entire flow of the Des Plaines River came to Chicago.

This condition existed up to about 1854, after the Illinois and Michigan Canal had been opened in 1848, when the Drainage Commissioners cut out the original divide at Kedzie avenue and drained out the Mud Lake region as it was known in Voyageur's days, and on the original land maps as "Portage Lake, Portage Swamp, and Portage Slough."

For a number of years thereafter, the entire flow of the Des Plaines River came in the direction of Chicago except at such times as in the fall and winter when the ice interests of the Des Plaines River Valley made a temporary dam in order to fill the ponds on the 12-mile level between Summit and Lemont, for ice-making purposes.

Finally the flow from this source became such a nuisance to the City of Chicago that after 1870 they constructed the Ogden-Wentworth Dam. That crossed the old Portage Slough at the range line at Summit, at an elevation of something over 11 feet above Chicago datum. And this was overflowed also, whenever the river rose above a volume of about 1,000 feet per second; and the waters continued to come this way in flood times when the volume exceeded that amount until 1893, when the Sanitary District executed its river diversion and created a spill-way above Summit, which restricted

the flow down the river until the volume reached between 3,000 and 4,000 feet per second. And in about 1909, this was finally closed, so that no waters from that source have come through the Chicago River to Lake Michigan since.

The effects of this overflow have been most pronounced and is noted from time to time in the narratives relating to Chicago and its portage. For a portion of each year boats in the fur trade made the trip from the Chicago River to the Des Plaines River and down the Illinois to the Mississippi River without any portage at all. For a portion of each year, a portage of two miles was required; for another portion seven miles, and in very dry seasons the portage was 51 miles to the junction of the Des Plaines and Kankakee Rivers at Dresden. Those conditions were availed of in trade and travel, from the time of the Discovery down to the time of the removal of the Indians from the State of Illinois in 1836.

The first white settler of Chicago, or the first white man to domicile here was Marquette, in 1674-5, and he was driven from his cabin on the West Fork of the South Branch near Robey street by a flood that came over the divide; and the next day he resumed his journey down the Des Plaines and Illinois Rivers without making a portage.

In 1832, the United States made an appropriation for opening the mouth of the Chicago River, and projected two piers from the vicinity of the present site of Rush street bridge, across the sand spit into the lake; and made a single dredge cut across the bar. This bar was washed out in 1834 by one of these floods that came across the divide.

A schooner entered the port of Chicago for the first time after this flood.

In 1849, a great flood came over the Divide and cleaned out all the bridges in the Chicago River, wrecked all the shipping, producing a great disaster for its day.

The same thing was repeated in 1858.

In 1881, the water came over the Divide for probably six weeks or eight weeks continuously, in large volumes.

In 1887, I measured a flow coming across the Chicago Divide of 7,000 feet per second, the flood of that year.

In 1892, this flood condition was very critically examined from the Chicago River to Lake Joliet, and a steamboat drawing three feet of water could at that time have gone from the Chicago River down to the Illinois River, and returned, in the absence of bridges. Aside from these conditions re-

specting the flood waters, the site of Chicago itself was substantially a morass, similar to what exists adjacent to the Calumet River up to a recent time, and still exists in some sections, awash in high waters of Lake Michigan, and overflowed in all these flood times. It was of much less extent than the Calumet marsh region; and along the lake shore there were the remnants of a sand spit, and wind blown sands rising from 10 to 20 feet above the lake; but generally behind that and out to the slopes beyond, the low lands bordering the Chicago River, the banks were only three to five feet high at low water, and consisted of ooze and muck and alluvial clay, interstratified with layers of sand.

Mr. Hopkins: I make the same motion for the same reasons, but on the statement of counsel as to the stipulation I withdraw any objection on the ground that it is not the best evidence, insofar as the witness has testified as to matters contained in public documents, which I understand to be contained in the stipulation.

I also make the further motion to strike out such parts of this last answer as have already been covered in certain written documents that have been offered by the defense and agreed to by the Government, subject to the objections of materiality and competency, as simply repetition.

Mr. Adcock: Q. You are familiar with the establishment of the water supply and sewerage system of the City of Chicago, are you not, Mr. Cooley?

A. Yes, sir, I looked up all those matters and wrote a digest upon the subject, in connection with the investigations that I was connected with at Chicago.

Q. Will you state the various steps that have been taken by the City of Chicago, and towns and villages adjoining it, in the years past, to establish its water supply and sewerage system?

A. The City of Chicago, or Village of Chicago was organized on August 10, 1833, 28 electors voting; population estimated at 350, from which I presume that none except those that were running for office voted.

At that time it was a mere frontier camp, and the usual well 6 to 12 feet deep in the front yard; slops thrown in the back yard; a privy vault on the back end of the lot. The soil conditions very soon made this intolerable, and the floods occurring annually diffused the deposits on these lots, without regard to sanitary discrimination.

As early as 1836, the conditions had so developed that

the people were taking their water in pails from the river and from the Lake Shore; and the first water system of the City of Chicago consisted of barrels mounted on two wheel carts, that were backed down into the lake and peddled on routes, much like the milk routes to-day.

As early as 1836, a franchise was granted for a water company to supply the citizens with water, but owing to the panic of 1837 and the financial stress of that period, this company did not get its works installed until 1840; and these works consisted of a 250 barrel tank mounted on blocks at the foot of Lake street, with a 25 horse power engine, a short pipe intake into Lake Michigan and two miles of log pipe, bored out by hand; laid in the streets as a distribution system.

The people of even that day were adverse to monopolies, and did not patronize this water company to the extent of making it a financial success; still preferring the institution of a barrel on two wheels. So in 1851, a charter was granted to a water company, a new water company. The city had been organized in 1837 with a population of about 4,400 to 5,000 in 1840. In 1851, the population had reached about 35,000 and a new water company had been chartered; but the city finally took over the whole proposition in 1854 and established the works at the present site at Chicago avenue on the North Side.

There was some discussion at that time in regard to whether the site should be on the north side of the river or the south side of the river, but the general opinion prevailed that there was a lake current tending southerly along this shore, and it would be safer from pollution to put it on the North Side.

There was another event happening about this time, the opening of the Illinois and Michigan Canal in 1848. The first shovel had been thrown on this Canal at Bridgeport within the present city limits July 4, 1836; and that had contributed greatly to the growth of Chicago during its construction.

The first railroad out of Chicago was opened out to Elgin, also in 1848. The Michigan Southern Road came to Chicago in 1852.

There was a sickly period in Chicago between 1849 and 1854, in which the death rate rose to 48 to 50 in a thousand; three times what is now normal to well sanitated cities.

All these events, what was happening to the water supply, the death rate which had grown so enormously, the feeling that Chicago had ceased to become a mere camp and had a

future before it, led the citizens to make an extraordinary effort to better the conditions here, in order that she might realize destiny. And so in 1855, or 1854, Mr. E. S. Chesbrough, of Boston, was employed as the Sanitary Engineer of the city; particularly at that time to devise a sewer system. Mr. Chesbrough went abroad and studied the conditions at Hamburg and at London and other foreign cities in 1856-7, but had submitted plans for his sewer system late in 1855.

In that connection I desire to say that this was the first comprehensive sewer sytem in the United States, and that we had at that time about 75,000 to 80,000 of population; and that other cities in the United States like New Orleans have only had a sewer system within the last ten years. Baltimore has not yet completed a sewer system.

I will say further that it was the second comprehensive sewer system built in the world. Hamburg had built a sewer system after its great fire, about 12 or 14 years before. London had started a sewer system, but its plans were not yet complete, and were not completed for three or four years later for a comprehensive system.

The state of the art up to that time had been that all human wastes were excluded from sewers by law. That was the law in England. And it was not until the report of the cities and towns commission in 1844 in England that that law was changed. At that time there had received general acceptance the filth theory of disease, and England and the Continent went on a general clean-up, you might say.

Berlin did not have a sewer system until 1860. All human wastes were excluded from the sewers of Paris up to 1880, so Chicago was a generation or so ahead of the world, and led the United States in regard to its sanitary provision in 1855.

Mr. Chesbrough planned his sewers so as to give a seven foot basement under the buildings, and as a result the grades of Chicago were established at 10 to 12 feet above city datum.

Q. That is the street grade?

A. Street grades; and in many places the sewers were built on mounds entirely above the level of the ground, the natural ground, or on embankments; and walls were built on the curb line; and that is the reason for the general condition that you notice in Chicago, that the basements all go out to the curb line so as to save the filling required to cover the sewers; and the sidewalk space beneath, which does not exist to the same extent in any other city.

After the Great Fire, the grade was again re-established

to the present level of 14 feet above the city datum. I was here in 1872, after the Great Fire in 1871, and remember distinctly the condition, that the sidewalk of the city was going up and down at every street crossing, on account of the new grades.

The sewer system then planned by Mr. Chesbrough discharged for the most part to the river. No sewers entered the lake on the north side, on account of the water supply. And the early main sewers came to the main river, so as to be within the influence of any circulation that might be established by way of the Illinois and Michigan Canal. The only sewers that were planned toward the lake was the one east of State street on 12th street and at 22nd street; and later when the city was extended down to 39th street, the 35th street sewer was added, also discharging into the lake. These plans were followed out substantially with the raising of the general grade of the city; and the conditions on the unimproved low lands continued as observed by me in 1872 and 1874 to 1878. Meantime the condition in the river itself was becoming intolerable.

I wish to say in that connection that on account of the great cost of raising the city to the grades required to produce a sewer system, the trunk sewers were laid on extremely low grades, 2½ to 4 feet per mile, which constituted them sewers of deposit in low water, under conditions of dry weather flow. And it was recognized from the beginning that catch basins and sewers would have to be cleansed from time to time, and it was only in storm time when the sewers were running substantially full that the sewers were self scouring, that is the trunk sewers.

The conditions in the river early became intolerable with the growing population. We had reached 125,000 by 1860. Chicago early became a packing center, and winter slaughtering was practiced at that time, before they had the refrigerator methods which permitted of all the year around slaughtering. And there had not been introduced at that time the saving in the by-products, bloods and other matter (this has since become a feature of Chicago slaughtering institutions), and everything went to the river, and so the river, particularly in winter time, became very bad.

Under some arrangement, which is indefinite, the pumps were operated during the later fifties in the interest of a better river.

Q. That is the pumps on the Illinois and Michigan Canal at Bridgeport?

A. Yes, sir, I will speak of that. The Illinois and Michigan Canal, as it was finally completed under the canal trustees, had a summit level 8 feet above Lake Michigan, and it was fed in ordinary seasons from the Des Plaines River and by a feeder through the Sag Valley and the Calumet River at Blue Island.

Q. That was known as the Shallow Cut Plan?

A. Yes, sir, where a dam was built across the Calumet River at an elevation of 11 feet above Chicago datum. This was insufficient in the dry seasons, and a Dutch Wheel or Lift Wheel was erected at Bridgeport, at the forks of the Chicago River and at the head of the canal for the purpose of supplementing the feed water of the canal, and in such seasons that was sufficient in cleansing the Chicago River and as I have stated, these were operated for that purpose in the later fifties.

But in 1863, after Chicago had established a Board of Public Works, the Chicago River became very offensive. An erysipelas epidemic occurred, which was co-terminus with the South Branch and was attributed to the blood and other matters from the slaughtering houses, and it was depicted on the spot maps as the "Valley of Death."

The Board of Public Works at that time made an arrangement with the Canal Trustees by which the Bridgeport Pumping Station should be operated and the city would contribute to the cost of doing so for the purpose of cleansing the Chicago River; and that arrangement continued up to the time that the canal deepening was completed in July, 1871.

Q. That was completed then on the Deep Cut Plan?

A. Yes, sir. I will speak of that later. That was in July, 1871. Meantime the effluent from the river was contaminating the water supply, and Mr. Chesbrough projected the first lake tunnel in 1862. It was authorized in 1863. It was to be five feet in diameter, and extended out to the crib two miles from shore, and it was thought that this would give immunity for a long time in the future. It was believed that the effluent from the river for the most part would stay near the shore line, and would not reach out that distance into the lake.

Nevertheless, in designing that tunnel, he made his plans in such a manner as to invite an extension in the future without disturbing the existing conditions, providing an exten-

sion out from the crib in a separate shaft, so it could be shut off and extended at a future time.

This work was severely criticised by all the wise men of Chicago at that time, and Mr. Chesbrough's life was made a burden to him, but in 1867 it was opened, and attracted the attention of the world and made the reputation of Mr. Chesbrough as an international engineer. It has since been followed in all lake cities and followed in all water works practice, to the extent that tunnels can be made available.

He immediately followed this tunnel with a seven foot tunnel parallel to the five foot tunnel, leading from the same crib by way of the Chicago Avenue Station southwesterly across the city some four miles from Chicago avenue to 22nd street and Ashland avenue. That station was opened in 1874.

The Chicago River at this time was in a deplorable condition. I was in Chicago nearly every day, or several times a week, from 1874 to 1878, and made a study of the conditions here, and was personally very well acquainted with Mr. Chesbrough. The North Branch, as I used to ride by it, between Evanston and the city, in the heated term of summer, exhaled an effluvia that compelled the passengers on the Northwestern Road to shut down the windows in order to keep themselves from being nauseated. No words can describe the potency of that smell.

This condition led Mr. Chesbrough to project the Fullerton Avenue Conduit, started in 1874 for the purpose of circulating the waters of the North Branch. I examined and wrote an article on that conduit while it was under construction. It was put in operation in 1878, and as operated it changed the waters of the North Branch about once in three days, which greatly mitigated the badness of the smell. But it was still far from a satisfactory exhibit.

The South Fork conditions were even more serious than the North Branch; the smell from that source reaching out to the lake shore in the then best part of the city, down in the vicinity of the Douglas monument and above. This was noticed particularly in the night time and on foggy days. The sun seems to have some resolving powers in dissipating these smells.

Mr. Chesbrough projected a similar conduit to the South Fork, but his enterprise in behalf of the welfare of the city by that time had reached such a magnitude that he was unable to carry out that enterprise, and we retained the con-

ditions of the South Fork with us until the Sanitary District finally changed the same along about 1908, I think.

Meantime, a Commission had proposed the deepening of the Illinois and Michigan Canal on the original plan; and in 1865 an enabling act was procured from the General Assembly which authorized the City of Chicago to deepen this canal on the original plan for sanitary purposes; and the city of Chicago did so, and expended thereon about Three Millions in cash and opened the same in July, 1871.

Q. That was a gravity flow, wasn't it?

A. Yes, sir, gravity flow.

The General Assembly was called in special session after the Great Fire of October, 1871, and repaid this money to the city of Chicago, and it was all the funds that it had until the city was in shape to again realize taxation.

This canal as originally projected and worked on from 1836 to 1841, when the state went broke, had a declivity of a tenth of a foot per mile or 2.9 feet between Bridgeport and Lockport. But when work was resumed under the trustees for the bond holders in 1843, they adopted the expedient of a temporary level 8 feet above Chicago datum for 26½ miles, which I have already described.

Q. What was the height of this divide above Chicago datum?

A. The original divide at Kedzie avenue was about 10½ feet above Chicago datum.

Q. That was called the "Continental Divide"?

A. Yes, sir, Continental Divide, but this was a mere alluvial deposit. The real divide was the rock floor at Lemont, which was between 7 and 8 feet above Chicago datum, and about 2 or 3 feet above the high water of 1838, which was the highest water on record. The original divide was only 5 to 6 feet above high water of 1838.

Shall I proceed with the statement?

Q. Yes, proceed with the answer to the original question.

A. This was the only relief that the city had until the canal was reinforced by pumping works in 1883. The canal when opened to gravity is estimated to have carried out 40,000 cubic feet of water per minute. But the lake was then high, and in later years as the lake fell, the capacity shrunk to 15 or 20,000 feet per minute, which was scarcely more than the dry weather flow and the water supply of the city, so it was ineffective in preventing the sewage from flowing towards the lake. And the condition of the canal became so

bad that at the instance of the State Board of Health, first in 1878, when it was organized, I think, in 1877, the Munn Resolution was passed by the Legislature in 1881, calling upon the city of Chicago to erect pumping works there of a capacity of not less than 60,000 feet per minute. These pumping works were installed in 1883, but were not actually accepted from the contractors and taken over by the city until 1886, although they were operated meantime.

I made a test for the city in 1886 in regard to the capacity of these pumps and works, and as to the contract having been carried out; and also at that time I made a comprehensive series of measurements in the Illinois and Michigan Canal, to establish its capacity in relation to the stage of water. And I think that determination was used ever afterwards, as long as the canal was operated by the pumping machinery.

These pumping works were instituted or authorized, or directed by the Legislature in response to the representations of the State Board of Health, which had taken a position supported by the report of Superintendent Thomas that the canal could be made to carry 100,000 cubic feet of water per minute, and that such a volume of water would dilute the sewage substantially beyond offense. But they did not get the recommendations carried out except with the minimum limit of 60,000 cubic feet. It was for the purpose of relieving the nuisance at Joliet, and in the Valley further down; and also for the purpose of purifying the Chicago River that these pumps were installed, or called for by the Legislature.

I left the city in 1878, and was engaged upon Western River Improvements until late in 1884. And the only thing that I did that had any bearing upon the Chicago problem was to examine the question of the feasibility of taking a water supply out of the lakes by way of the Des Plaines and Illinois River, for the low water improvement of the Mississippi River, about 1881.

There was one conversation with Mr. Chesbrough, which I would like to refer to because it has a bearing upon matters which came up later. Mr. Chesbrough was uncertain in his own mind in 1878 as to what the future solution of the sanitary question was to be. He had planned along the line of the State Policy, which had contemplated from the beginning the flow of water in the direction of the Illinois Valley, and which comes up from time to time in all the actions of the state. But the city was unable to finance a proposition of

that kind. Conventions had been had, reports had been made; there was a Great Waterway Convention in 1847 and again one in 1863, in which 14 states were represented, urging this project; the Board of Public Works had considered it in 1860, so the matter was a familiar one to the people of Chicago, the idea that eventually sewage disposal was to be down the Des Plaines and Illinois Valley.

I asked Mr. Chesbrough, late in 1878, before leaving the city, whether that was not going to be the final outcome, and he made this reply: That that solution would be ideal when this city reached a million inhabitants and was able to finance the undertaking, but he was unable at this time, with his knowledge of the growth of American cities, to project works on the theory that Chicago would reach a million inhabitants in such reasonable time in the future as would justify the investment.

The only incident that occurred of particular moment between 1878 and 1885, was the Great Flood in the Des Plaines River, which I investigated, secured all the data that was possible. This flood reached a magnitude of 13,000 second feet; continued at a uniform elevation for about four days; gradually shrunk, but exceeded 10,000 feet per second for 21 days, at Riverside. There was probably from five to 8,000 cubic feet per second coming across the Chicago Divide during that time; and a lesser amount probably for two or three times as long a period. In addition there was probably a maximum flood from the Chicago basin of not less than seven to 8,000 feet. These conditions swept the Chicago River clean and led the people of Chicago to renewed earnestness in the consideration of their sanitary problems. Between that time and 1885 various projects were mooted, one of which was to shift the water supply to Grosse Point, the North limits of the city of Evanston; another to shift it to Highland Park in Lake County, and let the water come down by gravity. Another was a deep cut proposition which was worked up by Mr. Matthiesen at Joliet, by which a narrow and deep channel with high velocity was to be constructed from the Chicago River and located between the Illinois and Michigan Canal to the Des Plaines River; and discharging in the upper basin at Joliet.

The Citizens' Association of Chicago had taken particular charge of this matter and had worked up this latter proposition of Mr. Matthiesen's and made a report thereon. On August 2, 1885, occurred a rainfall of over 6 inches in 24

hours, the greatest precipitation that has occurred during Chicago rainfall record, beginning in 1843. The effect of this rainfall was to sweep out the contents of the Chicago River; to scour out all the sewers and catch basins and to wash the streets. The entire effluent went into the lake and filled the lake with a black filthy mass extending several miles north and south along the shore, and out beyond the crib. And its effect was visible in the water supply for a long time afterwards.

The Standing Committee of the Citizens' Association appointed a sub-committee consisting of Mr. Ossian Guthrie, who had operated the Bridgeport Pumping Station, since its installation in 1848 up to the time it was abandoned in 1871 by the deepening of the canal. He had ice interests in the Des Plaines River, and was thoroughly familiar with all the flood conditions at Chicago. They selected also Doctor Frank Reiley, who was then the Assistant Secretary of the State Board of Health of Illinois, and they selected me as engineer.

We made a general examination of the situation, visited the Des Plaines River and all the points of interest in connection with the phenomena, and wrote a report which I drew; and this report substantially unchanged was adopted by the General Committee of the Citizens' Association, and printed in all the Chicago papers on August 27, 1885. A rainfall not quite so large occurring a week or two later, also producing a large flood, came in to re-enforce the findings of the report and give them general credence and acceptance among the people.

This report contemplated or recommended that all storm waters including all sewage be permanently excluded from Lake Michigan; that a channel large enough to accomplish this be built through the Des Plaines Valley to an outlet near Joliet; and that in order that this channel should not be unnecessarily large, the headwaters of the Des Plaines and North Branch should be diverted to Lake Michigan. Of course it involved taking out all the sewers and reversing them, or intercepting those that emptied into the lake; and also providing a circulation in those parts of the river which had no circulation; parts of the harbor.

This proposition was followed by an ordinance of the Council which I drew, and which was promptly vetoed by Carter Harrison, Senior, on the ground that the city had no means of financing the undertaking; and it was vicious to discuss these propositions, and unpatriotic under those circumstances.

Later Mr. Harvey B. Hurd, went to Mr. Harrison and pointed out to him a constitutional method of raising money through the creation of a blanket corporation, such as we have precedent for in the Park Boards, with its own power of taxation and bonding. Mr. Harrison later sent a message to the Council recommending the appointment of an expert Commission, and this was adopted.

In April, 1886, Mr. Rudolph Hering of Philadelphia was selected as Chairman of the Commission, and later Mr. Samuel B. Artingstall, who had been Assistant Engineer to Mr. Chesbrough and was then City Engineer, was made a member; and also Mr. Benezette Williams, who had been an Assistant Engineer to Mr. Chesbrough, and who had recently completed the Disposal Works at Pullman, which were looked upon as model works at that time, and an augury of the future disposal of sewage, by scientific and rational methods. I became chief assistant in general charge, in the absence of Mr. Hering, of all the work, and in special charge of those parts of the investigation which we are particuary concerned with in this inquiry.

I had the subject of streams examination through all the water sheds that affected the Chicago condition, the lake currents, lake levels, the ship canal surveys, borings, calculations of the capacity of channel; the Illinois River problems; its effect on the Illinois River of the proposed flow of water from Lake Michigan; the examination of the Chicago River and its contents and of the special filth producing industries; an examination of the conditions of the Illinois and Michigan Canal; an examination of the conditions produced in the Illinois River by the sewage which had been sent down the canal. Mr. Swan of Boston had particular charge of the investigations relating to land disposal, sewage treatment and lake disposal. Mr. Swan was a man who had been connected with the Massachusetts Board of Health, which had made perhaps the most extensive researches up to that time respecting the pollution of streams; and he had also made a number of trips abroad.

Recess to 2:30 P. M.

After Recess, 2:30 P. M.

LYMAN E. COOLEY resumed the stand and testified further on direct examination as follows:

The Witness: I wish to supply an omission respecting the consideration of the report of the Sub-Committee to the Drainage Committee of the Citizens' Association. I had included in that report a statistical statement to show that Chicago would reach one million inhabitants in the year 1890, and would be able to finance the undertaking. I was asked to strike out that matter as it would discredit the report, as nobody in Chicago believed that this city would reach a million inhabitants in the year 1890. There was no member of the Committee who believed it; and so I struck it out, as it had no material bearing upon the project itself. There were on that Committee such citizens still living as J. J. Glessner and J. Harley Bradley.

In my own work relating to the phenomena of lake fluctuations and lake currents, I carried out the most extensive series of observations ever made upon that subject.

In 1875 and '76, I made an investigation for Mr. Chesbrough on the record of an automatic gage kept on the Chicago Crib, and for the first time worked out the phenomena of seiches, there exhibited. These oscillations are characteristic of Lake Michigan, and have periods of 20 minutes; are never quite absent; sometimes reach amplitudes amounting to feet. I demonstrated by means of the formula respecting waves of translation in deep water, in connection with the Lake Survey charts, that period corresponded to a travel to the opposite shore and back. Later I found that these phenomena had been examined on Lake Geneva in Switzerland and on the lochs of Scotland; and that a pendulum formula had been adopted to express the conditions.

I also discovered, but this was not so well demonstrated, a longitudinal oscillation in the lake from end to end, which had a time interval of something over an hour. I kept an automatic gage at the foot of Randolph Street for four years, and had occasion to repeat the studies in this matter between the years 1886 and 1900.

I also ascertained, but this had been investigated by Colonel Graham, that there was a tide in the lake amounting to 2½ inches at springtide, occurring daily and not twice a day, as on the Seaboard.

Mr. Hopkins: For my own information, I would like to know what the original question was. Wasn't it simply something about the sewer conditions in Chicago.

(Question read as follows): "Will you state the various steps that have been taken by the City of Chicago, and towns and villages adjoining it, in the years past, to establish its water supply and sewerage system?"

The Witness: I will say that this investigation in 1886 to 1887, was taken as part of the investigation respecting the water supply of Chicago, and was conducted by me under the instruction of the Drainage and Water Supply Commission.

Mr. Adcock: Q. That was a Commission in which the Commissioners were appointed by the Mayor, were they not?

A. Yes, sir. I have already given the history of that.

Mr. Adcock: Yes.

The Witness: The only thing further that I will add at this time, in connection with the lake phenomena, is in relation to the currents which we found to be due solely to the winds; and that they traveled northwardly along this shore for ⅓ to ¾ of the summertime and southwardly for ⅓ to ¾ of the wintertime.

I also made a critical examination of the Chicago River and its contents, and dredged up every acre of its bottom within the city to ascertain the nature of the deposits there occasioned by sewage. The Chicago Harbor has an area of about 450 acres, which was actually used for shipping purposes. This river, as I have already stated, was swept clean in August, 1885.

In the fall of 1886, it had a sludge deposit in the North Branch from a foot and a half to 6 feet in depth; and in the South Branch about 4 feet in depth. This sludge was not what is ordinarily termed sludge in the nomenclature of sewage disposal. It was a black, jelly-like mass full of cavities like Swiss cheese, indicating a secondary decomposition, and emitting gases on its own account; and from all the studies and examinations and knowledge which I could acquire in regard to the same, it appeared to be largely hydro carbon, bacterial gases that are thrown down through the decomposition. I estimated that the South Fork would have filled up in four years from these deposits, except for the progressive decomposition that was going on.

I repeated this examination after the spring flood of 1887, and found that the river had been swept clean of these deposits.

Q. Those went out into the lake?

A. Yes, sir, they were of that constitution, so cellular in composition that when they are once broken up by a propellor or other disturbing forces, they would float readily in the water.

I also made an examination of the Illinois and Michigan Canal to ascertain its condition respecting these sludge deposits and what current must be maintained to keep the same from settling upon the bottom. I found practically no deposits similar to those which I have described in the Illinois and Michigan Canal. There were deposits in wide waters, which consisted very largely of earthy matters; and it seemed to be that a velocity of ½ to ¾ of a mile would maintain all these substances in suspension.

I also made an examination of the conditions in the Illinois Valley since the sewage had been down there through the canal, and made an extended trip from Joliet to La Salle, interviewing all the people and fishermen who were familiar with the conditions in the river, respecting that subject.

We had a breakup flood in 1887, occurring the latter part of February, which reached 10,000 second feet at Riverside, but was of extremely short duration, as a freezeup set in the next day, after the flood got fairly under way. I measured that flood in the North Branch and in the West Fork of the Chicago River, where I ascertained that 7,000 second feet was coming across the Divide. I also had a party at Riverside. Mr. Hering was in personal charge of a party at the mouth of the Chicago River, and as I recall measured 12,000 feet of water going out into the lake in that flood, which was by no means an extraordinary flood.

A preliminary report of the Commission was made January 30, 1887, and in that report they considered three methods of sewage disposal for Chicago.

One of these methods was to gather up the sewage by intercepting sewers and conduits, and pump the same to the sand ridges and dunes of Indiana, east of Hammond, and between the Little Calumet River and Lake Michigan; and there dispose of the sewage on land by broad irrigation and intermittent filtration. This scheme was regarded as impracticable by reason of divers political jurisdiction, and by reason of cost. And it still left problems to be solved in the circulation of rivers and the care of floods. It was known even at that time, and more fully developed later, that the conditions of flood waters and especially the conditions of the wa-

ter in the Chicago River when this city was taking a bath, the sewers were being scoured out and the streets washed, was worse than at any other time. And no such scheme could care for these flood conditions; and the conditions for the maintenance of proper sanitary conditions in the river itself.

The second scheme worked out was like the first, so far as gathering up the sewage was concerned, and a conduit was to be driven out into the lake opposite Jackson Park and the sewage there forced out through this conduit and diffused in the lake. The water supply was to be shifted north to Grosse Point at the Northern city limits of Evanston. This proposition was estimated, and it was also regarded as prohibitive. It was strongly objected to on the score of possible contamination of the water supply even at that distance, as the lake currents showed that to be possible: and also for sentimental and other reasons. The effect would be to pollute the bottom of the lake here over a very large area to be stirred up in storms and result in a bad condition of the water in this end of Lake Michigan. It also failed, like the first scheme, to take care of flood water conditions, and the circulation of the river.

The third proposition, which was affirmatively recommended, was the ship canal solution, substantially as outlined by the report of the Citizens' Association of August, 1885, and the capacity of the channel which it was then determined it would be necessary to take care of the flood conditions was fixed at not less than 10,000 second feet.

This would also take care of the Chicago River and produce proper circulation in its branches by means of adjuncts. The population estimated in all these schemes was two million and a half people, and on that basis the dilution was inferred at 4 cubic feet per second for each thousand of population; although this matter as to what population such dilution would take care of or such volume of water would take care of was not specifically passed on at that time.

It had other collateral merits which were mentioned. It would lend itself to the development of an inner harbor here in Chicago and would provide the water supply required to produce a deep waterway to the Gulf and would contribute to the extent of the cost of the main channel to such deep waterway, without expense to the State or to the United States, all of which were motives which left no doubt as to the proper scheme to select.

Following this report, a bill was introduced in the General

Assembly known as the Hurd Bill, the same being drawn by Harvey B. Hurd, an eminent constitutional lawyer of Chicago, which provided not only for the construction of this work, but also for taking over the sewer system and eventually the water system of the city, so as to combine under one jurisdiction all elements of the sanitary problem in Chicago.

Extensive hearings were had, which were printed at the time, before a Joint Committee of the General Assembly, which went into the merits of the whole question as then understood. The General Assembly considered the subject matter unripe for action and postponed the Hurd Bill, and passed a subordinate bill known as the Roach-Winston Bill, which gave authority to divert the head waters of the Des Plaines River and North Branch to Lake Michigan and enter upon other expedients of temporary relief pending the development of the major project.

The General Assembly also authorized a Joint Committee to sit ad interim to investigate the whole subject matter and report back to the next General Assembly; and constituted the Mayor of Chicago ex officio chairman of this committee.

The Drainage and Water Supply Commission reported on the schemes covered by the Roach-Winston Bill, in July, 1887, and did project various measures of temporary relief such as extending the water tunnels, enlarging the canal out to Summit, or the Ogden Ditch, and putting in pumping works there to pump 120,000 cubic feet of water per minute, but none of these measures were actually carried out.

The investigation of the Drainage and Water Supply Commission continued after this report until November, 1887, and then the Commission was disbanded, without ever having made a final report or completed all the topics which it had undertaken to consider. Following the disbandment of the Commission, I entered into the service of the State Board of Health of Illinois, as its consulting engineer.

The State Board of Health, in co-operation with the City of Chicago, had in 1885 and again in 1886, made an extended series of chemical analyses of samples from a number of points between Chicago and Peoria for the purpose of determining the effect of sewage in the Illinois River and the purification of the same. They presented a very sanguine report in 1886, in regard to the progressive oxidation of the sewage downstream, which was challenged and much criticised by the sanitary world as a misinterpretation of the facts; that the

real cause of the purification shown was sedimentation and dilution, and not purification.

The sanitary world at that time had been much impressed and still entertained the dogma which had been pronounced by the Royal Rivers Pollution Commission of Great Britain, which had issued a dictum much quoted even to this day, that there was not a river in Great Britain long enough to purify itself.

My work with the State Board of Health consisted of various examinations and consultations here at Chicago, special examinations of the Illinois River, in which I twice examined the conditions produced by the distilleries and the cattle pens of the Corn Products factories at Peoria and Pekin, which were producing a condition in the Illinois River at that time for 20 to 25 miles below Peoria only less offensive than that which existed in the Chicago River.

In 1888, they undertook a very comprehensive series of stream examination of the Illinois River and its tributaries, and the entire route from Lake Michigan to St. Louis, and continued these observations into the winter months of 1889. And I undertook to work up the physical facts connected with the flow of the river in that connection. These results were published in a preliminary report in 1889, along with my own contribution respecting the Illinois River System, and were before the Legislature in the session of 1889.

In the spring of 1888, the special joint committee of which Mayor Roach of Chicago was Chairman, got busy and employed Mr. John P. Wilson as legal adviser and he called in consultation eight of the most eminent constitutional lawyers that were then in Chicago and the State, to determine the legal basis of a proposed Sanitary District Act. I was employed as consulting engineer to this committee; and in the subsequent months hearings were had in Chicago and in the Illinois Valley in relation to all matters in controversy.

I was called upon particularly to pass upon and determine the capacity of the channel, and adopted the prior determinations that it should have a capacity of not less than 600,000 cubic feet of water per minute, but that in order that Chicago would be better able to finance it, only the rock cuts were required to have this capacity at the outset; the earth cuts permitting progressive development with the growth of population; and it was so entered in the law, or in the bill then prepared.

The other question that I was called upon most particularly

to consider was the subject of proper ratio of dilution. There was a difference of opinion in the Commission itself and in the hearings, ranging from 14,000 cubic feet of water per minute for each 100,000 of population up to 30,000 cubic feet of water per minute, and the subject matter was finally referred to the consulting engineer to make as exhaustive investigation as possible, and that whatever findings he made in the premises would be satisfactory to all parties.

At that time we had not only our own investigations here in Chicago and in the Illinois Valley, which perhaps were more comprehensive than had ever been undertaken upon a similar subject and upon a much larger scale.

And we had also the very excellent reports of the Massachusetts Board of Health, and some from other New England States going back for 15 years or more, dealing particularly with the subject of river pollution. We had also all the reports that had been made by Royal Commissions in Great Britain; the reports in regard to Paris and Berlin, and other foreign data.

In addition to this, I made a special compilation of the population of American cities in relation to the low water supplies of streams into which they discharged their sewage. So I felt then, and feel now, that we had all the data which was available for such a consideration. We had on the one hand a city so situated and conditioned that all the sewage that was produced by its population was practically tributary to the sewer system, perhaps more completely so than in any other city of the world. We had also at that time the established leadership in the preparation of food products of vegetable and animal origin, and the waste from those sources in themselves amounted to the equivalent of a very large city. But in respect to this matter, it was reasoned that there had been a very great development in by-products from these industries in the past, and that probably by the time the capacity of the channel approached exhaustion these wastes would be all converted into useful commercial products, so that there would remain substantially only the domestic sewage in the eventual windup.

On the other hand most of the data existing here and abroad were cases of actual pollution of streams, of natural streams which were all highly charged, in some cases to their practical limit in digesting the organic remains from the land. That matter had come up for very careful and full consideration in the studies by the State Board of Health, or under

the direction of the State Board of Health, and we had made estimates of the organic product from the Illinois watershed, a very rich watershed, in its vegetal cover, which showed that the organic wastes coming to the stream from this source were manifold the estimated wastes of a great city like Chicago.

These facts had led to very high estimates in different localities and in different countries in regard to the ratio of dilution that was tolerable in streams; whereas we had at Chicago a lake water charged to its limit with oxygen, in fact surcharged much of the time, so that it was not a case of river pollution in fact ,but a case of contributing a new stream to the Illinois carrying its own standard of purity.

After going over all these matters which I have outlined, I determined the ratio at 20.000 cubic feet of water per minute for each 100,000 inhabitants, as a minimum. The bill as drawn was submitted by the committee to the General Assembly as its report, February 1, 1889, and was passed in May of that year without any amendments whatever as affecting the sanitary provisions of the bill.

I was instructed to remain in Springfield by the Mayor of Chicago, and was eventually left in charge of the measure after the preliminary hearing. I am able to say that every feature of the bill that affected the Illinois Valley was canvassed at great length. In my work for the commission, I had the assistance of a party of men, among others Mr. John Erickson, now City Engineer of Chicago; and we were called upon and did compile everything relating to conditions in the Illinois Valley, and made the best estimates that it was possible to make at that time regarding the effect of this volume of water in the Illinois Valley. And those matters were fully explained.

In order to further safeguard the interests of the Valley, provisions were put into the bill to remove certain dams belonging to the State. A supplemental bill was drawn. I myself drew it at the request of the Valley interests providing for a cession of these dams to the United States, on condition that they should remove the same and change its policy to a deep water policy in conjunction with the water supply from Lake Michigan. In the event of the United States not accepting the same, the canal commissioners were directed to remove the dams whenever the water turned down from Chicago should give an equivalent depth for navigation.

A joint resolution was passed by the General Assembly,

which I prepared by request stating the policy of the State, which was to produce a channel not less than 22 feet deep across the Chicago Divide to Lake Joliet, and not less than 14 feet deep thence to Utica, so fashioned as to permit future increase in depth, and requesting the United States to stop work on the dams at La Grange and Kampsville and enter upon a policy of deepening the Illinois River by dredging, in conjunction with this water supply from Lake Michigan, and produce such depth as might be feasible by such method. This resolution was repeated in 1897, which I also drew by request, and there the proposition is mentioned of 14 feet through the Valley, which is the origin I think of that phrase.

Our examination of the Illinois Valley had determined that 14 feet could be produced by the aid of this water supply; and that by producing such depth of water, this channel would be self-sustaining and not subject to depreciation and would make a better drain for the Valley, and assist in the reclamation of the lands. All these matters were prime factors, as well as another matter which was uppermost in the minds of the State Board of Health and in the minds of the General Assembly, and that was that the solution that served Chicago would likewise serve all the populations that could exist between Chicago and the Mississippi River, by reason of the progressive purification of the sewage, through which it could take on an additional burden from point to point.

After the passage of this bill, the subject matter of a petition for the organization of the Sanitary District was taken up by the Citizens' Association, and I acted as consulting engineer to the petitioners and prepared a number of exhibits which were submitted to a committee of Judges of the Circuit Court, which was provided for by law, who held hearings and entertained objections in respect to the proposed boundaries of the District, and to finally determine the same. These hearings were continued over a number of days, and all interests subject to taxation within and without the proposed district appeared. And it became necessary to develop before this Commission a complete project, to determine you might say a complete project by which the Commission could judge that every part of the territory which it was proposed to tax would be benefited and could be served.

They finally determined the boundaries of the district on the North by the north line of Lake View and Jefferson; on the West, the west line of Cicero, and along the range line through the township of Lyons, including outside thereof

some eight square miles along the Des Plaines River below Riverside; thence easterly along the south line of the Town of Lake and across Hyde Park at 87th street; the same including 185 square miles.

At the time of the passage of the Sanitary District Act, this area was divided up into a number of municipalities. The city of Chicago itself covered 37 square miles and had a population in 1888 of 802,651; the town of Lake View 42,339; Jefferson, 10,622; town of Lake 56,661; Hyde Park north of 87th street 41,000.

All these areas above scheduled were consolidated with the City of Chicago at the general election in 1889 by authority of an act of the General Assembly. There was in addition the town of Cicero, with a population of 13,926 and a part of the township of Lyons with a population of 1,293, and these together aggregated nearly 1,000,000 (988,329). The proposition was voted upon at the general election in November, and the Sanitary District Act was adopted by vote of 70,000 to 200, in round numbers.

In the December immediately following, a special election was held for trustees; and the Board finally organized as a Board of Trustees of the Sanitary District in January, 1890, and elected its officers. I was elected Chief Engineer for the Sanitary District, and entered upon my duties at once. These consisted in bringing together all the data and exhibits that had been prepared during the prior investigations until the Supreme Court decision affirming the validity of the act was handed down on June 12th, 1890.

Q. That was the Nelson and Wilson cases, wasn't it?

A. Yes, sir. Immediately thereafter an engineering force was organized on a large scale and proceeded with the definitive surveys which preceded construction, and the actual carrying out of the work itself.

Q. What plans did you consider then as to the location of the main channel and its adjuncts?

A. At that time, our particular studies and surveys were directed towards locating the main channel and the river diversion from the Chicago River to Joliet, and making all land surveys required in connection with acquiring the right of way; and of course with a view to putting that work under construction as soon as possible.

Later, and in the course of my first term as engineer and trustee of the Sanitary District, we completed comprehensive surveys extending over the entire area of the District and

outside of the same for the purpose of taking up the border definitions on the collateral projects.

The plans except as to details and except as to specific definition had all been practically determined before the law was passed, and were exhibited with all needful detail before the Committee that determined the boundary of the District.

Q. Were any plans considered at that time with reference to the building of an auxiliary channel from the main channel to connect with the little Calumet River?

A. Yes, sir, the plans of that period not only exhibited such a channel but also the Evanston channel. In fact the Calumet proposition was worked up by the preliminary report of the Hering Commission in 1887 and was always regarded as one of the integral parts of the comprehensive plan.

It was further developed or reported upon in 1896-7 by the Intercepting Sewer Commission of the City of Chicago; and also considered at length by the Committee on a comprehensive plan in 1901. I was a member of the Intercepting Sewer Commission and also the Committee on Comprehensive Plan.

Q. Did you consider plans with reference to intercepting sewers for the city of Chicago at that early time?

A. Yes, sir; those were considered from the beginning, and plans were actually made in connection with the disposal schemes in Indiana and in the lake for intercepting the lake shore sewage, and this matter was taken up in final preparation for work by the Intercepting Sewer Commission or what was known as the Pure Water Commission of the City of Chicago in 1896, and definite plans prepared which have since been carried out with some amendments covering the entire city front from 87th street on the south to the northern city limits. There were two of the sewers that discharged into the lake under the old Chesbrough plan, the one at 12th street and the one at 22nd street, and they were actually reversed on or about this time, taken up and reversed.

Q. Prior to September, 1890, did the Sanitary District expend any money in connection with the carrying out of these plans that you have mentioned?

A. The Sanitary District was instituted for the specific purpose of carrying out the projects which were outlined prior to its organization, and had proceeded by that time in the definitive surveys in relation to the main channel from the Chicago River to Joliet. They had also instituted surveys on

the Chicago River with a view to the definitive surveys for its enlargement.

Q. When you became chief engineer in January, 1890, you proceeded immediately to further work upon those plans, did you?

A. Yes, sir.

Q. For the Sanitary District?

A. Yes, sir. There was nothing left to do except to define the things on the ground, practically. The genius of the whole proposition from the outset, held in mind unvaryingly, was to keep the flow of sewage away from Lake Michigan as far around the rim of the lake as was practicable.

Mr. Hopkins: I move that the answer to the question that was started this morning, the long answer, be stricken out for the reasons that have already been assigned, and in particular, in regard to this matter of stipulation, I do not understand that the stipulation covers legislative acts, or purposes and motives of that kind of the legislature. There is no objection to the testimony being secondary because the Journal is not produced, but I object in general to the testimony of intention, motive, purpose, genius.

Mr. Adcock: Q. After December, 1890, when you ceased to be the chief engineer, what work did you take up?

A. I again resumed my connection with the State Board of Health as consulting engineer, with a view of completing the report which had been made in preliminary form in 1889, and putting the whole subject matter of our knowledge of the conditions in the Illinois Valley in proper form for printing and record.

Q. Prior to the organization of the district, were any discussions, had in any engineering society with reference to the probable effect upon lake levels from the diversion provided for and contemplated in the third scheme, third plan of the Drainage Commission?

A. Yes, sir. That subject matter, I was charged with the consideration of, and I virtually incorporated my own findings in the Lakes to the Gulf Waterway discussion published in 1888, January, in regard to the probable effect on lake levels.

That year I was secretary of the Western Society of Engineers, and the subject matter was taken up as a topic for discussion, and a paper prepared and submitted to the Society in September of that year by Mr. George Y. Wisner, father of the present chief engineer of the Sanitary District, in regard to the probable effects of abstracting 10,000 second feet

at Chicago in the proposed Sanitary Canal. There joined in that discussion Mr. D. Farrand Henry of Detroit, a gentleman long connected with the Lake Survey, and who had made all the studies and observations in regard to the discharge of outlets of the lakes up to that time. There also joined in this discussion Mr. William Pearson Judson of Oswego, long connected with Lake Harbor Improvements; Mr. Louis M. Haupt of Philadelphia; Mr. J. B. Johnson of St. Louis, later Dean of the Engineering College at Wisconsin University; Mr. Clemens Herschel of New York, who was regarded as the leading authority in hydraulic engineering in this country, and Mr. Benezette Williams of Chicago. I edited these papers and included my own discussions. They were all printed together in the Journal of the Engineering Society, and were reprinted for distribution by the Citizens' Association of Chicago, and were before the General Assembly before the passage of the law.

Q. Was Mr. Wisner then in the Government service, do you know?

A. He had been. I don't think he was at that time. He had been connected with the Lake Survey, and also with the survey of the Mississippi River and the Illinois River. He made a survey in fact, under Major Benyaurd, between Joliet and La Salle in 1882 and '83.

Q. What is the available water supply of the City of Chicago?

A. No water supply has ever been entertained for the City of Chicago except Lake Michigan, and no other source of water for the city is really feasible, except Lake Michigan. The water supply from all the Great Lakes has been regarded perhaps as superior to any source of water supply elsewhere existing in this country, by reason of the age of its waters, through which all the biologic processes of nature have worked themselves out, those that are in any way detrimental to human kind.

The average flow over Niagara Falls would take one hundred and fifty years to drain out the contents of these lakes, if they were not replenished and in the absence of evaporation. The Chicago Sanitary Canal, if operated at 15,000 second feet, would be supplied for 2,000 years, so the average age of the water of the lakes is 150 years.

There is no possible substitution for these waters, which could equal them in value or efficiency. There is no possible treatment of water which is the equivalent of these aged waters. The matter of age in waters has been given in the

last few years a very great deal of consideration. Mr. Stearns of Boston in the Metropolitan Boston Supply projected a reservoir there and places considerable stress by reason of the fact that the average age of those waters will be 6 to 8 years, and they will have time to whiten and bleach, and work out their biologic cycle.

The same proposition I had up in connection with the Denver water supply where I was intrumental in constructing a reservoir that would carry three years' supply for the City of Denver, and secure the same object.

Q. Is that Mr. Frederic P. Stearns, the gentleman you mentioned?

A. Yes, sir. I might add that the production of the purity of this water supply has been almost a purpose, from the inception of sanitation at Chicago; and absolutely so since the report of 1885.

There is very little land water going into the south end of Lake Michigan; the nearest point of any tributary of considerable size being the mouth of the St. Joe River, more than 60 miles away.

The sanitary project contemplates and has contemplated from the outset extending this divorce between land waters and lake waters as far around the rim of the lake as possible; north to Lake Bluff at least, on the north and east across Lake County in the State of Indiana; and when the proposition is entirely worked out there will be some 60 and 70 miles of the lake shore entirely free from the intrusion of any land water or sewage whatever. And this puts Chicago in a better position in relation to its water supply, and secures for it a better water supply than is provided for perhaps in any city in the world; one that is automatically free from contamination or possibility of contamination.

Q. What was the condition of the pollution of Lake Michigan from 1880 to 1890, and what was the condition of the Chicago River during that period?

A. I have already stated that in part, in discussing the results of an examination made by me in 1886 and '87, respecting the product of decomposition from sewage in the Chicago River. In those years, especially after 1883, the Illinois and Michigan Canal was operated up to a limit of 60,000 feet of water per minute or a thousand feet per second, which was little in excess of the ordinary flow of the sewers coming from the water supply and the ground waters; and the result was that any range of any considerable amount that produced any run-off at all in the sewers or in the water-

sheds outside of the sewerage area produced a flow towards Lake Michigan, which entered the lake water and contaminated the same.

There were also conditions where lake fluctuations produced a similar result. This bobbing of the lake up and down, which I have observed through a range of 18 inches every 20 minutes, had the effect of sending the current up the river, and then set it back again; amounted to a species of milking process, by which the content of the Chicago River was gradually milked out into the lake.

Again, there were other changes; sometimes the lake would be up an extra foot, and all the bad waters would be sent up the slips and the South Fork and North Branch, and fish would attempt to make a trip through the blue waters of the river and the lake would fall as quickly, and all the bad waters would set out into the channel, and we would have large numbers of dead fish in the river and in the canal.

The South Fork was without circulation during this period, and in a malignant condition.

The North Branch had only the nominal circulation created by the Fullerton avenue conduit, which was changed once in about three days and was in a bad condition. Of course in flood time, when there was any considerable amount of water, the contents of the river went out in a most affirmative way into the lake.

I will say, further, that the duration of this positive flow into the lake was variable. Under the conditions of the flood of 1881, it probably was not less than 100 to 120 days; probably in the minimum years not less than 25 or 30 days, but that is an estimate and not a positive determination.

Q. Was there any smell arising from the Chicago River as the result of sewage being turned in there?

A. The smells were affirmative in the North Branch along the main river, and beyond any power to describe the same in the South Fork. In the examination which I made in 1887—1886 rather, I was on the river in a tug for several days dredging every acre of its content to ascertain the character of the deposits on the bottom. These were brought up and spread over a broad table on the fantail of the boat and examined carefully by working them over with a paddle and examining them with a glass, and samples of them taken from time to time for more critical examination. And in my trips up the river, and especially up the South Fork, men were so nauseated that they were unable to take their meals, and

some of them did not recover for a week afterwards their normal condition.

Q. There used to be a saying that a man could walk over the river; there was a scum or something or other arising there?

A. At times there would be a scum, sometimes extending clear across the South Fork, which appeared to be six or eight inches thick, and over which the fowls, geese and duck of that region, proceeded without difficulty. I have never seen anybody walk over it. I have heard of that scum having been afire; and the vessels that went up into those forks lost their white paint very quickly. Some of them that went up there pumped the waters into their boilers for the purpose of taking the scale off their boilers.

There was noticed, however, in the death charts which I prepared in regard to zymotic diseases in Chicago, covering the years 1890, 1891 and 1892, that the deaths from miasmatic or air-breathing diseases seemed to be more prevalent in the region where these bad gases were most intense. And in the inquiries which I made at that time among physicians, it was generally recognized that throat troubles and other air-breathing maladies were more malignant where these emanations were breathed.

Q. Did this pollution of the Lake Michigan water have any effect upon the death rate from typhiod fever and other water-borne diseases?

A. Yes, sir, a very pronounced effect. I investigated a typhoid fever epidemic in Lake View in 1889 for the State Board of Health, and later followed the matter up in 1891. The epidemic that started in Lake View continued with ups and downs through 1890, 1891 and 1892, and then gradually subsided.

In 1891, the death rate in Chicago was 480, I believe, in May of that year, and for the entire year the number of deaths from typhiod as then diagnosed was something over 1,700.

Q. That would be about 170 per 100,000?

A. Estimating the population at 1,000,000 within the city proper, it would be 170 per 100,000.

Q. Did you mention the death rate in Chicago just prior to the establishment of the sewer system, at the time Mr. Chesbrough was brought on here?

A. Yes, sir, 48 to 50 per thousand of population for the years 1849 to 1854, inclusive; about three times the normal to the city since we opened the Drainage Canal.

Q. In making your investigations as to the death rate from

typhoid fever in 1889, 1890, 1891 and 1892, did you examine the health statistics in Chicago?

A. Yes, sir; I sent men to the health records, or to the records at the City Hall, and we went through the entire list of deaths of the year. At that time they were not classifying and printing a classified statement of deaths. We made a card for each name for each location, and then proceeded to spot it out on the map. In that way we made up the charts for the years 1890, 1891 and 1892, for the particular purpose of disclosing that epidemic, and also the relation of other zymotics.

Q. From 1890, when you ceased to become Chief Engineer of the Sanitary District, will you state what was done by the Sanitary District on the work in the building of its main channel and adjuncts and additions thereto?

A. I was elected as trustee, and took office as a trustee in December, 1891, and continued in that position until December, 1895, and during that period we executed the river diversion, a collateral work of the main channel, by which the river was given a course by itself on the west side of the Des Plaines Valley.

Q. That is when you say "river diversion" you refer to the Des Plaines River, do you not?

A. Yes, sir; so as to leave an intermediate strip between the river and the canal, on which we located and built the Drainage Canal.

At the end of 1895, when I left the District, excavation on the Main Channel was about three-fourths actually made or completed. The right of way had all been procured at that time; the contracts for the Main Channel were also arranged before the close of my term as to be completed in November, 1897.

I was Consulting Engineer of the District in 1897, and we were overtaken at that time with a financial stringency, which seriously embarrassed the progress of the work of the District. The work was proceeding faster than the District could get the funds to pay for it, and so the real work on the channel, the Main Channel, which was scheduled to be completed in November, 1897, was not actually completed until about November, 1898, when it was substantially completed, and the District then notified the Governor of that fact and asked for the appointment of a Commission. I think the first action by the Board on that matter was in November, 1898, and the petition actually was transmitted to the Governor in January, 1899, as I recall it.

There was a delay at that time in view of the fact that the state had made no appropriation for the maintenance of this Commission, and the Sanitary District deposited the necessary funds with the State Treasurer, and the Commission proceeded later to perform its functions, and the Sanitary Canal was finally opened on the recommendation of the Commission to the Governor January 17, 1900.

Q. That was when the Governor granted the authority under the terms of the act?

A. Yes, under Section 27 of the act.

Q. The channel was then opened and the water flowed through the Main Channel into the Des Plaines River?

A. Yes, sir, and has been flowing continuously ever since.

Q. Do you remember when the work on the enlargement, the widening and deepening of the Chicago River, was commenced to accommodate the flow contemplated through the main channel of the District?

A. Very elaborate surveys were made of the Chicago River for the purpose of defining the property questions at the place of the enlargement while I was a trustee of the District prior to 1895; and the work of actual enlargement of the river began in 1896.

The United States took jurisdiction of the Chicago River and exercised authority over it for the first time under the clause in the Rivers and Harbors Bill of 1896, and a permit was then issued to the Sanitary District for the improvement of the stream, by the Secretary of War. The stream was prepared for a flow of 300,000 feet of water, the preliminary requirement of the Sanitary District law, some time prior to the opening of the channel.

After the flow of water had been established, in 1900, the Sanitary District then matured plans for enlarging the river for the purpose of getting the larger quantity of water required by the Sanitary District Act, and actually entered upon that proposition in 1900; and the whole subject matter was before the commission on a comprehensive plan of 1901, of which I was a member, and the trustees went to the Legislature and got an enlargement of their bonding power for the purpose of expediting the work in 1901.

I will say in regard to that, the improvement made prior to the opening of the channel was simply preliminary improvement. It was recognized that in order to obtain this flow in the water in the quickest possible time and at the lowest possible expense, it was recognized that there would have to

be a wholesale improvement from the beginning, such as was undertaken in 1900.

Adjourned to Friday, March 6, 1914, at 10:00 o'clock A. M.

Friday, March 6, 1914, 10:00 A. M.

LYMAN E. COOLEY resumed the stand for further direct examination by Mr. Adcock and testified as follows:

Q. I will call your attention, Mr. Cooley, to a resolution passed by the Board of Trustees of the Sanitary District of Chicago on April 21, 1891, appearing in the printed proceedings of the Board as follows:

"Resolved, That this Board hereby ordains that the Sanitary District of Chicago do forthwith enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the South Branch thereof, and also the South Branch thereof, together with the South and West Forks thereof, so as to make the same a proper and sufficient supply channel for the Main Channel heretofore surveyed from the Chicago River to Joliet;

And further, that the acting Chief Engineer be and he is hereby directed immediately to investigate and report upon the capacity of said river and its said South Branch and Forks for that purpose; and also as to any changes that should be made therein. And that a copy of this resolution, certified by the Clerk, be forthwith transmitted to the Mayor and Common Council of the City of Chicago and the Secretary of War of the United States."

I will ask you Mr. Cooley what the Sanitary District did pursuant to that ordinance?

A. The Chief Engineer of the District went ahead and made an exhaustive survey of the Chicago River from Robey street to the lake, defining all property rights and cross sections of the stream, with a view to definitive plans for the improvement of the river. And these surveys were completed prior to 1895, while I was on the Board. They were followed by definite plans for the improvement of the river, which were inaugurated in 1896, in co-operation with the United States, which made an appropriation for the improvement of the river in that year; and the river was improved to a depth of 20 feet by dredging the stream. And the bad angles in the stream were cut off, and in some places the river was widened, and in the vicinity of Adams street and Jackson street,

by-passes were constructed at the constricted parts of the river, in that vicinity, for the purpose of giving the preliminary flow required by the Sanitary District law of 300,000 cubic feet at the velocity of 1¼ miles per hour.

These surveys were also used as the basis of the larger improvement which was immediately defined and inaugurated after the opening of the channel in 1900, for a capacity of 10,000 feet per second.

That plan consisted in bascule bridges in the stream of a uniform width of 200 feet, and a central depth of 26 feet; and has also been carried out in part with the co-operation of the United States.

Q. During the period before 1900, the United States improved the river in connection with this work?

A. Yes, sir, from 1896, after there was an appropriation of $700,000 for the improvement of the Chicago River, which was the first appropriation ever made for improvements above Rush street.

Q. What was the capacity of the Main Channel at the Rock Section?

A. The Rock Section was actually 840,000 cubic feet capacity.

Q. That is cubic feet per minute?

A. Per minute, yes, sir.

Q. And after 1900, did the United States make any improvement in the Chicago River?

A. Yes, sir.

Q. At the time that the work was being carried on by the Sanitary District?

A. Yes, sir.

Q. In deepening and widening the river?

A. Yes, sir. They continued their work. There has been appropriated all told something over a million and a quarter of dollars, (expended June 30th, 1911, $1,253,957) as I recall it. I haven't the exact figures at hand, except the first appropriation which was $700,000 in 1896.

Q. What was the occasion for making further improvement in the Chicago River and its branches after 1900 by the Sanitary District?

A. The further occasion was to get the increased capacity which was required with the growth of population, after the initial capacity of 300,000 feet had been established.

Q. Was it to accommodate the maximum flow through the main channel?

A. That was the original intention, to accommodate 600,-

000 feet by way of the Chicago River, and later that was supplemented by the flow by way of the 39th street conduit.

Q. Was that new improvement or the improvement after 1900, known as the Chicago River Improvement Project of 1900?

A. Yes, sir.

Q. That was of the Sanitary District, of course?

A. Yes, sir. I went through all those propositions on the Expert Commission in 1901.

I will state in that connection that the 39th Street proposition was determined prior to 1901, but I do not remember the exact year.

Q. That is the pumping through the 39th Street intake?

A. Yes, sir. They were all part of a general plan for supplying the Main Channel with water in excess of 300,000 feet.

Q. If the flow through the Sanitary District Canal had been limited to 5,000 cubic feet per second after 1900, would it have been necessary for the Sanitary District to have made the changes and alterations in the Chicago River that it subsequently did make after 1900?

A. That is if the law had made that the capacity of the channel?

Q. Yes?

A. No, sir.

(Question read as follows) "If the flow through the Sanitary District Canal had been limited to 5,000 cubic feet per second after 1900, would it have been necessary for the Sanitary District to have made the changes and alterations in the Chicago River that it did make after 1900?

Mr. Hopkins: Necessary for what?

Mr. Adcock: For any purpose; that is to keep the flow down to 1¼ miles, or to make it safe for navigation.

Q. What purpose did you have in mind?

Mr. Adcock: For any purpose.

The Witness: I would like to supply an omission in my answer to the question in regard to conditions existing in Chicago between 1880 and 1890? In the examinations in regard to the deposits from sewage decomposition in the Chicago River, slips and branches, there was no signs of life such as usually accompanies filth production in any portion of the river until we reached the remote heads of slips and at the North Branch and out at the West Fork, where the septic action was limited in amount. In other words the toxins produced in this stream through the decomposition going on

were absolutely destructive to all life except the bacterial life in the waters themselves.

From this condition, and from the conditions of deposits existing in the main sewers of Chicago, it was reasoned at that time that no such things as disease germs reached the lake under low water conditions in the river and in the sewers, but that in flood time the disease germs from the population went to the lake, where they did not encounter this septic condition.

At that time, we had a large population discharging into the lake directly; and I also made examinations at the mouths of sewers on the lake, and opposite these mouths we did find these filth orders of life, which were not destroyed by reason of the septic action and which could exist there in the clay and in the deposits near the mouth of the sewers on the lake.

I wish also to say in that connection that I watched the effluents at that time from the 22nd street sewer and from the 35th street sewer, and have been able to see the same in the Lake, half a mile or more from the shore through the irridescent shimmer as the lake was dancing under a western sun.

At that time also in 1885, they operated occasionally the Fullerton avenue conduit into the lake, and I have seen the effluent going in an unbroken body out into the lake for more than a mile before it was diffused. That was not a usual occurrance but it was an occasional condition. And it would swipe across the crib at times like the tail of a comet and cause an eclipse, you might say, of the pure water which was being pumped through the crib. That was what I should have added yesterday, in completing the answer.

Q. I show you a plan Mr. Cooley marked Exhibit H, to the answer filed in this case entitled "Sketch of Plan for Increasing the Capacity of the South Branch of Chicago River." That was the plan which is attached to the permit of the Secretary of War issued in 1896, or purports to be. Do you know whether that indicates the preliminary improvement which you mentioned?

A. Yes, sir this does. I have seen this plan before.

Q. I also show you a map or plan Exhibit K 1, to the answer filed in this case entitled: "Sanitary District of Chicago, map of the Chicago River, Sheet number 3, from Kinzie street to 18th street; scale 200 feet to an inch," which purports to have been attached to the application made by the Sanitary District for a permit to the Secretary of War dated April 26, 1900, and ask you whether that indicates the plan

for the improvement of the Chicago River under the project of 1900, so far as it goes?

A. I made a critical examination of these plans when I was on the Expert Commission in 1901, and that is the same plans that we examined at that time.

Q. I show you another plan or map which is attached to the answer in this case as Exhibit K2, entitled: "Sanitary District of Chicago, Map of the Chicago River, Sheet number 2, from 18th Street to 31st Street, Scale 200 feet to the inch." This map or plan purports to have been attached to an application made by the Sanitary District to the Secretary of War for a permit dated June 7, 1900. I will ask you whether that map or plan shows the improvement of the Chicago River from 18th Street to 31st Street under the project of 1900 mentioned?

A. It shows the proposition which I reviewed in 1901, when a member of the Expert Commission. It was procured by the District in 1900.

Q. It is stated here that the scale is 200 feet to the inch on both of the maps which are mentioned?

A. That is the original scale of the maps, with which I am personally familiar, and these are photo reductions.

Q. The width of the river under the project to be 200 feet, as I understand it?

A. The width of the river generally was to be 200 feet, with a central depth of 26 feet. That was the minimum general width. There were parts of the river that were 300 feet in width in which no changes were made other than dredging.

Q. Do you know how much money the Sanitary District expended under the preliminary projects which you mentioned, commended in 1896 and finished before the opening of the channel, and also the amount that was expended under the 1900 project?

A. I have compiled those figures in detail from the beginning. The expenditures up to 1913, are as follows:

Total expenditure up to and including 1899,	$	727,441.02
Expended in 1900,		837,165.39
Total expenditure up to and including 1900,		1,564,606.41
" " five year period, 1901-5,		6,727,708.34
" " up to and including 1905,		8,292,314.75
" " five year period 1906-10,		2,082,229.92
" " up to and including 1910,		10,374,544.67
" " two year period 1911-12,		266,194.85
" " up to and including 1912,		10,640,739.52

Q. Has the old Illinois and Michigan Canal between the upper basin of Joliet and the Chicago River been used since 1908 for navigation purposes?

A. The Drainage Canal was officially substituted by an Act of the Legislature in 1910, although provision was made for that substitution in 1903. The Canal was used for some years after 1903 for navigation, but whether it actually ceased in 1908 I would not be able to say; but since 1910, the Sanitary District Canal has been used as the official channel.

Q. And the Illinois and Michigan Canal has not been used from the points mentioned?

A. No, sir.

Q. Will you state Mr. Cooley how the improvement of the Chicago River, the building of the Main Channel of the Sanitary District and the Sag Channel and the flow of water through the Des Plaines River into the Illinois River, through the Illinois River has benefited or will benefit navigation?

A. The building of the Main Channel and the improvement of the Chicago River which is a part thereof has extended Lake navigation to a depth of 24 feet 36 miles from Lake Michigan and within a mile or two of the city of Joliet. Lake navigation has not yet developed on a scale of 24 feet, but is predicated for that depth by the new lock now under construction at Sault Ste. Marie.

Below the water power station at Lockport, navigation is extended by a lock constructed by the Sanitary District suitable for small boats down to Dam Number 1, at Joliet 2.6 miles; and this channel is 20 feet or more in depth for most of the distance, and a limited depth of 10 feet after it reaches the Des Plaines River and the upper basin at Joliet. Navigation by small craft can extend to Dam Number 1, at Joliet.

The Sag Channel is of smaller dimensions than the Main Channel, and is available for barge navigation of any draft of barge which can pass under the bridges, such as has been repeatedly recommended by federal engineers, in connection with the route between here and the Mississippi.

At the end of the Main Channel near the power station, 36 miles from Lake Michigan, a location has been reserved for a lock of any dimensions that may be necessary or desired, by which the depths and capacity of the Main Channel can be extended down the Des Plaines River by future improvements thereof.

The jurisdiction of the Sanitary District, so far as producing channels for navigation is concerned stops at the upper basin at Joliet. The state has projected from the end of the Sanitary Canal at Lockport at the waterpower station, under the report of the Internal Improvement Commission in 1907, and by virtue of the constitutional amendment adopted in 1908, a project by which the navigable depth available in the Drainage Canal can be extended to Utica over the rock bound section and the high declivities of the upper Illinois River by means of five locks and four dams and the development of the pools between these dams. This project proceeds on the basis of 24 feet to the second lock at the head of Lake Joliet through the city of Joliet, where it is largely in rock cut. But from that point, the head of Lake Joliet to Utica, it proceeds on the basis of a preliminary depth of 14 feet, to be deepened progressively as the needs of navigation shall require.

Further than that, there has been no actual legislative provision as far as the state is concerned. The state has expressed its policy in a number of resolutions and statutes, and the United States has been asked to co-operate to the extent of building the locks in that part of the river, under the constitutional amendment, between the water power station at Lockport and Utica, at a cost of about eight millions of dollars, and to make the improvement by dredging in an open channel in the Illinois River between Utica and the mouth of the Illinois River, a distance of 230 miles; and there provide a channel of a preliminary depth of 14 feet, at a cost of about $8,000,000.

In other words the proposition as it now stands is this: That the state of Illinois by the Act of 1889, makes the Main Channel of the Sanitary District to the upper basin a navigable stream and gives the United States control of it when-

ever the river shall be improved below, and the Sanitary District has expended upon that and collateral works something like $80,000,000, and the state of Illinois has put itself in position by act of the Assembly, to spend an additional $20,000,000 in extending, a total of about $100,000,000. And the United States has been asked to co-operate to the extent of providing $16,000,000; the effect of it all being to produce a waterway from Lake Michigan 327 miles long to the Mississippi River at Grafton, with all structures, and rock cuts in the same channel for a depth of 24 feet and a preliminary depth of 14 feet in the river below the head of Lake Joliet.

Perhaps I may add in that connection that in the later consideration of the matter by the State after 1907, it is based on a flow of 14,000 second feet; and that the Deep Water Project is not practicable without the aid of the large water supply from Lake Michigan, which has been authorized by the State Law.

Outside of that, we would be limited to 8 or 9 feet as the best that could be done.

Q. This flow of water through the Sanitary District Channel, the maximum amount would be necessary for the improvements in the navigation of the Illinois River and the Des Plaines River which you just mentioned?

A. These depths of 14 feet were predicated by the original act and collateral legislation in 1889, and in all subsequent legislation, were based on a flow of 10,000 feet and the report of 1907 used that depth of 14 feet as a preliminary depth, but states that with the aid of the 14,000 feet, it will be possible to continue 24 feet to the city of Peoria and 20 feet more or less from thence to the mouth of the river.

And I assume from the fact that the constitutional amendment was based on that report, that is the project. It is the one that has been advocated by the Lakes to the Gulf Deep Waterways Association, and the one that was presented to Congress in the hearings of 1910, before the House Committee and before the Senate Committee, and Congress made conditional appropriation of a million dollars for the beginning of work, whenever an understanding should be reached with the State of Illinois regarding a plan of co-operation.

Q. How much greater width and depth has been provided by the improvement made by the Sanitary District in the Chicago River and its branches?

A. The Chicago River prior to this improvement was little more than an adaptation of the Chicago Creek, which

was known before Chicago was here; and its capacity for carrying a flow of water was limited. It is difficult to make a comparison where the stream was so little adapted to the present purpose, and where the change has been so radical.

Originally the Chicago Creek carried 12 feet up to the Forks, and its original improvement, the first improvement, was based on a depth of 13 feet, which was subsequently increased to 16, and the tunnels built under the river limited the use of the Chicago River to 16 feet, until they were removed within a comparatively recent period. They were removed by the city at a very considerable cost, which should be added to the expenditure of the Sanitary District and the United States, in getting at the true cost of the improvement of the Chicago River.

Q. When the Sanitary District entered upon the improvement of the Chicago River, it was approximately 16 feet in depth?

A. Yes, sir.

Q. The depth has been increased to approximately 26 feet?

A. It has been increased approximately to 26 feet.

Q. And that is the depth carried through the main channel. through the power house?

A. 24 feet.

Q. 24 feet?

A. Yes.

Q. And the river has been widened from an average width of approximately 100 feet to—

A. There were portions of the river that would run up to 200 feet and even 300, and again other portions that were less than 100. The narrow portions have been widened, or are being widened, except a very limited area near the Pennsylvania Central Station, which has been greatly delayed.

Q. It has been widened to a large extent throughout its entire length, the Chicago River and the South Branch?

A. Yes, sir, so much so that it could almost be considered a new river.

Q. Now with reference to the bridges, when the Sanitary District started to improve the river, they had the old center pier bridges mainly, did they not, in the river?

A. Yes, sir.

Q. And those center pier bridges have been replaced by lift bridges, leaving the channel free for navigation purposes and so forth, have they not?

A. There were center pier bridges with openings varying

all the way from 60 feet up depending on the width of the river; and the openings have now all been made uniformly 140 feet or more, so that vessels can go down the center of the stream without interfering with vessels that are moored at the docks, whereas formerly with the old type of bridge, they had to crowd the dock line making it unavailable, in order to pass through.

Q. Has this increase of depth and width of the river and the changing of the bridges been of benefit to navigation upon that river?

A. It has been of very great benefit. Under former conditions the river in many places was so constructed and tortuous that boats of the model prevailing along in 1900, 476 feet in length or thereabouts, were unable to pass through the river.

Since then, we have had boats up to 617 feet in length which could pass through. The alignment has been corrected and the channel deepened to a limit of 26 feet for a width of 140 feet in the center and the bridges have been put in with that central opening, so that the river is now available for a type of vessels which could not be considered in the early history of the stream and up to 1900.

Q. Now, has there been any increase in the depth of water in the Des Plaines and Illinois River, by virtue of the flow through the Drainage Channel?

A. There has been a very substantial and material increase in the depths. The lock and dam system built by the State between LaSalle and Havana provided for a depth of 6 feet on the mitre sills at low water of the Illinois River, and this low water has shrunk at times down to limits of 400 and 500 feet per second within the division that I am speaking of. The present flow of the Sanitary District would give 6 feet throughout all that reach above the plans of the old low water, to which you could add 20 inches for the depth existing under original low water. In other words you would have 7½ feet under the natural conditions in the river between those points without the dams.

The Board of Engineers known as the Ernst Board, which reported in 1905, stated that with a flow of 4200 second feet it would be possible to obtain in the Illinois River a navigation considerably in excess of 7 feet, without the aid of any dams whatever, and that there should be no objection to the removal of these dams.

It was examinations of these questions which led to the

project of the state for an open river improvement in these parts without the aid of the dams.

The estimates which were made at that time, made largely by me and my assistants have proven to be conservative, and that we can obtain better navigation without the dams than we had supposed when the state fixed its policy in that matter; and that we can obtain the 14 feet more readily than supposed, and obtain the 24 feet and the 20 feet which I mentioned above and below Peoria more readily than supposed.

Q. When you speak of dams, you refer to the two state dams?

A. I refer to the state dams.

Q. At what points are they?

A. At Henry and Copperas Creek; and the federal dams at LaGrange and Kampsville.

Q. The state dams were completed when?

A. The state dam at Henry was opened in 1871. The state dam at Copperas Creek was opened in 1877.

The federal dam at LaGrange was opened in 1889 and the federal dam at Kampsville was opened in 1893. They were all part of a project that goes back to 1866 and '67.

Q. There are locks at each of these dams are there?

A. There are locks at each of these dams.

Q. Before the Sanitary District flow was established through there, it was necessary for the boats to pass through these locks?

A. At low water and at ordinary stages of the river, boats used the locks. At high water they passed over the dams without obstructions.

Q. I presume the principal navigation was carried on in the summer time when the water was at ordinary stages?

A. Yes, sir, summer and fall months.

Q. Is it any benefit to navigation not to be compelled to use dams of that kind, or locks, I mean?

A. A very great benefit on account of delays; on account of tolls charged at the state dam, though there is no charge at the federal dam, and by reason of the fact that the capacity of the locks is limited and boats and barges and fleets have to be accommodated to the size of the locks. Boats without the dams today would come to LaSalle, and barge fleets would be made up there. They would not pass through the locks if the dams were absent.

Q. Does the Sanitary District own property on each side

of its main channel available for docks and dockage purposes?

A. The Sanitary District has an estate between Robey Street and Lake Joliet of between seven and eight thousand acres; and under the law is permitted to develop dockage and utilize this property.

Q. This property that the Sanitary District owns is adjacent to the channel and along the channel its entire length isn't it on both sides?

A. Yes, sir, it was obtained for the purpose of facilitating the construction of the channel and the river diversion.

Q. Of what benefit are these dockage rights and privileges to navigation?

A. Taking the channel at 30 miles from Robey Street, it really adds to the capacity of the Chicago Harbor and its potential value about 60 miles of dockage; and if the estate is developed further by slips, why the amount of dockage that can be thus developed is unlimited.

Q. It is capable of being developed by slips, isn't it?

A. It is so, yes, sir.

Q. So that it would be possible to establish practically an inner harbor?

A. Yes, sir.

Q. In Chicago, for commercial purposes and other purposes for Chicago?

A. Yes, sir. That is one of the propositions that has been held in view from the beginning, and was outlined in a report which I prepared in 1890, printed in 1891, that the Drainage Canal on its waterway site would be developed as an auxiliary to the Chicago Harbor, and that future industrial development would largely take place, by a natural evolution as the city expanded, alongside and down this channel into the state; and that that view of the proposition was in harmony with sound public policy, as these growing industries with their wastes would thus be automatically cared for in the simplest and cheapest manner. So it had a double reason, both commercial and sanitary, for the development of a harbor and its appurtenances in that direction.

That was one of the reasons why the item was put in the bill permitting the district to develop that as incidental to its other purposes. In fact it was the view held in constructing these works that all collateral advantages should be utilized; all by-products that were possible should be created, with a view of mitigating the heavy tax burdens of the community.

And I think that the Chicago Project in its entirety, involving the waterways and dockage and waterpowers and other things that it does is really the first example that we have in this country of a well considered, scientific project of conservation, for all the collateral utilities are to be developed and utilized.

Q. Does the Belt Railroad cross the canal, the main channel?

A. The Chicago & Western Indiana, which is the main Belt Road, crosses the channel near the city limits, between Robey Street and Summit. And the Calumet Terminal, which is also a Belt Road crosses the channel a mile below Summit. And furthermore the E. J. & E., which is the Outer Belt Line, crosses our channel between the water power station and Joliet; and makes the channel accessible to the entire railway system. And in that connection, it may be remarked that the report of the Federal Officer at this point recommends the development of a certain amount of harbor facilities adjacent to the channel, in the vicinity of Summit.

Q. These Belt Roads which you mentioned make it possible to bring all kinds of freight down to the Main Channel?

A. Yes, sir.

Q. And makes it possible, if the channel is developed as you have indicated, to have arrangements for the interchange of lake and rail freight?

A. Yes, sir. In my judgment the location of the Sanitary Canal is really the only practical and economical location for such an interchange about Chicago, the logical place for it to occur. It is centrally located with reference to our commercial facilities by rail. It is accessible directly by a number of the trunk lines, and this number is so large that it practically would do away with the switching charge for all the other lines and we would be rid of $5 to $8 per car on all reshipment business done at Chicago as at present.

On the other hand such facilities transferred more remotely to the south or north would subject the commerce of Chicago to that extra burden.

Q. The Calumet Sag Channel runs from the Main Channel at Sag, Illinois to the Little Calumet River does it at Blue Island?

A. Yes, sir, something over 16 miles long from the mouth of Stoney Creek, at its junction with the Calumet River to Sag Station; about 17 miles from the beginning of the Sanitary

Canal at Robey Street, and about 13 miles above the power station at Lockport.

It runs through a natural depression or valley called the Sag Valley, which is only less adapted to the development of a channel than the territory along the main channel of the District. This route has always been regarded as a favorite route in official reports of the United States, and has been frequently recommended for development for purposes of navigation.

Q. Has the United States taken any steps towards the improvement of the Little Calumet River for navigation up to the point where the Sag Channel will connect with the Little Calumet?

A. It has. The Calumet River is already improved for a width of 200 feet and a depth of 20 feet up to what is called the forks or outlet of the Calumet Lake; and in the last Rivers and Harbors Bill, there was an item calling for a project for the improvement of the river up to Blue Island.

Q. And that is the point at Blue Island where the Sanitary District Channel connects with the Little Calumet?

A. Yes, sir.

Q. That is the Sag Channel?

A. Yes, sir, and the Sanitary District in that connection has been called upon to express its intention in connection with such improvement.

Q. Under the plans laid out by the District, there will be free navigation into the Sag Channel from the Little Calumet River?

A. There will be, yes, sir.

Q. And free navigation from the Sag Channel into the Main Channel of the District?

A. Yes, sir. There is a lock provided for in the statute near the Calumet River, which is wholly unnecessary, and I presume that will be eliminated. At the same time, it will have sufficient capacity to accommodate anything that will go through.

Q. And boats would pass through the Little Calumet River under the improvement project of the United States Government in the Little Calumet River from the Forks to that point?

A. Any boats that would pass through would be able to pass through the Sag Channel, where it has a depth of 20 feet the same as the improvement of the Calumet River. Meanwhile, craft can all pass up this route to Blue Island. It only requires deepening to adapt it to deeper navigation.

There will be no limitation on the capacity of boats passing through except the bridges.

Q. Will navigation be aided or injuriously affected by the construction of this Calumet-Sag Channel, under the plans which the Sanitary District has adopted, and under which it is now being constructed?

A. It will be greatly aided. I think that fact is recognized by official authority.

Q. Has the flow of water through the Main Channel of the District, through the Des Plaines River and the Illinois River been of any benefit from the standpoint of sanitary conditions in the Illinois River and the increase of the fish industry; and will it be of any benefit as the flow increases pursuant to the increase of population within the limits of the Sanitary District?

A. The flow of water has been and will be of enormous benefit to the Illinois Valley for two reasons; the first of which relates to sanitary conditions and the other of which relates to the physical conditions attending upon the river itself, and the overflow lands.

In a condition of nature, the Illinois River had in dry seasons an extremely small volume, which was measured in 1867 as low as 633 second feet. The reclamation of the swamps, which constituted 1/3 to 1/2 of the drainage in some watersheds and the tillage of the uplands has greatly reduced the low water supply and greatly increased the load of detritus which the stream has to carry.

The Illinois watershed is also one of the richest watersheds of the United States in proportion to its area, and produces thereby an enormous vegetable growth which quite consumes the water supply that falls in the growing season, leaving practically nothing to run into the streams. It happens by reason of these conditions that the stream is incapable of taking on any considerable load of sewage from the cities and towns located along its banks.

Further the stream bed is rapidly depreciating on account of the detritus from the uplands. These conditions at times under an ice cover when the organic matters in the water depleted the oxygen supply resulted in the decimation of the fish crop. Nevertheless, even prior to the opening of the Drainage Canal, by reason of the use of the river as an outfall for Chicago sewage and the very considerable increase in the low water volume which was doubled by the canal, even the old Illinois and Michigan Canal in low water seasons in

the upper half of the river, this fish crop had grown to large proportions, reaching from six to eleven and even 14,000,000 pounds; and was the best fresh water fishery in the United States, but was not a reliable industry.

With the accession of waters, the occasional decimation of fish due to an ice cover and the exhaustion of the oxygen supply, and also through the summer floods which came to the river sometimes from this rich vegetable cover, like an infusion of tea entirely devoid of oxygen, which has also destroyed fish life there,—I say by reason of the introduction of the water from the Sanitary District in comparatively large volume multiplied the low water supply at LaSalle by ten times, the low water supply in the lower river by six or seven times, and by reason thereof the fish crop became a reliable industry and has reached a magnitude under the census of 1908 of about 46,000,000 of pounds, of all kinds. And the value to the fishermen had reached over $800,000, and double that to the consumers. This crop represented $10 per acre on all the water space of the Illinois River Valley, or has been otherwise expressed, that the annual output was equal to 50 cents a lineal foot for the river.

Some idea of the magnitude and importance of this industry may be gathered from the fact that the output of this single stream represents ten per cent. of all the fresh water fisheries of the United States, 30 per cent. of all the fisheries of the Mississippi Valley, and is equal to 25 per cent of the entire fish output of the Great Lakes.

I think it is a fair assumption, and is so regarded by our Fish Commission, and by the Natural History Survey of Illinois, that this fish crop is largely due to the use of the stream for sewage disposal. The plankton in the Illinois River at Havanna, which is the basis of fish food, have been under examination by the Natural History Survey of this state since 1894; and since the introduction of the water in 1900, they recognize that the plankton have increased about from two to three times per cubic foot of water. And in view of the fact that the average flow of the stream has or will be doubled at Peoria when the channel is operated to a capacity of 10,000 second feet, the plankton content of the Valley will be increased from four to six times, and the fish crop stimulated proportionately, so that it is likely to grow to far larger proportions than even the present output.

This matter of the fertilization of waters is a new thought to people who have not considered the matter, but has been practiced from time immemorial in the fish culture in China,

and is a recognized method of producing fish products as much as fertilization of land in the older countries, in the oriental countries.

On the other side of the question, in regard to the physical conditions in the Illinois River, we have below Utica a stream 230 miles long with only 28 feet fall, or less than an inch and a half to the mile. The upper half of the stream, down to Havanna, has less than an inch per mile. There are conditions in the Mississippi River when if the Illinois River were low, flood waters would set back clear to Utica, and the stream would be level. There are other conditions in which the Illinois River might be assumed to be in flood and the Mississippi River low, in which the slopes would be doubled.

These conditions make the reclamation of the bottom lands extremely difficult and the maintenance of the river itself as a drain under the increasing load of detritus also extremely difficult. The only salvation, and that has been recognized from the beginning of this project, for the lower Illinois Valley is to introduce into that stream a large supply of water, to remove the dams and deepen the stream by dredging so as to maintain a channel of a good depth with a positive current that will be self scouring.

That condition cannot be produced in nature because the heavy flows in the Illinois correspond more or less closely with the heavy flows in the Mississippi, and with a large supply of water introduced into the Illinois River when the Mississippi is low, we can maintain a scouring channel; and the presence of the dams in that river is not consistent with maintaining such a channel.

Some recent examinations which I have made respecting conditions in the Illinois River show that since the state dams were erected at Henry and at Copperas Creek, there has been a depreciation on the upper half of the river of 2½ feet in the depth of the water below the original low water line of 1867, as it was defined in that survey. In other words, the river bed below low water has shrunk already, between the surveys of 1867 and the Ernst Board surveys of 1903, by 30 per cent.; and the bank-full capacity of the stream has diminished by 15 to 20 per cent.

Further examination of the stream lower down shows that the federal dams have been instrumental in contributing to the depreciation of that portion of the stream, and as I have stated, the only remedy is to make a better drain of the Illinois by deepening it, without the dams, and introducing therein a positive and a large flow of water.

This is important, not only from the standpoint of maintaining navigation automatically, as it were, without maintenance from year to year; but is of absolute necessity from the standpoint of conservation in the reclamation of the bottom lands themselves, of which there are some 400,000 acres between Utica and the Mississippi River. So from this standpoint, not only the interests of sanitation, the interests of the salubriety of the Valley itself, which will become a morass if present conditions continue or if the natural conditions continue, but also in the interest of reclamation of the bottom lands, a deep channel with a sufficient supply of water to maintain a scouring current therein is an absolute necessity.

On the sanitary side, as respects the disposal of sewage in this stream, such disposal was intolerable under natural conditions of flow, practically impossible by reason of the fact already stated, that the waters are already highly charged with organic matter from the very rich watershed, and particularly in flood times more than in low water.

I have seen, when I was examining the river for the State Board of Health, the output at Peoria alone, and at Pekin, from the wastes of the population and the wastes of the industries at those points, produce a black water through which fish could not pass, all the way down to the Copperas Creek Dam, a distance of 25 miles, when the river resumed its normal appearance.

This was significant, not only as to the ease with which the industries and the limited population polluted the stream in its natural condition, but was also very significant in regard to the progressive purification of the stream, even with that limited volume of water.

It was a material consideration in the Legislation of 1889, not only from the standpoint of the State Board of Health but also from the standpoint of all the Valley cities that this water which served Chicago would through its progressive purification be able to serve also all the future population that might exist in the Illinois Valley in urban communities; and that in making a provision here as we did actually make for a population of over 4,000,000, we could assume at least that that would care for an additional future population in the Valley of 1,000,000. So that the Sanitary problem, from the state's point of view and the forces that prayed in the legislation of 1889 was a mutual problem, not only for Chicago but also for the Illinois Valley; the two representing over 70 per cent. of the urban population of the entire state. To deprive them of this water would force all the towns in the Val-

ley adjacent to the Des Plaines and Illinois Rivers to resort to artificial treatment, at very large cost, whereas their problems are now cared for automatically and without cost to themselves.

Q. Is the problem presented of the disposal of sewage of a large metropolitan population like Chicago and its environs, which is included within the limits of the Sanitary District of Chicago, different from the problem presented in the disposition of the sewage of a small city? If there is a difference, will you state that difference?

A. There is a material difference.

Q. State briefly what that difference is?

A. In small cities, they are not endowed usually with the industries of the great towns nor are their sewage wastes disposed of to the same extent by the sewer system as is necessitated in the large cities.

Again, in large cities, dimensions and magnitudes increase with the distances that have to be covered, so that the cost of any solution increases faster than the relative population, than the growth of population; or is out of proportion, you might say, to the growth of population, as compared to the small town or to the average small city, rather.

Q. What can you say as to the advisability of removing sewage so that neither an effluent nor the raw sewage nor the rain drainage from streets, etc., would reach the water supply of the city?

A. I should say that that is the very purpose to be attained with the greatest degree that it is practicable to do so. Fortunately, here, we can reach an ideal limit in that respect.

Q. What reasons have you for the conclusion stated, Mr. Cooley, applying your reasons to the conditions here at Chicago?

A. Any proposition that does not absolutely exclude sewage and land waters from the water supply is unsafe, by reason of the fact that no process of artificial treatment as now advocated, or of filtration of water supplies, gives immunity from any pathogenic germs that may be in the water; and by reason of the fact that any laxity in management or care is liable to bring about contaminations of the water supplies upon which the people may be relying as entirely safe.

I do not regard any proposition in connection with a water supply as safe, that is not automatic, and that depends upon human agencies and solicitude, under the civil service conditions that prevail in American cities.

The Chicago water supply, on the other hand, can be made

absolutely automatic and absolutely free from contamination, and the disposal of sewage can be put on the same basis, so that we can go away and forget about it; have no fear as to the consequences.

Q. It will always work?

A. Yes, sir.

Q. And does not depend upon the action of any person?

A. It depends upon the action of no person; does not depend upon the whims of an appropriation bill, or anybody's action as to whether they are exercising more care and vigilance than is necessary, or any of those things,—human frailties, it is free from. And experience has abundantly demonstrated that whereas in the early stages of these artificial methods much was expected of them in the way of absolutely arresting germ life that was deleterious to health; on the contrary none of them are quite safe. Filters and bacterial beds may get seeded down with the wrong kind of germs, so that the water supplies have to be watched with extreme care.

I think the best illustration of that is the recent report on the Milwaukee conditions by a Board of Engineers that is partial to artificial treatment, where they gather up the supply at the southern limits of the city, and after treatment pump it out into the lake as far south from the water supply as practicable. Then after doing this, they have to provide artificial methods for circulating the waters in the rivers in order that they shall not become offensive; and after going to all this cost, they find that it is necessary to filter the water supply. And then they proceed to say that filtration methods, and slow sand filtration is so uncertain that it will be necessary to watch the results very carefully, and to be prepared at all times to doctor the water with chlorine or some other preparation to kill any germ life that may escape the filters.

I think that probably is as severe a comment as could be made respecting conditions as they have been worked out for other cities not so fortunately situated as Chicago.

Q. How is the city of Chicago located as compared with other cities around the Great Lakes so that its sewage may be removed from its water supply, any effluent, raw sewage or rain drainage coming from streets or the surface of the ground?

A. It is the only city situated about the Great Lakes in which sewage disposal can be made through the back lots, and in which even storm waters for long distances along the Lake Shore may be absolutely excluded from the lake itself, the source of water supply. The pass that we have to cut down

to divert our waters to the southwestward are only 7 to 8 feet as measured by the rock floor at Lemont above the low water of 1847; and only 2 to 3 feet above the high water of 1838, so that a channel can be cut in that direction at a minimum cost.

On the other hand, the lowest divide to the East between the waters of the lakes and the Ohio River is the Wabash-Maumee Divide at Ft. Wayne, which is about 190 feet above Lake Erie. And on the north is the Fox-Wisconsin Divide at Portage, Wisconsin, between the Fox River that empties into Green Bay and the Wisconsin River which empties into the Mississippi River, and this divide is 210 feet above the lake. So it is not possible at any other point about the Great Lakes to make a solution at all similar to that which has been provided at Chicago.

It is one of the endowments of our site, and it is the reason we are here, and it is the reason that the city is here; and from my point of view we are entitled to avail ourselves of it like any other bounty of nature, and to utilize the lakes in that connection.

Q. You are speaking of that from the conservation standpoint, Mr. Cooley?

A. Yes, sir, utilize the lakes in that connection for all the utilities that can be worked out of it. It is perhaps the highest conservation to which waters have ever been put in the world.

Mr. Hopkins: I move that part of the answer as to the point of view be stricken out, as a conclusion.

Mr. Adcock: Q. Mr. Cooley, you have spoken of certain artificial methods of disposing of sewage which were considered in 1890. Will you state the history of these various methods that have been proposed, the condition of the art of artificially purifying the sewage as it exists at the present time, and the efficiency of the various methods of sewage disposal which have been suggested, as compared with the method adopted by the Sanitary District for the disposal of the sewage of Chicago and its environments?

Recess to 2:00 P. M.

After Recess 2:00 P. M.

LYMAN E. COOLEY testified further as follows:

Q. (Last question read.)

A. The investigations of the Sanitary District and of the State Board of Health in 1885 to 1890 considered a number

of propositions which were then seriously advocated as alternatives, and which are now regarded as obsolete.

The matter of land disposal, which is the most effective of all these methods is usually regarded as prohibitive on account of the cost, and because it can only be resorted to in favorable localities; and it is now recognized that if the effluents are to be disposed of in streams where water is used for water supply, that even in this case they must be sterilized. That was one of the principal methods advocated in 1886 and 87 as an alternative.

The other of lake disposal would not now be considered, even with sterilization, as a proper solution under conditions where it was humanly possible to do anything else. The objections are that sterilizing methods are subject to all the human limitations involved in the management of other methods, and are liable to be inefficient; sterilizing fluids are not considered as particularly conducive to public health and that even after sterilization the decompositions go on; there would be a tremendous pollution of the lake bottom, which would be a nidus in which deleterious germs might reproduce at a later period. And in a condition of stirring up of the lake bottom by wings, would make a very unwholesome looking water, if it was not actually dangerous to the health.

As applied at Milwaukee, as I have already remarked, they do not consider it, even with chemical treatment, to be a tolerable treatment without also at the same time filtering the water supply, and even after that sterilizing the water supply, after it had been filtered, when dangerous conditions appear in such filtration effluents.

It is recognized that disease germs will pass through even filters that are used for the purification of waters that are not contaminated with sewage. Unhappily, they get seeded down at times with the wrong kinds of germs.

The third method which was considered but not reported upon, but however was much advocated at that time and appeared in bills before the general assembly for consideration as alternatives were the methods of chemical treatment. The principal one of these was the scheme of Gordon H. Knott, which was endorsed by very influential men, including some engineers from Chicago, which contemplated a tunnel 20 feet in diameter to extend down to Joliet and there the sewage was to be treated and released to the Des Plaines River. The tunnel which was then projected would carry something like 1,000 feet of water per second, barely more than the present water supply of this city. It would not solve any of the other

problems associated with the good health of the city; and the treatment of the sewage proposed by chemical means only removes from 30 to 40 or 50 per cent depending upon the character of the putrescible matter; so that the effluent somewhat stableized would still go to the Des Plaines and Illinois Rivers, and in the known high condition of the organic matters contributed from the land would produce an intolerable condition and be an impossible solution.

The fourth method which has found advocates and was mentioned as an alternative in the St. Louis case is the method by septic tanks, which was developed however after our consideration here at Chicago. Abroad, it was known as the Cameron Tank Proposition, and originally contemplated decompositions without a supply of oxygen, or aeration, known as anaerobic, to be alternated with aerobic decomposition, or the presence of oxygen.

This is in effect the cess pool method, which through various appliances, or in the use of euphonious names is called a septic tank proposition. Everybody is familiar with the cess pool proposition as it existed before we had any method of sewage treatment, or any sanitary science, or where in the country sanitary provisions have not been adopted according to the modern method. But it seemed to have taken on a highly scientific value when proposed by wholesale, in the minds of its advocates.

That was, to my mind, effectually disposed of at Chicago, so effectively that it ought never to have been advocated by anyone, because we had a septic tank on the largest scale possible in this world in the 64 acres of the South Fork; and we had it in the North Branch in an area of more than 100 acres, and the conditions produced were so totally intolerable and inadmissible that it always seemed to me an impossible method of solution for any considerable body of people.

There have been a number of works even in this state and in Indiana constructed on that plan. 10 or 12 I think. I believe to-day there are only two of them in actual operation. So that method may be considered as having passed into disuse or having become obsolete, and it should never have been considered, in my opinion, in view of the conditions that were patent here at Chicago.

The later methods were an evolution from the experiments at Lawrence, in a large degree, and consisted of bacteria beds; first, what was known as the contact beds, consisting of a bed of stone in a tank, from 6 to 9 feet deep, which was charged

with sewage a number of times each day, and it was in fact a bacteriological stock farm on a concentrated scale.

The anaerobic decomposition was supposed to occur while the bed was filled with sewage, and then the water was allowed to drain out and was supposed to give place to the aerobic decomposition, and this was much practiced up to a recent time, but is now considered obsolete, or not exactly obsolete but is discarded for a method considered to be superior, which is the percolating beds, so called sprinkling filters, which also consist of a bed of stone or other material; is also a bacteriological stock farm, and in which the decompositions are entirely aerobic, except that it is usually recommended that some sedimentation be given in advance and a slight septic condition produced by 10 to 12 hours in the tank before it goes on to the bed. That is the last remnant of the septic tank proposition.

This method is the only alternative, a survival of all the experimental methods that have been tried out in the last forty years, and it may be said that no alternative that has ever been suggested for Chicago up to this time has proven up in practice, even for a moderate sized city, much less a city of this magnitude.

The method of nature in the percolating filter proposition, in fact in all methods that are practiced is the oxidation method, precisely the reactions which occur by dilution except in the dilution method the gases are absorbed and the operation is without offense; and the danger from the passage of pathogenic forms is probably much less.

All these methods in early times and up to a very recent time were presumed to dispose of the pathogenic germs, but it is now recognized that even the percolating filter does not do that, and that it must be followed by sterilization if the effluent is to be put into any possible source of water supply.

In regard to the chemical treatment, that is practiced still to a limited extent in the outfalls at Manchester and at London, for the purpose of getting rid quickly of a certain unstable element in the sewage, which they throw down as sludge. In the case of London, this sludge is put into tank boats and 7200 tons a day are taken out and dumped into the Sea.

In the case at Manchester, they carry on their purification by bacteria beds and chemical means; mostly by bacteria beds, and remove the sludge to the Sea, in order to save the conditions in the Manchester Ship Canal as far as possible from becoming a nuisance. And they even go so far as to purify the storm water and run that through beds also. I went over the Manchester Canal in the autumn of 1909, when the tem-

peratures were moderate and rode from Salford down to Liverpool on a sludge boat that was taking out a cargo of sludge to Sea, and the Manchester Canal, with all the efforts made in the communities about the Manchester Ship Canal, to purify the sewage outflow before it was put into the canal, was not what I would call in a tolerable condition at all. So that what they consider a measure of success over there in regard to the purification of sewage, I do not think would be looked upon here as a tolerable condition.

(The question pending was here read to the witness.)

The Witness: I will say that in regard to the subject of efficiency, there is no method at the present time available that can compare in efficiency with the method which we have adopted here at Chicago; and there is no alternative which could be adopted which would give us a water supply of any character approaching that which we may enjoy in connection with the dilution method.

I would say further that all these artificial methods are very costly in operation and maintenance, whereas the method here is automatic in action.

I will say further that with the possible exception of Berlin none of these methods make any returns against operating expenses, and even in the case of Berlin it is contributory rather than in any sense a profitable investment, whereas in our case I look upon the conduct of the sewage effluent and its purification on its way to the Illinois Valley as having produced the most successful and profitable sewage farm that has been produced in the world, to the fish product in the Illinois Valley; and that we have really here the only tried out and completely successful proposition in the world.

At the time that we proposed the Chicago proposition, it was looked upon by a large part of the sanitary and scientific world, who admitted their own superior achievements and attainments, as a barbarous one. I think the sentiment in that respect throughout the world has radically changed, and that dilution methods are now regarded as the best and the proper method wherever water supplies are adequate for such a purpose.

I wish to add to that, as a tribute to our own foresight and sagacity, that we are as far ahead today of the other parts of the United States and the rest of the world in regard to this subject of sanitary treatment as we were when Mr. Chesbrough projected the sewer system in 1855. And I believe if we had been able—this I consider very unfortunate for Chi-

cago—to have worked out all the results and made a record such as should have been made of the investigations that preceded and accompanied this work that it would have been regarded as a monumental achievement and revolutionary of the whole thought of sanitary engineering at the time; and would have changed the public thought, scientific thought in the matter as completely as it was changed along in the forties when the filth theory of disease originated.

Q. I refer you to Mr. John D. Watson's report (of Birmingham, England) to the Metropolitan Sewerage Commission of New York dated January 31, 1913, wherein in discussing the various methods of sewage disposal for the city of New York, he says (page 30 of book entitled "Preliminary Reports on the Disposal of New York's Sewage, Number VII"): "What influences me most in favor of scheme 4, is the conviction that where it is possible to remove the bulk of the sewage of New York entirely away from its source to the ocean, it should be so removed, although the cost may be somewhat higher than it would be under a project like Scheme 3."

Will you state the various methods discussed by Mr. Watson, and state how the above quotation is applicable to the conditions here at Chicago?

A. The Metropolitan Sewage Commission of New York was constituted a number of years ago for the purpose of studying the conditions and remedies therefor around New York Harbor and Bay; and it has projected four principal schemes or alternative methods for the treatment of the conditions at New York, which are discussed by Mr. John D. Watson, engineer for the Borough of Birmingham, England, and also by Doctor Fowler, who is in the same position in relation to Manchester, England, which are usually regarded as the highest development of artificial methods of treatment.

The 4th method, which is the one endorsed by both Mr. Watson and Mr. Fowler, is estimated to cost about $100,000,000 and is substantially a dilution method so far as the same can be applied to the New York conditions. It consists of interceptors for the purpose of gathering up the sewage; conduits for conducting the same to a common outlet, and pumping works. And an artificial island is to be created in the sea opposite Jamaica Bay and out beyond the entrance of New York Harbor; and the sewage conducted to this point and released on the outgoing tide, with only such treatment and screening as are necessary to operate the pumps and the system as a whole.

The alternative methods considered were three in number. One of them was known as land disposal, at an estimated cost of $180,000,000. Mr. Watson discusses this scheme as follows:

"Scheme 1.

Application of the Sewage to Land.

The popularity of irrigation as a means of purifying sewage is on the wane, chiefly owing to the extensive area required and the unsuitability of the land available.

The Berlin farm, which is the largest in Europe, continues to do good work. The largest farm in England was in Birmingham, but some years ago when land could no longer be obtained for less than three times its agricultural value, the authorities abandoned irrigation in favor of the intensive method of purification on bacteria beds. The largest farm in France is at Paris, and there also the authorities contemplate a change of method whenever it is necessary to increase the purification plant.

Where all the conditions are favorable, irrigation is undoubtedly successful as a vehicle of purification, and one which generally yields consistently good effluents, but in New York the farm would be so collosal in extent that the conditions would not be invariably favorable. The available land is, I fear, limited to Long Island, the area required would exceed 150 square miles. It would necessarily vary in its adaptability for the purpose, and although the standard of purification need not be exceptionally high in view of the large volume of water into which it would ultimately be discharged, it would still be necessary to limit the volume of sewage to 10,000 or 12,000 gallons per acre, unless a great expenditure for under drainage were undertaken.

Sanitary Objections.—A great area of land lying between Amityville and Quogue overlies one of the sources of the city's present water supply, and its use for sewage purification would be a potential source of plague which no one would care to risk.

The mere saturation of 150 square miles of land with sewage would be a menace to the inhabitants obliged to reside in the District, and would be sure to produce mal-odors during certain states of the atmosphere, which would be highly objectionable, even if they did not markedly influence the health statistics of the District.

I disapprove of this method of purifying New York sewage on grounds quite apart from cost."

The second method discussed by Mr. Watson was oxidation by means of bacteria beds at a cost of One Hundred and Forty Millions of dollars. This is particularly significant in view of the fact that this method is now the leading alternative, and represents substantially the survival of the experimental methods of artificial treatment that have been more or less in practice and advocated for the last 40 years. It is described by Mr. Watson as follows:

"Scheme 2.

* * * * *

As the oyster beds will probably depreciate in value as the population of the District increases, it would not be wise on this account alone to incur the expense of this operation, more particularly as it is now admitted on all hands that the passage of sewage through a biological filter does not necessarily deprive it of pathogenic organisms, and in order to protect the oysters from the attack of a stray typhoid bacillus, it would in this case be necessary to sterilize before 1940 a quantity of sewage equal to about 700,000,000 gallons.

Danger of Nuisance.—Perhaps Barren Island is the very best site available for placing an installation of percolating filters, but it would appear as if Jamaica Bay were on the eve of great developments, and that Barren Island would not for long be the isolated place it now is. I regard it as of the utmost importance to establish sewage purification works where they are not likely to become a nuisance, and I have grave doubts about the wisdom of placing so vast an area as 1,000 acres of bacteria beds so near to an industrial center as they would be on Barren Island. In contemplating such a scheme there is a factor which should be taken into account, and that is the after effects of the evaporation of so much foul liquid as there must necessarily be from such an area of filters.

In 1911, when the summer weather in England was warmer than usual, there were complaints of smell nuisance at Henley, where the sewage is of about the same strength as the average American sewage, and where it is distributed over rectangular percolating beds by mechanical distributors moving backwards and forwards. Complaints were also made by residents near the Birmingham Works, where the sewage is sprayed over the beds by fixed nozzles.

The chief lesson to be learned from the 1911 experience is that an increase of flies is to be looked for in the neighborhood of bacteria beds in hot weather, and that objectionable smell adjacent to them is more pronounced during prolonged hot weather than at other times, e. g., seasons like the average English summer, when the temperature rarely exceeds 65 Fahr. in the shade. But a much more serious drawback to a great area of bacteria beds during spells of prolonged hot weather is the formation of vaporous 'clouds' due to the evaporation of sewage. These clouds appear to form over the beds in quiet weather. They rise to some distance above the earth, and at sundown, when the earth begins to cool, they return not alone as refreshing dew, but with offensive odor. If this occurred only in the vicinity of the bacteria beds, where the land is generally less valuable than at some distance, it would not be so serious in its consequences, but it generally occurs at some distance from the bacteria beds, the direction and distance depending upon the tendency and the velocity of the wind."

The third method consists of treatment at a number of convenient points so as to best accommodate the sewer system, without gathering the sewage at any one point, and local treatment works, to be precipitated or sedimented at such points by the tank methods coupled with sludge removal in tank steamers to the sea. This purification is partial only, and the question is raised by Mr. Watson as to whether it will not be a severe tax on the digestive power of the waters in the harbor as the city grows; and particularly so in the East River and in other sections where the waters are not sufficiently removed by the ebb and flow of the tides. Mr. Watson comments on this method as follows:

"Scheme 3.

Local Treatment Works and Outfalls.

It is probably not far from the truth to say that the only purification of organic matter known to nature is an oxidizing one, which is brought about indirectly by the agency of bacteria, but whether the vehicle by which the process is brought to fruition is the irrigation farm, the biological filter or dilution with large volume of clean water, the 'combustion' process is practically the same.

To protect the harbor from pollution, it is neither essential to confine the purifying process to one method, nor to one

locality, but whether it is expedient or wise to construct dozens of sewage purification plants in and around New York is an entirely different matter. Sewage from the various districts delineated on the plans could be sufficiently treated to admit of being discharged in the adjacent waters without creating a nuisance, but in some cases the treatment would have to be very circumscribed, and a greater burden would be placed upon the assimilating powers of the waters than they ought to be called upon to bear. * * *

Under this scheme there would be many outlets, all of which would require to be equipped with screens, grit chambers, tanks, and some kind of treatment works, before the effluent could be discharged and left for the nearest water to com plete its purification by assimilation."

These reports reduce the proposition to about this: That there are no alternatives even for the situation in New York that are not objectionable from one standpoint or another and that are not costly to operate and maintain; and even the dilution method as here proposed involves a considerable cost for maintenance and operation, as contrasted with the method of dilution as worked out here at Chicago.

And further that in all the alternative schemes, you may say, or two of the alternative schemes like land disposal and disposal on bacteria beds, the effluent must be sterilized before going into areas where shell fish and other products of the sea are grown and harvested.

This is also a most interesting proposition, because it brings together the latest consideration upon the whole subject matter by the most eminent authorities in this country and England, respecting the solution of the sanitary problem for our largest cities.

Q. You have made investigations to determine whether or not there are any currents here in the lake at Chicago, have you not?

A. Yes.

Q. What did you find from that examination or investigation which you made?

A. That there are no currents in the lake except those induced by the winds, and that they change with the changes in wind direction.

Q. From those observations, Mr. Cooley, with the Calumet River reversed as it will be when the Calumet Sag Channel is completed and in operation, and the Main Channel of the District and other works in operation, as is provided by the

statute of 1889, and the project as now operated, do you consider that there will be any pollution of Chicago's water supply from cities like Waukegan or other cities near or around the city of Chicago?

A. No sir, not at any point within the central area or opposite the central area of Chicago. I cannot conceive of conditions which would bring currents of waters from that distance to opposite the mouth of the Chicago River, for instance. The probability would be so extremely remote as to be a vanishing quantity,—the possibility.

Q. How about the intake at the cribs, the water intakes for the City of Chicago?

A. Well, all our intakes are substantially this side of the Evanston line on the North and opposite 67th street on the South, and under the conditions that you speak of, there would be no sewage effluent going to the lake nearer than Michigan City or nearer than Waukegan. There is just the possibility that under contingencies that might occur in an occasional year we might get a little pollution from as far as Waukegan; but I assume that the conditions at Waukegan will be remedied as they already have the authority to organize a sanitary district on their own account at that point. Certainly with that done, I see no possibility of sewage pollution as affecting the water supply now taken at Chicago.

Q. Is there any pollution arising from lake vessels?

A. Yes, sir, especially these pleasure steamers going in and out morning and evening. I think that after the beams are all out of our eye, we are bound to go after the moats that come from that source, and there should be some regulation that will prohibit steamers from dumping their wastes into the lake within a reasonable distance of Chicago.

Q. Assuming that there was a regulation providing that the closets of lake vessels were closed and that they would not be allowed to deposit any wastes while passing from the Chicago River or from a position back of the break waters to points three or four miles beyond the intake cribs, what would be the effect if any of pollution from this source?

A. The chances of pollution would be greatly mitigated, as that distance in the lake would be more efficient in protection than 20 miles long shore. At the same time, I would like to see the limits extended further than that.

Q. The danger would not be material?

A. No, sir, it would be greatly mitigated.

Q. And there would be little danger from that source.

A. Yes. The fact of it is that normally all currents under all directions of wind resolve themselves into parallel currents along the shore and not usually setting in and out, in a direct line normal to the shore, so that distance in the lake means much more than distance along shore.

Q. What can you say as to the propriety of deriving an increment for the outlets of say Lakes Michigan, Huron, Erie and Ontario, from discharge measurements made at various times when the lake levels are shifting under conditions of unsteady flow, assuming that such measurements are plotted according to a simultaneous lake stage and discharge, and a line drawn through the center of gravity of the plottings.

Mr. Hopkins: Objected to on the ground that the witness has not shown qualification on this subject.

Mr. Adcock: Q. You may state in this connection Mr. Cooley, what studies and experience you have had, which would qualify you to answer this question?

A. My studies in relation to the subject matter go back to 1875 and '76 and 1881. And I was particularly charged with the investigation of the proposition in connection with the Drainage and Water Supply Commission in 1886-7, and at that time gave consideration to all the data that had been gathered by the Lake Survey and other agencies respecting the outflow of the lakes.

The results of these studies were printed in January, 1888, and later in connection with a series of papers before the Western Society of Engineers in 1888-9.

I also took up the matter in connection with the investigations of the International Waterways Commission, all the investigations of the United States section of the Commission being under my charge, and did at that time gather all the available material respecting lake fluctuations in the United States and Canada, and the same was published so far as relates to the stages of the lakes and certain fluctuations on Lake Erie, in the report of the Commission in 1896. I refer, in the matter that was gathered and printed in the report of the U. S. Deep Waterways Commission of 1896, to fluctuations in stage of water and not to oscillations or currents, except in relation to Lake Erie, in which case there was a special digest upon that subject.

In all these studies and investigations, it was recognized that the data was unsatisfactory, and in connection with all of it, it was recommended that there should be taken up by the United States a comprehensive series of measurements of

the outflow of the lakes over a wide range, so as to obtain a positive determination of the increment.

My conclusion from studies and investigations of this character, of the data when available, and from the special work which I had done in connection with oscillations of the lake, that it was not practicable to determine this increment by observations made through a limited range, owing to the effects of wind, of barometric change, of the oscillations known as seiches and other influences to which the lake surfaces and the connecting rivers with their very slender slopes are extremely sensitive.

In other words, we do not have in any of our outlets a condition of what may be called steady flow, and we could only determine the equivalent of a steady flow approximately by grouping a large number of observations within a limited range of a foot, and comparing it with some other group as far removed from that as possible.

The individual observation likens itself, to my mind, to the individual in a swarm of bees. Each bee is executing evolu tions on its own account, and it would not be competent to determine the direction of movement of that swarm by drawing a line from one individual bee to another individual bee, or from one group of bees to another group of bees. They are going about each on its own account. But the line drawn from the center of gravity of this swarm of bees in one locality to the center of gravity when it has changed its place to another locality would be indicative of the bee line, and in my judgment there are no determinations of this character in which these individual movemnets within a limited range of fluctuation can be differentiated from the personal equation of the man making the investigation. Even over this wider range of 3 or 4 feet which ought to obtain in determining that increment, it will be subject to the infirmities due to the fact that you are dealing with a phasing mass of elements at each point.

That is the general idea that I have, and I have not thought it worth while to take up in detail the analytical studies of the observations that have been made over a limited range. But I think the official reports which I have examined in 1907 and 1910 verify my statement in the premises, as indicating that the subject matter is extremely illusive, and that they vary among themselves in their different determinations as much as 20 per cent., presumably made in the same office at Detroit.

Q. You are referring to what observations?

A. I refer particularly to the determinations printed by the International Commission in its report in 1907, and the increments published in the report on the investigation of the control of Lake Erie in 1910, and to the Lake Survey bulletins which are issued from year to year, each of which gives determinations and none of these determinations are in accord among themselves.

Q. You refer to the observations made by the Lake Survey made at different times on the St. Clair, Niagara, Detroit and St. Lawrence Rivers?

A. Yes, sir. All these observations are made under the supervision of the Lake Survey and have been worked up at its office, except those reported in 1900, by the Deep Water Board, which made observations on its own account in 1897 and 1898 until the Lake Survey mobilized upon the subject matter under the act of 1898, under the authorization for the re-survey of Northern and Northwestern lakes.

Q. You refer to 1897 and 1898?

A. Yes, sir, 1897 and '98, and in that analysis, in that tabulation submitted for the Niagara River in connection with the project of the Deep Water Board for the control of Lake Erie, they print 72 measurements which I have given some attention to. And in projecting their curve, they feel called upon to throw out arbitrarily 29 of these 72 measurements and treat the other 43 as true determinations.

I speak of that because I have had a very large experience on western rivers in analyzing that class of data, and it is purely an arbitrary proceeding, not justified in any investigation, and it illustrates in a way what I have attempted to say that by a system of elimination it is possible to find any conclusion, if you eliminate everything that does not agree with your preconceived ideas.

Q. The Deep Waterway Board to which you refer is the Board of Engineers on Deep Waterways, is that the title?

A. Yes, sir.

Q. They made a report in 1900?

A. Yes, sir, printed in 1901. It was constituted by an act passed in 1897, and was the successor to the International Waterways Commission, of which I was a member, and was called upon to carry out the recommendations of the Commission substantially in developing projects for ocean navigation into the lake by various routes, and to examine the question of control of Lake Erie and other lakes.

Mr. Hopkins: I want to preserve an objection by objecting to all of this line of testimony in regard to the increments of the various rivers which discharge the lakes. I move that it all be stricken out on the ground that it was understood, when the Government put in its rebuttal testimony and recalled the Lake Survey men, the experts who had done this particular work, it was the understanding that the defense proper would not put on any testimony in regard to increments.

Also I want to ask leave to reserve objections as to the question which was put in the hypothetical form, as to whether or not it included all of the elements that should be included in the question, that might be regarded as formal matters.

Mr. Adcock: There was no agreement as to that. Mr. Hopkins asked me as to what we expected to prove by Mr. Cooley, and I told him that we expected to go over various matters; and he asked about the hydraulic questions, and I told him that I expected that I might ask some questions about that, but would not go into it to any great extent.

Mr. Hopkins: That was not my understanding at all.

Mr. Austrian: You are holding Mr. Shenehon in reserve anyway.

Mr. Hopkins: I took the position then that I would not call those men until the defense was through, and I was certainly impressed with the understanding that nothing would be taken up afterwards that they would touch upon in their testimony.

Mr. Austrian: This is not any new matter.

Mr. Hopkins: It is nothing new but there might be something new—he has expressed opinions which these men might have answered.

Mr. Austrian: We haven't any objection to recalling them.

Mr. Hopkins: That is why I did not want to call them until you were through. That means calling them again.

Mr. Adcock: Some questions that have been taken up by Mr. Cooley here were considered by the witnesses who were placed on the stand last month at Detroit; all of it was gone into.

Mr. Austrian: If there is any question that you are taken by surprise, and you want to recall them, we haven't any objection. I understand your principal expert, Mr. Shenehon, when you put him on the stand, will answer all the witnesses we have to put on. Isn't that correct?

Mr. Hopkins: We are going to recall Mr. Shenohon, I presume.

Mr. Austrian: That has been the understanding right along, that Mr. Shenehon was to be the last witness. If there was any misunderstanding on the subject, we want to state for the benefit of the record that you can recall any witness that you want.

Mr. Hopkins: It means obtaining another authority to go up there again.

Mr. Adcock: Q. You are familiar with the depth of channels connecting the Great Lakes in 1900, which were used for navigation, were you not Mr. Cooley?

A. Yes, sir.

Q. In your opinion, would there be any injury to navigation by the lowering the levels of Lakes Michigan and Huron approximately 5 to 6 inches, Erie somewhat less, Ontario somewhat less than Erie, and the connecting channels an intermediate amount in proportion, and also assuming that the lowering of the water at the Poe Lock, would be somewhat less than the lowering of Lake Michigan?

A. I think there would be substantially no injury. The changes which have been made which influenced lake levels since the improvement of lake channels was undertaken, exceed in several instances all the changes produced or alleged to be produced by the diversion at Chicago, and such changes have not been considered worthy of attention, nor have they occasioned any protest or comment by lake carriers.

Again, the amount of change alleged is nominal in comparison with fluctuations that are going on by hour, by day, and through the months and the year. And vessel owners are obliged to load safe for the trip, and give a very much greater margin of clearance beneath the boat than is indicated by the alleged change.

Again, it is not competent to estimate the effects as a diminution in a fixed plane of reference, or as the difference between a fixed plane of reference and the bottom, as made in a canal or other absolutely still body of water; and the estimates that have been made up have been framed on that basis, and do not recognize these oscillations and changes in level which occur many times in the course of the trip.

Again, it is recognized as sound practice to provide a margin beneath the boat, not of inches, but of feet. As early as 1888 I made a study of that question and wrote a paper to the effect that the future Ship Canal should have a depth of not less than 25 per cent. of its draft beneath the keel. The International Congress on Navigation at Philadelphia year be-

fore last declared as one of the principles which govern restricted channels and canals, that it should have a depth of at least one meter beneath the keel, depending, of course, upon the character of channel and the speed which was to be considered. And the same proposition is worked out by Black, in his report on the Hudson River, very recently.

Q. That is Colonel Black?

A. Yes, sir.

Q. An engineer officer of the United States Army?

A. An engineer officer of the United States Army, where he lays down the proposition that the river should have a depth of two or three feet of clearance beneath the boat; that is, the improved channels should have a clearance of two or three feet beneath the boat; and gives some remarkable data in regard to the effect of the Hudson River boats attempting to navigate with the restricted limit beneath the boat.

And also for the further reason that any item of cargo that would fall off the boat, like a barrel of cement, would roll the skin and frame out of the bottom of the boat if it happened to strike it. There should be enough clearance there for safety. I know from my own experience in navigation on western rivers that a boat that would attempt to run within a foot or two of the bottom would be utterly uncontrollable in passing through the channelways of the lakes. So that a mere margin of a few inches would not be thought of by practical navigators; would not be accounted for and would not be known to exist, in the absence of a specific knowledge of a diversion of something of that kind existing at Chicago.

On the other hand, a lowering of the lakes by one foot, better by two feet, would be of profound advantage to every lake city about the Great Lakes, in giving a better freeboard for its sewer system and better elevation to its docks. All the cities about the lakes are built on low ground, margining some creek originally awash at high water of the lake, and the benefits of such a lowering to the sanitary welfare of the cities about the Great Lakes would be so great in proportion to the cost of producing two feet additional depth in all the harbors and channels of the lakes that it would be a vanishing quantity. And, furthermore, I conceive that if there were not diverse jurisdictions in the matter, but were one jurisdiction that looked at public welfare as a whole, a proposition of that kind would be a proposition to at once elicit legislative attention.

Q. You are familiar with the water power development of

the Sanitary District in the operation of the channel, as far as the flow of water is concerned?

A. I am.

Q. Is the amount of flow in any way affected by the water power development?

A. It is not, except in the distribution of the flow to a slight extent in the daily run.

Q. That is simply so far as the day is concerned?

A. Yes, sir.

Q. This development, or water power development, is merely incidental to the operation of the channel for sanitary purposes?

A. Entirely so. It has never, so far as I know, been regarded differently in any of the statutes, the constitutional amendment of the State of Illinois or any court decisions, or in the actual practice of the District itself.

Q. If it were not for this water power development there, that water would simply go to waste, would it not?

A. Absolutely.

Q. And the development is simply for the purpose of conserving that energy which otherwise would be lost?

A. Yes, sir. As I have already stated, it is a part of the theory of all of the projects and of the legislation relating thereto, that this was a proposition in conservation, although the name had not been invented at the time it was undertaken; and that all collateral utilities would be developed, including water power, waterways, dockage, reclamation of land and sanitary interests in the Illinois Valley as well as Chicago; and it was hoped that through the by-products thus created the burden on the taxpayer might be in some degree mitigated.

Adjourned subject to notice.

Depositions in the above entitled cause taken before the Commissioner, pursuant to notice, at the offices of the Sanitary District, Chicago, Thursday, March 12, 1914, at 11:00 A. M.

Present:

Mr. Albert L. Hopkins, on behalf of the Government.
Mr. Edmund D. Adcock, on behalf of the Sanitary District.

LYMAN E. COOLEY, recalled for further direct examination by Mr. Adcock, testified as follows:

Q. Mr. Cooley, what can you say as to the value of an increment which is determined from a set of measurements running over several days when the lake was at a uniform stage and another set of observations of discharge, a similar set of observations of discharge running over a period of several days when the lake was at a different stage, but uniform, as compared with the value of an increment derived from observations made at different times when the lake was changing, but covering a given range of stage?

A. That question, as I understand it, calls for a comparison between an increment under uniform conditions of stage, or steady flow, from observations or groups of observations taken at different horizons as contrasted with an increment determined from fluctuating stages, but covering the same range of horizon, without any general change in the levels of the lake itself. Answering it as I construe the question, I would say that there was no comparison to be made in the relative values of the increment determined under those conditions as defined. That, in the first case, you have a group of observations that determines approximately a condition of steady flow at one horizon, and also at a second horizon, between which points you can draw a line which will indicate approximately the increment, whereas, in the other case, you have fluctuating conditions or phasing conditions, from which you attempt to draw an increment which may be suggestive, but in no sense determinative.

I may liken it to my former comparison in regard to the swarm of bees. In the first place, the swarm of bees is at two different localities, and you can draw a bee line between them. In the second case your determination is based on the idiosyncrasy of individual bees who are taking long ex-

cursions in different directions without any change of the position of the swarm itself as a whole.

Q. What is the influence of ice in the several rivers, St. Clair, Niagara and St. Lawrence, upon the outflow and elevations of the Great Lakes?

A. The effect of ice is similar to that of a dam or constriction which decreases the discharge in the streams and impounds the water in the lake, and to that extent diminishes the flow through the intermediate channels. This may come from actual gorging of the ice, which has occurred in some years in the St. Clair River, where the flow is very radically interfered with, or it may come from a sheet of ice which converts the river into a tube, increasing in that respect the frictional resistence and diminishing the flow. These phenomena have been particularly studied in the St. Lawrence River below Montreal, occasioning there what is known as the winter flood, by raising the elevation of the river much above what it is ever raised by the ordinary flood in the river.

Q. What would be the relative effect of the retardation of flow upon the elevations of Lakes Michigan and Huron as compared with the retardation in the Niagara River as compared with the elevation of Erie, the retardation being in the St. Clair River?

A. The effect would be to impound the waters of Lake Michigan and Huron and diminish the amount of water passing through the St. Clair and Detroit Rivers and lower the stage relatively in Lake Erie. In other words, Lake Erie would drain out under those conditions.

Q. What would be the relative lowering of Lake Erie as compared with the raising of Lakes Michigan and Huron?

A. Every inch of raising that would thus be occasioned to Lakes Michigan-Huron would lower Lake Erie by 4.6 inches, in that ratio, in the ratio of the water surfaces, which is about in that ratio. In other words, it would be 4 to 5 times as great as the rise produced in Lake Michigan-Huron.

Q. Are there any ice effects in the Niagara River?

A. I don't know of any. I think usually it is a comparatively free discharge in the Niagara River except at the Falls and below, although there have been jams at Horseshoe Reef, but how far they have affected the results I do not know; but they have been temporary. I have not looked that matter up especially.

Q. What should be the relative magnitudes of the increments of the St. Clair, Niagara and St. Lawrence Rivers?

A. The magnitude of the increment should be inversely

as the relative fluctuations. In other words, the general fluctuation of Lakes Michigan-Huron, also of Lake Ontario, is considerably greater than that of Lake Erie, and the increment of the outlet by the Niagara River should, therefore, be greater.

Q. You refer to the annual fluctuations, do you not?

A. I refer to the general fluctuations.

Q. From year to year?

A. From year to year and through a series of years.

Q. Are you familiar with the physical conditions at the International Bridge at Buffalo?

A. Yes, sir; I have been there and have examined that situation; in fact, three or four times. I have also made a study of the Niagara River; that was when I was on the International Commission, with a view to seeing how far it could be made available in connection with a ship canal from Lake Erie to Lake Ontario.

Q. How would you regard the downstream side of this bridge as a gaging station in determining the discharge of the Niagara River?

A. It is the worst point that you could select, unless you selected the crest of the falls below.

Q. Why?

A. It is at the end of a rapid, where the motions of the water are extremely irregular; and is further complicated by the piers of the International Bridge, which are like so many rocks sticking up in the channel, and produce turbulent waters and disturbances of the current. In fact, in the vicinity of those piers, a man could not be sure in what direction a meter was pointing. It might be standing on its head part of the time.

Q. What is your opinion of the correctness of the Niagara River discharges as shown by the Engineer's reports, Government reports?

A. As a general proposition I think they are—though they appears to be in some degreee consistent among themselves—as a whole they are all too low. They do not give the discharge of Lake Erie properly. I am led to that conclusion by the very small difference in the discharges as given for the St. Clair and also the Detroit River, as compared to the discharge in the Niagara River, and the very great increase in discharge over the Niagara River as given for the St. Lawrence at the Galops Rapids, as the increment of an additional basin in each case is about the same.

In other words, the Lake Erie basin adds about the same

additional area for drainage that the Lake Ontario basin does and the Erie Basin; and the results are not in accord with what they should be.

Furthermore the Erie basin is usually considered to be a little further south and to have a somewhat further consumption of water in vegetation and evaporation from the surface of the lake.

On the other hand, the rainfall on the Erie basin is given as 36 inches as against 33 for the Ontario basin, which compensates in some degree. Making every assumption either way that can be made, the discrepancy is larger than it should be.

Q. Where do you obtain your figures as to 36 inches on the Erie basin and 33 on the Ontario basin?

A. Those figures are from the U. S. Weather Bureau, a special compilation made a number of years ago (1899) and published from year to year in the bulletins of the U. S. Lake Survey.

Q. What effect would the dredging and dumping of dredge material in the shallows at the mouth of the Detroit River be likely to have on the discharge of that river?

A. It depends altogether as to where and how that material is placed. If the material from these deeper channels is placed in the shoal waters, and in such manner as to give a more regular channel than formerly existed, the effect would be to increase the discharge rather than diminish it, or compensate it.

In fact you might conceive a channel to be deepened and the material placed in such a way in the shoaler parts of the channel as to double its mean depth, and under those circumstances it would increase the discharge from 40 to 70 per cent. It is all a question of how the material is disposed with respect to that.

Q. What would be the effect of dredging, independent of the filling?

A. The effect of that would be to increase the hydraulic capacity of the stream, make a larger discharging capacity for a given stage.

Q. What has been the change in the outflow capacity in the St. Lawrence River?

A. There have been two or three,—three changes that have been made by works, two of which were under the Canadian Government. In 1881, the Galops Channel was deepened from 10 to 16 feet, for the purpose of enabling down-

stream navigation without passing through the canal; and the estimated change in the level of the river at Ogdensburg from that, was to lower it about 1 foot. The facts in regard to that are reported in the report of the Chief of Engineers for 1882.

A further change was made by closing the Gut Channel in 1903, and the effect of that was estimated locally at about half a foot, and Lake Ontario very nearly the same amount, about a third of a foot. This closing had the effect of raising the level of Lake Ontario. This was also done by the Canadian Government.

Then there has been another effect on the St. Lawrence produced by the opening of the Massena Canal between Farren's Point and Cornwall, by which the waters are diverted from the St. Lawrence over to Grass River to produce water power. This canal has a capacity of 25,000 second feet, and by the increment of the International Waterways Commission on that part of the river, this canal produces an effect of about 1.4 feet lowering the water surface in that reach.

Q. With reference to the Niagara River, what change has been made in the outflow capacity?

A. Along sometime prior to 1890,—I don't recall the date —the Horseshoe Reef was cut down, and certain improvements made in the Rapids by cleaning up the channel so as to take 18 feet. Formerly 17 feet had existed, in a sinuous channel. There were also quite extensive works down at Strawberry Island, down opposite the head of Grand Island, so as to extend this navigation of 18 feet down to Tonawanda. There has been some work done between that point and Slosser in cleaning up the bottom of the channel, and in some excavation, so that a navigation of 16 feet could be carried down to Slosser, immediately above Niagara Falls on the American side.

Q. What effect would that be likely to have on Lake Erie levels?

A. The effect is to make a better discharging channel of the Niagara River, and to lower the levels.

Q. Take the St. Clair and Detroit Rivers, what have been the changes in the outflow capacity?

A. The original depth at the Lime Kiln Crossing at the mouth of the Detroit River was about 11½ feet below the present improvement plan. This has been deepened to 21 feet in the Amherstburg Channel, and 22 feet in the Livingstone Channel, both of which are broad. I think the Am-

herstburg Channel is 600 feet wide and the Livingstone Channel 450 feet part of the way. There has also been dredging at Grosse Point and for some distance out into Lake St. Clair in order to improve the entrance to the Detroit River from Lake St. Clair.

There have also been improvements at the Ship Canal's south pass of Lake St. Clair (originally 8 feet, increased to 18.3 feet); and in the approach to the St. Clair River on the bars above Ft. Gratiot, the channel has been deepened 2,400 feet wide through these bars, to a depth of 21 feet below the old plane of reference. (18.9 on new plane.)

The effect of all these improvements has been to readjust the slopes in the St. Clair and Detroit Rivers; also the level of Lake Michigan and Huron and Lake St. Clair, with respect to Lake Erie.

There was also a change in the level of Lake Huron-Michigan, which has been attirbuted to these works occurring in 1886 to 1890, through the cutting out of the gorge at Port Huron, where formerly a rapid of 16 inches existed. The effect of this has been estimated at about .9 of a foot. Including these other changes, the Board of Engineers on Deep Waterways, report of 1900, estimated a change of about .9 between Lake Erie and Lake Michigan. The Lake Survey Report of 1911, reports a further change of about 3 per cent. in the capacity of the Port Huron outlet, an increase by 3 per cent., which would produce a change in level of 3 to 4 inches (3.3 inches) additional, according to their own increment—or the last increment of the Lake Survey, rather.

Q. What is your opinion as to whether or not the discharge due to a change of lake surface coincides in time with the crest of the wave set up by the change?

A. It does not. Any immediate change in lake surface would propagate a carrier wave from the outlets, that would travel very rapidly, like a tidal wave; whereas, the time required for the outlet itself to adjust its regimen or become entrain, as they say, would be a considerable period of time, many times longer than the time of propagation of the carrier wave. For instance, a carrier wave at depth of 25 to 30 feet, the water would travel from 19 to 21 miles an hour. Whereas, to establish a condition of steady flow in the river like the Niagara River, it would take from 12 to 24 hours, probably.

Q. What investigations or studies have you made to determine this question?

A. You might say I have been determining the matter for 40 years. I have given a good deal of study to movements in water in canals and to the movement of carrier waves as affecting navigation; and tidal movements which are of the same general character, where an impulse is transmitted through a stream or body of water without in itself transferring any considerable body of water. And where these impulses do exist, they produce local stages of water or oscillations, and they greatly complicate any relations of stage to flow.

For instance, a tidal wave will start from New York Bay up the Hudson River; produce a tide all the way to Troy, 150 miles, raising the water there a foot, and at Albany, 7 or 8 miles below, about 2 feet and ½, in the low water season. By the time that wave reaches Albany, the level at Poughkeepsie is at low water. You produce a high tide stage at Albany, with no flow and the steepest slopes below. It utterly destroys all the relations which are assumed to exist under conditions of steady flow. And observations made under the conditions of undulations in the lake are subjeet more or less to that class of influences producing false stages with respect to the measurements.

Q. You spoke of "phasing conditions." Would you describe a little more fully what you mean by that, with reference say to Lake Erie and the discharge of the Niagara River?

A. I refer to a phase as something that is produced by changes in level under conditions of unsteady flow. For instance, a river is rising and it produces a discharge curve which is quite separate and distinct from the discharge curve produced on the falling stage; and that is spoken of as the phase of the rising and falling stage.

A high barometer passing over Lake Michigan to-day will lower the lake by several inches and transfer that water to Lake Huron, and it may pass over Lake Huron to-morrow and transfer that water to Lake Michigan. And there will be a fluctuation at Port Huron, first upward and later downward. The whole level of Lake Huron, in fact, has been changed by perhaps a foot throughout the complete range. This occurs from barometric effects. You would get a phasing flow down the St. Clair River; in other words, not a condition of steady flow. Conditions of slope and head and reservoir capacity of the channel, as indicated a change which is not a steady flow. The same effect occurs from these phe-

nomena called seiches. Those are never quite absent, and sometimes reach amplitudes running up into feet, two or three feet. In fact higher undulations have been observed. Those are quick fluctuations that send pulses down the river and prduce temporary phases.

Then, again, the wind may lower or raise the level of Lake Erie at its mouth and produce a phase there that would take several days for it to readjust itself, provided the lake continued long enough for it to readjust itself between Lake Erie and Lake Huron. That would affect the flow. In other words you would get a condition differing from steady flow. Any condition that is not a condition of steady flow, and due to temporary causes of this character produced phases just as tidal waves do, by which they destroy the true relations between stage and volume.

Q. Volume of discharge?

A. Yes.

Q. Have you made any observations upon Lake Michigan which indicated any such conditions as you have described? If so, will you state what investigations you have made?

A. In 1886 and '87, I undertook a very comprehensive series of observations directed particularly toward lake currents, and the effect of fluctuations for the Drainage and Water Supply Commission, having relation primarily to the water supply at Chicago. I believe this is the most comprehensive set of observations ever made respecting lake currents and seiches. Our automatic gages recorded for two years the oscillations of the lake surface, and from the record of these gages the seiches running at 20 minute intervals are characteristic, usually running one to two-tenths, and quite frequently reaching a larger amplitudes, and on that record they ran up over 18 inches, and kept up for two or three days.

I also had gage observations made at five minute intervals on seven gages around Lake Michigan; and on one day found that every gage on Lake Michigan lowered by about five inches, as I recall the figures. In other words, five inches of water disappeared from Lake Michigan in one interval of 24 hours. I made investigations at that time to see whether it was feasible to transfer that water to Lake Huron through the Straits of Mackinaw, and found that it could have readily passed that way. The observed currents that take place at Mackinaw indicate the feasibility of such a transfer of water. It does actually take place.

Q. Do you remember where those gages were located?

A. One was located at Ludington, one at Manitowoc, one at Grand Haven, Milwaukee, St. Joseph, Michigan City and Chicago. I will add in that connection that I made very extensive series of current measurements in Lake Michigan by large floats and log lines, and some of those measurements were taken in 250 feet of water.

Q. Will you describe the method of making those measurements?

A. The bottom float so-called was made of galvanized iron 30 inches high and about the diameter of a flour barrel, and was connected to a small can as a surface float, which had just sufficient displacement to carry the lower float. When a surface current observation was sought, these floats were put inside of each other as it were and the cord connecting them was lengthened out so as to give the current at any depth up to 250 feet, which we did actually observe.

The measurements were made in the open lake from an anchored boat held in position by two anchors; directions taken by compass bearing; the distances measured on the log line and marked with red paint at intervals of ten feet, the log line consisting of the strongest procurable seine twine. These floats were started from the side of the boat and played out until they acquired steady velocity and the marking on the same twine was noted and the stop watch started. They were run then 100 or 200 yards further, and the time taken by stopping the stop watch. The strain on the twine was very heavy when pulling in the floats, but after the float was started back, the lower float came edgewise to the water and came back very easy, so we could pull it back with our log line.

Q. You are familiar with all parts of the main channel and the Chicago River, as you have stated?

A. Yes, sir.

Q. Assuming that you had a uniform flow of say 4,167 cubic feet of water per second through the channel, the Chicago River and the Main Channel of the District down to the power house at or near Joliet; and that you changed the dam, the openings at the power house, so that you immediately had a flow at that point of 10,000 cubic feet of water per second, how long would it take to establish a uniform flow of 10,000 cubic feet per second through the entire length of the Drainage Channel and the Chicago River to the Lake?

A. Speaking offhand, the least time, or the lower limit,

I estimate would be the time required for 10,000 feet of water to displace all the water in the channel, which would be something like half a day, and the other limit would be double that, which expresses the rule in regard to uniform acceleration. I should say somewhere between 12 and 24 hours from Robey street to Lockport. But I would not undertake to state that definitely unless the stream was running at the hydraulic capacity of the channel parallel to the bottom. The idea is this, that you cannot establish a regimen until you have at least displaced all the water in the river between the points considered or the points that are affected in the results; and then some to allow for the fact that the change is progressive.

Adjourned subject to notice.

Deposition in the above entitled cause taken before the Commissioner on the 23rd day of April, 1914, at 2:00 P. M. at the offices of The Sanitary District of Chicago.

Appearances:

Mr. Albert L. Hopkins,
On behalf of the Government.
Mr. Edmund D. Adcock,
On behalf of the Sanitary District.

LYMAN E. COOLEY resumed the stand and testified further as follows:

Cross-Examination by Mr. Hopkins.

Q. Mr. Cooley, you were rather opposed to what is known as the Calumet Project. weren't you?

A. I have been opposed to some phases of the Calumet Project.

Q. Just what phases?

A I was opposed to making a channel in the Calumet District which was unduly out of proportion to the main channel. There was proposed at one time a channel of 4,000 seconds feet in that region, and at another time a channel of about 1/3 of the capacity of the Main Channel. I regarded those as out of proportion to the population to be benefited, and opposed the construction of channels of those dimensions.

Q. What is the size of the channel now being constructed?

A. The channel now being constructed has a capacity of about 2,000 seconds feet, or about 14 per cent. of that of the Main Channel; whereas the original project of 1887, and the project of the Pure Water Commission in 1897, the Expert Commission in 1901, suggested about a thousand feet, or about 10 per cent. of the original projected capacity of the Sanitary Canal.

Q. In other words you do not believe in that Calumet plan to make it a ship canal for deep draft vessels?

A. No, sir, the navigation feature is in a way incidental, and whatever navigation advantages there may be out of a channel properly proportioned to meet the relative population which may exist in that region, why of course I am in favor of that incidental use, but not of constructing a channel *per se*, at a cost to the tax payers, for that especial purpose of navigation.

Q. You made a statement in January, 1905, didn't you, that "Chicago would be robbed of its commerce and compelled to pay 95 per cent. of the cost of being robbed"?

A. I did make such a statement.

Q. What was that in reference to, Mr. Cooley?

A. That was in reference to the project then under consideration, and advocated by the then Board of Trustees, to produce a channel in the Calumet region about 1/3 of the capacity of the Main Channel, which I considered as entirely subordinating the Main Channel and the interests of the great population at Chicago to what might be called the "appendix" of the district.

Q. What would have been the cost, what was the estimated cost of the channel as then contemplated?

A. I do not recall that; but I think about eighteen to twenty millions.

Q. What is the estimated cost of the present works?

A. About 6,000,000. The 6,000,000 that I have in mind is for the channel proper itself from the Main Channel to the connection with the Calumet River. The other elements of the problem have been estimated, but whether the intercepting sewer system that has been suggested in that connection is to be undertaken by the District or the City of Chicago is perhaps open to discussion.

Q. Wasn't the amount estimated that that canal would cost at that time about $12,000,000?

A. I don't recall the figures definitely.

Q. To refresh your recollection, wasn't this statement made by you: "Calumet would have to pay about 5 per cent. of the cost of the new Ship Canal, and the people of Chicago would have to stand the balance. In other words, Calumet would have to pay about $600,000 for a canal that will benefit a few local interests, while Chicago must spend $11,400,000 for the enterprise. The deep ship canal, I understand, would cost, as now figured, at least $12,000,000, and it would be built on the theory of draining the Calumet region." Didn't you make that statement?

Mr. Adcock: I object to that, unless there is a statement of the place and time, etc., included, wherein such statement might have been made.

Mr. Hopkins: At or about January, 1905.

Mr. Adcock: And subject to the further objection that there is no statement or specification as to how the statement was made, whether it was in conversation with someone, or whether it was a statement to a newspaper reporter, or what not.

Mr. Hopkins: Q Do you recall, did you make such a statement to anyone, Mr. Cooley?

A. I will not say in regard to the whole statement. The part that you first cited has been much quoted, and I remember that distinctly, but the estimates I do not recall; the estimates that you just now read, that part of it.

Q. Assuming the estimates in there are correct, the figures, that was the truth of the matter, wasn't it?

A. Yes, sir, those estimates were probably estimates that were given out by the District at that time. I had made estimates of my own, and my recollection in regard to those estimates is what I first testified to.

Q. You also made a statement that was printed in the Record-Herald of October 1, 1907, in regard to this matter, as follows: "It is not a question of the immediate expenditure of large sums of money, as would be required for a lake front harbor, or in the attempt to shift our commerce and population to the Calumet region, where less than 4 per cent. of our wealth is now located, if the assessor is the judge; but rather the expenditure of the normal tax levy in harmony with a defined policy and plan. Harbor developments that do not serve existing population are speculative and a fraud on the people who are compelled to pay for them. People are deceived by sophistry and by reasons invented

to justify the diversion of public funds." Didn't you make that statement, Mr. Cooley?

A. I think the statement is correctly quoted.

Q. In the same article you also said, didn't you: "Let us complete the Main Channel between Robey Street and Summit for a width of 300 feet, for which right of way and bridges have been provided." And then later: "A handful of population in the Calumet can be otherwise cared for at a moderate fraction of the cost, and the State of Indiana can be compelled to care for its own under the doctrine of law handed down in the St. Louis case." You made those statements, too, didn't you Mr. Cooley?

A. Yes, sir. I would like to make a remark in connection with those, when you are through making the citations.

Q. Go ahead?

A. The citations last made are from an article entitled The Harbor Problem of Chicago, which was intended to show that the proper development should be an evolution from the Sanitary Canal in and behind the city, and not on the Lake front, and not in the Calumet region. There has been a strong feeling in many quarters that the future harbor of Chicago should be in the Calumet, which I do not believe in and have so stated on many occasions. Nevertheless there is a population there now amounting to about 134,000 by the last census and about 63,000 more in the State of Indiana east of the State line and practically included in the Calumet region considered as a whole, which does have sanitary problems and which must be taken care of from the sanitary standpoint, entirely independent of any commercial development; and which, from the beginning of the consideration of this matter in 1887, has been considered worthy of a branch channel varying from 10 per cent. up of the capacity of the Main Channel.

Q. Have you yourself made any estimates as to other methods of sewage disposal in that region than by a channel, and dilution?

A. I did at one time entertain very strongly the idea that it was feasible to provide for that region by treatment on land; it being in effect the only part of the Sanitary District as now situated which had land which could be availed of for such a purpose. But the anticipations which I have entertained at times respecting the availability of such methods have grown less and less in my mind as experience has

not borne out the hopes which were entertained respecting such methods.

Q. Do you recall writing a letter about April 23rd, 1907, to Mr. E. A. Halsey, Chairman of Committee on Sanitary District Real Estate Board, Chicago, Illinois?

A. I do not recall it.

Q. To refresh your recollection, the letter is as follows:

"Dear Sir:

In respect to our conversation, I note as follows:

The Sanitary District bill at Springfield provided for 1 per cent. taxation without limit as to time, and for the full constitutional indebtedness of five per cent.

The original law of 1889 gave a tax limit of 1/2 of 1 per cent. and a bond limit of fifteen millions; and this has been sufficient for all purposes of the Sanitary District up to this time, except that the tax limit has been temporarily increased for special purposes for two or three times, and the bond limit increased on account of the Chicago River improvement, to a limit of twenty million.

It is a very sad comment that there should be occasion at this late day for any increase in bonds, or of taxation, for more than a temporary period of three to five years, for some such purpose as provides for the full volume of water at an early day, or completing the Main Channel for waterway purposes in co-operation with the United States.

It is understood that this unlimited increase of taxation and bonds is to be devoted to the suburbs which were annexed in 1903. The sum estimated as required for the suburbs ranges from sixteen to eighteen million dollars. These suburbs have paid into the tax account from $600,000 to $700,000, and their assessed valuation is but six per cent. of that for the entire Sanitary District, so that their contribution to the works which are projected for their benefit will not much exceed one million dollars, and Chicago proper must foot the balance of the bill. There is absolutely no occasion for this, as all works required for the suburbs can be produced for 30 to 40 per cent. of the estimate, and such works can be deferred until the Main Channel has been completed and the water introduced therein as contemplated by law.

But this is not the worst of it. The proposed solution

for the Calumet region gives to that section forty per cent. of the water supply allowed for the Chicago River basin. The assessed valuation of this region is only 3.71 per cent. of that of the Sanitary District, and the ratio has not changed since 1888, when the Sanitary District law was drawn. In other words, the statements that the Calumet region is growing faster than the balance of our city, and that it needs extraordinary provision out of proportion to its relative population and wealth, is absolutely false. At the present rate of growth, the Chicago River basin will exhaust the full capacity of the Main Channel before it can be completed and the bonds paid. There is the highest expert authority for a much cheaper solution of the Calumet problem, which will not be complicated with the State of Indiana, and which will not interfere with the uses of the Main Channel for the Chicago River basin. In view of this, it is entirely inexpedient for the Sanitary District to take a position hostile to the conclusions of the authorities of the United States, if this city and this state is to realize a deep waterway in the early future.

I can see absolutely no argument for the Calumet proposition as it is now being urged, and I cannot understand why the taxpayers of this city are not more alive to their self interest, nor can I understand further what motives are influencing the Drainage Board to such a gross misapplication of the public funds.

Yours truly,

LYMAN E. COOLEY."

Did you write such a letter as that to Mr. Halsey?

A. What date is that?

Q. April 23rd, 1907.

A. I think I did.

Q. When you speak of "There is the highest expert authority for a much cheaper solution of the Calumet problem, which will not be complicated with the State of Indiana, and which will not interfere with the uses of the Main Channel for the Chicago River basin," what method did you have in mind at that time?

A. I referred to the report of Messrs. Hering and Fuller.

Q. 1906, was it?

A. Yes, sir, in connection with the estimate and report to the International Commission or the American Section thereof, in regard to the Calumet region. They at that time

had developed a very attractive proposition by means of sprinkling filters for the treatment of the Calumet region, which could be applied progressively with the growth of population; and which involved at the outset only a fraction of the expenditure, capital expenditure, required to develop the alternative method by means of a channel through the Sag. And in view of what seemed to me to be a prior claim or necessity, which was the completion of the Main Channel, it seemed to me that the District at that time, as I expressed it very forcibly, should curtail its suburban enterprises and devote its resources to the Main Channel, and adopt expedients of that character for which there was, as I said, the highest expert authority. But the District did not take that course. Neither did they carry out the project for the enormous channel which was then proposed for that region; but the project at that time was academic; it has not proven up by experience, and so as I have already indicated, at that time I entertained very great hopes that these artificial methods would involve, and thought perhaps they did in view of the sanguine nature of the report, a competent solution, I am not now so persuaded that that opinion was justified.

Q. You are in favor of an inner harbor?

A. Yes, sir.

Q. And in order to get at that properly for big shipping, and a great amount of it, the river would have to be greatly improved, even as it now stands, wouldn't it, Mr. Cooley?

A. Yes, sir, either that or the alternative cut made across the South Side, or direct access. In fact the project of 1901, of the Expert Committee, of which I was the working member, did develop a project for a river 300 and 360 feet wide in its different parts, and 26 to 30 feet in depth in its different parts, which project was competent to take care of all the water which the Sanitary Canal was designed to carry and capable of carrying. But that project was not actually adopted, like other of my projects have failed of adoption.

Q. Of course you could not have any more water through the Chicago River as it now stands without increasing the current, could you?

A. The current in the Chicago River as we now have it is conditioned by the unimproved sections thereof, between Harrison and Madison Streets.

Q. My question is: As it now stands, any additional water means more current?

A. At those localities, yes, sir.

Q. Not necessarily at those localities, wouldn't it be any place, the more water you have through there now the more current you have?

A. Yes, it would be of greater velocity throughout.

Q. And at least to that extent it would change the condition of the Chicago River?

A. Yes, sir.

Q. Did I understand you to say on your direct testimony that you have made studies and investigations of various European methods of disposing of this sewage?

A. When you speak of European methods, I presume you mean the alternative methods?

Q. Yes, aside from the dilution method?

A. I have made general studies respecting that.

Q. What study did you make? Did you study reports or what?

A. I was a member of the original investigating machinery upon the subject matter for the city of Chicago, and for the State Board of Health in this state, and reviewed in that connection all of the information available respecting alternative methods, and have kept informed respecting their development since.

Q. In what way have you kept informed?

A. By reading reports and studies upon the subject matter.

Q. As a matter of fact sometime ago there was more or less of an extensive inquiry made of various American Consuls and representatives, in regard to European methods, wasn't there, either by you or by the Sanitary District?

A. I am the Chairman of a commission of the Sanitary District that has had under advisement for the past year and a half the whole subject matter of alternative methods. And that commission has been engaged in making inquiries respecting the practice abroad and in this country, with a view of making a full and complete special exhibit of the practice of the world respecting sewage disposal. That investigation is in progress.

We are also charged, not only with that general inquiry, but with every aspect of the question, and with an inquiry respecting filth producing industries in this city.

Q. Just what information, say, did you get from Paris, for instance? What I am trying to find out is whether someone went over and visited it personally or whether it is from

reports of the authorities in charge, or just what is the nature of the information?

A. Our inquiries have been through the Consular Agents of the United States, who have undertaken to answer or submit to the authorities a series of questions, and to gather up reports which would cover the questions that have been propounded.

Q. Wasn't the report in regard to the Paris condition that it was a good one and satisfactory?

A. I don't recall now. These reports are very voluminous. I had a couple of assistants working on them for a number of months in order to make a digest and get them in shape. I do not recall at this moment any particular point respecting Paris, except that the system of artificial disposal was not to be extended in Paris.

Q. Wasn't that due to the difficulty of securing land?

A. In part to that. That was given as one of the reasons. The sewage of Paris has never been fully disposed of on land. It has been disposed of to market gardners who take it as they find occasion to use it in their cropping, and the remainder has gone to the river.

Q. Now about Berlin, was the report there that the conditions were satisfactory or unsatisfactory? I mean with the artificial treatment?

A. The treatment at Berlin is a land treatment, and on the whole has proven satisfactory; perhaps more satisfactory than any metropolitan city in the world. But that is due to conditions which lend themselves peculiarly to the methods there adopted, and which forbid other methods.

For instance, the rainfall at Berlin is only about 24 inches, and an irrigation proposition in that region is good in itself. Berlin is surrounded by a large quantity of sand barrens which are infertile and which are peculiarly adapted to treatment of sewage. Its proper drainage is the River Spree, which is scarcely larger than the Des Plaines River and at times is substantially dry. And the putting of sewage into such a stream without dilution is intolerable, so every condition at Berlin demands some other treatment than by dilution, and all the conditions are more favorable to a land treatment than anywhere that I know of except Denver, where I had occasion to suggest a similar method, when I was consulting engineer of the Union Water Supply Company for the city of Denver some years ago.

Mr. Adcock: Q. How about the consumption of water per capita there, as compared with Chicago?

A. I do not recall the actual consumption at Berlin, but usually in those cities it runs from 40 to 60 gallons or about 1/4 what it is in Chicago; so that the volume of effluent required to be handled is relatively small.

Q. How about the climatic conditions there compared to Chicago, as related to sewage farming?

A. Much more favorable. Their rainfall is about two-thirds of that at Chicago and their summer temperatures are moderate and as I have already remarked, the soil conditions are good and proper.

Q. It does not get as cold there in winter either?

A. No, sir.

Mr. Hopkins: Q. It gets as cold in Denver, doesn't it, Mr. Cooley?

A. Yes, sir, but Denver is a place that I have been looking up. As I have already stated, I was consulting engineer of the Union Water Company there for about five years; a town of 80,000 inhabitants; it turns its sewage into the Platte River, the South Platte, which is entirely devoid of water at certain seasons; has a wide sand bed with a grade of about 7 feet to the mile. And with only the sewage of Denver going in there, without any dilution at all, there is no nuisance, and the sewage effects dissappear in about 12 or 14 miles. It is a remarkable case, which I am going to give further study to.

Q. Mr. Cooley, were there any cases reported where some treatment was made, some artificial treatment made of the sewage, and then the effluent deposited in the streams?

A. Yes, sir.

Q. Small or otherwise?

A. Yes, sir. The statements in regard to the Birmingham District, and in regard to the Manchester District are quite full in that matter. In the Manchester District there are four or five treatment works, in which all the sewage and commercial wastes and the large manufacturing wastes of the Manchester District are handled, and the purification is, perhaps, carried on to a greater extent than any other foreign city, and perhaps any city in the world, by reason of the fact that the effluent waters feed the Manchester Ship Canal; and they even go so far in the Manchester District as to treat the storm waters which run off the lands, and which are highly polluted, before they are allowed to go into the canal.

Q. Is that Ship Canal a sea level canal?

A. No, sir. It is a lock canal, and it is fed from these land waters, and in seasons when they are insufficient the water is re-pumped at the locks from the lower level to the higher level, in order to make the lockage.

Mr. Adcock: Q. To maintain the depths?

A. Yes, maintain the levels and the water for the lockage. I went over this Manchester Ship Canal in 1909, after all this treatment process, and I rode down to the Sea in a sludge boat from Salford; and the waters in the Manchester Ship Canal are worse than I have ever seen them in the Chicago Drainage Canal, after all this treatment.

Mr. Hopkins: Q. What is the average flow in cubic feet per second in that ship canal?

A. I would not undertake to say. I have no specific data respecting that at this moment in my mind.

Mr. Adcock: Q. There is nothing but the effluent coming into the canal?

A. There is at Manchester the river Irwell, and it has a drainage basin which contains the city of Manchester and a number of other Boroughs, and the River Irwell normally is not a large stream, nor does it drain a large water shed, but exactly how much I do not know.

Q. It is only the effluent that goes into the Ship Canal, is it not, from Manchester?

A. The effluent from Manchester and its suburbs.

Q. The effluent from sewage disposal works?

A. Yes, sir.

Q. That is the sewage that is discharged there has all been treated?

A. The sewage in that district before being allowed to enter the canal is treated. And the conditions are as I have stated.

Mr. Hopkins: Q. Mr. Cooley, isn't it your opinion, that if the sewage of Chicago were screened and settled by some artificial method, as for instance Imhoff tanks, that 4167 cubic feet a second would then take care of a much greater population, that is assuming that the 4167 feet is only to take away the effluent, after the screening and settling of the sewage?

A. No, sir. It would perhaps increase to a limited extent the number of people which could be served by a given volume of water. But these methods do not undertake to handle more than the coarser impurities, and take out a lot of inert matter. The real putrescible matter removed is perhaps 20

to 30 per cent., and that largely carbonaceous so that it seems to me that the advantage that you gain by that, the saving that you gained by applying such methods, involves a cost far out of proportion to any other element in the problem.

The theory has generally prevailed that such a method of sedimentation represented by the Imhoff tank stableized the effluents and made them less susceptible to rapid decomposition; and that by reason of that the dilution water would be more effective; but I think that that is a hope,—has been a hope rather than a reality.

I can see no reason in the rationale of sewage treatment why that should be so; and I am unable to find any experience that actually justifies such an anticipation.

The largest treatment works that we have had in this country, at Columbus and at Atlanta, in the past year seemed to show that the effluents have not in reality been stableized, although a part of the putrescible matter has been removed.

Q. Every winter, there is more or less a raising of Lakes Michigan-Huron due to ice conditions in the St. Clair River, is there not?

A. I should say as a general proposition that Lake Michigan-Huron reached their lowest stage usually in March. There are winters in which—

Q. Lowest or highest?

A. Lowest stages in March.

Q. Michigan-Huron?

A. Yes. There are conditions in the St. Clair River where the outflow is retarded, but at all times during the winter months it is still greater than the inflow, so that the most you can say respecting that is owing to ice, the lakes do not fall as rapidly nor get as low as they would in the absence of ice in the outlets. There have been cases of absolute gorging for several weeks.

Q. Such ice conditions would vitiate the exactness of any percentage fluctuations between the two lakes, which percentage fluctuations were based upon open season flow, wouldn't it?

A. It is an element that ought to be taken into account in determining ratios of fluctuations. How much it would modify or change those ratios, I am unable to say without making a critical examination. I think however, that the general historic relation that has existed ever since 1819 in regard to the fluctuations of the several lakes would not be

greatly changed, but would rather be increased than diminished, that is the discrepancies would be increased rather than diminished if the outlets were perfectly free and open throughout the year. In other words Lakes Michigan and Huron would fluctuate through a wider range than it actually does, in comparison with Lake Erie.

Q. I was speaking of the ratio of fluctuation between the two, whether it would be the same?

A. I understood the question to refer to the ratio in the complete range of fluctuation.

Q. No, one lake to the other, as to whether there would be a uniform fluctuation between the two, ratio of fluctuation between the two lakes?

A. Well, in answer to that view of the question, which I did not get, the retardation of the flow between Lake Erie and Lake Michigan-Huron, would have the effect of diminishing the stage of Lake Erie with respect to Lake Huron-Michigan, or vice versa.

Q. In other words the point I am trying to make is that the ice conditions interferes with the ratio of fluctuation between the two lakes, which ratio has been determined under open season conditions?

A. Yes, sir undoubtedly does.

Q. You spoke of certain observations made in the Hudson River in regard to tides, and that you did not think that the water traveled with the wave. How do you account for the difference in elevation, unless there is more water at a particular point?

A. The water is actually moved through a limited distance in waves of translation, and that in the actual distinction and the reason of the distinction between a wave of translation and an ordinary wave of oscillation.

For instance, a tidal wave which is a wave of translation goes from New York Bay to Albany or Troy in about 12 hours, 12 or 13 hours, a distance of 150 miles, or at the rate of 12 to 15 miles per hour; much faster in the deep water and much slower in the shallow water, and it is succeeding high tide at New York when the preceding high tide has reached Albany; there is a succeeding high tide at New York, and low water between, down in the vicinity of Poughkeepsie. It is utterly impossible for the water to actually travel from New York to Albany and Troy this 150 miles, in the course of 12 or 15 hours.

Q. But it has held back the flow of the Hudson River

there, and has changed the direction of flow in that time, hasn't it?

A. The flow of the Hudson River is impounded to a certain extent by the incoming tide,—held back, but at such times as the tide is characteristic at Troy or Albany, the flow is relatively small.

Q. You gave certain opinions as to the time it would take to start a flow of 10,000 cubic feet a second down the Drainage Canal, assuming that you have a uniform flow of 4167 cubic feet. Suppose your gates, traps, are open at Lockport to admit a flow of 14,000 cubic feet a second, how long would it take them to get the flow so started in that direction that it would take care of 10,000 cubic feet, assuming that that is coming from rain or storms and coming in through the Chicago sewers, or the sewers in the Sanitary District, or from run-off in the Sanitary District, and running into the Canal where it would naturally come?

A. I know of no way in which that matter could certainly be computed from theoretical presumptions or data. And the opinion that I gave in respect to the matter was an inference or analogy from experience that, for instance, a movement like a tidal wave would pass through the canal from Lockport to Lake Michigan, or vice versa, in perhaps an hour and a half. There are some data to indicate that it has traveled 20 miles of that distance in about 55 minutes. But that of itself does not represent the establishment of a regimen due to a change in condition. I am certain that it would take at least 12 to 14 hours, and it might take double that time to establish a flow.

Q. By that you mean it would take practically that long to clean out the water in the Drainage Canal and get a new quantity of 10,000 cubic feet a second?

A. Yes, sir, you must draw off the storage in the channel above the hydraulic grade that you are to establish, and you must get that water in complete motion from one end to the other, and there must at least be sufficient time for the water to travel the whole length of the canal, and then some.

Q. Suppose after that tidal wave, that you speak of that might travel the canal in an hour and a half, had passed to the lake from Lockport on an opening of 14,000 cubic feet a second of flow, in which the water should come into the canal, say at Robey street, somewhere along the canal, or it was added to the canal at various places, wouldn't the tend-

ency of that water after the wave had passed be to go towards Lockport?

A. Yes, sir, so far as any wave is concerned that is likely to be produced at Lockport, it would be just a heap of water traveling, and even the water on the top of the wave itself might be running the opposite direction. It is a pulse rather than the transference of a large body of water; but to establish a regimen of steady flow there under the conditions that you have stated, involves a large element of time. I will illustrate by some experiences I have had in a matter of that character.

Q. Before you go into that, I do not understand what you mean by regimen of steady flow. What I am trying to get at is the practical condition of water coming into the river regardless of steady flow, whether or not it would not go towards Lockport. Maybe I do not understand your terms?

A. Perhaps my mind shot by a little. Until such time as the volume of water that might be contributed from these sewers and from tributary water courses had exceeded this flow of 4167 feet, which you mention in your question, it certainly would travel towards Lockport. That when the volume contributed from the local watershed did exceed that, part of it would travel towards the lake until such time as the increment of flow was sufficient to take care of it. Is that responsive?

Q. You think that would take 12 hours?

A. Yes, sir.

Q. That any water in excess of 4,167 cubic feet a second, contributions that made the flow in the canal more than 4,167 cubic feet, would flow, some of it would flow into the lake?

A. Yes, sir.

Q. Within the 12 or 14 hours?

A. Yes, sir. It is my idea that, with the qualifications that I have made, the subject is difficult of computation and that experience itself,—an experiment is the best criterion that you would not produce a change at Chicago from opening the channel up at the lower end in less than about 12 hours, and perhaps considerably more.

Q. Haven't there been certain experiments made which show that it takes less time for the effect to be felt; or do you know?

A. The Sanitary District has made a series of experiments respecting that matter, but I have not had time to ex-

amine to see what the actual results are. The matter has been in charge of other engineers of the District, who I will presume will give you the information.

Q. There have been cases when a boat was stuck in the river, and the flow stopped at Lockport?

A. Yes, sir.

Q. How long does it take the effect of that stoppage at Lockport to be felt in the level where that boat is, say in the Chicago River?

A. I think it has usually taken about 12 hours.

Q. For it to be felt at all. The first wave would not lift that?

A. This wave is not always produced, this impulse that I speak of. It depends upon whether the controlling works are manipulated in such a manner as to produce it. It is rather an incident than an habitual occurrence, as I understand it.

Q. Suppose observations are made by an engineer measuring the current with the current meter, and he observes a certain crest at one point along the canal, and someone else at another point further down the canal observes when it gets there, that volume of flow that corresponds to it, and the time was taken, couldn't they determine that in that way,—or wouldn't that determination show that the water had passed from one place to the other?

A. They might have caught one of these swells or impulses, which we call a wave of translation, and those travel very long distances at times. They show up on gage records and specially automatic gage records and profiles of water surface, but they do not represent an actual transfer of water in any large volume beyond what is involved in producing the swell itself.

Q. Do those things take place in a canal like the Chicago Drainage Canal, say eight or ten miles down the canal produced by a greater inflow at the lake or outflow at Lockport, or vice versa?

A. I have not given any particular study to such phenomena in the Drainage Canal further than to be appraised of the fact that swells have been ooccasioned by opening and closing the Bear Trap Dam, which have been noted at points above; and have taken the trouble to apply the ordinary formula in regard to waives of translating to such phenomena for the purpose of checking it up, and found that they agreed as closely as such results usually do; closely enough to identify it as a wave of translation.

I started out to make a statement respecting an actual case with which I was connected on the St. Joseph River at South Bend, Michigan. There was very extended litigation between the South Bend Water Company and the Mishawaka Power Company. There was an intermediate pool of four miles, where the mean depth was 4 to 6 feet. The question involved was the question of backwater. They had a tainter gate at the lower dam which could be lowered by a number of feet, which was actually lowered two feet.

Mr. Adcock: Q. A regulating gate, you mean?

A. Yes, sir. Under the direction of [illegible] they had gages established at all points, or a gre[illegible]m[illegible] points, eight or ten points along this four miles [illegible] South Bend Dam and the Mishawaka Dam. It took six hours to establish a regimen of steady flow of four miles. Then on reversing the dam and putting it up again, it took six hours to re-establish the former record, before all the gages reached a condition where they were unchanged, where they remained steady; whereas a wave of translation would travel the length of that pool in about 15 to 20 minutes.

Mr. Hopkins: Q. How deep did you say that was?

A. It varied in depth. Without referring to the record, I would not say definitely, but the mean depth was 4 to 6 feet, generally speaking.

Q. As a matter of fact, doesn't that movement depend very largely, the speed of the movement depend almost entirely upon the depth?

A. Yes, sir. That is the only element that is involved in the formula, is the depth and the gravity. And with a depth of four to six feet, a tidal wave would have traveled through that pool in 15 to 20 minutes, over that four miles.

Q. Now suppose that depth had been 22 feet for that six miles, how long would it have taken in your opinion to have changed the entire regimen?

A. It would have adjusted itself more quickly.

Q. Can you give the proportion?

A. No, sir, I would not undertake to do so without—

Q. It would be in direct proportion to the depth, or doesn't the speed increase with the depth?

A. Most—

Q. Greater than in a direct proportion?

A. In impulse movements through water, speed varies as the square foot of the depth, but in establishing a regimen, I do not know that I have seen in any of the works a complete analytical discussion of the subject matter, and it is

a very illusive and difficult one to analyze. And it usually is so much easier to make the actual experiment than it is to figure these things out that that recourse is taken where the matter is involved.

Q. When you speak of establishing a regimen, you mean establishing a steady flow of the greater or the lesser amount?

A. Yes, sir, when the river—

Q. You do not mean to say that it takes that full length of time though for the flow to be started in that direction, and any contributions along the way would go that way?

A. What the French call entrain, everything running in order according to the hydraulic principles; whereas in the St. Joseph experiment, it took six hours to establish a condition entrain or in regimen. The closing of the dam probably produced some effect in a shorter time; how much shorter I don't now recall, but the effect was not complete until six hours had passed by and the full regimen had been established.

Q. Now, within that full six hours, say, in the St. Joseph case, when you have established your regimen, that would take your full increased flow—

A. 14,000 feet complete through the channel.

Q. Complete, but that would take it beginning at the source of it, wouldn't it?

A. Sure.

Q. It would take certainly a relatively a shorter time where some of the water comes in at intermediate stations wouldn't it, where the effect is traveling towards the source?

A. That would have the effect, of course, of shortening actually the channel, and would take place in a shorter time depending on where the water was supplied. But I wish to say that in any opinion upon a matter of that kind further than that the results are much longer deferred than usually anticipated, I think the true criterion is to experiment with it rather than to attempt to estimate it from any analytical data or analyses that we may have.

Q. Then you would not lay more stress on these theoretical opinions as compared with actual observations?

A. No, sir. No, sir, I do not. So I stated what I have stated in the matter with that caution, as merely an opinion; expressing the idea that a considerable length of time would be involved.

Re-direct Examination by Mr. Adcock.

Q. I will ask you this question, Mr. Cooley: If the Calumet Sag Channel when completed with a 2,000 foot capacity will not serve also to dilute the sewage of a population in addition to the sewage of the population of the Calumet District alone, the 134,000 that you speak of?

A. It will do so to the extent of its excess capacity. It joins the Main Channel only eight or ten miles below the city limits, and the surplus water is available at that point for dilution.

Q. And that would be the dilution of sewage of a population arising in that portion of the Sanitary District tributary to the Main Channel and the Chicago River?

A. Yes, sir, that would be true.

Q. And the dilution capacity of the flow of 2,000 second feet, would be approximately 600,000 people, wouldn't it?

A. Under the law, 2,000 seconds feet is the equivalent of 600,000 population.

Mr. Hopkins: Q. Under the law, you mean the State law?

A. Sanitary District law.

Mr. Adcock: Under the organic Act?

A. Yes, sir.

Q. The capacity of 2,000 feet per second of the Calumet-Sag Channel, as compared with 1,000 feet per second, will serve to reverse the flow of the Calumet River during the greater portion of the year?

A. It would be more effective. The time when the Calumet River exceeds a flow of 2,000 second feet is limited; and it would be more effective than a smaller channel; and coupled with a proposition which has always been considered in connection with the Calumet, which is the diversion of the upland waters directly to the lake, it would be sufficient to take care of the flood waters on the urban district and keep the water out of the lake at all times.

Q. It is your understanding at the present time there is a project being carried out of draining approximately 350 square miles at the headwaters of the Little Calumet?

A. Yes, sir the project known as the Byrne Ditch, has actually been under way, been started.

Q. There is a drainage district formed?

A. A drainage district, to drain the lands of the Upper Calumet direct to Lake Michigan, and to divert about half of its watershed. That same idea has been one of the early

considerations, and was analyzed by the Expert Committee of 1901 as a proper proposition in connection with the Calumet-Sag Channel; and I expect eventually to see it carried out.

Q. You spoke of the per capita consumption of water in Berlin, that it was about one-fourth to one-fifth of that in Chicago?

A. That is about correct.

Q. What bearing does that condition have upon works, or a plant in connection with sewage farming, such as they have at Berlin?

A. There is a limit to the amount of water that you can put on an acre of ground; and that limit is less where the rainfall is greater. As I stated, the rainfall at Chicago is practically 50 per cent. in excess of Berlin, which in itself would call for a larger area. The water supply being four times and upwards per capita that of Berlin, it would probably require at Chicago from five to six times as much area to take care of the sewage and raise crops at the same time as at Berlin.

Q. For the same population?

A. For the same population, yes.

Q. Then you spoke of the different climatic conditions, such as extreme temperatures here, as compared with even temperatures in Germany?

A. I have already stated that the rainfall is much less, which lends itself to sewage farming, and the summer temperatures are lower and the winter temperatures higher than here, less range in temperature which is also helpful.

In other words, works here would be maintained with much more difficulty during the winter season than at Berlin. And in the summer time, too, owing to excessive temperatures, the sewage would be less stable in the conduits and in the carriers. The nuisance would be greater here.

Q. You are familiar with the history of the sewage farm at Pullman, aren't you Mr. Cooley?

A. Yes, sir, I knew about it at the time, and was later associated with the man who designed those works, Mr. Benizette Williams, for The Pullman Company; and actually laid out some of the later additions to the Pullman sewers. They started out and constructed a complete model sewage farm at Pullman, and it was in operation as early as 1885, as I recall; a little earlier than that. But it was practically out of use after four or five years.

Q. And that served a comparatively small population, didn't it?

A. It served a comparatively small population, and the separate system was installed there; and the conditions were extremely favorable to an experiment of that kind.

Q. That is so far as this city is concerned?

A. Yes, sir. And in that case, in order to overcome temporary propositions, they conducted the sewage under ground, distributed the sewage to the land by hydrants, so that it would not freeze up; adopted other precautions that are not adopted on foreign sewage farms. Their works are more in the open. But it was found that market gardeners did not like to use the effluents. They could do just as well or better, and so there was really no market, no rental for the lands. They virtually used it for intermittant filtration for a time, and then even abandoned that; got rid of their sewage eventually in the easiest way possible by letting it go to the natural water courses.

Q. From your observations in England with reference to the Manchester District and the Ship Canal that you spoke about, the climatic conditions are better there than they are in this country, aren't they, in this city?

A. The climatic conditions in England are almost ideal. There is seldom a snowfall or ice. The winters are mild and the summer temperatures are moderate, rarely going above 70 to 80. The conditions are very favorable in the avoidance of extremes, both of freezing weather and of high temperatures with rapid sewage decomposition.

There are various methods used, practically all the methods that have been discussed, contact beds, sprinkling beds and chemical works for precipitation.

Q. And they treated the storm waters, didn't they?

A. Those methods are all used in the Manchester District, and they also handle the storm waters on bacteria beds before allowing the effluent to go into the canal; that is from the urban districts.

Q. Rainfall is distributed more evenly over the entire year; that would be a condition favorable also?

A. Yes, sir, the rainfall is distributed more evenly and the rainfall is also less and flood volumes are less than here. The problem is mitigated in all its range, in every direction.

Q. Now from your experience and observations, do you consider it likely with the rainfall here at Chicago, that there would be liable to be a large amount of water flowing into

the Chicago River at some point between say Robey Street and the mouth of the river, coming from sewers, the North Branch, and other points in the District?

A. Yes, sir.

Q. Now assuming that the flow was 4167 cubic feet per second, limited to that amount, would a condition be produced by such rainfall before the flow could be increased, so that the water coming from this drainage area would flow partly into Lake Michigan through the Chicago River, and partly down the Drainage Canal towards the Des Plaines River?

A. I think that condition would be produced under existing conditions before it would be possible to sufficiently increase the flow to care for it; and with the further development of the urban district, the carrying out of drainage schemes in the natural water sheds outside of the sewage district, the quickness of that flow will be increased and the peak will also be increased.

In other words, the problem will be accentuated by the extension of sewer systems, and pavements, and houses, and by complete drainage works throughout the District.

Re-cross Examination by Mr. Hopkins.

Q. What is the population of the Calumet District at the present time, Mr. Cooley?

A. In 1910, it was 134,000 in Illinois and 63,000 in Indiana.

Q. That part of it in the Sanitary District of Chicago is 134,000?

A. 134,000.

Q. And the canal that is being constructed down there now will take care of 600,000?

A. Adequate for 600,000. I would say that the projects that I originally opposed so vigorously in that region were for an estimated population of 1,200,000.

Q. And it was an estimated flow of 4,000 cubic feet a second?

A. Yes, sir.

Q. And this is for a flow of 2,000?

A. 2,000 feet. I will say further that there has been some change in the situation. There has been a joint problem of the State of Indiana, and the Indiana Legislature has within the last year and a half authorized the formation of a district in the State of Indiana, with the idea of co-operating

in a mutual problem with the State of Illinois, and making available this larger channel.

Q. There are times, or have been times when the Calumet River has a flow of as high as 15,000 cubic feet a second, hasn't it?

A. I think actual measurements have been made over 13,000 and estimates have been made that it might reach a maximum of 15,000. I think I have made those estimates myself.

Q. Are those days of flood time in that region any more or less numerous than flood times in the Chicago River, or would you say about the same?

A. Well, yes, about the same.

Q. How many days in a year on an average do you think that the flood in the Calumet River would exceed 2,000 cubic feet a second?

A. I don't know that I have any positive data upon that subject. I think it can be had, though. I think a gage has been kept at Riverdale by which some positive information can be given.

Q. It will be a great many more days than the flow in the Chicago River, normal flow would exceed 4,167 cubic feet a second, wouldn't it?

A. That is the volume there would exceed 2,000 feet for more days than the Chicago River would exceed 4167?

Q. Yes? Chicago River drainage area, I have in mind?

A. Yes. Answering offhand, I would say yes, with qualifications; that we have a tremendous built up area in Chicago that does not exist in the Calumet, and we have a very large area of swamp in the Calumet, which does prolong the flow there. Off of this built up area and pavement, two or three times the relative volume of water comes over that which comes from lands, so to answer that on the basis of areas and time might be misleading.

Q. I will ask another question, which I should have asked before: You did not make a detailed study of the river measurements, observations, made by the Lake Survey men that has been testified to in this case, did you?

A. No, sir.

Further Re-direct Examination by Mr. Adcock.

Q. Take the Calumet situation there, if the intercepting sewers and sewer systems in that locality are so constructed that no sewage is deposited in the Calumet River itself, and that all the sewage is deposited beyond the controlling works into the Sag Channel, which will prevent its going into the Calumet River or the Little Calumet River, the reversal of the Calumet River itself is not so important or so serious as the reversal of the Chicago River where there are great areas of paved streets draining directly into the river?

A. Why it would be far less important, of course, if the problem is treated in that way. And it goes without saying that under the conditions of drainage in the Calumet, it must either be treated in that way or the upland water must be diverted so as to reduce the local drainage to the capacity of the channel.

Q. This Byrne Ditch will reduce the number of days, will it not of excess flow?

A. Yes, the Byrne Ditch will handle part of the problem. The example can be followed until practically all the upland waters outside the urban district can be diverted; and is it feasible to reduce the proposition in the Calumet region, so that there will be no effluent into the lake. That is the channel which has been constructed will be adequate for what will remain. That is feasible, and that I consider the best possible remedy. On the other hand, an alternative is the construction of the intercepting sewers which will remedy it to the extent that the sewage itself pillutes the river, but not to the extent that the river may be polluted extraneously.

Q. The mouth of the Calumet River is very much further from the intakes for the general water supply of Chicago than the mouth of the Chicago River?

A. Yes, sir, it is much more remote. In fact there is only one of the general intakes of Chicago that is nearer than six miles to it, I think.

Adjourned subject to notice.

VOL. 4

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS, } ss.
EASTERN DIVISION

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,019, and Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

MR. JAMES H. WILKERSON,
United States Attorney, and
MR. ALBERT L. HOPKINS,
Assistant United States Attorney,
For Complainant.
MR. EDMUND D. ADCOCK and
MR. ALFRED S. AUSTRIAN,
For Respondent.

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UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS, } ss.
EASTERN DIVISION.

IN THE

District Court of the United States

UNITED STATES OF AMERICA,
Complainant,
vs.
THE SANITARY DISTRICT OF CHICAGO,
Defendant.

C. C. No. 29,019.

STIPULATION.

It is hereby stipulated that the following matter may be considered in evidence with like effect as if witnesses were called and testimony were taken in this case, subject, however, to all objections as to materiality and competency:

1. Extracts from testimony and historical data in the case of United States v. Economy Light and Power Company, as set out in detail hereinafter.

2. Historical data from Brown's Drainage Canal Report, Report of the Illinois and Michigan Canal Commissioners for the year 1900; Andreas' History of Chicago, and extracts from Reports of United States Engineers, and certain other public documents, all as set out in detail hereinafter.

J. H. WILKERSON,
United States Attorney.

EDMUND D. ADCOCK,
Attorney for Sanitary District of Chicago.

Chicago, April 8, 1914.

UNITED STATES VS. SANITARY DISTRICT OF CHICAGO.

MEMORANDUM OF EXTRACTS TO BE READ IN EVIDENCE ON THE PART OF THE DEFENDANT, FROM THE CASE OF UNITED STATES VS. ECONOMY LIGHT AND POWER CO., IN THE UNITED STATES DISTRICT COURT.

CLARENCE W. ALVORD, a witness for complainant (United States), testified as follows:

I live in Urbana, Illinois. I am connected with the University of Illinois, my title being Associate Professor of History. I also have the position of special editor of publications of the Illinois State Historical Library. The Library is a department of the state engaged in the study of Illinois history. It collects volumes on Illinois history and publishes from time to time in its collections documents illustrating the history of the state. I have edited and published several articles and volumes for the Illinois State Historical Library. The first was a bulletin entitled "Illinois in the Eighteenth Century." Since that time I have prepared volume 2 of the Illinois Historical Collections, having a sub-title, "Virginia Series, Volume 1, Cahokia Records." With Professor Greene, my colleague at the University, I prepared Volume 4 of the Illinois Historical Collections, having the sub-title "Executive Series, Volume 1, Governor's Letter Books." And I also prepared myself Volume 5 of the Illinois Historical Collections with a sub-title, "Virginia Series Volume 2 Kaskaskia Records." For the Chicago Historical Society I published an essay called "The Old Kaskaskia Records," giving an account of the records which I discovered.

For the American Historical Association as adjunct member of the Public Archives Commission, I published a report on "The French Archives of Illinois"; and there is in the press today a report upon "The Archives in the State Capitol."

In the Michigan Historical Collections, Volume 36, I published an essay entitled "The Genesis of the Proclamation of 1763."

In the proceedings of the Wisconsin Historical Society for 1908 I published an essay continuing the previous one entitled "The British Ministry and the Treaty of Fort Stanwix." For the Missouri State Historical Society I published an essay

entitled, "The Conquest of St. Joseph by the Spanish in 1780."

In the American Historical Review I published an essay with documents on "The Capture of Vincennes by George Rogers Clark, in 1788.".

For the Club of Colonial Reprints, having its headquarters in Providence, Rhode Island, I published a pamphlet with introduction and notes, entitled "Invitation Serieuse aux Habitants des Illinois, par un Habitant."

In connection with the preparation of these different publications to which I have referred, and these different manuscripts and articles, my study of the various historical data and materials and sources of compilations that relate to the early exploration and settlement of the Illinois country has been very extended. That is part of my business as editor of the Illinois Historical Collections. It is the intention of the trustees of that institution to publish in the course of time all available material, and it is my duty to inform them from time to time what material is available, and what it will be most feasible to publish, so I have been obliged to familiarize myself with the history of the state and the material upon which that history is based. As professor of history in the University of Illinois I have for years given a course to advanced students upon the history of Illinois. As professor in the graduate school, all of my courses for the doctor's degree have been in western history, taking in, of course the history of Illinois in a larger view.

One of the young doctors who took his degree at the University of Illinois recently wrote his thesis upon the history of Illinois under Great Britain, which thesis won the Justin Winsor prize of the American Historical Association, probably the most important prize offered for young writers in history in America.

My present position as a specialist in Illinois history dates from early in the year 1905. In 1905 I was a general teacher in the department of history; part of my time was given to other fields, but since 1906 all of my attention has been given to Illinois history and Western history.

I have made a special study of the early commerce of the Illinois country. Probably one of the most important contributions to the knowledge of the history of the west that I have made has been connected with the trade in the west. I have in my search for unprinted material found a mass of stuff, not only here in Illinois, but in Canada and in Boston and Albany and Philadelphia, bearing upon the trade of the

Illinois country in its early period, particularly the fur trade, the trade with the Indians. That material I have partially published, but a very large mass of it is still unpublished; but the originals or copies of the originals are in my possession, and in the course of the next three or four years I will publish that which I have already found.

(Father Marquette's trip up the Illinois and Des Plaines River to Chicago 1673.)

Taking up the historical references that I have found in this research which have a bearing upon the use of the Des Plaines river for commercial purposes, the first reference is to the book entitled "Travels and Explorations of the Jesuit Missionaries in New France, 1610 to 1791. The original French, Latin and Italian texts with English translations and notes; illustrated by portraits, maps and fac-similes. Edited by Reuben Gold Thwaites, Secretary of the State Historical Society of Wisconsin. Volume 59. Published at Cleveland in 1900." This is one volume of a set of books known as the Jesuit Relations, and the documents therein found are translated from French into English under the direction of Doctor Thwaites. Dr. Thwaites is Secretary of the State Historical Society of Wisconsin, and shares with Professor Turner, of whom I have previously spoken, the reputation of being one of the most important historians versed in western American history. I know his standing among historians in this country to be just what I have stated. He is the author of a great many works of high standing and also has edited a very large number of works. A few of the collections that are best known among historians are "Early Western Travels." The latter volumes of the Wisconsin Historical Society have been edited by him. He has edited Father Hennepin's narrative. He has written one of the volumes of the American Nation series under the general editorship of Professor Hart of Harvard. He is the author of the volume of the American History series which is generally used in our colleges as a text book for freshmen and sophomore classes known as "Colonial America." There are very few historians in America who have published as widely as Dr. Thwaites. Dr. Thwaites has been for a number of years now Secretary of the Wisconsin Historical Society, the general reputation of which I have already mentioned. That society contains the best collection of manuscripts preserved in the archives west of the Allegheny Mountains. Doctor Thwaites although not responsible for the collection of

all has been instrumental in adding very materially to the collection of the society since he became its secretary. He has put that collection in excellent order and made it accessible to students in a way that was not the case before he became secretary. In doing this he familiarized himself with the whole collection of the Wisconsin Historical Society, so that there are few men in America that are better versed in the printed and unprinted material of western American history than Dr. Thwaites. I refer to the portion of this volume 59 of Jesuit Relations containing the report of Father Marquette on the first voyage on the Mississippi made by a Frenchman. There is not only a translation but a reprint of the original report, and the translation of the Jesuit Relations contained such reports from their missionaries. To explain in full as to how this series of books was compiled, I would say the Jesuit order was one of the first religious orders to extend its missions to America, and its missionaries may be counted among the bravest and most faithful of those that sought to convert the Indians to Christianity in the early days. It was a rule of the Jesuit Order that every Jesuit report yearly to his immediate superior. Thus the missionaries in America reported directly to their superior at Quebec. This superior extracted from these letters what he thought available, sometimes even taking the whole letter, and made a similar report of all the activities in his district to his superior in Paris. The Jesuits were very anxious that the public should know of the work that they were doing in America, and every year they took these reports and printed a volume in Paris. These were known as the Jesuit Relations and continued to appear regularly for a number of years. The volumes of the Jesuit Relations are very scarce, and the individual volumes are quoted in our catalogues at very high prices. Doctor Thwaites therefore felt that there was call by historians for a new edition of these Jesuit Relations and he collected them and some other material bearing on the same subject and printed them with translations in seventy-three volumes. This is regarded as one of the great monuments of western scholarship. These reprints of the Jesuit Relations are regarded as having a very high character and being accurate, and are used exactly in the same way as the originals. Marquette, the writer of this letter, accompanied the expedition which was in command of Louis Joliet that made the first discovery by Frenchmen of the Mississippi river. The expedition occurred in 1673. Unfortunately on the return Louis Joliet lost the memorandum which he had kept, so that the best account we have of the

journey comes from the priest that accompanied him, Father Marquette. Father Marquette has enjoyed among contemporaries and by men who have since written about him, a most excellent reputation for religious zeal, capacity and accurate observation. Any statement of Marquette's in regard to a matter of fact of which he personally had knowledge would be regarded by historians as accurate and would be so used. The reason for their being so used by those who are engaged in the work of historical research is because of Marquette's character. The facts with reference to that are well known and well established. The letter to which I refer begins on page 87 of this volume and goes to page 163. The passage referred to here is found on pages 161 and 163.

Said passage is as follows:

"After a month's navigation, while descending Mississippi from the 42nd to the 34th degree, and beyond, and after preaching the Gospel as well as I could to the Nations that I met, we start on the 17th of July from the village of the Akensea to retrace our steps. We therefore reascended the Mississippi which gives us much trouble in breasting its currents. It is true that we leave it, at about the 38th degree, to enter another river, which greatly shortens our road, and takes us with but little effort to the lake of the Illinois.

We have seen nothing like this river that we enter as regards its fertility of soil, its prairies, and woods; its cattle, elk, deer, wildcats, bustards, swans, ducks, parroquets, and even beaver. There are many small lakes and rivers. That on which we sailed is wide and deep and still, for 65 leagues. In the spring and during part of the summer there is only one portage of half a league. We found on it a village of Illinois called Kaskasia, consisting of 74 cabins. They received us very well, and obliged me to promise that I would return to instruct them. One of the chiefs of this nation, with his young men escorted us to the Lake of the Illinois, whence, at last, at the end of September, we reached the bay des Puantz, from which we had started at the beginning of June."

(Prof. Alvord continuing):

The Lake of the Illinois which is there mentioned is Lake Michigan. The name given very frequently by old voyagers was the lake of Illinois, because at one time the Illinois Indians lived upon it. It afterwards was given the name of one of the tribes of the Illinois Confederacy, the Michiganies, and the route referred to is to the

use of the Desplaines and Chicago river, which was the water route that was followed by Marquette on a later voyage and by other Jesuits.

(Report of Father Dablon, 1673.)

I have before me a passage from 1 Margry, pages 267 and 268. "The relation of the new discovery of many countries situated to the south of New France, made in 1673," appearing in 58 Jesuit Relations, presents at page 105 a translation of the same passage that was translated by me from the same volume of Margry. This translation is by Thwaites. I have testified to the high character of his translations. The passage is as follows:

"The fourth remark concerns a very great and important advantage which perhaps will hardly be believed; it is that we could go with facility to Florida in a barque and by very easy navigation. It would only be necessary to make a canal by cutting through but half a league of prairie to pass from the foot of the lake of the Illinois to the River St. Louis. Here is the route that would be followed:

The bark would be built on Lake Erie, which is near Lake Ontario; it would easily pass from Lake Erie to Lake Huron, whence it would enter Lake Illinois. At the end of that lake the canal or excavation of which I have spoken would be made, to gain a passage into the River Saint Louis, which falls into the Mississippi. The Bark, when there, would easily sail to the Gulf of Mexico."

(LaSalle's use of DesPlaines River, January, 1861.)

(Prof. Alvord continuing):

The next passage to which my attention is directed is in Volume 1 of Margry, page 523. This passage is taken from the same official account of the undertakings of LaSalle in the years 1679 to 1681. It refers to LaSalle's own use of a river route leading to Lake Michigan in pursuit of Tonty. I have translated the portion of that account which relates to this use of the river route, and the translation is correct. Said translation is as follows:

"Finally he set out on the 28th with three canoes, twenty minots of Indian corn and his equipage which he and his men dragged over the snow, although the whole weighed more than 4000 pounds, and he arrived the 6th of January the year 1681 at the juncture of the river Divine with that of the Teatiki. He decided to follow

the first, because six leagues below he had found a cabin where he judged that Monsieur Tonty has passed, because, since he had not met him on the river Teatiki, he (Tonty) must have necessarily have followed the River Divine. The hope which he (LaSalle) had of joining him (Tonty) made him resolve to leave in this place at a distance from the usual trail of the savages all his merchandise, in order that he might make greater speed. He hid them as well as he could and left there Monsieur D'Autray who volunteered to guard them, together with the physician."

(Professor Alvord continuing): The word Teatiki refers to the Kankakee river and "Divine" to the DesPlaines.

LaSalle's Use of River, December, 1682.

As to the book to which my attention is now drawn, which is described on its back as "Discovery and Exploration of the Mississippi," by Shea, Volume 4, I would say that John Gilmary Shea was a historian who devoted his attention particularly to the history of Roman Catholics in America. On account of his own religion he had opportunities to examine archives of the Roman Catholic bodies in Canada that were not given to Protestant investigators. The result is that Shea has been able to publish much material on western history that is non-accessible in other forms. His reputation as a historian is a most excellent one, and his translations are regarded by historians as accurate.

In this particular volume he took up the question as to the discoverer of the Mississippi River. Up until that time there had been a great many candidates for the honor of the first discovery. Since Shea wrote this volume there has been no question among historians that Joliet and Marquette were the first French to make the voyage down the Mississippi. This particular account is the "Narrative of LaSalle's Trip in 1682," by Father Membre, a Recollect Friar that accompanied him. The passage to which I refer is found on page 166 and is as follows:

Discovery and Exploration of the Mississippi, Shea, Vol. IV, p. 166:

"On the 21st of December, I embarked with the sieur de Tonty and a part of our people on Lake Dauphin (Michigan) to go toward the Divine River, called by the Indians Checagou, in order to make necessary arrangements for our voyage. The sieur de La Salle joined us

there with the rest of his troop on the 4th of January, 1682, and found that Tonty had had sleighs made to put all on and carry it over the Chicago which was frozen; for though the winter in these parts is only two months long, it is notwithstanding very severe.

We had to make a portage to enter the Illinois river, which we found also frozen; we made it on the 27th of the same month, and dragging our canoes, baggage and provisions, about eighty leagues on the river Seignelay (Illinois), which runs into the river Colbert (Mississippi), we traversed the great Illinois town without finding anyone there, the Indians having gone to winter thirty leagues lower down on Lake Pimiteoui (Peoria) where Fort Crevecoeur stands."

(Prof. Alvord continuing):

Basing my answer upon my study and examination of these different historical authorities I would say that the particular passage refers to the journey which LaSalle made in 1682, wherein he made his famous voyage down the Mississippi to the Gulf, and took possession of the country watered by the Mississippi and its tributaries in the name of the King of France.

JOUTEL'S USE OF RIVER, MARCH, 1688.

The first one to which I refer is the volume in my hand, "Joutel's Journal of LaSalle's Last Voyage, 1684-7. New Edition with Historical and Biographical Introduction, Annotations and Index by Henry Reed Stiles, A. M., M. D., Albany, 1906."

This is an edition in translation of Joutel's Journal of the voyage of M. LaSalle. LaSalle proceeded to put into execution his idea of making the Mississippi the channel of trade and obtained from the King of France a fleet with which he sailed for the mouth of the Mississippi river. On account of the ignorance of the exact location of that river the fleet reached the coast of what is now Texas, and on account of disputes between LaSalle and the admiral, the party was there left and LaSalle with his party attempted to make their way to the Mississippi by land. They experienced great hardships and finally LaSalle was murdered by his followers. Joutel became the leader of the party then and with them made his way to the Mississippi and up the Mississippi to the Illinois river where he was received by Tonty; and from there he proceeded to Canada. This is a publication in trans-

lation, as I said, of that journal kept by Joutel and is regarded as an accurate translation and one of known character.

I find on page 196 of this book a passage which throws light on the question of the use of this route, which passage is as follows (Joutel's Journal, Stiles Edition, p. 196):

"We continued after this Manner, till the Month of December, when two Men arrived from Montreal. They came to give Notice to Monsr. Tonty, that three Canoes laden with Merchandise, Powder, Ball and other Things were arriv'd at Chicagou, that there being two little water in the River and what there was being frozen, they could come down no lower; so that it being requisite to send Men to fetch those Things. Monsr. Tonty desir'd the Chief of Chahouanous to furnish him with People. That Chief accordingly provided forty as well Men as Women, who set out with some French men. The Honesty of the Chahouanous was the Reason of preferring them before the Islinois who are naturally Knaves.

That Ammunition and the Merchandise were soon brought and very seasonably, the Fort being then in Want. We stay'd there till the End of February, 1688, at which Time we fix'd our Resolution to depart, tho' we had no News from Canada as we expected. We found there were some Canoes ready to undertake that Voyage, and we laid hold of that opportunity to convoy each other to the Micilimaquinay, where we hop'd to meet some News from Canada.

Monsieur Cavelier the Priest, had taken Care before the Death of M. deLaSalle, his Brother, to get of him a Letter of Credit to receive either a Sum of Money or Furs in the Country of the Islinois. He tender'd that Letter to M. Tonty, who believing M. deLaSalle was still alive, made no Difficulty of giving him to the value of about 4000 Livres in Furs, Castors, and Otter Skins a Canoe and other Effects, for which, the said Monsr. Cavelier gave him his Note, and we prepar'd for our Journey.

I have before observed, that there was a Jesuit whose name was Dalouez at Fort Lewis, and who had been very much surpriz'd to hear that Monsr. de La Sale was to come in a short Time being under great Apprehensions on Account of a Conspiracy intended to have been carry'd on, against Monsr. de la Sal's Interest. That Father perceiving our Departure was fix'd, mov'd first and went away foremost, to return to Miciliamquinay; so that they

were left without a Priest at Fort Lewis, which was a great Trouble to us because we were the Occasion of it, and therefore those, who were to remain in the Fort, anticipated the Time, and made their Easter, taking advantage of the Presence of F. Anastasius and M. Cavalier.

At length we set out on the 21st of March, from Fort Lewis. The Sieur Boisrondet, who was desirous to return to France, join'd us, we imbark'd on the River, which was then become navigable, and before we had advanc'd five Leagues met with a rapid Stream, which oblig'd us to go Ashore, and then again into the Water, to draw along our Canoe. I had the Misfortune to hurt one of my Feet against a Rock that lay under Water, which troubled me very much for a long time; and we being under a Necessity of going often into the Water, I suffer'd extremely and more than I had done since our Departure from the Gulph of Mexico.

We arrived at Chicagou the 29th of March, and our first care was to go seek what we had conceal'd at our former Voyage, having, as was there said, bury'd our Luggage and Provisions. We found it had been open'd and some Furs and Linens taken away, almost all which belong'd to me. This had been done by a French Man, whom M. Tonty had sent from the Fort, during the Winter Season, to know whether there were any Canoes at Chicagou and whom he had directed to see whether any Body had medled with what we had conceal'd and he made Use of that advice to rob us."

JOUTEL'S USE OF THE RIVER, MARCH, 1687.

(Prof. Alvord continuing):

The next book which is called to my attention is the 3rd volume of Margry, which contains the relation of Joutel, beginning at page 91. The particular passage which relates to the Des Plaines river is found on page 485. I have made a correct translation of that passage, which is as follows:

"We continued to travel until Thursday the 25th (March, 1687) when we arrived at the place called Chicagou, which according to what we were tolld took its name from the quantity of garlic which grows in the woods in that region. There is there a little river which is formed of the waters that drain from a great prairie or field at this place, and which takes its course towards the

lake named, as I have said elsewhere, Illinois or Michigan. About three or four leagues away on the other side of the great prairie, the waters discharge into the Illinois river and form that. It seems that this place must be the highest between the Gulf of Mexico and St. Lawrence river, since the waters flow from that place in one and the other direction so that the higher they are the less distance must be portages, for in navigation of this kind, the canoe or boat must be carried, as well as the clothing; there is no way of escaping that task."

(Prof. Alvord continuing):

The sentence "We continued to travel until Thursday" refers to Joutel and Abbe Cavelier, a brother of LaSalle, on their return from the expedition to the mouth of the Mississippi. As I have said before, LaSalle was murdered after the party had landed on the coast of what is now Texas; and Joutel, with a brother of LaSalle, Abbe Cavelier, made their way up the Mississippi to Illinois and it is the account of the continuation of that journey.

Champigny's Report 1697.

The next book to which my attention is directed is entitled, "Collections and Researches made by the Michigan Pioneer and Historical Society, Volume XXXIII, Lansing, Michigan, 1904." This volume contains what is known as the Cadillac Papers. Cadillac was for some time the French Governor or French Commandant of Detroit, and was the founder of that post, in fact. His papers have been printed by the Michigan Pioneer and Historical Society in translation. The transcripts were made in Paris at the expense of Mr. C. M. Burton, a well known historian of the west, and under his general oversight these translations were made, which are regarded by historians as of character and accuracy. The particular report I refer to begins on page 72, signed Champigny, Quebec, October 13, 1697. Champigny was an intendant of Nouvelle, France, and is writing to his Majesty, Louis XIV of France. In a general way the nature of this report is a report concerning Tonty and de la Forest, who were the successors of LaSalle in the Illinois country, and who were carrying on trade there. Champigny writes concerning their enterprises. The particular passage is on page 75 and is as follows (33 Mich. Pioneer & Hist. Col., p. 75):

"Paragraph 25. His Majesty has permitted the Sieurs

de Tonty and de la Forest to keep Fort St. Louis of the Illinois on condition that they do not trade in beaver skins there.

I can assure you my Lord, with absolute certainty, that they will not stay there, and in fact cannot stay there, except to trade in them; otherwise it will involve them in an expense which they will be unable to bear. Hence it must be expected and taken as beyond doubt that, if they are allowed to go and remain there with Frenchmen, they alone will carry on the trade with the savages in the distant countries with immense profits. It is also well to inform you, my Lord, that they have now a warehouse at Chicagou in the country of the Miamis and another at Missillimackinac and that they have sent boats to other places, two of which have been rifled by the Illinois savages when they wished to take them to the savages called Sioux who are the enemies of the others. And to show you in what hand and under whose command all the distant countries are, it is right to inform you that the Sr. de La Forest is in command at Missillimackinac; the Sr. de Tonty, owner with him of Fort St. Louis of the Illinois has gone to the country of the Assinibouelles savages which is a very distant tribe to the north, where there are beavers in abundance; the Sr. de Tonty half pay captain, his brother, is the one who left Montreal unknown to me at the beginning of September, to go and take command in the place of the Sr. de La Forest at Missillimackinac, and the Sr. de Liette, a subordinate officer of the troops, cousin of the Sieurs de Tonty, commands at the post of Chicagou, in the country of the Miamis. All have but one and the same mind and but one interest, tending solely to trading."

Q. Point out the historical connection between the passage just read and the statements already introduced made by LaSalle with reference to this route?

A. From the statements that have been read into the record it is evident that those men that were closely associated with LaSalle continued to make use of the Desplaines and the Chicago River route. Joutel and Cavelier on their return from the expedition to the south where LaSalle lost his life, returned by this route. The successors of LaSalle in the region of the Illinois country, Tonty, and de La Forest, were exploiting the fur trade, and for that purpose placed a post at Chicago in order to command the water route from that region to the Illinois River.

(Prof. Alvord continuing):

Speaking from the standpoint of the historian as to whether or not these passages have any bearing upon the solution of the controversy between LaSalle and Joliet, they would show that the river route in dispute was capable of being used by traders and was used by LaSalle's successor and associates.

St. Cosme's Trip.

The next historical author to which I refer is a volume by John G. Shea, whose work I have already characterized. It is entitled "Early Voyagers Up and Down the Mississippi by Cavelier, St. Cosme, Le Sueur, Gravier, and Guignas. With an Introduction, Notes and an Index." These are published in translation and these translations are regarded as of known character and accuracy.

St. Cosme was a member of the society known as the Seminary of Foreign Missions. The Seminary of Foreign Missions was established a short time before this was written, in Paris, and a branch was located in Quebec, and the priests were very active in their missionary zeal. They became rivals of the Jesuits. In 1698 St. Cosme, with others, was sent by the Seminary of Foreign Missions into the west to establish mission posts. They went through the lakes and down into the Illinois River, going as far as Arkansas, and then St. Cosme returned and established in 1690 a mission at Cahokia. That document which is published by Mr. Shea in translation is a letter to the Bishop of Quebec by St. Cosme, containing an account of the journey that he had made from Quebec to their missionary field.

The passage in which the writer gives the account of passing through the water route leading from Lake Michigan into the Illinois River begins at page 54. In regard to the passage on page 51 to which my attention has been directed, Mr. Shea says in a note in regard to it (Shea's Early Voyages, p. 51):

> "I do not find this name of Kipikawi, or Kipikuskwi elsewhere. The river is evidently that emptying into the Lake at Racine, and this route was up the Root river and then by a portage across to the Fox, or Pishtaka (Bestikwi) river, which they descended to the Illinois. The names in this memoir have suffered greatly in transcription, and the copyist seems to have been especially bothered by the 8, which he replaces by vv or w, and sometimes

by r and k. As a vowel it corresponds to the English oo (French ou) as a consonant to w.

Joutel on his map gives the name of Petescouy to this river, and Charlevoix (Hist. de La Nouvelle France, Vol. III, p. 380) mentions it as the Pisticoui; it is now called the Fox or Pishtaka or Pistakee, and a lake on its course is also called Pistakee."

The account of the use of the Desplaines River above referred to, is as follows (p. 50):

"Some Indians had led us to suppose that we might ascend by this river, and that after making a portage of about nine leagues, we could descend by another river called Pistrui, which empties into the river of the Illinois about 25 or 30 leagues from Chikagou. We avoided this river which is about twenty leagues in length up to the portage. It passes through quite pleasant prairies but as there was no water in it we judged sagely to that there would not be in the Bestikwi and that instead of shortening our way we should have had to make nearly forty leagues of the way as a portage. This obliged us to take the route of Chicagu which is about 25 leagues from it. We remained five days at Kipikuskwi."

Page 54:

"On the 24th of October the wind having fallen we made our canoes come with all our baggage and perceiving that the waters were extremely low we made a cache on the shore and took only what was absolutely necessary for our voyage, reserving till spring to send for the rest, and we left in charge of it Brother Alexander, who consented to remain there with Father Pinet's man, and we started from Chicaqw on the 29th and put up for the night about two leagues off in the little river which is then lost in the prairies. The next day we began the portage which is about three leagues long when the water is low, and only a quarter of a league in the spring, for you embark on a litle lake that empties into a branch of the river of the Illinois, and when the waters are low you have to make a portage to that branch. We made half our portage that day and we should have made some progress further, when we perceived that a little boy whom we had received from Mr. DeMuys having started on alone, although he had been told to wait. and had got lost without anyone paying attention to it, all hands being engaged. We were obliged to stop and look for him. All

set out, we fired several guns, but could not find him. It was a very unfortunate mishap, we were pressed by the season and the water being very low, we saw well that being obliged to carry our effects and our canoie, it would take us a great while to reach the Illinois. This made us part company, Mr. De Montigny, de Tonty and Davion continued the portage next day, and I with four other men returned to look for this littley boy and on my way back I met Father Pinet and Buinateau, who were going with two Frenchmen and one Indian to the Illinois. * * *

I set out on the second of November in the afternoon, made the portage, and slept at the River of the Illinois; we went down the river to an Island. During the night we were surprised to see an inch of snow and the next day the river frozen in several places, yet we had to break the ice and drag the canoe, because there was no water; this forced us to leave our canoe and go in search of Mr. de Montigny whom we overtook next day, the fifth of the month, at Stag Island (Isle aux Cerfs). They had already made two leagues portage, and there were still four to make to Monjolly, which we made in three days and arrived on the 8th of the Month. From Isle a la Cache to Monjolly is the space of seven leagues. You must always make a portage there being no water in the river except in the spring. All along this river is very agreeable. * * *

On leaving Monjolly we made about two leagues to another little portage of about a quarter of a league. As one of our men, named Carbonneau, had killed several turkeys and geese in the morning and a deer, we did well to give somewhat of a treat to our people and let them rest for a day.

On the 10th we made the little portage and found half a league of water, and then two men towed the canoe for a league; the rest marched on land, each with his pack, and we embarked for the space of a league and a half and stopped for the night at a little portage, five or six arpens off.

On the 11th, after making the little portage we came to the River Tealike, which is the real river of the Illinois; that which we had descended being only a branch. * * *

From Chicagvv to the Fort they reckon thirty leagues. Here navigation begins, which continues uninterrupted

to the Fort of the Permavevvi, where the Indians are now. We arrived there on the 19th of November."

Father Gravier's Trip, 1700.

(Prof. Alvord continuing):

Referring to page 101 of volume 65 of the Jesuit relations and allied documents, being one of the series of books concerning the preparation of which I have already testified, I find an extract which refers to this river route. This is the "relation or journal of the voyage of Father Gravier of the Society of Jesus, in 1700, from the country of the Illinois to the mouth of the Mississippi river. Written to Father de Lamberville and sent from Fort Mississippi, 17 leagues from its discharge into the Mexican Gulf or sea, on the 16th of February, 1701." Father Gravier, as the record shows, was a Jesuit and one of the successors of Father Marquette in the Illinois mission. This particular relation is a very famous one in Illinois' history because it was on this journey of Father Gravier that he found the Kaskaskia Indians on the point of moving south at the solicitation of the commander of the French at the mouth of the Mississippi river, because LaSalle's proposed colony had already been founded, and those that were pushing it were in the hopes of moving the Indians to that region for the assistance of the fur trade and also for the protection of French posts. The beginning of the letter reads as follows:

"My Reverend Father,

Pax Christie.

I received on my return from Michilimachinack the letters that you did me the honor of writing to me by way of the Mississippy, addressed to Father Aveneau, who sent it to me at Chikagoua whence I started in 1700, on the 8th of September to come here."

(Prof. Alvord continuing):

Taken in connection with all of the context this indicates that Father Gravier used the Chicago DesPlaines river route in going to the mission as the Jesuits were accustomed to do.

Report of Ramezay and Begon, 1715.

The book which is now shown me is volume 16 of the collections of the State Historical Society of Wisconsin. The last few volumes of this collection, among which this is, were

edited by Doctor Reuben G. Thaites, and he has included in them documents relating to the history of Wisconsin and the west in general, and where the documents were in French he has made a very careful translation which is regarded as authoritative and accurate. Volume 16 is a collection of various documents illustrating the French regime in Wisconsin. The document begins on page 327 and is entitled "Military Preparations against Foxes. Traders and Voyagers. Their Lawlessness. Restrictions on Trade. English seek to Control Fur Trade. French should Establish New Posts. (Letter of Ramezay and Begon to French Minister; dated November 7, 1715. Ms. in archives of Ministere des Colonies Paris; press-mark "Canada, Corresp. gen., Vol. 35, c. 11, fol. 15')".

Ramezay was commandant at Montreal at this time and Begon was the intendant of Nouvelle, France. The French administration of a province, whether in France or in America was in the hands of the Governor General and of the intendant of the police, justice and finance. The authority of these two officers was very great and the line between their functions was not sharply drawn. That was the principle of the French government to have two officers of almost equal authority residing within the province so that they could watch each other. The intendant, therefore, was what might be called the chief justice, civil governor, and chief of police of the province of Nouvelle, France. Begon is one of the well known intendants of that colony.

The nature of this document which I now refer to is a general description of the West and the necessity of military preparations against Indians and against the English who are just beginning to come into the western countries for the purpose of trade. It has particular advice to the French minister, to wit, a series of forts should be made in order to protect the country against Indians and against the English. It has in mind the protection of the fur trade. The passage begins on page 331 and is as follows:

16 Wis. Hist. Col. 331:

> "Sieur de la Perriere, who came down from Michilimakinak to Montreal at the end of last month, and who was charged with letters from Monsieur de Lagnery has informed Sieur de Ramezay that about 100 Frenchmen who secretly went up to Michilimakinak two years ago, after consuming the wears of the merchants who had equipped them, went to the Thamorois on the Mississippi river, where 47 were already established. He reports

that they are living there at their ease; as grain thrives in that region, they have built a mill and have a great many cattle. They get as many savage slaves as they wish, on the river of the Missouris, whom they use to cultivate their land; and they sell these to the English of Carolina, with whom they trade. This settlement is a dangerous one, serving as a retreat for the lawless men both of this Colony and of Louisiana. But as we see no possibility of preventing it, we believe, Monseigneur that we might render it useful for the service of the kind and of the colony by sending there a dozen soldiers, commanded by an officer, who could build a fort there and gradually establish order among these Frenchmen. With them he would be able to oppose the building of Forts by the English and all the enterprises carried on by them in that territory, which has been considered as French since the founding of the colony. As it is only about 60 leagues from the Thamarois post to that of ouabache, the French in either could, in case of need, come to the help of the other. It would also be very useful to establish a post at Chicagou to facilitate access to the Illinois and the Miamis and to keep those nations in our interest."

MEMOIR ON SAVAGES.

(Prof. Alvord continuing):

The passage now shown me, which appears on page 372, of the same volume 16 of the Wisconsin State Historical Collections, is a manuscript headed "Memoir on the Savages of Canada as far as the Mississippi river, Describing their customs and trade. (Translated from a Ms. in archives of Ministere des Colonies, Paris; press mark, "Canada, Corresp. gen., vol. 39, c11, fol. 354.)" This is in the nature of a report concerning the savages of Canada as far as the Mississippi river and describing their custom and trade. There is a passage there which refers to the DesPlaines river on page 372.

Whereupon said passage was read into the record as follows:

16 Wis. Hist. Col. 371:

"The quicapoux and the mascoutins are not far from Chicagou, it may be fifty leagues distant. When they wish to go to Detroit or the St. Josephe river they have to pass by way of Chicagou.

The River St. Josephe is to the south of Lake Michi-

gan otherwise called Lake of the Illinois. Many follow this river to go to LeRoche, because it is a fine river and they thus avoid the portage des chesnne and that of des perche. It is a river at the end of Lake Michigan and goes to LeRoche, which is an Illinois village."

(Prof. Alvord continuing):

The footnote on that page, 372 is written by Dr. Reuben G. Thwaites, whom I have referred to heretofore, and is explanatory of the passage which has just been read and is as follows:

"The St. Joseph river formed with the Kankakee (which was reached by a portage of three to five miles in length, at the present South Bend, Ind.), a convenient route from Detroit to the Illinois settlements. Of the portage here mentioned, that of des Chesnes ("the oak trees') was the one from the Chicago river to the Des Plaines—the earliest and best known route between Lake Michigan and the Mississippi, the other, des Perches (the poles), was probably that from the Calumet river to the Desplaines at the present south Chicago."

Report of James Logan, 1718.

(Prof. Alvord continuing):

The book which is now shown me is entitled "Chicago Antiquities, Comprising Original Items And Relations, Letters, Extracts, And Notes, Pertaining to Early Chicago, Embellished With Views, Portraits, Autographs, Etc., by Henry H. Hurlbut." Mr. Hurlbut had collected into his volume extracts of newspapers, letters, etc., which have come to his hands and has published them. The documents so published are regarded by Historians as correctly transcribed and as having the authority of the original, being accurate reproductions of the originals.

The passage to which my attention is called in this book is on the top of page 171. As Mr. Hurlbut describes it:

"The following is an extract from a 'rough draft' by James Logan, bearing date, December, 1718, designed to aid Gov. Keith, of Pennsylvania, in preparing his Memorial to the British Board of Trade. Various other routes to the Mississippi were referred to in the same paper." The foot note which tells who James Logan is is as follows:

"James Logan was born in Ireland, of Scottish par-

entage in 1674. He was a precocious scholar, being proficient in many of the dead languages at the age of 13 years. He came over with Wm. Penn on his second visit to America as his secretary, landing at Philadelphia in Dec., 1699. He filled with ability many offices in the Province, including that of Chief Justice as well as officiating as President of the Council, also as Governor for two years. 'He was a firm friend of the Indians; possessed uncommon abilities and great wisdom and moderation.' He died near Philadelphia in 1751."

(Prof. Alvord continuing):

He helped Governor Keith in drawing up several papers. Governor Keith published a volume upon the colonies and Governor Keith and Logan are regarded as men that were very familiar with colonial affairs.

The passage from Mr. Logan's report is as follows:

"From Lake Huron they passed by the Strait of Michilimakina four leagues being two in breadth and of a great depth, to the Lake Illinoise; thence one hundred and fifth leagues on the Lake to Fort Miami, situated at the mouth of the river Chicagou. This fort is not regularly garrisoned. From hence came those Indians of the same name, viz., Miami, who are settled on the forementioned river" (Miami now Maumee) "that runs into Erie. Up the River Chicagou they sail but three leagues to a portage of a quarter of a league. They then enter a very small lake of about a mile and have another very small portage and again of another of two miles, to the river of Illinoise; thence down the same one hundred and thirty leagues to the Mechasipi."

(Prof. Alvord continuing):

The object of the preparation of this rough draft of the report to the British Board of Trade by Governor Keith was that the English traders were now beginning to go in great numbers across the mountains and were beginning to realize more fully than they had previously that the French were occupying an extremely fertile valley and were likely to cut them off at the mountains. Governor Keith, being Governor of Pennsylvania, where many of the traders who were west of the mountains came from was extremely interested in this possibility and desired to draw the attention of the Board of Trade and through the Board of Trade of the British ministry to the danger that was threatening the British possessions in America from French operation.

Report of the British Board of Trade, 1721.

Volume 19 of the Michigan Pioneer and Historical Society, which is now handed me, is regarded by historians as containing documents in an authoritative form. This particular volume contains many copies of papers on file in the archives of the Dominion of Canada at Ottawa, and this particular document on page 5 is a copy of a representation of the Lord's Commissioners for trade and plantations to the King, upon the state of his majesty's colonies and plantations on the continent of North America, dated September the eighth, 1721. This is the report of the Board of Trade to which was sent the report of Governor Keith of Pennsylvania. The Board of Trade was founded for the promotion of the trade between the British colonies and the mother country and all matters pertaining to the Colonies generally were first referred to the Board of Trade for investigation and report. There was scarcely any action during the eighteenth century taken by the British Ministry or British Parliament concerning the Colonies without a report from the Board of Trade. The Board of Trade collected its information from reports from governors and other officials and even from private individuals. It was founded for the purpose of collecting such information and its archives are among the richest in London for colonial history. The report of the British Board of Trade would be regarded by historians, concerning matters in the United States with which that report had to deal, as a report of a body whose purpose it was to investigate, and as giving the information which the Board at that time possessed.

On page 5 of said volume there appears the following: (19 Mich. Pioneer & His. Col. p. 5):

> "From the Lake Huron they pass by the strait Michilimackinac four leagues, being two in breadth, and of a great depth, to the Lake Illinois; thence 150 leagues on the lake to Fort Miamis, situated on the mouth of the river Chicagoe; from hence came those Indians of the same name, viz.: Miamis, who are settled on the forementioned river that runs into Erie.
>
> Up the river Chicagoe they sail but three leagues to a portage of one-fourth of a league, then enter a small lake of about a mile, and have another very small portage, and again another of two miles to the river Illinois; thence down the stream 130 leagues to Mississippi."

CHARLEVOIX'S LETTER.

(Prof. Alvord continuing):

The title of the book now shown me is "Journal of a Voyage to North America, Undertaken by Order of the French King. In a Series of letters to the Dutchess of Lesdiguieres. Translated from the French of P. de Charlevoix. London 1761." The book covers the time Charlevoix made a journey for the purpose of examining the French colonies in 1721, and this is a publication containing letters that he wrote back to France from the various points that he visited. Charlevoix is regarded as a man of ability who was chosen by the King for this particular purpose, to make a journey to the French Colonies and to report on what he saw. He has an excellent standing among historians, and historians would use this book as the most excellent source material.

A passage beginning on page 165, as follows:

"Fort on the River St. Joseph, September 14, 1731.

Madam:

It is now three days since I set out from this place for Chicagou, by coasting along the south shore of Lake Michigan; but we found the Lake so stormy that we resolved to return hither and to seek out some other way to reach Louisiana. Our departure is fixed on the 16th, and I am going to make use of this delay of two days to continue my account of the customs and traditions of our Americans."

Also the passage from page 183 as follows:

"Source of the River Theakiki, September 17, 1721.

Madam:

I believe I gave you to understand in my last that I had two routes to chuse, in order to gain the country of the Illinois; the first was by returning to Lake Michigan, coasting along the southern coast and entering the little river at Chicagou. After ascending five or six leagues up this river, there is a passage to that of the Illinois, by means of two carrying places, the longest of which is not above a league and a quarter; but being informed that at this season of the year there is not water sufficient for a canoe, I have taken the other route, which has likewise its inconveniences, and is far from being agreeable, but it is more certain."

(Prof. Alvord continuing):

Having in mind the context, I would state that Charlevoix

took the St. Joseph and Kankakee route and the other route to which he refers is the Chicago and Desplaines portage. There is nothing in any of the writings of Charlevoix to show that he used the Chicago Desplaines River, and in fact he only passed through the country this one time, and he shows by his own writings that he took the route by the St. Joseph. The fact that he went through the country only once is regarded as an established fact, and I would state that there is no reference in his writings to the use of the other portage, from my own investigation. There is another passage on page 184 which shows a little more affirmatively that he did use the portage to which I have referred as being used by him.

Said passage is as follows:

(Charlevoix) 187:

"I departed yesterday from the fort of the river St. Joseph, and sailed up that river about six leagues. I went ashore on the right, and walked a league and a quarter, first along the water side and afterwards across a field in an immense meadow, entirely covered with copses of wood, which produce a very fine effect; it is called *the meadow of the Buffaloes head,* because it is said a head of that animal of monstruous size was once found there. Why might not there have been giants among the brutes? I pitched my tent on a very beautiful post, called the *fort of the foxes,* because the foxes, that is to say, the Ontagamies, had not long ago a village there, which was fortified after their fashion.

This morning I walked a league father in the meadow, having my feet almost always in the water; afterwards I met with a kind of pool or marsh which had a communication with several others of different sizes, but the largest not above a hundred paces in circuit. These are the sources of the river Theakiki, which by a corrupted pronunciation our Indians called Kiskiki. This signified a wolf, in I do not remember what language, but this river bears that name, because the Mahingans, who are likewise called the wolves, had formerly taken refuge on its bank.

"We put our canoe which two men had carried thus far into the second of those springs, and we embarked ourselves, but we had scarce water sufficient to keep her afloat. Ten men would in two days make a straight and navigable canal which would save a great deal of trouble

and ten or twelve leagues of way; for the river at its source is so very narrow, and such short turns must of necessity be constantly made, that there is danger of damage every moment to the canoe, as has just now happened to us. But we shall now return to the Indians, and after having seen in what manner they are treated during sickness, we shall take a view of them whilst they are a-dying, and of what passes after their death."

(Prof. Alvord continuing):

I have been reading from a translation made in 1761. The English people were particularly interested in all they could learn of the West at this time, and we have a great many publications from themselves; but also they translated the French Works and this is one of those translations. It is regarded by historians as a correct translation.

JOHN MITCHELL'S STATEMENT.

The book to which my attention is now directed is entitled "The Context in America between Great Britain and France, with its Consequences and Importance. By an Impartial Hand. London 1757."

The outbreak of the French and Indian War was due to the struggle between France and England for the possession of the Ohio country immediately and developed into a struggle for the possession of the whole west. The contest aroused the interest of the people of Great Britain and the Colonies, and a very large number of pamphlets were issued from the press concerning it. The most important pamphlet of the kind is this one, known as "Contest in America, By an Impartial Hand." It was soon known in England and America that the impartial hand belonged to John Mitchell. Such is the generally accepted historical fact as known by contemporaries and has been known ever since.

In 1773 the famous Arthur Young, economist, wrote a pamphlet on the possibility of western colonization in America, and he used portions of this book, and directly ascribes them to John Mitchell. I have myself made comparison with the passages he quotes in his foot notes with the passages in this book, so that I determined for my own self that the author of this book was John Mitchell.

Q. Before reading the passages you have before you and in order to make clear the meaning of the passages I wish you would state the historical fact with reference to the part

if any which this fur trade played in the contest between France and England?

A. As we have already seen, the French were the first to get hold of the fur trade of the Great Lakes and the Mississippi Valley regions, on account of their location on the St. Lawrence River. They were able to practically monopolize it for some time, although the Albany merchants in the Colony of New York were able to draw furs from this region by means of the Iroquois Indians. This, however, did not affect the Pennsylvania and Virginia merchants who were obliged themselves to go into the interior by crossing the Alleghenies. They therefore were the first ones among Englishmen to get into the western country.

By the middle of the second decade of the 18th century the French complained of the English traders on the Wabash, and for that reason they built the post at Vincennes. During the war known as King George's War, the French realized more fully the danger to their western country from the English colonies. Explorations by them in the upper Ohio showed that the country was full of English traders, and that they were in danger of losing the land not only for colonization but for the fur trade. They therefore determined to make a desperate attempt to close in the English people at the Alleghenies by locating a line of forts all along the rivers at the back of the Alleghenies, and thus cut off the passages that the Colonials were using in their pursuit of game.

Between the years 1750 and 1754 this line of forts was made and it was because of these activities on the part of the French that the English brought on the French and Indian War which was an undeclared war for two years carried on on the upper Ohio, a war in which George Washington participated.

On page 78, paragraph 3 there appears the following:

> "III. Their next view is, to secure those extensive territories, that they thus lay claim to; for which they have left no stone unturned for many years. For this purpose they have been securing one place after another, and building fort after fort, for many years. We see the plan and system they have laid down in North America, and all their proceedings are directed and tend immediately to execute and accomplish it. With this view they proceed from north to south across that continent, and seize every convenient place in their way; in order to

join their two colonies of Canada and Louisiana together. For this they have hitherto been obliged to go a vast way around about, by four of the great lakes and thence down the river Illinois into the Mississippi. But seeing a nigher and more convenient pass by the river Ohio, they at last seized that."

(Prof. Alvord continuing):

The first word of that passage, "their," refers to the French, taken in connection with the context.

INSTRUCTIONS FOR DRAFTING THE TREATY OF PEACE TO CONCLUDE THE FRENCH AND INDIAN WAR, 1761.

The document to which I am now referring is entitled "Affairs, etc., Correspondence, Politique etats Unis Supplement, Vol. 6, fols. 104-112." This document was enclosed in a letter written by the Duc de Choiseul on the 10th of August, 1761, wherein he said: "I send you a memorial on the limits of Louisiana which I have previously told you about, and which has appeared to me very well made."

This work was prepared under the circumstances that by the year 1761 the most important questions concerning North America that had led to the French and Indian War between Great Britain and France had been settled.

Under William Pitt, the British arms had been triumphant in America, Canada had been occupied and the fort that the French had built at the forks of the Ohio had been taken, so that it seemed possible both to the French and the English that a treaty of peace might be made.

The situation in England from the point of view of the French Minister was very favorable. In 1760 the young George III had come to the throne and he with his favorite Lord Bute were in favor of making a peace as soon as possible. The Duc de Choiseul was prime minister of France at this time, and sent to London as his agent a man by the name of DeBussy to enter into direct negotiations with William Pitt. Choiseul did not give Bussy discretionary powers; he was simply the agent of the French Minister and this memorial was sent by Choiseul to his agent, showing about what he was ready to concede to England and also along what lines he was ready to make the treaty of peace. The negotiations were opened up in 1761 failed by the fall of that year and the war was continued until the treaty was made in 1763.

This document which I have before me is a copy of the docu-

ment the history of which I have just given, and the original of which is found in the place here designated. The copy was made for me some time ago because I was interested as a historian in that treaty of peace, and was made for an entirely different purpose than introducing it here. The copy was corrected by Mr. Waldo Leland, the agent of Carnegie Institute in Paris, and he took great care to see that I received a correct copy as it was of the utmost importance, for the uses that I was going to make of it. The original from which the copy was made is in Paris. I do not know in whose handwriting the copy is that is before me. Mr. Waldo Leland who has collated it and made corrections furnished it to me as an accurate copy of the document in Paris for use in an entirely different matter than the one in which I am now using it.

The said passage reads as follows:

(Memorial on Louisiana by Choiseul):

"In the uncertitude in which France is that the position of affairs may decide her to cede Canada to England, the true manner of determining a general plan of the limits for Louisiana as well on the side of the English colonies as on the side of Canada is, to commence by making out a schedule of the natural advantages of Louisiana and of Canada. The purpose of this business is to have a result which may serve as a guide in the operation.

For the belligerent parties in America have not for their object in the present war the extent of territory, but only the profit that may be drawn from the country in contention between them.

With this point of view the spirit in which one should work in establishing the limits of Louisiana is to regulate them in such a manner that they do not take away any advantages which render this colony and that of Canada of some value for France, or that they cause the least possible loss.

This is the principal point and, indeed, the only one. Since this point will not suffer extinction whatever the extent of territory may be by the cession, it becomes indifferent, perhaps even it is useful. Advantages limited in a less space may appear preferable to the same advantages scattered in a very great space.

* * * Before then presenting any idea on the limits of Louisiana, it is best to show in what the natural advantages of this colony and of Canada consist and in what

they interest France. These two colonies embrace vast countries filled with fertile land and whose climate is healthy although the temperature is very different in the the parts situated under the most distant parallels. Canada furnishes grains, vegetables, hemp, cattle, copper, peltries, among which is the articles of beaver, timber, tar, gensing, iron, fish oil; it has mines of lead. * * *

Peltries, particularly beavers, copper, timber are the most interesting parts of the production of Canada in which old France can not supply herself from her own soil. * * *

From this short exposition there result two points: one that the conservation of Canada interests France only in relation to certain productions. If in ceding Canada one manages limits which preserve for France these same productions, the cession of this colony is not a loss. * * * It is necessary to observe that the peltries and beaver especially are exhausted in environs of Quebec and for one hundred leagues around this village one no longer gathers them for a long period. Peltries and beavers in which the Canadians trade (this amounting to 18,000 livres per year) come to them from a great distance in the west and north. These merchandise come into their hands in two ways: from the Outouacs and other savages neighboring the western banks of Lake Superior who come by way of the Lakes to Montreal or by coureurs de Bois, that is to say by the colonists who trade in peltries in the woods. These journey to the lakes and traffic in the country of the savages of which one has just spoken, or indeed they betake themselves to the southern extremity of Lake Michigan whence by means of a very short portage, which one calls the portage aux Chenes, they descend by the river, the Illinois, into the Mississippi. They then journey up this river and sometimes also the Missouri, and trade with the Penis, Sioux and other numerous nations who inhabit the north of Louisiana. These coureurs de Bois thus are accustomed to seek the skins which they bring back at eight hundred leagues from Quebec. It is easy to see in examining the map that they would have a shorter journey and less difficult by going to New Orleans than to Quebec, and that the savages who are accustomed to bring their booty to Montreal would have less journey and a less hazardous road than that, and one in which they would be less exposed to ambuscade by the

savages their enemies, in carrying their packages to the souther banks of Lake Michigan, near which is the post of the Illinois, one of the best established of Louisiana.

* * * To this observation concerning peltries it is necessary to add the subject of copper, hemp, timber, which one draws from Canada, first that a great part of this copper comes from the same countries where the coureurs de Bois are accustomed to seek the peltries; second, that the forests with which are covered the countries watered by the Missouri by the Mississippi, and by the rivers without number which empty into the two rivers, will furnish if one wishes to take the necessary care therefore, as much hemp and timber as one could have need of.

So that in order to lose nothing of the productions of Canada in ceding this province, the only attention that there is need to have in the establishment of the limits of Louisiana on this side appears to be to preserve the exclusive navigation from Lake Michigan from Lake Huron and from Lake Superior, in order that the savages of the north and of the northwest may have an easy and sure access to the Illinois post."

(Prof. Alvord continuing):

Mr. Leland states that this document is to be found in two places. He has given me the following note:

"This memorial is found (as copied) in Affair etr. Correspondence Politique Etats Unis Supplement, Vol. 6, fols. 104-112; and also in affairs etr. Correspondence Politique Angleterre. In Vol. 6 (Etats Unis) there is nothing to identify it, but in Vol. 444 (Angleterre) is found the legend 'Envoye copie a M. de Bussy le 10 Aoust 1761."

This document was written for the purpose of showing that the boundary line between Canada, which was to be ceded to Great Britain, and the French province of Louisiana which it was expected that France would retain, could be so drawn that the benefits that France had up to this time received from Canada might still be retained. The memorial points out that the chief products of Canada, particularly of peltry, copper and so forth, were obtained in the region of the Great Lakes and if the boundaries of Louisiana were so drawn as to control the waterways from Lake Michigan into the Mississippi, then the trade of this region could be conducted by the French traders and brought by means of water routes down the

Mississippi to New Orleans, even if Great Britain was put in possession of Canada.

This memorial was prepared for the negotiations looking toward peace that was entered into between the British government and the French government in the year 1761. The result of these negotiations was that the two countries failed to reach any agreement in regard to the boundaries of Canada. Also the Duc de Choiseul had entered into negotiations with Spain for the purpose of getting the support of Spain for France in making peace.

William Pitt, the British minister, had followed the Spanish French negotiations with considerable care and decided that if Great Britain was to reap all the advantages of the war, she must declare war upon Spain also. He proposed that to the Ministry and since they would not follow him, he resigned. The treaty negotiations were broken off, however, and England and Spain actually did enter into a war, the results of which changed the conditions very materially and resulted in the treaty of Paris in 1763. The result of the treaty at Paris in regard to this particular territory was that the French ceded to England Canada and gave up all of her claims in Louisiana east of the Mississippi River with the exception of New Orleans and the land contiguous. The particular territory in which is now situated the State of Illinois passed by this treaty into the hands of Great Britain.

Illinois, as a district of the Province of Louisiana, included all of the region between the Ohio and the rivers flowing into Lake Michigan. On the east this was bounded by the Wabash in general, and on the west its extent was from the Arkansas River indefinitely northward, that is, west of the Mississippi. In this region the French had certain posts that had been established. The seat of government was at a place that is known by the English term of Fort Chartres, the French name being Fort de Chartres. Situated on what is known as the American Bottom. Beside Fort de Chartres we have the following French villages also on the American Bottom, that is, extending from East St. Louis to Chester. Beginning at the North, Cahokia, St. Phillipe, Fort de Chartres, the village of which was known as New Chartres, Prairie du Rocher and Kaskaskia. Here they had a population of probably at this time under two thousand. None of these posts were on the Illinois River. They were all on the Mississippi River.

STATEMENT OF THOMAS HUTCHINS, FIRST SURVEYOR GENERAL OF THE UNITED STATES (1778).

This book which is now shown me is entitled Topographical Description of Virginia, Pennsylvania, Maryland and North Carolina, by Thomas Hutchins. It was published in London in 1778, and is the original edition. Thomas Hutchins calls himself in this book Captain in the 60th Regiment of Foot. Hutchins was a captain in the British army and fought during the French and Indian War against the French. He was one of the civil engineers employed by the British government in making maps of the west. We find him employed in Florida, on the Great Lakes, at Fort Pitt, making maps of the upper Ohio region. In 1766 he is in the Illinois country with the post at Fort Chartres mapping that region.

His map of the Illinois region was the basis for future maps of the region for many years afterwards. He visited Lake Michigan and Green Bay, and probably there was no man in the British army previous to the breaking out of the Revolutionary War who had a better knowledge of the west than Thomas Hutchins, and his information was used by the British ministry. He sympathized with the Americans at the outbreak of the Revolutionary War, and after the close of that war his reputation as a surveyor resulted in the appointment by the United States Government of himself as first surveyor general, and in that position he was the first to lay out the land on the upper Ohio around Marietta. This particular volume has been used again and again by historians as authority for statements concerning the west. I find in it a passage which refers to the Chicago-Desplaines at page 42, as follows:

> "The Illinois river furnishes a communication with Lake Michigan by the Chicago river, and by two portages between the latter and the Illinois river, the longest of which does not exceed four miles."

LETTER OF CAPTAIN BREHM TO GENERAL HALDIMAND, MAY 8, 1779.

(Prof. Alvord continuing):

Volume 19 of the Michigan Pioneer Historical Collections contains a large number of transcripts that were contained in the Canadian Archives at Ottawa, taken from what is known as the Haldimand Papers. General Haldimand was a Swiss officer who entered the British army and served for many years therein. He was in the French and Indian War. After

the war was closed he was sent to Florida as Governor, and then transferred from Florida to Canada, where he was Governor General for some time after the outbreak of the Revolutionary War. He had a vast correspondence of course, with army officers, and other people throughout the colonies. This correspondence he kept very carefully. It was finally given to the British Mus.um where it is situated today. Some years ago Douglas Brymner was Archivist of the Dominion Archives, and he obtained copies from the British Museum for the Dominion Archives which copies have been used again and again by state officials and historians. The Michigan Pioneer and Historical Collections have reproduced here in print some of these documents. I find among these documents letters that refer to the "Chicago Desplaines." These copies are regarded by historians as authentic transcripts of the originals. The first of these letters is from Captain Dederick Brehm to General Frederick Haldimand, Niagara, 8th May, 1779. The passage in question is found on page 405 and is as follows (19 Mich. P. & H. Col., p. 405):

> "After considering the situation of Major de Paister I apprehend he runs more risk from Chicagu by the Illinois River, then Capt. Larnould, as your Excellency will have and yet see, what precautions and means Col. Bolton has taken and is still constant sending partys towards Tuscarowas, and Fort Pitt to harass and disturb their proceedings but Clark having reduced Vincennes as early as February may have time to attach de paister by the above mentioned river, if the least preparation has been ordered by him at his leaving the Illinois."

(Prof. Alvord continuing):

This is a letter concerning a possible attack on the part of Virginians in Illinois territory against the British posts. This is an official letter from Captain Brehm to his Superior, General Haldimand.

LETTER OF CAPT. BREHM TO GEN. HALDIMAND, MAY 12, 1779.

In the letter in the same volume, page 410, he refers to the same Chicago-Desplaines portage. It is a letter from Captain Dederick Brehm to General Frederick Haldimand, dated Niagara, May 12, 1779. It is an official letter from Captain Brehm to his superior officer and reads as follows:

> "Col. Bolton has ordered some spades, shovels and Pickaxes to be got from this place, the former from Mer-

chants, he having none in store which I intend to carry up to Detroit for the use of said place or Michilimackinac, for which last Post I apprehend the most by the way of the Illinois & Chikago Rivers over Lake Michigan."

LETTER OF ..... TO CAPTAIN LANGLADE, 1780.

(Prof. Alvord continuing):

Mr. E. E. Ayer has made a collection of manuscripts on western history, and also of books on western history that is extremely well known throughout the country and contains a great many manuscripts of great value. This particular manuscript is regarded by historians as an original manuscript. This copy is in print. I have translated the certified copy and my translation is accurate to the best of my knowledge and belief.

It is as follows:

"To M. Capt. Langlade, Commandant of the Troops of His British Madjesty, ordered to make war upon all rebels all subjects of Spain or any other alien or domestic power allied with the said rebels.

Sir: You are commanded to put your detachment on land as near Milwaukee as the circumstances will permit and without losing time to get across the land in order to gain the first village of Illinois which is named Peoria. You will send by canoes as much provisions as you will find necessary by the River Chicago, taking good care not to overload your canoes and that they are sufficient in number to carry your detachment to Cahokia, the village opposite St. Louis. * * *

Hasten to set out quickly in order to inform M. Louison Hamelin to follow you by the same route and keep him informed of your march from time to time. In case you do not have on your return boats at Milwaukee or Green Bay, buy canoes in order to reach here. * * *"

There is nothing in the manuscript to show by whom it was written. It might have been written by several military officers of Great Britain. Evidently it was an official letter to Captain Langlade. There is nothing in the letter to show the date, but the circumstances are such as to place it in the year 1780.

LETTER OF PATRICK SINCLAIR TO LIEUTENANT COLONEL BOLTON.

Turning to Volume 19 of the Michigan Pioneer and Historical Society Collections, already identified I find in it a letter written by Patrick Sinclair, on page 529.

Patrick Sinclair was Lieutenant Governor following De Peyster at Michilimackinac when the latter was transferred to Detroit. This letter was written at Michilimackinac and seems to be an official letter written to Lieutenant Colonel Bolton, a lieutenant colonel in the British army. The letter is dated at Michilimackinac June 4, 1780, and is as follows (19 Mich. P. & H. Col., 529):

"I have the Honor to enclose you Returns of the Garrison, which account for all casualties since Major de Peyster's Departure. * * *

The Sloop Felicity with a small Vessel, private property, went into Lake Michigan and on the 29th Ultimo to land a Party of Canadians and Indians, who go by the Illinois River to second the attack of a Thousand Traders, Servants and Indians, sent down the Mississippi in obedience to my Lord George Germain's Circular Letter. * * *

The Two Vessels are returned from Lake Michigan with a part of the Indians & Volunteers on the attack against the Illinois, scarcity of Provisions obliged them to return by different Routes some by the Mississippi, some through the Country between Lake Michigan and that River, and some as directed by Chicagoe."

PLAN OF AN EXPEDITION BY LA MOTHE.

(Prof. Alvord continuing):

This volume which is now shown me is volume 10 of the Michigan Pioneer Collections which is one of the volumes already referred to. Volume 10 contains some transcripts of the Haldimand papers. On page 569 is a plan of an expedition against the Illinois drawn up by Giulhaume LaMothe, a Frenchman of Detroit, who joined the British and was captain of their militia in Detroit. It is dated April 24, 1782. It is a document drawn up to be presented to the military authorities and is as follows:

"April 24th, 1782.

Plan of an Expedition against the Illinois, which I have the honor to present to your Excellency. Leaving Detroit with a small army of & some neighboring indians,

Sauteaux, Hurons & Misthey will come by land to St. Josephs a journey of eight or ten days. Then after having taken the poux Nation, who are settled on this river they will come to the branch of the Chicagouet & the Quinquiqui to try to get the Indians of the small fort of Milanaquis & another village, who have appeared, till the present to give their services to the Illinois & Lately conducted a party to St. Joseph who took the Commandant placed there by Governor St. Clair. As the two villages are the refuse of all the malefactors of all the other nations of which the two chiefs are Dougurne Sauteux, the one named Segurnac & the other Macquivois who had their families near Michilimackinac & it would be easy for the leader of the party to send them with the belts & we would by these means keep back the intelligence which they would have given to the enemies. During this time we could bring the barges & ammunition & go to join the little army at the entrance of the Chicagous where is a portage of half a league in good weather, in this way we could come without difficulty to the Illinois."

(Prof. Alvord continuing):

Referring now to the last five letters or documents, these documents have to do with the use of the Chicago Desplaines portage by the military forces of Great Britain in making an attack upon the Illinois country in possession of the Americans, and upon St. Louis, which was in the possession of Spain.

Q. State what object a historian would consider these various officers had in referring to the Chicago Desplaines route as a means of transporting troops.

A. The Chicago Desplaines route seemed to them to be a very convenient route to get down the Illinois country.

Trip of John Baptiste Perrault.

The book now shown me is entitled "Archives of Aboriginal Knowledge. Containing all the Original Papers laid before Congress respecting the History, Antiquities, Language, Ethnology, Pictography, Rites, Superstitutions, and Mythology of the Indian Tribes of the United States. By Henry R. Schoolcraft, LL. D. In six volumes. Philadelphia 1860." This is volume 3.

Henry R. Schoolcraft was what we designate, probably by reason of his most important publications, an ethnologist, a student of the Indian tribes, although his interests were very

broad. He was one of the earliest and has remained one of the best known of the men dealing with this particular phase of our history. He traveled excessively throughout the west, visited a very large number of Indian tribes, explored many rivers, and his works are regarded as of high standard and accuracy. If we find in his book here a reference to the use of a certain route by certain traders, historians would consider that incident as being reported by a man of careful observation and one who had trained himself in the habit of recording. The incident would be regarded by historians in general as an authentic report of the incident which it purports to record. I have found a passage which refers to the Chicago-Desplaines portage. It is a document regarding the testimony concerning Indian life in the northwest in 1763 by John Baptiste Perrault. On page 353, occurs the following (3 Schoolcraft's Indian Tribes," etc., p. 353):

"My deceased father was born at Quebec in 1732, being of a respectable family of that city. He finished his studies at the age of twenty, under the French government, who gave him a situation at the foundery of St. Maruce. After the taking of the country by the English he was stationed at Trois Rivieres, in the capacity of an Inspector, under General Haldimand. In 1770, he commenced merchandizing at Rivere duLoup, from whence I was sent at a suitable age, in 1776, to the College of Quebec, where I remained until 1782.

My father, having dealings with Mr. W. Kay of Montreal, sent me about the middle of March, 1783, to adjust them. Then I was first seized with the desire to travel, seeing the preparations making by M. Marchisseaux merchant voyager, a friend of my late father, who had recommended me to his house. I declared to my father my intentions on the subject, and with his consent, I returned to Montreal on the first of April, and agreed with that gentlemen to go to the Illinois in the capacity of a clerk, at the price of a thousand livres and twenty sole, being exempt from all servile labor; to set out on the first intimation."

(Prof. Alvord continuing):

I find in the same article a reference to the use of the Chicago-Desplaines portage as follows:

"On the 16th of May, 1783, I received the orders I had long desired; for I had figured to myself the great advantages I should derive from that calling. M. Marchis-

seaux directed me to assemble the men whom he had engaged at Montreal for the voyage; namely, Sacharite, Quebec, St. Germain, Robert Dupuis of Maskinonge, Antoine and Francis Beauchemin, Menard L. Lavelle of Sorel and Yamaska; to conduct them to St. Francis, and take from the Wabanakis two canoes, and bring them to the house of M. Marchisseaux.

On the 12th day of May, at one o'clock in the morning, took leave of my mother, who pressed me to take supper, but my heart was too full to permit me. I had, at the time, a presentiment of what in reality took place before I again returned. I withdrew amidst a burst of tears, accompanied by theirs. I proceeded to St. Francis to take the canoes; and arrived at Montreal on the 15th of May, at noon. On the 16th, I received orders to go and conduct the equipages to LaChien, where the waters from the north detained us till the 27th. On the next day we set out, and encamped at the lake of Two Mountains on the 28th. Our canoes were loaded too heavy. Our bourgeois (a term in general use among voyageures for the master or proprietor of the adventure) was obliged to get a third to lighten us. We continued our route in safety, and with little detention. The water was, however, so high as to compel our bourgeois to engage two more hands; one of them deserted during the following night.

We arrived at Mackinac on the 28th of June and remained there until the 15th of July. * * * We continued our route towards LaBaye (Green Bay) with the intention of passing by the way of Prairie des Chiens, where we sojourned two days. On the third, being now en derive, we encamped at the Sauk village at Turkey river, about sunset; M. Marchisseaux being necessitated to pass there, instead of the direct route from Mackinac to St. Louis by way of the Illinois, in order to collect his credits from the Indians. We continued our route, and passed St. Louis during the night, fearing a seizure from the Spaniards, who did not at that time, suffer any person to import merchandise into Louisiana from Great Britain. We arrived at Kaos, then under the British government, on the 11th of August. M. Marchisseaux hired two apartments in the house of M. Soucier in the village, to establish a store of Franch goods and sold off his Indian goods to M. Choteau merchant of St. Louis, who equipped

on the Missouri, at an advance of 137½% payable in peltries namely, beaver at one dollar per pound, otter at one dollar and fifty cents; racoons at twenty cents; bears at two dollars; deer skins at fifty cents each; and in the same proportion for other furs." * * *

On page 355:

"That year there were a number of gentlemen from Montreal who had stores at Cahokia; namely Messrs. James Grant, Myers, Tabeau, and Guillon, who had but little business, on account of their having arrived too late. * * *

About the 15th of April the packs from the Missouri arrived. Our bourgeois settled his accounts with M. Choteau, and received seventy-four packs of furs. His retail store at Cahokia produced 500 Spanish dollars, and 400 pounds of tobacco. We left Cahokia on the 4th of May, for Mackinac. My directions were to pass by Chicago, having one barge and one canoe, and to await the arrival of M. Marchisseaux at Little Detroit in Lake Michigan, he having gone by way of Prairie des Chiens, to terminate his business with the Sauks. After fourteen days' detention, he arrived and continuing our route, we reached Mackinac the beginning of July, where I found myself at liberty."

(Prof. Alvord continuing):

Mr. Perrault was an Indian trader, that is, a trader for furs, and was well known for many years throughout the west. He was a prominent man later in Canadian history, and his family is living there to-day. He was of French nationality trading under the British government within the territory which became by the treaty of peace in 1783 United States territory. As to the other references or accounts of similar trading by British traders from Canada, I would say that in Volume 2 of the Illinois Historical Collections, Virginia Series, Volume 1, Cahokia Records, edited by myself, there are contained the records of the court established in Cahokia by the State of Virginia after that territory was occupied by the Virginia troops, under George Rogers Clark. The records show that during the closing years of the Revolutionary War, and years following, there were many English merchants trading at Cahokia. In fact, there was what was known as the English Store there. These English merchants being able to buy their goods cheaper than the Americans were usurping the trade much to the disgust of the local dealers,

and complaints were made to the Court against them, ineffectively. This trade by the British merchants continued until after the War of 1812, the British merchants of Canada practically monopolizing the trade of the Great Lakes region and the Illinois country.

Trip of Hugh Heward. 1790.

The manuscript now shown me is entitled "A Journal of a Voyage made by Hugh Heward, to the Illinois Country." This is a transcript belonging to the Chicago Historical Society, and the correctness of which has been authenticated as follows:

"State of Illinois } ss.
County of Cook. }

I Caroline M. McIlvaine, being first duly sworn on oath state that I am the librarian of the Chicago Historical Society, and that in the course of my duty as such librarian, I have personally compared the above and foregoing twenty-seven pages of Hugh Heward's manuscript with the original of said manuscript which was loaned to me by Clarence M. Burton of Detroit, Michigan, and I do further certify that the above and foregoing is a true and correct copy of said original manuscript.

Caroline M. McIlvaine.

Subscribed and sworn to before me this 7th day of November, A. D. 1910.

Edward J. Crocker,
Notary Public."

The original manuscript is in the possession of Clarence M. Burton of Detroit, Michigan, who possesses besides this a great many of Hugh Heward's manuscripts and manuscripts of a gentleman named John Askin closely associated with Hugh Heward in the trade of the Illinois country. The original manuscript is in a handwriting which upon comparing with the handwriting of Hugh Heward, appeared to me to be that of Hugh Heward himself. I have examined the original myself. It is regarded among historians that this manuscript in the possession of Mr. Burton of Detroit is the original manuscript of Hugh Heward.

Hugh Heward was a subject of Great Britain and engaged in the fur trade with other British merchants of Detroit, ex-

tending operations in various directions over the Great Lakes and down the Illinois country.

This manuscript is a diary describing a journey from Detroit to Cahokia which he took from Detroit through the Great Lakes and down to the southern end of Lake Michigan and describes his route the rest of the way, down the Chicago and down the Desplaines and down the Illinois River, finally reaching Cahokia. It is dated during the spring of 1790.

Hugh Heward was one of the British merchants who continued this trade after the treaty of peace was signed.

Said manuscript in part reads as follows:

(Heward MS)

"Sunday, May 9, 1790. Wind at southwest inclining from land. Loaded and set off. Our course in a bend nearly norwest. Strong wind from south southwest, but we recover a little, it being off the land. Arrived at Grand Calmanuck and afterwards at Little Calmanuck, the course norwest. From there arrived by a north course under sail at Chicago, under reefed sail, the wind blowing strong and in blasts. Missed the entrance of the river and were obliged to go about a mile past to land.

Monday, May 10, 1790, Slept at Point Sables. Entered with the Cannots, and began to hull corn and bake bread and arrange everything for next morning. Left the Cannots at Point Sables and took his fur robe. Bought of him forty-one lb. flour, baked in bread for 25 and 29 lb. pork at 2/8 the whole amounting to L %-10-8, and paid him with 13 yards 4/4 cotton.

Tuesday, May, 11, 1790, Engaged five Indians to help us over the carrying place with pirogue and paid them with two handfuls of powder. Duarrier this morning very saucy and abuseful about getting salt. I promised to requite him for it. A showery day and wind at west. Carrying place about one half mile. Got over nearly at midday. From thence passed in the run and small lake to the river DePlain, and course turning nearly southwest. A very wet afternoon and heavy thunder. Arrived at the river DePlain said to be 15 miles, and encamped.

Wednesday, May 12, 1790. Set off from the river DePlain which runs from the north. Our course down the Illinois River southwest past Lacroix and after Les Arbre—and a pass that goes in a small lake to the southeast and by this pass it is said to be three leagues to Little Calmanuck on the lake. This about eleven o'clock.

Passed the Petit and Grand Toxsil and afterwards the long rapids and came to the Village of Mount Juilette, course southwest. High hill at west resembling Fort Larnoult at Detroit. Passed afterwards the lake following. Here Maurice informed me not to be surprised, that there was so much danger that he would not return with me. Lomre said he was to make the voyage with him, and if he did not return, he would not.

Thursday, May 13, 1790. Finding the goods not dry enough, and very warm weather coming on, remained to dry them better in the afternoon. Threatened rain. We were obliged to take them in.

Friday, May 14, 1790. Remained and finished drying the goods and packed up. Belhumor, a Frenchman settled among the Indians, stopped to pass the village at the forks with us. Cool night and heavy thunderstorm.

Saturday, May 15, 1790. Loaded and set off Passed the village at the forks. The chief and village in feast and good humor. Gave him little tobacco and powder and he said he should be ready to assist me. Bought five sacs of corn for four shirts and powder, and paid Belhumor with powder. He was contented but begged two white shirts on credit till my return, which I gave him. He lent me his dog and a teakettle, and gave me nine eggs and a leg of venison. Passed the entrance of the river Teskekie about midday and from here arrived at the rapid of Demi Charge or rapid of (word undistinguishable) ten leagues from Theakekie carried over part and passed the pirogue. Came at the bottom. Elegant land with plum trees, oak, hickory, and so forth. Small sides, high banks."

CORROBORATION BY JUDGE MCCULLOCH.

The document which is now shown me is entitled "Early Days of Peoria and Chicago, an address read before the Chicago Historical Society at a quarterly meeting held January 19, 1904, by David McCulloch," which bears the seal of the society.

David McCulloch was a resident of Peoria, very much interested in the Peoria Historical Society and the local history of Peoria, and the relation of Peoria to Chicago, and this address which was delivered by request to the Chicago Historical Society was delivered at the quarterly meeting on

January 19, 1904. David McCulloch settled in Peoria April 22, 1853. He was elected circuit judge of the eighth circuit and held office until 1885. He was president of the Peoria Historical Society. He was regarded as being the best equipped of the local Peoria Historians, and the Chicago Historical Society regarded his work in local history of sufficient importance to ask him to give them a lecture. Mr. McCullough is dead.

Said passage from his report is as follows:

(Early days, etc., McCulloch, p. 92:)

"In May, 1790, Hugh Heward (a copy of whose journal is in the possession of this society) made a trip to the Illinois country, reaching the Chicago River on the 10th of that month, where he found Point de Saible living on the sands. In his journal of the day following he says: 'Slept at Point Sables with the canoes and began to hull corn and bake bread; arranged everything for the next morning. Left the canots (canoes) at Point Sables and took his porogue; bought of him 41 lb. flour and baked bread 25 & 29 lbs pork at 2-8, the whole amounting to 5 pounds 10s and paid him with 13 yds, 4-4 cotton.' According to this account Point de Saible must have been a trader, selling farm produce to the voyageurs and purchasing dry goods from them in return. The prices seem to have been better in those days than on the Board of Trade of today even in times of a corner in wheat or pork.

Heyward proceeded on his journey by way of the portage and the Illinois River to Peoria, where he found a few Frenchmen living among the Indians one of whom was Captain May, doubtless Jean Baptiste Maillet, whose name in French is said to have a sound much resembling May or Mai. He had derived his title of Captain from his having had command of a company of French militia raised at Peoria during or after the war, for which services he was afterwards awarded a donation of one hundred acres of land."

(Prof. Alvord continuing):

The fact that Mr. McCulloch makes use of the Heward manuscript as authentic, in view of the position which he held as judge and president of the Peoria Historical Society would have weight owing to the fact that Judge McCulloch was interested directly in that sort of history and had investigated

the material bearing upon or illustrating that phase of the history.

I have made an examination of the Heward account from the standpoint of a historian for the purpose of weighing it. In general historians would regard a diary of this sort which purports to be kept by a man going from one place to another, and wherein there is no discoverable motive for deception, as the best evidence of the fact that the men actually journeyed along the line that he had so designated. There is in this manuscript no evidence that he wished to deceive anybody as to the way he went or the method of his journey. On the face of it it is the diary of a trader and his motive is that of a trader, and he does trade as he goes along the journey and he is carrying merchandise to a point where he expects to dispose of it. I see no possible purpose for deception.

REPORT OF GOVERNOR ST. CLAIR TO PRESIDENT WASHINGTON, JUNE 11, 1790.

This book which is now shown me is entitled "The Life and Public Services of Arthur St. Clair. Soldier of the Revolutionary War; President of the Continental Congress; and Governor of the Northwestern Territory, with his correspondence and other papers, arranged and annotated by William Henry Smith, Volume 2, Cincinnati, 1882." This is a book of known character and accuracy and is so regarded by historians who have used it to study the correspondence and papers of Arthur St. Clair.

Arthur St. Clair came to this country and served in the British Army during the French and Indian War. At the close of that war he took up land in western Pennsylvania, where he became very familiar with the western situation, because just before the outbreak of the Revolutionary War, Virginia and Pennsylvania were struggling for the possession of the forks of the Ohio, both colonies claiming them. They also were extremely interested in the question of the further settlement of the western territory. Arthur St. Clair was the official of Pennsylvania that represented that colony in this dispute with the Virginia colony. At the outbreak of the Revolutionary War he entered the army and became a general in the Revolutionary Army. He was a close associate of General Washington. He afterwards became President of the Continental Congress and was the President of that body when it passed the Ordinance of 1787. He was then appointed

Governor of the Territory northwest of the river Ohio, which territory was formed by the United States, and it was under his administration that the first settlements in the northwest territory made by the Americans were laid out. He was instructed by Congress, and by the President, George Washington, to investigate the whole situation in the northwest, and particularly to investigate the situation with regard to the fur trade and the use of American territory by British merchants.

The report just referred to commences on page 164 and is entitled "Governor St. Clair to the President. Report of Official Proceedings in the Illinois Country from March 5th to June 11th, 1790." In that report I find a portion which bears upon water routes between Lake Michigan and the Mississippi River as follows:

(2 The Life, etc., of St. Clair, 174.)

"The commerce of the Illinois country is of some importance in itself, but more so when considered as connected with the Spanish side of the Mississippi. The villages on that side of the river having been originally settled by the French, and under the same government as that part which is now in the possession of the United States, the connection between them is still very intimate, and favors a commercial intercourse which, though illicit, might be carried on by the citizens of America without risk. It is carried on at present without risk, but is, unfortunately, almost entirely in the hands of the British. Even much the greatest part of the merchandise of the trade of the Missouri River is brought from Michilimackinac by that of the Illinois, partly by the Spanish subjects themselves, and partly by British traders. The manner is this: The Spanish subjects either introduce them at once in consequence of a secret connection with their commandants or they are brought down to Cahokia and landed there, and afterwards carried over to St. Louis, as opportunities can be found. What is brought by the British traders, the Spanish subjects purchase and pay for on the American side taking all the risk that attends the introducing them into their own country upon themselves. The furs in which these goods are generally paid for (deer skins answering better than furs at the New Orleans market), are carried to Canada by the same communication, that is to say, up the Illinois river, up the Chicago, and from thence by a small portage into

Lake Michigan and along that lake to Michilimackinac; or from the Chicago up the river Au Plain, and by a portage into the same lake.

In the spring of the year the waters of the Michigan and the Chicago rise each to such a height that the intermediate space is entirely overflowed, and is passable by the vessels in use there, which are bark canoes, but which carry a very considerable burden and are navigated by three or by five persons."

HISTORY OF GENERAL COLLOT, 1826.

(Prof. Alvord continuing):

This book which is now shown me is entitled "Voyage Dans L' Amerique Septentrional by the late General Collot, Ex-Governor of Guadeloupe Tome Premier Paris, 1826."

Collot was a French general and writer who was very well known at the close of the 18th century. He was Governor of Guadeloupe and at the close of his service there came to America and made a journey through western America, as so many other Frenchmen did, in the interest of France, which country at that time was looking for some advantage to itself in the west. Collot has the reputation of being a very careful observer and the maps which have accompanied this publication were among the best of the time. The volume was issued in England and France, the English translation being as authoritative as the French original edition; in fact the atlas that accompanied these works was only printed with the English edition. The volume I have here is the French edition, but the translation which will be introduced into the record is from the English edition.

I have taken occasion to compare the translation with the original and the translation is correct. The first passage is from page 325 in the French edition and on page 249 of the English edition, as follows:

Page 249:

"There are, moreover, strong conjectures that the Lakes Michigan and Superior empti d their waters formerly into this river (Mississippi). The evidence for this conjecture is, that when the waters are high boats carrying from fifteen to twenty thousand weight pass from the Illinois river to the lake Michigan, without portage, by traversing a marsh which joins the sources of the river Illinois with those of the river Chicago which now discharges itself into the Lake Michigan."

Page 257:

"the second by ascending the Illinois river and gaining by Chickago the sources of the river Kennomick (Calumet) which empties itself likewise into the same lake; this may be effected in high waters without carriage, by traversing a marsh where there is four or five feet of water."

BOOK OF GILBERT IMLAY, 1797.

(Prof. Alvord continuing):

The book now shown me is entitled "A Topographical Description of the Western Territory of North America, By Gilbert Imlay, A Captain in the American Army during the War, and Commissioner for laying out lands in the Back Settlements. London, 1797."

I am familiar with this writing as a work of history. It is regarded by historians as one of the best contemporary accounts of the west and has been used again and again by historians in their work. Imlay was in the west prior to the preparation of this book. He emigrated to Kentucky and was deputy surveyor of Louisville. He wrote those letters which are contained in this book while he was in Kentucky. I find a reference to the Chicago-Desplaines portage and to the river route between Lake Michigan and the Mississippi river, on page 71, as follows:

(Imlay, Topo, Desc. p. 71):

"I have mentioned that it is about 230 from the mouth of the Ohio up the Mississippi to the mouth of the Missouri and about 20 from thence to Illinois, which is navigable for batteaux to its source. From thence, there is a portage only of two miles to Chicago, which is also navigable for batteaux to its entrance into Lake Michigan, which is a distance of 16 miles. This Lake affords communication with the river St. Lawrence, through Lake Erie passing Niagara by a portage of 8 miles. The lakes Erie and Michigan are navigable for vessels drawing 6 and 7 feet water. This is one of the routes by which the exchange of commodities between the northern and southern parts of this empire will be facilitated."

LETTER OF ROBERT DICKSON TO ROBERT HAMILTON, 1793.

(Prof. Alvord continuing):

Concerning Volume 12 of the Wisconsin Historical Collections, which is now shown me, I have already testified with reference to the manner in which it has been prepared and the reliance to be placed upon it in making historical investigation. On page 133 is an article entitled "Robert Dickson, the Indian Trader. By Ernest Alexander Cruikshank."

Robert Dickson was a Scotchman who emigrated to Canada after the American Revolution. He became a trader in the Northwest Fur Company and was used as the agent in communication between the Spanish Governor of Louisiana and the Governor of Canada. He was well known as a fur trader and discoverer. During the War of 1812 he led a band of Canadians and Indians against Mackinaw, which he captured. He was, in 1813, made agent for the Indians west of the Mississippi River. In fact, during that war, he and his band reached the Mississippi River in southern Wisconsin. He was trading in the northwest until about 1823. On page 134 there is "A Letter from Robert Dickson to the Hon. Robert Hamilton of Queenston, describing the usual routes of trade between Mackinac and the Mississippi dated Mackinac, July 14, 1793, probably written at Simcoe's request." I find there a reference to the different water routes between Mackinac and the Mississippi, as follows (12 Wis. His. Coll., 134):

> "The communication between Mackinac and the Mississippi" he stated, "is carried on by two routes, the one by Chicago, the other by the Fox and Ouisconsin rivers, the latter is preferred on account of the shortness of the carrying-place. Leaving this place, the navigation is difficult for the course lies on the north side, owing to shoals until the Traverse at the entrance of the bay is reached. The land is poor and barren on the north side of the Lake until near LaBays where the soil is excellent and the seasons are early. Here it has long been settled from Canada by people who sow a little grain and have about 100 cattle which run in the woods."

TREATY OF GREENVILLE, 1795.

(Prof. Alvord continuing):

Thereupon counsel for the Government introduced into the record extracts from a "Treaty of peace between the United States of America and the Tribes of Indians, called the Wyan-

dots, Delawares, Shawanoes, etc.," the same being found in Volume 39 of the Senate Documents at page 39, which extracts were as follows:

"A treaty of peace between the United States of America and the Tribes of Indians, called the Wyandots, Delawares, Shawanoes, Ottawas, Chipewas, Putawatimes, Milamis, Eeel-river, Weea's, Kickapoos, Piankashaws, and Kaskaskias.

To put an end to a destructive war, to settle all controversies, and to restore harmony and a friendly intercourse between the said United States, and Indian tribes; Anthony Wayne, major-general, commanding the army of the United States, and sole commissioner for the good purposes above mentioned, and the said tribes of Indians, by their Sachems, chiefs and warriors, met together at Greenville, the headquarters of the said army, have agreed on the following articles, which, when ratified by the President, with the advice and consent of the Senate of the United States shall be binding on them and the said Indian tribes." * * *

Omitting now from Article I to the middle of Article III.

"And for the same consideration, and as evidence of the returning friendship of the said Indian tribes, of their confidence in the United States, and desire to provide for their accommodation, and for that convenient intercourse which will be beneficial to both parties, the said Indian tribes do also cede to the United States the following pieces of land, to-wit: * * *

(14) One piece of land six miles square at the mouth of the Chikago river, emptying into the southwest end of Lake Michigan, where a fort formerly stood.

(15) One piece twelve miles square at or near the mouth of the Illinois river emptying into the Mississippi.

(16) One piece six miles square at the old Piorias fort and village, near the south end of the Illinois lake on said Illinois river. * * *

And the said Indian tribes will allow to the people of the United States a free passage by land and by water, as one and the other shall be found convenient, through their country, along the chain of posts hereinbefore mentioned. * * *

Again, from the mouth of Chikago to the commencement of the portage between that river and the Illinois,

and down the Illinois river to the Mississippi. * * * And the said Indian tribes will also allow to the people of the United States the free use of the harbors and mouths of rivers along the lakes adjourning the Indian lands, for sheltering vessels and boat and liberty to land their cargoes where necessary for their safety. * * *

In testimony whereof the said Anthony Wayne and the sachems and war chiefs of the beforementioned nations and tribes of Indians, have hereunto set their hands and affixed their seals.

Done at Greenville, in the territory of the United States, northwest of the river Ohio, on the third day of August, one thousand seven hundred and ninety-five."

Letter of Prideaux Selby to Peter Russell.

In Volume 18 of the Wisconsin Historical Collections, at page 458, there appears a letter from one Prideaux Selby to Peter Russell. Prideaux Selby, according to Note No. 80 was Assistant Secretary of the Indian Department at Detroit from 1790 to the evacuation. He then removed to Sandwich, where he remained until his headquarters were removed (1807) to York. In 1812 he was a member of the council of Upper Canada." The passage appears on page 459, and is as follows:

"That the Barrier which the United States presents is of so high a consideration unless the people of Kentucky and of the Ohio should join our enemies or permit them to pass unmolested through their North Western Territory, little danger to this Province is to be apprehended by that Rout. But that the water communication by the Ouisconsin to Lake Michigan (except an inconsiderable carrying place between that and Fox river) opens an easy passage for the introduction of Troops and all manner of stores either by the way of Chicago or Missilimackinac.

That the route by the Illinois river tho' much nearer, does not afford such advantages for bringing forward supplies as the Ouisconsin and altho' in the Spring of the Year the waters are always high by the dissolving of the Snow and frequent rains at that season, yet it is presumed that swelling of the Illinois may have subsided before an army could be in readiness to take the advantage of that circumstance and it must be observed also that there are many interruptions on this communication

such as Rapids and Shallow waters. The Ouisconsin therefore appears their most (best rout as it is the easiest and most secret as well from its distance from anybody of traders as from the little intercourse we have with the Indians inhabiting that part of the Country."

COMMUNICATION FROM ALBERT GALLATIN, SECRETARY OF THE TREASURY, TO THE SENATE OF THE UNITED STATES, APRIL 6, 1808.

(Prof. Alvord continuing):

Whereupon counsel for the government offered in evidence a communication from Albert Gallatin, Secretary of the Treasury, to the Senate on April 6, 1808. The document is found on page 724 American State Papers, Documents, Legislative and Executive of the Congress of the United States from the First Session of the First to the Second Session of the Tenth Congress, inclusive. Commencing March 3, 1798, and ending March 3, 1809. Selected and edited, under the authority of Congress, by Walter Lowrie, Secretary of the Senate, and Walter A. Franklin, Clerk of the House of Representatives. Published by Gales and Seaton, 1834; the document being dated April 4, 1808, and being communicated to the Senate April 6, 1808; which passage so offered in evidence, was as follows:

"III. Niagara.

The fall from Lake Erie to Lake Ontario has already been stated at four hundred and fifty feet. A company had also been incorporated by the State of New York for the purpose of opening a canal at this place; but it does not appear that anything was attempted after the survey had been made. The intentions seems to have been to open a canal navigation for boats only from Fort Schlosser to Devil's Hole; the lake itself and Gile's Creek would have supplied the water, and the expense was estimated at four hundred and thirty-seven thousand dollars.

It is, however, evidence that the canal, in order to be as eminently useful as the nature of the undertaking seems to require, should be on such scale as to admit vessels which can navigate both lakes. Considering the distance which in that case must be extended to about ten miles, and the lockage of four hundred and fifty feet,

it is not believed that the expense can be estimated at less than one million of dollars.

* * * * *

The papers relative to these communications will be found under the letter B. But their utility will not be confined to the extensive navigation of the lakes themselves; for the mountains being completely turned when arrived into Lake Erie, the ridge which separates the waters emptying into that and into Lake Michigan from the northern branches of the Ohio, and from the waters of the Mississippi is of a moderate elevation, and is gradually depressed in its course westwardly. There is no doubt of the practicability of opening canals, at a future period, between several of those waters either by selecting proper levels or by means of short tunnels across favorable parts of the ridge. It will at present be sufficient to point out the principal communications now in use.

* * * * *

The Illinois river, which empties into the Mississippi above St. Louis, rises in a swamp which, when the waters are high, affords a natural canoe navigation to the sources of Chicago Creek a short stream, which falls into Lake Michigan at its southern extremity.

Another communication generally used by the Indian traders is that from Green Bay, also in Lake Michigan, to the Mississippi by Fox River and the Wisconsin. Nor is there any doubt that, if the inland navigation between the North river and the lakes was completely opened, the whole Indian trade either of the Mississippi by Lake Michigan, or of the northwest by Lake Superior, must necessarily center in an Atlantic port of the United States—a consideration of minor importance as a commercial object, when compared with the other advantages of that great communication, but of great weight in its relation to the political intercourse of the United States with the Indians."

Forsythe's Memorandum of Distances.

(Prof. Alvord continuing):

Thomas Forysythe was a fur trader; he was born in 1771 at Detroit and entered into the Indian fur trade in 1793. In 1809 he settled at Peoria; two years later he was Justice of the Peace of St. Clair County. In 1818 he became Indian

Agent for the Missouri Territory. He was very familiar with the whole region of Illinois and the countries bordering on the Mississippi, both as a fur trader and afterwards as Indian Agent. He died in 1833. These papers are now in the possession of the Wisconsin Historical Society and form one of their most valued collections.

The said copy is as follows (Forsyth Papers—Wis. Hist. Soc.):

"Reuben Gold Thwaites, secretary and superintendent of the State Historical Society of Wisconsin, at Madison, Wisconsin, being duly sworn testified that the following is a true and correct copy from a manuscript which has for many years past been in the possession of said society, entitled 'memorandum of distances as computed by voyagers, 1814,' and recognized by comparison to be the handwriting of Thomas Forsyth, who was for many year (including the said year 1814) the United States Indian Agent at St. Louis and elsewhere in the West; further that the press-mark of said manuscript in the library of the Society is '1T42' and is one of a collection known as 'Forsyth Papers.' Following is all of that portion of the manuscript that has reference to distances on the Illinois and Des Plaines rivers:

Distances from St. Louis to Peoria and from thence to different parts of the country as computed by travellers.

From St. Louis to mouth of Missouri	18
to Portage de Sioux	9
to mouth of Illinois	9
to Yellow Banks of Movez Terre	84
to mouth of Sangamon	48
to Peoria now Ft. Clark	72
	240
From Peoria to end of Lake	21
to Crow Prairie	24
to Prue's Marsh	15
to mouth of Vermillion the commencement of the rapids	30
to mouth of Fox River	18
to Coal bark	3
to falls	9
to Nettle Creek	15
To Sandy Creek	9
to Forks of Illinois River	6
	150

From Forks of Illinois to Mount Julet.....	15
to dry trees	15
to the portage	15
across the portage	9
to Chicago	6
	60
Total distance from St. Louis to Chicago by water..	450
but to go straight through the Prairies one-third of this distance may be deducted	150
	300

(Signed) REUBEN GOLD THWAITES.

Personally appeared before me this 24th day of June, 1910, the said Reuben G. Thwaites, to me well known as being the secretary and superintendent of the State Historical Society of Wisconsin aforesaid, and made oath to the correctness of the foregoing transcript and to the facts above set forth.

ANNIE A. NUNNS,

(Seal) *Notary Public, Dane County, Wisconsin.*

Commission expires August 27, 1911."

LETTER OF THOMAS FORSYTH.

Referring now to Volume 11 of the Wisconsin Historical Collections to which my attention is directed, at page 334, there is what purports to be a letter which is contained in a letter book of Thomas Forsyth, beginning on page 316. The explanation of this letter book with a biographical notice of Thomas Forsyth is contained in note 1 on page 316, which note reads as follows:

"Major Thomas Forsyth had been for several years engaged in the fur trade,—on Saginaw bay at Chicago, on an island in the Mississippi near Quincy, and at Peoria,—and had acquired much influence over the Indians of Illinois, especially the Pottow ttomies, previous to his appointment as government Indian agent for the Illinois district, at the outset of the war of 1812-1815. His headquarters were at Peoria. Upon the close of the war, he served as agent for the Sacs and Foxes, closing his official relations with them previous to the Black Hawk outbreak in 1832. In Wis. Hist. Colls., vi, p. 188 will be found a sketch of his career; and in the same volume (pp.

188-219), there are given the journal of his notable voyage from St. Louis to the falls of St. Anthony, in 1819 and a letter of his to Governor William Clark, of the same year. Further biographical material may be obtained in Scharf's Hist. St. Louis, pp. 1293, 1294; Reynold's Pion. Hist. Illinois (ed. 1887) p. 247; Hurlburt's Chicago Antiquities, pp. 469, 470, and miscellaneous references in Washburne's The Edwards Papers. In 1868, Major Forsyth's son, Robert, permitted the Society to make a complete transcript of his father's letter books covering the period, 1814 to 1825. The selections given in vol. vi. of these collections, above cited, are the only publications from these letter-books, thus far made. There are now selected such portions of the first book as refer to the war of 1812-15. They throw new light on this interesting period of our history, and are given in this volume, wherein the British operations are so fully set forth in the reports and letters of McDougall, McKay Dickson and Grignon, as showing the other side of the picture—the means adopted by the Americans to keep the Illinois Indians in line with our interests and prevent them co-operating with the savage allies of England. In this important work, Forsyth's services are shown to have been of great value.—Ed."

I find on page 334 a passage relating to the use of the Chicago-Desplaines route.

The said passage referred to is as follows:

"There is a good deal of talk at present in this place about the British and Indians coming down to attack our frontiers this season, but this I cannot believe, without they had a sufficienty of regular troops to garrison the different places, at this place, Ste. Genevieve Kaskaskia, &c. It is true they might come down this season with a very large Indian army and carry fire and sword through our frontiers as they can at any time raise from three to four thousand Indians without including the Sioux, or the Mississippi or any of the Missouri Indians, viz:

Saukies & Foxes amounting to 1200, deduct 200 said now to be friendly in Missouri remains.....1000
Pottawattamies can furnish 1200 warriors but suppose one-half will not come if asked..... 600
Winnebagoes will come to a man..... 400
Folle Avoines will come to a man. They are Dickson's garde de corps..... 200
Ottawas of Lake Michigan in their birch bark canoes can be easily brought down by way of Chicago & the Illinois river 800
Kickapoos when altogether 400
Chippeways in and about Green Bay & Milwaukee, without including the Chippewas north of Green Bay and those about Sault de Ste. Marie and Lake Superior 200

Total 3,600

Making an aggregate of thirty-six hundred on a very moderate calculation; nevertheless it does not appear to me that any invasion will be attempted this season, but if the reports are correct as respects Spain having declared war against us I should not be surprised if the Spaniards came down the Missouri by way of River Platte with a great body of Indians and perhaps the British at the same time may come down from the Mississippi or Illinois River, who will also bring down another body of Indians, by which means in indiscriminate massacre must take place, for let the British and Spaniards be ever so inclined to keep the savages from killing in cool blood, it will be out of their power from the great number of Indians they will bring with them."

LETTER OF LEWIS CASS TO SECRETARY OF WAR.

(Prof. Alvord continuing):

The Governor Cass referred to in the certified copy of certain papers of the office of Indian affairs in the Department of the Interior of the United States Government, to which my attention is called, was Governor of Michigan and naturally interested in stopping the monopoly which the subjects of Great Britain living in Canada had of the fur trade in the lake region, and this is a letter from the Governor which will speak for itself, in which he points out what must be done in order to develop the upper Northwest. As a part of that record there is a communication from John Kinzie. John

Kinzie was the first English speaking citizen of Chicago, living here for a great many years. He was a hard-headed trader seeking his own commercial advantages. He knew the upper Illinois region extremely well from personal experience, and has the indorsement of Governor Cass as to his knowledge and veracity. Kinzie was settled at Chicago for the purpose of trading with the fur traders, and also taking in their furs as they came to Chicago.

Whereupon there was offered in evidence a letter of Governor Cass to the Secretary of War, and the letter of John Kinzie to Governor Cass to which was attached a certificate from the Department of the Interior, certifying to their being true copies of the original, as follows:

"Detroit, June 20, 1815.

Sir: I had intended by this time to have submitted to you a general view of the state of Indian affairs in the Country and of the measures necessary to be adopted to secure permanent tranquility upon the frontiers.

But so much of my time is engaged by applications and visits from the Indians that I find it impracticable to effect this object immediately. I am only able to submit to you the accompanying propositions, which are the result of my inquiries and which is adopted will I trust cause a salutary reform in the state of our Indian Relations.

The privilege which British traders have heretofore enjoyed of carrying on a lucrative commerce with the Indians is a subject which will doubtless engage the attention of the Govt. To this source may be traced most of the difficulties we have experienced in our intercourse with them, I have every reason to believe that the Indian Department opposite to us are about to adopt the same systematick course of measures, which they have so long and so successfully pursued but with renewed activity and increased exertion—A deputation of one influential Chief from each of the different tribes left Malden shortly since for the lower province and another follows in a few days. What their precise object is we have not yet been able to ascertain, but such enquiries are making as will soon disclose it to us. There is little doubt however, of its relating to a general systematick and vigorous organization of their Indian Department. In the meantime a large quantity of goods have arrived at Malden to be distributed as presents and the Agents and subordinate officers are more numerous than at any for-

mer period. These unerring indications give us timely warning that the same measures are to be adopted, the same lying system continued (pardon the epithey, could all the facts be presented to you, you would say no milder term could be used) and the same plan of filling out Indian Country with the agents and Interpreters and traders which have at all former periods kept the North Western frontiers in a state of feverish alarm.

I am aware that the Government are compelled to view the whole ground and that it may become necessary to grant to the British the privileges heretofore held among the Indians in order to secure to our Country commercial rights more important to the nation at large. Is it with a view to such a possible event, that I submit these propositions to you. Their adoption will be found to counteract in a very considerable degree causes which have heretofore operated without any check.

Should it be found necessary in a treaty of commerce to make such a stipulation, the evil would be diminished by allowing to British subjects this privilege under the same restrictions it is granted to American citizens. This will secure to us the right of recalling them, when we find their machinations injurious or when their obvious purpose of trading is to cover a plan for scattering disaffection among the Indians.

There are three great channels of communication, by which traders may introduce the goods into the Mississippi and Missouri country from the British dominions. One is by the way of Chicago, and down the Illinois, another by way of Green Bay up the Fox River down the Ouisconsin. This has been the great thoroughfare along which goods have been taken: Immense quantities have been smuggled to the Mississippi and it is calculated that not more than one third part of those sold in the Indian Country, ever pay duties. The establishment of a post at Green Bay and at Prairie du Chien will close this line of communication. Another at Chicago will effect the same object upon the Illinois. There will, then remain a route to be taken, which has heretofore been little used. It is up a small river which enters Lake Superior near the Grand Portage and along a number of small lakes with portages to heads of the Mississippi. I am informed by intelligent men that this is the only route, after closing those by Chicago and Green Bay which is practicable.

If the British traders are eventually to be excluded, a

post near the Grand Portage will be necessary to effect this object. Should other considerations render their admission proper the post would still be necessary to ensure a collection of the duties and to enforce the regulations proper to be adopted. A display of the power of the United States in that remote quarter would be productive of salutary effects upon the minds of the Indians.

Should it be deemed proper to establish a post in that Country the previous arrangements should be made this fall in order that we may be ready to proceed at the opening of the navigation.

I am inclined to believe if these posts are all established and proper regulations adopted at the various agencies, that British traders may be admitted without very serious inconvenience. Certain I am that their admission will not be attended with the same evils, which have heretofore been experienced.

Mr. Jouett the Agent for Green Bay has arrived here, he has been long acquainted with Mr. Kinzie whom I recommended to you for the appointment of Agent at Chicago, I have requested Mr. Jouett to address you upon the subject.

Very respectfully Sir
I have the honor to be Yrs. etc. etc.

Directed to Hon. A. J. Dallas, Acting Secretary of War Indian Off. Bk. 204, Letter Bk. 1 Pens. Bldg. p. 90)"

LETTER OF JOHN KINZIE TO GOVERNOR CASS.

"Detroit, 15 July, 1815.

To His Excellency Lewis Cass, Esq.,
Governor of Michigan Territory.

Sir:

Taking into consideration the importance of that section of Country, lying on the Southern extremity of Lake Michigan, to our Government and having been upwards of twenty years residence of that portion of United States acquired a knowledge of its importance, I thus take the liberty of laying my observations before you. The executive of the United States appears anxious to establish a peaceable and friendly intercourse with the Indian tribes, the most determinedly hostile are the Chippewa, Pottawattomies, Ottawa of L'arbre Croche, and the Winnebago tribes, who inhabit the country between the Southern

extremity of Lake Michigan and Michillimackinac, and whose chief residence is upon Grand and Muskeegon rivers, but, who from the want of a proper supply of game, are compelled to emigrate at certain seasons to the waters of Chicago, Illinois and Fox Rivers. The hostility of those tribes is owing to their intercourse with the traders of S. W. Company, whose intercourse and of course whose policy is to render them inimical to all American traders, from what I have already said the importance of establishing a military post at or near the place of their general rendezvous will at once present itself the spot which is most important and which will possess the greatest advantages is that on which Fort Dearborn formerly stood as those tribes generally rendezvous there in the Spring consequently a garrison would be necessary to reduce trade and intercourse with them to a system and to prevent frauds and misrepresentations from the agents of another government whose interference will ever keep them hostile to the United States.

As the navigation of those waters will in a few years become an object of great importance to the U. States as at present boats of several tons burthen can pass from Lake Michigan into the Mississippi River there being only four, and half feet difference in the elevation of the two waters. Therefore it would be politick to adopt measures in due time that will secure the friendship of the hostile and fix that of the wavering. A judicious system of policy will in a few years effect more towards conciliating the tribes that are hostile than a long expensive exterminating war, and intercourse with the savages is absolutely necessary, Garrisons to protect trade and create respect for agents are equally so. Agents should act with the most impartial justice and should administer to their little wants the supplies they have been long in the habit of receiving from the British Government. While the citizens of the U. States are kept at such a distance from these tribes, and their trade so confined from the want of the arm of protection being extended over it and the intercourse of the foreign merchants (who bear away nine tenths of that important trade) allowed the American can do no other than submit in silence or coincide with the consummate and intriguing British trader or perhaps his scalp may be paid for and he fall victim of the hatchet it he has the temerity to support his country.

The only means to do away the mistaken animosity of the tribes is by the proper application of small presents to the chiefs a mild and conciliatory conduct to the nation at large and by keeping such an armed force in their neighborhood as will awe medling intruders into silence.

Chicago is all important to the Illenois country as it is the key of communication and has command of the trade a vast territory and whose navigation serves to forward the returns of the merchant to Michillimackinac at a much lower rate than they can at present be forwarded by the Mississippi owing to the difficulty of procuring boats. The Coal and Lead mines will when protected by the arm of authority become very important to this frontier as all transportation from them may be made by water.

The calling the above named tribes to Green Bay to receive annuities or other gratuities that may be granted them by the Government or to trade at that Factory will be attended with very little benefit unto the tribes mentioned, as the distance is great, the face of the country one continued morass and in the winter season impassable by the traveller owing to the depth of the Snow, therefore those tribes will suffer if they have to depend on the Agency or factory at G. Bay.

The above statement you may rely is correct. Having resided many years in the Country as an individual, I have combatted in trade against the whole Michillimackinac or S. W. Company and have many years employed a Vessel for my return furs to Detroit. I mention this to show you the importance of the Trade of the Chicago Country if correctly managed.

I am Your Excellency's
Most obt. Servt.

JOHN KINZIE."

TREATY WITH INDIANS, AUGUST 24, 1816.

The government thereupon introduced in evidence an extract from the treaty of August 24, 1816, found in volume 39, Senate Document No. 319, Indian Affairs, Laws on Treaties, Second Edition, Volume 2, the treaty having been concluded between Ninian Edwards and others, the commissioners plenipotentiary of the United States, on the one side, and the tribes of Ottawas and so forth, on the other side.

Said portion referred to is as follows:

"Whereas a serious dispute has for some time past existed between the contracting parties relative to the right to a part of the lands ceded to the United States by the tribes of Sacs and Foxes, on the third day of November one thousand eight hundred and four, and both parties being desirous of preserving a harmonious and friendly intercourse, and of establishing permanent peace and friendship, have, for the purpose of removing all difficulties, agreed to the following terms:

Art. I. The said chief and warriors, for themselves and the tribes they represent, agree to relinquish, and hereby do relinquish, to the United States, all their right, claim and title, to all the land contained in the before mentioned cession of the Sacs and Foxes, which lies south of a due west line from the southern extremity of Lake Michigan to the Mississippi River. And they moreover cede to the United States all the land contained within the following bounds, to-wit: beginning on the left bank of the Fox river of Illinois, ten miles above the mouth of said Fox river; thence running so as to cross Dandy creek, ten miles above its mouth, thence, in a direct line to a point ten miles north of the west end of the Portage, between Chicago creek, which empties into Lake Michigan, and the river DesPlaines, a fork of the Illinois; thence, in a direct line to a point on Lake Michigan ten miles northward of the mouth of Chicago river; thence along the lake to a point ten miles southward of the mouth of said Chicago creek; thence, in a direct line, to a point on the Kankakee, ten miles above its mouth; thence, with the said Kankakee and the Illinois river, to the mouth of Fox river, and thence to the beginning: *Provided, Nevertheless* That the said tribes shall be permitted to hunt and fish within the limits of the land hereby relinquished and ceded, so long as it may continue to be the property of the United States.

In witness whereof, the said Ninian Edwards, William Clark and Auguste Chouteau, commissioners aforesaid, and the chiefs and warriors of the aforesaid tribes, have hereunto subscribed their names and affixed their seals, this twenty-fourth day of August, one thousand eight hundred and sixteen, and of the independence of the United States the forty-first."

DARBY'S TOUR WITH EXTRACT FROM THE ST. LOUIS ENGINEER.

(Prof. Alvord continuing):

This book which is now shown me is entitled "A Tour from the City of New York to Detroit in the Michigan Territory, made between the 2d of May and the 22d of September, 1818, by William Darby, Member of the New York Historical Society. Author of a Map and Statistical Account of Louisiana; and Emigrant's Guide. New York, 1819."

William Darby was a very well known writer of that period, published quite extensively. He was a surveyor and was employed in 1818 by the United States and commissioned to run the line between Canada and the United States. Previous to that he had lived for many years in Louisiana, and it was after his residence there that he published his statistical account of Louisiana. He was particularly interested in opening up the trade of the West and was regarded by contemporaries as one of the authorities on the possibility of western trade. He was very much interested in the opening up of the Erie Canal which was to assist New York in getting her share of the western trade; and for similar reasons those merchants of New York that were interested in securing the trade, corresponded with him and talked with him about the possibilities of extending their trade farther westward, so that he investigated the conditions of the far west with the purpose of advancing the trade of the eastern colonies.

He himself was very broad minded, he did not feel that the opening up of the west should depend upon the interests of any particular state such as New York, but that the interests of all were the same; that the advantages which might accrue from opening up water routes into the west or road routes, must be based upon the common interests of all the people of the United States and the people of the west.

I find in that book a reference to the river route by way of the Chicago and Desplaines river in addenda No. 2, page xxvll, as follows:

(Darby's Tour. Add. No. 2. p. xxvll.):

"The foregoing correspondence and extracts, contains the substance of my own personal observations, and such explanatory matter from others, as I could collect during my tour, and since its termination; I cannot, however, take leave of the reader, without claiming his patience during a recapitulation, and an examination of some extraneous matter, which was not included in my original letters, though of some importance to elucidate the topo-

graphy of the country over which I ranged. I am aware that such productions as mine; where few personal incidents were introduced, must draw their interest from the geographical information they may contain. It has been my endeavor to throw as much light as in my power, upon the natural structure, and present improvements of the tract over which I ranged; how far I have succeeded, is now before the reader. There is one object of general interest upon which more is perhaps expected from me than I can fulfill; that is, the Grand Canal now in progress in the state of New York. On the subject of this truly great work, I have been careful to collect all the information I could procure, and have now presented the result to the public. Not having visited Ballston or Saratoga Springs, I addressed a letter to the Rev. Reuben Sears, desiring that gentleman to give me such information as he possessed, respecting these places of public resort. Mr. Sears very politely and satisfactorily replied to my letter; his answer I have annexed to this Addenda confident that it contains much valuable statistical matter.

In my letter to Mr. C. C. Haines, I have explained my views of the connexions that nature seems to have designed between New York and Pennsylvania, and can add but little in this place to what I then stated. From the demonstrations I have given of the true respective levels, between the head waters of the branches of Ohio river and those which flow into Lake Erie, the formation of water communication between these streams must be attended with great difficulty. We will now proceed to examine some of the various intended channels of intercommunication between the Mississippi and St. Lawrence vallies, and also the routes of the two New York canals.

No doubt now remains but that the Chicago and Illinois rivers, afford by far the most eligible natural connexion between the northern and southern waters of the United States. It appears that the great spine running from the Hudson to the Maumee river, terminates at, or is interrupted by the valley of the Illinois. The latter stream is formed towards its source by two branches, one of which rises south of lake Michigan and the other (river Plein) rises in the flat country west of the Chicago and flowing south, unite to the southwest of the extreme south part of Michigan. The Chicago heads in the same plain

with the river Plein and winding for some distance parallel to the latter stream, thence turns east, falls into lake Michigan. The Chicago and Plein intermingle their sources, and afford one of those instances where rivers have their sources in plains, so nearly approaching the curve of a real sphere as to leave for the discharge of the waters scarce inclination sufficient to determine their courses. This is the case with the two rivers we are now reviewing. The precise descent of the Chicago, from its nearest approach to the Plein, to the level of Lake Michigan has never been ascertained but it is known to be without falls, or even rapids. The Plein also flows with a very slight current and the two streams present almost a strait between the Mississippi river and lake Michigan."

At this point there is the following foot note:

"The following interesting notice, decides the long contested problem of a natural water communication between the waters of the St. Lawrence and Mississippi rivers, and contains also some other items of valuable information.

From the St. Louis Enquirer.

Communication with the lakes. Messrs. Graham and Phillips, commissioners on the part of the United States, and Mr. Sullivan, surveyor have set out to Lake Michigan to mark the boundary lines of the lands ceded to the United States by the Ottawa, Chippewa, and Pottawattima Indians in the summer of the year 1816.

They will run a line from the southern extremity of this lake to the Mississippi.

The Indians have ceded to the United States what lies to the south of this line.

The commissioners will run two other lines from the southwestern part of Lake Michigan, to the Illinois river. The lines will be parallel to each other, and twenty miles apart. They will begin in the shore of the lake at points ten miles north and south of Chicago and will embrace the little rivers Chicago and Plein and the carrying place between them, which form the channel of communication between Lake Michigan and the Illinois river. The Indians have ceded to the United States this important pass with ten miles of country on each side of it and it is the business of the commissioners to mark out the limits of

the grant that the American government may reduce it to possession.

The communication between the lake and the Illinois is a point which will fix the attention of the merchant and the statesman. They will see in it the gate which is to open the northern seas into the valley of the Mississippi and which is to connect New York and New Orleans by a water line which the combined navies of the world cannot cut off. Never did the work of nature require so little from the hand of art to complete so great a design.

The Lakes Superior, Huron, Erie and Ontario lie from west to east in the direction of the St. Lawrence, manifestly seeking their outlet through the valley of that river. But the Michigan departs from that direction; she lies from north to south. United to the other lakes by a strait, she stretches the body of her water down toward the head of the Illinois river, as if intending to discharge herself through that channel into the Mississippi. And no hills or mountains intervene to prevent the conjunction. On the contrary, the ground between is flat and covered with ponds in wet weather, which turn their waters partly to the lake and partly to the river. The Chicago and the Plein are the drains from these ponds; they have neither falls nor shoals; they have not the character of streams but of canals; the water hardly moves in their deep and narrow channels. The Illinois itself is more a canal than a river, having hardly current enough to bend the lofty grass which grows in its bed. The French of Canada and of the Valley of the Mississippi have communicated through this channel since the settlement of the countries. In high water, boats of ten or a dozen tons pass without obstruction. In dry season they are unloaded placed on vehicles and drawn by oxen over a portage of a few miles, and launched into the river or lake as the course of the voyage may require. Hundreds nay thousands of boats have been seen at St. Louis, which had made a similar passage.

The land contiguous to this important pass was ceded to the United States by the savage tribes who formerly possessed the right of soil. The land thus ceded, is now about being surveyed, and in course will ere long be sold to individuals and settled. The development of the natural resources of this region will be disclosed with the ordinary celerity, that marks the newly established settlements in our western world.

The course of Lake Michigan contributes in some measure to diminish the natural advantages of its connexion with the Illinois. The mouth of the Calumet River, or southern part of Lake Michigan, is near N. Lat. 42; whilst the straits of Michilimackinac is about 45 degrees, 40 minutes, making a difference of latitude of three degrees forty minutes. This difference of geographical position exposes the two extremes of Lake Michigan to great variety of climate; the navigation of the northern parts being annually and of the southern frequently impeded by ice. I have annexed to this Addenda, tables which will exhibit the relative distance from the City of New York to St. Louis by the Canadian Lakes and by the Ohio River. These routes, however, are so different from each other in climate, facilities and impediment, that very little accurate induction can be drawn from their respective length to determine a preference.

It can scarcely be doubted, but that beyond Buffalo when the contiguous countries are equally inhabited, the Illinois river and Canadian Lakes will form the channel of communication with the upper waters of the Mississippi in preference to the route by the Ohio. The navigation of the latter river is subject to great embarrassment from frost and long dry weather in the fall season. So much of the northern channel of commerce permits the use of vessels of considerable tonnage, that transportation from Buffalo to Chicago, will be less expensive than that of any equal distance by the Ohio route. If the people of the United States ought to ever unite, in opening a channel of communication it is that by the Illinois river and Lake Michigan. If the various points from St. Louis to Buffalo were united by commercial facility, a numerous population would be the immediate consequence, a population that would spread a shield before the interior parts of our country and would give a preponderance upon the St. Lawrence waters to the people of the United States, which in future wars would prevent a repitition of some of the disastrous events of the late contest with Great Britain."

REPORT OF MAJOR STEPHEN H. LONG.

(Prof. Alvord continuing):

Referring to the State papers of the First Session of the 16th Congress, and particularly to a report of Major Stephen

H. Long to the Secretary of War, I would say that Major Long was in charge of the expedition to investigate the practicability of waterways and particularly the use of this water course, Chicago and Desplaines, and has made a very careful report based upon observation. I am familiar with the publication of these various state papers and the facts with reference to their compilation and publication. They are the publications of the various reports and documents that are laid before congress.

The said report from Stephen H. Long is as follows:

"Department of War

28th December, 1819.

Sir: In compliance with a resolution of the House of Representatives of the 15th inst., directing the secretary of War to lay before that house the several topographical reports that have been made to the War Department, in pursuance of instructions to that effect, respecting the practicability of uniting by a canal the waters of the Illinois river and those of Lake Michigan, and such other information as he may be in possession of on that subject, I have the honer to transmit an extract of Major Long's report, and a copy of a report made by R. Graham and Joseph Philips, Esquires, which comprehend all the information on the subject in this department.

I have the Honor to be
Very respectfully, Sir,
Your most obedient Servant
J. C. Calhoun.

Hon. Henry Clay,
Speaker of the House of Representatives, U. S.

"Extract from a report of Major Stephen H. Long to George Graham, Esq., Acting Secretary of War, dated Washington, March 4, 1817.

The Illinois is formed by the union of three considerable rivers, the Des Planes, the DePage and the Kankakee, the last of which is nearly double the size of either of the two former. The Illinois is about three hundred miles in length and is of variable width from 70 yards to one mile. It has a very moderate current and a depth of water sufficient to render it navigable, at all time, for boats of considerable burden about 230 miles from its mouth. At the mouth of the Vermillion there are rapids, perceivable only

in the lower stages of winter. Farther up the water is not generally so deep as it is below the Vermillion.

The Valley of the Illinois varies in its width from three to ten miles; is, generally, flat and marshy, and, for the most part, subject to inundation, when the river has no more than a medial height. In some parts of it, however, prairies and bottoms of considerable extent are to be met with, elevated much above high water mark. In ascending the river, the bluffs, gradually decrease in height, being about 150 feet high at the mouth and about 100 feet at the head of the river. Imbedded in the bluffs, are strata of limestone, slate and coal, which, occasionally make their appearance along the surface of the declivities.

The river DesPlanes is a small stream rising in the lowlands, bordering upon the west side of Lake Michigan and has its general course in a southwesterly direction. The Valley of this river has an average width of about one mile and is terminated on both sides by regular banks nearly parallel to each other, extending along the river about thirty miles from the head of the Illinois. In ascending this river, also the banks and bluffs gradually decrease in height being as before mentioned about one hundred feet high at the mouth and only 100 or 125 at the distance of 30 miles higher up the river, where, instead of maintaining their parallel direction, they form nearly right angles with the course of the river, that on the right taking an easterly, and that on left a northwesterly course; but, being gradually inflected from these courses, they form extensive curves encircling a large tract of flat prairie, in no part elevated more than 12 or 14 feet above the common level of the water in this vicinity. The river, throughout the above mentioned distance has four or five short rapids or ripples that make their appearance only in times of low water. In every other part it has the appearance of being a chain, of stagnant pools and small lakes, affording a sufficient depth of water for boats of moderate draught.

In the flat prairie, above mentioned, is a small lake, about 5 miles in length and from 6 to 30 or 40 yards in width, communicating both with the river DesPlaines and Chicago river by means of a kind of canal which has been made partly by the current of water, and partly by the French and Indians for the purpose of getting their boats across in that direction, in time of high water. The dis-

tance from the river DesPlanes to Chicago river by this water course is about 9 miles through the greater part of which there is more or less water, so that the portage is seldom more than three miles in the driest season, but in the wet season boats pass and repass with facility between the two rivers.

The rivers DePage and Kankakee bear nearly the same character in regards to their bluffs, valleys, &c., that has been given to the DesPlanes. The former of these rivers takes its rise a few miles west of that of the DesPlanes and has a course nearly parallel with it. The latter rises in a flat marshy country in the neighborhood of the St. Joseph of the Lake, and runs meandering course westwardly passing the southern extremity of Lake Michigan at a distance of 20 or 30 miles from it. Near the head of this river is a small creek falling into St. Joseph, through which boats have passed in time of high water from the St. Joseph to the Kankakee. The country through which the DesPlanes, DePage and the Kankakee rivers take their course, appears to be underlaid with a vast bed of limestone which occasionally makes it appearance in the valleys of those rivers, covered with a soil too thin to support vegetation.

Chicago river is merely an arm of the lake dividing itself into two branches, at the distance of one mile inland from its communication with the lake. The north branch extends along the western side of the lake about 30 miles and receives some few tributaries. The south branch has an extent of only 5 or 6 miles, and receives no supplies except from the small lake of the prairie above described. The river and each of its branches are of variable widths, from 15 to 50 yards, and, for two or three miles inland have a sufficient depth of water to admit of almost any burden. The entrance into lake Michigan, however, which is 30 yards wide is obstructed by a sandbar about 70 yards broad, upon the highest part of which, the water is usually no more than two feet deep. The difficulty of removing this obstruction would not be great. Piers might be sunk on both sides of the entrance and the sand removed from between them. By this means, the river would be rendered safe and commodious harbor, for shipping, a convenience which is seldom to be met with on the shores of Lake Michigan.

The St. Joseph of the Lake is navigable to batteaux, to a very considerable distance in all stages of the water.

The St. Joseph and St. Mary's of the Maumes are rivers of considerable size and extent. The latter in wet seasons is navigable for perogues to fort St. Mary's, 150 miles from its confluence with the former, by the course of the river. Its branches interlock with those of the Wabash and Big Miami. The St. Joseph is navigable about 50 miles, its tributaries interlocking with those of the St. Joseph of the Lake, the Kankakee and the Wabash. The Maumee of the Lake is one hundred miles in length and is navigable for batteaux and perogues throughout its whole extent in all stages of water; about 30 miles above its mouth are the Wolf Rapids. The face of the water, however, is not so great as to occasion any very serious obstruction to the navigation of the river. The courses and relative positions of the several rivers and creeks may be seen by recurring to the plans.

Proposed Canals and Roads.

A canal uniting the waters of the Illinois with those of Lake Michigan, may be considered the first in importance of any in this quarter of the country, and, at the same time, the construction of it would be attended with very little expense compared with the magnitude of the object. The water course which is already opened between the river DesPlanes and Chicago river needs, but little more excavation to render it sufficiently capacious for all the purposes of a canal. It may be supplied with water at all times of the year, by constructing a dam of moderate height across the DesPlanes, which would give the water of that river a sufficient elevation to supply a canal extending from one river to the other. It would be necessary also, to construct locks at the extremities of the canal that communicating with Chicago river being calculated to elevate about six feet, and that communicating with the DesPlanes about four feet.

To render the DesPlanes and Illinois navigable for small boats and flats requiring but a small draught of water, nothing more is necessary than the construction of sluices, in a few places where there are ripples of a sufficient width to admit the boats to pass through them. This may be effected by clearing away the loose stones

from the bottom and forming banks rivited with stones two or three feet high on each side of the sluices, thus, the water communications between the Illinois and Lake Michigan may be kept open at all time sufficient to answer all the purpose for which a canal will be wanted for many years to come. A canal uniting the St. Joseph of the lake with the Illinois by way of Kankakee may be constructed also in a similar manner, and with great facility, except that the distance by this route is considerably greater.

There are various other places where water communications may be opened in this quarter by means of canals, to great advantage, of which the following are but a small proportion, viz; between the St. Joseph of the Lake and the St. Joseph of the Maumee; between the latter and the Wabash and between the Illinois and the Wabash by way of the Sangano river. A canal also uniting the Mississippi and Ohio, a little above their junction would be a great public utility, particularly should a general depot for military stores be established near the mouth of the latter. The objects of this canal would be to shorten the distance by water from the contemplated site of the depot, northwardly, to avoid a part of the Mississippi, difficult to navigate, and to render the depot accessible by an easy and safe communication both from the Ohio and the Mississippi."

REPORT OF R. GRAHAM, ASSISTANT SECRETARY OF WAR, AND JOSEPH PHILIPS, CHIEF JUSTICE OF ILLINOIS.

(Prof. Alvord continuing):

The next report attached to this same document is the report of R. Graham and Joseph Philips. Philips was one who accompanied this expedition of Major Long and made a report likewise on the subject. He was the first Chief Justice.

The said report of Graham and Philips is as follows:

"Kaskaskia, April 4th, 1819.

Sir: In addition to the notes of Mr. Sullivan, the surveyor, which describes the face of the country over which the lines were run, we beg leave to suggest some views which occurred to us in the subject of communications between the river Illinois and the Michigan Lake.

By reference to the map herewith forwarded, it will

be seen that the little river Plein coming from the northwest approaches within ten miles and a quarter of Lake Michigan, and then, bending to the southwest, unites with the Theakiki at the distance of about 50 miles, and forms the river Illinois.

The country between the Lake and the Plein at this point of approach, is a prairie (natural meadow) without trees covered with grass, and, to the eye, a perfect level. From the bank of the Plein standing on the ground, the trees are distinctly seen, with the naked eye, at Ft. Dearborn on the shore of the Lake; from Ft. Dearborn they are in like manner, seen on the bank of the Plein. Standing on any intermedeate point between the lake and the river and the judgment is at a loss to say which side the ground declines and whether the level of the Plein or the lake is the highest.

It was, however, determined, from certain data, that the level of the river was two feets, or thereabouts, above the level of the lake. From this view it would seem that the cutting of a canal in this place between the Plein and the Lake would be a work of neither skill, difficulty or expense. Small, however, as the labor would be under this view it is still diminished upon a close examination, and by finding that an arm of the lake called Chicago puts out in the direction of the Plein and that an arm of the Plein, also called Chicago, puts out in the direction of the lake. They approach within two miles of each other; so that, in common water, there is only dry ground to that extent between them. The character of these two arms is essentially different; that of the lake being about sixty feet wide, and from ten to forty feet deep; that of the river, being in high water, from four to six feet deep, and in, places a mile wide, and, in low water, either dry or reduced to a gutter. Between the heads of these two arms is also a gutter, which is dry in the dry seasons of summer and fall, and full of water in the spring, and, when thus filled with water, the boats, of six or eight tons, engaged in the Mackinaw and Mississippi trade, run through, backwards and forwards, so as to make no portage between Mackinaw and the Mississippi. This gutter, judging from the appearance of others now forming, was, at first, a path worn out by the feet of those who carried things across the portage, and afterwards deepened by the attrition of the waters until formed into

a little canal. The wind, alone, gives the water a current in this little canal, and its direction depends upon the course of the wind. Objects have been seen to float out of it from the same point to the river and to the lake.

It is incontestibly true, that an east wind will drive the water of the lake through this gutter into the Plein, and that water from Lake Michigan has been discharged by this outlet into the Mississippi, and thence into the Gulf of Mexico. It is equally incontestible, that the waters of the Plein have been driven, by the same channel, into the lake; and these phenomena may now be witnessed, at any time, when the waters are high and the wind blows hard. It follows, therefore, that to finish the canal began by nature, in this place, would require, as we have already said, but little of skill, time or expense. On opening the canal, however, two difficulties would be experienced.

1st. The Plein would be found to be above the level of the canal; its water, of course, would be diverted from its natural channel, and pass by the canal into the lake.

2d. Supposing that evil remedied by a lock to lift vessels into the Plein, yet the Plein during half of the year does not contain water enough to float a boat, and so could not become useful as a national highway.

To remedy this defect of water in the Plein two projects suggest themselves: 1st. To sink the bed of the Plein below the level of the canal and thus increase the depth of the Plein as well by feeling it out of the lake, as by collecting its water into a narrower channel. 2d. To make the canal unite with the Plein lower down in its course. A few miles lower would be sufficient to give the water of the lake a descent into the river, as the Plein has a sensible descent in this place, inasmuch that the people of Chicago, call it "The Rapids" having no other word to distinguish moving water from that which stands still. Of the Plein below its point of approach to the lake, we would remark, that it has hardly the attributes of a river, being in most places without current, and without banks lying as a sheet of water in the Prairie, some times a mile wide, and so shallow that the tall grass appears almost everywhere above its surface. Having said thus much of the facility of communication by the Chicago, we would now remark that several other routes are perfectly practicable. 1st. From a point in the lake

south of Chicago to enter the Plein below mount Juliet, at or near that is called lake du Page, but which is only a dilation of the waters of the Plein. This route would lay over level Prairie, through a multitude of small lakes or ponds, which have neither name or place in any map. 2. By a canal leaving the lake near its south end, and uniting with the Theakiki, just above its confluence with the Plein. Both of these canals would be fed from the lake, would require few or no locks, would go over ground of the same sort, would be 50 or 60 miles long, and would join the waters of the Illinois at points from which it is constantly navigable. A third route was spoken of, but not seen by us. It would lie between the Theakiki and the St. Joseph of the lake. Information says that it has been practiced by French traders. You will perceive, sir, that we have not spoken of the nature of the soil through which these several routes would pass. Not being our business to search for, and report upon the practicability of water communication, our observations were limited to what fell under the eye while engaged in another duty, and in making this report to you, it is our object to excite inquiry not to furnish plans of practicable projects. We shall, therefore, only say, on this point that the country, in general, and the bed of the Plein exhibited much loose stone and pebble, and firm ground.

To conclude, the route by the Chicago, as followed by the French since the discovery of the Illinois, presents at one season of the year an uninterrupted water communication for boats of six or eight tons burthen, between the Mississippi and the Michigan lake; at another season, a portage of two miles; at another, a portage of seven miles, from the bend of the Plein to the arm of the laek; at another, a portage of fifty miles, from the mouth of the Plein to the lake, over which there is a well beaten wagon road, and boats and their loads are hauled by oxen and vehicles kept for that purpose by the French settlers at the Chicago.

Respectfully,
Your obedient servants,
R. Graham
(Signed) Joseph Philips."

To Hon. J. C. Calhoun,
Secretary of War, Washington."

ENTRIES IN THE JOURNAL OF THE AMERICAN FUR COMPANY.

(Prof. Alvord continuing):

In Volume 12 of the Wisconsin Historical Society Collections, at page 154, which is now shown me, I find a list of the employes of the American Fur Company of 1818. On page 162 I find the following entry: "Engaged April 28, 1818. Hubbard, Gurdon S. Time, five years. Capacity, Clerk. Where engaged, Montreal. Wages $120. Where employed, Illinois river. Remarks Illinois River."

On page 376 of Volume 11 of the Wisconsin Historical Society Collections now shown me I find a list of invoices of the American Fur Co. On page 370 the following entry: "Accounts American Fur Company. Invoices 1821-2." On page 377 under a heading found on page 375: "For Account and Risk American Fur Company," there is this entry: "Antoine Deschamps & Gurdon S. Hubbard for the trade of the Iroquois River and its dependencies, Michilimackinac, Aug. 9, 1822."

ACCOUNTS OF GURDON S. HUBBARD OF HIS YEARLY TRIPS UP AND DOWN THE ILLINOIS AND DESPLAINES RIVERS, 1818-1824.

The book now shown me is entitled "Gurdon S. Hubbard, Sketch of Life, 1802-1886." It is further entitled "Incidents and Events in the life of Gurden Saltonstall Hubbard. Collected from Personal Narrations and other sources, and arranged by his Nephew, Henry E. Hamilton, 1888."

Mr. Hamilton was a nephew of Mrs. Hubbard, and lived with the Hubbards as their son. He had collected all possible data concerning his uncle and has published it in this volume, with many quotations from the Hubbard manuscript. I find in that book references to the nature of the trade in which Hubbard was engaged and the routes which were used by him on pages 39, 43, and 59-60. This account is based upon Hubbard's own narrative.

The passage on page 39 is as follows:

> "After a few days at Chicago spent in repairing our boats, we struck camp and proceeded up the lagoon, or what is now known as the South Branch, camping at a point near the present commencement of the Illinois and Michigan Canal, where we remained one day preparing to pass our boats through Mud Lake into the Aux Plaines River.
>
> Mud Lake drained partly into the Aux Plaines and partly through a narrow, crooked channel into the South

Branch, and only in very wet seasons was there sufficient water to float an empty boat. The mud was very deep, and along the edge of the lake grew tall grass and wild rice, often reaching above a man's head, and so strong and dense it was almost impossible to walk through them.

Our empty boats were pulled up the channel and in many places, where there was no water and a hard clay bottom, they were placed on short rollers and in this way moved along until the lake was reached, where we found mud thick and deep, but only at rare intervals was there water. Forked tree branches were tied upon the ends of the boat poles, and these afforded a bearing on the tussocks of grass and roots which enabled the men in the boat to push to some purpose. Four men only remained in a boat and pushed with the poles, while six or eight others waded in the mud alongside and by united efforts constantly jerking it along, so that from early dawn to dark we succeeded only in passing a part of our boats through to the AuxPlaines outlet, where we found the first hard ground. While a part of our crew were thus employed, others busied themselves in transporting our goods on their backs to the river; it was a laborious day for all.

Those who waded through the mud frequently sank to their waist, and at times were forced to cling to the side of the boat to prevent going over their heads; after reaching the end and camping for the night came the task of ridding themselves from the blood suckers.

The lake was full of these abominal black plagues, and they stuck so tight to the skin that they broke in pieces if force was used to remove them; experience had taught the use of a decoction of tobacco to remove them, and this was resorted to with good success.

Having rid ourselves of the blood suckers, we were assailed by myriads of mosquitoes, that rendered sleep hopeless, though we sought the softest spots on the ground for our beds.

Those who had waded in the lake suffered great agony, their limbs becoming swollen and inflamed, and their sufferings were not ended for two or three days.

It took us three consecutive days of such toil to pass all out boats through this miserable lake; when we finally camped on the banks of the river, our goods had all

crossed the portage and we were once more ready to proceed.

Our boats being again loaded, we resumed our voyage down the Desplaines until we reached Isle La Cache, where low water compelled us to again unload our goods in order to pass out boats over the shoal that here presented itself and again we camped after a hard days labor.

Isle La Cache took its name from a circumstance in the life of Mr. Sara, a trader who, when on his way with loaded canoes from Montreal to St. Louis, with goods for the Indian trade, on the Ohio River, camped at this point. A band of Indians demanded of him some of his goods as a tribute for the privilege of passing down the river; this was refused. The Indians then returned to their village, a short distance below, held a council, and determined to stop his canoes as he passed their village, and take by force what he had refused to give. Some of them, however, opposed this robbery and one of the band reported the act of the council to Mr. Sara.

The night was dark and misty, and Mr. Sara determined to pass if possible by strategy, but to fight rather than to accede to their demands? Fearing he might be overcome by numbers and thus lose his goods and in order to lighten his canoes, so that he could pass rapidly over the shoal places in the river, he ordered the most valuable portion of his goods removed to a grove about a mile distance on the prairie, and there hid them in holes dug in the ground (caches) removing the surplus earth to a distance, and carefully smoothing over the spot, so that no trace of the hiding place could be deen; he then armed his men with guns, tomahawks and knives, and at daybreak started on his way down the river.

Stopping at the village, he stationed his men so as to guard the canoes, and then called on the Indians for a talk which was granted; he told them that he should defend his goods; that the Great Father, the French King had given him permission to go to the Ohio River, and showed them a parchment ornamented with numerous ribbons and large red seals; he said to them 'here is my evidence, the King has made this writing and it tells you that I must not be stopped or disturbed in passing through the nations of his red children; if any harm shall

come to me he will revenge it by sending an army to destroy them and take possession of their country.'

This speech and demonstration had the desired effect, and the Indians were glad to excuse themselves; they however said that they were poor and needed clothing and tobacco; that they had no powder and but few guns and were preparing to send a delegation to St. Louis to see the Great Father's Captain to state their condition and make known their wants.

Mr. Sara replied that he was authorized to give them a present from their Great Father, and that he should have done so but for their demand and threat, but as they had repented, he would now give it to them; whereupon he handed them a small bale which he had previously prepared for that purpose, and ornamented with ribbons and sealing wax. The bale contained a few pieces of calico, powder and shot, tobacco and flints and steels for striking fire, which delighted them exceedingly.

* * * * *

Our progress from this point was very slow indeed, and most of the distance to the Illinois river our goods were carried on our backs, while our lightened boats were pulled over the shallow places, often being compelled to place poles under them, and on these drag them over the rocks and shoals. In this manner almost three weeks were occupied in reaching the mouth of Fox River and two days more brought us to the foot of Starved Rock.

* * * * *

After leaving Starved Rock we met with no further detentions from scarcity of water. We passed on our way a number of Indian villages and stopped a few hours at each, not for the purpose of trading, but only to barter tobacco and powder, for meat and Indian corn."

* * *

(Omitting to page 59, which passage describes the return trip up the river and is as follows:)

"The first night we halted at our old camp ground at the foot of Starved Rock. From this point until we reached Cache Island, our progress was very slow, averaging but from six to ten miles per day. The river was high, the current swift, and the rapids strong and as the boats were heavily laden and a cold storm prevailed, we were glad to camp early and afford the men a much-needed rest. Early the morning following we left Cache

Island and as the wind was strong from the southwest, we hoisted our square sails for the first time, and rapidly passed up the DesPlaines river, through Mud Lake to South Branch, regardless of the course of the channel, and soon reached Chicago.

We camped on the north side of the river, a small distance above Fort Dearborn, where we remained six or eight days, repairing our boats and putting them in condition for the more serious journey of coasting Lake Michigan."

(Prof. Alvord continuing):

In Volume 3 of the Michigan Pioneer and Historical Collections, on page 125, is an article entitled "Journel of Gurdon S. Hubbard, in 1818. Read before the State Pioneer Society February 4, 1880."

This was read by Gurdon S. Hubbard himself, and refers to the use of this water route by Mr. Hubbard.

The passage referred to is as follows:

"I was born at Windsor, Vermont, August 22, 1802. I first saw the Island of Mackinac on the 4th day of July, 1818, then the headquarters of the American Fur Company, under the management of Ramsay Crooks and Robert Stuart.

In March, 1818, I was engaged at Montreal as a Clerk to the American Fur Company for the term of five years on a salary of $120.00 per annum. We left Lachine on the 13th of May, in twelve Canadian Batteaux, and ascended the St. Lawrence river to Lake Ontario, sailed along its cost to Toronto, at that time called York, then we made a portage of eighteen miles to Lake Simcoe, coasting it to its southern part, then making another portage into Nottawassaga river. Our boats and effects were drawn to Lake Simcoe on wheels over what was called Young street; it was a fair road."

* * * * *

"We descended Nottawassaga river to Georgian Bay, coasting thence to Mackinac. This island was then in its gayest season. All the traders attached to the American Fur Company were assembled there, having brought in their furs, and were preparing to receive their outfits to depart again to their several trading-posts.

The resident population of this island was about 500, principally Canadian, French and half-breeds; their occupation was fishing and trading with the Indians; with

few exceptions they were poor and improvident. There was a garrison composed of about three companies.

After spending two months on the island I was detailed to the Illinois brigade of traders, under the command of Antoine des Champs, a highly educated gentleman who had been more than forty years an Indian trader on the Mississippi, Illinois, and Ohio rivers.

Our brigade of traders left Mackinaw in September, coasting the eastern shore of Lake Michigan to Chicago; there we found Fort Dearborn garrisoned by United States troops. John Kinzie and A. Ouilmett were the only white inhabitants at that period in Chicago and northern Illinois. Here, three miles up the south branch, our boats were unloaded, our merchandise was carried to the Desplaines river on the mens' backs and the empty boats were hauled through a ditch that was almost dry, to Mud Lake, half way, then through a like ditch into the DesPlaines (in high water this is good navigation), there reloading, we descended the DesPlaines river, having to partially unload our boats and carry the goods on our backs over shallow places and passing the boats over by means of rollers under them until reaching the Illinois river, where, at different points, our trading posts were located sixty or seventy miles apart. In tne spring following we returned by the same route; the rivers being full, we had no portage to make, passing the ditches and Mud Lake under full head."

(Prof. Alvord continuing):

Mr. Hubbard died in 1886 at the age of eighty-four.

Warden's History of United States, 1819.

This book which is now shown me is entitled "A Statistical, Political and Historical Account of the United States of North America; From the Period of their first Colonization to the Present Day. By D. B. Warden, Late Consul for the United States at Paris, etc. Volume 1, Edinburg 1819."

Mr. Warden was Consul at Paris for forty years. He was born in Ireland and died at Paris in 1845. He was distinguished for his scientific attainments and varied learning. He was appointed as secretary of the legation to General Armstrong, Minister of France. Later he was consul. He published an account of the United States in three volumes in 1819.

I find in Volume 1, page 120, a reference to the river route by way of the Chicago Desplaines, as follows (page 120, paragraph 17):

"The Illinois River, formerly the Theakiki is formed by the union of three considerable streams, the desPlanes (Plein), De Page and the Kankakee. The first, which rises in the low lands, bordering upon the west side of Lake Michigan runs a southwesterly course. The DePage takes its rise a few miles west of the former and has a nearly parallel course. The Kankakee rises in a flat marsh country, near the St. Joseph of the lake, and takes a meandering westerly course, passing the southern extremity of Lake Michigan, at the distance of twenty or thirty miles. After receiving the waters of this river, the Mississippi meanders through a broad valley, from six to twelve or fourteen miles in width, the sides of which rise in bluffs from the height of forty to a hundred feet. To a considerable distance from its mouth, the width of the Illinois is between 300 and 400 yards. The current runs at the rate of two miles and a half an hour, and affords an uninterrupted navigation of 230 miles for large boats, and for small ones to the distance of 460 miles, where it approaches Lake Michigan. The rapids at the mouth of Vermillion river are only perceivable when the water is low; and between it and the Chicago river. Of this water the largest portage does not exceed four miles and after heavy rains boats pass from one to the other across the isthmus, which is about eight miles in breadth; and, being low and level, a canal communication might be opened at a small expense, which, with the exception of nineteen miles of land carriage, would extend the inland navigation from New York to New Orleans."

(Prof. Alvord continuing):

Having in mind the context, the 19 miles of land carriage refers to the land carriage around Niagara Falls.

Trip of Ebenezer Childs, 1821.

The Volume now shown me is volume 4 of the Wisconsin Historical Society Collections. On page 153 begins an article entitled "Recollections of Wisconsin since 1820. By Col. Ebenezer Childs, of LaCrosse."

Ebenezer Childs was born in Massachusetts in 1797, and left that state in 1816. He went to northwest New York where

he remained for three years, and then settled in Cleveland, Ohio. He became a fur trader among the Indians. In 1821 he made a trip to St. Louis and back again. In 1827 he made a trip with cattle to Chicago. He was in 1841 with a party that was surveying the Michigan-Wisconsin line. He was appointed one of the exploring agents of the Indians in 1848. The latter part of his life was passed in Wisconsin.

I find on page 162 a reference to the use of river route in question by Colonel Childs.

Whereupon the said passage on page 162 was read into the record, as follows:

(Recollections of Wisconsin since 1820, by Col. Ebenezer Childs, of LaCrosse.)

"In 1821, I made a trip to St. Louis, in a bark canoe up the Fox river, across the portage, and down the Wisconsin to Prairie due Chien, and thence down the Mississippi. I was sixteen days on my journey, and saw but seven white men in the whole distance outside the forts. I met one keel-boat on the Mississippi bound up for Fort Armstrong at Rock Island. There was a small garrison opposite the mouth of the DesMoines River. There were but few Americans and few Spaniards at St. Louis; the inhabitants were mostly French. There was but one brick building in the place, and no buildings were located on Front street, or where the levee now is. I encamped on the sand beach, near where the old market is located. I remanied two weeks, did my business, when I was advised to return by way of the Illinois River.

I started by that route, and the next day was taken down with the ague and fever, and the day following one of my men was also taken with the same complaint, which left me with one Indian and one Frenchman to paddle my canoe. I did not provide a sufficiently large stock of provisions when I left St. Louis, presuming that I could get plenty on the Illinois. But all I was able to obtain was one ham, full of maggots and one peck of Indian meal. I saw but one house from the mouth of the Illinois to Fort Clark, where Peoria now is; at which latter place one French trader resided. When we reached there, I was completely exhausted and remained a few days to recruit a little, when we left to prosecute our journey. We continued up the Illinois to the junction of the Kankakee and Eau Plaines, and thence up the Eau Plaines to where I supposed we had to make a portage to Chicago

River; but I could not see any signs of the portage. There had been heavy rains for several days, which had so raised the streams that they overflowed their banks. I concluded that I had gone far enough for the portage. So I left Eau Plains and took a northeast direction. After traveling a few miles, I found the current of the Chicago River. The whole country was inundated; I found not less than two feet of water all the way across the portage. That night I arrived at Chicago, pitched my tent on the bank of the lake, and went to the fort for provisions."

A Gazetteer of Illinois and Missouri by Beck.

(Prof. Alvord continuing):

The book which is now shown me is entitled "A Gazetteer of the States of Illinois and Missouri, containing a general view of each State—A general view of their counties—and a particular description of their towns, villages, Rivers, etc., With a Map and other Engravings. By Lewis C. Beck, A. M., Member of the New York Historical Society, and of the New York Lyceum of Natural History. Albany, 1823."

Mr. Beck was an American physician, chemist, and mineralogist; was born in Schenectady and graduated at Union. He was a professor of chemistry at Rutger's, and later in the Albany Medical College. He was an author of books on chemistry and botany, and a report on mineralogy of New York based on his own researches when a member of the New York Geological Survey of 1835 to 1841, and published as Volume 1 of the Natural History of the State of New York in 1842. Mr. Beck's Gazetteer has a very good standing among historians and has been used again and again by historians of Illinois and all the historians of the northwest as the source of material for the history of these states, and particularly for its account of the state in the year in which it was published. In his preface Mr. Beck says:

"Under the impression that a more detailed description of these states than had hitherto been published, would be useful, and perhaps interesting I commenced, shortly after my removal to Missouri in 1819, the collection of materials for the present work. I travelled over a considerable portion of these states, and became acquainted with a number of intelligent gentlemen, residing in different parts of them, who afforded me much assistance in the prosecution of my design. The different state officers, also were so obliging as to allow me

the privilege of perusing many valuable documents in their offices, and making such extracts from them as I desired. By these means I acquired the greater part of the information which is contained in the following pages. In the meantime, my visit to New York gave me an opportunity of consulting many works which I was elsewhere unable to obtain. In the very valuable library of the Historical Society, to which I had access, I found, with few exceptions all the earlier, as well as modern authors who treated of that part of Louisiana and the western country, now the states of Illinois and Missouri. Although these works for the most part consisted of the narrations of travellers of general descriptions, they afforded me the means of comparing my own observations and of adding their descriptions of such places as I had either neglected, or had been unable to visit. From the works of Marquette, Hennepin, Tonti, and Charlevoix, I obtained many interesting facts concerning the history of these states, which I have presented in a condensed form. From the more recent works of Stoddard, Brechenridge, the travels of Lewis and Clark, Pike and Bradbury, I have also derived much assistance. In treating of the lead mines and minerals of Missouri, I have constantly referred to the 'View of the Lead Mines of Missouri,' published by Mr. Schoolcraft in 1820."

I find in this volume a reference to the river route to the Mississippi by way of the Chicago and DesPlaines on page 19. It reads:

"A mere glance at the map of Illinois will be sufficient to convince a person of the least observation, that the union of Lake Michigan with the Illinois river, by means of a canal, is not only practicable, but of easy accomplishment. The position, however, does not rest upon so slight a basis; but in its support, can be adduced the concurrent testimony of all who have explored and examined the country. The fact of an easy, and during some seasons an uninterrupted communication between Lake Michigan and the head waters of the Illinois, was observed by the French at the first discovery of the country; and on this account, they immediately erected trading establishments on different parts of the route. This trade was for a long time enjoyed exclusively by the French, and it contributed in no small degree to the importance of the Canadas. But, as is well known, this has since passed into other hands, and those who dis-

covered the country were for a long time the lords of the soil, are not the mere 'hewers of wood and drawers of water.' Alas, who can account of the strange vicissitudes of fortune? Perhaps, in a few more years, those republican institutions, which are now our pride and boast, may be demolised and the eagle of liberty, now soaring proudly on our air, be driven from our shores to distant and more congenial claims.

The information of traders and voyagers was such as left no doubt of the existence of a natural canal between Lake Michigan and the Illinois, at some seasons of the year. But as the country had never been carefully examined by men of science and observation, it was difficult to ascertain what were the facilities of forming an artificial communication. All talked of the project as practicable, but none knew the manner in which it was to be accomplished. That the lakes, should be united with the Hudson and Mississippi rivers, was a project none were willing to scrutinize lest its beauty might be destroyed. But thanks to the genius and enterprise of our citizens, theories and dreams have passed away, and have been succeeded by experiment and practice.

A few years since the country south and west of Lake Michigan, was explored by Messrs. Philips and Graham. In a very interesting report which they made to the secretary of war, four different methods of forming a communication between Lake Michigan and the Illinois were proposed, viz:

First: By uniting a branch of Chicago river, which empties into Lake Michigan, and a branch of the Desplaines, which runs a southeast course and approaches within ten or eleven miles of the lakes, and then turning to the southwest, blends its waters with the Theakiki. These streams approximate within three miles of each other, and when swelled by heavy falls of rain, actually united, so that boats of 8 or 10 tons burthen pass and repass from the lakes to the Mississippi through this natural route. * * *

I shall examine each of these plans somewhat in detail; and first the junction of the Chicago River with the Des Plaines.

What is called Chicago river or creek, is merely an arm of the lake, extending in a southwesterly direction three or four miles, and fed by one or two small streams coming from the north. Hence it is on a level with the

lake, but at some seasons has a gentle current, owing to the rains and freshets. On this stream, about 4 or 5 miles from the lake, is a trading establishment, and here the portage commences which, except, in very dry seasons, is seldom more than 3 miles. From this portage to the Des Plaines, a distance of 4 or 5 miles, is a swamp which is generally filled with water, and is navigable. The whole distance from the Des Plaines to the lake is about 12 miles. The height of the Des Plaines, at the point where the swamp unites with it, is calculated at from 8 to 12 feet. It approached so near the level, that the view from the swamp to the lake is almost uninterrupted. This is further proved by the very fact that at some seasons there is a communication between the Chicago and the Desplaines, which could not be the case if there was any high land intermediate.

The Des Plaines, for 14 to 16 miles below its junction with the swamp above mentioned, has scarcely any fall, and may be said to be on a level. Below this the rapids commence, and continue for a considerable distance. A short distance below the commencement of the rapids, the lake and Desplaines are supposed to be on a level. To this place, therefore, the canal would only require an average excavation of 6 or 8 feet. It is the opinion of some who have attended to this subject, that the canal should be fed from the Desplaines; but the objections to rivers for supplies of water, apply with double force in this section of country. It is well known that in the spring, all these streams are so filled with water as to overflow their banks for a considerable distance; during this season no canal would be safe, but must unquestionable to be swept away. Again, in the autumn they are on the opposite extreme; creeks, ponds and rivers are completely drained of their water, to supply that immense and greedy conductor the Mississippi. It is not unfrequently the case, that savages and travellers are compelled to carry water with them in bladders, and that they cross the beds of large streams without finding sufficient to quench their thirst. But there is another objection to using rivers as feeders, which, though not so imminent, becomes eventually of serious moment. When the country shall be cultivated, streams swollen by showers will bring down, mixed with their waters, a proportion of mud that, in the stillness of level canal, will subside and chock it

up. There are also other objections, which are that those who construct the canal may not be acquainted with the true character of the streams; and that by the progress of industry, the large springs, and swamps which are the principal supply of those streams will be dried up."

KEATING'S ACCOUNT OF LONG'S EXPEDITION, 1823.

(Prof. Alvord continuing):

The book which is now shown me is entitled "Narrative of an Expedition to the source of St. Peter's River, Lake Winnepeek, Lake of the Woods, etc., Performed in the year 1823 by Order of the Hon. J. C. Calhoun, Secretary of War, under the Command of Stephen H. Long, U. S. T. E. Compiled from the notes of Major Long, Messrs. Say, Keating & Calhoun. By William H. Keating, A. M., etc. Professor of Mineralogy and Chemistry, as applied to the Arts, in the University of Pennsylvania, Geologist and Histriographer to the Expedition. In two Volumes. Vol. 1. London, 1825."

In his preface on page VII he says:

"The principal object which the compiler had in view, was to unite the documents confided to him, so as to present a faithful description of the country over which the party travelled, and of the few adventures which interrupted the monotony of a journey through a wilderness.

It may be well to state, that the Historical part of the narrative, together with the topographical and much of the descriptive matter has been drawn from Major Long's notes. Mr. Calhoun's manuscripts, besides contributing to the same departments, and yielding the astronomical observations, have been very valuable in furnishing the greater part of the reference to older writers. The comparisons between the observations made by our party and the assertions of former travellers, are almost entirely due to that gentleman. From Mr. Say's notes, all that relates to the zoology and botany of the country traversed has been obtained, as well as much of the matter relating to the Indians. This last department has been completed from the compiler's own notes, which have likewise furnished the geological observations. Besides which, the journals kept by each of the gentlemen have frequently completed the observations made by some other member of the party. It has been deemed unnecessary to state, in all cases, by whom the observations were made or recorded. This had, however, been done whenever the

facts appeared sufficiently interesting to require that the names of the observers should be annexed to them.

As Major Long's report to the War Department presents a concise summary of the general features of the country visited by the party, it has been thought advisable to introduce in as a conclusion to the narrative. Having been ordered to the Ohio to make an experiment to improve its navigation, according to the provisions of a late act of congress, Major Long was absent from Philadelphia during the preparation of that part of the manuscript which follows the three first chapters of the first volume. This may account for some of the inaccuracies which the work will be found to contain; it is hoped that by his presence they would have been avoided." * * *

On page VIII:

"In conclusion, the compiler has much pleasure in acknowledging the great obligations under which he lies to George Ord, Esq., one of the Vice-Presidents of the Academy of Natural Sciences, and one of the Secretaries of the American Philosopohical Society, for his assistance in the preparation of this work. Mr. Ord's perusal of the greater part of the manuscript, previous to its being put to press, has preserved it from many of the inaccuracies which it would otherwise have contained."

(Prof. Alvord continuing):

I find a reference to the Chicago-Desplaines route on page 167 as follows:

"The south fork of Chicago river takes its rise, about six miles from the fort, in a swamp which communicates also with the DesPlaines, one of the head branches of the Illinois. Having been informed that this route was frequently travelled by traders, and that it had been used by one of the officers of the garrison, who returned with provisions from St. Louis a few days before our arrival at the fort, we determined to ascend the Chicago river in order to observe this interesting division of waters. We accordingly left the fort on the 7th of June, in a boat, which, after having ascended the river about four miles, we exchanged for a narrow pirroggue that drew less water; the stream we were ascending was very narrow, rapid and crooked, presenting a great fall, it continued so for about three miles, when we reached a sort of swamp designated by the Canadian voyages under the name of le petit lac. Our course through this swamp,

which extended for three miles, was very much impeded by the high grass, weeds, etc. through which our pirogue passed with difficulty. Observing that out progress through the fen was very slow, and the day being considerably advanced, we landed on the north bank, and continued our course along the edge of the swamp for about three miles, until we reached the place where the old portage road meets the current, which was here very distinct towards the south. We were delighted at beholding for the first time, a feature so interesting in itself, but which we had afterwards an opportunity of observing frequently on the route, viz: the division of waters starting from the same source, and running in two different directions, so as to become the feeder of streams that discharge themselves into the ocean at immense distances apart. Although at the time we visited it, there was scarcely water enough to permit our pirogue to pass, we could not doubt, that in the spring of the year the route must be a very eligible one. Lieut. Hopson who accompanied us to the DesPlaines told us that he had travelled it with ease, in a boat loaded with lead and flour. The distance from the fort to the intersection of the Portage road and Desplaines is supposed to be about twelve or thirteen miles; the elevation of the feeding lake above Chicago river was estimated at five or six feet; and, it is probable that the descent to the Desplaines is less considerable. The portage road is about eleven miles lone; the usual distance travelled by land seldom however exceeds from four to nine miles; in very dry seasons it has been said to amount to thirty miles, as the portage then extends to Mount Juliet, near the confluence of the Kankakee."

Trip of John H. Fonda, 1825.

(Prof. Alvord continuing):

Referring now to volume 5 of the Wisconsin Historical Society Reports, and to the portion thereof that commences on page 205, entitled "Early Reminescences of Wisconsin, by John M. Fonda," I find in small type introducing the article, the following:

"The following series of historical papers were written by the editor of the Prairie du Chien Courier, as dictated by the aged pioneer, whose name they bear, and appeared in that paper, commencing with the number of

Feb. 15th, 1858, and extending into May following. 'We would advise all,' says the editor, 'to read the Early Reminiscences, as they are extremely interesting, and contain many historical facts, that will pay for the time spent in perusal. The subject of these sketches has been in the West for over forty years, and thirty years a resident of Prairie du Chien. He has lived to see most of the early pioneers carried to the grave. His life has been an eventful one, abounding in incidents of travel, camp and field, that will prove interesting to our readers. They are as correct and truthful as memory can make them.'

Mr. Fonda was born in Watervliet, Albany County, N. Y., and is still residing in Prairie du Chien. We have the high authority of the venerable Rev. Alfred Brunson, of Prairie du Chien, for assuring the reader that 'Mr. Fonda's narrative is as reliable as anything of the kind given from memory.' "

The "L. C. D." is Lyman C. Draper, Secretary of the Wisconsin Historical Society for many years. I find also a reference to the Chicago Des-Plaines river route on page 216 as follows:

"While engaged in securing the choicest portions of the venison, our Indian guide told us it was but a short distance to a larger body of water, on the shores of which lived the chief of his tribe, whose name was Muck-ke-tay-pay-nay. This piece of intelligence made us think we were near the large lake—Lake Michigan; but we were disappointed, for late in the afternoon, we entered the foot of Lake Peoria, and were met at landing by a number of Indians, from whom we learned that it was more than two hundred miles to the nearest trading post on the lake, which was Chicago. We had to remain with this tribe several days, before our guide would leave the encampment; and during which time I saw several Indians of other tribes, one of whom was Black Hawk, whom I afterward found out, as then trying to get these Indians to join the Winnebagoes against the whites in the North-West. At length the councils were concluded, and our guide signified his willingness to proceed. Under his direction we paddled along until we came to the Desplaines river, from which we passed into a large slough or lake, that must have led us into a branch of the Chicago river, for we followed a stream that brought us opposite Fort Dearborn.'

At this period, Chicago was merely an Indian agency; it contained about fourteen houses, and not more than 75 or 100 inhabitants at the most. An agent of the American Fur Company named Gurdon S. Hubbard, then occupied the Fort. The staple business seemed to be carried on by Indians, and run-away soldiers, who hunted ducks and musk rats in the marshes. There was a great deal of low land, and mostly destitute of timber. The principal inhabitants were the agent, Mr. Hubbard, a Frenchman by the name of Ouilmette, and John B. Beaubien."

There is a foot note reading as follows:

"Antoine Ouilmette, whose wife was a Pottawattamie woman, is mentioned in the treaty at Prarie du Chien, in 1839, with the Chippewas, Ottowas, etc; and at the treaty of Chicago, September 1863, provision is made for his children. It would appear that he died during the interim between the two treaties. L. C. D."

Drown's Record and Historical View of Peoria.

(Prof. Alvord continuing):

The book now shown me is entitled "Drown's Record and Historical View of Peoria, from the Discovery by the French Jesuit Missionaries in the Seventeenth Century to the Present time. Also an Almanac for 1851. By F. DeWitt Drown, Peoria, 1850."

This is one of those volumes of local description written by a man that was interested in antiquarianism, who made a compilation, the basis of which was descriptions and histories written by others, and also the reminiscences of the men among whom he lived. Historians would use this as source material accepting those statements in it which would be based upon information which he might well have obtained.

This book was used by Judge McCulloch. I find it in a reference to the Des Plaines-Chicago river route on page 83. Said extract is as follows:

"Another of our old pioneers and citizens, who is still with us, Mr. John Hamlin, of Mass. He came here in the spring of 1821 from Springfield, in company with Judge Lockwood, Judge Lathem (who afterwards became a citizen and proprietor of city lots, and died here in 1826, and whom I shall have occasion hereafter to notice.) Maj. Iles, Gen. J. Adams, and a Mr. Winchester, Maj. Graham, Indian agent, of St. Louis, came here about that time with a keel boat and proceeded up to LaSalle prairie (Rome)

where he paid off the Indians their annuity. Some of them returned and settled here subsequently, and became useful citizens in building up our city.

In 1832 an Indian Agency was opened and established here by the Government, of which Judge Latham was appointed Agent, in place of Maj. Graham, of St. Louis, where it had heretofore been kept. John Hamlin, Esq., was a clerk, in and kept a branch of the American Fur Company's store in this place, in one of the buildings in the center of the view between Water st. and the Lake—the building from the right, just below the Inn sign-post. In this store were kept Indian commodities chiefly. A portion, however, was adapted to the wants of the citizens, who, at this time, were few. Mr. Hamlin while thus engaged in this store, exported the first produce to Chicago in 1825, in keel boats as far as the mouth of the Kankakee river, and from there in Durham boats to Chicago (having built a storehouse at the former place to store in from the keel boats to be taken by the Durham boats up the Aux Plain river.

The principal articles exported were pork, beans and other provisions for the use of the Fur Company. There were but a very few families till within a few years of this time, in the present bounds of the city, till about 1832."

(Prof. Alvord continuing):

If the historian were going to use this material he would regard Drown's Peoria as belonging to the primary source of materials, containing information by a man who would have been able to have perceived things himself and would have been able to have learned from others the facts. He would not use Drown's for the history of the 18th century. That he has taken, of course, from other narratives, and, he is not a trained historian capable of estimating historical evidence, but that information contained in the book, based upon his own observations, or based upon the observations of others, would be taken by historians as source material, and so used as they use other source material. I would regard the facts stated as of weight to be taken into consideration in connection with facts stated by others of a similar nature. All good histories are based upon the use of such material, and the fact that the historians states ultimately is the one which he deducts from a number of statements of that kind, from that class of material, and that is the way we have to write history.

I stated that David McCulloch had given some consideration to the book to which I have just referred. Mr. McCulloch is dead.

The book now shown me is entitled "Early Days of Peoria and Chicago, by David McCulloch," which I have already characterized. And he refers in this book to the Hamlin incident covered by Mr. Drown's book, as follows:

> "The difficulties and dangers accompanying trade and travel in those early days may be illustrated by a very few incidents. Farmers were accustomed to haul their grain, pork and other products from Peoria to Chicago by wagon, and there to purchase lumber for their houses, salt for their pork and supplies for their families. Those doing business on the river transported their pork, furs, peltries and other products by Mackinaw boats and canoes, making the portage between the Desplaines and Chicago rivers by land. While in the fur business at Peoria, John Hamlin conceived the bold idea of shipping his pork by keel-boat a portion of the distance, the remainder by Mackinaw boat to Chicago. Packing his pork in a keel-boat and his fur in a Mackinaw boat, he proceeded to the mouth of the Desplaines, where he unloaded his keel-boat and built a depot for his pork, leaving the same in charge of some boatmen, while he went through with his Mackinaw boat by way of Summit and Mud Lake to the Chicago river and arrived safely at Chicago with his furs. He then returned and brought his pork through in the same way, thus establishing a continuous waterway for trade between the Great Lakes and the Mississippi Valley."

REPORT OF SELECT COMMITTEE OF CONGRESS FEBRUARY 1, 1825.

Whereupon the attorneys for the government offered in evidence the "Report of the Select Committee to which was referred on the 3rd ultimo, a memorial of the General Assembly of Illinois, upon the subject of a Canal Communication between the Illinois River and Lake Michigan accompanied with a bill to aid the State of Illinois in the accomplishment of the same," which is found in the Reports of Committees, 18th Congress, Second Session, printed under the authority of Congress. Report No. 53, as follows:

> "February 1, 1825. Read, and, with the Bill, committed to a Committee of the whole House.

The Select Committee to which was referred the memorial of the General Assembly of the State of Illinois, praying for aid from the United States in opening a canal to connect the water of the Illinois river and Lake Michigan, respectfully submit the following report.

The memorial represents that the committee find to be true, that in 1820, a law was passed by Congress, authorizing the said state to open a canal through the public lands to effect this communication, which is required to be done within a given period. It further represents that the General Assembly has already proceeded so far as to appoint commissioners to explore the route and prepare the necessary surveys and estimates preparatory to its execution. It further represents that the state is unable out of its own resources, to defray the expenses of the undertaking; and, therefore, prays Congress to make to the state a grant of public land, or such other assistance, as may be thought most proper to enable the state to proceed with the work.

In examining this subject, the attention of the committee has been drawn to several points which seem naturally to bear upon it; the first, as to the practicability of making the proposed connection of those waters. On this branch of their inquiries the committee can see no room to doubt. Although the report of the state commissioners and engineers had not been made to the General Assembly at the time of adopting the memorial that has been referred to the committee, the legislature of that state entertained no doubt on that point. Such, indeed, is the concurrence of scientific observation and actual experience in relation to that fact, that in order to establish it the report was not necessary. The experience to which the committee refers, is that of many years, and which is matter of historical notoriety. It is that of repeated passages having been made, by uninterrupted navigation from the river into the lake. With respect to the scientific observations that have been made, the committee refer to the report of Major Long to the Secretary of War in 1817, and which was printed by order of Congress. In this report (see vol, 2, No. 17 of the reports of the first session of the 16th Congress) it is stated that 'the Illinois river is about 300 miles in length, and is of variable width, from seventy yards to one mile. It has a very moderate current, and a depth

of water sufficient to render it navigable, at all times, for boats of considerable burden, about 230 miles from its mouth.' In speaking of the proposed canal, Major Long observes, 'a canal uniting the waters of the Illinois river with those of Lake Michigan, may be considered the first in importance of any in this quarter of the country, and at the same time the construction of it would be attended with very little expense compared with the magnitude of the object. By a reference to the document before referred to it will also be seen that another report was made on the same subject by Richard Graham, Esq., and the late Chief Justice Philips, of the State of Illinois. Without quoting particularly from their intelligent report, it will be sufficient to observe that they coincide substantially with Major Long. They present, however, the further fact that is perfectly practicable to employ the water of the lake, as to furnish a full supply of water for the canal.''

REPORT OF THE COMMITTEE ON ROADS AND CANALS, MARCH 30, 1826.

Counsel for the government also offered in evidence the report of the Committee on Roads and Canals, "to which was referred a memorial of the General Assembly of the State of Illinois, concerning a canal to connect Lake Michigan and the Illinois river, the same having been made March 30, 1826," which is found in the report of Committees, first session 19th Congress, published under authority of Congress and stated that the full committee adopted the report of the Select Committee which has just been offered in evidence and that the final report of the entire committee was the same as the Select Committee, and it is not recopied in the record because it is a mere production of the preceding extract.

EXTRACTS FROM THE NAVIGATOR.

(Prof. Alvord continuing):

The book which is now shown me is entitled "The Navigator, Containing Directions For Navigating The Ohio and Mississippi Rivers; With An Ample Account of These Much Admired Waters, From The Head Of The Former To The Mouth Of The Latter; And A concise Description Of Their Towns, Villages, Harbors, Settlements, &c. With Maps Of The

Ohio And Mississippi, To Which Is Added An Appendix Containing An Account Of Louisiana, And Of The Missouri And Columbia Rivers, As Discovered By The Voyage Under Capts. Lewis And Clark." Published at Pittsburg, 1824.

In the advertisement at the beginning we find the following:

"This edition of the Navigator, being the eleventh since the year 1801 is respectfully presented to the public. It being designedly calculated as an useful and necessary guide to those who navigate or trade on the rivers of which it treats—much pains have been taken to revise, correct and enlarge it throughout. To do this satisfactorily, we have had the assistance of several of the most eminent pilots and navigators, and the use of late manuscript, journals of gentlemen of observation, to whom we present our compliments for their aid and politeness.

* * *

This edition is considerably enlarged by a more comprehensive description of the principal towns on and adjacent to the rivers; their commerce and manufacturers; natural curiosities of the country, etc. The directions for navigating the Mississippi river from the mouth of the Illinois to that of the Ohio river, with the description of the district of Mobile, and geographical notice of Florida will be found interesting."

(Prof. Alvord continuing):

This book is regarded by historians as the source of information in regard to the west and the navigation of the rivers in the west and has been used as such by historians. I find in this book a passage at page 113 a reference to the river route in question as follows:

"Between a branch of the Illinois and the Chicago river, which empties into Lake Michigan there is a portage of two miles; from this portage to the lake is a batteaux navigation of 16 miles. By this happy connection of waters, there is a complete communication from New York to New Orleans, through that northern and extensive route, having only about 28 miles land carriage in the distance of nearly 4000 miles, the greatest stretch of inland navigation perhaps known in the world. This route from New York is by the Hudson river to Albany; thence by land to Schenectedy, 16 miles; thence up the Mohawk river, and through a canal of 4 miles into Wood creek; thence into Lake Ontario, and up that lake and

Niagara river to Queenstown, 7 miles below the falls of Niagara; thence ten miles land carriage around said falls to Chippeway, thence up the river into Lake Erie, and through that lake into Lake St. Clair; thence into Lake Huron through Lake Michigan, and into the Chicago river mentioned above; thence down the Illinois and Mississippi rivers. This route comprehends the most extensive channels, and gives a wide scope to trade in general, and may one day be made a very profitable use of to individual citizens, as well as highly advantageous to the trade and commerce of the United States, especially if they get possession of the northern fur trade now carried on by the British."

FLINT'S HISTORY, 1832.

(Prof. Alvord continuing):

The book to which my attention is now directed is entitled "The History and Geography of the Mississippi Valley. To which is appended a Condensed Physical Geography of the Atlantic United States, and the whole American Continent. Second Edition. By Timothy Flint. Author of 'Recollections of the Last Ten Years in the Mississippi Valley.' In two volumes. Vol. 1. Cincinnati, 1832."

Timothy Flint was a very famous writer, and western pioneer. He was born in Massachusetts in 1780 and died in Salem in 1840. He was a Congregational minister and missionary to the Mississippi Valley after 1815. He left the active practice of ministry and became a teacher at Cincinnati and on the Red River. In 1825, broken in health, he went back to Massachusetts. In 1833 he was editor of the Knickerbocker Western Review, Cincinnati, and lived at Alexandria, Virginia. He published a history and geography of the Mississippi Valley, Indian Wars in the West; Memoir of Daniel Boone; Recollections of last ten years in the Mississippi Valley.

Flint was one of the most widely read writers on the west of his age. His books had a very large sale both in this country and in Europe. He traveled extensively over the west and everybody has given him the reputation of being a keen observer and a man who was careful in making statements of facts. On page 322 of his book occurs the following:

"Rivers. It is only necessary to look on the map of this state, to see what astonishing advantages for in-

land navigation nature has given it. On its northern extent it has for a great distance the waters of Lake Michigan, and the boatable streams that empty into it; and by this vast body of waters, a communication is opened with the northern fronts of Indiana and Ohio; with New York and Canada. On the northwest frontier it has Rock River, a long, beautiful and boatable river of the Mississippi. On the whole western front it is washed by the Mississippi; and on its southern by the Ohio. On the east it is bounded by the Wabash. Through its centre, winds, in one direction, the Illinois, connecting the Mississippi with Lake Michigan by the Plein and Kankakee, a river, excepting a short distance of shoals, almost as uniformly boatable as a canal; and in another direction, the beautiful Kaskaskia winds through the state. Besides these, there are great numbers of boatable streams, penetrating the state in every direction. Such is the intersection of this state by these waters, that no settlement in it is far from a point of boatable communication, either with Lake Michigan, the Mississippi, or the Ohio. It may be added that when the state shall have been inhabited as it will be, as no country affords greater facilities for making canals, from the friability of the soil, its levelness, and the proximity of the source of the boatable waters to each other, canals will complete the chain of communications, and transport will be almost as entirely by water in Illinois, as it now is in Holland or China. At present the state is supposed to have 4,000 miles of boatable waters in her limits.

The Illinois, which gives name to the state, may be considered the most important river, whose whole course is in it. It rises in the northeastern parts of the state, not more than 35 miles from the southwestern extremity of lake Michigan and interlocking by a morass with the river Chicago, which empties into that lake. Its two main head branches are Plein and Kankakee. Thirty miles from the junction of these rivers, enters Fox Rixer, from the north. Between this and the Vermillion, enter two or three inconsiderable rivers. The Vermillion is a considerable stream, which enters the Illinois from the south, 260 miles above the Mississippi. Not far below this river, and two hundred and ten miles above the Mississippi commences Peoria lake, which is no more than an enlargement of the river, two miles wide, on an average, and twenty miles in length. Such is the depth

and regularity of the bottom, that it has no perceptible current whatever. It is a beautiful sheet of water, with romantic shores, generally bounded by prairies; and no waters in the world furnish finer sport for the angler. M'Kee's and Red Bud enter not far from this point. Crow-Meadow River almost interlocks, at its course, with the Vermillion of the Wabash. Two or three inconsiderable streams enter the river from the north, not far from the lower extremity of Peoria Lake. Still lower down enters from the south Michilimackinack, a very considerable stream, boatable nearly a hundred miles from the river into the interior. Below this enter Spoon and Crooked Rivers. Still lower down on the same side enters the Sangamon by a mouth 100 yards wide; and is boatable 140 miles. From its position, and the excellence of its land, it is one of the most important rivers of the state. Chariton, Otter, Apple and Macoupin Rivers are all considerable streams, that water fine tracts of country.

On the north side of the Illinois, the rivers that enter on that shore, have their courses, for the most part, in mountainous bluffs, which often approach near the river. For a great distance above its mouth, the river is almost as straight as a canal; has in summer scarcely a perceptible current, and the waters, though transparent, have a marshy taste to a degree to be almost unpotable. The river is wide and deep; and for the greater part of its width, is filled with aquatic weeds, to such a degree that no person could swim among them. Only a few yards width, in the centre of the stream, is free from them. It enters the Mississippi through a deep forest, by a mouth 400 yards wide. Perhaps no river of the western country has so fine a boatable navigation for such a great distance, or waters a richer and more luxuriant tract of country. On the banks of this river the first French immigrants from Canada fixed themselves; and here was the scenery on which they founded their extravagant paintings of the western country. By a moderate amount of labor and expense, this river might be united with the Chicago of Lake Michigan. Appropriations have already been made by the state for the canal, that is intended to effectuate this purpose. We have already remarked that at certain seasons of the year, boats of five tons burden already pass through the morass, from one extremity of which the waters are discharged

into the Chicago of Lake Michigan; and from the other into the Plein of the Illinois; thus furnishing a natural communication between the two rivers, whose outlets are so wide and opposite from each other. Indeed, by the most obvious appearances, along the Illinois and some of its waters, as the Plein for example, it is manifest, that lake Michigan once discharged at least a part of its surplus waters into the Mississippi. This, too, may explain the obvious appearance in that lake of being now many feet lower than once it was. This fact is palpably marked everywhere along the rocky shores of the lake."

SCHOOLCRAFT'S STATEMENT OF 1832.

(Prof. Alvord continuing):

The next book called to my attention is entitled "Narrative of an Expedition Through the Upper Mississippi to Itasca Lake, the Actual Source of this River: Embracing an Exploratory Trip Through the St. Croix and Burntwood (Or Broule) Rivers; in 1832. Under the direction of Henry R. Schoolcraft."

The book is dedicated to Gen. Hugh Brady of the United States Army. In the preface occurs the following:

"The Hon. Hugh Brady, of the United States Army."

"The circumstances under which the present expedition was undertaken, are indicated in the following extract from the letters of instruction.

Detroit, Aug. 9, 1830.

Sirs: I have been directed by the War Department to request you to proceed into the Chippewas country, to endeavor to put an end to the hostilities between the Chippewas and the Sioux. The general route must be left to your discretion. Whether it will be necessary for you to go beyond Fond du lac, you can best determine on your arrival there. From the limited means applicable to this object, I am apprehensive that your journey cannot be extended beyond that place. But in that event, it will be necessary to summon some of the principal Mississippi chiefs to meet you, as without concurrence no durable pacification can be effected. * * *"

(Signed) "LEW CASS."

August 9, 1830.

(Prof. Alvord continuing):

The letter is dated August 9, 1830.

There also appears the following letter dated May 3, 1832:

"Department of War,

Office of Indian Affairs, May 3, 1832.

Sir:

Your letter of Feb. 13th has been received and its general views are approved. The Secretary of War deems it important that you should proceed to the country upon the heads of the Mississippi, and visit as many of the Indians in that, and the intermediate region, as circumstances will permit.

Reports have reached the department, from various quarters, that the Indians upon our frontiers are in an unquiet state, and that there is a prospect of extensive hostilities among themselves. It is no less the dictate of humanity, than of policy to repress this feeling and to establish permanent peace among these tribes. It is also important to inspect the condition of the trade in that remote country, and the conduct of the traders. To ascertain whether the regulations and laws are complied with, and to suggest such alterations as may be required. And finally to inquire into the numbers standing, disposition and prospects of the Indians, and to report all the statistical facts you can procure and which will be useful to the government in its operations, or to the community in the investigation of these subjects. * * *

Signed ELBERT HERRING."

(Prof. Alvord continuing):

Elbert Herring was in the Department of War office of Indian affairs.

In Schoolcraft's book entitled "Narrative of an Expedition Through the Upper Mississippi," etc., at page 121, occurs the following passage:

"Introductory Memoranda.

The principal points at which the waters of the Mississippi River, communicate, by interlocking rivers and portages, with the lakes, are the following, proceeding from south to north, namely.

1. By the Illinois and Chicago Creek, (with Lake Michigan).

2. By the Wisconsin and Fox Rivers, (with Green Bay).

3. By the Chippewa and Mushkee (or Mauvals Rivers, with Lake Superior.)

4. By the St. Croix and Burntwood (or Brule) Rivers (do).

5. By the Savanne and St. Louis Rivers. (do)

The routes by the Illinois, and by the Wisconsin, were first laid open by French enterprise, and have been used for canoes and flat-bottomed boats in their natural state, and without any practical improvement which as yet, facilitates the communication, about a hundred and sixty years. They are so familiar in our geography have been so much explored, and are so well appreciated, as prominent points for effecting canal and railroad routes, that it is only to be desired that early and efficient measures should be taken for opening them."

EXTRACTS FROM "A WINTER IN THE WEST" BY CHARLES F. HOFFMAN, 1835.

(Prof. Alvord continuing):

The next book called to my attention is entitled "A Winter in the West," by a New Yorker. In two Volumes. Volume 1. New York, 1835.

The book is written as is well known, by Charles F. Hoffman, who was a son of Judge J. Ogden Hoffman, and was born in New York in 1806. He studied law which he practiced for several years. He was editor, with Charles King, of New York of the American, and begun the Knickerbocker Magazine. Mr. Hoffman's description of the West has been regarded by historians and others as containing facts within his observation, and also knowledge that he has obtained from others. He has a very great reputation as a narrator of his experiences in the west. In his preface he says:

"Several of these letters have already appeared in the New York American;—the favorable reception they have met with has induced the writer to complete the series and publish them in the present form. In preparing them for publication, he has thought proper to illustrate some of the facts contained in them, by observations derived from other sources or made subsequent to their date. These additions the author has preferred to place in an appendix rather than embody them with the original matter, as he feared that whatever attraction his sketches or scenery and manners might possess would evaporate upon throwing them into a different form and their chief merit as first and faithful impressions would be lost. The eloquent writings of Mr. Flint, the graphic sketches of Judge Hall, and the valuable scientific researches of Mr. Schoolcraft, Professor Keating, and the lamented Say,

have already made the regions described in these pages well known to the public; but there is an ever-salient freshness in the theme of "The Far West."

On page 242 of his book occurs a letter which is dated Chicago, Illinois, January 10, 1834.

"The town (Chicago) lies upon a deal level along the banks of a narrow forked river, and is spread over a wide extent of surface to the shores of the lake, while vessels of considerable draught of water can, by means of the river unload in the center of the place. I believe I have already mentioned that four-fifths of the population have come in since last spring; the erection of new buildings during the summer has been in the same proportion; and although a place of such mushroom growth can, of course, boast of but little solid improvement in the way of building, yet contracts have been made for the ensuing season which must soon give Chicago much of that metropolitan appearance it is destined so promptly to assume. As a place of business, its situation at the central head of the Mississippi Valley will make it the New Orleans of the north; and its easy and close intercourse with the most flourishing eastern cities will give it the advantage, as its capital increases, of all their improvements in the mode of living.

There is one improvement to be made, however, in this section of the country which will greatly influence the permanent value of property in Chicago. I allude to a canal from the head of Lake Michigan to the head of steam navigation on the Illinois, the route of which has been long since surveyed. The distance to be overcome is something like ninety miles; and when you remember that the head-waters of the Illinois rise within eleven miles of Chicago River, and that a level plain of not more than eight feet elevation above the latter is the only intervening obstacle, you can conceive how easy it would be to drain Lake Michigan into the Mississippi by this route; boats of eighteen tons having actually passed over the intervening prairie at high water, Lake Michigan, which is several feet or more above Lake Erie, would afford such a never failing body of water that it would keep steamboats afloat on the route in the driest season. St. Louis would then be brought comparatively near to New York, while two-thirds of the Mississippi Valley would be supplied by this route immediately from the

markets of the latter. This canal is the only remaining link wanting to complete the most stupendous chain of inlaid communication in the world. I had a long conversation this morning on the subject, with Major N., the United States' engineer, who is engaged in superintending the construction of a pier at this place. He was polite enough to sketch the main features of the route with his pencil, in such a manner as to make its feasibility very apparent. The canal would pass for the whole distance through a prairie country, where every production of the field and the garden can be raised with scarcely any toil, and where the most prolific soil in the world requires no other preparation for planting than passing the plough over its bosom. The most effectual mode of making this canal would be to give the lands along its banks to an incorporated company, who should construct the work within a certain time. The matter is now merely agitated at elections as a political handle."

COMMENT BY PROFESSOR ALVORD UPON THE VALIDITY OF SCHOOLCRAFT'S STATEMENT.

The statement just referred to as contained in the volume of Henry R. Schoolcraft as follows:

"The routes by the Illinois, and by the Wisconsin, were first laid open by French enterprise, and have been used for canoes and flat-bottomed boats in their natural state, and without any practical improvement which as yet, facilitates the communication, about a hundred and sixty years."

coming from a man like Mr. Henry R. Shoolcraft would be regarded by historians as a statement by a man that was well versed in the history of the region, had made a special study of just such conditions, had had opportunities to talk with very many traders, who were accustomed to use the various trading routes, between the Mississippi waters and the great lakes, and therefore it would be given great weight as historical testimony.

WOODRUFF'S HISTORY OF WILL COUNTY.

(Prof. Alvord continuing):

The book which is now shown me is entitled "The History of Will County, Illinois, containing a History of the County, its Cities, Towns, &c., a Directory of its Real Estate

Owners; Portraits of Early Settlers and Prominent men; General and Local Statistics; Map of Will County; History of Illinois, Illustrated; History of the Northwest, Illustrated; Constitution of the United States, Miscellaneous Matters, etc., Chicago, 1878."

I find in the preface the following statement:

"In presenting our History of Will County, we deem a few prefatory words necessary. We have spared neither pains nor expense to fulfill our engagement with our patrons and make the work as complete as possible. We have acted upon the principle that justice to those who have subscribed, be they few or many, requires that the work should be as well done as if it was patronized by every citizen in the country. We do not claim that our work is entirely free from errors; such a result could not be attained by the utmost care and foresight of ordinary mortals. The General History of the County was compiled by Hon. Geo. H. Woodruff of Joliet, and the township histories by our historians, W. H. Perrin and H. H. Hill. Some of the township histories are indeed longer than others, as the townships are older, containing larger cities and towns, and have been the scenes of more important and interesting events."

(Prof. Alvord continuing):

Local historians who have compiled this book and other volumes like it, have had access to material that is not easily accessible to the general historian; and therefore they have used not only this book but books of this general character as source material for information on local conditions. I find in this book on page 607 a passage which refers to the use of the water route between Lake Michigan and the Desplaines river as follows:

"The Kankakee being navigable for small steamers to the eastern point, an outlet is thus furnished for the upper portion. Though navigation has been improved by the building of the dams at Wilmington, it has in reality been used for that purpose during wet seasons since the earliest settlements of the adjacent country. As early as 1834, the products of the farm were boated down the Kankakee to Desplaines and up the latter river to Chicago. It is related that during the year named some parties loaded a boat on Sugar Creek, a tributary to the Iroquois, with 300 bushels of oats, 300 bushels of wheat and some hams, with the design of taking them to

Chicago to supply the garrison stations there. The trip down the Kankakee was accomplished without accident or unusual trouble; but after entering the Desplaines, when near Treat's Island, the boat dipped water and so dampened the grain that they were obliged to unload and try to dispose of their produce at that point. At that time, settlers were arriving in that neighborhood quite rapidly, and they had no trouble in disposing of their whole cargo, the oats at 50 and the wheat at 75 cents per bushel. At present small steamers owned by Messrs. Small of Wilmington, and Stephen F. Hanford, of Warner's landing, ply regularly between these points and Chicago, carrying to that city corn, oats, rye, and other products, and bringing back lumber, salt, and other heavy articles. The 'Landing,' which is located near the eastern point of the township, is considered the head of navigation during the dry season but when the river is ordinarily full, boats can run much higher."

REPORT OF MAJOR WILSON, U. S. ENGINEER, 1867.

Whereupon counsel for the government introduced into the record from the report of the Secretary of War during the 3rd session of the 40th Congress, 1868-1869, the report of James H. Wilson, Lieutenant Colonel, 35th Infantry, Brevet Major General U. S. A., and William Goodwin, United States Civil Engineer to the Secretary of War. Said extract was as follows (p. 439):

"Report upon the Survey of the Illinois River. United States Engineer Office, Davenport, Iowa, December 17, 1867.

Having been designated by direction of the Secretary of War through engineer orders dated Washington, May 8, 1867, as a Board to conduct surveys and examinations and to prepare plans and estimates for a system of navigation by way of the Illinois river between the Mississippi and Lake Michigan adapted to military, naval and commercial purposes, in accordance with the Act of March 2, 1867, we have the honor to submit the following report." * * *

Omitting to page 439.

"By a careful examination of the report and profiles of this year's survey, with the map herewith submitted, it will be seen that the location of the present canal from

Bridgeport to the valley of the DesPlaines cannot be advantageously or economically changed; that it is the best, cheapest and most direct route which can be found, there having been more than enough work already done in this line to counterbalance the natural but not superior advantages of the slightly lower but more tortuous route by the way of Mud Lake; that the Calumet River and Saganaska creek route, along what is known as the Calumet feeder, would cost a great deal more than either of the others, being longer and ending at a point where there is neither a natural nor artificial harbor, and where it would be impossible to construct one which would answer the purposes of commerce and the national defense; and, finally, that it is not practicable at any cost to use any part of the Kankakee river as a part of the system of navigation in question. For the foregoing reasons, after a careful consideration of all the facts upon which they rest—a full analysis of which will be given hereinafter—we are decidedly of the opinion that in constructing such a system of navigation as the interests of the country require, the government must follow the general line of the Illinois and Michigan canal and the Illinois river. When it is considered that the summit of the Fox and Wisconsin river line is 315 feet, and that of the lake Winnebago and Rock river is 285 feet above the level of Lake Michigan, it will be seen that the line recommended by us is the only feasible route for deep-water communication between the great lakes and the Mississippi river, equally adapted to military, naval and commercial purposes." * * *

Then omitting again to page 432:

"The Desplaines river rises in the State of Wisconsin and runs nearly due south, parallel with the lake shore, and generally nor more than eight or ten miles from it, until it reaches a point about 13 miles in a southwest direction from the mouth of Chicago river. Here is a slight depression a mile or more in width extending across from the DesPlaines to the south branch of Chicago river, through which a part of the waters of the former river, in time of floods, flow into the lake. In this depression is what was once known as Portage Lake (so designated on the old maps of the country), but now better known as Mud Lake, a succession of shallow ponds on the same level connected with each other and with the DesPlaines river,

and extending about six miles toward Chicago river. This was the portage or carrying place between the waters of the lakes and the Mississippi made memorable by the early French voyageurs, and so well known to fur traders. But Portage or Mud Lake has ceased to exist, the shallow ponds having been drained, and the impassable swamps rendered valuable land.

There can be no doubt that through this depression there was once an outlet from the lakes to the Mississippi, which was closed by the recession of the waters of the lakes. Even now at the present state of Lake Michigan, its surface is only between eight and nine feet below this summit. The Desplaines river, from the depression described, changes its course and runs in a nearly southwest direction until it forms a junction with the Kankakee. The river itself, except in floods, is very shallow, being often reduced in dry seasons to a mere brook, discharging less than 1,000 cubic feet of water per minute. But the valley averages a mile wide, and is terminated on both sides by well-marked terraces which become higher and higher as they approach the Illinois. Evidence at every step presents itself that the water, when this was the great outlet of the lakes, extended from bluff to bluff."

Illinois In 1837.

(Prof. Alvord continuing):

The book which is now shown me is entitled "Illinois in 1837"; A sketch descriptive of the Situation, Boundaries, Face of the Country, Prominent Districts, Prairies, Rivers, Minerals, Animals, Agricultural Productions, Public Lands, Plans of Internal Improvement, Manufacturers, etc., of the State of Illionis; Also, Suggestions to Emigrants," and so forth, Philadelphia, 1837. The name of the author is not given. In the preface at page vii, the author writes:

"The bulk of the information hereinafter detailed is quite recent, being derived in part from the lately published and valuable Gazetteer of Illinois, and the Emigrant's Guide, by the Rev. J. M. Peck; also, from Flint's Geography and History of the Western States, Beck's Gazatteer of Illinois and Missouri, Schoolcraft's Travels and works of Darby, Hall, Long, etc. The work contains, likewise, extracts from different correspondents and

from various gazettes printed in the state, some of them only a few weeks before its publication; particularly the Peoria Register and Northwestern Gazetteer, the attention bestowed by the editor of which in distributing recent geographical and local information calculated to be useful to emigrants, renders it undoubtedly the most interesting print of the kind in the state."

(Prof. Alvord continuing):

On page 36 occurs a passage referring to this river route as follows:

"The DesPlaines river is the northern head branch of the Illinois. It rises in Wisconsin territory, a few miles west of the town of Racine, on Lake Michigan, and flowing through the north part of the state, it joins the Kankakee at the boundary line between LaSalle and Will counties, where they form the Illinois river. The Desplaines in its course of 150 miles runs generally over a bed of limestone. The country along its borders is populating rapidly, notwithstanding the apparent deficiency of timber. About forty-two miles above the mouth of this stream is a swamp connecting it with the Chicago river, through which boats of some burden have often been navigated into Lake Michigan. This route was used by the traders as a medium of communication between the Great Lakes and the Mississippi, from the first discovery of the country by Europeans;—this circumstance first suggested the idea of an artificial connexion by means of a canal at this point."

(Prof. Alvord continuing):

Referring to this work of local history and other local histories of this character, the scientifically inclined historian is obliged by the laws of his science to get back to the contemporary narrative as far as it is possible; or if it is impossible to reach the contemporary narrative, to reach these men that knew of the contemporary narrative, or had learned from contemporaries of the facts. The whole sicence of history is based upon the records that have come down to us from the past. We are unable to observe what has taken place in the past ourselves and so are obliged to trust to the narratives of men who have lived in the past for our facts.

We take these narratives and examine them, trying to find out their value as witnesses of the past facts and admits them in accordance with whether we regard them as reliable witnesses of the facts; as to whether they were capable of

knowing themselves or through others of the facts which they relate. I had this in mind in reference to Woodruff's History of Will County and the incident which is there referred to.

As to statements of old settlers in reference to that fact, historians of western America are obliged to use as source material in their investigations statements, by old settlers that have come down to us; and these are of as great value as sources, as the material that is used by the historians that have written of Greece, of Rome, and of the Middle Ages where very similar material is at hand, and in fact where material that is not as good as these statements by old settlers is used by historians.

That is the general method in which the authoritative histories in western countries have been written. The quotation from the volume "Illinois in 1837," just read, shows that when that volume was produced the fur trade in Northern Illinois had come to an end. With the close of the Black Hawk War and the transportation of the Indians in Northern Illinois across the Mississippi river, the hunters that had up until this time supplied the furs to the traders were no longer in existence in the region, and therefore there was no prospect of large profit open to traders, and the fur trade in the region came to an end.

The passing of the Indians from Northern Illinois opened the territory to immigration, and large numbers of farmers came in, men of different experience than the fur traders, with different demands. The northern portion of Illinois was quickly settled and agitation was immediately begun for transportation such as they were familiar with. The agitation was first for a canal and later for railroads and these were built and the old routes by which trade had been carried, passed out of the memory of man. As a matter of historical fact, the kind of motive power employed had something to do with the agitation for a different artery of commerce. The connection between the two was that steamboat navigation was introduced. The method of traveling on the deeper rivers by steamboats created a demand for rapid transportation, and the use of the steamboats on the lower Mississippi made of St. Louis one of the chief markets of the fur traders; traders sent their furs in that direction and down the Mississippi and through the Gulf of Mexico to Europe instead of using the old avenues of trade. St. Louis, of course, grew very rapidly after the introduction of the steamboats, and its chief history as a fur center dates from that time.

EXTRACT FROM LECTURE OF JOHN WENTWORTH.

Referring to the book now shown me, entitled "Fergus Historical Series, parts 6-9," it contains several articles which are bound into the volume. Number 7 is entitled "Early Chicago by Hon. John Wentworth," The title page reads "Early Chicago," a lecture delivered before the Sunday Lecture Society at McCormick Hall, on Sunday afternoon, May 7th, 1876, by Hon. John Wentworth, late Editor, Publisher and Proprietor of the 'Chicago Democrat,' the First Corporation Newspaper; Member of Congress for the Chicago District for twelve years; two terms Mayor; and a Settler of 1836."

I find in that article a reference to the Chicago and Desplaines river, on page 7 as follows:

> "Their route out of Chicago was down the north fork of the south branch through Mud Lake, then called la petit lac, to the Desplaines river, and generally in the same little boats with which they had passed over the lakes of the east. This route, partially interrupted by the construction of the Illinois and Michigan Canal, has been recently restored to the condition it occupied for so many hundred years, and the waters of Lake Michigan and of the Desplaines river again mingle, after a few years of unnatural separation."

EXTRACTS FROM THE NARRATIVE AND CRITICAL HISTORY OF AMERICA.

(Prof. Alvord continuing):

The volume which is now shown me is entitled "Narrative and Critical History of America, Edited by Justin Winsor, Librarian of Harvard University, Corresponding Secretary Massachusetts Historical Society. Volume V. Boston and New York. 1887."

Justin Winsor is regarded by historians as one of the greatest historians that America has produced; and this particular work of which he was general editor is one of the monuments of American scholarship. All parts of it are of course not by Winsor himself. It was prepared under his supervision and issued with his authority.

I find in that volume an article referring to this river route, on page 1 of Volume V, beginning at a chapter called "Canada and Louisiana, by Andrew McFarland Davis, American Anti-

quarian Society." On page 7 of that chapter there is contained the following statement:

"As the trade with the Valley of the Mississippi developed routes of travel began to be defined. Three of these were especially used,—one by way of Lake Erie, the Maumee, and the Wabash, and then down the Ohio; another by way of Lake Michigan, the Chicago River a portage to the Illinois, and down that river; a third by way of Green Bay, Fox River, and the Wisconsin—all three being independent of LaSalle's route from the foot of Lake Michigan to the Kankakee and Illinois rivers."

(Prof. Alvord continuing):

In Volume 4 of this same history I find a reference to this river route on page 198, which is an editorial note written by Justin Winsor himself. The particular extract occurs on page 224, note 1, as follows (4 Narr. & Crit. Hist., 224, n. 1):

"The principal portages by which passage was early made by canoes from the basin of the lakes to that of the Mississippi were five in number.

1. By Green Bay, Lake Winnebago, and the Fox River to the Wisconsin, thence to the Mississippi, the route of Joliet.

2. By the Chicago river, at the southwest of Lake Michigan to the Illinois, thence to the Mississippi. This appears in the earliest maps of Joliet and Marquette, and is displayed in the great 1684 map of Franquelin of this part of which Parkman gives a drawing in his LaSalle, which with various later ones is repeated in Hurlburt's Chicago Antiquities.

3. By the St. Joseph river, at the southeast corner of Lake Michigan, to the Kankakee and so to the Illinois. This was LaSalle's route.

4. By the St. Joseph's river to the Wabash (Ouabache); thence to the Ohio and Mississippi.

5. By the Miami River from the west end of Lake Erie to the Wabash; thence to the Ohio and Mississippi."

EXTRACTS JUSTIN WINSOR "THE MISSISSIPPI BASIN."

(Prof. Alvord continuing):

The book which is now shown me is by the same author, Justin Winsor, and is entitled "The Mississippi Basin. The Struggle in America between England and France. 1697-1763. With Full Cartographical Illustrations from Contemporary Sources by Justin Winsor, Boston and New York. 1895."

I find in this book the following reference to this river route, at page 24:

"Before the end of the seventeenth century, the portages at the head of Lake Michigan had become the best known of all, and there had been a trading-post for something like fifteen years at the Chicago River. What Herman Moll, the English cartographer called the 'Land carriage of Chekakou' is described by James Logan, in a communication which he makes in 1718 to the English Board of Trade as running from the lake three leagues up the river, then a half a league of carriage, then a mile of water, next a small carry, then two miles to the Illinois, and then one hundred and thirty leagues to the Mississippi. But descriptions varied with the seasons. It was usually called a carriage of from four to nine miles, according to the stage of the water. In dry seasons it was even farther while in wet times it might not be more than a mile; and, indeed, when the intervening lands were 'drowned' it was quite possible to pass in a canoe amid the sedges from Lake Michigan to the Desplaines, and so to the Illinois and the Mississippi."

EXTRACTS HINSDALE "THE OLD NORTHWEST."

(Prof. Alvord continuing):

The book to which I next refer is entitled "The Old Northwest. With a View of the Thirteen Colonies as Constituted by the Royal Charters. By B. A. Hinsdale, Ph. D., Professor of the Science and Art of Teaching, University of Michigan: Author of 'Schools and Studies' and Editor of 'The Works of James Abram Garfield.' New York, 1888."

Historians generally praise this work very highly and use it as the chief secondary source of their knowledge for the history of the period, which it covers. It is again and again referred to in Hart's American Nation Series, which is the latest and probably the most authoritative history of the United States.

I find in this work a reference to this river route by way of the Chicago and Desplaines, on page 44 as follows:

"The French located their principal missions and posts with admirable judgment. There is not one of them in which we cannot see the wisdom of the priest, of the soldier, and the trader combined. The triple alliance worked for an immediate end, but the sites that they

chose are as important today as they were when they chose them. The fact is, nature had decided all these questions ages before the soil of the New World had been pressed by the white man's foot. Marquette called the Straits of Mackinaw 'the key, and as it were, the gate for all the tribes from the south as the Saut is for those of the North, there being in this section of the country only these two passages by water, for a greater number of nations have to go by one or other of these channels in order to reach the French settlments. This presents a peculiarly favorable opportunity both for instructing those who pass here and also for obtaining easy access and conveyance to their places of abode.' The straits were called the 'Home of the fishes.' 'Elsewhere although they exist in large numbers,' says Marquette, 'it is not properly their home, which is in the neighborhood of Michilimackinac. It is this attraction which has heretofore drawn to a point so advantageous the greater part of the savages in this country, driven away by fear of the Iroquois.' LaSalle's colony of St. Louis was planted in one of the gardens of the world in the midst of a numerous Indian population, on the great line of travel between Lake Michigan and the Mississippi River, Kaskaskia and the neighboring settlements held the centre of the long line extending from Canada to Louisiana. The Wabash colony commanded that valley and the Lower Ohio. Detroit was a position so important, that, securely held by the French it practically banished from the English mind for fifty years the thought of acquiring the Northwest. The Indians and the beavers have long since disappeared from the region lying between the lakes and the Mississippi; that region has twice changed hands since those early days; the whole country has been transformed by the hand of man; but the Saut Canal, the Mackinaw shipping, and the cities of Chicago, St. Louis and Detroit show us how geography conditions history as well as that the savage and civilized man have much in common. Then how unerringly were the French guided to the carrying places between the northern and the southern waters, viz, Green Bay, Fox River, and the Wisconsin; the Chicago River, and the Illinois; the St. Joseph and the Kankakee the St. Joseph and the Wabash; the Maumee and the Wabash; and, later on, on the eve of the war that gave New France to England, the Chautaqua and French Creek routes from Lake Erie to the Ohio."

PROFESSOR FARRAND'S BOOK ON AMERICAN NATION SERIES.

(Prof. Alvord continuing):

The volume now shown me is a volume of the American Nation Series edited by Professor Farrand. This particular volume is regarded as one of the best of this series, and the series as a whole edited by Professor Hart is regarded as the most authoritative history of the United States that we possess, up to this time. Professor Hart is a professor of Harvard University. Just for the moment it has slipped me what institution Professor Farrand is connected with, but it can easily be found in the book.

The passage in question is as follows:

> "From the Great Lakes to the Mississippi basin there was a choice of paths. In the Northwest the French often crossed from the head of Lake Superior to the upper Mississippi by way of St. Louis River. The most important portage, however, was probably that which led from the Fox to the Wisconsin River, first used in 1673 by Joliet and Marquette, and later the site of Fort Winnebago. At the southern end of Lake Michigan an important trail led from the Chicago to the DesPlaines and so to the Illinois, on the same line as the present Chicago Drainage canal; the portage was from four to nine miles in length according to the season. Other carrying-places of that region were from the Calumet to the DesPlaines and from the St. Joseph to the Kankakee; but that from the St. Joseph to the Wabash was the principal channel of supplies from the early settlers at Vincennes."

EXTRACTS FROM SMITH'S HISTORY OF WISCONSIN IN 1854.

(Prof. Alvord continuing):

The book which is now shown me is entitled "The History of Wisconsin in three parts, Historical, Documentary, and Descriptive. Compiled by Direction of the Legislature of the State. By William R. Smith, President of the State Historical Society of Wisconsin. Part 1—Historical. Vol. 1. Madison, Wis., 1854."

This is regarded by historians as one of the best of the local state histories in the west. I know of no other book entitled "Smith History of Wisconsin." This is the volume referred to by the Supreme Court of the United States in the Montello case, in the 20th Wallace.

I find in this book a reference to this river route as follows:

"One among the first of the operations of the Western Company was to send eight hundred emigrants to Louisiana; they arrived in August, 1718, at Dauphine Island. Bienville had in the midsummer of the same year, selected the site for the capital, of the new empire, which in honor of the regent of France, he named 'New Orleans.' Of the recent emigrants from France, eighty convicts were sent among the coppices that overspread New Orleans, to prepare room for a few tents and cottages. At the end of three years the place was still a wilderness spot where two hundred persons, sent to construct a city, had but encamped among unsubdued cane-brakes. The character of the emigration was not that of industry, energy, or of information; some perished for want of enterprise, some from the climate; and in place of ascending the river in ships, they all blindly disembarked on the miserable coast, to make their way as best they could to the lands that had been ceded to them. An extraordinary instance of energy may be mentioned: DuTissenet, a Canadian emigrant, having purchased a compass, and procured an escort of fourteen Canadians, went fearlessly from Dauphin Island by way of the Mobile River to Quebec, and returned to the banks of the Mississippi with his family. At this period the three great avenues from the St. Lawrence to the Mississippi were, one by way of the Fox and Wisconsin Rivers; one by way of Chicago, which had been safely pursued since the days of Marquette; and one by the Miami of the Lakes, where after crossing the portage of three leagues over the summit level, a shallow stream led into the Wabash and the Ohio."

CONCLUSIONS OF PROFESSOR ALVORD.

Q. Now, having in mind the investigation which you have made, the different historical authorities to which you have called attention, what do you state to be your judgment as a historian with reference to the fact as to whether the Desplaines river at the point at which the dam in question in this case is being constructed, was in its natural condition actually used in the carrying on of trade and commerce?

A. As a historian, I would answer the question as follows: Giving due weight to all the sources of information that are available, my opinion is that from the latter part of the 17th

century through the first third of the 19th century, men engaged in the fur trade passed up and down the Chicago and Desplaines rivers in canoes and flatboats very regularly; that the fur trade was pursued by the French as long as they held possession of this country; was developed more fully by the English and later by the Americans. That the most active trade carried on the two rivers falls between the period of 1783 and 1825, or thereabouts; that the traders found a very easy passageway by means of these rivers in the early spring. That during the time of drought such as occurred in the summer or fall, the passage was hard, but even then they forced their boats through the waterway, often being obliged, however, to carry their packages around the shoals and rapids.

Q. Have you found in the investigation which you have made in any historical work, that in your opinion is entitled to weight, a statement to the effect that during the period with reference to which you have just testified this Chicago-Desplaines route was not used for the purpose which you have stated?

A. I have not found any historian writing of the situation in the west competent to pass judgment upon material, and who had investigated material, that denies that the Chicago and Desplaines rivers were so used.

CLIPPINGS FROM LETTERS OF EBENEZER FLAGG, 1818.

The document now shown me consists of clippings from the Alton Weekly Telegraph, the first beginning Thursday morning, April 27, 1876, and continuing for nine weeks thereafter. The editor in explanation writes:

> "Hon. W. C. Flagg has kindly placed at our disposal a number of letters written by his father, between fifty and sixty years ago. They are entitled 'Early Letters of an Early Settler' and will appear as a part of the Telegraph's Series of Pioneer Papers. The letters are nine in number and will appear under the following titles": He then gives the nine titles.
>
> "The first part of the letter appears in this number. Such of our readers, and there are many, who are interested in the pioneer history of the west, will be much interested in the 'Early Letters of an Early Settler.' "

(Prof. Alvord continuing):

These clippings were taken from the Alton Weekly Tele-

graph, published at Alton, Illinois, a well-known weekly paper of Southern Illinois.

The title of the article is: "Pioneer papers. Early Letters of an Early Settler," written by Gershom Flagg. Gershom Flagg's son, W. C. Flagg, states in the first clipping that he was the son of Dr. Ebenezer Flagg and a descendant, in the 7th generation, of Thomas Flagg.

Whereupon the witness was asked to read from the papers what was stated therein concerning Gershom Flagg.

Said extract so requested was read into the record, as follows:

> "Gershom Flagg, son of Dr. Ebenezer Flagg and a descendant, in the seventh generation, of Thomas Flagg, who emigrated from Norfolk, England, in 1637, and settled in Watertown, Mass., in 1641, was born in Orweel, Vermont, November 26, 1792, removed with his father's family to Richmond, Vermont, about the year 1800, and in 1816 at the age of 24, started west."

(Prof. Alvord continuing):

As to what I know personally of Gershom Flagg I would say, that Gershom Flagg finally settled in Madison County, Illinois, where he lived and where his descendants are now living. He was a well-known man of his age, as was his son and is his grandson today.

As to the standing of the articles of Gershom Flagg among historians in general, they would only have the standing of source material, as emanating from a pioneer of the west who had come into this region and made observations and written concerning them, letters. Such material is regarded always by historians as of the very best, as being first class, primary source material.

Q. Do you find in there any reference to the use of the Desplaines river for the purpose of navigation or as a waterway? State where it is found and what it is.

A. I find a reference to the use of the Desplaines river for the purpose of a waterway in the fifth article, entitled "Madison County, in 1818." These pioneer papers were published in the Alton Weekly Telegraph, beginning April 27, 1876, and appeared every week thereafter for nine weeks. In the fifth contribution, entitled "Madison County, in 1818," headed "Edwardsville, Madison County, Illinois ter. 12 Sept. 1818," is a passage concerning advantages for transportation; which passage is as follows:

> "The situation of this territory is good for trade, hav-

ing the advantage of water carriage on all sides. The Mississippi on the west, the Ohio and Wabash on the southeast and the Kaskaskia and Illinois in the interior of the territory. The Illinois, which is about 400 miles in length and heads near Lake Michigan. A branch of the Illinois heads within 4 miles of the head of the Chicago, a short river which empties into Lake Michigan. In freshets boats pass this portage, the waters being connected. They are made shallow for the purpose. I have seen them at St. Louis landing. I think there will be a canal cut to connect the waters of Illinois and Chicago at no distant period. From information the expense would not be great. One hundred thousand acres of land is appropriated for this purpose. This done, we have a water communication from almost any part of the territory to the States of Indiana, Ohio and Pennsylvania, on either side of these States. Also with New York by way of Lake Erie, and an easy communication with the ocean by New Orleans."

PROFESSOR A. C. McLAUGHLIN, called as a witness in the suit above referred to as a witness for the government, testified:

My full name is Andrew Cunningham McLaughlin. I live at 5609 Woodlawn avenue, Chicago. My occupation is that of professor and head of the Department of History in the University of Chicago. I have held that position four years and a half. Prior to that time I was a professor of American History in the University of Michigan since 1891. Prior to that I had been an assistant professor of history for three years, I think it was. Two years of the time when I was professor of history at the University of Michigan I was absent in charge of the Bureau of Historical Research of the Carnegie Institute at Washington. I have been associate editor of the American Historical Review for twelve years. Four years of that time I was managing editor of the American Historical Review from 1901 to 1905. I am a member of the American Historical Association; the Illinois Historical Society; corresponding member of the Massachusetts Historical Society; Wisconsin Historical Society and the American Antiquarian Society. In connection with my profession, I have written a number of historical arti-

cles and books. The principal ones would be the Life of Lewis Cass for the American Statesman Series, which I wrote about twenty years ago; an article on the Retention of the Western Coast by the British in 1783; a history of the American Nation so called, a text-book for schools; The Confederation and the Constitution, one of the volumes of the American Nation Series, published by Professor Hart; and various other articles for magazines and journals.

My department of historical research and writing has been American history in general, though I have specialized more particularly in American constitutional history. I have done some work in western history, more especially some years ago, and have overlooked the work of advanced students in the question of history to some extent. I have made a special study with reference to the methods which I used in historical research and the methods which historians use to arrive at a conclusion with reference to historical facts. I have studied books on historical methods and especially in my connection with teaching historical methods to students I have made special preparation in various ways; I have studied the methods of historical writers and I have been called upon as editor of the American Historical Review for years to examine critically articles that were sent in for publication. The object in view when I studied and made a review of these articles was to discover whether proper historical methods were used and the material handled properly, and the conclusions that were reached appeared justifiable and whether the articles were new and proprly put together and acceptable in general. One of the things which I have tried to determine has been the accuracy of the statements which appeared in those articles. There is a branch of writing in connection with the study of history and the methods of historical research which is devoted to the methods of history and there are well-recognized authorities which I have made a study and investigation of. The chiefest authority is Bernheim, Lehrbuch der Historischen Methode. Almost as well known though not as complete is Langlois and Siegnobos, introduction to the study of history. I know it in translation. George's Historical Evidence. Those are the chief things that I have in mind.

The classes of material recognized by students of history are classified commonly as source and secondary authorities. The historical investigator seeks to come just as near a fact which he is endeavoring to establish in time and place as pos-

sible. In doing so he uses the sources. In many cases in making such an investigation we may rely upon monographic material which is strictly secondary authority, but the historical investigator seeks to go to the sources technically so called. To define what I mean by sources: sources is a translation of the German word "quellen" and it means, of course, the headwaters and the actual source of a stream of information. It is defined by Bernheim in some such way as this, and this I should say would be the proper definition:

> "Sources are the relics of the past which enable us to reconstruct the past; those sources or relics either being purposely intended for the purpose of enabling us to know what went on in the past, or by nature adapted to such purpose."

The historical student seeks if possible to reduce every statement so far as he can to an actual observation and in order to do that he endeavors to get just as near to the facts as he can. As a matter of fact he often has to use very insufficient observations at times and he does not always have at his hand facts that are stated by participants in events or in those facts, or those that have actually seen the occurrences. The consequence is that there is a somewhat loose definition of different classes of historical sources. In the first place, they are the actual relics or survivals of the past activities of man. These include not only buildings, very evident tangible survivals of that kind, but books of account and papers of that kind which generally do not need to be submitted to the ordinary tests of psychological character. These first are commonly called the unconscious sources, though there might be other unconscious sources that would not come under this definition of survivals or ueberreste, as the Germans call it.

In the second place, we would have the account of a contemporary who knew of his own knowledge what happened, the events which he narrates.

In the third place, we should have accounts by a contemporary who very evidently and distinctly based his evidence upon the knowledge of others and upon the reports of others.

Also, in the next place, we have accounts that are not strictly by contemporaries but by persons much nearer the events in time and place than we are and who seem to have had opportunity for ascertaining those facts. These are not strictly primary sources and are necessarily subjected to a much closer criticism, perhaps used with more doubt in gen-

eral than are the other classes of sources of which I have spoken.

A contemporary map might be an actual description of what one himself had actually seen. If so, it would come under the second general division that I have marked here. Otherwise it would be under the third.

We might have maps which appear to us trustworthy which would be classified under the fourth of these general divisions which I have given, made by a man who had the reputation of being a careful map maker and seemed to have materials for reaching his conclusions that we do not have. Those would naturally be included under the fourth of these general divisions. I think, however, we should call those sources if they were not strictly contemporary but nevertheless of the general character I have described. It must be confessed when we get over into the fourth of these divisions our classifications is somewhat loose and I think that is true generally of the writers on this subject.

Having in mind the method of historical study and research which I have briefly outlined, and having in mind my experience as an investigator of historical subjects, I would state as the method that the historian would follow in seeking to ascertain whether or not a certain river, the Desplaines River for instance, was at any time used for purposes of trade and commerce, as a historian I should myself use the well recognized secondary authorities, first in order to get my general bearings and get the assistance of reference and other guidances of that sort. Then I should proceed to examine the accounts of men who had actually used the river as a route of trade and commerce, if any such could be discovered. I should also endeavor to discover statements by contemporaries concerning the use of that river even if they had not been actual users of it themselves. I should examine the maps and the gazetteers and the books of travel written or prepared by persons on whose general judgment and observation I felt I could rely.

As to classifying different books as accurate and inaccurate, and rejecting any of them with reference to determining whether each one was accurate or inaccurate, I would say that the historian commonly does not classify books in that way when he is endeavoring to establish a historical fact. Nothing is better established than that a single primary source may be trustworthy in some respects and untrustworthy in others. If the matter was in doubt he would subject the

source to various tests and see whether there were any reasons for doubting one portion and accepting another. When I said "on which I could rely," if a person is well known as a careful writer, if he appears to have a capacity for careful observations, his conclusions are naturally accepted with more force than if he appeared to be a careless observer or writer. But the statements of a person who is guilty of inaccuracies are not necessarily rejected if they appear on the whole to stand the test of the examination.

As to the standing of county histories, I should say that there are all kinds of county histories and town histories. Some of them are of the very highest quality. In general, however, the writer of a county or town history is not a trained historian and is likely to accept or is not unlikely let me say, to accept facts without the careful examination that the trained historian would accept them under. At the same time, those writers have access to a kind of material which the general historian cannot have access to and in many respects these town histories include material that is strictly source material and which the historical student necessarily uses and often uses with gratitude to the writer of these books. So that, in making a historical investigation of a given subject, I make use of incidents which I find referred to in material of that kind, giving to a particular reference the weight to which from all the circumstances it appears to be entitled. So that with reference to a particular statement that is found in the books there might be a distinction between the weight given to that statement and the weight given to the book as a whole. * * *

CONCLUSION OF PROFESSOR A. C. MCLAUGHLIN.

Referring now to the period from the time of Charlevoix to the year 1825, and basing my answer upon the sources of historical information to which my attention has been specifically directed, assuming that as a historical writer I was preparing a history of Illinois, concerning the use of the Desplaines River, I should say that the Desplaines River was used with apparently considerable frequency as a route of trade and commerce; that at certain seasons of the year it seemed to have presented some difficulties, other seasons of the year it was used with considerable ease, and that it was a well known means of communication between the lake region and the lower Illinois and Mississippi.

I know Mr. Alvord who testified in this case most favorably as an historian. I have had occasion in my extended historical work to come in contact with his work.

DR. REUBEN GOLD THWAITES, called as a witness in the case above referred to in behalf of the Government, testified:

I reside at Madison, Wisconsin. In the past twenty-four years I have been Secretary and Superintendent of the State Historical Society of Wisconsin. A part of my duties as Superintendent of what we shall call the Wisconsin Historical Society for a short cut, is to conduct investigations of the society and superintend its publications.

I am a member of the Wisconsin Historical Commission; also its secretary and the editor of its publications. I am a lecturer on American History in the State University of Wisconsin, my special field being the period of discovery, exploration and settlement of the basin of the St. Lawrence, the Great Lakes and the Mississippi River, from the period of earliest discovery to about the year 1850. I also give a course at the University on historical methods, especially with reference to the preparation of manuscript material for publication. I will say that in the course of preparation for these duties that I have mentioned, I have been obliged to make a study of source material, especially upon the history of the French occupation of North America from 1604 to 1763; and of the British occupation of the West from 1760 to 1816; and later, the American occupation of the West from 1776 to about the year 1850.

I will say that in the consultation of original sources I have sought access to all the material I could obtain, both printed and manuscript, concerning this region and this period that I have mentioned. I have spent much time in personal investigation of the various scholarly centers where such original source material is kept, including many of the official archives in Canada, in the United States, and to some extent in Europe, particularly Paris. I have also had a great many personal interviews with large number of voyageurs and fur traders and English and American pioneers in this region.

As a result of these various investigations and studies, I have published the following works as author: "Down Historic Waterways," in 1888; "The Story of Wisconsin," in 1890; "The Colonies" (meaning the American Colonies),

"from 1492 to 1750." That was published in 1891. "On the Storied Ohio," in 1897; "Stories of the Badger States," in 1900; "A History of the University of Wisconsin," in 1900; "The Life of Father Marquette," in 1902; "The Life of Daniel Boone" in the same year, 1902; "How George Rogers Clark Won the Northwest and other Essays in Western History," in 1903; "A Brief History of Rocky Mountain Exploration," in 1904. The volume entitled "France in America" in the American Nation Series, in 1905; and the volume entitled "Wisconsin" in the Commonwealth Series, in 1909.

I have edited the following works: "Volumes 11 to 19 of the Wisconsin Historical Collections." These have been published between the years 1908 and 1910; the 1910 volume is just out. "Chronicles of Border Warfare," in 1895; "The Jesuit Relations and Allied Documents," published in 73 volumes between 1896 and 1901; "Mrs. Kinzie's Wau-Nun," a reprint published for the Caxton Club of Chicago, in 1901; "Early Western Travels from 1748 to 1846," the series published in 31 volumes between the years 1904 and 1906; "Hennepin's a New Discovery" published in two volumes in 1903; "Lahontan's New Voyages to North America," a series of two volumes published in 1905; "Documentary History of Dunmore's War," in 1905; and the "Original Journals of the Lewis and Clark Expedition," published in eight volumes in 1904 to 1906. "The Revolution on the Upper Ohio, from 1775 to 1777" published in 1905.

In addition to the above, I have prepared and edited numerous monographs, magazine articles, and public addresses bearing upon my particular field of study.

I served for a time as Chairman of the American Historical Manuscript Commission, which is one of the activities or branches of the American Historical Association; I have also been a member of the council of the American Historical Association, and am at present a member of its committee on Historical Sites in the United States. I am a member of the American Antiquarian Association, corresponding member of the Massachusetts Historical Society, and am either an honorary or corresponding member of a large number of like associations and societies in the United States and Canada, some fifty in all I believe. Among these I may mention the historical societies of Minnesota, Illinois, Michigan, Chicago, Mississippi Valley, Ohio Valley, and the Southern Historical Association.

It is a fact that some of these societies elect members sim-

ply because of the actual work that those member have done in the field of historical research. The American Antiquarian Society is an organization of that character. I am a member of that society. The corresponding membership list of the Massachusetts Society falls under the same category. I have been a corresponding member of that society some ten years back.

I am superintendent, practically librarian, of the Wisconsin Historical Society. I was president of the American Library Association for the years 1899 and 1900. * * *

ADDITIONAL EXTRACTS FROM LIFE OF GURDON S. HUBBARD.

Prof. Thwaites (continuing):

Referring to a book which I hold in my hand entitled "Incidents and Events in the Life of Gurdon Saltonstall Hubbard, collected from personal narrations and other sources, and arranged by his nephew, Henry E. Hamilton," published at Chicago in 1888, being the book from which extracts have already been introduced into the record, I would say that this narrative of Mr. Hubbard's, from which this book is for the most part made up, appears to have been written about the year 1880. I gather this from a sentence from page 11, of that book, wherein he says:

> "Though sixty-two years have passed since then, I distinctly remember the animating and affecting scene presented that morning."

He here refers to an event which occurred in the year 1818. Mr. Hubbard had been engaged in the fur trade in Northern Illinois for a long term of years; his personal reminiscences, therefore, constitute a history of that trade, in this region, so far as his personal experience brought him into touch with that commerce?

On page 10 of his life, I learned that he was first engaged by the American Fur Company in the spring of 1818. He described upon that page the nature of his outfit, his wardrobe, and the other articles necessary to take with him, and he says:

> "On the 13th of May, 1818, having bid adieu to my mother and sisters, I started with my father and brother for Lachine, where I arrived about nine o'clock in the morning and reported for duty."

The American Fur Company, of which John Jacob Astor was the moving spirit, was at this time conducting a widespread commerce with the Indians for furs throughout the entire region of the upper Great Lakes, the upper Mississippi Valley and the upper Missouri Valley. This company was the

dominating force in the fur trade of this vast region. Their chief distributing point in the west was upon the Island of Mackinaw. Upon this island they had their general offices and large warehouses to which they transported in sailing vessels the merchandise which they took into the west for the purpose of exchanging with the Indians for furs. From Mackinaw Island they sent out brigades or crews of fur traders to visit the outlying fur trading posts upon the upper Great Lakes and the rivers of the west and the northwest. The fleets of boats were propelled by engages or voyageurs and there were at the head of such fleets one or more clerks or bourgeois.

Upon page 21, Mr. Hubbard says:

> "The force of the company when all were assembled on the island, comprised about four hundred clerks and traders, together with some two thousand voyageurs."

At Mackinac Island the brigades as they were for the most part called, were provisioned and equipped and otherwise made ready to go to the particular trading territory assigned to each brigade.

On page 24 Mr. Hubbard describes one of these brigades in the following language:

> "The 'brigade' destined for the Lake of the Woods, having the longest journey to make, was the first to depart. They were transported in boats called 'Batteaux,' which very much resembled the boats now used by fishermen on the Great Lakes, except that they were larger, and were each manned by a crew of five men besides a clerk. Four of the men rowed while the fifth steered. Each boat carried about three tons of merchandise, together with the clothing of the men and rations of corn and tallow. No shelter was provided for the voyageurs, and their luggage was confined to twenty pounds in weight, carried in a bag provided for that purpose."

On the same page Mr. Hubbard further says:

> "The clerks were furnished with salt pork, a bag of flour, tea and coffee, and a tent for shelter, and messed with the commander and orderly."

On page 25, Mr. Hubbard states that he was at first detailed to the brigade headed for Fond du Lac of Lake Superior,—that is, the bay on which is today situated the City of Duluth, Minnesota. But about this time he says that he received a letter from his father to the effect that his father and brother were to be in St. Louis and that the commander of the

"Wabash and Illinois outfit" always sent a boat to St. Louis to purchase supplies for his various fur trading posts. For this reason Mr. Hubbard asked to be assigned to that brigade and his request was granted.

On page 23 I learn that the commander of the "Illinois brigade" was Mr. Deschamps. Mr. Hubbard says of Mr. Deschamps:

> "He at the age of nineteen engaged himself to Mr. Sara (by whom he meant Gabriel Cerre), a fur trader at St. Louis, and had devoted many years of his life to the Indian trade on the Ohio and Illinois Rivers. When the American Fur Company was organized he was engaged by them and placed in charge of the 'Illinois brigade' or outfit."

I will now follow the first trip made by Mr. Hubbard. On page 28 of the book before us there is this description by Mr. Hubbard of the Illinois brigade:

> "Some of our boats were crowded with the families of the traders, the oldest of whom was Mr. Bieson, a large, portly, gray-headed man, who was then about sixty years of age, and for more than forty years had been an Indian trader on the Ohio, Mississippi and Illinois Rivers. His wife was a pure-blooded Pottawatomie Indian, enormous in size—so fleshy she could scarcely walk."

On page 29, Mr. Hubbard, says:

> "Among the others, who had with them their families were Messrs. Bebeau of Opa, (meaning Peoria), and Lefrombois, Bleau, and LeClare all of whom had Indian wives; and, in fact, there were but three or four single men in the party."

On page 59 of Mr. Hubbard's book, I find the following phrase:

> "The next day we spent in loading our boats and the day following the thirteen boats of the 'Brigade' pushed off from the shore, and, to the music of the Canadian boat-song we started on our long return journey."

Returning now to page 30, I learn from Mr. Hubbard's account that:

> "The boats progressed at the rate of about forty miles per day under oars, and when the wind was fair we hoisted our square sails, by the aid of which we were enabled to make seventy or seventy-five miles per day. If the wind proved too heavy, or blew strong ahead, we sought an entrance into the first creek or river we came to,

and there awaited a favorable time to proceed. If caught by a storm on the coast, when a shelter could not be reached, we sought the shore, where our boats were unloaded and hauled up onto the beach out of reach of the surf. This was a hard and fatiguing labor, and was accomplished by laying down poles on the sand from the edge of the water. The men then waded into the water on each side of the boat, and by lifting and pushing as each large wave rolled against it, finally succeeding in landing it high and dry on the shore."

Mr. Hubbard's narrative then proceeds to give details of the route followed until they reached Chicago, October 1, 1818, which event he records on page 32, saying:

"Thus I made my first entry into Chicago, October 1, 1818. We were met upon landing by Mr. Kinzie, and as soon as our tents were pitched, were called upon by the officers of the fort, to all of whom I was introduced by Mr. Deschamps, as his boy. I presented my letter of introduction to Mr. Kinzie and with it a package sent by his son."

We come now to the long description of the route taken by this expedition from Chicago to the Illinois River. I will not read this, however, because I find it in the transcript of Professor Alvord's examination. The account of this trip across the portage commences on page 39 of Hubbard's book. The month was October. The traders found the crossing of the portage very difficult at that season of the year, there being but little water available for the purpose of floating the boats. Having reached the Desplaines they were able to resume the voyage on the water as far as Isle la Cache, which I have been informed, is the Romeo Island of to-day. Here Mr. Hubbard says, on page 41:

"Low water compelled us to again unload our goods in order to pass our boats over the shoal that there presented itself."

From this point the progress of the expedition was slow, for according to Hubbard on page 43:

"Most of the distance to the Illinois River our goods were carried on our backs, while our lightened boats were pulled over the shallow places, often being compelled to place poles under them, and on these drag them over the rocks and shoals."

In Professor Alvord's redirect testimony, I find that

he has quoted a paragraph from page 46 of Mr. Hubbard's book. From this paragraph and from a further citation on page 25, of Mr. Hubbard's book, I find that Mr. Deschamps was in the habit of sending a boat every fall to St. Louis for supplies for his Indian trade. This citation on page 25 is as follows:

> "I had before this been told by Mr. Deschamps that he made a trip every fall to St. Louis, with one boat, to purchase supplies of tobacco and other necessaries for distribution among the various traders on the Illinois River."

Apparently one of the boats in the fleet of thirteen with Mr. Hubbard was the boat with which he made his trip this year.

After spending the winter on the Illinois river, Mr. Hubbard, with the other traders of the Illinois brigade returned by the route that they had come. This is referred to on page 269 of Professor Alvord's direct testimony and is taken from Mr. Hubbard's book, page 29. This return trip was made in the month of March. At that time the water was high and the boats "Heavily laden," as Mr. Hubbard says, were able to go up the Desplaines and after the wind changed to sail from Cache Island to Chicago without portage. This is recorded upon pages 59 and 60 of Hubbard's, and is given on page 269 of Professor Alvord's direct testimony.

The next winter, 1819-1820, Mr. Hubbard did not accompany the Illinois brigade, which was still under Deschamps, but was delegated to the Muskegon river, as is reported in his book, page 74.

The next winter, that of 1820-1821, was spent on the Kalamazoo river, as indicated on page 96 of Hubbard's. In the winter of 1821-1822 Hubbard was again with the Illinois brigade as recorded upon page 104 of his narrative. It then consisted of twelve boats still under Mr. Deschamps. On reaching Chicago the traders found, according to Mr. Hubbard, that the water was unusually low and "in places the Desplaines could be crossed on foot without wetting the sole of the shoe." This was the same year.

On page 105 Mr. Hubbard says:

> "We were compelled to carry our goods and effects from the South Branch to the Desplaines on our backs, leaving our empty boats to pass through the usual channel from the South Branch to Mud Lake, and through that to the West End and through the other channel. Having completed the portage to the Desplaines and

encountered the usual fatigues in descending that river, without unusual delay or accident, we reached Bureau Station where I had passed my first winter."

The return to Chicago in the spring of 1822 was made in April. On page 116 Mr. Hubbard says:

"About the first of April we resumed our journey towards Mackinaw, proceeding leisurely, and reaching Chicago in due season."

The next winter 1822-1823, Hubbard also went with the Illinois brigade. This time the brigade had a passenger who desired to visit southern Illinois. The record of this trip begins on page 121 of Hubbard's narrative. This is alluded to on page 730 of Professor Alvord's redirect testimony. The travelers proceeded by the usual route to the fur trade posts on the Illinois river. Mr. Hubbard states:

"We encountered the usual trials and hardships between Chicago and Starved Rock."

This winter proved an unusually good one for the fur traders and as Mr. Hubbard writes, on page 124:

"We had accumulated more furs and peltries than our boats could carry up the Desplaines River and I was accordingly despatched with four boats loads to Chicago; these I stored with Mr. John Crafts, and returned to the 'brigade,' when we all moved forward on our annual return to Mackinaw. A portion of our furs were shipped from Chicago, for the first time in a small schooner which had brought supplies for the garrison."

During the winter of 1823-1824, Hubbard was again with the Illinois brigade, as is recorded on page 129 of his narrative. Since his destination was the Iroquois river, he decided to try the route thither by the St. Joseph and Kankakee, in order, as he says to "save the remainder of the journey to Chicago, as well as the delays and hardships of the old route through Mud Lake to the Desplaines."

He, therefore left the rest of the party, who proceeded on to Chicago, as recorded on page 130 of his narrative.

In the spring Mr. Hubbard proceeded to Chicago, as recorded on page 132 of his narrative, and waited for the rest of the brigade at that fur trade post. In the fall of 1824, Mr. Deschamps resigned his position as commandant of the Illinois brigade and Mr. Hubbard was appointed in his place, as recorded in his narrative, page 136. This is referred to in Professor Alvord's cross-examination.

On page 136 of his narrative, Mr. Hubbard says:

"I now determined to carry out a project which I had

long urged upon Mr. Deschamps, but without success—that of unloading the boats upon their arrival at Chicago from Mackinaw and scuttling them in the slough to prevent their loss by prairie fires until they were needed to reload with furs for the return voyage."

Mr. Hubbard proposed to transport the goods and furs on pack horses. He says in regard to this on the same page 136:

"In this manner the long, tedious, and difficult passage through Mud Lake into and down through the Desplaines river would be avoided, and the goods taken directly to the Indians at their hunting grounds, instead of having to be carried on packs on the backs of the men."

By this I understand that he means that up to this time the traders who actually went among the Indians and visited them upon their hunting grounds had made other trips from the trading posts on foot, with their packs on their backs.

Thus, in 1824 the boats of the American Fur Company for the first time since that company was established in 1816, did not travel by the Desplaines river. Although Hubbard did not use the Desplaines river for the trading boats, he did use it himself.

In the spring of 1825, as appears from page 140 of his narrative, he went to Chicago on foot to consult with Kinzie about some goods which the latter wished Hubbard to buy for him in St. Louis. When Hubbard, upon this trip, reached Chicago, he found that Kinzie had sent "two men in a canoe" with a list of goods to meet him at Peoria. Hubbard thereon started in another canoe "with an old Frenchman for Peoria," and he writes "we got along without trouble until we reached Peoria Lake." This is referred to in Professor Alvord's redirect testimony, page 731. Hubbard found that his men had a boat all ready, so he started for St. Louis, "where," he writes, "we arrived in due season and without accident worthy of notice. I bought my goods, delivered them at Chicago, and returned as quickly as possibly to my post at Iroquois" (by which he means Iroquois river, a branch of the Kankakee river).

Now, from this analysis of Hubbard's narrative which I have given, I arrive at the following conclusions: From the time of the reorganization of the American Fur Company in 1816, until the year 1824, the Illinois brigade sent out by that Fur Company under command of Mr. Deschamps, came every year to Chicago in the fall. This brigade consisted of a dozen or more boats, each capable of carrying about 3,000 pounds of merchandise, besides the equipment of the crews,

the clerks and their wives. Each fall these boats passed over the Chicago portage to the Desplaines river. In places they found sufficient water to float the loaded boats, but in some other places they were obliged, from insufficiency of water, to unload the boats. Now, I do not find in this detailed account by Mr. Hubbard any evidence that the fur traders were obliged to take the boats from the water in these passages, but they were at times forced to use poles to get them over the rocks and shallows. In the springtime these same boats, heavily laden with furs, returned to Lake Michigan by the Desplaines and the Chicago rivers without difficulty.

TRIP OF GOVERNOR CASS, 1828.

As to whether there is any other passage in the life of Hubbard that throws light on the use of the Desplaines river, I should say there is a passage on page 150. It is an account of a visit to Chicago in the fall of 1828, of Governor Lewis Cass, Governor of Michigan Territory. Governor Cass had been upon a trip to Fort Snelling upon the upper Mississippi river, in search of hostile Winnebago Indians, who had been engaged in an outbreak against United States authority. According to Mr. Hubbard's statement here given, Governor Cass had proceeded from Green Bay up the Fox River and down the Wisconsin to the Mississippi. Upon returning from Fort Snelling, he descended the Mississippi river in a steamboat; then according to Mr. Hubbard:

> "On reaching the mouth of the Illinois river, the Governor (with his men and canoes, having been brought so far on the steamer) here left it and ascended that stream and the Desplaines passed through Mud Lake into the South Branch of the Chicago River, thus reaching Chicago."

This exhibits to my mind the fact that the Chicago-Desplaines portage route was well known at this time and that Governor Cass, as a public official used this route as a desirable one to proceed from the Mississippi river to the Great Lakes.

As to the weight historians would give this narrative of Hubbard's including the various references to the use of the Chicago-Desplaines route as a means for trade or travel, I should say that these narratives must be regarded as conclusive proof without reference to other sources, that the Desplaines was frequently used for a number of years by the traders of the American Fur Company for the transportation

of their boatloads of merchandise and furs between Lake Michigan and the Mississippi river. * * *

CONCLUSION OF DR. REUBEN GOLD THWAITES.

Q. Referring now, Doctor Thwaites, to the various sources of historical testimony to which your attention has been particularly attracted in this examination, and limiting your answer to such testimony, having in mind the testimony which you have given as a historian in reference to the value of historical testimony and its various kinds of source material, assuming that you were asked as a historian to determine the question as to whether the Desplaines river at, or near its mouth, was used as a route for trade and travel, what would your answer be?

A. As an historian I would answer your question as follows: Giving due weight to all of the sources of information that I have examined my opinion is that from the latter part of the 17th century through the first third of the 19th century, men engaged in the fur trade with the western Indians actually and quite regularly passed up and down the Chicago and Desplaines rivers in canoes and batteaux, Mackinaw boats and other boats propelled by oars, or poles, laden with merchandise and furs; that these traders and travelers found a comparatively easy passageway by means of these rivers in the early spring, and sometimes at other seasons that during times of drought such as often occurred in the summer and fall on most of the western portage routes between the Great Lakes and the Mississippi (as, for instance, on the well-known and much-used Fox-Wisconsin portage route) the passage was sometimes difficult; but even then these fur traders appear to have succeeded in forcing their boats over the Chicago-Desplaines waterway, although, perhaps, they were obliged here and there to make some carriage at that time of the year, the length of the carriage varying greatly from season to season, and from year to year, according to the stage of water. * * *

THE BOUNDARIES OF WISCONSIN.

(Doctor Thwaites continuing):

I am familiar with the early history of Wisconsin and Illinois in relation to the location of the boundary line between those states, and the discussion and the reasons for the settlement of the boundary as it finally was settled. The

books which throw light upon the location of that boundary are Volume XI of the Wisconsin Historical Collections, in which there is a monograph of which I am the author, entitled "The Boundaries of Wisconsin." Commencing at page 494 of that volume and of that monograph I particularly consider the southern boundary of Wisconsin, that is, the boundary between Illinois and Wisconsin. I should explain by way of introduction that under the provisions of the Ordinance of 1787 the territory northwest of the River Ohio was to be divided into five states, three of them south of a line running east and west between the latitude of the southern extremity of Lake Michigan, and two of them north of that latitude. One by one the states afterwards created south of that latitude induced Congress to grant them lake shore frontage to the north of that prescribed latitude. I then go on to state as follows:

> "In 1818 Illinois, the third state (meaning the third state to be formed from the old Northwest Territory) applied for entry to the Union. The original bill for the purpose, as introduced by Nathaniel Pope, the delegate from Illinois, provided for the northern boundary prescribed by the ordinance. (Meaning Ordinance of 1787.) But, while his measure was still pending, he appears to have suddenly bethought himself of the advantages of giving to his state a share of the lake coast, and proposed an amendment making the latitude of 42 degrees, 30 minutes, its northern limits. This was a bold move, for the additional strip of territory sought to be thus obtained for Illinois was 61 miles, 19 chains and 13 links in width, embracing a surface of 8,500 square miles of exceedingly fertile soil, and numerous river and lake ports, many miles of fine water power, and the sites of Chicago, Rockford, Freeport, Galena, Oregon, Dixon and numerous other prosperous cities."

I cite as a footnote as my chief authority for this statement, Ford's History of Illinois, at page 22. "Ford's History of Illinois from its Commencement as a State in 1818 to 1847," was published in 1854. I have a copy thereof before me. The author was Governor Thomas Ford. He died in 1850, before the book was published. In the introduction by General James Shields, General Shields says concerning Governor Ford:

> "The author, during his whole life, had very favorable opportunities for observing events and collecting information connected with the history of his state. He was yet

a child when his parents emigrated to Illinois. On arriving at maturity he was there admitted to the bar, and practiced his profession for many years with very considerable success. He was afterwards elected an associate justice of the Supreme Court of the state, and discharged the duties of that responsible station with distinguished ability. Subsequently he was chosen Governor of the state, which was the last public office he held. From this office he retired to private life, and during his retirement prepared this history for publication."

This book is regarded as one of the prime sources of infromation concerning the history of Illinois, particularly within the period 1818 to 1847 during which Governor Ford was a very prominent citizen and connected with most of the important public affairs of the State.

Upon page 20, Governor Ford, after setting forth the statement relative to the boundaries created by the Ordinance of 1787, as already outlined by me, writes as follows:

"Judge Pope, seeing that the port of Chicago was north of that line" (meaning the line of latitude impinging upon the southern limit of Lake Michigan as set forth in the Ordinance of 1787), "and would be excluded by it from the State; and that the Illinois and Michigan canal (which was then contemplated) would issue from Chicago, to connect the great northern lakes with the Mississippi, and thus be partly within and partly without the State of Illinois, was thereby led to a critical examination of the Ordinance, which resulted in a clear and satisfactory conviction that it was competent for Congress to extend the boundaries of the new State as far north as they pleased."

Later, upon page 23, he says:

"It therefore became the duty of the national government, not only to make Illinois strong, but to raise an interest inclining and binding her to the eastern and northern portions of the Union. This could be done only through an interest in the lakes. At that time the commerce on the lakes was small, but its increase was confidently expected, and indeed it has exceeded all anticipations, and is yet only in its infancy. To accomplish this object effectually, it was not only necessary to give to Illinois the port of Chicago and a route for the canal, but a considerable coast on Lake Michigan, with a country back of it sufficiently extensive to contain a population capable of exercising a decided influence upon the councils of the State."

PETITION OF LOUVIGNY AND MANTET TO THE FRENCH MINISTER.

(Doctor Thwaites continuing):

Turning to volume IV of Margry, page 9, I would say that this is a petition addressed to: LeSeiur de Louvigny, captain of the corps of the marine in Canada, formerly commandant upon the upper lakes, and le Seiur de Mantet, lieutenant, formerly commandant at Chicago.

This petition presented in 1697 to the French Minister of the Marine in Paris, under whose charge the French Colonies then were, is to the effect that Mantet and Louvigny be allowed to make fur trading voyage towards Mexico. Margry found this document in the French archives of the marine. In this document Mantet styles himself: "Former Commandant at Chicago." He asks to be granted "the post of Chicago," which is "the passage to enter into the river of the Mississippi." The date of the memoir is the 14th of October, 1697.

The citation of Mantet relative to his being formerly commandant at Chicago is in the title of the article which of course would precede it.

The passage on page 16 reads as follows:

> "For the purpose of accomplishing these results we entreat his Majesty to grant us the post of Chicago, which is the passage for entering upon the river Mississippi."

* * *

WHY WE DO NOT HAVE MORE ACCOUNTS OF THE EARLY USE OF THE RIVERS.

(Doctor Thwaites continuing):

As to why it is that we do not have more accounts of the use of the Desplaines river by travelers or traders, I would say that I can only reply to your question, Mr. Cressy, out of my general knowledge of conditions, the result of a considerable period of time spent in studying this region, especially during the French regime.

The great majority of the men who were traveling upon the fur trade or as military expeditions and so on, through this northwestern country in the early days were not men who were in the habit of making records of any sort. The most frequent of all the travelers during the French regime were that class of men called coureur de bois, or wood rangers, unlicensed fur traders who were roving all through this country, and who because they were liable to severe punishment be-

cause they were trading through the western country without a license from New France, found it greatly to their advantage not to make records or to send out reports concerning their wanderings. It is only now and then that we get little glimpses, occasional references, perhaps, in the reports of missionaries or in letters or reports that have come down to us from military officers and so forth, concerning the presence or the wandering of these coureurs de bois. But a sufficient number of documentary references have come down to us from the past concerning this very large and enterprising and far-wandering body of men to give us a pretty good notion of where they were and what they were at, their methods, their life, and so forth.

The Jesuit missionaries were of course men who were obliged under the rules of the Society of Jesus to make reports, to take observations, to send in their reports regularly to their superior officers in Quebec, by whom they were synopsized and forwarded to the general officers in Paris; and this is the reason that we have that great body of information concerning the west that is embodied in the collections known as the Jesuit Relations and Allied Documents.

Relative to military affairs in the west we are only just beginning to get good returns from the various archives of the French in Paris. Considerable quantities of documents have been printed through various channels, such as Margry, New York Colonial Documents, publications of the Michigan, Illinois and Wisconsin historical societies, and so forth; and yet there is a vast amount of material that we have not yet got at, and the American Historical Association is now engaged in making what they hope will be a complete sweep of the archives of France relative to the period of the French regime in North America. The skeleton of Western history has already been built up, although considerable portions of that skeleton have not been produced until quite recent years. Indeed, much of it within the last two or three years.

When we come down to the period of the British fur trade operations we find a somewhat increasing mass of material, and yet the greater part of that has been preserved and has come down to us very largely through accident; some family has preserved a paper, some office somewhere has reserved a letter or a document, but there is no great continuous body of material. What we have is very rich and very suggestive.

When we come down to the early American period the American Fur Company was not an institution which was

making known to the public at large very much of its operations, and yet here and there we do find a letter, a diary, some little journal, some memorandum or something of that kind, that accidentally through the various fortunes that befall historical manuscripts, familiar to historical investigators, has come down to us. I fancy that within the next fifteen or twenty years we shall discover a vast mass of new material for the reason that the various historical publishing agencies of this country, the State historical societies, the American Historical Association, the American Antiquarian Society, and other bodies of that kind, have now reached that condition in their work that they have larger funds to devote to the gathering and editing and publishing of such material than they ever had before, and the historical work is very much better organized, especially within the last five or ten years, than it ever has been before. So that to make the story short when one considers the various vicissitudes that happen to historical papers, the peculiar conditions under which some of these letters and journals were written in the past, I am often very much astonished that as much remains to us as has come down to us; little glimpses now and then, but to the historical student sufficiently illuminating to give us, I think, a pretty good knowledge of what has happened, putting two and two together, reading between the lines, applying to the interpretation of manuscripts one's general historical insight and knowledge,—a pretty good knowledge or picture of the past as it has happened in this western country during the periods of the French, British and American regimes. And yet, as I said, within the next ten years I believe there will be a great body of fresh information that will put the flesh and blood upon the skeleton of western history that has thus far been erected.

Mr. JUDSON F. LEE, a witness for defendant in the above mentioned case, testified as follows:

I have met Ellen Churchill Semple, whose work "American History, and its Geographical Condition" I have cited. She has written a number of articles on this and kindred subjects. She and Turner, and two or three others reported to the American Historical Association on the relation of geography to history, or the economic background of history, which is published in the American Historical Association report. She

gave a course at Chicago University, which I took, wherein she used that particular book. She was on the staff of the university at that time. She has been there two or three times, in the summer. She was not on the regular staff. I only know the general standing of the book.

The book should be examined with the same tests that are applied to other books which I have put in evidence if there be any question as to the value of the excerpts before they are taken as authority. I would attribute a certain value to it. In that particular book she has attempted to cover a very large subject; I would say that she was a careful writer. I remember a review or two which spoke of it as being a good book; one by Albert Bushnell Hart of Harvard University, who has published widely and has written a number of books; is editor of the American Nation series, and other books and articles. The fact that he reviewed it and said it was carefully written would have weight with me in determining its standing, especially as the review was given in the American Historical Review.

AMERICAN HISTORY AND ITS GEOGRAPHICAL CONDITIONS BY ELLEN SEMPLE, 22-28-30-159-272.

In "American History, and Its Geographic Condition," by Ellen Semple, I find the following, page 22:

> "Rivers were the only highways into the interior, and up the rivers, preferably those flowing from the north, went the American colonists,—the trapper, trader, and voyageur always in advance." * * *

(P. 28):

> "The great number of the portages both offered a choice to the traders, especially advantageous in time of war with one or the other of the Indian tribes inhabiting this region, and enormously increased the voyageur's sphere of activity by opening up to him all the country drained by the Ohio and Mississippi.
>
> The order in which these portages were discovered and used by the French was determined in part by the political neighborhood of the hostile Iroquois along the southern shores of the nearer lakes, and in part by geographical conditions. Up to 1670 the westward route of the canoe fleets was up Lakes Ontario, Erie and Huron to the westernmost outpost at Michillimackinac on the Strait of Mackinaw. This trading station could be reached also

by a more direct northern route from Montreal up the Ottawa river, across to Lake Nipissing and Georgian Bay, —a route which was often used when the Iroquois were on the warpath about Ontario and Erie. Further progress thence naturally led up the waterways afforded by Lake Superior and Lake Michigan to the portages which the Indian described as leading to the western waters. The consequence was that the passages earliest known were those remotest from the Canadian settlements. The first carry route used by the French led from the head of Green Bay up Fox river, across the northern part of Lake Winnebago, and along the upper Fox river for sixty or seventy miles to a narrow portage of two miles, leading to the head of the Wisconsin river. This was the route followed by Marquette and the fur-trader Joliet in 1673, when they explored the Mississippi to the mouth of the Arkansas. The other of these earlier portages was across the narrow lake-dotted watershed between the St. Louis river, which flows into the western extremity of Lake Superior, and the easternmost bend of the Mississippi.

By the end of the seventeenth century the portages at the head of Lake Michigan were the best known. There were a number of these close together. The Chicago river, the lesser and greater Calumet, and the St. Joseph all led by short carries to the Desplaines and Kankakee branches of the Illinois. The Lake Erie portage, though affording nearer, more direct routes by the Ohio tributaries to the Mississippi, came into use only in the eighteenth century, and here too, the progress was from west to east." * * *

(p. 30.) "Having swept westward up the broad highway of the Great Lakes to the upper reaches of the Ohio and Mississippi, the French went to work more slowly to secure all the portages to these rivers and to occupy every strategic point at the extremities of the lakes. Forts Frontenac (Kingston), Niagara, Rouille (Toronto), and Detroit were designed to command the lakes, as Fort St. Louis on the upper Illinois and the post of Outianon on the upper Wabash controlled the Chicago and Maumee portages; while Vincennes, Cahokia, and Kaskaskia completed the line of connection with the lower Mississippi. The vast area thus opened up to the French by their possession of the two great waterways of the continent led to the ultimate shipwreck of their colonial venture, be-

cause the large extent of the territory lured them to exploit its trade rather than make permanent settlements. They spread themselves thin over an enormous area, yielding to the danger of too great expansion." * * *

p. 159.) "Along the Mississippi boundary of Missouri was the gathering of the waters; hither turned the Ohio with its vast tributaries, the Illinois and the Missouri. The Mississippi furnished communication with the Gulf below, and with the Green Bay and Chicago portages above. Missouri was accessible to American settlers from the Lakes to the Gulf and straight across its broad territory ran the natural highway of its own mighty stream." * * *

(p. 272.) "The route of the fur-traders from Lake Michigan down the Illinois, which seemed peculiarly adapted to canalization, early (1816) attracted national attention as a military and commercial waterway between the Mississippi and Lake Michigan. The Massacre at the mouth of the Chicago river in the war of 1812 emphasized the isolation of the northwest lakes. In 1817 Major Long in his report to Congress regarded such a canal as 'first in importance of any in this quarter of the country'; but though projected in 1825, owing to difficulties both technical and financial, it was not opened till 1848, and then proved disappointing as an investment, chiefly because the upper Illinois river needed artificial aid to make it navigable to any but small craft. The same difficulty was present in the waterway of Green Bay, Fox river, and the Wisconsin. The canal connecting the great bend of the Wisconsin with the Upper Fox was only two and one-third miles long, but the sand-bars of the Wisconsin, the shallow, tortuous course of the Upper Fox, and the numerous rapids necessitating canals on the lower river, robbed this waterway of much of its value, and made it succumb rapidly to railroad competition. These western channels over the Great Lakes watershed, being constructed later (1848-53) than the Erie and Ohio canals, because on the frontier of settlement, felt the deadening grip of the railroad before their traffic had been established and suffered moreover the disadvantage of reaching less navigable outlets into the Mississippi river."

HULBERT'S HISTORIC HIGHWAYS PORTAGE PATHS, VOLUME 7.

(Mr. Judson F. Lee continuing):

Q. You referred in your direct testimony, Mr. Lee, to Hulbert's Historic Highways, Portage Paths, Volume 7; in connection with what you read from that volume, I call your attention to pages 180 and 181, and ask you to read the paragraph commencing at the bottom of page 180.

The Witness (reading from Hulbert, page 180):

"The Kankakee-St. Joseph's route was a favorite one for travelers returning from Illinois to the Great Lakes and Canada. The favorite early 'outward' route was from the western shore of Lake Michigan into the Illinois river. Here were two courses: by way of either the Calumet or the Chicago river to the Desplaines branch of the Illinois. The latter portage was best known and most used. Perhaps no one of the western portages varied more than this in length, as on the best authority it is asserted that sometimes no portage was necessary, and at others a portage of nine miles was necessary; 'The Chicago-Desplaines route involved "a carry" of from four to nine miles, according to the season of the year; in a rainy, spring season, it might not be over a mile; and during a freshet, a canoe might be paddled over the entire route, without any portage.' When Marquette reached the Desplaines, known as 'Portage river' because it offered a pathway to the Illinois, he was compelled to make a portage of only 'half a league.' The course of this portage is practically the present route of the famous Drainage canal which joins the Chicago river with the Desplaines at Elgin, Illinois."

(Mr. Judson F. Lee continuing):

My attention is directed to "Schoolcraft's Journal of Travels from Detroit * * * to the Sources of the Mississippi River in the Year 1820."

I read from page 384 an entry purporting to have been made August 30th. I am not sure whether I read what immediately precedes it under date of August 29th.

(Upon request of counsel for complainant, witness read as follows from the entry under date of August 29th.) (Reading):

"Chicago Creek is eighty yards wide, at the garrison, and has a bar at its mouth, which prevents shipping from entering, but is deep within. It is ascended eleven miles in boats and barges, where there is a portage of seven

miles across a prairie, to the River Plein, the main northwestern fork of the Illinois.

The intervening country consists of different strata of marl and clay, presenting great facilities for canal excavation, and the difference in the level of the two streams is so little that loaded boats, of a small class, may pass over the lowest parts of the prairie, during the spring, and autumnal freshets. But at mid-summer, it is necessary to transport them overland, to Mount Juliet, a distance of thirty miles. From thence the navigation is good, at all seasons, to St. Louis, a distance of four hundred miles."

(Mr. Judson F. Lee continuing):

Schoolcraft's statement here is that at mid-summer it is necessary to transport the goods overland to Mount Juliet, a distance of over 30 miles. This would have to be taken into consideration with other statements he made; examining that itself, it would show that at mid-summer overland transportation was necessary to Mount Joliet. And that during the spring and autumnal freshets no portage at all was necessary. * * *

BENTON'S WABASH TRADE ROUTE.

The Witness (reading):

"The earliest expeditions from the French settlements on the St. Lawrence to the upper lakes followed the course of the Ottawa river rather than the upper St. Lawrence. Successive expeditions pushed the route farther west until under the leadership of such intrepid explorers as Jean Nicollett, Allouez, and Marquette there was developed about the middle of the seventeenth century what may be regarded as a westward highway for the French, continuous from the settlements on the lower St. Lawrence to the Mississippi valley. The voyagers' canoes followed the Ottawa river from Montreal, then by portage to Lake Nipissing, and to Georgian Bay, an eastern arm of Lake Huron, and thence by the northern lakes to Green Bay, the Fox, and by portage to the Wisconsin and Mississippi rivers. It was the most natural route because in every way it was the line of least resistance. It avoided the near approaches to the Iroquois Indian limits and led directly to the numerous Indian haunts around the greater lakes. As the objective point for the westward expeditions was gradually moved farther south

in the Mississippi basin, shorter routes across the territory, later known as the Old Northwest, were used. The Wisconsin portage soon yielded in point of frequency of use to those at the south end of Lake Michigan. The route up the Illinois river and by portage into the Chicago river and Lake Michigan was followed by Joliet and Marquette on their return from the discovery of the Mississippi. A few years later La Salle followed the coast of Lake Michigan to the St. Joseph river and up that stream, thence by a portage to the Kankakee, and so again to the usual destination—points on the Illinois and the Mississippi.

About this time, in the course of the evolution of new routes leading to the Mississippi, occurred the first use of the Wabash river by white explorers. This stream was occasionally reached in the earliest period by leaving Lake Michigan on the St. Joseph river and then by a short portage to the headwaters of a northern branch of the Wabash, but the more important way to reach it was by the 'Miami river of Lake Erie' and a short portage. Of the five great portage routes this was the last one to come into general use by the whites. It proved to be the shortest route connecting the lower French posts on the Mississippi with those on the St. Lawrence and has been quite happily called the Indian Appian way. It was a common highway for the various Indian tribes of the Northwest. The French routes were in almost all cases the watercourses, portage paths, or overland trails in earlier use by the Indians, who now became the guides. The portage from French creek to the Allegheny was used by La Salle, but its importance dates from a much later period, when it came to connect strategic points on the English frontier. In the race with the English for the occupation of the interior, the French gradually drew the cordon tighter. The paramount task for them was to keep in ready and rapid communication with one another and with outlying posts their two commercial and political centers, Quebec and New Orleans." * * *

Canal Commissioner's Report of 1825.

Whereupon the witness (Judson F. Lee) read as directed by counsel for complainant from the Commissioner's Report of 1825:

"A portion of the commissioners, therefore, in the fall

of 1823, accompanied by Col. Justus Post, whom they had engaged as their engineer, explored and examined the country from the rapids of the Illinois river with the streams emptying into the same, to Lake Michigan; and the country bordering on the Chicago river and Kalimick, which streams also empty into Lake Michigan. The commissioners returned by water in canoes, examining the bed of the rivers, particularly the depth of water, and the height of the river banks. They also ascended the Chicago river, or arm of Lake Michigan, having its confluence with that lake on the west side, about 35 miles below the head of it, to the head of the river, 5 miles. From this point there is a portage of 7 miles to the river Desplaines. They then descended the Desplaines 50 or 60 miles to its mouth; where uniting with the Kan-kakee, a considerable river from the southeast, its source being in the country with those of the Wabash and Saint Joseph, the river Illinois is formed; thence down this river to its confluence with the Mississippi, 350 miles; thence down the latter, 18 miles, to Alton, the place from whence they had departed.

It is a source of much satisfaction for the Commissioners to be enabled to state, that the result of this examination eventuated in the conviction, that from the mouth of the Illinois river, to the Little Vermillion, a handsome stream 12 or 15 feet wide, discharging its waters into the Illinois river on the west side, and about 4 miles below the rapids of the Illinois, there is not the least obstruction to the navigation, excepting in two or three places below Spoon river, in extremely low states of water, where small sandbars show themselves, but which, however can be easily removed." * * *

EXTRACTS FROM SMITH'S LIFE AND TIMES OF LEWIS CASS—PAGES 185-188.

(Judson F. Lee continuing):

I have read the passages in Smith, Life and Times of Louis Cass, to which you have directed my attention, which have been read as follows, page 185:

"At that time, the communication between Green Bay and Prairie du Chien, upon the Mississippi river, where these events were passing, was by water up the Fox river about two hundred miles to the portage, thence across to the Wisconsin and down that stream to the Missis-

sippi, which it enters three or four miles below Prairie du Chien. General Cass embarked in a birch canoe with fifteen paddles to visit the scene of difficulty, and to take such measures for the protection of the people and for restraining the Indians as might be found necessary."

(Page 188):

"From St. Louis, General Cass ascended the Illinois in his canoe and passed into Lake Michigan, by the water communication, without leaving it." * * *

(Page 188):

"At the head of the Desplaines, a branch of the Illinois which approaches near Chicago, is a shallow lake, appropriately named Mud Lake. The party entered it towards evening, and it soon became so dark that they could not discern the bank. The lake was covered with broad leaves of a kind of a lily, favorable haunts of disgusting looking water snakes. A birch canoe cannot touch the shore without danger of having a hole broken through its slight material. It is brought near the land, and there retained while the passengers disembark, and this is effected by their being carried ashore upon the backs of the voyageurs. And in the same manner is the freight disposed of. The canoe is then taken from the water and carried by the men upon the land. Finding they could not get to shore safely, the party spent the night upon that slimy sheet of water. Eighteen men in a small canoe, on a hot summer night, with the poles stuck into the mud across the canoe to steady it, accompanied with the most intense rain and with the most intense thunder and lightning,—such are the reminiscences which belong to that memorial night. And he who was not there, or has never been in such a place, if such another place there is, has little conception of what a formidable enemy a mosquito can be. During that long night,—long in suffering, though short in the calendar, for it was in the month of July,—the venomous attacks were beyond the power of description. As soon as the dawn of day enabled the party to discern the surrounding objects, the anchor poles were taken from the mud, and the voyage was resumed. A small branch of the Chicago creek takes its rise close to this Mud Lake, and the whole region being flat and marshy, when the waters are high this creek flows back into the lake, and thus a communication was formed by which boats passed from the Des Plaines, which runs through the lake, to the Chicago creek, and

of course to Lake Michigan. This channel of communication, though almost shut up by the rank water vegetation, was found in the morning, and the travelers entered it, and as the descent to Lake Michigan is rapid and the distance but a few miles, that space was soon passed over, and the canoe rested upon the broad bosom of that great lake. The magnificent city which occupies the junction of the Chicago creek and the lake, and of miles around, had then no existence. The white man was not there with the power and the desire to change everything around him. There were no troops, and but few families, and these were connected with the Indian trade. They were of course exposed at all times to the sudden hostility of the Indians. As the canoe approached their cabins at the mouth of the creek, the voyageurs commenced their songs, and these were heard by the traders and at first mistaken for the shouts of the Indians. Knowing that the times were dangerous, they were at first in great fear, being entirely destitute of means of resistance, but they were soon and happily reassured by the sight of our flag and by the arrival of the canoe, and it was with demonstrations of the liveliest joy that they received General Cass upon the bank." * * *

Judson F. Lee (continuing reading from Vol. II Illinois Historical Collections, Virginia Series No. 1, known as Cahokia Records, page cxxiii):

"Affairs were further complicated by the presence of British merchants who had rushed into the region to capture the Indian trade. The Michillimackinac company, which had a store at Cahokia, was particularly conspicuous in this competition. The British were able to undersell the inhabitants in their commerce with the Indian and, since this deprived the villagers of a trade which they thought rightfully belonged to them, it was the cause of several complaints. All the British who appeared in the west were not simply traders. The British Government, which looked with covetous eyes on these rich lands, sent agents into all parts to report on the disposition of the people. Some of these, although not authorized by their government, openly urged the French people to unite with England, an issue out of their troubles which would not have been altogether unacceptable to the Illinoisans." * * *

CAHOKIA RECORD EDITOR'S PREFACE BY PROF. C. W. ALVORD, p. cxlvii.

"We have seen that the Kaskaskians complained of the establishment of the Michillimackinac company at Cahokia. From the year 1773 many British merchants found their way to the Illinois and established stores in the village. Among the names which occur are J. B. Perrault, representing Marchiosseaux of Montreal, James Grant, Myers, Tabeau, Bullion, William Arundel, John Askins, and others. These merchants practically monopolized the fur trade of Illinois; but the Cahokians, finding that they interfered with the indian trade as well, were strong enough to make regulations to protect their own interests and gave a limited monopoly of that trade to one of the citizens of the village and prohibited all sale of liquor to the savages by others. When the indian outrages reached their climax in the year 1789 and Kaskaskians were begging the military officer at Vincennes to send troops for their defense, the Court of Cahokia still further regulated intercourse with the Indians and forbade all sale of liquor by any one." * * *

CAHOKIA RECORDS, P. 509, POWER OF ATTORNEY, JOHN ASKINS TO HUGH HEWARD.

"Today the 24th of April, 1787, there appeared at the office of the Jurisdiction of Cahokia, in the Illinois, M. Hugh Heward bearer of the following documents and he has required the registry thereof, and has transcribed them in the present register himself, since the clerk does not understand the English language, as follows:

1st piece.

Know all men by these presents that I, John Askins of Detroit, merchant, have made, ordained, constituted and appointed and by these presents do make, ordain, constitute and appoint and in my place and stead, put and depute Mr. Hugh Heward, of Detroit, aforesaid, my true and lawful attorney for me, and in my name and for my use to ask, demand, recover, and receive of and from any person or persons indebted to me or any of my former co-partners; giving and granting to my said attorney my sole and full power and authority to take, pursue and follow such legal courses for the recovery, receiving and obtaining of the same as I myself might or could do,

were I personally present; and upon receipt of the same acquittances and other sufficient discharges for me and in my name to sign, seal and deliver; as also one or more substitute or appoint & again at his pleasure to revoke & further to do & perform & execute for me & in my name all singular Thing or Things which shall or may be necessary touching and concerning the premises as fully & entirely as I the said John Askins ought or could do in & about the same or as if more especial authority was required than is herein given—ratifying allowing & confirming whatever my said attorney shall lawfully do or cause to be done in & about the Premises by virtue of these presents.

In witness whereof I have hereunto set my Hand & Seal the fifteenth Day of November in the year One Thousand Seven Hundred & Eighty Six.

(Signed) JOHN ASKIN.

Signed Sealed and Delivered in the presence of
JOHN MCCASLAN, *Witness*
WILLIAM PARK
HUGH HEWARD.

That is followed by other powers of attorney; from John Askin, Geo. Leith, and Angus Mackintosh, of Detroit, and directors of Miamis Company, and Hugh Heward, of Detroit." * * *

CAHOKIA RECORDS, PAGE 523, POWER OF ATTORNEY TO WM. KAY.

"Know all men by these presents that we, Edw. Wm. Gray, Esq., Wm. Goodall, John Lilly, Peter Bouthiellier, and Robert Cruickshanks, merchants, executors of the last will and testament of Wm. Kay, late of Montreal, in the District of Montreal, in the Province of Quebec, merchant deceased, have made, ordained, authorized, constituted and appointed and by these presents do make, ordain, authorize, constitute and appoint Josiah Bleakley, late of Michillimackinac, but now of Montreal aforesaid, merchant, are true and lawful attorney, for us and in our name or (otherwise) and to and for our use, as executors as aforesaid, to ask, demand, sue for, recover and receive of and from, all and every person or persons whatsoever whom it doth, shall or may concern, and particularly of and from David McCrae, David McCrae & Co., Pierre Antoine Tabeau, Jean Baptiste Morelle; Jas. Aaron Holt and Chas. Gratoit at Michillimackinac or

elsewhere in the upper country, all such sum and sums of money, debts, dues and demands whatsoever, as are due, owing, payable or belonging to the said Wm. Kay at the time of his decease and now are or hereafter may become due, owing, payable, or belonging to as the executives of his said last will and testament, for or by reason of any cause, matter or thing whatsoever, and to compound and agree to take less than the whole for all or any of the debts or Demands aforesaid, where the whole in all appearance cannot be got; AND upon payment, recovery or receipt thereof or of any part or parts thereof, Acquittances or other Good and sufficient discharges in the Law for the same, for us and in our names as Executors as aforesaid, accordingly to make, Seal and deliver and Generally to do, transact, manage and perform all other matters and things anywise relating to the premises in such manner as to our said attorney shall appear most advisable and Expedient as fully, amply and effectually in all respects as if the most special powers were to our Said Attorney for the purposes aforesaid by us given, or as we ourselves might or could do personally; AND an Attorney or Attornies under him for the purposes aforesaid, with the like or more limited powers, to make and at his pleasure to revoke.

HEREBY allowing, ratifying and confirming all and whatsoever our said Attorney, or his Substitute or Substitutes shall Lawfully do or cause to be done in or about the Premises by Virtue of these Presents. IN WITNESS whereof we have hereunto sett our hands & Seals the twenty-fifth day of April in the year of our Lord, One Thousand Seven Hundred & Eighty-eight.

Signed, Seal'd and deliver'd
in the presence of
JN. BOUTHIELLER
SAM'L GENARD.

EDWD. WM. GRAY (L. S.)
W. GOODALL "
JOHN LILLY "
P. BOUTHIELLER "
R. CRUICKSHANK "

This registry was made on the requisition of M. Charles Gratoit and conforms to the original and was transcribed by me, Jean Dumoulin, merchant, in default of a knowl-

edge of the English Language by me, notary at Cahokia, October 28th, 1788.

CH. GRATOIT,
JEAN DUMOULIN,
JOSIAH BLEAKLEY."

(Judson F. Lee continuing):

I notice that this was registered in Cahokia same as other powers of attorney (reading):

"This registry was made on the requisition of M. Charles Gratoit and conforms to the original and was transcribed by me."

PETITION OF LA CROIX IN REGARD TO TRADE, OCTOBER 29, 1785.

(Judson F. Lee continuing):

Referring to pages 575 and 577 of same volume, petition of La Croix in regard to trade, I will read into record:

"Petition of La Croix in Regard to Trade, October 29, 1785.

To M. M. The Magistrates and the Honorable Court of the District of Cahokia.

Sirs:—

Jean Bte. La Croix has the honor to set forth to you that, for the public good, the Court granted him on the 8th of March, 1782, permission to trade with the savages in this village under the conditions declared in the decree of the said Court, rendered the said day, March 8, 1782. The said M. La Croix has not been troubled up to the present in his trading; but now he is in a position very prejudicial to the public and to the petitioner and which tends to cause the citizens to perish from hunger, especially at a time of such great calamity as we find ourselves in at present.

The alien merchants of Michillimackinac, gentlemen are here and, far from contenting themselves with the asylum which we give them to sell their merchandise to the French, they are trading with the savages who come to this village for all goods which the said savages bring and are taking from us in this way the means of making a living, since they overcharge us for these same commodities of trade at exorbitant prices; and to the detriment of the people they are making hords of the goods in order to transport them out of the place or to sell them at prices most burdensome to the public. Since these merchants have no right of trade in this village and since,

if we have some goods to trade with the Indians (this) advantage should belong to us and not to strangers; and since we suffer them here for convenience, after having been sent away from the Spanish bank, it is not just in us to permit these traders to carry off before our eyes what Providence offers us through the savages. But these traders are trading before our eyes and up to our very doors not only in merchandise but also in what is more pernicious, drink, and are favoring the savages at a time when one cannot be too careful. In order to avoid the evils which may result therefrom, I pray, gentlemen, that you have the goodness to continue me in my trading right and that all alien merchants for the future be forbidden to participate therein in this village or to trade in anything with the savages who come here, on pain of a fine, such as it shall please you to fix, and of confiscation of that for which they shall have traded; and in return the petitioner offers to conform to the conditions of the decree of the Court of the said 8th of March, 1782, so that this branch of commerce be preserved for us in our village (and not pass) to aliens; and this is my conclusion. At Cahokia Octbber 29, 1785.

J. B. H. La Croix."

Kaskaskia Record, Page 172—Letter of Thomas Bentley to A. S. De Peyster, Aug. 12, 1780.

(Judson F. Lee continuing):

I have volume 5 of Illinois Historical Collections and have turned to page 172 and 173, letters of Thomas Bentley (reading):

"Thomas Bentley to A. S. De Peyster, August 12th, 1780. (B. M. 21845, f. 42—A. L. S.)

Ouyah the 12th August 1780.

Sir:

I beg leave to refer you to what I have already wrote you on the subject of Mr. Dejean. I beg the favour of you after perusing the enclosed to address & forward to General Haldimand. As I wish to remit to Canada as well as to draw off from this Country I propose sending boats up this river for Detroit as well as the Illinois River for Macinac next Spring. I could wish for that purpose if it does not clash with the Service that the Savages might be requested not to molest any Boat going up

those Rivers for the purpose of carrying Remittance which I hope & doubt not but you will think reasonable. If the General or yourself should do me the honor to write me wish you would address me in a fictitious name for fear of accidents & send it by a person of confidence to be delivered only to myself. It is reported here that Canada is attacked by a French Fleet. It is likely to fall (which I hope will never be the case) beg of you to destroy these letters. I have the Mortification to inform you that Rochablave's malice has ruined me (irretrievably I fear) although my misfortunes originated with you yet I do not blame you. If you will be pleased to put me in a way of recovering myself at Detroit which you now have in your power to do, I will repair to you on your sending me proper Guides, but it must be in the Mercantile Line as I could not pay my debts & recover my lost Fortune by any other means. I have the Honor to be with real respect,

Sir, Your very obt hble Servt.

T. BENTLEY."

(Judson F. Lee continuing):

I know who Thomas Bentley was in a general way; he was a trader that had headquarters at Cahokia, traded at New Orleans, Montreal, Detroit and Michillimackinac, I believe; maybe other places. I think traded at Montreal; did at number of those places at least.

I read into record at page 369 of Volume 5 of Illinois Historical Collections: "Memorial of Francois Carbonneaux to Congress, December 8, 1784.

THE MEMORIAL OF FRANCOIS CARBONNEAUX TO CONGRESS—DEC. 8, 1784.

"To the Honble: The United States of America in Congress assembled. The Memorial of Francois Carbonneaux of the Illinois Country, Agent for the Inhabitants thereof humbly showeth:

That the said Inhabitants to the Number of four hundred Families exclusive of a like Number at Post Vincent, labour under the greatest Inconveniences for want of Order and good Government. That many ill disposed Persons have taken Refuge in their Country—That Population is daily encreasing—That their Property is invaded and arrested from them by the Hands of daring Intruders and that Violences are frequently committed

in various Ways, against their Persons and against the Persons and Properties of the Natives. Your Memorialist doth therefore in behalf of the Inhabitants aforesaid, humbly pray, that Congress will be pleased to take their distressed Case into Consideration, and either immediately establish some Form of Government among them, and appoint Officers to execute the same, or that they will nominate Commissioners to repair to the Illinois, to inquire into their Situation, and to consult with the Inhabitants thereon; and do and execute such Matters and Things as they shall find necessary, until some regular government can be established.

Your Memorialist conceives that it is in the Power of Congress by such a Measure, not only to restore Tranquility among the Inhabitants of an extensive and fertile Country but to give Peace to those of the Frontiers of Virginia, and to establish, a valuable Commerce not only with the Natives, but with new Spain which is now wholly carried on by British Subjects from Canada.

Trenton, December 8, 1784.

CARBONNEAUX."

KASKASKIA RECORDS, PAGE 410. LETTER OF JOS. PARKER TO PRESIDENT ST. CLAIR, PRES. OF CONTINENTAL CONGRESS. DATED OCT. 2ND, 1787.

(Mr. Judson F. Lee (continuing):

Turning to pages 410 and 411 of letter of Jos. Parker to President St. Clair, "Jos. Parker to President St. Clair, October 2nd, 1787," I read last paragraph (reading):

"The inhabitants also complain of the traders from Michilimackinac and Detroit, that they should be suffered to remain in their villages, and engross all the fur trade and country belonging to the United States to the great injury of American subjects. The inhabitants are of opinion that nothing but a government will check their practices of setting the savages upon them.

There is such a considerable trade carried on in the Illinois, that a sufficient revenue might be raised by laying a duty upon the goods carried into that country and upon the fur carried out. The traders in St. Louis and St. Genevieve on the other side of the Mississippi have not less than an hundred traders who are supplied with goods annually from Michilimackinac and Detroit and sent down to Kaskaskia and Cahokia and the Spaniards

come over and purchase them. Each trader purchases on an average from thirty to forty thousand livres annually which is $6000.00. The traders of St. Louis and St. Genevieve have often told me that if the Americans would supply them with goods at Kaskaskia & Cahokia, they would give them the preference and allow them the 125 pr ct advance on the Sterling cost. You will easily perceive the revenue that might be raised annually in that new country.

I am, sir, yr hble servt.

Jos. Parker."

(Mr. Judson F. Lee continuing):

Don't know whether Parker was sent out pursuant to Carbonneaux Memorial. Memorial is dated Dec. 8th, 1784; Parker's letter is dated 1787. Having read record before remember name Parker being connected with incident in Kaskaskia of driving out John Dodge. Find note here speaking of hostility of two men. Don't know full details of Parker or how long at that post; at Kaskaskia think very short time. Think St. Clair was President of Congress.

Kaskaskia Records, Page 381. Petition to Congress by Pierre Langlois.

I turn to page 381 and 382 petition of Pierre Langlois, bottom page 381 (reading):

"Pierre Langlois

Notary and Clerk.

Kaskaskia, county of the Illinois, this second day of June, of the year of our Lord one thousand seven hundred and eighty-six.

We, the undersigned pray Congress to take notice of the country of the Illinois and to establish immediately the government for the protection and defense of the inhabitants and their property, for we believe (that) the fertility of the land and the great advantage to be derived by Commerce (will attract) a great immigration to the advantage of the country. We think that this is not a small object for Congress. It is for this reason that we pray for a system of government to protect us, to strengthen our hand and to maintain our rights, not only against the Indians, but rather against Michilimackinac and a company of the subjects of Great Britain who are getting possession of the commerce from the good subjects of the states. They have established at Ca-

hokia a Village near us a trading post which causes great harm and detriment to the good subjects of the states. They have destroyed the establishment of the law which the inhabitants had made among themselves. We suffer a great loss in the recovery of our just debts.

We, therefore, again pray Congress not to abandon us any longer; but to send and grant us laws without delay, for the subjects of Great Britain threaten to take us under their laws. Likewise a few persons upholding the subjects of Great Britain have installed themselves as commanders to such a point as to take subjects of the states and transport them to the Spanish shore and have them imprisoned, to the disgrace of the establishment of the government of the states. The men who have assumed command are M. M. Nicholas Lachanse and John Dodge.

PIERRE LANGLOIS,
Notary and Clerk."

(Judson F. Lee continuing):

From my knowledge and recollection of passage in Vol. 2 of Illinois Historical Collections, page CXXXII, "The long expected reply from Congress was brought to Kaskaskia by Joseph Parker in January, 1787. The people were eager to learn its contents, and sent in haste to Barbau at Prairie du Rocher that he might come and open it," and of Perrault's statements, Heward's Governor St. Clair's statements, letter of Governor Cass to Kinzie, all in evidence, should think there was an indication that there was some little commerce, during period from 1782 to about 1817, that went by way of St. Louis, Cahokia and Kaskaskia and Canada? Don't know just how much. There was some commerce passing between Canada and territory in vicinity of Cahokia, Kaskaskia and St. Louis. Think there are evidences of that, as I have read over the letters in Kaskaskia records. I find a number of traders who were connected with Canadian towns, a number of references that are in the book, that I could not refer to at present, however, indicate that some of that trade went by way of Detroit and other places.

TRIP OF GALLOWAY AND FAMILY DOWN THE DESPLAINES RIVER IN 1827.

Mr. MILO M. QUAIF, called as a witness for the defendant in the above mentioned case, testified as follows:

I have used Blanchard's History. Historians need to be on their guard in my opinion in using it. Have not made a critical study of Blanchard for this case, except in a general way. Blanchard lived here in Chicago, about a generation ago and undertook to write a history of Chicago and to some extent the Northwest generally.

Blanchard's History, Chicago, Blanchard & Co., 1898, page 503 (reading):

"This young Miss is now, 1880, Mrs. Archibald Clybourn, residing on Elston avenue, Chicago; and to her is the writer indebted for the preceeding facts relating to her father. In the spring following their residence at Lee's Place 1827, her father, Mr. Galloway, moved with his family to the home he had purchased the year before. His transportation to the place was effected by means of a large boat fashioned on the dug-out plan, which he made himself from a black walnut tree, on the banks of the Chicago river. Taking advantage, of the usual spring freshets, he navigated this vessel, freighted with his family and all his valuables, through Mud Lake and down the Des Plaines and Illinois rivers, to his home. The place was then called the Grand Rapids of the Illinois. Here Mr. and Mrs. Galloway spent the remainder of their days, highly esteemed by all who knew them. Mrs. Galloway died in 1830, and Mr. Galloway survived till 1864, when he died, and many of the present inhabitants of Chicago will doubtless remember reading the becoming obituary notices which the Chicago papers gave of him at the time."

LETTER OF GORDON S. HUBBARD TO RUFUS BLANCHARD, OCT. 13, 1880.

Mr. Milo M. Quaif (continuing):

My attention is directed to a letter from G. S. Hubbard to Rufus Blanchard, dated Chicago, October 13, 1880, in Blanchard's "Discovery and Conquests of the Northwest. 1881." I know this work in a general way. In the sense that

historians use all printed works that happen to be of interest. I would say they would use this. I am not commending Blanchard.

The letter is as follows:

"Chicago Oct. 13, 1880.

Rufus Blanchard:

My Dear Sir:—Your favor of the 11th is at hand, and I most cheerfully give you what information I possess on the subject matter of your note.

Prior to 1800 the north branch of the Chicago river was called by the Indian traders and voyagers 'River Guarie' and the south branch 'Portage River'. On the west side of the north branch a man by the name of Guarie had a trading house, situated on the bank of the river about where Fulton street now is. This house was enclosed by pickets. He located there prior to 1778. This tradition I received from Messrs. Antoine Deschamps and Antoine Beson, who, from about 1778, had passed from Lake Michigan to the Illinois river yearly; they were old men when I first knew them in 1818. This tradition was corroborated by other old voyagers. The evidences of this trading house were pointed out to me by Mr. Deschamps; the corn hills adjoining were distinctly traceable, though grown over with grass.

I am of the opinion that these branches retained their names until about the time of the location of the first Fort Dearborn, and were afterwards known as the north and south branches.

My impression is that Elijah Wentworth opened his tavern on the West Side, near the present west Kinzie street in 1830 at what was then called the Forks. About this date Samuel Miller bought a small log cabin on the opposite side of the river from Wentworth's and south of the present Kinzie street bridge to which he added a two-story log building, finishing the outside with split clapboards. These two public houses were the first Chicago could boast of. Miller by his influence and enterprise, erected a bridge built wholly of logs, across the north branch, just north of his tavern. He and Wentworth being competitors for public favor, the Forks House getting the most patronage, Jos. and Robert Kinzie built stores there, and here resorted some of the officers of the Fort daily, for social intercourse and 'drinks' at Wentworth's bar. Wolves were in those days quite numerous;

one had the audacity to enter in the daytime Wentworth's meat house, and was by him killed. His house had for a sign a tall sapling topped off just above a prominent branch; it extended some distance above the top of the roof, and was a conspicuous notice, to be seen from the prairie, and surroundings, that 'here was food for man and beast'; it lacked however something to hang to the branch projection, to give it character; how to obtain a proper emblem, puzzled the good landlord, as there was no carpenter, or paint shop, or citizen artist; a happy thought struck him, that Lieutenant Allen might condescend to supply the deficiency, if properly approached; this was effected through a mutual friend. The boards of a dry goods box were obtained, from which was put in shape, under the superintendence of Lieut. James Allen, a well proportioned sign, the Indian Agency Blacksmith putting to it hinges, when Lieut. Allen took it in hand again, producing and presenting to Wentworth the picture of the slethy wolf, which was to serve not only an attractive painting, but a memorial of the landlord's valor in killing alone and unaided, of a ferocious wolf. Officers and citizens received invitations to be present at the hanging of the sign; the day and hour arriving found assembled a majority of the people; the sign was brought forth, duly veiled with a blanket, was attacned to the branch of the pole, the veil removed, and it swung gracefully, and was greeted with hurrahs from those present; in turn something else greeted the hoarse throats of friends. Thus was produced and baptized the name of 'Wolf Point.'

Besides Wolf Point was a place called Hard Scrabble, of early historic interest.

Mrs. John H. Kinzie, in her book, 'Wan-bun,' correctly describes the location as 'Lee's Place,' Mack & Conant, extensive merchants at Detroit, in the Indian trade, became the owners of this property about the year 1816. They sent Mr. John Craft with a large supply of Indian goods to take possession of it, and established a branch of their house there, the principal object being to sell goods to such traders as they could, residing throughout this country, without interfering with the interest of those traders who purchased goods from him.

Mr. Craft repaired the dilapidated building, adding thereto, and erecting others necessary for the convenience

of business. He, I think, named it 'Hard Scrabble'; whether he or someone else, it bore that name in 1818.

At the organization of the American Fur Company 1816, Mr. Astor's plan was to control the entire trade by absorbing other companies doing an Indian business. He succeeded in buying out the Southwest Company, whose headquarters were at Mackinaw, but failed in his efforts to buy out Mack & Conant.

Mr. James Abbott, however, their agent at Detroit, succeeded in buying them out in 1820 or '21, and they withdrew from the Indian trade, transferring their Indian goods, posts and good will to the American Fur, who constituted Mr. Craft their agent here, he removing his quarters from 'Hard Scrabble' to the company's warehouse, located north of and adjoining the military burying ground. They enlarged it and built a log warehouse, besides; J. B. Beaubien, who had previously occupied it, removing to the 'Factor House' adjoining Fort Dearborn. Craft died in the fall of 1826, and Mr. John Kinzie succeeded him. Mr. Wm. W. Wallace (who was one of Astor's men on his expedition to Columbia River) took possession of Hard Scrabble after Mr. Craft left the place, and died there during the winter of 1827-8. From that time till the land title passed from the government, it was occupied by several families temporarily, among whom were the Lawton's for a short time, and James Galloway, the father of Mrs. Archibald Clybourne.

Yours truly,

G. S. HUBBARD."

LETTERS OF JOHN EGAN TO GEO. ROGERS CLARK.

Mr. Milo M. Quaife (continuing):

My attention is called to 18 Wisconsin Historical Collections, pages 439-440, a letter from John Edgar to George Rogers Clark, dated October 23, 1786, which is as follows:

"Sir—I Recd, yours by Express of the Eighteenth Instant and Observe the Contents of your Letter and am very happy to find that you put Confidence in me. There is nothing that I would not do to Serve General Clark, & my Country.

And you may Depend on me that I will Execute your Order or any other Orders, that you may think proper to enfaire on me, to the last tittle that is in my power.

The inhabitants of these Villages is very much disaffected to the United States, owing much to the Michilimackinac Company, which holds a large Trading House at Cahokia for the supply of the Savages.

If any thing tourn up in the Illenois of Consequance I shall immediately give you intellegance by Express.

I am Sir your most Obedt. & Humble Servt.

JOHN EDGAR.

N. B. This Country is totally lost if we have not Government established here soon, etc. etc., I was oblig'd to give St. Ange a horse as the one he brought give out.

Kaskaskies 23d. Oct. 1786.

George R. Clark Esqr. Post Vincent."

EXTRACT FROM SCHOOLCRAFT'S LEAD MINES OF MISSOURI, pp. 41, 161, 243, read in evidence at the hearing of said above mentioned cause by and on behalf of the Government before Hon. K. M. Landis, Judge.

Mr Corneau: Yes. Just at this moment it seemed to be a good place to put it in because chronologically it fits right in. It is entitled "A View of the Lead Mines of Missouri, including some observations on the Mineralogy, Geology, Geography, Antiquities, Soil, Climate, Population and productions of Missouri and Arkansas, and other sections of the western country. Accompanied by three engravings. By Henry R. Schoolcraft, Corresponding Member of the Lyceum of Natural History of New York. New York. Published by Charles Wiley and Company, No. 3, Wall Street, 1819."

Schoolcraft's knowledge and competency on such questions is very fully discussed in the record. Some of it we have read and more of it will be stated as we proceed. The particular excerpt to which I now wish to call attention, or excerpts, rather, appear first on page 41, at which point he is speaking of the ultimate benefit to be derived by connecting Lake Michigan with the Illinois River by artificial means, evidently, and is as follows:

"The river Plein, the mean head fork of Illinois approaches so near the head of Chicago river, which enters Lake Michigan at Fort Dearborn, that a communication exists in high water. I conversed with a trader last summer at St. Louis, who had come through in the spring, and afterwards saw his boat lying at the wharf. It carried from 4 to 6 tons, and was built skiff fashion, with a

flat bottom. He represented the undertaking as easy of execution, not requiring an artificial cut of more than 2 miles, and this through an alluvial soil."

The next excerpt is at page 161. This seems to be a general description of rivers and mountains in the territory concerning which he was speaking. The excerpt is as follows:

"The Illinois is also a stream affording a great length of navigation, and lands of superior quality and has a natural connection with the great north western lakes, by which boats may, at certain seasons, uninterruptedly pass from Lake Superior, and the Lake of the Woods."

Mr. Corneau: The next excerpt is from page 243:

"The Illinois is navigable 300 miles, and when the communication between it and Lake Michigan between the Mississippi, and Lake Superior, and the Lake of the Woods—between the Missouri and the Columbia—between the Yellowstone and the Multnomah, shall be effected, communications not only pointed out, but almost completed by nature, what a chain of connected navigation shall we behold? and by looking upon the map, we shall find St. Louis the focus where all these streams are discharged, the point where all this vast commerce must centre, and where the wealth and the refinements flowing from these prolific sources, must pre-eminently crown her the queen of the west."

Mr. Cressy (on behalf of the Government):

I am now reading from the Life and Writings of DeWitt Clinton, by William W. Campbell, published at New York by Baker and Scribner, in 1849. This has been submitted to counsel for defendant and they have had a chance to check through it. That is the reason why it was omitted.

Reading from page 140 (reading):

"We visited the Adams, a brig of 150 tons and four guns, belonging to the United States, commanded by Commodore Brevoort"—

Mr. Scott (on behalf of the defendant in said above mentioned cause): Where was that?

Mr. Cressy: What?

Mr. Scott: Where was he when he visited this; where was he at?

Mr. Cressy: At Buffalo, he is writing at Buffalo. I think that is correct, Mr. Scott; if it is not you may correct it, but that is as I remembered it when I read it over.

(Reading page 140:)

"We visited the Adams, a brig of 150 tons and four guns, belonging to the United States, commanded by Commodore Brevoort, who appears to be a worthy officer. This is the only vessel we have on the lakes, and she is employed in transporting military stores. She can make a voyage to Fort Dearborn, upwards of 1000 miles, on lake Michigan, and return, in two months. The British have two armed vessels on this lake, one pierced for sixteen, and the other for twelve guns, and a fort to the southwest of Black Rock, called Fort Erie and garrisoned by a Lieutenant and twenty men.

Commodore Brevoort says that vessels drawing seven feet water, can at some seasons go from Fort Dearborn or Chaquagy (Chicago), up a creek of that name, and to the Illinois River, whose waters in freshets meet, and go down the Mississippi; he thinks he can effect it in his brig, which draws but six feet when lightened. A brig of 150 tons, sailing from Black Rock to Hudson, would seem incredible."

Mr. Cressy: I think this diary bears a date here, doesn't it, Mr. Scott?

Mr. Scott: Yes, it does.

Mr. Cressy: It is August 5, 1810.

"EXTRACT FROM PAMPHLET BY OSSIAN GUTHRIE IN REGARD TO THE OPERATION OF PUMPS AT BRIGEPORT."

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Mr. J. W. Woerman (continuing): On page 27 Mr. Guthrie gives a table which gives the period in each year during which the Bridgeport pumps were operated from 1860 to 1867, inclusive, and certain other data in connection therewith, which said pages 27 and 28, were considered as read and copied into the record, and are as follows, to wit:

Economy Abstract Page 1045

"EXTRACTS FROM PAMPHLET BY OSSIAN GUTHRIE IN REGARD TO THE OPERATION OF PUMPS AT BRIDGEPORT."

1860	Running time in min's.	Cubic ft. per min.	Population	Cubic feet per min. per 100,000 inhb's.	Remarks
June 31 to July 31	9,171	12,000	109,000	11,009	
Aug. 1-31.....	4,891	8,257	109,000	7,575	
Sept. 3-26.....	3,011	14,000	109,000	12,844	
1861					
June 23 to Aug. 31	23,100	11,000	124,000	8,800	
1862					
May 28-31.....	2,810	18,000	138,000	13,000	
June 22-30.....	5,390	12,000	138,000	8,834	
July 1-19.....	16,703	13,400	138,000	9,700	
1863					
July 5-31.....	15,710	12,500	153,000	8,170	
Aug. 1-31.....	16,430	10,500	153,000	6,680	
Sept. 1-30.....	10,915	10,000	153,000	6,500	
Oct. 1-15.....	About like Sept.			6,500	
1864					
June 11-30.....	11,900	10,800	169,000	6,400	This year showed the first deposit of sludge in the canal.
July 1-16.....	13,995	10,000	169,000	5,900	
Aug. 11-31.....	15,395	10,600	169,000	6,200	
Sept. 1-30.....	Same as August.			6,200	
Oct. 1-31.....	About			4,000	
1865					
May 29 to Oct. 25, inclusive.....			290	934,000	Irregularly.
1866					
June 7-30.....	24,480	10,000	200,000	5,000	After this date irregular.
1867					
June 19-30.....	15,840	12,340	225,000	5,500 or an ave'ge 5,041	This pumping was in excess of the needs of Chicago. Lockport millers wanted the water
July 1 to Nov. 15..	198,720	13,000	225,000	Ave'ge 5,500	

"EXTRACTS FROM PAMPHLET BY OSSIAN GUTHRIE IN REGARD TO THE OPERATION OF PUMPS AT BRIGEPORT."

"Sewage Dilution.

To the Joint Special Committee appointed to investigate in relation to the effect of Chicago Sewage upon the rivers through which it passes:

Gentlemen:—

You will recollect that at your meeting of March 31, Mr. J. D. Paige, representing the delegation from Joliet, contended that no benefit would be derived from dilution. In reply to my question he said that no disagreeable effects were ever experienced until after the deepening of the canal in 1871, and in this position he seemed to be supported by the whole delegation, or at least was not contradicted by a single member. My object in questioning Mr. Paige was to lay the foundation for introducing the above table showing the operation of the Bridgeport pumping works from 1860 to 1867, inclusive.

The pumps were operated to the close of the year 1870.

This record shows, particularly that in 1867, for a period of five months almost the entire sewage of Chicago (the city then containing 225,000 inhabitants), was sent down the canal diluted by 5,500 cubic feet of water per minute for each 100,000 inhabitants, and passed Joliet unnoticed, as shown by her own delegation it had done. To a greater or less extent, Chicago sewage, it was also shown, had, since the opening of the canal in 1848, passed Joliet; much of this time, by reason of long delay in starting the pumps, the Chicago river was in as offensive a condition as it has ever been since. This evidence, with that of Mr. Paige undisputed, viz.: that no inconvenience was ever felt until after the deepening of the canal in 1871, seems conclusive that sewage may be so diluted as to be inoffensive to the senses. In addition to the degree of dilution shown above, the flow of the Desplaines river was then uninterrupted, and summer packing, which now contributes largely to the river dilution, was unknown.

O. GUTHRIE."

The following are extracts from G. P. Brown's book entitled Drainage Channel and Waterway:

Chapter I—Water Supplies of Large Cities.

Chicago is the only great city in the world that has easy access to an unlimited supply of pure water—not the chemically pure product of distillation, but that which is free from organic pollution. Water is suitable for domestic use when it does not contain matter which is itself poisonous, or which is food for disease producing bacteria. In its natural state,

the water of Lake Michigan contains no trace of such matter, and in this sense is pure.

Not only does Chicago obtain unrivalled water from an exhaustless reservoir, but from one which lies at its very door. It needs to build no costly aqueducts, construct no artificial storage basins, and make no provision against drought. Nature has fairly lifted the cup to Chicago's lips. Lake Michigan has been one of the sources of the city's unrivalled prosperity. Good water flows through the arteries of a city as pure blood through the body, refreshing and sustaining it. Without wholesome water there can be no permanent aggregation of people. The growth of cities is limited by their ability to secure and maintain a suitable supply of water. The struggle for it is often so great as to excite pity. Vast sums of money are spent and useful lives sacrificed. Energies which should be used in developing commerce and manufacturers are wasted in a warefare with nature.

New York was compelled to go into the country forty miles and collect the waters of small streams into artificial lakes. These are more or less contaminated, and constant efforts are required to check the pollution. Dams, aqueducts and tunnels have cost the city nearly $30,000,000, and still the system must be extended as the city grows. Plans have been adopted recently for the construction of a new dam which will collect the waters of a region 376 square miles in extent. This and its auxiliaries will cost $5,000,000, and six years will be required for its completion.

Boston goes to Lake Cochituate for its water supply, a distance of twenty miles, and has paid more than $10,000,000 for storage reservoirs and a brick conduit.

Philadelphia is supplied mainly from the Schuykill River, whose waters are delecteriously affected by the sewage of towns, and the waste of factories. Three plans for an improved supply are now under consideration, any one of which will cost not less than $20,000,000.

London obtains about one-half the water it uses from the Thames above tidal limits, and the remainder from smaller streams and springs. At the present rate of increase in the population of the city it is estimated that, within thirty years, the amount required will exceed the supply of the entire Thames basin in times of drought. In the near future it will be necessary to provide increased storage capacity, or discover new sources of supply. Dr. Frankland says the water of the Thames and Lea is becoming more and more unfit for

domestic use, on account of sewage pollution, notwithtsanding the most efficient means of filtration are employed at the reservoirs.

Paris derives its supply from the Seine, the Marne, the Ourcq canal, artesian wells and springs. Only that from the wells and springs is fit for domestic use and this is limited in amount. Expensive works have been required to conduct the water supply from the various sources to reservoirs on heights near the city. The main aqueduct is 110 miles in length and there are subsiding conduits 50 miles long.

Vienna goes to the Styrian Alps for water, a distance of 56 miles. Marseilles also depends upon the melting snows of the Alps, and the canal it constructed to the Durance was one of the boldest undertakings of modern times. This canal is carried through three chains of limestone mountains, which are penetrated by forty-five tunnels. It crosses many valleys by aqueducts, one of which, carrying 198,000 gallons per minute, is 262 feet in height.

Manchester built seven impounding reservoirs, whose embankments are from 70 to 100 feet above the level of the valley in which they are constructed. The water with which they are filled is collected from the River Etherow and its tributaries, and is conveyed by an aqueduct 20 miles in length. The gross supply from the entire drainage ground will not exceed 40,000,000 gallons daily.

Versailles spent large sums of money and sacrificed many lives in an unsuccessful attempt to bring water from the River Eure, and the famous aqueduct bridge of Maintenon is the most magnificent structure of the kind in the world. Finally, the waters of the plateau between Versailles and Rambouillet were collected and led by channels 98 miles in length through the city.

Constantinople brings its water through valleys and by aqueduct from the valley of Belgrade, a distance of 15 miles.

The difficulties encountered by Glasgow were almost insurmountable. The beautiful scenery about Loch Katrine, was made generally known by Sir Walter Scott, in "The Lady of the Lake." Public attention was directed to the clear waters of the Highland Lakes, and their use by the city was suggested. After years of discussion, an Act was passed for tapping Loch Katrine. Water is now conducted from this lake to the city by built tunnels, mined tunnels, aqueducts and iron pipes. In all, there are seventy tunnels, eight feet in diameter. One of these is 600 feet below the surface. There are

twenty-seven aqueducts built over rivers and ravines. Some are of masonry and some of iron. A reservoir with a capacity of 500,000,000 gallons was constructed 26 miles from Loch Katrine, and 7 or 8 miles from Glasgow. Into this the water is first discharged. After undergoing a filtering process, it is conveyed in pipes through the city. It has cost nearly $9,000,000 to perfect the system.

Situation of Chicago on Lake Michigan.

Lake Michigan, from which Chicago derives its water, is the second in size in the group of the Great North American lakes. Its mean latitude is 44 degrees north. Its length is 320 miles, and maximum breadth 80 miles. Its greatest depth is 840 feet. Although its surface is 594 feet higher than the surface of the sea, at the bottom it is 246 feet below the surface of the sea. The area of Lake Michigan is 26,000 square miles, and its basin about 43,000 square miles, a total area of 69,000 square miles. The lake is supplied by rainfall and the small streams which empty into it on every side, and its outlet is through the Straits of Mackinaw into Lake Huron.

Chicago is located on the southwestern shore of Lake Michigan. Its original site was low and flat, only a few feet above the level of the lake. The Chicago river, with its two branches, separates the city into three divisions. This comparatively insignificant stream is the remnant of a great outlet from the lake to the westward, which once discharged into the Mississippi river. As the waters of the Great Lakes receded, a ridge of limestone rock, nearly parallel with the western shore of Lake Michigan, and 12 to 20 miles distant, rose above their surface and created the watershed separating the basins of the St. Lawrence and the Mississippi. The Chicago river then began to drain the ponds and the swamps which successively appeared on the eastern slope and turned its course toward Lake Michigan.

By artificial means the river has been made to turn backward much of the time since the city has had a population of 300,000 and has become an open sewer. Spring floods and heavy rains frequently counteract the work of pumps, and the sluggish current has been first to the east and then to the west. The so-called stream is usually a stagnant bayou. It has been the source of much annoyance and has endangered the health of the people. The city's first rude sewers, constructed of planks and even the open gutters along the streets,

emptied into the river; so have nearly all of the more systematic sewers ever since. There has never been sufficient means to lift the sewage above the ridge which separates the river from the outlet to the southwest and the result has been an almost constant discharge of sewage into the lake.

If the conditions could have remained as nature planned them, Chicago's water supply would never have been contaminated. When the city was small, the inhabitants were not troubled; a little sewage did not affect so large a body of water. As the city expanded, this method of sewage disposal became an evil, too great to be ignored. But the plan could not be easily changed, and the city has gone on ever since in a sort of blind fatuity, trying to convince itself the situation was not serious. Spasmodic efforts were made to cleanse the river when self deception was no longer possible. These efforts have failed to secure permanent relief.

Chicago's Water Supply System.

Chicago obtained its first water supply from wells. These were dug in the sand which had been heaped up by the winds, or in the silt deposited by the receding waters of the lake. Acting as a great filter bed the sand might have kept the water free from pollution, had there not been an impermeable stratum of blue clay near the surface. In spite of serious contamination the wells were used for twenty years after Chicago was incorporated as a village, although they were not the only source of water supply.

To understand how the wells became unfit for use, a reference to the geological structure of the region embracing Chicago is necessary. The underlying rock is Niagara limestone. Upon this rests the blue clay, whose average depth is about 100 feet. Lake Michigan formerly extended to the ridge already referred to as the watershed of the St. Lawrence and Mississippi basins. As the underlying rock comes to the surface at the ridge, so the clay stratum thins out at the rim. When the lake receded, sand banks, or dunes were formed across the basin, which extended from the bluffs at Winnetka southward twenty or thirty miles. Between these ridges of sand there were formed inland lakes or ponds in which a luxurious vegetation sprang up. From the resulting decay came the vegetable mold which lies on the surface in some places within the city limits. It is upon this bed of sand and vegetable mold with blue clay beneath that the city of Chicago

stands. At no place was the original level more than twelve feet above the lake. It was the custom when Chicago was a village, as in small villages everywhere today, to dig both the well and the vault on the same lot. The wells were never more than twelve feet deep and usually six. The seepage from the vaults moving freely over the surface of the clay was naturally toward the wells. No health statistics were kept but there were epidemics which were believed to be expressions of divine wrath. Dr. A. S. Martin, an early resident of Chicago wrote to *The Sanitary News* in 1884:

"The water supply was taken from wells sunk on individual premises, or on vacant lots—sometimes in the streets. Dish-water, wash-water, and all fluid refuse from the kitchen, were generally thrown on the ground in back yards. In time, the water drawn from the wells began to taste,—a little brackish at first, then saltish, and finally it had a perceptible odor, which ultimately became offensive. A well, at length, had the odorous characteristics of a privy vault. When it rained the water in well and privy vault rose accordingly; unless the prudent householder 'banked' the latter it often overflowed.

The disuse of wells brought into existence a new enterprise, that of hauling water from the lake and selling it. A hogshead mounted on an axle between two wheels and drawn by a horse was first used. The only opening was a hole at the top sufficiently large to admit a pail. The vehicle was backed into the lake until the water came conveniently near the top, when the hogshead was filled by the use of pails. The driver then proceeded up the street, mounted on a cross-piece in front of the hogshead, and served those who hailed him with water at a shilling per barrel. The use of the pail in emptying was finally superseded by a hose, tacked around a hole about four inches in diameter near the bottom. At length contracts were made and many families were supplied on certain days of each week, or every other week.

When Chicago became a city, water works were established just south of the south pier. Although primitive, they answered the purpose for which they were intended very well. I think the mains were originally of wood, and were tapped by lead pipes. At times they would fail, when the water carriers would have a harvest. As the system was extended, iron mains were laid along the principal streets. Various devices were tried; some

failed, others succeeded. On the whole, the people of the Garden City made very little complaint."

Official action was taken on November 10, 1834, to supply the people of Chicago with water. The village council appropriated $95.50 for digging a public well at the corner of Cass and Michigan streets. This well supplied only a small colony on the North side; persons living on the south side continued to draw water from their individual wells, or to buy it from the water purveyors. Water cart owners found their business a lucrative one, and a company was organized. Water was taken from the lake at the foot of Van Buren street, and supplied by carts as late as 1846.

But the lake was often tempestuous and it was impossible to fill the carts. The resulting dissatisfaction and hardship among the inhabitants prepared the way for a pumping system. The Chicago Hydraulic Company was incorporated by special Act of Legislature on January 18, 1836. The disastrous panic of 1837 checked the company's plans, and work was not fairly begun until 1840. The company's charter permitted it to operate a mill. The combined mill and water works were located at the present intersection of Michigan avenue and Lake street, then directly on the lake shore. An inlet pipe was laid on a crib-work foundation and extended out into the lake about five hundred feet. The pipe was of cast iron, about fifteen inches in diameter, turned downward at the lake end five or six feet. At the shore end was a tank with a capacity of five or six hundred barrels, raised above the ground a few feet by a block foundation. This slight elevation created the only pressure in the distributing system. The works were equipped with a 25 horse power engine and pump to draw the water from the lake to the reservoir, and about two miles of rude wooden pipe were laid. The sections of the pipe were pine logs, bored out by hand and strapped with hoop iron. The mains were six inches in diameter and were laid in the alleys about three feet below the surface. Remnants of these pipes have been unearthed from time to time, the latest when the foundations were dug for the new Chamber of Commerce building in 1889.

This primitive system supplied only a limited portion of the South division with water. Notwithstanding its apparent advantages, it is said that at least four-fifths of the people living within the corporate limits obtained their water for domestic use from the river or by water carts from the lake.

In a reminiscent lecture delivered in McCormick Hall, on January 23, 1876, Governor Bross said:

> "In 1848, Lake and Water, and perhaps Randolph streets, and the cross streets between them east of the river, were supplied from logs. James H. Woodworth ran a grist mill on the north side of Lake street, near the lake, the engine for which also pumped the water into a wooden cistern that supplied the logs. Whenever the lake was rough the water was excessively muddy; but in this myself and family had no personal interest, for we lived outside the water supply. Wells were in most cases tabooed, for the water was bad, and we, in common with perhaps a majority of our fellow citizens, were forced to buy our water by the bucket or the barrel from water carts. This we did for six years."

The Hydraulic Company does not appear to have made money out of its venture, but it maintained an existence until February 15, 1851, when the Legislature, again by special Act, incorporated the Chicago City Hydraulic Company. The indifference of the people was shown at the spring election. Of the 4,445 voters, 513 cast their ballots against the acceptance of the privilege granted by the legislature, and 1,244 did not vote on the question at all.

Dr. John H. Rauch, first secretary of the State Board of Health, says, in his Second Annual Report, that the effect of drinking well water was so marked during the prevalence of cholera in 1849 and 1850, compared with that of drinking lake water supplied to a few inhabitants by the Hydraulic Company, this was one of the reasons urged for the incorporation of the City Hydraulic Company. Concerning the contamination of the wells during the cholera epidemic, it was observed that nearly all who drank the water of a certain well on North La Salle street died. This attracted attention, and was supposed to be owing to the fact that the well received the drainage from privies in the neighborhood, and in this way infected those who drank the water. This was true. But Dr. Rauch discovered afterward that, in this neighborhood, the soil was stratified with thin layers of blue clay, which was impervious to water, and whenever these layers were penetrated by wells, they acted as drains for a great area, the remaining portion or the soil being composed of sand until the thick stratum of blue clay underlying the greater portion of the city was reached.

There was some dispute as to the right of the city to en-

croach upon the privileges of the old Hydraulic Company, and satisfactory terms could not be made with it until the year following the incorporation of the company. The city then began the construction of its own works, which were put in operation in February, 1854. This was the beginning of the present system. Authority over the works was vested in a Board of Water Commissioners. The first board consisted of John B. Turner, A. S. Sherman and H. G. Loomis. The pumping works were located on the lake shore at the foot of Chicago avenue. Already the discharge of sewage into the lake from the river had caused annoyance, and an alternative location for the pumping works at a considerable distance south of the river was suggested. In recommending the site chosen, Chief Engineer J. McAlpine said:

> "It is very questionable whether the small quantity which is discharged from the river would affect the quality of the water in the lake at a point 1½ miles south. From the consideration which I have given the subject, I am of the opinion that there is no perceptible difference between the quality of the water in the lake above the pier and that at the place 1½ miles south of the river, on which the estimates have been predicated."

The water was taken from an inlet basin on the lake shore, separated from the lake by a semi-circular break-water with an opening to the southeast, and distributed through three reservoirs, serving the three divisions of the city, situated, respectively, at La Salle and Adams street, Chicago avenue and Sedgwick street, and Morgan and Monroe streets. The first two were built in 1853, and the latter in 1854. Each held about two or three days' supply. The first iron distribution pipe was laid in Clark street in 1852, and was four inches in diameter. To keep the three reservoirs filled it was necessary to operate the pumps about twelve hours a day. The use of these reservoirs was discontinued after the completion of the West side tunnel in 1874.

In a sketch of the water supply system, written in 1876, Chief Engineer Chesbrough says that the increased growth of the city after the inauguration of the water works, and the introduction of sewerage, together with the establishment of the packing houses, distilleries, etc., so increased the quantity of filth discharged into the lake, that complaints began to be made of impurity and offensiveness in the supply from the pumping works. Governor Bross, in the address referred to on a preceding page, spoke of the new works, and added:

"But our troubles were by no means ended. The water was pumped from the lake shore the same as in the old works, and hence, in storms, it was excessively muddy. In the spring and early summer it was impossible to keep young fish out of the reservoir, and it was no uncommon thing to find the unwelcome fry sporting in one's wash-bowl, or dead and stuck in the faucets. Besides, they would find their way into the hot water reservoir, where they would get stewed up into a very nauseous fish chowder. The water at such times was not only the horror of all good housewives, but it was justly thought to be very unhealthy. Worse than all this, while at ordinary times there is a current on the lake shore south, and the water, though often muddy and sometimes fishy, was comparatively good; when the wind blew strongly from the south, often for several days, the current was changed and the water from the river, made from the sewage mixed with it into an abominably filthy soup, was pumped up and distributed through the pipes alike to the poorest street gamin and to the nabobs of the city."

In 1859, Mr. Chesbrough relates, one of the water commissioners, Mr. Edward Hamilton, proposed to sink a wrought iron pipe, five feet in diameter, one mile out into the lake, to obtain the supply from a point which could not be affected by the river. This plan was referred to the chief engineer of the Board of Sewerage Commissioners, Mr. Chesbrough himself, to be examined and reported upon, with the request "that he also take under consideration and report on the matter of erecting additional pumping works, in such locality as shall secure a supply of pure water." In his report Mr. Chesbrough discussed several plans, but made no specific recommendation. A tunnel was suggested, but it was thought best to defer action until there could be further expert examination of the water, in the hope that much of the complaint was without foundation.

But the water continued to grow worse and became very offensive both to the taste and smell. The Board of Public Works, created in 1861, discussed the various plans proposed for relief and experimented with filters, which were soon found inadequate.

The First Tunnel.

Ground for the tunnel was broken on March 17, 1864. The plan of the work included a land shaft at the western extremity of the tunnel at the foot of Chicago avenue, and the lake shaft at the eastern extremity. The tunnel was to be two miles in length, extending in an east-northeasterly direction from the pumping works. The horizontal diameter of the tunnel was fixed at five feet, and the vertical at five feet and two inches. Mr. Chesbrough says this size was determined upon for two reasons: It was sufficient to deliver a supply for one million inhabitants at the rate of fifty gallons a day for each person, the average quantity used at that time; and experience in Europe had shown that, while it was possible to make small tunnels in the most troublesome ground, the attempt to make large ones had sometimes failed, and at others had been attended with enormous difficulties.

> "Although there was every reason to expect easy work here, there was a possibility of meeting deposits of quicksand, or other soft, wet material. In order to remove as far as practicable every doubt of the final success of the work, this small size was adopted, in the full conviction that whenever it should prove insufficient to supply the demand upon it, the population and wealth of the city would be abundantly able to construct another, and, if necessary, a larger one."

The tunnel was completed substantially as planned, and the last stone was formally laid on December 6, 1866. The contract price was $315,139. The final settlement was for $380,784.60 including $27,420 for extras on the tunnel proper, and $41,225.60, for extras on the shaft, crib and east and west connections. The exact length of the tunnel was 10,567 feet.

The Second Tunnel.

In 1874 a second tunnel, seven feet in diameter, was completed under the lake from the crib to the North Side station. In the same year this tunnel was extended, also seven feet in diameter, under the city to the new West Side pumping station at Ashland avenue and Twenty-second street. There are other tunnels to connect the Central and Fourteenth street pumping stations with the West Side tunnel. In 1887 a shore inlet tunnel, seven feet in diameter and 1,500 feet long, was extended under the lake opposite the North Side pumping

station, to be used when the supply at the two mile crib should be endangered by ice or otherwise. This tunnel was seldom used until the latter part of 1891. In November of that year a new tunnel, planned to be eight feet in diameter, but which was made double and six feet in diameter for a part of the distance, was completed. It extended out under the lake four miles from the foot of Peck court. It was opened in November, 1892, and gave the city an ample supply of wholesome water. The use of the shore inlet tunnel was then discontinued.

Chicago's Sewerage System.

No effort was made to provide Chicago with a system of sewerage until the year 1855. Previous to that time the city was drained by submerged wooden boxes on a few of the principal streets. These were constructed primarily, to supply water for use in extinguishing fires. They were found to be serviceable in carrying away surplus water from the streets, and were afterwards used to a limited extent for house drainage. As they were laid without system and were limited in capacity they were of little use except for surface drainage. In wet seasons they failed to carry away even the surface water.

As a result the city was scourged by epidemics for six years in succession. The death rate became higher than that of any other city in the country. In 1854, with cholera raging, nearly 5½ per cent. of the population died. For the six years beginning with 1849 and ending with 1854, the death rate was 48.92 per thousand. In self defense the city was compelled to consider the construction of an adequate sewerage system. A bill was passed by the Legislature on February 4, 1855, creating a Board of Sewerage Commissioners to be appointed by the City Council. The first Board consisted of William B. Ogden, J. D. Webster, and Sylvester Lind, one from each division of the city. E. S. Chesbrough, then of Boston, was appointed chief engineer. The remainder of the first year was spent in making surveys and preparing plans, which were adopted in December. Work was begun on the sewers in the spring of 1856.

Summarized, the Act creating the commission made these provisions: (1) It shall be the duty of the commissioners to examine and consider all matters relating to the thorough, systematic and effectual drainage of the city of Chicago, not

only of surface water and filth, but also of the soil to a sufficient depth to secure dryness in cellars and an entire freedom from stagnant water, and in such manner as best to promote the healthfulness of the city. (2) It shall be the duty of the commissioners, before entering upon the construction of any sewer, to fix upon a plan or system of sewerage of such a nature that all subsequent sewers may be executed upon that plan.

(3) It shall be the duty of the Board to prescribe the location, arrangement, form, material and construction of every private drain or sewer emptying into the public drains or sewers, and to determine the manner and plan of such connection. (4) It shall be the duty of the board to see that proper drains or sewers are constructed from every lot in the city, which, in their judgment, requires it, and that such private drains or sewers are made to communicate with public drains or sewers in a proper manner, and they shall have power to require such number of drains or sewers to be thus constructed as they shall deem expedient.

Systematic sewerage in this country was unknown when Mr. Chesbrough was called upon to suggest the best method of complying with the law. Not only was the chief engineer unable to profit by the experience of other cities, but the local conditions were unfavorable. From a sketch written by Mr. W. H. Clarke, principal assistant engineer in 1877, it is learned that when the original surveys for the sewerage system were made the surface of the ground in the vicinity of the North and South branches of the Chicago River was only three or four feet above the surface of the lake. It rose irregularly eastward, until at Michigan and Rush streets it was from ten to twelve feet above the same level; to the westward it reached about the same level at Ashland avenue. This configuration made it necessary to raise the grade of the streets to keep the sewers underground. After considerable discussion it was decided to fill in to a level of ten feet above ordinary water on the streets adjacent to the river, raising them with an inclination sufficient to protect the sewers and to permit the construction of cellars seven to eight feet in height. A higher grade was recommended, but it was argued that there would be difficulty in securing sufficient earth to raise the streets to the minimum height decided upon. A few years later it was found that the surplus earth of the South division was sufficient not only to raise the grade of the streets but to fill up the entire lake basin between the Illinois

Central Railroad and Michigan avenue. For a number of years after the construction of the sewers began, some of them were partially above ground, and others entirely so, in what are now business districts of the city. In other localities where the ground was high enough to cover the sewers the grades of the street were fixed by cutting out abrupt irregularities. In places where the ground was too low to permit the construction of well-drained cellars the grade was established at such a height above the surface of the lake as to give not less than seven feet in height to the cellars if they were entirely below the surface of the ground, and at a greater height if the principal floor was elevated above the level of the street.

Soon after their organization the sewerage commissioners asked the public for plans and suggestions. Thirty-nine communications were received. Some of them according to Mr. Chesbrough, were very able and interesting papers. Although none of the plans proposed was adopted, there were many valuable suggestions. Mr. Chesbrough's report to the commissioners was made on December 26, 1855. The plan he proposed was adopted by the board on December 31. It provided for the discharge of the sewage mainly into the river, which the chief engineer argues, would deliver it well out into the lake. The general arrangement of the sewers placed mains in each of the alternate streets running to the river, or about eight hundred feet apart into which two-foot brick sub-main sewers in the streets running at right angles were to discharge. The main sewers were from three to six feet in diameter and built of brick, the walls being eight and one half inches thick.

The original plans provided for the sewerage of what now seems to have been a very small territory. Its southern limit in the South division was Taylor street. In the West division the boundary line ran north on Halsted street to Madison, west to Sangamon, north to Fulton and east to the river. In the North division the district was bounded by Franklin street on the west, Chicago avenue on the north and Rush street on the east. Considerable time elapsed before this limited territory was provided with sewers. Up to the close of 1857, two years after the inception of the work, mains had been built only on Michigan avenue, from Washington street to the river; on Madison street east from Halsted to the river; on Randolph street east from Sangamon to the river; on Clark street south from Chicago avenue to the river,

and on Rush street south from Huron to the river. This gave only one main to the South division; two to the West division; and two to the North division. There were sub-mains on Randolph and Washington streets, extending from the Michigan avenue sewer to the river. These have since been converted into main sewers from State street west, discharging into the river, while the portions east of State street still discharge into the Michigan avenue sewer.

Mr. Chesbrough foresaw the evils resulting from the discharge of sewage into the lake. It was impossible at that time to create an outlet to the southwest, but he appears to have believed that this would be the ultimate solution of the sewerage problem, and his plans were in harmony with it.

Investigation of 1856.

In December, 1856, Mr. Chesbrough was instructed by the sewerage commissioners to

> "proceed to Great Britain and the continent of Europe, for the purpose of examining the various methods of sewerage adopted there, and of taking such notes and drawings of the same as he may think necessary, and of examining into their operation, and into all matters connected with them, and which may, in his judgment, aid in the further prosecution and perfection of the sewerage of the city of Chicago."

Mr. Chesbrough complied with the order, and made a thorough investigation of the sewerage systems of Liverpool, Manchester, Rugby, London, Amsterdam, Hamburg, Berlin, Paris, Worthington, Croydon, Leicester, Edinburgh and Glasgow. The results of his trip are given in a detailed report transmitted on March 25, 1858. No one of these great cities, he said, furnished an exact criterion by which to judge of the effect of discharging the sewage of Chicago into the river and its branches. Yet, their experience led him to fear that this city might yet conclude, as they had, that it would be necessary to keep the sewage out of the river. Chicago's plan was based upon the supposition, well founded, as has since been shown, that the natural state of the river during the summer months would require artificial aid to keep it in a healthy condition, and therefore provided for driving fresh water into the upper portion of the South branch from the lake. But the scheme for flushing the river was never carried out, and the idea was practically abandoned in 1860. The deep cut of the

Illinois and Michigan canal had been proposed, and the commissioners concluded that the construction of the canal from the lake to the South branch along Sixteenth street according to the original plan, would be unnecessary.

Mr. Chesbrough did not overlook the advantages of an outlet to the southwest. He said:

> "The through cut for a steamboat canal to the Illinois river, which the demands of commerce are calling more and more loudly for, if ever constructed, would give as perfect relief to Chicago as is proposed for London by the latest intercepting scheme; that is, it would furnish a constant and abundant stream from the lake flowing westwardly throughout the season of navigation, and consequently during the warm and sickly portions of the year."

Population of District, 1892.

The following table, which shows the distribution of population in the Sanitary District, and particularly the fact that the waste from a population of 270,000 discharges at once into lake, was presented to the Trustees of the District in a report made by the joint Committee on Engineering and Finance on October 12, 1892:

"Distribution of Population in Sanitary District.

	1886	1892
North Branch above Fullerton Ave.....	28000	73000
North Branch below Fullerton Ave.....204000		345000
	232000	418000
Total Main River and South Branch) North Side	62000	86000
) South Side	72000	90000
) West Side 279000		416000
	413000	592000
Total South Fork	80000	200000
	725000	1210000
Total tributary to River Lake Shore 104000		185000
Total in District	829000	1395000

The destination of the sewage of the entire population of the Sanitary District and adjacent townships is shown

in the following exhibit for 1892, the figures being given in round numbers.

Chicago River	1,213,000
Lake Shore of Cook County (including the Calumet)	270,000
Desplaines Valley	22,000
Total	1,505,000

Of this total, less than 1 per cent. consists of rural population, and not over 2 per cent. are outside of sewered districts. The essential fact is, that on a shore front of thirty-two miles, 270,000 of population drains to the lake at all times, and 1,493,000 whenever the river, from any cause discharges lakeward; and further, that this population tributary to the river will reach a total of 2,000,000 before any radical change can be made."

Condition of River, 1861.

In 1861 the Board of Sewerage Commissioners went out of existence. Their duties, together with those of the Water Commissioners and of other departments, were transferred to the Board of Public Works, which was organized on May 6, 1861. In his first report to the new Board, on February 24, 1862, Chief Engineer Chesbrough called attention to the impurity of the river. "There have been several occasions during the last three years," he said, "when many persons thought they could perceive the effect of the river in the taste of the water, but not until the night of the 10th inst., and during several days since, did that effect become so striking as to convince all who have examined into it of its real nature. On the morning of the 10th the wind being from the south and westward, the lake fell to an unusually low point. This, of course, caused a very large amount of water to be discharged from the river into the lake, producing the well known disagreeable effect upon its taste and smell, so that it could be distinctly perceived along the shore, from a considerable distance south of the river to the cemetery on the north. Since the 10th the water has twice been free from this taste and smell, and twice it has become offensive. The taste thus given to the water supplied to the city is much more offensive than that caused by the fish, while it is utterly impossible by any means at the disposal of the Board to prevent it at present."

Agitation for Deepening I. & M. Canal.

Commercial and sanitary interests joined hands in the winter of 1864-5 and agreed upon measures for the deepening of the Illinois and Michigan canal. The river does not seem to have become more offensive than it had been during the previous two or three years, but it was apparent that the ultimate result would be most serious unless steps were soon taken to purify it. Public discussions were had as to the legislation which would best accomplish this object, and a joint committee was appointed by the City Council and Board of Trade to consider the matter. On the recommendation of this joint commiftee a commission was appointed by the City Council to continue the investigation. The commission consisted of Mayor F. C. Sherman, William Gooding, R. B. Mason, John Van Norwick, E. B. Talcott and E. S. Chesbrough.

In the meantime the question was agitated in the State Legislature, and an amendment to the charter of the city was secured which authorized the appointment of two additional members on the Board of Public Works, empowered to act with the other members of the Board, but only on matters relating to the cleansing of the Chicago river. The new members were William Gooding and Roswell B. Mason. The regular members at this time were John G. Gindele, president, Frederick Letz and Orrin J. Rose. Before the special commission made its report an Act was passed by the Legislature providing for the completion of the Illinois and Michigan canal upon the plan adopted by the state in 1836. This Act was approved February 16, 1865.

The preamble recited the fact that it had been represented that the city of Chicago, in order to purify or cleanse the Chicago River, by drawing a sufficient quantity of water from Lake Michigan directly through it and through the summit division of the Illinois and Michigan canal, would advance a sufficient amount of funds to accomplish this desirable object; that the original plan of the canal was to cut down the summit so as to draw a supply of water for navigation directly from Lake Michigan, which plan was abandoned for the time after a large part of the work had been executed in consequence of the inability of the state to procure funds for its continuance, and that under the law the plan of the summit division was changed, the level being raised so as to require the principal supply of water through the Calumet feeder, subject to serious contingencies, and by pumping at Bridge-

port. Then followed the enactment which made these provisions:

1. To secure the completion of the summit division of the Illinois and Michigan canal, upon the original "deep cut" plan, with such modifications and change of line, if necessary, as will most effectually secure the thorough cleansing or purification of the Chicago River and facilitate the execution of the work, the city of Chicago, through its constituted authorities, may at once enter into an arrangement with the Board of Trustees of the canal with a view to the speedy accomplishment of the work.

2. The canal shall not be constructed of a less capacity than provided in the plan adopted by the Canal Commissioners in 1836, nor shall the work of deepening it be prosecuted so as materially to interfere with navigation. By consent of the Board of Trustees navigation may be opened later and closed earlier than usual in former years, but it shall never be diminished to a less time than six months.

3. It shall be lawful for the city of Chicago to enter upon and use any lands which may be necessary for right of way, if the route should vary from the present line of the canal, and to take and use any materials necessary for the prosecution of the work, their value to be determined in the manner provided by the general laws of the state.

4. The amount expended by the city of Chicago in deepening the canal according to the plan of 1836 shall be vested lien upon the Illinois and Michigan canal and its revenues after the payment of the present canal debt, provided the cost shall not exceed $2,500,000.

5. The state of Illinois may at any time relieve this lien upon the canal and revenue by refunding to the city of Chicago the amount expended in making the contemplated improvement and the interest thereon.

Report of City Com. of 1865.

Under date of March 6th, 1865, the city's Commission made its report to the Mayor and Common Council. This report gave in detail the plan for cleansing the Chicago river and was an important document. It is reproduced in full:

> "The undersigned having been duly notified that they were on the 9th of January, 1865, appointed a Board of Commission to devise the best plan for cleansing the Chicago river, and having carefully considered the ques-

tions involved in this important subject, have the honor to submit the following report.

Knowing that various modes of purifying the river had been proposed by gentlemen of intelligence having a direct interest in the subject, we resolved to avail ourselves as far as practicable of their opinions. Accordingly, at our first meeting, we caused a notice to be published requesting all persons who had formed any plans for effecting the object in view to present them with the necessary explanations. In response to this request a great number of communications were received, some of them containing valuable suggestions and showing that much thought had been bestowed upon the important questions involved.

We here desire to express our thanks to the parties who so kindly and promptly came forward to assist us in the solution of a difficult problem, and especially to those who had devoted much time to the preparation of elaborate plans and estimates.

We do not deem it necessary to discuss, in this report, the merits of the various plans and suggestions which we have considered. Suffice it to say that at our different meetings we have endeavored to fully and impartially consider all their various merits and defects, and to give them all the weight to which, in our judgment, they were justly entitled.

These communications more or less directly bear upon three general plans which seem to be the only ones through which the main object in view can be accomplished, to wit:

1. Intercepting sewers which shall receive the filth that would otherwise flow into the river and carry it to the lake, to some point or points into which it would be pumped by machinery, thus keeping impurities out of the river to as great an extent as practicable.

2. Cutting canals or making covered sewers from the two branches of the river to the lake, and by pumping works erected thereon force the filthy water out or the lake water in, thus keeping up a constant and sufficient current to keep the river pure. We do not believe that the necessary current can be produced by the natural action of the waves of the lake, as has been suggested.

3. Cutting down the summit of the Illinois and Michigan canal below the level of the lake, so that a sufficient quantity of water may be drawn from it to create the

necessary current through the main river and the South branch (and perhaps, to some extent in the North Branch also) to thoroughly purify the same at all times.

Without recapitulating all the arguments which have been urged for and against these three general plans, it may be sufficient to briefly state a few of the prominent advantages and disadvantages of each. * * *

The estimated cost of the third plan for purifying Chicago river, which is to cut down the summit of the canal below the level of the lake, so as to draw from it, at a low state, not less than 24,000 cubic feet of water per minute, is $2,102,467.50.

This estimate provides for increasing the capacity of the canal somewhat over the plan adopted by the Canal Commissioners in 1836, so as to create a current in Chicago river which is deemed sufficient to cleanse it. The quantity of water drawn from the lake through the river would seldom be less than 24,000 cubic feet per minute, and at the average stage of water much greater.

The advantages of this plan are briefly as follows:

1. It furnishes the only possible self-acting means of cleansing the main river and the South branch (and possibly to a certain extent the North branch also) every hour of the day, and every day of the year, for all time to come.

2. The filth of the city which passes into the river will be drained off into the canal without contaminating the waters of the lake, and the continual current will prevent the water in the river from ever becoming very offensive.

3. The cost of construction will be the only expense to the city, as all subsequent expenses in keeping the channel open, and enlarging and improving it, will be borne by the state.

4. The money expended in cutting down the summit of the canal, so as to procure the supply of water directly from Lake Michigan, will constitute a part of the expense of enlarging the present canal so as to admit the passage of steamboats of the largest class,—an improvement which must soon be made.

5. By using the present summit locks, or, if the canal be enlarged, constructing other locks at each end of the 'deep cut' of the enlarged dimensions, a large quantity of water could be accumulated at any time by filling the canal to the present surface, which could be suddenly

discharged into Chicago river, making a strong current to the lake. This may never be necessary, but the plan admits of the arrangement described, should it hereafter be deemed desirable.

We have mentioned the prominent advantages of the plan. The principal disadvantages are its cost and the time which must be occupied in doing the work. The probable cost has been given. The time which would be required to execute the work economically, without seriously interfering with the navigation of the present canal, would be about three years.

But no other plan by which the river could be effectually purified could be executed in less than one year; so for a year, at least, some means within reach must be adopted to remedy the evils which it is intended ultimately to entirely obviate.

It is believed that the hydraulic works at Bridgeport, if worked to their full capacity, or even so as to raise all the water which the present canal, with some slight additions to its banks, could discharge, would prevent the river from becoming very offensive, if especial vigilance were exercised to keep out delecterious substances. This we deem of the utmost importance, and, in fact, indispensable to the well being of the city, until some plan of thorough drainage be carried out.

Even then, it appears to us, that the distilleries which have at times rendered the waters of the North branch almost putrid, and other establishments which have given Chicago a world-wide fame for its vile odors, should not be permitted to remain the nuisances which they have been. Certainly the process of thoroughly cleansing the river would be greatly simplified if no more offensive substances were discharged into it than could possibly be avoided. It would seem to be the part of wisdom as much to avoid an evil, if possible, as to cure it. * * *

In view of all the facts of the case, the best plan for cleansing the Chicago river that we can devise, is to cut down the summit of the canal so as to draw a sufficient quantity through it from the lake to create the necessary current in said river.

We are aware that the first cost of executing this work would exceed that of constructing short canals from the North and South branches to the lake and erecting the necessary machinery thereon. We are aware also that, theoretically, the interest on the additional cost would

be more than the expense of operating said machinery. But we do not think that in deciding this question we have a right to disregard other considerations of great importance to the interests of the city, especially the law passed at the recent session of our State Legislature which gives the city of Chicago a lien upon the Illinois and Michigan canal and its revenues after the payment of the present canal debt, until the whole cost of making the 'deep cut' and the interest accruing thereon shall have been reimbursed to the city.

With regard to the North branch, while we consider the proposed open canal from the lake to the river, along or near Fullerton avenue, the best plan to recommend for permanently cleansing it, if the discharge of filth into it must be suffered to go on as heretofore, we believe it is both the right and the duty of the city to prevent all such discharges. This would be by far the simplest, cheapest, and quickest way of purifying that branch; in fact, the only method we can think of to obtain immediate as well as permanent relief.

It has often been said within the last three years, that any effectual prohibitions of such discharges would drive the distilleries from the city and thus inflict a serious blow upon its prosperity. By an Act of Congress, of last year, such heavy taxes were imposed upon distilled liquors as to cause the stoppage of these distilleries last July. But one has resumed work since, and that within the last two months. As a result the north and northwestern portions of the city have enjoyed unusual freedom from nuisances, which were often before of a most abominable character, while no complaints of any injury to the general growth or prosperity of the city have been heard of.

The proposed canal on or near Fullerton avenue would cost, as already stated, about $500,000, and probably cost not less than $20,000 annually afterward to maintain it, particularly if steam power should be required. It would be better for the city to pay now at least $500,000 should that be necessary to prevent the North branch from being polluted, than to construct and maintain this canal, whatever may be the final necessity for keeping up an artificial current in said branch. We believe the true policy of the city is to prevent all nuisances, as far as possible, from being made, and then the unavoidable ones

will be comparatively easy to remedy. The proposed canal would probably encourage and increase, to a very great extent, filthy discharges into it and the river from establishments that would be, most probably, nuisances of themselves to their neighborhoods.

The present sewerage system of the city has been planned and thus far carried out at some additional inconvenience and considerable expense, with reference to keeping the North branch as free as possible from pollution, for the purpose of avoiding the heavy expense that would otherwise be required to purify it. Up to this time there is but one sewer, and that only a few blocks long, on Chicago avenue, that discharges constantly into the North branch. The West Kinzie street sewer discharges into it during heavy rains only. The probability is that, for many years to come, the amount of sewage it may be necessary to discharge into that branch would not be of sufficient to cause offensiveness, if the establishments above mentioned, as well as similar ones, can be prevented from discharging their filth into it."

Efforts to Purify the Chicago River.

By cutting away a temporary dam which had been thrown across the canal at Bridgeport to stop the flow of water from the river the final act in deepening the Illinois and Michigan canal was accomplished. This occurred on the afternoon of Saturday, July 15, 1871. "Quite a strong current was at once created, and an entire change of the water in the main river and the South branch was effected in about thirty-six hours." The water in the South branch is said to have become "quite clear and entirely free from noxious odors," and the favorable effect upon the water of the North branch was perceptible.

The completion of this work was an impressive event in the history of the city. "No more important and necessary public improvement has ever been undertaken by the city," said the Board of Public Works. "The water of the river has become more and more filthy and offensive with the increase of our sewers having their outlet therein, and the absolute necessity of providing a way of carrying off this accumulation of filth has become more and more apparent. It is confidently believed that this will prove an adequate and permanent means of relief so far as the main river and the South branch are concerned."

The total amount expended by the city in deepening the canal was $3,300,883.71. The discount on the canal bonds amounted to $95,682.61, and the total of lost tolls paid by the city was $43,501.07. By the Act of the Legislature authorizing the work the city was given a lien upon the revenues of the canal to the extent of $2,500,000 and interest. As a compensation for the loss by the great fire of 1871 the Legislature, on October 20 of that year, appropriated $2,955,340, with interest until paid, to relieve this lien. There was this provision in the Act that not less than one-fifth, nor more than one-third, of this sum should be applied by the city in reconstructing the bridges and public buildings and structures destroyed by the fire, the remainder to be applied to the payment of the interest on the bonded debt of the city and the maintenance of the fire and police departments.

Opening of Deep Cut July 15, 1871.

For some years the effect upon the South branch was wholly satisfactory. "At all ordinary times now," said the chief engineer in 1872, "the water of Lake Michigan enters the mouth of the river, flows up it and the South branch to feed the canal, thus completely deordorizing what was so offensive and unbearable a year ago." "But observation as well as reflection shows," he said a year later, "that the purifying power of the canal is limited, and it will not do to suppose that any amount of filth, from a city of the size to which Chicago promises to grow, may be discharged into the river and branches for all time to come without producing injurious results."

Originally at Outlet to the Miss. R.

By constructing an artificial waterway from Lake Michigan to Joliet, Chicago will restore an ancient outlet to the Mississippi. The great lakes were once an arm of the sea, like the Baltic in Europe. An upheavel of the earth left this body of water in a depression of its own. The tides of the ocean no longer swept through it, but its own overflow sought the sea in mighty rivers. Its surface was many feet, perhaps hundreds, higher than it is now. There is abundant evidence of this. Deposits of sand and clay containing fresh water shells on the shores of Lake Huron are found forty feet above the present water level, and extend back in some places twenty miles. Terraced deposits of alluvial material, indicating for-

mer water levels, extend along the shores at heights ranging from 120 to 200 feet. Seven ancient beaches were found by Logan at intervals up to a height of 331 feet above the level of Lake Superior.

With such a volume of water in a great reservoir at the summit of the continental watershed, continually increased by melting glaciers and almost constant precipitation, the outfall both to the east and the west was enormous. With the passing of the glacial epoch the ice withdrew to the north, the waters settled in their individual basins, the bed of the channel to the eastward yielded to their corroding action and there has since been a continuous discharge through the St. Lawrence to the Atlantic. The rocky ridge west of Lake Michigan, like an imperfect dam, weakened at one point and a crevasse was opened through the solid limestone to a depth of 200 feet. For ages the waters of the lake were poured into the Gulf of Mexico, through this outlet, by way of the Mississippi valley. The trough hewn out of the rock for a distance of twenty miles, the bottom of which is only six feet above the present level of the lake, is from one to two miles in width. It may be said to begin at Summit, eleven miles west of Lake Michigan, and to end at Lockport, twenty miles further west and south. It is in the bed of this natural outlet that a new channel is now being excavated, of sufficient depth to renew the outflow from the lake.

In Worthen's "Geological Survey of Illinois," M. H. Bannister says it is evident, with very little observation, that at a comparatively recent period, subsequent to the glacial epoch, a considerable portion of Cook County was under the waters of Lake Michigan, which at that time found an outlet into the Mississippi valley through the present channel of the Desplaines. The deposits of this period consist of beds of stratified sand and gravel in the central and eastern portions of the county, either underlying the flat prairies or arranged in the form of ridges, skirting the shores of the lake, and in one or two cases trending westward away from it to a distance of several miles. These ridges, he says, seem to indicate the shores of the ancient bay, which with these boundaries would require the level of Lake Michigan to be nearly forty feet higher than at the present time. The outlet was evidently near Summit, where an alteration of the level for a very few feet would send the waters of the Chicago river into the Desplaines.

Another very evident outlet, to the south of this was through the channel utilized by the Calumet feeder, joining the Des-

plaines at the Sag. The mound or ridge at Blue Island, Mr. Bannister thinks, must be referred to this level of the waters. He found numerous evidences of a powerful stream on the rocks at Athens, in the shape of waterworn surfaces, pot-holes, etc. The nearest ridges running parallel to the present coast line, appear to him to indicate a very gradual recession of the waters of the lake, before reaching its present limits. The structure of these ridges, he finds, is similar to that of beech deposits, generally consisting of irregularily stratified sand and gravel beds, with sometimes a thin seam of vegetable mold. This structure, he adds, is well displayed on the lake shore north of the University grove at Evanston, where the wearing action of the lake storms upon the shore has cut down one of the ridges upon which the town is built.

Frank H. Bradley, who wrote the geological history of Will county for the same work, says that throughout the valley of the Desplaines, Du Page and Kankakee rivers the alluvial deposits constantly remind the observer that Will county once bordered the lower end and the outlet of Lake Michigan. The mounds along the Desplaines which were formerly attributed to the industry of the aboriginal mound builders, are, to him, evidently the islands and banks of the old western outlet.

There are varying opinions as to the manner in which this outlet was created. Worthen says of all the river valleys of the state, that if we could strip off from the surface the superficial deposits of sand, clay and gravel, varying in depth from ten to one hundred feet, we should find broad and deep valleys, cut into the solid rock strata to a depth varying from one hundred to three hundred feet. It is his opinion that these valleys were excavated, in part, at least by streams of water, but that they may have been greatly enlarged by the joint action of ice and currents of water, perhaps during a period of submergence, and were afterward filled, either wholly or in part, by the superficial material called drift which now occupies them.

Ossian Guthrie, whose name has been associated with every effort of the past forty years to renew an outlet to the Mississippi, and who has made personal investigations of the physical conditions, believes that the Desplaines valley was excavated by glacial action. In a paper read before the Geological Society of Chicago he estimates that the glacier, which, he believes, once occupied the bed of Lake Michigan was 2,500 feet in height above the present surface of the lake at its southern extremity, and 16,000 feet in height at its source. He traces the course of this glacier by its moraines, and con-

cludes that it turned to the westward at the present location of Chicago and ploughed its way through the rocky divide. There were two channels, one by the way of Mud Lake and the other by way of the Sag. "Hundreds of acres of rock, easy of access and in many places exposed to view," he says, "are glacial scored and plainly indicate this; and along both channels glacial debris is scattered in such variety and profusion that it would seem to be more difficult for the geologist to lose the glacial trial than to follow it."

A remnant of the ancient stream is found in the Desplaines river, which now, a mere thread, winds through the valley over its rocky bed. This river rises in the southern part of the state of Wisconsin, and flows southward parallel with the western shore of Lake Michigan, twelve to forty miles distant. At Summit it turns abrutly to the southwestward and follows the valley to a point sixty miles below Chicago where it unites with the Kankakee to form the Illinois. The Illinois river continues southwestward across the state emptying into the Mississippi at Grafton, 325 miles from Chicago. From Chicago to Romeo, a distance of twenty-seven miles, the bed of the Desplaines river is six feet above the level of Lake Michigan. From Romeo to Joliet a distance of ten miles, there is a descent of seventy-seven feet, the greater part of it below Lockport. From Joliet to LaSalle, a distance of sixty miles, there is a further descent of seventy feet. From LaSalle to the mouth of the Illinois, 225 miles, the fall is only twenty-seven feet.

It is more than two hundred years since the Desplaines valley was discovered, but it became at once the path of communication between the previously settled portions of Canada and the valley of the Mississippi. History gives the credit of the discovery to Joliet and Marquette, but it is certain that French traders penetrated this region many years earlier. The latter faced the perils of exploration solely for purposes of gain, and have left no records of their discoveries and their transactions with the Indians. Organized exploration in the western parts of America was prompted by a desire to discover a waterway across the continent.

Description of Mud Lake.

Mud Lake is well described by its name, but it deserves a recognition which the name does not suggest. As the waters of Lake Michigan receded in prehistoric times, the Chicago divide, stretching from Summit to Lemont or beyond, became

a permanent barrier against the outflow toward the Mississippi, and alluvial deposits formed a second barrier in the vicinity of Bridgeport. In the depression between the Desplaines and Chicago rivers was thus created a pond or lake that stood at the summit of the watershed which separates the St. Lawrence and the Mississippi basins. For its own supply it depended upon the freshets of spring and autumn, its stagnant waters during the remaining months of the year furnishing sustenance for lillies, reeds and marsh grasses, and a home for every variety of the smaller amphibious animals. When its little basin was filled to overflowing it discharged its waters in both directions,—into the Mississippi by way of the Desplaines, and into the St. Lawrence by way of the Chicago river and the great lakes. To Le Petit Lac, as the wandering French Canadians called it, belonged the exclusive distinction of contributing to two of the greatest river systems of the world.

The dimensions of this lake were gradually contracted, and a strip of land varying in width from a mile and a half to three miles separated it from the Desplaines in the time of Joliet, Marquette and LaSalle. By them it was called the Portage. The Chicago river had its origin at the eastern extremity of Mud Lake, not far from the present location of Kedzie avenue. It is less than twenty years since this lake lost its identity, but its former bed was covered with water at every overflow of the Desplaines, until the latter was permanently diverted to a new channel by the Trustees of the Sanitary District in 1893.

Historical Account.

In 1817 Samuel A. Storrow, judge advocate of the United States army, made a three months' tour through the west. An account of his trip appears in a letter of Major General Brown, dated December 1, of that year. He speaks of the Chicago river as deep and about forty yards wide. His attention was attracted to the interesting fact of the division of the waters at its source, part flowing eastward to the lake and part westward to the Mississippi, and he commented on the practicability of a permanent waterway. He says:

> "Before it (the river) enters the lake its two branches unite, the one proceeding from the north, the other from the west, where it takes its rise in the very fountain of the Plein, or Illinois, which flows in an opposite direction. The source of these two rivers illustrates the

geographical phenomenon of a reservoir on the very summit of a dividing ridge. In the autumn they are both without any apparent fountain, but are formed within a mile and a half of each other by some imperceptible undulations of the prairie which drain it and lead it to different directions. But in the spring the space between the two is a single sheet of water, the common reservoir of both, in the center of which there is no current towards either of the opposite streams. This circumstance creates the singular fact of the insulation of all the United States excepting Louisiana, making the circumnavigation of them practicable from the Gulf of St. Lawrence to that of Mexico, with the single hindrance of the falls of Niagara. The Chicago forms a third partition of the great country I had passed. The Ouisconsin and Fox rivers make a water communication between the Mississippi and Michigan, with the exception of four miles. The Millewackie and River a la Roche, the same, with half the exception. The Chicago and de Plein make, in the manner I have described, the communication entire. The latter should not escape national attention. The ground between the two is without rocks, and with little labor would admit of a permanent connection between the waters of the Illinois and Michigan."

Report of Albert Gallatin.

Complying with this order Albert Gallatin, secretary of the treasury, made a report on roads and canals to the Senate on April 6, 1808. This was a very complete statement of the condition of the roads and canals then in existence or in preparation and contained definite plans for a system of internal improvements.

"The inconveniences, complaints, and perhaps dangers, which may result from a vast extent of territory," he said, "can not otherwise be radically removed or prevented than by opening speedy and easy communication through all its parts. Good roads and canals will shorten distances, facilitate commercial and personal intercourse and unite by a still more intimate community of interests the most remote quarters of the United States. No other single operation within the power of Government can more effectually tend to strengthen and perpetuate that

union which secures external independence, domestic peace and internal liberty."

Referring to the natural communication between Lake Michigan and the Mississippi he said of the Illinois River, that it "rises in a swamp which, when the waters are high, affords a natural canoe navigation to the sources of Chicago creek, a short stream, which falls into Lake Michigan at its southern extremity." He did not doubt that if the inland navigation between the western rivers and the lakes was completely opened the whole Indian trade, either of the Mississippi by Lake Michigan, or of the Northwest by Lake Superior, must necessarily center in an Atlantic port of the United States, a consideration of minor importance as a commercial object when compared with the other advantages of that great communication, but of great weight in its relation to the political intercourse of the United States with the Indians. His estimate of the cost of the improvements to reach Lake Michigan was $16,600,000; to reach the Mississippi, $20,000,000. To raise this sum he suggested that the Government sell ten million of its one hundred million acres of public lands. He believed the increase in the value of the remaining ninety million acres would more than repay the outlay. His report was referred to a committee and a week later 1,200 copies were ordered printed. That was the only official recognition it received, probably because Congress was in daily fear that it would exceed its constitutional powers.

SPEECH OF PETER B. PORTER IN CONGRESS FEBRUARY 8TH, 1810.

In the House on February 8, 1810, Peter B. Porter of New York rose to discuss the internal improvements of the United States by roads and canals. He said he had listened to appeals for the protection of commerce. It was to be presumed that Congress would be as willing to give a direct encouragement to agriculture as to do it indirectly through the medium of commerce. He referred to the bill introduced in the Senate by Mr. Pope, in the preparation of which he had had a part. Some great system of internal navigation, such as was contemplated in that bill, was not only an object of the first consequence in the future prosperity of the country, considered as a measure of political economy, but as a measure of state policy it was indispensable to the preservation of the integrity of the Government. * * *

Proceeding to show by geographical detail both the importance and the practicability of such navigation, he found west of the Alleghenies "a scene of natural internal navigation un

equalled in the world." To the south and the west of the great lakes

> "the waters of the Ohio and the Mississippi approach within short distance of and are interlocked by the waters of the lakes. The lands along these dividing waters are generally level, and the rivers are navigable and might be connected by short canals at little expense. At the southwestern extremity of Lake Michigan, the most inconsiderable expense would open a canal between the waters of that lake and the Illinois river, one of the principal branches of the Mississippi. Nature has already made this connection nearly complete, and it is not uncommon for boats in the spring of the year to pass from the lake into the Illinois and from thence by the waters of the Illinois and Mississippi to New Orleans without being taken out of the water."

Report of John C. Calhoun.

John C. Calhoun, when secretary of war, suggested to Congress in a report made on January 14, 1819, a plan for the application of such means as were within the power of Congress for the purpose of opening and constructing roads and canals that might deserve and require the aid of the government with a view to military operations in the time of war. Enumerating certain routes worthy of consideration he said:

> "If to those communications we add a road from Detroit to Ohio, which has already been commenced, and a canal from the Illinois river to Lake Michigan, which the growing population of the State of Illinois renders very important, all the facilities which would be essential to carry on military operations in the time of war, and the transportation of the munitions of war for the defense of the western portion of our northern frontier would be afforded."

Mr. Calhoun transmitted with his own report one made by Major Stephen H. Long, dated May 12, 1818, giving an account of a tour of exploration in the West the year previous. Major Long said a canal uniting the waters of the Illinois river with those of Lake Michigan might be considered the first in importance of any in this quarter of the country, the construction of which would be attended with very little expense compared with the magnitude of the object.

CONGRESSIONAL ACTION.

Illinois became a state in 1818. Daniel P. Cook, a son-in-law of Governor Edwards, was its second representative in Congress, serving from 1819 to 1827. He devoted himself assiduously to the interests of the proposed canal. Through his influence the Illinois State Legislature of 1820-1 had a partial survey of the route made, sufficient to demonstrate the practicability of the undertaking. A report of this survey was laid before Congress by Mr. Cook on December 7, 1821, with this resolution.

> "That the committee on public lands be instructed to inquire whether any, and, if any, what provision is necessary to be made to enable the State of Illinois to open a canal through the public lands to connect the waters of Lake Michigan with the Illinois river."

As an illustration of the opposition to the implied co-operation of the United States it may be noted that John Floyd of Virginia thought that Congress had already sufficiently evinced its liberality to the new States. On a former occasion he had proposed a resolution to appropriate a portion of the public lands for the endowment of colleges. That resolution had received the decided opposition of the new States. A constitutional question was raised on the subject, which, if it did not convince, at least it created so much doubt in his own mind as to induce him to forbear to press it. Nor could he, in the present instance, as a member of a State which had done as much at least as any State in the Union for the general benefit, consent to a proposition of this sort. As well might Virginia ask for an appropriation of the public funds for the purpose of completing canals to the city of Richmond. He was disposed to leave the subject of canals to the energy and ability of those States through which they passed and for whose benefit they were intended.

Mr. Cook replied that he did not expect a proposition so reasonable as he conceived this to be would meet with opposition. The States northwest of the Ohio felt grateful for all the favors they had received, but in the present case no favor was asked. The object of the resolution was not to solicit a donation from the General Government to assist in making the canal, but merely to reserve a narrow strip of land in the direction of the contemplated canal and through which it should pass. By this measure the Government instead of impairing its funds, would increase them. Such an

act would undoubtedly enable the Government to dispose of the reservation afterward at a price greatly enhanced and at the same time virtually authorize the government of Illinois to go on with its contemplated undertaking. The resolution was adopted.

A few days later the matter was brought to the attention of the Senate by Jessie B. Thomas of Illinois, who presented on December 19, 1821, a resolution adopted by the Illinois State Legislature praying to be authorized to construct a canal connecting the waters of Lake Michigan with the Illinois river, and asking for the donation of a certain quantity of land for that purpose. This was referred to the committee on roads and canals.

Resolutions and debates at last begun to bear fruit, although of doubtful quality. In the House on January 14, 1822, Christopher Rankin of Missouri, for the committee on public lands to whom the matter had been referred, reported a bill authorizing the State of Illinois to open a canal through the public lands, and a similar bill was introduced in the Senate on January 24, 1822, by Mr. Thomas. Having passed both Houses, it became a law on March 30, 1822. The Act reserved ninety feet of land on each side of the canal from any sale to be made by the United States.

> "The use thereof forever," said the bill, "shall be, and the same is hereby, vested in the said State for a canal, and for no other purpose whatever; on condition, however, that, if said State does not survey and direct by law said canal to be opened, and return a complete map thereof to the treasury department, within three years from and after the passage of this Act; or, if the said canal be not completed, suitable for navigation, within twelve years thereafter; or, if said ground shall ever cease to be occupied by and used for, a canal suitable for navigation, the reservation and grant hereby made shall be void and of none effect."

Congress took care that this meager grant should not carry with it any liabilities. It was provided that nothing in the Act should be construed to imply any obligation on the part of the United States to appropriate any money to defray the expense of surveying or opening the canal; also, "that the said canal, when completed, shall be, and forever remain, a public highway for the use of the Government of the United States, free from any toll or charge whatever, for any prop-

erty of the United States, or any persons in their service, passing through the same."

Permission to construct a canal through the lands owned by the United States was in no sense an aid to the young and struggling State of Illinois. Its population at this time was less than 60,000 and the people were unable even to pay for the survey of the route of a canal. It had been repeatedly shown that the proposed work was, at that time, of greater National than State importance, and every public officer of the National Government who had given any attention to the canal had recommended its construction. Not only were the indirect advantages apparent, but it was acknowledged by all that there would be a direct financial gain to the Government, if it were to donate sufficient land to pay for the work, in the increased value of the unappropriated lands. Mr. Cook was not disposed to accept a questionable favor, and on behalf of the state, he renewed his appeals in Congress for something like a reasonable recognition of the undertaking. On March 26, 1824, on his motion, the House committee on roads and canals was instructed to inquire into the expediency of vesting in the State of Illinois, for the purpose of defraying the expense of opening a canal between the waters of the Illinois river and Lake Michigan, the land bordering on the proposed canal that had been reserved from sale by Congress.

In the following year this committee reported in favor of the appropriation. Among other suggestions it urged that, in a political point of view, its importance would be found not less imposing than in either of those in which it had already been viewed. In uniting and drawing together the interests of the remote extremities of the eastern, the southern and the western sections of the Union, no work of the same magnitude, it was believed, could be more effectual. The geographical position of Illinois and Missouri, the two States particularly interested in it, was such that they would under the advantages of this communication, have a common and almost equal interest in preserving their connection with the North and the South. Their trade would ultimately flow through the lakes and the Mississippi, and the advantages of a choice of market would be so important to them that they must ever be unwilling to surrender it. By the reference to the map of the country, it would be seen that these States would have it in their power at all times, in the event, should it unfortunately ever occur, of any internal commo-

tion, to command the waters of the Ohio and Mississippi, From their commanding position, therefore, as well as from their capacity to sustain a dense, and it must mainly be a free population, they would always hold the balance of power in deciding every effort that might be made to separate the West from either or both of the great geographical divisions of the Union; and if from no other cause, their interests would direct their exertion of that power in favor of the Union. Nor was the interest of these States in preserving a free outlet for their commerce both through the lake and the Mississippi, the latter of which opened to them the New Orleans, the West Indies and South American markets, stronger than must be that of the North and South in being united with them.

The feeling among the people of Illinois was reflected in a letter written by ex-Governor Edwards to Henry Clay in 1825, just after the latter had been chosen secretary of state by John Quincy Adams. Mr. Edwards said:

> "A favorite object and, indeed, a political hobby that supersedes all others in this state and Missouri, is a canal to conect Lake Michigan and the Illinois river. Nothing could sustain the administration or its friends in these two States so effectually as its countenancing this measure."

The writer ventured to suggest that it might be very judicious in the President, without descending to any particular case, to introduce in his message to Congress some sentiment favorable to the connection of the great lakes with the Atlantic and western waters. He knew it would contribute greatly to the support of the administration.

In its anxiety to have the work on the canal begin the Illinois State Legislature, on January 17, 1825. incorporated the Illinois and Michigan Canal Association and granted it extraordinary privileges. It was provided in the charter of the association that all cessions, grants and transfers made, or that might thereafter be made by the Government of the United States, for the purpose of promoting the construction of the canal, should be vested in that corporation. Congress is said not to have approved of the State's giving away valuable privileges in advance of their possession, and the Act nearly deprived the State of any future grant of lands. Mr. Cook was alarmed over the action and hastened to advise the State Legislature to repeal the Act. The incorporators finally surrendered their charter, but not until Mr. Cook

had sent an address to the people of the State, setting before them the interest which the National Government had in the undertaking.

> "This is a work," he said, "in which the nation is interested, and which the General Government should, therefore, aid in executing. As a ligament to bind the Union together, no work of the same magnitude can be more useful. Occupying, as Illinois and Missouri do, a central position in the great semicircle of States on the north and west, and commanding, as they do, the commerce of the three great rivers of the West, the Ohio, Mississippi and Missouri, they may well be called the keystone of the widely projected arch. From New York to Louisiana, following the frontier curve of that portion of the Union, in the event of any political commotion or attempt at separation, the influence of these States would, ere long, be sensibly felt, and would even decide the contest. And their interest will be so happily balanced, by their desire for a free outlet through both the Mississippi and the lakes, that so long as commercial advantage continues to influence the policy of the States, they must and will decide against disunion. The friends of the Union, therefore, have a strong interest in this communication."

Having undone an injudicious act of the people at home, Mr. Cook redoubled his efforts in impressing upon Congress its duty in the matter of extending substantial aid to the canal. On December 30, 1824, he moved a resolution in the House providing that a committee be appointed to inquire whether any, and, if any, what provision it would be proper or practicable to make to aid the State of Illinois in opening a canal. By way of explanation he said it was not likely the State, from its ordinary means, could carry the measure already passed by Congress into effect. Congress had given to the State of Illinois a certain proportion of the net proceeds of the sales of the public lands for the encouragement of learning. If no better means should present themselves, and if the Government of the United States should not consider the canal, in a national view, of so much importance as to construct it at its own cost, the State might be allowed to convert its school lands into a fund for the purpose of making the canal, and to apply the tolls from the canal to school purposes, thus merely changing the land into a canal stock, the profits of which to be applied to the same purpose

the land was to serve, that of encouraging learning. The canal was really a national object, worthy of the employment of the national means.

After a number of discouraging postponements, Mr. Cook succeeded in getting his resolution before a committee, and in the following year a bill was reported. This was the basis for the Act under which the Illinois and Michigan canal was constructed. The bill was repeatedly postponed, lost and reconsidered, and there were many acrimonious debates. One member went into a calculation to show that the proposed grant of lands would not only defray all the expenses of the canal, but would leave a balance in the Illinois treasury of $500,000 to $1,000,000. Another denied that Illinois had any better right to a portion of the public lands than Virginia or any other State. The lands, when ceded, were to be set apart to pay the public debts, but Congress appeared to have forgotten that stipulation, and the lands, it seemed, were to be given to any person who lived nearest to them. Would it not be best, he asked, to sell the whole at once and divide the proceeds?

Charles Miner of Pennsylvania, wanted the bill recommitted with instructions to the committee to inquire into the expediency of subscribing on behalf of the United States for stock in the proposed canal, to an amount not exceeding one-third of the whole, the stock to be paid for out of the proceeds of lands on or near the route. He avowed his decided hostility to the bill. What did it propose? To give to the State of Illinois alternate sections of land along the whole line of the proposed canal from Lake Michigan to the Illinois river. What was the extent of this grant? It was estimated at about 200,000 acres; but, as the extent of the line of the canal was indefinite, so the grant was indefinite. Illinois might make the canal only fifty or sixty miles long and demand 200,000 acres; but she might extend the canal down the Illinois along the whole extent of the State, and under the bill, demand 500,000, 800,000 or 1,000,000 acres. Such uncertain, indefinite grants were extremely objectionable.

> "On the line of the canal," said Mr. Miner, "villages, towns and cities will grow up. Some of the tracts will be of great value. Take them all together it will not be an unfair estimate to put them at $5.00 an acre. Suppose the canal sixty miles in length and the land given 200,000 acres. You give then $1,000,000 to Illinois. The canal is estimate to cost from $600,000 to $800,000 so that

you make the canal and give a bounty to that State besides. Who makes the canal? Those who furnish the funds. The people of the United States make the canal, and then they are to be taxed to all enduring time for liberty to use it. This seems to me a wild waste of the public domain. I entreat you, gentlemen, to pause before you make this excessive grant. In my opinion it will bring a system of internal improvements more into disrepute than all the arguments of its enemies. Pennsylvania came this session, I will not say cap in hand and with bended knee, but in the most respectful manner, and asked the grant of one little township for her institution for the deaf mutes,—poor dumb mouths; they could not plead for themselves. What was the answer? This petition was rejected,—this request was refused. And now you propose to give to Illinois 200,000 acres. I hope the bill may be recommitted."

The bill was not recommitted, nor was it otherwise delayed. It passed both the House and the Senate on March 2, 1827, the day on which Mr. Miner made his vigorous opposing speech, and was at once approved by the Executive. Much credit is due Mr. Cook for his persistent and eloquent advocacy of the bill. Through his influence the Legislature of Illinois was called together in special session in January, 1826, and the following memorial to Congress was adopted:

Memorial of Illinois.

"The memorial of the General Assembly of the State of Illinois respectfully represents: That the construction of a canal, uniting the waters of Lake Michigan with the Illinois river, will form an important addition to the great connecting links in the chain of internal navigation, which will effectually secure the indissoluble union of the confederate members of this great and powerful Republic. By the completion of this great and valuble work, the connection between the North and South, the East and the West, would be strengthened by the ties of commercial intercourse and social neighborhood, and the union of the States bid defiance to internal commotion, sectional jealousy and foreign invasion. All the States of the Union would then feel the most powerful motives to resist every attempt at dissolution. To effect so great and desirable an object your memorialists be-

lieve to be of sufficient importance to engage the attention and awaken the munificent patronage of a Government whose principle of action is the promotion of the general welfare. Your memoralists are sensibly alive to the spirit of improvement that mainfests itself in almost every section of our extensive country, and would fain lend a helping hand in so great and good a cause; their situation, however, forbids their doing much, without the aid of the Federal Government, into whose treasuary almost all the funds, whether brought hither by immigrants, or earned by the industry of their citizens, are paid for the purchase of the public lands. While this state of things shall continue, and the money thus paid into the treasury of the Union is taken out of our State, our people will not be able to engage in the glorious work of improving our common country.

Ought the people of this State stand by, with folded arms, and behold the great work of internal improvement progress in other States, without making an effort to improve their own condition, and at the same time advance the interest of our beloved country? A condition thus paralyzed is at war, not only with our interests, but with the best feelings of our hearts. Did this State possess the public domain lying within its bounds, as is the case with older members of this confederacy, your memorialists would not appear before your honorable body to solicit aid in this important work. If, as your memorialists believe, the construction of the canal would be highly beneficial to the Union at large; if the receipts into the treasury of the United States would be augmented by the increased sales of the public lands, and if the interests of the State would be also advanced thereby, is it unreasonable to apply to a paternal government for assistance in the promotion of such beneficial ends? It is unnecessary for your memorialists to enlarge on the great advantages of this canal to the Union, in the facilities to be afforded in the event of a war either with the Indian tribes inhabiting our frontier, or the British Nation. Your honorable body is aware that this State is situated on the borders of an Indian country filled with numerous and powerful tribes of the sons of the forest. If our country should be again engaged in war, the saving of expense in the transportation of the munitions of war would alone defray the expense of the contemplated

canal, and justify the United States in making a liberal appropriation for its construction.

Your memorialists do not, however, ask your honorable body to appropriate money out of the treasury to aid them in this work. They only ask for a tract of land, through which the contemplated canal may pass, and which for a series of years will be wholly unproductive to the Government, unless the canal shall be commenced under auspices favorable to its construction, in which event all the land in its vicinity would immediately become available to the United States. Your memorialists sincerely believe that a liberal appropriation of land for this object would, even in a pecuniary point of view, be of immense importance to the treasury of the Union. The public lands in the vicinity would not only sell, but at a considerable advance of the minimum price. Should this opinion be correct (and does not experience justify it?) the United States would be gainer by the proposed donation to the State.

Your memorialists further state, that, at their last session, they passed an act of incorporation, upon very liberal terms, authorizing a company to construct the projected canal; but the remoteness of the country from the residence of capitalists has prevented them from engaging in the work. At their present session, your memorialists have repealed the charter, and their only hope of soon beginning the work depends upon the liberality of your honorable body. Your memorialists have caused the route to be explored and estimates to be made of the probable expense of the work, from which it appears that the cost of constructing the canal will not be less than $600,000 and may possibly amount to $700,000.

To the end, therefore, that your memorialists may be enabled to commence and complete this great work, we pray your honorable body to grant to this State the respective townships of land through which the contemplated canal may pass, the avails of which to be appropriated exclusively to the construction of said canal, upon such terms and conditions as to your honorable body may seem proper."

The bill which this memorial must have aided greatly in passing enacted:

"That there be and hereby is granted to the State of Illinois, for the purpose of aiding the State in opening a canal to unite the waters of Illinois river with those

of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each side of said canal, and reserving each alternate section to the United States, to be selected by the commissioner of the land office, under the direction of the President of the United States, from one end of the said canal to the other; and the said lands shall be subject to the disposal of the Legislature of the said State, for the purpose aforesaid, and no other: Provided, That the said canal, when completed, shall be and forever remain a public highway for the use of the government of the United States, or persons in their service passing through the same: Provided, That said canal shall be commenced within five years, and completed in twenty years, or the State shall be bound to pay to the United States the amount of any lands previously sold, and that the title to purchasers under the State shall be valid."

Period of Canal Construction.

Contracts for the first work on the Illinois and Michigan canal were let on June 6, 1836. The line was divided into three divisions, Summit, Middle and Western. The Summit division extended from the North fork of the South branch of the Chicago river to the first lock at Lockport, but incidentally included the river, about five and one-half miles in length. It was proposed originally to construct a towpath along the south side of the South Branch from the "point," or junction of the North and South branches, crossing the river by a bridge at the mouth of the North fork up which it would continue to the mouth of the slough. The eastern terminus was subsequently changed to its present location.

Chief Engineer Gooding found the prairie over which the line was run to be level and extremely wet except in times of severe drought. The cutting would be chiefly through a stiff blue clay, he said, from seven to nineteen feet deep. In his description of the route he said the canal would continue down the valley of the Desplaines. For thirteen or fourteen miles the river had little descent. The current at low water was scarcely perceptible, and the land along its borders was so low as to be overflowed at every slight rise of the water. After the line of the canal entered the valley the direction was changed by a gentle curve and another straight line obtained of 3½ miles. There were several other straight lines on this division and the curves were all gentle and uniform.

The depth of cutting continued about the same down the valley to Brewer's Ford. From that point the engineer announced that the cutting would be very much more expensive as the excavation was principally in rock. The depth of earth in rock above the mouth of the Saganshkee swamp was found to be much less than was anticipated. A difficult section of canal was encountered in crossing the mouth of the swamp where there was earth to the depth of five or six feet, the most of which was in a semi-fluid state, resting upon rock. The cutting here was about 17½ feet.

From this point to the first lock the rock was generally near the surface. The level ran out a short distance after the crossing Big Run, which was about 1¼ miles above the first lock and in the bed of which the cutting was about two feet. The first two locks were located on section 23, town 36 north, range 10 east of the third principal meridian, on land belonging to the State. The canal or basin, for about three-fourths of a mile above the first lock was planned to be 120 feet in width. The length of the canal from the beginning to the first lock was 34 miles and 35.78 chains. The estimates on the Summit division were for a canal 60 feet wide at the surface, 36 feet wide at the bottom in earth and 48 feet in rock, and six feet deep. A declivity was given to the bottom of the canal of one-tenth of a foot per mile.

The rock was found to be stratified limestone, the greater part of which, it was believed, could be quarried without much difficulty. The strata adhered to each other so closely as almost entirely to prevent the water from flowing between them, as was feared it might do. The strata were generally from two to six inches thick and of a quality, it was said, suitable for building purposes. The expense of constructing the Summit division of the canal and the time required for its completion were found before the end of the first year of construction likely to be much greater than was anticipated, but nothing had occurred to diminish confidence in the practicability of the work. The average price at which the contracts for the excavation in earth in the Summit division were let was 33.35 cents per cubic yard, and for that in rock $1.54.

When proposals were advertised for in the spring of 1836 there were no contractors in this part of the country and no mechanics or common laborers when the contracts were awarded in June. It was with difficulty that the contractors could secure workmen to build their shanties, or teams and

tools with which to begin work. Operations were formally begun on July 4, 1836. The occasion was a memorable one, and Chicago was in a state of considerable excitement. At a signal given by three cannons at Fort Dearborn the citizens assembled in the public square and moved in a body to the scene of the inaugural ceremonies at the head of the proposed canal. Some went by boat and others on foot or with teams along the Archer road. The steamer Chicago started from the foot of Dearborn street with her decks crowded and proceeded up the river. Two schooners and other vessels towed by horses followed, carrying as many people as could crowd upon them.

The locality where the canal was to connect with the Chicago river had been named Canalport and a public house called the New House opened. The crowd collected in front of this public building and saluted Judge Smith as he solemnly read the Declaration of Independence with the characteristic enthusiasm of a pioneer audience. Dr. W. B. Egan followed with an eloquent address, and Gurdon S. Hubbard spoke of the promising condition of the settlement as compared with that of the one he had found eighteen years previous when he ascended the river in a canoe. When one of the speakers in his exuberance of feeling ran along the scale of years and boldly prophesied that Chicago in a hundred years would have a population of 100,000 he excited the ridicule of his hearers and was booted off the barrel from which he was speaking. Ground was afterward broken for the canal by Colonel Archer, acting commissioner. Addresses by Judges Smith and Brown of the Supreme Court and Commissioner Hubbard followed.

Work was soon begun, but few laborers were to be had until about the close of the year, when there were 350 at work along the entire line, or so much of it as was under contract. The scarcity of laborers and sickness were the principal causes of delay throughout the entire period of construction.

By the Act of March 2, 1837, the appointment of Canal Commissioners was taken from the Governor and their election assumed by the Legislature. With a more direct interest in the work than it previously had the Legislature appointed a committee to inquire into the probable cost of a canal of the dimensions authorized. Out of the report of the committee grew a dispute over the propriety of continuing the deep cut, the committee contending that the estimates of the chief engineer were far too low, and the engineer maintaining that

the work could be done for less than he had estimated. The committee was right and the engineer wrong. But the discussion was dropped within a year and the work continued on the deep cut plan. It was not until the State was absolutely unable to raise the money to carry on the work that it accepted the alternative of a shallow cut and pumping works.

An incident of interest is found in the optimism of Chief Engineer Gooding which seems to have been shared by the Commissioners. By a revision of the plans in 1836 it was provided that the canal in passing through the Town of Lockport should be 120 feet wide. A hydraulic basin was to be constructed in such a manner that the mills or manufactories which, it was assumed, would spring up there, might be built upon the banks of the basin and be operated by the water drawn from it. Upon the side of the buildings next to the canal, and separated from it only by the towpath, there were to be a street and a tier of warehouse lots. The basin was to be connected with the canal in such a manner that boats or vessels could readily pass into it and load or unload at the mills or warehouses.

The value of the water power created there and at other points along the canal, by drawing a supply directly from Lake Michigan, could be fully appreciated, Mr. Gooding said, after a season of such severe drought as the previous one had been. The Desplaines River and many other considerable streams of the country had been nearly dried up, and probably three-fourths of the water mills throughout a large portion of the United States had been standing still for the preceding three or four months. Had the canal been completed there would have been during the season an unusual supply of water, as the surface of the lake had been nine feet and four inches above canal bottom, three feet and four inches higher than was originally counted upon.

Again Mr. Gooding expected phenomenal results at the Sag. "When the canal at this point is completed upon the present plan," he said, "a quantity of state land amounting to about 270 acres will be reclaimed, which is at present entirely valueless. The whole of the impassible marsh that now presents so forbidding an appearance will be made dry land."

On March 2, 1837, the legislature had authorized a survey and estimate to be made for a canal, diverging from the main trunk of the Illinois and Michigan Canal, through the Ausauganashke swamp and lake, to intersect the Calumet River at the nearest practicable point, the work to be constructed when-

ever the State of Indiana should undertake a corresponding work connecting her system of internal improvements with the Illinois and Michigan Canal. "The junction of the canal from the Calumet River with the main line being made at this point upon reclaimed state land," said Mr. Goodling, referring to the Sag, "will make it one of the most valuable town sites upon the line of the canal, or in the state."

Estimates made by E. B. Talcott, resident engineer in charge of the Summit division of the canal, on December 10, 1837, provided for turning or pivot bridges, the engineer believing that it would be frequently found advantageous to the commerce of the country for lake vessels to navigate the canal as far as Lockport. The formation of a basin at the forks of the Chicago River considered as part of the general plan of the canal, was also embraced in his estimates, and the Legislatre, by Act of July 21, 1837, authorized the enlargement of "the natural basin at the confluence of the North and South branches of the Chicago River so as to render the same as useful and convenient as possible."

The many extravagant schemes for internal improvement projected in 1837 injured the state's credit, and canal lands were not easily sold. On April 11, 1839, the Canal Commissioners ordered an issue of checks or scrip payable in ninety days. The total amount issued for that year was $394,554. This was used in paying the estimates of contractors and meeting other direct expenses. In 1840 the contractors agreed to take $1,000,000 worth of state bonds at par to 25 per cent. discount. These bonds carried the work along until March, 1843, when the expenditures could no longer be met and the work was entirely suspended. More than $5,000,000 had been spent and the canal was still far from being completed. The expenditures by years were as follows:

1836	$ 39,260.58
1837	350,649.90
1838	911,902.40
1839	1,479,907.58
1840	1,117,702.00
1841	644,875.94
1842	155,193.33
Superintendence	210,000.00
Contractors' damages	230,000.00
Total	$5,139,492.03

It became apparent at last that the resources of the state, aided by the unproductive sales of the canal lands, were en-

tirely inadequate to the completion of the canal on the basis of the deep cut. Reluctantly it was agreed by every one that a shallow cut must be made, and that water to operate the canal must be obtained from some other source than Lake Michigan. It had been shown that it was impracticable to construct a feeder from the Fox River to the eastern end of the canal, although there were many who believed it would be cheaper thus to divert the waters of the Fox River than to make the channel of the dimensions originally planned. At last the suggestion was made by Ira Miltimore, who constructed Chicago's first water works, that water might be pumped from the Chicago River into the canal. The idea was endorsed by the Mechanics' Institute and received the favorable consideration of the Canal Commissioners.

It was estimated that it would require $1,600,000 to complete the canal on the shallow cut plan and there followed the Act of the Legislature of February 21, 1843, by which the Governor was authorized to negotiate a loan for this amount. As security the Governor was empowered to pledge the canal, its tolls, revenues and lands. The loan was to run for six years and bear interest at the rate of 6 per cent. After the loan was subscribed, three "discreet persons" were to be appointed to constitute a Board, to be known as the Board of Trustees of the Illinois and Michigan Canal. One was to be appointed by the Governor of the state, and the two others by the subscribers to the loan. They were to possess all the powers and perform all the duties conferred upon the Canal Commissioners.

In the following March, Governor Ford, appointed Michael Ryan and Charles Oakley Commissioners to secure the loan. They proceeded to New York, where they obtained subscriptions to a part of the amount required. To secure the balance, they crossed the Atlantic and laid the matter before prominent European capitalists, some of whom were already holders of canal bonds. The latter doubted the ability of the State of Illinois to meet its obligations, and insisted on an investigation of the financial condition of the state as well as that of the canal. They agreed to accept the statement of a committee of Boston men, consisting of William Sturgis, T. W. Ward and Abbott Lawrence. This committee detailed Captain W. H. Swift, a United States engineer, and Ex-Governor John Davis of Massachusetts, to make an examination of the canal. The latter verified the statements made by Commissioners Ryan and Oakley, and reported that the securities for the proposed loan of $1,600,000 were satis-

factory. The money was then soon subscribed, the contract with the bondholders and the trust deed were executed, and the Trustees were appointed. W. H. Swift and David Leavitt were named by the bondholders to represent them, and Jacob Fry was appointed by the Governor to represent the state.

Work was resumed on the canal in September, 1845, now wholly under the control of the Trustees, and the business of the canal was directed from their office, first in Lockport, then in Boston, and finally in New York. The Trustees were in control of the canal until 1871, when the deepening of the canal for sanitary purposes was completed. At a meeting of the Trustees on April 20, 1846, the plan for pumping water from the Chicago River into the canal was adopted, and it was also ordered that navigable feeders should be constructed from the Calumet River to the Summit level at or near the outlet of the Sag. The contract for the construction of the Calumet feeder was let in May, 1846, and at the end of the year work on it was in full progress.

Engineer Gooding, in his annual report, covering the operations of the year 1846, gave a careful review of the changes made, and the reasons therefor. He said:

> "The existing law for completing the work having authorized a change of the plan of the canal without diminishing its capacity, and the amount of the funds raised for the purpose rendering it absolutely necessary that a cheaper plan than the one required by the original law should be adopted, my attention was early called to the various plans proposed. * * * The only important change proposed, and the only one which, in the then advanced stage of the work, could have resulted in much saving of expense, was the raising of the level upon the Summit division. This, it was supposed, could only be effected by introducing a supply of water from other sources, as a substitute for that which would have been derived from Lake Michigan upon the original plan. * * *
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> The original plan was to supply the canal with water from Lake Michigan, except what was to have been derived from the Desplaines and Du Page Rivers, as far down as Marseilles; and from this point to the western terminus at La Salle, the supply was to be received as at present designated from Fox River through the feeder introduced at Ottawa. There could be no doubt that the

supply of water for the canal below Marseilles would be ample, at least for the purpose of navigation, and consequently the investigation was more particularly directed to the demands and supply above. It had been ascertained that a feeder from the Kankakee River could be introduced upon the Dresden level, which commences at the Du Page River, at lock No. 7, at a moderate expense; and it was known that through this feeder a supply of water, to almost any extent for the canal between lock No. 7 and Marseilles might be drawn. It was also known that a feeder from this river might be introduced on the Joliet level, extending the supply up to dam No. 1, in Joliet village. Upon this same level the waters of the Desplaines and Du Page Rivers could be brought into the canal, whilst upon the Summit it had been proved that the waters of the Fox and Calumet Rivers could be brought through feeders of greater length. It was known, too, that a feeder of some seven miles in length would bring the waters of the Du Page on to the Summit, and that this and a part of the Fox River feeder might be identical. * * *

The obstacles in the way of this work (the construction of the Fox river feeder) led to a more attentive consideration of the plan for raising a supply of water, in part, from Lake Michigan by steam power. This plan had frequently been recommended by various individuals well acquainted with the application of steam power; but so long as it was believed practicable to procure an abundant supply of water through navigable feeders at a reasonable cost and without serious embarrassment, it was not thoroughly investigated. But measures were now taken to obtain the opinions of scientific and practical men upon this subject and to ascertain the probable cost of erecting the necessary machinery. The president of your Board kindly furnished me the communications upon this subject and several gentlemen, eminent for their science and skill; and the result of the information obtained from these and various other sources was such as to induce me to recommend the adoption of this mode of supply, and for the present not to construct the Fox river feeder."

In his annual report, dated December 10, 1847, Engineer Gooding refers to the fact that the canal is still unfinished, attributing the delay to sickness among the employes and to bad weather. Charles Oakley, Trustee for the State, took

exception to these excuses, and, in an appendix to the annual report of the Trustees, said:

> "There has been a culpable delay in the prosecution of the work, and its supposed remote causes are again referred to 'unusual sickness upon the line in the summer and autumn of 1840—high water and the scarcity of hands.' Those pleas have served their turn. * * * The places of the sick could have been supplied for the time at least, and the scarcity of hands could have been provided for if proper exertions had been made to do so. * * * The chief engineer now regrets that he is 'compelled to state that the canal is still unfinished,' and were it not for the galvanic shock which I may claim the credit of having administered to him, and which has aroused him from his usual apathy and torpor, he might be 'compelled' to make that statement in another annual report."

This indicates that an extremely bitter feeling had been aroused by the delay in the completion of the canal. When all the circumstances are considered, the delay seems to have been unavoidable. The financial difficulties which nearly wrecked the State itself and temporarily weakened the confidence of capitalists in the canal scheme, the inability of the contractors at times to secure all the laborers needed, the almost continual floods in the Desplaines valley and consequent sickness among employes approaching an epidemic in more than one season, were causes beyond the control of any person. Nevertheless Engineer Gooding was charged with blame so vigorously that his removal was ordered by Governor French on April 18, 1848, but not until the work was practically completed. In the light of all the facts the most severe criticism that can be made upon Mr. Gooding is, that he did not correctly estimate the cost of the canal and permitted the adoption of a plan impossible of completion within the resources of the State. If he had been more correct in his estimates and less hopeful of the future the work might not have been undertaken at all.

The canal was so nearly completed as to permit a Chicago boat, the General Fry, to pass over the Summit level, from Chicago to Lockport, on April 10, 1848. The formal opening was not announced until April 23, when the General Thornton of La Salle passed through the entire length of the canal, from La Salle to Chicago. This boat reached Chicago on April 23, and the event was celebrated by all the citizens.

Nearly twelve years had elapsed since the work on the canal was inaugurated, a period characterized by discouragement and misfortunate from beginning to end. Chicago and the State of Illinois owe much to it, for it was the cornerstone of their prosperity. The opening of the canal increased the price of lands in the northern part of the State at once, and immigration was given a new impetus. In 1835, the entire population of the State was only 271,727. By 1840 it had reached a total of 476,183, nearly twice the number of five years previous. Chicago really owes its existence to the canal, having been platted in order that town lots might be put upon the market. Its advantageous location was not fully realized until the canal was completed.

Edward B. Talcott, assistant chief engineer, in charge of the Summit division of the canal, was appointed chief engineer on the removal of Mr. Gooding. He took possession of the office on May 3, 1848. In his annual report dated November 30, 1848, he states that all the work on the canal had been completed, with the exception of three unimportant items. The total cost of the canal was $6,537,254.79. Of this amount $1,401,192.79 had been paid from the $1,600,000 loan.

Distances on the Illinois and Michigan canal were fixed as follows:

From Chicago to	
Bridgeport	4 miles.
Summit	12 "
Desplaines	21 "
Athens	25 "
Lockport	33 "
Joliet	37 "
DuPage	48 "
Kankakee Feeder	51 "
Dresden	54 "
Aus Sable	56 "
Morris	61 "
Marseilles	78 "
Ottawa	85 "
Utica	95 "
LaSalle	100 "
Calumet Feeder Head	38 "
Kankakee Feeder Head	55 "
Fox River Feeder Head	89 "

Installment of First Pumps.

Free navigation of the canal in the early part of the season of 1848 was impeded by a scarcity of water. From Lake Michigan to the Du Page river a distance of 44 miles, the entire supply of water was obtained from the Chicago river by pumping, and by gravity from the Desplaines and Du Page rivers. The Calumet feeder, which was expected to supply the Summit level, was not completed until the following year.

From Joliet to the Du Page river, the canal was constructed through a very porous soil. Although the sides and bottom had been lined, it proved to be very leaky. During the months of August and September 5,000 cubic feet of water per minute were discharged into this section of the canal, but the surface level was raised at the rate of only one inch in twenty-four hours.

The pumping engines proved to be a most important adjunct. The purpose of their construction was to raise water from the river to the Summit level in times of drought. It was not supposed that more than one would be needed after the Calumet feeder was completed, but it was thought prudent to provide two. The cost of the engines was $27,805.16. Buildings, engines and all other machinery cost $54,156.69. The pump house was located about 250 feet west of the South branch of the Chicago river and near the junction of the canal and the river. It was 166 feet in length and 55 feet wide, and was constructed of brick and stone. One of the engines operated four cast iron cylinder pumps, each 54 inches in diameter and seven feet long. Attached to the other was a wheel 32 feet in diameter, with sixteen float boards or buckets seven feet long working in a trough. The water was lifted by these buckets into a flume which communicated with a basin, the latter discharging into the main canal. The combined capacity of the four pumps was 6,300 cubic feet of water per minute, and that of the wheel 6,370 cubic feet per minute.

Transfer of Canal to State.

The lack of sufficient water in the Illinois river was the burden of complaint in succeeding years as it had been during the first decade. When the deepening of the canal by the city of Chicago was in progress in 1867 the Trustees were prompted to say that whether the canal had a depth of six or eight feet it mattered little so long as its great feeder, the Illinois river, remained unimproved. Up to that time, or at

the end of the first twenty years, the average yearly receipts from tolls had been $189,077. The average yearly cost of repairs and renewals had been $617 per mile.

The Trustees relinquished control of the canal on April 30, 1871, and on the following day the property was out of pawn and again in the possession of the State. On April 30 the Board of Trustees rendered the following statement of account with the State of Illinois, covering the period from June 26, 1845, the date of the execution of the deed of trust, to April 30, 1871, inclusive:

DEBIT.

Loan of $1,600,000 Principal & Int	$ 1,601,891.90
Construction of Canal, Feeders, etc	2,132.25
Canal Bonds, Sales, Protection, etc	4,706,482.68
Maintenance and Repairs of Canal and Feeders	111,003.97
Tolls, Collections, Inspection and Salaries	4,405,658.27
General Expenses and Contingencies	3.00
Premium on Gold for Dividends on Bonds Payable in London	923.27
Interest and Exchange	181,412.07
Total	$11,009,507.41

CREDIT.

Loan of $1,600,000, Principal and Int	$ 2,153.771.31
Construction of Canal, Feeders, etc	1,429,606.21
Canal Bonds, Sales, Protection, etc	115,523.23
Arrears of Interest on Registered Bonds	2,155,622.38
Principal Registered Bonds	2,195,463.67
Maintenance and Repairs Canal and Feeders	1,853,049.61
Tolls, Collections, Inspection and Salaries	160,462.71
Canal Damages, Flowage, etc	22,163.32
General Expenses and Contingencies	421,600.82
Premium on Gold for Dividends on Bonds Payable in London	370,864.42
Interest and Exchange	21,073.80
Losses on "Wild Cat" Currency, Counterfeit Bills, Broken Banks, etc., 1848 to 1863, incl.	14,563.52
Balance in Hands of Treasurer of the Board of Trustees Apr. 30, 1871	95,742.41
Total	$11,009,507.41

Government Surveys by Wilson and Gooding.

General J. H. Wilson made an examination of the Illinois river in the early part of the year 1867 and suggested the desirability of continuing it to Lake Michigan. He even roughly estimated the cost of a channel seven feet deep from the Mississippi to the lake. The re-survey ordered by Congress on March 2, 1867, was to establish the cost with a greater degree of accuracy.

The report of Engineers Wilson and Gooding on the new survey was made on December 17, 1867, and was transmitted to Congress by General A. H. Humphreys, chief of engineers, with his concurrence. The engineers stated in their report that they had been guided by the following considerations: The selection of the best route for the purposes proposed, the capacity which should be given to the improvement to adapt it most fully to the requirements, and the accomplishment of the object with the least possible cost consistent with the magnitude and permanency of the improvement.

Three surveying parties were organized and placed under the immediate supervision of Civil Engineer James Worrell, "for the purpose of making a thorough and exhaustive examination of the entire region lying between the southern and western end of Lake Michigan and La Salle on the Illinois river, and also for the purpose of conducting a low water survey of the river from La Salle to its mouth."

To the first party was assigned the duty of surveying the line of the canal from Chicago to La Salle, the Desplaines and Illinois rivers, and all the alternate lines which had at any time been spoken of, including that of Mud Lake. The second was directed to survey the Calumet and Kankakee rivers and the country lying between the Kankakee river and Lake Michigan, as well as the Fox river and a section of the lower Illinois. To the third party was given the assignment of a careful hydrographic survey of the bed of the Illinois river from La Salle to Grafton, paying particular attention to the location, cause, character and extent of different sandbars and obstructions to navigation during low water; also, to gauging the river and its tributaries and making examinations of the various points likely to be selected as sites for locks and dams.

The engineers concluded that the location of the existing canal from Bridgeport to the valley of the Desplaines could not be advantageously or economically changed. It was the best, cheapest and most direct route, they said, that could be

found. More than enough work had been done on it to counter-balance the natural but not superior advantages of the slightly lower but more tortuous route by way of Mud Lake. The Calumet river and Saganaska creek route, along what was known as the Calumet feeder, would cost a great deal more than either of the others since it was longer and ended at a point where there was neither a natural nor an artificial harbor, and where it would be impossible to construct one which would answer the purposes of commerce and the national defense. It was found to be impracticable at any cost to use any part of the Kankakee river as a part of the system of navigation.

"We have therefore to recommend," Messrs. Wilson and Gooding said, "that the improvement in question shall be made by widening and deepening the present canal from Bridgeport to the head of Lake Joliet with the exception of a section of 11¼ miles between Summit and the Sag, where it will be cheaper to excavate an independent canal. From Lake Joliet to Marseilles the line should follow to the bed of the river, the necessary depth being secured by a system of locks and dams. At Marseilles it will be necessary to construct a piece of independent canal in order to pass the grand rapids of the Illinois, striking the river again at or above Ottawa, as may be found to be the most economical. From the latter point to the mouth of the river the necessary navigation should be secured by a system of dams and locks. It is also recommended that all the canal on this line should have a width of not less than 160 feet and a navigable depth of six feet, corresponding to the lowest known level of the water in Lake Michigan, and an average depth of between seven and eight feet; that the present Summit shall be cut down so as to secure this depth in the canal from the inexhaustible reservoir of Lake Michigan."

Government Survey of Benyuard.

On August 11, 1888, Congress appropriated $200,000 for the improvement of the Illinois river. The Act making the appropriation also contemplated a survey for a serviceable waterway from Lake Michigan to the Mississippi river, as shown by the following clause:

"And for the purpose of securing a continuous navigable waterway between Lake Michigan and the Mis-

sissippi river, having capacity and facilities adequate for the passage of the largest Mississippi river steamboats, and of naval vessels suitable for defense in time of war, the secretary of war is authorized and directed to cause to be made the proper surveys, plans and estimates for a channel improvement and locks and dams in the bed of the Illinois and Desplaines rivers from La Salle to Lockport, so as to provide a navigable waterway, not less than 160 feet wide, and not less than fourteen feet deep, and to have surveyed and located a channel from Lockport to Lake Michigan, at or near the city of Chicago, such channel to be suitable for the purposes aforesaid."

Captain W. L. Marshall, who succeeded Major Benyuard, was then in charge of the river and harbor work in this vicinity. In a letter of instructions from General Thomas L. Casey, chief of engineers, Captain Marshall was directed, whatever line might be found most advantageous and economical to the United States, to submit plans and estimates for a route terminating within the limits of Chicago, sufficiently distinct and in detail to enable the chief of engineers to form a definite and conclusive opinion as to its merits from the standpoint of the commercial and sanitary interests of Chicago.

A survey party was organized and put in the field October 1, 1888, under the charge of Assistant Engineer L. L. Wheeler. By December 1, 1888, the field work relating to the superficial survey of the several practicable routes from Lake Michigan at or near Chicago by way of the Chicago Divide and the Desplaines river valley as far as Joliet were practically completed. The survey made by Major Benyuard and Engineer Wisner in 1883 from Joliet to La Salle was adopted, so far as it was sufficient for the purpose, to avoid unnecessary complication of work and expense.

In his exhaustive report Captain Marshall said there were two practicable routes across the Chicago Divide. One was by way of the Chicago river, the South branch and the Illinois and Michigan canal, or Mud Lake and the Ogden ditch, to the Desplaines river near Summit, about twelve miles from the city hall of Chicago and about eight miles from Bridgeport; thence by way of the Desplaines river valley.

The second route was by way of the Calumet and Little Calumet rivers to Blue Island, thence westward along the old Calumet feeder route to the Desplaines river at Sag, where the two routes became common. There was a practicable de-

tour from the second route which left the old feeder line a short distance west of Blue Island and continued in a more direct line south of Lane's Island, uniting again with the feeder line about five miles east of Sag bridge.

Captain Marshall did not favor a deep cut across the Chicago Divide at the expense of the United States and for the sanitary benefit in part of the city of Chicago. He sought to secure a modification of his instructions limiting the survey under his direction to a channel of smaller dimensions. He addressed a communication to General Casey on May 1, 1889, in which he stated that local necessities, for sanitary reasons, demanded a large discharge from Lake Michigan into the Illinois river. Navigation interests, he said, not only did not demand an increased discharge into the Illinois river, but such discharge would result in a positive injury to navigation. A navigable channel demanded no slope to the costly cut through the Chicago Divide, but local sanitary necessities required a slope of not less than four inches to the mile and a cut deeper by about seven to eleven feet in rock and three to seven feet in earth. He asked the department whether it desired that the estimates demanded by Congress should be rendered on the basis of the requirements of navigation, or whether the local drainage problem should also be considered.

Captain Marshall was asked in turn by the department for suggestions. In his reply he appeared to regret that the Act of Congress did not allow the capacity of the channel to be determined by the consideration of the size and draught of Mississippi river steamboats that could reach the mouth of the Illinois river. He desired to make the estimates required by law for a 14-foot channel, and for an 8-foot channel also, as required for steamers navigating the western rivers, leaving such modifications of the channel as might be required by local sanitary necessities to be attended to by local authorities.

General O. M. Poe, engineer of the Northwest division, endorsed the communication of Captain Marshall with this remark:

> "It does not appear that the project for a fourteen-foot channel must necessarily cover the whole distance from Lake Michigan to the Mississippi river, but may be limited to the portion between La Salle and Lockport. The only requirement imposed by the law for the remainder is that it shall provide for a channel having capacity and facilities adequate 'for the passage of the largest

Mississippi river steamboats and of naval vessels suitable for defense in time of war."

The communication was forwarded to General Casey who issued this order:

"Surveys, plans and estimates for a 14-foot channel as required by law, and for the 8-foot channel required by western river boats, should be made in the interest of navigation. Modifications required to adapt to local wants the navigable channels thus surveyed should be left to local authorities."

In his suggestions Captain Marshall seems to have been guided by a predetermination that a channel for navigable purposes would never be extended to the Chicago river through the upper Desplaines valley. In fact, he said in his report of the surveys, in direct opposition to the views of Government engineers who had preceded him, that the terminal facilities at the mouth of the Calumet river, "the ample landlocked natural basins (needing only deepening by dredging) for the construction of a great development of wharves and docks in public waters of the United States, scarcely excelled anywhere on the Great Lakes," pointed irresistibly to the Calumet region as the proper terminus of a great waterway between the Great Lakes and the Mississippi river. Under the direction of Captain Marshall large sums of money have since been spent by the Government in creating a channel in the bed of the Calumet river nearly a mile in length, 250 feet wide and 16 feet deep.

Acting under the orders received from his chief, Captain Marshall made surveys and estimates for two channels, one fourteen feet deep and the other eight. In his report, preliminary to an explanation of his plans, he analyzed the navigation of the Mississippi river and such of its tributaries as would be served by the proposed waterway. In the Desplaines and Illinois rivers the practical depth of navigation after the construction of the smaller channel, would vary with the stage of the rivers. From Joliet to La Salle there would be a navigable channel varying in depth from eight feet, when the discharge of the river was at a minimum, to ten to sixteen feet at mid-stages. Below La Salle to the Mississippi river there would be a depth of navigation varying from seven feet at extreme low water, to twelve feet at mid-stage and eighteen feet or more at floods. The minimum low water depths sought on the Illinois river were greater than those proposed for that portion of the Mississippi river with which it immediately connected.

The 14-foot channel would accommodate with increased facility all large vessels that could reach its terminus at La Salle through the channel of the Mississippi river. But vessels on the Mississippi that could not be accommodated by the 8-foot channel at extreme low water would not be accommodated by the 14-foot channel 160 feet wide, although a channel fourteen feet in depth at extreme low water in Lake Michigan to eighteen feet at high water across the Chicago Divide, could be navigated by large boats, if there were still water or a very moderate current, with greater facility than a still water channel eight to twelve feet in depth.

This was the best argument for such a channel, based upon the present or probable future navigation of the Mississippi river and its tributaries, Captain Marshall said, but it was not a public necessity. No greater depth of channel than nine feet at extreme low water in Lake Michigan across the Chicago Divide seemed to him necessary for navigation by vessels similar to the largest Mississippi river craft that could neither use it nor reach it. But a channel of much greater capacity discharging a large volume of water into the Desplaines and Illinois rivers not necessary for navigation in a canalized river, as this must necessarily be, was made locally urgent by the sanitary necessities of the city of Chicago for drainage and an uncontaminated water supply. These necessities ended when the Chicago Divide was passed and the discharge turned into the channels of the rivers.

Beyond the Chicago Divide there was no apparent necessity then nor likely to exist in the near future, either national or local, for a channel of materially greater capacity than the minimum estimated for between the Mississippi river and the Great Lakes, although every increase in depth and width up to a certain limit throughout the artificial channel would increase the facilities for navigation, probably without affecting the character, size or draught of the boats that would use it as a through route of transportation.

The Two Routes.

The two routes for which estimates were made by Captain Marshall, one by way of the Chicago river and the other by way of the Calumet river and the Sag, united at the Sag bridge, about seventeen miles respectively from Bridgeport and Blue Island. From Sag to La Salle they coincided. The Chicago route followed the Chicago river from its mouth by way of the South branch to a point near Bridgeport, the West

fork of the South branch and the Ogden ditch to Summit, thence parallel with the Illinois and Michigan canal on lower ground for about three miles, and entered the bed of the Desplaines river. Cutting off bends it followed the Desplaines river to the Sag bridge. This route was preferred to the line of the Illinois and Michigan canal for these reasons:

It occupied lower ground, and the probable amount of excavation was less, since the earth excavated from the old canal remained as spoil banks to be removed.

The old canal was parallel by a railroad on either side, and there was not sufficient room for the enlargement of the canal without condemning the railroad right of way and removing one or both tracks.

The present canal was the property of the State of Illinois, and the conditions of transfer had not been accepted by the United States. These conditions were such that their acceptance would involve greater cost than a new right of way.

The Illinois and Michigan canal was the main sewer of the city of Chicago, as well as a commercial highway, and could not well be enlarged without seriously interfering with its uses, or at increased cost of work from delays due to traffic on the canal.

As a means of transportation and drainage it was of advantage in the prosecution of the work parallel with it that it should be maintained in a serviceable condition during the construction of the larger canal.

The new route avoided excavation in solid rock for several miles, between Willow Springs and Lemont, which was found in the bed of the old canal.

The proposed Sag, or Calumet river route, followed the Calumet river from Lake Michigan to One Hundred and Tenth street, thence by way of a cut-off through Lake Calumet to its southwestern shore, thence by another cut-off to the Little Calumet river, thence to Blue Island, and nearly due west along the line of the old Calumet feeder north of Lane's Island to the junction of the two routes at Sag bridge. The line through Calumet lake was more expensive than by way of the rivers to Blue Island, but was preferred because it was five miles shorter, and because Lake Calumet afforded greater facilities for the construction of an "unobstructed land-locked harbor of great proportions, affording ample room for a turning basin and great development of docks and wharves suitable for an extensive commerce and easy transfer between lake and river steamers." The route north of Lane's Island,

although about two miles longer than the direct line south of the island, was preferred because the material to the south for several miles was a soft muck, peat and vegetable matter, in which it would be extremely difficult and expensive to maintain a definite channel.

Bridgeport Pumping Works.

When it was found necessary to abandon the deep cut in the construction of the Illinois and Michigan canal it was suggested that pumping works be erected at the head of the canal to supply it with water. The suggestion met with approval, and the pumping works were built and put in operation when the canal was opeend in the spring of 1848. Although constructed for the sole purpose of supplying the canal with water to make it navigable, the city soon discovered that they were performing a very useful duty in cleansing the Chicago river. This led to an arrangement with the Canal Commissioners in 1865, by which the latter agreed to pump water from the river into the canal at certain times for the relief of the city from the serious annoyances of a badly contaminated river.

A heavy rainfall in that year kept the river in a comparatively clean condition. In 1866 the pumps were operated 62 days; in 1867, 150 days; in 1868, 73 days and in 1869, 100 days. The amount of water raised by them in 1869 is estimated to have been 10,000 cubic feet per minute. The increase in the demands upon the pumps was due to a diminished rainfall, a lowering of the lake level and a greater pollution of the South branch of the river. The increasing business of the packing houses at Bridgeport was mainly responsible for the pollution. In 1860, 306,428 head of cattle and hogs were slaughtered, but in 1863 the number had increased to 1,029,948. The growth of the business and the consequent defilement of the river continued from year to year. Soon after the completion of the deep cut in the canal in 1871, the packing houses were removed from Bridgeport to the present location at the Stock Yards. The liquid refuse was then discharged into the South fork of the South branch, which soon became indescribably foul. This fork of the river, now a stagnant pond, the sickening contents of which overflowed into the South branch when it became full, has since remained the one plague spot within the city. In 1863 an epidemic of erysipelas occurred along the South branch and was traced by physicians to the decaying

animal matter in the river. This was one of the immediate causes of the appointment of the Commission in 1865 to devise a plan to cleanse the river. * * *

It was not many years before the citizens deplored the fate of the pumps. A constant current was not maintained through the river from the lake, owing to fluctuations in the lake level, the direction of the wind, and other causes. The action of a southwest wind on the water of the Chicago harbor at one time resulted in lowering the water in the canal at Lockport, 27 miles away, fifteen inches. The rainfall had much to do with the amount of water which flowed from the river into the canal. In 1879 the current of the river was lakeward for thirty days, and for ten days there was no perceptible current either way. In 1873 for sixteen consecutive days, it is said that the average amount of water passing through the canal at Bridgeport was 33,000 cubic feet per minute. In 1879 the amount was estimated to be only 17,000 cubic feet at any time and only 10,000 cubic feet in the winter when the canal was frozen over.

Dr. John H. Rauch, secretary of the State Board of Health, took up the question of the contamination of the water of the Illinois and Michigan canal in 1878 and 1879 in the interest of the people living in the valley of the Desplaines, they having begun to make serious complaint. Under his direction daily observations were made by Samuel M. Thorp, locktender at Joliet, to determine the daily stage of water in the canal, the offensiveness of the odor arising from it, the general force and direction of the winds, the temperature and the degree of contamination of the water. Mr. Thorp's observations were begun on October 14, 1877, and continued to the end of November, 1878. During the winter of 1877 and 1878 an increase in the amount of sewage and the degree of the odor arising from it were observed whenever the water at the dam was low. As the amount of water increased the offense from the sewage diminished. During the period of Mr. Thorp's observations there were 249 days in which the water was filthy, and only 14 in which it was clear. On 117 days the odor was marked, on 116 days it was slight, and on 140 days there was no odor. On 211 days the water was low, and on 90 days it was high. These observations demonstrated to Dr. Rauch that a low stage of water was always attended by increased contamination and by an increase in the offensive odor and that the condition of the water was invariably in a marked degree even by an increase in the depth of the water by an inch

or two. September 30, 1878, following a low stage of water, the observer noted that all the fish in the river were killed, and on October 15, persons passing over the bridge were nauseated by the offensive odor. From the close of Mr. Thorp's observations until February, 1879, the odor escaping from the river at Joliet was so offensive that public meetings were held and committees appointed to visit Chicago and demand relief. Dr. Rauch reports that during the fourteen months of Mr. Thorp's observations there was almost continued low water. Only once did the water rise fifteen inches above the low water mark and the average height above it did not exceed two inches. This indicated that the amount of water passing over the dam was diminishing, due to the lowering of the lake level 35 miles away.

Dr. Rauch concluded that the only remedy for the offensive condition of the canal and the Desplaines river would be found in an increased and constant flow of water from the lake into the canal. He suggested to the State Board of Health that it recommend to the city the rebuilding of the pumping works with the least possible delay. "This will be the first time," he said, "that the board has made a recommendation to the city of Chicago in relation to its sanitary affairs. There is another view of the case to which the attention of the municipal authorities of Chicago should be called, which is that the city has no right unnecessarily to injure the material and sanitary interests of any other part of the State. The community of interests which exists between the citizens of Chicago and the inhabitants of the country lying along the canal and river, forbids the injury of either by the other. It is but just to state that the plans heretofore adopted for the sewerage and drainage of the city of Chicago have been made with a view to such change as the future might require. The deepening of the canal, which was begun in 1865, was not completed until 1871, so that the relief afforded by that measure was delayed six years from the time when its necessity was recognized. The pumping works can be rebuilt in ninety days. My reasons for recommending this course are that the works will furnish almost immediate relief without great expense and without interfering with the project for a ship canal, or with any more permanent plan which may become necessary for disposing of Chicago sewage."

The amount of water needed to cleanse the canal, Dr. Rauch said, was from 60,000 to 100,000 cubic feet per minute.

William Thomas, general superintendent of the Board of Canal Commissioners, at the close of the year 1879, called the attention of the Canal Commissioners to the condition of the Summit level. When the water was let into the deep cut the lake was more than three feet higher than it was in 1879. Navigation had been seriously interfered with. Either the bottom of the canal must be lowered throughout the entire length of the canal, he said, or more water must be supplied at Bridgeport. In his judgment it was a great mistake that the old hydraulic works at Bridgeport had not been preserved. With those works restored the water in the canal could be kept nearly as clean as that in the lake itself, and the navigation of the Summit level restored to its normal condition at an expense not to exceed $75 a day. He thought the city of Chicago and the Canal Board should at once take steps to accomplish this purpose.

The recommendations of Dr. Rauch, fortified by the opinions of Mr. Thomas, were concurred in by the State Board of Health, and a copy of the secretary's report was transmitted to the Mayor and Common Council of the City of Chicago. The subject was earnestly discussed by the press, the Chicago Citizens' Association and the Engineers' Club. There were conferences between the State and city authorities and a convention was held at Ottawa to further the interests of a ship canal. The result was that the Common Council appropriated $100,000 on March 29, 1880, for the construction of pumping works at the head of the Illinois and Michigan canal.

During the year 1880 the condition of the river continued to grow worse. In June Dr. Rauch made an examination of the Chicago river and found it more foul and offensive than it had been since the deep cut was completed in 1871. In the main river the current was toward the lake indicating little change in the level of the lake. At Van Buren street the water was almost stagnant. At Eighteenth street there was no current, and there was none at Halsted street for the first time within the secretary's recollection.

On July 19, 1880, a petition from the citizens of the city of Joliet was sent to the Canal Commissioners asking the privilege of digging ditches, without cost of the board, between the canal and the Desplaines river with a view of the purification of the waters of the canal. The petition follows:

"Gentlemen:—We, the undersigned, citizens of Joliet, Will county, and State of Illinois, would most respectfully petition your Honorable Body (for the reasons herein-

after mentioned) for the privilege of digging, constructing and making such ditches, flumes, races and head gates, without cost to your Board, between the Illinois and Michigan Canal and the Desplaines river, and along the line of the same from Lockport to Bridgeport, as will allow a sufficient quantity of water to pass from said river into said canal to feed the same, or so much of it as said river may be able to furnish.

Your petitioners would most respectfully represent that for very much of the time during the last nine years, they have suffered to an extent beyond description from what they had supposed a nuisance caused by the city of Chicago cutting down the Summit Level of the Illinois and Michigan Canal, and turning its sewage matter, together with all other nastiness, from thence through the Chicago river into the canal. But having recently sent a committee of our business men to confer with the Mayor of Chicago, with reference to the proposed pumping works at Bridgeport, and, however strange it may appear to others, having learned from his Honor that the water in the Chicago river was pure and clean enough for bathing and toilet purposes and what was still stranger, that the nuisance complained of was not caused by the city of Chicago, but by your Honorable Board, that committee was instructed by his Honor to stir us up, to assist him in compelling your Honorable Board to abate the nuisance. And through his Honor, our committee was further informed that on account of the Fullerton avenue conduit and its pumping properties, the city of Chicago did not need the Bridgeport pumping works nor the Illinois and Michigan Canal itself; that the water that passed into the canal from the Chicago river was for the benefit of the canal and not for the benefit of the city.

In view of all these facts (and facts they must be, or surely Mayor Harrison would not so advise us), we come to you and most earnestly pray your Honorable Body to not only allow us to make the openings mentioned above, but also that your Board would avail itself of its right to restore the dam at the south end of what was once known as Lane's Lake, or head of Rock Creek, four miles northwest of Blue Island, and turn its waters back into the old Calumet feeder, and through it into the Illinois and Michigan Canal. By the assistance of these two sources of supply we are advised the water from the Chicago river

can be entirely prevented from entering the canal for about eight months of the year, and in part for a longer period of the year, so that to a very great extent we shall be relieved from what is now an intolerable nuisance. Your petitioners would most respectfully urge your Honorable Body to give the subject that careful consideration which its importance demands, at the next monthly meeting of your Board, August 12th, next, to the end that we may get whatever relief is possible during this season.

We have no doubt ample means can be obtained to do this work from parties who own lands at the Summit, that are now nearly worthless, and which by means of the drainage will become very valuable. Each sluice or race to have ample gates to be closed against floods, and for a brief time at the beginning of winter to allow the ice-fields south of Summit to fill with water.

All of which is respectfully submitted."

At the close of the year 1880 the Canal Commissioners reported that the sewage of the city of Chicago in passing through the canal caused such an offensive smell as to become an almost intolerable nuisance to the citizens of Joliet and other towns along the line of the canal.

The State Legislature was now induced to use its influence and power in compelling the city of Chicago to divert its sewage from the Desplaines and Illinois valleys or dilute it with a larger discharge of water from the lake. A joint resolution was introduced in the senate by Senator Munn of Will county, which made these alarming statements:

'The foulness of the water annually causes the death of millions of fish in the Desplaines and Illinois rivers, that float to the shores and decay. The sewage in an entirely undecomposed and putrid mass is carried by the current of the canal into the Desplaines river and thence into the Illinois river, rendering the air at all points along its passage so impure and foul as to be exceedingly offensive, and taking with it germs of disease of all kinds prevalent in the city of Chicago, thus spreading them broadcast through the entire Desplaines and Illinois river valleys, causing thereby much illness as well as poisoning the blood and debilitating the systems of 200,000 people. Careful investigation leads the people to fear that an epidemic may spread over said section of the state of Illinois from the causes above stated. In addition to the above distress there has been a great loss to prop-

erty, business industries and to the communities by reason of the causes herein mentioned. Prior to the deepening of the Illinois and Michigan canal the water necessary for all purposes of navigating the canal and propelling machinery was obtained from the Desplaines river and the Calumet feeder through Lane's lake. The bed of the Desplaines river at Summit and thence westward along the line of and adjacent to the canal is at a low stage of water eight above the surface level of the canal and will average a supply of water sufficient for all canal and power purposes during the seasons of navigation. The supplying of the canal from these sources will so dilute and weaken the sewage of the city of Chicago as greatly to relieve it of its foulness and stench, to the great delight, relief and health of the people near to and bordering upon the line of the canal, the Desplaines and Illinois rivers.'

Following this preamble was a resolution directing the Canal Commissioners to cause sluiceways of sufficient capacity, with the proper guard gates, to be opened from the Desplaines river to the canal at or near Summit in Cook county, and at or near Lemont in Cook county, and also to construct a dam across the former Calumet feeder at such suitable point as would cause the water from Lane's Lake to flow into the canal. The commissioners were required to commence this work immediately, the cost not to exceed $10,000.

This bold attempt to coerce Chicago into disposing of its sewage by some other method than discharging it into the Illinois and Michigan canal met with determined opposition on the part of Chicago, and several provisos were added to the resolution which gave the city the benefit of an alternative. The provisos authorized the Canal Commissioners to confer with the Mayor of the city of Chicago, or authorities of the city, concerning an increased flow of water into the canal. If the city should proceed without delay to cause a flow into the canal from the Chicago river sufficient to dilute and purify the waters and thus remedy the evils complained of, such flow to be not less than 60,000 cubic feet per minute, including the ordinary flow into the canal from the river, the work to be accomplished by the 1st day of September, 1881, the Commissioners were directed to accept it in lieu of obtaining a supply from the other sources named. The Commissioners were required to take care of 60,000 cubic feet of water per minute, but the State was not to be committed to a system of permanent drainage of Chicago sewage through either the canal or the Desplaines or Illinois rivers, the State

reserving the right to require the city of Chicago in future years to take care of its sewage through other channels. The city was also required to maintain and manage the pumping works, subject to the direction of the canal commissioners, relative to the amount of wa'er to be received into the canal.

The resolution, as amended, was adopted by the Senate on May 18, 1881, and by the house on the following day. * * *

At the time of the tests the lake level was at an average high stage, and the conditions were favorable to the pumps. Both river and canal were kept in a comparatively inoffensive condition for two years. In 1886 the average mean level of the lake below datum was 2.64 feet. In the following year it dropped to 1.96 and continued to fall until it reached 0.05 feet above datum in 1891. With the lowering of the lake levels the pumps were required to raise the water at the head of the canal through a greater distance, and the result was a less amount pumped. The required 60,000 cubic feet per minute was reduced to an average of 37,771 cubic feet during the year 1891. With little more than half the required amount of water pumped from the river, and the sewage discharged into the river greatly increased because of the rapid growth of the city, the river and the canal again became very foul and offensive. But the city of Chicago had complied with the requirements of the law of 1881, and the Canal Commissioners did not make the cuttings from the Desplaines and Calumet rivers which the people of the valley demanded. Had they done so the outlet for Chicago sewage toward the interior of the State and the Mississippi river would have been cut off, and Chicago would have suffered immeasurably. The resulting contamination of the city's water supply would have depopulated the city.

Ogden Wentworth Canal.

Before the deepening of the Illinois and Michigan canal in 1871 the low and swampy land lying east of Summit and north of the canal was covered with water during the greater portion of the year. This territory included several hundred acres and constituted what was known as Mud lake. It extended eastward from Summit about three miles and northward nearly to the West fork of the South branch of the Chicago river. Its surface was below the level of the water in the canal, but several feet higher than that of the Chicago river. The latter condition suggested to the owners of the

swamp property the feasibility of reclaiming it by dredging an outlet to the Chicago river. It was also proposed to improve other low-lying lands in the vicinity in the same manner. Ditches were dug in both directions from the East fork of the South branch, some of them connecting with Mud lake. But the latter were not effective until the completion of the deep cut in the canal, because the lake was filled with seepage from the lake as rapidly as it was drained through the ditches.

Fullerton Avenue Conduit.

In the original plans of the city's sewerage system, it was foreseen that the Chicago river and its branches would sooner or later become sources of great annoyance unless artificial means were taken to maintain a circulation through it. The main river and the South branch depended to a certain extent upon the Illinois and Michigan canal. The North branch had no such auxiliary. City Engineer Chesbrough, who planned the city's sewers, hoped, as he said in his report for the year ending March 31, 1870, that by arranging the system so that but very little filth would be discharged into the North branch it might be many years before it would be necessary to construct any expensive works to purify it.

But this branch of the river became foul much earlier than was expected. Up to the year 1870 less than 5 per cent. of the sewage of the city is said to have been discharged into the North branch, but it received the waste from distilleries and tanneries erected along its banks. It became so offensive that the State Board of Health was called upon to enforce the State law against the maintenance of nuisances. The Board's action brought some relief, but the condition became so serious that the Board of Public Works was of the opinion in 1870 that it was not wise nor safe to postpone further "entering upon some efficient plan for keeping clean the North branch."

City Engineer Chesbrough recommended in that year that a covered canal, or conduit, be constructed along Fullerton avenue between the North branch and the lake, A summary of his discussion of this subject is given in Chapter VI. The Board of Public Works agreed that "for flushing out the river but one of the many schemes proposed seems to them to promise to be effectual and worthy of adoption, that is, the construction of a canal, open or covered, between the lake and the North branch, through which the water shall be forced

by mechanical means, either into the river or into the lake, as shall at the time be necessary."

In September, 1872, the artesion well scheme for flushing the North branch was proposed and rejected. Still another year was spent in a discussion of other possible means of purifying the increasingly offensive stream. It was finally decided to construct the conduit, and proposals were advertised for three times. The contract was ultimately awarded to Geo. F. Norris & Co., under proposals opened on March 31, 1874, at $343,284. The work was to be completed on July 1, 1875, the conduit was to be circular in shape, twelve feet in interior diameter, the invert at a grade of thirteen feet below datum, and extend from the North branch of the Chicago river along Fullerton avenue to Lake Michigan.

Excavation was begun about the first of June, 1874, at Ashland and Fullerton avenues. The work was carried on in both directions until December 8, when it was discontinued. About 4,000 feet had been constructed. The contractors found, as they claimed, that the character of the work had been misrepresented, and that their price was too low. The Board of Public Works resisted their claim for an increase of price, but a settlement was effected on June 14, 1875, and the contractors were released. New proposals were received on July 26, and the contract for the completion of the work was awarded to FitzSimons & Connell. The contractors were given the option of doing the work in open excavation or by tunneling at a lower grade. This contract was concluded on September 13, and work was resumed on October 28. Shafts were sunk at the lake shore, Larrabee street and at Sheffield avenue. West of Racine avenue the excavation was an open cut; east of that point, a tunnel.

The conduit was completed and the machinery put in operation on January 9, 1880. It was a brick tunnel twelve feet in diameter and 11,898 feet in length. The bottom of the tunnel from the river to Racine avenue, a distance of 4,270 feet was level, and thirteen feet below datum. A short distance east of Racine avenue it dropped to a grade beginning at a depth of 27⅔ feet below datum. It was continued in a series of descending grades to the lake shore shaft where it was 54½ feet below datum. From this point to the lake shaft, 1,000 feet in length, the conduit was level. The change in the grade was made for convenience in excavation. * * *

When the conduit was opened the pumps were operated to draw water from the lake into the river. Other circumstances favored the cleansing of the North branch. There

was a heavy rainfall and long continued high winds from the northeast, which helped to drive the water from the main river up the South branch, thus aiding the Bridgeport pumps to do their work. So long as the pumping from the lake into the river through the Fullerton avenue conduit was continued the North branch was kept in a cleanly condition, and the conduit was pronounced a success. The condition of the main river and its branches in the year 1880, with other facts relating to the drainage and sewerage of the city, is shown by the following tabular statement:

CONDITION OF THE RIVER AND EXTENT OF THE SEWERAGE OF THE CITY IN 1880.

NAME	Area of surface in acres draining into each branch	No. sewers discharging into each branch	Aggregate area of their terminal openings in square feet.	Condition of the water in each division of the river.	Relative density of population on each of the given area.
North Branch.....	1,988.98	19	229.53	From rolling mill north comparatively pure; from same point south highly discolored, with little odor.	2/3 densely, 1/3 sparsely settled.
Main River.....	808.08	16	122.47	Nearly free from deleterious matter, little or no odor.	Densely settled.
South Branch.....	3,364.09	48	460.05	Highly discolored, with very little odor	7/8 densely, 1/8 sparsely settled
West Fork of South Branch...	581.73	2	56.94	No perceptible odor, water nearly pure.	Sparsely settled.
South Fork of South Branch...	354.45	5	52.82	Extremely foul, water charged with decomposing animal and vegetable matter, odor very offensive.	Sparsely settled.
	7,097.33	90	921.81		

That portion of the South division of the city which drains directly into the lake contained 1,270.43 acres, making a total area of 8,368 acres covered by the sewer system of the city in 1880, a little more than 36 per cent. of the entire area of the city.

The conduit pumps were operated irregularly during the first year, and by the aid of the rains and winds the North branch was kept in a comparatively inoffensive condition. In the following year the pumping was mainly from the river into the lake. Occasionally when the current of the river north of the pumping works was so strong that the pumps had little effect upon it the pumps were reversed. When the current was toward the lake the offense of the North branch was transferred to the lake shore, in a less degree, and the city's water supply was often contaminated by distillery refuse and sewage.

New wheels eight feet in diameter were put in during May and June, 1882, increasing the power and efficiency of the works. City Engineer Artingstall made these statements in his report covering that year:

> "The greater part of the year the water has been discharged from the river into the lake with good results, maintaining during such times the North branch and the main river in an excellent condition, free from offensive odors and the water comparatively clear. Twice during the year the experiment was made, for extended periods, of pumping from the lake into the river. During both times the water in the main branch became foul and very offensive."

The people differed from Mr. Artingstall as to the effects of the water pumped from the North branch into the lake and vice versa, and such protests were made against pumping into the lake that it was done only occasionally. It was entirely discontinued in 1885. While the North branch has been greatly improved by the conduit pumps, it has been very offensive in recent years due to the increase of the sewage discharge into it and the number of factories and other refuse producing operations on its banks.

The pumps have fallen considerably short of their original requirements, the average amount of water per day during the year 1891 being 15,000,000 cubic feet. This was about 10,416 cubic feet per minute. The conduit has a capacity of about 24,000 cubic feet per minute.

CITIZENS' ASSOCIATION.

Much was done by the Citizens' Association of Chicago between the years 1880 and 1889 in creating and fostering a public sentiment which demanded better drainage for the city. Several expert examinations were made by the association and its reports were given to the people through the daily papers and printed pamphlets. These investigations and the resulting discussions led to the more exact and complete investigation by the Drainage Commission under the authority of the municipality. Although the suggestions of the association were not always practical, they kept the people thinking, a very useful preliminary to public legislation.

The association referred the subject of main drainage for the City of Chicago to a committee in the year 1880 with a request that it recommend some system for the disposal of the sewage of the city which should be adequate for present and future needs. The committee consisted of John B. Sherman, George C. Morgan and S. B. Reed. In the course of its investigations the committee employed A. J. Mathewson, a civil engineer of Joliet, to make surveys and estimates. The results of the committee's inquiries were given to the association in a report made in December, 1880, which was endorsed by the association. * * *

Objections to these plans were found in the original and continually increasing expense and because they required a discharge of all or a portion of the sewage into the lake.

> "Our objections to any plan," the committee said, "which suggests the discharge of sewage or impure matter into the lake, where they could in any event contaminate the water supply, are so fixed that part of the recommendation in the plan we shall hereafter propose is that a radical change in the whole system of sewerage in the North and South divisions shall be inaugurated by which all sewers shall empty into the river. Although we have given careful consideration to all plans laid before us we make no reference to any except those mentioned above, which propose the use of the lake for the ultimate disposition of the sewage."

The committee thought it proper to remark in this connection that the filthy water discharged from the Fullerton avenue conduit, when it was operated in the direction of the lake, could be traced for a long distance in the direction of the water works crib. To attempt to get the water supply from a more distant point, either out in the lake or toward the north

would be only a partial remedy. Besides, the cost would be more than that of a permanent and wholly satisfactory plan for the disposal of the sewage. It was suggested to the committee that the lock and dams in the Illinois and Michigan canal might be removed when the water from the Chicago river would flow freely through it. To this the answer was given that the usefulness of the canal commercially would be destroyed, private interests seriously affected and a deepening of the canal necessitated.

The considerations of the committee were finally narrowed down to two popositions. One of these involved the construction of a ship canal, which seemed to have the sanction of public opinion.

> "We have given a large share of our attention to this scheme," the committee said, "with little knowledge of the methods of sewage purification, and although we are unanimously and cordially in favor of a ship canal as such, we cannot give it the sanction of our favorable opinion as a drain. At such it would be liable to all the objections now urged against the present canal, as to its annoyance of the inhabitants along its banks for the reason that any current which would move the water with sufficient velocity to prevent the deposit of filth would impair its usefulness for commercial purposes, it having been ascertained that no current greater than half a mile per hour is tolerable in slack water navigation. The project for such a canal is embarrassed also with many considerations of a political nature, which we do not deem it within our province to consider, preferring to present the other plan, which can be carried out within a reasonable time at a very moderate cost, and which is wholly within the scope of the pecuniary means of those for whose benefit it will have been constructed, and will, it is believed, be wholly devoid of offense to any locality or people."

The plan as revised and approved by the committee provided for the construction of a canal, or

> "New river," which is described by Engineer Mathewson, as starting "from the mouth of the Regula, or Mud Lake fork of the South branch of the Chicago river, running off west and through said lake toward the Desplains river north of Summit, and then curving round to the left, keeping away to the left, and passing along in a southwest direction between the canal and the river, past the ice houses and between said house and the river to Mount Forest, Willow Springs, Sag Bridge station and Lemont

to the Romeo bend of the canal, Norton's tailrace at Lockport, and to a point opposite lock No. 1 at Lockport; thence to a point at the head of the pond of dam No. 1, Joliet, a few hundred feet northwest of lock No. 4 of the Illinois and Michigan canal, a distance of not far from 31½ miles."

The committee thought this plan sufficient for the drainage of Chicago for all time to come. To complete it the sewers discharging into the lake would need to be reversed and made to discharge into the Chicago river, as well as local drains as far north as the source of the Chicago river and south in Hyde Park. The towns of Lake and Cicero would also come within the limits of the drainage district proposed. In reversing the city sewers such fall should be given to them that they would be self-cleansing. The Fullerton avenue conduit could be used for the purpose for which it was constructed, or it could be converted into a useful adjunct of the city's water supply system. The forks and branches of the Chicago river at the south end would purify themselves, as their contents would gravitate toward the new cut in the Desplaines valley. The current in the New river would be at the rate of 2.15 miles per hour. The water in the Chicago river would be changed every twenty-four hours, and the water of the entire Chicago river would become as pure as that of the lake, and remain so. The effect upon the waters at the point of discharge would be to improve them greatly.

To carry this project into effect would require State legislation creating a drainage district and a commission to carry out the provisions of the law. The estimated cost of the New river was $6,850,000 but it was thought the sum of $12,000,000 would be necessary to develop the scheme in all its necessary details. Commissioners should be authorized to borrow money on the credit of the district. A loan for the purposes required, it was thought, if redeemable in thirty years, would be readily taken at 4 per cent. At a low assessed valuation of the property of the district a tax of two mills would be sufficient to pay the interest and provide a sinking fund for the principal.

The importance of this report is found in the fact that it suggested the idea which developed into the law of 1889 creating the Sanitary District and providing for the drainage channel.

DRAINAGE AND WATER SUPPLY COMMISSION.

Prompted by the recommendations of the Chicago Citizens' Association and the urgent appeals of the press, the City Council passed a resolution on January 27th, 1886, authorizing the creation of a Drainage and Water Supply Commission. Mayor Harrison appointed Rudolph Hering as chief of the Commission. Benezette Williams and Samuel G. Artingstall were made assistants. A preliminary report was made by the Commission in January, 1887. In transmitting the report to the City Council Mayor Harrison recommended that a law be enacted to create the new metropolitan district suggested with power to issue bonds or levy assessments and to prosecute the work. The work of the Commission was not carried to a conclusion because the City Council was unwilling to appropriate the funds necessary for its expenses. The preliminary report was as follows:

CHICAGO, January, 1887.

To the Honorable Mayor and City Council of the City of Chicago:

GENTLEMEN:

On January 27, 1886, your Honorable Body passed a resolution authorizing the creation of a Drainage and Water Supply Commission. After being amended February 23, it read as follows:

"Whereas, pure water and scientific drainage are necessities of this community, and the people demand a system of water supply and drainage adequate to meet the requirements not only of the present, but of years to come, nor will any temporary expedient or makeshift satisfy them; and

Whereas, a thorough and permanent system of supplying pure water to our citizens and caring for the drainage of the municipality cannot be paid for out of current taxation, therefore it is desired that a plan shall be devised and perfected before the next meeting of the Legislature to the end that necessary legislation may be had.

For the purpose of carrying into effect the objects sought, there is recommended the appointment by the Mayor of a commission to consist of one expert engineer, whose reputation is so high that his opinion and report will command the respect of the community, and with him one or two consulting engineers of like experience in engineering and sanitary matters. The duty of this Drainage and Water Supply Commission, made up as above set

forth should be to consider all plans relating to drainage and water supply which may be brought to its attention; to make such examinations and investigations and surveys as may be deemed necessary; to collect all information bearing on this problem; to consider all recent developments in the matter of sewage disposal, and their application to our present and future needs; to consider and meet the necessity of increasing our water supply and of protecting the same from contamination; to remedy our present inadequate methods of drainage and sewage disposal; to consider the relations of any system proposed to adjacent districts, and whether there may not be a union between the city and its suburbs to solve the great problem; to determine the great question as to the interest which the State and the United States may have in the disposal of sewage by way of the Illinois river; to devise plans to meet any objections thereto, if such a system shall be thought best; and, in general, to consider and report upon any and all things which relate to the matter of water supply and drainage of the City of Chicago.

The Commission should report on the whole matter committed to it in the most full and comprehensive manner, with maps, plans and diagrams complete, and accompany the report with estimates of the first cost and annual requirements for the maintenance of the system proposed.

The report of the Commission should be made as early as practicable, and not later than the convening of the next session of the Illinois Legislature in January, 1887.

In consideration of the foregoing, be it

Resolved, That the Mayor be and is hereby authorized and directed to employ on behalf of the city one expert engineer of reputation and experience in engineering and sanitary matters, at a salary not to exceed $10,000 per annum, and also to employ such consulting engineers, not exceeding two in number, as may seem necessary, and such assistant engineers as may be required, all to be paid according to services rendered, for the purpose of carrying out the objects set forth in the preamble hereto. For the fees of said assistant engineers and for all expenses connected with said work there shall be allowed not to exceed the sum of $20,000. All fees, salaries and expenses connected with said work shall not

exceed in the aggregate the sum of $30,000 and the same shall be paid from the water fund of the city upon vouchers audited by the Mayor and City Comptroller."

In accordance with the terms expressed herein his Honor Carter H. Harrison appointed Rudolph Hering as chief engineer, Benezette Williams and S. G. Artingstall as consulting engineers, who, together, should constitute a Commission. Mr. Hering entered upon duty March 28, Mr. Williams September 17, and Mr. Artingstall December 21, 1886.

The sewerage works of Chicago and suburbs have been planned on what is called the combined system, in which the sewers serve for the removal of both sewage and rain water. In the town of Evanston they empty into the lake. In the town of Lake View they partly discharge into the lake and partly into the North branch. From the North and West divisions and part of the South division of Chicago the drainage enters the Chicago river and its branches, and from the remaining part of the South division it flows into the lake at three outlets situated respectively at Twelfth, Twenty-second and Thirty-fifth streets. The sewers of Hyde Park discharge into the lake excepting those of Pullman, where the sewage is disposed of on land. The town of Lake, including the Stock Yards district, drains into the South fork of the Chicago river.

When the sewerage works of the city were designed, in 1856, by Mr. E. S. Chesbrough, it was apprehended that ultimately some means would have to be found to change the water in the river from time to time or to keep the sewage entirely out of it. The first step toward improving the condition of the river was taken by deepening the Illinois and Michigan canal, so as to cause a current from the lake to the Desplaines river at Lockport. The next step was the building of the Fullerton avenue conduit in order to produce a circulation in the North branch; and the last step was the erection of the canal pumping works to increase the flow in the river, which had become greatly polluted.

The influence of these works is confined to the main river and its North and South branches. But the South fork of the latter, receiving a large amount of sewage from Chicago and the town of Lake, and charged with the waste from the Union Stock Yards and packing houses, has no artificial means for a circulation of its water, and as a consequence is in a condition of great filthiness.

The accompanying diagram has been prepared to show the present pollution of the Chicago river and its branches dur-

ing the time when all of their water is discharged into the canal by the Bridgeport pumps. On the left are shown the main river and the North branch, one above the other, their combined waters forming the South branch, and reaching Bridgeport on the right where they are lifted into the canal. At the latter point the South Fork is shown as joining it, the shaded portions indicate the amount of sewage entering and passing the respective points, and the blank portions the lake water diluting it. The degree of dilution is shown by the relative areas. It diminishes in the North branch from Fullerton avenue to the South branch, and becomes still less toward Bridgeport, and finally receives the foul waters of the South fork.

The depth and character of sewage deposits in the river and harbor, as might be expected, vary considerably. They are not great in the track of the vessels, but increase toward the docks and quieter portions of the slips, where they reach a depth of from one to four feet. While the deposits in the channel are of a heavier kind, such as cinders, those in the docks are mostly a foul mass of decomposing organic matter. No form of life is found to exist above Clark street bridge as far north as Clybourn place, and as far south as Ashland avenue. The effect of this condition of the river is to endanger the purity of the water supply whenever the river, with its accumulated deposits, flows into the lake, which occurs when the rain water that finds its way into the river exceeds the amount pumped into the canal. If this excess is great, as in the spring, and occasionally in the summer months, the contamination of the lake is considerable, and must constantly increase. * * *

To discharge the sewage from cities into comparatively large bodies of water is not only usual, but often the best method for its disposal. Dilution and dispersion thoroughly expose it to the action of the oxygen contained in both the water and the superincumbent air, and it is thereby gradually oxidized. Where the body of water is a large river with a strong current the best conditions for such purification are found. Where it is a lake in which the circulation is slight and irregular, the efficiency of the method is less and depends for its success on the character of the currents and the relative amount of sewage to be discharged into it.

The hydrographic surveys of the lake made during the past season were therefore partly for the purpose of ascertaining, if possible, the laws governing the currents, so that we

would know their effect in dispersing the sewage discharged into the lake. The trend of the shore current was actually ascertained by daily recording the direction of spar buoys placed at the Chicago waterworks crib, at Michigan City and at St. Joseph. A large number of bottle floats were thrown into the lake at different points and different times for the same purpose. They were partly single surface floats and partly double, the lower one being at varying depths according to the depth of the water. More than half of them have been picked up and returned, with place and date noted. The currents were also observed by means of large can buoys from an anchored tugboat at different points in the lake, extending from Hyde Park to Evanston, about six miles from the shore. And two general lake trips were undertaken, one to St. Joseph and back to Grosse Point, and another one parallel with the shore around the head of the lake.

When the observations are completed and compiled in detail some valuable information will be available for the question of water supply. Light will be thrown on the movement of the water under different winds, and the sudden changes of temperature of the water at the crib and on the turbidness of the same.

The following results have a bearing on the question of sewage disposal. Where not affected by local conditions the currents practically go with the winds in water of moderate depth and quickly respond to any change. In deep water also the surface currents run with the wind, but at the bottom and even at mid-depth the direction is usually different. The prevailing current along the shore of Cook County during the past summer has been observed to be toward the north, but it is possible that this result may be different during the winter months. In the open lake wave action seems to be effective in preventing the permanent deposits down to a depth of about sixty feet; inside of the breakwater sewage deposits are found on the bottom.

The general deduction from these results is clear that, as no constant current exists which would carry the sewage away in one direction, it should be discharged into the lake at one end of the future city, while the water supply should be obtained as far away from it as practicable toward the other end; a conclusion which is being acted upon in the other large lake cities. The proper place from which to bring the water would be opposite Grosse Point, and the sewage discharge should be east of Hyde Park. While it might be practicable to allow the sewage in its crude form to enter the lake

under such conditions for many years, the necessity would arise later for clarifying it at least partially previous to its discharge. It could not be allowed to run into the rivers as at present, but the dry weather flow and a considerable amount of storm water would have to be intercepted and carried to the outfall through many miles of special conduits. And this entire quantity would have to be raised by pumping in order to get sufficient head to empty into the lake, while the diluted sewage during storms, in excess of the capacity of the intercepting sewers, would be allowed to discharge directly into the river.

The water supply would have to be brought from Grosse Point in large conduits to the several pumping stations scattered over the city and its present suburbs. The circulation of the water in the Chicago river and branches would have to be maintained practically as it is at present, because the removal merely of the dry weather flow of sewage would not altogether prevent its pollution. * * *

Besides the economical advantages of the Desplaines scheme, its superiority is still further emphasized by advantages of another kind. The proposed canal will, from its necessary dimensions and its regular discharge, produce a magnificent waterway between Chicago and the Mississippi river, suitable for the navigation of boats having as much as 2,000 tons burden. It will establish an available water power between Lockport and Marseilles fully twice as large as that of the Mississippi river at Minneapolis, which will be of great commercial value to the State.

The Calumet region will be much enhanced in value by having a direct navigable channel to the Desplaines river, and by a lowering of the flood heights of Calumet lake and river. Within the city the water of the Chicago river and its South branch will get a much better circulation if it flows by gravity than if it has to be pumped, the necessity for which would remain even if the sewage should be discharged through intercepting sewers either into lake or upon land. Under either of the latter conditions an occasional overflow from the sewers into the river during heavy rains would be more objectionable than a constant discharge of sewage into a more rapidly flowing stream. Flood waters entering the lake by way of the Chicago river would carry into it much filthy matter, either suspended or deposited, notwithstanding the existence of intercepting sewers; but the proposed diversions of such waters before reaching the populated districts will for all time obviate this undesirable occurrence. Lowering the level of the

North branch at Bowmanville by its diversion to the lake will be equivalent to raising the low prairie extending toward Evanston and Niles, and greatly benefit parts of these towns.

In reaching the conclusion that the sewage of the city should be discharged into the Mississippi valley, the question of water supply is materially simplified, because the lake will then at all times furnish good water wherever intakes are desired for an extension of the works.

The preliminary inquiry, made with a view to ascertain the main features of an increased supply, comprised first a compilation of data concerning the existing works both in Chicago and its suburban towns, which were collected mainly through the courtesy of the respective authorities; and, secondly, a study into the most economical method of distributing the water over the metropolitan area. The following is a brief description of the existing works:

The present intake for the public water supply of Chicago is located in Lake Michigan, about two miles from the shore, and the water is conducted to the city in two circular brick tunnels 5 and 7 feet in diameter. They extend parallel to each other under the bed of the lake, and 50 feet apart, to the north pumping works, where they are connected, and where the 5-foot tunnel terminates. The 7-foot tunnel is continued under the city for a distance of 20,500 feet, to supply the west works on Ashland avenue, near Twenty-second street.

The tunnels from the source to the shore are built at a depth of 80 feet below city datum, or low water in the lake, and the 7-foot tunnel is continued on the same level for a distance of about 11,500 feet, where, to avoid rock excavation, it is inclined upward until at the west pumping station the top is but 21 feet below city datum. The economical capacity of the two tunnels is between 90,000,000 and 100,000,000 gallons per day, or less than the present average daily consumption of water. Their maximum capacity is reached when delivering about 150,000,000 gallons per day; which is now nearly equaled by the demand during the hours of greatest consumption, and, at the present rate of increase, it is estimated that during the summer of 1887 the maximum demand for water will be at the rate of 145,000,000 gallons per day; during 1888. 155,000,000 gallons per day; during 1889, 167,000,000 gallons per day, and in 1890, 180,000,000 gallons per day.

To provide against accident or obstruction from ice or other cause in the main tunnels, and to provide against an inadequate supply in the near future, which appeared inevitable, a

new tunnel is in process of construction. The intake is located 1,500 feet from the shore and connection is made with the other tunnels of the north pumping works.

The distribution of the water is effected by pumping it directly into the water mains at the north and west stations. At the north works the three tunnels are so arranged and constructed that any one of them can be emptied when desired for repairs or cleaning, and both the pumping stations still be supplied with water from the other tunnels. The total pumping capacity of this station is at present 67,000,000 gallons per day, but it will be increased to 91,000,000 gallons per day as soon as the new pumps now in process of erection are in operation.

The connections between the pumps, stand-pipes, and distribution mains at these works have become so complex by the successive additions to the plant that an unnecessary loss of head is the consequence. As this can be remedied to some extent without great expense, we recommend that it be done at the first favorable opportunity. The station being on the shore of the lake, is not centrally located with reference to any part of the city, which renders it necessary to use a greater length of main pipe, with a consequent loss of pressure to reach the consumers, than would otherwise be the case. The total pumping capacity of the West side station is 60,000,000 gallons per day, and the connections between the pumps, stand pipes and mains are simple and effective, and the loss of pressure from this cause is a minimum. The location is better adapted to secure economical and satisfactory results, than that of the north works, and with reference to additional pumping stations which will later be necessary in other parts of the city, these works are well situated.

Sanitary District.

Two bills were before the Illinois Legislature at its session of 1886-7 providing an adequate system of drainage for the city of Chicago. One of these was known as the Winston bill, which proposed to raise the money necessary to construct an outlet through the Desplaines valley by special assessment on the property to be benefited. The other has been known as the Hurd bill. It proposed to create a metropolitan district with power to issue bonds based on taxation to construct the required works.

It is related in a brief entitled "The Lakes and Gulf Wa-

terway," published by the Chicago Citizens' Association in 1888 and written by Lyman E. Cooley, that the joint committee of the Senate and the House to whom the bills were referred, "considered the question for several months, held many public sessions and heard much testimony on all the points at issue. The river cities from Joliet to Peoria organized to guard their interests and insisted that a channel should be specified not less than 160 feet wide and not less than 22 feet deep to carry not less than 600,000 cubic feet of water per minute. The Hurd bill as amended was reported favorably. Meantime, the question developed such broad relations and presented so many points of vital interest that a general conviction prevailed that the studies should be more fully concluded before legislation was effected and the bill was not pressed to a final vote."

Subsequently, the Act of June 6, 1887, was passed. This simply authorized the city of Chicago to construct a cut-off north of the city for the diversion of the Desplaines river, or an excess above the ordinary water mark in that stream. No action has ever been taken under the authority conferred by this Act.

The first official step toward the enactment of the present drainage law was taken in the passage of a joint resolution introduced in the House by Thomas H. Riley of Will county, on May 26, 1887. This resolution provided for the appointment of a committee of five, consisting of the Mayor of Chicago, ex officio, two members of the House to be appointed by the speaker, and two members of the Senate, to be appointed by the president of the Senate, whose duty should be to examine and report to the next session of the Legislature the subject of the drainage of Chicago and its suburbs. "If such commission shall find upon investigation," said the resolution, "that the most practicable solution of the problem is in the construction of a waterway for the sewage from Chicago to the Desplaines river at or near Joliet, the commission shall report what requirements should be made as to the construction of such waterway and the dilution of such sewage for the protection of the health and comfort of the people along the Desplaines river at and below Joliet." The commission was required to serve without pay, its expenses to be paid by the city of Chicago. The resolution passed the House at once and the Senate on May 31.

B. A. Eckhart of Chicago and Andrew J. Bell of Peoria were appointed members of the committee from the Senate

and Thomas C. MacMillan of Chicago and Thomas H. Riley of Joliet from the House. Mayor John A. Roche of Chicago was the fifth member of the committee, by virtue of his office.

The committee held many public meetings and had many conferences with the people living in the Desplaines and Illinois river valleys during the two ensuing years. As a result of this interchange of opinion, a careful study of the necessities of Chicago and the interests of the inhabitants of the valleys, and by the aid of the best legal counsel, the committee reported on Feb. 1, 1889, an Act creating the Chicago Sanitary District. "The commission," it said, "has diligently studied the subject submitted to it in all its sanitary and commercial aspects. It has visited and surveyed the territory sought to be improved. Conferences have been held with representatives from all the leading cities, towns and villages affected. An earnest spirit has been manifested to aid in the solution of this important problem. All plans proposed for meeting the demands of the river and valley communities and the pressing needs of Chicago have been carefully examined by this commission. The plan agreed upon by the commission, as set forth in detail in the bill which accompanies this report, is believed by the commission to be most feasible, practicable and satisfactory method for all the varied interests involved."

While the bill was pending in the Legislature and when before the committee of the whole, arguments for and against were heard from prominent citizens of Chicago and towns in the interior of the State. A delegation of citizens was sent from Joliet to Springfield to urge the passage of the bill, and resolutions advocating its passage were adopted by the business men of Marseilles and forwarded to the House.

After many amendments in the nature of concessions to the valley people the bill passed the House on April 11 by a vote of 92 to 42. After further amendments it was concurred in by the Senate on May 21 by a vote of 32 to 18. The Senate amendments were adopted by the House on May 24 by a vote of 97 to 39, and the bill received the signature of the governor on May 29. It was in force on July 1, 1889.

ORGANIZATION.

Petitions were prepared soon after the passage of the Sanitary District law, addressed to Hon. Richard Prendergast, County Judge of Cook County, asking him to cause to be submitted to the legal voters of the proposed Sanitary District of Chicago the question of organization. More than the requisite five thousand signatures were readily obtained. The petition was submitted on August 15, 1889. Judge Prendergast requested Judges Richard S. Tuthill and Samuel P. McConnell of the Circuit Court to sit with him as Commissioners. The Commission met on September 18, and heard arguments for and against the proposed boundaries of the District. * * *

The Commissioners having fixed the boundaries of the proposed Chicago Sanitary District, Judge Prendergast issued an order on October 14 requiring that the question of the establishment of the district be submitted to the people at the election to be held on November 5, 1889. The vote was as follows: For, 70,958; against, 242. * * *

On December 12, 1889, following the general election at which the Sanitary District was established, a special election was held for the selection of trustees. The successful candidates were John J. Altpeter, Arnold P. Gilmore, Christopher Hotz, John A. King, Murray Nelson, Richard Prendergast, W. H. Russell, Frank Wenter and H. J. Willing.

The first meeting of the Trustees was held on January 18, 1890. At the third meeting, held on February 1, Trustee Nelson was elected president; Austin J. Doyle, clerk; Byron L. Smith, treasurer; L. E. Cooley, chief engineer; S. S. Gregory, attorney, and Charles Bary, secretary. The salary of the president was fixed at $4,000 per annum, and that of each of the other trustees $3,000. Other salaries were as follows: Clerk, $6,000; treasurer, $5,000; chief engineer, $6,000; attorney, $5,000, and secretary, $1,500. The clerk was required to give bonds in the sum of $200,000; the treasurer, $500,000; chief engineer, $100,000; attorney, $100,000, and secretary, $20,000.

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LETTER OF SECRETARY OF WAR TO GOVERNOR EDWARDS OF ILLINOIS.

"War Department,
February 18, 1828.

Sir:

I have the honor to acknowledge the receipt of your letter of the 28 of last month, stating that as the Legislature of the State of Illinois will, at its next session make provision for commencing the canal to connect the waters of the Illinois river and Lake Michigan, you request, on behalf of the State, that a survey of a proper route for the canal may be made by some competent officer, or officers, of the Engineer Department of the U. States, and particularly setting forth the interest which the U. States have in its judicious execution in reference to the public domain.

The canal is one in which the United States are highly interested, both as it regards the increased value which it would give to the public lands, and the convenience and

facility which it will afford in a military point of view in communicating and moving the means of defense from the Lakes to the Mississippi, and from the more settled country to the Lakes. It would therefore afford the department much pleasure in complying with your request, if it shall be in its power to do so, and should Congress place the means at its disposal, an officer or other engineer will be directed in due season to fulfill the desire of the State over which you preside.

With great respect, I am, sir, your most obedient servant,

JAMES BARBOUR.

To his Excellency, Ninian Edwards, Gov'r of Illinois."

EXTRACT FROM A REPORT OF J. M. BUCKLIN, JANUARY 1, 1833.

"In making a feeder of Lake Michigan, by cutting through the dividing ridge between the lake and the head waters of the Illinois river the location of the canal is the same throughout as the foregoing, it being important in both plans to choose the lowest ground for the Summit Level, the arrangement of the lower levels being governed by the same indications in each. In the survey of 1830 of the upper part of the route, assuming the bottom of the canal at the head on the Chicago river, to be four and one-half feet below the level of the lake, no rock excavation is encountered until the line strikes the river DesPlaines, where it was ascertained by the boring to average about ten feet and the earth excavation about six feet in depth throughout the remaining distance of nine miles. By the late survey, beyond the Ausoganshkee Swamp, the rock excavation was found to increase in depth for several miles, on account of the greater elevations of the rock, which I have before had occasion to advert to in describing the location of the second division. The divisions of the route upon this plan, are the same as in the former, of which first and second division, it will be observed by referring to the estimates, are liable to any increase in the cost of construction, arising from the difference of plan, yet this increase amounts to upwards of two millions and a half, a fact that may be thought sufficient of itself to put the execution of the work on this plan entirely out of the question: Still it may not be superfluous to remark that although in the

estimate of the probable cost of the work, a liberal price is allowed for the rock excavation, the most important item; besides a sum amply sufficient to cover the ordinary contingent expenses, yet it is hardly possible to anticipate the limits of the expenditure when we consider that the bulk of the rock excavation lies below the rocky bed of the river DesPlaines and the interruption that the work will consequently be liable to from the water of the river finding its way through the numerous fissures of the rock into the canal."

EXTRACT FROM THE MESSAGE OF GOVERNOR DUNCAN, DECEMBER 7, 1835.

"The Governor of Illinois by proclamation convened the General Assembly in special session December 7, 1835. In his Message Governor Duncan used the following language:

'There are two other subjects of deep interest, requiring your immediate action which rendered it necessary in my judgment to convene the General Assembly at this time, the first of these in importance is the canal. It will be seen by the correspondence with Governor Coles, president of the board of canal commissioners, herewith communicated, that the effort to obtain a loan under the act of the last session entirely failed. I therefore trust that this subject will receive such consideration as its great importance demands. The sale of the alternate sections by the United States in the canal reservation at Chicago in June last furnishes the clearest evidence that the land in that reservation and the town lots in Chicago owned by the State, may be safely estimated at from one to three millions of dollars, and as the work progresses their value will increase, and it is now the opinion of well informed persons, that with judicious management a sum may ultimately be realized from them, sufficient to cover the whole expense of the contemplated canal; if, however, it should be found otherwise, I feel the most perfect confidence that the general government will extend its appropriations either in granting other donations of lands or moneys to enable us to complete this great work, which combines the interests of so many States, that it is universally admitted under every aspect of the subject to be an object of the first national import-

ance. The time has arrived when any further postponement of this subject will in my opinion amount to a violation of a sacred public trust committed to our care, and which the interest of the State and nation admonish us to preserve inviolate. I therefore earnestly hope we shall all unite in the adoption of some efficient measures for the speedy accomplishment of this object. Regarding this great work as one that affects deeply the national interest, and consequently justly entitled to that fostering care and support of the United States government, which it has hitherto, and if required, must continue to receive, I would suggest the expediency of making it the duty of those persons who may be charged with its construction, to make reports of their progress to the National as well as the State government, so that each may be informed of the expense, progress and character of the work.

As to the size and description of the proposed canal, my views were fully expressed in my message to you a year ago, those views have undergone no change, on the contrary, the importance of making this an ample channel for the passage of steamboats, has been fully developed by the fact that the commerce of the Erie Canal has quadrupled every five years since it was completed, and that that canal is found sufficient to accommodate its commerce. In consequence of which, the State of New York, is about widening its channel, which will be attended with very great expense, as all the locks will have to be rebuilt. In addition to this improvement two other channels of communication from Lake Erie to the Ocean are about to be constructed, one is the railroad from the lake to the North River, on the southern border of New York, the other is a ship channel around the falls of Niagara, which will take a portion of the trade of this country by the lower Lakes and the St. Lawrence. Should the commerce of the Lakes continue to increase, of which there can be no doubt, all must see the importance of constructing this work on the most liberal scale.

When we look abroad and see the extensive lines of internal communication penetrating almost every section of our sister states—when we see the canal boat and the locomotive bearing, with seeming triumph, the rich productions of the interior to the rivers, lakes and the ocean, almost annihilating time, burthen and space, what patriotic bosom does not beat high with a laudable am-

bition to give to Illinois her full share of those advantages, which are adorning and enriching her sister states, and which a munificient providence seems to invite by the wonderful adaptation of our whole country to such improvements.

Very respectfully,

JOSEPH DUNCAN.

December 7, 1835."

EXTRACT FROM THE MESSAGE OF GOVERNOR DUNCAN, DECEMBER 5, 1836.

The 10th General Assembly of Illinois began December 5, 1836. The Governor's message was voluminous and being principally devoted to the political issues of the day. He, however, referred to the canal as follows:

"Contracts have been made for the construction of several sections of the Illinois and Michigan Canal by which it appears that the expense of completing that work is likely to exceed very far the highest estimate ever made by any of the engineers who surveyed it. The increased price of labor and supplies account in some measure for the great difference in the estimates and the contracts. The work is of the highest importance both to this State and the United States, and no ordinary difficulty or expense should for a moment, deter us from its vigorous prosecution. The means arising from the canal lands and lots will be very large, and it is hoped will be nearly sufficient to meet the whole cost of the work. Should it turn out otherwise, additional funds will doubtless be furnished by the general government, as the national character of the work is fully established and acknowledged by several acts of Congress, the conditions of the cession of the northwestern territory by Virginia, and the universal judgment of the country; and as the work has been commenced under the auspices of the general government, it will doubtless in this, as in all other cases, furnish means to carry it through."

On the 19th of December, following, the General Assembly called upon the Governor for information relating to the operations on the canal, and received the following reply:

EXTRACT FROM THE REPORT OF CANAL COMMISSIONERS, 1836.

In obedience to the act for the construction of the Illinois and Michigan canal, the Board of Commissioners respectfully submit their Annual Report.

The forty-second and forty-third sections of the law under which the commissioners were appointed, make it their duty to transmit, annually, to the Governor a minute and particular report, setting forth in a plain and intelligible manner all their acts and doings in relation to the canal, and the canal lands and lots; all money received and expended, the work done and the prices allowed for it, the contracts made, with whom made and the security given by contractors the number of engineers, draftsmen, clerks and agents of every description in the employment of the commissioners and the amount of compensation paid to each; the contemplated plans of the board for future operation; the probable amount of money that will be required for canal purposes the ensuing year; the amount, time and rate of any loans authorized by law; and such other matters and things as they may see fit to add.

The topics thus especially prescribed will as far as practicable, be disposed of in the order in which they are enumerated.

Immediately after the appointment of the commissioners they were legally qualified and proceeded to business.

The board was organized at Vandalia on the 15th day of January and at their first meeting appointed Mr. Joel Manning of Jackson county their secretary. At a subsequent meeting Mr. Edward Smith of Wabash county and Mr. E. B. Talcott of Chicago were appointed assistant engineers; Mr. Samuel Hackelton of Fulton, commissioner and general agent; and the acting commissioner was authorized to engage the services of William Gooding, Esq., as chief engineer, which was soon afterwards done.

At the same period of time your Excellency communicated to the board a correspondence (accompanying document A) between yourself and the President of the State Bank of Illinois, which resulted in a four month loan of ten thousand dollars, bearing an interest of six per cent. per annum. By this arrangement the commissioners were enabled to commence their preparations much earlier than they otherwise could have done; and the amount was found amply sufficient to meet all necessary expenses prior to the June sale of the

Chicago lots, when the bank was reimbursed in principal and interest.

On the 16th day of January the board closed their session at Vandalia and on the 27th day of March they assembled at Chicago, where all the officers who had been appointed were found ready for duty. In the meantime the treasurer, under authority of the board, had made several explanations and had caused a temporary office to be erected and furnished on one of the canal lots in the town of Chicago, and the acting commissioner had procured instruments and outfits for the engineering department. The first attention of the board was directed to that section of the work next to Lake Michigan. Its difficult magnitude and greater length of time required for its construction demanded the preference. Early in the month of March an engineering party under the direction of Mr. Talcott was put in motion commencing their operations on the summit level, availing themselves of the frozen state of the country to make examinations which later in the season would have been more difficult and less satisfactory. For the details of those examinations and of all others, the commissioners refer your Excellency to the clear and satisfactory report of the chief engineer (accompanying document B). It expresses the opinion and views of the board as well as of the engineer, hence a bare reference to it will save repetition whenever additional illustration should be deemed necessary.

In the very threshold of their administration, the board were met by appalling difficulties, involving the highest official responsibility, and the most vital interest of the State. They soon became convinced that the magnitude of the undertaking had been miscomprehended both by the Legislature and the people. The largest estimate that had been previously made was about four millions of dollars, and without regarding the enlargement of the plan, or the increased value of the means of execution, it was confidently asserted by many members of the Legislature and other citizens, whose opinions were entitled to weight, that even that estimate was far beyond the truth.

The commissioners had but just begun their inquiries when they became satisfied that the four millions would be wholly inadequate; and before they had determined on any definite location, they saw that if the spirit of the law was adhered to, double that sum would be required. The seventeenth section of the act says that "*the canal shall be supplied with water from Lake Michigan, and such other sources as the commis-*

sioners may think proper." In other words Lake Michigan *must* be a feeder; and consequently the water of the lake must be carried into the valley of the Desplaines by a through cut, chiefly in stone, of eighteen feet deep, on an average of nearly thirty miles long. It was upon this plan that Mr. Bucklin made his four million estimate; but his canal was to be forty feet wide at the surface, twenty-eight feet base, and four feet deep; while the present law requires "*not less than forty-five feet* water surface, thirty feet base, and a sufficient depth *to insure a navigation of four feet.*" It is to be constructed, too, in the manner best calculated to promote the permanent interest of the country, and a discretionary reservation is authorized on each margin with a view to future enlargement.

To the difficulty which this view of the subject presented, another was added which exercised a strong influence on the movements of the board. It was at first believed by men of experience, and countenanced by the engineer, that steam power would have been freely resorted to in order to divest the Summit level works from the water which might probably flow in through the fissures of the rocks; and that the necessity of such a resort would not only increase the expense of excavations, but deter contractors from making acceptable proposals. Under the circumstances, the board came to the conclusion that if it were practicable to obtain ample feeders from other sources than the lake, they would direct their operations for the present year to some other division of the work and call the attention of the Legislature to a change of plan. The Calumet and the Desplaines having been ascertained to be insufficient, the upper region of the Fox river, as the only remaining chance, was ordered to be examined; but after a brief, yet convincing investigation, the project was abandoned; a reference to the engineer's report will afford all the particulars of the exploration.

Nothing now remained but to go through the Summit level, or suspend the whole work. To suspend the work, even for a season, and thereby create alarm, would, in the opinions of the commissioners, have been destructive of some of the brightest prospects of the State, and ruinous to the thousands of its citizens. It was resolved, therefore, to execute the plan pointed out in the law. With that view, further more accurate surveys were made, which, if they give up hope of a reduction of cost, confirmed the practicability of the flow, and lessened the apprehension of annoyance by the influx of water.

The next question to be decided was the size of the canal. After mature deliberation, the board determined to adopt the recommendation of the chief engineer, and construct it of the following dimensions, to-wit: sixty feet wide at the top water line, thirty-six feet wide at bottom and six feet deep. The fluctuation, or irregular tides, in the lake occasioned by the action of high winds rendered the depth agreed upon indispensably necessary to insure a navigation of at least four feet, and the commissioners were decidedly and unanimously of the opinion that the adopted width was that "best calculated to promote the permanent interest of the country." There can be no manner of doubt that a canal of less capacity would have answered all the demands of commerce for a few years, but when it is considered that this is a short and important link in the greatest chain of internal navigation known to the world; that it unites the Mississippi with our inland seas—the Gulf of St. Lawrence with the Gulf of Mexico—and the Rocky Mountains with the Atlantic coast that it passes through the most fertile and rapidly growing regions in the western valley—a region abounding in grain, in mead, in mineral, in fuel and in hydraulic power; and that it is soon to be connected with extensive internal improvements penetrating every part of our rich interior; when all these things are considered and like works are appealed to, it seems to the commissioners that few can be found so skeptical as to deny that in less than twenty years the present size will be none too large if indeed it may be large enough. Let it once be conceded that in any reasonable lapse of time a forty-five foot canal would be required to be enlarged, then the experience of New York is demonstrative that it is better to begin with the greatest size that may be wanted than trust to enlargement, since the process of enlarging is tedious, expensive and far more costly than the original work. Her abler engineers and commissioners support this position. But there are other and more immediate considerations which justify the increased size and give it great importance to the State. There is no avoiding the stupendous cost through the Summit Level. Water must be drawn from Lake Michigan, and that water will be of great value, as well for the improvement of the river navigation as for hydraulic purposes. The greater size of the canal will facilitate the passage of canal boats, overcome their burden and cheapen freights. It must have, too, a beneficial effect upon the prices of lands and town lots owned by the State; such an effect, in fact, was clearly perceptible at the

recent sales in Chicago, and will doubtless be felt at every other point."

EXTRACT FROM THE REPORT OF ENGINEER GOODING, 1836.

"To the Board of Commissioners of the Illinois and Michigan Canal:

Gentlemen:

In pursuance of the duties assigned me, I have the honor to submit the following:

Report.

A party was organized early in March and placed under the direction of Mr. Talcott, senior assistant engineer, to make examinations of the Summit division of the Illinois and Michigan Canal whilst the streams were yet frozen over and an opportunity presented of making those examinations perfectly satisfactory.

Two lines of levels were run across the country lying between Chicago and the DesPlaines river, near the mouth of Portage or Mud Lake, the one commencing near the mouth of a broad slough, on the north fork of the south branch of the Chicago River, at the point where the former canal surveys were commenced, the other on the north branch of said river and half a mile above the point or the junction of the north and south branches.

The former line or the route of the old surveys was found to be far the most favorable, the distance for which the through cut would have to be made, and the depth of cutting being much less. This line passes over ground but little elevated above the surface of Portage Lake at an ordinary stage of water, and which is mostly inundated during the floods of the DesPlaines, the waters of which, it is well known, frequently flows across this low country into the south branch of Chicago river. A particular examination was also made of Portage lake and of the DesPlaines river, with a view of occupying portions of each with the canal should the result prove favorable. But it was found that no saving could be affected by such an arrangement. Portage lake is a succession of ponds on the same level, connected with each other and with the DesPlaines river, and extending about six miles toward Chicago river, nearly in the direction of the canal line. The surface of the water at an ordinary stage is

10½ feet above Lake Michigan and the mud in the bottom is generally found 5 to 6 feet above Lake Michigan, or from 11 to 12 feet above bottom of canal. To excavate the canal to the requisite depth through these ponds and the marshes on their borders, would be attended with great difficulty and a cost far exceeding that of making the through cut along the borders of the marshes on ground more favorable."

REPORT OF COMMITTEE, 1837.

This communication and the reports of the Canal Commissioners and their engineer were referred to the Committee on canal and canal lands, who on the 15th day of February, 1837, submitted the following report:

The Committee on canal and canal lands, to which was referred the message of the Governor transmitting the annual report of the Canal Commissioners; also a report of the Committee on roads and canals of the House of Representatives, have had the various matters submitted to them under consideration, and submit the following as the result of their deliberations.

From the examination of those documents it will be seen, that the questions presented for consideration naturally bring before the committee inquiries touching the whole course of many years' legislation upon the subject of the canal. Questions which ought long since to have been investigated and definitely settled, and which it must be presumed have been fully considered and decided upon by previous legislative bodies, are again presented with the view of an almost entire change and total reversion of all previous legislative action. The Committee have not thought proper to assume the correctness of the policy and measures heretofore adopted without investigating the facts and reasons urged in favor of the change. In proceeding to the investigation of this subject, the committee will endeavor to divest themselves of all prejudice in favor of preconceived opinions, growing out of previous action in their legislative capacity upon the same subject. It is deemed proper, however, to state, that in the opinion of the committee it is incumbent upon those urging and proposing changes of action upon a subject of such vast importance to show that such changes are practicable, and are consistent with the public faith, and the character and dignity of the State. The first change proposed by the committee of

the House is upon the Summit division of the canal line, thirty-two miles in extent.

The proposition is to adopt the high level, as run by Mr. Bucklin, ten feet above the surface of Lake Michigan using the Calamic and Desplaines rivers for feeders.

The second is to substitute the improvement of the Illinois River, from the foot of the rapids to the head of Lake Juliet, for steam navigation by means of locks and dams.

The reasons urged by the Committee of the House in favor of the first changes proposed are: first, the large sum which the canal will cost upon the present plan; secondly, the length of time required for its completion; third, the difficulties of construction; and fourth, that a better plan can be adopted.

REPORT OF BUCKLIN AND REPLY, 1837.

"Vandalia, Feb. 8, 1837.

Mr. J. M. Bucklin.

Sir:

I am engaged as chairman of a committee of the Senate, investigating the questions which have recently arisen in regard to the change in the plans in constructing the Illinois and Michigan canal, and particularly the question in relation to the abandonment of the project of supplying the canal with water from the lake, and resorting to the Calamic. Not being an engineer, nor familiar with the calculations in relation to the quantity of water required to supply a canal of the size contemplated, I take the liberty of asking your assistance, and request the favor of you to review the calculations heretofore made by yourself and others in reference to the quantity of water in the Calamic, and to state the quantity required for the canal as at present proposed to be constructed. You will also state if there is anything peculiar in the character of the country, to justify the erecting of a canal without providing the usual quantity of water for evaporation and leakage. All the documents, except the report made by you in 1830, will be furnished if desired.

Very respectfully, your obedient servant,

WM. THOMAS,

Chairman of the Committee on Canals, Etc."

The following is Mr. Bucklin's reply:

"Sir:

It will give me great pleasure to afford you any in-

formation that I may possess in relation to the interesting subject which you have before you. I can, however, do little more than recapitulate the information that has been derived from various sources respecting it.

The river Des Plaines was gauged, at Laughton's ford, by Messrs. Post and Paul, in the first survey that was ever made of the route of the Illinois and Michigan canal, and the discharge found to be 72,000 cubic feet per hour. They also gauged it at the Cache Island, eighteen miles below, when they ascertained the discharge to be 117,000 cubic feet per hour. In October, 1829, it was gauged by Dr. Howard, U. S. civil engineer, who places the discharge at 96,480 cubic feet per hour. At the same place (Laughton's ford) it was again gauged by Messrs. Harrison & Guion, on the 8th of August, 1830, and found to discharge 60,000 cubic feet per hour. The Calamic river was gauged by me in the month of September, 1830, and found to discharge estimated at 320,000 cubic feet per hour. It was also gauged by M. Guion, assistant civil engineer in the service of the United States, about the same time, and the discharge placed by him at 1,033,000 cubic feet per hour. It may be proper to remark here that the fall of 1830 was a season of extraordinary drought.

On the Erie canal in the State of New York, the supply not being very abundant in some parts of it, great care was taken to ascertain the quantity of water required to supply the evaporation and leakage in dry seasons, and it was determined by experiment that on the middle and western divisions 100 cubic feet per minute per mile was a safe estimate 'with proper care in guarding against the waste of water.' On the eastern division 125 feet was required. On the canals in the State of Ohio, 100 cubic feet per minute was adopted as the minimum; and in the State of Indiana it has since been adopted as a standard in estimating the supply required for a canal of forty feet surface and four feet depth of water, except in one instance where the canal passes through an uncommonly wet region of country.

The allowance of 100 cubic feet per mile per minute for evaporation and filtration was assumed by me as the basis of all calculations in deliberating the minimum quantity of water to be provided for the Illinois and Michigan canal.

The surface of the canal as at present proposed to be constructed, is sixty feet, and bears the proportion of one and one-half to one to the surface of the canal, as at first proposed. The depth of water is now six feet whereas it was formerly four feet, consequently, the pressure of water being as the squares of the heights, and the leakage nearly as the square roots of the heights, the pressure will be more than doubled, and the leakage (taking into calculation the great surface) increased in proportion to one and one-half to one. The quantity of water then that will be required to supply the evaporation and leakage in a canal of the dimensions proposed, will be 150 cubic feet per minute per mile; and with reference to the peculiar character of the country through which the canal passes, I know of nothing which would justify a departure from the established rule, in regulating the supply of water. It is true, the upper level is situated in a very wet country, but the levels below dependent upon the summit for water, are located on ground very badly calculated to retain it, and it is possible that more than the ordinary supply may be required.

If the project of supplying the canal from Lake Michigan be abandoned, and the high level resorted to, the length of canal, including feeders, to be supplied with water on the upper level is fifty-six miles, which will require 8,407 cubic feet per minute to supply the evaporation and leakage, and a further supply of 2,112 for lockage, making in all a minimum supply of 10,512 cubic feet per minute.

Very respectfully, your obedient servant,

J. M. BUCKLIN."

EXTRACT FROM THE REPORT OF CANAL COMMISSIONERS, 1837.

The second reason urged, viz., that the cost of the improvement will be greatly diminished will not be controverted, but of the value of that improvement compared with the value of the canal and the comparative advantages of the two descriptions of improvements, have not been discussed in the report.

It is a work national in its character, and the people of Illinois should rejoice at the opportunity offered of being instrumental in executing a work of such vast magnitude and importance. The eyes of the civilized world are resting upon us with intense interest, for our success in a work which

promises such extensive and incalculable advantages to these United States. The people of the United States are looking to the completion of this work, as forming the last link in an endless chain which shall forever hold these United States in the bonds and pledges of union, and your Committee ask in the name of the civilized world, in the name of the people of the United States, and in the name of Illinois, that no local, sectional or private interest be consulted in the decision about to be made.

The magnitude of the work, and the difficulties attending its execution have been long known and considered. The representatives of the people did not engage in the work without a due consideration of those difficulties. The interest which the nation has taken in the project is evidenced by the act of Congress changing the northern boundary line of the State by the purchase from the Indians of a strip of territory extending from the Illinois to the Lake, with an eye single to this project, by the act of Congress granting right of way to the State, and by the subsequent act granting lands of value sufficient to defray the whole cost of the work.

It has always been regarded as a national work and the nation having furnished the means for its execution, have a right to expect that the work shall be projected and executed in a manner suited to the character and views of an united and enlightened people. The fund for this purpose is admitted on all hands to be ample and no citizen of Illinois ought to be willing to see the faith of the State violated, public expectation disappointed, and the beneficence of the national government abused by authorizing any other description of work.

The question may be confidently asked—why should any one desire to disappoint the hopes and expectations of the nation in regard to the character of this work? Can it be supposed that the nation would have extended assistance by so large and extensive a grant of lands towards the execution of a project purely local, a project which at best would not accommodate the trade of Illinois alone five years hence.

To engage in such a project would be sporting with the bounty of the nation and degrading to the character of the State. Who among us would be willing to stand forth before an enlightened, liberal and magnanimous nation and proclaim the sentiment; the nation has furnished us with means to execute a great national work, and although by accepting those means, we stand pledged to use them for the purpose intended yet as a work of a totally different and greatly inferior char-

acter, can be executed for one-half the amount furnished. We will make such a work, and vest the other half of those means in bank stock or in improvements of a character purely local. If there be among us any who would be willing to assume such an attitude and in the face of the world proclaim such a sentiment, it is to be hoped, for the honor of the people and dignity of the State, none such can be found in the walls of the Legislature. Such a sentiment strikes at the very foundation of the public faith, and if acted upon would lead to a total subversion and overthrow of our free institutions. The proposition is too monstrous and involves consequences to disastrous to be entertained for a moment; and your committee will not act upon the presumption, nor indulge the idea that any citizen of Illinois will ever be found giving countenance to such a sentiment. Your committee are satisfied that the canal lands will defray all expenditures required in the construction of the canal upon the enlarged plan proposed by the canal commissioners, and they hope to see the time when its navigation will be made free to all the people of these United States.

There should be no question asked in regard to a supply of water from any other source than the lake, so long as it is known that the means furnished by the nation are amply sufficient to execute the work. In the completion of such a project, computations of time should be made with reference to the existence of the Union, and not with reference to the growth of a village. If, contrary to all calculations, eight or fifteen years shall be required for its completion, this would not justify the State or the people in a violation of their plighted faith. The time is not distant when Illinois must stand at the head and in the front of all the western states, and when that time shall arrive, nothing could be a source of greater mortification to her citizens or her sisters, than a knowledge that in her infancy, she had been guilty of a violation of public faith.

Your committee are of the opinion that a lateral canal connecting the waters of the Illinois and Michigan canal with the waters of the Calamic is practicable, and will probably be required at some future time. Before any expenditure of money is authorized for that purpose, the consent of the State of Indiana should be obtained to the use of the water of that stream, and an agreement irrevocable, except by the consent of both states, should be entered into, fixing the terms upon which the water may be used, and the terms upon which the citizens of Illinois shall be allowed to navigate the said river.

Your committee highly approve of the decision of the commissioners fixing the size and dimensions of the canal and they cannot but remark, that nothing but the greatest industry and attention to their duties could have enabled the commissioners to have made such progress in the prosecution of the work.

It appears from the report of the commissioners that no addition will be required to the canal fund during the present year, but that provision must be made for the year 1838. For this purpose, it is proposed to sell alternate lots in the town at the termination of the canal, and other towns along the line, to the amount of one million dollars, and to authorize a further loan of five hundred thousand dollars in the event of that amount being required.

In the present state of things it is deemed bad policy to bring into market any of the canal lands. It is believed that under the provisions of an act passed during the present session, those lands can be protected against all further depredations. To carry out the views of the committee they report a bill, and recommend its passage.

Extract of a Report of Judge Wright, 1838.

In the quarterly report of the board, transmitted to the General Assembly in July, 1837, it was stated that a correspondence had been opened with Judge Wright, an eminently "skillful engineer," with a view of the surveys and examinations required by the third section of the amendatory law passed in the previous March. In the meantime, Mr. Burnett, who is the resident engineer of the third division, was instructed to make a critical and thorough survey of the dividing ridge between the Fox and DesPlaines Rivers, and within the limits of the State. This duty he performed with great care, eliciting information from every accessible source, and indulging those persons who desired explorations of particular depressions previously supposed and asserted to be sufficiently low to afford a cheap feeder.

Judge Wright arrived at Chicago in the early part of October, and on the 20th of the same month, Mr. Burnett made a detailed report, with a topographical map and estimates of the quantities of excavation and other work necessary to effect the object on the most favorable route of the country was susceptible. At that time and through the whole summer, the DesPlaines river was generally admitted to be unusually flush

as was also the Calamic. No gauges were therefore ordered, and consequently those of the DesPlaines made by the United States engineers in 1830, and of the Calamic, by Mr. Bucklin, were adopted as the basis of the investigation. Keeping in view, however, the truth of these gauges had been strenuously controverted by the advocates of the upper level or "shallow cut" and that the capacity of the Calamic had been contended to be even superabundant, the attention of the examining engineer was particularly directed to the question, whether the Calamic could in any event be classed among waters, which the law contemplated as "Sources within the legitimate authority of the State of Illinois"; a question which his reputation for sound judgment in everything connected with the canaling, his knowledge of the requirements of Indiana, dependent on the Calamic, and his great experience in the adjustment of similar claims, pre-eminently fitted him to answer with confidence. His plain, free and very decided report, marked G, to which Mr. Burnett's is appended, will afford all the information required by the statute which enjoined the examinations. But notwithstanding the opinion of the commissioners, that the report of Judge Wright—so completely confirming their original plan—should alone determine the mode of feeding the canal, they still thought it advisable to seize the first opportunity of regauging the summit streams and examining the suitability of the country for sustaining assistant reservoirs. The past dry season rendered the measuring of the Desplaines almost unnecessary, since for nearly four months the tightest dam that could be erected would not, at the point for taking out the feeder have saved water enough to propel a single pair of ordinary millstones. Repeated gaugings from the 20th of July to the 22d of August and it was afterwards still lower, gave an average of less than the measurement of 1830. The Calamic was gauged on the 8th of August and again on the 21st of September by Mr. Talcott, the competent and indefatigable engineer of the Summit division, under the superintendence of Chief Engineer and two of the commissioners, who assisted in the operation. Every precaution was taken to render the measurements perfect, but owing to the high stage of water in the lake which flowed back upon the only point adapted to the purpose and the quantity of grass that had recently grown up in the bed of the river, it was impracticable to compute the velocity of the current from top to bottom with all the precision that was desirable. Averaging the different gauges which are believed to be over the

truth, the quantity estimated was a fraction less than 7,000 cubic feet per minute, being only 1600 feet more than reported by Mr. Bucklin, but falling short 10,217 cubic feet per minute of Mr. Belin's estimate as given in the printed report. The inference is fair therefore, that Mr. Bucklin was right, and conclusive that Mr. Belin was either wrong in his calculation, or, which is more probable, that the error was typographical. It is proper to mention also that the volume of water continued to decline for some weeks after the last gauging by Mr. Gooding and Mr. Talcott, but the general sickness of the country prevented a repetition of their experiments. An attempt was made on the 8th of October, when it was found that the river had fallen two inches since the last and lowest previous gauge, but the measurement was carried no further. In regard to reservoirs, it is sufficient to say that, besides their pernicious influence upon the health of such a country, it is believed that they could have rendered but little aid in a protracted drought like the one just experienced.

In addition to the services required by law, the commissioners availed themselves of the valuable talents of Judge Wright in general consultation. He was employed to inspect the entire line, and invited to criticise freely and every part of the work in progress, as well as the plans of the chief engineer and of the board, all of which were detailed to him on the ground with great minuteness. A number of written interrogatories were likewise propounded to him, embracing every subject commented upon by the committee on Roads and Canals, in their report to the House of Representatives at the same session in which the examination was ordered. The report itself had attracted his attention before he arrived in the State. The answers to these interrogatories, and the result of the general inspection are embodied in a separate report to the board, marked H; by which it will be seen that the present plan of the canal, being the same originally adopted, has received the deliberate sanction of one of the ablest, most-experienced, and most distinguished engineers of the age. Nor was sanction given until after the most patient scrutiny, both of the plan itself, practically examined, and of all the published discussions and animadversions on the subject. Since that report was obtained the operations of another year, wide and varied in their range, develop nothing but additional confirmation. The fifteen sections, extending from Chicago river to the "Point of Oaks,"

eight miles, and lying through the low wet prairie periodically flooded by the DesPlaines river through Mud Lake, have been completely defended against any possible danger from surface water; and are now, by means of those defenses, accessible and tenable at any season of the year. The same plan of drainage and defense is gradually progressing from the "Point of Oaks" to the Saganaskee swamp and enough has been done to inspire the fullest confidence in the practicability and moderate cost of the work. Much less rock will be encountered than was once supposed but the earth excavation will in some few instances cost a shade more than the estimates. The quantity of water to be pumped is not greater on an average than was anticipated; although there are several sections that will require stronger machinery for that purpose than the others. The same remarks will apply to the rock cuttings between the Saganaskee swamp and Lockport, all of which have been permanently defended, and many of them so far advanced as to exhibit to the bottom every variety of material and every difficulty of excavation.

EXTRACT FROM THE REPORT OF ENGINEER GOODING AS FOUND IN THE CANAL COMMISSIONERS' REPORT FOR 1900.

The value of the water power created here and at other points upon the canal, by drawing a supply of water directly from Lake Michigan, can be fully appreciated after a season of such severe drought as the past. The DesPlaines river and many other considerable streams of the country have been nearly dried up, and probably three-fourths of the water-mills throughout a large portion of the United States have been standing still for the last three months. But had this canal been completed, there would have been during the past season an unusual supply of water, as the surface of the lake has been 9 feet 4 inches above canal bottom, or 3 feet 4 inches higher than was originally calculated upon for the supply.

EXTRACT FROM THE REPORT OF ENGINEER WRIGHT, DATED CHICAGO, OCT. 23, 1837.

From an examination of the various canal documents of the last session of the Legislature, it seems that the question stands as follows:

Shall the feeding water be taken from Lake Michigan by

a deep cut? or, shall the summit be raised ten feet above the lake, and fed from streams to be brought into it? It has been supposed, and no doubt correctly, that only three streams of water can be brought on the Summit level: First, the DesPlaines river; second, the Calumet river; third, the Fox river.

The DesPlaines was not in a proper situation to gauge, as there had been copious rains; I therefore take the former measurements of the United States engineers, as stated in the reports of the canal committee, at 54,800 cubic feet per hour.

By calculation it is found that, if twelve boats pass per hour, the lockage water to lock up and down ten feet will be 475,200 feet per hour. If we then add for leakage at the locks (a small item) and for the evaporation, we ought not to say less than 500,000 cubic feet of water per hour will be required, when boats are passing as fast as they can be let through (or twelve per hour). It is true that, if boats passing each way were to meet so as to pass a boat up with the same water which passed one down, then only half the above amount of lockage water should be estimated for the twelve boats per hour, although, I believe twelve boats per hour may be passed each way, if the locks are well attended, and are in perfect order for filling and discharging the water rapidly.

These premises being admitted, we have to look for 445,200 cubic feet of water per hour more than the DesPlaines gives us at low water.

* * * * *

The great objection to this immediate section of country is, that the lands do not drain freely; and for a permanent work, like the Illinois and Michigan canal, all the plans should be adopted, in reason, to make every part of the land more valuable by the drainage which the plan and the construction of the canal may give. The Illinois and Michigan canal, as now projected and under construction may truly be considered as one of the greatest and most important, in its consequences, of any work of any age or nation. In looking over this connection between the lakes and the Mississippi, it is no doubt superior in its advantages to any other which can ever be formed. It is the shortest artificial work, with the least lockage. The climate, soil, and the capability of productions of the country which will be benefited by the construction of this work, will certainly equal, if they do not

exceed, any other part of the United States; and when I view it in this light, I think it justly merits to be executed upon the best and most permanent plan, and will justify, by its revenue, any outlay which may be put upon it in reason.

Taking a view of the whole ground, and looking at the probable cost of the deep cutting, of the low level, and the length of time it will take to accomplish it, and the time the country will lose the benefit; looking, also, at the great good to the country, and the pecuniary advantage to the State and the canal, by the creation of water power at Lockport, and Juliet, I have no doubt upon my mind that the present plan of cutting down the Summit, so as to draw feeding water from Lake Michigan, ought to be continued, in preference to any other which I can suggest.

In my remarks I have not entered into calculation to show the many expenses and losses which would result from raising the level ten feet—such as the extra lock-keeper, annual repair of locks, loss to the country and State by not having water power—the advantages of vessels of large size reaching Lockport before unlading or lading—these and many other considerations having a bearing upon this question; and I might say would admit the case to be stated by putting down the expense of the low level, and then deducting the additional value given by water power to the State property at Lockport and Juliet, and the drainage of the State land otherwise, on one side—and on the other, the cost of the high level, with two locks, the cost of the attendance (brought into capital), the cost of introducing Fox river, and other contingencies, such as damages for the injury done to lands along the DesPlaines; and I fully believe the balance would be in favor of drawing the feeder water from Lake Michigan. In these remarks and opinions, I believe I have fully complied with the act of directing the appointment. I shall, however, in another communication, comply with your wishes in regard to the details of the work, in its location, and the various points of difficulty in construction, and make full remarks upon every point.

Respectfully submitted by Your obedient servant,

BENJ. WRIGHT,
Civil Engineer.

REPORT OF ENGINEER GOODING CANAL OFFICE, LOCKPORT, DECEMBER 10, 1840.

To the Board of Commissioners of the Illinois and Michigan Canal.

GENTLEMEN:—In the regular discharge of the duties assigned me, I have the honor to submit the following:

In adopting the original plans for the construction of the various parts of the Illinois and Michigan Canal, I was governed by the best data that it was in my power to obtain. The oldest and most intelligent settlers in the country were applied to for information in relation to the highest and lowest water marks of the rivers, and such other facts as could in any way be useful. But the country was then very new, the oldest residents having been here but a short time, and the information received was consequently very imperfect. Hence the necessity of changing the plans in several instances as facts were obtained from actual observation. These changes, however, will in few cases increase the cost or difficulty of construction and have been made to give greater security to the canal, or confer some particular benefit upon State property.

There is probably no canal in the United States of any magnitude, and certainly none in a country so new as this, where the location has been made under greater disadvantages. It is true that three different surveys of the line had been made prior to 1836, when it was placed under my charge, but as stated in my annual report of that year, little or no advantage was derived from them, as not a single field book or note of the engineers ever came into my possession. The general facts communicated in their reports were of but little service in making our survey and location, and in adopting plans of construction. This subject is alluded to at this time, as it might otherwise be supposed that facts enough had been obtained from former examinations to secure the adoption, at once, of such plans as would require no change. Since the commencement of canal operations, critical observations have been made upon every part of the line, and though first impressions have generally been found correct, they have sometimes been corrected by a "sober second thought."

At the commencement of the canal I used every precaution in my power to submit to your board such estimates of the probable cost of it, as would not deceive the public, and these estimates were revised and corrected from time to time

as portions of the work were executed, and the character of the remainder better understood.

All of which is respectfully submitted.

WM. GOODING,
Chief Engineer, Illinois and Michigan Canal.

Report of the Committee on Canals and Canal Lands.

Mr. Pearson, from the Committee on Canals and Canal Lands, made the following report:

Report.

The Committee to whom was referred a resolution, inquiring into the available means of the canal fund, and the ability of the State to complete that work, so successfully begun, beg leave to report:

By an act of Congress of March 30, 1822, the State was authorized to construct the canal over the public lands and ninety feet of land was given on each side of the canal to the State. The canal was to be begun in three and completed in twelve years. The act gave the State the right to use any materials upon Government Lands, necessary to complete the work. Another act was passed, March 2, 1827, which granted to the State a quantity of land, equal to one-half of five sections, on each side of the canal, and reserving each alternate section to the United States. Another act of Congress was passed March 2, 1833, granting to the State the right to construct a railroad in the place of a canal, and extending the time to complete either to five years. In consequence of this first grant, the Legislature of Illinois appointed, at the session of 1822 and '23, a Board of Canal Commissioners who made an examination and an estimate of the probable cost of the work. This estimate cost, which was only made from a surface survey, without ascertaining the amount of rock excavation, fell a little short of $800,000. This survey cost the State over $10,000. At the same session, a company, with a capital not exceeding one million, was chartered, to complete the canal, which was to be constructed and owned by the company for fifty years—after which the State had a right to purchase it, by paying the cost of construction and six per cent. per annum; but, in 1826, this act was repealed.

In 1829, a new board was organized, with power to make further surveys and begin the work. And by a further act, of 1831, the commissioners were authorized to lay out towns, and did proceed to lay off and sell lots in Chicago and Ot-

tawa, and sell lands along the route. They also reported separate statements of the cost of constructing a canal and a railroad between Lake Michigan and the Illinois river. By estimates of the first work they reported its cost at $4,043,086.50, and that of a railroad $1,052,488.19. At the next session, the Legislature abolished the office of canal commissioner, after these efforts had cost the State $16,974.83. Again, at the session of 1834 and '35, Mr. Forquer, the chairman of the Committee on Internal Improvements, considering the importance of this subject (which had been referred to in the Governor's message), and with the feeling of a patriot, and the views of an enlightened statesman, again brought this question, by his report, to the consideration of the Senate, and to every citizen who felt the great importance of this enterprise to the present and future prosperity of our State.

The people of Illinois had, in this manner, and by the sale of canal lands and the beginning of the work, so far accepted the grant of the General Government, and had duly considered and determined whether they would yield this grant of land to any company, or undertake the canal on the faith and credit of the State.

The lucid report of Mr. Forquer, of 1835, induced another enactment of the Legislature, which seemed conclusively to fix the settled policy which the State had determined to pursue, on the acceptance of this grant from the United States, and the manner in which the work was to be commenced and completed—that is, on the sole responsibility of the State. But owing to the imperfection of the act of 1835, the Governor was not enabled to borrow the money necessary to begin the work.

Again in 1836, the people, impressed with the magnitude and value of this work to the growth of our infant but fast settling State, asked the Legislature to pass another law, empowering the Governor to negotiate a loan, on the sole faith of the State. This last act created another board of canal commissioners, who commenced new surveys and estimates, preparatory to renewed exertion to its completion. Contracts were let, and labor performed to the amount of $35,744.83. In this year the commissioners laid off town lots, at Chicago, and sold them, to the amount of over $1,000,000, with a common understanding that the canal was to be completed. The action of the Legislature thus far, and in 1836 especially, had furnished to citizens of sister states and to

foreigners, sure reasons for emigration here, and the inducing and powerful motives for the investment of their capital. They became, from that time, identified with us, and feeling a warm solicitude for the speedy success of an enterprise that was to redound to the wealth, population and honor of their adopted State.

Such being the supposed fixed policy of the Legislature, in regard to this work, and the pervading sentiment, in and out of the State, as to the ability and determination of the people to finish it, that the population in that region and many other sections has, in consequence, increased in five years beyond any former period in our history, and beyond the most ardent anticipations of our citizens. Capital has flowed in upon us; extensive farms have been opened; mills and machinery erected on streams, in various parts of the State, likely to be advantaged by the construction of the canal; the cattle-grower on the Wabash and the more southern counties, and in the central part of our State; the grain grower of the west and southwestern part; all have participated in the expenditure of money thus far, and many emigated, with the expectation of receiving advantage by the finishing of this enterprise. Again in 1837, the Legislature, coming afresh from their constituents, after the work was begun, and impressed with its importance, passed an amendatory act of 1836, to aid in its completion. This year there was expended on the canal $346,899.43. The commissioners also sold additional town lots and lands, to assist in paying off the canal debt. These lots and lands, also, were sold, as the others had been, with the common understanding that this enterprise was not to languish or fail, by our neglect to put in requisition the available means, so ample, and which had been looked to, ultimately, for the final completion of this work. The close relation, then, which exists between this long contemplated improvement and the lasting interests of our citizens, and so universally acknowledged and by few questioned, induces the committee, with the more confidence, to ask its final completion.

In relation to this important enterprise, the time has passed when a timid and unsettled policy will satisfy the wants and expectations of an intelligent community. In this matter, then, a steady, economical action and well directed efforts are all that the people now expect of their public agents. With nothing short of this will they be satisfied.

The committee will not dwell longer on this branch of the

subject, but will hasten to answer a question which has been recently made by some gentlemen of standing, in and out of the Legislature, "whether it would not be the part of wisdom now to abandon this canal and construct a railroad along the route?" The committee are not insensible to the benefits arising to the country from the completion of well planned railroads. But they have no difficulty in coming to a conclusion to prefer canals over railroads. We know that a few years since opinion inclined to favor railroads in preference to canals, but well may the committee remark, in the language of a clear-minded statesman, "that time and experience seem to have tested the comparative value of these two modes of facilitating the commercial intercourse of different regions, and public judgment has settled down in favor of canals in preference to railroads, whenever the country is peculiarly suited for their construction;" and there can be no doubt that nature has pointed out this, as the character of the country lying between the navigable waters of the Illinois and Lake Michigan. That railroads are better adapted to the speedy transportation of passengers than canals, seems to be admitted, and not questioned, and wherever that is the main object intended to be effected by their construction, they are doubtless entitled to a preference over canals, but such can not be the case in reference to this work. The great end to be attained in connecting these waters by an artificial communication is doubtless the promotion of the manufacturing and agricultural interests of our country, "which are already languishing for an adequate market to the consumption of the superabundant productions. These, too, are generally of a bulky character, and such, too, is the kind of many commodities out of the State, which it will be our interest to receive in exchange for our own productions. Again, the committee would urge as a preference of canals over railroads, that the former are not proposed to be used and can not well be used as monopolies which are so repugnant to the feelings of a large majority of our citizens. On a canal a trader or farmer may use his own canal boat or craft, and in this way become his own carrier and vender of his own productions, and thus save the freight and the expense of hired labor. From the nature and use of canals, they admit of competition of all kinds of business connected with them. But can the committee say the same of railroads? They are necessarily confined to a few, or the exporter has necessarily to be subject to the pleasure of a com-

pany or their supercilious agents. When constructed, a canal is steadily improved by wear and time. A railroad, on the contrary, is rapidly wearing out and needs constant repairs. This canal when completed, as the committee will shortly prove, will necessarily create an exhaustless and valuable water power at seven different points on the route. A railroad can give no such advantages. Where, too, in any country, is valuable water power more needed and will advance the interests of the people more than in Illinois?

The committee think it unnecessary further to pursue this subject, satisfied as they are, that the superiority and advantage of canals, and especially the one to connect the waters of the Illinois river with Lake Michigan, is now almost universally admitted.

The State having, then, in its wisdom, weighed well this enterprise, in the beginning, and entered largely on the prosecution of it, upon its present plan, and having expended towards its completion, something over four millions of money, we find the question is now put by some gentlemen: "Shall this work be abandoned? or, shall it be completed?" The committee, in answering this question, which seems to them a novel and startling inquiry, after this work is thus advanced, and when nearly the whole country is vitally interested in its success, and would feel a deep mortification at its defeat, will state the facts and reasons which govern them in coming to the unchangeable conclusion that the abandonment or defeat of this enterprise would be a ruinous and suicidal policy to our State, and would the more deeply involve us in debt, if not in hopeless bankruptcy.

JACOB FRY.

REPORT OF GOVERNOR FORD AS FOUND IN THE CANAL COMMISSIONERS' REPORT FOR 1900.

Governor Thomas Ford in his inaugural to the Thirteenth General Assembly, delivered at Springfield, Illinois, December 8, 1842, used the following language:

> "Let us offer to our creditors all that we have, at fair and reasonable prices, at least the forty-two thousand acres of land entered under the international improvement system, together with two hundred and ten thousand acres donated to the State by the general government, the railroads finished and unfinished, and all the property of the State, pertaining to the railroad system.

It is believed that many of our creditors would receive this property at reasonable prices, and if so, a large amount of our debt would be immediately extinguished; if not, the lands will be continually increasing in value, and becoming more and more available as a resource in future.

The canal lands and lots and other property belonging to it, stand upon a different footing. This property was first given to the State in trust to make the canal. It was afterwards appropriated by the General Assembly to that specific object, and solemnly pledged to creditors for the payment of money heretofore borrowed, and which money has been used in the construction of the canal so far as it has proceeded. Those creditors, therefore, have such a separate and exclusive right to its avails, as would not without their consent, justify throwing it into an aggregate fund for a general payment of debt. If they should require it, we would be bound in duty and honor to surrender it to them. It is, however, believed that no such requisition will be made. They understand their true interest too well; they know as well as ourselves, the importance and profitable character of this great work, and would prefer looking to its probable completion rather than an immediate sacrifice of the means of carrying it on, for ultimate payment. They must, and do understand that if this property should be sacrificed, the State will have no means of payment for a long time to come; whereas, if the canal progresses, to completion, the lands and lots and water power will be quadrupled in value, and the tolls alone would in a short time pay interest on all the debt contracted for its construction.

In this view of the subject, it is manifestly for the interest of the people, as well as our creditors, that the work should progress to completion, if possible before any of the canal lands or other property shall be sold, and it is equally the interest of all, that the work should not be abandoned, but prosecuted with all the energy and reasonable means in our power as one of the surest and speediest measures tending to the extinguishment of our debt.

* * * * *

I therefore, respectfully recommend to the General Assembly, that the further measures to be adopted for the prosecution of the work, should be upon the plan of

a moderate sized high level canal. I am fully sensible of the great responsibility assumed by me, in making this recommendation, nothing but a full conviction of our inability to proceed with the enlarged work would justify a change of plan after it has progressed so far as it has. But, in view of our present and prospective want of credit and resources, it does seem that the enlarged work is not to be achieved by any means now in our power; and, indeed, it does seem that we are to choose between reduction and no canal of any description."

REPORT OF LEGISLATIVE COMMITTEE AS FOUND IN THE CANAL COMMISSIONERS' REPORT FOR 1900.

Report of the Committee on Canal and Canal Lands, To whom was referred that part of the ex-Governor's and Governor's message which relates to the canal.

Report.

An examination of the history and nature of this majestic work shows that it was first projected by the general government, and for more than twenty years has occupied the attention of the State of Illinois, during which time it has been the subject of repeated legislative action. From the nature of the work, its connecting with such great interests, the high source from which it emanated, and the long time its construction has been contemplated by the State, it would seem as if we might have long since expected its completion; but your committee regret to say that they find it yet remains unfinished, and it is now left for the Legislature to decide whether it shall longer continue in its present condition; whether the people shall still be deprived of its advantages, and the amount already invested in its construction, remain a total loss to the State, or whether by prompt, energetic and efficient measures they will hasten its completion and thereby secure a sure and profitable market for the abundant products of our fertile soil, relieve the pecuniary embarrassments of our industrious citizens, enhance the value of the property of the State, render available the large amount already invested, open a channel for the influx of wealth and emigration, and by the large amounts realized from the sales of canal property and the tolls from the canal, enable the State to lessen the public debt, to pay the interest upon her liabilities, redeem her plighted faith, preserve her honor and ultimately re-

move the burdens that are now paralyzing the energies, stifling the efforts and blighting the happiness of her citizens.

After careful investigation and close examination of the various plans and suggestions for carrying on the canal, the committee have come to the conclusion that there is but one plan which, at the present time, appears practical and worthy of consideration; they have come to this conclusion, from an examination of different letters and plans from the most distinguished citizens and capitalists in the City of New York and also from London. The views given in the letters and plans referred to are judicious, sound and practical, and if carried into effect would undoubtedly secure the completion of the canal and the ultimate payment of the whole debt of the State. There is no interest so immediately identified with that of the State as the interest of the bondholders. Whatever tends to raise the price of bonds benefits them alike with the State, and whatever plan insures the completion of the canal, confers alike benefits to the State and her creditors, for when once completed the canal not only opens new markets to the citizens of Illinois, and increased prices for her produce, but also gives greater security to the bondholders for the full payment of their interest and principal. So it will be readily seen that if a mutual arrangement, satisfactory to the State and her creditors, can be entered into to insure the speedy completion of the canal, it is the policy of both so to do. The time for theorizing upon abstract principles, for indulging in dreams of future greatness, or splendid schemes of grandeur has passed. We can no longer dwell upon what a sovereign state should be able to do, but we must complete things as they are; we must look at sober realities, and make the most judicious use of the little that remains of our imaginary wealth and apply those means yet within our power in repairing the ruined fortunes of the State. If we attempted to rear a structure of too gigantic proportions, one which fell of its own cumbrous weight, it does not become us to spend our time in vain regrets and grieve in idleness over our disappointments, but let us gather what yet remains uninjured from the ruins and erect a fabric more proportionate to our means. The proposition for carrying on the canal made by many of the creditors of the State, is as follows:

First, the State to convey all the canal lands, town lots, water power, coal beds, stone quarries, and all the canal property, together with all the tolls that may be derived from transportation upon the canal to trustees, who shall hold the

aforesaid property in trust for the canal bondholders. The aforesaid trustees to be appointed as follows: Two on the part of the creditors, and one on the part of the State. The canal bondholders are to subscribe a sum sufficient to complete the canal, to be disbursed by the trustees in the construction of the canal. The trustees to have all the powers given to the canal commissioners. After the canal shall be completed, the trustees are to proceed to sell the canal property from time to time, as the demand may require. * * *

In recommending the adoption of the foregoing plan, your committee have only been influenced by a desire to forward the interests of the canal. In all the attention they have been able to bestow upon the subject, they have been unable to discover any other plan that would be likely to insure the speedy completion of the canal. They have not thought proper to dwell upon any of the other various plans that have been suggested or presented before them for their consideration, simply for the reason that none of them come from the parties who would be required to make the necessary advances to complete the canal. It would be a matter of doubt and uncertainty, even if any of them should be consistent with the interests of the State, whether they would be accepted by the capitalists. The propositions upon which the foregoing plan is based, come from a source entitled to the highest credit, and propose all that the State can reasonably desire, and have, therefore, been more attentively considered by your committee.

We believe there are many causes that will tend to render the communication by the canal and lakes annually more favorable to our citizens.

* * * * *

In conclusion, the committee will say that they have no doubt but that it is within the power of the State to secure the speedy completion of the canal. And the committee also believe that when completed, it will enable the State to extricate herself from her present pecuniary embarrassments. Let Illinois be true to herself, carefully guard her honor, be prudent and economical, show a rigid adherence to principles of justice, and prove to the world by all her acts that though poor, yet she is honest, and she will soon rise above her present difficulties, and ere long will hold that proud position in the Union which she is destined to occupy.

The completion of the canal will secure to our farmers a rich reward for their honest labors, good prices and a ready

sale for their produce, revive business, restore prosperity, and give a new impulse to trade and commerce. Emigration will pour into the State, our vacant lands will be sought after, our wild prairies will be transformed into rich and beautiful farms. Capital will flow into the country, industry will be encouraged, enterprise will be stimulated, and the citizens of Illinois will soon become prosperous and happy.

REPORT OF ENGINEER GOODING, DATED LOCKPORT, DEC. 1, 1842.

From the foregoing extracts it is plain that no difficulty was anticipated in relation to a cheap supply of water for the canal. If the streams on the route would not afford sufficient water, it would cost no more to procure a never-failing supply from Lake Michigan than from these sources.

The surveys of the canal route by the United States engineers in 1830 and 1831, seem to have been made more to ascertain the practicability of the work and the general character of the route, than with a view to obtain data for a particular estimate of cost. In fact, I believe, that no estimate of the cost of the work was submitted until the summer of 1834, at least I have never seen one of an earlier date. Gen. Gratiot submitted his estimate in June, 1834, of the cost of constructing a steamboat canal from Chicago to the mouth of the Little Vermilion river. The dimensions were as follows, to wit:

For the first twenty-seven miles from the lake, or to the running out of the lake level, the canal, except two miles, is one hundred feet wide and ten feet deep. The remaining two miles to be distributed in short sections, at convenient distances, "to be two hundred feet wide, to accommodate boats while detained in changing cargoes without interruption to the navigation." The remaining distance of sixty-five miles "to be not less than one hundred feet at the surface and six feet deep." The total cost of this canal was estimated at $4,299,439.81.

The contest in the winter of 1836-7 closed by the passage of a law authorizing the canal commissioners to prosecute the work upon the present plan, but requiring them to procure a skillful engineer from abroad to examine and report whether "a supply of water from sources within the legitimate authority of the State of Illinois," could be procured without resorting to the lake, or, in other words, whether a shallow cut, or high level canal could be supplied with water, and if

so, whether enough could be gained to make it for the interest of the State to change the plan which had already been adopted by law, after a considerable portion of work had been placed under contract.

Judge Wright was the eminent engineer whose services were secured by the commissioners, and the substance of his report upon this subject is well known to the public. From the time his report was published until the work was nearly suspended on account of the financial embarrassments of the State, little was said about a change of plan.. It was supposed that there was nearly or quite canal property enough to complete it upon the deep cut plan, and so long as the State could procure money to carry on the work, little solicitude was felt as to the plan, though it was still believed by many that it should have been changed, or that the high level should have been adopted at the outset.

It never having been made a part of my duty to investigate this subject, I have hitherto deemed it improper to allude to it in my reports, but at this important crisis in the affairs of the canal, when the work is nearly suspended, the State credit gone, our citizens discouraged, and no hopes entertained of brighter prospects until the completion of this important improvement is rendered certain, I shall present a few facts and conclusions which I believe, may be of some public utility, and which certainly can do no injury to the best interests of the canal. * * *

Were the deep cut plan to be carried out at an average stage of Lake Michigan there would be an abundant supply of water drawn from the lake, not only for navigation, but for waterpower. There would be no locks to obstruct the passage of boats or lake vessels of good size between Chicago and Lockport. The water power at Lockport and Juliet would be greater and more permanent (at the usual stage of the lake) than it would be upon the shallow cut plan. The navigation of the canal would not be liable to interrupt from breaches in dams or embankments, and the plan is much more magnificent. Besides, if the waters of Lake Michigan do not get through this channel to the Mississippi, there is no other through which they can be conducted, and a great deal will have been said for nothing about mingling the waters of the lakes and with those of the Gulf of Mexico.

In constructing the Illinois and Michigan canal of the dimensions now adopted, reference has generally been had to a future enlargement. Through all the towns and proposed

town sites, as Lockport, Juliet, DuPage, Ottawa, etc., the canal is nearly double, and in some instances more than double, the ordinary width. In the deep cutting, the spoil-banks were removed a sufficient distance to leave room for the widening of the canal, and in few instances, if any, would there be any additional damages to be paid for property. However remote the period may be when an enlargement of this work will take place, it is certainly the part of wisdom to provide for it now. That it will be enlarged, sooner or later, there can be no doubt, and also that the Illinois river will be so improved (an indispensable improvement) as to meet the enlarged capacity of the canal.

Disheartened as our citizens now are, and prostrate as the credit of the State at this time is, my views upon this subject may be considered the wild speculations of an enthusiast. But such are the natural resources of the country, that with prudent legislation on the part of our legislators, and industry and frugality on the part of our citizens, this state of things cannot long continue. This great national thoroughfare once completed, and new life will be given to the whole country, and the prosperity of the State secured for all time to come.

All of which is respectfully submitted,

WILLIAM GOODING,
Chief Engineer.

Canal Office, Lockport, Dec. 1, 1842.

REPORT OF OPENING OF CANAL, 1848, AS FOUND IN THE CANAL COMMISSIONERS' REPORT FOR 1900.

The following excerpts from the report of the board of trustees for the year ending November 30, 1848, completes this report so far as it relates to the inception, construction, and completion of the Illinois and Michigan canal.

On the 24th of April, the board while in session at Chicago, received a report from the chief engineer, stating that the canal was so far completed as to be in navigable order, that the first boat (the General Fry) had passed over the Summit level from Lockport to Chicago on the 10th of April, and that the first boat which had passed through the entire length of the canal from LaSalle to Chicago (the General Thornton owned by Mr. Isaac Hardy) had arrived at Chicago on the 23d of April.

As a matter of some interest connected with the arrival

of this boat, it may be stated that sugar, etc., from New Orleans, brought by the General Thornton to Chicago was received at Buffalo (via Mackinaw), on the 30th April, some two weeks before the first boat had reached Buffalo by the Erie canal.

REPORT OF THE CALUMET DAM, 1856, AS FOUND IN THE CANAL COMMISSIONERS' REPORT FOR 1900.

Chicago, April 10, 1856.

Capt. William H. Swift, Western Railroad Office, Boston, Mass.

Dear Sir:—I returned from Indianapolis yesterday. I had an interview with Gov. Wright and the officers of the State of Indiana, and laid before them my views in regard to the Calumet ditch; and the result was, the Governor will suspend all action in regard to the matter, until after next meeting of Legislature.

He will call their attention to it in his message, and unless instructed so to do by the Legislature nothing farther will be done.

He will see that the canal trustees are notified, with a view of their being heard before the Legislature. The Governor and state officers treated the matter with great courtesy, and manifested liberal views; and unless the speculators in swamp lands raise a great clamor and influence the members of the Legislature, I think we can induce them to let the matter rest.

I will state very briefly the grounds on which I asked them to desist.

1. The Illinois and Michigan canal trustees are riparian owners of both banks of Calumet, continuously in the State of Illinois, and to some extent (by paying damages) in Indiana.

2. They as such have a *clear legal right* to have the stream continue to flow in its original *channel*, and Indiana cannot legally divest it or any part of it. If she attempts to do so, the court will enjoin her.

3. Indiana *knew* by her engineers, etc., that the canal trustees of Illinois proposed to make this dam as early as 1836. She contemplated connecting the *Wabash and Michigan canal* and to use Calumet and our Calumet feeder for that purpose. A meeting of engineers of both states was had and plan discussed and perhaps by mutual consent adopted.

At all events Indiana knew what we were doing—stood by and saw *without objection.* Illinois expended seven or eight millions on this plan. She is now stopped from raising the objection. She ought to have objected, if at all, before Illinois expended her money.

This acquiescence amounts to a license by Indiana, and a court of equity would enjoin her from interfering now, etc.

I will reserve details until I see you; I employed the State librarian to look up and prepare and send me all the legislative reports of commissioners, engineers, etc., to be found in Indianapolis on these subjects.

The difficulty in the case is, our dam throws back-water into Indiana, and is clearly illegal, except for the acquiescence of that State. I will reserve full details until we meet, as I can explain matters much more satisfactory then, than by writing. Meanwhile, we will have until next winter to examine our position.

Very truly yours,

I. N. Arnold.

Report of the Compiler of Records as Found in the Canal Commissioners' Report for 1900, Page 269.

In the various histories of Illinois there has been little said of the Illinois and Michigan Canal. The work was national in its character and its progress was observed with intense interest throughout all the states. The interest which the general government had taken in the project is evidenced by the act of Congress changing the northern boundary lines of the State, by purchasing from the Indians a strip of territory extending from the Illinois river to Lake Michigan—by the act of Congress of 1822 granting the right-of-way to the State and the act of 1827 granting land to defray the cost of construction.

The history of the canal is so interwoven with the early history of the State that in leaving it out of consideration, the historians were leaving out much that is now of interest. The teachers in the public schools of Chicago and Joliet are interesting themselves in its early history for educational purposes.

Prior to 1836, the magnitude of the undertaking was little understood by the majority of our State Legislatures and our people generally. The agitation of a deep waterway to connect the Great Lakes with the Mississippi was begun in 1812 during the war with Great Britain, and was vigorously

commented upon by the "Niles Register" of that period. That such a waterway would ultimately be accomplished, was the opinion of the men engaged in the construction of the canal. In 1842, William Gooding, an accomplished engineer, employed from 1836 to 1871 in the work of construction, etc., wrote as follows:

> "In constructing the Illinois and Michigan Canal of the dimensions now adopted, reference has generally been had to a future enlargement. Through all the canal towns the canal is nearly double and in some instances more than double the ordinary width. In deep cutting, the spoil banks were removed a sufficient distance to leave room for widening and deepening. In few instances, if any, would there be any additional damage to be paid for property. However remote the period may be, that it will be enlarged sooner or later, there can be no doubt. And also that the Illinois river will be so improved as to meet the enlarged capacity of the canal."

All the documentary evidence that can be found at the State capitol at Springfield or among the canal records, has been reproduced, consisting of the reports of the early commissioners and engineers (many of them never before published), extracts from messages of the Governors, from Session Reports, and Reports of Committees of the House and Senate, on canal and canal land.

* * * * * * *

Respectfully submitted,

E. W. WILLARD,
Land Agent.

EXTRACTS FROM ANDREAS HISTORY OF CHICAGO.

Vol. I (1670-1857)—	Water Works,	page	185-189
	Drainage	"	190-191
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Vol. II (1857-1871)—	Water System	"	66-70
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EXTRACTS RELATING TO THE EARLY HISTORY OF CHICAGO FROM ANDREAS HISTORY OF CHICAGO—VOLUMES ONE, TWO AND THREE.

Water Works. The first public effort made by Chicago to assist her inhabitants to a supply of fresh water, dates from November 10, 1834, when the Board of Trustees paid $95.50 for the digging of a well in Kinzie's addition. But the settlers early cast longing eyes towards the lake, realizing that that source of water supply was the true one and not to be compared to the sluggish and unprepossessing river. For some years private enterprise reaped a comfortable little financial harvest in the operation of water carts, which ran to and from the lake. These carts were two wheeled vehicles, upon which hogsheads were mounted. Having driven into the lake, generally at the foot of Randolph Street, the watermen loaded up their reservoirs by means of pails, and then commenced their journeys "around town." Backing their carts up to the doors of their customers' houses with a short leathern hose they filled the barrels or other receptacles placed there for the purpose. The price per barrel varied, according to competition, from five to ten cents. But there came a time when water-carts, tin cans, wooden pails and barrels were deemed too crude as "water works," and when even such persuasive and enterprising carriers as Peter Wolfe were thought to be behind the times. January 18, 1836, the State Legislature passed a law incorporating the Chicago Hydraulic Company. On March 19, an organization was effected as follows: George W. Dole, President; Gurdon S. Hubbard, David Hunter, Gholson Kercheval, William Forsythe, directors; and Edward W. Casey, secretary. The other incorporators were James H. Campbell, R. A. Kinzie and Solomon Wells. The capital stock was limited to $250,000. The charter was to continue in force seventy years. The company was allowed four years from the passage of the act in which to commence the construction of the necessary works. Although incorporated, the panic of 1837 so disarranged the affairs of the new company that it did not get fairly to work until 1840, when the four years had nearly expired. Ira Miltimore was then appointed machinist and superintendent of the works, and commenced at once to build a reservoir at the corner of Lake street and Michigan avenue, on the ground afterward occupied by the Adams House. Not until the spring of 1842 was this first water works system completed. The American of May 24 speaks in flowing terms of the purity

of the supply. The same paper of June 10 gives the following interesting facts in regard to the completion of the great undertaking:

"The whole outlay of the company has been about $24,000. A large two-story brick building has been erected with a pier running into the lake. The steam engine is of 25-horse power. The working-barrel of the pump is fourteen inches in diameter and forty-four inches stroke—double action. The suction pipe by which the water is drawn from the lake, is also fourteen inches in diameter, and three hundred and twenty feet in length. The pump raises upward of twenty-five barrels of water per minute, thirty-five feet above the level of the lake. There are two reservoirs, each of the capacity of one thousand two hundred and fifty barrels, one only of which is complete. A space of about fifty minutes is required to fill each of the reservoirs, equivalent, of course, to raising one thousand two hundred and fifty barrels in fifty minutes. The reservoir is of sufficient elevation to throw the water into the second story of any building in the city. About two miles in length of pipe are now laid down. The machinist under whose direction these works have been put into such complete and successful operation is Mr. Ira Miltimore. We allude to this gentleman with the more pleasure that it was for a long time confidently predicted that his undertaking would prove an entire failure. We know that though he had perfect confidence in his ability to accomplish his task, these predictions were to him a source of constant and harassing anxiety. It can scarcely be imagined how keenly intent were his feelings when the works were upon the point of being put into operation. The triumph, or it might be the disgrace, of the machinist was at hand. His feelings at that moment were assuredly not to be envied. They were to be envied when the regular evolution, the easy play, the harmonious action of every part of the machinery, announced the complete triumph of skill."

Elsewhere, and officially, the old hydraulic works have been described as consisting of an 18-inch inlet nearly seven hundred feet long, extending from a crib in the lake to a well fifteen feet deep, the inlet bending down nearly to the bottom; of pumping works on the lake shore at the foot of Lake street; and of wooden supply pipes, of which latter, before the abandonment of the works, there were several miles, none of which exceeded six inches in diameter. The wooden pipes

were frequently dug up, in excavating for the laying of sewers and iron water pipes, and appeared to be perfectly sound, twenty-five years after they were laid.

The Common Council in December, 1841, contracted with the Hydraulic Company to supply the city with water for the extinguishment of fires. The schedule of rates for domestic and manufacturing supply was published in April, 1842, and ranged from $10 per annum for a family of five persons, to $500 for large services in manufactories. The pipes from the mains to buildings were furnished at private expense.

In 1842 James Long entered into arrangements with the Hydraulic Company to do their pumping for supplying the city with water for ten years, without cost to the company, in return for the free use of the surplus power of their engine. Subsequently Mr. Long referred in the difficulties of his post in the following words:

> "In winter the pipes would be disarranged by the heaving of the frost, and I had frequently to spend hours at a time to caulk up the joints by throwing on water and thus freezing up the cracks before we could make the pumps available. When the end of this pipe from the pier was first put down it was three or four feet below the surface of the lake, but in 1842-43 the lake had receded so far as frequently to leave the end out of water, particularly when the wind blew from the south."

In addition to the work which he accomplished for the city, Mr. Long erected the "Hydraulic Mills," corner of Lake street and Michigan avenue, which he operated with the "surplus power of the twenty-five horse engine." The building cost about $12,000, was of three run of stone, and the mill did good business until the second water works were constructed, in 1853, when the enterprise was abandoned.

The great expectations entertained regarding the blessing which was to be brought to the homes of the people of Chicago were not realized, even within the next decade. During the fall of 1847, especially, the water supply was of a quality which called for purification. In August, ex-Street Commissioner Phillip Dean cleaned the works and repaired them. He was then acting as agent. But citizens were already putting the pertinent inquiry, "What good can Mr. Dean do, unless the pipe is extended out into pure water?"

The matter was so serious that everyone took part in the discussion. In the spring of 1848, at the season when little fishes were generally pumped into the reservoirs and thus distributed over the city, to the horror of the clean and fas-

tidious housewife, the public prints were full of "water works," and many shafts of ridicule were leveled against the primitive system of supply under which the city was suffering. A committee was appointed by the Chicago Mechanics' Institute, consisting of S. D. Childs, A. F. Bradley and W. H. Kennicott, to suggest a plan for getting water from the lake. They reported in May with a diagram, and proposed to lay down a pipe three feet below low-water mark; to extend it out into the lake at a point opposite First street to a sufficient distance to pass the muddy water, and then to continue the pipe down the center of said street, crossing the Chicago River near Mr. Gage's steam mill, and continuing it to the western boundary of the city. At the crossing of each alternate street lateral branches might be taken; the pipes to be of wood and to cost about $2,000 per mile. By carrying the pipes into twenty feet of water and attaching an elbow to that end, at least ten feet from the bottom, the water so drawn would be equally free from the floating impurities and the disturbances of the bottom; the water thus drawn to be introduced into two reservoirs, to be erected at the margin of the lake, each capable of holding twenty thousand cubic feet of water. Into the one nearest the lake the water should be first introduced, drawn off from the top and carried by an elbow to the bottom of the second reservoir, from which it should be drawn off again near the top, to be carried through the city by wooden pipes running down First street. The works then in operation (so it was computed) were throwing into the reservoirs a column of water equal to twenty-eight thousand cubic feet every twelve hours. This was drawn from the bottom of the lake, poured into the top of the reservoir and taken out at the bottom where the sediment must, of necessity, have been thrown.

Another influence, besides the quality of the water-supply, was at work to bring the life of the old Hydraulic Company to an end. A portion of the South Side, and a very small part of the West Side, were well supplied with water, while the whole of the North Side, and large districts of the other territory, were obliged to depend upon wells and the watermen, a number of whom were still kept busy bringing water from the lake. Many poor people, who were not able to take advantage even of these necessities to health, drew their supply from the filthy river. During 1850 the company laid one mile of pipe, making in all nine and a quarter miles in use. Of one thousand hydrants, eight hundred were used by families, the remainder by stores, public houses, livery stables, etc. It

was estimated that not over one-fifth of the city was being supplied by the company. For a large and rapidly growing city this state of affairs was alarming, especially as the general health was perceptibly suffering. In April, 1850, a meeting of citizens was held at the city hall for the purpose of devising means of supplying the city with pure and wholesome water. The following gentlemen, with the chairman of the meeting, Peter Page, were appointed to obtain facts and suggest remedies: South Division, R. H. Foss and T. M. Moody; West Division, A. S. Sherman and Luther Marsh; North Division, R. J. Hamilton and William E. Jones. It was through the efforts of these gentlemen, sustained by the general public sentiment, that a company was incorporated by the city during the succeeding session of the Legislature. The act approved February 15, 1851, to incorporate the City Hydraulic Company, provided for the organization of a board of water commissioners, composing John B. Turner, Horatio G. Loomis and Alson S. Sherman. This board entered on their duties of office June 18, 1851, and ten days later William McAlpine was appointed Chief Engineer. Under his directions the second water-works of Chicago were constructed. To point out distinctly the reason which the city assigned for the construction of such expensive works, an enumeration of buildings, etc., in which water-pipe were proposed to be first laid, was made in July, 1851. The total amount estimated to accrue from water-rates for the year succeeding the completion of the water-works was $37,366.

"The commissioners stated that the water will be taken from the lake north of the pier, at or near the termination of Chicago Avenue. There will ultimately be required in the carrying out of this plan three reservoirs, one of which will be located in each division of the city. The water will be taken from the lake at a distance of about six hundred feet from the shore, and conducted by an inlet pipe to a well, which will be within the engine-house, on or near the beach. From this well the water will be forced into the reservoirs, to a height of eighty-five feet above the surface of the lake and about seventy-five feet above the surface of the general level of the city, by a non-condensing engine of about 170-horse power. The pipes used will be of iron. Iron tanks will be used for the reservoirs. The estimated cost of constructing the work upon this plan, including the cost of about forty-eight lineal miles of distribution pipe, which it is supposed will be adequate to supply the in-

habitants of the city, when its population will be one hundred thousand souls, is $570,000."

Engineer McAlpine made his report September 26, 1851. His assistant, E. W. Smith, had remained in Chicago for over a month, to take soundings in the lake at the several places suggested by the board of commissioners, and also to examine the branches of the river where the water pipes were proposed to be carried. Mr. McAlpine submitted four plans, with estimates for the cost of carrying them out. The plan substantially adopted was the fourth. An estimate was made that the total cost of constructing the works would be $335,439.59 and that the annual expenses would amount to $18,000. The whole plan was submitted, as applying to a city which would number one hundred and sixty-two thousand souls in 1875. The system was considered as amply sufficient to cover any possible growth of the future, and the estimate was considered by many to be quite extravagant.

It would not be in human nature for the old Hydraulic Company to allow the new corporation to prosecute their enterprise without bitterly opposing it. The former claimed exclusive rights, and held that before the commissioners could proceed a step they must first purchase the old company's property and franchise, or its franchise alone. The Hydraulic Company claimed, without the income which was then being derived from water rents, that the tables of the new commissioners would be $15,000 less yearly than they calculated. As to the paucity of the water supply they stated, that a "charter was obtained for supplying the North Division of the city with water, but excepting such preliminary steps as were thought necessary to secure their charter, we believe they have advanced no farther. In 1850-51, the charter was extended, and calculating to supply the whole city, the company finding the limit of $250,000 in their charter too small, they are seeking power to borrow at once $350,000." After showing the advantages which the city would gain by purchasing their works, and that it was impossible for them to levy taxes upon the territory now occupied by them, the directors of the company intimated that unless the matters were settled, an injunction would be brought to prevent the building of the new works. The directors of the old Hydraulic Company, at this time were B. S. Morris, William Wheeler, B. W. Raymond, J. H. Foster and M. Laflin.

On March 2, at the regular municipal election, only five hundred and thirteen votes were cast against the adoption of the system proposed by the Chicago City Hydraulic Company.

Of the four thousand four hundred and forty-five persons voting at that time, one thousand two hundred and forty-four did not signify whether they cared for the works or not.

In compliance with a request from the old Hydraulic Company a special committee of the Common Council suggested that the water commissioners purchase their entire interests for $30,000, or their franchises for $15,000, the Hydraulic Company to retain their property and income of works until July 4, 1853. The paper, however, was laid on the table and could not therefore be considered as having received a municipal indorsement. The water commissioners then went on to negotiate their $400,000 bonds with Duncan, Sherman & Co., of New York City. The first loan was made in April—$250,000, payable in twenty years. In June the New York Tribune reports: "Under the active demands for the Chicago City Six's, which was fast exhausting the supply, Messrs. Duncan, Sherman & Co. have advanced the rate to ninety-seven and one-half and accrued interest. They are selling faster than the city officers execute and forward them."

The Hydraulic Company got out an injunction, but the two rivals compromised their difficulties under the 19th section of the act of incorporation of the new water company, which reads as follows:

> "Said commissioners may purchase the corporate rights and real and personal property, fixtures and stock of every name and description of the Chicago Hydraulic Company and when such purchase shall be made, the said commissioners shall succeed to and become invested with all the powers, rights, privileges and immunties exercised and enjoyed by the Chicago Hydraulic Company under their charter, and shall continue to supply water to the citizens of Chicago, under the same, and collect the money and rents therefor, in all respects as fully and effectually as the Chicago Hydraulic Company can or may do, until the said commissioners, acting under the provisions of this act, shall have completed their arrangements, machinery, engines, pipes, buildings and other things provided for in this act for the purpose of providing the said city with pure and wholesome water; after which time the said Chicago Hydraulic Company, and their said charter, shall become extinct and null: Provided, always, that if the said commissioners cannot agree with the said Chicago Hydraulic Company as to what sum shall be paid the said Chicago Hydraulic Company for their property, rights and privileges, then the

said company shall have the right to establish, by satisfactory proof, the actual cost of their said property, before the Judge of the Circuit Court of Cook County, upon petition to him in term time or vacation, and no greater sum shall be paid for the same than the Judge shall decide the actual cost to have been."

In April and August two loans were effected with the above named banking-house. The net amount realized from the sale of the $400,000 bonds—six per cent., twenty-five years—was $361,280. The difficulties between the two companies having been amicably adjusted, the water commissioners pushed their work along with commendable energy.*

The works were commenced in the summer of 1852, and were situated near the lake, at the foot of Chicago avenue. The pump-well was built, and a portion of the thirty-inch inlet pipe was laid towards the lake, and the foundations of the building and tower were put in, which closed the work for the season. During the spring and summer of 1853 the buildings and tower were finished and several attempts made to put in place the thirty-inch wooden inlet pipe, which was designed to extend six hundred feet into the lake, and terminate in a crib of timber. The efforts to complete this were unsuccessful. The boisterous condition of the lake rendered it difficult to secure the crib in place, so the work was abandoned and the water received in a pipe, close to the shore. During the fall of 1853, the stand-pipe was put up, and the condensing and non-condensing engines were erected. The former was started December 16, 1853, and the supply of water for the city commenced in February, 1854. The original pump-well was rectangular, twenty by thirty feet, and twenty-five feet deep from floor of engine-house to bottom. The walls were of stone, six to seven feet thick. Upon those walls the engines were located; the buildings were of brick, forty by fifty feet in the clear, and two wings for boiler-rooms, each thirty and one-half by forty and one-half feet in the clear. The water tower was square, composed of brick fourteen feet at the base, eleven feet at the top and one hundred and thirty-six feet high. The interior was divided by a wall, one part designed for a smoke chimney, the other for the iron stand-pipe. The foundation rested upon a bed of sand, some six feet below the surface, and at one time the tower leaned fourteen inches from a vertical line. It was, however, by an ingenious method made plumb, and remained so until its demolition. The original pumping-machine consisted of a vertical beam engine, located on the north side of the building, having

a steam cylinder of forty-four inches diameter and a stroke of nine feet, with two single-action pumps of thirty-four inches in diameter and five and one-half feet stroke. This engine was in use sixteen years, and continued through 1869. It was built at the Morgan Iron Works, New York, as were also the engines erected in 1857 and 1867. The non-condensing engine, erected in 1853, was horizontal. It was located on the south side of the main building, having a steam cylinder of eighteen inches, and six feet stroke, with one double-acting pump of the same dimensions. This engine was built by H. Moses, of Chicago. It was removed in the latter part of 1856 and a larger one substituted.

During the first four months water was supplied but nine hours per day, and none on Sunday except in case of fire; after that the supply was continued regularly throughout the twenty-four hours. At this time there were but few water-takers, and having no reservoir, the water was allowed to run to waste through the fire-hydrants, in order to keep the small engine running. In the early part of 1854 the twelve-inch river pipe at State street was broken by an anchor dragging from a vessel. This accident required the supply for the West Division to be forced through an eight-inch pipe across the river at Kinzie; and thence by a twelve-inch pipe across the river at Adams street for the South Division. As a temporary resort a large rubber pipe, manufactured at Boston, was procured. On its arrival its strength was found inadequate to the pressure. A new wrought iron pipe, thirty inches in diameter was subsequently put down at State street and was in use in 1869. This new main was manufactured by Charles Ressig, of Chicago, at a cost of $3,561, and was laid by S. S. Durfee, at an additional cost of $2,000. The connecting main was completed October 1, 1854. Thirty and one-half miles of pipe were laid up to December 31, 1854. The total cost of the works at that date was $393,045.32. During the first year much trouble was experienced from sand being driven from the inlet pipe into the pump-well. The mouth of the pipe being only a few inches under water, near the shore, was exposed to the heavy waves of the lake. On one occasion the water was entirely stopped by a vast number of insects accumulating on the strainer. To protect the inlet-pipe from those obstacles, a breakwater or basin was constructed in 1855. This being dredged to a considerable depth fully answered its purpose, and was in use until the completion of the first lake tunnel. In June, 1852, the water commissioners purchased from P. F. W. Peck a piece of land

upon which to erect the South Side reservoir. The lots had a frontage of 217½ feet upon Adams street, and cost the city $8,750. The reservoir was completed in November, 1854. It was filled within ten feet of the top, or twenty-eight feet deep, on November 22, and the next morning it was found that the immense weight of water had caused the masonry to settle so that fissures were discernible on every side of the building. The water was immediately drawn off, and the various methods of patching up the job, which had already cost $60,000, were canvassed. Various plans were laid before the Council and a committee was appointed to examine them. This committee could not agree upon one thing, viz: and it was necessary to construct substantially a new building. The water commissioners, therefore, strengthened the cracked walls as best they could with rods and braces, so that the tank could be partially filled with water and thus do some service during the winter. Pending the repairs of this reservoir the engines were run day and night. A portion of the thirty-inch inlet-pipe from the lake to the well was found to be defective, and a new one, three by four feet square made of oak plank, was put in at a greater depth. Considerable difficulty was experienced in laying this pipe, involving the removal of the cast wall of the engine house. Upon completion of the lake tunnel this arrangement was also abandoned and served subsequently as a waste-pipe for the water from the air pumps of the several engines.

In June, 1855, the reservoir was strengthened after the accident of the preceding fall, until it would hold eighteen feet of water, which with other charges for repairs and general expenses, brought up the construction account to $380,070.73. A large fracture was found in the main pipe near the standing column of the works, on December 22, 1855. Notice was immediately given that the water would be cut off at Monday noon. Care was taken to have the reservoir full, and a man was kept stationed there with orders to turn on the water instantly in case of fire. The pipe was repaired within a few days, and but little inconvenience was felt by the people.

Up to December 31, 1855, there had been expended upon the construction and extension of the water-works system $496,849.64. The whole amount of bonds issued by the water commissioners had been $650,000. Over forty-one miles of pipe had been laid, and 4,251 buildings were supplied with water.

During the early part of 1856 the quantity of water used was nearly equal to the maximum capacity of the high pres-

sure engine. Therefore it was necessary to replace it with a much larger one. A contract was made with the Morgan Iron Works for the construction of the south engine, which was set up and put in operation July, 1857. This engine was similar in construction to the condensing engine previously referred to, with a steam cylinder of sixty-inch diameter, stroke of ten feet, two single acting pumps, each forty-inch diameter, six and one-fourth feet stroke. Much difficulty was experienced in preparing a foundation for this engine, as a portion of the only pump-well then built, from which the city supply was pumped, as well as the site of the old high-pressure engine, was to be occupied. However, the high-pressure engine was moved to a temporary site, where it might be used until the new works were ready. The labor of setting the stone was carried on during the night only. While constructing the foundation, no water could be admitted to the well, which seriously retarded progress. The daily supply of water was uninterrupted, and the reservoir in the South Division kept full, so that in case of fire the water therefrom might be admitted to the mains. In the summer of 1857 a twenty-four inch main was laid from the pumping works to the West Division, crossing the river at Chicago avenue, by means of a wrought-iron pipe. Soon after it was completed, the river-portion was rendered useless by a pile twelve inches in diameter being accidently driven through it, permitting the water to flow into the river. From this accident the engine narrowly escaped injury by the sudden reduction of load. The damaged pipe was taken up, repaired and placed in its original position.

Up to 1857 two engines had been built by the North Side pumping works. The first one, that of 1853, was put in operation December 16. It had a capacity of seven and one-half million gallons every twenty-four hours; steam cylinder, forty-four inches in diameter, nine feet stroke; length of working beam, thirty feet; weight, nine tons; diameter of fly-wheel, twenty-four feet; cost of engine and boiler, $24,500. The engine of 1857 was put in operation in July; capacity, thirteen million gallons every twenty-four hours; steam cylinder, sixty inches in diameter; ten feet stroke; working-beam, thirty feet; weight, sixteen tons; diameter of fly-wheel, twenty-four feet; cost of engine and two boilers, $59,000. Some parts of the engine were made to conform to the conditions of the building. Owing to the position of the tower, the valve-gear or customary front of the engine was placed on the side, as it was deemed imprudent to cut the corner of the tower to admit locating the front in the usual place. In

December, 1853, water was first pumped into the pipes to test them, and the first hydrant was opened on North Clark street, near the bridge. The first permits to take water from the distribution pipes were granted February 12, 1854, to residents of the North and West divisions. Pipes were tapped February 15, and water introduced into the buildings of the city for the first time.

Following is a table exhibiting the "finances" of the waterworks from 1854-57:

Years.	Cost of Work.	Operating Exp. & Int.	Revenue.
1854	$393,045.32	$38,128.51	$26,808.50
1855	496,849.64	59,051.27	54,739.19
1856	641,509.93	73,087.23	76,806.36
1857	738,436.51	85,170.61	97,008.55

On May 1, 1857, the works were supplying seven thousand and fifty-three buildings with water, for $85,012 per annum. May 6, 1861, the Board of Public Works was instituted.

Early Efforts at Drainage.

Those who have made a study of the subject, in opposition to the popular error, testify that the substratum of the soil upon which the City of Chicago is built, far from being swampy and miry, is remarkably solid. Too nearly on a level for the rain to run off, it must evaporate or soak into the soil. Almost uniformly, except near the lake, a rich, black loam of one or two feet or more is gradually mixed with clay until it becomes pure, or hardpan intervenes. Occasionally a bed of quicksand occurs, rendering piling requisite for a sure foundation, but probably no other city ever arose where the ground was so perfectly adapted, by nature, to solid building. While groping after a good drainage system, in early days, the authorities made two mistakes. At first they attempted to dig down the streets, and construct crude sluices to carry off the surface water; next an effort was made to lay pavements and sewers upon the natural surface, or rather to let the drainage and sewage run along the gutters of the streets. Going more into detail, it is found that on February 16, 1847, the Legislature in an act supplementary to the charter gave the Common Council power to make and repair all sewers in the city. When, in 1849, the city virtually discarded stone pavements and commenced to plank the principal streets, the Common Council adopted a series of grades by which it was hoped to drain the surface as well as pave it. It was thought to be practicable in determining the grades to effectually

drain the lots contiguous to the streets by digging down the latter some eighteen inches beneath the common surface. Most of the planking of 1849 was upon that plan. Randolph, Lake and South Water streets were excavated, the grade ascending from the South Branch eastward to State street, which was to form the summit-level from north to south. Madison street was determined upon as the summit-level for all grades running toward the main river and in the opposite direction. Randolph, Lake and South Water streets were therefore cut down to conform to these grades. The object was to drain the South Division from State street into the lake on one side and into the South Branch on the other, and from Madison street into the main river on the north, and to some yet unestablished east and west line on the south. Fortunately the Council confined their experiments for the first year to the three streets named. Before one month had passed by after their completion, the plan was regarded as a failure, and the attempt to make streets answer the purpose of sewers was abandoned. In 1850, State, Clark, LaSalle and Wells streets were planked, mostly upon the natural surface, with only such grading as was found necessary to carry off the water that might fall upon it. The main sewers were constructed in Clark, LaSalle and Wells streets, running through their centers from the river to Randolph street. They were built of heavy oak plank, triangular in shape. Their length was one thousand feet each; the side sewers being nine hundred and sixty-seven feet. The sum of $2,871.90 was thus expended, and the property was specially assessed to the full amount of the cost. But although these improvements were in the march of progress, there was a determination among the far-seeing to look upon them as merely expedients. The formation and perfection of a system was demanded. The following extract from the Gem of the Prairie, of August, 1850, illustrates the advanced ideas:

> "To any intelligent person going about our city, who understands the physical condition of health, and the causes which, with mathematical certainty generate disease, the wonder is not that we have had cholera in our midst for two seasons in succession, and that the common diseases of the country are fatally prevalent during the summer months, but that a worse plague does not take up a permanent residence with us. Many of the populous localities are noisome quagmires, the gutters running with filth at which the very swine turn up their noses in supreme disgust. Even some portions of the planked

streets, say, for instance, Lake between Clark and La-Salle, are scarcely in better sanitary condition than those which are not planked. The gutters at the crossings are clogged up, leaving standing pools of an indescribable liquid, there to salute the noses of passers by. There being no chance to drain them properly, the water accumulates underneath the planking, into which flows all manner of filth, and during the hot weather of the last few weeks, the whole reeking mass of abominations has steamed up through every opening, and the misama thus elaborated has ben wafted into the neighboring shops and dwellings, to poison their inmates. Such being the state of facts, the people naturally expect the corporation will do something to abate the universal nuisance, or at least make the attempt to do so. But what has been done? Lime has been distributed to some extent, but in insignificant quantities, and some of the worst localities have been entirely neglected. * * * Here is a long bill of complaints to prefer in the ears of the city fathers, which for the future welfare and honor of the place, we hope they will take into serious consideration. The evil, though great and increasing, is yet susceptible of a remedy. The only condition of health and decency, is a regular, thorough system of drainage. Such a system is feasible, and must be adopted if the 'Garden City' is to be habitable. It may and probably will cost $30,000 or $40,000 to begin with, on an extensive scale, and eventually $100,000 or more; but what is such a sum in comparison with salubrity of atmosphere and health?"

The last attempt of any magnitude which citizens made to drain a large extent of territory without working under a clearly defined system, was under the direction of Henry Smith, George W. Snow, James H. Rees, George Steele, H. L. Stewart, Isaac Cook and Charles V. Dyer, who were appointed commissioners under an act of the Legislature dated June 23, 1852. They and their successors in office were empowered to locate, construct and maintain ditches, embankments, culverts, bridges and roads, on any lands lying in Townships 37, 38, 39 and 40, in Ranges 12, 13 and 14, Cook County; and to take land and materials necessary for these purposes, and to assess the cost of such improvements upon the lands they might deem to be benefited thereby. Their examination showed the commisioners that a vast body of land (more than one hundred and fifty thousand acres), within the limits of the commission which had before been deemed worthless, lay,

in fact, from four to twelve feet above the lake, and needed only proper drainage to make it available for purposes of agriculture and occupation. When the commission was first created, objection was made that its powers were too great, and a fear was expressed that the proposed reform would develop into a stupendous speculation—even into a gigantic peculation. But subsequent events showed that such fears and suspicions were groundless. Within two years the commissioners expended $100,000 in authorized improvements, with the most praiseworthy results. Large tracts of land were redeemed from the swamps and made valuable, and people were able to live comfortably, in dry houses, in localities which previously were thought to be uninhabitable. The lands drained extended four miles north, five miles west and ten miles south of the city. The ditches were mostly laid upon section lines, and parallel, draining into the Chicago and Calumet rivers. The Democratic Press in its annual review of 1854 has the following:

> "There are within the city four and half miles of sewers put down at a depth of from five to eight feet below the surface. These extend along our principal streets, in the business portion of the city, and so far as the removal of surface water is concerned, answer, so far as they go, a complete purpose. This may be inferred from the facts already stated in regard to cellars, since a cellar without a drain is only a pool or an eel pit. Before these sewers were put down, no cellar could be dug either upon Lake or Water streets, except in the driest of seasons. There was never perhaps, a city with features better fitted for drainage than this. The peculiar shape of its river, with its two branches, gives easy and short access to it from every section of the town; while there is, from every square rod of its surface, a gradual and sufficient inclination to the adjacent bank. The sewers only need to be extended as they have been begun to render the town as dry as is desirable. As they are, however, of a temporary and experimental make, if they are also to be made channels of the filth of the town, they will require to be laid in a more permanent manner."

By the act approved February 14, 1855, a board of sewerage commissioners were incorporated, consisting of one member for each of the three divisions of the city, to be elected for two, three and four years. It was their duty to consider all matters relative to the thorough and systematic drain-

age of the city; to advertise for plans and receive written objections, for thirty days; to report a plan to the Common Council with estimate of the necessary amount to complete it; to issue bonds, purchase lots and erect buildings, and appoint a secretary and treasurer. E. S. Chesbrough was appointed chief engineer, and insisted, from the first, upon the advantage of a high grade for the purpose of proper drainage and dry streets. The grade at last fixed upon was lower than he urged, but still sufficiently high to alarm the Common Council, who ordered a general extension of grades. By the system then in vogue about one-half the drainage from the South Division, all from the North Division except from establishments immediately along the lake, and all from the West Division ran into the river. The dividing ridge in the South Division was along State street, the water to the east of that line running into the lake. It will thus be seen that the river was the receptacle of all the drainage from packing houses, distilleries, and most of the hotels, business blocks and dwellings of the city, so that constant streams of filth were pouring into it, On December 31, 1855, Mr. Chesbrough made a report to the Common Council, stating that the commissioners had already decided that the plan of sewerage to be devised should "cover at present, the territory included within Division street on the north, Reuben street on the west, North street on the south, and Lake Michigan on the east. The plan of draining the sewerage into the river and branches directly, and thence into the lake, had been decided upon as being less expensive than draining directly into the lake. In order to keep improper substances out of the sewers, it was proposed to introduce a slight but constant current into the mains, and to resort to flushing or cleansing by hand. The sewers in the South Division were to have their principal dividing or summit line, on State and Washington streets. Starting from these dividing lines, they were to discharge westwardly into the South Branch, between North and Washington streets, northwardly from Washington street into the main river, between Market street and the lake, and eastwardly into large mains on Michigan avenue, one of which was to empty into the river, and the other have its outlet in the lake, on Twelfth street. Small branch sewers were to run through the streets, which lie parallel with the summit lines, so that every lot might be reached. In the North Division, three main lines extended from Division street to the main river, and had their outlets on Rush, Clark and Franklin streets, respectively. He also proposed a main having an out-

let into the North Branch, on Chicago avenue. All the intermediate streets between the mains, and those running east and west, it was proposed to drain by branches of different sizes, so that every lot might be reached the same as in the South Division. It will be observed that no sewer had its outlet into the lake in the North Division. In the West Division mains from Reuben street to the South and North branches were proposed. For the present it was recommended that they be constructed only in Prairie, Randolph, Monroe and Van Buren streets, and in these only as far as existing improvements might require them. The streets and parts of streets intermediate between the mains, were to be drained by branches as in the south and north districts. With regard to the outlets of the sewers it was recommended that they be so placed that the bottom of the interior surface of the mains would be six inches above the low water level of 1847; and to place the bottoms of the two-feet sewers, six inches higher, or about the level of the present surface of the lake. The estimates made did not cover the sewerage for all the territory embraced in the plan, but merely so much as was considered necessary for present purposes: South district, $157,893; north district, $156,522; west district, $188,-831. In the winter of 1856-'57 Mr. Chesbrough, upon the order of the board, visited some of the principal cities of Europe for the purpose of examining the various methods of sewerage adopted there, with a view of perfecting the system of Chicago. He recommended the system of intercepting sewers as the most feasible, the discharge to be into the lake at some point in the southern part of the city. With the idea of inaugurating the system the first sewers were constructed in 1856—a total of six and two one hundredths miles. During the next year four and eighty-six one hundredths miles were built, making a total of about ten and four-fifths miles included in the sewerage system in 1857.

The River Conditions.

Very early in the history of Chicago the attention of citizens was called to the sluggish nature of the river, and ordinances, were enacted by the town and municipal authorities against polluting its waters. The first measure was passed November 7, 1833. The ordinance of August 5, 1834, under the impetus of the cholera scare, was more stringent. Although the town and city authorities intended to be severe in times of epidemics, or when scourges were feared, very many

offensive substances did find their way into the river at all seasons of the year, and by 1845 the stream became terribly offensive, in consequence of blood and other refuse from slaughter houses being thrown into it. When that nuisance was abated, however, the odors of the "melancholy and slow" stream became comparatively bearable for some years. When the board of sewerage commissioners adopted Mr. Chesbrough's plan of draining directly into the river and its branches (in December, 1855) the public became alarmed lest this should endanger the city's health, and also fill up the river so as to obstruct navigation. Mr. Chesbrough discusses these objections, and explains his plan as follows:

> "It is proposed to remove the first (objection) by pouring into the river from the lake a sufficient body of pure water to prevent offensive or injurious exhalations, by means which will hereafter be described. The latter objection is believed to be groundless, because the substances to be conveyed through the sewers to the river could in no case be heavier than the soil of this vicinity, but would generally be much lighter. While these substances might, to some extent, be deposited there when there is little or no current, they would, during the seasons of rain and flood, be swept on by the same force that has hitherto preserved the depth of the river."

In speaking of the steamboat canal project, he says:

> "If it should ever be made for commercial purposes, the plan would be about as well adapted to such a state of things as it is to the present, making it necessary to abandon only the proposed method of supplying the South Branch with fresh water from the lake, and to pump up from the canal, or draw from the Desplaines directly, flushing water for the West District instead of obtaining it from the present canal at Bridgeport, as herein recommended. For the purpose of keeping the water in the South Branch fresh, it is proposed to construct a canal, twenty feet wide and six feet deep at low water, between the lake and the South Branch, through North street (Sixteenth), and for the purpose of purifying, as much of the North Branch as possible, it is believed that the necessary canal should be located as far north as Center street."

By reference to the history of the sewerage system, it will be seen that the first sewers were constructed in 1856. During the next spring occurred the freshet which increased the depth of the river two feet, sweetened its waters, and destroyed, for a time, the apprehensions of sensitive people.

EXTRACTS FROM ANDREAS HISTORY OF CHICAGO.

Vol. II.

Sewerage System.

Previous to the organization of the Board of Public Works, about 54.5 miles of sewerage had been constructed—6.02 miles in 1856; 4.86 miles in 1857; 19.29 miles in 1858; 10.45 miles in 1859; 13.07 miles in 1860; and .53 miles in 1861. Although but 2,826 feet were constructed in 1861, three-fourths of this amount was built by private and interested parties. The board had no resources from which to draw, and suit was commenced against the Sewerage Commissioners for $58,-882.84, on orders which the Marine Bank refused to pay at par, and for $107,746.53 against S. Lund, treasurer of the late board. In 1852, about three miles of sewers were constructed, principally of brick. The balance of the account due from S. Lund, now found to amount to $108,696.53, had not been obtained. After the year 1863, when the finances of the city were somewhat embarrassed, the construction of sewers and the growth of the system progressed favorably. Following is a table covering the period, commencing with the time the Board of Public Works assumed charge, up to and including 1871, the figures for 1861 being the number of feet constructed up to that year, with cost:

Year.	Feet Built.	Cost.
1861	283,586	$665,188.46
1862	2,856	3,617.31
1863	15,676	57,264.51
1864	39,605	169,299.29
1865	25,021	87,221.48
1866	29,948	137,643.02
1867	48,127	225,564.53
1868	89,661	416,730.51
1869	47,841	197,152.92
1870	139,705	654,141.26
1871	78,166	258,664.70
Totals	800,192 ft.	$2,872,487.99

or 151 288/528ths miles.

The damage to the sewerage system, by the great fire was comparatively light, consisting of injury to manhole and catchbasin covers, and in the extra expense occasioned in cleansing sewers and basins, caused by the deposits of lime and debris from burnt buildings. The loss in this department is estimated at $42,000.

The Water System—The Lake Tunnel.

The early settlers of Chicago were ever gazing toward Lake Michigan as the source from which, as a people, they were eventually to be saved from the vileness of their then water "privileges." Up to 1858 they had not gone more than a few rods from the shore; nor did they make the attempt for some years thereafter. It seemed to slowly dawn upon the municipal authorities that, as servants of the public, they were called upon to look to the quality as well as the quantity of the drinking supply. Two new reservoirs, each having a capacity of half a million gallons were erected in 1858, one being placed in the North and one in the West Division of the city. During that year the average daily supply was three million gallons. For several years the operations of the old works were uniform and satisfactory, except at periods during the coldest weather, when vast quantities of fish and ice collected at the mouth of the inlet pipe and threatened to cut off the supply entirely. The Board of Water Commissioners, having met the immediate wants of the community as to quantity, now began seriously to consider the question of purity of the water supply. Surveys and estimates of various improvements were made.

During 1860 five plans were submitted to the Council for attaining the requisite purity. First, by extending a pipe one mile out into the lake; second, by building a tunnel one mile under the lake; third locating the pumping works at Winnetka; fourth, by the construction of filter beds; fifth, by the erection of a subsiding reservoir. The suggestions did not receive much attention, but the people continued to cry for the purest water which could be obtained. The next year (1861) E. S. Chesbrough, as the newly appointed city engineer, submitted to noted chemists a number of samples of water, taken from the lake and river. One fact was ascertained which, at first, gave rise to some surprise, viz.: that water taken from near Clark street bridge, in the spring, was found purer than that taken from the lake, one mile from Cleaverville. This was afterward explained, on the ground of "freshets." The investigation continued from early in the spring to late in the fall, and the fact was demonstrated that the water of Lake Michigan, some distance from the shore, was superior in every respect to that used by any other city, and could not be excelled.

EXTRACTS FROM ANDREAS HISTORY OF CHICAGO.

The Gordian Knot.

Vol. III.

The great problem ought to be solved in connection with the sewerage system of the City of Chicago, was the cleansing of the bed of the Chicago River of sewage sediments and local impurities, without having the poisonous deposits washed out through the mouth of the river into the lake, and possibly contaminating the public water supply, which is taken from the bottom of the lake, three miles distant from the shore. To this end, all operations have had in view the changing of the natural current of the South Branch of the river so that it shall set down the Illinois & Michigan Canal instead of flowing toward the lake; and continuing the waters of the North Branch past its junction with the main river down to the canal outlet. For this purpose immense pumping works have been erected at Fullerton avenue, on the North Branch, intended to force water from a lake tunnel into the river basin, thereby creating a strong current to the south; and twin pumping works have been erected in Bridgeport, at the entrance of the canal, on the West Branch of the river, which takes the polluted water from the river and pours it into the supplementary basin of the canal, thus creating a vacuum in the river and inducing a strong current in a southerly and westerly direction.

The operations of the dual pumping works have been measurably successful, and are adequate, perhaps, for ordinary seasons; but whenever a freshet sets in, it is invariably the case that the country on the line of the Desplaines River, from Chicago city line all along the river valley, from twelve to twenty miles distant, is entirely submerged, the water often covering an area of twenty or thirty square miles. In the vicinity of Twenty-second street, during a heavy freshet, the water in the West Branch of the river not infrequently rises six or eight feet, while in the basin of the main river, north of Van Buren street, the rise is generally from eighteen inches to two feet. During the prevalence of a freshet, and often continuing two or three days, not less than 150,000 cubic feet of water a minute empty from the Desplaines River into the West Branch of the Chicago River. The flow of water from the Desplaines is much greater now than in former years, primarily because of the clearing up and ditching of swampy lands and acres of marshy country that

for years had been covered with thick underbrush; the removal of these natural obstructions affording the periodical rains uninterrupted course, so that a fall of rain which formerly was days in finding its way to the city, now sweeps in upon it in a flood in the course of a few hours.

But the principal cause of the great influx of water is the existence of the so-called Ogden Ditch, an excavation dredged by the late William B. Ogden, in 1868, through his lands about twelve miles west of the city, for the purpose of draining the large area of the Desplaines valley, some twelve or fifteen square miles, which, previous to his excavation, was submerged nearly the entire year. The Ogden Ditch, or Canal, is twenty-five or thirty feet wide, and extends through Mud Lake, in a northerly direction, about two hundred feet; then makes a sharp right-angular turn to the east, and continues some three hundred feet, forming a junction with, and emptying into, the West Fork of the Chicago River. During the season of the floods, the Ogden Ditch overflows its banks, receiving drainage and surface water beyond its capacity for discharge. To offset the trouble, and regulate the disturbances created in part by the Ogden Canal and in part by the rapid flow of surface and drainage water, the city constructed, in 1874, on land acquired from Mr. Ogden, a rude dam of piling, on which was spiked heavy plank, and filled in with earthwork to a sufficient depth to withstand the force of water. The top of this dam was on a level with the adjoining lands, and was built across the east arm of the Desplaines, and parallel with the north angle of the Ogden Canal, and served to wall out, to some extent, the waters of the big ditch, the flood of the Desplaines River, and the surface water from the Desplaines valley on the west and south.

This dam has been of good service, and has accomplished all that was expected of it; but at the same time it has been, from the first, a bone of contention, and has stirred up the ire and provoked the animosity of the neighboring property owners, who wished their lands flooded in the fall and winter, that they might reap abundant crops of ice for commercial purposes, and who again desired their lands drained in the spring and summer, for the successful pursuit of agriculture. It was their custom for a number of years, therefore, when the spring rains commenced to descend, and there was a reasonable prospect of a freshet, to repair to the dam with axes and other aggressive implements, knock the planking from

the piles, tear up the earth-works, and permit the water to have free course into the West Fork of the Chicago River; then, in the fall, before the wet season set in, to again fill in the earth on the dam, replace the planks on the piles, and permit the land to be flooded through the winter, thus insuring for themselves an abundant harvest of ice. In 1885, the city put a stop to these practices, by constructing a new and permanent dam on the site of the original works, excavating to proper depth, laying a solid masonry foundation, and building up the facade of the dam with heavy blocks of stone; then filling in with rip-rap material and gravel to the width of twenty-five feet, sloping down to the water's edge, and constructing a solid roadway over the dam, completing a wall and approaches which can not be readily thrown down or penetrated.

Another cause for the great rush of waters in this locality, is found in the fact that the State, in 1871, purchased a strip of land thirty-three feet wide, about a mile west and parallel with the city dam, and constructed thereon a public roadway of stone, six feet high, through the low and swampy region, thus damming in the water on the south, which has no egress save by one small watercourse.

The city acquired of Mr. Ogden the perpetual right to maintain the dam it located, and has the privilege of extending it south to where the Ogden possessions adjoin the land of Hon. John Wentworth, which it will soon be necessary to do. But beyond the Ogden line the city can not go, Mr. Wentworth absolutely refusing to sell, or to permit the dam to be built across his land to the banks of the Chicago River, some three hundred feet further south. As the city dam is raised only to the height of the adjoining land, which has always been a swampy district, submerged most of the year, it does not encroach upon property rights. The dam, however, would be far more efficacious if it could be raised a foot or eighteen inches; but in doing so the country to the west would be inundated for miles beyond the present outflow, and probably as far as Joliet, entailing much destruction, and making the city liable for extensive damages.

The Desplaines River is decidedly mercurial in its tendencies, being down today and up tomorrow. It will this week be nearly dry, so as to be fordable at many points, and a week later will be so swollen with rains and freshets as to overflow its banks and sweep everything before it. The early settlers of Illinois were accustomed to float down the Des-

plaines from points fifty to seventy-five miles up the river, boating it where the depth of water would permit, and dragging or carrying their boats through shoals and over dry places.

Notwithstanding the existence of the city dam, it was found by actual measurement, that, during the freshet of April 20-22, 1885, the Desplaines River was so swollen that 123,757 cubic feet of water a minute found its way over the top of the dam, through the West Fork, into the Chicago River; while the volume of water coming down the North Branch of the Chicago River, derived wholly from the watershed of the northwest section, was 26,467 cubic feet a minute, causing a rise in the main river of nearly two feet, a portion of the water flowing east into the lake, and a smaller portion flowing south into the canal. Yet this fall of water was only about one-half the quantity which usually enters the city during the height of the flood season.

The practical operation of the river sewerage is this: In the dry season, when the river and lake are low, and the water in the river is at a standstill or sluggish, the machinery of the Fullerton avenue pumping works, which forces water from the lake tunnel into the river, or reciprocally from the river into the lake, is utilized to swell the volume of water in the North Branch of the Chicago River, and creates a strong southerly current; while at the same time the pumpin works at the head of the canal, at Bridgeport, acting in correspondence, lifts the black, dirty water out of the West Branch of the river and empties it into the supplementary canal basin, thus creating a vacuum in the river, and inducing a current from the north. The water in the canal, which is usually raised from six to twelve inches in consequence of the water pumped into it, is prevented from flowing back into the river and buffeting the southerly current, by a lock built in the canal in 1884. The lock is constructed of timber, the walls being crib-work, composed of a 2 x 8-inch plank, laid flat, one on top of the other, spiked together and filled with broken stones. The lock chamber is two hundred and forty feet long between the gates, and nineteen feet wide. The floor is formed of 10 x 12-inch sleepers, bedded in the ground and covered with two thicknesses of two-inch plank. Outside the lock are waste-gates, thirty-eight feet high.

Frequently during the prevalence of strong easterly gales, the water in the lake rises from eighteen inches to two feet, and, flowing into the mouth of the river, raises it from twelve

to eighteen inches, creating a strong southerly current down the South and West branches of the river, and also up the North Branch toward the Fullerton avenue pumping works. At such times, pumping operations are suspended at the Bridgeport works, the lock of the canal is thrown open, and the entire volume of water in the river, with the sewage filth and sediment, is washed down the canal, and its place occupied by pure lake water, while the filthy river water, forced up the North Branch, is pumped throuh the conduit into the lake. When the North and West pumping works are acting in correspondence, the Fullerton avenue pumping works deliver from the lake into the North Branch of the river 24,000 cubic feet of water a minute, while simultaneously the Bridgeport pumping works remove 60,000 cubic feet of water per minute from the West Branch, and deliver it into the canal basin, the reciprocal action creating a strong and effective current at all times, save when the river is swollen by a freshet and general inundation. At such times, every effort of engineering skill and mechanical invention has thus far proved inadequate to cope with the action of the refractory elements, and the entire body of water in the main channel of the river and its several branches and tributaries is swept into the lake.

Although the capacity of the canal which drains the West Branch of the river is comparatively small, and the current consequently moderate, still the volume of water carried off daily is by no means inconsiderable. The mean velocity of water entering the canal is 6.9 inches a second, the height of the water being eight-tenths of a foot above city datum, and the area of the cross-section of the canal 381.1 square feet, showing that the amount of water passing into the canal is 219.13 cubic feet a second, or 18,932,832 cubic feet every twenty-four hours.

In order to give an idea of the extent to which the Chicago River serves as a common sewer, it may be stated that 7,097.33 surface acres drain into it, from ninety sewer-discharge openings, the area of these terminal openings aggregating 921.81 square feet. In addition, 1,270.43 acres in the South Division of the city drain directly into the lake. The water of the North Branch, from the rolling-mill south, is usually highly discolored, with a perceptible odor; of the main river, nearly free from deleterious matter, with little odor; of the South Branch, highly discolored, with considerable odor; of the West Fork of the South Branch, nearly pure,

with no perceptible odor; of the South Fork of the South Branch, extremely foul, charged with decomposing animal and vegetable matter, and odor very offensive.

Whi'e the highest engineering skill obtainable has been brought to bear on the question of the disposal of the public sewage of Chicago, and while money has been spent lavishly in building the most improved machinery for rendering the river an available and efficient agent for this purpose, it must be conceded that thus far only indifferent results have been attained; and as the population of Chicago shall double and quadruple, it will be found imperatively necessary to push to a successfull solution this perplexing problem.

The Fullerton avenue Conduit, which was completed and put in operation January 9, 1880, is a brick tunnel, circular in section, and twelve feet in internal diameter. It is 11,898 feet long from the lake shaft to the North Branch of the Chicago River, 4,270 feet at the bottom, from the river to Racine avenue, being level and 13 feet below city datum; while east of Racine avenue is a vertical reverse curve connecting the upper and lower grades, which at this point is 27¼ feet below datum. Thence the conduit continues by a series of descending grades to the lake shore shaft, where it is 54½ feet below datum, the grade from this point to the lake shaft, a distance of 1,000 feet, being level. The west end of the conduit excavation was an open cut, while from Racine avenue eastward it was tunneled. The upper part of the lake shaft is a cast iron cylinder, 1¼ inches thick and 24 feet long, lined with brick, and having an internal diameter of 12 feet, the dimensions of the shaft below the cylinder being the same. The top of the cylinder is 4½ feet below city datum, and is located in a wooden chamber, 34 by 18 feet inside, with openings on the east side into the lake, which are fitted with gates, to be closed only when the cover is on the shaft, and to prevent its being lifted or damaged by the violence of the waves. At this end the water is shut off from the conduit by a conical cover of boiler-plate iron, on the lower end of which is a strong inclined flange fitting on a corresponding flange cast on the top of the shaft, with a packing of rubber tubing between the two flanges, rendering the joint water-tight. The cover projects above the water, and an opening permits access to the shaft, which is protected from the turbulence of the lake by a pier of pile-work, securely braced together, filled to the water level with loose stones, and built so as to offer the least resistance to ice and storms. On the pier and over the shaft

is a house, fitted with a winch for raising or lowering the cover of the shaft. The shafts at the lake shore (Larrabee street and Sheffield avenue) are twelve feet internal diameter, while at each intersection are shafts of six feet internal diameter. All shaft are carried up to the level of the street, are so arranged as to form ready connections with the sewerage system, and are domed over, with openings on the top for access, provided with strong covers and with ladder-irons.

At the river end, where the machinery is located, the conduit forms two semi-circular channels, passing on each side of a wrought-iron chamber, where the two channels are re-united, forming one channel of size and section uniform with the main conduit, and continuing to the outlet of the river, where it is protected by a heavy masonry dock wall, in which is placed a series of iron rods, to guard against floating debris entering the tunnel and obstructing the wheels when the current is from the river to the lake. The water is forced through the conduit by means of two screws similar to those of an ordinary propeller, one fixed at either end of a horizontal shaft forty feet in length and placed in the center line of the conduit, passing through a boat-shaped iron-chamber, ten feet in its greatest diameter. The shaft and screws are operated by two single-cylinder condensing engines, having cylinders twenty inches in diameter and thirty-inch stroke, with side-valves, cut off motion, and reversing gear, permitting the engines, which are placed on top of the chamber, to run either way, reciprocally. The driving-shaft is eight inches in diameter, and the engines are coupled to the middle or crook-sections by connecting-rods sixteen feet long, this section carrying also eccentrics for working the valves. The screws are four-bladed, six feet and seven inches in diameter, with a pitch of eight feet, the blades being twelve inches in width. The total area of the four blades of each screw is equal to one-half the total area of a complete turn of the helicoid. There are three cylindrical boilers, sixteen feet long and sixty-six inches in diameter, with forty-five inch longitudinal tubes in each boiler. The boilers have thirty square feet of grate surface each, and one thousand square feet of heating surface, and are connected with a brick chimney three feet nine inches square inside and one hundred feet high. The boilers are calculated to stand a pressure of eighty pounds to the square inch, and the engines to work at a rate of one hundred and twenty-five revolutions a minute. The size and form of the screw are novel and without precedent, a pro-

pelling wheel having never before been used for the purpose of forcing water in a confined channel; but it has been found to work satisfactorily, and to perform the duty required of it with the greatest economy. With one hundred revolutions of the screw, a head of four feet is maintained in the line of the conduit, a force sufficient to deliver twenty-four thousand cubic feet of water a minute.

Careful observations, with experiments continuing through two days, gave results embraced in the accompanying table, which shows the velocity of water in the conduit, measured at different positions with an electric current meter. Diameter of the conduit, twelve feet; length, eight thousand nine hundred feet between stations; obstructions to flow, sixteen shafts of six feet diameter, two shafts of two feet diameter, two bands of forty-five feet radius; angle, thirty degrees.

It is interesting to note that the current through the conduit is induced with the same power when discharging into the river as when discharging into the lake. It has been demonstrated that, in pumping lakeward, the machinery does not actually displace and force before it the volume of water contained in a mile of conduit of twelve feet diameter, but that, instead, a whirling or screw-like motion is given to the water in the conduit, which obtains an edyying current through its entire length, similar to the motion given to a conical shot discharged from a rifled musket. So strong does this current become, that if the engines of the pumping works are shut off, the propeller screws in the chamber of the conduit continue in motion several minutes.

The original cost of these works was $564,253.99. During May and June, 1882, new wheels, eight feet in diameter, were put in the conduit, materially increasing both the power and the efficiency of the works.

During 1884, the pumps delivered the water mainly from the river into the lake, 5,175,000,000 feet being forced in that direction, as against 1,238,000,000 feet from the lake into the river.

The cost of operating the works during the year was $20,246.63. The effect of pumping from the lake into the river was unsatisfactory, the water in the North Branch quickly becoming foul, and fermenting, and in the main river, in three or four days, during the summer solstice, becoming very offensive, even while the pumps in the South Branch were in operation.

The propellers were operated almost continuously during

1885, usually with sixty revolutions per minute (about half their capacity), with about the same result as in previous years, excepting that the volume of water passing through the conduit was poured into the river, instead of being emptied from the river into the lake. Early in the year, the frame-house over the lake terminus of the conduit was burned, the debris falling into the mouth of the conduit. The smaller pieces of timber from time to time passed through the conduit and wheels without detriment, but in the summer, a shock was sustained by the machinery, and it was found that a solid oak timber, four feet long and twelve inches square, had wormed its way through the blades of both screws without occasioning any perceptible damage. In November a second timber, five feet long and a foot square, presented itself to the propeller wheel, stripping the four blades from the first wheel and two blades from the other wheel. This necessitated the shutting down of the works for two weeks. The influx and efflux gates were closed, a diver was sent into the conduit to remove the timber, the water chamber was pumped out, and new wheels were substituted for those broken.

The Canal Pumping Works, at Bridgeport, were completed and put in operation in 1883. The building is located across the old channel of the Illinois & Michigan Canal, two hundred and sixty-five feet west of the South Branch of the Chicago River. The influent channel is sixty feet wide, dredged to a depth of ten feet below city datum, the sides being vertical and maintained by a strong timber dock. The effluent channel is excavated to a depth of six feet below city datum, the side slopes being paved with stone. The machinery consists of four sets of pumps, each set being composed of two centrifugal cataract-pumps placed in a dry-well below the surface of the water in the river, and driven directly by a vertical condensing compound engine, the high-pressure cylinder being eighteen inches in diameter, and the low pressure cylinder thirty-four inches in diameter, each having a stroke of thirty-four inches. The pump-wheels are of cast iron, six feet in diameter. Each pump is coupled directly to the engine crank-shaft. The engines are adapted for running at high speed. There are eight horizontal return tubular boilers, each six feet six inches in diameter, eighteen feet long, and containing sixty tubes, each four and one-half inches in diameter and eighteen feet long. The boilers are capable of sustaining a pressure of eighty pounds to the square inch, and are placed in two boiler houses, one on each side of the influent chan-

nel. Each set of boilers is connected with a nine-inch steam-pipe in the engine-room. The machinery has a capacity for raising sixty thousand cubic feet of water per minute to a height of eight feet, and develops a duty of forty-five million pounds of water raised one foot high for every one hundred pounds of coal consumed. The total cost of the works was $268,000. The operations in 1884 resulted in maintaining the water in the South Branch of the river and in the canal in a satisfactory condition, besides improving canal navigation. The cost of operating the works during the year was $32,584.78. The operation of the pumps had no effect on the water in the South Fork of the river, extending from the pumping works to Thirty-ninth street, and which is a general cess-pool for the accumulations of refuse matter from the stock yards slaughter-houses. This putrid stream is a nuisance, detrimental alike to the section through which it passes and to the city at large, and no effectual plan has yet been devised for cleansing it. The pumps have discharged the full volume of water that could be carried away by the canal without overflowing its banks, the quantity being about forty thousand cubic feet a minute, or about two-thirds the capacity of the works.

EXTRACT FROM A REPORT OF MAIN DRAINAGE COMMITTEE TO THE CITIZENS' ASSOCIATION 1880.

The Topographical Situation of the drainage district under consideration may be briefly described as a strip of land, in the eastern part of Cook County, varying in width from 7 to 10 miles, traversed by the Chicago River its whole length, which is about 40 miles; the only outlet of this River to the Lake is at the point where the City of Chicago stands, about 35 miles south of the source of the river, and 5 miles north of the southern most of its branches or forks; the outlet to the lake at Chicago has been widened and deepened and its course changed so that it opens nearly due east, is called the main branch of the Chicago River, and is at right angles to the principal streams which are called respectively the North and South branches. These branches have also been widened and deepened to meet the necessary requirements of commercial enterprise, so that vessels of from 10 to 14 feet draft can navigate with safety the River and its branches, to a distance 1 mile west from the entrance and 6 miles north and south, all within the city. The process of enlarging the River, at Chicago, has destroyed what little natural current

there ever was in it, and there is now no other than that caused by winds, the inflow of water from the lake, or a freshet caused by extraordinary rainfall or the melting of snow and ice in the spring. For the purposes of this Report the Chicago River may be described as a great ditch 6 miles long, with a projection from about the center one mile long, and the whole averaging about 150 feet in width and 10 to 15 feet deep; this ditch receives at its north end a small stream, (30 miles in length), the force of whose feeble current is neutralized by the increased width and depth of the channel it enters, and it has at its south end several forks or branches which serve to take off a small amount of water; there is also, from the south end, the Illinois and Michigan Canal, to which reference will be made hereafter. Into this huge ditch the greater part of the sewage and other drainage of the City of Chicago falls, together with the offal of the immense slaughtering establishments, situated in the adjoining Town of Lake, the refuse of the manufactories great and small, and to far too great an extent, that of the distilleries and their adjoining cattle pens. A part of the sewerage system has its outlet directly into the lake in front of the city, but that part is by comparison so small as to have no bearing on the main question before us, at this point of its consideration. The whole geographical position is backed on the West by a ridge, which though of no great elevation, is sufficient to form a water shed of the greatest length given above, with the river running through it about equi-distant from the ridge and Lake Michigan; the land between the ridge and the lake traversed by the river is flat, and just where the city stands, is a little higher on the west bank of the river than on its East side, towards the lake; the natural flow of water from all points is towards the River and not to the Lake.

The Only Natural Means of flushing or scouring out this great ditch, is from the water during rains, which flows into it from the adjoining country, including that part bordering the northern projection, the freshet caused by the melting of snow and ice in the spring, and the overflow of the Des Plaines River, which sometimes swells over the low ridge referred to above, and comes in great and often destructive volume into the South Branch and so through the Main Branch of the Chicago River into the lake. Could this be relied on at all times, it might be so utilized as to relieve the drainage difficulty now before us, although it would necessitate some other plan than that we have adopted for our water

supply for domestic and all other purposes; it is, however, unfrequent and undesirable.

The obvious consequences of this state of affairs is that at all times since the city adopted a system of sewerage, the River has been befouled with its discharges and accretions, for which there has been no natural remedies, except those of the occasional character mentioned above. As the population increased this befoulment became more marked, and in time so unendurable that relief of some kind became imperatively necessary, as, although the pumping works at Bridgeport, originally erected in 1847 for the purpose of supplying water to the Illinois and Michigan Canal had been utilized for the purpose of cleansing the river to the extent of their capacity, that system was found to be very inadequate for the object, and after 5 years work the Canal was widened and deepened so that in 1871 it was opened for the inflow of the Chicago River, amidst public rejoicings, and there was a sanguine belief that our drainage troubles were at an end. It was soon found that these anticipations were doomed to disappointment; the depth of the canal after enlargement is about 8 feet less than that of the River, and the sides were cut down at an unfortunate angle, making them too steep or upright; the consequence has been that the water flowing from the lake to the canal, through the river, has only cleansed that portion of the last which was 5 feet above the bottom, there being a recoil at the miter sill of the canal, of the water below it, and a backward current of greater or less power according to circumstances; besides this, the canal began gradually to fill up from the sediment carried into it from the river, and from the deposits naturally coming over the sides, thus decreasing the depth and the capacity for taking water from the river; at about this time, (1871) also, the Lake began to fall, as it is known to do at periods, diminishing the volume of water in the river. The net result of all these causes was soon apparent. It was seen that by deepening the canal we had only lengthened the ditch which we call the Chicago River, and that after the canal had been filled, it was, with such relief only as is obtained by opening the locks for the passage of vessels or other purposes, fast becoming as foul as the river itself, to the unmitigated annoyance of the inhabitants along its line; and it was the subject of their loud protest. Nothing can keep it even moderately clean but constant dredging, rendered more expensive from the very fact that it has been deepened.

Some other means of cleansing the river was demanded,

and the Fullerton Avenue Conduit was projected, to scour the river by pumping from the lake, or, *vice versa*, to create a current through the main river, up the north branch, and so out into the lake, flushing the south branch as a collateral measure by the natural process of displacement or suction which would follow.

It were profitless to attempt to detail the various annoyances the public have been subjected to during these many years they have been waiting for some plan of relief for their sufferings from the foul condition of their principal sewer, which unfortunately for the purposes of drainage, is also a navigable river; an overflow of the Des Plaines or a freshet from any cause has been hailed with something akin to delight, and a easterly storm by driving in the water to dilute and carry off part of the filth has been looked upon as a blessing.

We have arrived, in this report, at that period of time, (February and March, 1880) when, while the Fullerton Avenue Conduit is in full and partly successful operation, the public meetings referred to above were held with the view of a free discussion of the whole subject.

In addition to the facts hereinbefore stated, some others having a very important bearing on this question were brought to light, the principal one being that which relates to the operation of the Fullerton Avenue Conduit, which had at that time been sufficiently tried in one direction, that of sending water from the lake into the river, and so out by the main branch into the lake again, to develop the danger there would at all times be of fouling the water supply for domestic purposes; the experiments made for the purpose of ascertaining such a probability, demonstrated conclusively that a very considerable quantity of the filth discharged from the mouth of the river found its way back into the water pipes, and further investigation has shown that except under favorable conditions this will always be the case, as the contents of the river will not, all of them, mingle immediately with pure water, and be carried away by any current that may be caused by winds, favorable for the purpose, but for a long time will float about the lake in a semi-isolated mass, subject to the effect of such winds and currents as may strike them, and always liable to run into the tunnel at the crib; and for this reason, that there is always there an effective current for a considerable distance in every direction, around and tending towards the crib. It was shown also, that temporary relief could be obtained by the immediate re-erection of the pump-

ing works at Bridgeport, and it is believed that with the aid of the Fullerton Avenue Conduit, these pumping works at the entrance of the Canal will afford such a measure of relief as will enable the city to get along with moderate annoyance for five years or so, or until some better system has been brought into operation. The immediate re-erection of those pumps, was, therefore, the recommendation made by our Committee, through you, to the municipal authorities, as a temporary expedient, and the money having been appropriated by the Council for the purpose, the action of the City Executive is awaited with becoming patience.

Review the topographical situation as hereinbefore given, revise the meagre history of the attempts to purify the river, consider the feeble means now in operation and those necessarily temporary adjuncts looked for at an early date, and tc these considerations add the probability that the drainage district we have contemplated is to be the home of 2,500,000 people within the period of existence of many now living, and you have before you the drainage problem as we understand it.

* * * * * * *

We present to you and the public a proposition or plan for an independent cut for the drainage of the district to which we have heretofore alluded, the details of which are embodied in the following report, from the well known and competent engineer whose name it bears, whose services you placed at our disposal, for the purpose of making the estimates, and drawing the map and profile accompanying it, reduced copies of which we append hereto, and the originals of which are on exhibition at your rooms in this city, for inspection of the public.

Such is the plan proposed for the drainage of Chicago, which, it is believed, will accomplish the object desired for all time to come.

To complete it, however, the sewers discharging into the lake will have to be reversed, and made to empty into the river, as also, the local drains in the adjoining towns north of the city, as far as the source of the Chicago River, and those of Hyde Park. The towns of Lake and Cicero will also come within the drainage district herein proposed. In reversing the city sewers, such a fall should be made as would carry the lake water through them, thus cleansing and rendering them inoffensive at all times. The Fullerton Avenue Conduit could remain as it is, or its tunnel could be utilized

for additional water supply. An intercepting sewer can be built if needed.

The forks and branches of the river at the south end of it will purify themselves, as their contents will gravitate towards the current created by the outflow of water to the cut or New River, as it may be called for the purpose of description. The current in this New River will be at the rate of about 2.15 miles per hour; the water in Chicago River will be changed every 24 hours, with One Million of cubic feet over, and the whole body of it within the city limits, will be by this operation, become as clear as that of the lake; the effect upon the waters at its point of discharge, will be to greatly improve them in every respect.

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REPORT OF THE COMMITTEE ON MAIN DRAINAGE AND WATER SUPPLY.

Chicago, Aug. 27, 1885.

To the Executive Committee of the Citizens' Association:

The undersigned committee appointed for the purpose of investigating the subject of Main Drainage and Water Supply of Chicago, begs leave to submit the following report:

A problem of the first magnitude is presented in the main drainage of a city of 700,000 inhabitants, with the immediate prospect of a population of 1,000,000, and a growth of 2,000,000 within the life-time of citizens who knew Chicago as an Indian trading-post. That the city should have attained this growth without the development of an adequate official plan, for a permanent system of main drainage would be startling in this day of sanitary science, were it evident that the conditions of the problem had ever been properly apprehended. The sanitary history of Chicago is a history of makeshifts and expedients, in which official provision has scarcely ventured beyond corporate limits to the consideration of the drainage basin of which the municipal area is but a small fraction. Even those expedients which, while involving a moderate expenditure for the relief of the present situation, might still be in harmony with a general plan, seem to be inadequately realized, or quite misapprehended.

Chicago, in regard to her water supply and main drainage, is perhaps, more fortunately situated than any other of the principal cities of the country, except those on our large rapidly flowing rivers, which carry away the sewage at once, a condition which may here be readily duplicated. Cities on

tide-water or minor streams, with much less population and having problems of greater difficulty to deal with, have not hesitated to make far greater expenditure, in proportion to their resources, than is required here for measures of permanent relief. They have considered it wise, before the public health was menaced, to call in the most eminent experts to consider the problem, with a view to the best solution that the conditions permitted. They have even regarded large expenditure in the collection of data and in exhaustive preliminary study as a measure of undoubted wisdom.

Your committee has been able to give to the subject only a few weeks of special observation and study. Its sources of information are accessible to any citizen who chooses to investigate the matter for himself. Cognizant of the facts of our sanitary history, it is a matter of no great difficulty to define present abuses, to point out measures of relief and to suggest a general plan for the permanent solution of our drainage problem, as a matter for popular discussion and expert consideration.

Pollution of the Water Supply.

In the great rain of August 2 of this year, the contents of both branches of the Chicago river, with the sewage accumulation of many weeks in the South fork, the contents of slips, and the flushings from several hundred miles of low-grade sewers, were, in a few hours, incontinently belched into the lake. At every considerable freshet in the Desplaines and in the North branch, or several times in an average season, a similar obnoxious flood, differing little in degree, is turned lakeward. At other times the flow from the Desplaines is quite sufficient to supply the canal, and the South branch is left in a stagnant condition of accumulating putridity, ready to take its way to the lake on slight occasion. Your committee found the South branch in bad condition a week after the great storm, and within ten days the South fork was pestilential—a seething, bubbling mass of decomposition, exhaling the most noisome odors.

The ejection of such volumes of sewage into the lake at irregular intervals, is a matter for most serious consideration in connection with the water supply. That it sometimes reaches the crib under favoring conditions of wind and current is a matter of direct observation and evidence from city hydrants. That it sometimes extends southward to the Hyde Park supply is also ascertained. Even the comparatively small discharge from the Fullerton avenue conduit has given

evidence of pollution when no other sewage was entering the lake. Recently the discharge from this conduit was observed in an unbroken stream for over a mile south and parallel to shore, and again in a similar position to the north, to the well-grounded alarm of the people of Lake View. That raw, unoxidized sewage occasionally and not rarely contaminates our drinking-water, does not admit of serious question.

((Foot-note a): On Wednesday, August 5, the river discharge was observed in an unbroken stream to and around the crib. Chemical and microscopical examinations of the water, collected under different conditions, are appended to the Supplementary Report.)

If we suppose the entire sewage of Chicago for one week—and such accumulation is sometimes greatly exceeded—to be turned into the lake at the mouth of our harbor and uniformly distributed through the water for four miles into the lake and eight miles along the shore, each 200 gallons of water would contain one gallon of sewage. Sanitary authorities variously estimate the dilution required to oxidize sewage beyond offense at twenty to one hundred times. As this oxidation requires time, no argument is needed to make it apparent that, in the general diffusion of the contents of our river through the body of water off-shore, partially oxidized sewage reaches the crib. Even though we admit the complete oxidation and diffusion of sewage through the waters off this shore, sanitary science would hardly commend the domestic use of oxidized sewage, nor will the average citizen feel reassured at the admixture of a half-gallon thereof in his daily water supply. (See microscopical and chemical examinations in Supplementary Report, pp. 22-32.)

The tendency, however, of streams of different specific gravity and constitution is to remain isolated, or to diffuse slowly, as may be observed where any stream debouches into a body of water, or where two rivers unite. For this reason a large sewage discharge may remain off our shores unoxidized for a much longer period than if we could suppose it rapidly and generally diffused. The danger from sewage contamination would thereby be greatly increased and of oxidized sewage in no wise lessened.

While the occasional admixture from sewage is beyond dispute, and the presence of oxidized sewage is probably far more frequent, the determination of any well-defined current that may prevail in the lake off our shores would be a matter of great interest. So far as the observations of your committee extend, they go to show that the surface current is

most largely a matter of direction of wind, and is accompanied by a counter-current near the bottom; so that with a stratum of sewage-water beneath, mere surface observation is not sufficient to determine the direction or extent of its movement.

It is obvious that if sewage is allowed to debouch into the lake at all, freedom from risk of contaminating our water supply can only be secured at great expense—far greater than would be required to permanently dispose of the sewage in some other direction.

* * * * * * *

The South Fork.

That this branch has been allowed to continue, from year to year, in an abominable condition of filth beyond the power of pen to describe, is one of the anomalies of our municipal history. Flushed only during periods of heavy rainfall, its contents inevitably find their way to the lake. Its highly offensive condition is most largely due to the extensive packing establishments, and the industries incidental thereto. As this is a special class of sewage, it would be fair to demand chemical precipitation, or other treatment equally effective, thus removing at once a large, and the worst, proportion of putrescible matter. Measures of permanent relief should be instituted at an early day. Several plans for regularly voiding the contents of this fork can be suggested. One of the best would seem to be a pumping station and a conduit on 39th street to Lake avenue, on Lake avenue to 56th street, and along 56th street to the lake, thus furnishing a proper outfall toward the South fork for the sewerage of the northern portion of Hyde Park, which is naturally tributary to the Chicago district. The opening of a navigable channel along 39th street is also worthy of consideration; a channel that may be demanded in the interest of permanent bridges in the heart of the city, and also by the requirements of commerce in the southwest district whenever the National government may have developed ample water communication to our Western rivers. Incidentally, it may be said that the main sewers on 12th, 22d, and 35th streets, which now discharge into the lake, should ultimately have their outfall at the river—the natural elevation being sufficient for that purpose—and that no new outfalls on the lake front should be contemplated in the future.

The west arm of the South fork is the natural outfall of a large portion of the town of Lake, south to 60th street. Unless it is filled up or farther extended through to the canal, at

an early day, its proper cleansing will present a serious problem. Meantime, to drain into it the surface water naturally tributary thereto, and which has been diverted to the canal, would at times afford some relief.

* * * * * * *

Flood Dangers.

The treatment of the flood discharge is a far more difficult matter, but a question of much moment, aside from its relations to our sanitary problem. Old citizens will remember the great flood of 1849, and the destruction produced thereby, a flood that is liable to recur under exaggerated conditions with unlimited capacity for mischief.

The Desplaines water-shed has been largely cleared up and water-courses opened, so that floods come more suddenly and in greater volume than in former years. There is liable to be an accumulation of from twelve to eighteen inches of water in the form of snow over this area, to be quickly melted by a warm rain, in a manner similar to the great Ohio river flood of 1882. If this be accompanied by an ice gorge in "Twelve-mile level," below Summit, as would be probable, this great flood would be precipitated through Chicago in untold damage. With no ice gorge, the result would be sufficiently disastrous.

It is unwise to argue that such danger is remote. All the conditions except the usual temperature and rainfall were fully satisfied in 1881. Fortunately, with an average temperature of 34 degrees, and a rainfall of only one-half inch during a period of twenty-one days, this great body of snow was gradually melted, not, however, without a long-continued large flood volume, attended with considerable damage. It is hardly supposable that nature would be again so considerate.

The necessary combination of circumstances has occurred too often at other localities to warrant the belief that Chicago will be definitely exempt, and she is built above no protecting bluff escarpment.

Suggestions for a Permanent Solution.

Your committee has incidentally brought to light facts bearing on a solution of the drainage problem, which would appear to have been hitherto unconsidered. They are stated as suggestions to, and in argument for, a body of experts, which should be constituted without delay, to adequately consider the whole subject in full detail.

The general problem as it appears to your committee may be stated as follows:

1. By keeping the sewage out of the lake, Chicago can avoid a nuisance on her shores and save, in future changes and extensions of her water-supply system, a large part if not the whole of the cost of an adequate main drainage.

2. Experience has not yet developed any artificial treatment of sewage that does not involve a large first-cost and continual expenditure. The best of these, by the method of intermittent downward filtration, is not feasible for Chicago, on account of the great distance to proper land. Even were all the conditions properly fulfilled, some means would still be required for circulating the water in our rivers. In the possibility of disposing of the sewage quickly, by natural flow, and at far less cost, any plan of sewage treatment may be dismissed from present consideration.

3. The proper disposal of the sewage is unquestionably down the valley of the Illinois. It must be diluted to that point which will speedily produce a complete oxidation, or the growing populations along the river will not permanently tolerate so insufferable a nuisance.

4. The contents of all channelways, into which sewage is discharged, should be changed so rapidly that no sewage will remain within the city limits over twenty-four hours.

5. The drainage area, now tributary to the sewerage district, should be reduced as much as possible in order to avoid the variations of rainfall over large outlying districts, the danger of floods, and the liability of an occasional discharge of the contents of our channelways into the lake. The main drainage of Chicago involves the entire water-sheds of the Desplaines above Summit and of the North branch, and the region south to the general east and west line of 60th street, an area of nearly one thousand square miles. It has already been suggested that the North branch can be readily diverted to the lake from Bowmanville, thus reducing the area by over one hundred and twenty square miles.

An examination of the Desplaines river shows far greater capacity for many miles above Summit than below; in fact, for twelve miles below Summit the bed is a succession of pools, with rock bars, differing little in height, and retaining the water at a uniform level of about eight feet above Chicago datum. With a mile of bank only three or four feet above low water, and broken by frequent crevasses of one and a half feet opening out into the rapid descent of Mud lake valley, it must be evident that a large proportion of all flood-waters, above a certain minimum discharge, find their way to the lake. The entire flood discharge of the Desplaines can, without

doubt, be readily confined in a course to the south, but this is a course which it has never pursued, and such diversion of its natural flow would render the city liable for any resulting damages. Unquestionably the channel could be greatly improved so as to diminish this liability, and this might be expedient did not a better solution offer.

From an examination of the divide between Desplaines and the North branch, it is found feasible, at moderate expense, to divert the Desplaines near the south line of the town of Maine into the North branch at its westerly bend; thence following the North branch valley to Bowmanville and to the lake through Lake View.

This diversion would dispose of from 75 to 80 per cent. of all the flood-waters of the Desplaines gathered from the watershed above Summit, besides the flood waters of the North branch as previously suggested. There will remain about 100 square miles, which may be called the Chicago sewerage district proper, and about 160 of the Desplaines, or 260, in place of about 1,000 square miles, to consider in a scheme of main drainage.

Assuming that an increased capacity of the canal is conceded as an essential in any scheme, your committee offers the suggestion that such enlargement be confined to the first eight miles, or to a point near Summit, at which the canal and the Desplaines are within less than a quarter of a mile of each other, and where they may be readily connected. A full consideration might show that from Bridgeport to Summit, the West fork and Ogden-Wentworth ditch route, would possess superior advantages.

For twelve miles below Summit, or until we reach Walker's quarry above Lemont, the water stands on a level about eight feet above datum, or less than five feet above present lake level. Throughout this reach there is much channel of twelve feet in depth and of ample width, and much more that would undoubtedly cut out to that depth under the influence of a brisk current. For only a small portion of this distance were rocky fords found, and it is believed that a full examination would not disclose a serious amount of rock excavation; so that channel may be produced here seven feet below present lake level, and not less than two hundred feet wide, for twelve miles, at comparatively small expense. For eight miles below Walker's quarry the channel would be practically in continuous rock-cut, the average declivity of this portion of the valley being about one foot per mile. Near Lockport it falls off rapidly to twenty feet below datum. It would seem from the

examination thus far made that a channel of sufficient capacity can be made on this route for about one-half the cost of enlarging the canal, and this channel would be capable of future enlargement at moderate cost. This route can only be considered, however, in connection with the diversion of the flood-waters of the upper river.

The duty of the new channel would be to take care of the natural flow of 260 square miles of territory and the sewage, properly diluted, of its population. It can be developed with ease into a great navigable channel, and furnish an ample water supply for the low-water navigation of the lower river from the most magnificent reservoir available as an aid to navigation, and make apparent the error of the opinion which led to the construction of locks and dams on the Illinois, below Peru. In an ample section, with all the depth and grade which could be given to a channel from Chicago to Joliet, the stream would be readily navigable, as experience has shown with much higher velocities on our Western and Southern rivers. If the project should ever be carried out with due regard to its possibilities as an aid to navigation, over one hundred thousand horse-power would be available between Lockport and Peru, the yearly value of which would represent a dividend on many millions of dollars.

The suggestion proposed has the merit of inviting expenditure for present relief in the direction of an ultimate plan, each step of which would be of substantial benefit. Thus, in a very few years, without the necessity of an increased indebtedness, a permanent plan may be carried out at a relatively small expense as compared to that of many of our cities. At the same time an important step would be taken in a proper project for connecting the navigation of the Great Lakes with that of the Mississippi river, which may be followed by the General government without suspicion that it is purely in the interest of a local drainage project.

The solution of our drainage problem involves contiguous territory, many diverse interests, and a mature expert consideration, after the most comprehensive data have been collected. It would be rash to urge any project as the best in advance of the competent study which should be provided for, but in calling your attention to what appears to be a ready solution of the problem, it must be apparent that the matter has not hitherto been adequately considered.

Your committee would urge with all possible force the necessity of an expert commission to make the fullest investigation. The commission should be constituted for an ample

period, and be sufficient in number to give competent expert consideration to all phases of the problem and to eliminate purely personal views. To suppose that those charged with executive duties in a great city will find the leisure to adequately consider the matter would be to ignore our past history.

* * * * * * * * *

Respectfully submitted,
O. GUTHRIE,
L. E. COOLEY, C. E.,
F. W. REILLY, M. D.,
WM. RUTHERFORD,
CHAS. A. MACDONALD,
DAVID BRADLEY,
J. J. GLESSNER,
EDWIN LEE BROWN,
Committee.

REPORT OF THE COMMITTEE ON DRAINAGE AND WATER SUPPLY.

To the Executive Committee of the Citizens' Association:

And by it Adopted and Ordered Printed, May 25, 1887.

The Committee on Main Drainage and Water Supply respectfully submit the following report:

On January 27, 1886, the City Council of Chicago passed the following resolutions:

WHEREAS, Pure water and scientific drainage are necessities of this community, and the people demand a system of water supply and drainage adequate to meet the requirements, not only of the present, but of years to come, nor will any temporary expedient or makeshift satisfy them; and,

WHEREAS, A thorough and permanent system of supplying pure water to our citizens and caring for the drainage of the municipality, cannot be paid for out of current taxation, therefore it is desired that a plan shall be devised and perfected before the next meeting of the legislature, to the end that necessary legislation may be had.

"For the purpose of carrying into effect the objects sought, there is recommended, the appointment by the Mayor of a commission to consist of one expert engineer, whose reputation is so high that his opinion and report will command the respect of the community, and with him one or two consulting engineers, of like experience in engineering and sanitary matters. The duty of this drainage and water-supply commission, made up as above set

forth, should be to consider all plans relating to drainage and water supply which may be brought to its attention; to make such examinations and investigations and surveys as may be deemed necessary; to collect all information bearing on this problem; to consider all recent developments in the matter of sewage disposal, and their application to our present and future needs; to consider and meet the necessity of increasing our water-supply and of protecting the same from contamination; to remedy our present inadequate methods of drainage and sewage disposal, to consider the relations of any system proposed to adjacent districts, and whether there may not be a union between the city and its suburbs to solve the great problem, to determine the great question, as to the interest which the state and the United States may have in the disposal of sewage by way of the Illinois River, and to devise plans to meet any objections thereto, if such a system shall be thought best; and in general to consider and report upon any and all things which relate to the matter of water-supply and drainage of the city of Chicago.

The Commission should report on the whole matter committed to it in the most full and comprehensive manner, with maps, plans, and diagrams complete, and accompany the report with estimates of the first cost and annual requirements for the maintenance of the system proposed.

The Report of the Commission should be made as early as practicable, and not later than the convening of the next session of the Illinois legislature in January, 1887."

The Commission on Drainage and Water Supply appointed under this resolution, consisting of Rudolph Hering, as Chief Engineer, and Benezette Williams and S. G. Artingstall as consulting engineers, in their preliminary report of January, 1887, recommended the adoption of sewage disposal which would turn a large stream of water from Lake Michigan through the Chicago River, and thence down the Des Plaines River into the Illinois River, carrying along with it in a highly diluted state, the sewage of the city as well as that of the towns along these rivers.

Two other possible methods were considered, viz.: Discharge of the sewage into Lake Michigan and taking the water at some point north, say Grosse's point; and "Land Disposal," which means collecting the sewage into great main sewers and

pumping it out upon land, to be procured for the purpose. The Des Plaines system is preferred for a number of reasons: 1st. It will be the least expensive by many millions of dollars. 2d. It is the most comprehensive and satisfactory. 3d. A channel of the requisite capacity to carry off the storm water from the area provided for, at the same time that it carried a large and steady stream of pure lake water through the heart of the city, taking up and completely diluting the sewage, will, to use the language of the commissioners, "from the necessary dimensions and its regular discharge, produce a magnificent waterway between Chicago and the Mississippi River, suitable for the navigation of boats having as much as 2,000 tons burden," and "establish an available water power between Lockport and Marseilles fully twice as large as that of the Mississippi River at Minneapolis."

This "Des Plaines System" involves the construction of the following works:

1st. A channel from the South Fork of the Chicago River along the Ogden Ditch to the Des Plaines River at Summit, and thence along the bed of that river to Joliet. The capacity of this channel, as appears by the preliminary report of the commission, is to be 600,000 cubic feet of water per minute, or say, 200 feet wide by 18 feet deep, or 160 feet wide by 22 feet deep, with a current of 2 miles an hour. This capacity is required, according to the testimony of the engineers,

> "to keep the sewage from backing out into the lake in times of flood, to contaminate our water supply when the city is virtually taking a bath. After the diversion of all possible tributary waters to Lake Michigan, there will remain 125 square miles of the future drainage district, partly paved and sewered, and 295 miles of country district below Summit, tributary to the new channel above the first weir at Lockport. In this (channel) the lake water will be entirely replaced at times by storm water."

The cost of this work for the wider channel is estimated by the commissioners at between $17,000,000 and $20,000,000; the narrower channel can be built for about $15,000,000.

2d. A cut off from the Des Plaines commencing in the northeast corner of Leyden and running thence easterly to the North Branch, thence down the North Branch to Bowmanville, thence east to Lake Michigan. The object of this cut off is to divert from the Des Plaines and the North Branch the storm waters of about 500 square miles of territory lying

north of the cut-off. This amount of flood water is in excess of the capacity of the proposed Des Plaines Channel and the cut-off is necessary, as before shown, to prevent these streams from forcing the sewage into the lake in times of flood. It will also be of great advantage, if not of necessity, in keeping the water of the Des Plaines out of the main channel during the progress of its construction below Summit. The cut below that point is through rock and the excavation cannot be carried on under water. This cut-off, with a dam at Summit, is estimated to cost between $2,500,000 and $3,000,000.

3d. Pumping works and locks in the North Branch in connection with the cut-off for the purpose of cleansing that branch south of the cut-off, to cost about $150,000.

4th. A separate system of sewers to collect the sewage now discharged directly into the lake and to carry it into the river, at a cost of about $600,000.

5th. A channel from Lake Calumet to the Sag at cost of between $2,500,000 and $3,000,000.

6th. A diversion of the flood water of the Calumet River at a cost of between $350,000 and $400,000.

The commissioners find that in designing any permanent plan of drainage and water supply for Chicago, a certain area embracing the city and several suburbs must be taken into account and treated together. They say:

> "Investigation has shown that topographical conditions clearly define two districts for the future metropolis. The main district extends from the line of 87th street on the south to the north line of Evanston and from the lake westward to the Des Plaines River. The other extends over the natural drainage area of Calumet Lake and River south of 87th street."

This area is occupied by several distinct municipalities, viz.: The city of Chicago, the towns of Hyde Park, Lake, Calumet, Worth, Cicero, Lyons, Riverside, Norwood Park, Jefferson, Lake View, Evanston, and Niles, and in some of these, incorporated villages. Neither of these has the requisite power to proceed with such a system alone, nor is it practicable, if indeed it is possible for them to act conjointly. There is therefore no way left but for all the outside towns to become annexed to the City of Chicago, or for Chicago and these towns to unite in creating a new municipality co-extensive in its limits and jurisdiction with the area and subject matter to be treated. If all the outlying towns mentioned were at the present time a part of the city of Chicago, several serious

practical difficulties would stand in the way of the execution of the system recommended. Chicago is incorporated under the general city and village act, which does not give power to construct the works necessary to be constructed outside its corporate limits, such as the Des Plaines Channel, the Bowmanville cut-off and Sag Channel. This might possibly be remedied by an amendment to that act; but a more serious difficulty would exist in the fact, that the debt of the city of Chicago is now about $2,000,000 in excess of the constitutional (5 per cent.) limitation upon the entire valuation of the property in the proposed municipality. The limitation upon the amount of annual tax a city may levy is still another difficulty that would stand in the way of the execution of so great a work.

The Committee, in the preparation of a bill to carry out the recommendation of the commission, were therefore driven to the necessity of providing for the organization of a new municipality, co-extensive in its territorial limits and jurisdiction with the area involved in the system proposed and with powers equal to the requirements. We refer to the bill now on third reading in the House of Representatives, and known as the Hurd Bill, and which was endorsed, and the passage of which has been urged by the executive committee of the Citizens' Association. Its terms are known by your body, but it may be well to give an epitome of it:

It authorizes the organization of a metropolitan town to contain not less than 500,000 inhabitants and comprising not less than five townships. It must be adopted by a vote of each of the towns that shall form a part of it. The corporate powers are to be exercised by a board of four commissioners to be appointed by the governor. Their term of office is four years. No more than two of the commission are to be taken from the same political party. The officers of the corporation are to be a clerk, a treasurer, a chief engineer, and an attorney, to be appointed by the commissioners. Careful provisions are made as to the mode of keeping the funds, keeping, auditing and paying accounts and warrants. The powers of the municipality are expressed in general terms and are sufficient to allow of the adoption of any plan of sewerage and water supply that may be thought best; but the Des Plaines System was kept especially in view and all the powers requisite to go beyond the corporate limits to acquire property and construct any and all necessary works, are contained in the bill. The corporation is authorized to borrow

money for the corporate purposes, not exceeding five per cent. of the valuation of the property within the corporate limits; but no greater amount can be borrowed in any one year than is needed for that year, and the bonds to be issued for the same are to be made to fall due at such times that the money which the constitution requires shall be provided for the payment of the loan can be applied as it is raised, instead of creating a sinking fund which generally lies idle while the bonds continue to draw interest.

The corporation is given power to levy taxes not exceeding in any one year one dollar on each $100 valuation. It is also given power to make special assessments and condemn property under Article IX of the City and Village Act.

The object of the corporation is the adoption, construction and maintenance of a system of main drains and sewers and of main water tunnels for the supply of water to the several municipalities embraced within the metropolis. These municipalities are each to take the water from the tunnels by their own pumps at a price (wholesale) to be agreed upon, and to distribute it to their people in their own way and at their own rates.

A joint committee of the Senate and House of Representatives was appointed to investigate and report to the two houses the effect the proposed plan of sewerage would have upon the Des Plaines and Illinois Rivers, and much time has been spent in presenting testimony before that committee upon that subject and finally a report was made by the committee to the several houses recommending the passage of the bill with certain amendments.

The most important of these amendments provides that if a channel is constructed along the Des Plaines River it shall be of a capacity of not less than 600,000 cubic feet of water per minute, and shall not be less than 160 feet wide on the bottom and not less than 18 feet deep. This capacity is the same that is recommended in the report of the Commission as necessary to carry off the storm water and prevent it from backing the sewage into the lake in flood times.

It has been said that the bill has been so amended as to require expensive iron bridges to be built by the corporation upon the demand of the towns along the channel, but this is not true. The only requirements on this subject is that bridges over the navigable part of the channel shall be so constructed so as to allow of the passage of vessels. Neither is it true, as has been said, that the bill gives away the water

power to be created at Joliet. The channel, according to the plans of the engineers, is to be built to a point in Joliet where the water power will be greatest. The law is well settled that when water escapes from an artificial channel into a public river, all right of property or control over it is gone from the proprietors of the channel. See Adams v. Slater, 8 Brad., 72.

An amendment was, however, put upon the bill in the House, upon the motion of Mr. Browne, of LaSalle County, which requires the purchase of a sewage farm and the treatment of the sewage with certain named chemicals. No doubt some voted for this amendment under the mistaken impression that it is practicable to extract from the sewage a valuable fertilizer to be introduced into commerce. It has been determined in those parts of the country where fertilizers have the highest merchantable value, as in Boston and Providence, that, in the present state of the arts, fertilizing material cannot be economically extracted from sewage. (See Boston City documents, 1887, No. 70, page 18.)

There are some reasons that seem to the Committee to be of great weight in favor of the passage of the bill, even with this objectionable amendment. If the bill were to become a law, we may reasonably expect, from subsequent legislation, such a modification of this amendment as would free the matter from serious embarrassment. In fact, such a modification was at one time agreed upon. You call our especial attention to the Roche-Winston Bill now pending in the Senate, and request a statement of its scope and probable utility.

The bill makes the city of Chicago a Drainage District and gives the corporate authorities of the city the powers expressed in the act of June 22, 1885. It expressly gives the city authority to construct the Bowmanville Cut-off for the diversion of the flood waters of the Upper Des Plaines and North Branch and to build a dam or levee along the east bank of the Des Plaines at Summit, to prevent that river from running over into Mud Lake and thence into the Chicago River in flood times. The bill gives the usual powers to enable the city to acquire right of way, etc. The cost of constructing and maintaining this work is "*to be defrayed by special assessment upon the property benefited thereby,* within such district (the city of Chicago) alone."

If a Metropolitan municipality shall be hereafter created and permission given it to dispose of the sewage by way of the Des Plaines River and through such a channel as we have

described, this cut-off will answer all the purposes of its construction. So long as we use the canal for sewage disposal, as now, this cut-off will be useful in controlling the flood waters of the Des Plaines and North Branch, and reducing the violent flushings which occasionally scour the Chicago River, carrying the sludge and filth into the lake.

The Roche-Winston Bill was not intended to antagonize or take the place of the Metropolitan plan of organization as contained in the Hurd Bill. On the contrary the Bowmanville cut-off is a part of the "Des Plaines System," and its construction is only consistent with the adoption and carrying out of that plan under such an organization.

The question is raised whether that work is the proper subject of a special assessment upon the land of the City of Chicago, or in other words, whether the expense of it is not in the nature of a general burden to be borne by general taxation. This is a question of law upon which the committee expressed no opinion. The bill provides that the work shall be done by special assessment, as that is the only way it can be done without submitting the act to a vote of the people which would cause the delay it was the purpose of the bill to avoid. It is desirable then, that both bills should become law at once and the people given their choice under which the work shall be done.

Under the Hurd Bill no more money can be raised by taxation or by borrowing, in any one year, than is required to be expended in that year. It is estimated that it will require from seven to ten years to complete the work, and that the amount to be raised and expended will not exceed $2,500,000 in any one year.

Your committee believe that nothing less than the adoption and completion of the whole system will remedy the great evils from which we are suffering, and that the city and its suburbs can well afford the cost involved for the relief which it will bring.

DANIEL L. SHOREY,
MURRAY NELSON,
H. B. HURD,
MARTIN A. RYERSON,
BRYAN LATHROP,
Committee on Main Drainage and Water Supply.

REPORT OF GEORGE Y. WISNER, ASSISTANT U. S. ENGINEER, CHICAGO, JANUARY 22, 1883. CHIEF OF ENGINEERS REPORTS 1883. PAGE 1773.

Survey and Estimates for Enlargement of the Illinois and Michigan Canal.

Report of Mr. George Y. Wisner, Assistant Engineer.

United States Engineer Office,

Chicago, Ill., January 22, 1883.

Major: I have the honor to submit the following report of survey and estimates for enlargement of the Illinois and Michigan Canal, from Chicago to the Illinois River at La-Salle.

In compliance with your instructions of October 3, 1882, I have made a careful survey of the Canal, and determined cross-sections at intervals of 500 feet throughout its entire length.

These cross-sections have been platted, and may be utilized for computing cost of enlargement in case any other size of prism of canal should finally be adopted than that now proposed.

The canal property consists of a strip of land 240 feet in width (90 feet each side of canal) with a few exceptions through villages and across the sixteenth sections of townships.

For about 15 miles from Chicago the cutting for canal is principally through clay, and for a larger portion of the next 20 miles the canal is cut through limestone rock. The remainder of the route is through clay and sand loam, with occasional beds of rock and gravel.

A large amount of material needed for construction may be obtained on the canal property, which, with the extensive quarries adjacent to the canal near Lockport, renders the cost of enlargement very reasonable. The present canal is a little over 60 feet wide at surface and of irregular section, averaging about 390 square feet sectional area.

The locks are 110 feet long, 18 feet wide, and 6 feet deep on miter sills.

The following estimates have been made for prism of canal similar in size to that proposed for the Hennepin Canal, viz: 80 feet wide at surface, 59 feet wide at bottom, and 7 feet deep,

with locks 170 feet long, 30 feet wide, and 7 feet deep on miter sills. The sectional area will be 485 square feet, or about 25 per cent. larger than that of present canal.

The new pumping works now being erected at Bridgeport are expected when completed to deliver in canal about 1,000 cubic feet of water per second, which will make a mean velocity of current in the present section of canal of about 1.7 miles per hour, and for the proposed section 1.4 miles per hour. With a loaded boat occupying a large portion of this cross section, the current will be much too heavy for economy of transportation, and if the canal is to be used as an outlet for Chicago sewage, I think the prism should be made much larger than that now proposed.

The water supply for the present canal will be ample. No survey was made of the feeders but from information obtained I think they are in about the same state of repair as the present canal.

It is expected to obtain the increase of depth in canal, from Chicago to the DuPage River by dredging, but from the DuPage River to LaSalle it will be much more economical to raise the height of water in the levels one foot, thus saving a large amount of excavation. The excavation being in excess of the amount of embankment required, no extra expense will be incurred by raising the banks.

No changes have been made in the location of locks. The estimates for material in locks have been made for cut stone for face of walls and culverts, and uncut stone for remainder of masonry. Feed culverts are to be built through the lock walls, for regulating the flow of water in canal, and the foundations to be of concrete, except where lock walls are built directly on the native rock. The aqueducts on the line at present have wooden trunks about 24 feet in clear width, supported on stone abutments and piers.

Estimates have been made for repair of masonry and for new trunks to correspond in size with the proposed enlargement.

All bridges less than 15 feet in the clear above water in the canal should be raised. The abutments for several of the bridges will have to be rebuilt.

The stone arch culverts under the present canal will need no alterations, but there are 12 wooden box culverts which should be replaced by stone ones.

Through sand, loam, and gravelly soils, slope walls will be

required to protect the banks from caving. The canal should also be fenced for a greater part of its length.

Estimates have been made for waste weirs with gates at Lockport and at Marseilles, which, with surface weirs on the longer levels for escape of water from heavy rains, will be sufficient for regulating the height of water in canal. The dams in Des Plaines River at Joliet, and in the DuPage River, will need no repairs at present.

The accompanying profile shows the elevation of ground with reference to water surface of present canal. The curves showing the amount to be excavated are platted from ordinates representing the number of square yards in the respective sections. The mean ordinate for any section multiplied by the length of section in yards will equal the number of cubic yards of excavation required.

There are 17 locks and watchmen's houses belonging to the canal property, nine of which have been built within the past five years, and the others have been recently repaired.

I am under obligations to Mr. Wm. Thomas, superintendent of Illinois and Michigan Canal, for valuable information furnished from the Canal office and also to Mr. John Ericson for able assistance in both field and office work.

Very respectfully submitted,

GEORGE Y. WISNER,
Assistant Engineer.

Maj. W. H. H. Benyaurd,
Corps of Engineers, U. S. A.

REPORT OF CAPTAIN W. L. MARSHALL, U. S. ENGINEER AT CHICAGO, ON A SURVEY OF A WATERWAY FROM LAKE MICHIGAN TO THE ILLINOIS RIVER AT LASALLE, APPENDIX JJ REPORT OF CHIEF OF ENGINEERS FOR 1890. PAGE 2419.

Survey of Waterway from Lake Michigan to the Illinois River at LaSalle, Illinois.

United States Engineer Office.
Chicago, Ill., February 28, 1890.

General: I have the honor to submit the following report upon a survey of a waterway from Lake Michigan to the Illinois River at LaSalle, Ill., forming part of a through route of transportation from Lake Michigan to the Mississippi River, required by Act of Congress of August 11, 1888.

The Act in question is entitled "An Act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes," and the items directing the survey, plans and estimates, and relating thereto, are as follows:

> "Improving Illinois River, Illinois: Continuing improvement Two Hundred Thousand Dollars. And for the purpose of securing a continuous navigable waterway between Lake Michigan and the Mississippi River, having capacity and facilities adequate for the passage of the largest Mississippi River steamboats, and of naval vessels suitable for defense in time of war, the Secretary of War is authorized and directed to cause to be made the proper surveys, plans, and estimates for a channel improvement and locks and dams in the beds of the Illinois and Des Plaines Rivers from LaSalle to Lockport, so as to provide a navigable waterway, not less than one hundred and sixty feet wide, and not less than fourteen feet deep, and to have surveyed and located a channel from Lockport to Lake Michigan, at or near the City of Chicago, such channel to be suitable for the purposes aforesaid; the necessary expenses of such surveys, estimates, plans and location to be paid for out of the sum herein appropriated for the improvement of the Illinois River."

In compliance with the orders of the Chief of Engineers a project for this survey was submitted September 21, 1888, which was approved September 25, 1888. The expenses of the survey to be paid from an allotment of $25,000 from the appropriation for the improvement of the Illinois River.

A letter of instructions was received from the chief of engineers, dated August 27, 1888, a copy of which is herewith, directing that whatever line might be found most advantageous and economical to the United States, and best suited to subserve the ends in view, that plans and estimates in any event should be submitted for a route terminating within the (then) limits of the City of Chicago sufficiently distinct and in detail to enable the Chief of Engineers to form a definite and conclusive opinion as to its merits regarded from the standpoint of the commercial and sanitary interests of Chicago.

In accordance with the approved project, and with the instructions received, a survey party was organized and put into the field October 1, 1888, under directions of Assistant

Engineer L. L. Wheeler, a gentleman of many years' experience of that character in the Government service, and by the close of the season, December 1, 1888, the field work relating to the superficial survey of the various practicable routes from Lake Michigan, at or near Chicago, via the Chicago Divide and the Des Plaines River Valley, as far as Joliet, Ill., were practically completed. From Joliet to LaSalle a survey was made under direction of Maj. W. H. H. Benyaurd, Corps of Engineers, U. S. Army, by Assistant Engineer George Y. Wisner, in 1883, and to avoid unnecessary duplication of work and expense this survey was adopted, as far as it was found sufficient for the purpose, for the basis of the estimates herewith, for that part of the route covered by it.

The most practicable routes across the Chicago Divide, and which have been long known and recognized, are two, each of which admits choice of location, the valleys being quite wide.

(1) By way of the Chicago River and its South Branch and the present location of the Illinois and Michigan Canal, or Mud Lake and the Ogden Ditch, to the Des Plaines, near Summit, about 12 miles from the City Hall of Chicago and about 8 miles from Bridgeport; thence via the Des Plaines River Valley, uniting at Sag Bridge with route.

* * * * * *

The 14-Foot Channel.

Page 2425.

The Act of Congress in question, requiring plans and estimates for a channel at least 14 feet deep and at least 160 feet in width, has been complied with, and estimates on this basis are also submitted. This channel will accommodate, of course, with greater facility all large vessels that can reach its terminus at LaSalle through the channel of the Mississippi River, at present about 4½ feet in depth at low water, to be increased, if practicable, to 8 feet at low water below St. Louis, and to 6 feet on the Upper Mississippi; and through the lower Illinois River, at present from 16 to 18 inches in depth on the unimproved section, to be ultimately 7 feet deep at extreme low water, with locks 350 feet in length and 75 feet in width of lock-chamber. Vessels now existing on the Mississippi River that cannot be accommodated by the 8 feet deep channel at extreme low water will not be accommodated by the 14 foot channel 160 feet wide, but every increase in depth up to a certain limit of a navigable waterway increases the facility with which it can be navigated by large vessels;

a channel from 14 feet in depth at extreme low water in Lake Michigan to 18 feet at high water across the Chicago Divide can be navigated by similar large boats if still water, or with a very moderate current, with greater facility and ease than a still-water channel from 8 to 12 feet in depth. This is the best argument for such a channel, based upon the present or probable future navigation of the Mississippi River and tributaries; *it is not a public necessity.*

As for the practicability of such a channel under the condition imposed by the Act that it shall occupy the bed of the Illinois and Des Plaines Rivers more will be said hereafter in this report.

Artificial waterways connecting superior navigations even are generally restricted and obstructive, and limited by motives of economy to the least dimensions that will accommodate the vessels that will probably seek their use. For this reason, probably, no channel has been recommended by any engineer under governmental or State authority exceeding 8 feet in depth across the Chicago Divide.

The supposed necessity for a minimum channel 14 feet in depth from Lake Michigan to the Mississippi River, at the mouth of the Illinois River, is given by the chief engineer of the Chicago Sanitary District, lately organized under the Act of the Illinois Legislature, approved May 29, 1889, entitled "An Act to create sanitary districts and to remove obstructions in the Des Plaines and Illinois Rivers," in an article published in the Chicago Tribune, dated January 29, 1890. It is given here because the author represents the only interest demanding such a channel and presumably offers the most cogent arguments available for governmental action.

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Page 2428.

No greater depth of channel than 9 feet at extreme low water in Lake Michigan across the Chicago Divide seems *necessary* for navigation by vessels similar to the largest Mississippi River craft, that can neither use it nor reach it; but a channel of much greater capacity, discharging a large volume of water into the Illinois and Des Plaines Rivers not necessary for navigation in a canalized river, as this must necessarily be, is made locally urgent by the sanitary necessities of the City of Chicago for drainage and an uncontaminated water supply, as shown in the Appendix to this report. These necessities end when the Chicago Divide is passed and the discharge turned into the channels of the river. Beyond

the Chicago Divide, then, there is no apparent necessity at present, nor likely to exist in the near future, either national or local, for any channel of materially greater capacity than the minimum herein estimated for between the Mississippi River and the Great Lakes, but every increase in depth and width of channel up to a certain limit throughout the artificial channels will increase the facilities for navigation without probably affecting the character, size or draught of the boats that will use it as a through route of transportation, i. e., Western river steamboats, barges, and towboats.

Location and Estimates.

The accompanying report of Assistant L. L. Wheeler, gives such a full description of the various routes surveyed that it is unnecessary to again repeat it herein, and reference is made to his report and the maps and profiles herewith submitted for such details. In locating the proposed routes and structures required, and in determining the bases of the estimates, much study was devoted by Mr. Wheeler and myself in this office, and his reported locations and estimates have been made after the various points involved were thus determined, and under the instructions of the Department.

The two routes estimated for, i. e. via Chicago River and via the Calumet River and the "Sag," unite at the Sag Bridge, about 17 miles from Blue Island and Bridgeport, and thence to LaSalle, coincide.

Chicago River Route.

The route proposed follows the Chicago River from its mouth via its South Branch to near Bridgeport, thence via the West Fork of the South Branch and the Ogden Ditch to Summit, thence paralleled to the present location of the Illinois and Michigan Canal, on lower ground, three miles more or less, where it enters the bed of the Des Plaines River, which it practically follows, cutting off bends to Sag Bridge, where it unites with the second or Sag route.

The route is preferred to the present location of the Illinois and Michigan Canal, or one adjacent to it.

(1) Because it occupies lower ground, and the probable amount of excavation required is less, since the earth excavated from the old canal still remains as spoil banks to be removed.

(2) Because the old canal is paralleled by a railroad on each side, and there is not sufficient room for the enlargement

of the canal without condemning the railroad right of way and removing one or both of the tracks.

(3) Because the present canal is the property of the State of Illinois, and the conditions of transfer have not been accepted by the United States. These conditions are such that their acceptance would involve greater cost than a new right of way.

(4) The Illinois and Michigan Canal is the main sewer of the City of Chicago, as well as a commercial highway, and cannot well be enlarged without either interfering seriously with its uses or at increased cost of work from delays due traffic upon the canal.

(5) As a means of transportation and drainage it is of advantage in the prosecution of the work parallel to it to maintain it in a serviceable condition during the construction of the larger canal.

(6) For several miles of its course between Willow Springs and Lemont it is excavated in solid rock that the new route avoids, so that the old canal location could not be followed in any event with advantage further than throughout the earth section.

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Page 2436.

Attached to this report will be found the full preliminary report of the special commission or board of experts employed by the City of Chicago to examine into the question of drainage and water supply, made in 1887; also the laws and joint resolutions of the Legislature of the State of Illinois relating to the same matter, and authorizing the establishment of "Sanitary Districts, etc.," which will give a clear explanation of the requirements of the case and the proposed remedies.

Without going into the subject in detail, which is better treated in the report mentioned than it could be by me, it is sufficient to state that after examination by capable experts the conclusion has been arrived at that it is necessary, for sanitary reasons, to construct a channel or channels from the lake to the Des Plaines valley, beyond the Chicago Divide, capable of carrying to the Illinois River from 300,000 to 600,000 cubic feet of water per minute, to carry off and dilute to inoffensiveness the sewage of this great city, to prevent contamination of its water-supply *necessarily taken from Lake Michigan;* and that the necessary legislation to enable the

city to undertake the work has been obtained from the State Legislature.

Many propositions have been bruited, involving various schemes for the diversion of the flood waters of the Des Plaines; channels of large capacity in addition to, and to supplement, the natural drainage lines of the Chicago River and the main Drainage Canal, etc., but up to this date no perfected plan has been formulated or adopted.

Whatever may be the ultimate fate of the various proposed cut-offs and diversions and auxiliary channels, it may safely be reasoned that economy will govern, and that the essential objects of the city of Chicago will be first obtained by the most direct and inexpensive use, to their full capacity, of the natural drains, with such sewers, conduits, and pumping works as will secure proper outfalls into these drains, and satisfactory transfers of the contents of otherwise dead branches to the main Drainage Channel, i. e., by the utilization to the full extent allowed by the law of the Chicago River and its branches.

From this may be inferred a current of not exceeding three miles an hour in the Chicago River and its south branch.

Any marked current in such an obstructed stream means danger to the heavy and unwieldly vessels that frequent it, especially if built of metal; and a current of even less than three miles an hour obstructed by numerous stone piers, a multitude of vessels, and many sharp bends will have its effect upon rates of insurance and upon the minds of vessel owners and owners of dock property.

In its present condition Chicago River cannot be navigated at all by large Mississippi River steamboats. Nearly all the bridges, which are the property of the city of Chicago, must be reconstructed if this route be adopted and a material increase in the already too great number of vessels using the river result. No large Mississippi-River steamboat can turn in the river, but must run the gauntle of all its bridges and piers, after reconstruction, to Lake Michigan for that purpose, or else a commodious turning-basin be constructed for such purposes.

In the practical execution of a channel via this route the Des Plaines waters must be contended with and may materially increase the cost of the route, but as there has been expressed by contractors of experience a doubt upon this point, based upon the ground that the facilities for dredging from Bridgeport to Summit are better and that the material

can be sold to brick-makers and for filling to reduce the ultimate cost, the estimates over the two routes are made on the same basis of cost per unit.

Generally speaking, then, it may be stated that the Chicago River is a very unfavorable terminus for this highway as far as the interests of navigation are concerned, also as far as future demands and facilities for increased commerce by water are concerned, but that for sanitary purposes a channel along substantially this line has been decided to be a vital necessity for the city of Chicago.
Page 2444.

2. Effects of Definite Increased Discharge on Channel Depths.

It will be seen from the appendices to this report that a discharge of from 300,000 to 600,000 cubic feet per minute from Lake Michigan into the Illinois River is contemplated for sanitary purposes by the city of Chicago, and that the United States Government is requested by the Illinois Legislature to abandon its adopted system of improvement by slackwater on the lower Illinois River and attain the same object by means of this increased discharge. The effects of such discharge upon this section of the river, as well as upon the part of the route from LaSalle to Lake Michigan, is, then, a proper subject of discussion herein.
Page 2449.

Chicago Drainage and Waterway Laws.

Up to the present time the improvement of the Illinois River has proceeded upon the strict national basis of the requirements of navigation, and as late as 1887, no reason for any increase in the dimensions of the channel proposed for this improvement and in course of execution on the lower Illinois had been developed. The Illinois legislature at its session in 1887 passed an act of cession, ceding to the United States the State works occupying part of the line, upon the condition that the United States should carry the improvement through from the Mississippi River to Lake Michigan on a basis of 7 feet depth of navigation, but in 1887, also, the commission of experts employed by the City of Chicago to examine into and report upon the best plan for drainage and water supply submitted its preliminary report, which contains the first official demand from any source for a navigable channel of *great discharging capacity* several times the depth neces-

sary for navigation across the Chicago Divide, and is the origin and basis of the present requests of the legislature of Illinois for the construction by the United States government of a waterway 160 feet wide and 22 feet deep across the Chicago Divide as far as to Lake Joliet, and for a channel 14 feet deep thence to LaSalle, the former act of cession of the State works at the same cession being repealed.

We now find this proposed route, instead of being urged upon a purely national basis, encumbered with conditions that have no relation whatever to any national ends or objects, but purely dependent upon local necessities for sewerage and water-supply as the real governing basis, while a great waterway is urged as a national necessity to secure United States aid.

With reference to the "Chicago Drainage and waterway laws," a few remarks may be found in the Annual Report of the Chief of Engineers for 1889, page 2130, et seq., to which reference is here made. These remarks are supplemented and made more clear by this report.

No channel as deep as 22 feet has yet been constructed upon the Great Lakes, nor have any of the harbors on the Great Lakes been constructed of that depth. The entrance to the harbor of Chicago, which exceeds any port of the United States in number of arrivals and departures of vessels, is only 16 feet in depth below low-water in Lake Michigan. At the Mississippi terminus of the line there exists less than 6 feet at low water.

Granting the necessity for a channel-way of large capacity across the Chicago Divide, a narrow and deep channel with a more or less rapid current is not of the character demanded by western river navigation. The heavy business of these rivers, especially of the Mississippi and Ohio, is transacted by barges and towboats, or by wide flat-bottomed steam boats of comparatively light draught. If any channel, therefore, of materially greater capacity than the minimum herein estimated for be constructed by the United States government across the Chicago Divide, it would be infinitely better for purposes of commerce and navigation that it should be doubled or trebled in width, with the locks suitably increased in span and length to accommodate powerful tow-boats with their full tows than that it should be restricted in width and made so deep, with a more or less obstructive current therein.

No one cognizant of the necessities of the city of Chicago for better drainage and a purer water supply can fail to

sympathize with her efforts to arrive at a solution of the problem, and as both the channel for drainage and the channel for navigation across the Chicago Divide must necessarily occupy the same field, it is manifestly the duty of the General Government, to prevent unnecessary expenditure, in planning its work to so construct them that while subserving strictly the necessities of the public generally, that they shall conduce also, as much as possible, to the health, comfort, and general welfare of the special locality. It is not so clear, however, that these works should be constructed of greater capacity, or at materially greater expense to the National Treasury, than demanded by national interests for the purpose of meeting purely local necessities, when these necessities have not arisen from any act of the general government.

If, then, the capacity of the channel required by national interests should be first definitely decided upon, and the work be constructed by the General Government in accordance with this decision, across the rock up-lift at Lemont, and the City of Chicago be then allowed to avail herself, under proper conditions, of this work by enlarging and deepening such parts of it as are necessary for her purposes, it would detract but little from its value as a navigable channel due to the introduction of a current into an otherwise slack-water canal, over such a short portion of the route, while saving at the same time probably 50 to 60 per cent of the cost of this most expensive part of her drainage canal to the city of Chicago.

Such a solution would seem just and proper, provided that, if the United States should be held responsible for flowage damages along the Illinois River due the water thus artificially introduced into the rivers through its channel, they should control the discharge of the canal thus constructed for such periods as it might cause overflows and damage, and possibly great obstruction to navigation in the river below that would not occur without this addition.

As shown in this report, the overflow stage is reached near LaSalle at about 7.5 to 8 feet above present low water, at a discharge of 18,000 cubic feet per second; at LaGrange at a discharge of aoout 30,000 cubic feet per second; at Kampsville, at a discharge of about 40,000 cubic feet per second, but when the Mississippi is high, at a much less discharge. Upon the upper Illinois there is no data to determine at what stage and discharge an introduction of an artificial discharge would cause damage.

This artificial discharge is not necessary for navigation

anywhere along the line, and cannot be said to benefit navigation anywhere to such an extent as to justify the United States government assuming responsibility for flowage damage caused by it.

The discharge is proposed to be constant, whereas if it were produced by the United States for the benefit of navigation it would be introduced into the Illinois only at low stages, when it would be beneficial to navigation and harmless to property.

Now, at any little summer freshet, producing a discharge exceeding 8,000 cubic feet per second at LaSalle, damage by overflow would begin at that point, the artificial discharge being 10,000 cubic feet per second, and with greater natural discharge become more and more wide-spread as we progress down-stream, at times when such overflows would not otherwise occur. Upon all rises of the river producing anywhere near bank-full stages this artificial discharge would cause flowage damages that would not otherwise occur. The lands would become submerged at high water earlier, and the water remain upon them longer than it otherwise would. From 100,000 to 300,000 acres of land in the Illinois River valley will be subject to such conditions.

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Page 2451.

That feature, therefore, in the Chicago drainage and waterway laws that requires a constant discharge of from 300,000 to 600,000 cubic feet per minute seems, in view of past experience, decidedly objectionable if the water is to be introduced through any canal either owned or used by the United States for public purposes if by such ownership or use the United States can be made responsible for damages due to such constant discharge.

There is nothing perfect under the sun, and the city of Chicago could find a reasonably satisfactory solution and a cheaper one, although not by any means a perfect one, of its sewage question by looking somewhat to the natural watershed of the Illinois to furnish some of the water required by the law for the dilution to inoffensiveness of its sewage by sending into the Illinois River a variable quantity of Lake Michigan water, depending on the state of that stream, *all* required by the law when it can be safely done, *less* than this when it cannot, and upon exceptional floods, the inconveniences of which all should share, suffer with the Illinois Valley some of the discomforts dependent upon such conditions.

Such would be the modifications that control over the artificial discharge into the Illinois River would produce.

These are matters of detail that can be remedied by subsequent legislation.

By properly guarding and limiting the liability of the United States for flowage damages due water not necessary for navigation, but introduced either through United States channels or over United States dams, doubtless a satisfactory arrangement may be made by which this great city could profit by the necessary United States works, while the United States would not be put to unnecessary expense.

As the State law stands, however, demanding a constant discharge and unnecessarily great and expensive channels not demanded or suitable for the commerce to be subserved, a compliance with its terms does not seem advisable for the United States.

In view of these facts and laws a thorough survey from Joliet to the Mississippi River, at least with the detail shown on the maps of the present survey, *i. e.*, with accurately determined contours at every foot elevation of surface, and with the areas of lands subject to overflow well determined, should be made by authority of Congress before any artificial discharge whatever is turned into the Illinois River, to determine the effects of such artificial discharge and the areas of lands that may be subject under any conditions to flowage thereby. Such a survey would cost probably $250,000, but ultimately save many times that amount to the organization held responsible for such flowage damages, whether it be the Government of the United States or the City of Chicago.

Commercial Advantages.

This route has invited attention as a practicable locus for a waterway between the Great Lakes and Mississippi River for many years, and its advantages have been so often reported to Congress that anything herein said would be mere repetition. It is sufficient to say that the minimum channel herein estimated upon will open a channel of commerce with a maximum annual capacity of 30,000,000 tons (foot note: Or 7,500,000 tons easily attainable capacity in practice.—W. L. M.) between the Great Lakes, with its terminus at their greatest port, and a system of navigable rivers penetrating one-half of the states and territories of the Union, with a total navigable length equal to more than half the circumference of the globe.

In the meantime attention is invited to the following reports hitherto submitted to Congress:

General J. H. Wilson, 1867, House Ex. Doc. No. 16 40th Congress, 1st session.

Colonel Macomb, Corps of Engineers, Report of the Chief of Engineers, 1875, volume 2, page 525.

Major G. J. Lydecker, Reps. Chief of Engineers 1879, page 1572; 1880, page 1995.

Maj. W. H. Benyaurd, Report of the Chief of Engineers, 1884, page 1958.

Maj. Thomas H. Handbury, Report Chief of Engineers, 1887, page 2119.

Report of the Board of Engineers on Hennepin Canal, 1887, Report of the Chief of Engineers 1887, page 2125.

Respectfully submitted,

W. L. MARSHALL,
Captain of Engineers.

Brig. Gen. THOMAS L. CASEY,
Chief of Engineers, U. S. A.

Page 2453.

United States Engineer Office.
Chicago, Ill., May 1, 1889.

General: The survey ordered by Congress in the River and Harbor Act of August 11, 1888, item Illinois River, for a water-way of large dimensions (14 feet depth, 160 feet width), across the Chicago Divide to Lockport, thence via the channel of the Des Plaines and Illinois Rivers to LaSalle, has now arrived at the point that allows the estimates of quantities of excavation, etc., and cost of the cut across the divide to be begun.

As the department is aware, local necessities, as determined after examination by a commission of experts employed by the City of Chicago, demand a large discharge from Lake Michigan into the Illinois River for sanitary reasons. Navigation interests not only do not demand increased discharge for the Illinois River, but also in so far as an increased discharge introduces into an otherwise slackwater system a current that increases the cost and the difficulties of navigation in some proportion to the square of its velocity, would be positively injured thereby to the extent of the obstruction.

A navigable channel, therefore, demands no slope to the costly cut through the Chicago Divide. Local sanitary necessities demand a slope of not less than four inches to the mile,

and a cut consequently deeper by from about seven feet to about 11 feet in rock, throughout about 12 miles, more or less, of the canal at the divide, at a probably increased cost of about $60,000 per mile per foot depth, and for about 15 miles, more or less, an increased depth of cut, in earth, varying from 3 to 7 feet in depth, at a probable increased expense of about $15,000 per mile per foot increased depth. In this case, also, the works below must be designed to provide for passing, at increased cost, the increased discharge.

The data accumulated by the survey is sufficient for estimating a water-way with any practicable slope and discharge consistent with reasonably easy navigation, 14 feet in depth; but, probably, not sufficient to estimate a channel of the extreme slope and discharge capacity required by Chicago.

I have to respectfully ask instructions from the Department whether it is the desire of the department that the estimates demanded by Congress shall be rendered on the basis of the requirements of navigation for the best channel for navigation, or whether the local drainage problem shall also be considered, or separate estimates made under each condition?

It is my desire to comply with the intent of the act, even if it involves the duty of touching upon purely local questions of sanitary engineering, still a matter of local discussion and dispute, but I am uncertain whether the elimination by amendment from the act passed of all mention of the discharge or capacity for discharge of the proposed channel, which was originally a feature of the bill, was intended to intimate that only estimates and plans for the channel, 14 feet deep, best adapted for navigation are desired by Congress, *i. e.*, that national interests only are to be presented officially by United States Officers, and the local necessities be presented to Congress, if at all, by the petitions of localities interested, or by their representatives in Congress, or whether the terms "not less than 14 feet in depth," taken in connection with the well-known capacities for navigation of the Illinois and Mississippi Rivers, was intended as equivalent to a direction to regard not only the interests of navigation which require no such depth of channel as the minimum indicated, but also other interests that, though purely local, may require the execution of such a scheme, if approved by the people of the locality, *i. e.*, whether it is not the intent of the act that the United States officers shall make estimates and plans for local engineering projects not yet put in form for execution, nor yet authorized

by State law, nor even accepted yet by local vote, making the interests of navigation not paramount but subsidiary thereto.

Very respectfully, your obedient servant,

W. L. MARSHALL,
Captain of Engineers.

The Chief of Engineers, U. S. A.
(Through the Division Engineer of the Northwest Division.)

(First indorsement.)

United States Engineer Office,
Detroit, Mich., May 3rd, 1889.

Respectfully returned to Captain Marshall, with suggestion that he present his own views upon this question and submit a definite proposition for carrying them into effect.

O. M. POE,
Colonel of Engineers,
Engineer Northwest Division.

REPORT OF CAPTAIN W. L. MARSHALL, U. S. ENGINEER AT CHICAGO. APPENDIX MM REPORT OF CHIEF OF ENGINEERS 1891. P. 2611.

MM 4.

Improvement of Illinois River, Illinois.

The ultimate object of this improvement is to furnish a through route of transportation by water from the southern end of Lake Michigan to the Mississippi River of sufficient capacity for its navigation by the largest class of Mississippi River steamboats that can reach the mouth of the Illinois River.

The dimensions that have been adopted for the locks to meet this requirement are:

	Feet.
Length of lock chamber	350
Width of chamber	75
Depth at low water over sills	7

The project now under execution is for the improvement of the lower sections of this route extending from the mouth of Copperas Creek to the Mississippi River, a distance of 137 miles. Another section of the river, 88 miles in length, from the mouth of Copperas Creek to LaSalle, has been improved by the State of Illinois by the construction of two locks and dams, one at Copperas Creek and one at Henry, Illinois.

Over this latter section the state still collects tolls, the United States not yet having accepted the conditions imposed by the act of cession of the Illinois legislature, which condi-

tions are such as to deprive the works of all value while demanding a great expenditure by the United States Government for works to be substituted therefor.

With regard to this subject reference is made to the Annual Report of the Chief of Engineers for 1889, page 2121, *et sequitur*.

Under the act of Congress of August 11, 1888, surveys and separate estimates have been made, based upon low-water depths of 8 and 14 feet, for carrying the improvement from LaSalle to Lake Michigan via the Illinois and Des Plaines Rivers, and a cut across the Chicago Divide, over which section there is a fall in water surfaces, Lake Michigan being the summit of about 141 feet.

The report upon this survey and estimates have been printed as House Executive Document No. 264, 51st Congress, first session, and is also published in the Annual Report of the Chief of Engineers for 1890, page 2419 and following pages.

Other surveys and estimates have also been made by the trustees of the sanitary district of Chicago, organized under laws of the State of Illinois for cutting a capacious channel carrying a large discharge from Lake Michigan into the Illinois River for drainage and sanitary purposes. The reports and estimates of the engineers of this latter body are hereto appended.

No provision has yet been made by Congress for embarking upon the construction of the necessary works of navigation over the last-mentioned section, *i. e.*, from LaSalle to Lake Michigan, but the State of Illinois has provided by law for the destruction of the navigation by locks and dams, over the section of the Illinois River from LaSalle to Copperas Creek, by requiring the removal of the locks and dams at Henry and Copperas Creek, in the event they are not accepted by the United States, under the conditions stated therein, within four years from July 1, 1889, whether any other system of navigation be substituted therefor or not by that time. The navigation of the Illinois River is now and will be necessarily dependent upon these works for years, and the utility of the Illinois and Mississippi Canal as a through route will depend upon the maintenance of the works at Henry until the same depth of water is otherwise obtained.

The present project involves the construction of two locks and dams, one at LaGrange, 79 miles above the mouth of the Illinois, the other at Kampsville, 31 miles above the mouth, and dredging the channels to 7 feet depth at extreme low water

over bars. More than 2,000,000 cubic yards of dredging is required.

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Page 2613.

PROPOSED APPLICATION OF FUNDS ASKED FOR, FOR THE FISCAL YEAR ENDING JUNE 30, 1893.

It is proposed to apply the funds now on hand and those asked for herein to the completion of the Kampsville Lock and Dam; to renovating the dredging plant and to dredging the channels through bars and completing the existing project.

Whatever may be the result of municipal or local works, the execution of which may make possible an improvement of the lower Illinois by other methods than by locks and dams, it must be considered that even yet, nearly two years after the creation and establishment of an organization to carry on a work which was said to be sufficiently understood to justify the legislature of the State of Illinois to indicate to the United States the work required, on the basis of municipal necessity, and to direct the destruction of valuable works of navigation on the Illinois River, no definite plans have been worked out, formulated, and adopted. The channels proposed have been twice located and estimated, in part; but the details as yet are unknown, the rights of way unsecured, and the inauguration of the work still in the future.

Doubtless this municipal work will be executed as a sanitary necessity, but it will take many years for its inception and completion. Meanwhile the interests of navigation on the Illinois River should be provided for by the completion of the existing project now so near consummation, and the future course of the improvement be adjusted to the conditions that will be probably revealed in time. It would not now be wise to abandon a work that will certainly fulfill the requirements of navigation on the lower Illinois at very small expense because that possibly in the next generation these works may be incidentally rendered unnecessary by the execution of work for another purpose and as yet not even begun.

Whenever the large channel contemplated by the City of Chicago for drainage is actually determined upon, in view of the fact that a channel for navigation and the channel for drainage across the Chicago divide must necessarily occupy the same field, it is evident that to avoid duplication of expense, the channel, at least in the expensive rock section,

should be constructed best to meet the requirements of navigation in slope, velocity of current, and dimensions of section, while at the same time of sufficient flowing capacity to carry off the drainage of the sanitary district. Such a compromise will necessarily be more expensive than either a channel best suited for drainage, or a channel best suited and sufficient for navigation. Elsewhere where locks and dams are necessarily used, and in the earth section, it may not seem advisable for the two channels to occupy the same location. The dams will obstruct the flow and the flow will make more expensive the dams and deprive the system of navigation more or less of its slack-water features and advantages. A current aids navigation downstream in direct proportion to its velocity within practicable limits, but obstructs upstream navigation nearly in proportion to its cube. A channel, therefore, with a velocity of 3 miles an hour, or even less, cannot be made equal in value to a similar slack-water channel.

It is doubtful whether there be anywhere on the face of the globe navigation in ordinary river channels by steamboats, upstream, more than 400 miles against a current of 3 miles an hour, or more, and in competition with a good system of land carriage by rail that will pay expenses, much less reduce the cost of transportation, and it must be understood that all water routes between the Great Lakes and the Mississippi River contemplate the transfer of western produce upstream to the Great Lakes, not manufactured and other products downstream westward. It is then evidently of the first importance, if this route is to be used, that the voyage from the Mississippi to the Great Lakes be made as easily and with as little expenditure in time, fuel, oil, and wear and tear as possible. This condition can only be met over this route by slack-water pools or very moderate currents. It cannot be met by 3 miles currents in artificial cuts, or even by large discharges over fixed dams in a river of steep slope, if the channels of this stream be not so greatly enlarged in capacity as to convert the pools approximately into reservoirs.

Under this view, in the report upon the waterway from Lake Michigan to the Illinois River at LaSalle (Annual report Chief of Engineers, U. S. A., 1890, page 2439), the opinion was expressed that a route navigable at all times and conditions could be had, in continuation of the improvement of the Illinois River to Lake Michigan, at practicable cost by a canal from Joliet to LaSalle better than by an improvement in the bed of the river, when a large low water artificial dis-

charge is to be produced and maintained and the artificial discharge uncontrolled at higher stages.

This opinion is, however, contrary to reports of other engineers hitherto made to Congress, and is strongly opposed.

In considering the extension of this route to Lake Michigan, therefore, it seems that it should be investigated in addition to the proper capacity and dimensions of the channel and works of navigation—

(1) Whether this extension should be made from LaSalle to Joliet by the improvement in the bed of the Illinois River or by means of a lateral canal of proper width and depth.

(2) To what extent it is advisable for the United States to co-operate with local authorities in constructing a channel across the Chicago Divide (rock cut) suitable for both local and national purposes, with a view to lessen the cost of construction to each.

(3) Can this be done, and in what way, without increasing the liabilities of the United States for damages to property by flowage from water not necessary for navigation but introduced through channels constructed in whole or in part for public purposes by the United States?

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P. 2658.

MM7

Preliminary Examination of Illinois River, Illinois, from LaSalle to the Mississippi River with a view to ascertaining lands subject to overflow by the construction of waterway between Lake Michigan and the Mississippi River.

United States Engineer Office
Chicago, Ill., January 15, 1891.

General:

I have to respectfully report concerning the item contained in the "Act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes," approved September 19, 1890, relating to a survey of the lower Illinois River, as follows:

Illinois.

Illinois River from LaSalle to the Mississippi River, as recommended by Capt. W. L. Marshall, Corps of Engineers, in his report dated March ten, 1890, with a view to ascertaining what lands would be subject to overflow by the construction of a navigable waterway between Lake

Michigan and the Mississippi River, but not more than Twenty-five Thousand Dollars of the money appropriated for surveys shall be allotted to this river.

I have to say that as far as any "navigable waterway" recommended by this office is concerned, which work is now in progress and nearly completed on the lower Illinois River, that there will be practically little or no lands overflowed or flooded, and that it is thought that the surveys already made are sufficient.

I have further to report that it is thought that this item is based upon the following paragraphs of the report upon the "survey of a waterway from Lake Michigan to the Illinois River at LaSalle," published as House Ex. Doc. No. 264, Fifty-First Congress, First Session, relating to a constant discharge from Lake Michigan into the Illinois River for sewage disposal purposes, of from 300,000 to 600,000 cubic feet per minute, on page 33 of that document.

> The artificial discharge is not *necessary* for navigation anywhere along the line, and cannot be said to *benefit* navigation anywhere to such an extent as to justify the United States Government assuming responsibility for flowage damage caused by it. * * *
>
> P. 2659.
>
> At any little summer freshet, producing a discharge exceeding 8,000 cubic feet per second, at LaSalle, damage by overflow would begin at that point, the artificial discharge being 10,000 cubic feet per second, and with greater natural discharge become more and more widespread as we progressed downstream at times when such overflow would not otherwise occur.
>
> * * * * * *
>
> From 100,000 to 300,000 acres of land in the Illinois Valley will be subject to such conditions.
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> * * * * * *
>
> That feature, therefore, in the Chicago Drainage and Waterway laws that requires a *constant discharge* of from 300,000 to 600,000 cubic feet per minute seems, in view of past experience, decidedly objectionable, if the water is to be introduced through any canal either owned or used by the United States for public purposes, if by such ownership or use the United States can be made responsible for damages due to such constant discharge.
>
> * * * * * *
>
> As the State law stands, however, demanding a con-

stant discharge and unnecessarily great and expensive channels neither demanded by nor suitable for the commerce to be subserved, a compliance with its terms does not seem advisable for the United States.

In view of these facts and laws (Chicago Drainage Laws) a thorough survey from Joliet to the Mississippi River, at least with the detail shown on the maps of the present survey, i. e., with accurately determined contours at every foot elevation of surface, and with the areas of land subject to overflow well determined, should be made by authority of Congress, before any artificial discharge whatever is turned into the Illinois River, to determine the effects of such artificial discharge and the areas of lands that may be subject under any conditions, to flowage thereby. Such a survey would cost probably $250,000, but ultimately save many times that amount to the organization held responsible for such flowage damages, whether it be the government of the United States or the city of Chicago.

As the survey recommended by me covers a length of the Illinois River of some 290 miles of bottom lands, densely timbered over a major part of it, and including some 500 square miles or more of area of swamps, lagoons, timbered, and cultivated lands, the amount appropriated ($25,000) is utterly insufficient to secure the information required and cannot be expended to good purpose if confined to the survey of the character recommended by me in said report, and spread out over that area.

The Illinois River is worthy of improvement, and its improvement is now in progress. The survey as recommended by me should also be made as a protection for the United States against claims for damages for overflow by water turned into United States channels and over United States dams proposed by the Chicago sanitary district, but the amount appropriated is not more than one-tenth of the amount required to make such survey.

There is certain work, however, that may be done with the amount appropriated that could form part of a complete survey as recommended, and at the same time be of advantage to the improvement of the Illinois River as now being executed by the United States Government, viz.:

(1) A line of precise levels from Grafton, near the mouth of the Illinois River, connecting there with the work of the Mississippi River Commission to Lake Michigan, via the Illi-

nois River Valley and the Chicago Divide, with numerous permanent bench marks in the Illinois River Valley as points of departure for the detailed contoured maps recommended.

(2) Any excess of funds over and above what is necessary for this line of precise levels to be applied in making a hydrographic survey of the United States pools created by the dams at LaGrange and (when completed) Kampsville, Illinois, to ascertain the amount of dredging required to complete the present project of improvement.

A further appropriation of $225,000 to complete the survey recommended by me will be necessary.

Very respectfully,

W. L. MARSHALL,
Captain, Corps of Engineers.

Brig. Gen. Thomas L. Casey,
Chief of Engineers, U. S. A.
(Through Col. O. M. Poe, Corps of Engineers, Division Engineer, Northwest Division.)

(First indorsement.)

U. S. Engineer Office
Detroit January 20, 1891.

Respectfully Forwarded.

I concur in the views of Captain Marshall, and recommend that he be authorized to apply the appropriation in the manner proposed by him.

O. M. POE,
Colonel, Corps of Engineers, Bvt. Brig. Gen. U. S. A. Division Engineer, Northwest Division.

Survey of Illinois River, Illinois, from LaSalle to the Mississippi River, with a view to ascertaining lands subject to overflow by the construction of waterway between Lake Michigan and the Mississippi River.

(Received with letter of Captain W. L. Marshall, Corps of Engineers, dated July 10, 1891, page 2595.)

This work was directed by the river and harbor act of September 19, 1890, in the following terms:

Sec. 17. That the Secretary of War is hereby directed, at his discretion, to cause examinations or surveys, or both, to be made and the estimated cost of improvement to be estimated at the following location, to-wit:

* * * * *

Illinois.

* * * * *

"Illinois River from LaSalle to the Mississippi River, as recommended by Captain W. L. Marshall, Corps of Engineers, in his report dated March 10, Eighteen Hundred and ninety, with a view to ascertaining what lands would be subject to overflow by the construction of a navigable waterway between Lake Michigan and the Mississippi River, but not more than Twenty-Five Thousand Dollars of the money appropriated for surveys shall be allowed to this river."

The recommendation contained in the report cited was as follows:

In view of these facts and laws (Chicago Drainage and Waterway Laws), a thorough survey from Joliet to the Mississippi River, at least with the detail shown on the maps of the present survey, i. e., with accurately determined contours at every foot elevation of surface, and with the areas of lands subject to overflow well determined, should be made by authority of Congress before any artificial discharge whatever is turned into the Illinois River to determine the effect of such artificial discharge and the areas of lands that may be subject under any conditions to flowage thereby. Such a survey would cost probably $250,000, but ultimately save many times that amount to the organization held responsible for such flowage damages, whether it be the government of the United States or the city of Chicago.

As the estimated cost of this survey is $250,000, and the act limits the expenditure to one tenth of this amount for the contoured survey of from 500 to 750 square miles of territory, densely timbered, swampy, covered with lagoons, and in many places nearly impenetrable, it can at once be seen that the object of the survey cannot be met to any extent by this small sum.

As far as any project by United States officers for a waterway via the Illinois River is concerned the damages by flowage are already known to be insignificant and that no further surveys to determine them are needed.

For such a waterway as contemplated under state laws ten times the amount appropriated, at least, is necessary for results of value in suits for damages.

The amount allotted can be expended to advantage in carrying a line of precise levels from the Mississippi River to

the Great Lakes, connecting with the levels of the Mississippi River Commission, to serve as a basis for the survey indicated, also in making an hydrographic survey of the pools of the Illinois River to ascertain the amount of dredging required to complete the existing project of improvement and to form part of the more extended survey.

Before making such uses of this fund it is judged advisable to further submit the matter to Congress in order that such use may be authorized or proper funds be allotted for the survey of the alluvial lands of the Illinois River Valley subject to overflow, or an indication that annual appropriations will be made for the continuance and completion of such a survey as recommended.

REPORT OF CAPT. W. L. MARSHALL, U. S. ENGINEER AT CHICAGO. APPENDIX J. J., CHIEF OF ENGINEERS. REPORT OF 1892. PAGE 2255.

Improvement of Illinois River, Illinois.

The ultimate object of this improvement is to furnish a through route of transportation by water from the southern end of Lake Michigan to the Mississippi River, of sufficient capacity for its navigation by the largest class of Mississippi River steamboats that can reach the mouth of the Illinois River.

The dimensions that have been adopted for the locks to meet this requirement are:

	Feet.
Length of lock chamber	350
Width of chamber	75
Depth at low water over sills	7

The project now under execution is for the improvement of the lower section of this route, extending from the mouth of Copperas Creek to the Mississippi River, a distance of 137 miles. Another section of the river, 88 miles in length, from the mouth of Copperas Creek to La Salle, has been improved by the State of Illinois by the construction of two locks and dams, one at Copperas Creek and one at Henry, Ill.

Over this latter section the State still collects tolls, the United States not yet having accepted the conditions imposed by the act of cession of the Illinois legislature, which conditions are such as to deprive the works of all value while demanding a great expenditure by the United States Government for works to be substituted therefor.

With regard to this subject reference is made to the Annual

Report of the Chief of Engineers for 1889, page 2121, et sequitur.

Under the Act of Congress of August 11, 1888, surveys and separate estimates have been made, based upon low-water depths of 8 and 14 feet, for carrying the improvement from La Salle to Lake Michigan via the Illinois and Desplaines Rivers, and a cut across the Chicago divided, over which section there is a fall in water surfaces, Lake Michigan being the summit, of about 141 feet.

The report upon this survey and estimates has been printed as House Ex. Doc. No. 264, Fifty-first Congress, first session, and is also published in the Annual Report of the Chief of Engineers for 1890, page 2419 and following pages.

Other surveys and estimates have also been made by the trustees of the sanitary district of Chicago, organized under laws of the State of Illinois, for cutting a capacious channel carrying a large discharge from Lake Michigan into the Illinois River for drainage and sanitary purposes. In the reports of the Chief of Engineers, U. S. Army, for the years 1890 and 1891, the reports and estimates of engineers acting under authority of the city of Chicago, and later under the trustees of the sanitary district of Chicago, relating to this matter will be found. Further reports and estimates from the engineering department of the sanitary district of Chicago are hereto appended.

No provision has yet been made by Congress for embarking upon the construction of the necessary works to establish navigation over the section from La Salle to Lake Michigan, but the legislature of the State of Illinois has provided for the destruction of the navigation established by locks and dams over the section of the Illinois River from La Salle to Copperas Creek, by requiring the removal of the locks and dams at Henry and Copperas Creek within four years of July 1, 1889, whether or not any other system of navigation be substituted therefor. Under this law these dams must be removed by July 1, 1893.

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Page 2258.

The completion of the La Grange Lock and Dam has been followed by a material increase in the tonnage passing La Grange. The completion of the Kampsville Lock and the dredging the channel below it by extending the period of navigation there will have a more marked effect still in increasing

the size and tonnage of vessels navigating the Illinois River and the value of this stream as a means of transportation.

Doubtless the slow improvement of this river has resulted from a difference of opinion as to the method of improvement that should be applied: On the one hand, the necessities of the city of Chicago for better drainage has demanded a large discharge into the Illinois River for sanitary purposes, which discharge would make an open river improvement practicable below La Salle; on the other hand is the fact that the most economical and effective system, as far as navigation is concerned, is that by slackwater, modified, perhaps, by movable dams in the alluvial valley of the Illinois, Lake Michigan being the summit level, the channels being comparatively shallow but of greater width than proposed for sanitary purposes. Additional friction and consequent injury to both the scheme for a navigable channel and to the local drainage measure, delaying both, has been due to the demand by advocates of the latter that the United States shall construct the navigable channel of the dimensions necessary for the drainage scheme, without regard to the most economical channel and speedy method of meeting the absolute requirements of commerce by water over the connecting link between 14,000 miles of interior navigation existing upon the Mississippi River and its tributaries, and the Great Lakes.

These dissensions are now apparently quieted, and without friction the question of the extension of the navigation existing on the Western rivers to the Great Lakes, the best dimensions and location of channel from Joliet to La Salle, and the advisability and conditions of joint use by the United States for navigation and the city of Chicago for drainage of the channel that must be cut for both purposes across the rock in place, from near Willow Springs to near Lockport, can be now examined.

Upon this subject the reports of the Chief of Engineers for 1889, page 2121 et seq.; for 1890, page 2419, et seq.; and 1891, page 2611 et seq., are referred to.

The authorities of the sanitary district of Chicago have progressed so far with their work as to have definitely located for the third time a part of the drainage channel, and have taken an additional step in advance by soliciting and receiving proposals for the construction of their channel for drainage across the rock between Willow Springs and Lockport. The prices secured are very favorable; the contract

has not yet been awarded, but the proposals are under advisement by the trustees.

REPORT OF W. H. MARSHALL, U. S. ENGINEER AT CHICAGO, FOUND IN CHIEF OF ENGINEERS REPORTS UNITED STATES ARMY, PAGES 2150-2151.

1894.

The ultimate object of this improvement is to furnish a through route of transportation by water from the southern end of Lake Michigan to the Mississippi River, of sufficient capacity for the navigation by the largest class of Mississippi River steamboats that can reach the mouth of the Illinois River.

The dimensions that have been adopted for the locks to meet this requirement are:

Length of lock chamber	350 feet
Width of chamber	75
Depth of low water over sills	7

The project now under execution is for the improvement of the lower section of this route, extending from the mouth of Copperas Creek to the Mississippi river a distance of 137 miles. Another section of the river, 88 miles in length, from the mouth of Copperas Creek to LaSalle, has been improved by the State of Illinois by the construction of two locks and dams, one at Copperas Creek and one at Henry, Illinois.

Over this latter section the State still collects tolls, and United States not yet having accepted the conditions imposed by the act of cession of the Illinois legislature, which conditions, if accepted, are such as would deprive the works of all value, while demanding a great expenditure by the U. S. government for works to be substituted therefor.

With regard to this subject, reference is made to the Annual Report of the Chief of Engineers for 1889, p. 2121, et seq.

Under the act of Congress of August 11, 1888, surveys and separate estimates have been made, based upon low water depths of 8 and 14 feet, for carrying the improvement from LaSalle to Lake Michigan, via the Illinois and Des Plaines river, and a cut across the Chicago divide over which section there is a fall in water surfaces, Lake Michigan being the summit, of about 141 feet.

The report upon this survey and estimates has been printed as House Ex. Doc. No. 264, Fifty-first Congress, first session, and is also published in the Annual Report of the Chief of Engineers for 1890, p. 2419 and following pages.

In the reports named above and in the Annual Reports of the Chief of Engineers, U. S. Army, for the fiscal years 1891, 1892 and 1893, and in the various reports and estimates made by authority of the trustees of the sanitary district of Chicago, organized under the laws of the State of Illinois, full information relating to the objects and expected results of this improvement, and discussions correlated improvements by local authority, may be found.

The existing project involves the construction of two locks and dams in the Illinois River, one at LaGrange 79 miles and the other at Kampsville, 31 miles above the mouth of the Illinois, and dredging the channels from the mouth of Copperas Creek to the Mississippi River, a distance of 137 miles to give 7 feet depth at low water over bars. More than 2,000,000 cubic yards of dredging in this section is required.

The reach, 88 miles in length, between LaSalle and Copperas Creek, also requires dredging to carry the channel from LaSalle to the Mississippi River.

As far as the construction of locks and dams are concerned, the project is practically completed and in use. The dredging remains to be done, and an efficient snagging service provided.

The depths of navigation under this project, when attained, will meet all the requirements of navigation by Western river steamboats, but until this navigation is extended to the Great Lakes at the southern end of Lake Michigan the improvement will be of comparatively small value.

Congress has so far made no provision for extending the navigation on the same or equivalent basis from LaSalle to Lake Michigan, although repeated surveys and estimates have been made. It is now apparently necessary to consider the question of this extension and the relation thereof to the State works now existing or in process of construction.

Up to this time no satisfactory basis for the transfer of the State works of navigation has been presented by the Illinois authorities.

Extract from a Report of Board of Engineers March 17, 1900.

Appendix MM of Report of Chief of Engineers 1900. Page 3858.

Having considered the available facts bearing upon the questions presented, the Board has the honor to submit the following preliminary report, in compliance with Department letter of February 13, 1900.

The instructions of the Board are found in the act of Congress approved March 3, 1899, as follows:

"The Secretary of War is directed to appoint a board of three engineers, which board shall make a survey and estimates of cost for the improvement of the Upper Illinois River and Lower Des Plaines River, in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago; said board of engineers shall report the estimates of cost for a channel seven feet deep, and also for a channel eight feet deep, throughout said proposed route; said survey and estimates of cost shall be made in pursuance of and according to the recommendations in report of January twenty-seventh, eighteen hundred and ninety-seven, and there is hereby appropriated for the expenses of said board and such survey the sum of thirty thousand dollars, or so much thereof as may be necessary."

The report of January 27, 1897, is a "Preliminary examination of Upper Illinois River and Lower Des Plaines River, Illinois, with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago," made by Maj. W. L. Marshall, Corps of Engineers, U. S. A., and published in the report of Chief of Engineers, 1897, pages 2882-2887.

Detailed reports and surveys have also been submitted to Congress by the following officers:

Gen. J. H. Wilson, 1867, report published in House Ex. Doc. No. 16, Fortieth Congress, first session.

Col. J. N. Macomb, Corps of Engineers, Report of Chief of Engineers, 1875, Vol. II, page 525.

Maj. W. H. H. Benyaurd, Corps of Engineers, Report Chief of Engineers, 1884, page 1958.

Board of Engineers on Hennepin Canal and Illinois and Michigan Canal, Report of Chief of Engineers, 1887, page 2125.

Capt. W. L. Marshall, Corps of Engineers, Report of Chief of Engineers, 1890, page 2419.

The last report covers most thoroughly the entire subject, as far as it had then been developed, considers the various routes, shows the character and location of the works required on each, with detailed estimates of cost, and the 8-foot channel of those estimates is a water-way of so nearly the same dimensions as the 7 and 8-foot channels now called for that the work of the Board might be confined to the presentation of revised plans and estimates derived from this report, if it were not for the change in conditions which has resulted from the

construction by the Sanitary District of Chicago of a drainage canal through the divide between Chicago and Lockport. This channel opens a waterway over this part of the route which more than meets the requirements of the one called for or of any other likely to be called for by those interested in navigation.

If the route by the Chicago River and drainage canal be adopted, there remains but little more than half of the work involved in the 8-foot project of 1890 for the Government now to take in hand in order to complete the improvement, since the estimated cost of this portion of the channel (about 28 miles) was nearly $14,000,000. By the Calumet and Sag route only about 10½ miles of the drainage canal can be utilized.

But while the drainage canal covers about half of the work involved in the project by way of Chicago river, it at the same time has turned an additional flow into the Des Plaines River, materially changing its low-water regimen. The requirements of this flow at present are 5,000 cubic feet per second, while the limit of 10,000 is probably more nearly the flow that will have to be dealt with, at least not long after the completion of the present project. As nearly as can now be estimated, this flow gives a water line indicated on the accompanying profile, and the contrast is shown with the low-water conditions hitherto existing. The steep slope shown on the profile indicates that with so large a volume of discharge the velocity of the current would be too great for up-stream navigation in an open river. This might be overcome to a great extent by canalizing the river by high dams, entailing great expenditures for the necessary works, as well as for the purchase of lands overflowed, the cost of which cannot even be approximated from present information.

EXTRACT FROM A REPORT OF MAJOR J. H. WILLARD, U. S. ENGINEER AT CHICAGO, AS TO THE CONDITION OF THE CHICAGO HARBOR AND THE EFFECT OF THE SANITARY DISTRICT CHANNEL. APPENDIX MM REPORT OF CHIEF OF ENGINEERS 1901. P. 2989.

Owing to the general dissatisfaction of the people living along the lake shore between 16th Street and 39th Street with the selection of the inshore dumping ground, by agreement with the proper officer of the city and approved by the Secretary of War, as provided by law, and also to the general objection on the part of the Health Department of the city to the 2-mile ground heretofore acceptable on account of the

danger to the water supply, I am of the opinion that all future dumping should be in accordance with the wishes of the people and the views of the health officers, and be made at least eight miles lakeward and far removed from the city intakes, to avoid all danger of polluting the water supply. This rule should apply, in any event, to all future contracts made by the United States or others for dredging the Chicago River, into which the greatest part of the sewage flows or is planned to flow when the intercepts are finished. The people have paid an enormous sum to divert the sewage from the lake in the interest of the public health, and they feel entitled to protection at the hands of the United States.

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Page 2992.

MM 2.

Improvement of Chicago River, Illinois.

This river constitutes the inner harbor of Chicago, Ill. Its navigable parts lie wholly within the city limits of Chicago.

In the annual report of the Chief of Engineers for 1893, page 2974, may be found a full report upon this stream and its needed improvement, and in his annual report of 1897, page 2793, a history of the improvement and some detailed information as to the obstructions to navigation existing along its channels.

The present project was adopted by Congress in the River and Harbor Act of June 3rd, 1896, and modified by the sundry civil act of June 4, 1897. It contemplates dredging the river and its branches from the mouth of the river to the stockyards on the south branch, and to Belmont Avenue on the North Branch, as far as may be admitted by existing docks and wharves, to allow passage by vessels drawing 16 feet of water; *also to acquire title to and cut away certain obstructive bends and projecting docks that narrow and obstruct the channel.*

Since the flow of the Chicago River has been reversed through the South Branch by the discharge into the Sanitary Canal, the slope has also been reversed from the lake upstream, and the depth correspondingly reduced. To compensate for this loss in navigable depth the sanitary trustees have undertaken to dredge to a depth of 26 feet below hydraulic grade, and will continue to dredge to that depth while enlarging the river to 200 feet width upon plans approved by the Secretary of War. To reduce the dangers to navigation by the upstream flow, and to provide for the discharge of 20,000

cubic feet per minute for each 100,000 inhabitants of the Sanitary District, as required by State law, the trustees have submitted plans for seven bascule bridges, which have been approved by the Secretary of War upon the recommendation of the Chief of Engineers.

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P. 3006.

MM 5.

Improvement of Illinois River, Illinois.

The object of this improvement is to secure ultimately, in connection with an enlargement of the Illinois and Michigan Canal, or an equivalent enlarged canal, a waterway from the southern end of Lake Michigan to the Mississippi River of sufficient capacity for large-sized Mississippi River steamboats and for military and naval purposes.

The present project was adopted in 1880, and contemplates the extension of the slack-water improvement begun by the State of Illinois from the mouth of Copperas Creek to the Mississippi River at Grafton, Ill., a distance of 135 miles. The project includes the construction of two locks, each 350 feet in length of chamber, 75 feet in width, and with 7 feet depth at low water over sills, and dredging the channel where necessary to secure that depth of water at low water throughout the pools created by the dams.

The locks and dams have been completed and have been in use since 1889 and 1893, respectively. One is situated at La-Grange, 79 miles above the mouth of the Illinois, the other at Kampsville, 31 miles from the Mississippi.

The State of Illinois, aided by the United States, has executed part of the general project by the construction of locks and dams at Hennepin and Copperas Creek, completing, except dredging, that part of the project between LaSalle and the mouth of Copperas Creek, a distance of about 90 miles, over which section the State of Illinois collects tolls.

In executing this work the United States has expended prior to June 30, 1897, $1,344,090.62, including $25,000 from appropriation of August 11, 1888, for surveys, and exclusive of $62,-359.80, expended upon a foundation for Copperas Creek Lock, afterwards completed by the State of Illinois, and since that date in dredging, care and repair of plant, etc., $86,065.10, making a total expenditure on this work to June 30, 1901, of $1,430,155.72.

The State laws authorizing the construction of the Sanitary Canal require the removal of the state dams, when the flow required by the state law of 20,000 cubic feet per minute for

each 100,000 inhabitants of the Sanitary District shall have become permanent, the expectation being that the increased discharge would furnish an open navigation equivalent to that pooled by the dams. The discharge of the sanitary canal, however, is regulated by the Secretary of War *insofar as it affects the interests of navigation in the Chicago River*, and has been reduced by his order to 200,000 cubic feet per minute until the South Branch shall have been widened and deepened sufficiently to permit the full flow required by the state law, or so much thereof as may be found safe.

Unless, therefore, a large amount of dredging is done in the Henry and Copperas Creek State pools, the compensated navigable depth is not likely to be gained, the discharge through the openings in the dams most probably pulling the new water line below present crest heights throughout both pools.

The United States has a general interest in this question because it has spent large sums in extending the navigation of the river, but it has a direct interest in the effect the change must have on the LaGrange pool. This should be surveyed and dredged before the Lower State Dam is removed; otherwise the navigable length of the LaGrange pool must be shortened.

But if the results should approximate the theories of those advocating the removal of the State Dams, Congress would be asked to authorize the removal of the United States dams and thus convert the Illinois into an open river again.

Congress has indicated its purpose to have a thorough survey of the river for a deep waterway, but whether that is done soon or not at all, the War Department should begin collecting information in anticipation of a demand for removing the United States dams. I am not authorized to recommend a survey, but it is not improper to say that precise levels are absolutely necessary to a proper study of the questions that will arise in the near future. A duplicate line between Chicago and the mouth of the Illinois River would require two seasons' work, and would cost $10,000, including instruments, monuments, etc., and would furnish the basis for any future surveys that should be required, whether general or local.

I am of the opinion that an open river with a low-water navigable depth equivalent to that now furnished cannot be obtained except by dredging on a large scale with the most approved hydraulic plant. The dredging now in progress is only that necessary to furnish a low-water depth of 7 feet in the pools.

Final Report on Survey of Upper Illinois and Lower Des Plaines Rivers, Illinois, with a View to the Extension of Navigation from Illinois River to Lake Michigan at or Near Chicago.

(Printed in House Doc. No. 112, Fifty-Sixth Congress, Second Session.)

Office of the Chief of Engineers
United States Army,
Washington, December 4, 1900.

Sir: The river and harbor act approved March 3, 1899, contains the following item:

> Illinois river and Des Plaines river, Illinois: The Secretary of War is directed to appoint a board of three engineers, which board shall make a survey and estimates of cost for the improvement of the Upper Illinois River and Lower Des Plaines River, in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago; said board of engineers shall report the estimates of cost for a channel seven feet deep, and also for a channel eight feet deep, throughout said proposed route; said survey and estimates of cost shall be made in pursuance of and according to the recommendations in report of January twenty-seventh, eighteen hundred and ninety-seven, and there is hereby appropriated for the expenses of said board and such survey the sum of thirty thousand dollars, or so much thereof as may be necessary.

Preliminary report dated March 17, 1900, by the board of engineers appointed by authority of the Secretary of War in accordance with requirements of the above-quoted item of law, was submitted to the Secretary of War with my letter of March 24, 1900, and is printed in House Doc. No. 548, fifty-sixth Congress, first session, and in my Annual Report for 1900, page 3856 *et seq.*

I have now the honor to submit the accompanying copy of the Board's final report on the subject dated November 17, 1900.

The plans presented are for waterways of seven and eight feet depth from Utica to Marseilles in the bed of the river, thence around the Marseilles Rapids by canal, thence in the bed of the river to near the mouth of the Kankakee, thence through the Illinois and Michigan Canal to the Joilet basin, thence by canal to the Sanitary Canal at Lockport, and thence via the

Sanitary Canal and Chicago River to Lake Michigan. These projects involve the construction of 12 locks and 2 dams with movable weirs, the estimated cost being:

For the 7-foot project.....$7,317,977
For the 8-foot project..... 8,653,247

These estimates are based upon the assumption that such franchises as are necessary in connection with the constructions contemplated will be ceded free of cost to the United States.

The cost of an independent 8-foot waterway from Sag Bridge on the Sanitary Canal to Lake Michigan via the Little Calumet and Calumet Rivers (the Sag Route) is estimated at $5,680,186, making a total of $14,333,433, as the estimated cost of an 8-foot waterway via the Sag route.

Very respectfully,
Your obedient servant,
JOHN M. WILSON,
Brig. Gen. Chief of Engineers, U. S. Army.

Hon. ELIHU ROOT,
Secretary of War.

Page 3049.

Report of Board of Engineers.

Chicago, Ill., November 17, 1900.

General: The Board of Engineer officers constituted by paragraph 1, special orders, No. 14, March 12, 1899, headquarters Corps of Engineers, United States Army, in accordance with the provisions of the Act of March 3, 1899, to make "a survey and estimates of cost for the improvement of the Upper Illinois River and Lower Des Plaines River, in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago," submitted a preliminary report March 17, 1900, with estimates for channels eight feet deep and seven feet deep. (House Doc. No. 548, 56th Congress, 1st session.) The Board reconvened at Chicago November 9, 1900, and having revised its estimates after fuller information now presents its final report.

The Board finds the most economic route for waterways of 7 feet and 8 feet depth to be from Utica to Marseilles in the bed of the river, 11.4 miles; thence around the Marseilles rapids by canal, 7.4 miles; thence in the bed of the river to near the mouth of Kankakee River, 21.2 miles; thence by enlarging the Illinois and Michigan Canal to the Joliet basin, 18.3 miles; thence by canal through Joliet Basin and along the east bank of the Des Plaines River, 4½ miles, connecting with the Sani-

tary Canal at Lockport, and thence through the Sanitary Canal and the Chicago River to Lake Michigan, thus complying with the terms of the Act of March 3rd, 1899.

For the 8-foot project the dimensions proposed for the river sections and canal from Utica to the mouth of the Des Plaines River are not less than 300 feet wide at bottom for the river divisions and not less than 170 feet surface width for canal, with depths in the river divisions of 8 feet below extreme low water and in the canal of 10 feet. Existing railroad and highway bridges over these divisions must be remodeled to give suitable draw openings over the proposed channels. With locks of the same dimensions as the United States and State locks now in operation in the Lower Illinois River, viz., 75 feet wide by 350 feet between miter sills, steamboat navigation will be extended to the head of the Illinois River.

For the remaining canal divisions the width will not be less than 130 feet at water surface and the depth 10 feet, but the locks are reduced to 40 feet width by 260 feet between miter sills. With fixed bridges giving 22 feet headroom, the Board is of the opinion that these dimensions should furnish ample navigation for the largest barges heretofore in use on the Mississippi River, and that the combination will afford a waterway of 10 feet depth at stages 2 feet above extreme low water in the Illinois River of sufficient capacity for any through barg traffic likely to seek it.

To overcome a mean difference of elevation of 133 feet between the river surface at Utica and the surface of the Sanitary Canal at Lockport, with allowances for variations in stages at either end of the route, 12 locks have been provided as follows:

Locks 75 by 350 feet—Utica River Division: One lift lock, 15 feet lift. Marseilles Canal: Two lift locks, each 15 feet lift; one guard lock.

Locks 40 by 260 feet—Canal to Joliet Basin: Three lift locks, each 15 feet lift; one lift and guard lock, 15 to 9 feet. Canal, Joliet Basin to Lockport: Two lift locks, each 12 feet lift; one lift lock, 10 feet; one lift and guard lock, 10 feet to zero.

Two dams will be required, one at Utica and one at the head of the Marseilles Canal. The board is of the opinion that both dams should be surmounted by some form of movable weir to reduce the elevation of flood discharge by an amount at least equal to that which has been caused by the additional discharge from the Sanitary Canal.

The 7-foot waterway will follow the same route as that for

8 feet, and the dimensions of river channels, canals and locks will be the same except in depth. This will furnish a 9-foot navigation at a 2-foot stage in the Illinois River to the mouth of the Des Plaines River and a through barge navigation to Lake Michigan at Chicago. The principal reduction in the estimates is in the amount of excavation, the dimensions permitting little change in the cost of locks and other structures.

Estimates.

Utica Division.

	7-foot project	8-foot project
Dam and movable weir,	$106,000	$106,000
1 lock,	307,807	317,575
River walls,	57,098	57,098
Levees,	69,667	69,667
Excavation, rock,	73,250	210,125
Marseilles Canal:		
3 locks,	616,343	645,247
River walls,	105,282	105,282
Levees,	16,410	16,410
Excavation,	446,455	494,396
Revetment,	45,500	45,500
Kankakee pool:		
Dam and movable weir,	146,000	146,000
Excavation,	65,375	156,025
Enlarging Illinois & Michigan Canal:		
4 locks,	561,212	584,578
Excavation, rock,	77,598	778,876
Excavation, earth,	402,094	353,426
Culverts,	75,000	75,000
Aqueduct,	100,000	105,000
Canal Joliet to Sanitary Canal:		
4 locks,	487,798	512,490
Excavation, rock,	234,675	327,594
River walls,	464,750	464,750
Culverts,	75,000	75,000
Bridges,	865,000	865,000
Right of way and damages,	700,000	700,000
Engineering and contingencies, 20%,	1,219,663	1,442,208
Total,	7,317,977	8,653,247

As in the preliminary report, the Board invites attention to the fact that the estimates are based upon the assumption that

the State of Illinois and the sanitary trustees of the City of Chicago will cede the necessary parts of their respective franchises free of cost to the United States, both for construction and use.

The Sag Route.

Since the Board's report of March 17, 1900, the trustees of the sanitary district have undertaken to co-operate with the United States in deepening the South Branch of Chicago River to 21 feet and widening it to at least 200 feet. They have already planned to substitute 7 bascule bridges for the center-pier bridges now obstructing the river. It is expected that this project will be extended, and that the City of Chicago will undertake a part of the bridge reconstruction and lower, or cause to be lowered, the three tunnels now limiting the navigable depth of the river to 17 feet. The fears entertained with respect to the dangers of navigating the South Branch of the river under the new conditions of reversed flow have been allayed to a great degree by the practical experience of the past season. For this reason, and because the plans for both the 7-foot and 8-foot waterways comply with the requirements of the act contained in the words "with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago" in connection with the Sanitary Canal, the Board is of the opinion that the additional cost will not justify the construction at the present time of an auxiliary canal from the Sanitary Canal to Lake Michigan by way of the Sag and Calumet Route, and is also of the opinion that such a route would not become a necessity until the commerce of either the 7-foot or 8-foot route should develop to a degree not expected for years.

The estimates for this auxiliary route are based upon the same dimensions for canal and structures as those for the canal from the Illinois River to Lockport in the 8-foot project.

Estimate for the Sag Route.

1 lock connecting with Sanitary Canal at Sag Bridge,	$155,000
Rock excavation,	603,800
Earth excavation,	1,924,688
Bridges,	1,500,000
Right of way,	550,000
Engineering contingencies, 20 per cent.,	946,698
Total,	5,680,186
Grand total for 8-foot waterway by the Sag route,	14,333,433

The report of Assistant Engineer James A. Seddon, is appended, and there accompanies the report an index map with profile and 19 maps of the route from the Sanitary Canal at Lockport to LaSalle on the Illinois River.

Money Statement.

Amount appropriated by act approved March 3, 1899,	$30,000
Amount expended to November 17, 1900,	22,155.88
Outstanding liabilities,	3,044.12
Balance available,	4,800.00
	30,000.00

Respectfully submitted,

J. W. BARLOW,
Colonel, Corps of Engineers.
J. H. WILLARD,
Major, Corps of Engineers.
C. McD. TOWNSEND,
Major, Corps of Engineers.

Brig. Gen. JOHN M. WILSON,
Chief of Engineers, U. S. A.

EXTRACT FROM A REPORT OF MR. JAMES A. SEDDON, ASSISTANT ENGINEER. PAGE 3052.

United States Engineer Office,

Chicago, Ill., November 9, 1900.

Colonel: In accordance with the instructions of the Board of Engineers, I have the honor to report upon the location of waterways for 7-foot and 8-foot navigation, with estimate of cost.

Under the terms of the Act of March 3, 1899, these waterways are required for an extension of the navigation of Illinois River through the Upper Illinois and Lower Des Plaines to Lake Michigan at or near Chicago.

The Sanitary Canal having been opened in accordance with the State law and under a provisional permit from the Secretary of War, the flow of the Des Plaines and Illinois Rivers has been increased by a discharge of 5,000 cubic feet per second, which will be raised to the maximum of 10,000 cubic feet per second under the provisions of the State law authorizing the construction of the Sanitary Canal.

* * * * * * *

P. 3059.

REPORT OF BOARD OF ENGINEERS.

United States Engineer Office,
Chicago, Ill., November 18, 1900.

General: The river and harbor act approved June 6, 1900, provides—

"That the board of three engineers appointed by the Secretary of War, in pursuance of a paragraph in the river and harbor Act approved March 3rd, Eighteen Hundred and Ninety-nine, to make a survey and estimates of cost of the improvement of the upper Illinois River and the lower Des Plaines River in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near the city of Chicago, is hereby authorized to report the estimates of cost for a channel 10 feet deep, and for a channel 12 feet deep, and for a channel 14 feet deep through said proposed route, and that the said estimates cover and include a proper connection at Lockport with the sanitary and ship canal which has been constructed by the sanitary district of Chicago. The said board of engineers is also further authorized to make a survey and estimate of cost for the improvement of the Lower Illinois River from the end of said proposed route to the mouth of said river, for channels 10, 12, and 14 feet deep, respectively, and to report the estimates of cost thereof: *And provided further*, That surveys and estimates of cost shall be made in pursuance of the provisions contained in the Act aforesaid and especially in accordance with section twenty-two of said Act: *And provided further*, That said surveys shall be commenced and the expenses for said surveys and reports shall be paid as follows: Any unexpended balance of the appropriations of Thirty thousand Dollars not required for the completion of the survey already contained in said Act shall be first applied and used, and no further expense shall be incurred for such estimates and surveys without the further direction of Congress, and the Secretary of War shall ascertain and report to Congress what amount of money shall be required to complete said surveys and estimates of cost."

In compliance with your instructions in accordance therewith, contained in Department letter dated June 11, 1900, the Board has the honor to submit the following preliminary report:

Section 22 of the river and harbor act approved March 3, 1899, under which surveys and estimates are to be made, is as follows:

> That the Secretary of War is hereby directed to cause preliminary examinations or surveys to be made at the localities named in this section as hereinafter provided. In all cases a preliminary examination shall first be made, which shall embrace information concerning the commercial importance, present and prospective, of the river or harbor mentioned, and a report as to the advisability of its improvement. Whenever such preliminary examination has been made, in case such improvement is not deemed advisable, no further action shall be taken thereon without the direction of Congress; but in case the report has been or shall be to the effect that such river or harbor is worthy of improvement, the Secretary of War is hereby directed at his discretion, to cause surveys to be made and the cost of improving such river or harbor to be estimated and to be reported to Congress.

It therefore devolves upon the Board to express its opinion as to the advisability of the improvement before surveys can be undertaken. As Congress has approved the project for the improvement of the Illinois River from its mouth to LaSalle, providing for a depth at low water of 7 feet, and authorized surveys to determine the cost of obtaining waterways with depths of 7 and 8 feet from LaSalle to Lake Michigan, at or near Chicago, upon which we have submitted a report dated November 17, 1900, the question now before the Board is the advisability of a further enlargement of this waterway to depths of 10, 12 and 14 feet.

The preliminary examination of the Lower Illinois River from Grafton to Peru was made by members of the Board on the Steamer *Reindeer*, chartered for the purpose August 2 to 4, 1900. The Board had also examined the portions of the route from the end of the Drainage Canal at Lockport to the mouth of the Des Plaines River and the rapids at Marseilles, in connection with the survey for determining the cost of the 7 and 8 foot waterways along the Upper Illinois and Des Plaines Rivers.

The present commerce of the Lower Illinois River practically all terminates at St. Louis, and the traffic of the river is represented by the Illinois River freight received and shipped at that point. There is appended a statement of the receipts and shipments at St. Louis of Illinois River freight

for the past 8 years, derived from the reports of the Merchants' Exchange of St. Louis. This commerce averages 44,425 tons per annum. (Appendix 1.)

While the Upper Illinois and Des Plaines Rivers are at present non-navigable, the commerce of the Illinois and Michigan Canal which has been constructed in the valleys of these rivers may be taken to represent the present commerce of such a route. The tonnage carried on the Illinois and Michigan Canal since 1860, derived from the Reports of the Board of Trade of Chicago is also appended. (Appendix 2.)

To determine the prospective commercial importance of the proposed route an expression of opinion was invited from those interested, who had made the matter a subject of special study. There accompany this report the papers submitted:

A. Memoir of the trustees of the sanitary district of Chicago.

B. Commercial utility of a waterway of a navigable depth of not less than 14 feet between Chicago and St. Louis, brief by Lyman E. Cooley.

C. Paper on a deep waterway from the Great Lakes to the Gulf of Mexico, presented by the Illinois River Valley Association.

The commerce of the waterways of the Illinois and Des Plaines Valleys is small and has been diminishing in recent years. It is not sufficient to warrant any increase in existing navigable depths, and it is only by considering the development of a connecting link between the system of river commerce in the Mississippi Valley on the one hand and the commerce of the Great Lakes on the other that even a waterway with a depth of 8 feet will be justified.

The adopted projects for the improvement of the Mississippi River provides from the mouth of the Illinois River to the mouth of the Missouri "for a channel of a depth of *four and a half feet of low water*, to be eventually increased to six feet"; from the mouth of the Missouri River to St. Louis "eventually a minimum depth at standard low water of six feet, and of eight feet from St. Louis to the mouth of the Ohio," and below the mouth of the Ohio ten feet at low water. The projects for the improvement of all the tributaries of the Mississippi, except the Illinois River, provide for waterways of not exceeding six feet at low water.

The project for the Lower Illinois River provides for locks 75 feet wide and 350 feet between miter sills with 7 feet on the miter sills at low water. The discharge of the Chicago

Drainage Canal should increase the navigable depth to over 8 feet, and if the project be extended to Lake Michigan by the 8 foot project on which estimates have been submitted by the Board, there will be afforded a connecting link between the Great Lakes and the Rivers of the Mississippi Valley, not only ample for river navigation as it now exists, but also for any improvement therein that has been authorized by Congress.

But it is held by not a few that the United States should take the initiative and construct a great waterway of which the Illinois Valley line should be a link, extending lake navigation to the interior of the country, and that a commerce which does not now exist will then develop to such a magnitude as will more than justify the expenditures. For such a project a depth of 14 feet or greater will be required, and further surveys and estimates for a waterway of less depth than 14 feet cannot be considered by the terms of Section 22, under which the Board is instructed to act.

The engineering questions presented in a project for a deep waterway to connect Lake Michigan with the Illinois River, although attended with considerable difficulty, are by no means insuperable. The proposed line would embrace, first, the Chicago River, consisting of the main river and a portion of the South Branch for a distance of about 5 miles. This section is now under improvement by the United States in co-operation with the trustees of the Sanitary District of Chicago, and will, when the many changes in bridges and tunnels have been made, and the widening and deepening of the channel completed, afford a navigable depth of 21 feet and an available width of 200 feet.

Connecting with this section the sanitary canal affords a magnificent waterway, 28 miles in length, of sufficient depth and width for any possible requirement of navigation.

From the west end of this canal the waters of Lake Michigan, in a steady flow amounting to from 5,000 to 10,000 cubic feet per second, are discharged into the bed of the Des Plaines River, and are carried thence down through the Illinois to the Mississippi.

The velocity of current along the Des Plaines river, which would have resulted from confining this discharge to a channel of 8 feet depth for barge navigation, will be sufficiently reduced in a ship canal of *14* feet depth *or over to make upstream navigation feasible.* On the lower Illinois River the prevailing slope of less than 0.15 foot per mile will insure

so gentle a current that the depth required can be secured simply by enlarging the existing waterway by dredging in an alluvial deposit, at a cost which will be small when compared with the work which has been done by the city of Chicago in cutting through the divide between the Lake Basin and the Illinois Valley watershed, so eloquently described in the memoir of the Board of Trustees of the Sanitary District of Chicago.

But such a channel to be of commercial value should either form a through line of communication between the lakes and the Gulf of Mexico or extend to some large center of population, as St. Louis. A waterway stopping at the Village of Grafton would have little commercial importance, except locally, over one to the present terminus of the Drainage Canal at Lockport. The terminal arbitrary described by Mr. Cooley in his paper submitted will be as applicable in the one case as in the other.

The commercial possibilities of navigation by lake vessels to St. Louis and the Gulf of Mexico have been ably discussed in the papers accompanying this report, but all of these projects are based upon the assumption that the Mississippi River can be rendered navigable for such vessels. The feasibility of the development of the navigation of the Mississippi River is the essential element, which must first be determined before any project for extending lake navigation inland can be considered advisable.

REPORT OF COL. O. H. ERNST, U. S. ENGINEER AT CHICAGO, ON THE IMPROVEMENT OF THE CHICAGO RIVER. APPENDIX KK—REPORT OF CHIEF OF ENGINEERS, 1902. PAGE 2097.

K K 2.

Improvement of Chicago River, Illinois.

This river constitutes the inner harbor of Chicago, Ill. Its navigable parts lie wholly within the city limits of Chicago.

In the Annual Report of the Chief of Engineers for 1893, page 2974, may be found a full report upon this stream and its needed improvement, and in his annual report for 1897, page 2793, a history of the improvement and some detailed information as to the obstructions to navigation existing along its channels. * * * At the beginning of the fiscal year the project was nearly completed, there remaining to be done only the final approval by the Attorney-General of the title

to one of the tracts, and the excavation by dredging of two tracts. The last excavation was completed August 28, 1901.

Since the flow of the Chicago River has been reversed through the South Branch by the discharge into the sanitary canal the slope has also been reversed from the lake upstream and the depth correspondingly reduced. This loss in navigable depth will be more than restored in the main stream and in the South Branch by the excavations of the sanitary district, which, in order to facilitate the flow of the large volume of water required for the dilution of the sewage discharged into the drainage canal, has undertaken to enlarge these portions of the Chicago River to a width of 200 feet and central depth of 26 feet. These dimensions have no relation to the draft of vessels using the river, and if maintained as they should be for drainage purposes will furnish a navigable depth in excess of the requirements. The south fork of the South Branch, and the North Fork, however, do not share in these benefits. In the South Fork particularly the dimensions of channel obtained by the operations of the Government were seriously impaired by the change of slope. The sanitary district has undertaken to restore these dimensions, and will no doubt do so, though it has been prevented from fully accomplishing the work by some difficult rock excavation. But it has not undertaken as yet to maintain them.

The Chicago River is the main sewer of Chicago, and as such is subject to deteriorating influences as a navigable channel from which there is no escape. The city ordinances against dumping solid matter into it are ample, and, I think, generally well observed. But a very large amount of solid matter must of necessity go into it with a perfectly legitimate use of it as a sewer. Periodical dredging will be necessary to maintain it as a navigable channel and, eventually, to maintain it even as a sewer. That work would seem to be as much the duty of the city as the maintenance of any other part of its sewer system. So far as the South Branch is concerned, the question has been solved by the necessities of the drainage canal, as already mentioned, but the sanitary district has not accepted responsibility for maintaining the other branches. Whether that organization or some other representing the people of Chicago should do the work is for them to decide, but it seems to me clear that the United States should not be called upon to do it. Accordingly, no estimate for maintaining the channel excavated under the project of 1896 is submitted.

The river and harbor act of June 13, 1902, contained the following item, viz.:

Improving Chicago River, Illinois: Continuing improvement, three hundred and six thousand four hundred and fifty-seven dollars: *Provided,* That the sum of one hundred and ninety-three thousand five hundred and forty-three dollars, unexpended balance of money heretofore appropriated for the improvement of the Chicago River, making the total sum five hundred thousand dollars, may be used in the improvement of said river by constructing turning basins of proper size in said river, said turning basins to be located by, and said money to be expended under the direction of, the Secretary of War.

It is proposed to apply these funds to the acquisition of the necessary land and to the excavation of two turning basins, one on the South Branch near its junction with the South Fork and West Fork, and the other on the North Branch near the head of Goose Island.

It is probable that the amount available will be sufficient to create those turning basins, though their exact cost cannot now be given. No additional appropriation is asked for, but it is suggested that all of the "unexpended balance of money heretofore appropriated for the improvement of the Chicago River" be made available for the turning basins. That was no doubt the intention of the present law, quoted above. But this law specified the amount of the unexpended balance as $193,543. It was estimated a year ago that that would be the amount unexpended after the closure of existing contracts. As a matter of fact, the unexpended balance June 30, 1902, is $201,497.61, which is $7,954.61 more than the estimate of a year ago. There is no good reason why the whole of this balance should not be made available for the turning basins.

The volume of business transacted in the river during the calendar year 1901 was slightly larger than in the previous year, but with that exception it was less than in any year since 1893, as appears from the comparative statement attached to my report on Chicago Harbor herewith. The commodities received and shipped by lake were in 1901 6,184,242 tons against 7,958,963 tons in 1893, and this notwithstanding the great revival of business activity since 1893. This decline has been steady and is bound to continue unless the obstructions to navigation in the river are removed. The people of Chicago, through the officials of the sanitary district, are doing good work in that direction, and are engaged in a systematic and extensive system of improvements in the South Branch, widening and deepening the channel and remodeling the bridges.

These improvements are of great value and importance, and of necessity as well, but they will accomplish little without the removal of the tunnels under the river. These tunnels now have about 17 feet of water over them and limit safe navigation to a draft of 16 feet. The attitude of Congress toward them is that they are legal structures, and until removed by the authority which placed them there—the City of Chicago—they limit the extent to which the river can be improved. No lake port which cannot safely accommodate vessels drawing more than 16 feet can hold its own in these days of deep-draft vessels. The evil which these tunnels are doing does not seem to be fully appreciated by the people. The bridges and narrow channels are obstructive, but the tunnels absolutely close the door to the best class of vessels. Chicago will do well to remove the tunnels without further delay if she is to arrest the decay in her lake shipping, which has been going on almost continuously for the last ten years.

54th Congress, 2d Session. House of Representatives. Document No. 333.

PRELIMINARY EXAMINATION OF THE UPPER ILLINOIS RIVER AND LOWER DES PLAINES RIVER, ILLINOIS.

Letter from the Secretary of War, Transmitting, with a Letter from the Chief of Engineers, a Report of a Preliminary Examination of the Upper Illinois River and Lower Des Plaines River, Illinois.

March 2, 1897.—Referred to the Committee on Rivers and Harbors, ordered to be printed.

War Department,

Washington, D. C., March 3, 1897.

Sir: I have the honor to enclose herewith a letter from the Chief of Engineers dated March 2, 1897, together with a copy of a report from Maj. W. L. Marshall, Corps of Engineers, dated January 27, 1897, of a preliminary examination made by him in compliance with the provisions of the river and harbor act of June 3, 1896, of the upper Illinois River and lower Des Plaines River, Illinois.

Very respectfully,

DANIEL S. LAMONT,
Secretary of War.

The Speaker of the House of Representatives.

Office of the Chief of Engineers,

United States Army,

Washington, D. C., March 2, 1897.

Sir: I have the honor to submit the accompanying report of January 27, 1897, by Maj. W. L. Marshall, Corps of Engineers, of the results of a preliminary examination of the upper Illinois River and lower Des Plaines River, Illinois, with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago, made in compliance with requirements of the river and harbor act of June 3, 1896.

Major Marshall states that the locality embraces an important commercial route between the Great Lakes and the Mississippi River system, and its utility and worthiness have long been recognized by Congress.

The division engineer, Col. Henry M. Robert, Corps of Engineers, is of the opinion that the upper Illinois and lower Des Plaines rivers are worthy of improvement, and I concur in his views.

It is estimated that the cost of the necessary survey and preparation of detailed plans of improvement will be $75,000.

Very respectfully, your obedient servant,

JOHN M. WILSON,
Brig. Gen., Chief of Engineers, U. S. Army.

Hon. DANIEL S. LAMONT,
Secretary of War.

PRELIMINARY EXAMINATION OF UPPER ILLINOIS RIVER AND LOWER DES PLAINES RIVER, ILLINOIS, WITH A VIEW TO EXTENSION OF NAVIGATION FROM ILLINOIS RIVER TO LAKE MICHIGAN AT OR NEAR CHICAGO.

United States Engineer Office,

Chicago, Ill., January 27, 1897.

General: In accordance with your letter dated August 11, 1896, I have the honor to submit the following report upon a preliminary examination of "the upper Illinois River and lower Des Plaines River, with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago," directed by the river and harbor act of June 3, 1896.

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The latter reports are in so full detail that little can now be added to them by any preliminary examinations, as such are understood by me, and all that can be submitted now is simply a repetition of a small part of the information contained in these reports, with a brief statement of the conditions brought about by local engineering works constructed for drainage purposes by the trustees of the sanitary district of Chicago.

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The sanitary district of Chicago has nearly completed a canal for drainage purposes from Chicago River at Robey street to near Lockport from 18 to 22 feet in depth below the proposed water surface, and varying in width from 160 feet in rock to more than 200 feet in earth, a length of 28 miles, which may be made available as part of any enlarged waterway over the route in question, and is of much greater dimensions than required by any commerical canal adapted for the conditions and requirements of present or prospective traffic by water between Lake Michigan and the region along the water courses of the Mississippi Valley. To comply with the law of the State of Illinois under which this drainage canal is constructed—it has been constructed of a capacity to discharge 600,000 cubic feet per minute through the section excavated in rock and 300,000 cubic feet per minute throughout the earth section—the law requires a discharge of 20,000 cubic feet per minute for each 100,000 inhabitants of the drainage district, which at present requires more than 300,000 cubic feet and in a few years will require the full 600,000 cubic feet discharge through the canal. The taking of water from Lake Michigan, however, for drainage purposes (or rather for dilution of sewage) has not yet been authorized by Congress. This deep channel abruptly terminates at Lockport, and it is proposed to discharge the water through controlling gates into a non-navigable tail race down the slope to and through the City of Joliet into the lower Des Plaines and Illinois rivers. Any navigable channel, therefore, constructed in continuation of the drainage canal must connect with this canal at Lockport and terminate at or above LaSalle, about 66 miles distant, but the lockage after the opening of the drainage canal will be reduced by at least the amount that the increased discharge will raise the water surface of the Illinois River at LaSalle, increased by the slope in the drainage canal from Lake Michigan to Lockport, or, say, at least 12 feet when the drainage canal is actually discharging. This will result in reducing the number of locks required in any of the proposed schemes by one, but will substitute an obstruction due to the current in the

canal and river, repeated in each pool of the river, if the natural channel be improved.

* * * * * * * * *

The trustees of the Chicago sanitary district are constructing their canal with fixed bridges with 22 feet clear headroom over the canal. This is ample headroom for a commercial barge canal of the largest capacity, and the difference in cost between fixed and drawbridges crossing the canal between Chicago and Lake Joilet, with a reasonable allowance for difference in cost of operation, is probably sufficient to construct the canal from the present terminus of the drainage canal to Lake Joliet of from 8 to 10 feet depth, with locks suitable for the passage of the largest Mississippi River barges. Mississippi River towboats could then carry their tows to Lake Joliet, then transfer them to more handy tugs for passage through the more obstructive canal portion of the route. For an 8-foot channel from Lockport to Lake Joliet the estimated cost in 1890, exclusive of bridges, was $3,900,000. Swing bridges from Chicago to Lake Joliet were estimated at $3,653,000. The cost of operating the swing bridges would far exceed the cost of operating the locks without any corresponding advantages for a commerical canal, other than sentimental, over the part of the route where towing on the Mississippi River style cannot be applied.

Conclusion.

1. In my opinion the surveys already made are in sufficient detail for preliminary estimates of the cost of any suitable extension of the navigation of the Illinois River to Lake Michigan that does not involve enlargement of the Illinois and Michigan Canal from Joliet to LaSalle.

2. That prior to embarking in any such improvement it is advisable to secure from the State of Illinois the State works along the Illinois River and such parts of the Illinois and Michigan Canal as may be utilized; also to thoroughly complete the lower Illinois River improvement which has slowly progressed for thirty years, resulting in diversion of water traffic to rail.

3. That the dimensions and route of the proposed extension should be examined into and decided by a competent board of engineers, with means and authority to make such additional surveys as their proper enlightenment demands. The expenses and costs of such a board of the surveys are estimated at $30,000; if detailed plans, etc., are to be made, at $75,000.

The locality embraces an important commercial route between the Great Lakes and the Mississippi River system, and its utility and worthiness has long been recognized by Congress.

Preliminary estimates of cost on various plans have been heretofore made, and reports containing them are referred to hereinbefore.

Very respectfully, your obedient servant,

W. L. MARSHALL,
Major, Corps of Engineers.

Brig. Gen. W. P. CRAIGHILL,
Chief of Engineers, U. S. A.
(Through the Division Engineer.)

(First indorsement.)

U. S. Engineer Office,

Northwest Division,

New York, February 20, 1897.

Respectfully forwarded to the Chief of Engineers, United States Army.

I am of the opinion that the upper Illinois and lower Des Plaines rivers are worthy of improvement with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago.

HENRY M. ROBERT,
Colonel, Corps of Engineers, Division Engineer.

EXTRACT FROM A PAMPHLET ENTITLED "THE LAKES AND GULF WATERWAY," WITH ILLUSTRATIONS AND NOTES, PUBLISHED BY THE CITIZENS' ASSOCIATION. PREPARED UNDER THE DIRECTION OF THE COMMITTEE ON MAIN DRAINAGE BY LYMAN E. COOLEY, CIVIL ENGINEER, CHICAGO, JAN., 1888.

The Deep Waterway Convention at Peoria in 1888 had submitted to it a brief entitled, "The Lakes and Gulf Waterway," by Mr. Lyman E. Cooley. Subsequently the Citizens Association had printed the report submitted by Mr. Cooley and added thereto a summary statement, and the entire pamphlet was distributed among the members of Congress for the purpose of securing the co-operation of the Federal Government in the construction of a deep waterway from Lake Michigan to the Mississippi River, using the proposed Sanitary District channel as a part of that waterway. This effort on the part of the Citizens Association of Chicago was referred to by Captain W. L. Marshall in his report of 1891, Chief of Engineers Reports, United States Army, page 2613. The following extract is taken from the summary statement by the Citizens Committee:

"A channel of this capacity, if designed for sewage purposes alone, can be constructed at a less cost than if also suited to navigation. Uniting the two purposes in the same channel makes a navigable waterway a certainty, in the near future, while a channel for navigation alone, on account of its great expense, would most likely be delayed many years. It is proposed that Chicago shall pay the full cost of taking care of her sewage, leaving to the United States only the expense of suiting the channel to the purposes of navigation and improving the river below —in other words, while Chicago will, at her own expense, restore the ancient channel connection between the lakes and the rivers, the United States is simply asked to utilize the great waterway thus created for the purposes of commerce and national defense. The work of digging the channel between Joliet and Chicago (mostly through rock) and the construction of locks and dams at and below Joliet should proceed simultaneously, because the stone taken out of the cut may be used for the construction of these locks and dams, thus saving a large expense. What is asked of Congress at the present is a survey, location, plans and estimates, with a view to such co-operation.

All that is asked of the Legislature of Illinois is suitable legislation to enable Chicago to do its part of the work, at its own expense."

Page 1146.

EXTRACTS FROM THE ACT OF MARCH 3, 1899.

Pages 1146 and 1156, Vol. 30 U. S. Statutes at Large.

Improving the Illinois River, Illinois: Continuing improvement, one hundred thousand dollars.

Illinois River and DesPlaines River, Illinois: The Secretary of War is directed to appoint a board of three engineers, which board shall make a survey and estimates of cost for the improvement of the upper Illinois River and Lower Des-Plaines River, in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago; said board of engineers shall report the estimates of cost for a channel seven feet deep, and also for a channel eight feet deep throughout said proposed route; said survey and estimates of cost shall be made in pursuance and according to the recommendations in report of January twenty-seventh, eighteen hundred and ninety-seven, and there is hereby appropriated for the expense of said board and such survey the sum of thirty thousand dollars or so much thereof as may be necessary.

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Page 1156.

Improving the Chicago River, in Illinois: Survey and estimates of cost for a channel twenty-one feet deep from its mouth to the stock yards on the South Branch, and to Belmont Avenue on the North Branch, so far as may be permitted by existing docks and wharves, exclusive of the cost of removing or constructing bridges or piers or lowering tunnels; and the aforesaid depth of twenty-one feet is hereby adopted as the project depth for the improvement in lieu of that fixed by the Act of June third, eighteen hundred and ninety-six: Provided, That all the work of removing and reconstructing bridges and piers and lowering tunnels necessary to permit a practicable channel with said depth to be obtained shall be done, or caused to be done, by the City of Chicago, without expense to the United States.

MEMORIAL.

PRESENTED BY THE TRUSTEES OF THE SANITARY DISTRICT OF CHICAGO, FAVORING THE CONSTRUCTION BY THE GOVERNMENT OF THE UNITED STATES OF A DEEP WATERWAY FROM LAKE MICHIGAN, VIA THE CHICAGO SANITARY AND SHIP CANAL AND THE DES PLAINES AND ILLINOIS RIVERS, TO THE MISSISSIPPI RIVER. FEBRUARY 26, 1900.

I.—INTRODUCTORY.

To the Congress of the United States:

Your memorialist—William Boldenweck, Joseph C. Braden, Zina R. Carter, Bernard A. Eckhart, Alexander J. Jones, Thomas Kelly, James P. Mallette, Thomas A. Smyth and Frank Wenter—respectfully state that they constitute the present Board of Trustees of the Sanitary District of Chicago, and that, as such Trustees, they feel warranted in speaking for and on behalf of the population of said District, numbering about 1,800,000 people. They firmly believe they voice the sentiment of this population, with which sentiment they themselves are in entire accord, in saying that practically all the residents of the said District heartily favor the construction by the Federal Government of a deep waterway from Lake Michigan, via the Chicago Sanitary and Ship Canal and the Des Plaines and Illinois Rivers, to the Mississippi River. Since the opening of the said Sanitary and Ship Canal—January 17, 1900—a current of water from Lake Michigan approximating in volume 300,000 cubic feet per minute, and capable of floating vessels having a draught of twenty feet or less, has been flowing along the route of the proposed waterway, and the said Sanitary and Ship Canal was built without any expense whatever to the Federal Government.

Your memorialists respectfully represent that for more than half a century it has been the hope and desire of the people of the Middle and Northwestern States, and of the entire Mississippi Valley, that a deep waterway would be constructed at the earliest practicable date by the Federal Government, connecting the Great Lakes and the Gulf. Especially is this true of all persons residing in the territory mentioned who are interested in agriculture, commerce and manufacture. The existence of such a waterway would be a powerful factor in the matter of equalizing rates charged by other lines of transportation. Nor is the fact unworthy of consideration that the proposed waterway would afford an independent outlet to the sea, and would make it possible, in a time of emergency, for

the Government of the United States to send its light draught warships to the northern lakes without delay and without the possibility of having their passage blockaded or interrupted by any foreign foe. While it is not expected that the Federal Government would commit itself to the effort to secure a uniform depth of twenty feet of water from Chicago to the Mississippi River, it is believed, and the opinions of competent engineers show, that it is practicable to construct and maintain a waterway which would have a minimum depth of at least fourteen feet at the lowest point.

It is the purpose of your memorialist, speaking now for themselves, only, to co-operate earnestly and heartily with all associations or organizations now existing or that may hereafter be formed, with a view to carrying this great enterprise to a successful conclusion. To that end the aid of the Congress of the United States is respectfully and urgently invoked, for we realize that without favorable Congressional action nothing can be done. It affords us much gratification to be able to state that the item of cost, which is nearly always the chief factor to be considered in such undertakings, is happily, in the present instance, reduced to a place of minor consideration. The most difficult problem in connection with this enterprise has already been solved. According to estimates made by the most competent and reliable engineers, considerably more than one-half of the total expenditure required to assure its success has already been paid, or assumed, by the Sanitary District of Chicago. The property owners of said District have submitted to an assessment of millions, and tens of millions, in the way of taxation for the construction of a Sanitary and Ship Canal, which, including six miles of the Chicago River, extends to Lockport, a distance of a little more than thirty-four miles from Lake Michigan. Full particulars of the cost and construction of this canal are set out hereafter. It is sufficient to say here that the profound conviction that the canal would certainly be utilized by the Federal Government as a part of the deep waterway which is to connect the Great Lakes and the Gulf of Mexico, induced the taxpayers to submit to these enormous levies with much more grace than they would have exhibited under other circumstances.

Your memorialists further respectfully represent that they have made a complete investigation as to the feasibility of the proposed undertaking, the difficulties which must be met and overcome, the natural conditions favoring such a waterway, together with what is believed to be an approximately correct

estimate of the cost necessary to carry on the work beyond the present terminus of the Sanitary and Ship Canal. They have also prepared data showing that all the States in the Union are deeply interested in this enterprise and that all the people will be benefited if it is undertaken and completed. Figures will also be submitted hereafter, showing the tonnage now passing through the Detroit River, the St. Mary's Falls Canal, the Erie Canal and the Welland Canal. In short, they have endeavored to make this memorial an elaborate compendium of information bearing on the subject in all its phases, and the attention of the Senators and Representatives is respectfully invited to a careful perusal of this document in the hope that it may assist, even in a small degree, to persuade them that it is their duty, as it should be their pleasure, to commit the Federal Government to the support of this great enterprise.

II.—The Chicago Sanitary and Ship Canal.

The project for a deep waterway to connect the northern lakes with the Mexican Gulf is far from being a new idea. On the contrary, as has been hereinbefore stated, it has been actively agitated by the people of the Northwest, of the Middle States and of the entire Mississippi Valley, for more than half a century. It has been the dream of explorers and navigators for nearly three hundred years. As long ago as August 1, 1674, Joliet, the great explorer, writing to his friend, Father Dablon, said concerning a possible outlet from the Great Lakes to the Gulf:

> "A very important advantage, and one which some, perhaps, will find it hard to credit, is that we could quite easily go to Florida in boats and by a very good navigation. There would be but one canal to make, by cutting only one-half a league of prairie, to pass from the Lake of Illinois (Lake Michigan) into the St. Louis River (the Des Plaines River). The route to be taken is this: The bark should be built on Lake Erie, which is near Lake Ontario. It could easily pass from Lake Erie to Lake Huron, from which it would enter the Lake of Illinois. At the extremity of this lake would be the cut or canal of which I have spoken to have a passage to the St. Louis River, which empties into the Mississippi. The bark having entered this river could easily sail to the Gulf of Mexico."

When Joliet landed in Illinois he anchored his boat in the body of water now called Lake Michigan at a point near Summit, which is about eleven miles beyond and west of the present shore line at Chicago. Only a small stretch, composed

mostly of glacial drift, at that time prevented the water of the lake from discharging into the Illinois River. But this stretch, by natural accretions and artificial filling-in for the purpose of "making land," had extended from one-half a league of prairie to a distance of about ten miles in a little more than two centuries.

It has been said that the Chicago Sanitary and Ship Canal is a reversal of natural conditions, because it diverts the water of Lake Michigan from its natural flow. This statement, though made recently, was doubtless made in ignorance and, at any rate, is not true. Those persons who have only a slight knowledge of geological history know that the building of the canal has merely renewed conditions as they existed not many centuries ago. The Canal is simply the restoration of an ancient outlet from the Lakes to the Mississippi River which existed for ages. The Great Lakes, with their connections, were once an arm of the sea. Some great upheaval left them in a depression, from which their overflow sought the ocean in two mighty rivers, one setting its current towards the east from Lake Ontario, and the other sweeping away to the south from Lake Michigan and finally mingling its waters with those of the Gulf.

Ancient Connection of Lake and River.

The geological developments during the construction of the Sanitary and Ship Canal demonstrated conclusively that its course follows the track of the ice packs at the end of the latest glacial period, and that this track became in turn the bed of a great river. The rocky ridge encompassing Lake Michigan on the west and the southwest, weakened by the incessant pounding of the ice, gave way at one point and a crevasse 200 feet in depth was made in the solid limestone. Through this opening the waters of the Lake poured for many centuries, forming the river before mentioned.

When the preliminary surveys for the Sanitary and Ship Canal were made it was found that the trough or bed which had been ground in the rock by the action of the water was only six feet above the present lake level, and was about two miles wide and about twenty miles in length. It practically began at Summit, eleven miles from Lake Michigan, and extended to Lockport, twenty miles to the southwest. In the bed of this natural outlet the Sanitary and Ship Canal was constructed.

Reference has heretofore been made to the fact that the section now covered by the Sanitary and Ship Canal was long

regarded as an almost insuperable objection to the proposed waterway which was to connect the Lakes and the Gulf. The tremendous cost of constructing the channel through this section was always urged as a fatal obstacle to the success of the greater project. But this objection is no longer of any force. As has been before said, this weightiest and most perplexing problem of the entire scheme has been solved. The Sanitary District of Chicago has constructed a channel through this section capable of accommodating the largest sea-going craft that will ever come up the Mississippi River as far as St. Louis, even after the improvements in the Mississippi now under way, or that may hereafter be undertaken, have been completed. The completion of this section likewise removes the project from the inhibition of the Federal Government, whose policy, while favorable to improving rivers, harbors and canals by dredging, has been averse to cutting new channels through stone. Beyond Lockport, or the terminus of the Sanitary and Ship Canal, the only stone cutting to be done is that necessary to connect the extension channel with the Sanitary and Ship Canal.

The construction of the Sanitary and Ship Canal was authorized by an act of the General Assembly of the State of Illinois, approved May 29, 1889. Under that act the Sanitary District of Chicago was organized. Its boundaries include all that part of the City of Chicago lying north of 87th street, and forty-three square miles of territory in Cook County outside the city limits. The District is eighteen miles long from north to south and about nine and one-half miles wide on a line passing through the court house in Chicago. Its extreme width is about fifteen miles. The district contains about 185 square miles and a population estimated at 1,800,000. The law establishing the District authorized the Trustees to levy and collect taxes for the construction of the canal and other improvements to the extent of one-half of one per cent. of the value of the taxable property within its corporate limits. Afterwards, by other acts of the Legislature, this power of levying taxes was increased to one and one-half per cent. for a period of five years, beginning with the year 1895. The Trustees were also empowered to issue bonds to the extent of five per cent. of the value of the taxable property of the District, as determined by the assessment for state and county taxes. It was, however, provided that the bonded indebtedness of the District should never exceed the sum of fifteen million dollars. Under this authority the District has issued $14,990,000 of bonds, most of them being payable in from one

to twenty years. Of these bonds $3,630,000 have been retired, leaving $11,360,000 outstanding.

Organization of the Sanitary District.

The first election of Trustees was held December 12, 1889. John J. Altpeter, Arnold P. Gilmore, Richard Prendergast, William H. Russell, Frank Wenter, Christoph Holtz, John A. King, Murry Nelson and Henry J. Willing were the successful candidates and constituted the first Board. Owing to dissensions among the Trustees, which made their appearance soon after the organization, the beginning of actual work on the Canal was delayed nearly two years. Trustees Nelson, King and Willing resigned in 1891, and at the November election of that year William Boldenweck, Bernard A. Eckhart and Lyman E. Cooley were chosen to fill the vacancies thus created. Trustee Holtz tendered his resignation January 16, 1892, and, it having in the meantime been accepted, Thomas Kelly was elected as his successor on the eighth day of the following November. However, the accession of Trustees Boldenweck, Eckhart and Cooley in the preceding year had operated to secure a harmonious majority in the Board, and the preliminary work of making surveys, securing rights of way and letting contracts was being aggressively pushed.

Ground was broken for the work of excavation September 3, 1892. The first shovelful of earth was thrown by Trustee Wenter, then President of the Board. From that time the work was pushed at every point, and though appalling obstacles were encountered now and then, and occasional interruptions were inevitable, the actual progress of the gigantic undertaking was not at any time seriously impeded. In a little more than seven years from the time the excavation was begun, the Sanitary and Ship Canal was so far completed that it was ready for use. The water was first turned into the channel January 2, 1900, and on the 17th of that month, the channel in the meantime having filled, the great Bear Trap Dam, constituting a part of the Controlling Works at Lockport, was lowered, and the water from Lake Michigan, after an interval of several centuries, once more resumed its flow toward the Gulf. While the required flow at present is limited to 360,000 cubic feet per minute, the channel is capable of carrying nearly twice that amount, and it is practically assured that within five years from this time arrangements will have been perfected to secure the maximum flow of 600,000 cubic feet per minute.

At the election held November 5, 1895, Trustees Wenter,

Boldenweck, Eckhart and Kelly were re-elected. Trustees Joseph C. Braden, Zina R. Carter, Alexander J. Jones, James P. Mallette and Thomas A. Smyth were at the same time elected to succeed Altpeter, Gilmore, Prendergast, Russell and Cooley, whose terms expired December 2, 1895.

The first President of the Board was Murry Nelson, who served from February 1, 1890, to December 2 of that year. His successor was Richard Prendergast, who held the office about one year. Frank Wenter was elected to succeed Prendergast December 8, 1891, serving as President continuously from that date to December 3, 1895, a period of four years. Bernard A. Eckhart was elected to the Presidency of the Board December 3, 1895, and held the office until December 8th of the following year. He was succeeded by Thomas Kelly, who presided over the deliberations of the Board from December 8th, 1896, to December 7th, 1897. William Boldenweck, who was elected to succeed Mr. Kelly, has been twice re-elected, and is now serving his third term as President of the Board.

Improvement of the Chicago River.

Before speaking of the Sanitary and Ship Canal proper, it may be well to describe the work which has been done by the Sanitary District in the Chicago River, which consisted chiefly of dredging from the Lake to Robey Street (at which point the river intersects with the Canal) to a uniform depth, except over tunnels, of twenty feet below the flow line. The District has also constructed a covered conduit, or by-pass, which extends from Monroe to Van Buren Streets. This by-pass accommodates a flow of water fifty feet wide and sixteen feet deep. Likewise two center pier bridges have been removed—one at Taylor Street and the other the railroad bridge just south of it—and in their places have been constructed bascule bridges of the rolling lift type. A bascule bridge will also be substituted for the "jack-knife" bridge at Canal Street. At sundry places the river has been or is being widened and redocked. The last-named work is properly in the hands of the Federal Government, and the result of all these improvements has been to make adequate provision for a flow of 360,000 cubic feet of water per minute.

Negotiations are now under way, which your memorialists believe will be successful at an early date, for the lowering of the tunnels and the substitution of bascule bridges for all remaining bridges having center piers.

The Sanitary and Ship Canal begins at the junction of Robey

Street with the West Fork of the South Branch of the Chicago River, and extends to Lockport, which is 28.05 miles distant in a southwesterly direction. As the improved portion of the river from its mouth to Robey Street, a distance of six miles, may fairly be considered a part of the Sanitary and Ship Canal, its total length is therefore about 34 miles.

The dimensions of the channel are as follows: From Robey Street to Summit, a distance of nearly eight miles, it is 110 feet wide at the bottom and 198 feet at the water line, with a minimum depth of twenty-two feet. From Summit to Willow Springs, the distance being a little more than five miles, the channel is 202 feet wide at the bottom and 290 feet wide at the water line, with twenty-two feet depth. These are earth sections. At Willow Springs the Canal narrows to the walled and rock sections, extending about fifteen miles to Lockport, and is 160 feet wide at the bottom and 162 at the top. The cross-section of the channel just above the Controlling Works, which is cut in stone, is enlarged for the purpose of forming a "windage basin," in which large vessels may be turned around. This enlargement was also made in order that the extension of the Canal could go on from the terminus of the channel without interfering with the Controlling Works. The grade in the earth sections is one foot in forty thousand feet, or one and five-eighths inches per mile; in the rock sections it is one foot in twenty thousand, or three and one-fourth inches per mile. It is intended to make the width of the channel uniform throughout the earth sections, 202 feet at the bottom and 290 feet at the water line, with a minimum depth of twenty-two feet from one end of the Canal to the other. The bottom of the channel at Robey street is 24.448 feet below Chicago datum, which is the same as low water in Lake Michigan at Chicago.

Construction of Sanitary and Ship Canal.

The total amount of excavation included 28,500,000 cubic yards of glacial drift and 12,910,000 cubic yards of solid rock, or an aggregate of 41,410,000 cubic yards. One of the most interesting features of the work of construction was the diversion of the Des Plaines River. As the plans provided that the channel should follow the bed of this river, it became necessary to excavate a new channel for the Des Plaines about thirteen miles in length. The new channel parallels the main channel throughout the distance mentioned, but about nineteen miles of levee had to be built in order to divorce the water of the Des Plaines watershed from the Sanitary and Ship Canal.

The width of the Diversion Channel at the bottom is 200 feet. At the head of the Diversion it became necessary to provide a safety-valve in the form of a spill-way to allow surplus water to flow toward Chicago. However, this spill-way will be dispensed with when arrangements have been perfected for carrying the entire flood-waters of the Desplaines through Joliet. The material excavated from the River Diversion included 1,810,000 cubic yards of glacial drift and 258,659 cubic yards of solid rock, making a total of 2,068,659. Adding this to the excavation from the Main Channel, gives a grand total of 43,478,659 cubic yards of material which was excavated. The whole volume of spoil (earth and rock), if deposited in Lake Michigan in forty feet of water, would make an island one mile square, with its surface twelve feet above the water line.

The Controlling Works at Lockport comprise seven sluice gates of metal with masonry bulkheads and one Bear Trap Dam. The sluice gates have a vertical play of twenty feet and openings of thirty feet each. The Bear Trap Dam has an opening of 160 feet and an oscillation of seventeen feet vertically. The Controlling Works are operated by admitting water through conduits controlled by a valve. Several tests have been made both of the sluice gates and the Bear Trap Dam, since the Canal was opened, and in each instance they have worked satisfactorily. Indeed, it is no exaggeration to say that the Bear Trap Dam is the greatest triumph of engineering genius that has ever been achieved in this or any other country.

All the bridges across the Sanitary and Ship Canal are movable structures. There are six bridges for public highways, one having double roadways. There are seven railway bridges, one being an eight-track rolling lift structure with a channel span of 120 feet. One is a four-track swing bridge, and the others are double-track structures. These bridges are of the very latest designs, and the entire weight of the iron and steel used in their constructions was 22,678,000 pounds. Every bridge is capitalized in a sufficient amount to provide for necessary repairs besides creating a fund to replace the structure when it has become no longer safe or useful.

Chicago's Contribution to the Waterway.

The total cost of construction, including interest account, aggregated $34,000,000, January 1, 1900. Of this vast sum $21,379,675.36 was expended in the work of excavation alone.

The cost of securing rights of way was more than $3,000,000, and the expense for building railroad and highway bridges and capitalizing the same exceeded $4,000,000.

One of the most remarkable developments in connection with this work was the great improvement made in excavating machinery. In this connection, it may be well to quote a statement made by ex-Senator Warner Miller, of New York, who, after reviewing the work in progress on the Chicago Sanitary and Ship Canal, said, "That the use of the improved excavating machinery on the Isthmian Canal would undoubtedly reduce the cost of construction from 30 to 40 per cent." A description of some of the devices which were invented and built expressly for use on the Sanitary and Ship Canal would undoubtedly be very interesting, but the limits of this memorial will not permit further detail.

Finally, it is no exaggeration to say that the Chicago Sanitary and Ship Canal is one of the greatest artificial waterways ever constructed. Other canals may have cost more money and they may exceed this in depth, but this Canal has a greater cross-section than any other. It is safe to say that none presented half the difficulties which were encountered and overcome in this undertaking. The national value of the Canal will, of course, depend largely on the action taken by Congress.

Section 24 of the Act of the Illinois General Assembly creating the Sanitary District of Chicago and authorizing the construction of the Canal is as follows:

> "When such Channel shall be completed and the water turned therein to the amount of 300,000 cubic feet per minute—the same is hereby declared a navigable stream, and whenever the General Government shall improve the Desplaines and Illinois Rivers for navigation to connect with this Channel, said General Government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary and drainage purposes."

It is the earnest desire of your memorialists that the Congress of the United States will, without delay, provide for the improvement of the Desplaines and Illinois Rivers to the extent set out in the section of the Illinois act just quoted, in order that the time may not be far distant when it shall become the great pleasure, as it will be the agreeable duty, of your memoralists to surrender such control of the Chicago Sanitary and Ship Canal to the General Government as will

permit it to be utilized as a part of the great navigable waterway which will connect the Northern Lakes and the Gulf of Mexico.

III.—Conditions of the Illinois Valley from Lockport to the Mississippi River at Grafton.

From Lake Michigan at Chicago to St. Louis the distance is three hundred and sixty-five miles. Of this distance thirty-four miles is traversed by the Chicago Sanitary and Ship Canal and forty-two miles by the Mississippi River. From the end of the Sanitary and Ship Canal at Lockport to the mouth of the Illinois River is two hundred and eighty-nine miles. Of this distance nineteen and one-half miles is covered by the Desplaines River, which joins the Kankakee to form the Illinois. For purposes of description and estimate the total distance is divided into three characteristic sections, namely: The Joliet section, from the end of the Sanitary and Ship Canal to Lake Joliet, eight miles; the upper Illinois, from Lake Joliet to Utica, fifty-four miles, and the lower Illinois, from Utica to the mouth, two hundred and twenty-seven miles.

The Joliet section is quite a regular declivity over Niagara limestone (the same formation through which the Sanitary and Ship Canal was cut) through the city of Joliet, with an elevation of twelve to fifteen feet below Lake Michigan at the end of the Sanitary and Ship Canal and descending to seventy-six feet below the Lake at the pool known as Lake Joliet. There is little soil over the rock along these eight miles and the Desplaines River has formed only a shallow channel in the rock. The pools formed for the Illinois and Michigan Canal and those created for water power were made chiefly by retaining walls and embankments. In geological history this slope was a great rapids in the ancient outlet of the lakes, and the pool known as Lake Joliet was formed in the softer rock at the foot of the rapids.

From the construction standpoint this stretch is the most expensive. Any waterway through this section must have ample prism to care for the flood waters of the Desplaines, as well as the flow of the Sanitary and Ship Canal, and it will normally be constructed partly by excavation and partly by walls and embankments. It has been considered that this amply prism could be best constructed by giving it a depth equal to that of the Sanitary and Ship Canal.

Several plans for treating the Joliet section have been studied for purposes of estimate, and it is believed that a project in harmony with the Sanitary and Ship Canal can be carried out for about eight million dollars. The pool known as Lake Joliet is five miles long and has ample depth when cleared of deposits. The project outlined contemplates an extension of the Sanitary and Ship Canal, and a part of the right of way needed has already been acquired, and all obstructions except one dam and water power and the old Illinois and Michigan Canal have been removed.

Conditions Favorable from Joliet to Utica.

From Lake Joliet to Utica the distance is fifty-four miles, with a descent from seventy-six feet below Lake Michigan to one hundred and forty-two feet below. The river bed is deeply cut and is divided into pools and rapids, according to the nature of the resisting strata. Lake Joliet, already mentioned, Lake Du Page, above the mouth of the Kankakee, and the pool above Marseilles cover over one-third the total distance. The average width of the river is from five hundred to six hundred feet between banks. There are no artificial obstructions on the upper Illinois except the mill-dam at Marseilles. The tributary watershed varies from 6,400 square miles at the mouth of the Kankakee to 10,400 square miles at Utica, and gives rise to floods, which come in part during the season of navigation. Owing to the very considerable declivity, high velocities exist in localities, and this makes expedient a large and deep channel in the interest of navigation and without regard to the depth which may be utilized. The studies thus far made show that the upper Illinois can be treated on three levels or pools with a depth of fourteen feet by means of three dams or locks. This depth will require considerable dredging for a channel three hundred feet wide, though a part of this may be dispensed with, but at the expense of efficiency.

A proper treatment will not injure any great area of bottom lands. Six highway and three railway bridges will require alteration. Trial estimates for actual projects show that a depth of fourteen feet with locks designed for larger depths can be produced throughout the upper Illinois for ten million dollars.

The lower Illinois, or alluvial section, extends for two hundred and twenty-seven miles from Utica to Grafton, with a declivity which depends largely on the stage of water in the

Mississippi. From the low water surface of the pool formed by what is known as the Henry dam at Utica bridge to the low water line of the Mississippi River, the descent is but thirty-four feet. Natural low water at Utica is but thirty-one feet extreme or twenty-eight feet at ordinary low water, and for much of the year it is considerably less, owing to the longer periods of moderate stages in the Mississippi. This remarkable feature of low declivity is coupled with low banks, not averaging more than twelve or fourteen feet above low water, and extensive bottom lands, some seven hundred square miles, intersected by sloughs and marshes. These conditions make a stream of low velocity and occasion wide and deep overflows in the flood season.

The low water width is generally from six hundred to one thousand feet and the ruling depth on bars at extreme low water is from eighteen to thirty inches. Experience in dredging these bars has shown a reasonable permanence in the channel produced, but the extreme low water volume before the opening of the Chicago Sanitary and Ship Canal was insufficient for a depth greater than four to six feet. The river has been improved by four dams and locks, two built by the State at Henry and Copperas Creek and two by the United States at La Grange and Kampsville.

These dams have been the subject of much protest by the adjacent land owners, who claim that they increase the liability of overflow by moderate rises in the river. It is also claimed that they raise the water plane, thereby provoking deposits in the beds of tributary streams as well as in the river itself. The deterioration of the pools seems to be well established and is naturally to be expected in a stream of the character of the Illinois River. In 1889 the General Assembly of Illinois passed an act making the removal of the dams at Henry and Copperas Creek mandatory before the opening of the Chicago Sanitary and Ship Canal. The Legislature at the same time requested the Federal Government not to complete the works then in progress at La Grange and Kampsville and to change its policy to one of channel deepening in connection with the water supply from Lake Michigan. This request was repeated by the General Assembly in 1897.

Illinois' Policy Favors Fourteen-Foot Channel.

The policy of the State of Illinois requires an open channel of not less than fourteen feet in depth and a width of three hundred feet, to be secured by dredging, and a water supply

of 10,000 cubic feet per second from Lake Michigan. This would mean a volume sixteen times greater than that of natural low water at La Salle and eight times greater than at the mouth of the Illinois. Such a virile stream would better maintain the channel and such an improvement would make a better drain, so that an increased volume of flood water would be provided for. On the other hand, such increase of volume, without removing dams and deepening the channel, would cause widespread injury to material interests.

Official measurements have been made of the volume of water passing in the river at different stages. The bank-full stage, twelve feet above low water, would indicate a flow of 18,000 to 22,000 cubic feet per second from Utica to Havana; 30,000 cubic feet at La Grange and 40,000 at Kampsville. The quantities show the probable effect of adding 10,000 cubic feet at low water. It is estimated that with the addition of 10,000 cubic feet of water per second there would be a uniform depth of not less than seven feet on the natural bars throughout the lower Illinois, except near the mouth. An additional depth of seven feet, making a total of fourteen, would have to be secured by dredging. A dredging of the shoals for the most efficient results would materially lower the flow line. An estimate has been made for a navigable channel three hundred feet wide and fourteen feet deep, which calls for the removal of from sixty to seventy million yards of earth at a cost of $7,000,000. The material to be removed is easily handled, and the recent improvements in dredging appliances would doubtless make the above figures cover the cost of removing one hundred million yards.

In making these estimates the scouring action of the augmented volume is not considered, and there are special conditions which make this an important aid.

From the mouth of the Illinois to St. Louis, a distance of forty-two miles, no sufficient study has been made of the conditions to justify an estimate of the cost of improvement. This section forms the boundary line between the two States and is less directly subject to the policy of the State of Illinois. It may be fairly assumed, however, as practicable to obtain fourteen feet of water in the Mississippi River from Grafton to St. Louis throughout the year, except when obstructed by ice. Records kept at Morris, on the Upper Illinois River, show that the ice season lasts on the average from sixty to seventy days, as against one hundred and twenty to one hundred and forty days in the year on the lake routes

from Chicago to Buffalo. During the past twelve years there would have been no interruption to navigation on the river route for two-thirds of the winters, and the stream could probably have been kept open in winter during the other years by the aid of ice boats.

Your memorialists respectfully call attention to the fact that in legislating for the Illinois and Mississippi Canal, better known as the Hennepin Canal, which provided for a channel from the Illinois River above Hennepin to the Mississippi River at Rock Island, the Congress failed to make any provision for that part of the route required to reach Lake Michigan, which is absolutely necessary to make that canal useful. It may be assumed, however, that it was the intention of the Congress to utilize the Chicago Sanitary and Ship Canal when completed, and to improve the Desplaines and Illinois Rivers from Lockport, the terminus of the Chicago Canal, to the entrance of the Hennepin Canal, nineteen miles below Utica. If this was not the case the construction of the Illinois and Mississippi Canal could hardly be justified. However, that canal is only seven feet deep and is designed to reach points on the Upper Mississippi.

The Illinois River is susceptible to a far more radical improvement just as the Lower Mississippi justifies a much greater depth than does the Upper Mississippi. It would, unquestionably, be a great mistake to dwarf the Illinois River to the capacity of the Hennepin Canal. The larger depths and greater widths of the Illinois will serve the Hennepin better in permitting barge navigation to and from its eastern terminus.

Summary of Arguments Favoring Project.

In conclusion, we sum up as follows:

1. An available navigation of fourteen feet, with locks for fleets of barges, and so designed as to permit greater depths in the future, may be had between the present terminus of the Sanitary and Ship Canal at Lockport and the Mississippi River for $25,000,000. The channel improvements include five locks and dams in conjunction with a water supply of 10,000 cubic feet per second from Lake Michigan, and it is not possible to produce such a waterway without this water supply.

2. This depth will undoubtedly provide such a prism in the upper Illinois as will reduce the flood velocity to tolerable limits. It is believed that such a depth on the lower Illinois will avoid increased damage by overflow and produce a cur-

rent strong enough to maintain itself against obstructive deposits. Its superiority for navigation needs no statement. This depth was determined upon as the least to be considered when the Chicago Sanitary and Ship Canal was authorized, and has been formally expressed as the public policy of the State of Illinois.

3. The first effect of turning in the water from Lake Michigan after removing the dams is to extend an available steamboat and barge navigation as far up the Illinois River as Utica, which is only sixty-two miles distant from lake navigation at Lockport. Before the opening of the Chicago Sanitary and Ship Canal, lake and river navigations, for practical purposes, were three hundred and twenty miles apart.

4. The plans made on which the foregoing estimates were based were to test the possibilities of the route and for purposes of calculation. They were not intended to determine a final design, but it is not assumed that a final design would lessen the estimate, although it might greatly improve its scope and make the work more efficient.

5. A variety of plans for extending deep water from the mouth of the Illinois to St. Louis have suggested themselves, but no estimate has been made. It is considered practicable to accomplish this improvement.

6. That portion of the work between the end of the Chicago Canal and a point nineteen miles below Utica, a distance of eighty-one miles, and covering all the structural and most expensive operations, is necessary to be done in order to form an outlet for the Hennepin Canal. This portion, in fact, practically covers all the work necessary to open the waterway as a whole, and subsequent work will simply be in the nature of betterment.

7. Finally, a navigation of fourteen feet from Chicago to St. Louis is justified, without regard to any river connection at St. Louis, yet the fact will at once suggest itself that, as a connection with the Mississippi River, this depth can be carried through to the Gulf of Mexico and maintained for enough months in the year to justify the expenditure. With the maintenance of eight to nine feet minimum of depth in the Mississippi River beyond St. Louis by the Mississippi River Commission, a depth of fourteen feet ought to be had for eight to nine months. The proposition is in harmony with such a natural development of the Mississippi as is believed to be not only possible but in the highest degree desirable from every standpoint.

IV.—Policy of the State of Illinois Always Favorable to the Great Waterway—History of the Illinois and Michigan Canal.

From the time that Joliet suggested the feasibility of a deep water connection between the lakes and the Gulf, coming down through more than two hundred years, the suggestion has been generally approved by navigators, explorers, engineers, scientists and other public men. The only exception was Marquette, who professed to regard the proposition as impracticable. It has been said that Marquette was influenced by jealous promptings to take an opposite view of the project, but this assertion is, probably, untrue.

There were also many men versed in statesmanship who realized the beneficial effects, commercial and otherwise, which would inevitably follow the construction of the connecting link. From the time Illinois was admitted as a State into the American Union, and even during territorial days, the proposition for a navigable waterway from the lakes to the Mississippi River was ever foremost in the minds of her ablest statesmen and of her greatest political leaders. But interest in the project was not confined to the State of Illinois. It attracted the attention of public-spirited citizens all over the country.

Thus we find that in 1817 Samuel A. Storrow, Judge Advocate of the United States Army, who made a three months' tour through the west, was attracted by the situation in the Chicago River, and in a letter to Major General Brown, dated December 1, in that year, he commented on the practicability of a permanent waterway as follows:

> "Before the Chicago River enters Lake Michigan its branches unite, the one proceeding from the north, the other from the southwest, where it takes its rise from the very fountain of the Plein (Desplaines), or Illinois, which flows in an opposite direction. The source of these two rivers illustrates the geographical phenomenon of a reservoir on the very summit of a dividing ridge. In the autumn they are both without any apparent fountain, but are formed within a mile and a half of each other by some imperceptible undulations of the prairies, which drain it and lead it in different directions. In the spring the space between the two is a single sheet of water, the common reservoir of both; in the center of which there is no current towards either of the opposite streams. This

circumstance creates the singular fact of the insulation of all of the United States except Louisiana, making the circumnavigation of them practicable from the Gulf of St. Lawrence to that of Mexico, with the single hindrance of the Falls of Niagara. The situation of the Chicago and De Plein Rivers should not escape National attention. The ground between the two is without rocks and with little labor would admit of a permanent connection between the waters of the Illinois and Lake Michigan."

Missouri Metropolis Favored the Canal.

As the idea of a navigable waterway between Lake Michigan and the Mississippi River rolled through the minds of thinking men in the early part of the present century, it acquired increasing importance. It was not too much to hope for a passage for any vessel that traversed either the lake or river. St. Louis was then a considerable town, and the idea of an artificial channel which would discharge the waters of Lake Michigan into the Illinois and Mississippi Rivers was enthusiastically advocated by her editors, orators and other prominent citizens.

In 1816 the Ottawa, Chippewa and Pottawatomie Indians ceded to the United States a strip of land twenty miles in width from Chicago to Ottawa, embracing the valley of the Desplaines and Illinois Rivers. Two years later surveyors were sent out to locate the boundary lines of the proposed channels, one beginning ten miles north and the other ten miles south of Chicago. Commenting on this work, the Enquirer, a newspaper published in St. Louis, expressed the sentiments of the people of that city in regard to the proposed waterway as follows:

"The communication between the Lake and the Illinois is a point which will fix the attention of the merchant and the statesman. They will see in it the gate which is to open the northern seas into the Valley of the Mississippi and which is to connect New York and New Orleans by a water line which the combined navies of the world cannot cut off. Never did the work of nature require so little aid from the hand of art to complete so great a design."

The few permanent settlers at the mouth of the Chicago River at the time St. Louis was agitating the construction of the proposed channel had no influence, and their interests were hardly taken into consideration. As late as 1836, the year in which work on the Illinois and Michigan Canal began, Chi-

cago had a population of only 3,820. But the East never lost sight of the benefits it would derive from a water communication with the Valley of the Mississippi, and the National Government was repeatedly urged to develop it. Various efforts were made in Congress to secure an appropriation for this purpose, but the policy of the Federal Government at that time was hostile to the idea of taking money out of the general treasury to devote to internal improvements.

Repeated reference to the importance of a canal communication between Lake Michigan and the Illinois River in the many years of Congressional discussion and attempted legislation in the line of internal improvements was an acknowledgment of its National character. No link in the chain of interstate commerce was more important than this, since it was on the great highway from the manufacturing East to the agricultural West and South. The speeches in the National Legislature indicate the prevailing sentiment, but the following paragraph from an editorial which appeared in Niles' Register of August 6, 1814, published in Baltimore, shows an exuberance of feeling:

> "By the Illinois River it is probable that Buffalo may be united with New Orleans by inland navigation through Lakes Erie, Huron and Michigan to the Illinois River, and down that river to the Mississippi. What a route! How stupendous the idea! How dwindles the importance of all the artificial canals of Europe compared with this water communication!"

Cession of Illinois Valley Lands by Indians.

The first practical steps towards the construction of a canal between Lake Michigan and the Illinois River was the execution of the treaty before mentioned with certain Indian tribes by which a strip of land about twenty miles wide, extending through the Desplaines and Illinois valleys from Chicago to Ottawa, was ceded to the United States. This treaty was negotiated at St. Louis, August 24, 1816, by Ninian Edwards, Governor of Illinois Territory; William Clark, Governor of Missouri, and Colonel Auguste Chouteau, of St. Louis. Immediately following the execution of this treaty, John Holmes, a representative from the State of Massachusetts, introduced into the lower House of Congress, December 11, 1817, a resolution instructing the committee on so much of the President's message as related to roads and canals to inquire into the expediency of providing by law for

constructing a navigable canal to unite the waters of Lake Michigan with the Mississippi. The resolution was carried, but the committee made no report. In the House, on April 3, 1818, when the question of admitting the Territory of Illinois to statehood was under consideration, Mr. Pope, of Kentucky, offered an amendment, which was adopted, providing for the extension of the boundary of the State farther north. By that amendment Illinois gained the City of Chicago.

Illinois became a State in 1818. At that time the facility of opening a canal between Lake Michigan and the Illinois river was acknowledged by every one who had visited the place. Daniel P. Cook, a son-in-law of Governor Edwards, was the second Representative of Illinois in Congress, serving from 1819 to 1827. He devoted himself to the interest of the proposed canal, and it was largely through his influence that the State Legislature, in 1821, caused a partial survey of the route to be made for the purpose of demonstrating the practicability of the undertaking. From that time the Senators and Representatives from Illinois in Congress worked with unceasing diligence to secure an appropriation for the construction of the Canal. Finally a bill was passed March 2, 1827, granting to the State 200,000 acres of the public lands, which were to be sold and the proceeds applied to the work of construction.

The Illinois and Michigan Canal was completed in 1848, but the project was never carried out as originally contemplated. It received considerable financial aid from the State and the agitation for its improvement began soon after its completion. About 1867 the Federal Government and the State of Illinois united in the work of improvement. Many alterations were made, the channel being deepened in places and extended to Ottawa on the Illinois River.

When the people of Chicago began the agitation for a Sanitary Canal which was to become a part of a deep waterway extending from Lake Michigan to the Mississippi River, they had no difficulty in securing the active co-operation of the State administration and the members of the General Assembly. Indeed, the fact that it was proposed to construct a channel of sufficient depth and width to float the largest lake craft then sailing from Buffalo to Duluth, removed all possibility of opposition to the enterprise. In the Act creating the Sanitary District of Chicago the Legislature provided as follows:

Legislation Favoring a Ship Canal.

"Section 23. If any channel is constructed under the provisions hereof, by means of which any of the waters of Lake Michigan shall be caused to pass into the Desplaines or Illinois Rivers, such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be a depth of not less than fourteen feet, and a current not exceeding three miles per hour, and if any portion of any such canal shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than eighteen feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than one hundred and sixty feet at the bottom capable of producing a depth of not less than eighteen feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000, such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than three miles per hour, and if at any time the General Government shall improve the Desplaines or Illinois Rivers so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property, so as to save harmless the said district from all liability therefrom, then such Sanitary District shall within one year thereafter, enlarge the entire channel leading into said Desplaines or Illinois Rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute, with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom; in case a channel is constructed in the Desplaines River, as contem-

plated in this section, it shall be carried down the slope between Lockport and Joliet to the pool, commonly known as the upper basin, of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act, may correct, modify and remove obstructions in the Desplaines and Illinois Rivers, whenever it shall be necessary so to do to prevent overflow or damage along said river, and shall remove the dams at Henry and Copperas Creek, in the Illinois River, before any water shall be turned into the said channel. And the Canal Commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said Canal Commissioners to cause such dam or dams to be removed. This Act shall not be construed to authorize the injury or destruction of existing water power rights.

Section 24. When such channel shall be completed, and the water turned therein to the amount of three hundred thousand cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the General Government shall improve the Desplaines and Illinois Rivers for navigation, to connect with this channel, said Government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary or drainage purposes."

Illinois Asks General Government to Extend Canal.

Again, at the session of 1897, the Illinois General Assembly adopted a series of joint resolutions regarding the Chicago Sanitary and Ship Canal, and calling upon the Federal Government to extend the deep waterway thus begun to the mouth of the Illinois River. Only such portions of the preamble and resolutions as bear directly on the subject in hand are here given, as follows:

"Whereas, the construction of the Sanitary Canal of Chicago, and the large volume of water required to flow through the same, will bring lake and river navigation, which are now 320 miles apart, within 60 miles of each other, and the development of the intermediate section

between Lockport and Utica will furnish a through route from the Great Lakes to the Lower Mississippi by way of the Lower Illinois River, and the Upper Mississippi by way of the Hennepin Canal; and, further, that the proportion of three routes constructed by the Sanitary District of Chicago will exceed the cost of extending the largest useful navigation by way of the Illinois River to the Lower Mississippi, together with that of the Hennepin Canal, to the Upper Mississippi; and

Whereas, we believe the making of a deep waterway of the Illinois River to be an undertaking which is national in its character and should be accomplished by the General Government for the general welfare, the inland and maritime commerce of the nation, and for the nation's defense in time of war; therefore, be it

Resolved by the Senate, the House of Representatives concurring therein:

1. That it is the policy of the State of Illinois to procure the construction of a waterway of the greatest practicable depth and usefulness for navigation from Lake Michigan by way of the Desplaines and Illinois Rivers to the Lower Mississippi River, and by way of the Hennepin Canal to the Upper Mississippi River, and to encourage the construction of useful feeders thereto.

* * *

3. That the rock-bound section of the Desplaines and Illinois Rivers form (from) the end of the Sanitary Canal of Chicago at Lockport to the head of the Alluvial River at Utica, should be developed for a navigable depth of not less than fourteen feet, and that the United States is requested to enter upon this work in co-operation with all lawful agencies provided for in this state and in harmony with the policy herein set forth."

The character of the Illinois and Mississippi Canal, better known as the Hennepin Canal, and its relations to the Chicago Sanitary and Ship Canal, have already been fully described in Section III of this memorial.

V—National Character of the Proposed Deep Waterway—Its Importance from a Commercial and National Standpoint.

If the proposed waterway which is to connect the lakes with the Gulf is not National in character, then it follows as a matter of course the project is not worth the consideration of the American Congress. If the beneficial effects to follow its construction would be confined exclusively to the State of Illinois, it would then become a purely local enterprise and the state would go ahead and complete it in accordance with its own well established policy and in the spirit of modern progress.

But the fact that it is a National project was long ago understood and appreciated by such men as Albert Gallatin, of Pennsylvania; John Pope, of Kentucky; Peter B. Porter, of New York; Henry St. George Tucker, of Virginia; John C. Calhoun, of South Carolina; Jessie B. Thomas, of Illinois; Christopher Rankin, of Missouri; Henry Clary, of Kentucky, and many others.

The people of the Sanitary District of Chicago realized that the sanitary canal would ultimately be utilized as a part of a great National enterprise. While they would not have hesitated to incur the expense necessary to provide a complete and perfect system of sanitation for the City of Chicago, they knew that the sanitary canal was not to be limited to the single purpose of drainage. They knew that for every dollar paid out for a sanitary canal, another dollar was expended to make the capacity of the channel sufficient to carry any ship that traversed the Great Lakes at the time the work was begun. For instance, the extraordinary expense required to make the bridges crossing the channel, movable structures, was about $2,500,000. The tax payers understood that in order to have a navigable waterway the bridges must be of this character.

No one can study the situation and environments without coming to the conclusion that this project is national in character, and being so, the remainder of the work should be completed by the Federal Government. Under the law the Federal Government would have control of the entire waterway and would be solely responsible for exercising that control for purposes of navigation. Interest in the movement for a deep waterway from Lake Michigan to the Gulf of Mexico intensifies in the presence of the overwhelming sentiment favorable to the construction of an Isthmian Canal, which is t

connect the Atlantic and Pacific Oceans. With the Isthmian Canal a reality, as it will undoubtedly be in a few years, it becomes evident that a navigable waterway crossing the center of the continent and connecting with the Great Lakes will become not merely a desirability, but an actual necessity. A deep waterway from New Orleans to Chicago will traverse the greatest agricultural and industrial area on the globe, populated with the most moral as well as the most intelligent citizenship. Where can another such area be found as that of the Mississippi Valley? A valley with the greatest variety of soil and climate, extending from the Allegheny to the Rocky Mountains, and limited on the north by the Canadian boundary and a chain of fresh water lakes. The great tributaries which go so far as to increase the fertility of this valley are the Ohio and Missouri Rivers, the one rising in the Northeast and the other in the Northwest, and both flowing obliquely to form a junction at the heart of the continent. This valley contains within its boundaries everything essential to constitute one of the greatest empires of history.

Effect on Trade With South America and the Orient.

Apart from the changed conditions which would surely result from the construction of the Isthmian Canal and the resultant stimulating effect a deep waterway from the Gulf to the Lakes would have on our Asiatic commerce, we may well consider the immense benefits to our steadily growing trade with South America, which would be caused by the building of the smaller waterway. From every lake port as far east as Detroit, and probably Cleveland, the prevailing disposition among the agricultural, manufacturing and mining interest would be to send their products destined for a South American port by way of Lake Huron, Lake Michigan, and thence by the Chicago Sanitary and Ship Canal and the Mississippi River to the Gulf of Mexico.

It would be impossible, even if it were advisable, to confine the beneficial effects of the proposed waterway to a single state. Possibly these effects might be more apparent in the Middle, Southern and Western States, but this is by no means certain. As the waterway would be a national enterprise, its blessings would naturally extend to every part of the Union. Albert Gallatin, who was Secretary of the Treasury during President Jefferson's administration took this broad view of the project when he said in a special report on roads and canals, dated April 6, 1808:

"That good roads and canals will shorten distances,

facilitate commercial and personal intercourse and unite by a still more intimate community of interest the most remote quarters of the United States. No other single operation within the power of government can more effectually tend to strengthen and perpetuate that union which secures external independence, domestic peace and internal liberty."

Referring to the desirability of a connection between Lake Michigan and the Mississippi River, he said that if navigation between the Western Rivers and the Lakes was opened, either from the Mississippi to Lake Michigan, or from the Northwest by Lake Superior, the whole Indian trade of those regions would necessarily center in an Atlantic port of the United States. He regarded the commercial phase of the subject as being of minor importance, however, when compared with other advantages of that great communication and the immense weight they would have in its relation to the political intercourse of the United States with the Indians. The estimate of the cost of the improvements necessary to reach the Mississippi River from the Lakes was $20,000,000, and to raise that sum he suggested that the government sell 10,000,000 of its 100,000,000 acres of public lands. He believed the increase in the value of the remaining 90,000,000 acres would more than repay the outlay. His report was referred to the committee and a week later 1,200 copies were ordered printed.

Necessity for Waterway Grows With Time.

If in the time of President Jefferson, when the white population of this country constituted a mere fringe extending along the Atlantic Coast and around the Gulf Coast to New Orleans, the connection of the lakes with the Gulf by a navigable waterway was considered of paramount importance, it seems the proposition should require no advocate now, when the combined population of the states of Illinois, Indiana and Missouri alone is greater than that of all the states at the time Secretary Gallatin wrote the first report favorable to this project.

Your memorialists respectfully represent as further reason for the construction of the proposed waterway, that it will provide for competition in freight rates during the open season in navigation between the Northwestern and Middle Western States to the Gulf. It will also create from the Canadian line to the Gulf a through water route owned by the people and not by the corporations. It will provide ample

facilities for modern and popular barge transportation. It will afford the Great Lakes and their ports double connection with the Atlantic, east and south, and with the completion of the Isthmian Canal, will put them in closer touch with our new possessions in the Pacific and the Orient.

It would be easy to extend this memorial indefinitely with the opinions of public men touching its feasibility and practicability. These are matters, however, which will suggest themselves to the Congress if it in its judgment sees proper to consider this project. In this connection, however, the following extract from the annual report of Mr. George F. Stone, Secretary of the Chicago Board of Trade, would seem to be of great interest:

> "With the growth of our country," Mr. Stone writes, "and a general development of transportation facilities in foreign lands, the project for a navigable connection between Lake Michigan, at Chicago, and the Mississippi River, via the Des Plaines and Illinois Valleys, assumes an importance in our domestice commerce comparable to that which the Suez Canal or the crossing of the American Isthmus will have in regard to the commerce affected by those great works. Its completion would result in a continuous navigable waterway from the Atlantic, via the St. Lawrence, through the lakes to Chicago, thence to the Mississippi, and thence to New Orleans. Its military and commercial importance might be conclusively demonstrated. It is, I am aware, insisted upon that we have no need, in these peaceful and enlightened times, to keep in view the liability of war. Certainly, in this age, no permanently aggressive character should be given to our military facilities, but we are not justified in wholly neglecting them or ignoring a remote possibility of foreign complications. It has been an embarrassment, evident and inevitable to our diplomatic correspondence in momentous crises, that our means of defense have been inadequate, and that the country could not afford to be otherwise than cautiously pronounced in the assertion of her rights. The completion of this great national project would, besides conferring inestimable benefits upon commerce, enable the government to place her gunboats by way of the Mississippi upon the lakes for the protection of immense marine interests. Think you that the existence of such facilities as this waterway from the Gulf to the north Atlantic would create, would have no effect upon state discussions of grave issues, when treaty

or other rights are threatened or violated? Means of defense are as valuable in times of peace as in war; they tend to prevent war by forcibly suggesting the concession of right. By the completion of this waterway, the entire system of transportation upon the continent would be straightway affected in the interest of consumer and producer; the south and the north, the east and the west, would feel its beneficent results. The movement of cotton, grain, coal, timber, iron and merchandise of all kinds would be beyond the power of dictation by transportation monopolies, because countless salutary irresistible restraints would spring into life. It would be a section of an interstate commercial law which could never be repealed, and the authority of which could never be questioned. It is national in its character, and appeals for its support to every citizen in the land. Its most enthusiastic advocates should not be found here, but in the south and in the east, where are consumed the products of the west, and which, in turn, wish cheap transportation for their manufactures to sections the yearly resources of which have not been absorbed by excessive freight rates."

Statistics of Traffic on Great Lakes.

Not until the eleventh census was taken were full statistics gathered of the movement of commodities upon the whole lake system, and since then the data collected has been far from complete. In fact, the information is so meager, and in part so incomplete, that it is very difficult even to give the total movement on the Lakes. Nothing in reference to the subject can be obtained prior to the year 1889. However, many circumstances have recently directed attention to the transportation of facilities of the Great Lakes. The rapid growth of traffic, the increasing size of lake vessels, the celerity with which ships are loaded and unloaded, and other developments have interested a large number of people, while the vital significance of cheap carriage to the mining, farming and lumbering interests and their numerous dependent industries has compelled all persons engaged in these occupations to give careful consideration to the main question, and the whole subject of the inland waterway has been given public attention by appeals to Congress for large appropriations to improve existing harbors and channels and to construct a deep waterway from the Great Lakes to the Sea. Yet, in spite of this widespread desire for information about lake commerce and its far-reaching importance to many great national indus-

tries, the question has been almost neglected, not only by writers on transportation, but by the government as well; and this in the face of the fact that Congress is annually called upon to vote large sums of money to facilitate traffic upon these waters.

In former years the commerce passing through the Detroit River was practically equal to the total movement on the lakes, but in recent years business between Lake Superior and Lake Michigan ports has so greatly increased that the commerce through the Detroit River is not now so good an index of the whole movement on the lakes as formerly.

Statistics bearing on this phase of the matter have been derived from reports of chief engineers, mainly those of Colonel O. M. Poe. The following table covers the traffic passing up and down the Detroit River during the years named:

Year.	Registered Tonnage.	Freight Tonnage.
1873		9,000,000
1880	20,235,249	
1881	17,572,240	
1882	17,872,182	
1883	17,695,174	
1884	18,045,949	
1885	16,777,828	
1886	18,968,065	
1887	18,864,250	
1888	19,000,000	
1889	19,646,000	19,717,860
1890	21,684,000	21,750,913
1891	22,160,500	23,209,619
1892	21,785,000	26,553,819
1893		23,091,899
1894	26,120,000	24,263,868
1895		{ 25,845,679 } { 29,000,000 }
1896		27,900,520

It is impossible to secure sufficient information on which to base even an estimate of the percentage of traffic from Lake Superior ports which does not go through the Detroit River into Lake Erie. It is known, however, to be considerable. It is probably true that the traffic from ports on Lakes Michigan and Huron is equal to that coming through the St. Mary's Falls Canal, but the figures showing the tonnage passing through the Detroit River do not indicate this to be a fact. There must be a considerable diversion of the traffic from the upper lake after it enters Lake Huron.

Increased Tonnage Passing Through St. Mary's Canal.

While the traffic statistics show satisfactory increase, considering the unreliability of the figures, the best evidence of an increased traffic on the Great Lakes is the growth of the lake fleet. The charts indicate that during the five years from 1868 to 1872, inclusive, the lake fleet did not quite maintain its own, but made rapid gains from 1872 to 1875, when the total tonnage stood at 587,234. Then the tonnage declined to 552,602 in 1879. During the ensuing four years there was a rapid increase, and then a moderate increase for one year until 1886 when the tonnage stood at 690,359. Since 1886 the tonnage has almost doubled, large accessions having been made every year except in 1894 and 1895. Improved facilities for fueling, loading and unloading vessels have also very greatly increased the carrying power of the whole fleet, to say nothing of the enlarged carrying power, due to better locks and the lighting of channels so as to permit passage by night. Taking into account all the improvements, other than the substitution of steam for sail, conservative estimates show that this power has increased from 742,286 in 1868 to 3,326,502 in 1897.

The extraordinary growth of the tonnage passing through the St. Mary's Falls Canal is in striking contrast with the slow increase of that passing through the Detroit River. The registered tonnage going through the St. Mary's Falls Canal increased from 1,204,446, in 1873 to 17,619,933 in 1897. There was also an increase in freight tonnage from 1,567,741 in 1881 to 18,982,755 in 1897.

The latest reliable statstics attainable on the subject of lake shipping show that the amount of freight passing through the various canals in 1897 was as follows:

St. Mary's Falls,	18,982,755
New York (Erie Canal),	1,878,218
Detroit River (1896),	27,900,520
Welland Canal (1896),	1,279,987

It is conceded that a considerable percentage of the traffic passing through the St. Mary's Falls Canal does not pass out through the Detroit River, but comes direct to Chicago.

The Congress is respectfully requested to give earnest attention to the facts and arguments set out in this memorial. The fact that the project is an old one, and has engaged the attention of public men for almost a century should not be urged as an excuse for treating it lightly. It is a propo-

sition worthy of being judged upon its merits alone, and by them alone it should be permitted to stand or fall.

Your memorialists have the honor to subscribe themselves,

Yours respectfully,

(Signed) WILLIAM BOLDENWECK,
JOSEPH C. BRADEN,
ZINA R. CARTER,
BERNARD A. ECKHART,
ALEXANDER J. JONES,
THOMAS KELLY,
JAMES P. MALLETTE,
THOMAS A. SMITH,
FRANK WENTER,
Members of the Board of Trustees of the Sanitary District of Chicago.

I, Joseph F. Haas, clerk of the Sanitary District of Chicago, and keeper of its records and seal do hereby certify that the above and foregoing memorial to the Congress of the United States was prepared under and by authority of a certain order adopted by the Board of Trustees of said District at a regular meeting held February 14, 1900; and I hereby certify that the following is a true and correct copy of said order that day adopted:

Ordered, That the joint committee on Federal Relations and Engineering are hereby authorized and directed to prepare a suitable memorial, to be presented to Congress, advocating the establishment of a deep waterway from the terminus of the Chicago Sanitary & Ship Canal at Lockport, Illinois, through the Illinois Valley to the Mississippi.

Ordered, further that said committee be empowered to have said memorial printed in such number and at such times as in its discretion may be deemed advisable, and lay the same before Congress.

Witness my hand and the seal of the Sanitary District of Chicago, this 26th day of February, A. D. 1900.

(Signed) JOSEPH F. HAAS,
(Seal) *Clerk of the Sanitary District of Chicago.*

EXTRACT FROM A REPORT OF BREVET MAJOR GENERAL J. H. WILSON, UNITED STATES ARMY, LIEUTENANT COLONEL 35TH INFANTRY, ON THE SURVEY OF THE ILLINOIS RIVER FROM LA SALLE TO ITS MOUTH.

United States Engineer's Office,

Des Moines and Rock Island Rapids Improvement and Illinois and Rock River Surveys,

Davenport, Iowa, February 15, 1867.

General: Having been charged by instructions from the Engineer Department with "the survey of the Illinois River from La Salle to its mouth," provided for by Act of Congress, June 23, 1866, I have the honor to submit the following report:

The act just specified simply provides for the survey as designated above, and gives no indication whatever of the object of the survey, or the kind of improvement which it is intended to illustrate. It was assumed, however, that, as the general government had originally provided for the improvement of the Illinois River by dredging its bars to a navigable depth, and had actually expended a considerable sum of money in operations of this sort, this act in question specially requires estimates for the completion of this plan. Under date of September 13, 1866, I received the following from the Engineer Department:

> "Minute instructions have not been given to you in relation to these surveys, since the intentions of Congress were not fully known to the department. Especially is this the case with the survey of the Illinois River, as no report from this department to Congress was made during the last session when the appropriation was made. The supposition is that the survey of this river has immediately in view its capacity for navigation to La Salle for the largest possible class of steamers that the river will admit when certain obstructions shall have been removed, and ultimately the determination of canal facilities with Lake Michigan, and the solution of the question of an adequate supply of water from Lake Michigan as a reservoir for the canal and river during periods of low water. The act of appropriation, however, only provides for the survey of the river from its mouth to La Salle, and to this your operations must be restricted."

Subsequently, by letter from the Engineer Department,

dated January 8th, 1867, I was directed to continue the examination of the Illinois River as far towards its source as there may be reason to believe that it is susceptible of improvement for the purposes of commerce and navigation.

* * * * * * *

On the 16th of September I gave Mr. Abert the following instructions:

"The object of this survey is to obtain such specific and accurate information in regard to the obstructions to navigation in that river as will enable you to submit estimates for its improvement, so that the largest boats navigating the Illinois and Michigan Canal, and steam boats drawing four feet of water, will be enabled to pass through the river to St. Louis during the season of extreme low water without breaking cargo. To this end you will examine and carefully delineate the various features of the river at and in the vicinity of the difficult bars and shoals; projecting your maps of these localities on a scale sufficiently large to show the amount of excavation necessary in order that the water may be sufficiently deepened. You will observe, as far as may be practicable, the specific cause of the bars and shoals; the influence of islands and bends of the river; the width, depth, velocity and cross-section, with capacity of the back-channels or chutes at the islands, and of the river itself at the *locality* of the obstructions; the width of the bottom lands; and, in general, will obtain every class of information likely to throw light upon the entire subject of improvement, whether by dredging, wing-dams, or other means.

The river having been already surveyed several times it may not be necessary to accurately triangulate it through its entire length, although it is desirable to have its fall from the initial point of the survey to its mouth accurately determined."

* * * * * * *

This plan of improvement, although it applies to a part of the river only, and cannot be depended upon to give more than four feet navigation under the most favorable circumstances, without a feeder from the lake, has many friends along the river. This is due, however, in many cases to the belief that any other plan will unfavorably affect the interests of some towns and localities, and unduly benefit others. But such considerations as these, whether well or ill-founded, are not of sufficient importance to exert a material influence in the

solution of the questions under discussion. There is no doubt that dredging alone, or, at most, dredging and a feeder from the lake, can be made to answer every purpose in the improvement of the Illinois River, if it is to be considered as independent navigation of no other than local importance; but it must be remembered that this river is not the exclusive property of those living upon its banks. It forms already an important link in a net work of river navigation extending, with it various branches, through 17 states of the Union, and is destined at no distant day to become the great commercial highway between the productive states of the West and Northwest and the markets of the world.

The Illinois River seems to have been specially designed by nature as the line by which the waters of Lake Michigan are to be connected with those of the Mississippi. Its two principal tributaries, the DesPlaines and the Kankakee, rising the one in Wisconsin and the other in Indiana, run for many miles almost parallel with the western and southern lake shore, and are separated from the lake basin by a ridge of insignificant height and width. A moment's consideration will show that at no remote period the waters of the lake must have been carried off by these streams as well as by the St. Lawrence. It has been already shown that the highest point of this ridge on the line of the Illinois and Michigan Canal is only 14 feet above the ordinary level of the water in the Chicago River at Bridgeport, and it is by no means certain that a lower line may not be found by a careful survey. In fact, it is the opinion of many old contractors who are well acquainted with the entire region, that a much more favorable location for a steamboat canal can be obtained from Bridgeport to Section 46 of the present canal, by following the line through Mud Lake. But let this result be as it may, the data herein contained, together with the existence of a canal of limited capacity already in operation, demonstrate beyond a doubt that the waters of the lake may be carried into the Illinois River through a navigable channel of any required dimensions, and at a cost which cannot be regarded as excessive when the objects to be obtained are duly considered.

As all the lockage will be descending from the lake, it is apparent that the only limit to the capacity of the canal will be that which depends upon the velocity with which the locks can be filled and emptied. The summit will be inexhaustible, and this cannot be said of any other practicable line of water communication between Lake Michigan and the Mississipi.

Macomb Report of 1875.

Extract from a Report Entitled "Second Subdivision of the Northern Transportation Route—Hennepin Canal," the Same Being Part of a Report Upon "Transportation Routes to the Seaboard." Page 94.

Report of Colonel J. N. Macomb, Corps of Engineers.

Rock Island, Ill., January 25, 1875.

General: I have the honor to present herewith the report of Mr. F. C. Doran, assistant engineer, who was charged by me with the duty of making the surveys and estimates for the Hennepin Canal Route, and particularly for the extension to Chicago.

In considering the Hennepin Canal as a part of the water-communication desired for connecting some point of the Mississippi River near Rock Island, with Lake Michigan, at Chicago, it appears that the basin at Hennepin is about 100 feet below the level of the Mississippi River in the vicinity of Rock Island, and nearly 140 feet below the level of Lake Michigan.

A survey was made to ascertain if the lockage required to pass this depression of the Hennepin Basin could be avoided. This survey led to the conclusion that, on every account, the Hennepin Canal and Upper Illinois River, and enlarged canal from Joliet to Chicago, will afford the best through route for navigation between the Mississippi River and Lake Michigan that can be secured in this vicinity.

* * * * * * *

The most important and costly part of the route across this section of the country is the portion between Hennepin and Chicago; for this part is essential as affording an eastern outlet for the Hennepin Canal traffic, and for perfecting the navigation to Chicago from the Lower Mississippi River through the Illinois River, which is now being improved for steamboat navigation from the Hennepin Basin down to the Mississippi River. Indeed, the Hennepin Canal, without the improvement of the Upper Illinois River and the enlargement of the eastern portion of the Illinois and Michigan Canal, would be useless as an outlet for the freights of the Upper Mississippi River; and a careful consideration of the subject has shown that the improvement of the Upper Illinois River to accord with the scheme of improvement now in progress

for its lower portion, is greatly to be preferred as a measure of economy in its broadest sense, rather than to undertake the enlarging of the western portion of the Illinois and Michigan Canal lying between Joliet and the Hennepin Basin.

The improvement of the eastern portion of the Illinois and Michigan Canal involves the further cutting down of the summit level and enlarging the waterway so as to afford an unfailing supply of water from Lake Michigan for the improved Illinois River.

It will be seen by the report of the assistant engineer that the estimate for the route, as above sketched out, for a navigable waterway from the Mississippi River, near Rock Island, to Chicago, on Lake Michigan is.....$19,780,535

To which should be added the amount of increase in estimate for locks of proper size on Hennepin Canal 641,284

Making a grand total of $20,421,819

All of which is respectfully submitted by your most obedient servant,

J. N. Macomb,
Colonel of Engineers, U. S. A.

Brig. Gen. A. A. Humphreys,
Chief of Engineers, U. S. A.

Report of Mr. F. C. Doran, Assistant Engineer.

Rock Island, Ill., January 9, 1875.

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Colonel: I have the honor to submit the following report upon the examination and survey of a route for a canal between Lake Michigan and the Mississippi River, together with the survey of a portion of the Illinois River. This survey having been committed to me, in obedience to your instructions bearing date Rock Island, Ill., July 9, 1874, I proceeded to organize and equip a party for field-service. The whole time employed by the party in field-operations was 83 days. Of this time, five weeks, or a little more than one month, were spent in examinations and surveys of a direct line joining the lake and the Mississippi; the remaining six weeks were devoted to the survey of the Illinois and Michigan Canal and a part of the Illinois River. These surveys have traversed quite a large expanse of country, having, within the time specified, examined and surveyed lines to the extent of Two Hundred and twenty-five miles.

As will be seen, this report is intended to embrace a statement of facts in relation to the Illinois and Michigan Canal and Illinois River as they at present exist, with a description of the several improvements and enlargements proposed, together with a detailed tabular statement showing the estimated cost of the improvement throughout the entire line, extending from the lake to the Mississippi.

I would preface with a condensed statement of the results of my examination of the direct route first mentioned. One of the principal objects to be attained by the survey was to obtain data and accurate notes of the topography of the country lying between Lake Michigan on the east and the great bend of the Mississippi on the west, and from the information obtained, to determine as to the practicability of a plan for a water-route to connect the lake and the river at the points specified.

* * * * * * *

The survey of the Illinois and Michigan Canal and the Des Plaines and Illinois Rivers was commenced October 5, at the old lock in the canal at Chicago, and was continued along the canal and river to where the canal unites with the river at La Salle, suspending field-work at this point, November 10, The entire distance, as measured along the canal and river, is 99.28 miles. Of this distance 36.53 miles is canal and 62.75 miles river-line; 32.65 miles of the former lie between Chicago and Joliet; the first 29.55 miles of this constituting the summit-level of the canal. The lockage on this route is all descending from the lake, and amounts to an aggregate of 145.6 feet, as determined by our levels.

In order to carry out your instructions, a thorough reconnaissance was made of the country, extending from the lake to a point, in the present line of canal, some 18 miles out from the lake, known as Sag Ridge, including the Calumet Feeder route. But as these examinations failed to discover any route possessing as favorable features as the existing line of canal presented, and as this canal had been originally located with great care, it was determined to adhere to the present alignment.

The original proposition in regard to the enlargement of this work, to dimensions corresponding to those adopted on the Lower Illinois River improvement, has been kept in view, and all quantities and the cost of the entire work have been calculated in accordance therewith. The dimensions there adopted, as you are aware, are as follows, viz., lock-

chamber, 350 by 75 feet. A restriction to these dimensions is rendered necessary in order to produce a complete and homongeneous system of navigation between the lake and the great rivers of the west.

It is believed that the proposed plan of enlargement of the Illinois and Michigan Canal, combined with the improvement of the river and the construction of the Hennepin Canal, will, when completed, meet the wants of the commercial world, affording as well facilities for the passage of war vessels from the rivers to the lakes, or vice versa.

The plan of locks adopted, although identical in size of chamber with those constructed on the lower part of the Illionis River, would differ somewhat in detail of construction and in the material employed in the gates.

The general features of the country along the line of canal and river are so well known to you that any minute description in this report would seem superfluous. Yet, while refraining from such description, I deem it necessary to call your attention to the geology of the district, as it is believed that in no other route between the lakes and the Mississippi River are the natural elements used in construction found in such abundance and in such accessible positions. In fact the geological features of this route render it pre-eminent in the matter of economy of construction.

In view of the fact that different styles of navigation are proposed on different parts of the route, I have divided it into three divisions. The first division consists of independent canal from Chicago to Joliet; the second division, extending from Joliet to La Salle, will consist of an improvement of the river by locks and dams, being virtually a continuation of the slack-water navigation projected in the river below La Salle. The third division consists of independent canal, corresponding to the line adopted and known as the Hennepin Canal, extending from the Illinois to the Mississippi River.

As it is proposed to draw the supply of water for the canal and river from the lake, all elevations are referred to the low-water plane of Lake Michigan; and as the course of the canal is laid down on the maps, it will not be necessary to advert to that here.

First division.—The canal commences with an average water-section equal to 448 square feet, with a variable depth of from 6 to 8 feet of water. As will be noticed, its course coincides with a right line for a distance of 7½ miles, at which point it is deflected to the south and continues parallel to

the valley of the Des Plaines River until it unites with the latter at Joliet. The physical difficulties to be overcome along this line are of an ordinary character, being such as are common to works of this class in almost all parts of the country.

The first 14½ miles of canal are excavated through a compact blue clay to an average depth of 16 feet. On the latter half of the 15-mile rock-excavation begins, and, with the exception of a few short intervals, this material continues to exist along the line to a point below Joliet.

At Lockport a section of the valley of the Des Plaines River was taken, which will be shown on the sheets accompanying this report, from which it will be seen that the valley is a little more than one mile in width, with a thin drift of clay over the rock, the river bed occupying at this point the central line of the valley.

As this had previously been designated as a favorable point at which to leave the canal for the river, I examined the valley with great care, and submit a section to show the superiority of the present location and the impracticability of any plan tending to a change in the direction mentioned.

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Prior to the year 1872, the summit-level of the Illinois and Michigan Canal was some 8 feet above the standard-level of Lake Michigan, and the quantity of water requisite to maintain navigation on the summit-level of the canal was supplied from Lake Calumet by a feeder and from the Chicago River by expensive pumping-machinery.

Sometime during the year 1866, the Board of Public Works of the City of Chicago entered into a contract with the State to cut down and reduce the summit-level of the canal to the elevation of the lake.

The object of this work on the part of the city authorities was to obtain an outlet for the south branch of the Chicago River; that being a receptacle for the sewerage of a large part of the city.

This contract was satisfied, the work completed, and navigation on the canal resumed July 18, 1872. The exertions and labors of the city to rid itself of a nuisance were not in vain; the residents of the city were relieved of a truly great evil, and the problem of securing a permanent and ample supply of water for the canal was practically solved.

Happy as such results were, the work, from its contracted dimensions afforded only partial relief; and recent drainage

improvements in the vicinity of the city have proved quite detrimental to and interfered very seriously with the city's purposes and interests in respect to this work.

In view of the many benefits that would accrue to the city in case of a further enlargement of this canal, as contemplated, the question is believed to be pertinent, will the city assume her portion of the cost of such enlargement?

One of the important duties of this survey was to determine accurately the volume of water to be drawn from the lake to maintain a depth of water in the river after it should be improved.

Experience on the summit-level of the canal, since it has been supplied from the lake, proves conclusively that the varying stages of water in the lake very materially affect navigation on this part of the canal. This fact is more noticeable during periods when the direction of the wind is parallel with the axis of the canal; the fluctuations in the elevation of the surface of the water being directly traceable to this cause.

EXTRACT FROM U. S. CHIEF OF ENGINEER'S REPORT 1880, APPENDIX EE, PAGE 1995. SURVEY OF ILLINOIS RIVER.

UNITED STATES ENGINEER OFFICE.

CHICAGO, ILL., May 10, 1880.

General: I have the honor to submit the following report on a survey of the Illinois River, executed in pursuance of the act of Congress making appropriations for the improvement of certain rivers and harbors, approved March 3, 1879.

The question of a through line of water communication from the Mississippi to Lake Michigan, via the Illinois River, has been before Congress since an early date. In 1822, the State of Illinois was authorized to make through the public lands of the United States a route for a navigable canal connecting the Illinois River with Lake Michigan, and between that date and 1854, Congress had granted to the State 321,760 acres of land to assist in its construction. The canal was first opened to navigation in 1848, its cost up to that time being $6,409,509.95; since then the state has spent a great deal towards its enlargement and maintenance. In the meantime several surveys, having in view the improvement of the Illinois River, have been made, the first in 1838 by Capt. Howard Stansbury, Topographical Engineers; the next of any considerable importance was made under the direction of General J. H. Wilson, in 1866, the object of which was "to obtain

such specific and accurate information in regard to obstructions to navigation in that river as will enable you to submit estimates for its improvement, so that the largest boats navigating the Illinois and Michigan Canal, and steamboats drawing four feet of water, will be enabled to pass through the river to St. Louis during the season of extreme low water without breaking cargo."

His report on this survey led Congress to direct a more complete survey in 1867 (act approved March 2), the object of which was to prepare plans and estimates "for a system of navigation by way of the Illinois River, between the Mississippi and Lake Michigan, adapted to *military, naval,* and *commercial* purposes." This duty was committed to a Board of Engineers composed of General J. H. Wilson and Mr. William Gooding, Civil Engineer, the latter having been for a long time the Chief Engineer of the "Illinois and Michigan Canal." The report of this Board was submitted to the Chief of Engineers under date of December 17, 1867, and is published in his annual report for 1868, pages 438 to 468. It recommended that the Illinois River be improved by the construction of five locks and dams, creating thereby a slack water system with a navigable depth of 7 feet at the lowest stage, from the mouth of the river at Grafton to Utica, 227 miles above; the lock chambers were to be 350 feet long, 75 feet wide, and the estimated cost of the entire work was $1,953,600. To complete the through line to Lake Michigan, an enlargement of the canal was recommended, the estimated cost of this enlargement being, in round numbers, $16,250,000.

No appropriations were made by Congress to carry out the plan of improvement above indicated, but the State of Illinois, in substantial conformity with that plan, has constructed *two* of the proposed locks and dams (viz, at Henry and Copperas Creek), at a cost of $747,747, while the annual appropriations by Congress for improving the Illinois River (aggregating to date $589,150) have been applied mainly to ameliorating its navigable condition by dredging channels through the worst bars, and constructing dikes and wing-dams for contracting the waterway. For a more detailed description of these operations I would respectfully refer to my report dated August 30, 1878 (which was published as House Ex. Doc. No. 81, 45th Congress, 3rd Session), a copy of which is transmitted herewith.

The several surveys and reports above referred to gives so complete a description of the physical characteristics of the

route, and present the arguments in favor of its improvement so forcibly, that it seems unnecessary to extend this report by repeating what has been so fully set forth before; accordingly it is limited to a brief outline of operations on the last survey, and a statement of what is necessary to complete the improvement of the river.

A substantial improvement having been effected from its point of connection with the canal down to Copperas Creek Lock, it was decided to apply the $5,000 allotted for our survey to the remainder of the river, viz, from Copperas Creek to Grafton, where the Illinois empties into the Mississippi.

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Page 1998.

The laws of Congress require that reports of surveys of rivers and harbors shall contain "statements of all existing facts tending to show to what extent the general commerce of the country will be promoted by the several works of improvements contemplated by such examinations and surveys." In fulfillment of this requirement it seems only necessary to note that the improvement of the Illinois River, supplemented by the enlargement of the Illinois and Michigan Canal as heretofore proposed, will furnish a reliable and commodious channel of water communication from the Mississippi River to the Northwestern lakes; by this line the vast Mississippi Valley, and all the country tributary thereto, is brought into direct water communication with Lake Michigan, at the great City of Chicago, with its flood of commerce eastward and westward; the route exists as a practicable one of considerable importance today, and the question is simply one of enhancing its value by increasing its capacity to a degree commensurate with the important interests involved.

Other routes have been examined and studied with care but neither of them occupies so central a position, can be built so soon, and with such certain results, maintained so economically, nor utilized through so great a part of the year.

Considering this simple statement, the facts so fully set forth in previous elaborate reports, and noting the wonderfully rapid development of the entire western country, it would seem that nothing further is necessary to indicate "to what extent the general commerce of the country will be promoted" by the contemplated improvement, nor to show how desirable it is that the work should be accomplished with the least delay practicable.

The total amount appropriated for the improvement of the Illinois river from 1869 to date is,		$589,150.00
From which there has been expended as follows:	$545,909.57	
For foundation of Copperas Creek Lock,	$62,358.90	
For dredging, wing dams, etc., including machinery,	483,550.67	
Total expended,	$545,909.57	
Leaving balance available May 8,1880	43,240.43	
		$589,150.00

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I am very respectfully your obedient servant,

G. J. LYDECKER,

Major of Engineers.

Brig. Gen. H. G. Wright,
Chief of Engineers, U. S. A.

EXTRACT FROM THE CHIEF OF ENGINEER'S REPORT 1884, APPENDIX HH, P. 1957, ENTITLED "PRELIMINARY EXAMINATION OF ILLINOIS AND DES PLAINES RIVERS BETWEEN LA SALLE AND JOLIET, ILLINOIS."

UNITED STATES ENGINEER OFFICE,

CHICAGO, ILL., September 2, 1882.

General: I have the honor to present the following report in regard to the proposed survey of the Illinois and Des Plaines Rivers from Joliet to La Salle, Ill., as provided for in the river and harbor act of August 2, and assigned to my charge by letter of August 11.

Several surveys have been made of the route by the State and by the General Government, and I have not deemed it necessary therefore to make a personal examination of the stretch of river in question, in order to report upon the necessity of an instrumental survey. I have examined the maps and consulted the reports and other sources of information, and deem it necessary to make survey, estimates for which are presented herewith.

The necessity of the improvement derives its importance from several considerations. The State has improved the river for ship navigation from La Salle to Copperas Creek, and the Government is now engaged in continuing the im-

provement thence to the mouth. I am directed to report upon the cost of enlarging the Illinois and Michigan Canal, which extends from Lake Michigan to La Salle. This work, if ever carried on, will give through navigation for large vessels from the lake to the Mississippi. The canal runs in close proximity to the river the entire distance from Joliet to La Salle, and in making up the estimates for the enlargement of the canal it will be necessary to discuss whether or not it will be more economical to enlarge the canal between those two points, or to improve the river and abandon the other.

Very respectfully, your obedient servant,

W. H. H. BENYAURD,
Major of Engineers.

Brig. Gen. H. G. Wright,
Chief of Engineers, U. S. A.

PAGE 1958.

SURVEY OF ILLINOIS AND DES PLAINES RIVERS BETWEEN LA SALLE AND JOLIET, ILLINOIS.

UNITED STATES ENGINEER OFFICE,

CHICAGO, ILL., March 5, 1884.

General: I have the honor to present the following report upon the survey of the Des Plaines and Illinois Rivers from Joliet to La Salle, with estimates of cost of improvement, as provided for in the river and harbor act passed August 2, 1882.

The survey party, under the charge of Mr. George Y. Wisner, assistant engineer, was not sent into the field until the 1st of October, 1883, as it was deemed better to wait and take advantage of the very lowest stage of water that could be found, not only as a matter of economy, but as affording the advantage of obtaining the fullest information when the rivers were in their worst condition, upon which state it was necessary to base the proper plan of improvement.

The survey was commenced at Dam No. 1 on the Des Plaines River, at Joliet, and continued to a point on the Illinois River near La Salle, where the Illinois and Michigan Canal enters the pool created by the lock and dam constructed by the State at Henry.

The rivers have an average width of about 600 feet, with banks from 8 to 23 feet in height above low water, so that within ordinary stages the stream flows within fixed banks. The oscillation between high and low water is about 15 feet,

though a height of 23 feet has been recorded, occasioned by an ice-gorge.

The fall in the low-water surface between the points indicated above, a distance of 64.2 miles, is 100.25 feet. This fall is not, however, equally distributed over the entire distance, but occurs at various points, principally at the ripples separating the different pools, and amounting in some cases to 10 feet per mile.

It is evident, after consideration, that the only feasible plan to render the stream navigable is to slackwater the entire distance. This can be accomplished by the construction of nine locks and dams, the cost of which depends upon whether the plan adopted shall be in conformity with that now in course of execution for the lower Illinois River, or whether the locks shall be of the size recommended for the Hennepin Canal. In addition to the requisite locks and dams, the plan also contemplates the construction of a short canal at the falls of Joliet, and one at Marseilles. The location of the various structures and the two canals were fixed upon, so that there should be no conflict between the United States and persons owning valuable manufacturing interests along the river, where water power is used. Certain low lands will necessarily be submerged if the plan be carried into execution; very little of it, however, is of any considerable value, and can very easily be estimated for. On this point the notes of the survey are very complete, and the maps are constructed showing the contours at every five feet elevation, so that the amount and character of the land submerged at any height above low water can readily be determined.

The Illinois River, below the termination of the present survey, has been rendered navigable by the State by the construction of the locks and dams at Henry and Copperas Creek. Two additional locks are now in course of construction by the Government, which will carry the navigation through to the Mississippi. All the locks are 350 feet long between gates, by 75 feet wide, and adapted for the passage of the largest size steamers navigating the river.

With the improvement of the river now in question carried on, navigation will be brought to within 33 miles of the lake, and this stretch can be opened by improving the Des Plaines higher up, and by enlarging the present Illinois and Michigan Canal. In the report I have estimated for locks of the same size as those on the lower river, and with the same lift—7 feet. At the same time, as the question of the construction of the Hennepin Canal and the enlargement of the Illinois and

Michigan Canal is under consideration, I have had other estimates made for locks of the same size as those recommended for these works.

As stated in my preliminary report under date of September 2, 1882, I had intended instituting a comparison between the cost of enlarging the Illinois and Michigan Canal between Joliet and La Salle and that of improving the rivers between the same points; but as the survey of the latter was not at that time authorized, I merely confined my report on the Illinois and Michigan Canal to the cost of enlargement throughout its entire length, and without making any change to the river route. With the data furnished by the present survey it has been ascertained that the cost of enlargment of the canal for the middle-sized locks is less than what the improvement of the river would cost for the same class of works, while in the case of the larger locks the expense would be greatly in favor of the river route. The additional cost of the river route in the first instance would be offset by the lesser amount that would be required for maintenance, repairs, &c., as the long line of canal, with its aqueducts, feeders, weirs, &c., would be a constant source of expense. The river route has also the advantage, when it is considered that we have navigation on a stream 600 feet wide instead of the narrow channel of the canal.

Looking at the matter in an engineering point of view, it is difficult to understand what led originally to the construction of the canal, rather than the improvement of the natural channel of the river. Should the Illinois and Michigan Canal be accepted by the Government, and its enlargement undertaken, that part between Joliet and La Salle should be abandoned and the river route between these points adopted.

Another point in the contemplated improvement, or in the acceptance of the Illinois and Michigan Canal, demands notice. As before mentioned, two locks and dams are in course of construction on the lower river by the government, above which there is a stretch of 88 miles of river improved by and now under the control of the State. Should the United States continue the improvement between Joliet and LaSalle, there will then be a part of the river forming a link between the upper and lower portions over which the state now exercises control and upon which tolls are collected for the passage of boats through the locks.

The act of the legislature of the state ceding the Illinois and Michigan Canal did not, as I understand, include the

locks and dams at Henry and Copperas Creek, but only the canal as originally constructed.

The estimated cost of improvement, with locks having chambers 350 feet long and 75 feet wide is $3,433,562, and for the size of locks adopted for the Hennepin Canal, 170 feet by 30 feet, $1,975,446.

There is transmitted herewith the report of Mr. George Y. Wisner, assistant engineer, to which reference can be made for details of survey, &c.

The maps will be completed in the course of the present month and forwarded to the Department.

Very respectfully your obedient servant,

W. H. H. BENYAURD,
Major of Engineers.

To the Chief of Engineers, U. S. A.

REPORT OF MR. GEORGE Y. WISNER, ASSISTANT ENGINEER.

CHICAGO, ILL., February 23, 1884.

Major: I have the honor to make the following report on the survey of the Des Plaines and Illinois Rivers from Joliet to LaSalle, Ill., and to submit estimates of cost for improvement of the rivers by locks and dams, so as to give a minimum depth of seven feet at low-water stage.

* * * * * *

The survey was commenced at Dam No. 1 on the Des Plaines River, at Joliet, and continued to the mouth of the Illinois and Michigan Canal, on the Illinois River, at LaSalle. The fall of the low-water surface from above Dam No. 1 to LaSalle, a distance of 64.2 miles was found to be 100.25 feet. The greater portion of this fall, however, occurs in less than half the above distance, at the ripples separating the various pools, and which in some cases amount to 10 feet per mile.

The river for the entire distance flows either over a rock bed or a strata of earth of only a few feet thickness, overlying the rock formation.

With one exception, at Treat's Island, all the locks and dams may be established on rock foundations.

There are no indications of any material change of location having occurred in the river bed for a number of years. A comparison of results with those from the survey made by Mr. Doran in 1874 shows that scour has occurred in the bed of the river, amounting in some instances to 12 feet in depth, but otherwise the general outlines of the river-bed remain the same.

The average width of the river is about 600 feet, with banks from 8 to 25 feet in height above low water, or such that at ordinary stages the stream flows within fixed banks.

The damage to farming lands from raising the low-water surface so as to give a minimum depth of 7 feet will not be of any great amount.

Treat's Island and a large island just below Buffalo Rock, will be submerged so as to be of little value. At Marseilles about 50 acres of land will have to be purchased for the proposed canal around the rapids.

From an examination of high-water marks it was found that in several places where the river has been gorged with ice the surface rose to 23 feet above the low-water plane, but ordinary high water probably in no case exceeds 15 feet above low stage. All bridges across the river will require draw spans to admit the passage of boats at high water.

The plan proposed for the improvement of the river at Joliet is a lock of 10 feet lift at Dam No. 1, and a canal 12,500 feet long from Dam No. 2 at the foot of Jefferson Street, to the head of the pool below, known as Lake Joliet. Guard gates will be required at the head of this canal, and a combined lock of 20.8 feet lift at the lower end.

This plan was adopted for the reason that valuable manufacturing interests derive water power from Dam No. 2, and from the Adams Dam, 2300 feet below, which power would be practically ruined if the surface of the river were raised so as to give a depth of 7 feet.

It will also be seen from the accompanying maps that the river below the Adams Dam is shallow, with channel obstructed with numerous small islands, and if improved by raising water surface by a dam at the head of Lake Joliet, the pool thus formed would, in all probability, soon fill up with deposits from the Illinois and Michigan Canal, so that a navigable way could only be maintained by continual dredging.

Lake Joliet, however, is 5 miles long and 10 feet to 20 feet deep, and consequently, by commencing slack water improvement at the head of this pool, there will be little or no liability of the navigable channel becoming obstructed by deposits.

At the lower end of this pool Treat's Island, 4,500 feet long, is situated, past which the low water plane of the river has a slope of 10 feet to the mile.

At the lower end of Treat's Island (6.3 miles below canal) Lock No. 3 is located, having a lift of 9.9 feet, and dam 350

feet in length. This lock will probably have to be built on a timber foundation. No borings were made, but the strata of sand and gravel overlying the rock formation probably does not exceed 12 feet in thickness.

Below lock number 3 a pool from 4 feet to 15 feet deep extends down to the mouth of the DuPage River (two miles), below which there is a ripple three-quarters of a mile long, having a low-water slope of 2 feet per mile.

From this point the river is from 10 feet to 20 feet deep to within a short distance of the mouth of the Kankakee River (three miles), the junction of which with the DesPlaines forms the Illinois. At the mouth of the Kankakee the river flows over a rock bed, and for a distance of 1.7 miles has a low-water slope of 4.4. feet per mile.

EXTRACT FROM A REPORT OF MAJOR HANDBURY, CHIEF OF ENGINEER REPORTS 1887, APPENDIX II, p. 2119, ENTITLED "IMPROVEMENT OF ILLINOIS RIVER, ILLINOIS."

The project now in the course of execution for the reach of the Illinois River lying between the state lock at Copperas Creek and the mouth, a distance of 135 miles, contemplates the construction of two locks and dams and the dredging of a channelway where necessary, so as to insure a continuous depth throughout of not less than 7 feet at low water.

The sites selected for the locks and dams are one at Kampsville, about 30 miles above the mouth of the river; the other at LaGrange, 45 miles above Kampsville. These locks are 350 feet long and 75 feet wide, with 7 feet over miter-sills at low water.

The ultimate object of this improvement is to provide a channelway from the lower end of Lake Michigan to the Mississippi River of sufficient capacity to accommodate large-sized Mississippi River boats, so that the products of the country may be carried from the Lake to the Gulf without breaking bulk; also to enable vessels of war of considerable capacity to pass freely from the Gulf of Mexico into the defenseless waters of our northern lakes, should the exigencies of our foreign relations ever require this to be done.

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Page 2121.

When this work is completed it will then be practicable for the large steamers belonging to the Upper and Lower Mississippi, the Ohio, and Missouri Rivers to come with their unbroken cargoes to within 100 miles of Lake Michigan. All

this can be brought about by an expenditure on the part of the government of less than $600,000.

The Illinois River, from the western terminus of the Illinois and Michigan Canal at LaSalle to Copperas Creek, about 80 miles below, has been improved by the State of Illinois by means of two locks and dams similar to those in process of construction by the United States on the river below. From LaSalle to Joliet the Illinois and Des Plaines Rivers have been carefully surveyed, and plans and estimates of cost for their improvement to the same navigable capacity as the river below have been made and submitted to Congress. The report on this project submitted by Maj. W. H. H. Benyuard, Corps of Engineers, U. S. Army, may be found in the Chief of Engineer's Report for 1884, page 1958. The estimated cost of improving this reach of the river is $3,433,562. The distance is 64 miles and the fall 100 feet. Congress has now before it the engineering data showing the feasibility and cost of a water communication between the Mississippi River and a point 30 miles distant from navigable water leading into Lake Michigan sufficiently commodious for the commercial and military exigencies of the country, and from this point to the lake perfectly practical routes over which the line can be constructed are known to exist. It only remains for Congress to provide the means for making the necessary surveys and estimates of cost for continuing this work from Joliet to Lake Michigan, when it will have the engineering features of the whole subject before it in a shape necessary for intelligent legislation. I estimate that about $10,000 will be sufficient to defray the expenses of the necessary surveys and examinations and preparation of the plans and estimates of costs of the work.

The United States and the State of Illinois have long been committed to the project of opening a water communication between the Mississippi River and the northern lakes of capacity sufficient for the wants of commerce and for the exigencies of our national defense, should these ever arise. The amount expended by the United States to the end of the present fiscal year in carrying out this project is $680,633.42, exclusive of $62,359.80 expended on the foundation of the Copperas Creek Lock, which was afterwards turned over to the State. The cost of the locks and dams built by the State of Illinois at Copperas Creek and Henry was $747,747.

The distance by this route from the Gulf of Mexico to the southern end of Lake Michigan is about 1,620 miles. When the projected improvement of the Illinois River below Cop-

peras Creek, on which we are now working, has been finished, more than 1,520 miles of this distance will be available for the water transportation of commerce in bulk between these points. Pushing this improvement through to the lake, the connecting line will be formed which will join the northern lakes with the vast net-work of navigable rivers whose waters flow into the Gulf of Mexico on a scale to a certain degree commensurate with the importance of the commerce that will be affected by it. The mere fact that such a route is available will serve as a wholesome regulator to the rates that would be exacted by other methods of transportation were this one not in existence. Besides the immense commercial advantages that may be expected from the completion of the project, there are military and naval exigencies that might easily arise where it would figure as a prominent factor in the problem of our national defenses. From whatever point we look at the subject there is nothing local or sectional in it. It is true that all the work to be done happens to be in the State of Illinois. The benefits to be derived belong to the nation at large. It is fortunate, too, that at this time the subject is unencumbered by any phase of a political character. The problem of connecting Lake Michigan with the Mississippi River by a commodious waterway, that could be used for commercial, military and naval purposes, has received attention from our most thoughtful statesmen from the day of Albert Gallatin to the present.

The question of enlarging the Illinois and Michigan Canal from Joliet to Chicago, Ill., to a capacity equal to the low water capacity of the improved Illinois River has been discussed at some length by General J. H. Wilson, in a report to the Chief of Engineers, U. S. Army, published as House Ex. Doc. No. 16, 40th Congress, first session. Since the date of that report the conditions which affected the problem in its most essential features have materially changed. Additional engineering data that we are not now in the possession of have become a matter of absolute necessity, and must be collected and compiled before all the facts necessary to a thorough understanding of the subject can be laid before Congress. The Board of Engineers appointed under provisions of the river and harbor act approved August 5, 1886, to examine and report upon the Illinois and Michigan Canal and the proposed Hennepin Canal, says in its report (House Ex. Doc. No. 79, 49th Congress, 2nd session) that "the waterway from Chicago to Grafton, on the Mississippi River, is a most important one, and when completed there is little doubt

that it will richly pay for itself in the reduction and regulation of freights." These remarks are concurred in by the Chief of Engineers in his letter submitting this report to the Secretary of War. In the same report the Board remarks:

> In view of the possibilites of the case, it would appear that whatever enlargement of the canal is made from Joliet northward should not be carried further than the "Sag," a point whence the line of the canal could be easily diverted to a more favorable terminus.

The Secretary of War, in laying this matter before Congress, remarks upon this point:

> In this connection another question is suggested by the report of the Board of Engineers. At present the canal has its northern terminus in the South Branch of the Chicago River, about five miles from Lake Michigan. This branch runs through the central business portion of Chicago and is crossed by numerous draw-bridges. At present these bridges are a great impediment to navigation and to the land traffic of Chicago. If this river becomes the only outlet to the large commerce that may follow the opening of this new route of transportation between the Mississippi River and Lake Michigan, another outlet for the canal will be necessary, and economy and convenience may demand another channel to the waters of Lake Michigan. As to the cost of such a change, should it be necessary, we have no knowledge, no preliminary surveys of the country, with a view to the constructing of a new route to the lake, having been made.

In my report to the Chief of Engineers dated February 10, 1886, supplementary to that of Major W. H. H. Benyaurd, Corps of Engineers, on the subject of the Hennepin Canal, published in House Ex. Doc. No. 117, 49th Congress, 1st Session, I have the honor to state:

> Before taking steps looking to the enlargement of the Illinois and Michigan Canal in the interests of Commerce, or as a military expedient, the advisability is suggested of ascertaining whether or not some route can be found from Joliet to Lake Michigan at a point where better facilities can be provided for handling the large commerce of this section. It is thought by some that a practical route exists between the valleys of the Des Plaines and Calumet Rivers, along which a canal such as will accomodate the largest vessels using the improved Illinois River can be constructed, at a cost less than that

estimated for the enlargement of the Illinois and Michigan Canal from Joliet to Chicago.

Before definitely locating that portion of this route which is to lie between Joliet and Lake Michigan, and which will involve in its construction the expenditure of a very considerable amount of money, every possible route should be examined, and every engineering phase of the problem should be considered. For these reasons I venture to respectfully suggest the advisability of calling the attention of Congress to the necessity for making available the sum of $10,000; as much thereof as may be necessary to be expended in examinations and surveys between the southern end of Lake Michigan and the Des Plaines River at or near Joliet, Ill., and on the preparation of plans and estimates of cost of constructing, along the most practical route so determined, a waterway having sufficient capacity to accommodate the same class of vessels and commerce that the present improved condition of the Illinois River is designed to accommodate.

EXTRACT FROM H. R. DOC. 263, 59TH CONGRESS, 1ST SESSION, KNOWN AS THE ERNST SURVEY OF 1902-1905.

LETTER OF THE SECRETARY OF WAR.

WAR DEPARTMENT.

WASHINGTON, December 18, 1905.

Page 3.

Sir: I have the honor to transmit herewith a letter from the Chief of Engineers, U. S. Army, dated December 12, 1905, together with copies of reports of the Mississippi River Commission and a Board of Engineers dated February 28 and August 26, 1905, respectively, of a survey, with plans and estimates of cost, for a navigable waterway 14 feet deep from Lockport, Ill., by way of Des Plaines and Illinois Rivers, to the mouth of said Illinois River, and thence by way of the Mississippi River to St. Louis, Mo., and for a navigable waterway of 7 and 8 feet depth, respectively, from the head of navigation of Illinois River at LaSalle, Ill., through

said river to Ottawa, Ill., made in compliance with the provisions of the river and harbor act of June 13, 1902.

Very respectfully,

WM. H. TAFT,
Secretary of War.

The Speaker of the House of Representatives.

LETTER OF THE CHIEF OF ENGINEERS.

WAR DEPARTMENT.

OFFICE OF THE CHIEF OF ENGINEERS,

WASHINGTON, December 12, 1905.

Sir: The river and harbor act approved June 13, 1902, contained an item as follows:

The sum of two hundred thousand dollars, or so much thereof as may be necessary, is hereby appropriated for making such surveys, examinations, and investigations as may be required to determine the feasibility of, and to prepare and report plans and estimates of cost of, a navigable waterway fourteen feet in depth from Lockport, Illinois, by way of the Des Plaines and Illinois rivers to the mouth of said Illinois River, and from the mouth of the Illinois River, by way of the Mississippi River, to Saint Louis, Missouri: *Provided*, That twenty-five thousand dollars of said sum, or so much thereof as may be necessary, may be expended by the Mississippi River Commission in making surveys, examinations, and investigations herein required from the mouth of the Illinois River to Saint Louis; *provided further*, that the Secretary of War shall appoint a board of three engineers to make the surveys, examination and investigations hereinbefore required from Lockport, Illinois, through the Des Plaines River and Illinois River, to the mouth of said Illinois River, and that all such surveys, examinations, and investigations shall be made to determine the feasibility of, and to prepare and report plans and estimates of cost of, a navigable waterway fourteen feet in depth from Lockport, Illinois, to Saint Louis, Missouri.

The said Mississippi River Commission shall make said report covering such proposed improvement from the mouth of the Illinois River to Saint Louis and the said board of engineers shall make such report from Lockport, Illinois, to the mouth of the Illinois River: *And provided further,* That the said board of engineers shall also make such surveys, examinations, and investigations as may be required to determine the feasibility of, and to prepare a report and plans, and estimates of cost, of, a navigable waterway seven feet in depth and of a navigable waterway eight feet in depth from the head of navigation of the Illinois River at LaSalle, Illinois, through said Illinois River to Ottawa, Illinois, and said board of engineers shall make such report of said navigable waterways of seven and eight feet, respectively, of said Illinois River from LaSalle to Ottawa, Illinois.

In accordance with this provision, a Board of officers of the Corps of Engineers, consisting of Col. Oswald H. Ernst, Lieut. Col. Charles J. Allen, and Maj. Thomas L. Casey, was appointed and charged with the duty of making the surveys, examinations, and investigations from Lockport, Ill., by way of the Des Plaines and Illinois rivers, to the mouth of the Illinois River. By operation of law, Lieut. Col. Charles J. Allen, Corps of Engineers, one of the members of the board, was retired from active service as brigadier-general January 8, 1904, and was replaced by Maj. James L. Lusk, Corps of Engineers, April 21, 1904, who in turn was relieved on account of ill health on April 6, 1905, being replaced by Lieut. Col. W. H. Bixby, Corps of Engineers. This Board was also charged with the duty of making the necessary surveys, etc., of the waterways named in the final proviso of the item quoted above.

The Mississippi River Commission was charged with the duty of making the required surveys, examinations, and investigations from the mouth of the Illinois River to St. Louis, Mo.

The Board of Engineers above referred to and the Mississippi River Commission have made their reports, which are now submitted for transmission to Congress.

To provide the 14-foot channel from Lockport by way of the Des Plaines and Illinois rivers to the mouth of the Illinois River, the Board proposes to canalize the river from Lockport to Utica by 9 locks and 5 new movable dams, and to

utilize the open river from Utica to Grafton by removing the four existing dams and dredging a channel 200 feet wide at the bottom. It is thought that such a channel will have the requisite depth of 14 feet when the natural discharge of the river is augmented by the contemplated flow of about 10,000 cubic feet per second from the Chicago Drainage Canal.

The channel will connect with the Chicago Drainage Canal by a lock in the dam which is now under construction by the Sanitary District of Chicago at Lockport; it then follows the canalized river in the main, having lateral canals, each about 3 miles long, at Marseilles and Joliet.

The Board estimates the cost of the channel from Lockyort to Grafton at $23,543,582. This estimate is based on concrete locks 600 feet long, 80 feet wide, and 14 feet deep over the miter sills. The Board remarks that this depth, while corresponding to the channel mentioned in the act, will not provide for any future increase, which may be made possible by augmenting the flow through the Chicago Drainage Canal above 10,000 cubic feet per second. The Board states that, to take full advantage of such possible increase in navigable depth, the locks would have to be entirely rebuilt, or would have to have increased depths given to them at the present time. To increase the depth over the miter sills 6 feet now would add about $1,376,000 to the cost of the project. The plan proposed is based upon the assumption that the abstraction of 10,000 cubic feet of water per second from Lake Michigan, a quantity contemplated in the State legislation affecting the drainage canal, will eventually be permitted by competent Federal authority.

In this connection the Board states that it does not condemn the present plan of taking 10,000 cubic feet per second, believing as it does that some such amount will be needed to protect the lives and health of the people of a great city and of a populous valley; but it invites attention to the fact that if a much larger amount be taken it will be necessary to construct remedial works elsewhere, and that these are, or should be, of an international character. It is led to make this remark by the attitude of the Illinois legislature and of the other principal advocates of this enterprise, which is that the 14-foot waterway is only a beginning, and that a much deeper channel ultimately should be constructed, which means that a much larger volume of water must be taken from Lake

Michigan. It is the opinion of the Board that the sanitary reasons for the abstraction of water so far exceed and overshadow the commercial reasons that the amount should be strictly limited by the sanitary necessities of the case. It is impossible to fix a limit to the future growth of Chicago. In a future not remote larger amounts of water may be needed for sanitary purposes, and channels deeper than 14 feet will then become practicable, in the open alluvial portion of the Illinois River."

* * * * *

Very respectfully,

A. MACKENZIE,
Brig. Gen., Chief of Engineers, U. S. Army.

Hon. WM. H. TAFT,
Secretary of War.

EXTRACT FROM THE REPORT OF THE BOARD, PAGE 9, ENTITLED CHICAGO DRAINAGE CANAL.

Besides being a highway of commerce, the Illinois and Michigan Canal has from the beginning served to carry off the sewage of Chicago. The Chicago River has always been the main receptacle of the sewage of the city, and as the volume of sewage has increased with the growth of the city additional facilities for discharging it into the canal have become necessary. When the canal was opened in 1848, a pumping plant was established at Bridgeport, where it joins the Chicago River. In 1860 the capacity of this plant was nearly doubled, being increased to about 400 cubic feet per second. Later on the summit level of the canal was cut down so as to provide a continuous gravity flow from the Chicago River and Lake Michigan. That work was completed in 1871 and the pumping plant abandoned. In 1883 a new pumping plant was brought into use, having a nominal capacity of 750 cubic feet per second, but it soon became evident that the discharging capacity of the old canal was quite inadequate to carrying the volume of water required to dilute the sewage and that a new and greatly enlarged channel must be provided. The Chicago Drainage Canal was then constructed and was

brought into use in January, 1900. It has not yet been completed to its full capacity as designed. When fully completed it will have a capacity of about 10,000 cubic feet per second, flowing at a low velocity. As now constructed, it has a depth of about 22 feet and a bottom width in different parts 110 feet, 160 feet and 202 feet, respectively. It constitutes a navigable channel able to accommodate the largest vessels now navigating the Great Lakes. It extends from the Chicago River to Lockport, where it discharges into the Des Plaines River and is now being extended 2 miles farther to a new power house. With the six miles of the Chicago River and the 2 miles extension just mentioned it provides a wide and deep channel for a distance of 36 miles from Lake Michigan. At present it has no navigable connection with the streams below, but under State legislation a connection is to be made. It creates an important water power.

Although the primary object of the Chicago Drainage Canal was the discharge of Chicago sewage, its function as a channel, for navigation, was kept in view from the beginning. All of the bridges over it are draw bridges with ample openings. The original act of the Illinois legislature providing for its construction dated May 29, 1889, contained the following item, viz.:

> 24. When such channel shall be completed, and the water turned therein, to the amount of three hundred thousand cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the General Government shall improve the Des Plaines and Illinois rivers for navigation, to connect with this channel, said General Government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary or drainage purposes.

As its utility for sanitary or drainage purposes is dependent upon the supply of water which it may obtain from Lake Michigan, a matter wholly at the discretion of the Federal Government, the degree of control which the State offers to the United States in this act, although limited, is probably sufficient. It is conditional, however, upon the improvement by the Federal Government of the Illinois and Des Plaines rivers, and the degree of improvement is described in section 23 of the above mentioned State law, which contains the following language:

If at any time the General Government shall improve the Des Plaines or Illinois rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute, from such channel may cause to private property, so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter enlarge the entire channel leading into said Des Plaines or Illinois Rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet per minute, with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom.

The taking of large quantities of water from Lake Michigan for drainage purposes has not been authorized by Congress. It has been the policy of the War Department thus far to regulate the quantity of water which is admitted to the canal by the necessities of navigation in the Chicago River. The capacity of that stream at present is such that not more than about 4,200 cubic feet per second can pass without creating velocities which will unreasonably obstruct navigation. The quantity of water admitted to the canal is, for the present, limited to that amount, or, as expressed in the permit of the Secretary of War, to 250,000 cubic feet per minute. This is less than is required by the State law. It will no doubt be increased as the obstructions in the Chicago River are removed, and its discharging capacity increased, a work upon which the Sanitary District is now engaged. In preparing its estimates the Board has assumed that the full discharge of 10,000 cubic feet per second contemplated in the plans of the Sanitary District will eventually be permitted by the Secretary of War.

Vested Rights.

The effect upon the level of Lake Michigan of withdrawing 10,000 cubic feet per second for an indefinite period has been the subject of an elaborate investigation under the office of the Lake Survey in Detroit, and the conclusion reached is that the final effect will be to lower the level about 6 inches. (See Annual Report of Chief of Engineers for 1900, p. 5401, and for 1902, p. 2779 and p. 2825; also for 1904, p. 4120.) Oscillations of more than 6 inches in the level of the lake's surface are very common, often occurring hourly for many hours in succession, while oscillations of 2 or 3 feet within an hour are not uncommon. Still greater oscillations within a year or series of years occur, all from natural causes. Moreover, during a severe winter the discharge of St. Clair River is reduced by ice to less than one-third its normal discharge, the remaining two-thirds being stored up in Lakes Huron-Michigan and raising their levels; and the difference between the total discharge during a severe winter and the discharge during a mild winter will probably equal, or nearly equal, the discharge of the Chicago Drainage Canal for a year. A permanent average lowering of 6 inches in the lake's level, therefore, is not easily observed and will probably not be noticed by navigators. Nevertheless the effect is real and important. Evidently there is a limit to the amount of water which can be taken from the southern end of Lake Michigan without compensating works at the outlet of Lake Huron. The Board does not condemn the present plan of taking 10,000 cubic feet per second, believing as it does that some such amount will be needed to protect the lives and health of the people of a great city and of a populous valley; but it invites attention to the fact that if a much larger amount be taken it will be necessary to construct remedial works elsewhere, and that these are, or should be, of an international character. It is led to make this remark by the attitude of the Illinois legislature and of the other principal advocates of this enterprise, which is that the 14-foot waterway is only a beginning, and that a much deeper channel ultimately should be constructed, which means that a much larger volume of water must be taken from Lake Michigan. It is the opinion of the Board that the sanitary reasons for the

abstraction of water so far exceed and overshadow the commercial reasons that the amount should be strictly limited by the sanitary necessities of the case. It is impossible to fix a limit to the future growth of Chicago. In a future not remote larger amounts of water may be needed for sanitary purposes, and channels deeper than 14 feet will then become practicable in the open alluvial portion of the Illinois River.

The natural discharge of the Illinois River at La Salle varies from about 500 cubic feet per second at the lowest stage to about 85,000 cubic feet during floods. The effect of adding thereto 10,000 cubic feet per second is to raise the water surface at all stages and to increase the extent and duration of overflow upon the bottom lands of the valley. Some damage will be done to these lands; in many cases no doubt small, but in all cases sure to be exaggerated by the owners. A multitude of damage suits is to be expected. With the discharge limited, as it now is, to 4,200 cubic feet per second, 224 suits have been brought against the trustees of the Sanitary District of Chicago, the claims aggregating $4,409,180. Making due allowance for exaggeration of claims, a considerable sum of money is involved, besides much litigation. In the State legislation quoted above it is proposed that the Sanitary District of Chicago shall asume responsibility for damages caused by the discharge of 5,000 cubic feet per second, and that for additional damages caused by amounts greater than 5,000 cubic feet the United States shall be responsible. The introduction of dams in the portion of the route where dams will be required to secure the prescribed depth has a tendency to further increase the overflow. To keep this at a minimum it is proposed to make the dams of the movable type, which shall have no effect upon the water surface except at low and medium stages.

The steep slope of the Des Plaines River and of the Illinois River above Utica is favorable to the development of water power. Rights of this nature have acquired additional importance with the recent increase in the discharge of the drainage canal, and will acquire still further importance with the furthe increase contemplated. An important water power has been developed by the State of Illinois at Joliet and is now in use under lease by a private corporation. The Sanitary District of Chicago is engaged in the construction of works for the development of water power just above

Joliet. An important water power is in use also at Marseilles. Various other schemes for the development of water power have been projected. In all such cases fixed dams, with their resultant back flowage, are a necessity. In fixing the location and height of its dams the Board has endeavored to avoid the injury of any of these schemes. It has succeeded in doing this for all that are developed and probably also for those that are undeveloped. It has accepted the levels of the pools at and above Joliet as fixed by the dam now in existence at the former and that under construction at the latter; and at Marseilles the canal around the rapids has enabled it to avoid the power dam at that place entirely. At other places economy in excavation and avoidance of overflow have been the guiding considerations. The best development of water power would no doubt in some cases call for a different arrangement. Fewer dams and those of a greater height and of the fixed type might, from that point of view, be desirable. The plan submitted is not designed to develop water power; but there will probably be no difficulty in modifying it so as to conform to such development if those who are to benefit thereby will co-operate with the Government. They should pay the cost of the dams and the damages from flowage, which is no more than they would be compelled to do if the Government made no improvement.

RESOLUTION OF APRIL 21, 1891, OF THE BOARD OF TRUSTEES OF THE SANITARY DISTRICT OF CHICAGO.

"RESOLVED, That this Board hereby ordains that The Sanitary District of Chicago do forthwith enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the South Branch thereof, and also the South Branch thereof, together with the South and West Forks thereof so as to make the same a proper and sufficient supply channel for the main channel heretofore surveyed from the Chicago River to Joliet; and further, that the Acting Chief Engineer be, and he is hereby, directed immediately to investigate and report upon the capacity of said River and its said South Branch and Forks for that purpose, and also as to any

changes that should be made therein, and that a copy of this resolution, certified by the Clerk, be forthwith transmitted to the Mayor and Common Council of the City of Chicago, and the Secretary of War of the United States."

Proceedings of the Board of Trustees of the Sanitary District of Chicago, 1890-1891, page 173.

EXTRACTS FROM THE NEGOTIATIONS BETWEEN THE UNITED STATES AND GREAT BRITAIN REFUSING THE UNITED STATES THE USE OF THE ST. LAWRENCE RIVER.

Extracts from Message of the President of Jan. 7, 1828, State Papers 1st Session 20 Congress, Vol. 2, Doc. 43, Page 8, entitled "Extract of a Dispatch from Mr. Rush to Mr. Adams, Dated London, August 12, 1824."

"The act of parliament of August 5, 1822, having immediate relation to the commercial intercourse between the United States and the British continental possessions in their neighborhood, I naturally regarded it as your instructions to me had done in connection with the act of June 24, 1822. This brought under consideration our claim to the navigation of the St. Lawrence. Between this question and the questions of commercial intercourse under the act of June, 1822, the British plenipotentiaries were constantly unwilling to acknowledge any connection. Nevertheless, looking to your instructions, and as well to the reason of them as to their authority, I treated the two questions as belonging to one and the same general subject. They asked whether, taking the two acts of parliament together, the United States did not already enjoy the navigation of this river? I said that they did; by the act of June 24, 1822, they enjoyed it from the ocean to Quebec; and by that of August 5, 1822, from any part of the territories of the United States to Quebec. But from the fact of the colonial government in Canada being invested with a discretionary power to withdraw the latter of these concessions by excepting any of the Canadian ports from those to which our vessels were made admissible, it followed that our enjoyment of the navigation of this river was rendered contingent upon British permission. This was a tenure not reconcilable in the opinion of the government of the United States with the growing and permanent wants of their citizens in that portion of the Union, or with the rights of the nation. It was due to both these considerations that it should stand upon a different tenure, and the time had arrived when it was desirable that the two nations should come to an understanding upon a question of so much importance."

"The British plenipotentiaries next asked, whether any question was about to be raised on the right of Great Britain to exclude all together vessels of the United States from trading with British ports situated upon the St. Lawrence or elsewhere in Canada? I replied that I was not prepared to deny absolutely such a right in Great Britain, to whatever

considerations its exercise might be opened. I remarked also that it seemed already to have been substantially exercised by the act of August 5, 1822; for, by its provisions, only certain enumerated articles were allowed to be exported from the United States to Canadian ports, and the duties were laid upon these articles which might be said to amount to a prohibition. I added that although the foregoing act had not laid any duty on the merchandise of the United States descending the St. Lawrence, with a view to exportation by the sea, yet that an act of the preceding year did, viz., upon their timber and lumber which made it highly expedient that the relative rights of the parties to the use of the waters of this great stream should be ascertained. * * *

"I approach the interesting part of this negotiation where I come to make known in what manner the British received this disclosure. They said that, on principles of accommodation they were willing to treat of this claim with the United States in a spirit of entire amity; that is, as they explained it, to treat of it as a concession on the part of Great Britain for which the United States must be prepared to offer a full equivalent. This was the only light in which they could entertain the question. As to the claim of right, they hoped that it would not even be advanced; persisted in, they were willing to persuade themselves it would never be. It is equally novel and extraordinary. They could not repress their strong feelings of surprise at its bare intimation. Great Britain possessed, absolutely, sovereignty over the river, in all its parts, where both its banks were of her territorial dominion. Her right hence to exclude a foreign nation from navigating it was not to be doubted, scarcely to be discussed. That was the manner in which it was at first received. They opposed to the claim an immediate positive and unqualified resistance."

"I said that our claim was one that had been well considered by my government and was believed to be maintainable on the soundest principles of public law. The question had been familiar to the past discussions of the United States, as the state papers, which were before the world, would show. It had been asserted and successfully asserted in relation to another great river of the American continent flowing south, the Mississippi, at a time when both of its lower banks were under the dominion of a foreign power. The essential principles that had governed one case were now applicable to the other."

"My reply was not satisfactory to the British. They combated the claim with increased earnestness, declaring it was

altogether untenable and of a nature to be totally and unequivocally rejected. Instead of having the sanction of public law, the law and the practice of nations equally disclaimed it. Could I show where was to be found, in either, the least warrant for its assertion? Was it not a claim plainly inconsistent with the paramount authority and exclusive possession of Great Britain? Could she for one moment listen to it? * * *

"The necessity of my recounting to you the British argument in answer to our claim is superseded by my being able to transmit it to you in their own words upon paper. It is sufficiently elaborate, and is drawn up with great deliberation. It is annexed (marked 'N') to the protocol of the 24th Conference. The intention avowed by the British at the 19th Conference of obtaining for its doctrines, before its delivery to me, the full sanction of their highest professional authorities on matters relating to the law of nations may serve to show the gravity and the importance which the question had assumed in their eyes. Their argument was prepared under the advice and assistance of five of the most eminent publicists of England. * * *"

N.

British Paper on the Navigation of the St. Lawrence—24th Protocol. Aug. 12, 1824.

The claim of the United States to the free navigation of the river St. Lawrence wears a character of peculiar importance when urged as an independent right.

The American Plenipotentiary must be aware that a demand, rested upon this principle, necessarily precludes those considerations of good neighborhood and mutual accommodation, with which the Government of Great Britain would otherwise have been anxious to enter upon the adjustment of this part of the negotiation.

A right claimed without qualification on the one side, affords no room for friendly concession on the other; total admission, or total rejection, is the only alternative which it presents.

On looking to the objects embraced by the American claim, we find them to be of no ordinary magnitude. The United States pretend to no less than the perpetual enjoyment of a free, uninterrupted passage, independent of the territorial sovereign, through a large and very important part of the British possessions in North America. They demand, as their

necessary inherent right, the liberty of navigating the St. Lawrence from its source to the sea, though, in the latter part of its course, which lies entirely within the British dominions, and comprises a space of nearly six hundred miles, that river traverses the finest settlements of Canada, communicates by the south with Lake Champlain, and washes the quays of Montreal and Quebec.

A pretension which thus goes to establish a perpetual thoroughfare for the inhabitants, vessels, and productions, of a foreign country through the heart of a British colony, and under the walls of its principal fortress, has need to be substantiated on the clearest and most indisputable grounds. It requires, indeed, an enlarged view of what is owed in courtesy by one nation to another to justify the British Government in entering, at this late period, on the discussion of so novel and extensive a claim.

There will, however, be little difficulty in showing that the claim asserted by the American Plenipotentiary rests, as to any foundtation of *natural* right, on an incorrect application of the authorities which he has consulted. With respect to the claim derived from an acquired title which he has also alleged, that ground of claim will remain to be examined hereafter; but it may be observed, in the outset, that the natural and acquired title depend on principles essentially distinct; that the one cannot be used to make good any defect in the other; and although they may be possessed independently by the same claimant, that they can, in no degree, contribute to each other's validity.

Proceeding to consider how far the claim of the United States may be established on either of these titles, it is first necessary to inquire what must be intended by the assertion that their claim is founded on *natural* right. "The right of navigating this river," says the American Plenipotentiary, "is a right of nature, pre-existent in point of time, not necessary to have been surrendered up for any purpose of common good, and unsusceptible of annihilation." The right here described, can be of no other than of that kind which is generally designated in the law of nations a perfect right. Now, a perfect right is that which exists independent of treaty; which necessarily arises from the law of nature; which is common, or may, under similar circumstances, be common to all independent nations; and can never be denied or infringed, by any State, without a breach of the law of nations. Such is the right to navigate the ocean without molestation in time of peace.

Upon these principles, now universally received, it is contended for the United States that a nation possessing both shores of a navigable river at its mouth, has no right to refuse the passage of it to another possessing a part of its upper banks, and standing in need of it as a convenient channel of commercial communication with the sea. Applying the same principles to the case of the St. Lawrence, the American Government maintain that Great Britain would be no more justified in controlling American navigation on that river, than in assuming to itself a similar right of interference on the high seas.

To this extent must the assumption of a perfect right be carried, or such claim is no longer to be considered in that character; but falling under the denomination of an imperfect right, it becomes subject to considerations essentially and entirely different.

The first question, therefore, to be resolved is, whether a perfect right to the free navigation of the river St. Lawrence can be maintained according to the principles and practice of the law of nations.

Referring to the most eminent writers on that subject, we find that any liberty of passage to be enjoyed by one nation through the dominions of another, is treated by them as a qualified occasional exception to the paramount rights of property. "The right of passage," says Vattel, "is also a remainder of the primitive communion in which the entire earth was common to men, and the passage was everywhere free according to their necessities." Grotius, in like manner, describes mankind as having, in their primitive state, enjoyed the earth and its various productions in common, until after the introduction of property, together with its laws, by a diversion or gradual occupation of the general domain. Among the natural rights, which he describes as having in part survived this new order of things, are those of necessity and of innocent utility; under the latter of which he classes the right of passage. Following his principle, this natural right of passage between nation and nation may be compared to the right of highway, as it exists, in particular communities, between the public at large and the individual proprietors of the soil, but with this important difference, that, in the former case, commanding and indispensable considerations of national safety, national welfare, and national honor and interest, must be taken especially into the account.

It is clear that, on this principle, there is no distinction between the right of passage by the river flowing from the pos-

sessions of one nation, through those of another, to the ocean, and the same right to be enjoyed by means of any highway, whether of land or of water, generally accessible to the inhabitants of the earth. "Rivers," says Grotius, "are subject to property, though neither where they rise, nor where they discharge themselves, be within our Territory." The right to exclusive sovereignty over rivers, is also distinctly asserted by Bynkershock, in the ninth chapter of his treatise "on the dominion of the sea." Nor is this, by any means, the full latitude to which the principle, if applied at all, must, in fairness, be extended. "All nations," says Vattel, "have a general right to the innocent use of the things which are under any one's domain." "Property," says the same author, "cannot deprive nations of the general right of traveling over the earth, in order to have communications with each other, for carrying on trade, and other just reasons." The nature of these other just reasons is explained by Grotius, in the following sentence: "A passage ought to be granted to persons, whenever just occasion shall require, over any lands or rivers or such parts of the sea as belongs to any nation, as for instance, if, being expelled from their own country, they want to settle in some uninhabited land, or if they are going to traffic with some distant people, or to recover, by a just war, what is their own right and due."

For other purposes then, besides those of trade, for objects of war, as well as for objects of peace, for all nations, no less than for any nation in particular, does the right of passage hold good under those authorities to which the American Plenipotentiary has appealed. It has already been shown that, with reference to this right, no distinction is drawn by them between land and water, and still less between one sort of river and another. It further appears, from Vattel, that the right in question, particularly, for the conveyance of merchandise, is attached to artificial, as well as to natural, highways. "If this passage," he observes, "occasion any inconvenience, any expense" for the preservation of canals and highways, it may be recompensed "by rights of toll."

Is it then to be imagined that the American Government can mean to insist on a demand, involving such consequences, without being prepared to apply, by reciprocity, the principle on which it rests in favor of Great Britain? Though the sources of the Mississippi are now ascertained to lie within the territory of the United States, the day cannot be distant when the inhabitants of Upper Canada will find convenience in exporting their superfluous produce by means of the chan-

nel of that river to the ocean. A few miles of transport over land are of little consequence, when leading to a navigable river of such extent. Even at the present time, a glance upon the map is sufficient to show that the course of the Hudson, connected as it now is with the waters of the St. Lawrence, would afford a very commodious outlet for the produce of the Canadian provinces. The comparative shortness of this passage, especially with reference to the West Indies, would amply compensate for any fair expense of tolls.

It would also be, in some instances, convenient and profitable for British vessels to ascend the principal rivers of the United States, as far as their draft of water would admit, instead of depositing their merchandise, as now, at the appointed ports of entry from the sea. Nor is it probable that other nations would be more backward than the British in pressing their claim to a full participation in this advantage. The general principle which they would invoke, in pursuance of the example given by America, and a partial application of such principles no country can have a right to expect from another, is clearly of a nature to authorize the most extraordinary and unheard of demands. As for the right of passage from sea to sea, across any intervening isthmus, such, for instance, as that of Corinth or of Suez, and, more especially, from the Atlantic to the Pacific, by the Isthmus of Panama, that right of passage follows as immediately from this principle, as any such right claimed from one tract of land to another, or to the ocean, by water communication.

The exercise of a right, which thus goes the length of opening a way for foreigners into the bosom of every country, must necessarily be attended with inconvenience, and sometimes with alarm and peril, to the State whose territories are to be traversed. This consequence has not been overlooked by writers on the law of nations. They have felt the necessity of controlling the operation of so dangerous a principle, by restricting the right of transit to purposes of innocent utility, and by attributing to the local sovereign the exclusive power of judging under what circumstances the passage through his dominion is, or is not, to be regarded as innocent. In other words, the right which they have described is, at best, only an imperfect right.

It is under the head of innocent utility, that Grotius has classed the right of passage, as before laid down in his own expressions.

"Innocent utility," he adds, "is when I only seek my own advantage, without damaging anybody else." In treating of

the same right, Vattel remarks that, "since the introduction of domain and property, we can not otherwise make use of it, than by respecting the proper right of others." "The effect," he adds, "of property, is to make the advantage of the proprietor prevail over that of all others."

The same author defines the right of innocent use, or innocent utility, to be "the right we have to that use which may be drawn from things belonging to another, without causing him either loss or inconvenience." He goes on to say, that "this right of innocent use is not a perfect right like that of necessity: for it belongs to the master to judge if the use we would make of a thing that belongs to him, will be attended with no damage or inconvenience."

With respect to the assertion of Grotius, as quoted by the American Plenipotentiary, "that the mere apprehension of receiving injury from the exercise of this right, is not a sufficient reason for denying it," the author, it must be observed, is addressing himself to the conscience of the Sovereign through whose territories a passage may be demanded; impressing upon his mind that he cannot fully discharge his moral obligations in giving such refusal, unless he be well convinced that his fears originate in just causes. But it would be absurd, and contrary to the general tenor of his argument, to suppose, that a well founded apprehension was not to have its due effect, or that the advantage, or even necessity, of a foreign nation could be justly recognized by him as paramount, in the one case, to the leading interests, in the other, to the safety, of his own.

It is further to be observed, that Grotius, in the argument referred to, had clearly in view an occasional liberty of passage, not of that perpetual, uninterrupted kind, which the regular activity of modern commerce requires. But the doctrine of Grotius, applied to merchandise, and taken in the sense ascribed to it by the American Plenipotentiary, is distinctly contradicted by other eminent writers on the law of nations. Puffendorf, for instance, in his great work on that subject, expresses himself as follows: "We may have good reasons for stopping foreign merchandise, as well by land as on a river, or on an arm of the sea, within our dependence. For besides that a too great affluence of foreigners is sometimes prejudicial or suspicious to a State, why should not a Sovereign secure to his own subjects the profit made by foreigners, under favor of the passage which he allows them?" "I admit, that in allowing foreigners to carry their merchandise elsewhere, even without paying for the passage, we do

not sustain any damage, and that they do us no wrong in pretending to an advantage of which we might have possessed ourselves before them. But, at the same time, as they have no right to exclude us from it, why should we not try to draw it to ourselves? Why should we not prefer our interest to theirs?"

The same author observes, in the next section of his work, "that a State may fairly lay a duty on foreign goods conveyed through its territory, by way of compensation for what its subjects lose by admitting a new competitor into the market."

To appreciate the full force of these opinions, it must be borne in mind that Puffendorf appears to speak of a foreign nation so situated as to depend exclusively on the passage in question for the sale of its superfluous produce, and the importation of supplies from abroad. This part of the subject may be closed with the following decisive words of Barbeyrac, in his Notes on Grotius: "It necessarily follows from the right of property, that the proprietor may refuse another the use of his goods. Humanity, indeed, requires that he should grant that use to those who stand in need of it, when it can be done without any considerable inconvenience to himself; and, if he even then refuses it, though he transgresses his duty, he doth them no wrong, properly so called, except they are in extreme necessity, which is superior to all ordinary rules."

But the American Plenipotentiary maintains that the right of passage, as understood by him in opposition to his own authorities, that is, independent of the Sovereign's consent, and applied to the single predicament of the St. Lawrence, has been substantially recognized by the Powers of Europe, in the treaties of general pacification, concluded at Paris in 1814, and in the following year at Vienna.

It is true that, in the solemn engagements then contracted by them, the Sovereigns of the leading States of Europe manifested a disposition to facilitate commercial intercourse between their respective countries, by opening the navigation of such of the principal rivers as separated or traversed the territories of several Powers. This policy was applied more particularly to the Rhine, the Necker, the Maine, the Moselle, the Maese, and the Scheldt. But neither in the general, nor in the special stipulations, relating to the free navigation of rivers, is there anything to countenance the principle of a natural, independent right, as asserted by the American Plenipotentiary. We find, on the contrary, that, in the treaty concluded at Paris, between France and the Allied Powers, the

Rhine was the only river at once thrown open to general navigation. With respect to the other rivers, it was merely stipulated that the means of extending that arrangement to them should be determined by the Congress about to assemble at Vienna. In the instance of the Rhine, it was natural for France, in giving up possessions which she had for some time enjoyed on the banks of that river, to stipulate a reserve of the navigation. The stipulations relating to river navigation, in the general treaty of Vienna, commence in the following manner: "The Powers whose States are separated or crossed by the same navigable river, engage to regulate by common consent, all that regards its navigation." They close with an agreement that the regulations, once adopted, shall not be changed, except with the consent of all the Powers bordering on the same river.

It is evident, therefore, that the allied Governments, in concurring to favor the circulation of trade through the great water communications of continental Europe, did not lose sight of what was due to the sovereignty of particular States; and that, when they referred the common enjoyment of certain navigable rivers to voluntary compact between the parties more immediately concerned, they virtually acknowledged the right of any one of those parties, till bound by its own engagements, to withhold the passage, through its dominions, from foreign merchant vessels. As freedom of navigation in favor of all nations, and not merely of those which border on the rivers thus opened by treaty, was the immediate object of the above mentioned stipulations, it must be presumed that the Powers assembled in Congress, if they had felt themselves borne out by the practice or general opinion of Europe, would not have hesitated to proclaim the measure which they adopted as one of natural independent right. Their silence alone on this point might have been taken as strongly indicative of their belief that the prevailing usage of Europe would authorize no such declaration. But the principle of mutual consent is surely irreconcilable with the contrary supposition, and must, at least, be understood to give a special character to the engagements contracted under it, confining them to the rivers enumerated in the treaty; and, however laudable, as an example to other States, whose circumstances may allow of their imitating it without danger or detriment, expressive of no obligation beyond the occasion for which the treaty was framed.

It would take up too much time to demonstrate by a detailed investigation of every case to which the American ar-

gument applies, the negative proposition that no nation exercises the liberty of navigating a river, through the territories of another, except by permission or express concession under treaty. It is rather for the American Government to present a single instance in which the liberty claimed for the United States is exercised explicitly as a natural independent right.

The case of the Scheldt, though referred to by the American Plenipotentiary, is certainly not one of this kind. The leading circumstances relating to that river were, first, that its mouths, including the canals of Sas and Swin, lay within the Dutch Territory, while parts of its upper channel were situate within the Flemish provinces. Secondly, That the treaty of Westphalia had confirmed the right of the Dutch to close the mouths of the river. Thirdly, That the exercise of this right was disputed, after a lapse of more than a hundred years, by the Emperor of Germany; and, fourthly, that the dispute between that monarch and the Dutch Republic terminated, in 1785, by leaving the Dutch in possession of the right which had been disputed. It is true, that, at the latter period, the Dutch founded their claim, in part, on the expense and labor which they had undergone in improving the river; but, it is true at the same time, that they also grounded it on the general law of nations. Above all, they rested it on the treaty of Westphalia. But if the right of the Dutch Republic had been countenanced by the law and practice of nations, why, it may be asked, should it have been thought necessary to confirm that right by the treaty of Westphalia? The reply is obvious, that confirmation was the resort of the weak against the strong: of the former dependents of Spain against the encroachments of a haughty power, still sovereign of Antwerp, and the neighboring provinces, and not having yet renounced its claim of sovereignty over Holland itself. It was natural for the Dutch, under such circumstances, to fortify their right by the general sanction of Europe; but it was not natural for the principal parties in the pacification of Munster, to lend their sanction to a measure in direct contradiction to acknowledged principles; or, if their scruples, as to the admission of such a measure, had been removed by special motives, it is strange that they should not have taken the obvious precaution of recording those motives. During the discussions about the Scheldt, in 1785, the Empress of Russia was the only Sovereign who officially declared an opinion in favor of the House of Austria. But the United States can derive no great advantage from a declaration couched in such

terms as these: "Nature herself hath granted to the Austrian Low Countries the use and advantage of the river in dispute: Austria alone, by virtue of the law of nature and nations, is entitled to an exclusive right to the river in question. So that the equity and disinterestedness of Joseph II, can only impart this right to other people—it belonging exclusively to his States."

The opinions proclaimed on this subject by the Russian Government are the more remarkable, as there is no country which has a greater interest than Russia in the disputed questions. It is well known, that the only approach to the Russian ports on the Black Sea, from the Mediterranean and Atlantic, is by the passages of the Dardanelles and Bosphorus. These canals are, in fact, salt-water straits, communicating from sea to sea; passing, it is true, between the Turkish territories in Europe and Asia, but with no great length of course, and leading to a vast expanse of inland water, the shores of which are occupied by no less than three independent Powers.

There is manifestly a wide difference between such a case and that of the St. Lawrence, nor can the marked difference in principle between rivers and straits be overlooked; and yet, as matter of fact, the navigation of the Black Sea, and the adjacent canals is enjoyed by Russia—by that Power which has so often dictated its own conditions to the Porte—in virtue of a treaty, founded, like other treaties, on the mutual convenience and mutual advantage of the parties. Even the navigation of the Danube, downwards to the ocean, was first accorded to Austria by the Turkish Government, as a specific concession made at a juncture when the Porte, involved in a quarrel with the most formidable of its neighbors, was compelled to propitiate the good will of other Christian Powers.

The case of the Mississippi is far from presenting an exception to this view of the subject. The treaty of 1763, which opened the navigation of that river to British subjects, was concluded after a war in which Great Britain had been eminently successful. The same motives that prevailed with France to cede Canada, must have restrained her from hazarding a continuance of hostilities for such an object as the exclusive navigation of the Mississippi. The agreement respecting that river makes part of the general provisions as to the western boundary of the British possessions in America, by which the whole left side of the Mississippi was ceded to

Great Britain, with the exception of the town and island of New Orleans. This reservation was admitted on the express condition, that the navigation of the whole channel should be open to British subjects. The very fact of its having been thought necessary to insert this stipulation in the treaty, in consequence of France having retained possession of both banks of the river, at a single spot, leads irresistibly to an inference the very reverse of what is maintained by the American Plenipotentiary.

At a later period, the navigation of the Mississippi became subject of arrangement between Spain and the United States. By the fourth article of their treaty of boundary and navigation, concluded in 1795, a similar agreement to that which had before subsisted between France and Great Britain, was effected between those Powers, with this remarkable difference, that the liberty of navigating the river was expressly confined to the parties themselves, unless the "King of Spain", to use the words of the treaty, "should extend the privilege to the subjects of other Powers by special convention."

It must not be overlooked, that, when the clause which is here quoted, and the exclusive stipulation immediately preceding it, were drawn up, the sources of the Mississippi were still supposed to be within the British territory; and at the same time, there was in force a treaty between Great Britain and the United States, declaring that "the navigation of the river Mississippi, from its source to the ocean, should, forever, remain free and open to the subjects of Great Britain."

Some additional light may, perhaps, be thrown on the object of the present discussion, by the quotation of a note on the fourth article of the Spanish treaty, which is printed in the collection of the United States' laws, arranged and published under the authority of an act of Congress. It is as follows:

> "Whatsoever right his Catholic Majesty had to interdict the free navigation of the Mississippi, to any nation, at the date of the treaty of San Lorenzo el Real, (the 27th of October, 1795,) that right was wholly transferred to the United States, in virtue of the cession of Louisiana from France, by the treaty of April 30th, 1808. And, as the definitive treaty of peace was concluded previously to the transfer to the United States of the right of Spain to the dominion of the river Mississippi, and, of course, prior to the United States' possessing the Spanish right, it would seem that the stipulation contained in the 8th

article of the definitive treaty with Great Britain, could not have included any greater latitude of navigation on the Mississippi, than that which the United States were authorized to grant on the 3d of September, 1783."

"The additional right of sovereignty which was acquired over the river by the cession of Louisiana, was paid for by the American Government; and therefore any extension of it to a Foreign power could scarcely be expected without an equivalent."

The natural right asserted by the American Plenipotentiary being thus examined in respect both to the principles which it involves, and to the general practice of nations, the acquired title, as distinct from the natural, stands next for consideration.

This title is described in the American argument, as originating in circumstances which either preceded or attended the acquisition of the Canadas by Great Britain. It is said, "that, if Great Britain possessed the navigation of the St. Lawrence before the conclusion of peace in 1763, so did the People of the United States, as forming, at that time, a part of the British empire; but if Great Britain only first acquired it together with the Canadas, then did the People of the United States acquire it common with her at the same period." In both the supposed cases, it is taken for granted, that whatever liberty to navigate the St. Lawrence, in the whole length of its course, the inhabitants of the United States enjoyed when those States were part of the British Empire, continued to belong to them after their separation from the Mother country. Now, if this were so it would also be true, and in a far stronger degree, that the subjects of Great Britain have an equal right to enjoy, in common with American citizens, the use of the navigable rivers and other public possessions of the United States, which existed when both countries were united under the same Government. For the acquired title, be it remembered, does not affect the St. Lawrence, as a river flowing from the territories of one Power, through those of another, to the sea, but is manifestly grounded on the supposition that an object which had been possessed in common by the People of both countries, up to the time of their separation, continues to belong in point of use, to both, after they have ceased to be parts of the same community. If it be true, that the inhabitants of the United States contributed as British subjects, to effect the conquest of Canada, it cannot, at the same time, be denied, that the United States, be-

fore their separation from Great Britain, were frequently indebted to the councils and exertions of the parent country for protection against their unquiet and encroaching neighbors.

Specifically did they owe to Great Britain their first enjoyment of the waters of the Mississippi, conquered in part from France by the very same efforts which transformed Canada from a French settlement into a British Colony. The pretension of the American Government as grounded on the simultaneous acquisition of the St. Lawrence, as well by the inhabitants of the adjacent, and, at that time, British Provinces, as by those of the countries originally composing the British monarchy, must, therefore, if admitted even for the sake of argument, be applied reciprocally in favor of Great Britain.

The fact, however, is, that no such pretension can be allowed to have survived the treaty by which the independence of the United States was first acknowledged by Great Britain.

By that treaty a perpetual line of demarcation was drawn between the two Powers, no longer connected by any other ties than those of amity and conventional agreement.

No portion of the sovereignty of the British empire, exclusive to the actual territory of the United States, as acknowledged by that treaty, could possibly devolve upon the People of the United States, separated from Great Britain.

By the same instrument, the territorial boundary of the States, as recognized by their former sovereign, were carefully defined, for the express purpose of avoiding disputes in future; and the articles stipulating for a concurrent enjoyment of the North American fisheries, and of the navigation of the river Mississippi, prove that equal care was taken to determine, in the general act of pacification and acknowledgment, those objects, of which the usufruct in common was either retained or conceded by Great Britain.

Is it conceivable, under these circumstances, that the treaty of 1783, should have made no mention of the concurrent navigation of the St. Lawrence, if the claim, now raised by the United States, had rested on any tenable grounds?

But the commercial treaty of 1794, would afford additional proof, if it were wanted, that the channel of the St. Lawrence, from the sea to the 45th parallel of latitude, was never for a moment considered as forming any exception to the territorial possessions of Great Britain.

The third article of the commercial treaty shows, most

clearly, that the power of excluding foreign vessels from those parts of the river which flow entirely within the British dominions, was deemed to belong of right to the British Government. The leading purpose of that article is, to establish a free commercial intercourse between the two parties throughout their respective territories in North America.

The same article contains a limitation of this privilege with respect to a considerable portion of the St. Lawrence, to which it was declared that American vessels were not to have access; and the corresponding restriction against Great Britain, was an exclusion of British vessels from such parts of the rivers of the United States as lie above the highest ports of entry for foreign shipping from the sea.

It necessarily results, from the nature of the two clauses thus viewed with reference to each other, that the authority of Great Britain over the part of the St. Lawrence interdicted to American vessels, was no less completely exclusive, that that of the United States over such parts of their interior waters as were, in like manner, interdicted to the shipping of Great Britain.

The former limitation is, besides, of itself inconsistent with the notion of a right to a free uninterrupted passage for American vessels, by the St. Lawrence, to the ocean.

Nor is it less conclusive as to the merits of the case, when coupled with the declaration contained in the very same article, that the navigation of the Mississippi was to be enjoyed in common by both parties, notwithstanding that a subsequent article of the same treaty expresses the uncertainty which already prevailed with respect to the sources of that river being actually situated within the British frontiers.

With these facts in view, it is difficult to conceive how a tacit enjoyment of the navigation now claimed, can be stated by the American Plenipotentiary to account for the silence maintained on this subject by his Government, from the establishment of its independence to the present negotiation.

In the course of forty years, during which no mention whatever has been made of this claim, there has been no want of opportunities fit for its assertion and discussion. To say nothing of periods, anterior to the rupture of 1812, it is strange that an interest of such vast importance should have been wholly neglected, as well on the renewal of peace, in 1815, as during the negotiation of the commercial treaty which took place in the close of that year. This long continued silence is the more remarkable as the mere apprehen-

sion of an eventual change in the regulations, under which a part of the St. Lawrence is actually navigated by foreign vessels, has been alleged by the American Government as their reason for now raising the discussion.

The regions contiguous to the upper waters of the St. Lawrence are doubtless more extensively settled than they were before the late war, anl the inhabitants of those regions might at times find it advantageous to export their lumber and flour by the channel of that river. But mere convenience, and the profits of trade, cannot be deemed to constitute that case of extreme necessity under the law of nations, to which the rights of property may perhaps be occasionally required to give way. It has already been shown, that such interests can, at most, amount to an imperfect right of innocent utility, the exercise of which is entirely dependent on the will and discretion of the local sovereign. Of this description are the rights and accompanying duties of nations to trade with each other, and to permit the access of foreigners to their respective waters in time of peace; but will any one, at the same time, call in question the co-existing right of every State, not only to regulate and to limit its commercial intercourse with others, but even, as occasion may require, to suspend or to withhold it altogether?

If ever there was a case, which particularly imposed on a sovereign the indispensable duty of maintaining this right unimpaired, even with every disposition to consult the convenience and fair advantage of friendly nations, it is the present unqualified demand of the United States.

It cannot be necessary to enumerate the various circumstances which make this claim peculiarly objectionable; but there is no concealing, that, besides the ordinary considerations of territorial protection, those of commercial interest and colonial policy are alike involved in the demand of a free gratuitous, unlimited right of passage for American citizens, with their vessels and merchandise, from one end of Canada to the other.

Interests of such high national importance are not to be put in competition with the claims of justice; but when justice is clearly on their side, they have a right to be heard, and cannot be denied their full weight. That the right is, in this instance, undoubtedly on the side of Great Britain, a moment's reflection on the preceding argument will suffice to establish.

It has been shown that the independent right asserted by

the United States, is inconsistent with the dominion paramount sovereignty and exclusive possession of Great Britain.

It has been proved, by reference to the most esteemed authorities on the law of nations, with respect as well to the general principle as to the opinions distinctly given on this point, that the right of sovereignty and exclusive possession extends over rivers, in common with the territory through which they flow.

The same principles and the same opinions have been cited to prove that those parts of the river St. Lawrence which flow exclusively through the British dominions, form no exception to the general doctrine so applied to rivers.

The existence of any necessity calculated to give the United States, in this case, a special right, in contradiction to the general rule, has been distinctly denied, and the denial conclusively supported by a reference to known facts.

With no disposition to contest such imperfect claims and moral obligations, as are consistent with the paramount rights of sovereignty and exclusive possession, it has been proved, from the authorities already quoted, that of those imperfect claims and moral obligations, the territorial sovereign is the judge.

The title of the United States, as derived from previous enjoyment at the time when they formed part of the British empire, has been shown to have ceased with the conclusion of that treaty by which Great Britain recognized them in the new character of an independent nation.

It has also been shown, that, while the American government acknowledge that their claim is now brought forward for the first time, not only have they had, since their independence, no enjoyment, under treaty, of the navigation now claimed, but that the provisions of the commercial treaty, concluded in 1794, and described as having been till lately in force, are in direct contradiction with their present demand.

It has finally been made to appear, that the treaties concluded by European Powers, as to the navigation of rivers, far from invalidating the rights of sovereignty in that particular, tend, on the contrary, to establish those rights; and that the general principle of protection, essential to sovereignty, dominion, and property, applies with peculiar force to the present case of the river St. Lawrence.

EXTRACT OF LETTER FROM MR. GALLATIN TO MR. CLAY, DECEMBER 21, 1827.

"The British plenipotentiary will not entertain any proposition respecting the navigation of the St. Lawrence founded on the right claimed by the United States to navigate that river at the sea."

EXTRACT OF LETTER FROM MR. GALLATIN TO MR. CLAY, OCTOBER 1, 1827.

"The British plenipotentiary reply that however well disposed Great Britain might be to treat with the United States respecting the free navigation of the St. Lawrence as a question of mutual convenience, yet the views of the British government, being the same now as they were in 1824, and they being prohibited by express instructions from entering into any discussion respecting the free navigation of the river, if claimed as heretofore by the United States on the ground of right, they could not entertain any proposition to that effect if now made by me. * * *

In an interview I had with Lord Dudley, after having expressed regrets that no arrangement could be made at this time on the subject, and after having urged the other reasons which should induce Great Britain no longer to prevent navigation of American boats and vessels between Montreal and Quebec, and that if she persisted in denying it, which although I had no authority to say such was the intention of my government, yet, it seemed a natural consequence, and ought not to be considered as giving offense, that the United States should adopt corresponding measures in regard to the navigation of the river St. Lawrence within their own limits. Lord Dudley, who appeared to acquiesce in my general remarks, made no observation on the last suggestion."

Act of January 9, 1836.

An Act for the Construction of the Illinois and Michigan Canal.

(Governor authorized to negotiate a loan on the faith of the State.)

Section 1. *Be it enacted by the People of the State of Illinois, represented in the General Assembly:* That the Governor of this State be, and he is hereby authorized and empowered to negotiate a loan on the credit and faith of this State, as hereinafter provided for the purpose of aiding in connection with such other means as may be hereafter received from the government of the United States, in the construction of the Illinois and Michigan canal, a sum not exceeding five hundred thousand dollars, which shall be required to be paid at such times and by installments as the same may be needed in the progress of the said work, as near as the same can be estimated.

Sec. 2. (Certificates of stock—Faith of the State pledged.) The Governor shall cause to be constituted certificates of stock for the said loan, to be called the "Illinois and Michigan Canal Stock" signed by the auditor and countersigned by the treasurer, bearing an interest not exceeding six per cent per annum, payable semi-annually at the Bank of the State of Illinois or any of its branches, or at some bank in the cities of New York, Philadelphia, Boston, or either, as may be agreed upon and reimbursable at the pleasure of the State, at any time after the year one thousand, eight hundred and sixty, and the faith of the State is hereby irrevocably pledged for the payment of the stock hereby created and the interest accruing thereon.

Sec. 3. (Transferring of stock.) The Governor shall take and use all proper means and measures for the transferring of the said stock.

Sec. 4. (Certificates of stock to be sold.) It shall be deemed a good execution of the said power, to borrow, for the Governor to cause the said certificates of stock, when created, to be sold; *provided,* that the said stock shall not in any case be sold for less than its par value.

Sec. 5. (Monies to be deposited in the bank at interest.) It shall be the duty of the Governor to cause the said monies from time to time, when paid or advanced, to be deposited in some safe bank or banks until wanted for use, at the best in-

terest that can be obtained for it, to be drawn out as hereinafter provided, taking therefor the proper securities for the safekeeping of the same.

SEC. 6. (WHAT CONSTITUTES CANAL FUND—PROVISO.) The money thus loaned, the premiums arising from the sale of any stock thus created, the proceeds of the canal lands and town lots, and all of the monies in any way arising from the contemplated canal shall constitute the canal fund, and shall be used for canal purposes and for no other whatever, until the said canal shall have been completed; *provided*, that nothing herein contained shall be so construed as to prevent appropriations from being made out of the said fund for semi-annual payment of the interest upon the canal stock herein authorized to be created, and the Governor is hereby authorized to cause the said interest to be paid out of the said fund.

SEC. 7. (GOVERNOR TO APPOINT BOARD—VACANCY, HOW FILLED.) The Governor of this State by and with the advice of the Senate, shall appoint three practical and skillful citizens of this State to constitute a board, to be known by the style and description of "The Board of Commissioners of the Illinois and Michigan Canal," and he shall designate one of said commissioners to be president thereof, one to be treasurer and one to be acting commissioner; whenever any vacancy shall occur in the said board of commissioners by death, resignation or from any other cause the Governor of this State shall fill such vacancy during the recess of the legislature, and the Governor shall have power to remove from office any canal commissioner for good cause which he shall make known in a communication to the next ensuing General Assembly.

SEC. 8. (TERM OF SERVICE.) The board of commissioners to be appointed as aforesaid shall hold their office until the first Monday in January, 1837, and thereafter the said board of commissioners shall be biennially appointed in such manner as the legislature may from time to time direct.

SEC. 9. (SALARY.) The acting commissioner shall be allowed a salary of twelve hundred dollars per annum, and the rest of the board shall each be allowed a compensation of three dollars per day while necessarily employed in the business of the canal.

SEC. 10. (INCORPORATED.) The said board of commissioners is hereby constituted a body politic and corporate with full power and authority in their corporate name to contract and be contracted with, sue and be sued, defend and be defended, plead and be impleaded, in all matters and things relating to

them as canal commissioners, and they shall have and use a common seal of such device as the Governor may direct.

SEC. 11. (TO APPOINT A SECRETARY.) The board shall appoint a secretary, whose duty it shall be to keep a true record of all their proceedings; they shall hold quarter yearly meetings, and special meetings whenever any two of them or the acting commissioner may desire it, any two of them shall constitute a quorum to do business.

SEC. 12. (COMMISSIONERS TO BE SWORN—PROVISO.) Before entering upon the duties of their office each of the said commissioners shall make oath or affirmation, faithfully, honestly and truly to execute and discharge all the duties and obligations herein imposed upon them, and each of them as canal commissioners and they shall severally give bonds to the Governor and his successors, in office for the use of the State, in the sum of ten thousand dollars with sufficient securities, for the faithful discharge of the duties imposed upon them by this Act; *provided*, that the Governor may at any time require additional bonds of said treasurer, whenever he may think that the safety of the funds require it.

SEC. 13. (WHEN MONEY DUE TREASURER MAY DRAW CHECK ON BANK.) Whenever all or any part of the money upon any contract shall become due, it shall be the duty of the treasurer to draw his warrant or check, therefore, in favor of the contractor upon the bank or banks in which the canal fund shall have been deposited, which warrant or check, shall be countersigned by the acting commissioner and shall be under the seal of the board.

SEC. 14. (COMMISSIONERS TO OBTAIN A QUANTITY REPORT FROM BANK AND LAY IT BEFORE BOARD.) It shall be the duty of the acting commissioner to obtain from the cashier of the bank or banks, in which the said fund shall have been deposited, a quarterly report, exhibiting a true account of all monies received in deposit on account of the canal fund and paid out of the said fund during the previous quarter, which report shall be laid before the board of canal commissioners, and within twenty days thereafter, shall be examined by the said board and compared with the accounts of the treasurer and an entry shall be made in the books of the said board that the said examination has been made by them, and that the two accounts correspond, if such be the case, by each commissioner present shall sign his name to the record of such examination.

SEC. 15. (COMMISSIONERS TO CONTRACT FOR MATERIALS AND LABOR—CONDUCT OF ALL OFFICERS—TO ENFORCE DUTIES—TO EX-

AMINE STATE OF CANAL AND HAVE SUPERINTENDENCE THEREOF.) It shall be the duty of the acting commissioner:

1st.—To make under the direction of the board, all necessary contracts for the material and the performance of labor.

2nd.—To inquire into the official conduct of the agents, clerks, superintendents and all subordinate officers and to receive and hear all complaints that may be preferred against them.

3rd.—To enforce the faithful execution by all persons concerned, of the duties and obligations imposed upon them by this Act.

4th.—To examine frequently and carefully, into the state of the canal and the progress of the works thereon.

5th.—To have the immediate care and superintendence of the canal and all matters relating thereto.

SEC. 16. (DESCRIPTION—PROVISO.) The said canal shall not be less than forty-five feet wide at the surface, thirty feet at the base and of sufficient depth to insure a navigation of at least four feet, to be suitable for ordinary canal boat navigation, to be supplied with water from Lake Michigan and such other sources as the canal commissioners may think proper, and to be constructed in the manner best calculated to promote the permanent interest of the country; reserving ninety feet on each side of said canal, to enlarge its capacity, whenever in the opinion of the board of canal commissioners, the public good shall require it; *provided*, that all persons who have purchased, or shall hereafter purchase lands fronting the said canal shall be permitted to lease from the said board the said reserved ground on each side of said canal, from year to year, or until the said ground shall be wanted to enlarge the capacity of said canal, for the best price that can be obtained to be paid into the canal fund.

SEC. 17. (MEASURES FOR CONSTRUCTING.) They shall take efficient and proper measures for the immediate construction of the said canal; shall put such parts of it as they may deem proper under contract as herein provided and shall have the general care and superintendence thereof.

SEC. 18. (INSPECT ACCOUNTS.) They shall inspect and examine into the accounts, books, state of the treasury and all of the proceedings of the treasurer and of the acting commissioner.

SEC. 19. (FURNISH MEANS.) They shall furnish the acting commissioner with all proper means and facilities that may be necessary to enable him to discharge the duties herein imposed upon him.

SEC. 20. (POWERS.) They shall have full power and authority in their good judgment to do, in relation to the construction and completion of the said canal, all things, not otherwise herein provided for.

SEC. 21. (MAY USE LANDS, WATER, STREAMS.) It shall be lawful for them to enter upon and use any lands, water, streams and materials of any description necessary for the prosecution of the works contemplated by this Act.

SEC. 22. (TO EMPLOY AGENTS, ENGINEERS.) They may employ such and so many, agents, engineers, surveyors, draftsmen and other persons as they may judge necessary to enable them to discharge their duties as commissioners, and may pay such compensation as they shall judge reasonable to each person so employed.

SEC. 23. (NOTICE OF THE ENTERING INTO CONTRACTS.) Public notice shall be given of the time and place at which proposals will be received for entering into contracts; which notice shall be previously published for at least six weeks, in a newspaper printed at Chicago and in such other papers either in this State or elsewhere as may be deemed proper.

SEC. 24. (PROPOSALS.) Proposals for contracts shall be sealed and shall be for a sum definite and certain, as to the price to be paid or received, and shall be let to the lowest and most responsible bidder, accompanied with good and sufficient security for the faithful performance of such contract.

SEC. 25. (TO LET OUT CONTRACTS.) And it shall be the duty of the commissioners to let out all contracts for labor on conditions to be expressed in the contracts, as will authorize said commissioners to declare all contracts to be abandoned and to relet the same to more efficient contractors, whenever in the opinion of the acting commissioner, or the principal engineer on the work, the contractor or contractors refuse or neglect to prosecute his or their contract, with a force proportionate to the amount of work to be performed and the time within which the same by the terms of the contract is required to be completed; and in all cases where an unfinished contract shall be declared to have been abandoned as aforesaid, the percentage on the amount of work performed, which the commissioners are required to retain until the completion of the job, shall be forfeited to the use of the canal fund.

SEC. 26. (CONTRACTS TO BE RETURNED TO AUDITOR.) All contracts concerning the contemplated canal shall be made in writing under the seal of the board, and of each contract, three copies shall be executed by the parties, one of which shall be

retained by the board, and one shall be immediately forwarded to the Auditor of Public Accounts and by him filed in his office.

SEC. 27. (MATERIALS EXEMPT FROM EXECUTION.) All materials procured or partially procured under any contract with the commissioners, shall be exempt from execution; but it shall be the duty of the commissioners to pay the money due for such materials to the judgment creditor of the contractor under whose execution such materials might have been sold upon his producing to them due proof that his execution would have so attached, and such payment shall be held a valid payment on the contract.

SEC. 28. (DEATH OF CONTRACTORS—PROVISO.) In case of the death of any canal contractor who shall at the time of his decease, be indebted to any laborers for work done on the canal, it shall be lawful for the board, if they think proper to pay such laborers out of any money that may be due to the deceased contractor, and the receipt of such laborers shall be a good voucher in offset to the sum due the deceased contractor, from the board, on the final settlement between them and his executors or administrators; *provided*, that the said persons shall first obtain a judgment against the administrator of such deceased contractor, and produce a certificate from the court, judge or justice of the peace, that the judgment was rendered for work done on the canal or for materials furnished therefor and for no other cause.

SEC. 29. (RULES AND REGULATIONS.) The board shall from time to time make such rules and regulations, not inconsistent with the laws of this State, in respect to the perssons employed about the canal, injury done to the said canal or locks, and the management and navigation of the same, and impose such forfeitures of money for the breach of such rules and regulations, as they may judge reasonable, but no forfeiture imposed, shall for a single offense exceed the sum of fifty dollars over and above the amount of actual damage done.

SEC. 30. (TO BE POSTED.) They shall cause a sufficient number of such rules and regulations to be posted up for public inspection, and shall transmit a copy of them, from time to time to the Governor, as they may be made, in their next quarterly and annual reports.

SEC. 31. (FILED IN AUDITOR'S OFFICE.) All rules, regulations, and forfeitures, established by them as aforesaid, shall be filed in the office of the Auditor, and a copy thereof certified by him under his hand and seal of office, shall be received

in all courts of law as due proof, that such rules, regulations and forfeitures were by them established.

SEC. 32. (TO SELECT CANAL ROUTE—TOWNSITE AND LAY OFF LOTS.) The commissioners shall examined the whole canal route, and select such places thereon as may be eligible for townsites, and cause the same to be laid off into town lots, and they shall cause the canal lands in or near Chicago, suitable therefor, to be laid off into town lots.

SEC. 33. (TO SELL LOTS IN CHICAGO AND OTTAWA—PROVISO.) And said board of canal commissioners shall on the twentieth day of June next, proceed to sell the lots in the town of Chicago and such part of the lots in the town of Ottawa, as also fractional section fifteen, adjoining the town of Chicago, it being fire laid off and subdivided into town lots, streets and alleys, as in their best judgment will best promote the interest of the said canal fund; *provided, always,* that before any of the aforesaid town lots shall be offered for sale, public notice of such sale shall have been given in such newspapers, not less than five in number, including the one printed at Vandalia, either in this or other states as the board may thing best, at least eight weeks prior to any sale; *provided, further,* that if no sale be made on the day herein named, such sale may be made at any time thereafter, upon giving the notice and upon the terms herein required.

SEC. 34. (TO MAKE OUT A LIST OF LOTS, &C.—CERTIFY THE SAME TO THE TREASURER—SECOND SALE—PROVISO—IMPROVEMENTS MAY BE REMOVED BEFORE SALE.) It shall be the duty of the canal commissioners, before the day appointed for any sale of lots, to make a list of the lots intended to be offered, describing them by their numbers, and value, each lot separately and certify the same under their hands and seals, which list and certificate shall be filed with the treasurer and preserved, and no lot shall be sold for less than the valuation; and all lots remaining unsold shall be again advertised for sale in the manner aforesaid, and said commissioners shall continue from time to time to advertise for sale all lots remaining unsold, at any public sale, until the whole shall be sold, and no lot shall be sold, except at a public sale, to the highest bidder; *provided,* that all persons who may have made improvements upon any of the lots authorized to be sold shall be permitted to remove such improvement at any time before the day fixed for the sale of any such improved lots, being responsible for all unnecessary damages done or suffered by such removal.

SEC. 35. (TERMS OF SALE—WASTE.) The terms of sale shall

be as follows, to wit: one-fourth of the purchase money to be paid in advance at the time of purchase, and notes taken for the payment of the residue in three equal annual installments, bearing an interest of six per cent. per annum, payable annually in advance, and a failure to pay such interest or residue of such principal within twenty days after the same or any installment thereof becomes due, shall forfeit to the State for the benefit of the canal fund, the said lot or lots, and all claim thereon; and if any purchaser before forfeiture, shall commit unnecessary waste upon any lot or lots not paid for, he, she or they, so offending shall be subject to an action at law for damages to said commissioners, and a certificate of the acting commissioner of any forfeiture, shall authorize the sheriff of the proper county, with the *posse comitatus*, to give such board possession of such forfeited lot or lots, on behalf of the State, and the lot or lots so forfeited as aforesaid shall be resold without let or stay, extent of time or subsequent relief of any kind whatever, the same bringing the appraised value.

SEC. 36. (SECRETARY AND TREASURER TO ACT AS REGISTER AND RECEIVER.) In all sales of canal lots, the secretary and treasurer shall act as register, and receiver, and shall be governed by the same rules, that now govern registers and receivers in the United States land offices in this State, except as is herein provided.

SEC. 37. (TREASURER TO GRANT CERTIFICATE.) It shall be the duty of the treasurer upon the payment of the purchase money, to grant to the purchaser or purchasers, a certificate, containing a description of the land or lots purchased, and the price for which the same was sold and shall forward a duplicate of such certificate to the Auditor of the State, who shall record the same; and the person holding such certificate shall upon presenting the same to the Governor receive a patent for the land described therein, signed by the Governor, and countersigned by the Secretary of State, with the seal of the State affixed thereto.

SEC. 38. (MONEYS TO BE DEPOSITED IN BANK.) All monies paid to the treasurer for the purchase of any canal lands or lots shall be by him immediately deposited in some bank, under the direction of the Governor, for the payment of the interest of the canal loan, and for work done on the canal.

SEC. 39. (NO COMMISSIONER TO PURCHASE LANDS OR LOTS—COMMISSIONER TO BID FOR LAND OR LOT FOR THE STATE—PROVISO.) None of the Board of Canal Commissioners shall be allowed to purchase any of the canal lands or lots herein author-

ized to be sold, nor shall they, or either of them directly or indirectly, be concerned in any such purchase or have any manner of interest therein, and all sales in which the said commissioner, or any of them, shall be in any way interested, shall be absolutely null and void, the purchase money shall be forfeited, and the land shall revert to the canal fund; but said canal commissioners, or either of them, are hereby required and authorized to bid for any tract or lot of land so offered for sale, if in their opinion the interest of the canal fund requires it, and in such case the bid shall be in the name of such commissioner for the use of the State, and the said lot or tract shall revert by such bid to the State for the use of the canal fund, and shall be subject to sale thereafter, as other lots or tracts are now, or hereafter may be by law subject to sale. Any commissioner who shall be guilty of a violation of the provisions of this section shall be deemed to have perpetrated a fraud, and upon indictment and conviction thereof in any court having competent jurisdiction, shall be punished by forfeiture of his office, and fined in a sum not less than one thousand nor more than five thousand dollars; *provided*, that a prosecution for such offense shall be commenced within ten years after the commission of the same.

SEC. 40. (PERSONS COMBINING AT SALE NOT TO BID AGAINST EACH OTHER—PROVISO.) If any two or more persons shall combine themselves together for the purpose of lessening competition at the sale of any of the canal lands or lots, or if they shall agree or have any understanding among themselves, that they will not bid upon one another at any such sale for the purpose of obtaining the said canal lands or lots at a low price; the same shall be deemed a fraud and any person or persons convicted thereof, in any court having competent jurisdiction shall be fined in a sum not less than one hundred nor more than one thousand dollars, one moiety thereof, to the use of the person informing, and the other moiety to the canal fund, and any patent issued for any lands or lots purchased as aforesaid shall be absolutely null and void; the money paid therefor shall be forfeited, and the lands or lots so purchased shall revert to the canal fund. And it is hereby declared to be the duty of the State's Attorney to prosecute for all such offenses; *provided*, that all such prosecutions, shall be commenced within ten years after the commission of the offense.

SEC. 41. (REVENUE, TOLLS, &C., PLEDGED.) The revenues arising from the Illinois and Michigan canal, and from the lands granted, or that may hereafter be granted to the State of Illinois, by the Congress of the United States, for the con-

struction of the said canal, and the net tolls thereof, are hereby pledged for the payment of the interest accruing on the stock, that may be created in pursuance of this Act, and for the reimbursement of the principal of the same.

SEC. 42. (MAKE REPORT TO THE GOVERNOR, QUARTERLY) The board of commissioners, shall, quarterly, viz.: on the first Monday of March, June, September and December in each year, make a minute and particular report to the Governor, which report shall set forth in a plain and intelligible manner, all of their acts and doings in relation to the said canal, and the canal lands and lots, all of the money received and expended, the work done, and the price allowed for the various kinds of work, the contracts made, with whom made, and the security given, the number of engineers, draftsmen, clerks and agents of every description by them employed, and the amount of compensation paid to each, the progress of the canal, their contemplated plans for the next three months, with an estimate of the probable amount of money, that will be required to be expended for canal purposes, during that time together with such other matters and things as they may see fit to add; and also the amount, time and rate of any loan made by virtue of this Act, which report or the outlines thereof, the Governor shall cause to be published.

SEC. 43. (ANNUAL REPORT.) They shall annually on the first Monday of December, make a report to the Governor, setting forth all of their acts and doings in relation to the canal and canal lands and lots, during the previous year, in like manner as is required of them in their quarterly reports, containing such statements, and estimates for the year as their quarterly reports do for the quarter.

SEC. 44. (COMMENCEMENT AND TERMINATION.) The said canal shall commence at or near the town of Chicago, on canal lands and shall terminate near the mouth of the little Vermillion in La Salle County and on land owned by the State.

SEC. 45. (ACT REPEALED.) The Act entitled an Act for the construction of the Illinois and Michigan canal, approved February the tenth, eighteen hundred and thirty-five, is hereby repealed, and any canal commissioner heretofore appointed under any law of this State be and the same is hereby declared to be out of office from and after the passage of this Act, any law to the contrary notwithstanding.

JOINT RESOLUTION OF THE SENATE AND HOUSE OF REPRESENTATIVES OF THE STATE OF ILLINOIS IN 1861.

(Laws of Illinois, 1861-3, p. 277.)

JOINT RESOLUTION IN RELATION TO THE IMPROVEMENT OF NAVIGATION OF THE ILLINOIS RIVER.

Resolved by the Senate, the House of Representatives concurring herein, That the Board of Trustees of the Illinois and Michigan Canal be and are hereby authorized and instructed to cause prompt and thorough surveys, examination and estimates to be made of the Illinois River, and of the Illinois and Michigan Canal, and also of portions of the DesPlaines and Chicago rivers, and of the portage between said rivers, for the purpose of accurately ascertaining the comparative value, cost, efficiency, benefits and advantages, direct, prospective and incidental, of the different methods proposed or desirable for improving the navigation of the Illinois River, by dredging or excavation of the channel and wing dams, or by supplying water from Lake Michigan, through the enlargement and deepening of the Illinois and Michigan Canal, or otherwise, or by opening a channel from Lake Michigan by way of the south branch of the Chicago River and Mud lake to the Desplaines river, and down said canal to a point that will secure a free flowing, ample and never-failing supply of water, sufficient for the navigation of the Illinois river at all seasons and times, when not obstructed by ice. Such surveys, examinations and estimates to include a plan of enlargement of the Illinois and Michigan Canal, sufficient for the introduction and use of stern-wheel river steamers and propellers upon it, and also of side-wheel river steamers, and to include also an estimate for the channel hereinbefore mentioned, of sufficient size to admit of full and free steamboat navigation from the Illinois River to Chicago and Lake Michigan, as well as a size sufficient for supplying water for all the deficiencies of navigation in the Illinois river, at all seasons. And the said trustees are hereby authorized to employ efficient and competent engineers of high character, to make such surveys, examinations and estimates and to avail themselves, in their labor of all reliable surveys and data heretofore made or obtained of the said Illinois river and Illinois and Michigan Canal, and to report the result of all such examinations and surveys to the Governor of the State, as soon as the same shall be completed, and to furnish ample abstracts thereof to the

newspapers of the State for publication, so far as may be desired by them. And the said Board of Trustees are hereby authorized to pay the necessary expenses of said surveys, estimates and examinations out of any funds that may be received by them from the earnings of the Illinois and Michigan Canal; *provided,* that the expenses thereof shall not exceed the sum of six thousand dollars. *Provided,* that no payment shall be made by the said trustees, for or on account of any liability heretofore incurred, or moneys heretofore advanced for surveys, plats or otherwise, exceeding twelve hundred dollars.

Joint Resolution of the Senate and House of Representatives of the State of Illinois, in 1889.

(Laws of Illinois, 1889, pp. 375-376.)

River Improvement, Des Plaines and Illinois.

Whereas, The Illinois river, from La Salle to Grafton, is the remnant of an ancient stream bed bordered by wide and low bottom land, much cut up by lake, bayou and marsh; an alluvial stream of small, low water volume and sluggish current, with a declivity of only 26 feet in 225 miles, a declivity so small as to require a large volume of water to maintain an effective channel; a stream which in its natural condition is able to maintain but a small depth through the deposits with which the tributaries constantly tend to choke the channel; a tendency ever increasing with the inhabitation of the water-shed and the cultivation and reclamation of lands.

Whereas, The erection of dams with a view to the creation of pools of slack water for the purpose of navigation, diminishes the scouring force of the current at medium and low stages and promotes channel decay, causes deposits in the mouths of tributaries and the more ready overflow of the bottom lands; and generally the tendency is to restore the natural channel of equilibrium at a higher level with great ultimate injury to the valley from overflow and unhealthfulness, a tendency already exhibited in a notable degree from the conditions created by the dams erected by the State at Henry and Copperas creek in 1872 and 1877 respectively.

Whereas, The completion by the United States of the dams at LaGrange and Kampsville will raise the general level of the river below Copperas creek by several feet and promote all those injurious tendencies to channel decay, with overflow

and unhealthfulness already exhibited through the agency of the state works at Henry and Copperas creek.

Whereas, The official report of the United States for 1868 showed that it was practicable to obtain by dredging and a minimum low water volume at Peru of 38,000 cubic feet per minute, a channel for navigation of a width of 160 feet and a depth exceeding four feet, and the official report for 1880 showed that it was practicable to obtain a channel for navigation 200 feet wide and six feet deep by dredging, and a minimum flow of 94,000 cubic feet per minute in the river below Copperas creek, and that the cost was not materially different from the cost of the improvement by locks and dams.

Whereas, The present addition to the low water volume of the Illinois river through the summit level of the Illinois and Michigan canal from Lake Michigan more than doubles the volume of water used in the estimate of 1868 for the channel below Peru and adds 50 per cent. to the volume used in the estimate of 1880 for the channel below Copperas creek, and said contribution from Lake Michigan will be increased in the immediate future, thus enabling the depth now projected for navigation below Peru to be obtained by channel improvement at moderate cost and with decided advantage to material interests and to healthfulness along the valley.

Whereas, It is contemplated to increase the volume from Lake Michigan to 300,000 cubic feet per minute within a few years and ultimately to add 600,000 cubic feet or more, thus enabling a large depth for navigation to be obtained by an improved channel, and that said channel will be self-sustaining and self-improving and will discharge flood waters more readily, thus benefitting the bordering lands and increasing the healthfulness of the valley.

Whereas, Works now projected by the City of Chicago will form part of a water-way of large proportions from Lake Michigan via the DesPlaines and Illinois rivers to the Mississippi river, of which the dams and locks upon the alluvial section of the Illinois river can form no part and which, if allowed to remain, will increase the overflow and be detrimental to the welfare of the Illinois valley and the interests of the State. Therefore be it

Resolved, by the Senate, the House of Representatives concurring herein,

1. That it is the policy of the State of Illinois to procure the construction of a water-way of the greatest practicable

depth and usefulness for navigation from Lake Michigan via the DesPlaines and Illinois rivers to the Mississippi river, and to encourage the construction of feeders thereto of like proportions and usefulness.

2. That the United States is hereby requested to stop work upon the locks and dams at LaGrange at Kampsville and to apply all funds available and future appropriations to the improvement of the channel from La Salle to the mouth with a view to such a depth as will be of present utility and in such manner as to develop progressively all the depth practicable by the aid of a large water supply from Lake Michigan at Chicago.

3. That the United States is requested to aid in the construction of a channel not less than 160 feet wide and 22 feet deep with such a grade as to give a velocity of 3 miles per hour from Lake Michigan at Chicago to Lake Joliet, a pool of the DesPlaines river, immediately below Joliet, and to project a channel of similar capacity and not less than 14 feet deep from Lake Joliet to La Salle, all to be designed in such manner as to permit future development to a greater capacity.

Adopted by the House May 27, 1889.

Concurred in by the Senate May 28, 1889.

EXTRACTS INTRODUCED IN EVIDENCE ON THE PART OF THE SANITARY DISTRICT IN RELATION TO THE DEPTH OF WATER UNDERNEATH THE KEEL OF VESSELS IN CANALS.

EXTRACTS FROM PAPERS DELIVERED BEFORE THE INSTITUTION OF CIVIL ENGINEERS (GREAT BRITIAN).

EXTRACT FROM A PAPER BY SIR CHAS. HARTLEY, K. C. M. G. M. INST. C. E., ENTITLED "A SHORT HISTORY OF THE ENGINEERING WORKS OF THE SUEZ CANAL," DELIVERED ON MARCH 13, 1900.

Information collected by the sub-commission (1884-5) during the inspection of the Isthmus opinions of experts as to the adequacy of the proposed enlarged canal

* * *

2. How much water should a large vessel have under her keel to enable her to steer well at a speed of 8 knots an hour?

Replies—The answers vary from a minimum of 6 inches

to a maximum of 6 feet under the keel, but the average depth demanded by the captains was 3½ feet and by the pilots 3 feet."

Institute of Civil Engineers, 1899-1900, Part 3, Vol. CXLI, page 168.

"Actual and Prospective Depths in the Canal.—On the 1st January, 1899, there was an available depth of 9 metres (29 feet 6 inches) over an aggregate length of 90 kilometres, and by continuing to dredge down to 9.40 metres (31 feet) as at present practiced, the engineers of the company hope by 1902 to obtain the latter depth throughout the whole length of the canal. It should here be explained that this contemplated depth of 9.50 metres in 1902 includes the provision of a receptacle for deposit ½ of a metre deep over the entire bottom width of the canal from end to end.

Depth at Suez.—At the Suez entrance, at the present time, a vessel drawing 7.80 metres (the maximum draught allowed) has a depth of 1 metre under her keel at ordinary low water of spring tides, and a minimum of 40 centimetres under her keel at an extraordinary low tide."

Institution of Civil Engineers (1899-1900) part 3, Vol. CXLI, page 179.

EXTRACTS FROM APPENDIX 4, ATTACHED TO PAPER OF SIR CHAS. HARTLEY, ABOVE REFERRED TO ENTITLED "REGULATIONS FOR THE NAVIGATION OF THE SUEZ MARITIME CANAL. ISSUED JANUARY, 1899.

"The transit through the Suez Canal is opened to ships of all nationalities, provided that their draught of water does not exceed 7 metres 80 centimeters (25 feet 7 inches English), and that they conform to the following conditions:

Sailing vessels above 50 tons gross are bound to be towed through.

Steam vessels may pass through the canal by means of their own steam power or be towed subject to the conditions hereinafter notified.

Of course the towage of steamers through the canal is not compulsory on the company; it will only be performed in so far as they have unengaged tug boats."

Institution of Civil Engineers (1899-1900) part 3, Vol. 3, CXLI, page 187.

EXTRACT FROM DISCUSSION OF SIR CHAS. HARTLEY'S PAPER BY DR. E. L. CORTHELL.

"Dr. E. L. Corthell contributed the following correspondence on the subject— he desired to refer to only one point in the paper, viz., the depth of the channel. It was an interesting coincidence that, at the time the paper was under discussion, he had been engaged in writing a paper for the International Congress on Navigation about to be held at Paris, in which he predicted that a depth of 31 feet (9.50 metres) would be necessary by the end of the next quarter of a century. During the past three years he had investigated this matter very carefully, and had given, in a paper read before the American Association for the Advancement of Science, many facts of this special subject of dimensions of vessels, and also the reasons for the rapidly increasing draughts. He worked out from the records of the earlier steam ships, and through successive periods up to 1898, the loaded draught of the 20 largest steam ships, and predicted that in 1923 the draught would be 31 feet, and in 1948, 33 feet. Since that time he had obtained more recent information, all confirmatory of the opinion expressed in 1895 by the author, that a depth of 31 feet would be necessary in the Suez Canal. All of the very deep draught vessels were not trans-Atlantic liners. The draught of the ordinary cargo steam ship was rapidly increasing. As to Atlantic liners, there were at the beginning of 1899 at least thirty-four with a loaded draught of 28 feet and over, nineteen of 29 feet and over, nine of 30 feet and over, and four of 31 feet and over. Of the regular steam ship lines trading at the Port of New Orleans, which might be taken as a characteristic first class American Port, and where the present available depth (not through the South Pass jetties, where the depth was 30 feet, but within 12 miles of the South Pass itself) was nominally 26 feet, but really not over 25 feet, the loaded draught was as follows: forty-two vessels with a draught of more than 26 feet, thirty over 27 feet, fifteen over 28 feet, ten over 29 feet, two over 30 feet, and two with a draught of 30 feet 9 inches. The view expressed by a large number of the experts upon the question submitted to them by the Sub-Commission in 1884, namely, that there should be 3 feet or 3½ feet of water under the keel of a vessel moving at any speed,

was borne out by the experience of pilots and navigators elsewhere. With less depth than this under the keel it was difficult to steer a vessel in a restricted channel, a fact which had been frequently noticed in the channel through the South Pass, where there was often a restricted depth under the keel. It might be mentioned that the proposition now before the United States Congress for the deepening of the mouth of the Southwest Pass of the Mississippi river, which was about five times the size of the South Pass, provided for a depth of 35 feet, throughout the channel. The depth of the channel provided for the entrance to the New York Harbor, the contract for which had been made by the government, was forty feet; and it was proposed at Philadelphia, Baltimore and Boston to make channels 30 feet deep—in all cases below low water. There were the strongest possible reasons from every point of view—navigation, construction and economy—for deepening the channels into all first class ports to allow of the free movement of steam ships drawing, when full loaded, 31 feet."

Institution of Civil Engineers 1899-1900, part 3, Vol. CXLI, pages 206-207.

EXTRACT BEING THE REPLY OF SIR CHAS. HARTLEY TO REMARKS OF DR. CORTHELL.

"The remarks of Dr. Corthell on the advisability of providing an ample depth of water in maritime canals and harbors for vessels of the largest class, were a valuable contribution to the Discussion, coming as they did from an expert of high authority in the United States on all matters connected with the safe navigation of vessels in contracted channels. He was gratified to notice that the conclusions arrived at in this respect by Dr. Corthell were fully shared, not only by Sir John Wolfe Barry and Mr. Vernon Harcourt, but also by two other distinguished authorities of European reputation who had contributed to the Discussion orally and in writing, namely, Sir Edwyn Dawes of London, and Mr. Fulscher of Berlin. In short, there seemed to be a consensus of opinion in favor of providing an ultimate depth of ten metres (32 feet 9 inches) in the Suez Canal from sea to sea, as he had ventured to recommend."

Institution of Civil Engineers, 1899-1900, part 3, Vol. CXLI, page 212.

EXTRACT FROM THE PAPER PREPARED BY LEVESON FRANCIS VERNON-HARCOURT, M. A. M. INST. C. E., DELIVERED BEFORE THE DUSSELDORF NAVIGATION CONGRESS, 1902.

Remarks on the Kaiser-Wilhelm Canal.—Although the commercial traffic along the canal may not be as large as was anticipated, it has steadily increased; and as the canal was constructed for naval purposes, and not primarily for commerce, the traffic it has attracted is so much to the good towards the repayment of the cost of the works undertaken as a measure of national importance. The value of the waterway, in view of the large fleet usually stationed in Kiel Harbor, and the growing importance of Kiel as a naval arsenal, is sufficiently evident; but the canal, with a bottom width of only 72 feet and six passing places in sixty-one miles, would require to be widened if it should ever be called upon to provide for a large traffic. Thus its width compares unfavourably with the bottom width of the Soulanges Canal of 96 feet, with a depth of 17½ feet, only intended to accommodate vessels of about 2,000 tons and 14 feet draught. Provision, however, has been made to some extent on the Kaiser-Wilhelm Canal for a future widening, by means of the berm formed at the side in constructing the canal.

Institution of Civil Engineers (1902-03), Part II, Vol. CLII, page 227.

EXTRACTS FROM PAMPHLET ENTITLED LAKES AND GULF WATERWAY AS RELATED TO THE CHICAGO SANITARY PROBLEM BY LYMAN E. COOLEY, 1890.

8. A Channel of Adequate Depth.—An absolute depth of ten feet below low water, however, admits no clearance beneath the boats. Actually, a greater depth must exist for the boat to navigate at all, and the greater the clearance the better. Maj. A. Mackenzie says:

> "A boat drawing four feet to run and handle well should have at least six feet and her speed will be considerably increased on a depth of eight feet.
>
> The large side-wheel boats run during the greater part of the season, but during low water do not go up higher than LaCrosse. They could always reach Hastings as well as LaCrosse, but between these points the crossings are so numerous, and deep pools so short, that the river is, as they term it, 'slow.'" (See Report Miss. Riv. Com., 1881, p. 16.)

"It is a well known fact that vessels of every class are propelled at much greater speed and economy in deep than is possible in shallow water." (Report Chief of Engineers, 1868, p. 447.)

Capt. Marshall admits (p. 11) that "Every increase in depth and width of channel up to a certain limit will increase the facilities for navigation." Maj. Mackenzie shows that boats actually do not run on the Upper Mississippi where the depth is sufficient because the smaller proportion of deep water makes navigation too slow and tedious. An occasional bar over which for a short distance the depth is just sufficient for a boat to float, is very different from a channel of a uniform and no greater depth through which a boat must be propelled for thirty miles and probably a good fraction of seventy more.

No channel should be contemplated across the Chicago Divide that does not give from two to three feet depth in excess of the draft of boats as a virtual necessity, and an excess of four or five feet would be justifiable, and up to this limit probably far more valuable than increase in width. Taking ten feet below low water of Lake Michigan as the absolute minimum for draft, then the channel should have not less than twelve feet below that line and fourteen feet is fully justifiable for easy navigation. The channel of eight feet is none too much for such boats as now run upon the Upper Mississippi and the tributaries, as the Tennessee, Cumberland, Upper Ohio, Missouri, Arkansas and Red, but is entirely inadequate for those of the lower Mississippi.

Lakes & Gulf Waterway, 1890, page 19.

EXTRACT FROM A PAPER BY A. E. KEMPEES, C. E., ROYAL ENGINEER IN HOLLAND. THE ENLARGEMENT AND IMPROVEMENT OF THE NORTH SEA CANAL OF HOLLAND (AMSTERDAM SHIP CANAL). PREPARED FOR THE INTERNATIONAL ENGINEERING CONGRESS OF THE COLUMBIAN EXPOSITION 1893.

"The present Special Regulations of Police for the North Sea Canal (established by Royal Decree of May 23d, 1892, Official Gazette, 113) allows to vessels entering the canal a maximum of draught, wherever measured, of—

7.30 m. at a level of 0.30 m. below A. P. and higher,
7.20 " " " 0.40 " " "
7.10 " " " 0.50 " " "

With a view to the draught of inward-bound vessels

being increased through their passing from sea water into fresh or brackish water, the regulations direct that for the draught such vessels will get in the canal a standard of 0.1 m. shall be added to their draught in the outer harbor or outer canal. The maximum of breadth allowed to vessels is now 17.75 m. for the main canal; the maximum of length, 115 m., for lockage through the North Sea locks, and 90 m. for lockage through the Orange locks at Schellingwoude. The present dimensions of the canal and harbor are by no means calculated to open the way to the docks of Amsterdam to the largest-sized ships, although they could pass the new locks at Ymuiden. The stages for loading and unloading vessels will also require important improvements before they are fit for the giants of modern navigation."

American Society of Civil Engineers Transactions, Vol. 30, 1893, page 404.

EXTRACT FROM A PAPER BY J. FULSCHER, GEHEIMER BAURATH, MEMBER OF IMPERIAL BOARD OF CANAL COMMISSIONERS AT KIEL, GERMANY. TRANSLATED FROM THE GERMAN BY KENNETH ALLEN, M. AM. SOC. C. E.

PREPARED FOR THE INTERNATIONAL ENGINEERING CONGRESS OF THE COLUMBIAN EXPOSITION, 1896.

"The Cross-Section (see the accompanying map.)—The bed of the canal in the straight reaches and the curves of over 2500 m. (8 200 ft.) radius has a width at the bottom of 22 m. (72.16 ft.), and up to 3 m. (9.84 ft.) above the bed a 3 to 1, and, to 4 m. (13.12 ft) height, a 2 to 1 slope. The upper portions of the profile are built differently for the reaches in the lowlands from those in the higher lands. In the latter reaches, a berm at a height of 7 m. (22.96 ft.) above the bed, that is, about 2 m. (6.56 ft.) below the mean water-level, connects with a 1½ to 1 slope protected by stone, which reaches to 1 m. (3.28 ft.) above the usual water-level. At this height lies a second berm 2.5 m. (8.2 ft.) wide which joins the excavated slope of 1½ to 1.

In the lowlands the lower berm is widened on both sides, in order that the cross-section may be widened later without disturbing the dikes.

The dikes, which are to be built on either side, are given slopes of 2 to 1 where the underlying ground has

sufficient firmness—natural or artificially increased by laying sand; but where long stretches have a soft foundation, in order to distribute the pressure as much as possible, they are given an inner slope of 6 to 1.

The cross-section of the canal has, at the lowest stage of water, 6.17 m. (20.24 ft.) depth below the surface, an available width of 36 m. (118.08 ft.), and offers a passage to the largest steamers employed in the East Sea traffic, which, with a few exceptions, have a draft of not over 6 m. (19.68 ft.), with a berm of 12 m. (39.36 ft.)."

American Society of Civil Engineers Transactions, Vol. 30, 1893, page 425.

EXTRACT FROM REPORT OF THE UNITED STATES DEEP WATERWAY COMMISSION OF 1896 IN REFERENCE TO THE WORK OF THE AMERICAN SECTION. THE FOLLOWING EXTRACT IS PREPARED BY MR. LYMAN E. COOLEY.

Page 22, Paragraph 22. This Section Relates to a Future Type Vessel drawing 27 to 28 feet of water.

Page 23, paragraph 24. Locks are taken at a depth of 28 feet on the meter sill for the above type of vessels.

Page 23, paragraph 25. Discusses the depth in canal prism and in other restricted channels and lays down the proposition that such prisms and channels should have a depth of 33⅓ feet where feasible, or, 25 per cent. in excess of vessel draught and 20 per cent. in excess of lock depth.

Page 24, paragraph 26. "Discusses a type vessel with a draught of 20½ feet for which the lock depth is to be 21 feet and the channel-ways are to be 25 feet."

The foregoing report discusses future Lake development and sea-board connections on the basis of channel-ways that exceed the draught of vessels by 23.4 per cent. and that exceed the depth in mitre sills of locks by 19 per cent.

Page 28, paragraphs 34 and 35 show that the radical improvements herein outlined will materially change slopes and levels between Lakes Erie and Huron and in the Saint Mary's river and result in the lowering of Lake Michigan-Huron and the Saint Mary's river below the locks.

United States Deep Water-Ways Commission, Report 1896, pages 22 to 28.

EXTRACT FROM REPORT OF THE UNITED STATES BOARD OF ENGINEERS ON DEEP WATERWAYS TRANSMITTED TO CONGRESS ON DECEMBER 2, 1900.

"Adaptability to Traffic Conditions.

Our vessel No. 1, which is the type vessel adopted for the 21-foot waterway, has a draft of 19 feet and can enter all the important lake harbors as well as navigate along the seacoast. It is, therefor, much better adapted to domestic traffic than vessel No. 2, the type vessel for the 30-foot waterway, since the latter has a draft of 27 feet and can not enter the lake harbors. The smaller vessel is not so well adapted to deep-sea navigation as the larger one."

The above extract is taken from the report of the board, which consisted of C. W. Raymond, Lieut. Col. Corps of Engineers, United States Army, Alfred Noble and George Y. Wisner.

United States Board of Engineers on Deep Waterways, 1900, page 127.

As an appendix attached to the foregoing report is appendix No. 1, entitled "Locks," in which appears the following extract, p. 140:

"Although the existing channels do not have quite 21 feet of water, the larger ships are designed to be loaded to 19 feet or more. For the rapid and safe movement of a ship in the 21-foot waterway there should be about 2 feet of water under its keel. The larger ships now in use, therefore, have reached the limit of draft that should be permitted in this waterway."

In a report to the Board made by Alfred Noble, one of the members of the Board, occurs the following extract, p. 234:

"*First.* Ship 480 by 52 by 19 feet draft in the 21-foot channel. A channel 1,000 feet wide is obviously the equivalent of a channel of unlimited width as regards the movement of a ship. The Lake St. Clair observations show that in the shallow water of that lake, where the depth of water exceeded by about 2½ feet the draft of the boat, the loss of speed was considerably less than 20 per cent.; 20 per cent. was taken for this discussion to be on the safe side."

And in a report signed by George Y. Wisner, one of the members of the Board, entitled "Comparison of Waterways," appears the following, p. 237:

"A draft of 19 feet is necessary for vessels best adapted for the commerce and safe navigation of the lakes, and since the free movement of ships in shallow water requires at least 2 feet of water between the keel and bottom where the shallow channel is of considerable length, it appears that 21 feet is about the least depth which can be established for the lake waterways consistent with securing a minimum rate of transportation for ships best adapted for the lake service."

* * * * *

p. 240.

Referring to Tables III and V of Appendix No. 4 it will be seen that the type ships of 19 feet and 27 feet draft, capable of steaming 12½ miles per hour in the open lake, are estimated as being able to maintain 7.55 miles and 7.47 miles per hour, respectively, on tangents in waterways 21 and 30 feet deep. * * *

p. 246.

Many of the South Atlantic ports will not admit ships of over 20 feet draft, and therefore the expenses for transfer of domestic freight, if carried in deep-draft ships, would probably be fully as large as for transfer of export traffic through the canal if transported in vessels adapted to 21-foot channels through the connecting waterways of the Great Lakes."

REPORT MADE TO THE DEPARTMENT OF PUBLIC WORKS BY THE GEORGIAN BAY SHIP CANAL IN 1908, ON WHICH PROJECT THE REPORT WAS MADE BY THE COMMISSIONERS, EUGENE D. LAFLEUR, CHIEF ENGINEER; A. ST. LAURNET, ENGINEER IN CHARGE; C. R. COURTLEE, DISTRICT ENGINEER, AND S. J. CHAPLEAU.

The Board in its report dated January 20, 1909, says, p. 19:

"Sir:—The government surveys and investigations regarding the feasibility and probable cost of a deep waterway from the Great Lakes to the Seaboard, by way of the French and Ottawa rivers, initiated in 1904, by the Honourable C. S. Hyman, Minister of Public Works, under authority of parliament, and continued under your direction, have led your engineering board to formulate the following results and conclusions:

1st. That a 22-foot waterway for the largest lake boats (600 ft. x 60 x 20 ft. draft) can be established for one hundred million dollars ($100,000,000) in ten years,

and that the annual maintenance will be approximately $900,000, including the operation of storage reservoirs for the better distribution of the flood waters of the Ottawa river."

A special report was made to the Board by C. R. Courtlee referring to the canal reach from Montreal to Des Joachims, in which he says, p. 69:

"In designing these reaches, it was necessary to know the style of navigation proposed. A depth of 22 feet was set by the department, which indicates a vessel of 20-foot draft, corresponding to the large lake boat. I will therefore describe this draft; her speed, load, habits, etc., and also the channels, curves and currents which the lake boat is accustomed to navigate.

* * * * *

Long boats, especially when deeply laden, so that they, as it is said, 'smell the bottom' are very liable to 'take a sheer' and run aground or collide with an approaching boat; consequently, a 22-foot channel is provided for a 20-foot draft boat.

* * * * *

p. 71.

Depth on Miter Sills of Locks—Ample allowance beneath a vessel's keel is always desirable. A boat is said 'to squat' or settle down when in motion. If drawing loaded 19 feet at the dock, the draft will be 20 feet when the propeller is moving. If a vertical steel plate, 60 feet long and 20 feet deep, were forced broadside on through the water at 18 feet per second (12¼ miles an hour), the commotion caused by a ship would be imitated. There would be a piling up of water in front, an escape at each side, and a flow into the depression behind.

Between a vessel and the channel bottom there is a tendency to compress the water, making the boat tremble as though it were moving on rollers. This tends to sweep loose stone and debris into heaps upon which the flat steel bottoms of heavy carriers may scratch and grind.

A minimum depth of 22 feet has been allowed over the top of the miter sill against which the lock gates close. The lock floor is still lower.

* * * * *

p. 167.

The above elevation creates the storage called for, of 4 feet throughout the summit level, or 4 feet over the 22 feet standard depth on the sills of the summit locks."

Report of Courtlee, Georgina Bay Ship Canal Survey, pages XIX, 68, 69, 71, 167.

In a detailed report by Mr. Alex. McDougall, M. Can. Soc. C. E., he says:

"The possibility of giving an available depth of 25 feet from the St. Lawrence Ship Canal to the Recollect lock has been considered, with a view of affording terminal facilities, back of Montreal Island, for vessels of a maximum draft of 24 feet. This would allow the extension of Montreal harbor in a very desirable location, when need would be felt for more space, leaving the front or main part of the harbour free for deeper draft ocean vessels."

Georgian Bay Ship Canal Survey, page 320.

In a subheading of a memorandum entitled "Barge Canal vs. Ship Canal" occurs the following extract:

"At present all the connecting channels on the lakes are from 19 to 21 feet in depth at low water stage, and a great many harbours will accommodate vessels of 20 feet draft. A decided movement in the deepening of harbors and channels to a depth of 12 feet, by the United States government commenced in the seventies. In the eighties, the tendency was to secure 16 feet, and the policy of securing 21 feet was carried out in the next decade.

Since then the size of vessels has increased gradually and now the commerce of the Great Lakes is carried in ships drawing 15 to 20 feet of water."

Georgian Bay Ship Canal Survey, pages 395-396.

In a paper prepared by Mr. S. J. Chapleau, member of the Board, entitled "Data Relating to Channels Connecting the Great Lakes," he says:

"It is a question if the depth of 21 feet cannot meet the demands of the lake traffic for the future; 20 feet draft at the extreme low stage means 22 feet to 23 feet draft at mean summer level and while each additional inch draft means 60 to 80 tons additional cargo—depending upon its nature—in the largest carriers, it would seem that the natural increase in the number of lake carriers with probable increased facilities at the Sault Falls in the way of more locks of the same present capacity, would suffice to pass an increasing traffic at less expense than by the deeping of the connecting channels.

* * * * *

In the present case an increased area through the Huron to Erie stretch would affect the level of the former,

not appreciably at first, nor suddenly at any time, but would be shown by gradually lower averages of the mean monthly elevation of the Huron-Michigan basin and consequently in time, of a lower extreme low navigation stage therein.

* * * * *

It must not be inferred from the foregoing that 19 feet draft is the probable limit during the navigation season; a greater draft than that, possibly even up to 23 feet, may be possible during certain stages of the lake levels as it must be remembered that those stages absolutely control the depths in the artificial channels between.

As to a future depth in the connecting channels between Lakes Erie, Huron and Superior, greater than that of 21 feet during extreme low stage which will eventually be completed, the following quotations from a report of Charles E. L. B. Davis, Lieut. Colonel, Corps of Engineers, United States army, to Brig. General A. Mackenzie, Chief of Engineers (under date of January 12, 1906), may be given here, in which he refers to the Livingstone channel in particular, and the connecting channels between the lakes in general:—'The depth of 22 feet is recommended for this channel because the future growth of commerce may warrant the expenditure necessary to secure an extra foot over the present depth (21 feet) while the cost of securing 25 feet in these channels and tributary harbours will probably be prohibitive, at least for many years to come.' "

Georgian Bay Ship Canal Survey, pages 497-498.

At the 12th International Congress of Navigation held at Philadelphia on May 23, 1912, a general report was made by C. E. Grunsky, of San Francisco, California, in which paper he said, among other things:

"The following conclusions appear to be justified and are recommended for adoption by the Congress.

1. It is desirable that a limit be set to the draft of sea going vessels.

2. Government aid should not be extended to the building or operation of sea going vessels whose draft exceeds 32.2 feet.

3. There should be an international agreement fixing the maximum dimensions of sea going vessels built or operated under government supervision, and there are tentatively suggested the following:

Length over all	900 feet
Breadth	105 "
Draft	32.2 "

4. Any maritime canal which has locks with a usable length of 1000 ft., a width of 110 feet and a depth of water on the sill of 35 feet will fulfill every reasonable requirement of commerce.

5. In a maritime canal a wet section five times as large as the immersed portion of the largest ships which are to use the canal is desirable, as also, a depth of 1 meter under the keel; but these values are functions of the speed at which the canal is to be navigated, and therefore to some extent also of the volume of commerce, and are to be determined by local conditions.

International Marine Eng., p. 222, Vol. 17, 1912.

In a paper delivered by Henry Goldmark, entitled "Locks and Lock Gates for Ship Canals," Mr. Goldmark says:

"The depth of water on the sill of the lock should equal the maximum draw of the boats with an additional clearance of 1½ to 2 feet."

Transactions Cornell Univ. 1899-1902, Vol. 7-10, p. 76.

In an appendix contained in the Report of Board of Consulting Engineers, Panama Canal, 1906, entitled Appendix D, Principal Canals of the World, under the Manchester Ship Canal, by W. Henry Hunter, appears the following:

"The largest vessels which regularly navigate the canal at present are (1) twin-screw steamers of the Somerset class, 7,010 tons gross register, 460 feet between perpendiculars, by 58.2 feet beam, and (2) single screw steamers of the Silverlip class, 470 feet between perpendiculars, by 55.2 feet beam. The draft of water of these vessels is 25 feet and the areas of midship section are about 1,310 square feet and 1,240 square feet, respectively."

In the same appendix is an article entitled "Suez Canal," by E. Quellennec, appears the following:

4. "Cross-Sections.—The average cross sections are figured, four in number, in the annexed sketch. In these sketches the original sections are shown just as they were executed at the time of the construction of the canal. Since then the depth has been changed from 8 to 9.50 meters (26.24 to 31.1 ft.) at least and the bottom width from 22 to 33 meters (72.17 to 108.26 ft.) at least. * * *

5. Authorized Draft.—At present the authorized draft is 8 meters (26.24 ft.); it will be 8.23 meters (27 ft.) from January 1, 1906."

Report Panama Canal, 1906, pages 171 and 176.

The following matter, to the end of Volume IV, was printed and offered in evidence by the Sanitary District, defendant herein, but is objected to by complainant on the ground that it is incompetent, irrelevant and immaterial. It is not objected that the documents copied are not what they purport to be.

EXTRACTS OFFERED IN EVIDENCE ON THE PART OF THE SANITARY DISTRICT FROM OFFICIAL DOCUMENTS OF THE WAR DEPARTMENT OF THE UNITED STATES AND EXTRACTS FROM THE OFFICIAL PROCEEDINGS OF THE SANITARY DISTRICT OF CHICAGO.

Report of Isham Randolph, Chief Engineer to the Board of Trustees, August 2, 1893.

Page 1360:

"Change in Grade of Main Channel.

The Clerk presented a report, accompanied by three enclosures and drawing from the Chief Engineer with reference to the change in grade of the Main Channel, which matter was referred back to the Chief Engineer at the meeting held June 21, 1893 (page 1293 of the Proceedings); and the report was read.

Mr. Eckhart, seconded by Mr. Kelly, moved that the report be printed, and with enclosures and drawing, be referred to the Joint Committees on Engineering and Finance.

The motion prevailed unanimously and the report was ordered printed with enclosures and plat so referred.

The following is

The Report:

"Chicago, August 2, 1893.

To the Honorable the Board of Trustees of the Sanitary District of Chicago:

Gentlemen:

As the time is fast approaching when the grade of the channel now being constructed must be finally determined, it seems desirable that you should consider the subject in its bearings upon capacity and cost. For my own enlightenment upon the merits of these questions I have had Mr. Johnston make the calculations necessary for developing the comparative merits of the question involved, and I submit herewith his reports to me. Guided by this information, I am decidedly opposed to a reduction of grade to .053, as recommended by my predecessor, without a compensating enlargement of channel, but I recog-

nize the advantage of raising the grade of mean low water at Station 1480, as urged by him. This result, however, can be accomplished, as shown by Mr. Johnston's report, by deepening the channel to 22 feet. This increased depth between Robey street and Station 1480 would increase the cost of the work about $200,000, or less than 1½ per cent. This excess of cost, however, will be diminished by an amount not yet ascertained in the cheapening of the work beyond Station 1480, by reason of the lessened depth of cutting required in making the channel.

Respectfully submitted,
(Signed) ISHAM RANDOLPH,
Chief Engineer.'"

(Three (3) enclosures and drawing.)

PROCEEDINGS OF THE SANITARY DISTRICT OF CHICAGO, pp. 2688, 2689.

"Report on Depth, Dimensions, Grade, etc., of Main Channel.

The Clerk presented a report from the Chief Engineer, making statement with reference to the depth, dimensions, grade, etc., of the Main Channel as set forth in the report.

The same was read, and, by unanimous consent, was ordered printed and placed on file.

The following is

The Report:

'Chicago, June 20, 1895.

To the Honorable the Board of Trustees of the Sanitary District of Chicago:

Gentlemen:

The frequency of inquiries relating to the depth of our Channel prompts me to make the following concise statement:

The reasons for the depth adopted for the Channel of the Sanitary District are as follows: The ultimate volume of flow determined upon for this Channel is 600,000 cubic feet per minute. The slope or grade of the Channel as finally adopted September 6, 1893 (page 1439 of Proceedings), by your Honorable Board, after careful consideration of the report and recommendations of the Chief Engineer, presented August 2d, 1893 (page 1360 of the Proceedings), is one (1) foot in 40,000 feet or 1⅛

inches per mile nearly, for the earth, and one (1) foot in 30,000 feet, or 3¼ inches per mile nearly, for the rock channel. The change of grade then adopted resulted in raising the water surface at the Lockport end two feet, and in deepening the channel as it approached Chicago to an extent which permits the width of the earth sections between the Summit range line and Robey street to be reduced to 183.26 feet for the bottom instead of 202 feet, for the ultimate flow of 600,000 cubic feet per minute thus reducing to a minimum the excavation above water surface.

The width of earth channel in those sections which are under contract, prior to the change of grade hereinbefore referred to, for the maximum flow of 600,000 cubic feet per minute was 210 feet, with side slopes of one (1) foot vertical to two (2) feet horizontal; holding the top width established for the 210-foot channel and maintaining the same side slopes, the bottom width for the new grade became 202 feet.

With a depth of 22 feet of water, the velocity for 600,000 cubic feet per minute will be at the rate of 1 26/100 miles in earth, and 1 92/100 miles in rock per hour. The wet cross-section in earth for that flow is 5,412 square feet, and in rock 3,542 square feet. The cross-sections used have been demonstrated by careful computations to be about the most economical which could be adopted to give the required flow of 600,000 cubic feet per minute, as set forth in the Sanitary District law, within the limits of width therein prescribed.

A wider and shallower channel would have involved excavating a very much greater volume of material above the water line, without any compensating capacity in volume of flow. It may be stated that no material excavated above the water surface adds to channel capacity, but every foot in depth below the water surface increases the flowage capacity. The low velocity contemplated is justified on grounds of economy in construction, because increased grade or slope means a progressive deepening from Chicago westward, until the volume of the wedge excavated would exceed the excavation involved in the channel now under construction. Furthermore, the velocity in the earth sections must not be such as to cause erosion of the bottom or sides, an action apt to take place in sandy soil which may become soft by prolonged contact with water.

The whole question of comparative cost of channels of different depths and carrying widths was treated very exhaustively and presented to your Honorable Body in elaborate detail in December, 1892 (see report of the Chief Engineer, transmitting the results of computations made by Mr. T. T. Johnston, then First Principal Assistant Engineer, December 28, 1892, pages 966-70 of Proceedings). These tables are now in print, and accessible to all who wish to use them. A narrower and deeper channel would have been less costly than the one now being constructed, but the Sanitary District law fixed 160 feet as the minimum width, which limitation fixed the width in rock channel and the earth channel was made of dimensions giving a corresponding capacity.

Yours respectfully,

(Signed) ISHAM RANDOLPH,
Chief Engineer.'"

EXTRACTS FROM THE OFFICIAL PROCEEDINGS OF THE BOARD OF TRUSTEES, MARCH 22, 1899, CONTAINING THE MESSAGE OF WILLIAM BOLDENWECK PRESIDENT OF THE BOARD OF TRUSTEES TRANSMITTING TO THE BOARD LETTERS OF THE SECRETARY OF WAR AND FORWARDING PERMITS FOR IMPROVING THE CHICAGO RIVER.

Proceedings Sanitary District, 1899, pages 5581-5582.

"Message in Reference to Permits for Certain Construction Work.

President Boldenweck presented and the Clerk read a message transmitting, for printing and filing, letters from the Secretary of War in reference to permits for the construction of coffer-dam at Adams street, for the construction of temporary and permanent bridges, for the Chicago Terminal Transfer Railroad Co. and the construction of permanent bridge at Taylor street, which by unanimous consent was ordered received, printed and placed on file.

The following is

The Message:

Chicago, March 22, 1899.

To the Honorable the Board of Trustees of the Sanitary District of Chicago:

Gentlemen:

I transmit herewith to your Honorable Body, for printing in the proceedings and filing, letters enclosing permits granted by the Hon. R. A. Alger, Secretary of War,

for the construction of coffer-dam at Adams street, for the construction of temporary and permanent bridge for the Chicago Terminal Transfer Railroad Company, and the construction of permanent bridge at Taylor street.

Respectfully submitted,
(Signed) WILLIAM BOLDENWECK,
President.'

(3 enclosures.)
The following are

The Letters.

'War Department,
Washington, November 30, 1898.

Sid:

Referring to your application of 12th inst., I have the honor to transmit herewith an instrument granting permission to the Board of Trustees of the Sanitary District of Chicago to construct a temporary coffer-dam around the east side of the center pier of Adams street bridge in Chicago River, at Chicago, Illinois, and to deposit clay outside the coffer-dam running north and south from center pier and extending into the bank, upon the conditions set forth in said instrument.

Very respectfully,
(Signed.) R. A. ALGER,
Secretary of War.'

Mr. William Boldenweck,
President, the Sanitary District of Chicago,
Security Building,
Chicago, Illinois.
(Inclosure: Instrument-2 of 8302)

'War Department,
Washington, January 13, 1899.

Sir:

Referring to your application of 16th ultimo., I have the honor to transmit herewith an instrument approving the location and plans of a permanent and a temporary bridge to be constructed by the Sanitary District of Chicago over the south branch of the Chicago River, at Chicago, Illinois.

Very respectfully,
(Signed) R. A. ALGER,
Secretary of War.'

Mr. William Boldenweck,
President of the Sanitary District of Chicago,
Security Building, Chicago, Ill.
(Inclosure: Instrument-1 of 8887)

'War Department,
Washington, March 10, 1899.

Sir:

Referring to your application of 27th ultimo., I have the honor to transmit herewith an instrument approving the map of location and plans of a bridge to be constructed by the Sanitary District of Chicago across the South Branch of the Chicago River, at Taylor street, Chicago, Illinois, to replace the existing bridge at this point.

Very respectfully,
(Signed.) R. A. ALGER,
Secretary of War.'

Mr. William Boldenweck,
President, the Sanitary District of Chicago,
Security Building,
Chicago, Illinois.
(Inclosure: Instrument-2 of 1394.)"

EXTRACT FROM THE ANNUAL REPORT OF CHIEF OF ENGINEERS, UNITED STATES ARMY, PART 3, APPENDIX J. J., PP. 2550-2556.

The above appendix consists of the report of Capt. W. L. Marshall, United Engineer at Chicago, July 11, 1890, pages 2550 to 2556. Major Marshall inserts the Act of May 29 1889, entitled "An Act to create sanitary districts and to remove obstructions in the Desplaines and Illinois Rivers." The Act is set out in full, Sections 1 to 27, inclusive.

The Act is set out in full, together with amendments, as "Exhibit A" of the answer filed by the Sanitary District and therefore not recopied at this place.

EXTRACT FROM THE REPORT OF CHIEF OF ENGINEERS, UNITED STATES ARMY, 1890, PART 3, APPENDIX J. J., PAGES 2556-7.

Being an act to provide for the improvement of the Illinois and Desplaines rivers passed by the Legislature of Illinois and approved June 4, 1889, commonly called the "Little Waterways Bill."

United States. Improvement of the Illinois and Desplaines Rivers.

Section.
18. Repeal.
19. Works ceded to the United States on condition.
20. Conditions—removal of dam.
21. Basis of act of cession.

An Act in reference to the improvement of the Illinois and Desplaines rivers, and to repeal an act entitled "An Act to cede certain locks and dams in the Illinois River to the United States," approved May 31, 1887; in force May 31, 1887. Approved June 4, 1889, in force July 1, 1889.

18. Repeal.) § 1. *Be it enacted by the People of the State of Illinois represented in the General Assembly,* That an act entitled, "An Act to cede certain locks and dams in the Illinois River to the United States," approved May 31, 1887, in force May 31, 1887, and ceding the State works at Henry and Copperas Creek, and the pools created by said works, to the General Government upon certain conditions as to the opening of a waterway of a depth of seven feet from the Mississippi River to Lake Michigan, upon plans to be determined by the United States engineers, is hereby repealed.

19. Works ceded to the United States on condition.) § 2. That the State works at Henry and Copperas Creek, and the river now slackwatered by said works, are hereby ceded to the United States, on condition that the dams shall be removed whenever the depth now available for navigation can be secured and maintained by channel improvement without the aid of said dams: *Provided,* That said depth shall be assured upon the removal of said dams, or that such removal shall not materially impair navigation.

20. Conditions—removal of dam.) § 3. That in the event of the non-acceptance of these works upon the conditions mentioned in section 2, within four (4) years after this act becomes a law, the Canal Commissioners of the State of Illinois are authorized and instructed to remove the dams at Henry and Copperas Creek.

21. Basis of act of cession.) § 4. That the State of Illinois bases this act of cession upon the condition that the plan of improving the Illinois River below La Salle by slackwater maintained by dams and locks, be changed to a plan of improvement by means of an open channel in conjunction with a water supply from Lake Michigan.

JOINT RESOLUTION.

Whereas the present addition to the low-water volume of the Illinois River through the summit level of the Illinois and Michigan Canal from Lake Michigan more than doubles the volume of water used in the estimate of 1868 for the channel below Peru, and adds 50 per cent. to the volume used in the estimate of 1880 for the channel below Copperas Creek and said contribution from Lake Michigan will be increased in the immediate future, thus enabling the depth now projected for navigation below Peru to be obtained by channel improvement at moderate cost, and with decided advantage to material interests and to healthfulness along the valley.

Whereas it is contemplated to increase the volume from Lake Michigan to 300,000 cubic feet per minute within a few years, and ultimately to add 600,000 cubic feet or more, thus enabling a large depth for navigation to be obtained by an improved channel, and that said channel will be self-sustaining and self-improving and will discharge flood waters more readily, thus benefiting the bordering lands and increasinf the healthfulness of the valleys.

Whereas works now projected by the City of Chicago will form part of a waterway of large proportions from Lake Michigan via the Desplaines and Illinois rivers to the Mississippi River, of which the dams and locks upon the alluvial section of the Illinois River, can form no part, and which, if allowed to remain, will increase, overflow and be detrimental to the welfare of the Illinois Valley and the interests of the State: Therefore be it Resolved,

By the Senate of the House of Representatives concurring herein (1) That it is the policy of the State of Illinois to procure the construction of a waterway of the greatest practicable depth and usefulness for navigation from Lake Michigan via the Desplaines and Illinois rivers to the Mississippi River and to encourage the construction of feeders thereto of like proportions and usefulness. (2) That the United States is hereby requested to stop work upon the locks and dams at La Grange and at Kampsville, and to apply all funds available and future appropriations to the improvement of the channel from La Salle to the mouth with a view to such a depth as will be of present utility and in such manner as to develop progressively all the depth practicable by the aid of a large water supply from Lake Michigan at Chicago. (3) That the United States is requested to aid in the construction of a channel not less than 160 feet wide and 22 feet deep with such a grade as to give a velocity of 3 miles per hour from

Lake Michigan at Chicago to Lake Joliet, a pool of the Desplaines river, immediately below Joliet, and to project a channel of similar capacity and not less than 14 feet deep from Lake Joliet to La Salle all to be designed in such manner as to permit future development to a greater capacity.

Chief of Engineers Reports, 1890, part 3, Appendix J. J., pages 2556-2557.

EXTRACT FROM REPORT OF CHIEF OF ENGINEERS, UNITED STATES ARMY, 1890, PART 3, APPENDIX J. J., PAGES 2557-2574.

Same being a preliminary report of the Drainage Water Supply Commission of the City of Chicago, dated January, 1887, signed by Rudolph Hering, Chief Engineer, Benezette Williams, and Samuel G. Artingstall, Consulting Engineer. The above report was copied into the record at the direction of the United States District Attorney, James H. Wilkerson, on the cross-examination of Rudolph Hering and is found on transcript, page 831, abstract, volume I, page 496.

EXTRACT FROM THE REPORT OF CHIEF OF ENGINEERS, 1891, APPENDIX M. M., BEING REPORT OF CAPT. W. L. MARSHALL, UNITED STATES ENGINEER AT CHICAGO, JULY 10, 1891, TRANSMITTING THE PRELIMINARY REPORT OF W. E. WORTHEN, CHIEF ENGINEER, JOHN NEWTON, CONSULTING ENGINEER OF THE BOARD OF TRUSTEES OF THE SANITARY DISTRICT OF CHICAGO. Pages 2617-2618:

"Preliminary Report of W. E. Worthen, Chief Engineer, and John Newton, Consulting Engineer, to Board of Trustees of Sanitary District of Chicago, on Feasible Routes for Drainage Channel from Chicago to Joliet.

We have the honor to submit a preliminary report, with a map, showing certain feasible routes for the proposed drainage channel from Chicago to Joliet.

The dimensions of the drainage channel have been described by the act 'to create sanitary districts and remove obstructions in the Desplaines and the Illinois Rivers,' etc. (Section 208.)

This act provides that the drainage channel 'shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than 14 feet, and a current not exceeding 3 miles per hour, and if any portion of any such channel shall be cut through a territory with rocky stratum

where such territory with rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than 18 feet, such portion of such channel shall have double the flowing capacity before provided for, and a width of not less than 160 feet at the bottom, capable of producing the depth of not less than 18 feet of water.

Description of New Routes and Estimates.

Of all the new routes that have been surveyed, plotted, profiled, cross-sectioned, and estimated, two only have been selected for comparison—those marked on plan in full line "D." We think the former to be the better, as it is somewhat less expensive, and it provides at the same time for carrying off the storm water of the Upper Desplaines without the necessity of constructing expensive cut-offs from the Desplaines to the lake north of Chicago. In this view the channels estimated and designed for the maximum flow of 600,000 cubic feet per minute will suffice and with the gate cut-off in the Ogden ditch line, somewhere in the west fork of South Branch, will prevent the high water of the Desplaines flowing back into the Chicago River.

Approximate Estimates.

We estimate the total cost of entire line of 18 feet water depth by way of Ogden ditch at $25,700,000.

If the excavation in earth be reduced to 14 feet water depth and the side rubble walls be omitted, we estimate the cost at $22,700,000.

If the difference between 14 feet and the maximum depth provided by law is ever to be taken out it could be much more cheaply done when the channel is dry than by dredging after the water has been let in. Most of the work in the excavation and transfer of material must be done by machinery, and under a thorough system, with the best modern appliances, ample space for the piling up of waste, and ready removal by rail, the channel should be completed in 4 years.

Between Bridgeport and Willow Springs there will be 17,526,000 cubic yards of waste material if the water depth is 18 feet, and 14,656,000 if the water depth is 14 feet.

Between Willow Springs and the Joliet Basin there will be 3,500,000 cubic yards of earth excavation, 3,537,000

cubic yards of hardpan excavation and 13,351,830 cubic yards of rock excavation.

Between Willow Springs and the Joliet Basin there will be 18,948,600 cubic yards of waste material, of which 13,351,830 cubic yards are rock.

How far earth and rock may be found to be of marketable or other value we leave to experts; but it would seem that the rock has already a market, and it could be stored on the banks while waiting disposal.

The dimensions of the section of the channel are shown in the drawing, being an average width of 180 feet, with nearly vertical sides, and the depth of 18 feet below the flow line of water.

A route following the line of canal is feasible, but it must be considered that the canal is already a part of a drainage system, and cannot at present be dispensed with. To attempt to convert it, while thus used, into the main channel of the new system would be attended with great difficulty and cost.

Although not urgently required until the completion of the system, we have considered it expedient at this time, with the view of eventually securing an ample supply of lake water, to call attention to the necessity of straightening, widening and dredging in certain places the Chicago River and its branches, and of increasing the discharge of pumps at Fullerton avenue. That discharge now averages 12,000 feet per minute, and it should be increased to 30,000 at the lowest. Provision must be made also for conveying a supply of fresh water into the east and west arms of the south fork, and for carrying off the diluted contents.

The law provides for the new drainage channel to terminate at the upper basin at Joliet. The addition of 300,000 cubic feet per minute, the usual estimated flow of channel, will drown out Locks 5 and 6. Consequently some adequate means must be devised to dispose of the discharge of the channel at that place, so that property, persons and health in the Illinois River Valley shall not be endangered.

From the termination of the channel at Joliet to a point above the Sag, rock excavation could be advertised as soon as the title to the lands is secured. It is proposed, first, to cut a longitudinal trench—a part of the channel—through the rock in that portion of the route just described. The trench thus excavated will

save much in pumping and in plant, and its completion will constitute an important progress in the execution of the whole system. In fact, to effect the drainage of the whole work during the progress of excavation, the lower portion, toward Joliet, would naturally be first undertaken.

W. E. WORTHEN,
Chief Engineer.
JOHN NEWTON,
Consulting Engineer.

To the Honorable Board of Trustees of the Sanitary District of Chicago, January 13, 1891."

REPORT OF CAPT. W. L. MARSHALL, JUNE 10, 1891, TRANSMITTING TO THE SECRETARY OF WAR REPORT OF S. G. ARTINGSTALL, CHIEF ENGINEER TO THE BOARD OF TRUSTEES OF THE SANITARY DISTRICT ON THE CHEMICAL ANALYSIS OF SEWAGE.

Pages 2622-23:

"Report of Samuel G. Artinsgstall, Chief Engineer to Board of Trustees of the Sanitary District of Chicago, on Results of Chemical Analysis of Sewage Taken from Chicago River and Branches.

Gentlemen:

Herewith find the mean results of 133 samples of sewage taken from the Chicago River and its branches and analyzed by Prof. J. H. Long. The original reports of each sample are in the possession of this department.

Yours respectfully,
SAMUEL G. ARTINGSTALL,
Chief Engineer.

The Honorable Board of Trustees of the Sanitary District of Chicago.
May 20, 1891."

MEANS OF ANALYSES OF SEWAGE SAMPLES (RESULTS GIVEN IN PARTS PER MILLION).
(BY PROFESSOR J. H. LONG.)

	Number of Samples	Temperature of Samples (Centigrade)	Total Solids in Whole	Fixed Solids in Whole	Volatile and Organic	Total Solids in Solution	Fixed Solids in Solution	Volatile and Organic	Solids in Suspension	Total Nitrogen (Kjeldahl)	Total Nitrogen as Ammonia	Free Ammonia in Filtrate	Albuminoid Ammonia in Filtrate	Oxygen Consumed in Filtrate	Chlorine in Filtrate
Halsted Street and Thirty-sixth, Nov. 5 to 25, 1890	21	10.04°	973.0	604.9	278.1	815.4	638.6	156	157.6	30.6	37.2	14.6	5.0	73.6	108.0
Halsted Street and Thirty-ninth, storm water, Nov. 16, 1890	1		782	588	194	674	566	108	108	42.0	51.0	20.8	2.1	38.7	116.1
Ashland Avenue and Bronson Sewers, Dec. 5 to 30, inclusive, 1890	24	17.7°	6,475.7	4,048.0	2,427.7	5,051.3	3,890.3	1,721.0	894.4	327.4	418.5	81.7	112.7	428.8	1,894.5
I. & M. Canal at Bridgeport, Oct. 16 to Dec. 30, inclusive, 1890	76	8.6°	492.2	391.7	101.5	388.2	330.5	167.7	105.0	18.01	21.86	13.17	1.85	20.66	70.33
Main Street, South Branch, Dec. 26 to 30, 1890	3		320.7	236.0	84.7	287.3	218.7	68.6	33.3	11.39	13.83	15.66	2.80	14.55	25.25
Thirty-fifth Street and South Fork, Nov. 26, 1890	1		2,304	2,092	30.2	2,258	2,008	250	136	157.92	191.76	152.60	6.20	70.40	916.15
Twenty-second Street and South Branch, Nov. 29, 1890	1		396	344	54	236	200	36	162	6.44	7.82	2.56	0.96	11.52	16.28
Polk Street Bridge, South Branch, Nov. 28, 1890	1		360	286	74	268	214	54	92	7.56	9.18	2.88	1.28	11.12	18.01
Madison Street Bridge, South Branch, Nov. 26, 1890	1		272	226	46	216	170	46	56	5.04	6.12	2.94	1.10	7.66	14.51
Kinzie Street Bridge, North Branch, Nov. 27, 1890	1		342	276	66	254	198	56	88	6.16	7.56	2.40	1.66	10.88	15.40
Goose Island, North Branch, Nov. 27, 1890	1		294	226	68	244	206	38	50	5.04	6.12	1.92	1.04	11.52	14.33
Fullerton Avenue Bridge, North Branch, Nov. 28, 1890	1		216	188	28	174	146	28	42	2.52	3.06	1.44	0.67	2.94	5.86
Clybourn Place Bridge, North Branch, Nov. 28, 1890	1		226	190	36	216	186	30	10	3.64	4.42	2.18	1.56	2.72	8.67

REPORT OF CHIEF OF ENGINEERS UNITED STATES ARMY, 1892, PART 3, APP. J. J., BEING THE REPORT OF CAPT. W. L. MARSHALL, UNITED STATES ENGINEER AT CHICAGO, AUGUST 18, 1892, TRANSMITTING TO THE SECRETARY OF WAR COMMUNICATION OF MR. FRANK WENTER TO THE BOARD OF TRUSTEES OF THE SANITARY DISTRICT OF CHICAGO, APRIL 21, 1891.

Pages 2270-2273.

"Communication to the Board of Trustees of the Chicago Sanitary District, Submitted by Mr. Wenter, Member of the Board, April 21, 1891.

Memoranda in relation to main outlet, Sanitary District of Chicago. These memoranda relate to the following topics: (1) The Worthen-Newton estimate; (2) prices for work; (3) estimate for various channels; (4) capacity for dilution of sewage; (5) available revenue; (6) large expenditures by cities.

They are presented as a series of notes for the purpose of showing that the sanitary works called for by the law are within the resources of the community and are necessary.

1. THE WORTHEN NEWTON ESTIMATES.

Their channel followed the Ogden-Wentworth ditch and the west bank of the Desplaines River. The dimensions were 180 feet wide and 18 feet deep with a grade of 5 inches per mile. The estimate of cost was $25,700,000, not including land damages or passages of the water through Joliet.

Their estimate is excessive and for the following reasons: (1) The location follows higher ground than is necessary; (2) the route covers more work than any other line that can be considered; (3) the proportions of the channel are not the best for economy; (4) unnecessary retaining walls are provided; (5) the prices for work are nearly double those for which this work can be done, as compared with other works of the world.

In addition, it may be stated that the location is not well suited to the needs of the city, and the better and less expensive channel can be made for navigation.

The following table compares the prices used with those adopted by the Hering Commission of 1886-7, consisting of Rudolph Hering, Benezette Williams and S. G. Artingstall.

Price Per Yard.

Class.	Worthen Newton	Hering Commission
Rock	$1.20	$.75
Hardpan, etc.	.60	.30
Clay	.30	.15

The prices for work were carefully considered by the Hering Commission, and the data in regard to extensive works, since gathered, sustain those prices as sufficiently liberal.

2. Prices for Work.

Solid rock in narrow railway cuttings, where disposal of material is difficult, is now being done at 70 to 90 cents per yard.

Rock is now being quarried at Lemont for $2.00 per cord of 13,000 pounds, or one hundred cubic feet solid. This is a rate of 54 cents per yard. It is delivered on board cars for $1.08 per yard and has actually been delivered in this city for $1.62 per yard, or $6.00 per cord.

Rock for wharves on the Mississippi River is actually delivered on board barges for 50 to 75 cents per loose yard for quarries on the banks of rivers.

In the Amsterdam Canal at Holland (1865-76) 21,000,000 yards of material were moved at an average rate of about 4 cents per yard. In the St. Petersburg Canal (1878-85) 63,000,000 yards were moved for about 5 cents per yard. The St. Lawrence has been deepened over a length of 40 miles between Montreal and Quebec from a depth of 10½ feet to 27½ feet; material, clay, sand, hardpan, bowlders and some ledge rock; aggregate cost for last ten years' work, 13 cents per yard. The clay has been done at from 3 to 6 cents per yard.

The records of several dredges on harbor works in Europe and Australia give rates of from 4 to 6 cents per yard in free material and at American prices.

The Lake Erie and Ohio River Ship Canal Commissioners of Pennsylvania recently reported on a canal 100 miles long from Conneaut on Lake Erie to Beaver on the Ohio River. Total excavation, 43,282,475 yards, at $8,656,495, or an average of 20 cents per yard for all classes of material. Much of the work was estimated at 12 cents per yard.

The Manchester Ship Canal involves 47,250,000 yards, one-sixth of which is rock. Total cost of canal, complete,

$30,000,000. Less than half of this amount is for excavation, but the figures are not reported.

The North Sea (Holstein) Canal involves 67,000,000 yards of excavation, and the total cost is estimated at $39,000,000. No details as to cost of excavation are given.

Various harbor work in the United States is being done at 10 to 20 cents in limited quantities.

The information available indicates that with special machinery and full preparation the work can be done as cheaply as similar work has ever been done, or well inside the prices of the Hering Commission—viz., 15 cents for clay, 30 cents for difficult dredging and 75 cents for rock.

3. *Estimate for Various Channels. Channel from Ashland Avenue to Lockport, 30 Miles.*

Capacity Per Minute Feet	Width Feet	Depth Feet	Grade Per Mile Inches	Excavation Cubic Yards	Cost of Excavation
210,000	160	10	6.84	22,196,000	$ 9,917,000
300,000	160	10	15.60	32,231,000	15,817,000
300,000	160	14	4.44	22,882,000	9,721,500
600,000	160	18	7.00	29,685,000	13,136,000
600,000	160	21.6	3.62	29,086,000	12,263,000
600,000	200	18	4.00	30,169,000	14,931,400
600,000	180	18	5.00	37,914,830	14,228,900

Prices of rock, 75 cents; hard material, 30 cents; clay, 15 cents. All the estimates above are on the same basis as to prices per yard.

Between Ashland avenue and Lockport right of way, bridging and miscellaneous will add $5,000,000 to each of the foregoing estimates for the total. One million may be added for passing the volume of water from Lockport to Lake Joliet.

Below Joliet the entire value of landed property throughout the Illinois Valley is estimated at less than $3,000,000. Any damage from overflow will be but a fraction of this.

It will be noticed that a channel 10 feet deep for either 210,000 or 300,000 cubic feet is more expensive than one 14 feet deep. It will also be noticed that a channel to carry 600,000 cubic feet and 21.6 feet deep is cheaper than a channel 18 feet deep and of the same capacity. It will also be noticed that to double the capacity from 300,000 to 600,000 only adds $2,541,500, or some 17 per cent., to the total between Chicago and Lockport.

The reason for these results are due to grade and its effect on the amount of rock excavation at the lower end of the channel.

The best proportion of channel can only be told after full borings have been made. It will be noticed that the Hering Channel, with a width of 200 feet, cost little more than the Worthen-Newton channel, with a width of 180 feet. This estimate involves more rock than is since found to exist, and is accordingly high.

The actual channel is not likely to exceed these estimates, as the actual rock is less than that assumed.

By comparing the quantities with the total for the Manchester Canal some ideas of outside limit of cost may be obtained. That work involves a vast amount of docking, bridging and locks and is greater than a channel 25 feet deep carried clear to Lake Joliet, complete with locks and revetment.

4. Capacity for Dilution of Sewage.

The best results of investigation up to the time the law was passed placed the dilution at 20,000 cubic feet for each 100,000 inhabitants, as needed for a sanitary condition, and the probable population at 3,000,000 in 25 years.

During the past season the canal carried about 50,000 cubic feet per minute up to December last. The amount of organic matter carried out by the canal at that time was about 250 tons per day. This was not far from the amount going into the South Fork alone at that time, and was probably less than one-fourth of the total organic waste produced by the city as sewage. This cannot be definitely known until a sanitary survey is carried over the city.

It may be stated that if all the sewage of the city was made tributary to the canal before decomposition had set in, then a volume of 200,000 cubic feet per minute sent out of the city would not improve the condition now found to exist in the canal.

The provisions of the law do not require unnecessary dilution, and it may be wise to provide the full amount of 600,000 cubic feet from the beginning.

No engineer of this Board, nor of any previous investigations, have recorded an opinion that the dilution mentioned is not required for a sanitary condition, and no engineer has said that with this dilution the Illinois river would be fit to drink.

5. Available Revenue.

Assume that the assessed valuation for 1891 will be $220,000,000 and that the valuation increase at the rate of 5 per cent. each year, which is certainly a conservative estimate, at the end of ten years the valuation would be $341,292,000. This would permit a bond issue of about $17,000,000 in ten years, were it not limited in the law to $15,000,000.

If these bonds are issued at the rate of $1,500,000 per year for ten years, and the rate of taxation of one-half of 1 per cent. is applied, then the total realized during the ten years from bonds and taxation would be $25,535,000 after paying interest currently on bonds issued at the rate of 4 per cent.

If one-twentieth of the bonds are retired each year by money from the tax levy, then the available revenue in ten years will be less, or about $20,000,000 to $22,000,000, according to the magnitudes of the annual issues and the fiscal policy which may be adopted.

It is well not to lose sight of other sources of revenue which may be made available on a broad range policy.

1. Special assessment will be available for lateral channels, which seem a local territory, and perhaps to a limited extent on the main channel.

2. Property values may be created by applying the material excavated. The possibility of large resources are covered in this.

3. Co-operation on the part of the United States. This seems to have been lost sight of.

4. The dockage and water power will be sources of revenue in time, though this may be of slow development.

It is impracticable to construct an economical channel for drainage which is not also a good navigable channel, and the United States should be willing to put into this the cost of the 8-foot channel which its officers have estimated and recommended.

A practical fiscal policy should be possible under this law, and relief can never be had sooner than by making a beginning.

The sanitary project of this city is a necessity, and well-considered investigation had determined that the ship canal solution is the only one practicable and within the financial resources of this city. The problem must be solved or this city must stop growing.

6. Large City Expenditures.

Cincinnati put from $25,000,000 to $30,000,000 into the Cincinnati Railway. So far as direct revenue is concerned, the capital is largely sunk, though indirectly the city is richly repaid.

Chicago has put the same amount in her park system since 1869, and has not felt the burden, nor does she begrudge the expenditure.

This city expends about $25,000,000 each year for all purposes, including the money for special assessments. (See last city report.) This is as much as it may ever be necessary to raise under this law and is spread over a term of years.

Considering the sums spent by other cities for public works, the sanitary project at twice the cost ought not to be regarded as serious."

Chief of Engineers' Report, 1892, Part 3, Appendix J. J., pages 2270-73.

Extract from the Report of Capt. Marshall, Supra, Transmitting to the Secretary of War Report of the Committee on Engineering of the Sanitary District of Chicago to the Board, January 9, 1892.

"Report of Committee on Engineering to Board of Trustees of the Sanitary District of Chicago, Submitted January 9, 1892.

Gentlemen: On December 12, 1891 (page 298 of proceedings), your honorable board instructed the engineering committee as follows:

'Resolved, That the engineering committee be instructed to carefully examine the work of the engineering department and any proposed plan of operations and make such recommendations as will expedite the beginning of actual construction upon the main channel between Chicago and Joliet, and secure the completion of the entire channel at the earliest date and with the greatest economy, and that said committee report as soon as practicable.'

This resolution calls for a comprehensive review of the work of the district and the formulation of a policy for the consideration of the board. The committee has made full use of the time at its disposal, and now submits a general report, reserving detailed recommendations for further consideration.

The committee has consulted maps, diagrams and reports, conferred with the chief engineer, heard experts upon the relative cost of rock excavation under water and by dry quarrying and listened to the objections offered to the Chicago end of the route as adopted, on behalf of the several railway corporations interested. In addition, each member has used every opportunity to inform himself upon the matter in hand.

Past Policy of the Board.

Your committee cannot ascertain from the records or by personal inquiry that the action of the board has been guided hertofore by a definite policy or a specific plan of operations. If so, it was not a matter of general information.

The following have appeared to the committee:

(1) The estimates of the engineer contemplated fixed bridges throughout the route from Chicago to Lockport. The requirement of swing bridges and a navigable channel was one not anticipated by the railways, as appeared in the hearings by the committee.

(2) The channel of a capacity of 600,000 cubic feet per minute through the rock begins at Sag, when the law requires that it should begin at Willow Springs, five miles nearer Chicago. (See Section 23 in regard to 'territory with a rocky stratum.')

(3) The dimensions of the channel, its depth at the starting point, and its grade, are not matters of official record, nor are the works proposed for the development of water power below Lockport. In fact, there are no proper records which indicate the plans of the board. So far as the committee can infer, one foot only is allowed for fall in a distance of seven miles from the lake through the river to the stockyards, and the grades are relatively much less than those adopted by Messrs. Worthen and Newton. It is extremely doubtful if the channel as designed will pass muster under Section 27 of the law.

(4) Every engineer of the board has suggested that work should begin on the rock cut, between Sag and Lockport, as the completion of this section requires the longest time and is a measure of the period when the entire work may be made available. Statements have been made which led to the inference that condemnation proceedings here would require one year. It has

been ascertained that they can be completed for practical purposes in sixty days.

(5) The attention of the board was largely concentrated on the work between the stockyards and the Desplaines River at Summit, a section that would have been useless for several years until the remainder of the work could be completed. It was intended to erect pumping works at Corwith, and it is inferred that pumping works were also to be erected at Summit to throw water into the Desplaines River, a purpose certainly contrary to the spirit of the law. The report of the engineering committee, July 11, 1891 (page 201 of proceedings), seems to contemplate this section as the only work prior to 1893.

The above, and all that has come to the attention of the committee, is in harmony with the following:

That the work immediately contemplated was a channel by the most direct route from the South Fork to the Desplaines River, near the Ogden-Wentworth Dam, the lines as adopted, said channel to be spanned by fixed bridges and to be operated by pumping works to the capacity of the canal at Corwith, and similar works at the Desplaines River, the work to be completed during 1892-'93. No investment was to be made on the remainder of the work.

The Rock Cut.

As the estimated cost of fifteen miles of work, covering the rock cut between Willow Springs and Lockport, is about 80 per cent. of the entire cost of excavation between Chicago and Lockport, and as the time required to do this portion of the work is longer than that required for any other section, the committee has given this portion of the route special attention, as the progress here made is a measure of the time when the entire work may be made available.

The line adopted follows the course of the Desplaines River, and it was proposed to excavate the rock under water. The chief engineer asserted that no other location was feasible, and that, in any event, the rock could be excavated as cheaply under water as by dry quarrying. Upon diligent inquiry, he failed to adduce any experience in justification of his conclusions or in support of the price used in the estimate ($1.10 per cubic yard), which appeared to be entirely too low for the character of rock

(Niagara limestone), nor did it appear that the chief engineer had any experience of his own upon which to base an opinion.

The committee was not prepared to accept these conclusions. The method proposed seemed liable to serious interruption by ice and flood and to be subject to every contingency, thus rendering very uncertain the time of completion and the cost, and the channel itself would be left in very irregular condition, thus seriously impeding the flow of water and necessitating a larger section to carry the requisite volume. It was doubted whether the method would be followed in actual practice, and it seemed probable that the work would be done better, quicker and more cheaply by dry quarrying during such months of the years as the cut could be maintained free from the waters of the river.

One the other hand, could a location be obtained capable of protection against the river and all surface water, except what fell directly from the clouds, and should the rock itself not be water-bearing to the extent of requiring a large outlay to maintain dry quarry pits, the work could be prosecuted continuously throughout the year and free from contingencies, thus greatly expediting the completion of the work and insuring the very lowest prices.

The matter was of such grave import that the committee sought the advice of experts, and men of the widest experience cheerfully responded to the request of the committee either in person or by letter, as Gen. Charles Fitz Simons, the McArthur Brothers, John Dolese of Dolese & Shepard, Mr. Earnshaw, Mr. Merriman, Gen. O. M. Poe, U. S. Engineer Corps, of Detroit, and Dunbar & Son of Buffalo.

It was the unanimous opinion that when dry pits could be readily maintained the work could be done much cheaper and more expeditiously by dry quarrying, and that under such condition the work could be prosecuted throughout the year. Such testimony as was specific indicated that it could be done by this method for one-third to one-half the cost of under-water work. Such testimony as was given in regard to the rock lying between Sag and Lockport, and such other information as the committee has gathered, indicates that the amount of quarry water to contend with over these ten miles will be small, and not an item of moment in the cost of the work.

Over these five miles from Willow Springs to Sag the rock is relatively small in amount and overlaid with drift, and no conclusion is offered at this time.

Your committee finds that between Sag and Lockport there is considerable latitude for the choice of a route that can be protected from surface water at comparatively small expense and that will afford ready drainage for any quarry water that may require pumping; and it is probable that such routes may be considered; the total amounts of rock will not greatly differ.

The probable saving ranges in the millions, according to the method of work that may prove expedient and the contingenies involved in the present location, and the time required may be reduced and made an element of certainty. Your committee, therefore, urges an immediate reconsideration of this section of the route, and the preparation of plans for its protection from surface water.

The Railway Objections.

In view of the determination of the board to make the channel available for navigation as required by law, the location adopted from the South Fork to Summit became a matter of serious moment to the railway corporations which must cross the same by means of swing bridges, and especially so in proximity to yards and junctions. The committee, therefore, gave three hearings, at which all the corporations interested were fully represented.

The route between Chicago and Lockport is crossed at eight points by ten distinct lines, belonging to six corporations, and seven of these points are within the first nine miles. The Santa Fe Railway is crossed four times, three crossings of the main line and one at the throat of their large yard at Corwith.

On any route selected there will be railway crossings, and the number of these on alternate routes cannot be reduced below seven lines crossing at four points, to eight lines crossing at six points.

The constructive cost of the first nine miles of feasible routes will not greatly differ, and the difference in cost of right of way will probably be far less than the variation in claims for railway damages, so this factor becomes of prime importance, except as it may be outweighed by considerations which pertain to the efficiency of the channel.

Your committee finds that the railways are not disposed in any way to needlessly embarrass the work. They regard a draw bridge as a serious matter and insist that such structures shall not be unnecessarily introduced in their lines and that they be located, if practicable, at such points as to occasion the minimum of inconvenience. The route adopted has been characterized as one that inflicts the maximum possibility of damage between the waters of the Chicago River and Summit. At Corwith the route crosses the throat of the main yard of the Santa Fe system, the canal and junction point of three railway lines, all in a short distance. The situation is capable of some amelioration. The Santa Fe Railway could be relocated for five miles to the north of the proposed channel between Corwith and Summit, thus avoiding two main-line crossings, but the position of the yards and junctions would not be materially modified. It is claimed that the value of this yard would be destroyed and a yard in some other locality necessitated, the entire cost of which would fall upon the district, an item in itself stated at over $1,500,000. This situation may be avoided or bettered by a route to the south of the yards, by the Illinois and Michigan Canal, or by one to the north of the canal.

The crossing at Western avenue and Thirty-ninth street is only less serious. Here are encountered the tracks of the Northern Pacific (not yet laid), the Panhandle, and the Stockyards Company leading to their railway yard. It is a waiting point for trains, and bridges would seriously embarrass the business to the stockyards, as the point is now operated. The situation is capable of some amelioration, but not to the extent of reducing the point to the status of the main lines without radical rearrangement. This may be possible, but the situation must be met in any route from the South Fork.

The route adopted as probably the most available from the South Fork to the vicinity of Summit, for the purpose of pumping works at the canal crossing and at the Desplaines River, and was not intended for navigation. It certainly could not have been more objectionably located for the latter purpose. It is suggested by the chief engineer that the West Fork, to the junction point near Crawford avenue, was to be utilized as the navigable connection with the Chicago River, but no record of

such intention is found in any report or proceeding, and this view is not in harmony with the estimates for fixed bridges over the entire route and with the channel of full section carried through to the South Fork.

The whole question of a route at this end should be reconsidered. The constructive cost should be re-estimated, the right of way appraised, and the railway damages valued for each line that may be available. On any line that may be adopted the final determination of the basis of railway compensation is likely to be a matter of tedious litigation.

The cost is not, however, the only criterion. Within limits of cost, considerations which pertain to the efficiency of the channel and its adaptation to future needs should also govern. Some of these may be stated without further argument at this time.

(1) The channel should effectively remove the sewage without expensive adjuncts and auxiliaries which require large expenditures for operation and maintenance, thus making the efficiency dependent on the whims of an annual appropriation bill.

(2) The plan should contemplate the easy development of the water supply in excess of the capacity of the Chicago River when the occasion therefor shall arise, as contemplated by the law.

(3) All conditions should be avoided which will in any way militate against the fullest development of a navigable route from the lakes to the Mississippi, or the development of a deep-water harbor. While these are not issues immediately pending, they can not be ignored. The only feasible line for a waterway between the basin of the St. Lawrence and that of the Mississippi is by the Chicago divide, and the only hope for a waterway in this generation is through the operations of this district, and for this object we may confidently enlist the aid of the United States in proper time. The deep-harbor question may be best and most cheaply solved through the works of the district when the occasion therefor may arise.

Proper consideration has not been given to the Chicago end of the route, and for this purpose the matter should be given the most deliberate judgment. The committee has no fear that the completion of the work will thereby be delayed or its cost increased; in fact, such a course is likely to diminish the actual total of expenditure during the period for which the bonds will be issued.

Other Sections of the Route.

Any changes in the location of the section of 10 miles lying in the Desplaines River valley, between Summit and Sag, will depend largely upon the changes made in the rock section below Sag, and in the Chicago end this side of Summit.

The line runs through material varying widely in character and subject to all the contingencies of the Desplaines River. The channel for the 5 miles below Willow Springs will be partly in rock and will be necessarily slow in execution. The committee has not given the attention to this section of the route which would warrant advice at this time, and especially as any changes will depend in some degree upon the action taken upon the sections below and above.

The work necessary below Lockport is relatively small, not requiring a long time for its execution, though condemnation proceedings may be somewhat tedious. The plans contemplate the development of water power. It is submitted that all rights in the premises will be guarded by securing the right of way, and that the plans for such development should be in accord with the future requirements of a navigable channel. The work below Lockport is pre-eminently a matter in which to enlist Federal cooperation, and before any necessity arises for treating this section ample time will be permitted to define the policy of the district in this regard.

The relations of the Chicago River system to the works of the district are not yet determined, and surveys will be required for this purpose.

It is doubtful whether a velocity of over 1¼ to 1½ miles per hour through the river can be tolerated with due regard to the interests of navigation or the stability of the channel, with so many necessary obstructions in piers and angles. Some 400,000 cubic feet per minute passed through the South Branch in the flood of 1887, but the velocity at local points was excessive and the water at Bridgeport stood some 4 feet above the lake.

The channel can be greatly improved at localities and probably made available for a volume of 300,000 cubic feet per minute, but beyond this the cost is likely to be so large as to make a channel in some other locality a measure of economy when the occasion therefor arises.

Outline of Policy.

The policy of the district is governed by the time when the works as a whole may be made available and the financial operations by which this result may be achieved within the resources of the district and at the least cost.

The 10 miles of continuous rock cut between Sag and Lockport demands the longest time in execution. This will require one thousand actual working days, or four years, and work should begin in the next six months. The 5 miles from Willow Springs to Sag, in part rock, will be scarcely less tedious, and actual work should also begin this season. Other items will not add over 10 per cent. to the cost of excavation, so the preparation for work is not a serious matter. These two sections will include about 80 per cent. of the total cost for excavation between Chicago and Lockport.

The work from Chicago to Willow Springs, 14 miles, can be completed in 1896, if actually begun in force in the spring of 1894. The preparation of plant will require some time, and this should be put under way in 1893. The cost of excavating this section will be exceeded by cost of right of way and damages. The adjustment of all questions in issue at the Chicago end will require considerable time.

The work below Lockport can be completed, if undertaken, in 1894, or early in 1895. The litigation here will involve some delays. The plans should be in harmony with future development for navigation. The water power will be conserved in the right of way.

The work in the Chicago River can also await the latest date, though the plans for its development should be early matured, so that the new bridges built by the city and any changes made may conform to future requirements.

The general plan of operations outlined is calculated to make the shortest possible investment for the funds prior to the actual completion of the work.

The cash now in the treasury ($720,000) will cover the necessary cost of preparing the work from Willow Springs to Lockport, and the amount to be received in taxes during the year ($1,050,000) will cover any work of construction that can be undertaken this season.

The amount required for the work outlined is not yet a subject of close estimate. The section from Willow

Springs to Lockport will probably fall inside of $11,000,000, and the section from Chicago to Willow Springs should not exceed $7,000,000, much depending on the matter of damages, a total of $18,000,000. Below Lockport $1,000,000 may be sufficient for present consideration. The work in the Chicago River is an uncertain item, but certainly $1,000,000 will greatly better the stream for the uses of the district and for navigation.

Through taxes, bonds, and special assessments not less than $20,000,000 may be made available, so there is no present reason to suppose that the resources will be inadequate.

After the main works outlined are completed, any further development will come logically and progressively, without entertaining any serious financial question, provided the general plan is now properly matured.

Recommendations.

Your committee has the honor to recommend as follows:

1. Reconsider the route from Sag to Lockport at once and prepare plans for protecting the same from surface water, with a view to beginning work on this section at the earliest practicable date.

The reconsideration of this section will require little if any field work prior to staking out the adopted line on the ground. It should be possible to adopt a new route and prepare plans for the same in sixty to ninety days, and actually begin work in June. Sufficient property can be acquired by that time.

2. Relocate the route where necessary between Willow Springs and Sag, with a view to beginning work this season. This may be done in sixty to ninety days after the Sag-Lockport section.

3. Reconsider the whole question of route from Chicago to Willow Springs, in the light of present needs and the requirements for future development.

Provision for actual construction on this section should be made not later than the latter part of 1893.

4. Reconsider the route and the treatment of the problem below Lockport.

Litigation here may require one year. Work need not begin until early in 1895. Meantime the plans may be

matured in harmony with some plan for navigation with Federal co-operation.

5. Fix the conditions to be met through the Chicago River as soon as practicable, so that all structures and modification in dock line may conform to a general plan.

The city will doubtless co-operate in this policy so far as it is has occasion to deal with the river in the interests of navigation. The work will be fragmentary and may involve some tedious litigation, and any opportunity for correcting the river at localities should be availed of. The larger part of the work, however, may be postponed should financial considerations render this expedient.

Your committee is persuaded that every energy should be bent to secure the actual beginning of work between Sag and Lockport, and that meantime every other consideration should be subsidiary. After this is begun ample time will be available for the careful consideration of other sections of the route, without delaying the completion of the work as a whole. We are also persuaded that such a course will apply the resources of the district to the best advantage.

Conclusion.

In view of some current misconceptions, your committee would add the following as bearing upon the character of the project as a whole:

(1) This solution of the sanitary problem was adopted because it was much the cheapest, involved little or nothing for maintenance and operation, and had collateral advantages as a waterway.

(2) The capacity was fixed by two considerations: (a) That the channel should provide the necessary dilution to maintain a sanitary condition for the probable growth of population during the time for which the bonds are issued, or until the work is paid for. (b) That it should be adequate, in conjunction with other works, to remove snow and rain water in floods, and thus prevent contamination of the lake at such times.

(3) It is not practicable, on account of excessive cost, to make a channel that will carry the requisite volume of water and at the same time be unnavigable. This is determined by the physical conditions. A channel flowing at a high velocity requires a high grade, thus increasing

the depth of rock-cutting at the lower end. Such a channel will be unstable in the clay.

(4) For the required capacity a deep channel is less costly than a wide one. It is also subject to less variation in flow, by changes in the level of the lake, by floods, and by ice, and it is more easily regulated at the lower end on account of less fall.

These are the substantial considerations which determined the present general plan as outlined in the law. Fortunately, all these conditions are also in the interest of navigation. The only incident for actual navigation is proper railway and highway crossings.

This law was matured after long consideration, and is explicit in its provisions. It lays down the conditions which must be met, and definitely prescribes the limitations upon capacity and size of channel. It is no part of the duty of this board to question these provisions, and it has no option other than to carry them out in accordance with their full spirit.

Very respectfully submitted.

LYMAN E. COOLEY,
WILLIAM BOLDENWECK,
JOHN J. ALTPETER,
Committee on Engineering.

The honorable the Board of Trustees of the Sanitary District of Chicago."

Chief of Engineer's Report, Part 3, Appendix J. J., pages 2273-2278.

EXTRACT FROM REPORT OF CAPT. MARSHALL, SUPRA, TRANSMITTING TO THE SECRETARY OF WAR REPORT OF MR. WILLIAMS, CHIEF ENGINEER OF THE SANITARY DISTRICT OF CHICAGO, DATED FEBRUARY 17, 1892.

"Report of Mr. Williams, Chief Engineer, to the Board of Trustees of the Sanitary District of Chicago, Submitted February 17, 1892.

Chicago, February 17, 1892.

Gentlemen: On January 16 your honorable board passed an order as follows:

'*Resolved*, That the chief engineer is hereby instructed to submit, as soon as practicable, alternative locations for the route between Sag and Lockport, with comparative estimates in sufficient detail to determine the rela-

tive cost of the several lines that may be considered, and that he include in said estimates all collateral works and damages.

In complying with this order it is found that to make a proper preliminary location and estimate for alternate lines between the points named that will admit of the best method of treatment and be conformable to the sanitary district law involves a consideration of the work which will be necessary to improve, for the passage of water, the Desplaines River from some point above Lockport to the upper basin at Joliet and that which will be necessary in excavating the main channel between Sag and Willow Springs. I have hence exceeded the instructions to the extent of submitting alternative locations for the route between Willow Springs and the upper basin, with comparative estimates for quantities and cost for the whole distance, based upon the most economical channel of uniform depth. Within these limits is comprised nearly all the rock excavation on the line of the proposed main drainage channel from Chicago to the upper basin.

Each of the several lines considered in the comparative estimates have received similar treatment, and the estimates are based upon the same method of working, except so far as differences of location compel variations.

There are three distinct routes from Willow Springs to Lockport and four from a point above Lemont to Lockport covered by these estimates. At or about Lockport all four lines merge into one. These various lines are shown upon the accompanying map, which is made in two sections, the estimates being given in Appendix A. The fifth line shown on the map is considered wholly as regards a different method of treatment and receives separate consideration hereinafter.

Line No. 1 follows the location made by Mr. William E. Worthen to a point above Lockport, where there is a deflection into a line common to all routes. This line is situated almost entirely on the north and west side of the Desplaines River, striking the river only at a very few points.

Line No. 2 is on the location made by Mr. Samuel G. Artingstall, intersecting the common line at Lockport. It follows the bed of the river as closely as is consistent with a satisfactory alignment.

Line No. 3 is a new location throughout. As far as possible it lies on the south and east side of the Desplaines River, between the river and the Illinois and Michigan Canal. It necessarily crosses bends of the river in a few places, but in such a manner that with a comparatively small amount of excavation the river channel may be changed so as to protect the new work. It involves a new location of the Chicago, Santa Fe and California Railway for a distance of 22,200 feet, 6,000 feet of which the company is now engaged in making for the purpose of improving their line, leaving 16,200 feet to be changed should the route be adopted.

Line No. 4 and No. 4A are still other new locations; the former following line No. 3 to a point nearly 1½ miles above Lemont, where it diverges, crossing the Illinois and Michigan Canal one-half mile below Lemont, and again crossing the canal about 1 mile above Lockport. This line involves a shifting of the tracks of the Chicago and Alton Railroad near Romeo for a distance of 4,000 feet, and either the abandonment of the Illinois and Michigan Canal below the first crossing, or the carrying of that canal across the new channel in flumes, with a waiver of the navigability of the latter.

No. 4A is a variation of line 4 lying between the two canal crossings. It does not differ materially from the latter.

Line No. 5, as heretofore stated, is considered wholly with reference to a different treatment of the project from that proposed for lines 1, 2, 3, and 4. This difference of treatment is described in another place. This line starts at Willow Springs, coincident with line 2, and continues in that line a distance of 7,000 feet, thence in the same course to the west line of section 14, below Sag Junction, crossing the Illinois and Michigan Canal on the way, 3¼ miles below Willow Springs. Thence the line deflects northward into the Lemont tangent of the present canal produced; thence it follows the bed of the canal past Lemont, and continues in a straight course to the Romeo point, which it rounds with an easy curve, thence taking a straight course to Dam No. 1, at the lower end of the upper basin at Joliet. It follows close to line 4, east of the canal, and passes east of the wire mill at Lockport, and under the bridge of the Elgin, Joliet and Eastern Railroad. From Willow Springs to Dam

No. 1 there are but two curves, the whole distance being accomplished by three tangents.

The adoption of this line will involve the reconstruction of the present canal in three sections aggregating a total distance of 26,000 feet. It involves two canal crossings, a change in the Chicago, Santa Fe and California Railroad for one-half mile, and a reconstruction of the Chicago, Alton and St. Louis Railroad in two sections aggregating in all 28,000 feet of double track. Like No. 4, it necessitates the abandonment of the Illinois and Michigan Canal, or the carrying of the same across the proposed new canal in flumes.

Within the range of the above described lines, almost the whole of the Desplaines River Valley is included, that can be said to be available for canal construction.

In the estimates of cost, given in Appendix A, for the first four lines that of the right of way has been excluded, except to state approximately the number of acres. The results are peculiarly notable in the small variations that there is between the lowest and the highest, viz, No. 3 and No. 1, respectively, which is slightly less than 5 per cent. Indeed, this variation is so small that without considering the question of right of way, facilities for working which the various lines present and the probable hazard from floods in the Desplaines River, one would be in grave doubt as to which line to recommend. This doubt is still further increased when we consider that where the surface of the rock is overlaid with glacial drift, as it generally is from Willow Springs to Lemont, the profiles of the rock from which the estimates are made are not absolutely reliable, owing to the incompleteness of the borings, and that this unreliability exists probably to a greater extent with lines 3 and 4 than with either of the others.

Probably the surer and more conclusive way to arrive at a decision relative to these lines is by a process of exclusion.

Comparison of 3 and 4.

Comparing No. 3 and No. 4 it is seen that the estimated cost of the latter line is $271,752 greater than the former; the estimated cost of No. 3 being $11,740,678.

No. 4 for a part of its length has some advantage in the matter of exposure to floods of the Desplaines River,

but on the other hand is exposed to all drainage from the south of the line for several miles. It is also 1,000 feet shorter. It will require, in order to prevent damages by overflow, the condemnation of 435 acres of land more than No. 3. It crosses the canal twice, which will be an obstruction in working, and involves the raising, complicated questions with the canal commissioners, since the canal will either have to be abandoned or carried in flumes across the new channel. The estimates are based on the proposition to abandon the canal, as to carry it across the channels in flumes would defeat the purpose of the plan.

In this comparison it should be borne in mind that the doubt which exists as to the relative quantities for some of the lines does not exist as between these two, for the reason that throughout that portion of their length where they follow different routes surveys of the surface of the rock and of the ground have been carefully made. It is only in the section common to each that the profile of the rock is not reasonably reliable. Hence, as between these two lines, I have no hesitation in preferring No. 3.

Comparison of 2 and 3.

In comparing lines Nos. 2 and 3 it is seen that omitting right of way No. 3 is apparently $140,966 cheaper than No. 2, and that it is 1,600 feet shorter. It is also much less hazardous in the matter of floods, and is likely to be less subject to water in the excavation during ordinary stages of the river. During the construction of line No. 2 the river will be forced into a new bed for a considerable part of the way, which will not be thoroughly puddled and comparatively water tight, as the old bed is. The levee that must be built along the new channel will for a large part of the way fall in the bed of the old river, and the land will slope toward it rather than from it, rendering it more difficult to exclude water. In some places also the river must be forced into very narrow confines between the new canal and the Chicago, Santa Fe and California Railway. Indeed, in at least one place, either the line or the road will have to be changed.

It has the advantage of saving 600 acres in right of way and in land subject to overflow, which, at $100 per acre, makes it cost but little more than No. 3. Its alignment,

however, is inferior, and if selected should be modified in places.

A careful balancing of the arguments for and against each of these two lines makes it clear that line 3 is much to be preferred to line 2, though for reasons other than those shown in the estimates. Indeed, estimates are incapable of showing the real differences between lines under conditions such as these.

Comparison of 1 and 3.

The difference in cost between lines Nos. 1 and 3 is apparently $539,375, omitting right of way. Line No. 1 is also 3,000 feet longer than No. 3. In the facility with which it can be protected from floods in the Desplaines River, line No. 1 is perhaps slightly superior to line 3; but it has the disadvantage of being on the north and west sides of the river, and hence exposed to the drainage from all the creeks and ravines and drainage areas tributary to the river. On the other hand, the canal protects line 3 by intercepting the drainage from the south and east, which would otherwise reach the new channel.

The lands which it will be necessary to condemn for line 3 are in excess of those for line 1 by 663 acres. Giving these lands an extravagant price will still leave the balance largely in favor of line 3. This line also has a better alignment than any that have been considered.

In thus analyzing the advantages and disadvantages of the several routes above described upon which estimates have been made, I am decidedly of the opinion that line No. 3 is the proper one to adopt for the main drainage channel.

The conclusion reached regarding the merits of the four lines under discussion stands independently of the manner of treating the problem after encountering the sloping ground just above Lockport.

Though the comparison of cost has been made upon the basis of completed work in each case, from Willow Springs to the upper basin, the fact that all the lines merge into one at Lockport, the plan below being common to all, still leaves the relative showing correct for any treatment that may be given.

That there may be a full understanding of what this plan is, and its merits, if any, it is presented with two other projects that have heretofore been proposed, cover-

ing the length of about 23,000 feet lying between the end of the 18-foot channel, as proposed by the late Chief Engineer, and the upper basin.

Plan 1.—Mr. Worthen's plan was to continue the main channel with a uniform slope along the line shown on the map, to a point opposite the upper basin, and from this point the water was to pass through Joliet by means of a 24-foot steel pipe. In lieu of this the water could be allowed to escape into the upper basin and the river channel from the basin down improved to the proper capacity. If this plan were carried out, the upper or lake level would be maintained as far as the upper basin, and incidentally an excellent development of water power secured. On the west of the river valley would be the high level canal, and nearly parallel therewith and from 25 to 35 feet below it the river bed and the upper basin to act as a tail race.

Plan 2.—Mr. Artingstall's plan contemplates an improvement of the river bed by excavating and revetting the sides, and by building three dams, which will allow a descent in as many stages. This plan would allow of a partial utilization of the water power, but without extensive subsidiary canals would not give a full development thereof.

Plan 3.—The present plan, the cost of which is given in the estimates, is to use sufficient of the waste excavation from the canal between Willow Springs and Lockport to build a water-tight bank 100 to 120 feet wide on top, from a point 9,000 feet above Lockport to the upper basin, confining the water between this bank and the high ground on the west side of the river. It is also proposed to waste a large amount of material on the west side of the channel formed by this embankment, and thereby limit the spread of the water. This plan will incidentally furnish as good a development of water power as it is possible to secure.

It is proposed to build this retaining bank to a height of 8 feet above datum and to let the water out into the upper basin through 5-foot cast-iron pipe sluices, controlled with gates. Such an arrangement will remove any possible chance of the bank being overflowed under the worst conditions.

The general scheme as outlined on the map is quite preliminary and to a considerable extent nearly (merely?)

suggestive; it cannot be worked out properly in detail until the territory covered by it has been surveyed.

Indeed, it should be said that in this matter of the terminal, below Lockport, there are modifications which can be made in the plan, and probably will be made on fuller study, which it is premature to enter into here.

A comparison of the cost of covering this stretch of 23,000 feet, by each of the three several plans described is given in Appendix B.

The right of way required for plans 1 and 3 is the same, though it is impossible to state how much it is without considering the question with reference to the legal rights of the district to water power created by it. Plan 2 does not require so much land by about 670 acres.

In arriving at the results in Appendices A and B, it will be noticed that 11,000,000 yards waste is estimated as being hauled at 7 cents per cubic yard, and that 3,000,000 cubic yards of rock are allowed at a reduced price, and credit given it in Appendix B, plan 3.

This waste enters into the bank that confines the water below Lockport, into a bank for the Elgin, Joliet and Eastern Railroad, and into spoil banks west of the proposed canal, thus raising the land and limiting the spread of the water.

As to the rate of 7 cents per cubic yard, due to the haul of the material from the excavation to the place of deposit, it should be said that it has been arrived at by very thorough investigations and estimates made by Assistant Engineer H. B. Alexander, the results of which are embodied in a report from Mr. Alexander, which I submit herewith as Appendix C.

The rate is shown to be the difference in cost between wasting the material adjacent to the line of the canal, and hauling it into banks an average distance of 10 miles, full allowance being made for cost of track, equipment and operation. In regard to the cost of the road it should be said that the mere building of the roadbed without track and ballast is a part of the excavation of the canal, material from the channel being used to build the bank for the road. Such a bank, or something its equivalent, is necessary to protect the excavation from the floods in the river, so that the bank serves a double purpose.

The allowance of 10 cents per cubic yard on 3,000,000 cubic yards of rock is based on the theory that if all but

this amount of the best quality of rock is permanently disposed of from the first, that contractors will be found, who in making bids will for the sake of owning this stone, take the work at a very low price.

There are large quantities, running into hundreds of thousands of yards, of just such stone quarried and sold every year in and about Chicago, and there seems little doubt that the reason why this waste rock has heretofore been considered of no importance arises from the immense quantity which might belong to a great number of persons and thereby become valueless from its very plentifulness.

The incidental advantages which will be derived and the ultimate profits which may be reasonably expected to accrue from carrying out this plan, run up into millions of dollars. Some of these may be summed up as follows:

1. By permanently disposing of all but about 3,000,000 yards of rock, this amount will, as heretofore stated, be of value, and the contractor, who may own it after the work is done, can dispose of it at remunerative prices, for ballast, for crib work, and rubble masonry; and will doubtless in submitting a proposition to do so with this in view, making allowances to the benefit of the sanitary district. On the other hand, if the whole amount of rock is wasted, it will have little or no value to any one, as the market will be glutted with cheap stone.

2. As far as possible, it should be the policy of the sanitary district to so dispose of excavated material as to leave the banks clear of spoil. Much value will accrue to the right of way for the canal if it is kept clear of waste banks; but if it is encumbered with a chain of mountains on each side, its value will be almost destroyed. Four hundred feet of right of way clear will be of more value than 800 feet cumbered with spoil.

3. By carrying out the proposed plan below Lockport a channel of full depth will be extended 4 miles further, and whatever the depth of the waterway which the United States Government may build to the Mississippi River, these 4 miles will be of great benefit, and, in dealing with Congress, as the sanitary district will ultimately do, it should receive recognition to the financial benefit of the district.

4. This plan furnishes means for the complete con-

trol and measurement of the water which passes down the river at all times, and will doubtless prove of great value in preventing actual damages in the river below in the time of excessive floods, and particularly in furnishing a check by which claims for fictitious damages may be met.

5. By carrying out this plan the sanitary district will own the best mill sites, and control the steadiest and most reliable water power in the Northwest.

A fall of 33 feet, which will generally obtain 300,000 cubic feet per minute, will furnish 18,000 horse power, and with 600,000 cubic feet per minute it will furnish 36,000 horsepower. At the very low price of $10 per horsepower, the first quantity when leased will bring an annual rental of $180,000, which capitalized at 5 per cent. is $3,600,000, while the greater quantity will capitalize at $7,200,000. That this power would be readily taken at these rates admits of little doubt. It should be borne in mind that the execution of the proposed plan creates this power without another cent of expenditure other than short flumes and pipes to conduct the water to the wheels.

Line No. 5.—Surveys and estimates are being made of Line No. 5, the location of which is hereinbefore described.

The estimates, when completed will show the cost of this line by two methods of treatment.

(1) The main channel proper will terminate at a point above the lower crossing of the Illinois and Michigan Canal, at which place controlling gates and waste flumes will be built. Below this point the channel will become a tailrace, and the water will be conducted to the lower basin in the cheapest manner consistent with safety.

(2) Parallel banks will be built—one on each side of the line below the lower crossing of the canal, and as far down as a point just above the Elgin, Joliet and Eastern Railroad bridge. There they will end in a cross-bank forming the inclosed space. At this point waste flumes and controlling gates will be provided for.

The banks of the channel will be carried up to a height of 8 feet above datum. This method will accomplish to a considerable extent the same ends accomplished by the plan heretofore described, and which is included in the estimates for lines 1 to 4 exclusive.

Work was only begun on this line a few days ago, and as the results are not likely to affect the conclusions of

this report in any way that cannot be properly considered by the engineering committee as a part of the same, it is thought best to submit the whole question in its present stage, and let the new data go to the engineering committee direct and be conveyed by that committee to the Board, rather than to delay another week.

Respectfully submitted,

BENEZETTE WILLIAMS,
Chief Engineer.

The honorable the Board of Trustees of the Sanitary District of Chicago."

Chief of Engineers' Report, 1892, Part 3, Appendix J. J., pages 2278-2282.

EXTRACT FROM REPORT OF CAPT. MARSHALL, SUPRA, TRANSMITTING TO THE SECRETARY OF WAR REPORT OF MR. WILLIAMS, CHIEF ENGINEER TO THE SANITARY DISTRICT OF CHICAGO, MAY 4, 1892.

"Report of Mr. Williams, Chief Engineer, to the Board of Trustees of the Sanitary District of Chicago, submitted May 4, 1892.

Chicago, May 4, 1892.

Gentlemen: My communication of April 20, relative to a board of consulting engineers has been returned to me with the direction from your honorable board that I submit in writing at the next regular meeting the specific points which such board should consider.

It is true that the rules, technically construed, contemplate that all issues shall be defined and reduced to writing before the appointment of a board of experts; but as the opinion was entertained that it is fully within the powers of your board to engage experts to act in any capacity which you may see fit to prescribe, the request was made, expecting that if granted it would be upon broad grounds rather than in a manner strictly in compliance with the rules.

When the communication was submitted no issues had arisen that could be defined, nor can any such arise until the whole question is presented in the light of the bids which have been invited. The hope was indulged that by the choice of engineers of recognized standing and ability to consider the subject in all its bearings, it might be possible to avoid all differences.

Though issues cannot be defined before they exist, it is not impossible to state the points about which they may cluster in certain contingencies.

As is well known, bids have been invited on three propositions, and a comparison of the same will be necessary before awards can intelligently be made.

'Proposition 3' will give the cost of excavating and constructing the main channel complete, from Willow Springs to the upper basin at Joliet, waiving the right of way and a few collateral structures of relatively small importance.

'Proposition 1' will give the cost of excavating, but in order to be comparable with Proposition 3, the cost of drainage and of the transportation of about two-thirds of the excavated material must be added. The determination of this additional cost is important, and any conclusion of your chief engineer relative thereto is not likely to receive universal assent.

'Proposition 2' will give the cost of excavating and disposing of a part, and only a part, of the material required to be excavated to furnish a channel for water to the upper basin. A tailrace, some 5 miles in length, will have to be located and excavated. Where shall this race be, and how much will it cost to excavate it? These are important points which your engineer can hardly hope to determine in such a manner as to be satisfactory to all.

Again, the work, if carried out in accordance with the proposed plan under either Propositions 1 or 3, will ultimately develop a water power above Joliet of fully 30,000 horse power, which will be utterly lost under Proposition 2. Will such a water power have any value, and if so, how much? And should it be considered at all in connection with the work of the sanitary district, however small its cost and however great its value?

By carrying out the work under either Proposition 1 or 3, a very large portion of the banks of the channel will be kept clear of spoil, while absolutely none will be left unincumbered under Proposition 2. Does any value attach to this consideration?

A navigable channel under Propositions 1 and 3 will extend with deep water 5 miles farther than under Proposition 2. Such a channel, or its equivalent, is a necessity to the navigation of the Desplaines and Illinois rivers, and without it the money being expended by the

United States Government on the Hennepin Canal and the improvement of the Illinois River will be utterly thrown away. Should this receive any consideration in carrying out this work?

Should it be shown that such a contribution to the work which the Government has in hand can be made at a nominal cost—work which would cost the Government, if carried out independently, many times what it would cost the sanitary district if done in connection with the main excavation—may it not be worthy of an effort to secure Government co-operation to the extent of the extra cost? And might not a thorough consideration of all these questions by a properly constituted board of engineers be the initiatory step to such co-operation?

These are mere hints as to the good which may come out of such a board if wisely chosen. But in view of the fact that the sanitary district is engaged in a work which incidentally is contributing immensely toward the project of a waterway which the Government is expending money upon, may it not be the proper time to take a step which may lead to results greatly to the financial benefit of the sanitary district?

I am profoundly impressed with the importance of the questions which must be decided after the bids are received on the 8th of June—questions which it may appear will affect the interests of the sanitary district to the amount of several millions of dollars—and I believe that the only safe way to approach them is in the manner suggested. Should your honorable board reach the same conclusion, then I think that all unsettled questions connected with the work below Willow Springs, coming within the domain of the engineering department, should be referred to such board after your chief engineer shall have made a report upon the same.

Or what, as it seems to me, would be conductive to greater expedition and better results, the consulting engineers might act with the chief engineer in making a joint report.

Respectfully submitted.

BENEZETTE WILLIAMS,
Chief Engineer.

The honorable the Board of Trustees of The Sanitary District of Chicago."

Chief of Engineers' Report, 1892, Part 2, Appendix J. J., pages 2282-2283.

EXTRACT FROM REPORT OF CHIEF OF ENGINEERS, UNITED STATES ARMY, 1893, PART 4, APPENDIX L. L., P. 2794, BEING THE REPORT OF CAPT. W. L. MARSHALL, UNITED STATES ENGINEER AT CHICAGO, DATED AUGUST 9, 1893, ENTITLED "IMPROVEMENT CHICAGO HARBOR, ILLINOIS, CAPT. MARSHALL STATES:

Chicago River.

The river and harbor act of July 13, 1892, in making appropriations for "improving harbor at Chicago," contained the mandate: "and the engineer in charge of the harbor is directed in his next report to submit what, if any, improvement should be made by the Government in Chicago River, and the cost of same."

Without going into detail it may be said that this river, so far as navigable parts are concerned, is wholly within the limits of the City of Chicago and the County of Cook, State of Illinois. Originally it was a sluggish bayou or creek nearly stagnant for the greater part of the year, but in rainy seasons, when discharging not only water from its own watershed, but also a large quantity from Desplaines River passing over the low divide between its South Branch and the Desplaines River, it was, and still is, a rapid stream. At such times the large discharge kept scoured a natural channel varying from 8 ft. or less to 14 ft. or more in depth as far as to its mouth, where it was obstructed by a bar due to the antagonistic action of the river currents and lake storms and waves. This bar varied from 4 ft. or less to 9 or 10 ft. in submergence.

The stream is bifurcated, the north branch adjoining the south branch one mile or more above the mouth. The north branch is of greater natural length, but is not reinforced at flood from other low water drainage areas, and is of less natural depth and importance. The total length of main river and branches is about 16 miles.

The United States about 1833 began improving the mouth of the river and the passage over the bar by constructing approximately parallel jetties to confine the discharge of the river at floods to definite widths of channel, and to prevent the influx of sands drifting under the influence of wind and wave, and by dredging across the inclosed parts of the bar to water in the lake suitable in depth to the navigation seeking this port.

As sands accumulated and vessels increased in draft the

piers on jetties have been extended, from time to time, farther into the lake, and as commerce by water increased, greater facilities for entering the river and sheltered harbors in Lake Michigan have been provided, as shown hereinbefore in the vicinity of the mouth of Chicago River, by the General Government. All works were completed in 1890 as hereinbefore shown.

From the inception of this great city to the present time the United States Government has restricted its work to providing a safe and free entrance to Chicago River by such constructions as have been required lakeward of the original shore line of Lake Michigan.

Within the original shore line of Lake Michigan, which extended approximately along the present location of Pine street, the stream has been improved partly by the City of Chicago, but mainly by individual and corporate riparion owners for their own uses and gain, by dredging and constructing wooden bulkheads, or docks, sometimes within and sometimes without the original shore line or meander of the stream, as individual uses, fancies, or profit determined. These wooden bulkheads or limiting docks or wharves have been constructed without co-ordination or regard to the demands of navigation for non-obstructive angles and curves, and the results attained have been further modified and the capacity of the stream as a navigable waterway further limited by numerous bridges built in the same manner, *i. e.*, without reference to any general plan in the interest of navigation.

Each bridge has been constructed seemingly without reference to the location of the bridges above and below it, in such situation as locally demanded by the growing necessities for intercommunication between the sections of the city separated from each other by the Chicago River and its branches. In many cases, where the cupidity or exigencies of corporations or individuals have demanded space, there has been extensive filling in within the original meander lines. There has been little regard paid of late to the marine interests, which has by encroachments by bridges and otherwise on the channel been hindered and harassed, and today the Chicago River is regarded by nine-tenths of its population not interested directly in its commerce as a nuisance to be abated, rather than as one of the indispensable arteries of commerce upon which is based the eminence among American cities attained by Chicago. This state of public opinion is due to the fact that the commerce by water of the City of Chicago is concentrated in comparatively few but wealthy

hands. The large elevators, coal and lumber yards, facilities for transfer from land to water transportation, and all the adjuncts of a great marine commerce, are in the hands of individuals and corporations embracing but comparatively few of the voting population of Chicago, who, as a mass, while without direct and apparent pecuniary interest in the marine commerce of the city, are daily incommoded and disgusted by this river. The inhabitants of Europe and the Northwest of the United States are more directly interested in the commerce of this river than are the citizens of Chicago.

The matter of inconvenience arises from the necessity for opening the bridges for the passage of vessels and closing them for the passage of overland pedestrians and vehicles. The land traffic is enormous. Vessels, in number that has attained 22,000 in seven months seek passage. Ten to twelve millions of tons of freight must annually pass through the river and bridge spans over it in seven months. The bridges are crowded in the downtown districts when closed, with overland traffic; the draws of bridges jammed with vessels when open. The City of Chicago has exercised control over the movement of vessels and opening of bridges by the maintenance of a harbor master, and by ordinance regulating the movements of vessels and the opening and closing of the bridges. As far as they have not been constructed by corporate lines of overland communication the bridges have been constructed, and are owned and operated by the City of Chicago.

With reference to the feeling of disgust entertained by the populace towards this stream, it must be said that from the earliest settlement of Chicago the most obvious disposal of their sewage and refuse, *i. e.*, into the lake and river, has been followed. As the city grew, the old sewers were enlarged and additional ones built. The Illinois and Michigan Canal was constructed, and the contents of the river loaded with sewage was to a then sufficient degree pumped into it; later, this proved insufficient, and the canal was cut deeper to allow a flow by gravity towards the Mississippi River; this also proved in time inadequate, and it was required by the Illinois Legislature that sixty thousand cubic feet of water per minute should be pumped into the Illinois and Michigan Canal from the Chicago River to purify that stream. This requirement has never been attained. As far as ascertained, the discharge has never for any length of time for the past four years exceeded forty-five thousand cubic feet per min-

ute, and it is not believed to have averaged much, if any, above one-half the legal requirements, or thirty thousand cubic feet per minute. To purify the North Branch, pumping works and a tunnel from Lake Michigan to the North Branch at Fullerton avenue have been for years in use. Lake water is pumped through this tunnel and creates a feeble current towards the main river. This supply forms part of the thirty thousand to forty-five thousand cubic feet per minute pumped into the Illinois and Michigan Canal at Bridgeport.

The insufficient discharge of the pumps into the canal results, in rainless weather in a very feeble current from the lake towards the pumps at Bridgeport, and in an indescribable state of putridity and offensiveness in Chicago River, due to domestic sewage and a discharge from manufacturing establishments through the sewers into the river. At ordinary rains, upon freshets in the Desplaines or Chicago rivers draining areas, great volumes of putrescent matter are disgorged into the lake through the mouth of Chicago river threatening the water supply of the city, which in the main is taken through tunnels under the bed of the lake from two inlet cribs, situate, one north of and the other south of, and a few miles distant from the mouth of the river.

To remedy the, at times, insupportable and disgusting condition of the river and its branches; to purify the river and to preserve the city water, relief is now sought under state laws by constructing a drainage canal from the south branch of Chicago river to the Desplaines river above Joliet, capable of discharging into the Illinois River Valley from three hundred thousand to six hundred thousand cubic feet of water per minute.

It is a remarkable fact that this city, while seemingly unable or unwilling to provide funds for purifying Chicago river by pumping sixty thousand cubic feet per minute is ready to embark in, and has commenced the execution of a canal for discharging ten times that amount by gravity at a comparatively enormous expense.

This channel has been located from the south branch of the Chicago River to Lockport, and is under construction, but no provision has yet been made for channels of supply from Lake Michigan. Whatever the outcome or plans of the local officials having this work in charge may be, it can be said that the Chicago River and its branches cannot in their present condition, supply materially more than from one-third to one-half of the minimum requirements of the law, without

producing currents that will be prohibitory to navigation at some of the bridges and obstructions now existing. It is certainly evident, granting the proposition that effective channels for the purpose will be constructed, that if this method of solving the drainage problem is to be carried to conclusion, there must be a complete remodeling of Chicago river throughout both its branches, and there must be also artificial channels of large capacity to furnish even approximately effective outfalls to the sewerage systems of a great city founded on low lands extending some twenty-two miles long, and for miles back from the lake, as well as other large feeders connecting the lake with such channels.

Without criticizing in any way the local measures taken for local relief, it may be said that the state laws, if effectively executed for the purposes specified, seemingly require changes in the capacity of Chicago River and its branches that may increase, may diminish, or may even entirely destroy their value for commercial purposes. In any case under existing laws, no alteration in the capacity of Chicago river can be made without the consent of the Secretary of War, or without full examination by agencies established by Congress, and the execution of the state laws are therefore limited by superior authority.

As before said, the navigable channel of Chicago river is now maintained by the City of Chicago by dredging out the solid matter cast into it through sewers, and dumped into it, especially in winter, by its street cleaning department. The city also maintains bridge tenders, harbor master, and vessel dispatchers, patrols the stream with fire boats; pumps inefficiently the sewage from the river into the Illinois and Michigan canal; constructs and maintains all bridges except such as are necessary for corporate public carriers.

Riperian owners have constructed the docks and wharves, of which there are none for public use, and dredge for landings alongside.

It is estimated that the total annual expenditure of the City of Chicago on the Chicago River is $350,000, of which about $120,000 is for dredging. This latter work is the only work than can be said to be in the interest of navigation.

The expenses for pumping of sewage, for bridges, for lighting and fire service, and other expenditures, are the necessary costs of encroachments upon this public highway to be paid by the profiting parties.

The dredging also is to remove solids and filth passed by the city into this navigable stream, contrary to the laws of

the United States. It is necessary that either the law be enforced and the sewers sealed, or else awaiting a change of system which is not at all contemplated to require that solid matter necessarily placed in the river by the citizens of Chicago shall be removed by them before accumulating to such an extent as to obstruct navigation.

General Remarks.

Chicago river is the most important navigable stream of its length on the globe. In the number of arrivals and departures of vessels annually it leads all harbors of the United States in tonnage it is second only to New York. In these elements it is the head of the great commerce of the lakes, but in capacity, depth, and width of navigation it is but a third-class port. Improvements are in progress along the chain of Great Lakes contemplating 20 to 21 feet depth of water at low water. Several harbors have 18 feet or more depth of channel. Chicago Harbor has 16 feet at entrance to the river, is obstructed by three tunnels with from 16 to 18 feet of water over their crowns, and can carry through but a comparatively small part of its navigable channel exceeding 15 feet. The entire inner harbor can be regarded as only a long private slip; there are no public wharves or docks, throughout its length, including branches; it is an offensive though navigable open sewer, obstructed by an average of four bridges to the mile, and lined for a greater part of its course by wooden docks in great part built up to the waters' edge by heavy buildings, elevators, etc., that will not admit a channel against them exceeding 16 to 18 feet without damage. The docks are generally of cheap construction of piles and sheet piles reaching but a few feet below the bottom of the channel existing when they were constructed but anchored back into the bank to other piles by iron tie rods about 1 and 1/2 to twice the channel depth in length. The docks are backed with earth. In many cases, as stated, over these cheap docks, but on foundations of additional tiles are constructed warehouses, etc., that may be more or less damaged by dredging close to the dock line to deepen the channel.

The river at numerous points, notably near Adams and Van Buren streets, has been contracted by filling within the meandered lines to less than one-half its original width. At other places in rebuilding docks, new docks have been constructed outside the first dock line. Abutments of bridges also project into the river, and piles or rip rap stone have been placed

in the stream to butress insufficient bulkheads or docks. Bends in the river now rigidly fixed by docks, of curvature with chords of sufficient length to allow the free passage of vessels of dimensions of twenty years ago, taken in connection with obstructive bridges prohibit passage by the largest modern vessels.

At the same time the increasing value of lands for other purposes near the mouth of the river is causing grain elevators, coal yards, lumber yards and manufacturing establishments, dependent upon marine transportation either to recede farther and farther from the mouth of the river, or to go elsewhere. Some establishments have moved to South Chicago, and Waukegan and Milwaukee have also profited at the expense of Chicago.

Consequent upon this recession vessels must pass an ever-increasing number of obstacles in reaching places of transfer of cargoes. Tugs, often two of them to a vessel, must be employed in all movements of vessels in the river above the junction of the two branches, and it is averred by prominent vessel owners that the cost of moving one of the larger vessels from the lake to the elevators above Twenty-second street and returning it to the lake is one-half the cost of transferring the cargo from Chicago to Buffalo.

This excessive cost, due entirely to the obstructions in Chicago River, is shown by differential freights on coal and other heavy commodities to other harbors on the Great Lakes, comparing mileage and rates, against Chicago.

In the present condition of Chicago River no material widening or deepening of the channel can be effected without great expense. A large proportion of the docks or bulkheads must be constructed, and in some cases precautions are necessary to prevent damage to buildings if the water is materially deepened against their foundations.

There should always be at least 2 feet of water between the bottoms of vessels and the crowns of tunnels to guard against damages to vessels by chance obstructions of small extent lodging temporarily over the rigid crowns. To secure 18 feet available water the three tunnels under the river should be lowered until there will be from 20 to 21 feet of water over their crowns. If the improvement be made on the basis of 18 feet and the use of Chicago River and its branches be conceded by the United States to the State of Illinois as a drainage channel, of the capacity indicated by the State law, the modifications therein must be radical and

costly whether the expense thereof be borne by the United States or the city of Chicago.

Heretofore, under recent river and harbor acts, the United States Government has exercised a limited control over Chicago River. It has been simply a conservative control, the United States intervening only where encroachments prejudicial to the rights of the public in the navigation of Chicago River were in question. Plans for bridges across Chicago River have been acted upon by the Secretary of War, and at least one bridge, *i. e.*, that bridge originally constructed at Canal street, has been condemned as an obstruction to navigation by the War Department and has been altered or changed by the city of Chicago upon the mandate of the Secretary of War, but not in exact accordance with that mandate either as to plan or time. The Secretary of War has not exercised his authority under the law to stop the deposit of filth in the river, nor interfered in any way with the regulations of the city with reference to the movement of vessels and bridges in or over the stream or with local police regulations relating to this stream.

In the opinion of the engineer officer in charge of this district, for the present awaiting developments of local plans under State authority, no improvement in Chicago River should be made by the General Government; nor any public funds be expended thereon so long as the city of Chicago uses it as a dumping ground for its filth and refuse of all kinds. The City should be required to remove all deposits made therein that tend to diminish its present navigable capacity, or to cease depositing its sewage therein.

This disposition of its sewage and deposit is now a necessity to this city and it is not in accord with public policy to prevent it as long as the city continues to remove the solid residue. The United States should continue its control so far as to preserve the navigation of the river from injury.

It will soon be necessary for Congress to provide for the extension to Lake Michigan of the navigation established on the Illinois River below La Salle, and to determine to what extent, if at all, it will utilize for navigation the great channel now being cut by local authorities in the rock divide, separating Lake Michigan from the Mississippi Valley. The question is at hand and must be determined at some date not far in the future, whether the national highway will utilize this cut and Chicago River as part of this communication, or the Calumet River route in connection with this local channel, or otherwise. There are no other practicable routes.

If Chicago River be adopted (which is not, in the opinion of the officer in charge, in view of the rapid expansion in territorial area as well as in population of this city, advantageous to either the local population for drainage purposes or for the United States for navigation), material improvements in the Chicago River channel will be required, but as before stated, even if Chicago River be utilized, the most direct channel for navigation is not the channel demanded by the necessities for drainage by the city of Chicago. If navigable channel must be arranged to best subserve local purposes, it is evident that material modifications will be required in Chicago River that may properly demand other navigable inlets than the one already provided at the mouth of Chicago River.

It seems, therefore, that before making appropirations for the improvement of Chicago River, the question of the future uses of this stream should be settled, whether it shall continue to be as now simply a long slip or succession of private slips, docks and wharves, utilized indeed for interstate and foreign commerce, but mainly for private and corporate gain, and for the main sewer of a great urban community, or whether it shall constitute a connecting link under federal control between the navigation of the Great Lakes and that of the Mississippi River and tributaries.

This opinion is given as required by the law of July 13, 1892, but for the information of Congress the following is respectfully submitted:

To reasonably accommodate existing commerce without extensive changes in Chicago River and without reference to future developments, the following work would be in the interest of commerce and navigation:

First: That the Chicago River from its mouth to the stock yards on the south branch and to Belmont avenue on the north branch as far as may be permitted by existing docks and wharves be dredged to admit passage by vessels drawing 16 feet of water.

Second. All encroachments on the stream by docks within the original meandered lines of the streams obstructive to navigation, as it exists today, should be removed at the expense of the encroaching parties, and obstructive bridges be required altered or changed.

To admit the passage of the largest lake vessels drawing not exceeding 16 feet of water at load draft, with no changes in the dock lines beyond the obstructive abutments of bridges and projecting obstructive angles of docks, will require

1,200,000 cubic yards of dredging, approximately, and 8,000 linear feet of docking, at an expense of about $700,000, first cost, with an annual charge for dredging of from $80,000 to $120,000 to maintain the channel.

The cost of maintenance, for reasons stated above, should evidently be borne by the city of Chicago as long as sewage is emptied into the river and the United States should be released from all damages to property by reason of the improvement in Chicago River, as required on the Calumet River.

Should a discharge of 250,000 cubic feet per minute be required through the south branch and main river, wholesale modification of bridges, tunnels and docks, and a widening of the river at many points will be required, and deepening to at least 18 feet of water below Chicago city datum with a slope necessary for this discharge, will be required at an estimated cost of $6,000,000, primarily, not including consequential damages, and an annual expenditure for maintenance of from $60,000 to $75,000.

Chief Engineer's Report, 1893, Part 4, Appendix L. L., Pages 2794 to 2801.

EXTRACT FROM THE CHIEF OF ENGINEERS REPORTS 1895, PART 4, APPENDIX J J, P. 2715, BEING REPORT OF CAPT. W. L. MARSHALL, UNITED STATES ENGINEER AT CHICAGO IN CHARGE OF CHICAGO RIVER AND ILLINOIS RIVER REFERRING TO THE IMPROVEMENT OF THE ILLINOIS RIVER. CAPT. MARSHALL SAYS:

"The city of Chicago expects to turn into the channel of the Illinois at some future time 5,000 cubic feet of Lake Michigan water per second; at some more remote period there may be 10,000 cubic feet per second, but not probably within a generation. By law it is now required to pump 1,000 cubic feet per second into that channel, so that we may expect 4,000 cubic feet per second additional discharge given to the Illinois River at low water. Discharge measurements on the Illinois show conclusively that this amount of water, or even the maximum discharge, will not produce a channel without dredging or without locks and dams equal in depth to that easily attained now at very small expense by completing the dredging required. Under any probable condition an equal or nearly equal amount of dredging will be required to give an equivalent channel in the Illinois River. The proposed discharge (5,000 cubic feet) will increase

the depth of water over the crest of the Kampsville dam at low water about 8 inches, and the depth over Six Mile Bar near the mouth of the Illinois but little if any more. A low-water channel 7 feet deep will exceed in depth very materially the low-water capacity of the Mississippi River, and there can be no rational demand for one of greater capacity.

These facts were presented to the Chief of Engineers U. S. A., as far as relates to the Illinois River work, in a supplementary project dated June 11, 1895, and authority obtained to present to Congress in this report estimates for the additional work required, as follows: For 3,600,000 cubic yards dredging, at 12 cents, $432,000. Deducting from this amount the balance of former estimate $112,500, including $35,000 appropriated August 17, 1895, leaves the amount by which the original estimate is deficient $319,500, and the amount still to be appropriated $397,000. Tc perform this work it will be necessary to construct a dredging plant and renew the hulls of the two dredges now owned by the United States.

At least four additional dredges, with the necessary scows and tenders, will be necessary."

Chief of Engineers Report, Part 4, App. J J, pages 2715-2716.

EXTRACT FROM REPORT OF MAJ. W. L. MARSHALL, U. S. ENGINEER AT CHICAGO, JULY 16, 1897, BEING APPENDIX II TO REPORT OF THE CHIEF OF ENGINEERS, 1897, PART 4, PAGE 2795, SAME BEING AN EXTRACT FROM A REPORT ENTITLED "IMPROVEMENT OF THE CHICAGO RIVER, ILLINOIS."

"The fact that Chicago River can accommodate vessels of 16 feet draft only, and for but a small part of its length can admit vessels not exceeding 325 feet length and 42 feet beam, when large modern vessels now being rapidly added to the fleets of the Great Lakes are 432 feet in length, 48 feet beam, and designed for a draft of water of 19 to 20 feet, is disquieting and hampering to all interests at Chicago dependent upon commerce by water, and the demand for better accommodations in Chicago River is growing in intensity.

No practical method of procedure to remove the obstructions to navigation has been proposed the authorities of the sanitary district have contracted for dredging the main river and South Branch from Lake Michigan to

the connection with the drainage canal to a depth of 20 feet (or more in places), and propose some increase in the capacity if the channel for discharge by widening between docks at a few narrow points, and some more important aids to navigation in widening at a few bridge draws; but these changes, as well as those proposed in the Report of 1893, and allowed to be made by the sundry civil act of June 4, 1897, are not in accord with the radical improvements demanded for the accomodation of the largest modern vessels."

Report of the War Department 1897, Chief of Engineers, Part 4, p. 2795, App. II, Report of Major Marshall.

EXTRACTS FROM CHIEF OF ENGINEERS REPORT, 1899, PART 4, APPENDIX K K, P. 2826, BEING THE REPORT OF MAJ. W. L. MARSHALL, UNITED STATES ENGINEER AT CHICAGO:

"Improvement of Chicago River, Illinois.

This river constitutes the inner harbor of Chicago, Ill. Its navigable parts lie wholly within the city limits of Chicago.

In the annual report of the Chief of Engineers for 1893, page 2974, may be found a full report upon this stream and its needed improvement, and in his annual report for 1897, page 2793, a history of the improvement and some detailed information as to the obstructions to navigation existing along its channels.

The present project was adopted by Congress in the river and harbor act of June 3, 1896, and modified by the sundry civil act of June 4, 1897. It contemplates dredging the river and its branches from the mouth of the river to the stock yards on the South Branch and to Belmont avenue on the North Branch, as far as may be admitted by existing docks and wharves, to allow passage by vessels drawing 16 feet of water; also to acquire title to and cut away certain obstructive bends and projecting docks that narrow and obstruct the channel. * * *

Congress has not provided for maintaining the dredged channels, and at present rate of fill by deposits of filth the river in four or five years will require another million and three-quarters cubic yards of dredging to restore its present capacity. These conditions will be somewhat bettered after the opening of the Chicago Drainage Canal, as far as relates to the South Branch, but as the current

will be slack, all but light suspended matter will still be deposited in the channels. The condition in the North Branch will not be materially improved in this respect over the present."

Chief of Engineers Reports 1899, part 4, Appendix K K, pages 2826-2827.

EXTRACTS FROM THE OFFICIAL PROCEEDINGS OF THE SANITARY DISTRICT, AUGUST 31, 1892, ON WHICH DATE PRESIDENT OF THE SANITARY DISTRICT, MR. FRANK WENTER, TRANSMITTED TO THE BOARD CORRESPONDENCE BETWEEN CAPT. W. L. MARSHALL, UNITED STATES ENGINEER AT CHICAGO, DATED AUGUST 24, 1892, AND MR. WENTER'S REPLY TO THE SAME.

"Federal Relations.

The President presented a communication from Captain W. L. Marshall, U. S. A., with reference to federal aid in construction of the main channel, and also his reply to the communication; and the same were read.

Mr. Eckhart, seconded by Mr. Boldenweck, moved that the communications be referred to the Committee on Federal Relations.

The motion prevailed unanimously and it was so ordered.

The following are the communications:

'United States Engineers Office,
Chicago, Aug. 24, 1892.

To the President Board of Trustees, Sanitary District of Chicago, Chicago, Ill.:

Sir—The river and harbor act of July 13, 1892, contains the following provision:

"Improving harbor at Chicago, Illinois: Completing improvement, seventy-two thousand dollars; and the Engineer in charge of the harbor is directed, in his next report, to submit what, if any, improvement should be made by the Government, in Chicago River, and the cost of same."

Under this provision I have to report what work should be done by the United States, if any, on Chicago River, and the probable cost thereof.

It has been my desire since the inception of the Chicago drainage scheme, to submit to Congress and have published in the Annual Reports of the Chief of Engineers, all official information emanating from your Hon-

orable Body, more particularly engineering projects and reports bearing upon a navigable waterway between the great lakes and the Mississippi River, whether I agree with your objects and conclusions or not.

I think that it is desirable in this connection that the views of your Honorable Body shall be submitted to Congress, and if it be agreable to you I would be glad to receive your views on the subject matter of the act of July 13th, 1892, and to submit the same, with my report, to Congress.

If this course be not agreeable to your Honorable Body, I beg that you will so notify me. The matter of Federal cooperation with you must necessarily soon come up, but I can readily see that you may prefer to bring it up as a distinct proposition. Nevertheless, I should be glad to receive any information, memorandum or assistance from your point of view, in making my report, that may seem suitable or advisable at this time to you, or to your authorized engineers.

Very respectfully,
(Signed) W. L. MARSHALL,
Captain Corps of Engineers.' "

" 'Chicago, August 25, 1892.

Capt. W. L. Marshall, U. S. Corps of Engineers, 134 Van Buren St., Chicago:

Dear Sir—Your communication of the 24th is duly received. The entire matter will be submitted to our board at our next regular meeting, and will take such action as we see proper.

I am personally very glad to note in your communication your good will towards the enterprise in which we are engaged, and I trust that the good feeling which exists will tend towards a proper solution of the question of a waterway from the Lakes to the Mississippi.

Yours very truly,
(Signed) FRANK WENTER,
President of the Board of Trustees.' "

Proceedings of the Sanitary District of Chicago, 1892, page 713.

EXTRACT FROM THE OFFICIAL PROCEEDINGS OF THE SANITARY DISTRICT, AT THE MEETING HELD ON MAY 24, 1893, AT WHICH TIME THE CLERK PRESENTED A LETTER DIRECTED TO FRANK WENTER, PRESIDENT OF THE BOARD OF TRUSTEES, SIGNED BY W. L. MARSHALL, MAY 23, 1893.

"UNITED STATES ENGINEER ON FILLING OF CHICAGO RIVER.

The Clerk presented a communication (accompanied by five enclosures) directed to President Wenter, as the result of a conference, by Captain W. L. Marshall, Corps of Engineers, U. S. A., with reference to the encroachments on the Chicago River; and the communication was read.

Mr. Boldenweck, seconded by Mr. Cooley, moved that the communication be ordered printed, and with enclosures, referred to the Committee on Engineering.

The motion prevailed unanimously, and the communication was ordered printed, and with enclosures, referred to the Committee on Engineering.

The following is the communication:

'United States Engineer Office,
Chicago, Ill., May 23, 1893.

Hon. Frank Wenter, President Board of Trustees, Sanitary District of Chicago, Chicago, Ill.

Sir—I have to return herewith the tracing loaned me by you this afternoon, showing the encroachments upon the navigable channel of Chicago River, near Van Buren street, which tracing I have had copied.

I have to say for the information of your Honorable Body, that however I may differ from the local authorities as to the methods adopted by them for the amelioration or care of their defective sewerage, and water supply, that I recognize their right and the authority and capacity of the commonwealth of Illinois and the municipality of Chicago to deal with their local matters in their own way, and that having declared their choice, United States officers shall place full faith and credence in their acts. This office then, as far as not called by law to express opinions, etc., shall work in accord with local laws to further rather than obstruct, their ends and objects, as expressed clearly by the laws of the locality.

As far as the obstructions to navigation in Chicago River are concerned, we will deal with them under United States laws, but in case these laws are silent, or where

questions arise where under these laws things may be done that may not be done under state and local laws, the custom of this office has always been to respectfully suggest to the Secretary of War that no action be taken until the local authorities expressed their assent, and that in no case should a permit be granted by the War Department until it be shown that the authorities of the State of Illinois expressed their concurrence in such action.

I have to enclose herewith copies of some endorsements relating to this matter of the Pennsylvania Railroad Company filling in in this vicinity, made on the various applications of this road for authority to encroach on the limits of the Chicago River.

I have to say that I desire the backing and co-operation of the Trustees of the Sanitary District of Chicago to prevent any encroachments whatever upon the present channel of Chicago River, and to express to the Trustees of the Sanitary District my disinclination to recommend to the Secretary of War any restriction by bridges, filling or otherwise upon the capacity of the Chicago River, except where imperatively demanded by the people of Chicago in crossing the river by bridges.

An examination of the locality in question will be made at the earliest practicable date, and if it be found that it comes within the purview of the instructions issued to the United States District Attorney to stop by injunction from an United States Court such encroachment this action will undoubtedly be taken on my application, by the District Attorney.

Very respectfully,
(Signed) W. L. MARSHALL,
Captain, Corps of Engineers.'"

(Five enclosures)

Proceedings of the Sanitary District of Chicago, 1893, pages 1244-1245.

EXTRACT FROM THE OFFICIAL PROCEEDINGS OF THE SANITARY DISTRICT AT A MEETING HELD MAY 24, 1895, AT WHICH TIME THE CLERK PRESENTED A COMMUNICATION ADDRESSED TO PRESIDENT WENTER BY COL. O. M. POE, UNITED STATES ENGINEER AT CHICAGO, DATED MAY 22, 1895.

"REQUEST FOR INFORMATION IN EFFECT OF MAIN CHANNEL ON LAKE LEVELS.

The Clerk presented a communication, addressed to President Wenter, from Col. O. M. Poe, Corps of Engineers, U. S. A., requesting certain information with reference to the effect of the Main Channel on the levels of the Lakes, as set forth in the communication; and the communication was read.

Mr. Boldenweck, seconded by Mr. Eckhart, moved that the communication be ordered printed and referred to the Joint Committee on Engineering and Finance.

The motion prevailed unanimously, and the communication was ordered printed and so referred.

The following is the communication:

'United States Engineer Office,
Chicago, Ill., May 22, 1895.

Hon. Frank Wenter, President of Board of Trustees, Sanitary District of Chicago, Chicago, Ill.:

Sir—The Board of Engineers appointed by direction of the Secretary of War to consider and report upon "the probable effect of the operation of the Chicago Drainage Canal upon the lake and harbor levels and upon the navigation of the Great Lakes and their connecting water ways" would be pleased to receive from your Honorable Board of Trustees any information or data bearing upon the subject submitted to us, and especially the following:

First—The conclusions arrived at from investigations made by your authority or by others as to the effects upon the levels of the great lakes by the operation of your Canal, including any mathematical analyses and discussions of the question from which these conclusions have been arrived at.

Any references to printed discussions by titles, etc., will be very much appreciated if copies cannot be furnished.

Second—Description of the Canal, including dimen-

sions of wetted perimeter, slopes, and character of material through which excavated.

Third—Whether any part of the inner harbor of Chicago, which includes Chicago River and its branches, will be utilized as part of the proposed Canal, and if so what amount of water you propose to take through these river channels.

Fourth—If Chicago River be utilized, what changes you propose to make in the navigable channels of the river, in dimensions, slopes and structures to adapt them to your purposes; and what additional channels of supply other than the main branch of the Chicago River; which is now the only evident connection between Lake Michigan and the proposed canal, your Board proposes to make.

In making these inquiries, the Board of Engineers consider that your Honorable Body is much interested in the solution of the questions submitted to us, and therefore desirous to aid as far as practicable in arriving at correct conclusions.

Any communications you may desire to make should be addressed to me at Detroit, Michigan.

Very respectfully,
Your obedient servant,
(Signed) O. M. Poe,
Colonel, Corps of Engineers.' "

Proceedings of the Sanitary District of Chicago, 1895, page 2653.

EXTRACT FROM THE OFFICIAL PROCEEDINGS OF THE SANITARY DISTRICT OF CHICAGO AT A MEETING HELD FEBRUARY 9, 1898, THE SAME BEING THE RESOLUTION PASSED BY THE BOARD OF TRUSTEES INVITING THE COMMITTEE OF CONGRESS TO INSPECT THE CHANNEL OF THE SANITARY DISTRICT AS THE GUESTS OF THE BOARD OF TRUSTEES.

"Invitation to Congressional Committee.

Mr. Wenter presented, and seconded by Mr. Eckhart, moved the adoption of the following Resolution:

'Whereas, it is currently reported that the Committee on Rivers and Harbors of the National House of Representatives is going to make a tour of inspection at the various rivers and harbors in the west; and,

Whereas, The importance of the Chicago River and

Harbor is second to none in the United States and deserves the fullest attention and consideration on the part of said Committee; and,

Whereas, The Main Channel of the Sanitary District of Chicago is nearing its completion, and as such it is one of the connecting links of said Chicago River and Harbor; therefore, be it

Resolved, That the President be authorized and directed to send an invitation, in the name of the Board of Trustees, to said Committee to inspect the Channel of the Sanitary District, and that said Committee be the guests of this Board while sojourning in the city.'

On roll-call, on the motion for the adoption of the resolution, the vote stood: Yeas—Messrs. Boldenweck, Braden, Carter, Eckhart, Jones, Kelly, Mallette and Wenter—eight. Nays—none.

Upon which result the President declared the motion carried."

Proceedings of the Sanitary District of Chicago, 1898, pages 4553-4.

EXTRACT FROM THE OFFICIAL PROCEEDINGS OF THE SANITARY DISTRICT AT A MEETING HELD FEBRUARY 24, 1898, SAME BEING THE REPORT OF MR. WENTER AS CHAIRMAN OF THE COMMITTEE ON FEDERAL RELATIONS AND REPORTED THAT THE INSPECTION OF THE SANITARY DISTRICT CHANNEL WAS MADE ON FEBRUARY 23, 1898:

"INSPECTION OF MAIN CHANNEL BY CONGRESSIONAL COMMITTEE.

Mr. Wenter, Chairman of the Committee on Federal Relations, made a verbal report that the inspection of the Main Channel by the Committee on Rivers and Harbors of the National House of Representatives on February 23, 1898, had been made pursuant to the Resolution of February 9, 1898 (Page 4554 of the Proceedings), but that the Committee had not prepared a written report on the matter."

Proceedings of the Sanitary District of Chicago, 1898, Page 4575.

EXTRACT FROM REPORT OF THE CHIEF OF ENGINEERS, 1900, PART 5, APPENDIX M. M., PAGES 3858-9, IS ALREADY IN EVIDENCE UNDER THE U. S. ENGINEERS' REPORTS, SUPRA, VOL. 4, PAGE 2183.

EXTRACT FROM PROCEEDINGS OF THE SANITARY DISTRICT OF CHICAGO AT A MEETING HELD JULY 11, 1900, AT WHICH TIME MR. WILLIAM BOLDENWECK, PRESIDENT OF THE SANITARY DISTRICT TRANSMITTED TO THE BOARD A LETTER SIGNED BY MAJ. J. H. WILLARD, U. S. ENGINEER AT CHICAGO, DATED JUNE 20, 1900:

"MESSAGE TRANSMITTING REPORT IN REFERENCE TO CURRENT IN CHICAGO RIVER.

The Clerk presented a message from the President transmitting the report of Major Willard, United States Engineer, in reference to the current in the Chicago River due to the flow of the Drainage Canal, which, with accompanying report, was ordered printed and placed on file.

The following is the message:

'Chicago, July 9, 1900.

To the Honorable, The Board of Trustees of the Sanitary District of Chicago:

Gentlemen—I transmit herewith a copy of Hon. J. H. Willard, Major, Corps of Engineers, U. S. A. preliminary report of the Chicago River, which I respectfully request be printed in our Proceedings,

Respectfully submitted,

(Signed) WILLIAM BOLDENWECK,
President.'"

The following is the Preliminary Report:

"'Chicago, Ill., June 20, 1900.

Brig. Gen. John M. Wilson, Chief of Engineers, U. S. Army, Washington, D. C.:

General—Complying with your wishes, indicated in your dispatch of this date, I have the honor to submit a preliminary report upon the current in Chicago River due to the flow of the Drainage Canal.

Since the Canal was opened under the provisional permit of the Secretary of War, only that member of the controlling works at Lockport known as the Bear Trap Dam has been operated, the stoney gates having been kept closed.

The Bear Trap, as you know, is a counter-poised hydraulic gate and can be set to remain at any elevation

between closed and wide open. During the observations for velocity and discharge the dam has been set at various heights to give estimated flow between 150,000 and 320,000 cubic feet per minute, and the observations have been taken at an interval after each setting that should give the full effect on the river. But inasmuch as the lake level is not constant and the reservoir capacity of the river between lake and Drainage Canal is large, it should not be expected that the mean velocity and discharge at any point in the river should be constant for a given setting of the Bear Trap Dam.

The subject cannot be covered by anything short of an elaborate investigation over a long period and through wide ranges of lake level, and therefore has not been attempted.

The observations made to ascertain facts under existing conditions consisted in measuring discharges with current meter at critical points in Chicago River between lake and Canal, especially at bridges where the greatest dangers were to be feared, through as large a range as could be got with safety by successive settings of the Bear Trap Dam.

The discharges in the Canal were measured by meter and by rods for different settings to compare with Weir estimates and with measurements previously taken in the Illinois and Desplaines Rivers.

The bridge sites giving the most restricted sections naturally were the places to expect the greatest velocities. They made the most convenient points for measurements. The observations have just been completed, as far as intended for the present, and the discharges are being computed.

Using preliminary computations for estimated volumes of discharge through the Canal, they are shown in two series with extreme velocities observed at each station, in the following table:

MAXIMUM VELOCITIES IN CHICAGO RIVER IN FEET PER SECOND AND MILES PER HOUR FOR DISCHARGES IN CUBIC FEET PER MINUTE OF THE DRAINAGE CANAL.

Place of Observation.	Discharge 150,000-210,000		Discharge 270,000-310,000	
	F.S.	M.H.	F.S.	M.H.
Rush Street bridge	1.88	1.28	2.36	1.61
Clark Street bridge	1.80	1.23	2.40	1.64
Wells Street bridge	1.51	1.03	2.40	1.64
Washington Street bridge	2.12	1.46	3.21	2.19
Van Buren Street bridge	1.88	1.28	2.72	1.85
Eighteenth Street bridge	1.67	1.14	2.77	1.88
Canal Street bridge	1.76	1.20	3.29	2.24
Halsted Street bridge	1.67	1.14	2.64	1.80
Average	1.79	1.22	2.72	1.85

It is probably safe to estimate the mean velocities of the sections at about eighty per cent. of the maximum, giving an average of less than one mile per hour for discharge not exceeding two hundred and ten thousand cubic feet per minute and less than one and a half miles per hour for discharge not exceeding three hundred and ten thousand cubic feet per minute, and therefore the general current of Chicago River must be much less.

The greatest velocity corresponding to the greatest discharge of the Canal was observed at the Canal Street bridge, say two and a quarter miles per hour, and approximately one and three-quarters miles per hour for a mean velocity. This is one of the first bridges authorized to be replaced by a bascule, with large opening, under the general project of the Sanitary District for replacing bridges and widening Chicago River.

There is no doubt that the reversed current in Chicago River has increased the difficulty of navigating it with the large boats now demanded by commerce, but it is a noteworthy and gratifying fact, not unexpected by me at least, that the pilots have been quick to adapt themselves to the new conditions and I have little doubt but that they could handle their boats safely even in greater currents than now obtain.

If I have not overestimated pilots' skill, and considering the immense benefit of the Drainage Canal to the City of Chicago since its opening only a few months ago, I recommend that no restrictions be placed upon the

legal requirements of flow into the Sanitary Canal, unless it should be found absolutely necessary to do so.

The Engineer Department, the City of Chicago, and the Sanitary District are of one mind as to the need of improving Chicago River, and are co-operating heartily to that end, and large sums are appropriated and being expended judiciously by each for the objects in view. The interests of navigation are not only being protected, but are being advanced practically sooner than could be hoped for in the usual course.

Very respectfully,
Your obedient servant,
(Signed) J. H. WILLARD,
Major, Corps of Engineers.'"

Proceedings San. Dist. of Chicago, 1900, pp. 6641-43.

EXTRACT FROM THE REPORT OF THE BOARD OF ENGINEERS ON DEEP WATERWAYS BETWEEN THE GREAT LAKES AND THE ATLANTIC TIDE WATERS. HOUSE OF REPRESENTATIVES DOC. 149 (56 CONG. 2D SESSION), BEING A REPORT BY LIEUT. COL. C. W. RAYMOND, ALFRED NOBLE AND GEO. Y. WISNER, 1900.

The board said:

"The board is of the opinion that the best location for works for regulating the level of Lake Erie is at the foot of the lake, just below Buffalo Harbor. The location in the Niagara River below Tonawanda has been advocated, but the board finds upon investigation that regulation by works at this point would be less effective and much more expensive than at the adopted location.

The works projected by the board are designed to distribute the discharge of the lake so as to reduce its variation of level to a small amount. The result cannot be attained by the use of submerged fixed weirs only, and a series of sluices is added to secure, in combination with fixed weirs, the control desired. The weirs will be constructed of concrete blocks and will have an aggregate length of 2,900 feet. The sluices, 13 in number, of the Stoney type, will each have an opening of 80 feet, making an aggregate of 1,040 feet. The piers separating the sluice openings will be of substantial, first-class masonry. The sluices can be operated under rules easily formulated, and, in the opinion of the Board, amply provide for conditions more unfavorable than any recorded.

The location of these works and the details of their de-

sign are shown on plates 84, 85, 86 and 87. Their estimated cost is $796,923.

Effect Upon Lake Erie.

The extreme high-water stage of Lake Erie is about 575 feet above tide water. The level adopted by the board for regulation is 574.5 feet, or about 0.5 feet below the level of extreme high water. This is the lowest elevation at which regulation can be effected without enlarging the cross section of the river at the gorge. Should it, for any reason, be considered desirable to regulate the lake at a lower level, the desired result can be accomplished by enlarging the cross section of the river so as to provide for the maximum discharge at the adopted level.

The board is of the opinion that with the works proposed the level of the lake can be maintained during the season of navigation within about 0.6 foot below the level adopted for regulation, under all conditions of supply heretofore recorded. Considerable changes of level due to violent winds would be temporary and infrequent, and, in the opinion of the board, would not seriously interfere with the regulation of the lake level.

Conclusion.

The board is of the opinion that works can be established for regulating the level of Lake Erie which will be of great value to navigation, not only in Lake Erie, but also in the upper lakes and connecting waterways, and will be of no injury to the lower waterways of the lake system, and that such works can be constructed at a cost which will be small compared with their benefit to commerce."

H. R. Doc. 149, 56 Cong. 2d Sess., pp. 48, 49.

EXTRACT FROM A REPORT MADE BY FRANCIS C. SHENEHON, PRIN. ASST. ENGINEER, TO CONGRESS IN REFERENCE TO THE PRESERVATION OF NIAGARA FALLS, MAY 30, 1908.

In conclusion Mr. Shenehan says:

"While this report has dealt with injurious effects on the Rapids and Falls of the Niagara River and with interferences with navigable ways in river and lake, and has shown these up in their limiting, hurtful amounts, it

seems proper to suggest certain remedial measures that may serve to harmonize the preservation inviolate of the scenic grandeur with the useful application of the splendid power of the falls. Both of these things are eminently desirable and feasible.

A volume of 210,000 cubic feet per second with a descent between the 'dead line' and the Upper Gorge of 220 feet has a potential of over 5,000,000 horsepower. This is the power of 15,000,000 strong draft horses, each limited to an eight-hour day. If it takes 10 able-bodied men to do the work of one of these draft horses, the work potential in this fall is that of 150,000,000 men, nearly twice our population of men, women and children.

The great companies at the Falls have created in good faith power plants to lessen the hardships of human labor, to aid transportation, to illuminate the night hours, and to add to the wealth of two nations. The power houses for the most part are architecturally excellent, harmonizing with the scenic surroundings, and the mechanical wonders wrought in solving the engineering problems of the utilization of this great head and volume of water rival as a spectacle the scenic grandeur of the Falls and add to the attractiveness of the region.

It, therefore, appears proper to permit and foster such ultimate developments in addition to those already in force as are compatible with the perpetuation of the scenic grandeur appreciable undiminished.

The water, however, and the power that is in it should be regarded as a national resource, and its use should be under definite conditions and regulations.

No water should be used wastefully. Users of water should return in mechanical or electrical power all the energy that can reasonably be derived from it. The wasteful use of this national resource is illustrated by the expenditure of 1,332 cubic feet of water per second by the hydraulic company (see Chapter XIII) to secure 7,991 horsepower, or 6 horsepower to the cubic foot. As the water has a potential of 25 horsepower, or 19 horsepower on the shaft, more than two-thirds of the power is wasted. The balance of the water of this company is used economically.

The Niagara Falls Power Company (see Chapter XII) expends over a third of its potential power in getting the water to and from its turbines.

The use of the water by the Canadian companies in some cases shows corresponding waste.

The supervision of the economical use of the water should extend to all details of canals, sluices, forebays, penstocks, tailbays, tailraces and tunnels, and to all water wheels, generators, transformers, transmission lines and motors.

Supervision and regulation should extend to rates charged for power or light. The right to use a public resource implies the right of the people to an economic benefit.

The maintenance of scenically harmonious premises and surroundings should be required.

Provided there be no large increase in up-lake diversions, the possibilities of continued and extended use of power at the falls are conditioned upon the construction of regulating works in the Niagara River to avoid the wasteful outflow of the water of Lake Erie. The injury to the scenic grandeur of the Falls, and the interference with the navigable waters of the Niagara River and Lake Erie, due to up-lake diversions, and the injury and interference coming from periods of drought would be largely obviated by impounding in the lakes a portion of the winter outflow. During the months of December to April, inclusive, enough water may be saved to hold the lakes to a proper and economical level to the betterment of navigation, and yield a surplusage to partially offset diversions at the falls. This is a practicable engineering proposition, but as the power companies are beneficiaries they should pay a fair share of the cost of the work.

The lessened winter flow over the Upper Rapids and falls would not scenically injure either, because ice and frost effects are an added attractiveness that cover up unsightly shoals or unwatered crest lines.

A final consideration should be stated. The falls are operative only as a scenic spectacle during the daylight hours. When the night shuts in, partial depletion would not be scenically injurious.

Should permits issue for half the flow of the river from sunset to sunrise, or for 12 or 16 hours every day, a tremendous power would become available that would furnish its own light, and factories might work by night instead of by day.

The temporary lowering of the river would immediately readjust itself when the sunrise shutdown came. The in-

terference with night navigation on the river would no be prohibitive in view of the benefits to be conferred i cheap power and light. The use of the night power a Niagara implies regulation of Lake Erie's outflow."

Sen. Doc. 105, 62d Congress, 1st Sess., pages 75-76.

EXTRACT FROM A PAPER PREPARED BY MR. ALFRED NOBLE FO THE BOARD OF ENGINEERS ON DEEP WATERWAYS AND SUBMITTE AS APP. 4 TO THE REPORT OF SAID BOARD, PAGE 219.

"Principal Causes of Reduction of Speed of Ships i Restricted Waterways.

1. The speed attained by a ship in open sea will b reduced in a marked degree on entering shoal water, eve if of unlimited width.

2. If the channel is restricted laterally as well as i depth, the water moves back past the ship in the effort t maintain a uniform level in the channel. The speed of th ship past a fixed point becomes less than its speed in rel tion to the water through which it moves.

3. The piling up of water in front of the ship and th lowering of water behind it set up a resistance to i motion. This takes place to some extent in open sea. Th discussion is concerned only with changes of conditio when passing from open sea into a restricted channel.

4. The speed in a restricted channel must be limite to that which will not cause too great injury to the sid slopes.

5. The speed must not be great enough to make th ship unmanageable.

6. The speed in narrow channels must be reduced wh meeting other ships.

7. A lower rate of speed will be required in curv than on tangents by reason of the greater difficulty steering the ship.

As already stated, some of these conditions can only discussed in a general way with results only approx mately correct; others can be evaluated wholly or in pa from the results of observation, as will appear in wh follows:

(1) *Retardation in Shoal Water.*—This depends the form of the ship, so much so that the design of ship varied with regard to the depth of water in which it is navigate. Observations made recently on the freig steamship *Angeline* in the deep water of Lake Huron a

the shoal water of Lake St. Clair indicate that the retardation is about 18 per cent. The depth of water under the keel was about 2 feet 10 inches, no allowance being made for the settlement of a ship in the water, which always occurs when the water is shoal. The log of a recent trip of the steamship *Senator*, from Detour to Detroit, shows a speed of 12.2 miles in open lake and about 16 per cent. less in the shoal water of Lake St. Clair. The depth of water under the ship's keel, without allowance for settlement, was about 2 feet. These results are not so concordant as might have been expected, and the need of further observations is manifest. The estimated reduction of speed of the *Angeline* is derived by adding to an observed reduction of 11 per cent. in the speed of revolution of the wheel a further 7 per cent. for an estimated increase of slip. In the case of the *Senator*, the time was observed for the passage across Lake Huron, giving an accurate determination for speed in open lake and for the passage from the foot of St. Clair Flats Canal to Detroit. The latter includes 15 miles of shoal water, where the current is imperceptible, and 8 miles at the foot of Lake St. Clair and in Detroit River, where the water is 25 to 40 feet deep and the current about 1.8 miles per hour.

The log record would have been more satisfactory if the time had also been taken at the end of the 15 miles of shoal water in Lake St. Clair. The reduction of wheel speed of the *Senator* was about the same as for the *Angeline*, and it is, therefore, probable that the increase of slip of wheel of the latter ship was overestimated and the actual reduction of speed on entering shoal water was probably less than 18 per cent. For this discussion, however, it is deemed best to be on the safe side, and the reduction of speed is taken at 20 per cent. On this basis the speed of the ship will be reduced from 12½ miles to 10 miles per hour on entering shoal water. It should be noted that the depth of the channel for the lake ship is assumed to be 2 feet more than the draft of the ship, while the depth of channel for the ocean ship is 3 feet more than its draft. Obviously, the excess for the deeper draft ship should be the greater, but the additional 1 foot is doubtless more than needed to equalize the conditions.

In designing the 21-foot waterway it was found that in the lower portion of the Mohawk Valley, where a slack water navigation is intended, a deep channel will be cheaper than a shallow one. This led to the adoption of

a 30-foot channel in this section for both the 21-foot and 30-foot navigation. The reduction of speed sustained by a ship drawing 19 feet will be much less in water 30 feet deep than in water 21 feet deep. While there are no available data to determine what the difference will be, it appears safe to assume that the reduction of speed of a ship drawing 19 feet will not be more than 10 per cent. when passing from deep lake into 30 feet of water of unlimited width. If the speed is 12½ miles per hour in deep, open water, its speed in water 30 feet deep will be, on this basis, 11¼ miles per hour.

These reductions of speed for the several channels and type ships appear in column 5 of Tables III, IV and V." H. R. Doc. 159, 56 Cong., 2d Sess., pages 219-220-221.

EXTRACT FROM MECHANICAL ENGINEERS' POCKET BOOK BY WILLIAM KENT, SECOND EDITION, 1896, PAGE 1008.

"Results of Progressive Speed Trials in Typical Vessels. (Eng'g, April 15, 1892, p. 463.)

	'Medusa' 3d-Cl. Cruiser.	Atlantic Passenger Steamer.
Length in feet.....	265	525
Breadth in feet.....	41	63
Draught (mean) on trial...	16′ 6″	21′ 3″
Displacement (tons)	2,800	11,550
I. H. P.—10 knots.....	700	2,000
I. H. P.—14 knots.....	2,100	4,600
I. H. P.—18 knots.....	6,400	10,000
I. H. P.—20 knots.....	10,000	14,500

The figures for I. H. P. are 'round'; the 'Medusa's' figures for 20 knots are from trial on Stokes Bay, and show the retarding effect of shallow water. The figures for the other ships for 20 knots are estimated for deep water."

EXTRACT FROM REPORT BY COL. W. M. BLACK, C. E. UNITED STATES ARMY, FEBRUARY 27, 1912, THE SAME BEING A PRELIMINARY EXAMINATION OF THE HUDSON RIVER, NEW YORK, WITH A VIEW TO SECURING INCREASED DEPTH AS REQUIRED BY THE RIVER AND HARBOR ACT OF JUNE 25, 1910.

"83. *Minimum Clearance for Safety.*—Navigation is possible wherever the depth of channel exceeds the draft of the vessel in motion. As affected by the depth, naviga-

tion is safe only where the channel is at all times free from obstructions rising above the general level of its bottom or where the depth is such that there is sufficient clearance between the bottom of the moving vessel and the channel bottom to enable her to pass over any obstruction whose presence is not definitely known and which, therefore, cannot be avoided. The nonexistence of obstructions can be assured only in channels which are continually watched, and is practically attainable only in very restricted water ways such as the entrances to important locks; while sufficient clearance to avoid all possible obstructions can seldom be secured in artificial channels except at prohibitive cost. Hence, a compromise must be made, based on the character of obstructions likely to be encountered, and the nature and volume of the commerce. Under the conditions obtaining in the Hudson River it is thought that reasonable safety required that the clearance be such that obstructions whose presence is known to be probable will be passed over. Such obstructions are building stone or barrels of cement dropped from the decks of barges, snags brought down by the freshets, pieces of wreckage, lost anchors, etc., and the condition of the bottoms of most of the steamers and bills for repairs on the books of the navigation companies bear evidence of the frequency of their occurrence. Great stress is laid on this phase of the question by the officials of the Hudson River Day Line. Where freight-carrying vessels are forced for other reasons to run at very slow speed in a carefully watched channel such as that of a canal, the risk involved in operating with little or no clearance may not be sufficient to justify the expense of obtaining a deeper channel. In the Hudson River effective precautions cannot be taken against the creation of small obstructions, while the river is navigated by both freight carriers and large passenger steamers, making the danger from hitting small obstructions too great and the results too disastrous to justify operation with an adequate clearance. While the existence of obstructions is at present evidenced chiefly by the guarded slow running in the shoal reaches of the river, the liability of serious disasters from this cause is always present, and must increase in a geometrical ratio with the increase in traffic, there being more vessels to create obstructions and more to hit them. Considering the character of most of the obstructions encounterd and the volume and character of traffic anticipated, it is believed that the minimum

clearance allowable for safe navigation in the Hudson River is 2 feet. In Germany the clearance adopted as safe is 1 meter (39 inches).

84. *Relations Between Factors in Channel Design.*—It is a matter of common knowledge that a vessel in motion apparently draws more water than when at rest; that this increase in draft is greater in shoal water than in deep water, and that for a given speed, more power is required in shoal water than in deep water. The increase in draft referred to is commonly known among boatmen as 'squat.' While the existence of these phenomena is well known, there is either an absence of knowledge or a great diversity of opinion with regard to the exact relations obtaining between them. These relations are of vital importance in the determination of proper channel depth, since they affect directly the clearance, power consumption, cost of channel maintenance, and speed; and for this reason it has been attempted to demonstrate, at least approximately, the relations existing between draft, speed, power, and channel cross section under the local conditions prevailing on the upper Hudson. A study has been made of past researches along this line and observations were taken on vessels in actual operation.

85. Details of the information obtained and of the results of the observations made are given in inclosure G of this report. The most important deductions are as follows:

(*a*) The squat of a given boat underway is a function of the channel depth and of the speed of the boat. For channels varying in depth from 12 to 16 feet the squat decreases as the depth increases.

The curves deduced show the following relations (pl. 5 of inclosure G):

	Channel Depths.			
	12 to 13 (Feet.)	13 to 14 (Feet.)	14 to 15 (Feet.)	15 to 16 (Feet.)
Speed 8 miles per hour, squat	1.4	1.2	1	0.9
Speed 10 miles per hour, squat	2.25	1.9	1.5	1.4

In the observed case of the paddle wheel steamer *Hendrick Hudson,* 400 feet long, 45 feet beam of hull, and with normal draft of 9½ to 10 feet, when moving in water 135 feet deep at a speed of 22.5 miles per hour, the squat was 0.99 foot. In the same depth at 11.5 miles per hour

the squat was 0.15 foot. In water 14.4 feet deep at a speed of 9.14 miles per hour the squat was 1 foot. In water of practically the same depth the greatest speed she could make was 9.48 miles per hour, and the squat was 3.25 feet.

(*b*) As might be deduced from the above, the squat at any depth is a function of the power consumed. For a given boat in a given depth of from 12 to 16 feet the squat increases rapidly under the exertion of from 0 to 250 horsepower and more slowly after that power is reached. Here, again, the squat is shown greatest for the least depth. (See inclosure G.)

(*c*) The relation of power to speed in varying depths for a given boat of 7 feet 6 inches draft is shown by the curves of plate 2 of inclosure G, the relative increase of power required being the greater in the lesser depths. For example, to attain a speed of 8 miles per hour in depths varying from 12 to 20 feet the power required will vary from 250 to 125 horsepower. To attain a speed of 10 miles per hour the power runs from 700 to 300 horsepower. In other words, for the given boat moving in 12 feet of water the expenditure of 225 horsepower will give her a speed of 8 miles per hour; while to attain a speed of 10 miles per hour 700 horsepower must be exerted. In 20 feet of water the same boat would have a speed of 9.4 miles per hour with the expenditure of 225 horsepower, and of 12.4 miles per hour for 700 horsepower.

In the case of the *Hendrick Hudson*, previously cited, in about 14 feet of water she exerted 350 horsepower in attaining the speed of 9.1 miles per hour and 730 horsepower for a speed of 9.48 miles per hour.

(*d*) For a given boat the swells produced were a function of the depth and speed, and the destructive effect a function of the channel width.

In 135 feet of water, at a speed of 22.5 miles, the swell produced by the *Hendrick Hudson* was about 1 foot and was inappreciable at a distance of 1,000 feet.

At Bogart Island, near Albany, in a width of 770 feet and a channel depth of 12 feet, while running at a rate of 11 miles per hour, the swell raised at the shore was 5.5 feet from hollow to crest.

86. *Specific Deductions.*—A study of the curves and of

inclosure G will lead to the following conclusions for vessels of the class found in the Hudson River:

1. That in 12 feet of water safe clearance cannot be maintained.

2. That in 13 feet of water safe clearance can be maintained with a speed less than 8 miles per hour.

3. That in 14 feet safe clearance can be maintained with a speed of 10½ miles per hour, but that at this speed the power consumption will be uneconomical and the swells damaging.

4. That in 16 feet a speed of 12 miles per hour can be maintained safely and economically.

5. That speeds greater than 14 miles per hour are uneconomical or unattainable except in very deep water.

The large steamers of the Day Line are designed to operate economically at a speed of 20 miles per hour in deep water. They are scheduled to make the run from New York to Albany as a daylight trip in about 10 hours, and the volume of their through business depends largely on the time element. At present the average speed of both day and night boats north of Hudson is from 7 to 12 miles per hour. The night boats are designed for an economical speed of 15 miles per hour. As they make no stops between Albany and New York, the question of speed is not so important to them as to the Day Line. The most important benefits to be gained by an increase in depth would be for the day boats greater speed and for both day and night boats economy in power and safe clearance."

House of Representatives, 62d Congress, 3d Sess. Doc. No. 1160, pages 34-35-36.

EXTRACT FROM REPORT OF LIEUTENANT R. D. BLACK, INCLOSURE G. OF THE REPORT OF COL. W. M. BLACK ON THE EXAMINATION OF THE HUDSON RIVER, NEW YORK, H. R. DOC. NO. 1160, 62D CONGRESS, 3D SESSION, PAGES 100 AND 102.

"(b) From a set of observations made by the United States under the supervision of H. N. Babcock, United States assistant engineer, on screw steamers operating in a relatively deep channel near Sandy Hook, N. Y., the data contained in the following table were obtained:

Draft of vessel at pier.		Draft in channel	Depth of water in channel.	Squat	Velocity of vessel in miles per hour.	Clearance
Bow	Stern,					
24.6	25.8	29.2	31.7	3.4	18.0	*5.9*
24.0	26.0	29.0	32.3	3.0	15.2	*6.3*
29.1	29.5	32.1	35.8	2.6	17.9	*6.3*
24.3	25.2	26.7	33.3	1.5	15.2	*8.1*
22.2	24.7	25.8	37.7	1.1	14.5	*13.0*

H. R. Doc. No. 1160, 62d Congress, 3rd Session, page 100.

* * * * *

"8. These relations were deduced for and apply exactly to one class and size of steamer only. By using Froude's Laws of Comparison, a similar set of relations may be obtained for other types. However, for use in determining channel requirements in the Upper Hudson, it is thought proper to assume that the relations as given above apply to a vessel not over 500 feet long, with beam over guards of 90 feet, beam of hull 60 feet, and a load draft at rest of 10 feet as the standard steamer to be accommodated. Under these assumptions the following deductions can be made:

(1) That in 12 feet of water safe clearance cannot be maintained.

(2) That in 13 feet of water safe clearance can be maintained with a speed less than 8 miles per hour.

(3) That in 14 feet safe clearance can be maintained with a speed of 10½ miles per hour, but that at this speed the power consumption will be uneconomical and the swells damaging.

(4) That in 16 feet a speed of 12 miles per hour can be maintained safely and economically.

(5) That speeds greater than 14 miles per hour are uneconomical or unattainable except in very deep water.

The large steamers of the Day Line are designed to operate economically at a speed of 20 miles per hour in deep water. They are scheduled to make the run from New York to Albany as a daylight trip in about 10 hours, and the volume of their through business depends largely on the time element. At present the average speed of both day and night boats north of Hudson is from 7 to 12 miles per hour. The night boats are designed for an economical speed of 15 miles per hour. As they make no stops between Albany and New York, the question of

speed is not so important to them as to the Day Line. The most important benefits to be gained by an increase in depth would be, for the day boats, greater speed, and for both day and night boats economy in power and safe clearance."

H. R. Doc. No. 1160, 62d Congress, 3d Session, pages 102-103.

EXTRACT FROM A SPECIAL REPORT BY LT. COL. W. H. BIXBY, U. S. ENGINEER, AT CHICAGO, ENTITLED "EFFECT OF WITHDRAWAL OF WATER FROM LAKE MICHIGAN BY THE SANITARY DISTRICT OF CHICAGO," DATED MAY 22, 1906.

(H. R. Doc. 6, 59th Cong., 1st Sess.)

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Furthermore, by reason of winds and barometric effects, oscillations of 6 inches several times in a single day are frequent, and 2 to 4 feet within an hour are occasionally experienced. Consequently, individual exceptional levels are misleading, and the general effects of water diversions must be measured by annual average rather than by monthly or daily.

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The only way of avoiding such extra dredging will be by holding up the water levels of all these lakes by dams and other controlling works across the exits of these lakes, which will be expensive and probably impracticable for Lakes Michigan and Huron and expensive, but practicable and eventually probable, for Lake Erie. The diversion of the 14,000 cubic feet per second named in the request of the Chicago sanitary district of April 11 would therefore mean future dredging some day to 0.7 foot extra depth in all harbors of Lakes Michigan and Huron and to 0.6 foot in those of Lake Erie (or its equivalent in dams, etc.). The cost of such dredging or of dams, etc., will be the price to be eventually paid by the Federal Government for granting such privileges to the sanitary district.

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In the few cases where past troubles from currents have been real, they have been due to the contracted channel ways at bridges, tunnels, and other special points, where full dimensions of water flow have already been secured or are be-

ing secured by the drainage district improvements, or will be soon provided by tunnel owners. These troubles in the past have been quite freely and fully commented upon or reported upon by the boat interests and by this office, the most important of such reports being those of the hearing before the honorable Secretary of War, May 16, 1900 (E. D. 35242/7), that of Major Willard, February 16, 1901 (with third indorsement on E. D. 35242/26), that of Major Willard, June 20, 1900 (E. D. 35242/(?)), that of Major Willard, March 29, 1901 (with third indorsement on E. D. 35242/40), and that of Colonel Ernst, November 5, 1901 (which led to permit E. D. 35242/74, quoted above). These reports show that the greatest velocity heretofore actually observed at any single point of the worst old bridge draw opening (that of Canal street, now greatly improved), was 2.24 miles per hour (3.29 feet per second), while the average for a whole cross section at this draw was only about 1.8 miles per hour (2.6 feet per second), and the average for a full 200-foot width of river just above and below the bridge would not have been over 1.2 miles per hour (1.8 feet per second); and that even a large part of this was probably due to sudden changes of lake levels for which the drainage district was not responsible. These currents, although much complained of at the time, are not greater than are constantly encountered in many tidal rivers on the Atlantic coast, where no complaints are made, because all boat captains and pilots are accustomed to such currents and make their arrangements accordingly.

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17. In the capacity of sewer to properly carry off all the diluted sewage which the sanitary district must dispose of in the future, the South Branch and West Fork of Chicago River and the district drainage canal will need the use of the full cross section now being given to them at their typical points of constriction, viz., 4,700 square feet in South Branch, Chicago River, where a future 8,000 cubic feet per second is now asked for; 5,200 square feet in West Fork, South Branch, Chicago River, 5,412 square feet in the earth sections and 3,542 square feet in the rock sections of the drainage canal, for all of which 10,000 cubic feet per second is now asked for; and 5,412 square feet in the lower (south) end of the drainage canal, where 14,000 cubic feet per second is now being asked for. I assume that after this volume of water

reaches the Des Plaines and Illinois rivers it can be taken care of more easily than in the Chicago River and that the 2,800 square feet cross section of the proposed 14-foot waterway, now under consideration by Congress, will be supplemented sufficiently by the rest of the natural river on each side of the improved boat channel. The above cross-sections, so long as no boats lie at wharves or pass up and down the river, will allow the passage of the 8,000 cubic feet per second through the South Branch, with average velocities of not exceeding about 1.2 miles per hour (1.7 linear feet per second); 10,000 cubic feet through the West Fork, with average velocities of not exceeding about 1.3 miles per hour (1.9 linear feet per second), and the same flow through the earth sections of canal at not exceeding 1.2 miles per hour (1.8 linear feet per second), and through the rock section of canal at not exceeding 1.9 miles per hour (2.8 linear feet per second); and 14,000 cubic feet through the lower end of canal at not exceeding 1.8 miles per hour (2.6 linear feet per second).

Wherever the full free cross section of the river is obstructed by bridge abutments or by boats, either at docks or passing, the average 8,000 to 10,000 cubic feet per second water flow must pass through the reduced cross section at increased speed. The full development of this increase, while not instantaneous, will require only a few moments. In this manner, at bridges, the velocities will be increased for a short length by about 30 per cent.; at places where two boats of 40 to 50 feet beam and 800 square feet wetted cross section are abreast the increase of velocity will be about 50 per cent.; at places where three such boats are abreast the increase will be about 100 per cent.; and in case four such boats should be abreast (one tied up at the wharf on each side of the stream and two others trying to pass in mid-river), the increase will be about 200 per cent. The drainage currents in the South Fork, South Branch, due to the 2,000 cubic feet per second coming from the Thirty-ninth street pumping station, and in the North Branch, due to a similar pumpage probably soon to be established at some street near Evanston, in the north end of Chicago, will be only about one-half of those in the South Branch, and their effects will probably be so small as not to be complained of by navigation interests. The drainage currents in the canal proper between the West Fork and Lockport will be about the same as in the South Branch; but as this part of the canal was

not originally a public water way and has not yet been accepted as such by the Federal Government, it is doubtful whether the United States can object to any currents which its owners may establish or desire to establish therein. It is therefore evident that so long as the Chicago River serves merely as a sewer and is not to be used by boats the drainage district currents will not be objectionable, but as soon as it is also used as a harbor or as a canal or water route the currents begin to be seriously questionable.

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25. Summing up the above it may be briefly stated, therefore, that 10,000 cubic feet per second dversion of water from Lake Micihgan into the drainage canal will be, probably, not unreasonably obstructive to navigation and injurious to property if divided up into 6,000 cubic feet per second through the main river and south branch, increased by 2,000 cubic feet per second more through the Thirty-ninth street sewer and 2,000 cubic feet per second more through Calumet River (10,000 cubic feet per second in all), but that an increase in these amounts to 8,000, 2,000, and 4,000 cubic feet, respectively (14,000 cubic feet per second in all), will probably prove to be unreasonably obstructive and injurious. Also that the 10,000 cubic feet per second will eventually and permanently lower the levels of Lakes Michigan and Huron by about 0.5 foot and Lake Erie by about 0.4 foot, and 14,000 cubic feet per second will make these depths 0.7 and 0.6 foot, respectively, which will be quite costly in future results.

EXTRACT FROM THE REPORT ON A WATERWAY FROM LOCKPORT, ILL., TO THE MOUTH OF THE ILLINOIS RIVER, BY A SPECIAL BOARD OF ENGINEERS OF WHICH GEN. W. H. BIXBY WAS CHAIRMAN, DATED JAN. 23, 1911.

(H. R. Doc. 1374, 61st Congress, 3rd Session.)

* * * * *

By virtue of the act of Congress of March 30, 1822, dedicating to the State of Illinois the land necessary for a canal connecting the Illinois River with Lake Michigan, and the act of March 2, 1827, granting to the State certain public lands for the purpose of aiding in its construction, and the acceptance by the State of the conditions imposed therein, the State of Illinois obligated itself to construct a suitable

waterway from Lake Michigan to the navigable waters of the Illinois River. In accordance with this agreement the State constructed the Illinois and Michigan Canal, from Bridgeport to LaSalle, and improved the upper portion of the Illinois River by the construction of locks and dams at Henry and Copperas Creek.

For many years this waterway was a valuable transportation route, but in recent years the State has neglected it and failed to maintain it abreast of the needs of commerce. The work now proposed by the State in connection with the canal of the Chicago Sanitary District contemplates a waterway from Lake Michigan to Utica, which, although departing from the line of the old canal, substitutes a waterway more than sufficient for any probable navigation. This will in effect fulfill the original agreement between the State and General Government for this section and incidentally develop a water power which the State considers a profitable business investment. State or local agencies are better adapted than the General Government for conserving water power for their citizens.

The Board believes that the State is more generous in its provisions for navigation than necessity requires, that the locks it proposes are larger than will be utilized, and that its original agreement would be amply fulfilled if it constructed locks 600 by 80 by 11 feet, and reserved at each lock ground sufficient for an additional lock should it ever be required, but it is also of the opinion that the State should be permitted to expend its own funds in such manner as it deems proper. With locks of the dimensions suggested by the Board the $20,000,000 authorized to be appropriated by the State should complete this part of the waterway; and unless large expenditures are required for power rights, even the larger locks could be constructed for that amount.

The General Government will then fully co-operate with the State in a waterway from Lockport to the mouth of the Illinois River if it assumes charge of the State structures at Henry and Copperas Creek, and enlarges the existing channel in the Illinois River below Utica to suitable dimensions. The Mississippi river from the mouth of the Illinois to St. Louis should also be suitably deepened.

ORDINANCES OF THE CITY OF CHICAGO, IN CHICAGO CODE, 1911. ARTICLE V, SECTIONS 1130, 1131, AND 1134, PP. 429-430.

Article V.

SANITARY REGULATIONS OF HARBOR.

1130. Befouling Stream—Dredging—Penalty] No person shall cast or deposit or suffer to be cast or deposited in the harbor of the city or anywhere in Lake Michigan within five miles of the harbor, any earth, ashes or other heavy substance or substances, filth, logs, or floating matter, or any obstructions. No tug owner or captain or other person in charge or command of a tug shall tow, inside the harbor, any dumping scow or like vessel, with or without a collapsible or adjustable bottom, loaded with clay, earth, ashes, filth or other substance or substances unless there is on board at the time of such towing an inspector from the department of public works. It shall be unlawful for any dredge or other machine to cut clay or dredge sand or other material from the bed or bottom of the harbor of the city, unless the person present conducting such work have in his possession a permit in writing from the department of public works, in which permit the location and time occupied in such work shall be specified, and such person conducting such work shall produce such permit on demand of the harbor master or any of his assistants. It shall be the duty of the harbor master to cause the arrest of any person in charge of any tug, scow or dredge who violates any of the provisions of this section, and such person shall be fined not less than fifty dollars nor more than one hundred dollars for every such offense.

1131. Garbage in Lake, or River—Penalty] No person shall throw, place or deposit or cause to be thrown, placed or deposited any garbage, vegetable matter, dung, carrion, dead animal, offal or putrid or unwholesome substance, or the contents of any privy, upon the margin or banks or into the waters of the harbor.

Any person who violates, or fails to comply with, any of the provisions of this section shall be fined not less than ten dollars nor more than two hundred dollars for each offense.

1134. Contents of Privy, Etc., in Lake or River.—Penalty] No person shall throw, drop or permit to fall into the harbor, any offal or any unwholesome substance being or having been part of the contents of any vault, cesspool, catch basin, privy, sink, tub or receptacle.

Any person who violates or fails to comply with any pro-

vision of this section shall be fined not less than ten dollars nor more than two hundred dollars for each offense.

EXTRACT FROM INTERNATIONAL WATERWAYS COMMISSION PROGRESS REPORT, TRANSMITTED TO CONGRESS BY PRESIDENT TAFT, DECEMBER 3D, 1912, SENATE DOC. No. 959, 62D CONGRESS, 3D SESSION, PAGE 8.

(Extract from the report of the American Commissioners, Col. Ernst, George Clinton and E. E. Haskell):

"Niagara River.

9. Upon taking up the subject of the Niagara River the commission found that great amounts of capital had been, and were continuing to be, invested in power works at Niagara Falls by private corporations under the authority of the State of New York or of the Province of Ontario. Many millions of dollars had been expended in the works themselves and many millions more in the industrial enterprises to which they furnished power. In addition to the five principal corporations actually engaged in the development of water power, there were several other corporations preparing to engage in that work under franchises, some of which had been granted and others of which were being sought for. The total destruction of Niagara Falls, as a scenic spectacle was threatened. It seemed desirable that this movement should be checked without delay, and as the collection of all the data and the preparation of a full report would require time, the commission at its meeting of October 28, 1905, passed the following resolution, of which copies were sent to the Secretary of War of the United States and the minister of public works of Canada, viz.:

Resolved, That this commission recommends to the governments of the United States and Canada that such steps as they may regard as necessary be taken to prevent any corporate rights or franchises being granted or renewed by either Federal, State or Provincial authority for the use of the waters of the Niagara River for power or other purposes until this commission is able to collect the information necessary to enable it to report fully upon the 'condition and uses' of those waters to the respective governments of the United States and Canada.

10. By March, 1906, the information necessary for the report had been collected, public hearing, had been held and an original map of the locality, specially constructed for the purpose, had been prepared, when Congress passed

the following joint resolution, approved March 15, 1905, viz.:

> *Resolved, By the Senate and House of Representatives of the United States of America in Congress assembled,* That the members representing the United States upon the international commission created by section four of the river and harbor act of June thirteenth, nineteen hundred and two, be requested to report to Congress at an early day what action is, in their judgment, necessary and desirable to prevent the further depletion of water flowing over Niagara Falls; and the said members are also requested and directed to exert, in conjunction with the members of said commission representing the Dominion of Canada, if practicable, all possible efforts for the preservation of the said Niagara Falls in their natural condition.

The American section accordingly submitted a report, dated March 19, 1906. It was published as Senate Document No. 242, Fifty-ninth Congress, first session. It was subsequently concurred in substantially by the Canadian section, and the joint report of the full commission, dated May 3, 1906, was published as Senate Document No. 434, Fifty-ninth Congress, first session.

11. The report of March 19 was followed by an exhaustive investigation of the subject by the Rivers and Harbors Committee of the House of Representatives, who, during several weeks, held public hearings in Washington, at which all persons interested were given an opportunity to be heard, and who sent a subcommittee to Niagara Falls, where a thorough inspection of the works was made, and where also there was a public hearing. The result was a confirmation of the report in all essential particulars.

12. An 'act for the control and regulation of the waters of Niagara River, for the preservation of Niagara Falls, and for other purposes,' approved June 29, 1906, was then passed by Congress. It authorized the Secretary of War to grant permits for the diversion of water on the American side, and for the transmission of electrical power from Canada, under certain prescribed conditions and to certain prescribed limits. The total amount authorized being considerably less than the amounts applied for by the power companies, a more detailed investigation, which should embrace particularly the commercial

and financial side of the power-producing industry at Niagara Falls, became necessary to insure an equitable division of the amounts authorized. Capt. Charles W. Kutz, Corps of Engineers, United States Army, was detailed by the Secretary of War to make the investigation, his reports to be submitted to the American section for review and recommendation. Under these instructions the American section submitted two reports, dated September 29, 1906 (Appendix A), and November 15, 1906 (Appendix B) respectively. Special difficulties having arisen in granting a permit for the diversion of water from the Erie Canal, the American section, under instructions from the Secretary of War, caused a map of Lockport, N. Y., to be prepared, and new measurements of flow to be made at that place, and under date of March 5, 1907, submitted a special report with a form of permit. (Appendix C.)

13. Other reports relating to power development in the Niagara River were dated September 9, 1907, and March 3, 1908. The first was by the American section, and related to a letter from the Niagara Falls Hydraulic Power & Manufacturing Company to the Secretary of State, in connection with the treaty then under negotiation with Great Britain. (Appendix D.) The second was by the full commission, and related to a bill to authorize the diversion of water below the Falls, which had been referred to the commission by the Rivers and Harbors Committee of the House of Representatives of the United States. (Appendix E.)

14. During the summer of 1908 the works of the Niagara Falls Power Company were shut down on three occasions, and upon one of these occasions the works of the other power company on the American side, the Niagara Falls Hydraulic Power & Manufacturing Company, also were almost completely shut down. The commission, having been notified in advance, took advantage of the opportunity to observe the effect upon the river and the Falls of the diversion or nondiversion of the considerable body of water used by those companies. By its direction its American secretary installed water gauges at various points at and above the falls and had them observed before, during and after the shutdowns, and afterwards discussed his observations in a report. The conclusions which he reached were that the diversion of 8,000 cubic feet per second through these plants lower the level of Niagara River at Grass Island, near the intake of the

Niagara Falls Power Company, about 3¼ inches; near the Ontario intake, on the Canadian side, about 1¼ inches, and at Prospect Point, the crest of the American Falls, about four-tenths of an inch. The observations are a valuable contribution to existing knowledge of the effect of power diversion upon the falls." * * *

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"CHICAGO DRAINAGE CANAL.

21. On the 4th of January, 1907, the full commission submitted to the two governments a report upon the Chicago Drainage Canal, which closed with the following summary and recommendations:

SUMMARY.

(*a*) Chicago obtains its water supply from Lake Michigan, and to avoid polluting it must either dispose of its sewage otherwise than in the lake or place its intakes for water at a great distance from the city.

(*b*) The topography of the country favors the discharge of the sewage into the Des Plaines River, a tributary of the Mississippi, through two depressions in the divide which separates the river from Lake Michigan.

(*c*) The slope on the lake side of the divide is drained by two streams, the Chicago River and the Calumet River, into which the sewers of the city empty. By a cut through the northerly depression the flow of the Chicago River has been reversed and diverted into the Des Plaines River instead of into Lake Michigan, and by a cut through the southerly depression the same process can be applied to the Calumet River.

(*d*) To make this reversal effective the channels must be large enough to take all the water which falls upon the respective drainage areas during the most violent rain storms. This amount is estimated at 10,000 cubic feet per second for the Chicago River and 15,700 cubic feet per second for the Calumet River.

(*e*) The City of Chicago was originally built upon the Chicago River, and that stream now drains the richest and most populous part of the city. It is now spreading over the Calumet region.

(*f*) In 1889 the plan of diverting the Chicago River into the valley of the Des Plaines was definitely adopted and the Chicago Drainage Canal was undertaken. It was designed to carry 10,000 cubic feet per second. Though

not entirely completed, it has been in use since January, 1900. The amount expended upon the canal and accessory work is about $41,000,000.

(*g*) The Illinois law which authorized the canal required a flow of 333 cubic feet per second for each 100,000 of population in order to render the sewage inoffensive. This amount of dilution is probably not excessive. It is reasonable to expect a population in a future not remote of five or six million or more, involving the diversion by this standard of some 20,000 cubic feet per second. The Chicago River, with its 10,000 cubic feet, provides for a population of 3,000,000. The present population of the city is about 2,000,000.

(*h*) It is now proposed to apply to the Calumet River a treatment similar to that applied to the Chicago River—viz., to reverse its flow, so that instead of discharging into Lake Michigan it shall discharge into the Des Plaines, but for a part of the new route it must follow the drainage canal already excavated for the Chicago River.

(*i*) Although the Chicago Drainage Canal was designed to carry 10,000 cubic feet per second, it is found to have, in its completed rock portion, an actual capacity of 14,000 cubic feet. This additional capacity fixes the amount which it is proposed to divert from the Calumet at 4,000 cubic feet per second. Any greater amount from the Calumet will overtax the drainage canal at the expense of the richest part of Chicago and for the benefit of a suburban part.

(k) The diversion of only 4,000 cubic feet will not be effective at all times, since a much larger amount must be diverted from the Calumet during heavy rainstorms if the lake is to be protected. Moreover, it provides for a population not exceeding 1,200,000, which number will probably be exceeded at a date not far distant.

(l) The large channels necessary to provide for the contingencies of rainstorms are capable of discharging a volume of water largely in excess of sanitary requirements during the greater part of the year, but the development of water power creates the demand that they be employed to their full capacity throughout the year.

(m) The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress, but there appears to be a tacit

general agreement that no objection will be made to the diversion of 10,000 cubic feet per second, as originally planned.

(n) The diversion of 10,000 cubic feet per second, will lower the levels of Lake Michigan-Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, besides the important connecting channels, the Detroit and St. Clair Rivers, by amounts varying from 4½ to 6½ inches for the different waters, and the diversion of 14,000 cubic feet will lower them from 6 to 8½ inches. The diversion of 20,000 cubic feet will lower Lake Michigan-Huron about 13 inches and Lake Erie about 11 inches.

(o) The lake traffic which passed through the Detroit River in 1905 was about 58,000,000 tons, valued at about $615,000,000. It is increasing annually with marvelous rapidity. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit River in 1906 exceeded 65,000,000, valued at $690,000,000. The lowering of the water surface has a very injurious effect upon this traffic and upon that of the Welland and St. Lawrence Canals. Chicago being one of the principal lake ports, there will be very few communities which will feel the injury more than she will.

(p) The cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is estimated at $10,000,000 and of restoring it in the Welland and St. Lawrence Canals at $2,500,000. This expenditure would not prevent very serious annoyance to the navigation interests during the execution of the remedial works, which would occupy several years. In Lake St. Clair, navigation of the open lake would be replaced by that of an artificial channel or canal with submerged banks.

(q) The extension to the Calumet region of the method of sewage disposal already applied to the Chicago River is not necessary to preserve the health of Chicago, there being other and better methods available for the Calumet region. The final cost of these methods is somewhat greater than that of the one proposed, but the works can be developed as the population increases, and only a part of their cost need be incurred at present,

while their greater efficiency justifies the increase of final cost.

(r) The diversion of 10,000 cubic feet of water per second at Chicago will render practicable a waterway to the Mississippi River 14 feet deep. Any greater depth must be obtained by the abstraction of more water from Lake Michigan and at the expense of the navigation interests of the Great Lakes and of the St. Lawrence Valley.

(s) The effect upon Niagara Falls of diverting water at Chicago is of secondary importance when considering the health of a great city and the navigation interests of the Great Lakes and of the St. Lawrence Valley, but it is proper to note that the volume of the Falls will be diminished by the full amount diverted at Chicago.

RECOMMENDATIONS.

(t) The waters of Lake Michigan in the United States, the waters of Georgian Bay in Canada, and the waters of Lake Superior, partly in the United States and partly in Canada, all form sources of supply of the Great Lakes system, finding their way by the St. Lawrence to the sea. All are interdependent, and there can be no diversion from any of them without injury to the whole system. By Article XXVI of the treaty of 1871, it is provided that 'navigation of the River St. Lawrence, ascending and descending from the forty-fifth parallel of north latitude, where it ceases to form the boundary between the two countries, from, to, and into the sea, shall forever remain free and open for the purposes of commerce to the citizens of the United States, subject to any laws and regulations of Great Britain, or of the Dominion of Canada, not inconsistent with such privileges of free navigation.' It is desirable that in any treaty arrangement the water of Lake Michigan, Georgian Bay, and all other waters forming part of the Great Lakes system should be declared to be 'forever free and open for the purposes of commerce' to the citizens of the United States and the subjects of His Britannic Majesty, subject to any laws or regulations of either country not inconsistent with such privilege of free navigation.

(u) The preservation of the levels of the Great Lakes is imperative. The interest of navigation in these waters

is paramount, subject only to the right of use for domestic purposes, in which term is included necessary sanitary purposes. In our report of November 15, 1906, upon the application of the Minnesota Canal and Power Company to divert certain waters in Minnesota, we recommended among other things:

'That any treaty which may be entered into should define the uses to which international waters may be put by either country without the necessity of adjustment in each instance, and would respectfully suggest that such uses should be declared to be—

'Uses for necessary domestic and sanitary purposes.

'Service of locks for navigation purposes.

'The right to navigate.'

It is our opinion that so far as international action is concerned a treaty provision of that kind is all that is required in this case. We accordingly renew our recommendation of November 15, 1906, just quoted.

(v) A careful consideration of all the circumstances leads us to the conclusion that the diversion of 10,000 cubic feet per second through the Chicago River will, with proper treatment of the sewage from areas now sparsely occupied provide for all the population which will ever be tributary to that river, and that the amount named will therefore suffice for the sanitary purposes of the city for all time. Incidentally, it will provide for the largest navigable waterway from Lake Michigan to the Mississippi River which has been considered by Congress.

We therefore recommend that the Government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal.

Two editions of this report were printed as a War Department document, and were distributed to all persons applying for them. A copy is hereto appended. (Appendix I.) * * *

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DAM AT THE OUTLET OF LAKE ERIE.

32. The organic act creating the commission prescribed as one of its duties that it should 'report upon the advisability of locating a dam at the outlet of Lake Erie with a view to determining whether such dam will benefit navigation.' It so happens that the term 'dam' may apply to various works of which the character and object are very different. At the time of passing the act

Congress had before it the report of the board of engineers upon deep waterways between the Great Lakes and Atlantic tide-waters, dated June 30, 1900, in which it was recommended that the level of Lake Erie be 'regulated'—that is, that its oscillations be reduced—by means of a submerged weir in connection with a set of sluice gates placed at its outlet near the head of Niagara River. It seemed probable that this was the kind of works which Congress had in mind when using the term 'dam.' Their object would be to raise the low-water surface of the lake without raising the high-water surface. But the term 'dam' may also be applied to a submerged weir without sluice gates, the object of which would be simply to raise the level of the lake without reducing its oscillations. The low-water surface would be raised, but so would the high-water to nearly an equal amount. To distinguish works of this kind from those designed to 'regulate' the lake, they may be called 'compensating works.'

33. The Great Lakes, with their connecting channels, constitute the most important system of inland navigation in the world. The traffic which passed through Detroit River, its busiest link, in 1907, amounted to 71,226,895 tons, valued at about $700,000,000 (the traffic of the most important river in Europe, the Rhine, was in 1905, about 4,000,000 tons). About 80 per cent. of this traffic is carried in large freight carriers which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the lakes, but could be loaded much deeper if the depth of water permitted. Some of the larger of these vessels carry an additional load of 85 tons for each inch of additional draft. Every inch added to the available depth of water would therefore be of material benefit to commerce.

34. The Great Lakes constitute a series of enormous natural reservoirs, each of which serves to regulate the flow in the river constituting its outlet and to maintain the lake below. They are interdependent. The study of one, to be complete, must include the study of all. The total area drained by them is about 287,688 square miles, an area considerably larger than the German Empire. Of this total about one-third is occupied by the lakes themselves—that is, devoted to reservoir purposes. The result is a uniformity of level and a uniformity of flow which are truly wonderful—a perfection of regulation

which no work of man ever did or ever will approach. The question propounded was, Could he add to any important extent to the degree of regulation which nature provided? Enormous forces were to be dealt with, and the results were to be measured in inches. The subject was therefore as difficult as it was important.

35. Soon after the organization of the commission, a committee of two of its engineer members was appointed to collect all of the available data and to make an hydraulic analysis of the general regulation of all the lakes. It was well known at the outset that this would be a long and laborious task, but it proved to be more so than was expected, and the death of a member of the committee, Mr. Wisner, in 1906, was the cause of considerable delay. All existing records of water-level observations and discharge measurements made since 1860 were collected, analyzed, tabulated, and studied. By the end of 1909 the commission was able from these studies to form an opinion as to the first kind of works covered by the term 'dam'; that is, regulating works. The conclusions then reached were that only a very moderate degree of improvement in regulation over what nature provides is practicable in any of the lakes, and that such as it is, this improvement is obtained at the expense and to the injury of the navigable channels below. In the case of Lake Erie, it would be possible to raise the extreme low-water stages about 1 foot, and this in turn would raise the low-water stages of Lake St. Clair about 0.61 foot, and of Lake Huron-Michigan about 0.27 foot, all without appreciable increase in the extreme high stage. But in doing this the low-water stage of Lake Ontario would be lowered about 4½ inches, the available depth in the St. Lawrence canals would be diminished about 7 2/3 inches, and the city of Buffalo would suffer by increased damage from floods and from a postponement of the date of opening navigation in the spring. The question of damage to vested rights was thus introduced in a particular intricate form.

While the advantages of regulation might outweigh the disadvantages if the persons who were to benefit from the former were identical with those who were to suffer from the latter, the difference was not great enough to justify the two Governments in entering upon the vexatious question of damages. The commission therefore

decided to recommend that the 'regulation' of Lake Erie be not undertaken and to proceed to the consideration of the other kind of works covered by the term 'dam' or compensating works. As this would require surveys and investigations which would cover many months, it decided also to submit to the two Governments without further delay the data which it had collected and the conclusions which it had reached concerning one branch of the subject committed to it. This it did in its report dated January 8, 1910. The report was forwarded to Congress by the President and was published as House Document No. 779, Sixty-first Congress, second session. An edition was printed also for the use of the commission, at the joint expense of the Canadian and American sections. The report is accompanied by 42 tables, many of them of elaborate character, and by 29 plates. An examination of it will give an idea, though a faint one, of the amount of time and labor expended upon it.

36. There remained to be considered the other kind of works covered by the term 'dam' or compensating works. The Niagara River at its extreme upper end is an important safety valve for the protection of Buffalo from the effect of storms upon Lake Erie, and should not be obstructed by a dam, but it was believed that somewhere in the river between Lake Erie and the Falls a submerged dam might be placed which would greatly benefit the navigation of the waters above without injury to those below, and with only minor damages, if any, to the adjoining lands. Without any attempt to 'regulate' Lake Erie, the general level of the lake might be raised sufficiently to compensate for the damages heretofore inflicted by the Chicago Drainage Canal and other deteriorating influences. To determine the best site for such a dam it has been necessary to make additional surveys. To determine the best form for this dam, which must be of the submerged type, a large number of experiments upon several different forms was necessary. These experiments were made at the hydraulic canal of the college of civil engineering of Cornell University, the use of which was given free of expense. The results of these experiments were very satisfactory and they will be given in the report soon to be submitted. It was hoped that this work would be completed and a final report rendered before this time, but the illness of a mem-

ber of the committee, Mr. Coste, and his absence in Europe, has caused an unexpected delay."

EXTRACT ENTITLED APPENDIX I ATTACHED TO THE INTERNATIONAL WATERWAYS COMMISSION PROGRESS REPORT ABOVE MENTIONED.

Page 67:

"Report Upon the Chicago Drainage Canal by the Commission, January 4, 1907.

International Waterways Commission,
Toronto, Ontario, January 4, 1907.

The Honorable Secretary of War of the United States and the Honorable Minister of Public Works of Canada:

The International Waterways Commission has the honor to submit the following report upon the Chicago Drainage Canal:

1. The headwaters of the Illinois River, an important tributary of the Mississippi, approach within 10 miles of Lake Michigan near its southerly end, where stands Chicago. The river, called here the Des Plaines, is separated from the lake by a low and narrow divide running nearly north and south. In the divide are two depressions, about 8 miles apart, in which the height is only about 10 feet above the surface of the lake. The area eastward of the divide is drained by two streams, the Chicago and the Calumet Rivers, which empty into Lake Michigan.

The City of Chicago was originally built on the Chicago River, and, although it is now spreading into the Calumet region, it was for many years drained exclusively by the Chicago River, and its principal parts are now so drained. This river constitutes the main sewer of Chicago. The lake furnishes the city's water supply. To prevent the pollution of the water supply by sewage has always been the most important municipal problem with which Chicago has had to deal. Its solution has from a very early day been found in diverting a part of the river's flow into the valley of the Des Plaines through the most northerly of the two depressions mentioned above. The Illinois and Michigan Canal, which was opened to navigation in 1848, was at once utilized for this purpose, and all subsequent improvements consisted in efforts to force more sewage through that canal until, in 1889, it was decided to build a new and greatly enlarged

channel which should completely divert the Chicago River from Lake Michigan and draw from that lake a body of pure water large enough to make the sewage inoffensive to the communities by whose doors it must pass.

2. Before embarking upon this work the city in 1886 appointed a commission of three engineers 'to consider and report on any and all things which relate to the matter of water supply and drainage of the City of Chicago.' In January, 1887, the commission submitted a report to the mayor and city council of Chicago (copy appended marked 1), which it styled a preliminary report. It intended to submit an additional or final report in which the data upon which its conclusions were based should be given in greater detail, but such additional report was never submitted. After remarking that 'almost every conceivable way of dealing with these questions had been suggested and in some form applied during the past thirty years,' the commission stated that 'among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy of consideration, namely, a discharge into Lake Michigan, a disposal upon land, and a discharge into the main river.' It considered the first method too expensive, involving as it does a wide separation between the outlets of the sewers and the intakes of the water supply. It pronounced the second inapplicable to the metropolitan district as a whole, under the topographical conditions existing, but thought that it might be employed for the extreme northern and southern parts, the latter including the Calumet region. It recommended the third method. It was uncertain as to the quantity of water required to dilute the sewage so as to make it inoffensive, but in order to prepare an estimate of cost it was compelled to assume some approximate size of channel, and it did assume a size large enough to discharge 600,000 cubic feet per minute, that being the estimated amount of water falling upon the area tributary to the Canal during storms and not otherwise disposed of. It includes the drainage basis of the upper Des Plaines and of the Chicago Rivers, but not that of the Calumet River. With a channel of less dimensions in times of storms and floods the Chicago River would not be fully diverted into the Des Plaines, but would back up into Lake Michigan. The result was a supply of 24,000

cubic feet per minute for each 100,000 people in a population of 2,500,000, the population which the commission thought it desirable to provide for, and the opinion was expressed that this would equal the maximum requirements.

3. Following this report the Illinois Legislature passed an act approved May 29, 1889, 'to create a sanitary district and to remove obstructions in the Des Plaines and Illinois Rivers,' of which the twenty-third and twenty-fourth paragraphs read as follows, viz:

'Paragraph 23. If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Des Plaines or Illinois Rivers, such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than 14 feet, and a current not exceeding 3 miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than 18 feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than 160 feet at the bottom capable of producing a depth of not less than 18 feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000, such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than 3 miles per hour, and if at any time the General Government shall improve the Des Plaines or Illinois Rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall, within one year thereafter, enlarge the entire channel leading into said Des Plaines or Illinois Rivers from said district to a suffi-

cient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute, with a current of not more than 3 miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water of not less than 18 feet throughout said channel, and shall have a width of not less than 160 feet at the bottom. In case a channel is constructed in the Des Plaines River, as contemplated in this section, it shall be carried down the slope between Lockport and Joliet to the pool, commonly known as the upper basin, of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act may correct, modify and remove obstructions in the Des Plaines and Illinois Rivers wherever it shall be necessary so to do to prevent overflow or damage along said rivers, and shall remove the dams at Henry and Copperas Creek, in the Illinois River, before any water shall be turned into the said channel. And the canal commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers by any drainage district or districts, to maintain a depth of not less than 6 feet from any dam owned by the State to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dams, at low water, then it shall be the duty of said canal commissioners to cause such dam or dams to be removed. This act shall not be construed to authorize the injury or destruction of existing water-power rights.

'Paragraph 24. When such channel shall be completed, and the water turned therein, to the amount of 300,000 cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the General Government shall improve the Des Plaines and Illinois Rivers for navigation, to connect with this channel, said General Government shall have full control over the same for navigation purposes but not to interfere with its control for sanitary or drainage purposes.'

By this act a flow of not less than 20,000 cubic feet per minute is required for each 100,000 inhabitants and provision is made for a population of 3,000,000. The evidence before the legislative committee which framed the

bill as to the quantity required was contradictory. The amount fixed for dilution of the sewage was a minimum. (See Appendix I_2.)

4. Under this act the Sanitary District of Chicago was organized, embracing all of the city north of Eighty-seventh street and some 43 square miles of Cook County outside of the city limits. The total area of the district was 185 square miles and did not include the Calumet region nor the north shore. The trustees held their first meeting January 18, 1890. The Chicago Drainage Canal was then constructed, water being turned into it for the first time in January, 1900. It was not then, and has not since been, completed to its full capacity as designed. In some places where the excavation was in rock the full dimensions of the prism were taken out, but in earth a considerable volume was left to be removed by the easy method of dredging hereafter. When fully completed it was designed to have a capacity of 600,000 cubic feet per minute, or 10,000 cubic feet per second, flowing at a velocity of 1.25 miles per hour in earth and 1.9 miles per hour in rock.

5. The canal is 28.05 miles in length. For a distance of 7.8 miles from its junction with the Chicago River at Robey street its dimensions are 110 feet width at bottom, side slopes 1 on 2, depth of water 22 feet at low stage of Lake Michigan, with a grade of 1 in 40,000, the material being earth. This section is eventually to have a width of 200 feet at bottom.

6. For a farther distance of 5.3 miles, although the material is principally earth, the dimensions are 202 feet width at bottom, side slopes 1 on 2, minimum depth of water 22 feet, with a grade of 1 in 40,000. This section is completed.

7. For the remaining 15.95 miles the canal is excavated wholly or partially in rock. Where the natural rock does not come to the surface walls of masonry have been built upon the rock surface, thus artifically carrying it to a height 5 feet above datum. The dimensions here are 160 feet width at bottom, 162 feet width at top, minimum depth of water 22 feet, with a grade of 1 in 20,000. This section also is completed.

8. The controlling works are situated near the town of Lockport at the western end of the canal. They consist of a bear- trap dam 160 feet wide, with a vertical

play of 17 feet, and of seven sluice gates of the Stoney type, each 30 feet wide and having a vertical play of 20 feet. These works provide a very efficient means of controlling the flow of water through the canal.

9. The project of the sanitary district for the disposal of sewage by the canal when completed is briefly as follows: All sewers will discharge into the Chicago River, either directly or through intercepting sewers. From the mouth in Lake Michigan to the point where the North and South Branches unite the river will flow 8,000 cubic feet per second, less such quantity as may be pumped into the upper portion of the North Branch, which under the original project was 200 cubic feet per second admitted through a conduit at Fullerton avenue. From this point the combined flow will be 8,000 cubic feet to the point where the South Fork enters the South Branch, where it will be increased to 10,000 cubic feet by water pumped from Lake Michigan at Thirty-ninth street and flowing through a large conduit in Thirty-ninth street to the South Fork. The volume which will finally enter the canal under this project will be 10,000 cubic feet per second.

10. The channel of the Chicago River is not large enough to transmit that volume from the lake to the canal except at velocities which are an obstruction to navigation. The amount which the Secretary of War has thus far permitted the sanitary district to pass through the river is 4,167 cubic feet per second. In order to obtain authority for a larger amount the trustees have undertaken to enlarge the channel of the river and have accomplished a large amount of work in that direction.

11. By act of the Illinois Legislature in 1903 the sanitary district was enlarged by annexing thereto the north shore district, containing 78.6 square miles, and the Calumet district, containing 94.48 square miles. The total area of the sanitary district is therefore now 358.08 square miles. The same legislature authorized the development of the water power created by the diversion.

12. The plans for the north shore region involve two additional conduits from the lake to the North Branch of the Chicago River, one at Lawrence avenue, into which 583 cubic feet per second, and one at Wilmette, into which 1,000 cubic feet per second, are to be pumped. As this water is to form a part of the 10,000 cubic feet originally to be taken out through that river, it does not add

to the amount of water to be taken from Lake Michigan.

13. The plans for the Calumet region involve a treatment of the Calumet River similar to that of the Chicago River. The river is to be diverted into the Des Plaines Valley. For this purpose a new channel is to be cut through the southerly depression in the divide, and to join the present drainage canal at Sag, about 11 miles from the controlling works at Lockport. From Sag to Lockport the drainage canal must carry the flow from the Calumet River in addition to that from the Chicago River. It was designed to accommodate the latter river alone, or 10,000 cubic feet per second, but improved methods of excavation, particularly channeling in rock, gave it a greater capacity than was computed; and the hydraulic formulae with which its dimensions were figured, being adapted to smaller streams, gave results which proved to be too large. It is found that the portion completed in rock, which includes the reach from Sag to Lockport, will carry an amount stated by the chief engineer to be 14,000 cubic feet per second. The difference, 4,000 cubic feet per second, is the amount which it is proposed to divert from the Calumet River. For this purpose it is proposed to excavate a channel having in earth a bottom width of 72 feet, with side slopes 3 on 5, and in rock a bottom width of 90 feet with vertical sides, the depth in both cases to be 25 feet.

14. Work in the territory annexed in 1903 has been limited to surveys, and the preparation of plans, and the expenditures in that territory have been small. The amount expended upon the drainage canal and accessory works, including the above, to December 31, 1905, is $40,873,629.71; in addition to which $1,556,226.56 has been expended for the development of water power and $7,290,101.27 has been paid out for interest. For a financial statement more in detail, see Appendix I_3.

15. Although the primary object of the Chicago Drainage Canal was the discharge of Chicago sewage, its function as a channel for navigation was kept in view from the beginning. All of the bridges over it are drawbridges with ample openings. A provision of this kind, as well as the care exercised to make the sewage inoffensive by liberal dilution, was necessary to conciliate the interests in the valley of the Des Plaines and Illinois River, which would otherwise be adversely affected. It can

hardly be doubted that the canal will eventually form a part of an improved waterway between the Great Lakes and the Mississippi River, though its full depth will probably not be required for that purpose. Congress has not adopted any scheme for this improvement, but by its direction a survey was made, and plans with estimates for a waterway 14 feet deep were submitted, by a board of engineers in a report dated August 26, 1905. The board found that for a distance of about 100 miles from Chicago the improvement must be with locks and dams, and as the quantity of water required would be merely that needed for the service of locks and other incidentals, the extent of the improvement of depth which could be obtained in that part of the route was without limit so far as it depended upon the amount of water available. For the remaining distance, about 223 miles, the improvement would be an enlargement of the open channel and the degree to which it was practicable was entirely dependent upon the quantity of water flowing. The board assumed that the Chicago Drainage Canal would eventually be permitted to take 10,000 cubic feet per second from Lake Michigan, and it expressed the opinion that with that volume added to the natural low-water discharge of the Illinois River a depth of 14 feet in the open channel could be maintained; also that if a much greater depth was to be secured a much larger volume of water must be taken from Lake Michigan.

16. In the neighborhood of Lockport the natural level of the ground falls away rapidly and excellent facilities are found for the development of water power. Under the state legislation of 1903 the sanitary district is now engaged in utilizing this incidental advantage of the drainage canal. The plans provide for an extension of the canal 10,700 feet between concrete walls and earth and rock embankments to the site selected for the power house and for the excavation of a tail race 6,800 feet long, 160 feet wide, and 22 feet deep. If the maximum quantity of water which the sanitary district now claims to be necessary for sanitary purposes—14,000 feet per second—be utilized it will be possible to develop about 40,000 electrical horsepower under a head of 34 feet. With 10,000 cubic feet per second about 28,000 horsepower can be developed. A power house is being erected which will

accommodate 8 turbines, each capable of generating 5,000 horsepower.

17. The sanitary district has acquired land on both sides of the canal throughout its length, the width of the strips varying from 200 to 800 feet. This land is offered to manufacturers at moderate prices, and it seems probable that they will in the course of time be attracted thereto, particularly after arrangements for furnishing them with cheap power from Lockport are completed.

18. The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress. The plans of the sanitary district, except those for the enlargement of the Chicago River, have not been submitted to any Federal authority for approval. It was only after the opening of the canal that application was made to the Secretary of War for permission to divert the quantity of water required by the State law. The secretary granted permission for such quantity as would pass through Chicago River without detriment to navigation, a quantity considerably less than that required by the State law. After experimenting with various amounts it was fixed at 250,000 cubic feet per minute, or 4,167 cubic feet per second, and that is the amount now authorized. It is 'subject to such modification as, in the opinion of the Secretary of War, the public interests may from time to time require.' Copies of all the permits granted by the Secretary of War in this connection will be found in Appendix I_4.

19. In the expenditure of $40,000,000 for the drainage canal the people of Chicago, with its population of 2,000,000 incurred a burden equivalent to that due to an expenditure of $1,600,000,000 by the United States, with its population of 80,000,000—that is, enough to build eight or more Panama canals. It was a very serious effort and has commanded the admiration and sympathy of all observers. The diversion of 10,000 cubic feet per second from Lake Michigan affects other interests adversely, but these interests have withheld their opposition, seeming to believe that some such amount was necessary, and apparently willing to contribute their share to protect the lives and health of the people of a great city. The plans calling for that amount have been under public discussion for some years. Although withholding formal approval, the Federal authorities have taken no steps

to prevent their execution. Congress has called for a plan and estimates for an improvement of the waterways connecting with it, the scope of which is fixed by that amount. There appears to be a tacit general agreement that Chicago needs or will need about 10,000 cubic feet of water per second for sanitary purposes and that the city should have it without further question.

20. It was not generally known until after the publication in March last of the report of the American section of this commission upon Niagara Falls that an amount greater than 10,000 cubic feet per second would be asked for. In that report, subsequently concurred in by the Canadian section, it was recommended that the diversion of 10,000 cubic feet be allowed. The preservation of Niagara Falls alone was considered, and that in the light of the tacit agreement above described. It was supposed at the time that this was all that Chicago needed, but the recommendation gave offense to the officials of the sanitary district, and the further demand then came out in the form of appeals to the committees of Congress and to the Secretary of State. It is necessary now to take up the question anew, and, after considering it in all its bearings, to reach some conclusion as to whether there should be a limit to the amount of water to be diverted at Chicago, and, if so, as to what that limit is.

21. That the abstraction of water from Lake Michigan has a tendency to lower the level of that lake and of all the waters to which it is tributary is self-evident; but the exact effect of abstracting a given amount can be ascertained only from prolonged observation of the natural outlets under the varying conditions to which they are subjected during a series of years. An elaborate investigation of this subject was made under the office of the United States Lake Survey in Detroit, the results of which were published in the annual reports of the Chief of Engineers for 1900, page 5401; for 1902, pages 2779 and 2825; and for 1904, page 4120. Further observations are needed to be made when the difference of the level between Lake Erie and Lake Huron is greater or less than when the existing observations were made, but the results obtained from the latter are believed to be reliable within one-tenth of a foot. The amounts by which the mean level, as derived from observations of the last 46

years of the various waters will be lowered by a discharge of 10,000 and also by 14,000 cubic feet per second are given in the following table:

Location.	Water level lowered by diversion at Chicago of—	
	10,000 cubic feet per second.	14,000 cubic feet per second.
	Foot.	Foot.
Lakes Huron and Michigan.....	0.52	0.70
Lake St. Clair.....	.45	.64
Lake Erie	.45	.64
Lake Ontario	.35	.49
St. Lawrence River at Rapids Plat	.40	.56

From this table it appears that all the waters, including Lakes Michigan and Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, besides the important connecting channels, the Detroit and St. Clair Rivers, will be lowered by amounts varying from 4¼ to 6¼ inches for 10,000 cubic feet and from 6 to 8½ inches for 14,000 cubic feet per second. The length of time required to produce this effect is about 5 years; about half of it will be produced at the end of 18 months. The above figures give the effect at average level; they are much more considerable during low-water periods.

22. Variations in the level of the lakes' surface, due to winds and to change of barometric pressure, are frequent and irregular and at times violent. Variations of more than 6 inches are very common, often occurring hourly for many hours in succession, while variations of 2 or 3 feet within an hour are not uncommon. Besides these irregular variations there is a regular annual variation due to difference in rainfall, evaporation, and runoff, the water level being highest in midsummer and lowest in midwinter. The levels are affected also by the greater or less severity of the winter and the consequent greater or less decreases in the discharging capacity of the outlets by ice. In order to study the annual oscillations it is necessary to eliminate the irregular oscillations, and that is accomplished by using the average levels

for a month. Using the monthly mean levels it is found that the regular fluctuation in Lake Huron-Michigan usually does not exceed 2 feet in any one year, but in a long series of years there is a great difference in the height to which high water will rise. The highest high water (monthly mean) recorded for that lake was in June, 1886, and the lowest high water in June, 1896, the difference between the two being over 3½ feet. The first is what navigators of the Great Lakes call a high-water year and the second a low-water year.

23. It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they can not see it they will not know it and will not feel it. The argument is fallacious. It is true that they can not see it immediately, but they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works.

24. The most important lake traffic is now carried on in large freight carriers which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the lakes. With the depth now available they are usually loaded to a draft of about 19 feet, but careful watch is kept on the stage of the waterways and advantage is taken of any temporary increase of stage to load the vessels deeper. In the modern vessel each inch of increased draft adds about 50 tons to the carrying capacity. To lower the water surface 6 inches is to reduce the capacity of the vessel about 300 tons. If the freight rate on iron ore be taken at 55 cents per ton, exclusive of the cost of loading and unloading, and the number of trips during the season at 22, there appears a loss of over $3,600 for the season for each vessel. The number of vessels navigating the Great Lakes which draw 19 feet or more is 417, and their tonnage is 1,541,414 tons, which is about three-quarters of

the total tonnage of the Great Lakes. It is a conservative estimate that the loss to the navigation interests resulting from a reduction of 6 inches in the depth of water is $1,500,000 per annum, which capitalized at 4 per cent., amounts to a loss of $37,500,000. With a greater reduction of depth the resulting loss would be proportionately greater. The number of deep-draft vessels and the share of lake traffic which they carry is increasing each year, while the lake traffic itself is increasing with marvelous rapidity. The total number of tons of freight which passed through Detroit River in 1905 was about 58,000,000, valued at about $615,000,000. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit River in 1908 exceeded 65,000,000, valued at $690,000,000. The loss will be even greater in the future than it is now. It is quite certain that the loss will not pass unnoticed, and that the Governments will be compelled to restore the depth either by additional excavations or by regulating works.

25. Careful estimates have been made of the cost of deepening the channels between the lakes 1 foot. To deepen the Detroit River is estimated to cost $4,115,430. In Lake St. Clair the full depth of the lake is now utilized, and any lowering of its surface involves the excavation of an artificial channel entirely across the lake, a distance of 18 miles, of which it has been necessary heretofore to artificially deepen only one-third. To deepen the channel here and at certain shoal places in St. Clair River and at the foot of Lake Huron is estimated to cost $1,080,720. It results in replacing open lake navigation by canal navigation for a distance of 12 miles in Lake St. Clair, a decided disadvantage.

26. The data are not at hand for an accurate estimate of the cost of restoring the depths in the harbors of the Great Lakes, but an approximation may be reached from a consideration of the cost of improvements heretofore made. The depth to be gained being small, the cost will not vary largely, whether that gain be a few inches more or less. The United States has improved 35 harbors on Lake Michigan, Huron, Erie, and has expended thereon about $20,000,000, of which about one-quarter was for maintenance. The average increase of depth is 10 feet and the cost per foot of increase was therefore about

$1,500,000, but as the cost of a small increase would be much greater per foot than an increase of 10 feet, and as several harbors on Lake Ontario are to be added, the cost per foot in this case would probably be not less than $2,000,000 for harbors in the United States. The Canadian Government has improved over 50 harbors on Georgian Bay, Lake Huron, St. Clair, Erie and Ontario. A large amount, say $3,000,000, must be added for increasing the depth of these harbors.

27. The depth in the Welland Canal and in the six canals employed to overcome rapids in the St. Lawrence River is now 14 feet, of which every inch is needed. At the head of the Cornwall Canal in the St. Lawrence River the abstraction of 14,000 cubic feet of water per second at Chicago will lower the surface about 6¾ inches at mean level and much more at low water. To restore the depth in these canals involves the reconstruction of all the end locks and deepening the approaches thereto, and is estimated to cost $2,500,000.

28. The total cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is therefore roughly $10,000,000, and of restoring it in the Welland and St. Lawrence Canals is $2,500,000 additional, or $12,500,000 in all.

29. The shores of the Great Lakes are very far from being fully developed, and it is highly probable that many harbors not now in existence remain to be created, or if in existence remain to be improved. The lowering of the lakes' surface increase the difficulty and cost of such improvements. This consideration is of importance, although no money value can now be given it.

30. The expenditure of the sums mentioned above will restore the depths now existing, but it will not prevent very serious annoyance to the navigation interests during the execution of the work. The time required will be several years, and in the meantime the vast commerce of the Great Lakes will be hampered, not only by deficient depth, but also by the occupation of the channels, already crowded with commerce, by the excavating machines.

31. It is evident from the foregoing that large bodies of water cannot be diverted by the Chicago Drainage Canal without very serious detriment to the navigation interests of the Great Lakes and of the St. Lawrence Valley. The greater the amount of water diverted the greater

the injury. Chicago being one of the principal lake ports, there will be very few communities which will feel this detriment more than she will.

32. In the presence of these interests, the effect upon Niagara Falls may be simply mentioned with a reference to our former reports upon that subject. The volume of Niagara Falls will be reduced by the full amount diverted at Chicago.

33. The City of Chicago was organized as a city in 1837 with a population of about 4,000. Its population in 1840 was 4,479; in 1850, 28,269; in 1860, 112,172; in 1870, 298,977; in 1880, 503,185; in 1890, 1,099,850; and in 1900 it was 1,698,575. It is estimated now to be about 2,000,000. Should the rate of growth continue which prevailed between 1880 and 1900, the population will be 3,000,000 in the year 1922 and 4,000,000 in the year 1939. It is impossible to foretell its future growth, but there is no reason to doubt that it will in time greatly exceed the largest of these numbers. The city is the commercial center of an empire still in its infancy. It is entirely reasonable to expect a population of five or six millions or more. It will cover territory not now covered. Methods of sewage disposal appropriate to one portion of it may not be appropriate to other portions. If the diversion of 20,000 cubic feet per minute (or 333⅓ cubic feet per second) for each 100,000 of population, as required by the State law, is accepted as the standard, then from 17,000 to 20,000 cubic feet per second will be required, and the 14,000 cubic feet now contemplated will not be sufficient. Even more than 20,000 cubic feet will be required for a population greater than 6,000,000. The diversion of 20,000 cubic feet per second would lower Lakes Michigan and Huron about 13 inches and Lake Erie about 11 inches. Plans which lead to this result should be carefully scrutinized.

34. One of the reasons given in 1889 for adopting this method of disposing of Chicago sewage was that it offered the advantage of furnishing a navigable waterway from Chicago to the Mississippi River. The navigable depth or capacity of such a waterway has never been authoritatively fixed. Congress has considered a depth of 14 feet to the extent of ordering a survey and estimates of cost for that depth, but the Illinois legislature has declared its policy to be to secure the construction of a deeper channel, not limiting its proposed capacity in

terms, but defining it to be 'of the greatest practicable depth and usefulness for navigation.' See joint resolution adopted May 27, 1889, copy omitting preamble hereto appended, marked 'I_8.' A fair interpretation of this language gives a proposed depth of 20 feet, that being the depth required to accommodate the most important vessels now navigating the Great Lakes. It will require a volume of water greater than the 10,000 cubic feet per second originally contempated.

35. The amount which it is proposed to divert from the Calumet River 4,000 cubic feet per second, is fixed by accident rather than by design, being the excess which the Chicago Drainage Canal is found capable of carrying after providing for the 10,000 cubic feet from the Chicago River, for which it was originally constructed. It is certain that no greater amount than 4,000 cubic feet can be diverted from the Calumet without checking the flow from the Chicago River, and thus giving relief to a suburban portion of the city at the expense of the richest and most populous centers.

36. It is equally certain that the diversion of 4,000 cubic feet or less will not at all times afford the desired relief to the Calumet. In the first place, it provides for a population of only 1,200,000, a number which will in all probability be greatly exceeded at a day not remote. At present the population is estimated at about 200,000, but for the present necessities it is not a question of population, but of drainage area and rainfall. A flood discharge of the Calumet has been measured at Riverdale, about 10 miles from its mouth, of about 13,300 cubic feet per second from a drainage area of about 700 square miles, and even that amount may at times be exceeded. The total drainage area of the Calumet region, including the Sag Valley, is about 825 square miles, and assuming the discharge to increase in proportion to the area, the flood discharge to be provided for is over 15,700 cubic feet per second. The diversion of only 4,000 cubic feet will not prevent a heavy discharge into Lake Michigan in time of flood. To overcome this difficulty it is proposed, if suitable legislation can be secured, to divert the upper Calumet into Lake Michigan through an artificial channel to be excavated in Indiana about 17½ miles east of the State line. Indiana has not authorized such diversion, but supposing it to be accomplished, there will still be times when the discharge from the drainage area re-

maining to be cared for by the canal, 238 square miles, will exceed 4,000 cubic feet per second. The excess must enter Lake Michigan through the mouth of the Calumet, and at such times the system will fail. Of course it makes no provision for the future occupation of the upper Calumet region and the pollution of the lake from that source. It thus appears that the diversion of the Calumet River as now proposed by the Sanitary District will not be complete even for the present, and will not make adequate provision for the future.

37. The diversion of 4,000 cubic feet per second provides for a population of 1,200,000 by the standard fixed by the State law. The population of the Calumet region is now about 200,000, and until it reaches 1,200,000 only a part of the flow will be needed for sanitary purposes during a large part of the year; but the channel must be there, available for the full flow, if this method of sewage disposal is to be useful to any population, however small. Likewise the channel from the Chicago River must be, as it is, large enough to provide for a population of 3,000,000, whether that number of people are ever to become tributary to the Chicago River or not. The channels having once been constructed, any reduction of flow below their fullest capacity is a dead loss to the water power dependent upon them. It has been said that it would be absurd to develop water power at the cost per horsepower which this water power costs if the drainage canal be included, and that is true. But being given the channels, it would not be absurd to use them to their fullest capacity. The Chicago Drainage Canal having been constructed, with a capacity, as it turns out, of 14,000 cubic feet per second, full power development will call for the whole of that amount, and in fact power works are now under construction at Lockport to utilize it. Inasmuch as the sanitary requirements by the standard fixed in the State law are only 6,667 cubic feet per second for the present population of 2,000,000, it is evident that power development incidental though it be, does lead to demands for water not required for sanitary purposes.

38. It remains to be seen whether any diversion, complete or otherwise, is necessary to preserve the health of Chicago. Upon this point the commission sought the advice of two eminent sanitary engineers—Messrs. Rudolph Hering and George W. Fuller—whom it instructed as follows, viz.: 'To examine the sanitary situation at Chi-

cago, so far as it is affected by sewage disposal, and to report whether it is or is not necessary to the health of the city to extend to outlying territory the system which was adopted in 1889 for the main city. * * * The commission desires an emphatic opinion from authoritative sources as to whether the system of diverting the water of Lake Michigan in large quantities into the Illinois Valley is the only way to preserve the lives and health of the people of Chicago. It does not desire an investigation of the effect upon the navigation interests of the Great Lakes. It has satisfied itself upon that point. Nor does it wish to reopen the case of the Chicago Drainage Canal as designed and built. It accepts that as a fixed fact, with its attendant diversion of 10,000 cubic feet per second through the Chicago River. The extension of the system to the Calumet River alone is in question, and the question is, Are there not other methods of sewage disposal which can be applied here at a cost not exceeding much, if at all, the cost of the method proposed, and which will be equally effective in preventing the pollution of the lake? It desires a report upon the various systems which may be found available for application here, with a statement of their relative efficiency. It also desires a statement of their relative cost, so far as that can be given without the preparation of detailed plans. The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive should be given.' These gentlemen visited Chicago, and after a thorough examination of the situation submitted a report, of which a copy is hereto appended, marked 'I_6.' The entire report should be carefully studied. Its conclusions only are here quoted. They are as follows, viz.:

'The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive are that a dilution of 3½ cubic feet per second for each 1,000 persons connected with the sewers, as provided for in the enactment of the Illinois legislature in 1889, is as low a figure as it is now possible to state. We believe that with the elimination of objectionable trade wastes and the occasional dredging of the river this amount of dilution will be sufficient to prevent offensiveness.

The extension of the dilution method to the outlying territory is not the only way to preserve the lives and

health of the people of Chicago. The application of the method, with flow of 10,000 and 14,000 cubic feet per second, respectively, for the area tributary to the present drainage canal, will serve populations not exceeding 3,000,000 and 4,200,000, respectively. For greater populations other methods of sewage disposal will be required.

For the Calumet area, as well as other districts, there are several methods for the disposal of sewage as effective as the present method of dilution in preventing the pollution of the lake waters.

All these methods involve intersecting sewers and pumping stations to collect and deliver the sewage at suitable sites. Septic tanks are used for partially clarifying the sewage, which may then be applied to any one of three methods, of filters, viz.: intermittent sand filters, contact filtersand sprinkling filters.

All of these filters if well built and well managed remove the suspended and organic matters so that the effluents are practically clear and nonputrescrible. The removal of bacteria by these three types of filters average at least 98, 80 and 90 per cent., respectively. Such effluents may be discharged into any of the water courses of the Calumet region.

The approximate total costs, liberally estimated, without the preparation of detailed plans, for a population of 1,200,000 are as follows:

A—Intermittent Sand Filters.

Construction	$11,063,000
Annual cost of operation, $866,000, capitalized at 5%	17,320,000
	28,383,000

B—Contact Filters.

Construction	$11,787,500
Annual cost of operation, $551,000, capitalized at 5%	11,020,000
	22,807,500

C—Sprinkling Filters.

Construction	$ 9,257,500
Annual cost of operations, $419,000, capitalized at 5%	8,380,000
	17,637,500

The present population on the Calumet area of the sanitary district being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expended at the outset.

Of the available methods of disposing of the sewage of the Calumet area other than by dilution, the sprinkling filter method, being the cheapest both in cost of construction and of operation and accomplishing an adequate degree of purification, is clearly the most advantageous one.'

These engineers stand in the front rank of their profession as sanitary experts. One of them, Mr. Hering, was chairman of the commission of 1887, whose report to the mayor and city council of Chicago was the foundation of the subequent legislation and led to the construction of the drainage canal. The conclusions reached are those of friends of Chicago and not of her enemies or rivals.

39. A method of sewage disposal for the Calumet region is proposed which for a population of 1,200,000 is estimated to cost $17,637,500. For the present population of about 200,000 only a part of the expense need be incurred, and the works can be developed as the population increases. It can, when the necessity arises, be applied with a population much exceeding 1,200,000. The cost of diverting the Calumet River into the Chicago Drainage Canal is estimated at $12,000,000. The greater efficiency at present and in the future of the method now proposed would justify a considerable increase of cost, but in view of the fact that the entire expense of the diversion must be incurred at the outset, while by the new method the expenditures will be regulated by the growth of population, the difference in cost may be considered unimportant.

Summary.

40. The following is a summary of the more important facts recited in this report:

(a) Chicago obtains its water supply from Lake Michigan, and to avoid polluting it must either dispose of its sewage otherwise than in the lake or place its intakes for water at a great distance from the city.

(b) The topography of the country favors the discharge of the sewage into the Des Plaines River, a tributary of the Mississippi, through two depressions in the divide which separate that river from Lake Michigan.

(c) The slope on the lake side of the divide is drained

by two streams—the Chicago River and the Calumet River—into which the sewers of the city empty. By a cut through the northerly depression the flow of the Chicago River has been reversed and diverted into the Des Plaines River instead of into Lake Michigan, and by a cut through the southerly depression the same process can be applied to the Calumet River.

(d) To make this reversal effective the channels must be large enough to take all the water which falls upon the respective drainage areas during the most violent rainstorms. This amount is estimated at 10,000 cubic feet per second for the Chicago River and 15,700 cubic feet per second for the Calumet River.

(e) The City of Chicago was originally built upon the Chicago River, and that stream now drains the richest and most populous part of the city. It is now spreading over the Calumet region.

(f) In 1889 the plan of diverting the Chicago River into the valley of the Des Plaines was definitely adopted, and the Chicago Drainage Canal was undertaken. It was designed to carry 10,000 cubic feet per second. Though not entirely completed, it has been in use since January, 1900. The amount expended upon the canal and accessory work is about $41,000,000.

(g) The Illinois law which authorized the canal required a flow of 333 cubic feet per second for each 100,000 of population in order to render the sewage inoffensive. This amount of dilution is probably not excessive. It is reasonable to expect a population in a future not remote of five or six millions or more, involving the diversion by this standard of some 20,000 cubic feet per second. The Chicago River with its 10,000 cubic feet provides for a population of 3,000,000. The present population of the city is about 2,000,000.

(h) It is now proposed to apply to the Calumet River a treatment similar to that applied to the Chicago River, viz.: to reverse its flow, so that instead of discharging into Lake Michigan it shall discharge into the Des Plaines, but for a part of the new route it must follow the drainage canal already excavated for the Chicago River.

(i) Although the Chicago Drainage Canal was designed to carry 10,000 cubic feet per second, it is found to have, in its completed rock portion, an actual capacity of 14,000 cubic feet. This additional capacity fixes the amount which it is proposed to divert from the Calu-

met at 4,000 cubic feet per second. Any greater amount from the Calumet will overtax the drainage canal at the expense of the richest part of Chicago and for the benefit of a suburban part.

(k) The diversion of only 4,000 cubic feet will not be effective at all times, since a much greater amount must be diverted from the Calumet during heavy rainstorms if the lake is to be protected. Moreover, it provides for a population not exceeding 1,200,000, which number will probably be exceeded at a date not far distant.

(l) The large channels necessary to provide for the contingencies of rainstorms are capable of discharging a volume of water largely in excess of sanitary requirements during the greater part of the year, but the development of water power creates the demand that they be employed to their full capacity throughout the year.

(m) The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress, but there appears to be a tacit general agreement that no objection will be made to the diversion of 10,000 cubic feet per second, as originally planned.

(n) The diversion of 10,000 cubic feet per second will lower the levels of Lake Michigan-Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, besides the important connecting channels, the Detroit and St. Clair Rivers, by amounts varying from 4¼ to 6¼ inches for the different waters, and the diversion of 14,000 cubic feet will lower them from 6 to 8½ inches. The diversion of 20,000 cubic feet will lower Lake Michigan-Huron about 13 inches and Lake Erie about 11 inches.

(o) The lake traffic which passed through the Detroit River in 1905 was about 58,000,000 tons, valued at about $615,000,000. It is increasing annually with marvelous rapidity. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit River in 1906 exceeded 65,000,000, valued at $690,000,000. The lowering of the water surface has a very injurious effect upon this traffic and upon that of the Welland and St. Lawrence Canals. Chicago being one of the principal lake ports, there will be very few communities which will feel the injury more than she will.

(p) The cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is

estimated at $10,000,000, and of restoring it in the Welland and St. Lawrence Canals at $2,500,000. This expenditure would not prevent very serious annoyance to the navigation interests during the execution of the remedial works, which would occupy several years. In Lake St. Clair navigation of the open lake would be replaced by that of an artificial channel or canal with submerged banks.

(q) The extension to the Calumet region of the method of sewage disposal already applied to the Chicago River is not necessary to preserve the health of Chicago, there being other and better methods available for the Calumet region. The final cost of these methods is somewhat greater than that of the one proposed, but the works can be developed as the population increases, and only a part of their cost need be incurred at present, while their greater efficiency justifies the increase of final cost.

(r) The diversion of 10,000 cubic feet of water per second at Chicago will render practicable a waterway to the Mississippi River 14 feet deep. Any greater depth must be obtained by the abstraction of more water from Lake Michigan and at the expense of the navigation interests of the Great Lakes and of the St. Lawrence Valley.

(s) The effect upon Niagara Falls of diverting water at Chicago is of secondary importance when considering the health of a great city and the navigation interests of the Great Lakes and of the St. Lawrence Valley, but it is proper to note that the volume of the falls will be diminished by the full amount diverted at Chicago.

Recommendations.

41. The waters of Lake Michigan in the United States, the waters of Georgian Bay in Canada, and the waters of Lake Superior partly in the United States and partly in Canada all form sources of supply of the Great Lakes system, finding their way by the St. Lawrence to the sea. All are interdependent and there can be no diversion from any of them without injury to the whole system. By Article XXVI of the treaty of 1871 it is provided that 'navigation of the river St. Lawrence, ascending and descending from the forty-fifth parallel of north latitude,

where it ceases to form the boundary between the two countries, from, to, and into the sea, shall forever remain free and open for the purposes of commerce to the citizens of the United States, subject to any laws and regulations of Great Britain, or of the Dominion of Canada, not inconsistent with such privileges of free navigation.' It is desirable that in any treaty arrangement the waters of Lake Michigan, Georgian Bay, and all other waters forming part of the Great Lakes system should be declared to be 'forever free and open for the purposes of commerce' to the citizens of the United States and the subjects of His Britannic Majesty, subject to any laws and regulations of either country not inconsistent with such privilege of free navigation.

42. The preservation of the levels of the Great Lakes is imperative. The interest of navigation in these waters is paramount, subject only to the right of use for domestic purposes, in which term is included necessary sanitary purposes. In our report of November 15, 1906, upon the application of the Minnesota Canal & Power Co. to divert certain waters in Minnesota, we recommended, among other things 'that any treaty which may be entered into should define the uses to which international waters may be put by either country without the necessity of adjustment in each instance, and would respectfully suggest that such uses should be declared to be (a) uses for necessary domestic and sanitary purposes; (b) service of locks for navigation purposes; (c) the right to navigate.' It is our opinion that so far as international action is concerned a treaty provision of that kind is all that is required in this case. We accordingly renew our recommendation of November 15, 1906, just quoted.

43. A careful consideration of all the circumstances leads us to the conclusion that the diversion of 10,000 cubic feet per second through the Chicago River will, with proper treatment of the sewage from areas now sparsely occupied, provide for all the population which will ever be tributary to that river, and that the amount named will therefore suffice for the sanitary purposes of the city for all time. Incidentally it will provide for the largest navigable waterway from Lake Michigan to the Mississippi River which has been considered by Congress.

We therefore recommend that the Government of the

United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal.

All of which is respectfully submitted.

O. H. ERNST,
Brigadier General, U. S. Army, Retired,
Chairman American Section.
GEORGE CLINTON,
E. E. HASKELL,
Members American Section.
GEO. C. GIBBONS.
Chairman Canadian Section.
W. F. KING,
LOUIS COSTE,
Members Canadian Section.

Attest:
W. EDWARD WILSON,
Secretary American Section.
THOMAS COTE,
Secretary Canadian Section."

International Waterways Commission progress report, Senate Doc. 959, 62d Congress, 3d Session, pages 67-77.

INTERNATIONAL WATERWAYS COMMISSION.

MESSAGE FROM THE PRESIDENT OF THE UNITED STATES, TRANSMITTING THE FINAL REPORT OF THE INTERNATIONAL WATERWAYS COMMISSION UPON THE PROPOSED DAM AT THE OUTLET OF LAKE ERIE.

Senate Doc. 118, 63rd Congress, 1st Session, pp. 1-15.

June 27, 1913.—Read, referred to the Committee on Foreign Relations, and ordered to be printed.

July 2, 1913.—Illustrations ordered printed.

"To the Senate and House of Representatives:

Pursuant to the provisions of an item contained in the river and harbor act of 1902, and subsequent amendments, providing for the formation of an International Waterways Commission and defining its duties, I have the honor to transmit herewith the final report of said commission upon the proposed dam at the outlet of Lake Erie.

Should Congress make provision for the printing of such report as a document, the American section of the

commission requests that 500 copies thereof be made available for its use.

WOODROW WILSON.

The White House, June 27, 1913.

International Waterways Commission,
Office of American Section,
Buffalo, N. Y., June 20, 1913.

The honorable Secretary of War of the United States:
The honorable Minister of Public Works of Canada:

1. The act of the Congress of the United States which requested that the Government of Great Britain be invited to join in the formation of the International Waterways Commission defined one of the duties of that commission as follows:

> The said commissioners shall report upon the advisability of locating a dam at the outlet of Lake Erie, with a view to determining whether such dam will benefit navigation, and if such structure is deemed advisable, shall make recommendations to their respective Governments looking to an agreement or treaty which shall provide for the construction of the same, and they shall make an estimate of the probable cost thereof.

2. It so happens that the term 'dam' may apply to various works of which the character and object are very different. At the time of passing the act Congress had under consideration the report of the board of engineers upon deep waterways between the Great Lakes and Atlantic tidewaters, dated June 30, 1900, in which it was recommended that the level of Lake Erie be 'regulated'— that is, that its oscillations be reduced—by means of a dam consisting of a submerged weir and of a set of sluice gates placed at its outlet near the head of the Niagara River. The object of these works would have been to raise the low-water surface of the lake without raising the high water, thus completely regulating its level.

It seems probable that this was the kind of works which Congress had in mind when using the term 'dam.' But the term 'dam' may also be applied to a submerged weir without sluice gates, the object of which would be to raise the level of the lake at low water as well as at high water almost to an equal amount, though in the study of the question it was found possible to give the dam a form which will accomplish a partial regulation.

To distinguish works of this latter kind from those designed to 'regulate' the lake, they may be called 'compensating works.' Thus, the subject has two branches—one, the complete regulation of Lake Erie, and the other, the raising of its level without complete regulation.

3. Naturally, consideration of the complete regulation of the lake was taken up first. It was the subject of our report, dated January 8, 1910, which was printed and distributed by this commission, and was also published by the United States Government as House Document No. 779, Sixty-first Congress, second session. A few of the statements made, as well as the conclusions reached, in that report will bear repetition here.

4. The Great Lakes, with their connecting channels, constitute the most important system of inland navigation in the world. The traffic which passed through Detroit River, its busiest link, in 1910 amounted to 73,526,602 tons, valued at about $771,000,000. About 80 per cent. of this traffic is carried in large freight carriers, which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the Lakes, but could be loaded much deeper if the depth of water permitted. Some of the larger of these vessels carry an additional load of 85 tons for each inch of additional draft. Every inch added to the available depth of water would therefore be of material benefit to commerce.

5. The Great Lakes constitute a series of enormous natural reservoirs, each of which serves to regulate the flow in the river constituting its outlet and to maintain the lake below. They are interdependent. The study of one, to be complete, must include the study of all. The total area drained by them is about 287,688 square miles, an area considerably larger than the German Empire. Of this total, about one-third is occupied by the lakes themselves—that is, devoted to reservoir purposes. The result is a uniformity of level and a uniformity of flow which are truly wonderful—a perfection of regulation which no work of man ever did or ever will approach. The question propounded was. 'Can the degree of regulation provided by nature be improved?' Enormous forces were to be dealt with, and the results were to be measured in inches. The subject was, therefore, as difficult as it was important.

6. Soon after the organization of the commission a committee of two of its engineer members was appointed

to collect all of the available data and to make an hydraulic analysis of the general regulation of all the lakes. All existing records of water-level observations and discharge measurements made since 1860 were collected, analyzed, tabulated and studied. After a careful consideration of all the data, the commission found that only a very moderate degree of improvement in regulation over what nature provides is practicable in any of the lakes, and that, such as it is, this improvement is obtained at the expense and to the injury of the channels below. In the case of Lake Erie it would be possible to raise the extreme low-water stage about 1 foot, and this in turn would raise the low-water stages of Lake St. Clair about 0.61 foot and of Lake Huron-Michigan about 0.27 foot, all without appreciable increase in the extreme high stages. But in doing this the low-water stage of Lake Ontario would be lowered about 4½ inches, the available depth in the St. Lawrence Canals would be diminished about 7⅞ inches, and the City of Buffalo would suffer by increased damage from floods and by a postponement of the date of opening navigation in the spring. The question of damage to vested rights was thus introduced. While the advantages of regulation might outweigh the disadvantages if the persons who were to benefit from the former were identical with those who were to suffer from the latter, the difference was not great enough to justify the two Governments in entering upon the vexatious question of damages. The commission therefore recommended that the 'regulation' of Lake Erie be not undertaken, meaning thereby the most complete practicable regulation such as can be secured by a dam and sluice gates located at or near Buffalo.

7. The second branch of the subject committed to us, or works to raise the level of Lake Erie with partial but not complete regulation, which we have called 'compensating' works, is the subject of this report. Appended hereto is the report of the committee specially charged with the investigation.

8. As was stated in our former report, the Niagara River at its extreme upper end is an important safety valve for the protection of Buffalo from the effect of storms, and should not be obstructed by a dam, but it seemed possible that somewhere in the river, between Lake Erie and the Falls, a submerged dam might be placed which would greatly benefit the navigation of the

waters above without injury to those below and with only minor damages, if any, to the adjoining lands. To determine this question it was necessary to make a complete survey of the Niagara River from Lake Erie to the falls, including the topography of the adjoining lands. This survey was made by the commission. A survey was made also by the Canadian Government of the Welland River, in Canada, which enters the Niagara about a mile above the rapids approaching the falls. A sketch upon a reduced scale, showing the Niagara River in outline, is appended. (Pl. I.)

9. From a study of the maps it appears that the best site for a submerged dam, or weir, is just above the Welland River, extending from Hog Island, at the mouth of that river, to the mouth of Gill Creek, on the American side, as shown on Plate II. As the Welland is a navigable stream, there would be some advantage in placing the weir below its mouth, but the survey of that river showed that a moderate increase in the height of its surface would submerge a considerable area of valuable land. To provide for the navigation of the Welland it is necessary to construct a lock at the Canadian end of the weir. The object of placing the weir as near as possible to the foot of navigation is to improve all of the navigable portion of the Niagara River above. A study of the topography on both sides of the Niagara River showed that the water surface at mean stage could be raised as much as 3 feet at the site of the weir without inflicting damage upon adjacent lands, except for a distance of about 1½ miles immediately above the weir on the American side. At this place it is proposed to construct a levee of suitable height to protect the land from overflow.

10. The form to be given the weir has been the subject of careful investigation. In order to disturb as little as practicable the natural distribution of flow through the different parts of the cross section of the river, the crest of the weir is broken into four sections, as shown on Plate VI, the height given to each section being such as will raise the surface of the water in that section 3 feet at mean stage.

11. A cross section of the weir is shown in figure 1, Plate V. This form was adopted after experiment with various types of weir made under as nearly as possible true river conditions. The experiments were made at the hydraulic laboratory of the college of civil engineer-

ing at Cornell University, which was generously placed at the disposal of the commission for the purpose by the authorities of the university. They are described in the report of the committee, hereto appended. The type of weir desired is one which shall be very efficient at high stages of the river, and much less so at low stages. The form adopted fulfills these conditions, though it is quite possible that a still better form may be developed with further experiment.

12. The effects of the weir upon the Niagara River at different places and upon Lake Erie at low, mean, and flood stages are shown upon Plates III and IV, the former through the Tonawanda Channel and the latter through the Chippewa Channel. The plates show the natural surfaces at these three stages, and also the backwater surfaces caused by the weir as computed by Bernouilli's theorem for steady flow. The effects are also given in Table No. 1. It appears from this table that the level of Lake Erie will be raised 0.51 foot at extreme low stage, 0.39 foot at mean stage, and 0.11 foot at extreme flood stage. At low water the surface of the Niagara River will be raised 1.08 feet at the Buffalo waterworks; 1.66 feet at Strawberry Island, about 5½ miles from the lake; 2.14 feet at Black Creek, about 11 miles from the lake; 2.99 feet at La Salle Landing, about 18 miles from the lake; and 3.05 feet at Schlosser's Dock, the foot of navigation. At flood stage these numbers are: For Buffalo waterworks, 0.19 foot; for Strawberry Island, 0.42 foot; for Black Creek, 0.59 foot; for La Salle Landing, 0.82 foot; and for Schlosser's Dock, 0.91 foot.

13. The effect of raising the mean level of Lake Erie 0.39 foot would be to raise the mean level of Lake St. Clair about 0.23 foot; and the mean level of Lake Huron about 0.09 foot.

14. To change the level of a great inland sea like Lake Erie, upon the shores of which are many populous cities, is a matter to be approached with caution. Any important increase in the height of the high-water level may cause serious damage to the wharves and low-lying lands. Care must be taken to avoid injury to vested rights. In this case, the ordinary high-water level is increased only 0.38 foot, or 4½ inches, and the extreme flood stage at Buffalo is increased only 0.11 foot, or 1⅓ inches.

15. The construction of the weir recommended in this report will affect to some extent the levels in the first

reach of the Barge Canal from Tonawanda to Lockport. The level of the Niagara River at Tonawanda would be raised by 1.71 feet at mean stage, and by 0.55 foot at flood stage, so that inasmuch as no provision has been made at the entrance of the canal against the rise which the construction of the weir will cause, it is in our opinion necessary to provide for the construction of a guard lock, the cost of which is included in our general estimate.

16. It is our opinion that the capacity of the lock to enter the Welland River is a domestic question to be decided by the Canadian Government. We have introduced an item of $500,000 in the estimates to provide for the construction of that lock, but its dimensions should conform to the capacity which the Canadian Government shall determine to give to the connecting waterways, and this estimate can be regarded only as a rough approximation.

17. The weir is to be constructed of concrete and its cost is estimated as follows:

Rock excavation, 36,300 cubic yards, at $4 per yard	$145,200
Concrete, superstructure, 44,000 cubic yards, at $12 per yard	528,000
Concrete, substructure, 48,500 cubic yards, at $10 per yard	485,000
Cofferdam, 105,500 cubic yards, at $3.50 per yard	369,250
Pumping and maintenance, lump sum	210,000
Lock into Welland River	500,000
Guard lock at Tonawanda	500,000
Excavation for retaining walls along Niagara River, 16,000 cubic yards, at $3 per yard	48,000
Concrete for retaining walls, 12,500 cubic yards, at $10	125,000
	2,910,450
Add for engineering and contingencies about 20 per cent	589,550
Total	3,500,000

18. The great value to the navigation interest of an increase of 6 inches in the low-water depth of Lake Erie has already been pointed out. The improvement of Niagara River to be effected by the proposed weir is important. An incidental advantage in its construction is that

it would eliminate the possibility of the power companies at the Falls having any injurious effect upon the level of Lake Erie. The Niagara River below the weir and the conditions upon Lake Ontario and the St. Lawrence River would remain without appreciable change. The weir has small regulating effect upon the levels of Lake Erie, the range of the oscillations of the lake being reduced about 4½ per cent. The average natural low stage, 571.3, is raised 0.45 foot, and the average natural high stage is raised 0.38 foot, a difference of 0.07 foot. The storage in Lake Erie is reduced only by that amount, which is not sufficient to affect the level of Lake Ontario seriously.

19. It is possible that the Canadian Government may prefer to assume the damages from overflow in the valley of the Welland River, which would be caused by placing the Canadian end of the proposed weir below the mouth of the Welland, and thus make the lock unnecessary. If so, provision for this should be made in any treaty.

20. The commission believes that the very great advantages to navigation interests will justify and amply repay the necessary expenditure, and we recommend that a treaty be entered into between Great Britain and the United States providing for the construction of the weir.

O. H. ERNST,
Brigadier General U. S. Army, Retired,
Chairman American Section.
GEORGE CLINTON,
Member American Section.
E. E. HASKELL,
Member American Section.

Attest:

W. EDWARD WILSON,
Secretary American Section.
GEO. C. GIBBONS,
Chairman Canadian Section.
LOUIS COSTE,
Member Canadian Section.
WM. J. STEWART,
Member Canadian Section.

Attest:

THOMAS BOTE,
Secretary Canadian Section.

TORONTO, ONTARIO, December 13, 1912.

The INTERNATIONAL WATERWAYS COMMISSION:

Your committee, which was appointed to investigate the advisability of locating a dam at the outlet of Lake Erie and the maintenance and regulation of suitable levels on the other lakes in the Great Lakes system, closed its report of December 4, 1909, upon this subject with the following paragraph:

> 'Your committee had hoped to present a discussion of a project for compensating Lake Erie for the loss of level due to diversions by works placed above the rapids approaching Niagara Falls. A preliminary examination, however, revealed a lack of data which prevents consideration of the question at this time.'

Your committee now has the honor to submit a report upon this question, thereby completing the duties assigned it.

It may be well at this point to quote a part of the act of the Congress of the United States approved June 13, 1902, to more clearly understand this report:

> 'SEC. 4. That the President of the United States is hereby requested to invite the Government of Great Britain to join in the formation of an international commission, to be composed of three members from the United States and three who shall represent the interests of the Dominion of Canada, whose duty it shall be to investigate and report upon the conditions and uses of the waters adjacent to the boundary lines between the United States and Canada, including all of the waters of the Lakes and rivers whose natural outlet is by the River Saint Lawrence to the Atlantic Ocean; also, upon the maintenance and regulation of suitable levels; and, also, upon the effect upon the shores of these waters and the structures thereon, and upon the interests of navigation, by reason of the diversion of these waters from or change in their natural flow; and, further, to report upon the necessary measures to regulate such diversion, and to make such recommendations for improvements and regulations as shall best subserve the interests of navigation in said waters. The said commissioners shall report upon the advisability of lo-

cating a dam at the outlet of Lake Erie, with a view to determining whether such dam will benefit navigation; and if such structure is deemed advisable, shall make recommendations to their respective governments looking to an agreement or treaty which shall provide for the construction of the same, and they shall make an estimate of the probable cost thereof.'

Niagara River is the outlet of Lake Erie and discharges into Lake Ontario; it is divided into two reaches by the Falls, the 'upper' and the 'lower.' The upper reach is navigable from Lake Erie to Chippewa, Ontario, and to Niagara Falls, N. Y., and is the reach with which we are at present concerned. Strawberry and Grand Islands divide a part of this reach into two channels, known as Tonawanda and Chippewa. The distance from Lake Erie to the head of Strawberry Island is approximately 4 miles and the fall in this distance at mean stage is 5.8 feet. The distance from the head of Strawberry Island to the end of navigation by the Tonawanda Channel is 16½ miles, and between the same points by the Chippewa Channel is 12¾ miles. The fall in these reaches at mean stage is 4.8 feet.

The natural conditions in this upper reach of river are therefore such as to indicate that by placing a submerged weir of proper size at the end of navigation, or below Navy and Connors Islands, it might be possible to create sufficient backwater to restore to Lake Erie a part, at least, of what it has lost in stage by diversions, and at the same time greatly improve the navigation of the reach of river under consideration.

It was this project that your committee had in mind when it closed its report on December 4, 1909. Naturally, the question arises: Can the water be raised sufficiently at the location indicated to actually restore to Lake Erie a quantity worth while and at the same time keep within control all flood waters, particularly those that come from heavy southwest windstorms on Lake Erie?

To answer this question it was necessary to have more data than existed at the time of our previous report. A careful topographic survey was required of all lands likely to be affected and a type of weir best suited for the location and conditions had to be determined.

Surveys were started early in 1910 and prosecuted as diligently as the affairs of the commission would permit. The results from these did not become available, however,

until about the beginning of the present year. A detailed topographic survey was made of the shores of the Niagara from Lake Erie to within a mile of the Falls; the islands within this reach, and of the Welland River from its mouth to its source, a distance of about 40 miles.

In order to determine the best type of weir, it was deemed necessary to study various types under as nearly as possible true river conditions. These studies were made at the hydraulic laboratory of the college of civil engineering of Cornell University, the use of which was generously offered for this purpose. They covered experiments on seven different types, ranging in height from 3.7 to 6.02 feet and having in general a 3 to 1 upstream slope and a 1 to 1 downstream, five having a flat crest and the remainder a rounded crest. In two of the flat-top types, the upstream, and in all the downstream corners were rounded on a radius of 9.5 feet. On two of the flat-top and all of the round-top types, the downstream nappe was an ogee curve.

These experiments were conducted by Mr. E. E. Haslam, assistant engineer to the commission, and the results, which are given more in detail presently in this report, furnish what was being sought—namely, a type of submergd weir that would be very efficient at high stages and much less so at low stages.

Fortified with these new data, a study was made of the probable effect of submerged weirs placed at right angles to the general direction of the river in the following localities: Willow Island, Port Day, Grass Island and Gill Island, as well as one on a line between Gill Creek and Hog Island, at the mouth of Welland River, all as shown on Plate II. Only the last of these met the conditions desired, and it is not thought necessary to give the results of the studies of the rejected location because the end to be attained is clearly set forth in the consideration of the site finally chosen.

As shown in our previous report, the stage of water in several of the Great Lakes will be materially lowered by artificial diversions of water therefrom. This loss of level on Lake Michigan-Huron, if 10,000 c. f. s. be taken through the Chicago Drainage Canal, will for mean stage amount to $\frac{10{,}000}{18{,}900} = 0.53$ foot, while the loss of level to Lake Erie due to this diversion and 1,000 c. f. s. through

the Erie Canal and 1,100 c. f. s. through the Welland Canal will at mean stage amount to $\frac{10,000}{23,400} = 0.43$ foot and $\frac{2,100}{23,400} = 0.09$ foot, respectively, a total of 0.52 foot. The American power companies have also lowered the level of Lake Erie probably by 0.08 foot.

The project here proposed for restoring the loss caused by these diversions is the construction of a submerged weir of suitable type, on a line between Gill Creek and Welland River, as shown on Plates I and II, of such a height of crest as will create sufficient backwater to offset it.

To determine this, backwater curves have been computed, based upon Bernoulli's theorem for steady flow, and these are shown on Plates III and IV, the former being for the Tonawanda and the latter for the Chippewa Channel. These plates and Table I show the natural stages of upper Niagara River for low, mean, and flood conditions and also the compensated stages and backwater curves for 3-foot backwater at mean stage, at the proposed Gill Greek-Welland River weir.

The backwater on Lake Erie caused by the submerged weir has also been computed by the supply, storage, and discharge method described on pages 53 and 54 of the commission's report upon the regulation of Lake Erie, dated January 8, 1910, and the results by the two methods check very satisfactorily, the latter giving 0.07 foot greater backwater in the high-water year of 1876 and 0.08 foot greater in the low-water year of 1895.

Owing to the fact that the weir has an increasing efficiency with increase in stage, it was thought that the flow of the river might vary slightly from present natural conditions and therefore might affect injuriously the stage of water in the St. Lawrence Canals. The computed results show that the effect on Lake Ontario of any variation in the flow from Lake Erie caused by the submerged weir would be negligible. See Tables II and III, the former for effect on Lake Erie, and the latter for effect on Lake Ontario.

The type of weir chosen, as best meeting requirements, is shown in cross section on Plate V, Figure I. The longitudinal profile of its crest is shown on Plate VI, where it will be seen that it has been divided into four

sections, and the weir crest for each section set at such an elevation that it will produce 3-foot backwater at mean stage with the same distribution of flow of water across the river under compensated conditions as under natural conditions.

This 3-foot rise in mean stage at the proposed weir would raise the level of Lake Erie by 0.51 foot at low stage (570); by 0.39 foot at mean stage (572.6); and by 0.11 foot at flood stage (579.18). The increased stage of Lake Erie would decrease the slope in Detroit River and would cause Lake St. Clair to rise until the discharge through that river had a value equal to the present discharge under natural conditions. When this condition occurred Lake St. Clair would have risen in level by about 0.23 foot at mean stage. Likewise, the increased stage of Lake St. Clair would in turn decrease the slope in St. Clair River and Lake Huron-Michigan would rise until the slope became such as to produce a discharge in St. Clair River equal to its present discharge under natural conditions. This increased stage in Lake Huron-Michigan, corresponding to 572.6, mean level of Lake Erie, would be about 0.09 foot.

The discharge of the Niagara, corresponding to mean level of Lake Erie of 572.6 (see report on regulation of Lake Erie) and fall of 5.12 feet Lake Erie to Austin Street, Buffalo, is 209,100 c. f. s.; the low-water discharge for stage 570, and fall of 4.52 feet Lake Erie to Austin Street is 153,200 c. f. s.; and the flood discharge for stage 579.18 and fall of 6.42 feet Lake Erie to Austin Street is 376,700 c. f. s. It is this flood with which we are particularly concerned. By reference to Plates III, IV, and VI and Table I it will be seen that this compensated flood stage at the proposed weir would be 1.2 feet higher than the present natural flood stage at this point. The compensated flood stage at Tonawanda Island would be raised 0.55 foot above the present natural flood stage at this point.

Knowing the elevation of the flood waters of this new compensated flood stage from Lake Erie to the site of the proposed weir, the topographic surveys previously referred to were studied with a view to determining the effect that these new flood waters might have upon adjacent lands. So far as can be seen, but little, if any, damage would result from the proposed weir placed on the

Gill Creek-Welland River section. Our investigation has also shown that it would not be possible to raise the water at the weir by much more than 3 feet without danger of damage from floods.

It should be here stated that it was found impracticable to place this weir below the mouth of Welland River because of the large land areas that would be affected along this stream by increased stage of flood waters.

As Welland River is navigable and as there is a connection between the Welland Canal and the Niagara by this stream, it would be necessary to provide a lock at the Canadian end of the weir, as shown on Plate II.

The construction of the weir recommended in this report will affect to some extent the levels in the first reach of the Barge Canal, from Tonawanda to Lockport. The level of the Niagara River at Tonawanda would be raised by 1.71 feet at mean stage, and by 0.55 foot at flood stage, so that inasmuch as no provision has been made at the entrance of the canal against the rise which the construction of the weir will cause, it is in our opinion necessary to provide for the construction of a guard lock, the cost of which is included in our general estimate.

Having discussed the various engineering features of this project, we may now set forth the advantages that would result. First among these is the restoration to Lake Erie of 0.39 foot to its mean level. It is difficult to estimate this in money value, but it certainly would be many times the cost of the weir, in betterment of Lake Erie harbors and conditions at the mouth of Detroit River.

Secondly, it would greatly improve the navigation of the upper Niagara and thereby greatly benefit a locality which must sooner or later become a harbor or shipping port for important industries.

Thirdly, it would eliminate the possibility of the power companies at Niagara Falls having any injurious effect upon the stage of water in Lake Erie. The river below the weir would remain unchanged.

Fourthly, conditions on Lake Ontario and St. Lawrence River would remain unmolested.

Lastly, a bridge could be made a part of this weir, which would provide a free highway from one country to the other, open to the citizens of both.

Estimate of Cost of Proposed Weir.

Rock excavation, 36,300 cubic yards, at $4 per yard	$145,200
Concrete, superstructure, 44,000 cubic yards, at $12 per yard	528,000
Concrete, substructure, 48,500 cubic yards, at $10 per yard	485,000
Cofferdam, 105,500 cubic yards, at $3.50 per yard	369,250
Pumping and maintenance, lump sum	210,000
Lock into Welland River	500,000
Guard lock at Tonawanda	500,000
Excavation for retaining walls along Niagara River, 16,000 cubic yards, at $3 per yard	48,000
Concrete for retaining walls, 12,500 cubic yards, at $10 per yard	125,000
	2,910,450
Add for engineering and contingencies 20 per cent.	582,090
Total	3,492,540

SUBMERGED-WEIR EXPERIMENTS.

As previously stated in this report, submerged-weir experiments were made upon seven different types of weirs, ranging in height from 3.70 to 6.02 feet. All of the models were approximately 4 feet long. The following table, No. 4, gives the dimensions of the several models tested:

TABLE NO. 4.—*Dimensions of submerged-weir models.*

Model No.	Length.	Height.	Crest.	Width bottom.	Upstream face.	Downstream face.	Remarks.
	Feet.	*Feet.*		*Feet.*			
1	4.005	6.02	Flat, 6 feet wide....	31.76	1-3 slope..	1-1 slope..	Upstream corner sharp, downstream corner rounded, radius 9.5 feet.
2	4.01	4.53	.....do.....	35.79	...do.....	...do.....	Do.
3	4.01	4.53	.....do.....	27.33	...do.....	...do.....	Up and down stream corners rounded, radius 9.5 feet.
4	4.02	5.17	Rounded, radius 9.5 feet.	27.70	...do.....	...do.....	Ogee curve downstream face.
5	4.005	4.35	.....do.....	23.50	...do.....	...do.....	Ogee curve bottom, downstream face.
6	4.005	3.70	Flat, 6 feet wide...	23.50	...do.....	...do.....	Upstream corner sharp, downstream corner rounded, radius, 9.5 feet Ogee curve bottom do wn stream face.
7	4.005	3.70	.....do.....	25.04	...do.....	...do.....	Up and down stream corners rounded, radius 9.5 feet. Ogee curve bottom downstream face.

These models were placed in a wooden flume 95.5 feet long, 10 feet high, and 4 feet wide, constructed in the open concrete canal of the hydraulic laboratory at Cornell University, Ithaca, N. Y. The dimensions of the canal are 418 feet long, 16 feet wide, and 10 feet deep. The grade of bottom of channel is approximately 1 foot in 500. A bulkhead located about 60 feet from upper end of canal divides it into two parts. A standard sharp-crested weir placed on top of this bulkhead measures the quantity of water flowing in canal. The wooden flume mentioned above was built in this canal, the upper end being located about 87 feet below the standard weir. The upper end of flume had a bell-shaped mouth, about 15 feet long, converging from 16 feet, the width of canal, to 4 feet, the width of flume. The crest of weir of tested models was placed about 46 feet below upper entrance to bell mouth. The flow of water over the standard weir, through the canal, and over the experimental models was regulated by gates at the head and foot of canal. By the manipulation of these gates various discharges, submergences, and heads on the experimental weir models were secured. The upstream head was measured in the flume with a plumb-bob attached to steel tape at a point about 25.5 feet above the upstream edge of crest of flat weir, while the downstream head was measured in the same way in still water behind the flume on both sides and about 16.6 feet downstream from the upstream edge of crest of flat weir. The longitudinal water surface curve over the weir was determined for all models under various conditions

of flow. The flow of water over these experimental models varied between 27.6 and 203.2 second-feet, equivalent to 6.87 and 50.75 c. f. s. per linear foot of weir, respectively. The upstream heads on the weir varied between 1.66 and 6.35 feet and the ratio of submergences between 0 and 95. The experimental coefficients as derived are based upon the submerged

$$d$$

weir formula $D=cF^{\frac{1}{2}}(H+\frac{}{2})$, where D=discharge per linear

foot of crest, H=upstream head, d=downstream head, F=fall or upstream head minus downstream head, c=experimental coefficient. The weir coefficients for the flat-crest models are given in Table 5 and are shown on Plate V.

TABLE No. 5.—*Weir coefficients, flat-top model.*

Weir condition.	Average minimum river flow per linear foot of weir.	Coefficient.	Average mean river flow per linear foot of weir.	Coefficient.	Average maximum river flow per linear foot of weir.	Coefficient.
	C.f.s.		*C.f.s.*		*C.f.s.*	
Free	18.00	3.120	25.00	3.160	45.00	3.260
0.1 submergence	18.00	3.145	25.00	3.190	45.00	3.300
0.2 submergence	18.00	3.195	25.00	3.245	45.00	3.345
0.3 submergence	18.00	3.260	25.00	3.308	45.00	3.419
0.4 submergence	18.00	3.340	25.00	3.397	45.00	3.500
0.5 submergence	18.00	3.480	25.00	3.540	45.00	3.655
0.6 submergence	18.00	3.720	25.00	3.780	45.00	3.900
0.7 submergence	18.00	4.125	25.00	4.190	45.00	4.320
0.8 submergence	18.00	4.850	25.00	4.910	45.00	5.060
0.9 submergence	18.00	5.930	25.00	6.025	45.00	6.210

The weir coefficients of the rounded-crest models were about 5 per cent greater than those of flat-crest models, but the coefficient increment was about the same for each type within the limits for river conditions. The flat-crest model was therefore adopted on account of the easier construction, inspection, and repair.

Plate VII is a diagram of submerged-weir coefficients for the flat-top model shown in Fig. I, on Plate V, based upon and derived from the experiments hereto described and made at the Cornell University hydraulic laboratory, Ithaca, N. Y., in November and December, 1911.

Your committee do not wish it understood that the type of weir here proposed is the most desirable one for the purpose.

The experiments made were by no means sufficient to settle this question. It is very probable that further experiments would reveal a still better type. The one proposed does demonstrate, however, that the project is feasible.

E. E. HASKELL,
Member American Section.
WM. J. STEWART,
Member Canadian Section.

Attest:
W. EDWARD WILSON, C. E.,
Secretary American Section.

TABLE No. 1.—*Natural and compensated stages and backwater curves of Niagara River between Niagara Falls and Lake Erie.*

Niagara River sections.	Distance from Buffalo light.	Natural mean stage.	Compensated mean stage.	Backwater at mean stage.	Natural low stage.	Compensated low stage.	Corresponding backwater at low stage.	Natural flood stage.	Compensated flood stage.	Corresponding backwater at flood stage.
	Feet.			*Feet.*			*Feet.*			*Feet.*
Buffalo Breakwater Light, Lake Erie	0	572.60	572.99	0.39	570.00	570.51	0.51	579.18	579.29	0.11
Old Fort Erie, opposite angle Bird Island Pier	7,000	571.88	572.32	.44	569.31	569.92	.61	578.39	578.51	.12
Fort Porter	10,250	570.48	571.07	.59	567.96	568.79	.81	576.80	576.96	.16
Waterworks	11,250	569.34	570.08	.74	566.87	567.95	1.08	575.39	575.58	.19
Albany Street	12,500	568.84	569.25	.91	565.97	567.20	1.23	574.57	574.57	.24
Ferry Street	14,000	568.14	569.18	1.04	565.83	567.16	1.33	574.00	574.29	.29
Austin Street	21,700	567.36	568.52	1.16	565.23	566.68	1.45	572.76	573.09	.33
Strawberry Island	29,200	566.83	568.34	1.32	564.74	566.40	1.66	572.18	572.60	.42
Black Creek (Chippewa Channel)	57,000	565.05	567.49	1.84	562.91	565.05	2.14	570.06	570.65	.59
Tonawanda Island	64,900	565.01	567.62	1.71	562.91	565.05	2.14	570.98	571.53	.55
La Salle Landing	93,000	564.16	566.45	2.32	562.43	565.41	2.90	568.57	569.39	.82
Schlosser's Dock:										
Via Tonawanda Channel	107,500	563.82	566.33	2.51	562.29	565.34	3.05	567.70	568.61	.91
Via Chippewa Channel	85,700									
Gill Creek-Welland River Weir section:[1]										
Via Tonawanda Channel	112,800	[1]562.98	565.98	3.00	[1]561.50	565.11	3.61	566.55	567.75	1.20
Via Chippewa Channel	90,700									
Grass Island:										
Via Tonawanda Channel	115,200	561.98	561.98	0	560.62	560.62	0	565.66	565.66	.....
Via Chippewa Channel	93,200									
Willow Island:										
Via Tonawanda Channel	119,100	560.30	560.30	0	559.20	559.20	0	562.68	562.68	.....
Via Chippewa Channel	97,000									

[1] Not observed gauge readings; obtained by interpolation.

TABLE No. 2.—*Compensation of Lake Erie in high-water year 1876 and low-water year 1895.*

Date.	Water levels of Lake Erie.				Storage in Lake Erie.		Niagara River discharge, 100 c. f. s.	Total supply Lake Erie, 100 c. f. s.	Natural water levels, Gill-Creek-Welland River weir section.		Compensated lake level, Buffalo, N.Y., first of month.	Compensated outflow Niagara River, 100 c. f. s., first of month.	Compensated storage in Lake Erie.		Compensated lake level, Buffalo, N. Y., mean of month.	Compensated outflow Niagara River, mean of month, 100 c. f. s.	Compensated discharge minus natural discharge Niagara River, 100 c. f. s., mean of month.
	Cleveland, Ohio.		Buffalo, N. Y.														
	First of month.	Mean of month.	First of month.	Mean of month.	Foot depth.	100 c. f. s.			First of month.	Mean of month.			100 c. f. s.	Foot depth.			
1876.																	
January	572.35	572.36	572.70	572.81	+0.35	+276	2,081	2,358	562.04	562.99	573.09	2,104	+252	+0.212	573.20	2,182	+81
February	572.64	572.99	573.78	573.95	+ .60	+484	2,162	2,796	563.06	563.17	573.30	2,158	+436	+ .536	573.57	2,226	+64
March	573.24	573.57	573.25	573.55	+ .59	+454	2,311	2,935	563.35	563.51	573.54	2,206	+540	+ .538	574.14	2,307	+66
April	573.83	574.09	573.76	574.00	+ .62	+444	2,425	2,980	563.64	563.76	574.26	2,440	+428	+ .390	574.56	2,400	+66
May	574.25	574.41	574.16	574.31	+ .21	+222	2,507	2,729	563.85	563.93	574.74	2,542	+189	+ .159	574.82	2,463	+66
June	574.46	574.52	574.40	574.49	.00	0	2,567	2,567	563.96	564.09	574.90	2,585	− 28	− .024	574.80	2,582	+25
July	574.46	574.41	574.47	574.45	− .20	−211	2,546	2,335	564.02	564.01	574.88	2,579	−244	− .205	574.78	2,552	+ 6
August	574.26	574.11	574.25	574.07	− .24	−254	2,444	2,190	563.91	563.80	574.67	2,520	−330	− .277	574.48	2,483	+39
September	574.02	573.94	574.02	573.96	− .34	−360	2,414	2,054	563.77	563.74	574.39	2,443	−389	− .327	574.23	2,398	−15
October	573.86	573.41	573.72	573.49	− .23	−243	2,296	2,053	563.61	563.48	574.06	2,353	−300	− .252	573.94	2,221	+25
November	573.45	573.49	573.58	573.68	− .13	−137	2,344	2,207	563.43	563.59	573.81	2,267	− 80	− .067	573.76	2,200	−84
December	573.32	573.15	573.60	573.53	− .37	−391	2,306	1,915	562.54	563.50	573.74	2,270	−355	− .298	573.57	2,226	−80
1895.																	
January	571.40	571.23	571.76	571.68	− .28	−296	1,875	1,579	562.51	562.47	572.20	1,900	−311	− .266	572.06	1,838	−17
February	571.13	571.00	571.84	571.00	− .12	−127	1,728	1,601	562.27	562.06	571.93	1,839	−228	− .197	571.82	1,807	+79
March	571.00	571.01	570.96	570.92	+ .14	+148	1,712	1,860	562.06	562.04	571.73	1,784	+ 76	+ .066	571.76	1,791	+79
April	571.14	571.26	571.02	571.13	+ .23	+243	1,786	1,999	562.09	562.16	571.80	1,800	+180	+ .172	571.85	1,818	+62
May	571.37	571.48	571.30	571.46	+ .15	+159	1,829	1,988	562.25	562.25	571.97	1,838	+160	+ .139	572.04	1,854	+35
June	571.52	571.57	571.53	571.59	.00	0	1,851	1,851	562.36	562.41	572.10	1,867	− 16	− .014	572.10	1,867	+16
July	571.59	571.46	571.57	571.56	− .10	−106	1,846	1,740	562.40	562.39	572.09	1,865	−125	− .108	572.04	1,854	+ 8
August	571.42	571.28	571.49	571.42	− .09	− 95	1,817	1,722	562.36	562.32	571.96	1,840	−118	− .102	571.93	1,829	+12
September	571.23	571.20	571.42	571.44	− .29	−307	1,821	1,514	562.23	562.23	571.86	1,818	−304	− .262	571.73	1,789	−32
October	571.04	570.80	571.32	571.20	− .29	−307	1,771	1,464	562.20	562.19	571.82	1,760	−296	− .255	571.40	1,732	−39
November	570.78	570.70	570.96	570.71	+ .08	+ 82	1,670	1,752	562.06	561.91	571.36	1,704	− 2	− .002	571.36	1,704	+34
December	570.78	570.68	570.84	570.97	+ .13	+137	1,723	1,860	561.99	562.06	571.36	1,704	+156	+ .134	571.42	1,717	− 6

The flow of 1,250 c. f. s. through the Erie Canal and that of 1,100 c. f. s. through the Welland Canal have been omitted.

TABLE No. 3.—*Effect of compensation of Lake Erie on water levels of Lake Ontario in high-water year 1876 and low-water year 1895.*

Date.	Natural water levels of Lake Ontario at Charlotte, N. Y.		Actual rise of lake during month, in feet.	Inflow from Niagara River.		Change of inflow to Lake Ontario due to compensating works.	Effect of change of inflow on level of Lake Ontario for month, in feet.	Effect of change of outflow through St. Lawrence River on level of Lake Ontario, for month, in feet.	Total effect from change of inflow and outflow on level of Lake Ontario, in feet.	Compensated conditions.			Compensated level less natural level of Lake Ontario.	
	First of month.	Mean of month.		Natural condition.	Compensated condition.					Rise or fall during month, in feet.	Stage of Lake Ontario first of month.	Stage of Lake Ontario mean of month.	First of month.	Mean of month.
				100 c. f. s.	100 c. f. s.	100 c. f. s.								
1876.														
January	245.28	245.48	+0.52	2,061	2,122	+51	+0.056	0.000	+0.056	+0.576	245.280	245.868	0.000	+0.068
February	245.80	246.11	+ .60	2,162	2,226	+64	+ .070	− .018	+ .052	+ .652	245.856	246.152	+ .056	+ .072
March	246.40	246.70	+ .76	2,311	2,367	+56	+ .061	− .034	+ .027	+ .787	246.508	246.902	+ .108	+ .202
April	247.16	247.62	+ .80	2,426	2,490	+65	+ .071	− .044	+ .027	+ .827	247.295	247.705	+ .135	+ .088
May	247.96	248.30	+ .40	2,507	2,593	+86	+ .061	− .054	+ .007	+ .407	248.123	248.326	+ .162	+ .026
June	248.36	248.42	+ .07	2,557	2,582	+25	+ .027	− .057	− .030	+ .040	248.520	248.549	+ .169	+ .129
July	248.43	248.44	− .20	2,548	2,552	+ 6	+ .006	− .047	− .041	− .241	248.560	248.448	+ .139	+ .008
August	248.23	248.03	− .55	2,444	2,483	+39	+ .043	− .033	+ .059	− .541	248.328	248.058	+ .098	+ .033
September	247.68	247.35	− .89	2,414	2,398	−16	− .017	− .035	− .052	− .552	247.787	247.511	+ .107	+ .161
October	247.18	247.00	− .35	2,296	2,321	+25	+ .027	− .018	+ .009	− .341	247.238	247.064	+ .055	+ .064
November	246.85	246.66	− .31	2,344	2,280	−64	− .070	− .020	− .090	− .400	246.894	246.624	+ .054	+ .034
December	246.62	246.39	− .34	2,366	2,286	−80	− .088	+ .008	− .080	− .420	246.494	246.284	− .026	− .106
1895.														
January	244.54	244.55	− .07	1,675	1,658	−17	− .019	.000	− .019	− .099	244.540	244.496	.000	− .054
February	244.47	244.39	− .07	1,728	1,807	+79	+ .088	+ .006	+ .094	+ .024	244.451	244.403	− .019	+ .073
March	244.40	244.40	+ .17	1,712	1,791	+79	+ .088	− .023	+ .066	+ .226	244.478	244.593	+ .078	+ .193
April	244.57	244.74	+ .26	1,738	1,818	+62	+ .069	− .042	+ .027	+ .307	244.711	244.864	+ .141	+ .124
May	244.85	244.96	+ .08	1,820	1,854	+25	+ .028	− .050	− .022	+ .008	245.018	245.022	+ .108	+ .092
June	244.88	244.79	− .23	1,851	1,867	+16	+ .018	− .044	− .026	− .246	245.026	244.903	+ .146	+ .113
July	244.66	244.53	− .26	1,846	1,854	+ 8	+ .009	− .036	− .027	− .287	244.780	244.630	+ .120	+ .166
August	244.40	244.28	− .25	1,817	1,830	+13	+ .013	− .028	− .015	− .265	244.493	244.360	+ .093	+ .100
September	244.15	244.04	− .24	1,821	1,788	−33	− .035	− .023	− .058	− .308	244.228	244.044	+ .078	+ .004
October	243.84	243.64	− .32	1,771	1,723	−48	− .043	− .006	− .049	− .369	243.860	243.676	+ .020	+ .036
November	243.53	243.41	− .06	1,670	1,704	+34	+ .038	+ .008	+ .046	− .014	243.491	243.484	− .029	+ .074
December	243.46	243.51	+ .10	1,728	1,717	− 6	− .007	− .005	− .012	+ .108	243.477	243.561	+ .017	+ .051

EXTRACT FROM REPORT OF CHIEF OF ENGINEERS' REPORT, 1900, APPENDIX III:

"APPENDIX III:

Northern and Northwestern Lakes—Correcting and Issuing Charts—Surveys—Water Levels.

Report of Lieut. Col. G. J. Lydecker, Corps of Engineers, for the Fiscal Year Ending June 30, 1900.

III 1.

United States Engineer Office,

Detroit, Mich., August 15, 1900.

General: I have the honor to submit herewith my annual report on survey of the Northern and Northwestern Lakes for the fiscal year ending June 30, 1900.

Very respectfully, your obedient servant,

G. J. LYDECKER,
Lieut. Col., Corps of Engineers.

Brig. Gen. John M. Wilson,
Chief of Engineers, U. S. A.

Northern and Northwestern Lakes—Correcting and Issuing Charts—Surveys—Water Levels.

The survey of the lakes as a connected and systematic work was commenced in 1841 and completed in 1882, but local surveys by officers of engineers for special purposes, including harbor improvements, date back to 1817. After the general survey was completed, in 1882, operations were limited to the publication and issue of the Lake Survey Charts until 1889, under annual appropriations of two or three thousand dollars, but from the last-mentioned date additional appropriations, varying from five to

twenty-five thousand dollars, were made annually for surveys relating to additions to and corrections of the original charts. In 1898 these operations were extended to include observations and investigations of lake levels, with a view to ascertaining the causes of changes in level, determining the hydraulic data needed for formulating the laws of interlake flow, and devising the most feasible method of lake level maintenance or regulation."

Chief of Engineers Report, 1900, App. III, page 5317.

EXTRACT FROM REPORT OF CHIEF OF ENGINEERS, 1900, APPENDIX III, BEING REPORT OF ASST. ENGINEER F. C. SHENEHON, DATED BUFFALO, JULY 18, 1900:

"The Niagara River, as it breaks out of Lake Erie, flows almost due north. It narrows rapidly and passes swiftly through a choken section of limestone, where the speed at mid-river must approximate 8 miles an hour. Emerging from this, the river grows wider and deeper and slows up to about 5 miles an hour as it approaches the International Railway Bridge, 12,000 feet below the head of the river.

In this distance the fall is about 5 feet at mean lake stage.

The bridge consists of nine spans on masonry piers carrying a single-track railway. Enough clearance exists between the track and the through trusses for footways on each side, which are, however, cramped and not open to public travel. The base of rail is about 24 feet above the water surface. The piers rest in timber caissons and are provided with cutwaters. Protective masses of large stone are dumped about the piers, making a somewhat ragged profile and a bottom dangerous to instruments.

The piers have a small battir, but may be considered vertical for river-gauging purposes.

The length in feet of clear waterway and the maximum depth of the several spans are as follows:

Number of span.	Length	Maximum depth.	Percentage of discharge passing each span.
1	151.5	13.1	0.5
2	154.1	13.8	2.5
3	156.2	35.7	9.7
4	234.2	48.3	28.2
5	235.8	47.3	26.7
6	235.3	50.7	18.2
7	187.0	26.6	8.6
8	184.3	17.1	5.5
9	138.4	9.6	0.7

The numbering of the spans as used in the gauging begins on the east end, the drawbridge spanning the second and third openings, the ship channel passing through the third.

The long spans, 4, 5 and 6, naturally divide up into three station lengths of about the same size as the half-span lengths in which the remaining openings are conceived as divided. This cuts up the clear waterway of the river into 21 station areas, each about 80 feet long. Each of these is divided again into four substations of about 20 feet. Midway of each station area, and at approximately three-tenths depth, a point is taken as representative of the velocities throughout the area. Because it indicates the station discharge it has been called the index.

The measurement of the discharge consisted in obtaining the velocities at each of the 21 station indexes in quick succession. Coefficient work then established the ratio between the mean velocity in the station area and the observed index velocity. With cross-sectional area determined by the soundings, the station discharge = coefficient × index velocity × cross-sectional area; and the full-river discharge is a summation for all stations of these partial discharges.

In the open section below the bridge the 1,720 feet between the terminal cribs was divided into 16 stations of 100 feet and 1 of 120 feet; and the indexes were taken at mid-station at approximately four-tenths depth.

Reconnaissance soundings from the bridge were taken by the Board of Engineers on which index depths were founded, and the station scheme as used by them was followed in the Lake Survey work on this section.

The Lake Survey soundings were subsequent to considerable meter work, but as logically soundings should precede this they will be taken up here.

A current of 5 miles an hour with a depth of nearly 50 feet in the fourth and fifth spans of the bridge rendered ordinary methods of sounding inaccurate. Even as heavy a lead as 40 pounds on a sash cord thrown upstream and quickly dropped to bottom gave results that are indeterminate in two particulars. First, the observer is unable to say whether the lead is on the bottom above, below, or in the plane of the section; second, with the lead touching bottom and dragging a belly is created in the sounding line by the current pressures on it of unknown form, and the indicated depth is too great by an unknown amount. An error of 2 to 3 feet in 50 may readily enter in a 5-mile current from these causes.

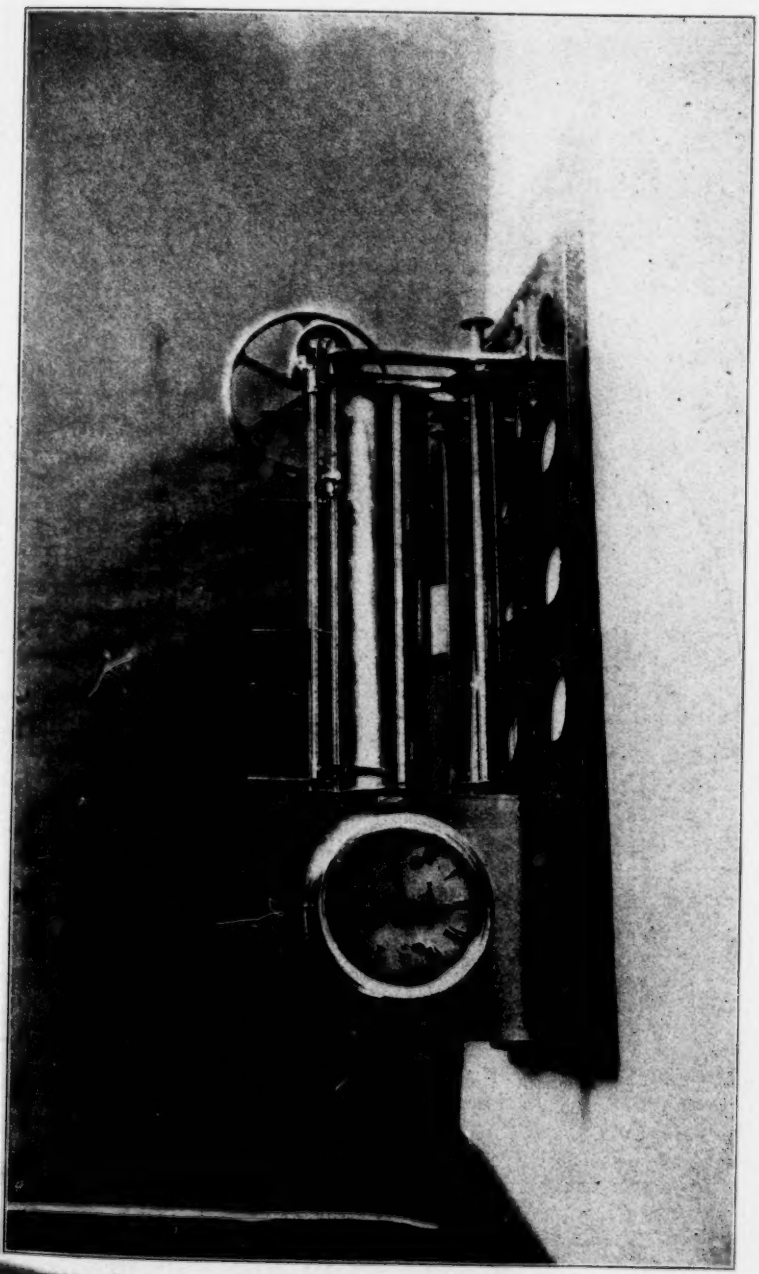
A percentage error in the soundings of a station produces the same percentage error in the volume of discharge of that station, since mean depth $\times$ width $\times$ mean velocity $=$ discharge.

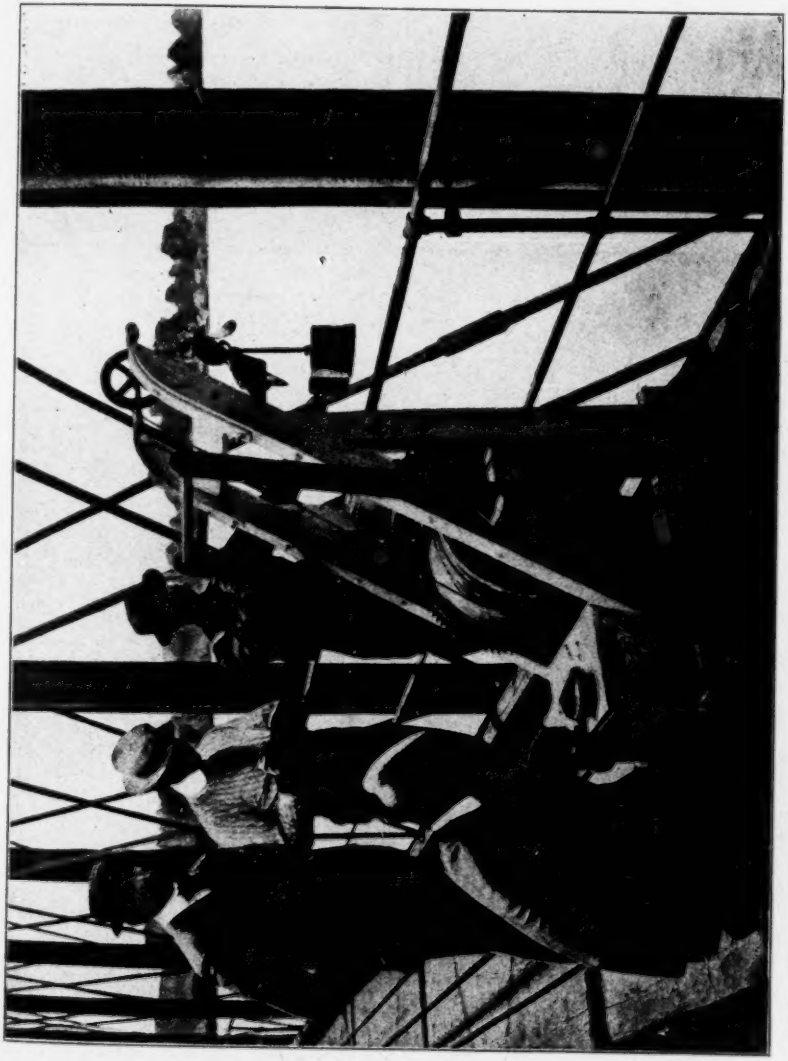
Moreover, it is in the important stations where, with highest speed and greatest depth, the discharge is largest that this percentage error is most likely to occur; and it is in these stations that accurate soundings is most imperative by reason of their weight in the aggregate volume of flow.

Any refinement in the other factors that enter into the problem of river gauging is annulled by less refinement in the sounding."

Report of Chief of Engineers, 1900, App. III, pages 5328-5329.

Attached to said report of Francis C. Shenehon are plates 5 and 6 opposite page 5326 of said report, which are inserted opposite hereto in connection with Mr. Shenehon's report.





Further Extract from Report of Francis C. Shenehon, Dated Buffalo, July 18th, 1900:

page 5338.

"An excellent rating of the B meter was made of 67 observations and a very elaborate rating of the A meter consisting of 173 observations.

This latter was stretched over five days in an attempt to trace the cause of what has appeared elsewhere as a diurnal variation of the rating constants. The several days, however, failed to show any considerable change, and the observations almost deny what is clearly indicated throughout all the two meter work, and what other ratings made by myself and by other observers show to be a fact. This variation of 1 or 2 per cent. on either side of a mean rating line is baffling in the extreme.

Whether it is in the manipulation of the instrument or independent of the slight condition changes that may be controlled by the observer, and in the metallic structure of the bearings or the varying pressures of the contact pin, is yet to be solved. As the mean rating of the instrument was known the mean discharge line will be true in spite of this, but the error of individual observations has a wider range.

In coefficient work this was eliminated by comparisons of the two meters employed, as their wheels spun side by side in the river current.

Assuming that the velocity of the current in which the two meters are running is measured by one of them whose rating constants have been established on a still-water base, it is apparent that a series of these simultaneous runs in stations of different velocities constitutes a rating of the second meter.

It is apparent also that any small percentage error existing in the velocities indicated by the first meter will be present in the second as well.

From this it follows that when one meter is rated by comparison with another the two instruments become a compound instrument, and that when velocities are simultaneously measured by the two wheels the ratio of the two velocities is correct, notwithstanding the percentage error in the absolute velocities, since this is eliminated in the ratio by appearing both in the numerator and denominator.

On this principle the two-meter system depends. It is

slightly in error in practice, since rating variations do not follow strictly percentage lines. But a small error in small quantities may be treated as a differential of the second degree and neglected. Daily ratings were made in the current as a basis for the value of the revolutions of the B wheel.

Coefficient work in river gauging consists in determining velocity ratios of many points in a station area with respect to some central point.

Discharge observations measured the *absolute* velocity at this central point.

It must be emphasized that these two classes of work furnish two criterions of ratings.

For discharge work the absolute rating is necessary, and this was dependent in the Lake Survey gaugings of this river on still-water calibrations.

For coefficient work, the relative rating is alone required and this was obtained by current comparisons.

This distinction, which is vital, will be made clear by the following parallel:

Revolutions of wheel per second	1	2	3	4	5	6
Corresponding absolute velocity	1.35	2.57	3.79	5.01	6.23	7.44
Corresponding relative velocity	.270	.513	.756	1.000	1.244	1.485

The relative velocities are here derived from the absolute by dividing through by 5.01, which gives a percentage scale in which the velocity at four revolutions is taken as unity.

In judging the rating used on the meter which measures absolute velocities, the criterion is whether the velocities corresponding to given revolutions are the same as derived by other ratings, and that it is internally consistent.

In passing on the rating used on the meter, measuring ratios, it is enough if the velocity percentages for even revolutions are constant; and two ratings that are widely different in absolute velocities may be in perfect agreement in relative velocities. * * *

page 5340.

For the work on Niagara River velocities below 2 feet per second are of very little moment, so little that an error of 5 per cent. in them would not amount to an error of one-tenth of 1 per cent. in the final result of the dis-

charge. For this reason the rating line below this was ordinarily determined graphically.

The most luminous way found of doing this was by platting the total number of revolutions on the rating base as abscissae, with the velocities per second as ordinates, and sketching in the line of variation of the total revolutions; then solving the corresponding revolutions per second for a number of velocities and interpolating the balance.

When all observations, high and low, were platted in this way, the rating line for high velocities could be drawn in with an accuracy exceeding one-half of 1 per cent.

After solving a straight-line equation for the higher velocities, the residuals (computed minus-observed velocities), were taken out, grouped for velocity intervals, and platted. This method revealed the line of the A meter to be a reversed curve. An examination of the total number of revolutions on the base shows the same tendency for this meter, as the revolutions reach a maximum at 3-foot velocity and fall off for higher or lower speeds.

The B line is parabolic, with little curvature in high velocities.

These slight curvatures are refinements that need not be emphasized, but were taken into consideration in the reductions.

The velocities derived by curve and straight line formulae are compared in the summary table. See ratings 6 and 7, and 8 and 9 for A meter.

Rating No. 1 for the B meter was used on all discharge measurements taken with this instrument during the season of 1898 on the bridge section.

Rating No. 5 for the A meter was used for the October-November, 1899, discharges on the open section. The December discharges platted off the line of the previous discharges by using No. 5, but are aligned by using No. 6, which represents the rating of the meter at the close of the season.

For coefficient work on the bridge section the current rating No. 2 of the B meter, which depends on rating No. 5 of the A meter, was used.

The validity of this rating is shown by a comparison with still-water rating No. 3, which immediately followed the coefficient work.

The rating of the B meter used in coefficient work on the open section was No. 6, derived from No. 5 rating of the A meter by 388 side-by-side current comparisons.

That a certain rating was used in coefficient work must be stated, with the reservation that velocity ratios obtained on any day by using two specified ratings of the two meters were corrected by the same percentage as was necessary to apply to the ratios of the meters in the same current to bring them to unity.

From the rating equations, rating tables of absolute velocities were made giving all velocities corresponding to wheel revolutions from 0.00 to 6.00 per second, by 0.01 increments. These were used in discharge work.

For coefficient work, velocity percentage curves were constructed, from which the velocity ratio was taken off directly from the indicated revolutions per second of the two wheels.

This proved of great service in the vast amount of this work done on the two sections. Each day's work in the river on the open section by the two-meter method gave upward of a hundred velocity ratios to solve in duplicate. Without this graphic method of solution the winter office force of four men would have been overwhelmed by the accumulated mass of observations.

The percentage curves gave results accurate to a fifth of 1 per cent., with no systematic error, and were skillfully used by assistants of little office experience.

The correction applied to percentages derived from this curve was indicated by the ratio obtained by speeding the meters side by side. It is evident that the velocity percentage obtained from the curve when the meters run side by side should be 100, but in practice it varied 1 or 2 per cent. on either side of this. This was due to the daily fluctuations of ratings before mentioned, and coefficient work done on each day was corrected for this, as follows: When the mean of the daily current ratings indicated by the curve was 102 per cent., it was assumed that all ratios obtained that day were too large by 2 per cent., and each was therefore divided by 1.02. If the mean daily rating showed 98 per cent., all ratios were increased 2 per cent.

The calibration of the instruments is such an important part of river gauging that considerable space has been devoted to describing the methods used on the

Niagara River as precedent to their use in current measurement.

In discharge work on the bridge, the B meter was carried on the same reel, mounted on trucks, that was used in sounding. Each revolution of the drum reeled off exactly 5 feet of the quarter-inch steel cable, by which the meter was suspended. Electric connections between the meter cable on the moving drum and the stationary batteries (which were carried in a box beneath) was maintained by brass springs bearing against concentric brass rings on the head of the drum.

From the drum the cable led up over a pulley on an overhanging arm which swung the meter clear of the hand rail of the bridge, so that it could be dropped between the eyebars of the lower chord to the water.

With the meter at the index, which was approximately at three-tenths depth at each station, a two-minute run was made. The meter was then wheeled to the next, and to all stations successively, taking a two-minute measurement of the current speed at each. The mean length of current thread measured at stations was about 650 feet in the run of 120 seconds, being more than this in the mid-river spans, and less toward the shore.

The observing party consisted of five men—the observer, the recorder, two men on reel, and one watchman to warn the party of the approach of trains, and to keep a lookout for the drift that might injure the meter.

It took from an hour and a half to two hours to measure a discharge.

The location of the meter at the index depth was somewhat complicated by the swinging of the instrument downstream by the current, with a resulting inclination of the cable, which was different from each lake stage. By taking the angle that the cable made with the vertical at mean stage for each of the swift-water stations, the amount of cable to reel off after the meter axis was at water service was computed for each.

To this was added algebraically for any other stage three-tenths of the change in the section gauge.

The precedent of making no correction for the greater inclination of the cable under high velocities, established by the Board of Engineers on Deep Waterways, was followed in the lake-survey discharges.

As the velocity ratio is so nearly constant close above

and below the three-tenths depth, the dipping of the meter a foot or two below the proper index depth in low stages, and rising as much above it in high, which with this amplitude was confined to the deepest, most rapid stations, resulted in no great inaccuracy. This range was much reduced in the winter and spring of 1899 by the use of the 136-pound lead on the B meter instead of the standard 36-pound one.

In coefficient work the A meter was set at the index more closely than in discharge observations, and the B meter, with its great weight, was placed accurately in its proper position in the vertical by corrections that took into consideration the curvature of the cable below water and the inclination above, as detailed in the discussion on methods of sounding.

Coefficient work was carried on with two meters, the A meter at the index, while the B meter made simultaneous runs, obtaining the velocity ratio directly for as many points in the station area as was judged desirable to establish the mean velocity ratio.

Coefficient work follows essentially a cross-sectioning process, similar in many respects to earth work measurement. Its object is to find the volume of water at the mean section-gauge height passing a station area when the index velocity is taken as unity. This volume, divided by the cross-sectional area developed by the soundings, gives the mean velocity as a percentage of the index velocity.

This is the velocity coefficient, which reduces the product—the cross-sectional area into the velocity obtained in a discharge measurement—to station volume of flow.

In such a section as that of the international bridge the proper derivation of the velocity coefficients is the most difficult part of the river gauging.

To obtain it the writhing mass of water streaming through the bridge openings and eddying about the piers, spurting and lagging in minor pulsations, speeding faster as the lake rises and flowing leisurely in low stages, must be congealed to a solid by some instantaneous method of survey, and its dimensions taken.

The two-meter method of work was the instantaneous process used to attain this result.

With all its variations of velocities a law of flow is followed by which percentage velocities tend to remain

constant. If the current threads speed up at the index where the A meter was placed, it quickens proportionally 20 feet away, where the B meter is spinning; so that, with a large range in absolute velocities, so long as the relative position is held, the ratio, B's velocity divided by A's velocity, tends to remain constant.

The abruptly changing conditions of the bottom at the bridge made it necessary to observe velocity percentages from surface to bottom at many substations. This was done on all the regular substations—about 20 feet apart—into which each station was divided, and in addition pluses were put in near the piers, and wherever else the conditions seemed to indicate a possible change.

The following summary shows the number of points at which these vertical curves were measured in each station area:

Summary of Vertical Curves, Bridge Section.

Span.	Index station.	Number of curve stations.	Span.	Index station.	Number of curve stations.
2.....	2	5	5.....	10	6
2.....	6	5	6.....	2	6
3.....	2	5	6.....	6	4
3.....	6	6	6.....	10	5
4.....	2	7	7.....	2	7
4.....	6	4	7.....	6	6
4.....	10	4	8.....	2	7
5.....	2	7	8.....	6	6
5.....	6	4			

Curves were taken in spans 1 and 9 at all substations, but were not used, coefficients previously derived being accepted.

A duplicate set of observations was made on each curve. Beginning just below the surface, the B meter was started simultaneously with the A meter (which remained at the index) and both stopped at the end of four minutes. This was repeated at different depths until the B meter reached bottom. The B meter, then observed at the same depths as it was brought upward, obtaining a duplicate set of percentage velocities. As the observations were made, they were reduced and platted on the bridge, and any showing widely different from its original, or off the line traced by the others, was again repeated.

Guys above water were used to hold the B meter from sagging down stream in the strong current. Side-by-side ratings of the two wheels maintained the integrity of the compound meter.

These ratings were ordinarily carried on as follows: The A meter was set at 5 feet depth, well away from the piers; the B meter was set at same depth, abreast, and about 4 feet west of it.

Two or three 2-minute runs were then made simultaneously, after which the B meter was placed the same distance east of the A and the observations repeated. Observing east and west of the B meter eliminated the effect of the change of velocity along the section.

This current rating was repeated for different velocities.

Early in the observations the importance of this as a basis of corrections was not fully grasped and the ratings were not always made daily, but enough were made to give an excellent key for interpolation.

It will be observed that what have been mentioned as vertical curves are, more accurately, vertical-transverse curves, because each point has been referred to the index, which involves the change in velocities latterally as well as vertically, so that the mean ordinate of any of these curves is the vertical-transverse coefficient for the sub-station which it governs.

The third element that enters into the sub-station coefficient is the direction coefficient.

The direction of the current flow was not, as a rule, at right angles to the bridge, but at mid span the trend was 2 or 3 degrees to the eastward, and nearer the piers was deflected from them, so that for each opening the threads tended to converge in a vena contracta.

The surface indication of the direction was taken as the direction at all depths, and the angle taken by a 20-foot line flush with the water surface, to which was attached a weighted float, while the upstream end was attached to the weight of the B meter lowered from the south side of the bridge just below the water, was accepted as a basis for direction coefficient.

This was observed for all substations, and additional observations were put in around the piers.

The influence of the direction element on the measured discharge is minute, almost negligible.

With the many substations coefficients, transverse, vertical, and direction, which combined make the required velocity coefficient, the proper methods of combining them to arrive at an accurate result is important.

In discussing the methods used to compute the volume of river flow, it will be necessary to derive some equations that are fundamental in an elementary manner.

This is peculiarly true of those involving the velocity coefficient. As the conditions at the bridge section are such as to call for the observance of accurate methods in the derivation of this ratio, instead of the more simple approximations that may be safely used in an unbroken stream, the detail of the theory on which it was computed is given.

It has been demonstrated in river hydraulics that the velocities throughout a certain area maintain definite percentage relations, and when these relations are firmly established by ample observations, a single known velocity is the key to all others simultaneously existing, and hence to the discharge in the area involved.

On this characteristic of river flow are based the methods used to determine the volume of water which the river carries in its various stages and conditions. Like most hydraulic laws, this has its limitations, and is more nearly absolute as the area considered approaches an element of river width.

How accurate it is for the full river width is shown by the following tabulation, in which the mean velocities for each station derived from groups of discharge measurements are expressed as percentages of the mean velocity of all stations for the same group.

OPEN SECTION

TABLE 5. INDEX VELOCITIES AS PERCENTAGES OF MEAN INDEX VELOCITY.

	GROUP NO. 1	2	3	4	5	6	Total	Weighted means
Number of observations in group.....	10	10	10	10	10	7	57	
Elevation of lake gauge.....	572.0	571.4	571.2	571.1	570.9	570.5	.....	571.2
Mean index velocity.....	4.84	4.58	4.51	4.45	4.38	4.21		4.51
Station—								
1.....	42.6	33.9	28.4	23.5	25.6	29.2	.....	30.6
2.....	81.3	79.0	78.6	77.6	77.3	77.2	.....	78.5
3.....	95.9	96.8	97.7	99.7	98.8	97.6	.....	97.8
4.....	104.5	105.1	105.4	106.0	106.7	106.2	.....	105.6
5.....	126.6	127.8	129.3	127.9	128.1	126.6	.....	127.8
6.....	129.2	130.5	133.1	133.0	134.4	136.1	.....	132.5
7.....	124.1	125.1	126.1	126.4	125.6	125.7	.....	125.5
8.....	121.3	122.9	124.6	124.9	124.5	123.3	.....	123.6
9.....	118.2	121.1	120.5	121.4	121.6	122.1	.....	120.7
10.....	108.9	110.5	110.3	110.4	110.7	112.4	.....	110.4
11.....	107.7	110.6	110.7	111.9	110.8	110.2	.....	110.3
12.....	106.7	107.6	106.9	108.6	108.3	109.5	.....	107.8
13.....	92.6	93.5	91.9	92.7	91.2	91.9	.....	92.3
14.....	100.0	99.8	99.3	99.9	101.0	98.8	.....	99.9
15.....	92.4	90.9	91.3	90.4	91.8	90.7	.....	91.3
16.....	84.1	84.3	84.6	84.2	83.7	83.1	.....	84.0
17.....	64.1	64.9	61.4	62.1	61.0	59.9	.....	61.8

No serious error will enter from the proposition of fixed relations within the area limited by a proper station width.

It is apparent, however, that velocities will maintain their relation the more accurately as they are closer together, and for this reason the point which is selected as the key to a station discharge should be centrally located in its area. This consideration would point out the center of figure as the desirable location, but a modification of this grows out of the fact that it is more important to know accurately the velocity ratios of the high speeds where the greatest discharge occurs than those of the low. It would therefore seem that the center of gravity of the solid figure in which a second's discharge may be conceived to congeal is the proper location of this point.

As has been stated before, since the velocity here is taken as indicative of the station discharge, this point has been called the index.

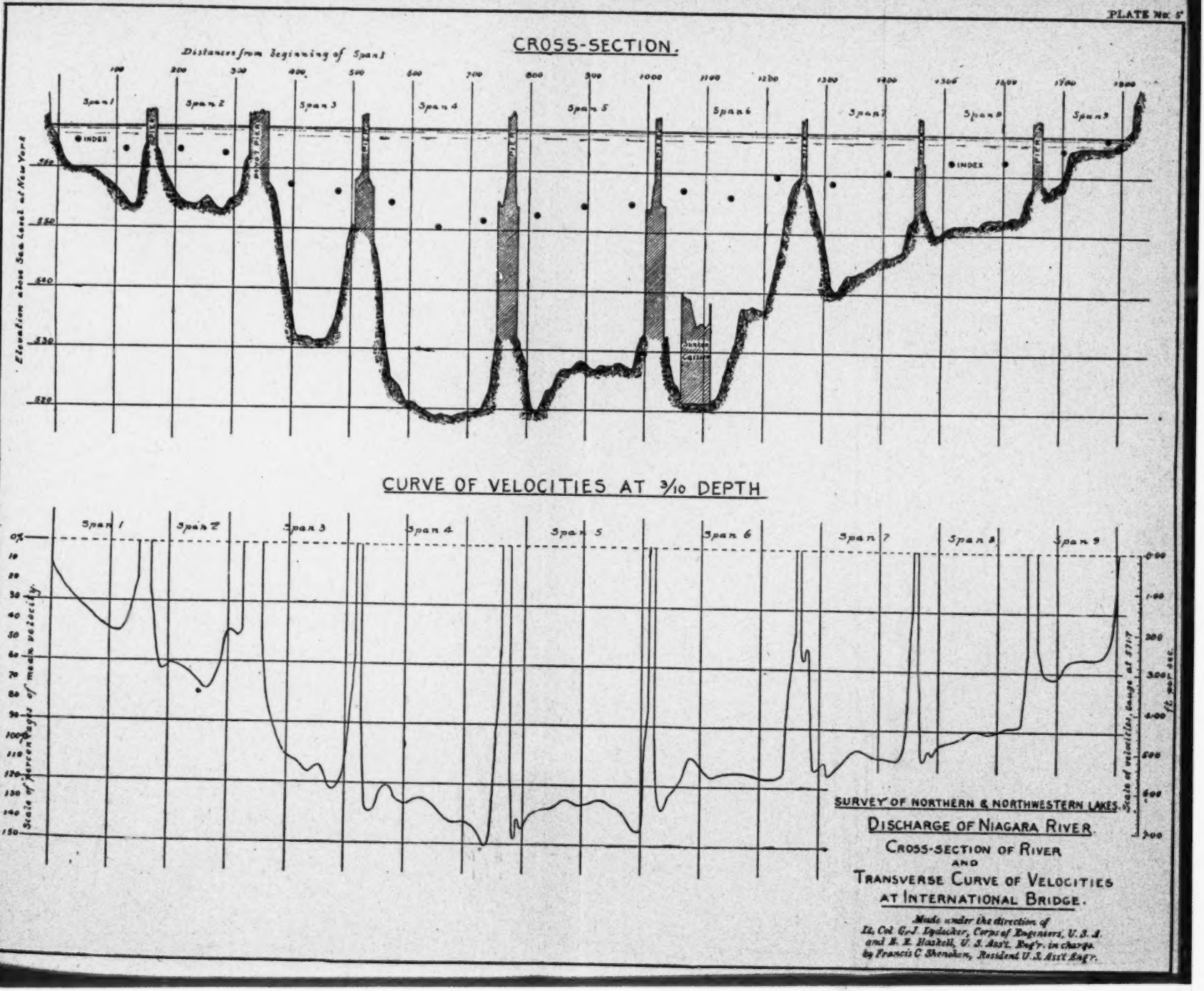
Other practical considerations generally prevail to put the index at mid-station and at a lesser depth than the gravity center. In the bridge section it was taken at three-tenths depth and in the open section at four-tenths depth. The center of gravity would fix it between four-tenths and mid-depth.

For gauging purposes the river width having been divided into N stations of such size that the index in each will accurately reflect changes throughout, the discharge of the river must be the summation of the partial discharge in all these stations."

Chief of Engineers' Report, 1900, Appendix III, pages 5338, 5340-44.

From the report *supra* of Mr. Francis C. Shenehon, Assistant Engineer, dated Buffalo, July 18, 1900, are inserted opposite hereto plates 5, 6 and 7 which appear in said report opposite page 5360.

PLATE No. 5



SURVEY OF NORTHERN & NORTHWESTERN LAKES.

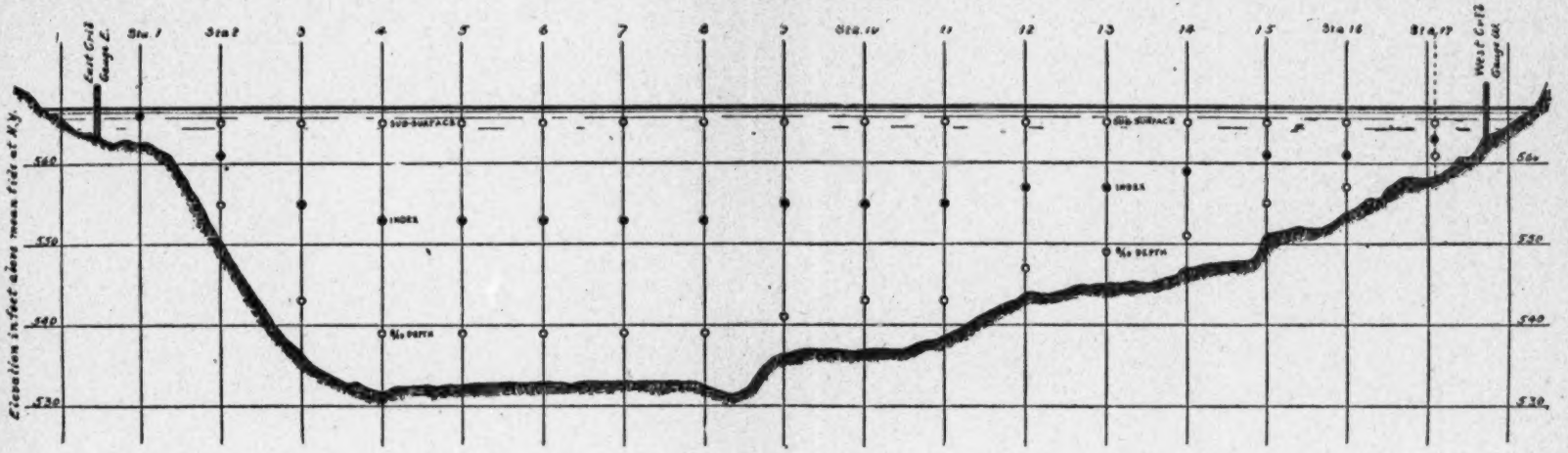
DISCHARGE OF NIAGARA RIVER.

CROSS-SECTION OF RIVER AND TRANSVERSE CURVE OF VELOCITIES AT INTERNATIONAL BRIDGE.

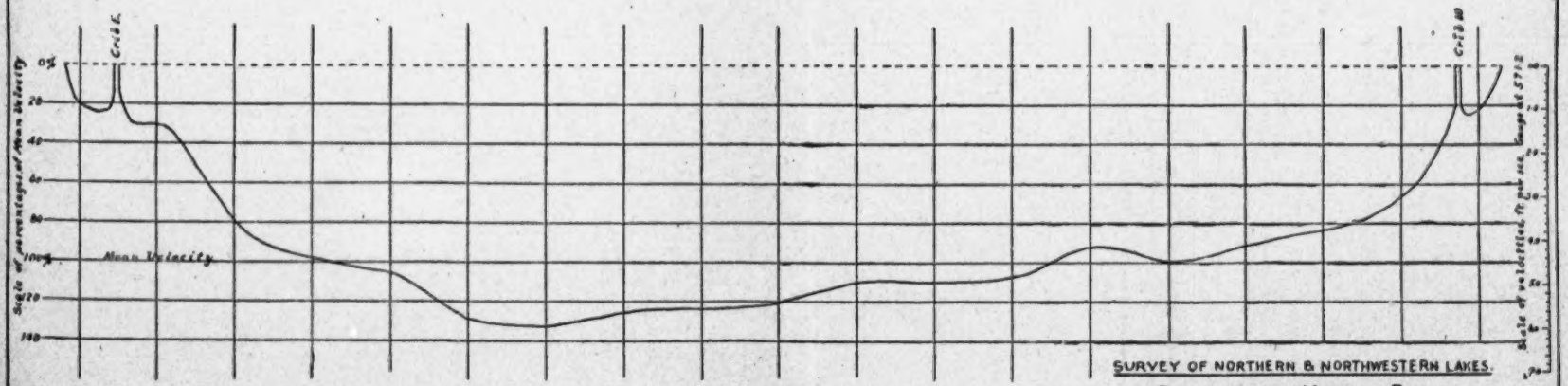
Made under the direction of
Lt. Col. G. J. Lydecker, Corps of Engineers, U. S. A.
and E. E. Haskell, U. S. Ass't. Eng'r. in charge.
by Francis C. Shenehon, Resident U. S. Ass't Eng'r.

PLATE No. 6

CROSS-SECTION.



CURVE OF VELOCITIES AT 9/10 DEPTH.



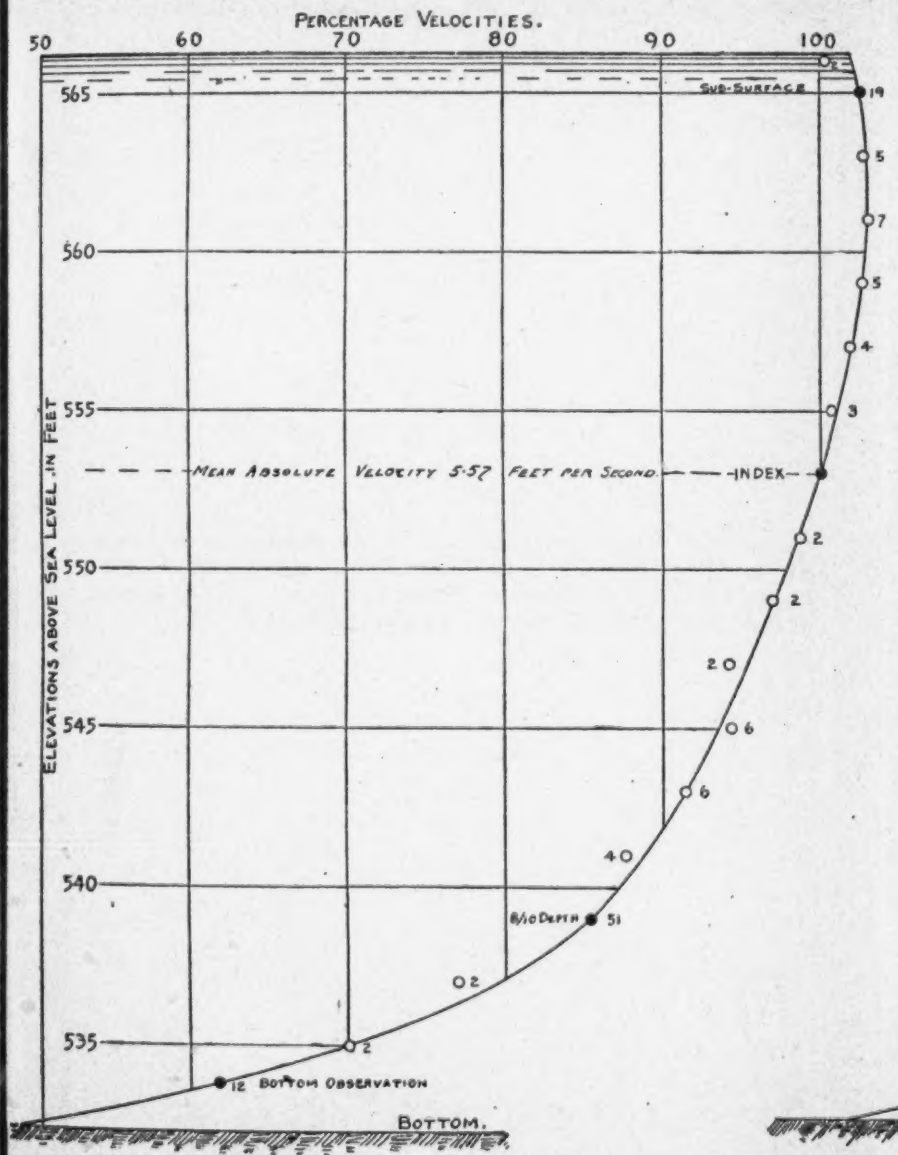
SURVEY OF NORTHERN & NORTHWESTERN LAKES.

DISCHARGE OF NIAGARA RIVER.

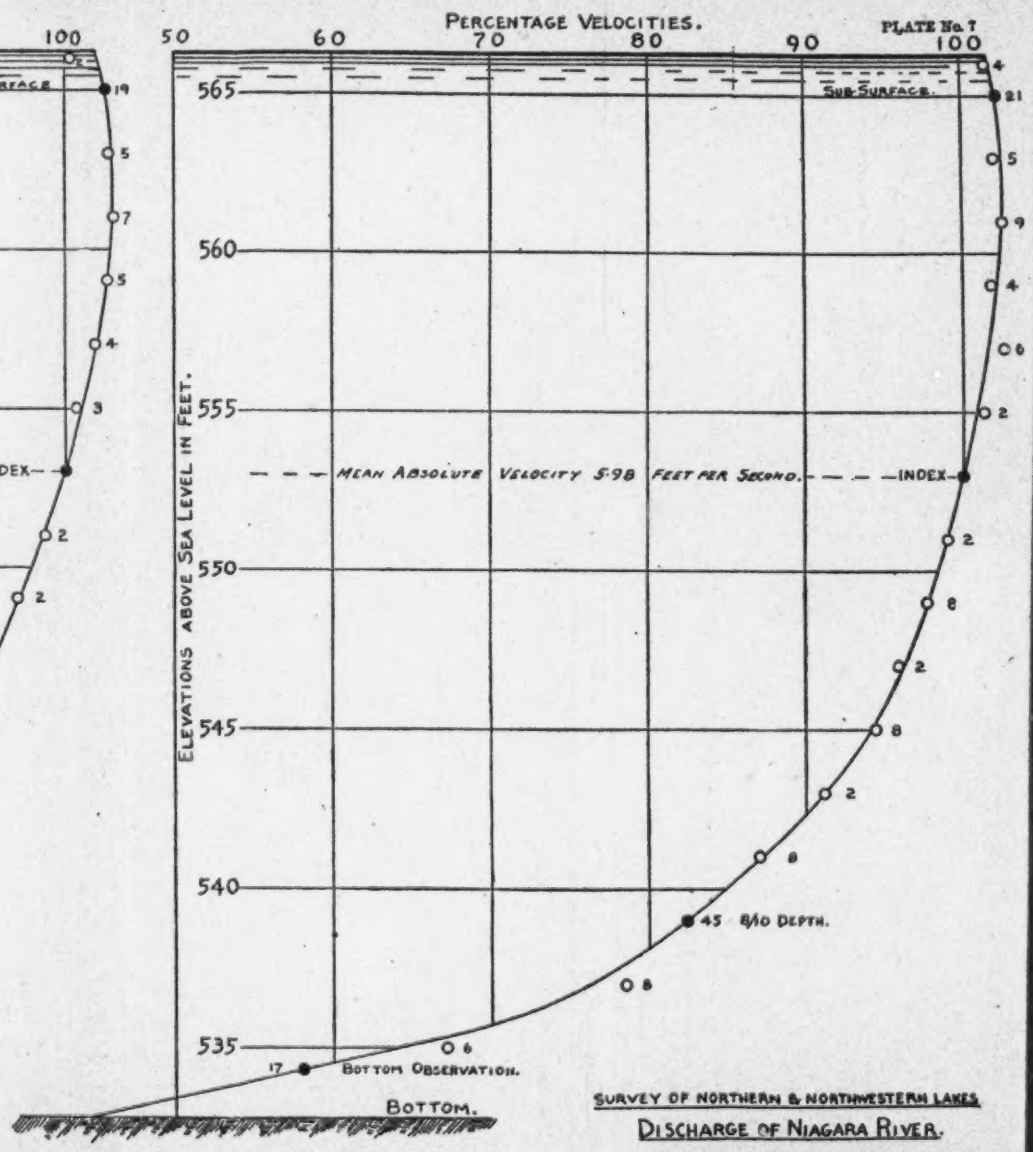
CROSS-SECTION OF RIVER
AND
TRANSVERSE CURVE OF VELOCITIES
ON OPEN SECTION

Made under the direction of
Lt. Col. G. J. Lydecker, Corps of Engineers, U. S. A
and E. E. Haskell, U. S. Asst. Eng'r. in charge
by Francis C. Shenehon, Resident U. S. Asst. Eng'r.

Eng 66 2



STATION 8.



STATION 6.

SURVEY OF NORTHERN & NORTHWESTERN LAKES.

DISCHARGE OF NIAGARA RIVER.

TYPICAL VERTICAL CURVES.

OPEN SECTION.

Made under the direction of
Lt Col. G. J. Lydecker, Corps of Engineers, U. S. A.
and E. E. Haskell, U. S. Asst. Engr. in charge.
by Francis C. Shenehon, Resident U. S. Asst Engr.

Note: Numbers opposite circles indicate by how many observations each point was determined. Solid circles indicate points fixed by Discharge Verticals.

From the Report of Mr. L. C. Sabin, Assistant Engineer, on the Discharge of the St. Clair River, made July 1, 1900, are inserted opposite hereto Plates 1, 2 and 12, which appear in said report of Mr. Sabin opposite page 5400.

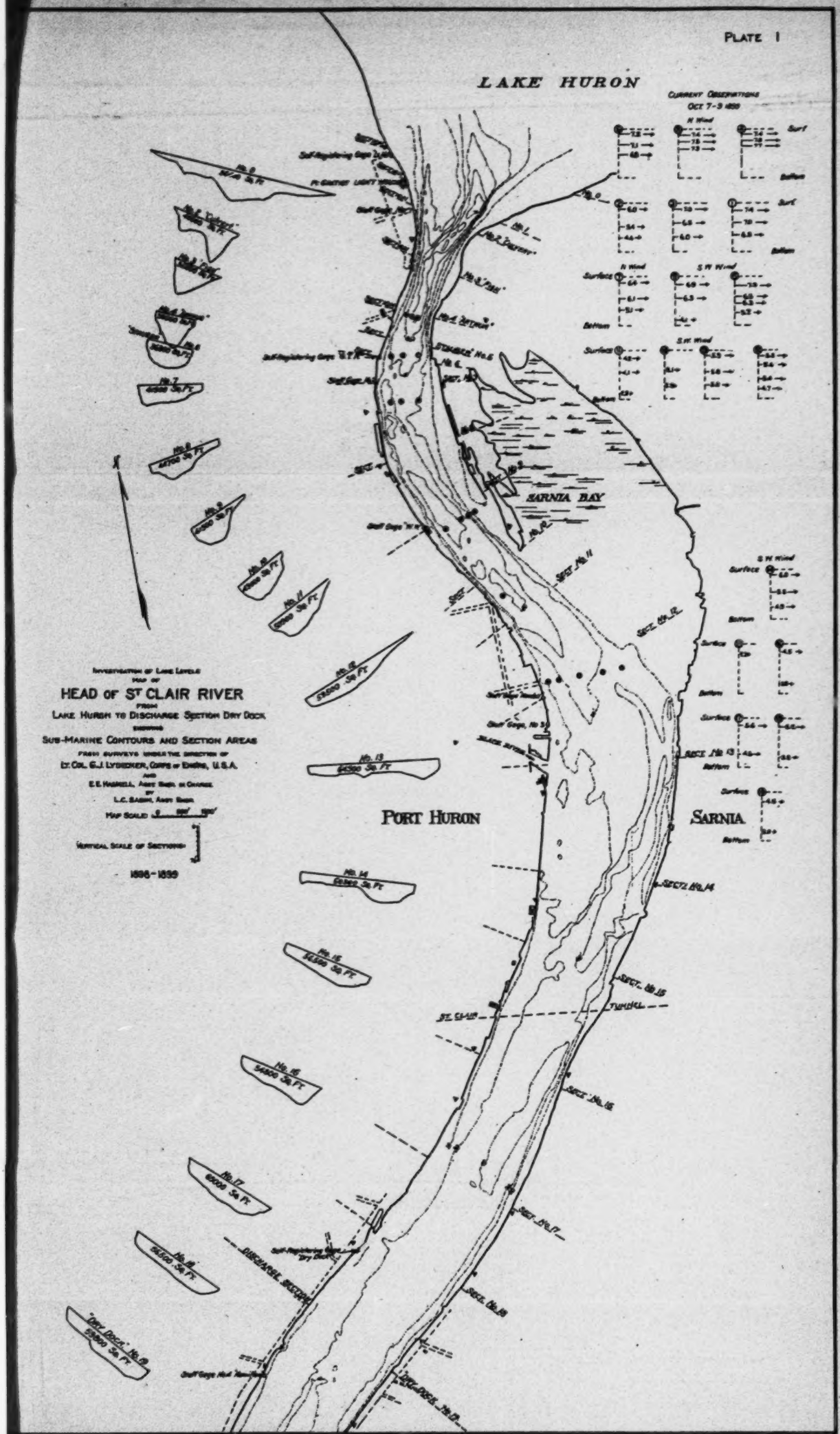


PLATE I
LAKE HURON
CURRENT OBSERVATIONS
OCT 7-9 1899
SARNIA BAY
PORT HURON
SARNIA
INVESTIGATION OF LAKE LEVELS
MAP OF
HEAD OF ST CLAIR RIVER
FROM
LAKE HURON TO DISCHARGE SECTION DRY DOCK
SHOWING
SUB-MARINE CONTOURS AND SECTION AREAS
FROM SURVEYS UNDER THE DIRECTION OF
LT. COL. G.J. LYDECKER, CORPS OF ENGRS, U.S.A.
AND
E.E. HASKELL, ASST. ENGR. IN CHARGE
BY
L.C. SABIN, ASST. ENGR.
MAP SCALED
VERTICAL SCALE OF SECTIONS
1898-1899
No. 1 60,000 Sq. Ft.
No. 2 Upper 58,000 Sq. Ft.
No. 2 Lower 58,000 Sq. Ft.
No. 3 58,000 Sq. Ft.
No. 4 Upper 58,000 Sq. Ft.
No. 4 Lower 58,000 Sq. Ft.
No. 5 58,000 Sq. Ft.
No. 6 58,000 Sq. Ft.
No. 7 58,000 Sq. Ft.
No. 8 58,000 Sq. Ft.
No. 9 58,000 Sq. Ft.
No. 10 58,000 Sq. Ft.
No. 11 58,000 Sq. Ft.
No. 12 58,000 Sq. Ft.
No. 13 58,000 Sq. Ft.
No. 14 58,000 Sq. Ft.
No. 15 58,000 Sq. Ft.
No. 16 58,000 Sq. Ft.
No. 17 58,000 Sq. Ft.
No. 18 58,000 Sq. Ft.
DISCHARGE SECTION
"DRY DOCK" No. 19 58,000 Sq. Ft.
DRY DOCK 78 Ft.
SECT. No. 11
SECT. No. 12
SECT. No. 13
SECT. No. 14
SECT. No. 15
SECT. No. 16
SECT. No. 17
SECT. No. 18
ST. CLAIR
TUNNEL

PLATE II
SLOPE IN CHANNELS CONNECTING LAKES HURON AND ERIE
AS DETERMINED IN OCTOBER 1898 AND JUNE 1899
(From Table No. 2.)
ELEVATION IN FEET ABOVE MEAN TIDE AT NEW YORK (LATEST 'IN)
DISTANCE FROM Ft. GRATIOT L.T. HO. IN MILES.
580
579
578
577
576
575
574
573
572
JUNE 99
OCT 98
LAKE ST. CLAIR
M.R. 4 GIBRALTAR
M.R. 3 TRAVERSE
M.R. 2 ST. CLAIR
M.R. 1 MONROE
M.R. 0 MAUMEE CITY
M.R. 5 ALGONAC
M.R. 6 ST. CLAIR
M.R. 7 MARINE CITY
M.R. 8 MEMPHIS
M.R. 9 ST. CLAIR FLATS CANAL
M.R. 10 MUSKRAT POINT
M.R. 11 ST. CLAIR
M.R. 12 DETROIT

Plane XII
Fig. 1.
Curves of Equal Velocity
Section Dry Dock
Fig. 2.
Transverse Curve of Mean Velocities
Section Dry Dock

EXTRACT FROM REPORT OF CHIEF OF ENGINEERS, 1902, APPENDIX EEE, BEING EXTRACT FROM THE REPORT OF MR. F. C. SHENEHON, ASSISTANT ENGINEER, DATED OGDENSBURG, N. Y., JULY 7TH, 1902, p. 2792:

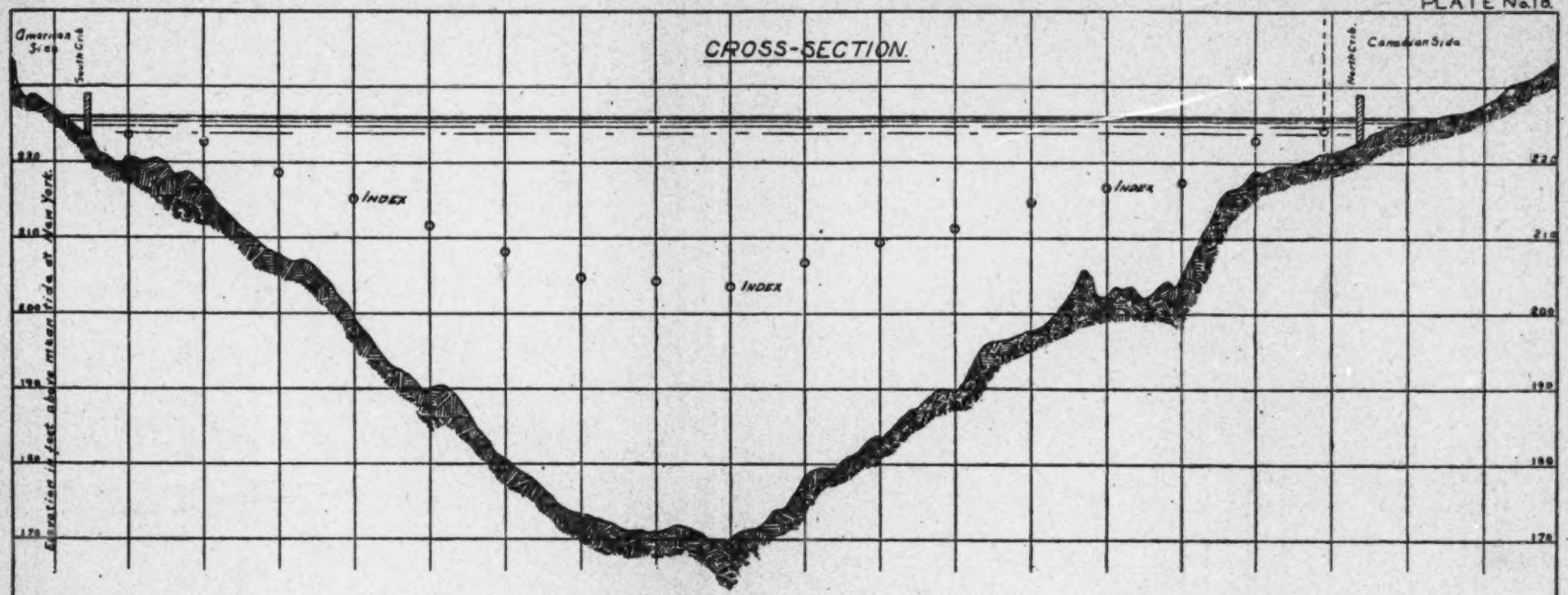
"The Ontario-St. Lawrence Basin is a series of linked pools, each pool being held intact and its rate of fluctuation regulated by the natural dam of weir at its foot. The Lake Ontario and Upper St. Lawrence pool is dammed by the Galops Rapids shallows. The second pool, reaching from the foot of the Galops to the head of Ogden Island, finds its regulating weir at the Rapids Plat. Below this the reach from Morrisburg to the head of the Cornwall Canal is governed by the Long Sault Rapids orifice. Beyond this is the Lake St. Francis pool and a new series.

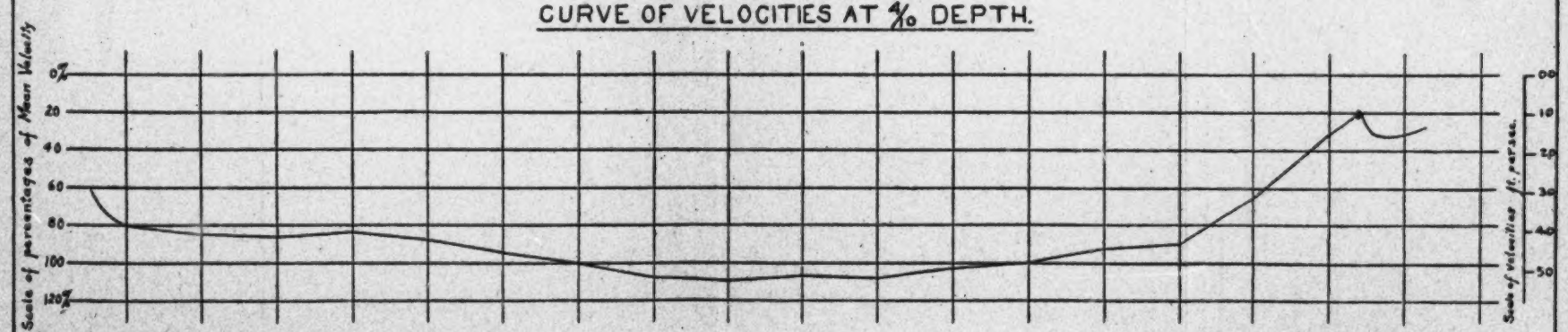
The practical importance of this formation from the point of view of river gauging lies in the fact that each of these natural weirs may be calibrated by a single set of discharge measurements, as at Three Points, a discharge table constructed for each, and the volume of flow henceforth is shown by the gauge reading at the head of the rapids or the crest of the weir."

Chief of Engineers Report 1902, Appendix EEE, page 2792.

Opposite hereto is shown Plate 18 prepared in connection with report of Mr. F. C. Shenehon, which appears opposite p. 2792, *supra.*

PLATE No. 18.





TRANSVERSE CURVE IS MEAN INDEX VELOCITY BY TABLE 19
PERCENTAGE VELOCITY IS DERIVED FROM ABOVE BY DIVIDING
BY WEIGHTED MEAN VELOCITY OF ALL STATIONS, 4.79

SURVEY OF NORTHERN & NORTHWESTERN LAKES.

ST LAWRENCE RIVER

CROSS-SECTION OF RIVER
AND
TRANSVERSE CURVE OF VELOCITIES
ON THREE-POINTS SECTION

Made under the direction of
Maj. W. L. Fisk, Corps of Engineers, U.S.A.
and E. E. Haskell, Chief Assistant Engineer
by Francis C. Shenehon, Assistant Engineer.

Extract from the Report of Francis C. Shenehon. P. 2803 supra.

TABLE No. 19.—THREE POINTS SECTION, ST. LAWRENCE RIVER.—STATION ELEMENTS.

Elements.	Stations.								
Section Gauge 226.03.	1	2	3	4	5	6	7	8	9
1. Depth at station	4.7	7.2	21.2	23.8	28.4	36.4	42.4	47.6	56.1
2. Width	86	100	100	100	100	100	100	100	100
3. Area—square feet	422	801	1,948	2,263	2,793	3,479	4,215	4,880	5,530
4. Approximate index velocity	1.71	3.19	4.33	4.46	4.79	4.93	5.19	5.11	5.26
5. Coefficients—									
Vertical	.888	.908	.885	.856	.877	.895	.907	.948	.941
Transverse	1	1	1	1	1	1	1	1	1
Direction	.956	.951	.970	.988	.993	.996	.996	1	.999
Combined	.849	.863	.858	84.6	.871	.891	.903	.948	.940
6. Direction angle	17° S.	18° S.	14° S.	9° S.	7° S.	5° S.	5° S.	1° S.	2° N.
7. Percentage discharge	.3	1.1	3.7	4	5.3	6.9	8.9	10.8	12.4
8. Weight used	0	1	4	4	6	7	9	10	12

Elements.	Stations.								
Section Gauge 226.03.	10	11	12	13	14	15	16	17	Weighted means (total)
1. Depth at station	55.1	52.7	45.3	36.2	26.7	18.3	9.1	5.3	.....
2. Width	100	100	100	100	100	100	100	100	1,686
3. Area—square feet	5,476	5,242	4,494	3,567	2,656	1,788	986	551	51,091
4. Approximate index velocity	5.20	4.81	4.52	4.22	4.02	4.14	4.07	3.83	4.79
5. Coefficients—									
Vertical	.920	.922	.905	.899	.920	.927	.910	.927	.898
Transverse	1	1	1	1	1	1	1.020	1	1
Direction	.998	.996	.990	.996	.995	.990	.990	.985	.994
Combined	.918	.918	.896	.895	.916	.918	.918	.914	.908
6. Direction angle	4° N.	5° N.	8° N.	5° N.	6° N.	8° N.	8° N.	10° N.	0°.3 N.
7. Percentage discharge	11.8	10	8.2	6.1	4.5	3.1	1.8	1	.....
8. Weight used	12	10	8	6	5	3	2	1	0

Chief of Engineers' Report, 1902, Appendix EEE, page 2803.

Extract from a Report by L. C. Sabin, Asst. Engineer, dated Port Huron, Mich., June 30, 1902.

TABLE No. 5.—DISCHARGE OF ST. CLAIR RIVER.

(Measurements at section Dry Dock during winter of 1900-1901 when river was partially blocked with ice.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Observed data									Results from equation No. 3					Results from equation No. 2				
No. of measurement	Date	Water levels (above mean tide at New York).			Fall		Meters used	Observed discharge Q (cubic feet per second)	Q=10,000 (G.T.R. -579.2) (cubic feet per second)	Discharge computed by equation 3 (cubic feet per second)	Residual discharge (computed observed) (cubic feet per second)	Fall f_1 computed for observed discharge by equation 3	Residual fall (computed observed)	Q=12,000 (G.T.R. -579.2) (cubic feet per second)	Discharge computed by equation 2 (cubic feet per second)	Residual discharge (computed observed) (cubic feet per second)	Fall f_2 computed for observed discharge by equation 2	Residual fall (computed observed)
		G.T.R.	M.B.R.	D.D.	G.T.R. to M.B.R. f_1	G.T.R. to D.D. f_2												
	1901	Feet	Feet	Feet	Feet	Feet						Feet	Feet				Feet	Feet
37	Jan. 2	579.370	578.872	578.507	0.498	0.873	7A, 11B	195,800	194,100	190,900	—4,900	0.530	+0.032	193,800	193,500	— 2,300	0.893	+0.020
68	4	9.173	8.725	8.368	.448	.805	7A, 11B	184,200	184,500	181,000	—3,200	.468	+ .020	184,500	183,600	— 600	.815	+ .010
69	7	9.081	8.697	8.362	.384	.719	7A, 11B	174,300	175,500	169,300	—5,000	.413	+ .029	175,700	172,400	— 1,900	.734	+ .015
70	8	8.379	7.962	7.662	.417	.717	7A, 11B	159,700	167,900	168,000	—8,300	.370	— .047	169,600	163,700	+ 4,000	.684	— .033
71	9	9.192	8.664	8.271	.528	.921	7A, 10B	195,200	195,300	193,600	—1,600	.539	+ .011	195,300	196,700	+ 1,500	.908	— .013
72	10	8.678	8.210	7.854	.468	.824	7A, 10B, 11B	176,900	182,100	179,300	+2,400	.454	— .014	183,200	179,800	+ 2,900	.798	— .026
73	11	8.920	8.389	8.015	.531	.905	7A, 10B, 11B	185,200	188,000	191,300	+6,100	.490	— .041	188,600	191,600	+ 6,400	.845	— .060
74	14	8.726	8.243	7.891	.483	.835	7A, 10B	175,700	180,400	182,100	+6,400	.443	— .040	175,700	181,700	+ 6,000	.783	— .052
75	15	8.875	8.412	8.008	.463	.867	7A, 10B, 11B	181,200	184,400	180,500	— 700	.468	+ .005	185,100	187,000	+ 5,800	.815	— .052
77	30	9.489	9.383	9.277	.106	.212	7A, 10B	97,000	94,100	104,800	+7,800	.087	— .019	93,500	97,800	+ 800	.208	— .004
78	Feb. 2	9.254	9.165	9.067	.089	.187	7A, 10B	94,500	94,000	95,500	+1,000	.087	— .002	93,900	89,200	— 5,300	.210	+ .023
112	Mar. 25	9.023	8.752	8.506	.271	.517	7A, 11B	150,100	151,900	146,500	—3,600	.287	+ .016	152,200	145,300	— 4,800	.552	+ .035
113	29	9.105	8.593	8.167	.512	.938	7A, 11B	197,200	198,200	190,300	—6,900	.560	+ .048	198,300	197,400	+ 200	.936	— .002
114	30	8.927	8.428	7.963	.499	.964	7A, 11B	193,100	195,800	186,600	—6,500	.543	+ .044	196,400	198,000	+ 4,900	.918	— .046
115	Apr. 1	8.613	8.139	7.789	.474	.824	7A, 11B	185,500	191,400	179,600	—5,900	.515	+ .041	192,500	179,100	— 6,400	.882	+ .058
116	2	8.299	7.913	7.669	.386	.630	7A, 11B	159,200	168,200	161,800	+2,600	.372	— .014	170,000	152,000	— 7,200	.687	+ .057
117	5	9.209	9.065	8.965	.144	.244	7A, 11B	108,500	108,400	115,200	+6,700	.124	— .020	108,400	101,400	— 7,100	.280	+ .036
118	10	9.980	9.943	9.880	.037	.100	7A, 11B	74,000	66,200	74,700	+ 700	.036	— .001	64,600	74,200	+ 200	.099	— .001
119	11	9.814	9.766	9.700	.048	.114	7A, 11B	79,200	73,100	80,300	+1,100	.046	— .002	71,800	76,700	— 2,500	.122	+ .008
120	12	9.679	9.612	9.541	.067	.138	7A, 11B	86,900	82,100	89,600	+2,700	.062	— .005	81,200	81,800	— 5,100	.157	+ .019
121	13	9.378	9.174	8.991	.204	.387	7A, 11B	128,700	126,900	133,800	+5,100	.184	— .020	126,600	129,600	+ 900	.381	— .006
122	15	9.241	8.899	8.663	.342	.578	7A, 11B	163,400	163,000	163,200	— 200	.345	+ .003	162,900	156,300	— 7,100	.632	+ .054
123	16	9.188	8.766	8.490	.422	.698	7A, 11B	178,300	178,400	176,900	—1,400	.429	+ .007	178,400	171,100	— 7,200	.757	+ .059
124	19	580.269	580.225	580.142	.045	.128	7A, 11B	76,000	65,300	83,000	+7,000	.035	— .010	63,200	86,200	+10,200	.095	— .033
126	24	0.060	0.026	579.965	.033	.094	7A, 11B	75,500	66,900	72,500	—3,000	.037	+ .004	65,200	73,200	— 2,300	.101	+ .007
127	25	579.879	9.834	9.756	.046	.122	7A, 11B	78,200	71,400	79,700	+1,500	.044	— .002	70,100	79,700	+ 1,500	.117	— .005
128	26	9.851	9.784	9.675	.066	.176	7A, 11B	90,500	84,000	90,800	+ 300	.065	— .001	82,700	93,900	+ 3,400	.162	— .014

Chief of Engineers' Report, 1902, Appendix EEE, page 2835.

TABLE No. 6.—*Discharge of St. Clair River.*

[Measurements at Section Craig during winter of 1900-1901 when river was partially blocked with ice.]

1.	2.	3.	4.	6.	8.	9.	10.	11.	12.	13.	14.
		Observed data.					Results from equation No. 3.				
No. of measurement.	Date.	Water levels above mean tide at New York.		Fall from G. T. R. to M. B. R. f_1.	Meters used at 0.4 depth.	Observed discharge Q (cubic feet per second).	Q—10,000 (G. T. R.—579.2) (cubic feet per second).	Discharge computed by equation 3 (cubic feet per second).	Residual discharge (computed—observed) cubic feet per second.	Fall f_1 computed for observed discharge by equation 3.	Residual fall (computed—observed).
		G. T. R.	M. B. R.								
	1901.	*Feet.*	*Feet.*	*Feet.*						*Feet.*	*Feet.*
79	Feb. 4	579.579	579.482	0.098	10 B.	100,000	98,200	102,500	+ 2,500	0.092	—0.006
80	5	.558	.463	.095	10 B.	103,800	100,400	100,900	− 2,900	.102	+ .007
81	6	.305	.190	.115	10 B.	100,500	99,500	105,300	+ 5,800	.100	− .015
82	7	.193	.077	.116	10 B.	100,800	100,900	105,500	+ 4,700	.103	− .013
83	8	.152	.037	.115	10 B.	102,100	102,600	104,800	+ 2,700	.108	− .007
84	12	580.002	.916	A. .087	10 B.	111,800	103,800	102,100	− 9,700	.111	+ .024
85	16	579.252	.143	.110	10 B.	104,300	103,800	103,900	− 400	.111	+ .001
86	19	.505	.398	.108	10 B.	112,200	109,200	105,700	− 6,500	.126	+ .018
87	20	.700	.612	B. .090	10 B.	115,600	110,600	100,400	−15,200	.130	+ .040
88	21	.348	.240	.108	10 B.	108,500	107,000	104,100	− 4,400	.120	+ .012
89	23	.163	.058	.105	10 B.	105,400	105,800	101,100	− 4,300	.116	+ .011
90	25	.145	.037	.108	10 B.	108,100	108,700	102,100	− 6,000	.124	+ .016
91	26	.255	.142	.113	10 B.	108,900	108,300	105,100	− 3,800	.124	+ .011
92	27	.292	.178	.113	11 B.	111,600	110,700	105,400	− 6,200	.130	+ .017
93	28	.066	578.960	.106	11 B.	105,100	106,400	100,600	− 4,500	.118	+ .012
94	Mar. 1	578.855	.723	.132	11 B.	106,300	109,700	107,800	+ 1,500	.128	− .004
95	2	579.400	579.300	C. .100	11 B.	111,300	109,300	101,500	− 9,800	.126	+ .026
96	4	.168	.008	D. .160	11 B.	113,900	114,200	119,800	+ 5,900	.141	− .019
97	5	.398	.258	.140	11 B.	114,700	112,700	115,800	+ 1,100	.137	− .003
98	6	.242	.087	.156	11 B.	115,600	115,200	119,300	+ 3,700	.144	− .012
99	7	.016	578.869	.147	11 B.	108,500	110,300	114,300	+ 5,800	.129	− .018
100	8	.100	.938	.162	11 B.	113,100	114,100	119,700	+ 6,600	.140	− .022
101	9	.419	579.289	E. .130	11 B.	116,100	113,900	112,700	− 3,400	.140	+ .010
102	11	578.695	578.560	.135	11 B.	107,100	112,100	107,200	+ 100	.134	− .001
103	12	579.482	579.347	.135	11 B.	119,800	117,000	115,000	− 4,800	.150	+ .015
104	13	.237	.108	.138	11 B.	115,900	115,500	113,600	− 2,300	.148	+ .006
105	14	.067	578.899	.168	11 B.	115,800	117,100	121,200	+ 5,400	.150	− .018
106	15	.748	579.610	.138	11 B.	126,900	121,400	118,700	− 8,200	.165	+ .027
107	16	.292	.161	.131	11 B.	119,300	118,400	111,800	− 7,500	.154	+ .023
108	18	.381	.206	.176	11 B.	123,900	122,000	126,600	+ 2,700	.167	− .009
109	19	.192	.034	.158	11 B.	117,500	117,600	119,400	+ 1,900	.152	− .006
110	22	.349	.177	.172	11 B.	122,400	120,900	125,100	+ 2,700	.163	− .009
111	23	.301	.108	.192	11 B.	128,400	127,400	130,200	+ 1,800	.186	− .006

NOTE.—The range in value of observed fall f_1 = G. T. R.−M. B. R., is as follows:

A. No. 84, 0.03 to 0.14.
B. No. 87, .02 to .12.
C. No. 95, .00 to .13.
D. No. 96, .11 to .23.
E. No. 101, .06 to .16.

TABLE No. 7.—*Effect of ice in St. Clair River during winters of 1900, 1901, and 1902.*

1.	2.	3.	4.	5.	6.	7.
Date.	Elevation of Lake Huron at Sand Beach.	Discharge of St. Clair River by equation 4 of 1900, cubic feet per second.	Discharge derived from fall at head of river by equations Nos. 2 and 3, cubic feet per second.	Difference, or effect of ice. Cubic feet per second.	Depth Lake Michigan-Huron.	Depth Lake Erie
1900.	*Feet.*				*Feet.*	*Feet.*
January	579.98	183,100	147,300	35,800	0.07	−0.24
February	579.98	183,100	139,200	43,900	.09	− .41
March	579.62	165,900	128,300	37,600	.12	− .54
April	579.58	186,000	173,200	12,800	.03	− .12
Total for winter					.31	
1900.						
December	580.02	195,300	191,100	4,200	.01	− .04
1901.						
January	579.77	193,600	163,300	30,300	.06	− .28
February	579.64	185,100	102,200	85,900	.18	− .81
March	579.62	167,700	133,900	58,800	.11	− .51
April	580.10	195,300	130,500	64,800	.14	− .62
May	580.31	200,800	189,000	11,800	.02	− .11
Total for winter					.52	
1901.						
December	579.60	187,300	174,300	13,000	.03	− .12
1902.						
January	579.51	185,600	124,700	60,900	.13	− .57
February	579.31	181,800	129,100	52,700	.11	− .50
Total for winter					.27	

EXTRACT FROM REPORT OF MR. MURRAY BLANCHARD, JUNIOR, ENGINEER, DATED, DETROIT, MICH., JUNE 30, 1902, CHIEF OF ENGINEERS REPORT 1902, APP. EEE, p. 2856.

"Report of Mr. Murray Blanchard, Junior Engineer.

United States Lake Survey Office,
Detroit, Mich., June 30, 1902.

Major: I have the honor to submit the following report on the resurvey and discharge measurement of Detroit River.

The outfit used on this work was brought from Port Huron on July 5, 1901, and is the same as used for the discharge measurement of the St. Clair River. After receiving the outfit on May 15, 1901, from Mr. L. C. Sabin, assistant engineer, the St. Clair River discharge measurements were continued until July 1, 1901. In June, 1901, a hydrographic resurvey was also made at the head of St. Clair River, on the four sections established by Mr. Sabin in 1900, to test the permanence of the regimen. The results of this survey and of the St. Clair River discharge measurements will be reported by Mr. Sabin."

* * *

P. 2869.

"Vertical curves.—The multiple meter outfit and the method of making the observations for the determination of the vertical curves was practically the same as given in Mr. Sabin's report on the St. Clair River discharge measurements for 1900, with the following exceptions: A hole was bored through the body of each meter and the meters were suspended by a single one-fourth inch plow-steel cable passing through each. Clamps on the cable under each meter supported them at the tenths of the depth. Insulated wires were run along the outside of the cable down to each meter to enable the use of a small cable.

Stringing the meters on a single cable overcomes some of the disadvantages encountered in suspending the meter in a gimbal clamped between two cables.

The lowest meter was set about 2 feet from the river bed and the top meter was 1 foot below the water surface. The space between these meters was divided into ten equal parts and a meter placed at each point of division. After seven or eight runs of different lengths had been taken at each depth, the cable was reeled in the amount of the spacing, so that for the second position each meter came to the elevation occupied by the meter above during the first run, except the top meter, which came out of the water and was not used after the first run. A like number of runs were taken in the second position and the meters again raised the same amount. In these three sets or positions the bottom point has been occupied by one meter (in the first run only), the nine-tenths point run by two meters, while at all other points there has been a different meter in each of the three sets. By combining the three sets of runs the errors of meter rating and other errors of observation are largely corrected.

All of the stations were occupied in one week. A complete set of observations for three or four stations, consisting of twenty or more runs on each station, could be made in one day. The average time of taking twenty runs at a station (total length of runs being about sixty-five minutes) was one hour and thirty-seven minutes. On one station twenty runs were completed in one hour and twenty minutes, and the longest time required was two hours. With a single meter this amount of vertical curve observing would require at least twenty-eight days of ten hours each. A list of the observations is given in Table No. 8.

TABLE NO. 7. COEFFICIENTS AT TENTHS OF DEPTH.

STATION	Surface	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	Bottom
1 + 30	0.867	0.867	0.885	0.914	0.945	0.978	1.026	1.078	1.152	1.237	1.335
2	.849	.845	.869	.895	.931	.976	1.030	1.098	1.183	1.283	1.400
3	.889	.866	.879	.899	.932	.971	1.009	1.064	1.143	1.268	1.487
4	.909	.881	.890	.912	.938	.970	1.007	1.061	1.134	1.231	1.366
5	.912	.885	.892	.910	.933	.960	.994	1.046	1.127	1.255	1.460
6	.915	.889	.897	.912	.933	.958	.995	1.046	1.120	1.248	1.459
7	.908	.894	.903	.917	.938	.960	.989	1.035	1.115	1.244	1.442
8	.937	.901	.896	.909	.925	.948	.981	1.034	1.121	1.259	1.513
9	.888	.868	.880	.907	.935	.967	1.002	1.050	1.123	1.271	1.590
10	.907	.885	.896	.915	.939	.963	.999	1.046	1.113	1.234	1.476
11	.917	.901	.900	.922	.942	.966	.994	1.038	1.101	1.206	1.405
12	.869	.871	.892	.914	.937	.964	.996	1.045	1.120	1.273	1.585
13	.900	.876	.895	.917	.943	.971	1.000	1.042	1.104	1.227	1.547
14	.877	.869	.890	.915	.939	.967	1.000	1.043	1.111	1.254	1.635
15	.886	.875	.886	.906	.930	.959	.997	1.049	1.125	1.274	1.604
16	.940	.890	.885	.902	.930	.960	.996	1.050	1.125	1.245	1.461
17	.872	.875	.896	.918	.945	.973	1.007	1.052	1.119	1.230	1.465
18	.896	.870	.879	.902	.930	.963	1.003	1.061	1.141	1.273	1.521
19	.910	.869	.869	.894	.922	.955	.996	1.051	1.130	1.282	1.797
20	1.110	1.046	1.010	.982	.963	.957	.957	.969	.989	1.031	1.127
Mean [a]	.897	.878	.889	.909	.935	.959	1.001	1.052	1.127	1.252	1.503

a Station 20 is omitted from mean. Station is in shallow water and the curve is abnormal. (See plate No. 3.)

"Every run was plotted to detect any large errors, and a single vertical curve of velocities was derived and plotted for each station. From the velocities at the tenths of the depth the coefficients for reducing the observed velocity at each tenth to the mean velocity of the station were derived. These coefficients are given in Table No. 7. The vertical curves of velocities for each station are shown on plate No. 3.

TABLE NO. 8—LIST OF OBSERVATIONS FOR VERTICAL CURVES, 1901.

STATIONS	Dates stations were occupied. August	September	Days occupied	Total sets (meter positions)	Curves	Observations 700 sections	600 sections.	300 sections.	200 sections.	100 sections.
1 + 30	28	.....	1	2	1	.....	.....	2	4	4
2	28	.....	1	3	1	.....	3	.....	4	13
3	28	.....	1	3	1	.....	3	.....	2	15
4	28	.....	1	3	1	.....	3	.....	3	14
5	26	6	2	6	3	.....	7	.....	5	37
6	22	.....	1	3	1	.....	3	.....	1	13
7	22	.....	1	5	2	.....	2	5	2	11
8	22	.....	1	3	1	.....	3	1	.....	6
9	26	6	2	7	3	.....	6	.....	6	38
10	26	.....	1	3	1	.....	3	.....	2	15
11	23	.....	1	3	1	1	2	.....	1	16
12	24	.....	1	3	1	.....	3	1	5	11
13	24	.....	1	3	1	.....	3	.....	3	14
14	24	.....	1	3	1	.....	3	.....	6	16
15	23	.....	1	3	1	.....	2	.....	7	14
16	23	.....	1	3	1	.....	3	.....	1	16
17	27	.....	1	3	1	1	2	.....	3	14
18	27	.....	1	3	1	1	2	.....	3	14
19	27	.....	1	3	1	.....	3	.....	2	15
20	27	.....	1	3	1	.....	2	.....	3	15
Total	7 days		.....	68	25	3	58	9	63	311

COPY OF PLATE NO. 1 WHICH APPEARS IN SAID REPORT OPPOSITE PAGE 2870.

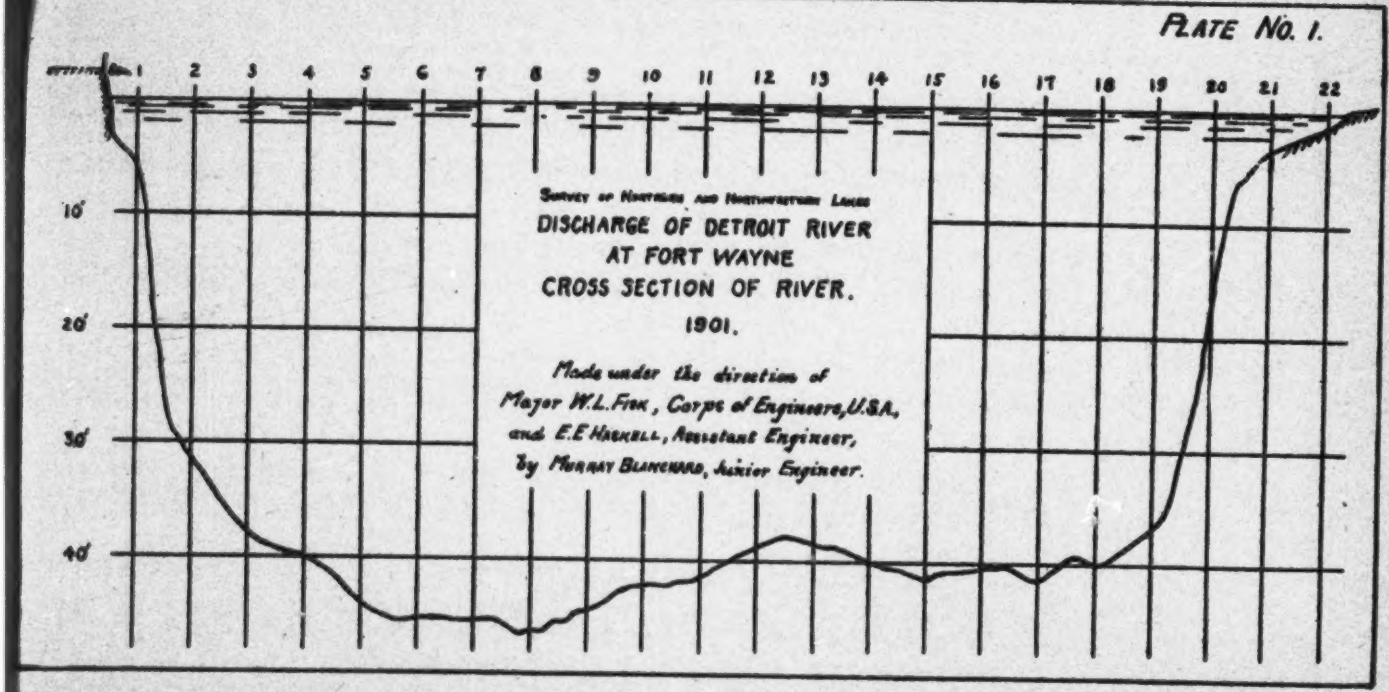


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TABLE NO. 9.—SUMMARY OF MEASUREMENTS OF DISCHARGE OF DETROIT RIVER, MADE IN 1901.

No. of measurement.	Date of observation.	Water levels above noon tide at New York.			Fall.			Discharge in cubic feet per second.
		Windmill Point. A.	Fort Wayne. B.	Amherstburg. C(W't'd).	A-B.	B-C.	A-C. (w't'd).	
					Feet.	Feet.	Feet.	
1....	July 19	574.98	574.11	571.99	0.87	2.12	2.99	205,900
2....	July 20	574.93	574.05	571.91	.88	2.14	3.02	200,210
3....	July 22	575	574.11	571.87	.89	2.24	3.13	208,710
4....	July 23	574.95	574.11	572.07	.84	2.04	2.88	201,970
5....	July 25	575	574.18	572.11	.82	2.07	2.89	205,010
6....	July 26	575.02	574.25	572.37	.77	1.88	2.65	197,200
7....	July 27	575.08	574.26	572	.72	2.26	3.06	206,060
8....	July 30	574.92	573.98	571.53	.94	2.45	3.39	210,280
9....	July 31	574.97	574.14	572.14	.83	2	2.81	202,180
10....	Aug. 1	575.03	574.15	571.75	.88	2.40	3.26	215,560
11....	Aug. 3	575.05	574.25	572.21	.80	2.04	2.85	193,900
12....	Aug. 15	574.84	574	571.68	.84	2.32	3.17	199,490
13....	Aug. 15	574.84	573.97	571.64	.87	2.33	3.20	202,550
14....	Aug. 16	574.93	574.15	572.01	.78	2.14	2.92	197,140
15....	Aug. 16	574.90	574.06	571.64	.84	2.42	3.27	206,580
16....	Aug. 17	574.94	574.19	572.15	.75	2.04	2.79	198,950
17....	Aug. 17	574.94	574.15	571.96	.79	2.19	2.98	197,830
18....	Aug. 19	574.94	574.16	572.05	.78	2.11	2.89	197,560
19....	Aug. 19	574.94	574.12	571.78	.82	2.34	3.16	202,760
20....	Aug. 20	574.96	574.13	571.98	.83	2.15	2.98	205,700
21....	Aug. 20	575	574.19	572.08	.81	2.11	2.92	204,210
22....	Aug. 21	574.96	574.15	572.05	.81	2.10	2.90	198,400
23....	Aug. 29	574.93	574.09	571.89	.84	2.20	3.04	202,160
24....	Aug. 29	574.93	574.09	571.87	.84	2.12	3.06	201,060
25....	Aug. 30	574.88	574.09	572.01	.79	1.98	2.87	192,460
26....	Aug. 30	574.96	574.14	571.90	.82	2.24	3.07	198,900
27....	Aug. 31	574.99	574.12	571.90	.87	2.22	3.08	203,630
28....	Aug. 31	574.98	574.08	571.70	.90	2.38	3.28	212,940
29....	Sept. 3	575.01	574.17	572.01	.84	2.16	3	200,980
30....	Sept. 3	575	574.13	571.80	.87	2.33	3.20	204,380
31....	Sept. 4	574.99	574.17	572.03	.82	2.14	2.96	201,000
32....	Sept. 4	575.01	574.19	571.96	.82	2.23	3.05	202,810
33....	Sept. 5	574.99	574.14	571.89	.85	2.25	3.10	206,580
34....	Sept. 5	575	574.21	572.11	.79	2.10	2.89	198,340
35....	Sept. 7	574.96	574.13	571.93	.83	2.20	3.03	205,740
36....	Sept. 7	575	574.16	571.98	.84	2.18	3.02	201,640
37....	Sept. 17	574.61	573.82	571.75	.79	2.07	2.86	189,230
38....	Sept. 24	574.77	573.92	571.76	.85	2.16	3	204,770
39....	Oct. 7	574.63	573.82	571.70	.81	2.12	2.93	191,980
40....	Oct. 8	574.52	573.67	571.36	.85	2.31	3.16	192,080
41....	Oct. 10	574.49	573.61	571.31	.88	2.30	3.16	196,710
42....	Oct. 10	574.51	573.61	571.30	.90	2.31	3.20	201,130
43....	Oct. 11	574.51	573.68	571.47	.83	2.21	3.02	190,980
44....	Oct. 12	574.57	573.74	571.65	.83	2.09	2.92	188,620
45....	Oct. 16	574.59	573.78	571.56	.81	2.22	3.02	192,980
46....	Oct. 17	574.24	573.30	570.82	.94	2.48	3.42	197,220
47....	Oct. 19	574.44	573.45	570.70	.99	2.75	3.74	214,820
48....	Oct. 21	574.42	573.51	571.04	.91	2.47	3.38	199,710
49....	Oct. 21	574.47	573.62	571.41	.85	2.21	3.05	195,770
50....	Oct. 31	574.30	573.50	571.48	.80	2.02	2.82	182,190
51....	Nov. 29	574.16	573.25	571.11	.91	2.14	3.05	195,760
52....	Nov. 30	574.22	573.31	571.08	.91	2.23	3.14	193,530
53....	Dec. 2	574.15	573.25	571.08	.90	2.17	3.07	191,480
54....	Dec. 3	574.31	573.45	571.46	.86	1.99	2.83	197,690
55....	Dec. 4	574.16	573.19	571	.97	2.19	3.17	197,170
56....	Dec. 10	574	573.14	571.20	.86	1.94	2.90	177,220

Discharge Observations.—A substation occupied in place of station No. 1 was 95 feet from. Middle Base. Station No. 22 was 30 feet from the Canadian shore. As there is only a few feet of water and practically no current close to either shore, the discharge area was taken as from 30 feet outside of the fort wall to station 21 plus 50 feet, or 2,100 feet from the wall. The velocity at station 21 was always less than 0.5 foot per second. If we assume a velocity as high as 0.2 foot per second, the discharge for the end area between station 21 plus 50 and shore is only 30 cubic feet per second, or one one-hundredth of 1 per cent. of the total discharge. This area has been disregarded. Two runs of 200 seconds each were taken at each station. Meter No. 11 B remained at mid-depth, while meter No. 5 A occupied the three-tenths and seven-tenths depth successively.

A summary of the results of the measurements is given in Table No. 9.

The present data is considered insufficient for the determination of a discharge curve.

Recorders H. H. Atwell, W. H. Vandeburgh, and C. L. Vandeburgh, who have assisted at different times in the field observations, have been careful and painstaking in the execution of the work assigned to them.

Very respectfully, your obedient servant,

MURRAY BLANCHARD,
Junior Engineer.

MAJOR W. L. FISK,
Corps of Engineers, U. S. A."

Chief of Engineers Report, 1902, Appendix EEE, pages 2856, 2869-2872.

EXTRACT FROM THE REPORT OF MR. MURRAY BLANCHARD, JUNIOR ENGINEER, DETROIT, MICH., JUNE 30, 1903:

"Report of Mr. Murray Blanchard, Junior Engineer.

United States Lake Survey Office,

Detroit, Mich., June 30, 1903.

Major: I have the honor to submit the following report on the discharge measurements of the Detroit and St. Clair Rivers, under my charge during the past year.

At times when the discharge work could not be carried

on, stadia surveys were made along the river fronts of Detroit and Windsor, where recent changes have occured.

The field work was commenced on the Detroit River at section Fort Wayne (Detroit) one week before the beginning of the fiscal year, and four discharges not included in the summary of the last annual report were measured in June, 1902. The discharge measurements of Detroit River were continued until August 8, when the party, with the discharge outfit, including tug *U. S. L. S. No. 2* and one catamaran, was taken to Port Huron. The next six weeks were devoted to the gauging of St. Clair River on section Dry Dock, at Port Huron. The section was resounded. Three stations were selected for vertical curve observations to determine whether there had been any change in the curve since the multiple meter observations of 1899, and about 30 curves were measured on each of the three stations. Forty-eight discharges were measured, the notes of which were turned over to Asst. Engineer L. C. Sabin for reduction.

Before returning to Detroit a survey was made on a portion of the shoal at the mouth of Black River where the steamer *City of Rome* grounded. This survey was platted and has been reported.

On returning to Detroit October 1 the discharge measurements were resumed and continued until the 20th of November, when the field work was closed.

Discharge of Detroit River.—The discharge section at Fort Wayne was sounded at the beginning of the season with a 70-pound 'fish' weight suspended on a No. 9 galvanized wire. The heavy weight made the deflection of the sounding wire from the vertical considerably less than in the 1901 soundings. It appears that too large a deflection correction was applied to the soundings in 1901, so that a recomputation of the area for that year has been made by applying the corrections given in Table No. 1, found on page 5330, Appendix III, Report of the Chief of Engineers, United States Army, for 1900. This table, computed by Asst. Engineer F. C. Shenehon, has been tested on soundings made in the swift current of the Niagara River with various deflections. The close agreement of the two seasons' determinations of the partial areas on section Fort Wayne indicates that no scour has taken

place, and the discrepancy in the total areas has been attributed to errors of observation. The mean of the two determinations of the area has been used in computing all of the discharges summarized in this report, which accounts for the disagreement with the volumes of discharge summarized in the last report. The two area measurements and the mean value used are given in Table No. 1.

The meters were rated about once a month, and a rate comparison, whenever the meters were used, was made by running them side by side on the section at the same depth. The rating equations of the meters and their application are given in Table No. 2. A comparison of all the ratings made in 1901 and 1902 is shown in Tables Nos. 3 and 4.

Stations Nos. 4, 9, 15, and 20 were selected for vertical curve observations, and about 20 curves were measured at each station. A comparison with the 1901 multiple meter curves is shown on Plates Nos. 1 to 4. The coefficients at the 0.3, 0.5, and 0.7 depths are those used in the discharge computations. The mean of the discharges at these depths is used as one discharge, and the means of the three coefficients for each station agree closely for the two years, except for the shallow station No. 20, where the curve is abnormal and varies. The discrepancy on this station in the two years, although amounting to 2 per cent., would not affect the partial discharge more than 60 cubic feet per second, or 0.0003 of the average total discharge. Therefore the multiple meter coefficients have been used for both seasons.

In the two seasons 117 discharges have been measured, with a range of 1.6 feet in the Windmill Point or Lake St. Clair stage, of 2.5 feet in the Amherstburg or Lake Erie stage, and of 50,000 cubic feet per second in the discharge. Some of the observations were made when the river was rough and the wind strong, because such conditions are generally found with extreme stages and accompany a very high or low discharge. In such cases, however, there is generally a large fluctuation in the stage of Lake Erie and an uncertainty as to the effective stage of that lake.

In Table No. 6 the results of the discharge measurements for 1901 and 1902 are given, with the correspond-

ing gauge readings at Windmill Point, Fort Wayne section, and Amherstburg.

Very respectfully, your obedient servant,

MURRAY BLANCHARD,
Junior Engineer.

MAJ. W. L. FISK,
Corps of Engineers, U. S. Army."

TABLE 1.—AREA MEASUREMENTS, 1901 AND 1902.

Station	Area for stage 574.4		Mean used
	1901	1902	
1	822	773	798
2	3,090	3,024	3,057
3	3,760	3,761	3,760
4	4,021	4,019	4,020
5	4,421	4,435	4,428
6	4,571	4,591	4,581
7	4,582	4,623	4,602
8	4,648	4,640	4,644
9	4,474	4,490	4,482
10	4,285	4,294	4,290
11	4,154	4,182	4,168
12	3,910	3,936	3,923
13	3,862	3,912	3,887
14	4,022	4,068	4,045
15	4,117	4,161	4,139
16	4,107	4,131	4,119
17	4,138	4,190	4,164
18	3,959	3,961	3,960
19	3,624	3,555	3,590
20	1,742	1,717	1,729
21	383	385	384
Total	76,692	76,848	76,770

Chief of Engineers' Report, 1903, Appendix FFF, pages 2813-2814.

TABLE No. 5.—COMPARISON OF 1901 AND 1902 COEFFICIENTS AT TENTHS OF DEPTH.

Station	Year	Method	No. of obs.	0.3	0.5	0.7	Mean of 0.3, 0.5 and 0.7
4	1901	Multiple meter	20	0.912	0.970	1.061	0.981
	1902	Two meter	17	.923	.972	1.036	.977
9	1901	Multiple meter	45	.907	.967	1.050	.975
	1902	Two meter	20	.907	.969	1.066	.981
15	1901	Multiple meter	23	.906	.959	1.049	.971
	1902	Two meter	20	.915	.958	1.035	.969
20	1901	Multiple meter	20	.982	.957	.969	.969
	1902	Two meter	21	.985	.989	1.009	.994

TABLE 6.—SUMMARY OF MEASUREMENTS OF DISCHARGE, DETROIT RIVER, 1901-2.

Number of measurement	Date of observation	Wind (average)		Water surface—570 feet above mean tide at New York			Fall		Depth ratio		Discharge observed
		Direction from which blows	Velocity (miles per hour)	Windmill Point A	Fort Wayne B	Amherstburg C	A-B	A-C	First	Second	
	1901										cu. ft. sec.
1	July 19	E	7	4.97	4.11	1.99	0.86	2.98	0.3, 0.5	0.5, 0.7	207,500
2	July 20	SW	13	4.93	4.05	1.91	.88	3.02	.3, .5	.5, .7	201,770
3	July 22	NE	13	5.00	4.11	1.90	.89	3.10	.3, .5	.5, .7	210,340
4	July 23	E	10	4.95	4.11	2.03	.84	2.92	.3, .5	.5, .7	203,540
5	July 25	SSW	6	5.00	4.18	2.14	.82	2.86	.3, .5	.5, .7	207,020
6	July 26	ENE	10	5.02	4.26	2.38	.76	2.64	.3, .5	.5, .7	198,740
7	July 27	S	14	5.08	4.26	2.08	.82	3.00	.3, .5	.5, .7	207,660
8	July 30	W	18	4.92	3.98	1.55	.94	3.37	.3, .5	.5, .7	211,900
9	July 31	NW	14	4.97	4.14	2.09	.83	2.88	.3, .5	.5, .7	203,730
10	Aug. 1	NE	8	5.03	4.15	1.87	.88	3.16	.3, .5	.5, .7	217,240
11	Aug. 3	NNW	9	5.05	4.25	2.13	.80	2.92	.3, .5	.5, .7	195,410
12	Aug. 15	SW	10	4.84	4.00	1.68	.84	3.16	.3, .5	.5, .7	201,040
13	do	W	13	4.84	3.97	1.59	.87	3.25	.3, .5	.5, .7	204,130
14	Aug. 16	ENE	8	4.93	4.15	1.98	.77	2.95	.3, .5	.5, .7	198,680
15	do	E	8	4.90	4.06	1.64	.84	3.26	.3, .5	.5, .7	208,200
16	Aug. 17	ESE	10	4.94	4.19	2.13	.75	2.81	.3, .5	.5, .7	200,500
17	do	ESE	8	4.94	4.15	1.96	.79	2.98	.3, .5	.5, .7	199,370
18	Aug. 19	S	10	4.94	4.16	2.05	.78	2.89	.3, .5	.5, .7	199,100
19	do	SW	9	4.94	4.12	1.84	.82	3.10	.3, .5	.5, .7	204,330
20	Aug. 20	NE	10	4.96	4.13	1.98	.83	2.98	.3, .5	.5, .7	207,300
21	do	E	10	5.00	4.19	2.08	.81	2.92	.3, .5	.5, .7	205,800
22	Aug. 21	SW	10	4.96	4.15	2.05	.81	2.91	.3, .5	.5, .7	200,040
23	Aug. 29	SW	10	4.93	4.09	1.89	.84	3.04	.3, .5	.5, .7	203,740
24	do	SW	10	4.93	4.09	1.87	.84	3.06	.3, .5	.5, .7	202,620
25	Aug. 30	NW	7	4.88	4.09	1.97	.79	2.91	.3, .5	.5, .7	193,990
26	do	SSE	4	4.96	4.14	1.90	.82	3.06	.3, .5	.5, .7	200,450
27	Aug. 31	N	14	4.99	4.12	1.94	.87	3.05	.3, .5	.5, .7	205,210
28	do	N	14	4.98	4.08	1.70	.90	3.28	.3, .5	.5, .7	214,600
29	Sept. 3	N	7	5.01	4.17	2.01	.84	3.00	.3, .5	.5, .7	202,420
30	do	N	7	5.00	4.13	1.82	.87	3.18	.3, .5	.5, .7	205,980

TABLE 6.—SUMMARY OF MEASUREMENTS OF DISCHARGE, DETROIT RIVER, 1901-2.

Number of measurement	Date of observation	Wind (average)		Water surface—570 feet above mean tide at New York			Fall		Depth ratio		Discharge observed
		Direction from which blows	Velocity (miles per hour)	Windmill Point A	Fort Wayne B	Amherstburg C	A-B	A-C	First	Second	
	1901										cu. ft. sec.
31	Sept. 4	NW	6	4.99	4.17	2.03	.82	2.96	.3, .5	.5, .7	202,570
32	do	W	7	5.01	4.19	1.96	.82	3.05	.3, .5	.5, .7	204,390
33	Sept. 5	WSW	7	4.99	4.14	1.89	.85	3.10	.3, .5	.5, .7	208,200
34	do	SW	7	5.00	4.21	2.11	.79	2.89	.3, .5	.5, .7	199,890
35	Sept. 7	W	7	4.96	4.13	1.93	.83	3.03	.3, .5	.5, .7	207,340
36	do	WSW	10	5.00	4.16	1.98	.84	3.02	.3, .5	.5, .7	203,210
37	Sept. 17	W	17	4.61	3.82	1.72	.79	2.89	.3, .5	.5, .7	190,710
38	Sept. 24	NE	14	4.77	3.92	1.76	.85	3.01	.3, .5	.5, .7	206,350
39	Oct. 7	SSW	8	4.63	3.82	1.66	.83	2.97	.3, .5	.5, .7	193,460
40	Oct. 8	SSW	17	4.52	3.67	1.36	.85	3.16	.3, .5	.5, .7	193,590
41	Oct. 10	W	12	4.49	3.61	1.28	.88	3.21	.3, .5	.5, .7	198,250
42	do	WNW	7	4.51	3.61	1.28	.90	3.23	.3, .5	.5, .7	202,700
43	Oct. 11	S	18	4.51	3.68	1.51	.83	3.00	.3, .5	.5, .7	192,460
44	Oct. 12	S	15	4.57	3.74	1.67	.83	2.90	.3, .5	.5, .7	190,090
45	Oct. 16	NW	4	4.59	3.78	1.56	.81	3.03	.3, .5	.5, .7	194,470
46	Oct. 17	NW	16	4.24	3.30	.85	.94	3.39	.3, .5	.5, .7	198,760
47	Oct. 19	NNW	12	4.44	3.45	.77	.99	3.67	.3, .5	.5, .7	216,480
48	Oct. 21	SW	12	4.42	3.51	1.06	.91	3.36	.3, .5	.5, .7	201,270
49	do	SW	12	4.47	3.62	1.41	.85	3.06	.3, .5	.5, .7	197,300
50	Oct. 31	SW	21	4.30	3.50	1.45	.80	2.85	.3, .5	.5, .7	183,600
51	Nov. 29	NW	10	4.16	3.25	1.13	.91	3.03	.3, .5	.5, .7	197,290
52	Nov. 30	SSW	10	4.22	3.31	1.08	.91	3.14	.3, .5	.5, .7	195,040
53	Dec. 2	N	10	4.15	3.25	1.10	.90	3.05	.3, .5	.5, .7	192,980
54	Dec. 3	NNE	17	4.31	3.45	1.46	.86	2.85	.3, .5	.5, .7	199,220
55	Dec. 4	NW	9	4.21	3.19	1.05	1.02	3.16	.3, .5	.5, .7	198,690
56	Dec. 10	SW	16	4.00	3.14	1.10	.86	2.90	.3, .5	.5, .7	178,600

TABLE 6.—SUMMARY OF MEASUREMENTS OF DISCHARGE, DETROIT RIVER, 1901-2.

TABLE 6.—SUMMARY OF MEASUREMENTS OF DISCHARGE, DETROIT RIVER, 1901-2.

Number of measurement	Date of observation	Wind (average)		Water surface—570 feet above mean tide at New York			Fall		Depth ratio		Discharge observed
		Direction from which blows	Velocity (miles per hour)	Windmill Point A	Fort Wayne B	Amherstburg C	A-B	A-C	First	Second	
	1902										cu. ft. sec.
57	June 25	S	19	4.74	4.29	2.66	.45	2.08	.3, .5	.5, .7	165,500
58	June 26	W	19	4.84	3.84	1.81	1.00	3.03	.3, .5	.5, .7	184,100
59	June 27	N	4	4.76	4.05	2.10	.71	2.66	.3, .5	.5, .7	209,540
60	June 28	E	7	4.88	4.17	2.11	.71	2.77	.3, .5	.5, .7	199,450
61	July 1	W	7	5.09	4.35	2.30	.74	2.79	.3, .5	.5, .7	200,800
62	July 3	W	16	5.28	4.45	2.43	.83	2.85	.3, .5	.5, .7	205,420
63	July 5	WSW	16	5.59	4.72	2.54	.87	3.05	.3, .5	.5, .7	219,480
64	July 7	SW	12	5.44	4.70	2.68	.74	2.76	.5, .3	.3, .7	208,460
65	July 8	WSW	6	5.43	4.70	2.70	.73	2.73	.5, .3	.3, .7	206,540
66	July 9	WSW	12	5.36	4.62	2.65	.74	2.71	.5, .3	.3, .7	206,500
67	July 10	NNE	13	5.45	4.71	2.82	.74	2.63	.5, .3	.3, .7	215,290
68	July 11	SW	7	5.39	4.68	2.90	.71	2.49	.5, .3	.3, .7	198,920
69	July 12	W	8	5.36	4.65	2.82	.71	2.54	.5, .3	.3, .7	198,320
70	July 14	WSW	9	5.27	4.59	2.80	.68	2.47	.5, .3	.3, .7	199,280
71	July 15	NW	14	5.27	4.37	2.32	.90	2.95	.5, .3	.3, .7	211,880
72	July 18	E	7	5.34	4.59	2.67	.75	2.67	.5, .3	.3, .7	200,730
73	July 19	SW	15	5.25	4.62	2.99	.63	2.26	.5, .3	.3, .7	170,520
74	July 21	NW	13	5.48	4.61	2.51	.87	2.97	.5, .3	.3, .7	211,180
75	July 22	NW	8	5.61	4.81	2.96	.80	2.65	.5, .3	.3, .7	208,300
76	July 23	WSW	12	5.52	4.74	2.80	.78	2.72	.5, .3	.3, .7	203,550
77	July 24	SW	8	5.55	4.85	3.02	.70	2.53	.5, .3	.3, .7	200,600
78	July 25	SE	7	5.54	4.90	3.11	.64	2.43	.5, .3	.3, .7	206,800
79	July 26	SW	11	5.51	4.81	2.95	.70	2.56	.5, .3	.3, .7	204,860
80	July 28	E	5	5.54	4.84	2.90	.68	2.64	.5, .3	.3, .7	209,720
81	July 29	NE	9	5.63	4.90	3.14	.73	2.49	.5, .3	.3, .7	204,900
82	July 30	E	8	5.56	4.89	3.06	.67	2.50	.5, .3	.3, .7	205,240
83	July 31	SW	7	5.59	4.82	2.98	.77	2.61	.5, .3	.3, .7	206,350
84	Aug. 1	N	10	5.62	4.84	2.96	.78	2.66	.5, .3	.3, .7	209,940
85	Aug. 2	SE	6	5.56	4.80	2.95	.76	2.61	.5, .3	.3, .7	202,900
86	Aug. 4	NW	7	5.46	4.77	2.90	.69	2.56	.5, .3	.3, .7	199,560
87	Aug. 5	SW	13	5.40	4.68	2.97	.72	2.43	.5, .3	.3, .7	190,000

TABLE 6.—SUMMARY OF MEASUREMENTS OF DISCHARGE, DETROIT RIVER, 1901-2.

Number of measurement	Date of observation	Wind (average)		Water surface—570 feet above mean tide at New York			Fall		Depth ratio		Discharge observed
		Direction from which blows	Velocity (miles per hour)	Windmill Point A	Fort Wayne B	Amherstburg C	A-B	A-C	First	Second	
	1902										cu. ft. sec.
88	Aug. 6	N	10	5.43	4.70	2.70	.73	2.73	.5, .3	.3, .7	191,860
89	Oct. 7	WNW	10	4.99	4.27	2.62	.72	2.37	.5, .3	.3, .7	188,520
90	Oct. 8	SW	17	4.82	4.07	2.12	.75	2.70	.5, .3	.3, .7	180,140
91	Oct. 9	NE	15	5.19	4.57	3.31	.62	1.88	.5, .3	.3, .7	186,820
92	Oct. 14	WNW	14	4.63	3.80	1.82	.83	2.81	.5, .3	.3, .7	198,880
93	Oct. 16	NNE	14	4.79	4.25	2.86	.54	1.93	.5, .3	.3, .7	184,390
94	do	NE	12	4.85	4.12	2.17	.73	2.68	.5, .3	.3, .7	201,360
95	Oct. 17	ENE	11	4.91	4.14	2.37	.77	2.54	.5, .3	.3, .7	191,830
96	Oct. 18	SW	12	4.76	4.05	2.25	.71	2.51	.5, .3	.3, .7	183,010
97	Oct. 20	W	10	4.72	4.00	2.15	.72	2.57	.5, .3	.3, .7	193,680
98	Oct. 21	NE	9	4.80	4.09	2.38	.71	2.42	.5, .3	.3, .7	195,530
99	Oct. 22	SSE	7	4.74	4.05	2.30	.69	2.44	.5, .3	.3, .7	195,380
100	Oct. 23	ENE	12	4.87	4.19	2.56	.68	2.21	.5, .3	.3, .7	188,520
101	Oct. 24	SW	12	4.60	3.84	2.24	.76	2.36	.5, .3	.3, .7	170,120
102	Oct. 25	NE	12	4.93	4.12	2.48	.81	2.45	.5, .3	.3, .7	188,790
103	Oct. 27	W	9	4.66	3.89	1.85	.77	2.81	.5, .3	.3, .7	199,520
104	Oct. 28	NNW	12	4.67	3.91	1.91	.76	2.76	.5, .3	.3, .7	200,900
105	Oct. 29	WNW	10	4.58	3.98	2.18	.60	2.40	.5, .3	.3, .7	192,880
106	Oct. 31	NNE	6	4.71	3.99	2.47	.72	2.24	.5, .3	.3, .7	194,150
107	do	SSE	7	4.77	4.11	2.37	.66	2.40	.5, .3	.3, .7	184,780
108	Nov. 1	S	10	4.70	3.93	1.95	.77	2.75	.5, .3	.3, .7	192,830
109	Nov. 3	NW	14	4.58	3.63	1.55	.95	3.03	.5, .3	.3, .7	208,100
110	do	NW SE	12 5	4.64	3.85	2.26	.79	2.38	.5, .3	.3, .7	199,530
111	Nov. 4	SSW	10	4.61	3.91	2.04	.70	2.57	.5, .3	.3, .7	188,420
112	Nov. 14	SW	10	4.50	3.88	2.18	.62	2.32	.5, .3	.3, .7	185,450
113	Nov. 15	W	14	4.33	3.47	1.34	.86	2.99	.5, .3	.3, .7	201,230
114	do	W	12	4.38	3.62	1.94	.76	2.44	.5, .3	.3, .7	187,060
115	Nov. 17	NE	14	4.73	4.03	1.94	.70	2.79	.5, .3	.3, .7	192,080
116	Nov. 19	SW	11	4.56	3.84	2.14	.72	2.42	.5, .3	.3, .7	187,960
117	Nov. 20	SW	8	4.59	3.84	2.07	.75	2.52	.5, .3	.3, .7	189,760

Chief of Engineers Report, 1903, Appendix FFF, pages 2815-16-17.

EXTRACT FROM THE REPORT OF MR. THOMAS RUSSELL, ASSISTANT ENGINEER, DETROIT, MICH., MARCH 24, 1903.

Chief of Engineers' Report, App. EEE, p. 4106.

"DESCRIPTION OF ST. CLAIR RIVER.

From Lake Huron to the Grand Trunk Railway gauge, a distance of 0.8 of a mile, the St. Clair River flows southwest. The river is comparatively narrow over the stretch, 1,015 feet wide on the average and 37.1 feet deep. The fall is 0.755 of a foot and the velocity relatively great.

From the Grand Trunk Railway gauge to Roberts Landing the river may be divided into eight well-marked stretches of nearly uniform width and depth.

From the Grand Trunk Railway gauge the river flows nearly southeast for 7,392 feet to the mouth of Black River; the average width and depth are 1,498 feet and 31 feet, and the fall 0.554 of a foot.

From Black River to Dry Dock section, 14,300 feet, the river flows southwest; the average width is 2,167 feet and the depth 27.3. The fall is 0.375 of a foot.

At Dry Dock the river bends, flowing more nearly south, and for a distance of 17,952 feet to Marysville the average width is 2,078 feet and the depth 29.6 feet. The fall is 0.491 of a foot.

From Marysville to St. Clair the river flows nearly south for 30,096 feet. The average width is 3,002 feet and the depth 24.3 feet. The fall is 0.786 of a foot. In this stretch Stag Island divides the river into two channels for a distance of 1¼ miles.

From St. Clair to a point 20,000 feet below to (a) the river flows south, slightly toward the east, with an average width of 1,828 feet and a depth of 34.3 feet. The computed fall is 0.473 of a foot.

From the point (a) to Marine City the river flows a little west of south for 21,120 feet with an average width of 2,984 feet and a depth of 25.6 feet. The computed fall is 0.448 of a foot.

From Marine City to a point (b) 12,000 feet below, the river flows southwest with an average width of 3,135 feet and depth of 25.1 feet. The computed fall is 0.214 of a foot. In this stretch Woodtick or Fawn Island divides the river into two channels for a distance of one-half mile.

From the point (b) to Roberts Landing, 10,032 feet, the river flows between south and southwest with an average width of 2,289 feet and a depth of 29.9 feet. This average width and depth includes 6,000 feet of the river below Roberts Landing. The computed fall is 0.197 of a foot.

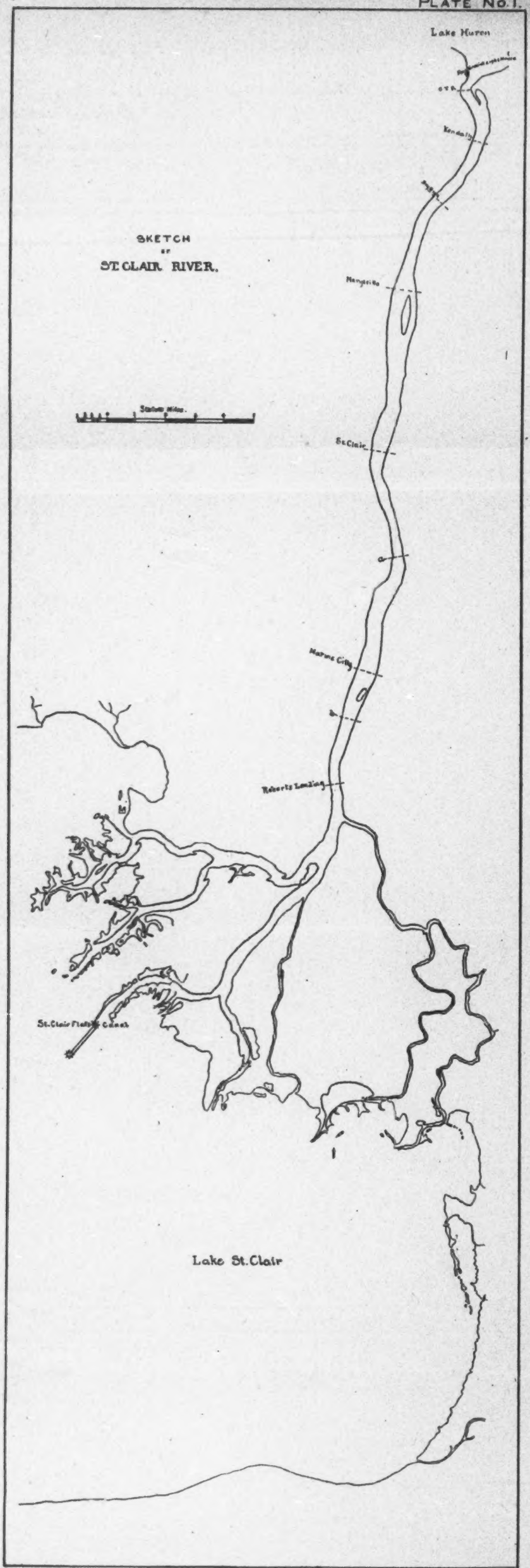
The first distributary from the river is Chenal Ecarte, 7,000 feet below Roberts Landing. At Russell Island 16,000 feet below Roberts Landing, the river divides, going to Lake St. Clair through North Channel by Algonac and through South Channel to St. Clair Flats Canal.

The differences of level given above are for a height of Lake Huron of 580,479 feet at Sand Beach and depend on observations of water level made on six days in June, 1899, at ten-minute intervals, from 7 a. m. to 5:30 p. m. (Report of 1900, p. 5365.)

The height of river at Roberts Landing for the same time is derived as 576, 186, considering the level of river to fall uniformly from Marine City gauge, 21.8 miles below Fort Gratiot light-house, to the Algonac gauge 29.1 miles. The distance from light-house to Roberts Landing is 26 miles."

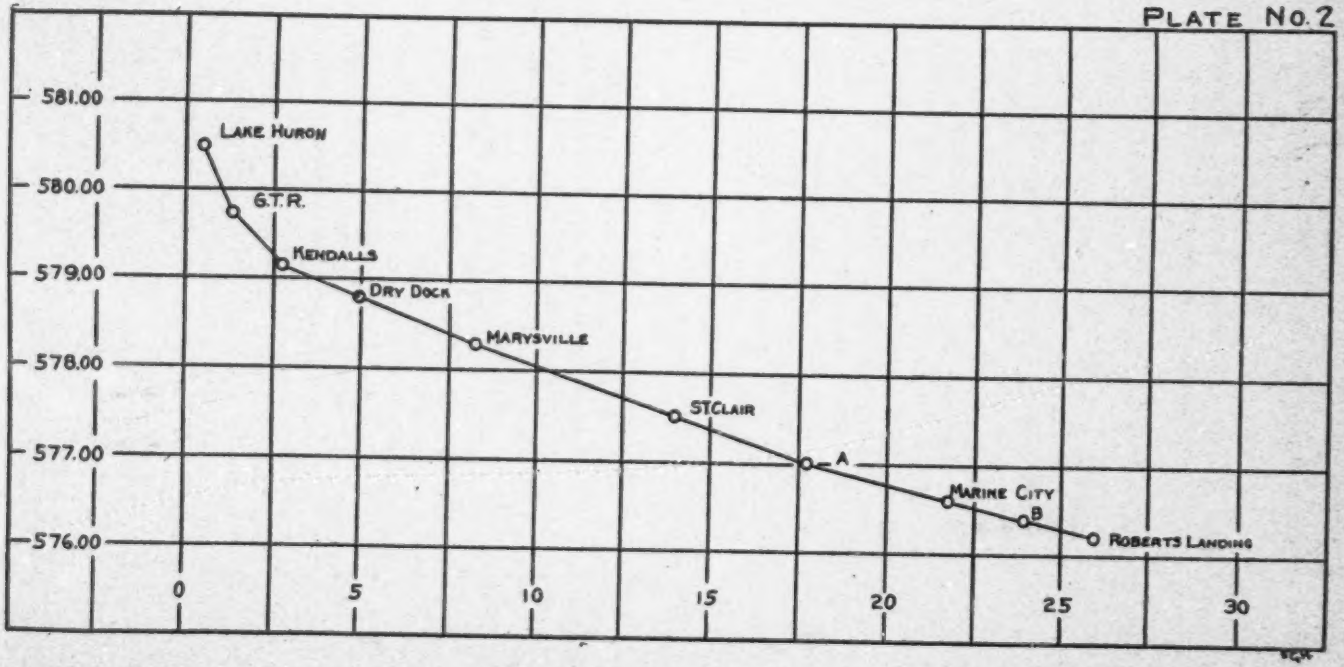
Report of Mr. Thomas Russell, Asst. Engineer, Detroit, Mich., March 24, 1903, page 2839.

Opposite hereto are attached Plates 1 and 2, which appear in said report, opposite page 2841.


Lake Huron
SKETCH
OF
ST. CLAIR RIVER.
Sarnia
Mooretown
Courtright
Kimball
Port Huron
Marysville
St. Clair
Algonac
Marine City
Belle River
Roberts Landing
St. Clair Flats Canal
Lake St. Clair

SLOPE St. CLAIR RIVER

PLATE No. 2



SCALE

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EXTRACT FROM REPORT OF THOMAS RUSSELL, ASSISTANT ENGINEER, DATED DETROIT, MICH., MAY 18, 1904:

"Effect of Ice on Discharge.

The differences, St. Clair minus Detroit, are often very great in the winter months. This is due to ice blockades in either the St. Clair or the Detroit Rivers. When the difference is plus, as in February, 1860, +125,100; March, 1877, +115,600; January, 1884, +95,700; February, 1886, +100,200; April, 1901, +87,500, it indicates that the blockade is in the St. Clair River. The discharge being diminished the level of Lake St. Clair falls. The gauge readings for St. Clair Flats Canal and Cleveland give the true discharge of the Detroit River, which must be the same as the water actually passing through the St. Clair River. The gauges at Sand Beach and St. Clair Flats Canal do not give the true discharge of the St. Clair River when blocked with ice. The effect of the great blockade of 1901, extending into May, is visible in these differences.

The effect of an ice bockade in the Detroit River is to cut down the discharge. This increases the height of Lake St. Clair, which checks the flow from the St. Clair River. The computed discharge of the Detroit River under these circumstances is greater than the true discharge, and the differences, St. Clair minus Detroit, are largely minus. The largest cases of this kind are: February, 1857, —102,700; March, 1876, —37,300; March, 1885, —52,800; January, 1895,—56,400; February, 1895,—59,700; February, 1897,—45,200.

Sometimes when there is no blocking by ice St. Clair minus Detroit gives minus differences which are large. These may be due to heavy rains over the drainage area of Lake St. Clair. Ossasionally there is a summer month with St. Clair minus Detroit a small plus value, indicating great evaporation from Lake St. Clair.

In the case of ice blockades the difference of the two-rivers given in Table XII is not the true amount of water held back. For ice in the St. Clair River the Detroit River gives the true discharge, but on account of the lowering of Lake St. Clair the computed discharge of the St. Clair River is too great. A better difference for com-

parative purposes is the normal discharge pertaining to the height of Lake Huron, and the normal height for Lake St. Clair computed from Lakes Huron and Erie by formula (23).

When there are ice blockades in both rivers the true discharges are not given by either formula and the differences are not significant. With ice in the rivers the formulae always give results more or less inaccurate. A complete covering of ice a foot thick, such as may often occur, diminishes the cross section of river and gives a computed discharge too great in the case of both rivers by about 10,000 cubic feet per second. The velocity of water under the ice is reduced by friction, and the discharge thereby also diminished. For the St. Marys River, where observations of discharge were made under ice, the diminution of average velocity of water due to ice covering was about one-thirtieth of the whole. (See Report of Chief of Engineers, 1897, p. 4092.)

The ice effects shown by the differences in Table XII for the winter months are mainly due to gorges at the St. Clair Flats or higher up on the middle grounds at Marine City and St. Clair. The level of the river along the stretches above the gorge rises sometimes up to the level of Lake Huron at Fort Gratiot lighthouse.

Observations of the discharge of St. Clair River were made during one of these gorges. Results of these measurements are given in report for 1902, page 2837. In that report the diminished discharge is related by an empirical formula to the decreased slope of river between Grand Trunk Railway and Dry Dock gauges, or between Grand Trunk Railway and Mouth of Black River gauges. The normal difference between Grand Trunk Railway and Dry Dock is 0.84 foot. In ice blockades this difference may diminish to 0.10 foot. For the great blockade of 1901 the discharge of the St. Clair River is shown below as given in the 1902 report derived from the fall at the head of St. Clair River, or measured, and the discharge of Detroit River as given in Table XII, with 4,700 subtracted, which is, presumably, the true value of the discharge of St. Clair River. The discharge of the St. Clair River, as it would have been, was derived by means of the formula for discharge using the elevation of Lake St. Clair as derived from Lakes Huron and Erie by formula (23).

Ice Effect.

St. Clair River Monthly Mean Discharges in Cubic Feet Per Second.

	From report of 1902		As determined in this report.	
	Computed discharge.	Ice Effect.	Discharge derived from Detroit River.	Ice Effect.
1901				
January	160,300	30,300	185,300	8,070
February	102,200	85,900	160,300	34,070
March	133,900	53,800	173,700	18,970
April	130,500	66,300	138,200	56,770
May	189,000	11,800	185,300	16,770

The method of deriving the quantity of water held back by an ice gorge, as given in 1902 report, dependent on the relation between the restricted discharge and the slope at head of river as observed in some particular year, is not a method strictly applicable for other years unless the ice obstruction is located in the same part of river. The relation of slope to discharge must depend on the location of the obstruction. For this reason it is believed the computed discharge of the Detroit River is a better measure of the quantity of water passing through the St. Clair River during ice gorges than any derivation based on slopes over short stretches of the river. The determination by Detroit River is by no means certain. When there is a gorge in the Detroit River the gauge readings give an erroneous result for discharge. Ice gorges in the Detroit River. however, are less frequent than in the St. Clair River."

Chief of Engineers Report, 1904, App. EEE, pages 4106 and 4107.

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page 4115.

"Change in Regimen of St. Clair River.

The differences in the St. Clair and Detroit River changes of discharge may be due either to errors in the discharge formulae or in the gauge readings. Systematic errors of such extent in the gauge readings as to account

for the differences are not very likely and may be left out of consideration.

In the discharge formulae the error may occur in two ways, either in the coefficients of the formulae or in the datum discharge. In the formula for St. Clair River,

$$D(\text{St. Clair}) = D_o + AH + Bh$$

the datum discharge Do may be different at different times if there are considerable changes in the river. If a layer of 1 foot in thickness was scoured off the bottom of the river while the surface remained at the same elevation the cross-section of river would be increased and the datum discharge increased by about 15,000 cubic feet per second. If then it be granted that the bottom of the river is lower in later years than formerly, the discharge formula determined from observations in recent years would give a discharge for the earlier years too great by the amount of the error in the datum discharge. That there may have been such a change in the river is possible, for the beds of rivers are continually wearing away by erosion. With the greater velocities accompanying high stages, the cutting is presumably more rapid at high stages than at low stages of water. The swift current in the narrow rapids from Fort Gratiot lighthouse to G. T. R. gauge is an especially favorable place for this kind of action. The bottom of the St. Clair River is subject to very great changes during ice blockades, the grounded ice plowing up the bottom and the concentrated currents at constricted places cutting away soft material very rapidly. When the ice blockade is lifted it causes temporary steep slopes along the lower stretches of river with velocities of great cutting effect. After the great ice blockade of 1901 the swift current through St. Clair Flats Canal caused a deepening of several feet at places in the lower end of the canal.

The delta of St. Clair River, the St. Clair Flats, is no doubt composed in part of material carried away from the banks and bottom of St. Clair River and deposited in that region. While some of the delta consists of this material, the greater part, however, is material from Lake Huron, which, shifting along the shore under the action of waves and currents due to storms in passing across the entrance to St. Clair River, is carried down by the current. The water of Lake Huron at entrance to St.

Clair River contains very little solid matter in suspension, except during storms. There is some silt carried into St. Clair River by its tributaries, the Black, the Pine, and the Belle rivers.

The cutting of the river in the upper part where the current is strong tends to deepen it and increase the discharge. This is in a measure counteracted by the deposition of the material in the slack currents of the channels and shoal parts of the flats, which tends to raise the bottom and diminish the discharge. This deposition is going on over a great part of the area below the first distributary, the Chenal Ecarte, which leaves the St. Clair River a mile and a half below Roberts Landing.

In the shallow stretches of the river the propeller wheels of steamers stir up the material of the bottom, which tends to deepen the channel and increase the discharge. From the head of Russel Island to St. Clair Flats Canal, a distance of 10-1/2 miles, the depth of channel only exceeds by a few feet the draft of the largest steamers passing. In the last ten years the draft of vessels passing has increased a good deal. The number of vessels, moreover, now passing is greater than formerly. In the season of navigation there are 33,000 vessel passages through Detroit and St. Clair rivers. This may have had some effect in making the present discharge of river greater than it was in former years. (See Report of Chief of Engineers 1903, p. 2040.)

Changes in Detroit River to explain the differences in discharge between it and St. Clair River would require to be from a greater discharge to a less, and this is very improbable. The changes in Detroit River are very likely to be in the same direction as in the St. Clair, but much less in amount. The Detroit River at the upper end near Lake St. Clair has a large cross-section and very little slope and the velocity of water is small. At the lower end of the river near Limekiln Crossing where the slope is steep and the velocity of water great, at times of low water in Lake Erie, the bottom is not subject to much erosion on account of it being a limestone ledge. There has been, in recent years, considerable excavation of the bottom rock in this region in widening the channel and deepening it to 21 feet. This may have affected the discharge of the Detroit River, but probably only slightly. The river at Limekiln Crossing is a mile and a half wide and the deepening of a part 600 feet wide

by a few feet would have only a relatively small effect on the cross-section.

The building of docks on the river front of the city of Detroit has diminished the width and cross-section of the river along a stretch of about 4 miles and must have changed considerably the relation of discharge to stage for the present time as compared with what it was many years ago. Very little change, however, can be due to this cause in recent years, since 1892.

The railroad bridge at Trenton Crossing, over the channel west of Grosse Isle and from Grosse Isle to Stony Island and the pier extending from Stony Island 1,300 feet into the main channel of Detroit River, must have had some effect on the relation of discharge to stage. This bridge was built in 1872.

St. Clair River and Niagara River Discharge.

A comparison of the outflow from Lake Erie through the Niagara River with the discharge of the St. Clair River for the ten years 1883-1892, June to November, shows that the computed discharge of the St. Clair River for that time is probably too large.

The six months' means of gauge readings, June to November, for Breakwater lighthouse gauge at Buffalo, the corresponding means at Cleveland, and the differences are as follows, levels of 1903:

Year.	Cleveland.	Buffalo.	Cleveland minus Buffalo.
	Feet.	Feet.	Feet.
1887.....	573.31	573.44	—0.13
1888.....	572.83	572.96	— .13
1889.....	572.53	572.68	— .15
1890.....	573.22	573.33	— .11
1891.....	572.03	572.22	— .19
1892.....	572.73	572.93	— .20
1893.....	572.40	572.70	— .30
1894.....	572.25	572.50	— .25
1895.....	571.20	571.42	— .22
1896.....	571.67	571.79	— .12
1897.....	572.20	572.27	— .07
1898.....	572.22	572.38	— .16
1899.....	572.17	572.00	+ .17
1900.....	572.06	572.12	— .06
1901.....	571.60	571.66	— .06
1902.....	572.38	572.37	+ .01
1903.....	572.57	572.56	+ .01
Mean			— .12

The mean gauge reading at Buffalo, June to November, 1883 to 1892, is 573.24. The discharge of the Niagara River (Report of 1900, p. 5361) is 222,400 cubic feet per second for 573.15, new levels, by Breakwater gauge at Buffalo. The discharge for Niagara River for 573.24 is 224,490 cubic feet per second. The increase in discharge of Niagara River for 1 foot rise is 23,205 cubic feet per second, the mean of values given for open section and bridge section.

The discharge of Niagara River should have 1,200 cubic feet per second added for the flow through the Erie Canal and 1,100 cubic feet per second for the flow through the Welland Canal. This gives the outflow from Lake Erie 226,790 cubic feet per second. In Report for 1903, page 2858, the amount for Welland Canal is estimated by the department of railways and canals of Canada: for the Erie Canal as estimated by the New York engineer for water supply.

The average discharge of St. Clair River, June to November, 1883 to 1892, is 223,338 cubic feet per second by

formula (20). Adding to this 4,700 for the water added by the drainage area of Lake St. Clair, the water entering Lake Erie from the Detroit River is 228,038 cubic feet per second.

The mean of the monthly means of gauge readings for May and June gives the gauge reading for the epoch of June 1. The mean of monthly means of gauge readings for November and December gives the gauge reading for epoch of December 1. The difference between the reading of gauge on June 1 and on December 1 shows the depth by which the lake has increased or decreased.

In Table XVI are given the means of gauge readings, June to November, 1883-1892, by which the discharges of St. Clair River are computed and the differences of level of Lake Erie between June 1 and December 1 determined.

TABLE XVI.—MEAN GAUGE READINGS, JUNE TO NOVEMBER, LAKES HURON, ST. CLAIR AND ERIE, AND HEIGHTS OF ERIE ON JUNE 1 AND DECEMBER 1—LEVELS OF 1903.

Year	Sand Beach, mean, June-Nov.	St. Clair Flats, mean, June-Nov.	Cleveland, mean, June-Nov.	Gauge at Cleveland.		
				June 1	Dec. 1	Difference
	Feet	Feet	Feet	Feet	Feet	Feet
1883.....	583.00	577.15	573.76	573.61	573.11	—0.50
1884.....	582.85	576.86	573.45	574.10	572.49	—1.61
1885.....	583.17	576.91	573.83	573.72	573.55	— .17
1886.....	583.23	576.78	573.51	573.86	572.88	— .98
1887.....	582.49	576.42	573.31	574.06	572.44	—1.62
1888.....	582.07	575.98	572.83	573.05	572.35	— .70
1889.....	581.46	575.65	572.53	572.73	571.89	— .84
1890.....	581.44	575.92	573.22	573.80	572.65	—1.15
1891.....	580.60	575.06	572.03	572.51	571.25	—1.26
1892.....	580.75	575.46	572.73	572.37	571.69	— .68
Mean.....	582.11	576.22	573.12	.....	.....	— .95

Denoting the quantity of water in Lake Erie on June 1 by W, the number of seconds from June 1 to December 1 by t, the average number of cubic feet per second of water added to Lake Erie by the rainfall over its drainage area from June 1 to December 1 by x, and the number of cubic feet per second evaporated from the surface of the lake by y, then the quantity of water in Lake Erie on June 1, plus the amount added by the St. Clair River and the Lake St. Clair drainage area, plus the

amount added from the drainage area of Lake Erie, minus the amount evaporated from the surface, minus the amount taken out through the Niagara River and the Welland and Erie canals, must be equal to the quantity of water in the lake on December 1, which is also equal to the quantity in the lake on June 1, minus a layer of water equal to the fall in the surface of the lake from June 1 to December 1.

The average fall of the lake from June 1 to December 1 for 1883-1892, as shown by Table XVI, is 0.95 foot; this is equivalent to 16,975 cubic feet of water per second from June 1 to December 1. The area of Lake Erie is 9,968 square miles.

$$W+(228038)t-(x)t-(y)t-(226790)t=W-(16975)t \quad (28)$$

Cancelling the W and dividing by t this becomes

$$y=x+18223,$$

which means that the evaporation from the surface of Lake Erie is equal to the entire amount of water supplied to the lake by its drainage area of 34,573 square miles, and, in addition, 18,223 cubic feet per second. The total outflow from the lakes through Niagara River is 222,400 cubic feet per second, and the drainage area of the lake region above Niagara River is 254,708 square miles. Taking the water furnished to Lake Erie by its drainage area as proportional to the area, the quantity is 30,100 cubic feet per second. This would make the evaporation from the surface of the lake 48,323 cubic feet per second from June 1 to December 1, which is 0.451 foot per month, or 32.4 inches from June 1 to December 1, an amount which seems too great.

Coefficients of Discharge Formulae.

The large differences in the monthly discharges of the St. Clair and Detroit rivers, computed from the monthly mean gauge readings, may be due in part to error in the coefficients of the formulae as well as in the datum discharges for the St. Clair and Detroit rivers. An examination of Table XV bears out this view to some extent, as the differences, St. Clair minus Detroit, have a tendency to be greater the higher the stage of Lake Huron. In 1886, for example, Lake Huron was 2.53 feet above datum stage, the highest for any season, and the differ-

ence of discharge, St. Clair River minus Detroit River plus 26,600 cubic feet per second, is also the greatest.

The theoretical values of A and B for St. Clair River are +29500 and —16390, while the values derived from discharge observations are +35145 and —20928. Even if the theoretical values of the coefficients were used in computing the dicharges, the difference for 1886 would be diminished only 5,200 cubic feet per second. As long as the coefficients A and B change by the same amount, it makes very little difference in the discharges, unless the slope of river changes. The absolute magnitude of A and B, then, has little effect in changing the computed discharge. The difference of the coefficients A and B, which is the change in discharge for 1 foot rise in the river, is well determined by the discharge observations. The datum discharge may be in error by a considerable amount on account of unavoidable errors in determining the cross-section of river at the discharge section, as this depends on soundings made on the cross-section, which may be two or three-tenths of a foot or even more in error. The observed change in discharge from datum stage to other stages, which determines the coefficients A and B, is not affected with much error, as the determination of change in cross-section for increase in height of water depends on gauge readings of the height of river surface, which are made accurately to the hundredth of a foot.

In the case of the Detroit River, the theoretical values of the coefficients A' and B', +43940 and —32340, differ a good deal from the values found from the observation equations, +37483 and —21784. No great stress, however, is laid on the accuracy of the theoretical values. The flow of water in the Detroit River, through the many channels of varying width and depth, is too complicated to admit of very satisfactory theoretical treatment. The determination of the coefficients A' and B' for the Detroit River from the discharge observations are not as accurate as for the St. Clair River, as the rapid changes of water level at Amherstburg interfere to some extent with the precise determination, and the observations do not cover much range in stage between Windmill Point and Amherstburg. The difference of the coefficients for Detroit River is, however, fairly well determined. The variations in slope of the Detroit River, in the monthly means, are not as great as in the case of the St. Clair

River. Any errors that there may be in the absolute values of A' and B' have therefore only a slight effect on the computed changes in discharge. Errors even as great as 4,000 in the values, provided they are the same in both coefficients, would make very little difference in the computed discharges.

It would seem, then, that a great part of the difference in discharges between the St. Clair and Detroit rivers, computed from the monthly means of gauge readings for past years, might properly be attributed to changes in the datum discharge of the St. Clair River, indicating a greater height of the river bed in former years than at the present time.

For the ten years, June to November, 1873-1882, the difference is +10530 cubic feet per second. For the ten years 1883-1892 the difference is +12180 cubic feet per second. For the eleven years 1893-1903 the mean difference is —300, being —8500 for 1896 and +4000 for 1897. The mean of the twenty years 1873-1892 indicates an increase of 11,355 cubic feet per second in the datum discharge of St. Clair River. The change in discharge for 1 foot rise of the surface of river is 14,217 cubic feet per second. A lowering of the bed of river by about 0.8 foot is therefore indicated since 1893, as compared with the twenty years preceding.

A change in the datum discharge of the St. Clair River, through a lowering of the bed of the river, would cause a lowering of the level of Lake Huron by the same amount and a rise in level of Lake Erie for the time being. The level of Lake Erie, however, after equilibrium was restored and the surplus water had run off, would be the same as before, provided there were no change in the bed of Niagara River.

If there has been a lowering of the level of Lake Huron since 1892 due to scour of the St. Clair River, it would seem that a comparison of the levels of Lakes Huron and Erie before and since that time should show it. No satisfactory comparison of this kind, however, can be made, as the water supply to the lakes from rainfall differs so much in different years and is so variable over different parts of the drainage area. Besides this, the ice blockades in the St. Clair River have such a variable effect in storing water in Lake Huron in winter time and raising the level of the lake that any lowering of level due to scour can not be certainly distinguished.

The differences in the discharges of St. Clair and Detroit rivers for years preceding 1873, June to November, are as follows, in units of 100 cubic feet per second:

Year	St. Clair minus Detroit	Year	St. Clair minus Detroit
1855.....	+20	1864.....	—61
1856.....	+90	1865.....	—54
1857.....	+196	1866.....	—179
1858.....	+167	1867.....	—89
1859.....	+395	1868.....	—143
1860.....	+582	1869.....	—37
1861.....	+316	1870.....	—75
1862.....	+140	1871.....	—20
1863.....	+86	1872.....	+100

The discharges for years previous to 1872 depend on values for St. Clair Flats Canal gauge heights, derived from observations of river surface at Detroit waterworks, foot of Orleans street. The old levels at waterworks show many discordances and are probably in some cases largely in error. No great stress, therefore, can be put on these differences as showing changes of regimen in the St. Clair or Detroit rivers."

Chief of Engineers Report, 1904, Appendix EEE, pages 4115-4119.

"Rainfall, Evaporation and Run-off.

page 4120.

For the sixteen years 1883 to 1898, the rainfall observations of the United States Weather Bureau in the region of the Great Lakes have been collated for the drainage areas of the various lakes, and this makes it possible, with the discharges through the connecting rivers and with the levels of the lakes, to form some idea of the evaporation from the lake surfaces and the fractional part of the rainfall on the land part of the drainage areas that run into the lakes. The rainfalls for Lakes Superior, Michigan-Huron, and St. Clair-Erie are given in report for 1903, page 2872. In Tables XVII and XVIII the rainfall for Lakes St. Clair and Erie are given.

Curves showing the mean monthly elevations of Lake Superior, Michigan-Huron, and Erie for 1883-1898 are given in sketches Nos. 3, 4 and 5. The mean monthly rainfalls over the drainage areas for same period are also shown on the sketches.

TABLE XVII—LAKE ST. CLAIR DRAINAGE AREA—MONTHLY RAINFALL, IN INCHES.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1882.....	.....	.....	.....	.....	.....	.....	a1.49	a5.58	a1.42	2.22	1.86	2.06	.....
1883.....	1.55	3.75	1.99	1.65	5.28	5.48	6.17	1.21	2.13	3.00	2.69	1.80	36.70
1884.....	1.55	3.36	2.76	1.75	2.14	2.60	3.78	1.37	2.40	3.88	1.90	2.99	30.48
1885.....	2.66	1.76	.96	2.37	3.32	4.35	2.87	4.53	2.43	2.97	3.18	2.83	34.23
1886.....	3.36	2.03	2.66	2.63	2.97	2.13	2.34	2.87	2.50	1.50	2.87	2.91	32.77
1887.....	2.47	4.26	1.50	1.29	2.00	2.50	1.21	1.79	2.73	2.28	2.08	2.86	26.97
1888.....	1.89	1.50	2.44	1.82	2.29	2.97	2.70	1.65	1.65	2.92	2.99	1.65	26.47
1889.....	2.95	1.60	1.03	1.79	4.41	2.79	1.73	.86	1.65	1.10	3.23	3.55	26.69
1890.....	3.99	2.07	1.70	2.70	4.73	3.58	1.52	3.68	1.99	5.30	2.99	1.44	35.69
1891.....	1.79	3.12	2.66	2.13	1.76	2.08	3.02	3.99	2.68	2.16	5.34	1.99	32.72
1892.....	2.11	2.50	1.45	1.61	5.68	5.49	2.15	2.47	4.62	1.18	3.16	1.50	33.92
1893.....	3.15	3.65	1.65	3.71	2.47	3.86	2.21	1.61	1.45	4.29	3.33	3.62	35.00
1894.....	1.19	2.60	1.32	2.24	7.01	1.86	.86	.06	3.50	2.47	1.42	1.76	26.29
1895.....	3.39	.50	1.50	1.45	2.50	.87	2.20	2.57	2.91	.53	4.07	4.60	27.09
1896.....	1.36	1.89	2.07	2.83	2.81	3.78	3.31	4.49	4.52	1.50	2.16	1.00	31.72
1897.....	2.37	1.46	3.25	2.06	3.99	2.58	3.86	2.69	.79	1.40	4.58	2.08	31.11
1898.....	3.01	2.54	3.41	1.58	2.02	3.03	1.55	1.57	2.93	.....	.....	.....	.....
Mean (16 years)...	2.42	2.41	2.02	2.10	3.46	3.12	2.59	2.34	2.68	2.42	2.99	2.42	.....

a Not used in mean, July, August and September, 1882.

TABLE XVIII—LAKE ERIE DRAINAGE AREA—MONTHLY RAINFALL, IN INCHES.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1882	.....	.....	.....	.....	.....	.....	a2.49	a3.95	a2.21	2.29	2.69	2.26	.....
1883	1.68	3.97	1.36	2.10	6.17	4.86	4.94	2.17	2.65	3.24	3.06	2.40	38.60
1884	2.26	4.03	2.58	1.46	2.83	2.59	3.58	1.87	2.37	2.21	1.97	2.77	30.52
1885	2.71	1.31	.96	2.69	4.02	4.86	2.89	5.49	2.58	3.94	3.21	2.44	37.10
1886	3.39	1.91	2.50	2.61	2.81	2.53	1.83	2.99	4.44	1.49	3.93	3.16	33.59
1887	1.89	6.44	2.01	1.80	2.58	3.13	1.47	2.42	2.71	2.25	3.31	2.85	32.86
1888	2.65	1.81	2.96	2.33	2.94	3.43	2.94	2.72	2.32	2.86	3.57	1.89	32.42
1889	2.99	1.67	1.70	2.22	4.53	3.54	2.88	1.21	2.98	1.50	3.44	3.40	32.06
1890	4.13	3.28	3.10	3.42	5.44	3.93	1.36	3.40	3.75	4.81	2.98	1.43	41.03
1891	2.20	4.39	3.21	2.00	1.59	3.07	2.72	3.07	1.83	2.05	5.59	2.23	33.95
1892	2.29	2.81	2.59	2.72	8.26	6.07	3.66	2.95	3.28	1.09	3.07	1.65	40.44
1893	2.72	4.75	2.21	4.93	4.40	2.72	2.46	2.15	1.50	3.72	3.13	3.16	37.85
1894	2.05	2.78	1.90	2.04	5.26	2.75	1.77	.78	4.10	3.34	1.96	2.37	31.10
1895	3.11	.75	1.41	1.70	2.24	1.62	2.07	2.76	2.21	1.40	4.72	4.63	28.62
1896	1.79	2.72	2.70	3.01	2.53	3.79	5.98	3.37	4.50	1.30	2.57	1.76	36.02
1897	2.53	1.70	3.69	2.68	3.80	2.80	4.07	2.84	.78	1.18	5.40	2.09	33.56
1898	3.88	2.46	4.23	1.92	3.42	2.89	3.25	3.15	3.38	.....	.....	.....	.....
Mean 16 years. ...	2.64	2.92	2.44	2.48	3.93	3.41	2.99	2.71	2.84	2.42	3.41	2.53	.....

a Not used in mean, July, August and September, 1882.

These mean values of rainfall include not only the observations at all the regular Weather Bureau stations, but also numerous observations made by voluntary observers under the direction of the Weather Bureau scattered over the area and the stations of the weather service of the Dominion of Canada. The voluntary observations begin about 1883.

Lake Superior—Evaporation and Run-Off.

In discussing the evaporation and run-off the average annual oscillation of the level of the lake for sixteen years, 1883-1898, will be used.

The level of the lake presents in the average for the sixteen years one large wave with the period of a year. The difference between the lowest level, that of April 1, 601.11 feet, and the highest, that of August 1 and of September 1, 602.20 feet, is 1.09 feet.

The mean monthly elevations and the elevations of the lake on the 1st day of each month are shown in Table XIX, and also the mean rainfall for sixteen years.

Table XIX—Lake Superior—New Levels—Monthly Means of Gauge Readings, and Gauge Readings on 1st of Month of Upper Gauge, Saulte Ste. Marie, for Sixteen years, 1883 *to* 1898.

Month	Means of months.	Stage on 1st of month.	Rainfall.
	Feet.	Feet.	Inches.
January	601.34	601.49	1.60
February	601.15	601.24	1.35
March	601.08	601.12	1.33
April	601.14	601.11	1.90
May	601.60	601.37	2.54
June	601.96	601.78	2.72
July	602.17	602.06	3.08
August	602.24	602.20	2.70
September	602.16	602.20	2.73
October	602.11	602.14	2.62
November	601.95	602.03	1.97
December	601.64	601.80	1.73

Taking the year in two parts of six months each from March 1, near the time of minimum level of the lake, to September 1, near the time of maximum level, the rainfall for the first period is 15.67 inches, equal to 1.31 foot, and for the second period 10.60 inches, equal to 0.88 foot. The area of Lake Superior drainage area is 76,134 square miles, and that of the lake itself 32,060 square miles. The ratio of land to water surface is 1.37. The mean discharge of the St. Marys River, adopting the results given in 1903 report, page 2873, is 69,540 cubic feet per second for the first period and 70,250 cubic feet per second for the second. A discharge of 57,460 cubic feet per second for six months is equal to a depth of water of 1 foot over the whole surface of the lake. The discharge for the first period is then equal to 1.21 feet on the lake, and for the second period 1.22 feet.

Denoting by x' the part of rainfall on the land area that runs into the lake, and by E' the evaporation from the lake surface for the first period, then the fractional part of rainfall on the land, plus the rainfall on the lake, minus the evaporation, minus the discharge of the St. Marys River, is equal to the rise in the level of the lake.

$$1.78x' + 1.31 - E' - 1.21 = +1.09 \quad \ldots\ldots\ldots\ldots\ldots\ldots (33)$$

for the second period, in the same way, x'' being the fractional part of land rainfall running into the lake and E'' the evaporation, the equation is obtained—

$$1.21x'' + 0.88 - E'' - 1.22 = -1.09 \quad \ldots\ldots\ldots\ldots\ldots\ldots (34)$$

For the whole year the equation is:

$$2.99x + 2.19 - E - 2.43 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (35)$$

Equation (34) shows that to make the evaporation of the winter part of the year small very little of the winter precipitation should go into the lake. Making x'' zero gives the evaporation for the winter period 0.75 feet, or 9 inches. It would be more if there was much water running into the lake from ground storage. The temperature of the water in the lake is higher than that of the air, and the winds are very strong. Evaporation increases greatly with the strength of the wind. As regards the run-off for the winter period in the Lake Superior

region, it is likely that very little of what falls on the land goes into the lake.

There are numerous lakes in the area, some of considerable size, as Lake Nipigon, with 1,730 square miles of surface.

If the evaporation from the lake in the winter period is 0.75 foot the evaporation from the land in the snow months must be large. It would probably not be quite so great in forest areas as on the open lake, the snow being shaded from the sun and sheltered from the wind. The total fall on the land is only 0.88 foot, which indicates very little supplied to the lake from melting snow. The total fall for the snow months, December to March is 6.01 inches melted snow, and it would seem, therefore, the greater part of that must evaporate and very little reach the lake.

Regarding the evaporation for the summer part of the year, it would seem that it ought to be greater than for the winter part, but in equation (33) to produce this result would require that all or nearly all of the land rainfall should go into the lake. Taking $x' = 1$ gives $E' = 0.78$ foot, and the evaporation must certainly be less than this. The whole evaporation from Lake Superior for a year is then probably less than 1.53 feet, or less than 18 inches.

As a matter of fact a greater part of every rainfall except winter snow, sinks into the ground or is stored in the smaller lakes and runs out gradually throughout the whole year.

Adopting 1.53 feet as the evaporation from the lake, equation (35) gives x equals 0.6, or the run-off from the land surface of Lake Superior drainage basin is 0.6 of the rainfall on the land surface for the entire year.

The levels of Lake Superior given are by the gauge on St. Marys River above the locks at the entrance to the canal, Sault Ste. Marie, Mich. The level of water here is 0.202 foot, on the average, lower than the level of the lake at Iroquois Point, 13.5 miles above. Sometimes the difference is as small as 0.089 foot and sometimes as great as 0.611. (Report of Chief of Engineers, 1902, p. 2210.) In winter the river is covered with ice from early in January to the middle of April; when at its greatest it is 2 feet thick and extends to about 1,000 feet above the International Bridge, where the open water of the rapids be-

gins. When the ice forms the discharge of the river is diminished and the slope is increased, which causes some fall at the lock gauge for which there is no corresponding fall in the surface of Lake Superior. The oscillation of the lake is then really less than 1.09 feet by some hundredths of a foot, and possibly by even as much as one-tenth of a foot.

LAKES MICHIGAN-HURON—EVAPORATION AND RUN-OFF.

In Table XX are shown the means of the mean monthly heights of level of Lake Huron at Sand Beach for the sixteen years 1883-1898, the heights on the 1st day of month derived from these means, and the means of the monthly rainfalls for the sixteen years.

Table XX—Lake Huron—New Levels—Monthly Means of Gauge Readings and Readings on First of Month of Sand Beach Gauge, For Sixteen Years, 1883 *to* 1898.

Month	Means of months.	Stage on 1st of month.	Rainfall.
	Feet.	Feet.	Inches.
January	580.88	580.86	2.90
February	580.84	580.86	2.23
March	580.91	580.87	2.01
April	581.09	581.00	2.19
May	581.42	581.25	3.04
June	581.69	581.55	3.08
July	581.79	581.74	2.68
August	581.74	581.77	2.75
September	581.52	581.63	2.94
October	581.28	581.40	2.66
November	581.05	581.17	2.89
December	580.83	580.94	2.75

The range in the level of the lake from February 1, 580.86 to August 1, 581.77, is 0.91 foot. The drainage area of Lake Michigan-Huron is 137,807 square miles; the area of lake surface is 45,314 square miles; the land surface is therefore 2.04 times the water surface.

The rainfall from February 1 to August 1 is 15.23 inches, equal to 1.27 feet; from August 1 to February 1 it is 16.89 inches, equal to 1.41 feet. Lake Huron receives from the St. Marys River, February 1 to August 1, 66,300 cubic feet of water per second, and discharges through the St. Clair River 198,190 cubic feet per second. The discharge of the Detroit River with 4,700 subtracted is adopted as the discharge of the St. Clair River on account of the winter month discharges computed from gauge readings being erroneous at times due to the effect of ice blockades. This equation is then obtained for February 1 to August 1:

$$2.59x'+1.27-E'-0.82-2.44=+0.91 \quad \ldots\ldots\ldots\ldots (36)$$

From August 1 to February 1, 73,520 cubic feet per second is received from the St. Marys River and 200,850 cubic feet per second discharged through the St. Clair River. For August 1 to February 1, then, the equation is:

$$2.88x''+1.41-E''+0.91-2.47=-0.91 \quad \ldots\ldots\ldots\ldots (37)$$

For the year the equation is:

$$5.47x+268-E+1.73-4.91=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots (38)$$

Adopting six-tenths of the rainfall for the year on the land surface as the run-off from the land into the lake, the evaporation from the lake for the year is 2.76 feet or 33 inches. Equations (36) and (37) show that taking the evaporation for the two parts of the year nearly equal, the summer run-off from the land is a large part of the land rainfall and the winter run-off a small part of the winter rainfall, indicating storage in ground or small lakes and a gradual discharge into the lake in the summer time.

TABLE XXI. LAKE ERIE—MEAN MONTHLY ELEVATIONS AND RAINFALL, 1883-1898—ERIE REDUCED FOR VARIATIONS IN LEVEL OF LAKE HURON.

MONTH	Lake Huron at Sand Beach	Change (+Rise —Fall)	Elevations of water surface, Lake Erie.				Rainfall
			Observed	Derived from Lake Huron	Corrected for changes in Lake Huron	Mean on first of Month Corrected	
	Feet	Feet	Feet	Feet	Feet	Feet	Inches
January	580.88	+0.05	572.00	572.38	572.10	572.07	2.64
February	580.84	— .04	571.97	572.32	572.13	572.12	2.92
March	580.91	+ .07	572.11	572.28	572.31	572.22	2.44
April	581.09	+ .18	572.50	572.30	572.68	572.50	2.48
May	581.42	+ .33	572.92	572.37	573.03	572.86	3.93
June	581.69	+ .27	573.18	572.48	573.18	573.10	3.41
July	581.79	+ .10	573.11	572.59	573.00	573.09	2.99
August	581.74	— .05	572.91	572.66	572.73	572.87	2.71
September	581.52	— .22	572.63	572.67	572.44	572.58	2.84
October	581.28	— .24	572.34	572.64	572.18	572.31	2.42
November	581.05	— .23	572.04	572.56	571.96	572.07	3.41
December	580.83	— .22	572.01	572.46	572.03	572.00	2.53
Means	.....	.....	572.48	572.48	572.48	.....	2.89

Lake Erie Evaporation and Run-Off.

In Table XXI is shown for sixteen years, 1883-1898, the mean monthly levels of Lake Huron, the mean level of Lake Erie at Cleveland, the level of Lake Erie due to changes in Lake Huron, the level of Lake Erie corrected for changes in Lake Huron, the mean heights of Lake Erie on the first day of the month and the mean rainfall for the months.

The level of Lake Erie due to varying level of Lake Huron was derived as follows: For a rise of 1 foot in Lake Huron equation (30) gives Lake Erie gaining water from Detroit River at the rate of (22553—7805y) cubic feet per second, where y is the rise in Lake Erie produced eventually by a rise of 1 foot in Lake Huron. Lake Erie loses water through Niagara River at the rate of $23205y$ cubic feet per second. The gain to Lake Erie is the difference of the two or (22553—31010y) cubic feet per second. In formula (25) then for the time t

$$t = \frac{F}{b} \log \left(1 + \frac{b}{a} y\right)$$

a=22553 and b=—31010

The rise y eventually produced in Lake Erie is $\frac{22553}{31010}$ = 0.727 foot. Substituting in the equation in succession for t the number of seconds in one month, two months, etc., to seven months, the fractional parts of the rise occurring at the end of one month, two months, etc., to seven months are obtained. The differences of these numbers are the parts of rise occurring in the successive months. These differences multiplied by 0.727 give the rises in Lake Erie during the successive months due to a 1-foot rise in Lake Huron. The phases of the rise in Lake Erie being independent of the magnitude of the rise in Lake Huron, these factors multiplied by the actual monthly rises in Lake Huron give the actual rises in Lake Erie in successive months due to the rises in Lake Huron for one month, two months, etc., to seven months preceding. These parts of rise and factors are shown below.

MONTHS.	Part of rise in Erie at end of month. Foot.	Part of rise in Erie during month. Foot.	Erie rise during month for 1 foot rise in Huron. Foot.
First	0.251	0.251	0.182
Second	.439	.188	.137
Third	.580	.141	.103
Fourth	.685	.105	.076
Fifth	.763	.078	.057
Sixth	.823	.060	.044
Seventh	.868	.045	.033

The rise occurring in Lake Erie in any month is, then, 0.182 times the rise in Lake Huron for the month preceding plus 0.137 times the rise the second month preceding, etc., to plus 0.033 times the rise the seventh month preceding. The sum of rises in successive months gives the total rise.

In sketch No. 5 the curve of level of Lake Erie derived in this way is shown by broken line, the curve of actual level is shown by full line, the curve of level corrected for variation of Lake Huron by dotted lines, and the mean monthly rainfall by heavy line.

The maximum stage for Lake Erie corrected is 573.10 on June 1, and the minimum stage 572.00 on December 1, a fall of 1.10 feet. The fall of the uncorrected surface of Lake Erie, 1.02 in the same time, is not very different. The drainage area of Lake Erie is 34,573 square miles, and the area of the lake 9,968 square miles. The land area is 2.47 times the water area. The rainfall from June 1 to December 1 is 17.78 inches, or 1.48 feet; from December 1 to June 1 it is 16.94 inches or 1.41 feet.

The discharge of Detroit River for eleven years, 1893-1903, is, on the average, 193,854 cubic feet per second, The discharge of Niagara River for the same time is 197,328 cubic feet per second. The discharge of Niagara River should be 30,100 cubic feet per second greater than the discharge of Detroit River. It would require a very great and totally inadmissible evaporation from the lake to have the difference in discharges as small as the observations indicate. The most that can be done, then, with the water heights, discharge, and rainfall is to see what a reasonable value of the land run-off and the lake evaporation will give for the difference in the discharges of Detroit and Niagara rivers.

Denoting by x' the fractional part of rainfall on land that runs into the lake for the part of the year, June 1 to December 1, by E' the evaporation, and by d' the excess of discharge of Niagara River over Detroit River, expressed in heights taken off the lake surface by the excess of discharge, then for June 1 to December 1,

$$3.66x'+1.48-E'-d'=-1.10 \quad \ldots\ldots\ldots\ldots\ldots\ldots (39)$$

and for December 1 to June 1,

$$3.48x''+1.41-E''-d''=+1.10 \quad \ldots\ldots\ldots\ldots\ldots\ldots (40)$$

and for the year,

$$7.14x+2.89-E-d=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (41)$$

Taking the run-off for the year as 0.6 and the evaporation as 3 feet, the difference in discharges, d is 4.17 feet in height of the lake. One foot in height of water on Lake Erie is equal to 8,934 cubic feet of water per second for one year; 4.17 feet on the lake, then, corresponds to an average discharge of 37,255 cubic feet per second for the year.

The mean corrected level of Lake Erie, June 1 to December 1, is 572.57 and December 1 to June 1, 572.41. The quantity of water coming into Lake Erie from the Lake Erie drainage area being taken as 37,255 cubic feet per second, and the increase in discharge of Niagara River for a rise of 1 foot being 23,205 cubic feet per second, if the supply from Lake Erie drainage area was uniform throughout the year would maintain the level of lake

$$\frac{37255}{23205}=1.61$$ feet higher than it would be without this supply.

The depth maintained, then, from June 1 to December 1 is 1.69 feet and December 1 to June 1, 1.53 feet.

Dividing $d=4.17$ into two parts that are to each other as 1.69 to 1.53 gives $d'=2.19$, $d''=1.98$. Substituting these values of d' and d'' in (39) and (40), and adopting for x' and x'' the values six-tenths, give E' the evaporation June 1 to December 1, 31 inches, and December 1 to June

1, 5 inches. The great inequality in the values of evaporation derived for the two halves of year indicate the winter run-off is probably more than six-tenths of rainfall and the summer run-off somewhat less.

Windmill Point, Fort Wayne, and Amherstburg Gauges, Detroit River.

It is possible, when the heights of water surface at Windmill Point and at Fort Wayne on the Detroit River are known, to form a somewhat accurate estimate of what the height of water at the same time is at Amherstburg. The slope of the river is determined by any two gauges on the river, assuming that at a given instant the same quantity of water is passing through every cross-section of the river. There are only slight deviations from this condition in the case of the Detroit River, owing to small waves of short period traversing the river. Independent of seasonal variations, Lake Erie is subject to rapid changes of level due to strong winds. In the course of the 190 days in 1901 and 1902, for which there are observations of the gauge at Fort Wayne, the water at Amherstburg was as low as 569.62 December 10, 1901, and as high as 573.96 October 9, 1902. At Windmill Point during the same time the water was as low as 574.01, December 10, 1901, and as high as 575.82, July 29, 1902.

The least difference between Fort Wayne and Windmill Point gauge readings is 0.40 foot for the highest water at Amherstburg and the greatest difference 1.32 feet for the lowest. The range from high to low water at Amherstburg, corresponding to a variation in difference of 0.92 foot for Windmill Point minus Fort Wayne, is about 4.3 feet.

The sole cause of variation in difference of height of water at Windmill Point and Fort Wayne is the stage of water at Amherstburg. Any change in the stage at Amherstburg is followed by a corresponding change at Fort Wayne. It is not possible to determine very closely from the observations of water level what the wave time is from Amherstburg to Fort Wayne. In 15 cases examined, where the maximum stages apparently corresponded, the time varied from 15 minutes to 1 hour and 20 minutes.

Winds or secondary waves probably produce minor irregularities that mask the true time of maximum. The theoretical wave time between Amherstburg and Fort Wayne, 15.07 miles apart, is 46 minutes, taking the velocity of wave the same as that acquired by a body falling through a height equal to half the depth of the water traversed. The average depth of water from Amherstburg to Fort Wayne is 26 feet.

The stage at Windmill Point rises slowly for a rise at Amherstburg on account of the storage capacity of Lake St. Clair, which has an area of 503 square miles.

The stage at Amherstburg can not be told with any degree of accuracy from the stage at Fort Wayne only. The Fort Wayne stage varies directly as the Windmill Point stage, while the Windmill Point stage has no immediately effect on the Amherstburg stage.

The relation of the Windmill Point, Fort Wayne, and Amherstburg stages has been derived by taking the observation of stages and arranging the differences, Windmill Point minus Fort Wayne corresponding to the differences, Windmill Point minus Amherstburg; according to the magnitude of the difference, Windmill Point minus Amherstburg. For this purpose the observations at the full hours were taken on all days when there were observations at Fort Wayne. The means of groups were taken for the differences, Windmill Point minus Amherstburg, 1.8 to 1.9 feet, 1.9 to 2.0, 2.0 to 2.1, etc., up to 3.8 to 3.9. The number of observations in a group varied from 12 for the small difference to 160 for the group 3.0 to 3.1. There were only four observations in the group greater than 3.9 feet.

TABLE XXII—*Relation of Windmill Point, Fort Wayne and Amherstburg Gauges, Detroit River* (1903 *Levels*).

Windmill Point minus—		Windmill Point minus—		Windmill Point minus—	
Fort Wayne.	Amherstburg.	Fort Wayne.	Amherstburg.	Fort Wayne.	Amherstburg.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0.45	1.26	0.71	2.36	0.97	3.42
.46	1.33	.72	2.40	.98	3.46
.47	1.40	.73	2.44	.99	3.50
.48	1.48	.74	2.48	1.00	3.53
.49	1.55	.75	2.52	1.01	3.56
.50	1.62	.76	2.55	1.02	3.59
.51	1.66	.77	2.59	1.03	3.62
.52	1.70	.78	2.63	1.04	3.65
.53	1.74	.79	2.67	1.05	3.68
.54	1.79	.80	2.71	1.06	3.70
.55	1.83	.81	2.75	1.07	3.72
.56	1.86	.82	2.79	1.08	3.75
.57	1.89	.83	2.83	1.09	3.78
.58	1.92	.84	2.87	1.10	3.80
.59	1.95	.85	2.91	1.11	3.83
.60	1.99	.86	2.96	1.12	3.85
.61	2.02	.87	3.01	1.13	3.88
.62	2.05	.88	3.05	1.14	3.90
.63	2.08	.89	3.10	1.15	3.92
.64	2.11	.90	3.15	1.16	3.95
.65	2.14	.91	3.19	1.17	3.97
.66	2.18	.92	3.23	1.18	3.99
.67	2.22	.93	3.27	1.19	4.02
.68	2.25	.94	3.31	1.20	4.04
.69	2.29	.95	3.35		
.70	2.33	.96	3.39		

The means of these groups were plotted on cross-section paper, the differences Windmill Point minus Amherstburg being abscissas and Windmill Point minus Fort Wayne ordinates. A curve was drawn through these points. In Table XXII the relations of the gauges given are taken from the curve.

The mean of the Windmill Point stages for the observations was 575.0 and the extremes about half a foot higher and half a foot lower. The difference between Windmill Point and Fort Wayne would vary slightly with the height at Windmill Point, even for the same difference between Windmill Point and Amherstburg. A half a foot rise or fall at Windmill Point causing a change of half a foot in the mean depth from Windmill

Point to Fort Wayne, which is 28 feet, would cause a variation of only 0.01 of a foot in the difference between Windmill Point and Fort Wayne for the average difference of level, which is 0.77 foot.

From Table XXII with the observed differences between Windmill Point and Fort Wayne the stages at Amherstburg were computed for the full hours 8 a. m. to 5 p. m. for the 1,579 cases on the 190 days for which there are observations at Fort Wayne, with the following results for the signs and magnitudes of the residuals Amherstburg stage, computed minus observed:

Number of residuals.

Between—	Plus.	Minus.	Total.
0.00			32
0.00 and 0.10	370	282	652
.10 and .20	261	167	428
.20 and .30	127	145	272
.30 and .40	47	61	108
.40 and .50	20	30	50
.50 and .60	2	14	16
.60 and .70	5	4	9
.70 and .80	0	8	8
.80 and greater	2	2	4

In about nine-tenths of the cases, then, the error in computed stage at Amherstburg is less than ± 0.30 foot. The cases where the errors are large are more numerous for high stages at Amherstburg than for low stages.

It may be said, then, that a fairly accurate estimate can be made of the height of water surface at Amherstburg, and consequently of the depth in the channel there, when the heights of water at Windmill Point and Fort Wayne are known. This would be useful information in the case of large boats coming down heavily loaded and drawing nearly all the depth of water available, when the water at Limekiln Crossing and Amherstburg is low. An indicator gauge at Windmill Point which the steamers pass quite near and one at Fort Wayne would give the heights from which, with Table XXII, the height at Amherstburg can be derived.

The distance from Windmill Point to Fort Wayne is 9.5 miles. The level of water in Lake St. Clair is not

subject to much change. In the hour required for the vessel to make the distance the change in Windmill Point level would rarely be as much as 0.01 foot. There have been, however, rare occasions when the change has been as much as 0.20 foot in an hour, changing back to the original stage very quickly. This has probably been due to boats passing near the gauge. At Amherstburg the greatest change in level of the water is not often more than 0.10 foot per hour.

To lower the water in Lake St. Clair to a new normal corresponding to a low water at Amherstburg takes time. As has been shown, half the fall would be accomplished in two days and nine-tenths of the fall in six days. After the level of Lake St. Clair has reached the new normal the former normal slopes of the Detroit River are resumed very nearly. In such cases, then, the difference of level between Windmill Point and Fort Wayne would not give an indication of a low stage at Amherstburg. Long-continued low water at Amherstburg, however, rarely occurs. The very low stages that interfere with navigation last only part of a day.

The readings of a gauge at Limekiln Crossing were made from November 30 to December 12, 1903, at ten-minute intervals from 7:30 a. m. to 4:30 p. m. A comparison of these with the record of the automatic gauges at Amherstburg and Windmill Point gives the relations shown in Table XXIII. From Limekiln Crossing to Amherstburg gauge is 2.07 miles. The Windmill Point and Fort Wayne water heights give the height of water surface at Limekiln Crossing as well as at Amherstburg. From Tables VIII and XXIII Table XXIV is obtained, which gives the difference in level of water between Windmill Point and Limekiln Crossing, corresponding to difference in height between Windmill Point and Fort Wayne.

TABLE XXIII.—*Relation of Windmill Point, Limekiln Crossing, and Amherstburg Gauge.* (1903 *Levels.*)

Windmill Point minus Amherstburg.	Limekiln Crossing minus Amherstburg.	Windmill Point minus Amherstburg.	Limekiln Crossing minus Amherstburg.	Windmill Point minus Amherstburg.	Limekiln Crossing minus Amherstburg.
Feet	Feet	Feet	Feet	Feet	Feet
1.5	0.15	2.4	0.33	3.3	0.63
1.6	.17	2.5	.35	3.4	.69
1.7	.19	2.6	.38	3.5	.75
1.8	.21	2.7	.41	3.6	.81
1.9	.23	2.8	.44	3.7	.87
2.0	.25	2.9	.47	3.8	.94
2.1	.27	3.0	.51	3.9	1.01
2.2	.29	3.1	.55	4.0	1.10
2.3	.31	3.2	.59	4.1	1.19

TABLE XXIV.—*Relation of Windmill Point, Fort Wayne, and Limekiln Crossing Gauges, Detroit River.*

Windmill Point Minus		Windmill Point Minus		Windmill Point Minus	
Fort Wayne	Limekiln Crossing	Fort Wayne	Limekiln Crossing	Fort Wayne	Limekiln Crossing
Feet	Feet	Feet	Feet	Feet	Feet
0.45	1.16	0.71	2.04	0.97	2.72
.46	1.21	.72	2.07	.98	2.74
.47	1.27	.73	2.10	.99	2.75
.48	1.33	.74	2.13	1.00	2.76
.49	1.39	.75	2.17	1.01	2.77
.50	1.45	.76	2.19	1.02	2.79
.51	1.48	.77	2.21	1.03	2.80
.52	1.51	.78	2.24	1.04	2.81
.53	1.54	.79	2.27	1.05	2.82
.54	1.58	.80	2.30	1.06	2.83
.55	1.62	.81	2.33	1.07	2.84
.56	1.64	.82	2.35	1.08	2.85
.57	1.66	.83	2.38	1.09	2.85
.58	1.69	.84	2.41	1.10	2.86
.59	1.71	.85	2.44	1.11	2.87
.60	1.74	.86	2.47	1.12	2.88
.61	1.77	.87	2.50	1.13	2.88
.62	1.79	.88	2.52	1.14	2.89
.63	1.81	.89	2.55	1.15	2.89
.64	1.84	.90	2.58	1.16	2.90
.65	1.86	.91	2.60	1.17	2.90
.66	1.89	.92	2.63	1.18	2.90
.67	1.93	.93	2.65	1.19	2.90
.68	1.95	.94	2.67	1.20	2.90
.69	1.98	.95	2.69		
.70	2.01	.96	2.71		

SUMMARY.

1. The formula for discharge of the St. Clair River in terms of heights of water surfaces of Lakes Huron and St. Clair, derived from observations of discharge made from 1899 to 1902, in cubic feet per second, is:

$$D \text{ (St. Clair)} = 195574 + 35145H - 20928h$$

H= Fort Gratiot lighthouse minus 580.52 or Sand Beach minus 580.70

h=St. Clair Flats Canal minus 575.12.

2. The formula for discharge of the Detroit River, in terms of heights of water surfaces of Lakes St. Clair and Erie, derived from observations of discharge made in 1901 and 1902, in cubic feet per second, is:

$$D \text{ (Detroit)} = 200274 + 37483H' - 21784h'$$

H'=Windmill Point lighthouse gauge minus 574.78 or St. Clair Flats Canal gauge minus 575.12.

h'=Amherstburg gauge minus 572.22 or Cleveland gauge minus 571.96.

3. The height of water surface of Lake St. Clair in relation to heights of Lakes Huron and Erie is given by the equation

$$h = 0.602H + 0.373h'$$

h=St. Clair Flats Canal gauge minus 575.12
H=Sand Beach gauge minus 580.70.
h'=Cleveland gauge minus 571.96.

4. The formula for the discharge of St. Clair and Detroit rivers considered as one, in terms of heights of Lake Huron and Lake Erie, is:

$$D \text{(St. Clair-Detroit)} = 200274 + 22553H - 7805h'$$

This formula is derived from the formulae for St. Clair and Detroit rivers by eliminating the St. Clair gauge. The formula is only applicable for mean values covering a considerable period, at least one month.

5. The value of c in the Chézy formula is 60.6 derived from the stretch of St. Clair River from Fort Gratiot lighthouse to G. T. R. gauge. The distance is 0.80 mile, the slope 0.0001989, the width 1,015 feet, the depth 37 feet, and the velocity of water 5.19 feet per second. The value of c for the stretch of river from G. T. R. gauge to St. Clair Flats Canal is 111. The distance is 39 miles, the slope 0.0000239, the width 2,430 feet, the depth 28 feet, and the velocity of water 2.87 feet per second.

The discharge formulae apply for small values of H, h, H', and h' near the datum stages. For stages very different from the datum, terms in the squares and products of H and h derived theoretically are appreciable and should be applied to obtain the best value of the discharge.

7. The difference of 4,700 cubic feet per second adopted in the datum discharges of the St. Clair and Detroit rivers is derived by taking it to be a part of the discharge of the Niagara River proportional to the Lake St. Clair drainage area as compared with the whole drainage area of the lakes above Niagara River.

8. The observed discharge of Detroit River for the stages Windmill Point 574.99 and Amherstburg 572.35, which are the means during the time of observation of discharges, is 198,959 cubic feet per second. Reduced to the datum stage Windmill Point 574.87, Amherstburg 572.22, the discharge is 197,293 cubic feet per second.

9. With the discharge of the Detroit River 4,700 cubic feet per second greater than that of the St. Clair River on the average for the year, and giving St. Clair double the weight of Detroit on account of the greater number of observations, the datum discharge of the St. Clair River is 195,574 and of the Detroit River 200,274 cubic feet per second. These are the adopted datum discharges.

10. The average discharge of Detroit River for eleven years, 1893 to 1903, is 193,854 cubic feet per second. The average discharge of Niagara River for the same time is 197,328 cubic feet per second. The discharge of Niagara River should be greater than the discharge of Detroit River by the quantity of water coming from the drainage area of Lake Erie. This quantity, if taken as a part of the outflow through Niagara River proportional to the area of the Lake Erie drainage area as compared with the whole drainage area of the lakes above the Niagara River,

should be 30,100 cubic feet per second. Either the Detroit River discharge, therefore, is too large or the Niagara River discharge too small.

11. If there is no greater difference in the discharges of the Detroit and Niagara rivers than the observations show, it would indicate an evaporation from the surface of Lake Erie of 81.4 inches for the year, a quantity greater than seems admissible. This assumes a run-off of six-tenths of the rainfall on the land part of the drainage area of Lake Erie.

12. The adopted datum discharges for the St. Clair and Detroit rivers are possibly too large and the discharge of the Niagara River too small by very considerable quantities, 10,000 cubic feet per second, or even more.

13. The differences in the discharges of the St. Clair and Detroit rivers, derived from the monthly mean gauge readings for past years at Sand Beach, St. Clair Flats Canal, and Cleveland, show great differences in the winter months, which are due to ice gorges in the St. Clair and Detroit rivers. These ice gorges are more frequent in the St. Clair than in the Detroit River. When the computed St. Clair discharge is very much greater than that of the Detroit, it indicates the blocking of water is in the St. Clair River. When the Detroit discharge is larger than the St. Clair, it shows the blocking is in the Detroit River. As the discharge of one river must be equal to that of the other, the less value of the discharge is probably more nearly the true one. There is no certainty, however, but what both rivers may be blocked and both computed values incorrect. Even without an ice blockade, an ice covering in winter diminishes the discharge for January, February, and March about 10,000 cubic feet per second by diminishing the cross-section of river. The friction of water on underside of ice probably reduces the discharge 6,000 cubic feet per second farther.

14. The differences in the monthly mean discharges in the summer season show that previous to 1893 the computed St. Clair River discharges are greater by about 11,000 cubic feet per second than those of the Detroit River. This may be due to errors in the formulae for discharge, or changes in either the St. Clair or the Detroit rivers. A change is more likely in the St. Clair than in

the Detroit River, because of the swifter current, softer bottom, and more frequent ice gorges.

15. The error, if in the formulae, may be either in the co-efficients or in the datum discharge. Any reasonable supposition in regard to error in the co-efficients would not account for more than one-fourth of the amount of the differences. Very considerable changes in the Detroit River co-efficients would not alter the differences much, as there is very little variation in the mean monthly slope of the Detroit River.

16. For given datum stages of the St. Clair River there is a certain discharge of the river. If a layer 1 foot in thickness was removed from the bottom of the river without disturbing the surface elevation of the water, the discharge for datum stage would be increased, by reason of the increased cross-section and the increased velocity due to the greater depth.

17. The computed discharges of the St. Clair River being larger than those for the Detroit River can be explained by supposing the bottom of the river lower since 1893 than it was previous to that time. The differences of computed discharges for 1873 to 1892, as compared with 1893 to 1903, indicate a lowering of about 0.8 foot.

18. A rise of 1 foot in Lake Huron produces a proximate rise of 0.602 foot in Lake St. Clair before producing much rise in Lake Erie. A rise of 1 foot in Lake Erie produces a proximate rise of 0.373 foot in Lake St. Clair before the backwater effect in Lake Huron takes place.

19. Five-tenths of the proximate rise in Lake St. Clair, due to a rise in Lake Huron, occurs 46 hours after the Lake Huron rise, and nine-tenths of the rise 154 hours after.

20. A rise of 1 foot in Lake Huron, if continued, would eventually produce a rise of 0.727 foot in Lake Erie.

21. Five-tenths of the rise in Lake Erie, due to a rise in Lake Huron, will be accomplished 72 days after, and nine-tenths of the rise 239 days after.

22. Taking 10,000 cubic feet of water per second from Lake Michigan through the Chicago drainage canal will eventually lower the level of Lake Huron 0.521 foot, the level of Lake St. Clair 0.455 foot, and the level of Lake Erie 0.379 foot. Half the fall in Lake Huron will take place in 1.46 years, and nine-tenths of the fall in 4.86 years.

23. The times required for changes in Lake St. Clair,

corresponding to changes in Lakes Huron and Erie, are independent of the magitudes of the changes and are the same whether one lake is falling and the other rising, or the reverse.

24. The backwater rise in Lake St. Clair for a rise of 1 foot in Lake Erie will be 0.581 foot when the backwater rise in Lake Huron will have been completed. The backwater rise in Lake Huron for a rise of 1 foot in Lake St. Clair is 0.595 foot. The backwater rise in Lake Huron for a rise of 1 foot in Lake Erie is therefore 0.346 foot.

25. Comparing rainfall over the lake region for sixteen years, 1883-1898, with the annual change of lake levels and discharges through the connecting rivers, it is possible to form some idea of the evaporation from lake surface and the run-off from the land part of drainage area.

For Lake Superior the evaporation from the surface of lake is less than 18 inches for the year, with a run-off from the land surface of six-tenths of the rainfall. Very little of the winter precipitation on land reaches the lake.

26. For Lakes Michigan-Huron, taking the run-off from the land as six-tenths, the evaporation from the lake surface is 33 inches for the year.

27. For Lake Erie, adopting the run-off from the land part of the drainage area for the year as six-tenths of the rainfall and the evaporation from lake as 3 feet, gives the excess of discharge of Niagara River over that of Detroit River as 37,255 cubic feet per second.

28. With indicator gauges at Windmill Point and Fort Wayne docks, the readings made from the deck of a passing steamer would enable one by means of Table XXII to tell the height of water surface at Amherstburg within half a foot throughout a range of about 4 feet.

Credit is due to Mr. Sherman Moore for much valuable assistance in the preparation of this report and in making a great part of the computations.

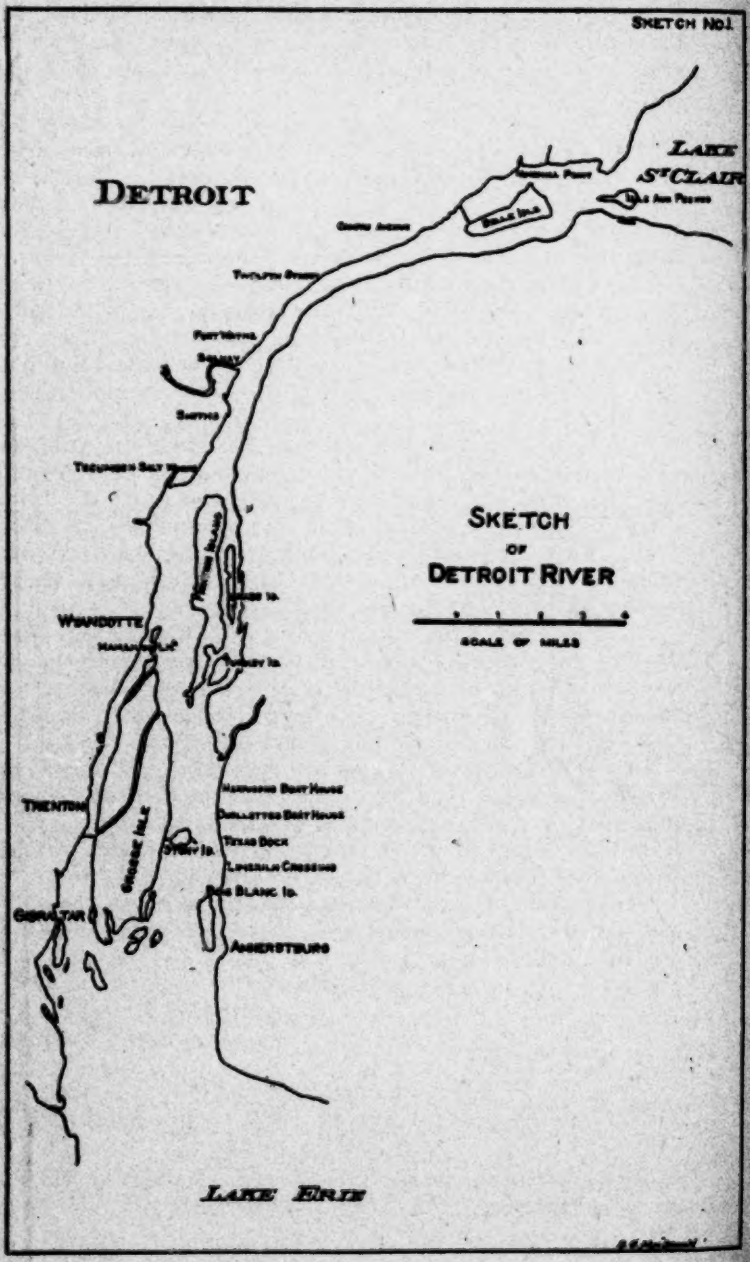
Very respectfully,

THOMAS RUSSELL,
Assistant Engineer.

Maj. W. L. Fisk,
Corps of Engineers, U. S. Army."

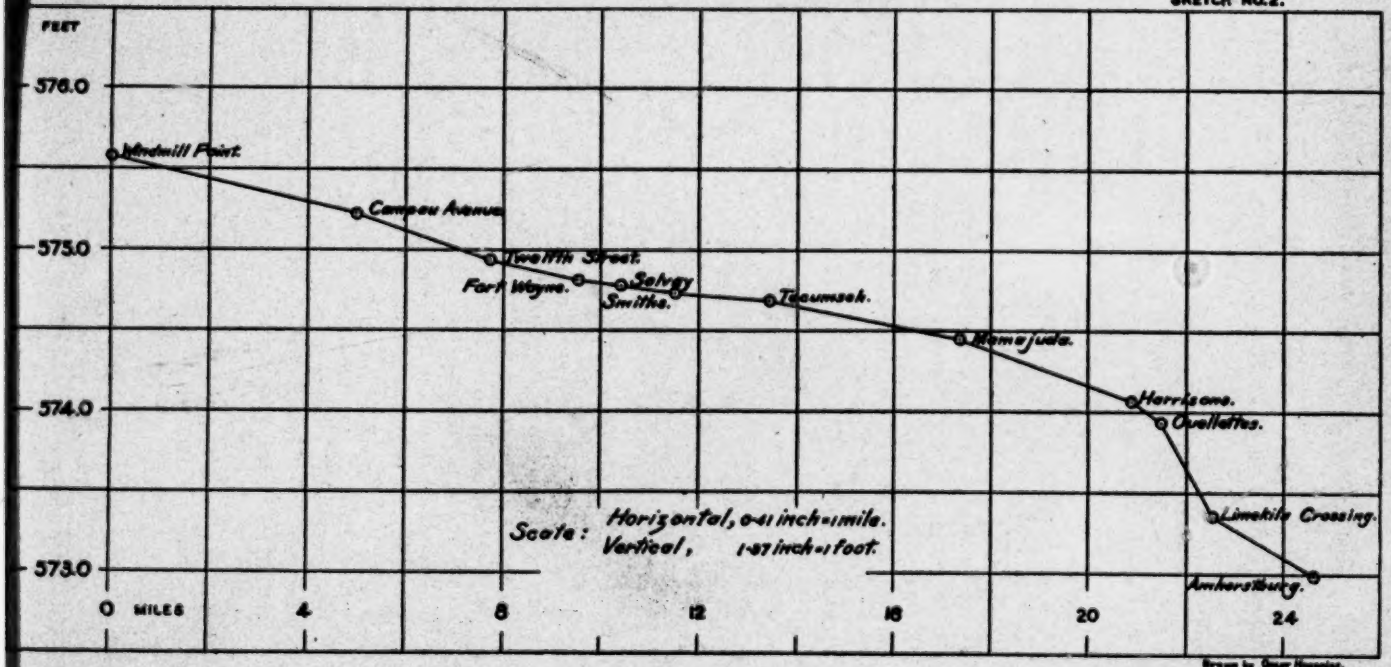
Chief of Engineers Report, 1904, App. EEE. pages 4120-4131.

Opposite hereto are inserted Sketches No. 1 and No. 2 which appear in said report.


SKETCH NO.1
DETROIT
LAKE ST. CLAIR
SKETCH OF DETROIT RIVER
SCALE OF MILES
WYANDOTTE
TRENTON
GIBRALTAR
AMHERSTBURG
LAKE ERIE

Slope Detroit River Surface.

SKETCH NO. 2.



Drawn by Chas. Haywood.

EXTRACT FROM REPORT OF MAJOR KELLER, U. S. ENGINEER, DETROIT, JULY 19, 1909.

Chief of Engineers Report, App. FFF, p. 2490.

* * * * *

"During the year 1908 the level of Lake Ontario was higher than it has recently been, the highest monthly mean, 248.62, that of June, being the highest stage for that month since 1870. The July stage, 248.34, was slightly exceeded in 1876, but in no other July since 1862. Accordingly a valuable opportunity offered for extending the range of the discharge observations of the St. Lawrence River, those of 1900 and 1901, which covered only the range from 243.7 to 246.2 feet on the Oswego gauge.

The hydraulic party of the Lake Survey was, at the beginning of the fiscal year, engaged on work on the Niagara River in connection with allotments from the appropriation made in the act of June 29, 1906. This work was not completed until late in August, so that necessarily the high stages of July and August for Lake Ontario were lost. On August 28, 1908, this party, under Junior Engineer Sherman Moore, on the steamer *No. 1*, left Buffalo via the Welland Canal, for the St. Lawrence River.

On September 8 the party arrived at Waddington, N. Y., near Section Three Points, which had been used in the discharge measurements of 1900 and 1901. This section was relocated and all preliminary work completed by September 21, and between that date and October 2, 26 separate discharges were measured at stages between 246.6 and 247.3 on the Oswego gauge. Including the work of 1908, 122 separate discharge measurements, covering a range of 3.6 feet on the Oswego gauge—i. e., from 243.7 to 247.3—have now been made. The following tables contain the details of the recent discharge measurements and also certain characteristic and limiting discharges computed from the results of all available measurements.

U. S. LAKE SURVEY, HYDRAULICS OF ST. LAWRENCE RIVER.

Summary of discharge measurements.

No.	Date.	Elevation of water surface.					Fall, Ogdensburg to section.	Change in level at Ogdensburg.	
		Ogdensburg.	Section.	Lock 27.	Lock 24.	Lock 21.		Rise.	Fall.
	1908.								
101	Sept. 21	246.08	228.47	17.02	16.68	16.81	17.61	0.00	0.18
102	Sept. 22	245.85	228.25	16.87	17.78	16.66	17.60	.00	.06
103	...do.....	245.82	228.13	16.80	17.65	16.61	17.69	.04	.05
104	Sept. 23	245.89	228.23	16.86	17.81	16.68	17.65	.03	.00
105	...do.....	245.94	228.30	16.92	17.86	16.66	17.64	.02	.02
106	Sept. 24	245.89	228.23	16.86	17.75	16.67	17.66	.08	.00
107	...do.....	245.86	228.20	16.79	17.79	16.64	17.65	.02	.13
108	...do.....	245.90	228.20	16.86	17.74	16.62	17.70	.08	.08
109	Sept. 25	245.82	228.13	16.80	17.63	16.63	17.69	.08	.00
110	...do.....	245.86	228.16	16.84	17.73	16.65	17.70	.01	.02
111	Sept. 26	245.80	228.13	16.77	17.69	16.65	17.67	.05	.03
112	...do.....	245.83	228.15	16.81	17.76	16.69	17.68	.00	.00
113	...do.....	245.88	228.21	16.86	17.83	16.73	17.67	.03	.01
114	...do.....	245.90	228.18	16.84	17.78	16.73	17.72	.03	.09
115	Sept. 28	245.75	228.04	16.69	17.67	16.56	17.71	.00	.01
116	...do.....	245.79	228.11	16.76	17.71	16.57	17.68	.10	.09
117	...do.....	245.88	228.22	16.84	17.80	16.67	17.68	.01	.01
118	Sept. 29	246.13	228.67	17.13	18.25	17.03	17.46	.06	.03
119	...do.....	246.28	228.72	17.33	18.31	17.03	17.56	.26	.18
120	Sept. 30	245.79	228.14	16.72	17.66	16.59	17.65	.01	.07
121	...do.....	245.84	228.22	16.80	17.75	16.60	17.62	.16	.00
122	Oct. 1	246.07	228.49	17.00	18.05	16.82	17.58	.01	.02
123	...do.....	246.16	228.59	17.21	18.22	16.89	17.57	.11	.09
124	...do.....	246.17	228.64	17.20	18.26	16.92	17.53	.01	.04
125	Oct. 2	245.78	228.09	16.74	17.68	16.56	17.69	.07	.01
126	...do.....	245.78	228.06	16.73	17.64	16.62	17.72	.03	.04

No.	Date.	Wind.		Volume of discharge.				Weighted mean index velocity.
		Direction.	Velocity.	1 B meter.	14 B meter.	15 B meter.	Adopted.	
	1908.							
101	Sept. 21	.....	.....	267,530	.....	264,420	266,000	4.35
102	Sept. 22	.....	.....	254,050	.....	256,910	255,500	4.28
103	...do.....	0	0	262,440	.....	256,340	259,400	4.28
104	Sept. 23	0	0	264,720	257,760	.....	264,700	4.36
105	...do.....	SW.	6	268,180	259,670	.....	268,200	4.43
106	Sept. 24	SW.	4	.....	261,060	262,760	262,800	4.35
107	...do.....	SW.	6	.....	256,240	260,810	260,800	4.30
108	...do.....	W.	4	.....	254,610	260,250	260,400	4.29
109	Sept. 25	0	0	265,160	.....	262,110	263,600	4.36
110	...do.....	W.	2	263,800	.....	261,060	262,300	4.33
111	Sept. 26	0	0	263,420	254,700	.....	263,400	4.35
112	...do.....	0	0	262,290	254,300	.....	262,300	4.33
113	...do.....	W.	2	262,800	254,330	.....	262,900	4.34
114	...do.....	W.	4	262,360	255,060	.....	262,300	4.32
115	Sept. 28	SE.	4	.....	254,060	258,320	258,300	4.27
116	...do.....	SE.	12	.....	251,380	259,370	259,400	4.28
117	...do.....	S.	18	.....	253,470	261,210	261,200	4.30
118	Sept. 29	SW.	25	268,420	262,120	.....	268,400	4.39
119	...do.....	SW.	40	271,720	260,220	.....	271,700	4.43
120	Sept. 30	SW.	12	260,820	.....	258,780	259,800	4.28
121	...do.....	SW.	18	266,620	.....	262,010	263,800	4.35
122	Oct. 1	SSW.	30	267,630	.....	267,090	267,400	4.38
123	...do.....	SW.	40	270,150	.....	270,370	270,300	4.41
124	...do.....	SW.	35	271,420	.....	270,420	270,900	4.43
125	Oct. 2	NW.	20	258,290	249,060	.....	258,300	4.26
126	...do.....	NW.	40	260,300	251,420	.....	260,300	4.30

U. S. LAKE SURVEY, HYDRAULICS OF ST. LAWRENCE RIVER—continued.

Equivalent gauge heights and corresponding discharges.

Elevation of water surface at—					River discharge.	Equations.
Oswego.	Ogdensburg.	Lock 27.	Lock 24.	Lock 21.		
243.00	242.22	13.21	12.77	13.16	162,100	Discharge $=5417\,(6.809+0.943$ Oswego$-240)^{\frac{1}{2}}$.
243.50	242.69	13.68	13.46	13.63	174,100	Ogdensburg$=239.392+0.943$ (Oswego$-240)$.
244.00	243.16	14.15	14.14	14.10	186,300	Discharge $=5417\,(7.417+$Ogdensburg$-240)^{\frac{1}{2}}$.
244.50	243.64	14.63	14.82	14.57	199,200	Lock 27 $=10.99+$(Ogdensburg$-240)$.
245.00	244.11	15.10	15.47	15.02	212,000	Discharge $=5417\,($Lock 27$-3.573)^{\frac{1}{2}}$.
245.50	244.58	15.57	16.11	15.47	225,100	Lock 24 $=7.982\,($Lock 27$-3.573)^{\frac{1}{2}}-14.18$.
246.00	245.05	16.04	16.74	15.91	238,500	Discharge $=16.14\,($Lock 24$+14.10)^{3/2}$.
246.50	245.52	16.51	17.36	16.34	252,100	Lock 21 $=3.432\,($Lock 27$-3.573)^{\frac{1}{2}}-1.88$.
247.00	245.99	16.98	17.98	16.77	265,900	Lock 21 $=0.2736\,($Lock 24$+14.10)^{\frac{2}{3}}-1.88$.
247.50	246.46	17.45	18.56	17.20	280,000	Discharge $=317.6\,($Lock 21$+1.88)^{3/2}$.
248.00	246.94	17.93	19.16	17.63	294,700	

Immediately upon the conclusion of this work the discharge section was permanently marked by concrete monuments, adequately referenced to adjacent prominent objects, and on October 5 the steamer carrying the party and its equipment left for Detroit and Port Huron, arriving at the latter place on October 30, after delays en route for various purposes, including necessary repairs to the steamer and rating of meters at Buffalo. Arrived at Port Huron, the party at once proceeded to establish the necessary gauges and to reproduce and sound Section Dry Dock, on which most of the discharge measurements of the St. Clair River have in the past been made. In all, on November 7, 9, 10, 11, 21, 23, and December 14 and 18, fifteen discharge measurements were made at this section, and for the purpose of verifying the results obtained these were compared with twenty-two discharges measured between November 18 and December 19 at a carefully chosen and accurately sounded new cross section, called "Section Gorge," located in the narrow reach of the river just below its head. While these discharge measurements do not extend the range of the former work on the St. Clair River, they are valuable in that the work at Section Gorge gives results varying less than 2 per cent. from those derived from Section Dry Dock. The equations derived from the hydraulic work at the latter section remain, therefore, uncontradicted and, within the limits of observation, deserve confidence.

In 1898 and 1899 a number of sections of the St. Clair River were established by Assistant Engineer Sabin, closely sounded, and referenced to surrounding objects. The object

of these sections was to determine the presence or absence of scour and consequent change of river regimen in the upper river. Four of these sections (Culvert, Fish, Arthur and Stauber), well toward the head of the river, which had been resounded in 1901 and 1904, were again sounded December 5 to 8, 1908.

The following table furnishes a comparison between the areas of cross section as originally determined and those derived from the soundings of 1908.

U. S. LAKE SURVEY—HYDRAULICS OF ST. CLAIR RIVER.

Comparison of soundings on sections at the head of St. Clair River.

Data for 1889 from report of Assistant Engineer L. C. Sabin for 1900; lead-line work.
Data for 1901 and 1904 from report of W. J. Graves, junior engineer, May 11, 1905; 45-pound weight on No. 14 bronze wire.
Data for 1908 from soundings of December, 1908, by Sherman Moore, junior engineer; 135-pound weight on steel piano wire.

Section	Distance from Fort Gratiot light-house.	Year.	Width of section.	Depth.		Area.	Remarks.
				Maximum.	Mean.		
	Feet.		*Feet*	*Feet.*	*Feet.*	*Sq. feet.*	
Culvert..	1,200	1889	1,420	72.0	33.0	39,800	
	.....	1901	1,410	72.8	31.8	43,900	A scour of about 1.3 feet is indicated on this section since 1901.
	.....	1904	1,410	72.8	31.9	45,000	
	.....	1908	1,400	71.8	32.2	45,200	
Fish.....	2,150	1889	1,020	65.0	35.0	35,800	
	.....	1901	1,010	63.8	33.9	34,200	Apparent shoaling indicated by mean depth is due to increase in width. No change is shown in area.
	.....	1904	1,010	64.2	34.7	35,100	
	.....	1908	1,050	62.8	33.1	34,800	
Arthur...	3,200	1889	800	65.0	43.7	35,000	A filling in of about 2.5 feet is indicated on this section. May be due in part to wreck of *Morris*, which lies just above.
	.....	1901	800	63.2	40.5	32,400	
	.....	1904	800	63.9	41.0	32,800	
	.....	1908	820	60.4	38.1	30,200	
Stauber..	3,800	1889	940	49.0	39.2	36,800	
	.....	1901	940	45.5	38.2	34,600	No change shown here. Soundings of 1901 probably slightly in error.
	.....	1904	940	44.0	34.5	32,400	
	.....	1908	940	44.2	36.6	34,400	

It will be seen that virtually no change has taken place at the head of the river, and that for the period covered by the observations its regimen appears to be stable.

Chief of Engineers Report, 1909, App. FFF, pages 2490-2493.

EXTRACT FROM REPORT OF LIEUT. COL. C. S. RICHE, DETROIT, MICH., JULY 27, 1912.

Chief of Engineers Report 1912, App. FFF, p. 3544.

"Water Levels.

The stage of water in the lakes and in the interlake and outflow rivers has been recorded as heretofore by the regular series of self-registering gauges. A small-type automatic gauge was also maintained during the summer season of 1911 on the pile cluster at the head of St. Clair River, for the purpose of further strengthening the determination of relationship between this—the Fort Gratiot gauge—and other standard gauges. The records of this gauge have been used in connection with the determination of slopes and the reductions of discharge measurements for the St. Clair River. The automatic gauge at Buffalo was moved in October, 1911, from the end of the breakwater to a new gauge house at the inner end of the slip belonging to the Bureau of Lighthouses. The change was made necessary by the rebuilding of the fog-signal station in which the gauge was formerly located. All of the standard gauges are now in excellent condition.

Including the St. Clair Flats gauge, which is maintained by the United States engineer office under charge of Col. C. McD. Townsend, Corps of Engineers, during the season of navigation, and by this office during the winter, the Lake Survey now maintains 10 self-registering gauges and 1 staff gauge, as follows:

1. Lake Ontario, at Tibbetts Point.
2. Lake Erie, at Buffalo.
3. Lake Erie, at Cleveland.
4. Detroit River, at Fort Wayne.
5. Lake St. Clair, at Windmill Point (Staff).
6. St. Clair River, at head of St. Clair Flats Canal.
7. St. Clair River, at Port Huron.
8. Lake Huron, at Harbor Beach.
9. Straits of Mackinac, at Mackinaw City.
10. Lake Michigan, at Milwaukee.
11. Lake Superior, at Marquette.

In addition, this office received records of the self-registering gauges maintained by the district offices, as

follows: Detroit River at Amherstburg, Lake Michigan at Chicago, St. Marys River below the locks, and St. Marys River above the locks, and records of staff gauge readings on Lake Ontario at Oswego and on Lake Superior at Houghton and Duluth.

The zeros of all gauges maintained by the Survey have been carefully checked during the past year and the instruments overhauled. The records are for the most part excellent.

Monthly means of water level for stations named, expressed in feet above mean tide at New York. (Adjusted levels of 1903.)

1911	July.	August.	September.	October.	November.	December.
Marquette.....	601.62	602.09	602.18	602.18	602.03	601.90
Milwaukee.....	579.85	579.80	579.71	579.61	579.33	579.44
Harbor Beach..	579.93	579.85	579.58	579.56	579.44	579.39
Cleveland.....	571.75	571.61	571.52	571.53	571.13	571.42
Oswego.....	245.54	245.19	244.88	244.62	244.50	244.63

Monthly means of water level for stations named, expressed in feet above mean tide at New York—Continued.

1912	January.	February.	March.	April.	May.	June.
Marquette.....	601.76	601.53	601.43	601.45	601.91	602.21
Milwaukee.....	579.27	579.29	579.35	579.52	580.05	580.46
Harbor Beach..	579.35	579.23	579.22	579.44	579.89	580.45
Cleveland.....	571.28	571.08	571.23	572.28	572.59	572.66
Oswego.....	244.76	244.87	245.10	246.32	246.82	247.34

There is herewith a sheet showing the monthly mean water levels of all the Great Lakes from January, 1860, to June, 1912, inclusive.

During the year there has been issued a series of notices to navigation interests giving the monthly mean stages for all the lakes during the preceding month, comparing these stages with corresponding ones for critical years, and predicting the stages to be expected for the following month. These notices have been accepted as authoritative and of great usefulness.

INVESTIGATION OF LAKE LEVELS.

The taking of air and water temperatures was continued during the field seasons by the steamer parties engaged on hydrographic and magnetic work. The study of river flow and the related subject of lake levels have received particular attention during the year. Slope relations on the rivers have been revised from all available data, and profiles of St. Marys, St. Clair, Niagara, and St. Lawrence Rivers have been constructed to show surface slopes at mean stages and at low-water planes.

The hydraulic measurements on the St. Clair River obtained in 1910 have been combined with the measurements of 1899-1902 and 1908-9 in deriving a new discharge formula for this river. After considerable study and a test of several formulas with groups of observed gauge heights and discharges, a modification of the submerged-weir formula was accepted as best fitting the conditions. The formula adopted is:

$$Q = K[(\text{Fort Gratiot}-y)+a(\text{St. Clair Flats}-y)]F^{\frac{1}{2}}$$

in which F is the fall from Fort Gratiot to St. Clair Flats and K, a, and y are constants to be derived by solution. In applying this equation as first solved to the observed quantities it was found that residuals were grouped by size or sign for the various years. Assuming that this variation of discharge for the different years of observation is due to change of regimen, a second solution was made, in which the constants K and a were determined from all the observations, and y, which represents the elevation of the mean river bed, was determined for each separate year. This solution gives the equation:

$$Q=3758[(\text{Fort Gratiot}-y)+1.25\ (\text{St. Clair Flats}-y)]F^{\frac{1}{2}}$$

in which the value of y for different years is as follows: 1899, 567.44; 1900, 567.58; 1901, 567.33; 1902, 567.64; 1908, 567.61; 1909, 567.51; and 1910, 567.51.

These values give equations which satisfy closely the relationship between observed discharges and gauge heights for each year. The mean residual for the 488 measurements of flow is 1.41 per cent. From the 1910 equation the increment at mean lake level for Lake Huron (Harbor Beach) is 28,310 cubic feet per second. The backwater increment for Lake St. Clair (St. Clair Flats) is 8,280 cubic feet per second.

The variation in stage on Lake St. Clair during the years of

record averages 66 per cent. of the change at Harbor Beach, and the stage at St. Clair Flats is represented by the equation:

St. Clair Flats=574.85+0.66 (Harbor Beach—580).

From this relationship the flow of the St. Clair River for mean lake level, 1860-1911, inclusive, by the 1910 equation is 207,750 cubic feet per second and the normal increment for 1 foot on Lake Huron is 22,850 second-feet.

The above equation may be applied to Lake Huron stages at Harbor Beach by first reducing these stages to terms of Fort Gratiot gauge heights by the equation:

Fort Gratiot=579.85+0.987 (Harbor Beach—580).

Table No. 1 gives the discharge of St. Clair River by the 1910 equation in terms of stages at Harbor Beach and St. Clair Flats.

TABLE No. 1.—*Discharge, in hundreds of cubic feet per second, for water-surface elevations at Harbor Beach and St. Clair Flats.*

Elevation at Harbor Beach.	Elevation at St. Clair Flats.												
	574.0	574.1	574.2	574.3	574.4	574.5	574.6	574.7	574.8	574.9	575.0	575.1	575.2
578.5	1480	1482	1474	1466	1459	1449	1439	1429	1418	1407	1396	1385	1370
578.6	1514	1507	1499	1491	1484	1475	1465	1455	1445	1434	1423	1410	1393
578.7	1539	1532	1524	1517	1509	1500	1491	1481	1471	1460	1448	1437	1426
578.8	1563	1556	1549	1542	1534	1526	1517	1507	1497	1487	1476	1465	1454
578.9	1588	1581	1574	1567	1559	1552	1543	1533	1523	1513	1503	1492	1481
579.0	1613	1606	1599	1593	1584	1577	1568	1560	1550	1540	1530	1519	1508
579.1	1637	1631	1624	1618	1610	1602	1594	1586	1576	1566	1556	1546	1535
579.2	1662	1656	1649	1643	1636	1628	1620	1612	1602	1593	1583	1573	1562
579.3	1687	1681	1674	1668	1661	1653	1645	1638	1628	1620	1610	1600	1589
579.4	1711	1705	1699	1693	1686	1679	1671	1664	1655	1646	1636	1627	1616
579.5	1736	1730	1724	1718	1711	1705	1697	1690	1681	1672	1663	1654	1643
579.6	1761	1755	1749	1743	1736	1730	1722	1715	1707	1698	1690	1681	1670
579.7	1786	1780	1774	1768	1762	1756	1748	1741	1733	1724	1716	1707	1697
579.8	1810	1805	1799	1793	1788	1781	1773	1767	1759	1751	1742	1734	1724
579.9	1835	1830	1824	1818	1813	1806	1799	1793	1785	1778	1769	1761	1751
580.0	1859	1854	1849	1844	1838	1832	1825	1819	1811	1804	1795	1787	1778
580.1	1884	1879	1874	1869	1864	1857	1850	1844	1837	1830	1823	1814	1805
580.2	1909	1904	1899	1894	1889	1882	1876	1870	1863	1856	1849	1841	1832
580.3	1934	1929	1924	1920	1914	1908	1902	1896	1889	1882	1875	1867	1859
580.4	1958	1954	1950	1945	1940	1934	1928	1922	1916	1909	1901	1894	1886
580.5	1983	1979	1975	1970	1966	1960	1954	1948	1941	1936	1928	1921	1913
580.6	2008	2004	2000	1995	1991	1986	1980	1974	1967	1962	1954	1947	1940
580.7	2033	2029	2025	2021	2016	2011	2006	2000	1994	1988	1981	1974	1967
580.8	2058	2055	2050	2046	2041	2036	2032	2026	2020	2015	2008	2001	1994
580.9	2083	2080	2075	2071	2067	2062	2058	2053	2046	2041	2034	2027	2021
581.0	2108	2106	2100	2096	2092	2087	2083	2078	2072	2067	2060	2054	2048
581.1	2131	2130	2125	2121	2117	2113	2109	2104	2099	2094	2088	2080	2074
581.2	2156	2155	2150	2147	2143	2139	2135	2130	2125	2120	2113	2107	2101
581.3	2181	2180	2176	2173	2169	2164	2160	2156	2151	2146	2139	2134	2128
581.4	2205	2205	2201	2198	2194	2190	2186	2182	2177	2173	2166	2160	2154
581.5	2233	2230	2226	2223	2220	2216	2213	2207	2203	2199	2196	2187	2181
581.6	2258	2255	2251	2249	2246	2242	2237	2233	2230	2225	2219	2212	2208
581.7	.....	2280	2276	2274	2271	2268	2263	2259	2256	2251	2246	2240	2234
581.8	.....	.....	2301	2299	2297	2293	2289	2285	2280	2277	2272	2267	2261
581.9	.....	.....	2326	2324	2322	2318	2314	2310	2305	2302	2298	2293	2287
582.0	.....	.....	.....	.....	.....	2344	2340	2336	2332	2328	2324	2320	2313

TABLE No. 1.—*Discharge, in hundreds of cubic feet per second, for water-surface elevations at Harbor Beach and St. Clair Flats*—Continued.

Elevation at Harbor Beach.	Elevation at St. Clair Flats.												
	575.3	575.4	575.5	575.6	575.7	575.8	575.9	576.0	576.1	576.2	576.3	576.4	576.5
578.5	1357	1343	1329	1313	1298	1279	1260	1244	.....	.....	.....	.....	.....
578.6	1385	1371	1358	1342	1327	1309	1291	1273	1256	.....	.....	.....	.....
578.7	1413	1399	1386	1370	1356	1339	1322	1306	1287	1269	.....	.....	.....
578.8	1441	1427	1414	1399	1385	1369	1353	1336	1318	1300	1280	.....	.....
578.9	1468	1455	1442	1428	1414	1398	1383	1368	1349	1331	1312	1293	.....
579.0	1496	1483	1470	1456	1443	1428	1413	1398	1379	1363	1344	1323	1305
579.1	1523	1511	1499	1486	1472	1457	1442	1427	1410	1394	1376	1357	1337
579.2	1551	1539	1527	1514	1501	1487	1472	1457	1441	1425	1407	1386	1369
579.3	1578	1566	1555	1543	1529	1516	1501	1487	1471	1455	1438	1420	1401
579.4	1605	1594	1583	1571	1558	1545	1531	1517	1501	1486	1469	1451	1434
579.5	1633	1622	1610	1599	1586	1573	1561	1547	1531	1516	1500	1483	1466
579.6	1660	1649	1638	1627	1615	1602	1590	1576	1560	1546	1531	1514	1497
579.7	1687	1677	1666	1655	1643	1630	1618	1605	1590	1576	1561	1544	1529
579.8	1715	1705	1694	1683	1671	1659	1647	1634	1620	1606	1591	1573	1560
579.9	1742	1732	1722	1710	1699	1688	1676	1663	1649	1635	1621	1606	1592
580.0	1770	1760	1750	1738	1727	1716	1704	1692	1678	1665	1651	1636	1623
580.1	1797	1787	1777	1766	1755	1744	1733	1721	1707	1694	1680	1666	1651
580.2	1823	1814	1805	1794	1783	1772	1762	1750	1737	1724	1710	1698	1682
580.3	1850	1843	1832	1822	1811	1800	1790	1778	1766	1753	1740	1726	1713
580.4	1877	1869	1859	1849	1839	1829	1819	1807	1795	1782	1770	1756	1743
580.5	1904	1896	1887	1877	1867	1857	1847	1835	1824	1811	1800	1786	1773
580.6	1931	1922	1914	1905	1895	1885	1875	1864	1853	1841	1829	1816	1802
580.7	1958	1951	1941	1933	1923	1913	1903	1892	1882	1870	1858	1846	1833
580.8	1985	1978	1969	1961	1951	1942	1932	1921	1910	1899	1887	1876	1863
580.9	2013	2005	1997	1989	1979	1970	1960	1949	1939	1928	1916	1905	1891
581.0	2040	2033	2024	2016	2007	1998	1988	1977	1967	1956	1945	1934	1921
581.1	2067	2060	2051	2044	2035	2026	2016	2006	1996	1985	1973	1963	1950
581.2	2094	2087	2079	2072	2063	2054	2044	2035	2025	2014	2004	1993	1980
581.3	2121	2114	2106	2099	2091	2082	2073	2063	2053	2043	2033	2022	2010
581.4	2148	2141	2134	2127	2118	2110	2101	2092	2082	2072	2062	2051	2039
581.5	2175	2169	2161	2154	2145	2137	2129	2120	2111	2101	2091	2080	2069
581.6	2202	2196	2189	2181	2173	2165	2157	2149	2139	2129	2120	2109	2098
581.7	2229	2223	2215	2208	2201	2193	2185	2177	2168	2158	2149	2138	2128
581.8	2255	2249	2242	2236	2228	2220	2213	2205	2196	2187	2178	2167	2157
581.9	2282	2276	2269	2263	2255	2248	2241	2233	2224	2215	2206	2196	2186
582.0	2308	2302	2296	2290	2282	2275	2268	2260	2252	2243	2234	2224	2215

The discharge measurements of the St. Lawrence River made in the spring and fall of 1911 have been combined with the measurements of 1908 in deriving a new discharge formula for this river in terms of Lake Ontario levels recorded at Oswego. Hydraulic data for the St. Marys and Niagara Rivers have been revised and combined.

Revised discharge equations and the years of measurement from which they were derived are as follows:

St. Marys River, 1909:

$$\text{Discharge (rapids)} = 26.740 + 15{,}300\ (\text{S. W. Pier} - 600).^{3/2}$$

For total river flow add 20,060 cubic feet per second.

St. Clair River, 1910:

$$\text{Discharge} = 3{,}758\ [(\text{Ft. Gratiot} - 567.51) + 1.25\ (\text{St. Clair Flats} - 567.51)]\ (\text{Ft. Gratiot} - \text{St. Clair Flats})^{\frac{1}{2}}$$

Niagara River, 1899-1900, 1907-8.

Discharge=3,904 (Buffalo—558.37)$^{3/2}$

St. Lawrence River, 1908, 1911.

Discharge=4,009 (Oswego—230.65)$^{3/2}$

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The following table gives a summary of discharges by these present accepted formulas corresponding to mean elevations of the various lakes for the last 52 years;

Table of mean discharges.

Mean elevation for 52 years (1860-1911) above mean tide at New York City, in feet.		Corresponding mean discharge in cubic feet of water per second.[1]	
Lake.	Stage.	River.	Discharge.
Superior	602.28	St. Marys	85,000
Michigan-Huron	581.25	St. Clair	208,000
St. Clair at Flats Canal	575.67	Detroit	213,000
Erie	572.56	Niagara	210,000
Ontario	246.18	St. Lawrence	245,000

Chief of Engineers Report, July 27, 1912, Appendix FFF, pages 3544-3548

TREATY BETWEEN THE UNITED KINGDOM AND THE UNITED STATES OF AMERICA RELATING TO BOUNDARY WATERS AND QUESTIONS ARISING ALONG THE BOUNDARY BETWEEN CANADA AND THE UNITED STATES, SIGNED AT WASHINGTON, JANUARY 11, 1909.

*Treaty relating to Boundary Waters and Questions arising along the Boundary between Canada and the United States, signed at Washington, January 11, 1909**

His Majesty the King of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas, Emperor of India, and the United States of America, being equally desirous to prevent disputes regarding the use

*Ratifications advised by the Senate.....March 3, 1909
Ratified by the President.....April 1, 1910
Ratified by Great Britain.....March 31, 1910
Ratifications exchanged at Washington.....May 5, 1910
Proclaimed.....May 13, 1910

of boundary waters and to settle all questions which are now pending between the United States and the Dominion of Canada involving the rights, obligations or interests of either in relation to the other or to the inhabitants of the other, along their common frontier, and to make provision for the adjustment and settlement of all such questions as may hereafter arise, have resolved to conclude a Treaty in furtherance of these ends, and for that purpose have appointed as their respective Plenipotentiaries:

His Britannic Majesty, the Right Honourable James Bryce, O. M., his Ambassador Extraordinary and Plenipotentiary at Washington; and

The President of the United States of America, Elihu Root, Secretary of State of the United States;

Who, after having communicated to one another their full powers, found in good and due form, have agreed upon the following Articles:

Preliminary Article

For the purposes of this Treaty boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms, and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers, and waterways, or waters flowing from such lakes, rivers, and waterways, or the waters of rivers flowing across the boundary.

ARTICLE 1

The High Contracting Parties agree that the navigation of all navigable boundary waters shall for ever continue free and open for the purposes of commerce to the inhabitants and to the ships, vessels, and boats of both countries equally, subject, however, to any laws and regulations of either country, within its own terrtiory, not inconsistent with such privilege of free navigation, and applying equally and without discrimination to the inhabitants, ships, vessels, and boats of both countries.

It is further agreed that so long as this Treaty shall remain in force this same right of navigation shall extend to the

waters of lake Michigan, and to all canals connecting boundary waters and now existing or which may hereafter be constructed on either side of line. Either of the High Contracting Parties may adopt rules and regulations governing the use of such canals within its own territory, and may charge tolls for the use thereof; but all such rules and regulations and all tolls charged shall apply alike to the subjects or citizens of the High Contracting Parties and the ships, vessels, and boats of both of the High Contracting Parties, and they shall be placed on terms of equality in the use thereof.

ARTICLE 2

Each of the High Contracting Parties reserves to itself, or to the several State Governments on the one side and the Dominion or Provincial Governments on the other, as the case may be, subject to any Treaty provisions now existing with respect thereto, the exclusive jurisdiction and control over the use and diversion, whether temporary or permanent, of all waters on its own side of the line which in their natural channels would flow across the boundary or into boundary waters; but it is agreed that any interference with or diversion from their natural channel of such waters on either side of the boundary, resulting in any injury on the other side of the boundary, shall give rise to the same rights and entitle the injured parties to the same legal remedies as if such injury took place in the country where such diversion or interference occurs; but this provision shall not apply to cases already existing or to cases expressly covered by special agreement between the parties hereto.

It is understood, however, that neither of the High Contracting Parties intends by the foregoing provision to surrender any right which it may have to object to any interference with or diversions of waters on the other side of the boundary the effect of which would be productive of material injury to the navigation interests on its own side of the boundary.

ARTICLE 3

It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter provided for by special agreement between the Parties hereto, no further or other uses or obstructions or diversions, whether temporary

or permanent, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line, shall be made except by authority of the United States or the Dominion of Canada within their respective jurisdictions and with the approval, as hereinafter provided, of a Joint Commission, to be known as the International Joint Commission.

The foregoing provisions are not intended to limit or interfere with the existing rights of the Government of the United States on the one side and the Government of the Dominion of Canada on the other, to undertake and carry on governmental works in boundary waters for the deepening of channels, the construction of breakwaters, the improvement of harbours, and other governmental works for the benefit of commerce and navigation, provided that such works are wholly on its own side of the line and do not materially affect the level or flow of the boundary waters on the other, nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes.

ARTICLE 4

The High Contracting Parties agree that, except in cases provided for by special agreement between them, they will not permit the construction or maintenance on their respective sides of the boundary of any remedial or protective works or any dams or other obstructions in waters flowing from boundary waters or in waters at a lower level than the boundary in rivers flowing across the boundary, the effect of which is to raise the natural level of waters on the other side of the boundary unless the construction or maintenance thereof is approved by the aforesaid International Joint Commission.

It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other.

ARTICLE 5

The High Contracting Parties agree that it is expedient to limit the diversion of waters from the Niagara River so that the level of lake Erie and the flow of the stream shall not be appreciably affected. It is the desire of both Parties to accomplish this object with the least possible injury to invest-

ments which have already been made in the construction of power plants on the United States' side of the river under grants of authority from the State of New York, and on the Canadian side of the river under licenses authorized by the Dominion of Canada and the Province of Ontario.

So long as this Treaty shall remain in force, no diversion of the waters of the Niagara River above the Falls from the natural course and stream thereof shall be permitted except for the purpose and to the extent hereinafter provided.

The United States may authorize and permit the diversion within the State of New York of the waters of the said river above the Falls of Niagara, for power purposes, not exceeding in the aggregate a daily diversion at the rate of 20,000 cubic feet of water per second.

The United Kingdom, by the Dominion of Canada, or the Province of Ontario, may authorize and permit the diversion within the Province of Ontario of the waters of said river above the Falls of Niagara for power purposes, not exceeding in the aggregate a daily diversion at the rate of 36,000 cubic feet of water per second.

The prohibitions of this Article shall not apply to the diversion of water for sanitary or domestic purposes, or for the service of canals for the purposes of navigation.

ARTICLE 6

The High Contracting Parties agree that the St. Mary and Milk Rivers and their Tributaries (in the State of Montana and the Provinces of Alberta and Saskatchewan) are to be treated as one stream for the purposes of irrigation and power, and the waters thereof shall be apportioned equally between the two countries, but in making such equal apportionment more than half may be taken from one river and less than half from the other by either country so as to afford a more beneficial use to each. It is further agreed that in the division of such waters during the irrigation season, between the 1st of April and 31st of October, inclusive, annually, the United States is entitled to a prior appropriation of 500 cubic feet per second of the waters of the Milk River, or so much of such amount as constitutes three-fourths of its natural flow, and that Canada is entitled to a prior appropriation of 500 cubic feet per second of the flow of St. Mary River, or so much of such amount as constitutes three-fourths of its natural flow.

The channel of the Milk River may in Canada be used at the convenience of the United States for the conveyance, while passing through Canadian territory, of waters diverted from the St. Mary River. The provisions of Article 2 of this Treaty shall apply to any injury resulting to property in Canada from the conveyance of such waters through the Milk River.

The measurement and apportionment of the water to be used by each country shall from time to time be made jointly by the properly constituted reclamation officers of the United States and the properly constituted irrigation officers of His Majesty under the direction of the International Joint Commission.

ARTICLE 7

The High Contracting Parties agree to establish and maintain an International Joint Commission of the United States and Canada composed of six Commissioners, three on the part of the United States appointed by the President thereof, and three on the part of the United Kingdom appointed by His Majesty on the recommendation of the Governor in Council of the Dominion of Canada.

ARTICLE 8

This International Joint Commission shall have jurisdiction over and shall pass upon all cases involving the use or obstruction or diversion of the waters with respect to which under Articles 3 and 4 of this Treaty the approval of this Commission is required, and in passing upon such cases the Commission shall be governed by the following rules and principles which are adopted by the High Contracting Parties for this purpose:—

The High Contracting Parties shall have, each on its own side of the boundary, equal and similar rights in the use of the waters hereinbefore defined as boundary waters.

The following order of precedence shall be observed among the various uses enumerated hereinafter for these waters, and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of precedence—

1. Uses for domestic and sanitary purposes;
2. Uses for navigation, including the service of canals for the purposes of navigation;

3. Uses for power and for irrigation purposes.

The foregoing provisions shall not apply to or disturb any existing uses of boundary waters on either side of the boundary.

The requirement for an equal division may in the discretion of the Commission be suspended in cases of temporary diversions along boundary waters at points where such equal division can not be made advantageously on account of local conditions, and where such diversion does not diminish elsewhere the amount available for use on the other side.

The Commission in its discretion may make its approval in any case conditional upon the construction of remedial or protective works to compensate so far as possible for the particular use or diversion proposed, and in such cases may require that suitable and adequate provision, approved by the Commission, be made for the protection and indemnity against injury of any interests on either side of the boundary.

In cases involving the elevation of the natural level of waters on either side of the line as a result of the construction or maintenance on the other side of remedial or protective works or dams or other obstructions in boundary waters or in waters flowing therefrom or in waters below the boundary in rivers flowing across the boundary, the Commission shall require, as a condition of its approval thereof, that suitable and adequate provision, approved by it, be made for the protection and indemnity of all interests on the other side of the line which may be injured thereby.

The majority of the Commissioners shall have power to render a decision. In case the Commission is evenly divided upon any question or matter presented to it for decision, separate reports shall be made by the Commissioners on each side to their own Government. The High Contracting Parties shall thereupon endeavour to agree upon an adjustment of the question or matter of difference, and if an agreement is reached between them, it shall be reduced to writing in the form of a Protocol, and shall be communicated to the Commissioners, who shall take such further proceedings as may be necessary to carry out such agreement.

ARTICLE 9

The High Contracting Parties further agree that any other questions or matters of difference arising between them involving the rights, obligations, or interests of either in relation to the other or to the inhabitants of the other, along the

common frontier between the United States and the Dominion of Canada, shall be referred from time to time to the International Joint Commission for examination and report, whenever either the Government of the United States or the Government of the Dominion of Canada shall request that such questions or matters of difference be so referred.

The International Joint Commission is authorized in each case so referred to examine into and report upon the facts and circumstances of the particular questions and matters referred, together with such conclusions and recommendations as may be appropriate, subject, however, to any restrictions or exceptions which may be imposed with respect thereto by the terms of the reference.

Such reports of the Commission shall not be regarded as decisions of the questions or matters so submitted either on the facts or the law, and shall in no way have the character of an arbitral award.

The Commission shall make a joint report to both Governments in all cases in which all or a majority of the Commissioners agree, and in case of disagreement the minority may make a joint report to both Governments, or separate reports to their respective Governments.

In case the Commission is evenly divided upon any question or matter referred to it for report, separate reports shall be made by the Commissioners on each side to their own Government.

ARTICLE 10

Any questions or matters of difference arising between the High Contracting Parties involving the rights, obligations, or interests of the United States or of the Dominion of Canada either in relation to each other or to their respective inhabitants, may be referred for decision to the International Joint Commission by the consent of the two Parties, it being understood that on the part of the United States any such action will be by and with the advice and consent of the Senate, and on the part of His Majesty's Government with the consent of the Governor-General in Council. In each case so referred, the said Commission is authorized to examine into and report upon the facts and circumstances of the particular questions and matters referred, together with such conclusions and recommendations as may be appropriate, subject, however, to any restrictions or exceptions which may be imposed with respect thereto by the terms of the reference.

A majority of the said Commissioners shall have power to render a decision or finding upon any of the questions or matters so referred.

If the said Commission is equally divided, or otherwise unable to render a decision or finding as to any questions or matters so referred, it shall be the duty of the Commissioners to make a joint report to both Governments, or separate reports to their respective Governments, showing the different conclusions arrived at with regard to the matters or questions so referred, which questions or matters shall thereupon be referred for decision by the High Contracting Parties to an Umpire chosen in accordance with the procedure prescribed in the fourth, fifth, and sixth paragraphs of article 45 of The Hague Convention for the pacific settlement of international disputes, dated October 18, 1907. Such Umpire shall have power to render a final decision with respect to those matters and questions so referred on which the Commission failed to agree.

ARTICLE 11

A duplicate original of all decisions rendered and joint reports made by the Commission shall be transmitted to and filed with the Secretary of State of the United States and the Governor-General of the Dominion of Canada, and to them shall be addressed all communications of the Commission.

ARTICLE 12

The International Joint Commission shall meet and organize at Washington promptly after the members thereof are appointed and when organized the Commission may fix such times and places for its meetings as may be necessary, subject at all times to special call or direction by the two Governments. Each Commissioner, upon the first joint meeting of the Commission after his appointment, shall, before proceeding with the work of the Commission, make and subscribe a solemn declaration in writing that he will faithfully and impartially perform the duties imposed upon him under this Treaty, and such declaration shall be entered on the records of the proceedings of the Commission.

The United States and Canadian sections of the Commission may each appoint a Secretary, and these shall act as

joint Secretaries of the Commission at its joint sessions, and the Commission may employ engineers and clerical assistants from time to time as it may deem advisable. The salaries and personal expenses of the Commission and of the Secretaries shall be paid by their respective Governments, and all reasonable and necessary joint expenses of the Commission, incurred by it, shall be paid in equal moieties by the High Contracting Parties.

The Commission shall have power to administer oaths to witnesses, and to take evidence on oath whenever deemed necessary in any proceeding, or inquiry, or matter within its jurisdiction under this Treaty, and all parties interested therein shall be given convenient opportunity to be heard, and the High Contracting Parties agree to adopt such legislation as may be appropriate and necessary to give the Commission the powers above mentioned on each side of the boundary, and to provide for the issue of subpoenas and for compelling the attendance of witnesses in proceedings before the Commission. The Commission may adopt such rules of procedure as shall be in accordance with justice and equity, and may make such examination in person and through agents or employes as may be deemed advisable.

ARTICLE 13

In all cases where special agreements between the High Contracting Parties hereto are referred to in the foregoing Articles, such agreements are understood and intended to include not only direct agreements between the High Contracting Parties, but also any mutual arrangement between the United States and the Dominion of Canada expressed by concurrent or reciprocal legislation on the part of Congress and the Parliament of the Dominion.

ARTICLE 14

The present Treaty shall be ratified by His Britannic Majesty and by the President of the United States of America, by and with the advice and consent of the Senate thereof. The ratifications shall be exchanged at Washington as soon as possible, and the Treaty shall take effect on the date of the exchange of its ratifications. It shall remain in force for five years, dating from the day of exchange of ratifications, and

thereafter until terminated by twelve months' written notice given by either High Contracting Party to the other.

In faith whereof the respective Plenipotentiaries have signed this Treaty in duplicate and have hereunto affixed their seals.

Done at Washington, the 11th day of January, in the year of our Lord one thousand nine hundred and nine.

(L. S.) JAMES BRYCE
(L. S.) ELIHU ROOT

The above Treaty was approved by the United States' Senate on the 3rd March, 1909, with the following Resolutions:—

Resolved,—That the Senate advise and consent to the ratification of the Treaty between the United States and Great Britain, providing for the settlement of international difference between the United States and Canada, signed on the 11th day of January, 1909.

Resolved further (as a part of this ratification),—That the United States approves this Treaty with the understanding that nothing in this Treaty shall be construed as affecting, or changing, any existing territorial, or riparian rights in the water, or rights of the owners of lands under water, on either side of the International Boundary at the rapids of the St. Mary's River at Sault Ste. Marie, in the use of the waters flowing over such lands, subject to the requirements of navigation in boundary waters and of navigation canals, and without prejudice to the existing right of the United States and Canada, each to use the waters of the St. Mary's River, within its own territory; and further, that nothing in this Treaty shall be construed to interfere with the drainage of wet, swamp, and overflowed lands into streams flowing into boundary waters, and that this interpretation will be mentioned in the ratification of this Treaty as conveying the true meaning of the Treaty, and will, in effect, form part of the Treaty.

PROTOCOL OF EXCHANGE.

On proceeding to the exchange of the ratifications of the treaty signed at Washington on January 11, 1909, between Great Britain and the United States, relating to boundary waters and questions arising along the boundary between the

United States and the Dominion of Canada, the undersigned plenipotentiaries, duly authorized thereto by their respective Governments, hereby declare that nothing in this treaty shall be construed as affecting, or changing, any existing territorial, or riparian rights in the water, or rights of the owners of lands under water, on either side of the international boundary at the rapids of the St. Mary's river at Sault Ste. Marie, in the use of the waters flowing over such lands, subject to the requirements of navigation in boundary waters and of navigation canals, and without prejudice to the existing right of the United States and Canada, each to use the waters of the St. Mary's river, within its own territory; and further, that nothing in this treaty shall be construed to interfere with the drainage of wet, swamp, and overflowed lands into streams flowing into boundary waters, and also that this declaration shall be deemed to have equal force and effect as the treaty itself and to form an integral part thereof.

The exchange of ratifications then took place in the usual form.

In witness whereof they have signed the present Protocol of Exchange and have affixed their seals thereto.

Done at Washington this 5th day of May, one thousand nine hundred and ten.

JAMES BRYCE (SEAL)
PHILANDER C. KNOX (SEAL)

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*The British ratification of this further Instrument was deposited with the United States Government July 23, 1910.

63d Congress, 2d Session. HOUSE OF REPRESENTATIVES. Document No. 762.

FINAL REPORT, WATERWAY FROM LOCKPORT, ILL., TO THE MOUTH OF THE ILLINOIS RIVER.

LETTER

FROM

THE SECRETARY OF WAR,

TRANSMITTING,

WITH A LETTER FROM THE CHIEF OF ENGINEERS, FINAL REPORT BY A SPECIAL BOARD OF ENGINEERS UPON WATERWAY FROM LOCKPORT, ILL., BY WAY OF THE DES PLAINES AND ILLINOIS RIVERS, TO THE MOUTH OF SAID ILLINOIS RIVER, AND CERTAIN RELATED SUBJECTS.

February 20, 1914.—Referred to the Committee on Rivers and Harbors and ordered to be printed, with illustrations.

WAR DEPARTMENT,
Washington, February 18, 1914.

The Speaker of the House of Representatives.

Sir: I have the honor to transmit herewith a letter from the Acting Chief of Engineers, United States Army, dated 17th instant, together with copy of final report by a special board of engineers, dated August 15, 1913, with maps, upon waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers, to the mouth of Illinois River, the construction of dams at or near Jefferson Barracks and Commerce, and certain related subjects, made in compliance with the provisions of the river and harbor act approved June 25, 1910.

Very respectfully,

LINDLEY M. GARRISON,
Secretary of War.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, February 17, 1914.

From: The Chief of Engineers, United States Army.

To: The Secretary of War.

Subject: Waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers to the mouth of Illinois River.

1. There is submitted herewith, for transmission to Congress, final report, dated August 15, 1913, with maps, by a special board appointed pursuant to the requirements of the river and harbor act approved June 25, 1910, to consider and report upon a waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers to the mouth of Illinois River, the construction of dams at or near Jefferson Barracks and Commerce, and certain related subjects.

2. Under date of November 1, 1910, the special board submitted a preliminary report, which is printed in House Document No. 1061, Sixty-first Congress, third session, and under date of January 23, 1911, it submitted a further report, printed in House Document No. 1374, Sixty-first Congress, third session, covering five of the nine questions specifically mentioned in the act. Attention is invited to these reports for detailed information regarding the project recommended for the construction of this waterway. The subjects treated in the present report of the special board include such measures as may be required to properly preserve the levels of the Great Lakes, the influence on volume and height of waters in the Mississippi River below Cairo, the effect upon the climate of the Lake States by a change in the natural currents of Lake Michigan, and the improvement of the Mississippi River between the mouth of the Illinois River and the mouth of the Ohio River by the construction of a dam at or near Jefferson Barracks, and a dam at or near Commerce, and the development of water power incidentally created by such dams.

3. The special board finds that the diversion of 10,000 cubic feet of water per second through the Chicago Drainage Canal would lower the water surface at mean lake level 0.465 foot in Lakes Huron and Michigan, 0.448 foot in Lake Erie, and 0.431 foot in Lake Ontario. It proposes the construction of summerged weirs in Niagara River to hold up the level of Lake Erie and submerged weirs in St. Clair River to hold

up the level of Lakes Michigan and Huron, at a total estimated cost of $475,000, with $15,000 annually for maintenance. The influence on the volume of the Mississippi River due to any diversion from Lake Michigan will be an increase approximately equal to the amount of water diverted.

4. The effect upon gauge height will be small, even at low stages, and at high stages it would scarcely be appreciable and of no importance. The effect on the climate of the Lake States, caused by the diversion of 10,000 second-feet of water through the Chicago Drainage Canal, whether beneficial or injurious, would be so small that it could not be measured by the most delicate instruments. The special board reports that the construction of dams at or near Jefferson Barracks and Commerce is not necessary for the execution of existing projects for the Illinois and Mississippi Rivers, nor of the projects recommended in the partial report printed in House Document No. 1374, Sixty-first Congress, third session. The work would be enormously expensive and not justified by resulting benefits to commerce and navigation, nor by the returns from water-power development.

5. The recommendations of the special board are contained in the partial report referred to above. It states that since the submission of that report nothing has developed to require any changes in the statements and conclusions therein given.

6. This final report has been referred, as required by law, to the Board of Engineers for Rivers and Harbors, and attention is invited to its report herewith, dated December 16, 1913, which gives a brief analysis of the entire investigation. The board concurs in general with the views of the special board, though with the information now available it is not prepared to indorse the discussion in all its details. Subject to certain conditions fully explained in its report, the board recommends the adoption of the project presented by the special board, which involves an original outlay by the United States of $1,050,000 for the Illinois River and $3,710,000 for the Mississippi River, or a total of $4,760,000 for a navigable channel 8 feet deep from Utica to St. Louis.

EDW. BURR,
Colonel, Corps of Engineers,
Acting Chief of Engineers.

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS.

[Second Indorsement.]

BOARD OF ENGINEERS FOR RIVERS AND HARBORS,

December 16, 1913.

To the Chief of Engineers, United States Army:

1. The Board of Engineers for Rivers and Harbors has had under consideration the final report of the special board of engineers, submitted pursuant to the following item contained in section 1 of the river and harbor act approved June 25, 1910:

> For the construction of a waterway from Lockport, Ill., by way of the Desplaines and Illinois Rivers to the mouth of said Illinois River, $1,000,000. The Secretary of War shall appoint a board of five members, to be composed of four engineer officers of the Army and one civil engineer taken from civil life. The president of the board of five members authorized under act of March 2, 1907, to examine the Mississippi River below St. Louis and report to Congress on the project of a 14-foot channel, shall be a member of and president of the board herein provided for. Said board shall report upon the feasibility of such waterway, and the most advisable depth and dimensions therefor, in case the same is recommended; also upon such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable for the diminished level in said lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway herein described, or diversion for any other purpose and further, also, upon the influence on volume and height of waters in the Mississippi River below Cairo; and further, also, as to the effect upon the climate of the Lake States by a change in the natural currents of Lake Michigan. The board shall, after full conference with the authorized agency of the State of Illinois, submit a report upon the extent to which the United States may properly co-operate with the State of Illinois in securing the construction of a navigable waterway from Lockport to the mouth of the Illinois River in conjunction with the development of water power by said State

between Lockport and Utica, for which the people of the State of Illinois have authorized their general assembly to appropriate $20,000,000; the report shall state the extent and character of the cooperation recommended and the conditions considered necessary in connection therewith to fully protect the interests of the United States. Should the board consider cooperation to be advisable, the report herein called for shall include plans and estimates of cost of the work recommended to be done by the United States alone or in cooperation with the State of Illinois; and until these plans and estimates have been submitted and a project for the improvement adopted by Congress the appropriation of $1,000,000 herein made shall not be available for expenditure. The board also shall consider and report upon the improvement of the Mississippi between the mouth of the Illinois River and the mouth of the Ohio River by the construction of a dam at or near Jefferson Barracks and a dam at or near Commerce, and the development of water power incidentally created by such dams. In the perforamnce of its duties the board may consider all reports heretofore made; and the force, plant, and records of the Mississippi River Commission and the several engineer districts between Chicago and Cairo shall be available for the use of the board. The members of the board herein authorized shall be entitled to compensation at the rate of $6,000 per annum, but the official salary of any officer appointed on said board from the Engineer Corps of the Army shall be deducted from the compensation provided for in this act. For salaries and expenses of said board, including all necessary clerical and other personal services, there is hereby appropriated the sum of $50,000. The reports herein called for shall be submitted to the Chief of Engineers not later than November 1, 1910, reviewed by the Board of Engineers for Rivers and Harbors, and submitted to Congress not later than the first Monday in December, 1910.

2. Complying with the requirements of the above item, the special board under date of November 1, 1910, submitted a preliminary report outlining the steps being taken to procure the necessary data, and under date of January 23, 1911, it submitted a further report covering five of the nine questions specifically mentioned in the act. The former report is printed in House Document No. 1061, Sixty-first Congress, third ses-

sion, and the latter in House Document No. 1374 of the same Congress and session. The report now under consideration covers the remaining four questions, but for convenience of reference, a summary of the entire investigation is given below.

I. FEASIBILITY OF THE WATERWAY.

3. In the valley of the Des Plaines and upper Illinois Rivers, excellent foundations for locks are available; the lower Illinois has a gentle slope, so that any reasonable depth can be obtained by dredging, and the present diversion of water from Lake Michigan through the Chicago Drainage Canal is more than sufficient for navigation purposes. It is therefore the opinion of the special board that the waterway from Lockport to the mouth of the Illinois River is feasible.

II. THE MOST ADVISABLE DEPTH AND DIMENSIONS FOR THE WATERWAY

4. In determining the most advisable depth for the waterway, the special board gives consideration to the character, origin, and destination of the probable commerce, and the type and dimensions of the vessels best suited to handle the traffic. It states that if the waterway is to be used by vessels capable of navigating the ocean and the Great Lakes, it should be given a depth suitable for the economic carriers now used on those bodies of water, which would fix the depth at not less than 24 feet; but if it is to be constructed for vessels adapted to river traffic, navigation does not require its depth to exceed 9 feet. A depth of 14 feet, which has been frequently urged for this waterway, is greater than necessary for river navigation and entirely insufficient for either lake or ocean vessels. A uniform depth on the Mississippi and its leading tributaries will be far more beneficial to the navigation interests of the United States than a main channel of great depth with shallow feeders. As a channel of 8 feet depth is now maintained from Cairo to St. Louis, and can be extended from St. Louis to Utica, on the Illinois River, at relatively small cost, business caution dictates that a waterway of this depth be obtained and tested before entering upon enormously expensive projects of questionable utility.

5. The special board considers a bottom width of 160 feet in canal and 200 feet in the open river above the mouth of the Illinois sufficient for a channel of 8 or 9 feet available depth.

For safety and ease of navigation, the channel should be excavated to 11 feet in rock cuts and canals, and the locks should be given 11 feet depth, 80 feet width, and 600 feet usable length. A waterway of these dimensions would have a capacity exceeding 100,000,000 tons per annum.

III. CO-OPERATION WITH THE STATE OF ILLINOIS.

6. A project has been presented by the State of Illinois which contemplates the development of water power at four sites between Lockport and Utica, and the improvement of navigation by the construction of five large locks, 80 by 900 feet in horizontal dimensions, with 24 feet depth on their miter sills. This project proposes the utilization for power purposes of the water which may flow through the Chicago Drainage Canal and contemplates an ultimate channel depth of 24 feet for navigation purposes, though the estimates, amounting to approximately $20,000,000, provide for 24 feet only to Brandon Bridge and for 14 feet below. The special board states that the waterway proposed is more than sufficient for any probable navigation. It believes that the General Government will fully cooperate with the State in a waterway from Lockport to the mouth of the Illinois River if it assumes charge of the State structures at Henry and Copperas Creek, and enlarges the existing channel in the Illinois River below Utica to suitable dimensions.

IV. CONDITIONS NECESSARY IN CONNECTION WITH COOPERATION TO FULLY PROTECT THE INTERESTS OF THE UNITED STATES.

7. The special board states that a primary condition of any cooperation between the United States and the State of Illinois should be the acceptance in perpetuity of full responsibility by the State of Illinois or its agencies for all damages by changes in lake levels, including cost of compensating works, and for all damages to riparian owners, and the State should transfer to the United States the locks and the control of the new waterway thus created so far as needed by navigation, and the locks and dams at Henry and Copperas Creek on the Illinois River. With such a transfer the obligations of the State of Illinois to the United States with reference to the maintenance of the Illinois and Michigan Canal may be considered as adequately fulfilled, and any equities of the United

States in the rights of way and other properties of this canal should be transferred by the United States to the State of Illinois. The special board believes that should the State of Illinois be unable to complete the locks suggested by the board or the bridges required by navigation, the United States might then properly undertake to complete these parts of the project.

V. PLANS AND ESTIMATES OF THE COST OF WORK RECOMMENDED TO BE DONE BY THE UNITED STATES.

8. The existing Federal project for the improvement of the Illinois River, adopted in 1880, together with the existing State project, provides for a 7-foot slackwater navigation from Utica to its mouth, which has already been obtained by dredging and by the construction of four dams, with locks 350 feet long and 75 feet wide. The opening of the Chicago Drainage Canal in 1900, however, added an increased volume of water, which has raised the level of low water so that 8 feet can be carried to Grafton, provided the upper miter sills at Henry and Copperas Creek are lowered about 1 foot, the crests of the dams are restored at the heights to which they were oirginally constructed, and portions of the pools deepened slightly by dredging. The estimate of cost is as follows:

Excavation in pools and in river below Kampsville..	$887,545
Lowering miter sills and reconstructing gates.....	60,000
Restoring crest of Kamspville Dam.....	7,000
Miscellaneous and contingencies, 10 per cent.....	95,455
Total.....	$1,050,000

The estimate for the 9-foot waterway, which ultimately may be required, with new locks 80 by 600 feet, is $4,005,000. The annual cost of maintenance is estimated at $115,000 for the 8-foot waterway and $141,000 for the 9-foot waterway. An estimate of $3,710,000 is also submitted for open-river improvement in the Mississippi River to provide a depth of 8 feet between the mouth of the Illinois River and St. Louis, the estimate for maintenance being $125,000 annually. After the 8-foot channel has been provided, a depth of 9 feet can be obtained by dredging between these points, with an additional annual expenditure of $75,000.

VI. SUCH MEASURES AS MAY BE REQUIRED TO PROPERLY PRESERVE THE LEVELS OF THE GREAT LAKES, ETC.

9. The investigations and studies of the special board show that the diversion of water from the Lakes lowers the levels progressively in proportion to the amount so diverted, the full effect not being observable for some time; and that for the 10,000 second-feet diverted through the Chicago Drainage Canal, at mean lake level, the water surface will be lowered in Lakes Huron and Michigan 0.465 foot; in Lake Erie, 0.448 foot; in Lake Ontario, 0.431 foot. Such lowering would materially affect the carrying capacity of the large freight vessels, estimated at 88 tons per inch of draft, and would cause a loss on American vessels alone at the lowest estimate of $1,000,000 per annum.

10. Three methods for compensating for such diversion have been considered by the special board: (1) By the construction of submerged weirs with arbitrarily controllable sluices at the lower ends of the Lakes; (2) by reducing the area of the natural outlets by the construction of fixed contraction works therein; (3) by dredging harbors and connecting channels. The investigations of the board show with certainty that the result of diversion of water through a new outlet is a lowering of Lake level. The effect of the great storage capacity of the lakes and of the natural fluctuations of level due to natural causes, such as the varying amount of rainfall and the varying amount and direction of wind pressures, is such that the absolute level at a given time at any given place can not be predicted, and human wisdom is inadequate to regulate a variation of discharge through the outlet in such a manner as to produce a definite desired result. Method No. 1 therefore must be classed as impracticable. Compensation by dredging is practicable, but on account of the extensive areas involved, this method would be unduly costly. Of the three methods, the second only is therefore favorably considered. The special board proposes to hold up the level of Lake Erie by the construction of three submerged wiers in Niagara River, at an estimated cost of $150,000, and that of Lakes Michigan and Huron by submerged weirs in St. Clair River, at an estimated cost of $325,000, the total for compensating works being $475,000, with $15,000 annually for maintenance.

VII. THE INFLUENCE ON VOLUME AND HEIGHT OF WATERS IN THE MISSISSIPPI RIVER BELOW CAIRO.

11. The influence on the volume of the Mississippi River due to any diversion from Lake Michigan will be an increase approximately equal to the amount of water diverted. The effect upon gauge height will be small even at low stages, and at high stages it would scarcely be appreciable and not of any importance.

VIII. THE EFFECT UPON THE CLIMATE OF THE LAKE STATES BY A CHANGE IN THE NATURAL CURRENTS OF LAKE MICHIGAN.

12. After extensive investigation and discussion of this subject the conclusion is reached that the effect on the climate of the Lake States, caused by the diversion of 10,000 second-feet of water through the Chicago Drainage Canal, whether beneficial or injurious, would be so small that it could not be measured by the most delicate instruments.

IX. UPON THE IMPROVEMENT OF THE MISSISSIPPI RIVER BETWEEN THE MOUTH OF THE ILLINOIS RIVER AND THE MOUTH OF THE OHIO RIVER BY THE CONSTRUCTION OF A DAM AT OR NEAR JEFFERSON BARRACKS AND A DAM AT OR NEAR COMMERCE, AND THE DEVELOPMENT OF WATER POWER INCIDENTALLY CREATED BY SUCH DAMS.

13. The construction of such dams is not necessary for the execution of existing projects for the Illinois and Mississippi Rivers or of the projects recommended in the partial report printed in House Document No. 1374, Sixty-first Congress, third session. The special board reports that the work would be enormously expensive and not justified by resulting benefits to commerce and navigation or by the returns from water-power development.

CONCLUSIONS.

14. After due consideration of the reports of the special board the Board of Engineers for Rivers and Harbors concurs in general with the views and conclusions expressed therein. With the information now available, it is not prepared to indorse certain details of the discussions in the appendixes and elsewhere pertaining to the regulation of the level of Lake Superior, the regulation of the day and night

discharge at Niagara Falls, and the estimates of cost for the dams across the Mississippi River. But inasmuch as this difference of opinion on these points does not affect the final conclusions, the board believes that nothing would be gained at this time by pursuing its investigation further. The board concurs fully with the general conclusions expressed by the special board in its final report, but differs slightly from those given in its preceding report. In this connection attention is invited to the following statements made by the Board of Engineers for Rivers and Harbors in its report of January 30, 1911, printed in House Document No. 1374, Sixty-first Congress, third session:

> It does not concur with the view of the special board that the United States should assume that part, if any, of the cost that is in excess of $20,000,000 for constructing the portion of the waterway between Lockport and Utica. Moreover, it suggests that the amount of diversion to be permitted from Lake Michigan should be determined, if practicable, before the project is undertaken.
>
> * * * * *
>
> It is understood that the sanitary district of Chicago and the State expect to develop considerable water power on that portion of the waterway between Chicago and Utica. As it is proposed that the navigable channel between these points shall be built without cost to the United States, it is believed that the General Government should relinquish to these local agencies any rights that it may have in the power to be thus developed. It does not appear that there is any question of water power, flood control, or other matter that can be coordinated with that portion of the work to be done by the United States for the improvement of navigation, so as to lessen the cost and compensate the Government for its expenditures made in the interest of navigation.
>
> In conclusion it is recommended that the work proposed by the special board for the United States in the Illinois River be not undertaken until the Secretary of War has received satisfactory assurance from the State of Illinois that the State will build that portion of the waterway from Lockport to Utica without cost to the United States, and in accordance with plans to be approved by him; and, further, until the interests of the United States have been satisfactorily safeguarded as indicated by the special board, viz., that the State of Illi-

nois, or its agencies, shall assume entire responsibility in perpetuity for all damages by changes in lake levels incident to the work, including cost of compensating works, and for all damages to riparian owners along the proposed waterway from Lake Michigan to the mouth of the Illinois River, and that the State shall transfer to the United States the locks and the control of the new waterway thus created so far as needed for navigation, and the locks and dams at Henry and Copperas Creek on the Illinois River.

15. It is the distinct recommendation of the Board of Engineers for Rivers and Harbors that the term "control of the new waterway thus created so far as needed for navigation" shall be interpreted to include such control of the use of water for power purposes as shall be necessary to insure the conditions of flow required for navigation. Further, the board believes that the total volume of water to be diverted from the natural discharge channels of the Lakes should be definitely fixed by Congress; that a project, with estimate of cost, for works necessary to compensate for such diversion should be prepared to the satisfaction of the Chief of Engineers and the Secretary of War; that before any diversion is made beyond that at present existing, the State of Illinois shall transfer to the Secretary of War the funds necessary for such works as given by the approved estimate of cost; that the works shall be built by the United States with the funds so provided; and that the control and maintenance of such works shall be in and at the cost of the United States.

16. As indicated above, the work proposed by the special board involves an original outlay by the United States of $1,050,000 for the Illinois River and $3,710,000 for the Mississippi River, or a total of $4,760,000, and provides for a navigable channel depth of 8 feet from Utica to St. Louis. The act ordering the investigation appropriated $1,000,000 "for the construction of a waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers to the mouth of said Illinois River," and provided that "until these plans and estimates have been submitted and a project adopted by Congress the appropriation of $1,000,000 herein made shall not be available for expenditure." If the project be adopted by Congress, this conditional appropriation should be made available for the improvement as a whole, and subsequent appropriations should be made with a view to completion of the work in four years. The Board of Engineers for Rivers

and Harbors recommends the adoption of the project under the conditions stated above.

For the Board:

W. M. BLACK,
Colonel, Corps of Engineers,
Senior Member of the Board.

FINAL REPORT BY A SPECIAL BOARD OF ENGINEERS ON WATERWAY FROM LOCKPORT, ILL., TO MOUTH OF ILLINOIS RIVER.

New York City, August 15, 1913.

From: A Special Board of Engineers.
To: The Chief of Engineers, United States Army.
Subject: Report on waterway from Lockport Ill., to the mouth of Illinois River, and on certain related subjects.

The Board of Engineers appointed by the Secretary of War September 8, 1910, in Special Orders, No. 43, Office of the Chief of Engineers, for the consideration of a waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers, to the mouth of the said Illinois River, in its reports of November 1, 1910, and January 23, 1911, has discussed certain of the questions referred to it—namely: I, Feasibility of the waterway; II, the most advisable depths and dimensions for the waterway; III, cooperation with the State of Illinois; IV, conditions necessary in connection with cooperation to fully protect the interests of the United States, and V, plans and estimates of the cost of work recommended to be done by the United States. Since the submission of the above reports nothing has developed to require any changes in the statements and conclusions therein given. For convenience of reference these reports are attached hereto marked as Appendixes E and F.

The necessary additional investigations having been completed, the results of which are shown in Appendixes A, B, C, and D, the board now has the honor to submit the following report upon the remaining questions submitted to it for consideration:

> VI. Such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished level in said lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway * * * or for any other purpose.

This subject is specially discussed in Appendix A.

Since 1895 the United States Lake Survey, under the direction of the Chief of Engineers, has made a systematic series of measurements of discharges in the St. Mary's, St. Clair, Detroit, Niagara, and St. Lawrence Rivers, to determine the relation which exists between the volumes of water discharged by these rivers and the levels of the lake surfaces. These discharge measurements have been numerous and demonstrate conclusively that there is a direct connection between the height of each lake and the volume of water discharged at its outlet.

For a change of 1 foot from the mean of the stages covered by the observations on each lake the discharge will vary as stated in Table I, and conversly the changes of level in feet, due to diversions from the natural outlets of varying amounts, will be as shown in Table II.

TABLE I.

Lake.	Mean stage.[1]	Discharge at mean stage.	Change in discharge due to 1 foot change in level close to mean stage.
	Feet.	Second-feet.	Second-feet.
Superior	601.80	75,000	18,300 gauge at S. W. canal pier.
Michigan-Huron	580.28	192,300	21,800 Fort Gratiot gauge. Lake St. Clair normal.
Erie	571.96	198,500	22,300 Buffalo L. H. gauge.
Ontario	244.60	230,000	22,300 Ogdensburg gauge. Discharge adjusted for effect of closure of Gut Channel in Galops Rapids, estimated to reduce existing discharges 9,000 cubic feet per second below those formerly existing at the same stages.

[1]Mean of range during discharge measurements.

TABLE II.—CHANGES OF LEVEL, IN FEET, DUE TO DIRECT DIVERSION OF AMOUNTS VARYING BETWEEN 1,000 AND 14,000 CUBIC FEET PER SECOND.

1,000 cubic feet.	Superior.	Michigan and Huron.	Erie.	Ontario.
	Foot.	Foot.	Foot.	Foot.
1	0.055	0.046	0.045	0.043
2	.131	.093	.090	.086
3	.196	.139	.134	.129
4	.261	.186	.179	.173
5	.327	.232	.224	.2165
6	.392	.279	.269	.260
7	.457	.325	.314	.303
8	.523	.373	.359	.346
9	.588	.419	.404	.390
10	.654	.465	.448	.431
11	.719	.511	.493	.474
12	.784	.558	.538	.517
13	.850	.605	.583	.560
14	.915	.650	.628	.603

These changes are obscured by variations in the supply of water from rains, by evaporation, by the effects of winds, and by the obstruction of the outlets by ice, and due to the reservoir capacity of the different lakes the action will not be immediate. As shown in the report of the Lake Survey for 1904, page 4120, one-half of the ultimate fall of Lakes Michigan and Huron will occur in 1.46 years, and nine-tenths of the fall will be completed in 4.86 years. For Lake Erie 50 per cent. of the ultimate lowering will occur in 2.5 months and 90 per cent. in 8 months; for Lake Ontario, in 2.1 months and 7 months, respectively.

It is therefore evident that when the Lakes stand at mean lake level a diversion of 10,000 cubic feet per second from Lake Michigan through the Chicago Drainage Canal will ultimately produce a lowering of the water surface of Lakes Michigan and Huron and its connecting harbors and channels of 0.465 feet (5.58 inches), of Lake Erie of 0.448 feet (5.38 inches), and of Lake Ontario of 0.431 feet (5.16 inches); at lower stages the effect will be greater, due to the relatively smaller area of the cross section of the outlets.

The largest lake freighters recently built carry over 80 short tons of freight for each inch of loaded draft, and an uncompensated Chicago diversion of 10,000 second-feet would cause a loss to each vessel of at least 446 tons in carrying capacity for each down trip through the channels connecting with Lakes Michigan and Huron. This, based upon 25 trips per season, with vessels returning light, means a loss of at least 11,150 tons per year, and at a freight rate of 55 cents per ton represents a monetary loss of at least $6,000 per large vessel per year. During the season of 1912 there passed through the locks at Sault Ste. Marie over 72,000,000 tons of freight, the greater part of which was carried in vessels of such size as to be affected by any loss of depth caused by a Chicago diversion. The tonnage of 1913 bids fair to exceed the tonnage of 1912. The lowest estimate of the loss to American vessels alone that has been brought to the attention of the board is over $1,000,000 per annum, and the loss will increase with the increase in the number and size of vessels.

It is evident therefore that any diversion with consequent lowering of lake levels will cause a direct financial loss to vessel owners and such a loss can be prevented only by the adoption of remedial measures. For this purpose three methods have been proposed. First, to regulate the level of the Lakes between fixed limits by the construction of sub-

merged weirs and adjustable sluices at the lower ends of the Lakes, and by this means not only to prevent the oscillations of lake levels which occur daily each season, but also to equalize the flow over a series of years. Second, to compensate for the diminished discharge by reducing the area of the natural outlets by construction of contraction works therein. Third, to restore the original depths of the harbors and connecting channels by dredging.

It is the opinion of the board that while it is feasible to raise the average surface of the Lakes to any desired elevation by means of weirs and sluices it will be exceedingly difficult and in many ways impracticable to regulate the oscillations of the Lakes to a greater extent than nature now does automatically. These oscillations arise from winds, from the relative amount of rainfall and evaporation, and from other natural causes, which man can neither control nor foresee. The effect of any attempted regulation will be local rather than general, and the local benefits will be offset by injuries elsewhere. The difficulties in regulating lake levels are fully discussed by the International Waterways Commission in House Document No. 779, Sixty-first Congress, second session, and a resume of the views expressed therein is given in Appendix A.

To restore the diminished levels in the Lakes by constructing contracting works in their outlets does not however present any serious difficulties. A careful discussion of the proper locations and dimensions of such works is also given in Appendix A.

At the foot of Lake Ontario the closure of the Gut channel of the Galops Rapids by the Canadian Government has had the effect of raising the level of Lake Ontario an amount nearly equal to the computed lowering of the lake by a diversion of 10,000 second feet at Chicago, and no compensation is at present deemed necessary to restore former conditions in this lake.

In Appendix A it is proposed to diminish the outflow of Lake Erie by the construction of three *submerged weirs in Niagara River* in the vicinity of Squaw Island, which would average about 4.2 feet in height and would contain about 15,000 cubic yards of masonry. The estimated cost is $150,000.

To raise the level of Lakes Michigan and Huron *submerged weirs* are proposed *in St. Clair River,* covering 3 miles of river below the mouth of Black River at Port Huron. The

weirs as suggested in Appendix A have a height of from 5 to 6 feet above the river bed, contain about 65,000 cubic yards of material, and their estimated cost is $325,000. It is computed that these weirs will increase the velocity of the water flowing over them slightly (from a mean of 3.28 feet to 3.89 feet per second), but, on the other hand, above the mouth of Black River the river slopes and velocities which are now excessive will be diminished, and navigation on the whole will be considerably benefited.

The Chicago diversion has no effect on Lake Superior.

Compensation for the loss of elevation on Lakes Michigan, Huron, and Erie, and their connecting waters, due to an assumed diversion from Lake Michigan of 10,000 second-feet, will by the plan above outlined involve an expenditure of about $475,000, to which should be added an amount for the maintenance of the weirs, estimated at about $15,000 per year, the total cost being much less than the cost of restoration of depths by dredging. It is the opinion of the board that while other plans have been proposed, compensation by fixed contraction works similar in general to those above described affords the cheapest and most satisfactory method of preserving the levels of the Great Lakes.

No estimates have been considered for compensating for the loss of depths in the St. Lawrence River, as such work is regarded as outside the scope of the duties of the board.

VII. The influence on volume and height of waters in the Mississippi River below Cairo.

This subject is specially discussed in Appendix B.

The influence on the volume of the Mississippi River due to any diversion from Lake Michigan will be an increase approximately equal to the amount of the diversion, since the losses due to evaporation and other causes will not be large, and at extreme high water the increase, due to a 5,000 second-foot diversion, will be less than one-third of 1 per cent. from Cario to the mouth of the river.

Except as increase in volume results in increase of gauge height or depth of water available for purposes of navigation, it will be of no importance within any limits of diversion heretofore considered as permissible.

The effect of any diversion upon gauge height will always be small, and at the highest stages practically nothing, but the exact effect at any time or at any stage can not be determined, since this effect will be complicated or obscured by various other changes in the regimen of the river.

An extended series of discharge observations of the Mississippi River was taken under the direction of the Mississippi River Commission from 1879 to 1885, at Columbus, Ky., below the mouth of the Ohio River; at Helena, Ark., below the mouth of the St. Francis River; at Arkansas City, Ark., at Wilsons Point, Miss., and at Hays Landing, below the mouths of the White and Arkansas Rivers; at Warrenton, Miss., below the mouth of the Yazoo River; at Red River Landing and at Carrollton, La. Mean discharge curves have been derived from these observations, and extended and checked by numerous observations made at later dates.

On plate 1 of Appendix B are shown the mean discharge curves at Columbus, Ky., Helena, Ark., Vicksburg (and Warrenton), Miss., and Red River Landing, La., and the curves of theoretical increase in gauge heights deduced from them. These curves show that the influence of a given diversion from Lake Michigan through the Chicago Drainage Canal upon the volume and height of the Mississippi River varies with the localities and at the same locality with every change in discharge and that in all cases the increase in gauge heights will be small.

Assuming that increase in gauge height will not be accompanied by changes in cross section of the river or that its effect will not be otherwise obscured, the diagram indicates that at all four places considered it would require in discharge considerably exceeding 10,000 cubic feet per second to increase the gauge heights by 1 foot even at the lowest stages of the river; under similar assumption at stages corresponding to 40 feet at Columbus the curves indicate that it would require an increase of over 50,000 cubic feet per second to increase the gauge height 1 foot at Columbus, Helena, and Red River Landing, or over 5,000 cubic feet per second to affect the gauge height one-tenth of a foot. At higher stages the effect would be even less and it is evident that on extreme flood heights the effect of any permissible diversion would be trifling and would have no important bearing upon the heights of levees or other works designed to afford protection against floods.

But even these small increases of gauge heights are not an exact measure of the increase in depths which would result from an increase in the volume of the river. As the discharge increases, not only does the surface of the water rise, but that of the bars also. This subject was discussed by a former board, and it was shown by an extended series of observa-

tions that a rise of the river of 1 foot is accompanied by a rise of bar of not less than 6 inches. The rise of the bar occurs more slowly than the rise of the water surface, and as the river is continually fluctuating the full effect does not appear in the observations. Where a permanent addition is made to the discharge, the rise of the bar may more closely approach that of the water surface, but in any case the influence of the increase in discharge on navigable depths will be insignificant.

The board has also shown in discussing the sixth subject that the effect of diverting 10,000 second-feet through the Chicago Drainage Canal from the Great Lakes will appreciably injure their navigability, and in its preceding report that such a diversion was not necessary to obtain either the 8 or 9 foot navigation recommended from Chicago to the mouth of the Illinois River. Since its last report it has been in conference with the authorities of the State of Illinois in reference to the advisability of removing the existing dams in the Illinois River. Even with the diversion of not more than 4,167 second-feet at present authorized, the board agrees with the State authorities that the dams could be removed and the desired channel depths obtained by dredging alone; but the project for obtaining channels of 8 and 9 feet depth, recommended by the board in the report of January 23, 1911, contemplates the fullest possible use of the work already done on the Illinois River, which has been improved to a depth of 7 feet. To remove the locks and dams, and thereafter obtain depths of 8 and 9 feet by dredging alone, will add greatly to the cost of the improvement.

If large amounts of water are to be admitted into the river, the removal of dams would reduce the damage to the valley from overflow from this discharge; but the board reiterates that a diversion exceeding 1,000 second-feet is not necessary for navigation purposes alone in the Illinois River, and that an added discharge will produce a slight and inadequate effect on the Mississippi River.

The object of diverting 10,000 or more second-feet from Lake Michigan is not primarily to benefit navigation, but to dilute sewage and to create power, and the United States should not be burdened with the cost of protecting the lowlands of the Illinois Valley from overflow where such diversion and overflow are unnecessary for navigation alone.

VIII. The effect on the climate of the Lake States by a change in the natural currents of Lake Michigan.

This subject is specially discussed in Appendix C.

While the variations of the levels of the Great Lakes have been carefully studied for a long period on account of their effect on the depths of harbors and connecting channels, it is only during recent years that data have been collected relating to their temperature and currents. The information thus obtained is not only incomplete, but the conclusions derived therefrom by some observers are contradictory. To properly investigate the subject, the Board has therefore found it necessary to make a series of independent observations. A report on the results of these investigations is given in Appendix C.

It has been quite generally believed that there exists in Lake Michigan a surface current flowing in a southerly direction along the Wisconsin shore and northerly along the State of Michigan, and that it is quite fixed in direction, particularly during the summer months, but the observations conclusively show that this belief is a popular fallacy, and that the surface currents, instead of being fixed in direction, are extremely variable. They tend to follow straight lines dependent on the direction of the winds and other conditions. With a wind blowing from a northerly direction, there is a tendency for a southerly surface flow of water on both the Wisconsin and Michigan shores, and when the wind blows from a southerly quadrant the currents on both shores tend to flow to the north. A westerly wind raises the water on the Michigan shore, and an easterly wind on the Wisconsin shore. Changes of level and of currents are also frequently produced by variations in barometric pressure.

The observations also show that the temperature of the surface water at any locality is affected by the direction of the wind. During the summer months at any locality where the wind is blowing on-shore the surface water is warmer than on the opposite side of the lake, and a change to an off-shore breeze will frequently reduce the temperature of the surface water at this locality from 10 to 15 degrees. This phenomenon is accounted for by the fact that the wind raises the water on the shore toward which it blows and depresses it on the opposite shore. Due to this disturbance of the equilibrium, there is a return flow, which does not occur on the surface, but at a considerable distance below it. Instead of

being in a southerly direction on one side of the lake and a northerly on the other, the path described by the waters is, on the surface, in the direction of the winds, and thence on the leeward shore, the current is directed toward the bottom of the lake, whence it flows at a great depth back to the windward side and finally up to the surface, thus completing the cycle.

While the temperature of the surface waters of the lakes varies from 32° F. during the winter months to nearly 80° in summer, the variations at 100 feet below the surface are within much narrower limits. In Lake Superior the temperature of the water at great depths appears to remain at approximately 39° during the entire year and on the other Great Lakes, at depths of 100 feet, does not exceed 50° F. during the warmest weather.

The return subsurface currents are continually bringing the lower waters to the surface and affecting its temperature, making it cooler in summer and warmer in winter. They also retard the formation of ice, as they render it necessary to reduce a large volume of water approximately to the freezing point before it congeals.

The effect of water on the temperature of the air passing over it is a function of the strength of the winds and the area and depth of the lake. Lake Michigan has an area of over 22,000 square miles. Its greatest length is 307 miles, its width 118 miles, and its maximum depth 870 feet. It exposes an enormous water surface to the action of winds, and its depth gives an immense volume to absorb or radiate heat. Moreover, it is connected to Lake Huron, which also has an area exceeding 22,000 square miles and a maximum depth of 750 feet, by a broad and deep channel, through which not infrequently there is a flow of over 2,000,000 cubic feet per second, and any material change of temperature in one lake will be transmitted to the other.

These, rather than lake currents, are the principal factors which affect the climate of the Lake States, and the diversion of any water through the Chicago Drainage Canal will primarily affect the climate only to the extent that it reduces the area or volume of the lake. As has been previously stated, the diversion of 10,000 second-feet will ultimately lower the level of the lake 5.58 inches. The reduction in volume or area of a lake 870 feet deep and having an area of 22,000 square miles, by a reduction in depth of this amount is inappreciable.

It may therefore be stated that the effect on the climate of the Lake States, caused by diverting 10,000 second-feet of water through the Chicago Drainage Canal, whether theoretically beneficial or injurious, would be so small that it could not be measured by the most delicate instruments.

IX. Upon the improvement of the Mississippi between the mouth of the Illinois River and the mouth of the Ohio River by the construction of a dam at or near Jefferson Barracks and a dam at or near Commerce and the development of water power incidentally created by such dams.

This question is specially discussed in Appendix D.

The existing projects for improving the navigation of the Mississippi River contemplate a channel 6 feet deep at low water from the mouth of the Illinois to St. Louis, and 8 feet deep from St. Louis to the mouth of the Ohio. These depths are ample for all existing river navigation. To provide for a reasonably prospective commerce this board, in its report dated January 23, 1911, House Document No. 1374, Sixty-first Congress, third session, recommends that an 8-foot channel be made from St. Louis up the Illinois River, thus affording a depth of 8 feet from the upper Illinois to the mouth of the Ohio, and that, should an increasing traffic demonstrate the necessity for additional facilities, a channel 9 feet deep be made. A depth of 8 or 9 feet, properly utilized, is sufficient for an enormous traffic.

The construction of the two dams referred to in the portion of the act of June 25, 1910, quoted above, is not necessary to create depths of 8 or 9 feet. The desired improvement may be made at a much less cost, by the simpler methods of regulation and dredging.

The board is aware that a channel depth greater than 8 or 9 feet has been considered by some as desirable, and that a low-water channel depth of 14 feet or more has been advocated. Methods for obtaining a depth of 14 feet have been considered by a former board, whose report, published in House Document No. 50, Sixty-first Congress, first session, shows that even for this greater depth the method of regulation and dredging is preferable.

The present board concurs in the conclusions of the former board and is of the opinion that the construction of high dams is not the better method for securing such greater depth of channel, even should the latter ever become necessary, and

that only an extremely low cost of the water power incidentally created by such dams can possibly warrant their construction.

To determine the best location for the upper one of the dams described in the act, a survey was made at the request of the board by the United States Engineer office at St. Louis to ascertain the depth of the rock at sites regarded as most advantageous. These rock borings are described in Appendix D. For the lower or Commerce dam the board uses the information procured by a former board, whose report is published as House Document No. 50, Sixty-first Congress, first session.

The least objectionable site for the St. Louis dam is at the foot of Stein street, where rock occurs within the low-water bed of the river at a general depth of about 77 feet, as shown in plate 1, Appendix D. East of the low-water bed some of the borings showed the rock to be at depths of over 119 feet below low water. (See plate 2, Appendix D.)

The site selected near Commerce is at Grays Point, near mile 137, below St. Louis, where, although the soundings show the rock of the river bed to range between 24 and 85 feet below low water, it is possible to found most of the dam on rock at the higher elevation. Accordingly, the difficulties of construction would be somewhat less than at the site of the proposed St. Louis dam.

In the discussion of the construction of these two dams, it seems desirable first to consider fully the details of the only plan that has, so far as we know, been seriously advocated. This is the plan of the consulting engineer of the Lakes to the Gulf Deep Waterway Association, which is quite fully described in Appendix D and in the papers accompaying the latter.

Briefly, this plan contemplates the construction of two dams, the upper one near St. Louis with crest at elevation 413, Memphis datum, the lower one near Commerce with crest at elevation 343, the dams to be substantially similar, each with 3,000 feet of fixed spillway in the form of "an equilateral slant" with vertex upstream and with "a bear-trap section" at right angles to the stream 1,000 feet long, with a range of 15 to 16 feet below fixed weir level. Each dam is figured to pass the bank-full discharge with a depth of 10 feet on the crest "and greater floods within desirable limits." Bank-full stage at St. Louis is about 30 feet above low water. The flood of 1903, which did an enormous amount of damages at

East St. Louis, was, at its maximum, 38 feet above low water, and the greatest recorded flood, that of 1844, 41.4 feet above low water.

This plan of the Lakes to the Gulf Deep Waterway Association proposes the development of power at St. Louis at all stages below the bank-full stage, and as greater floods are to be passed through the dam by means of bear-trap gates, the dam will at those higher stages create practically no head, and during such stages the power will fail. In 1883 the river was above the bank-full stage for 17 consecutive days, in 1892 for 36 consecutive days and again for 12 consecutive days, and in 1903 for 16 consecutive days. As a power proposition the proposed dam, without an auxiliary steam plant, is evidently not sufficiently trustworthy from a business point of view. Arrangements based upon the expectation of constantly securing power at anything like the maximum rate would eventually prove disappointing; while a steam auxiliary would necessarily have to be of capacity equal to the maximum estimated output of the proposed water power.

The effect of the proposed St. Louis dam upon flood elevations merits serious consideration. At the St. Louis site there are no falls or rapids such as generally suggest the feasibility of power development and permit the work to be done with relatively little or no changes of river stages. On the contrary, the general slope of the river near St. Louis is about six-tenths of a foot per mile, and as the low-water elevation at the St. Louis site is 385.6, a dam whose crest is at 413 would concentrate at this locality the fall of about 46 miles of river. With banks which, even now, are submerged during floods, it is readily apparent that, while the raising of the level of the water surface in the pool above the dam might be permissible during low water, the effect during floods would be disastrous.

The Mississippi River in the vicinity of St. Louis has been extensively contracted by bridges and by works to improve the low-water channel and by levees constructed on reclaimed land. This contraction has already produced a dangerous increase in flood heights. In as thickly settled a country as surrounds St. Louis, a further increase in flood heights in the present contracted section, such as might be produced by a high dam, can not be permitted.

In House Document No. 772, Fifty-ninth Congress, first session, the Board of Engineers for Rivers and Harbors invites attention to the fact that the effect of confining a flood

such as that of 1844 in a channel 2,000 feet wide will require a mean velocity of 14 feet per second for the maximum discharge, estimated at 1,360,000 cubic feet per second, to pass through the present channel at the Eads Bridge with the water surface at an elevation of 45 feet above the zero of the gauge (the grade proposed for levees now under construction). Even if the flood should cause a scour to bedrock, a distance of some 20 feet below the present river bottom, a mean velocity of 8 feet would result. Either assumption appears less probable than a material further increase in flood heights.

It is our opinion that, before the power dam proposed by the Lakes to the Gulf Waterway Association could be permitted at this locality, the levee under construction around East St. Louis must be set back about 2,000 feet and all buildings and embankments which are in front of the new levee, not absolute necessities to transportation and which interfere with the run-off of water, be removed, or provision otherwise made for discharge of at last 400,000 second-feet more than at present provided for.

It is impracticable to set back the levees of East St. Louis 2,000 feet and to remove all structures between the levees and the river. It is equally out of the question, within reasonable limits of cost and without obliterating the working head, to provide at the dam for an excess flow of 400,000 cubic feet per second. Consequently the construction of the dam under the plans advocated by the Lakes to the Gulf Waterway Association would expose the people of the vicinity to great disaster.

While power can be created at low heads, in view of the high probable cost of construction of the dam and power house, its economical development at this locality appears to demand a low-water head of at least 25 feet. At Keokuk, where foundation conditions were most favorable and the cost of construction certainly far less than it would be at St. Louis, a head of 40 feet was regarded as necessary. The development of power in commercially available form requires a regulated output of alternating electrical current, to the production of which a substantially uniform speed of revolution of the electric generators is essential. This uniformity of speed can best be secured when there is little or no variation in the head of water on the turbines. Moderate reduction in the normal head reduces the output of current while maintaining uniformity of speed. Greater reduction of head

makes it impossible to maintain the required speed of revolution and then the output of alternating current ceases. The extreme variation which is usually permitted occurs when the minimum head is 55 to 60 per cent. of the maximum head, but by appropriate design the range may be extended, permitting the minimum head to be 40 to 45 per cent. of the maximum, accompanied, however, by a considerable loss of efficiency at the high heads which correspond to low water. In the case of the dam proposed by the Lakes to the Gulf Deep Waterway Association, the design does not contemplate the development of power at stages above the bank-full stage. At and for some distance below the latter stage the head will be below the permissible limits, so that considerable dredging below the dam will be nesessary in order to permit power to be developed even to this partial and unsatisfactory degree. Considered alone upon the basis of the power to be developed, the proposed dam is therefore not satisfactory, and the dredging which is necessary to make it available up to the bank-full stage will not only add greatly to the cost, but will also be attended with unusual difficulties.

As is well known, the Mississippi River at St. Louis carries large quantities of sediment, most of which is derived from the Missouri River. The amount discharged by the Missouri River during the year 1879, a year of extremely low water, was estimated by the president of the Missouri River commission as about 400,000,000 cubic yards. (See Annual Reports, Chief of Engineers, 1881, p. 1653, and 1887, p. 3090.) The quantity of sediment transported at any time varies with the velocity of the water. The velocity of the water flowing through the pool which the dam would create above it would be reduced at low water from about 2 feet per second (which at present exists in the river) to about three-tenths of a foot, and at bank-full stage from about 7 feet to 4 feet. As long as the current flows without interruption material in suspension moves down the river with the same velocity as the water, but a checking of the current will cause a deposit of immense amounts, deposits of from 20 to 60 feet in depth having been formed in a single season behind the permeable dikes constructed to improve the navigation of the river below St. Louis.

While no complete investigations have been made to determine the fill above such dams, the results are of record at two important dams, one a high dam at Austin on the Colorado River of Texas, and the other a low dam for irrigation pur-

poses at Laguna, on the Colorado River of southwestern United States. Above the dam constructed at Austin, Tex., in 1893, there is reported by Prof. Thomas U. Taylor, of the University of Texas, a deposit in the first four years after its construction of 31,667,000 cubic yards, or 38 per cent. of its reservoir capacity. In a paper presented to the American Society of Civil Engineers, January 1, 1913, by Mr. H. T. Cory, a fill is reported above the dam at Laguna, Ariz., in one season of 20,000 acre-feet (over 32,000,000 cubic yards). Some idea of the extent of the fill to be expected on the Mississippi may be obtained from the sediment observations on the Missouri River near its mouth, taken at St. Charles in 1879. These observations show that at a stage of about 20 feet above low water, with a mean velocity of 6.7 feet per second and a discharge of 257,000 second-feet 3,971,000 cubic yards of material were carried downstream in suspension per day. When the velocity was reduced to 3 feet per second, the amount carried in suspension per day was only 65,000 cubic yards, the volume of discharge at this velocity being 40,000 second-feet. A volume of 257,000 second-feet at this reduced velocity would therefore carry about 416,000 cubic yards, and a deposit of 3,555,000 cubic yards per day is indicated for this stage as a result of the construction of the dam. The observations do not extend to the higher discharges, but assuming that at a bank-full stage in the Mississippi River below St. Louis with a discharge of 600,000 second-feet the amount per cubic foot carried in suspension did not exceed that at a 20-foot stage in the Missouri River, a reduction of velocities to 4 feet per second would cause a deposit of over 2,000,000 cubic yards per day for that stage. The pool above the dam would therefore rapidly fill, and unless dredging operations were undertaken on a scale never before attempted the bed of the river would rise, flood heights would increase, and the pool would soon cease to be of any value as a means of improving navigation.

As a means of overcoming these difficulties, it has been suggested that the regimen of the river above the dam be radically changed by increasing the depth and diminishing the width of the stream, so as to secure velocities equal to those which obtain under existing conditions. In a sewer or canal of regular section the corresponding problem admits of ready solution. In a river conditions vary from section to section, and the true mean depth can at best be only approximately determined. The mean velocity of the Mississippi River at this locality at low water is about 2 feet per second, which requires for exist-

ing slopes and widths a mean depth of about 6 feet. The slopes would be reduced by the construction of the dam to about one-half those at present existing, and to maintain the low-water velocity unchanged would require that the mean depth be increased to about 12 feet.

To insure a uniform velocity of flow in the proposed channel the tendency of the river to scour its bed and banks must be prevented, otherwise the pool and bar formation that now obtains in the river will be perpetuated. This renders necessary a complete regulation of the portion of the river affected.

It is, however, a mistake to assume that the excavation work could be left to be done gradually after first completing the dams. The erection of the dams would cause a radical change in the regimen of the river which, as shown above, would cause immense deposits unless a reduction of the velocities could be at the same time prevented. The channel excavation and regulation necessary for any adopted channel depth must therefore be carried on rapidly and, so far as possible, simultaneously with the creation of the pools. Every year's delay in the completion of the project would add enormously to its original cost, by reason of these deposits and their removal. Of the 400,000,000 or more cubic yards of sediment flowing out of the Missouri River annually, the amount deposited would, therefore, depend on the rapidity with which the channel was built; but assuming that not more than 10 years were required to complete the channel and that the deposit were only 100,000,000 cubic yards per year, the increase in cost from this item alone would be not less than $100,000,000.

If abnormal accumulations of sediment, resulting from change of regimen due to the construction of the dam, must be removed as they occur, and if the regulation works must be prosecuted systematically and continuously so that the average depth shall increase as the average slope above the dam is diminished by its progressive construction, the problem of executing the dredging and building the regulation works becomes one of extreme difficulty, since both operations, must be performed upon a scale not hitherto attempted. Considering the dredging alone, the dredged material must be completely removed from the limits of the regulated channel and deposited well beyond the reach of floods, to avoid interference with their free discharge. For handling even 100,000,000 cubic yards annually, the services of at least fifty 20-inch hydraulic dredges, working continuously throughout the year with double crews, would be required.

To construct and operate these dredges would in itself prove a formidable task. The regulation of the channel above the dam would present additional difficulties.

The proposed St. Louis Dam furthermore involves the complete closure of a very large river, whose floods are exceeded in magnitude by few of the great rivers of the earth. To prevent disaster to the work and to the occupants of the valley below, the dam, power house, and head bay walls must be built of masonry, founded on solid rock, at depths averaging about 77 feet below low water and 118 feet below extreme floods. Variations of stage whose frequency and extent are illustrated by the accompanying hydrograph (see plate) and floods of as much as 1,300,000 cubic feet per second might occur during the construction work. Bridge piers have been built under such circumstances, but no dam has ever been attempted under conditions approximating these in severity. At the Keokuk Dam, which has just been completed, rock was everywhere found within 5 to 12 feet of the low-water surface, the extreme flood discharge for which provision had to be made was only about 325,000 cubic feet per second, with a height above low water of about 20 feet, and the site was otherwise naturally adapted to power-dam constructions, yet the work was difficult and expensive, requiring over two years to complete and costing about $20,000,000. A detailed estimate of a project considered by the board to be preferable to that proposed by the Lakes-to-Gulf Deep Water Association is given in Appendix D. This estimate and a comparison of the difficulties of the Keokuk and St. Louis sites indicate that the St. Louis Dam, power house, and locks alone would cost over $58,000,000. Dredging of deposits and regulation above and below the dam would add at least $100,000,000.

It has already been noted that to permit the generation of power up to a bank-full stage it is necessary to lower the pool below the dam by the removal of a quantity of material estimated by the Lakes to Gulf Deep Waterway Association at 100,000,000 cubic yards, but computed by this board to be from 200,000,000 to over 750,000,000 cubic yards, dependent upon the channel depths to be obtained. Assuming the figure of 100,000,000 to be correct for the yardage of this special dredging and its cost to be $25,000,000, and adding the cost of land damage and levee protection, amounting to over $8,000,000, the total for the St. Louis dam would be over $191,000,000. The greatest quantity of continuous power which the dam could generate would be that of low water, at which time, assuming the low-water discharge, including present authorized

diversions from Lake Michigan, as reaching a total of 40,000 second-feet, and the head as reaching 46 feet, the maximum output would not exceed 146,000 electrical horsepower, and the cost per horsepower would be over $1,300, which far exceeds the cost at which water power can successfully compete with coal, even when the latter is much higher in price than it now is in the vicinity of St. Louis. Moreover, although the conditions are so unusual that it is impossible to submit a definite estimate of the cost of maintaining the proposed improvement, it is the opinion of the board that the mere cost of the dredging necessary to maintain the river channel in the unnatural condition contemplated by this project would far exceed the cost of the coal necessary for a steam plant capable of creating the same power as that of the dams.

The plan of the Lakes to the Gulf Deep Waterway Association for the dam near Commerce, which it is proposed should be similar to the St. Louis dam already discussed in detail, while not equally open to objection because of increase in flood heights, is nevertheless objectionable because of the failure of power at stages above bank-full stage and because of excessive cost, which latter, including cost of all requisite contingent works, would be about the same as that of the St. Louis dam.

As the dams proposed by the Lakes to the Gulf Deep Waterway Association would raise extreme floods 3 feet or more at St. Louis, as the power at both dams would fail above bank-full stage, as the cost of construction would far exceed the highest figure at which water power can successfully compete with steam power, and as the greater depths which the dam would create are not needed for navigation, this plan is without justification.

The board has, however, made studies of other plans, with a view to overcoming the objections above cited. Some of these studies are fully described in Appendix D, in which it is shown that by suitable arrangement of the dams as to crest, elevation, and length, and by dredging, it may be possible to avoid the danger of increased flood heights at St. Louis, and of the failure of power at high stages at both dams, yet, under the most favorable circumstances, the final cost of dam construction, dredging, regulation, power installations, and other requisite contingent works would be more than $428,000,000 for the two dams, while their continuous output would be not over 250,000 electrical horsepower, and therefore the final cost of development of power will be far too high to justify the undertaking.

The board accordingly reports that the improvement of the Mississippi River by high dams below St. Louis is without merit and unworthy of further consideration.

W. H. BIXBY,
Brigadier General, U. S. Army, retired,
President of the Board.
C. McD. TOWNSEND,
Colonel, Corps of Engineers, U. S. Army.
C. KELLER,
Major, Corps of Engineers, U. S. Army.
J. B. CAVANAUGH,
Major, Corps of Engineers, U. S. Army.
JOHN BOGART,
Civil Engineer.

[For report of the Board of Engineers for Rivers and Harbors, see page 3.]

APPENDIX A.

UNITED STATES ENGINEER OFFICE,
Rock Island, Ill., August 13, 1913.

From: Maj. C. Keller, Corps of Engineers.
To: The President, Lakes to Gulf Waterway Board.
Subject: Report on preservation of and compensation for diminishing levels of Great Lakes, etc.

The following report upon "such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished level in said Lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway * * * or for any other purpose" is now submitted:

1. It seems hardly necessary to prove that if unaccompanied by works which will diminish the flow in the natural outlet, an artificial diversion caused by creating a new outlet for any body of water must lower its level below that which would have existed in the absence of the artificial outlet and diversion, and that the amount of such lowering will depend upon the size of the new outlet and the volume thus diverted. Certainly the asserted lowering would hardly be questioned were the diversion at Chicago of volume, for instance, equal to that of the natural discharge at Port Huron. Familiar examples in proof of this might readily be multiplied, but one will suffice: Consider the case of a trough or fountain basin

which receives a constant supply of water and from which the waste flows through a rectangular notch or cut in the rim, the maximum discharge capacity of the notch being slightly greater than the constant volume of water flowing into the trough or basin. As a result of the excess discharge capacity of the notch, the basin will never fill flush to the rim, but will reach and maintain some level of equilibrium slightly below the top, and the waste will then equal the constant supply. If now the size or cross section of the outlet is increased either by widening the first notch or by adding another one elsewhere in the rim, the volume of water outflowing will at once be increased and will then temporarily exceed the supply. The surface level of the basin will therefore fall until it is so low as once more to bring supply and waste into equilibrium. It is plain that the difference between the new level of the basin and its former elevation is due to the additional notch and is dependent on its size or cross section. The same effects will follow even if the supply is variable, but it will of course be more difficult to demonstrate them directly.

2. On an enormously enlarged scale each of the Great Lakes reproduces these familiar conditions. The Lakes are large basins of water and formerly discharged through a single outlet. It is evident and has been definitely proven by gauge measurements that the volume discharged through any outlet varies with its size, increasing as the area of the outlet is increased when the level of the basin rises, and diminishing as the area of the outlet is reduced by a fall in the basin. The opening of the drainage canal at Chicago produced precisely the same effect on the Lakes as the second notch. It increased the total area of the outlets, and if the water supply to Lake Michigan had been a fixed quantity, under constant atmospheric and barometric conditions, the lowering effect of this artificial outlet would have been definite and might after a suitable interval of time have been read directly from the gauges giving the elevation of the lake's surface.

3. But the amount of water supplied to each lake from its drainage basin and reaching its outlet varies from year to year with the quantity of rainfall (including snow), with the evaporation dependent upon the relative temperature of air and water and upon the prevalence or absence of wind, with the soil absorption dependent upon temperature, capillarity and dryness of the soil, and with other less important causes which affect the quantity of water and snow falling within the drainage basin, its return to the air direct or

through the soil and growing crops, and its delay by temporary storage within the soil. The surface levels of the Lakes vary correspondingly. In addition to the variations in the quantity of water supplied to each lake, complications are introduced by ice in the outlets, which may gorge and cause the lake above to maintain an abnormally high stage in calendar years with late springs and by wind and barometric effects, the latter two of which especially on Lake Erie sometimes cause large fluctuations in monthly surface levels. Plate 1 shows in separate curves the annual mean levels of all the Lakes, these levels being the integrated results of all the influences above described. A glance at these curves of annual levels will show their irregular rise and fall and the consequent difficulty of proving by direct evidence just what and how much is the effect upon lake levels produced by the creation of an artificial outlet, such as that at Chicago. It is further a well-known fact that the levels of all the Great Lakes are subject to considerable seasonal fluctuations, shown on plates 2, 3, 4, 5 and 6, which show certain curves of monthly mean lake levels. Generally speaking they are low in the early spring and late fall, and high during 3 to 4 of the spring and summer months. Such seasonal fluctuations are due to corresponding variations in the net supply of water to the various lakes, this net or available supply being in general low during the months of November, December, January, and February; high, due to precipitation and run-off during March and April; moderate in quantity during May and June; and thereafter again below the average. These differences in net supply are not immediately productive of corresponding changes in monthly levels which may and do lag as much as 3 or 4 months behind the acting causes. The extreme range of the monthly levels of the Great Lakes for the period 1860-1911, inclusive, has varied from 3.32 feet for Lake Superior to 5.54 feet for Lake Ontario, with maximum changes in a single period of 12 months of from 2.58 feet on Lakes Huron and Michigan to 3.97 feet on Lake Ontario. High water does not occur at precisely the same time on all the Lakes. Due to climatic causes, it is earlier for the lower lakes (Ontario and Erie) than for those above, the average difference in time between high water on Lake Ontario (May-June) and high water on Lake Superior (August-September) being nearly 3 months, and there is a corresponding interval between low waters (December-March on Ontario and February-April on Superior).

4. Thus while it is certain that the diversion of water through any artificial outlet cannot raise the lake levels and must either delay and diminish the raising or hasten and increase the lowering of the lakes involved, the proof of this conclusion must, because of the variations in the elevations of the lake surfaces just described, be indirect. Beginning in 1895, over five years before any diversion took place through the drainage canal, the United States lake survey, under the direction of the Chief of Engineers, United States Army, began a systematic series of measurements of discharge in the St. Marys, St. Clair, Detroit, Niagara and St. Lawrence Rivers to determine the relation, if any, which exists between the volumes discharged by those rivers and the levels of the lake surfaces. In order to determine the law connecting lake discharge and lake levels, the discharge observations have covered as wide a range of lake levels as possible. Up to the present the surface elevations during the measurements have for Lake Ontario (Ogdensburg gauge) varied between 242.9 feet and 246.3 feet above sea level; for Lake Erie (Buffalo gauge), between 570.0 and 573.92 feet; for Lake Huron (Fort Gratiot gauge), between 579.43 and 581.22 feet, and for Lake Superior (above Soo Locks), between 601.30 and 602.30 feet. The observations used for Lake Superior are those of September, 1909, at Sault Ste. Marie, which are the latest taken at this locality.

5. These discharge measurements have been numerous and the range of lake-surface heights has been sufficient to demonstrate conclusively that there is a direct connection between the height of each lake and the volume of water discharged at its outlet. The observations have been carefully made, so that it is possible to state with some precision how much the discharge of any one of the lakes is increased by a given rise in its surface or, conversely, how much the discharge will decrease for a corresponding fall. For a change of 1 foot from the mean of the stages covered by the observations on each lake the discharge will change as stated in Table 1.

TABLE I.

Lake.	Mean stage.[1]	Discharge at mean stage.	Change in discharge due to 1 foot change in level close to mean stage.
Superior.....	601.80	75,000	15,300 gauge at S. W. canal pier.
Michigan-Huron..	580.38	192,300	21,500 Fort Gratiot gauge. Lake St. Clair normal.
Erie.....	571.96	195,500	22,200 Buffalo L. H. gauge.
Ontario.....	244.60	230,000	23,200 Ogdensburg gauge. Discharge adjusted for effect of closure of Gut Channel in Galops Rapids, estimated to reduce existing discharges 9,000 cubic feet per second below those formerly existing at the same stage.

[1]Mean of range during discharge measurements.

A change in level of 1 foot at high stages is accompanied by a somewhat greater change in discharge than at lower stages, because at the higher stages a given change in level has a greater effect upon the area of the outlet, but only the mean values given in the above table are used in this discussion. Thus it would appear that for each level of any of the lakes there is a corresponding discharge fixed and determined by that level, and that on the other hand when the discharge is given the level of the corresponding lake is also fixed. With a definite change of surface height there is a corresponding increase or decrease of flow, as shown in the preceding table. The fact that an artificial increase in outflow, such as that due to the diversion at Chicago, will lower the lake immediately concerned and all dependent on it for their supply, is a direct and necessary inference from the above discharge measurements. Any such increase of discharge above that which is the natural result of an existing lake level will have the effect of drawing upon the stored water available in the lake at a greater rate than before. Hence the lake will fall more rapidly and further than it would have done due to the natural discharge at the natural outlet, and the level to which the lake will finally fall is that at which the discharge through the natural or main outlet equals the normal discharge less the diversion. The total drop in the level of the lake surface, due to the diversion, is then plainly that which is necessary to make the total outlet area (the sum of the areas of the natural and artificial outlets) correspond to the total available supply. Conversely, a reduction in outlet area causing a diminution in outflow will result in raising the level until the discharge area once more corresponds with the available supply. This is actually taking place on Lake Ontario, where the closure of the Gut Channel of the Galops Rapids has apparently caused a rise in the surface of Lake Ontario of 0.39 foot or more. Based upon

the quantities given in Table 1, the changes of level, in feet, due to direct diversions of amounts varying between 1,000 and 14,000 cubic feet per second, are shown in Table 2.

TABLE 2.

1,000 cubic feet.	Superior.	Michigan and Huron.	Erie.	Ontario.
	Feet.	Feet.	Feet.	Feet.
1	0.065	0.046	0.045	0.043
2	.131	.092	.090	.086
3	.196	.139	.134	.129
4	.261	.186	.179	.173
5	.327	.232	.224	.2165
6	.392	.279	.269	.260
7	.457	.325	.314	.303
8	.523	.373	.359	.346
9	.588	.419	.404	.390
10	.654	.466	.448	.431
11	.719	.511	.493	.474
12	.784	.558	.538	.517
13	.850	.602	.583	.560
14	.915	.649	.628	.603

6. With the outlets free of ice at any instant the volume of water discharged from one of the lakes is a definite quantity fixed by the level of the lake. With a constant supply of water and constant evaporation there would then be no change in the elevation of the lake's surface, except such temporary changes as might be caused by winds and barometric disturbances. But the flow into each lake is, as has been explained, constantly varying, and while the discharge from the lakes is also ever changing, so as in the long run to tend to counterbalance changes in supply, yet these adjustments of supply and discharge are not simultaneous, and the surface levels of the lakes are therefore constantly fluctuating, as is readily seen from the plates attached.

7. These regular but uncontrollable changes in lake level mask the effect produced by an artificial diversion. Such diversion plainly is an increase of the natural discharge and therefore disturbs the general equilibrium between supply and discharge which in the long run exists. If at the time of this diversion the lakes are rising, it will reduce the rise; if they are falling, it will increase the fall; and the net effect of the diversion will unquestionably be a reduction of the level which would have existed. This diminution of level is simply that corresponding to the finally lessened outflow at the natural outlet, and its amount can be determined from Table 2.

8. The above diminution of level caused by a diversion of given volume will not be immediate. A considerable time

will elapse before any large part of the ultimate lowering of any of the lakes will have taken place. The time required to produce the lowering due to an artificial diversion from any of the lakes will depend on its surface area, so that the smaller the lake the sooner a diversion of given volume will produce its corresponding effect. As shown in the report of the Lake Survey for 1904, page 4120, half of the ultimate fall of Lakes Michigan-Huron will occur in 1.46 years, and nine-tenths of the fall will be completed in 4.86 years, so that the effect of a diversion is slow to appear, and, as stated, changes in precipitation and run-off may serve to obscure the effect. For each lake of the Great Lakes system the time required for 50 per cent. and for 90 per cent. of the ultimate lowering is shown in Table 3.

TABLE 3.

Lake.	Time required to produce 50 per cent of ultimate lowering.	Time required to produce 90 per cent of ultimate lowering.
Superior	14.4 months	47 months.
Michigan-Huron	18 months	58 months.
St. Clair	46 hours, or 0.006 month	6.4 days, or 0.213 month.
Erie	2.5 months	8 months.
Ontario	2.1 months	7 months.

9. The lowering due to an artificial diversion is not, moreover, confined to the single lake from which the diversion proceeds, but like effects may be caused in the lakes and connecting channels above and below. The diversion at Chicago, now under consideration, is widespread in its hurtful effects, Lake Superior, by reason of the fall of 20 feet between it and Michigan and Huron, being the only one not injured thereby, though it should be noted that injury is unquestionably done at all of the channel of the St. Marys River in the 49½ miles from the upper sills of the locks at Sault Ste. Marie down to Lake Huron.

10. From plates 1 to 6, herewith, it will be seen that the annual level of Lake Superior has been falling since 1905, during the six years between 1905 and 1911 having dropped about 1.3 feet, corresponding to a loss of storage capacity of more than six months' total discharge. Lakes Michigan, Huron, and Erie have been falling since 1908. In the three years between 1908 and 1911 they have each dropped more than 1.13 feet, and Lake Ontario has dropped about 2.2 feet in the same time. On all the four lower lakes the mean water surface for 1911 was at least 1.2 feet below the mean level of the past 52 years. Lakes Michigan and Huron were in March,

1911, at elevation 579.30, only 0.30 foot above their lowest recorded monthly stage since 1860, and the lowest monthly stage in 1911 on Lake Erie, 571.04, was only 0.35 foot above the lowest recorded monthly mean for that lake. These low stages are accompanied by corresponding reductions in the depths of the St. Marys, St. Clair, and Detroit Rivers, and the harbors upon Lake Erie, and as the depths of these harbors and connecting channels limit the draft to which vessels may load, the result is a corresponding loss of productive capacity in the large lake fleet, which is now designed and built to take advantage of every inch of depth available at these critical points. The largest lake freighters when nearly fully loaded carry over 80 tons of freight for each addition inch of draft. A diversion of 10,000 cubic feet per second from Lakes Michigan and Huron by the Chicago Drainage Canal will, as shown above, eventually reduce the average level of those lakes at least 0.465 foot, or 5.58 inches, and of Lake Erie 0.448 foot, or 5.38 inches, the losses of depth along the St. Clair and Detroit Rivers being intermediate between these values. Consequently, in addition to the unavoidable losses caused by the reduction of lake levels due to natural causes, an uncompensated Chicago diversion of 10,000 second-feet for each single down trip of such a vessel would cause a loss of about 446 tons of carrying capacity. An average of 25 trips per season would mean a loss of at least 11,150 tons, which at 55 cents per ton would during a busy season represent an annual loss of over $6,000 for the down trips of each large vessel. Each season many vessels of such size as to be affected by any loss of depth caused by a Chicago diversion pass through the locks at Sault Ste. Marie. Based upon the known characteristics and numbers of the lake fleet, it has been estimated that the total annual loss due to a Chicago diversion of 10,000 second-feet might be over $1,000,000, and this would increase with number and size of vessels. A diversion of 10,000 second-feet at Chicago has not been authorized, but the diversion already made has produced a proportionate loss in depth and revenue. To prevent this loss, remedial measures are necessary.

11. The Board of Engineers on "Deep Waterways between the Great Lakes and the Atlantic Tidewaters" in its report of June 30, 1900, House Document No. 149, Fifty-sixth Congress, second session, pages 273 to 293, presented a plan for the regulation of Lake Erie between fixed levels by the construction of submerged weirs aggregating 2,900 feet in length, combined with 13 adjustable sluices, each 80 feet wide, con-

trolled by Stoney gates, these works to be built at the foot of Lake Erie, just below Buffalo Harbor. The regulated level proposed was 574.7 feet above sea level, about a half foot below extreme high water in Lake Erie, and it was stated that these works would hold the lakes within 0.6 foot of the adopted level, temporary violent fluctuations not considered. It was further stated that the result of such regulation would be to raise the lake surface about 3 feet above its ordinary low-water elevation. Moreover, while the low-water level of Lake Erie would be raised about 3 feet, it was estimated that by backwater Lake St. Clair would be raised about 2 feet and Lakes Michigan-Huron about 1 foot.

12. In House Document No. 779, Sixty-first Congress, second session, pages 10, 11, and 12, and pages 49 et seq., it is clearly shown to be impossible to regulate Lake Erie within the limits proposed in House Document No. 149, owing primarily to its wide and lawless variation in supply and further to the lake's sudden and violent oscillations, which have amounted to as much as 2 feet in an hour and 8 feet in a day, the difference in levels between the two ends of the lake in extreme cases having at times been as much as 15 feet. The views expressed in House Document No. 779 are summarized as follows: The regulating works, situated as proposed, would tend to aggravate ice jams at the head of the Niagara, which in turn might, during southwesterly storms, cause disastrous inundation of the lower lying parts of Buffalo. Moreover, the ice gorges now occurring at the Horseshoe Reef at the head of the Niagara River retard the opening of the season of navigation at Buffalo, and an aggravation of these gorges might serve to increase this delay, while the works themselves might under these conditions be difficult to maintain, and furthermore, even during the ice-free months, raising the level of Lake Erie by 3 feet would increase the overflow damage caused at Buffalo by severe southwesterly storms. Floods from Buffalo Creek would also be more damaging, while low-lying lands along the entire extent of the shore line of Lake Erie would be permanently submerged. Such regulation, accompanied as it would be by a change in the outflow of Lake Erie, would prove detrimental to depths in Lake Ontario and in the St. Lawrence River. Regulation of the level of Lake Erie between wider limits, even between 572 and 574.5, does not, in view of its disadvantages, appear to be desirable. Regulation of the level of Lakes Michigan and Huron would, if feasible, prove beneficial only on those lakes and in the lower St. Marys River, and would be detrimental to

the lakes and rivers below. Due to the extremely wide variations in supply, however, the regulation of Lakes Michigan and Huron is not considered feasible. Moreover, the works necessary for regulation would probably cause a serious obstruction to navigation at the head of the St. Clair River.

13. In the Transactions of the American Society of Civil Engineers, vol. 63, June, 1909, Mr. C. E. Grunsky, member American Society of Civil Engineers, proposes the use of Lake Superior as a storage reservoir, regulating it at a high stage within the narrow limits with a view to delivering a large flow at low stages of Lakes Michigan and Huron, thereby neutralizing in part at least the harmful effect of the Chicago diversion. Concerning this it may be said that the level of Lakes Michigan and Huron depends on the total quantity of water supplied to them and the area of their outlet, and that, unless one or both of these are altered, it is impossible to cause any change in their mean level over a series of years. Since storage in Lake Superior cannot increase the total supply to Lakes Michigan and Huron, its only effect will be to lower the latter lakes and those below while accumulation of water is going on in Lake Superior. When the stored water is subsequently discharged at perhaps an abnormally high rate of flow, the surface of the lakes below may, for a relatively brief period, be elevated above its natural height more than it had previously been depressed, but the duration of such increase will be correspondingly brief, and in the long run, the mean stage of the lakes will not be benefited. Storage in Lake Superior may also, at the expense of an increase in its fluctuations, reduce the range of fluctuation of Lakes Michigan and Huron. Such a change will not compensate for the absolute loss of water caused by the Chicago diversion, and will not benefit navigation. Vessels habitually load to the extreme draft permitted by the minimum depth along their route, and reduction of the range of annual fluctuation of Lakes Michigan and Huron will, during the season of navigation, afford no greater average depth in the lakes and channels below the locks at Sault Ste. Marie, while the increased fluctuation of depth in the St. Marys River and in Lake Superior may prove exceedingly damaging.

14. In House Document No. 779, Sixty-first Congress, second session, pages 56, 57 et seq., is a further discussion showing the impracticability of regulating Lake Superior between fixed limits and of using it as a storage reservoir to

compensate for the loss of levels on the lower lakes due to the diversion at Chicago. Moreover, the mean level of Lake Superior for 1911 was 0.84 foot below its average of the 52 years, 1860-1911, and its outflow should now be restricted rather than increased, although the need for water below was never greater.

15. Mr. F. C. Shenehon, member American Society of Civil Engineers, has presented for the consideration of the board two plans, one for compensating, the other for regulating the levels of Lake Erie, each of them involving the construction of certain works in the Niagara River.

16. The first plan, as set forth in his letter of October 12, 1912, with plates 8 and 9 attached hereto, proposes the construction immediately above the Falls of a submerged dam or weir across the Niagara River from Port Day to a point opposite it on the Canadian shore. This weir would, it is asserted, raise the Chippewa-Grass Island Pool about 6 inches, and, through back-water effects, raise Lake Erie about 1 inch, with proportionate effects at intermediate points. In another place it has been estimated that a diversion of 20,000 second-feet from the Chippewa-Grass Island Pool will lower Lake Erie about 1 inch. The existing diversion on the American side of the pool is 15,100 second-feet, so that the proposed weir would compensate the level of Lake Erie for somewhat more than the lowering estimated to result from the diversions of the American power companies at Niagara Falls. At the same time the weir, located as proposed, might considerably improve conditions of flow at both ends of the Horseshoe Falls. This plan, while probably of benefit in connection with power and scenic conditions at Niagara Falls, does not, however, fully compensate for "diversion of waters from Lake Michigan," and while it may have merit, the board does not deem it necessary to discuss it further.

17. The second plan of Mr. Shenehon is for intermittent regulation of the level of Lake Erie by constructing, 1,000 feet below the Buffalo waterworks intake pier and just above the International Bridge, an adjustable weir about 480 feet in clear width, which, when completely closed, will diminish the outflow of Lake Erie by about 30,000 second-feet. Were the gates constantly closed, this would result in raising the level of the lake somewhat less than 1.5 feet, but it is proposed to operate this weir so that the flow shall be intermittent and to hold the level of Lake Erie during the navigation season a little higher than elevation 573.

18. Largely in the interest of the power companies and of scenic conditions at Niagara Falls, Mr. Shenehon proposes to keep the gates continuously closed during November and December and to remove them entirely during January, February, March, and April. During the months May to October, inclusive—that is, during the season of navigation and of pleasant weather when visitors at Niagara Falls are most numerous—the gates are to be operated so as to reduce the flow of the Niagara River to about 190,000 second-feet during evening, night, and early morning hours—16 hours in all, and to increase the flow to 220,000 second-feet during eight daylight hours. Such an arrangement would, it is urged, improve scenic conditions at Niagara Falls and would further help the power companies better to carry their peak loads without diminishing the daily flow over the Falls below its former natural volume.

19. The mean level of Lake Erie for the 52 years, 1860-1911, inclusive, is 572.56. Were it possible to hold its mean level at 573 during the months of navigation, the level of this lake would be raised about half a foot above its annual mean, and this would compensate Lake Erie for the lowering due to a diversion from Lake Michigan of over 11,000 second-feet and by back-water effects would, it is believed, compensate Lakes Michigan and Huron for a diversion at Chicago of about 3,250 second-feet. The benefits of this plan of regulation would be greatest whenever the lake fell below its mean level, 572.56, and, at lower natural stages of Lake Erie, such regulation might result in compensation on Lakes Michigan and Huron for a Chicago diversion of perhaps 6,000 second-feet. Mr. Shenehon's proposal differs in detail, but not in principle, from that proposed by the Board of Engineers on "Deep waterways between the Great Lakes and the Atlantic tidewaters," in House Document No. 149, Fifty-sixth Congress, second session, which is discussed in paragraphs 11 and 12 of this appendix. The objections to this plan are those which apply to any scheme for regulating the lakes—i. e., to substituting controlled and artificial levels and fluctuations of levels for those which now exist. It is not believed that any scheme of regulation has sufficient advantage over the plan of compensation by means of contraction works in the outlets to justify its adoption. The contraction works permit the natural oscillations to continue undisturbed and cause no vital change in stages and in oscillations of the lakes below. Moreover, under Mr. Shenehon's plan the extent of compensation on Lakes Erie and Michigan-Huron will vary with natural conditions, compensation on Lakes Michigan and

Huron at times being sufficient for a Chicago diversion of perhaps 6,000 second-feet; at other times for a diversion of perhaps less than 3,000 second-feet, with similar variations on Lake Erie. For full compensation on Lakes Michigan and Huron, for diversion greater than about 6,000 second-feet, supplementary works in the St. Clair River would probably be necessary. Contraction works on the other hand, operate automatically and fully compensate for the actual diversions. Further objections to this plan of regulation are the deleterious effect upon Lake Ontario and the St. Lawrence River, due to prolonged storage in Lake Erie, and there is also a possibility that a succession of years of low precipitation might render the plan wholly inoperative. Mr. Shenehon's letter of October 29, 1912, with plate 10 attached, appended hereto, fully explains this plan of intermittent regulation.

20. As shown by the great uniformity of flow in their connecting rivers when compared with other streams of corresponding magnitude, the Lakes themselves in their natural state regulate the flow in these rivers automatically and far more perfectly than can be done by human agency. Artificial regulation is impracticable because of the utter impossibility of predicting precipitation, run-off, and evaporation for one or more years in advance of needs. Moreover, it is in the connecting rivers that the limiting depths available for navigation have usually been found, and there the depth might be affected unfavorably by any plan involving storage. To prevent dangerous interference with this beneficial natural adjustment of the flow, compensation must be attempted only so far as will not interfere with natural oscillations.

21. The diversion at Chicago transfers from the drainage basin of the Lakes to that of the Illinois River a considerable portion of the water supply which naturally belongs to the Great Lakes and lowers the level of the entire system from and including the lower sills of the locks in the St. Marys River down to the mouth of the St. Lawrence. The water once diverted at Chicago is forever lost to the St. Lawrence Basin. To restore the natural depths of the channel in the lower St. Lawrence River is impossible except by dredging, and in the upper St. Lawrence only by more or less extensive and expensive works.

22. The loss of depth on Lake Ontario, due to a diversion of 10,000 second-feet, would be 0.431 foot, or 5.2 inches. The closure of the Gut Channel of the Galops Rapids by the Canadian Government in 1903 has had the effect of raising the

level of Lake Ontario by about the same amount. No further compensation is therefore at present necessary on Lake Ontario to restore its natural levels. The head of Galops Rapids will probably afford an advantageous site for a submerged dam or weir to obstruct further the area of the channel through which Lake Ontario discharges, and no great engineering difficulty should be experienced in securing any reasonable increase of level on this lake, but storage in this lake would, temporarily at least, diminish depths in the St. Lawrence River. On plate 7 is shown an extract from the Lake Survey chart of the locality, where additional compensation works may most readily be built when desired.

23. For the channels and lakes from the foot of Lake Erie to the St. Marys Locks, so far as affected by the Chicago diversion, a plan of compensation seems feasible which will not disturb natural conditions.

24. To compensate for the reduction of level in Lake Erie, the outflow capacity of the Niagara River must be diminished. By building submerged weirs or contraction works a short distance below its head, this may be done without altering the range and the periods of the natural oscillations of the lake. At the same time, the free flow down the Niagara River will remain practically unchanged. A proper location of the weirs, which will be of moderate height, or of the contracting dikes will not increase the danger of ice gorges in the upper Niagara River. A diversion of 10,000 cubic feet per second at Chicago would lower Lake Erie 0.45 foot. Weirs and contraction works may safely be built in the portion of the Niagara River at the foot of Squaw Island, near Austin Street, shown on plate 7, and computation shows that to produce a rise of 0.45 foot on Lake Erie, the rise at Squaw Island must be 0.85 foot. Three weirs, one at the foot of Squaw Island, the others half a mile above and below, respectively, and averaging 4.2 feet in height above the present river bed will produce the desired rise of 0.85 foot at Squaw Island and will thereby compensate for the diminished levels of Lake Erie. With a top width of 6 feet and side slopes of 3 horizontal to 1 vertical, these three weirs would contain about 15,000 cubic yards of material and, if built of solid masonry, at $10 per yard would cost $150,000. In place of these submerged weirs contraction works at the same locality would produce the same result at somewhat higher cost, but to avoid undesirably great effects at higher stages these contraction works should not extend above mean stage.

25. It is known that when the surface of Lake Erie is elevated there will be some backwater effect on Lakes Michigan and Huron, estimated to be slightly more than one-third the rise of Lake Erie. Assuming the surface of Lake Erie raised 0.45 foot, it is estimated that the backwater rise of Lakes Michigan and Huron may be as much as 0.16 foot. A diversion of 10,000 second-feet at Chicago would lower Lakes Michigan and Huron 0.47 foot, and the difference between this and the above backwater effect, or 0.31 foot, represents the additional amount which the surface of Lakes Michigan and Huron must be raised to compensate for such diversion. The St. Clair River is a main artery of the highly important lake traffic, and if submerged weirs are to be built in this river to raise the level of Lakes Michigan and Huron, sites must be chosen and the weirs built to such height that the depth over them will be ample and that navigation may remain convenient and unobstructed. The average depth of the St. Clair River for a considerable distance below the mouth of Black River at Port Huron is 30 feet, and six weirs may be built below that point, at distances averaging half a mile apart, which will raise the surface of Lakes Michigan and Huron the desired amount and will not reduce the depth over the weirs and elsewhere below 24 to 25 feet. The mean velocity of the current in this vicinity would be increased from about 3.28 feet to about 3.89 feet per second, or to about 2⅔ miles per hour, and the effect of this increase would be felt over a distance of about 3 miles below the upper weir, while above it the river slopes and velocities, now excessive, will be diminished and navigation will be benefited. The weirs, located as above, should have a height of about 5 to 6 feet above the river bed, and six weirs would require about 65,000 cubic yards of stone, which, at $5 per cubic yard, will cost about $325,000. Contraction works in the same locality will, at higher cost, produce the same result, but they must, as previously noted, be restricted in height to mean stage.

26. The Chicago diversion, nor any from the lower lakes, will have no effect upon Lake Superior.

27. The plan of compensation herein proposed has the advantage of simplicity and relative economy. Moreover, the submerged weirs may be systematically and progressively built, so as to permit close observation of their effect and such changes in plan as experience gained during construction may suggest. On the other hand, the Niagara River weirs, so long as they exist, would certainly interfere with the navigation of the main channel of the Niagara River and at some

future time might thereby interfere with the deepening of the channel. Present navigation would, however, be sufficiently served by the new lock at Black Rock. A further minor criticism of the proposed Niagara River weirs is that they do not, as would a high weir close to Niagara Falls, prevent the power diversions at Niagara from slightly lowering the level of Lake Erie; but the weirs are designed to compensate for the effects of diversions from Lake Michigan only. The consideration of compensation for the effects of diversions from the Niagara River is not included in the board's duties, but such compensation could readily be provided by slight modification of the weirs proposed.

28. Compensation for the loss of elevation on Lakes Michigan, Huron and Erie and connecting waters, due to an assumed diversion from Lake Michigan of 10,000 second-feet will, by the plan above outlined, involve a total expenditure of at least $475,000, to which must be added a small amount, possibly $15,000 annually, for the maintenance of the remedial works. This volume of 10,000 cubic feet per second has been assumed merely as a basis for computation. The cost of compensation for a diversion of different volume may be determined in the same manner. The cost of these compensation works is only part of the price that must be paid because of any diversion from Lake Michigan, and it is believed that this at least should be paid by the direct beneficiary of the diversion.

C. KELLER,
Major, Corps of Engineers.

LETTER OF MR. FRANCIS C. SHENEHON.

Minneapolis, October 12, 1912.

Board of Engineers on Lakes to Gulf Waterway.

Sirs: 1. On behalf of the Hydraulic Power Co. of Niagara Falls, I have placed in your hands two blueprints,[1] showing in plan and in section a proposed submerged rock weir in the Niagara River above the Cataract Rapids. This weir will reach from Port Day to the Canadian shore.

2. These blueprints are submitted, and this statement of the object of the weir, because I understand that the compensation of the water diverted by the Chicago

[1] Not printed.

Drainage Canal or by the Lakes to Gulf Waterway is a part of the matter to be included in your report.

3. It is well known to you that at the present time 15,100 cubic feet per second of water is diverted from the Niagara River above the crest of the rapids by the two large American companies. It is further known that the treaty with Great Britain permits a diversion ultimately of 20,000 cubic feet. It has been reported that the diversions of the above amounts in the Niagara River cause some small lowering of the river in this vicinity. The object of this weir is to raise the water level in the Grass Island Chippewa Pool to the betterment of navigation, and in compensation of the computed lowerings from diversions in the Niagara River itself and at Chicago.

4. The weir is built of bastard limestone in large blocks and will have a crest width of about 100 feet. As designed it will require about 42,000 yards of rock and its crest level will be about 6 feet below mean water level.

5. The rise in the river due to this compensating weir will be approximately as follows:

Lake Erie level.	Volume of flow in square feet.			Rise caused by weir.
	River.	Diversion.	Over weir.	
Feet.				*Feet.*
571.26	180,500	19,500	161,000	0.62
572.26	202,500	19,500	183,000	.58
573.26	224,500	19,500	205,000	.55
574.26	246,500	19,500	227,000	.52

The greater rise for low water is beneficial to navigation.

6. As to the method of computing the effect, it should be stated that engineering literature does not contain any great help in a problem of this kind, except as it teaches certain fundamental hydraulic principles which govern flowing water. The river section on the line of the proposed weir has an area of 38,400 square feet, when Grass Island-Chippewa Pool is at elevation 562.32, and the discharge of Lake Erie for its corresponding elevation is 224,500 cubic feet per second. Of this 19,500 cubic feet is taken as diverted above the weir. This leaves the flow over the weir 205,000 cubic feet per second, with a mean velocity of 5.34 feet per second. When the section of the river is reduced to 27,200 square feet of area by

the rock weir, the mean velocity must be 7.54 to pass the flow. In order to speed the water up to this velocity, a head of 0.43 foot with 100 per cent. efficiency is required. As some wasted effort enters, the efficiency of the velocity head is taken at 80 per cent., and the river rise must then be 0.54 foot, or, in view of some uncertainties, 6 inches roundly.

7. This operation may be expressed by the following equation:

$$R = \frac{\left(\frac{Q'}{a}\right)^2 - \left(\frac{Q'}{A}\right)^2}{2gk}$$

In this equation—

R is the river rise created, in feet.

Q′ is the discharge over the weir, in cubic feet per second.

A is the natural cross-sectional area of the river, in square feet.

a is the river section, with the weir constructed, in square feet.

g is the acceleration of gravitation, 32.2.

k is a coefficient of flow, taken here as 0.80.

8. It should be stated that it is not necessary to build any more of this compensating weir than will give the desired change or rise in the water level. As the construction progresses water gauges at Buffalo, at Chippewa, at Suspension Bridge, and in the Whirlpool will measure accurately the effect produced. When enough rise is secured, the construction may be stopped. Should the weir as designed be insufficient, some small addition will bring the rise to the proper amount. For this reason the proposition does not rest on any involved mathematical deductions.

9. It should be stated that the rise in river elevations due to this submerged rock weir will have its maximum value of about 6 inches just above its crest, and that the rise in Lake Erie will be about 1 inch. Between these two points the rise in river level will vary somewhat as the distance upstream above the weir.

10. This submerged rock weir is suggested to the Board of Engineers as an engineering proposition which will be beneficial to the navigation of the river and as tending to compensate more than twice the effect which could possibly be attributable to the diversions present

or anticipated of this particular company. It is known to the board that the authorized diversion of this company is 6,500 cubic feet per second, and that the actual diversion is slightly less than this. The original recommendation of the American section of the International Waterways Commission for the quantity of water to be apportioned to this company was 9,500 cubic feet per second, and was based on the commission's interpretation of the charter rights of this company from the State of New York. Their canal has a capacity for this flow. Should the Government issue a permit to the Hydraulic Power Co. to divert this additional 3,000 cubic feet per second, it might attach as a condition thereto that the company should contribute toward the expense of the proposed submerged weir. It is understood that the jurisdiction of this board does not touch the question of additional diversions to be authorized. It does seem proper, however, to state the condition under which the company might be called upon to contribute to a construction which will compensate for the lower river, not alone their desired diversion, 9,500, but will compensate in addition, in the immediate vicinity of Port Day, a diversion of 10,000 cubic feet per second at Chicago.

Respectfully submitted.

FRANCIS C. SHENEHON.

LETTER OF MR. FRANCIS C. SHENEHON.

Minneapolis, October 29, 1912.

To the Board of Engineers on Lakes-to-Gulf Waterway.

SIRS: 1. In addressing you upon the subject of the regulation of Lake Erie, I wish to express my feeling of personal humiliation that, after so many years of investigation of all the hydraulic elements involved in making Lake Erie, the Detroit River, and Lake St. Clair better navigable ways, nothing has been accomplished up to the present time in regulation. The low water on the Great Lakes of 1895-96 demonstrated the fatuity of letting unrestricted natural conditions produce random results. This was economically most harmful to the carrying trade of the great Lakes.

2. As a result of the low water of 1895-96, the Angell-Cooley-Russell Commission recommended the appoint-

ment of a board of engineers to investigate the subject of regulation, in connection with the larger subject of waterways to the sea.

3. In the report of the resulting board, consisting of Col. Raymond, Alfred Noble, and George Y. Wisner, the regulation of Lake Erie was specifically recommended. The distinguished personnel of this board gives great weight to its recommendation. In some respects, however, the scheme of the board was critcised. An attempt was made in the scheme of regulation to maintain Lake Erie at a level probably too high for all the conditions involved. The regulating works were to be placed above the head of the river, and with piers spaced so close together that the retardation of the ice fields was likely to be brought about. In addition the expense of building the regulating works was very considerable. The report of this board was made in 1898.

4. The present International Waterways Commission, so far as may be learned from its report of 1910, is not likely to make any recommendations for the regulation of Lake Erie, but will report in favor of compensating works instead. It is understood that the functions of this commission so far as international boundary streams are concerned has now been taken over by the commission created by the treaty of 1910 with Great Britain. Unless your honorable board should find the regulation of Lake Erie a proper subject for report, this important matter is likely to be relegated to a commission not of engineers.

5. My own investigations and studies of the hydraulics of the Niagara River, begun in 1898, have convinced me that a considerable betterment of the level of Lake Erie, of the Detroit River, and Lake St. Clair is entirely feasible at a reasonable expenditure for controlling works and at a small cost for maintenance. It was estimated by the Angell-Cooley-Wisner Commission that a foot in depth on Lake Erie harbors would save in dredging operations $1,000,000. This estimate, I understand, does not take into consideration the shallow west end of Lake Erie, including the approach to the Detroit River, the Detroit River itself, and Lake St. Clair.

6. The question of the regulation of Lake Erie has grown additionally important by reason of the entrance of two elements other than navigation. These are the

desirability of maintaining scenically effective the cataract at Niagara Falls, while the average flow over the cataract is diminished by such considerable quantities of water as are authorized by the treaty of Great Britain, and the need of making the diverted water, under the treaty with Great Britain, as efficient as possible as a power resource of the people of two nations. While navigation may still be regarded as predominant, the economic value of water power in the Niagara River and the æsthetic value of a spectacle internationally in trust must receive the highest consideration.

7. In presenting to you a scheme for the regulation of Lake Erie it is believed that the method used will be helpful to the three things involved—navigation, water power, and scenic grandeur.

8. It may be claimed for the method of regulation used that while it does not aim to hold Lake Erie within narrow limits, it will better the low-water level of the lake by at least a foot, and that no danger will arise from the method used of excessive high water.

9. It is a well-known fact that ice in the St. Lawrence River so retards the river flow that Lake Ontario is on an average about 7 inches higher than it would be in the absence of the winter season. It is well known also that the flow of the St. Clair River is at times much reduced by ice conditions. It has been estimated that the value of the ice period on the levels of Lakes Michigan and Huron is perhaps 6 inches. The peculiar beauty of the ice regulation is that during the season of navigation not a vestige of the ice-regulating works remains. They have completely disappeared and have left the channels in their full outflow sections. The peculiar disadvantage of the ice dam lies in the fact that this formation bears no relation whatever to need, but is a function of the coldness of winter. The coldest winter may come at a time when the lake has no need of any further lift. In the Niagara River the effect of ice is practically negligible so far as the level of Lake Erie is concerned.

10. The regulating works recommended by me take the one from nature and the ice dam by providing a form of dam which practically retains, when the gates are lifted, the original outflow section of a river. This insures the avoidance of unduly high lake stages.

11. It is proposed to place three piers on the solid limestone bottom of the upper Niagara River, perhaps a thousand feet below the Buffalo Water Works' intake pier. These three piers, with gates to work from truss work built upon these piers, intercept, when the gates are lowered, about 500 feet of the river flow. The piers are spaced so as to have a clear waterway of 240 feet. With this clear waterway between piers no danger of ice blockades will be present. This is a known fact because the International Bridge crossing the river a little further below has clear openings of from 187 feet to 235.8 feet. The clear openings for the regulating works proposed by me are greater than any opening of the International Bridge. The plan proposed is shown in sheet 1 appended to this report.

12. The regulating works are designed to lessen the river flow at any time by about 30,000 cubic feet per second. Should the gates remain permanently closed, this would result in raising Lake Erie a little less than a foot and a half. It is purposed, however, to operate the gates so that the flow is intermittent. That is, the gates during the open season will perhaps be wide open during certain of the daylight hours and closed during the night hours. The effect of this will be to create night conservation for larger daylight flow. The resulting effect on Lake Erie will, as before stated, be perhaps a betterment in level of 1 foot. It should be stated, however, that the betterment of level would consist in the avoidance of levels below 573 rather than in any attempt to keep the lake at high lake levels.

13. The conditions leading to the intermitten regulation of the flow of the Niagara River are developed from the following conditions of the three uses of the water of Lake Erie and the Niagara River. Only one use, that for power, needs to go on continuously 24 hours a day, and every day in the year. Navigation has a duration of 8 months out of 12. Scenic grandeur, so far as it depends on great volume of flow, may be limited to the six months, May to October, inclusive, and to the daylight hours of those months. As pointed out in my report on the preservation of Niagara Falls (S. Doc. No. 105, 62d Cong., 1st sess.) during the winter months volume of flow is subordinated, because ice and frost effects add new scenic beauty, and because visitors are few; perhaps a tenth of all visitors coming in the months November to April.

14. Notwithstanding the closing in of the night or the absence of seeing eyes, the splendid barbaric, prodigality of nature maintains the seaward rush of the waters. Just a lttle lessening comes in the midwinter months, when ice affects a slight restraint. During the night hours a chance is presented to lessen the prodigal waste and to store up water to maintain in the daylight spectacle much of its natural grandeur.

15. Taking 200,000 cubic second-feet as the mean river flow, after deducting all up-lake diversions, and 572.2 as the corresponding Lake Erie elevation, suppose by proper controlling works at the head of the Niagara River the flow is increased to 220,000 cubic second-feet during 8 hours each day and reduced to 190,000 feet for 16 hours. Exactly the same amount of water is discharged from Lake Erie in the 24 hours, and no effect whatever appears on Lake Ontario. To accomplish this large increase of daylight discharge Lake Erie must be as high as elevation 573.1, and the controlling works must be designed to shut off 30,000 cubic second-feet, or 15 per cent. of the mean flow. Tentative figures indicate that a section of controlling gates from 400 to 500 feet in length will suffice to accomplish the change in flow desired.

16. The evolution of this simple method of nighttime storage is interesting:

On page 76 of my report on the Preservation of Niagara Falls is the following:

"The Falls are operative only as a scenic spectacle during the daylight hours. When the night shuts in partial depletion would not be scenically injurious. Such permits issue for half the flow of the river from sunset to sunrise, or for 12 or 16 hours every day, a tremendous power would become available that would furnish its own light, and factories might work by night instead of by day. The temporary lowering of the river would immediately readjust itself when the sunrise shutdown came. The interference with night navigation on the river would not be prohibitive in view of the benefits to be conferred in cheap power and light. The use of the night power at Niagara implies regulation of Lake Erie's outflow."

Maj. Charles Keller, of the Corps of Engineers, in commenting on my suggestion, states (p. 16, S. Doc. 105):

"As compensation for the restrictions necessarily im-

posed, the suggestion * * * that the power companies be permitted to use half the flow of the river between sunset and sunrise is worthy of consideration. Many factories now run at night, and if the rate for power used between sunset and sunrise were made appreciably lower than the rate ruling during daylight hours, the amount of night use would probably increase. A further development of the storage battery might even render it commercially possible to use in the daytime the surplus power of the larger volume of night diversion. Such enlarged use of water at night, unless compensated, would result in a lowering of the level of Lake Erie. The necessary compensation works should, of course, be erected at the expense of the beneficiaries—the power companies."

The storage battery mentioned has its counterpart in the proposed storage of water in Lake Erie, for the purpose of making practicable the utilization of water according to the treaty with Great Britain, without diminishing too greatly the volume of flow on which the scenic grandeur largely depends. Instead of electric potential in the battery, the storage of water gives hydraulic potential.

17. As to the regulation of Lake Erie, it is not purposed necessarily to lessen the amplitude of the yearly stage cycle, except in the avoidance of elevations below, say, 572.5 and above 574. The flow should be unrestricted during the months of January, February, March, and April to avoid low river levels. The gates may be continuously closed during November and December. During the months May to October, inclusive, storage by night with a river flow of 190,000 cubic second-feet and by day a heavy flow of 220,000 feet would be the normal condition.

18. No detailed analysis of the effect to be produced on Lake Ontario has been made. It should be understood, however, that the initial impounding to bring Erie to an annual mean elevation of 573.1 should be at a time of generous supply. The holdup of 10,000 cubic second-feet in November and December will raise Erie 0.3 feet and lower Ontario 0.4 feet. The increased flow of January to April will compensate these changes. In periods of scant supply, as in 1895-96, an adjustment between Erie and Ontario would need to be made.

19. As regards Michigan-Huron, a betterment of Erie's level by 10 inches may lift these lakes 3 inches. Lake St. Clair would benefit to the extent of 6 inches or more.

20. The results to be obtained will be a betterment of conditions for the power companies, because the greater winter flow will lessen the difficulties coming from combinations of ice and low water. Nighttime storage will return to the daylight flow an amount of water equal to that permissible for the American side at Niagara Falls under the treaty with Great Britain. Navigation in Lake Ontario will not suffer substantially, and navigation in Lake Erie and above will be greatly improved.

FRANCIS C. SHENEHON.

Opposite hereto are inserted plates 1-10, which appear in said report opposite p. 38

and

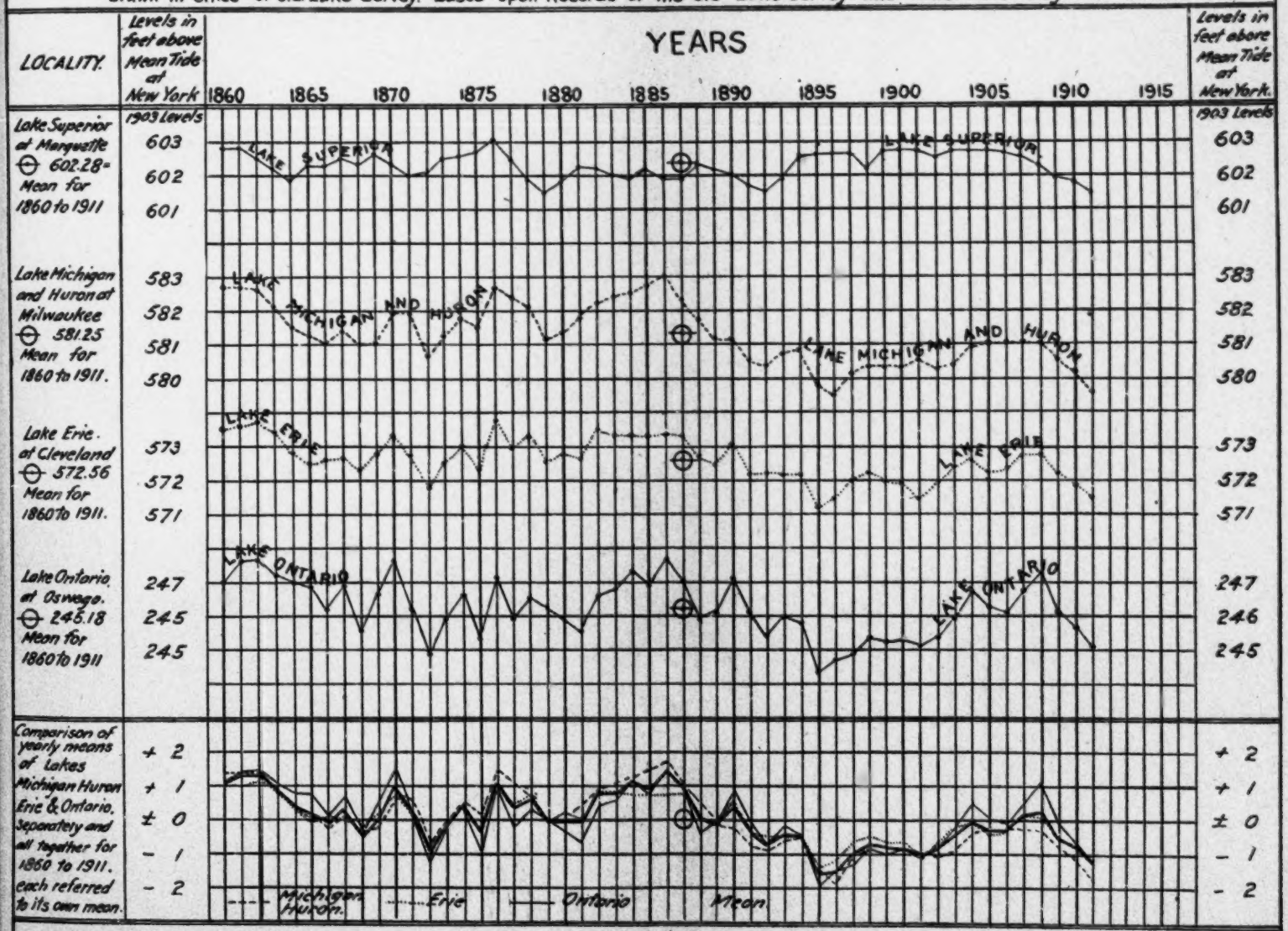
Plates 1-4 which appear in said report opposite p. 48.

WAR DEPARTMENT. CORPS OF ENGINEERS, U. S. ARMY.

SURFACE LEVELS OF THE GREAT LAKES

CURVES OF ANNUAL MEANS OF EACH LAKE FROM 1860 TO 1911.

Under direction of Brigadier General W. H. BIXBY, Chief of Engineers, Washington, D.C., November. 1911.
Drawn in Office of U.S. Lake Survey. Based upon Records of the U.S Lake Survey and other U.S. Engineer Offices.



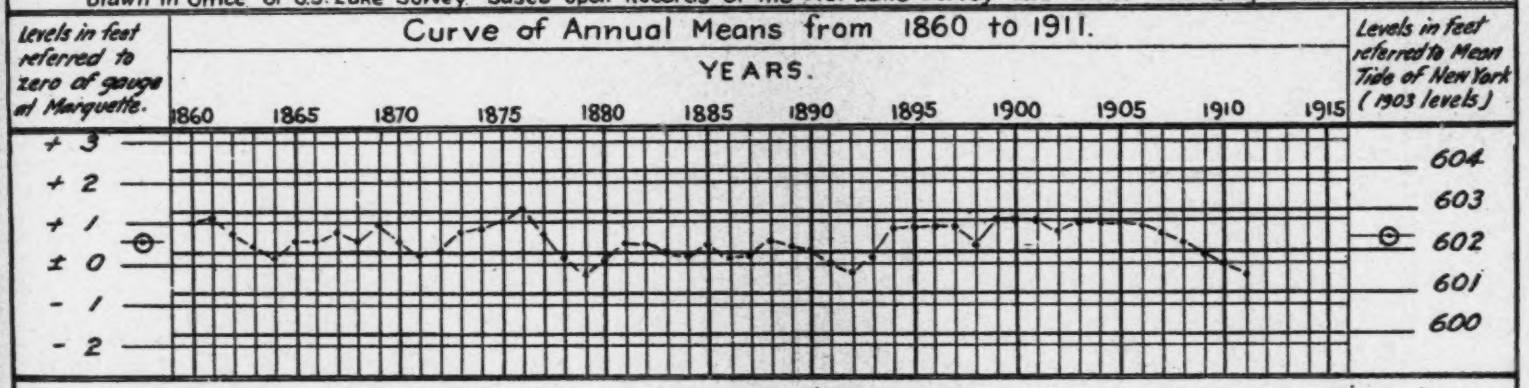
APPENDIX A. PLATE 1. To accompany report of Board appointed by Secretary of War in S.O.* 43. Office of Chief of Engineers. U.S. Army Sept. 8. 1910.

THE HOOVER PRINTING CO., WASHINGTON, D. C.

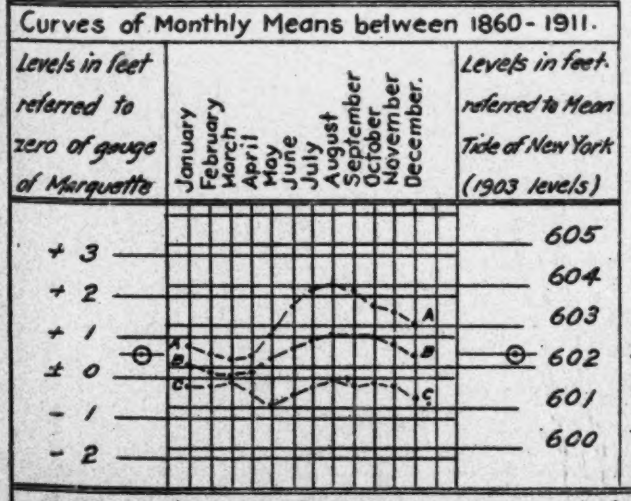
WAR DEPARTMENT. CORPS OF ENGINEERS, U.S. ARMY.

SURFACE LEVELS OF LAKE SUPERIOR AT MARQUETTE, MICH.

Under direction of Brigadier General W. H. BIXBY, Chief of Engineers. Washington, D.C., November, 1911.
Drawn in Office of U.S. Lake Survey. Based upon Records of the U.S. Lake Survey and other U.S. Engineer Offices.



Zero of Marquette gauge = 601.75 above New York (U.S. Lake Survey level adjustment of 1903)
Mean level for 1876 or highest annual mean = 603.06, Highest monthly mean = 604.08. Sep. 1869.
" " " 1879 lowest " " = 601.43. Lowest " " = 600.54. Apr. 1911.
" " " Averages for 52 years or for 1860 to 1911 incl. = 602.28 (see in side columns)



A - curve of 1876 or year of highest annual mean.
B - " " averages for 52 years, 1860 to 1911.
C - " " 1879 or year of lowest annual mean.
⊖ Represents the Average for 52 years, 1860 to 1911 incl. = 602.28.

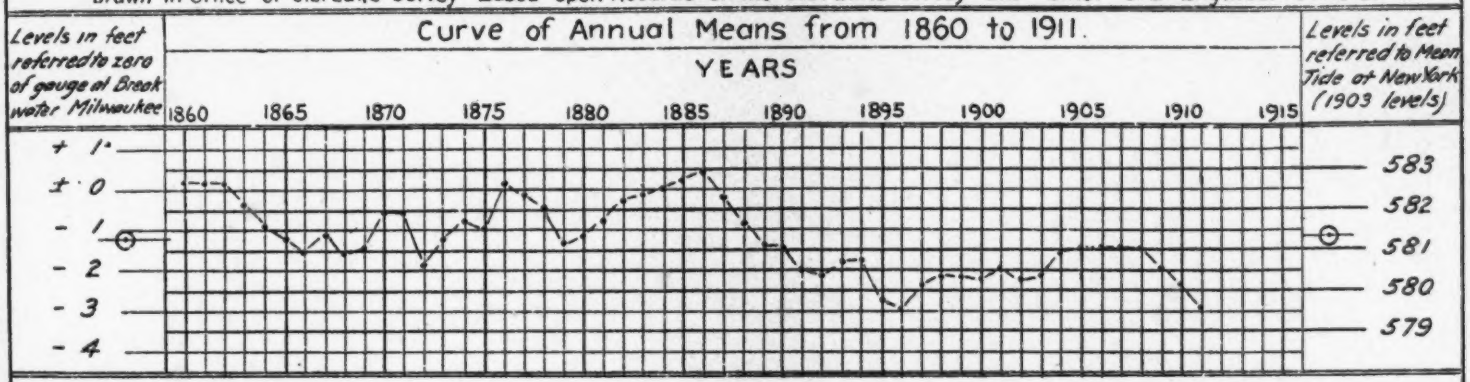
APPENDIX A. PLATE 2. To accompany report of Board appointed by Secretary of War in S. O. # 43. Office of Chief of Engineers, U.S. Army. Sept. 8. 1910.

House Doc. No. 762 ; 63d Cong., 2d Sess.

WAR DEPARTMENT. CORPS OF ENGINEERS, U.S. ARMY.

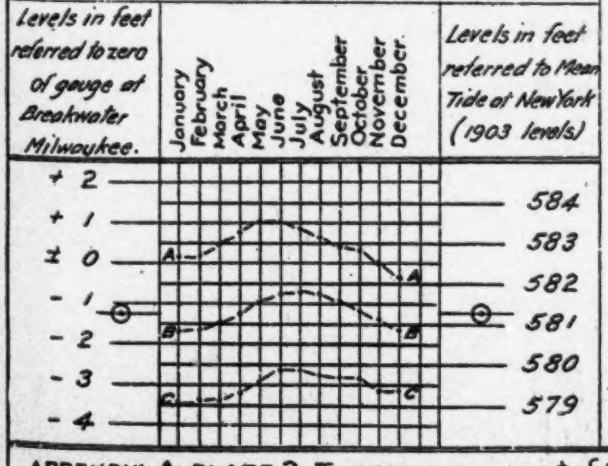
SURFACE LEVELS OF LAKE MICHIGAN AT MILWAUKEE, WIS.

Under direction of Brigadier General W. H. BIXBY, Chief of Engineers, Washington, D.C., November, 1911
Drawn in Office of U.S. Lake Survey Based upon Records of the U.S. Lake Survey and other U.S. Engineer Offices.



Zero of Milwaukee gauge = 582.53 above New York (U.S. Lake Survey level adjustment of 1903)
Mean level for 1886 or highest annual mean = 582.96. Highest monthly mean = 583.57 June, 1886
" " " 1896 = lowest " " = 579.47 Lowest " " = 578.98 Dec. 1895
" " " Averages for 52 years or for 1860 to 1911, incl. = 581.25 (see ○ in side columns.)

Curves of Monthly Means between 1860-1911.



A = curve of 1886 or year of highest annual mean.
B = " " averages for 52 years 1860 to 1911.
C = " " 1896 or year of lowest annual mean.
⊖ Represents the Average for 52 years, 1860 to 1911, incl. = 581.25

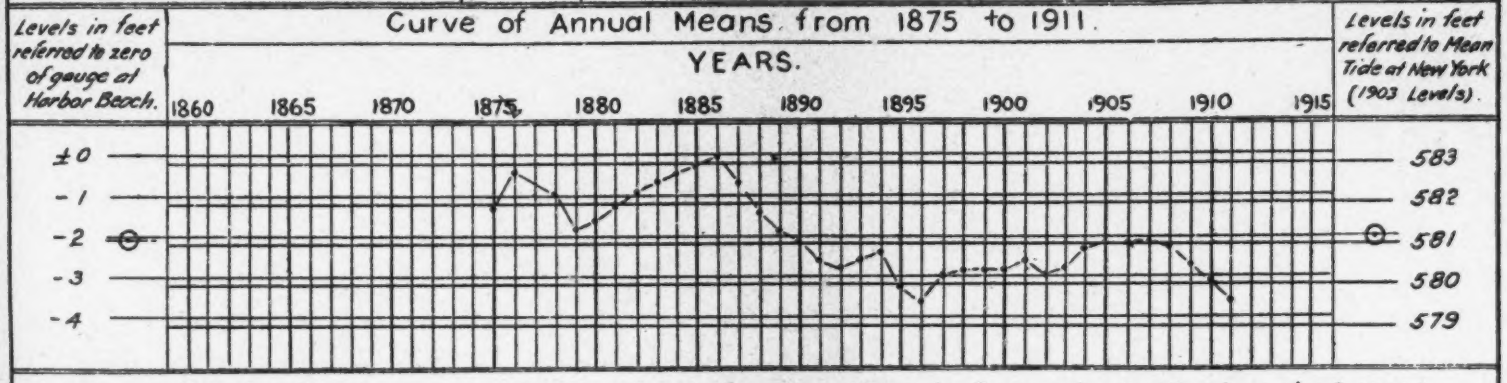
APPENDIX A, PLATE 3. To accompany report of Board appointed by Secretary of War in S.O. #43, Office of Chief of Engineers, U.S. Army, Sept. 8, 1910.

THE HARRIS PRINTING CO., WASHINGTON, D.C.

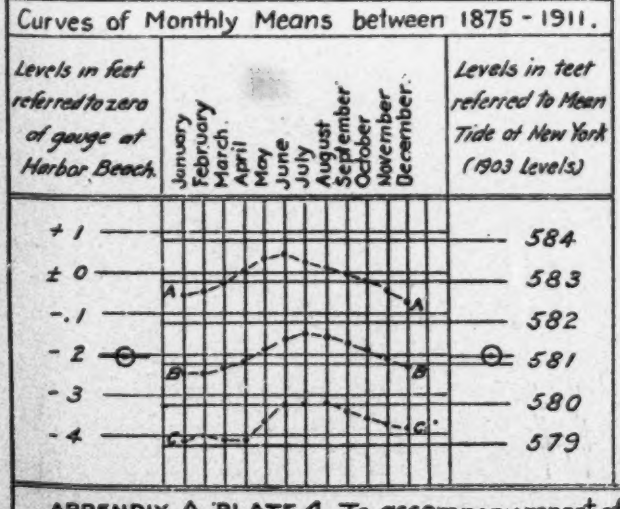
WAR DEPARTMENT. CORPS OF ENGINEERS U.S. ARMY.

SURFACE LEVELS OF LAKE HURON AT HARBOR BEACH, MICH.

Under direction of Brigadier General W. H. BIXBY, Chief of Engineers, Washington, D.C., November, 1911.
Drawn in Office of U.S. Lake Survey, Based upon Records of the U.S. Lake Survey and other U.S. Engineer Offices.



Zero of Harbor Beach gauge = 583.21 above New York (U.S. Lake Survey level adjustment of 1903)
Mean level for 1886 or highest annual mean = 583.08. Highest monthly mean = 583.66. July 1876.
" " " 1896 or lowest " " " = 579.53. Lowest " " = 579.02. Dec. 1895.
" " " Averages for 37 years or for 1875 to 1911 incl. = 581.14 (See ⊖ in side columns.)



A = Curve of 1886 or year of highest annual mean
B = " " Averages for 37 years, 1875 to 1911
C = " " 1896 or year of lowest annual mean
⊖ Represents the average for 37 years, 1875 to 1911 incl. = 581.14.

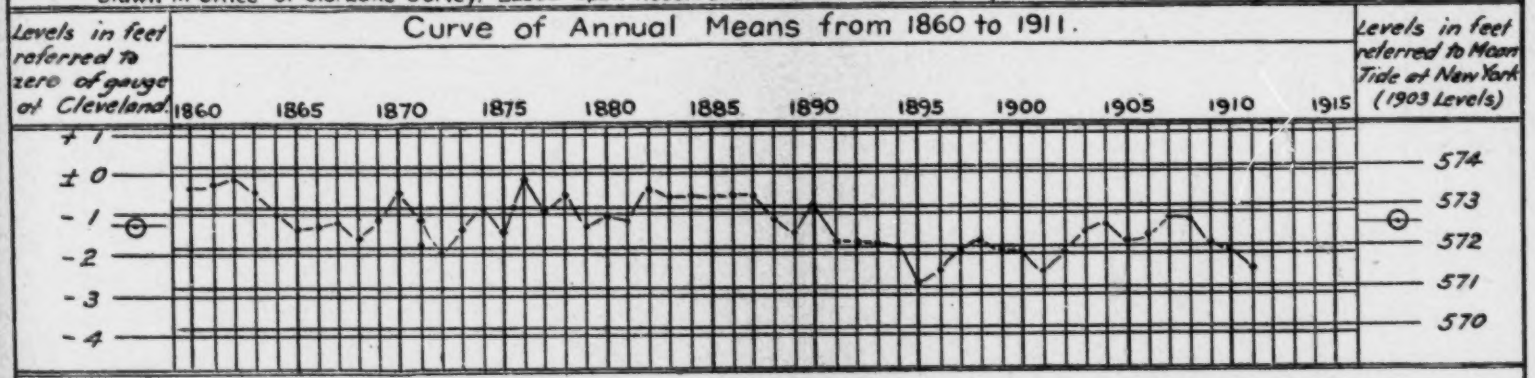
APPENDIX A. PLATE 4. To accompany report of Board appointed by Secretary of War in S.O. # 43. Office of Chief of Engineers, U.S. Army. Sept. 8, 1910.

THE HARRIS-PETERSON CO. WASHINGTON, D.C.

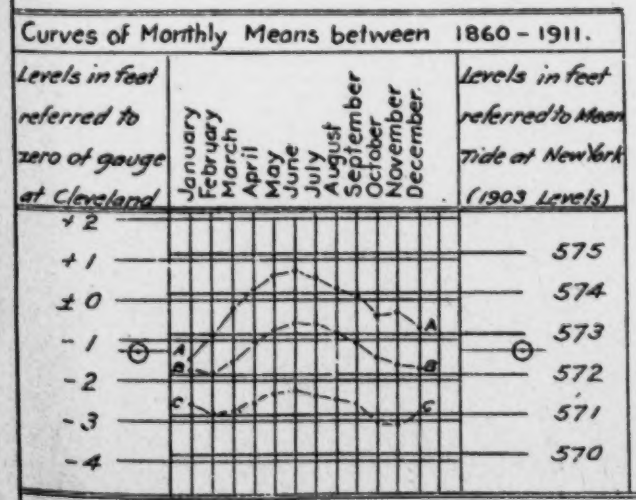
WAR DEPARTMENT. CORPS OF ENGINEERS, U.S. ARMY.

SURFACE LEVELS OF LAKE ERIE, AT CLEVELAND, OHIO.

Under direction of Brigadier General W. H. BIXBY, Chief of Engineers. Washington, D.C., November, 1911.
Drawn in Office of U.S. Lake Survey. Based upon Records of the U.S. Lake Survey and other U.S. Engineer Offices.



Zero of Cleveland Gauge 573.82 above New York (U. S. Lake Survey Levels of 1903.)
Mean Level for 1876 or Highest Annual Mean = 573.70. Highest Monthly Mean = 574.52 June, 1876.
" " " 1895 = Lowest " " = 571.17. Lowest " " = 570.70 Nov. 1895.
" " " Averages for 52 Years or for 1860 to 1911 incl. = 572.56 (see ⊖ in Side Columns.)



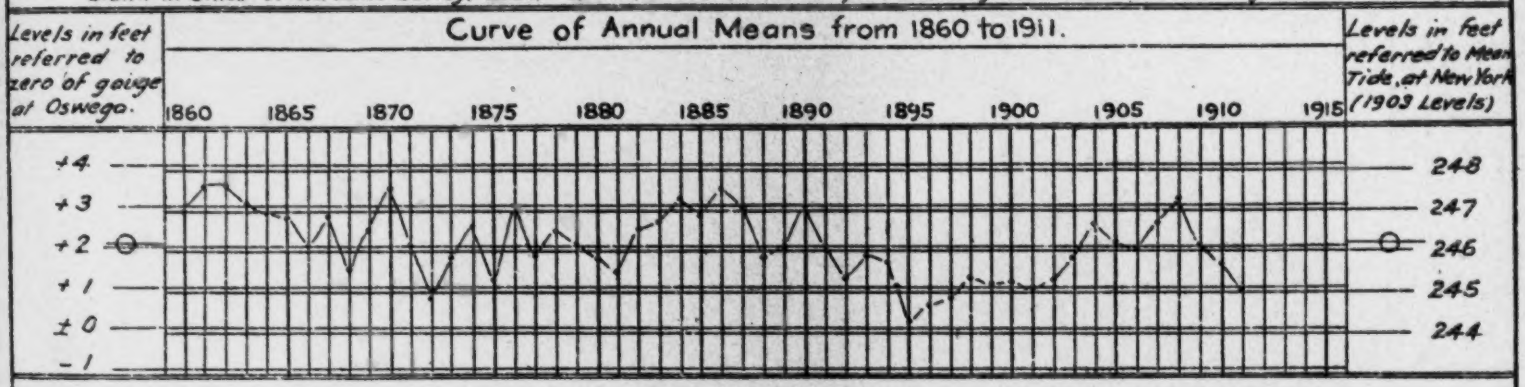
A = Curve of 1876 or of highest annual mean.
B = " " Averages for 52 years 1860 - 1911.
C = " " 1895 or of lowest annual mean
⊖ Represents the Average for 52 years, 1860 to 1911 incl. = 572.56.

APPENDIX A. PLATE. 5. To accompany report of Board appointed by Secretary of War in S.O. 43. Office of Chief of Engineers, U.S. Army Sept 8-1910.

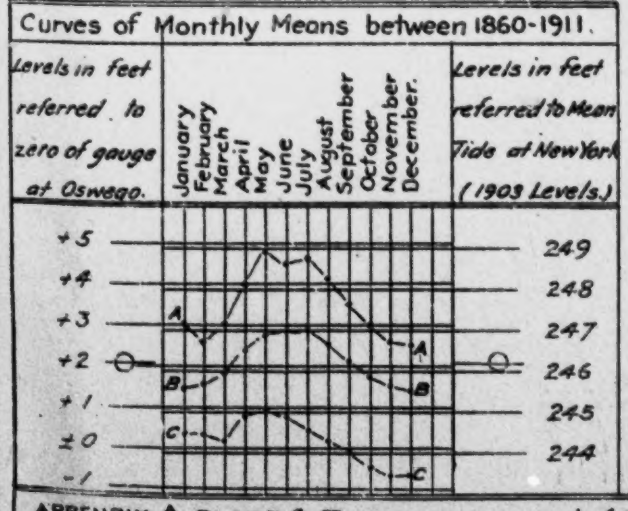
WAR DEPARTMENT. CORPS OF ENGINEERS U.S. ARMY.

SURFACE LEVELS OF LAKE ONTARIO AT OSWEGO, N. Y.

Under direction of Brigadier General W. H BIXBY, Chief of Engineers, Washington, D.C., November 1911.
Drawn in Office of U.S. Lake Survey. Based upon Records of the U.S. Lake Survey and other U.S. Engineer Offices.



Zero of Oswego Gauge 244.12 above New York (U.S. Lake Survey level Adjustment of 1903.)
Mean Level for 1862 or Highest Annual Mean = 247.63. Highest Monthly Mean = 248.95. May. 1870.
" " " 1895 - Lowest - " = 244.29. Lowest " " = 243.41, Nov. 1895
" " " Averages for 52 years or for 1860 to 1911 incl. = 246.18 (see -⊖- in Side Columns.)

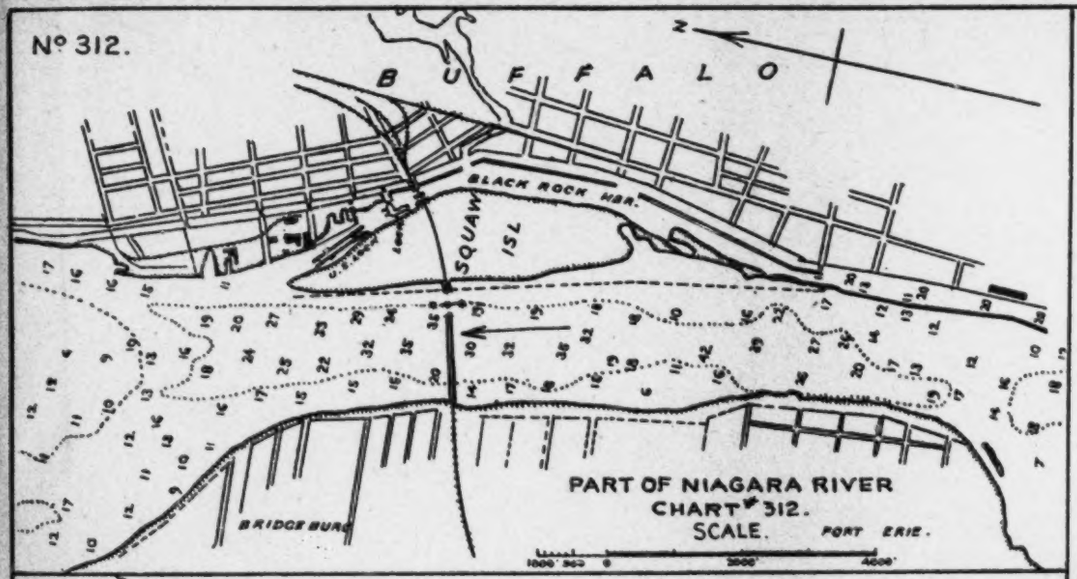


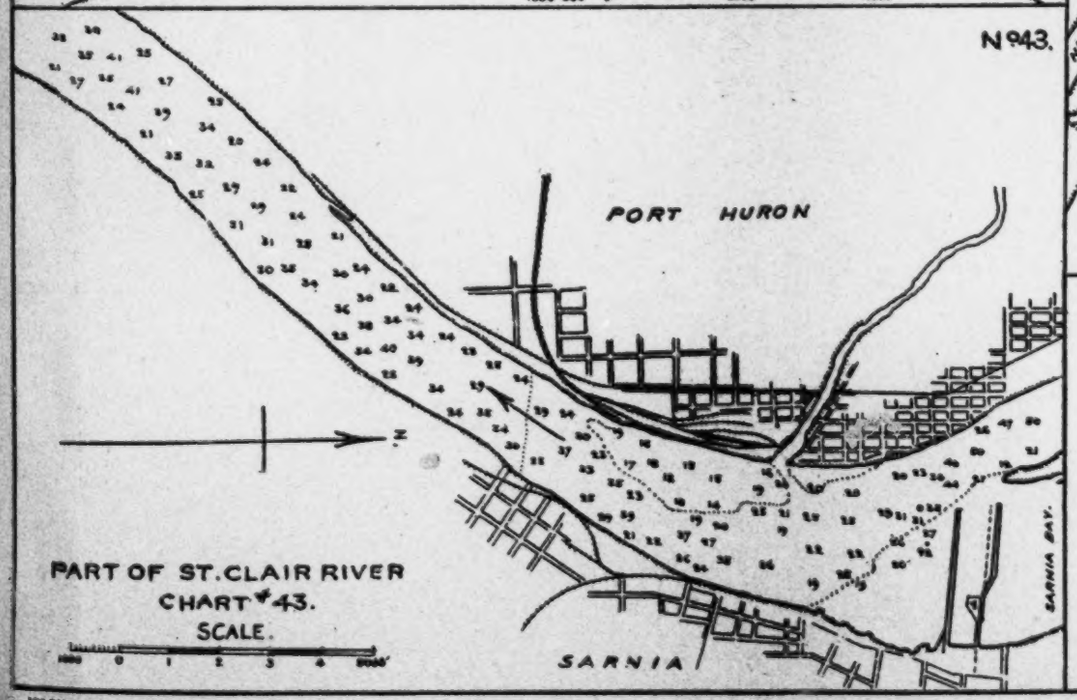
A - Curve of 1862. or year of highest annual mean.
B = " " Averages for 52 years. 1860 to 1911.
C = " " 1895, or year of lowest annual mean.
⊖ Represents the Average for 52 years. 1860 to 1911 incl. = 246.18.

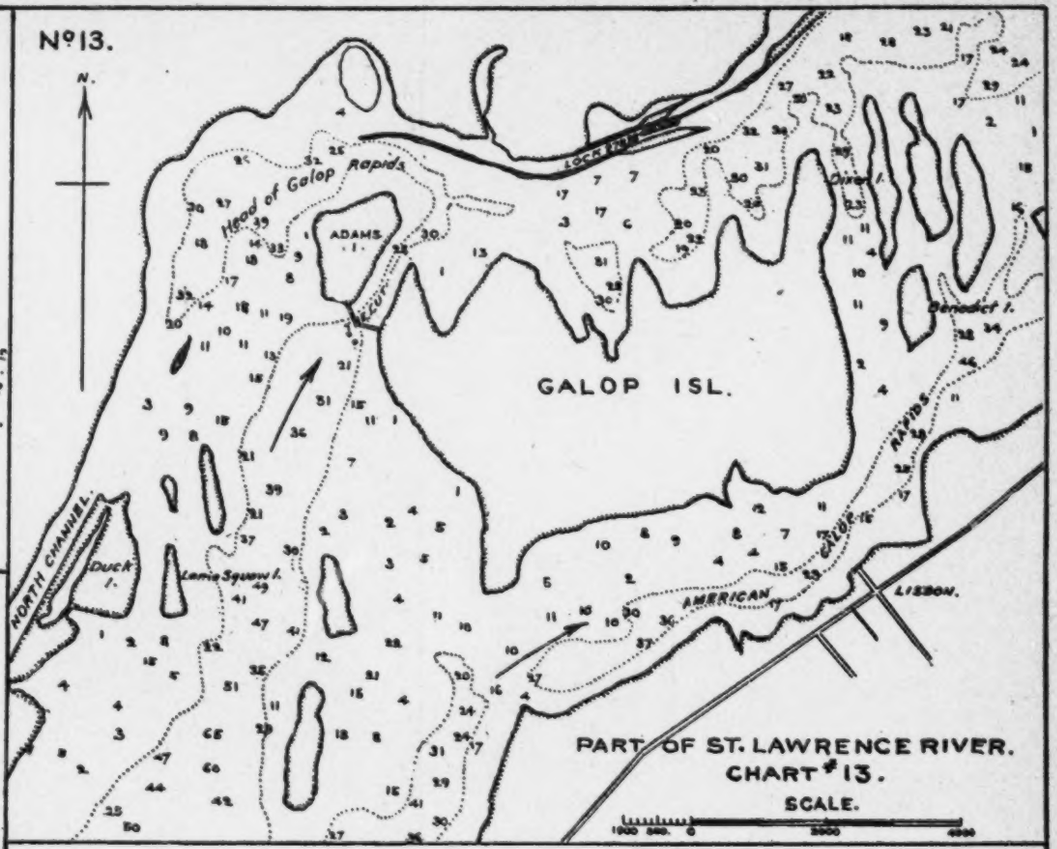
APPENDIX A. PLATE 6. To accompany report of Board appointed by Secretary of War in S.O. 43. Office of Chief of Engineers. U.S. Army. Sept. 8. 1910.

House Doc. No. 762 ; 63d Cong., 2d Sess.

WAR DEPARTMENT. CORPS OF ENGINEERS, U.S. ARMY.





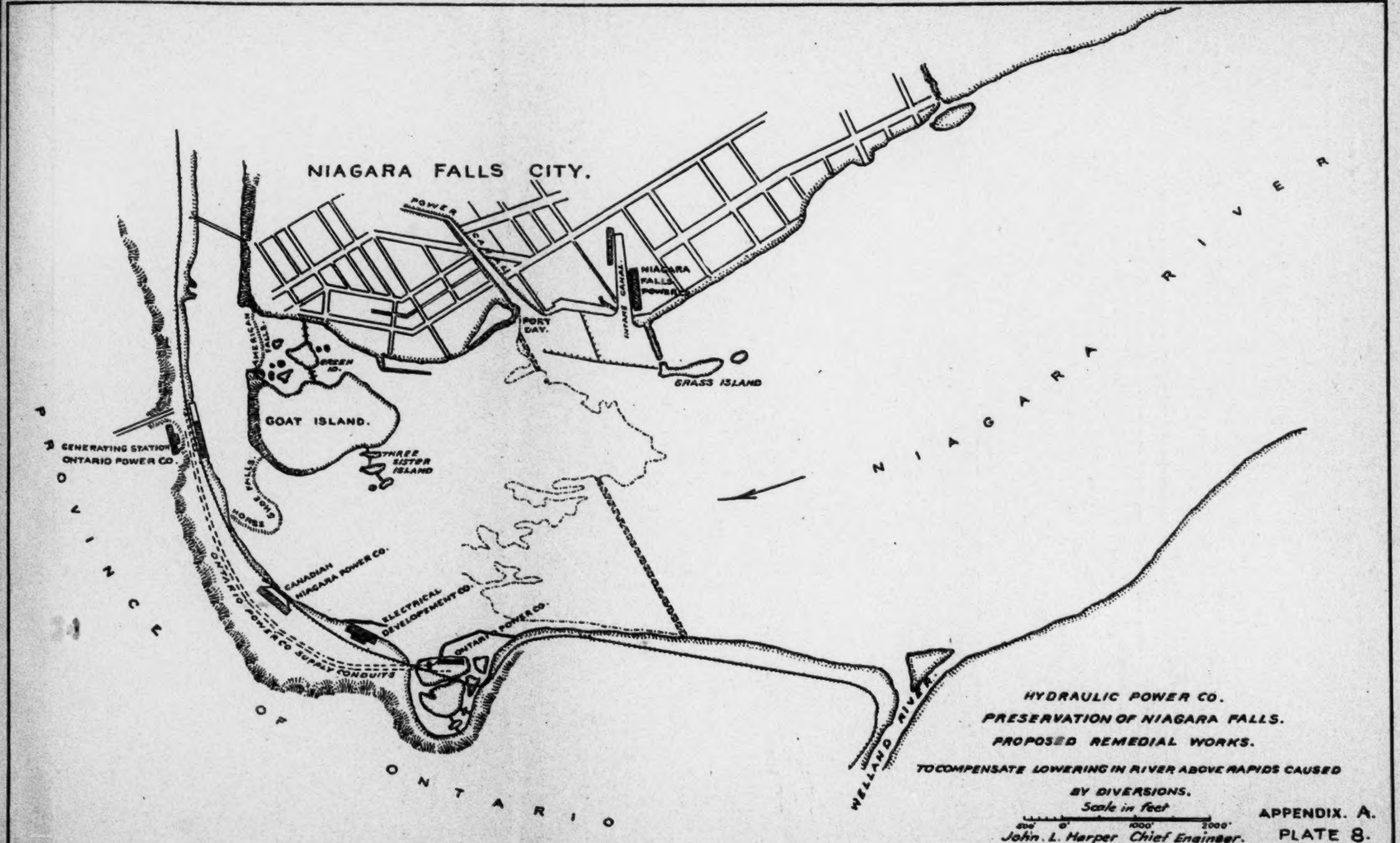


Extracts from U.S. Lake Survey Charts Nos 13,- 312, and 43 showing approximate locations of suggested compensation works.
To accompany Appendix "A" of Report of Board appointed by Secretary of War in S.O. 43. Office of Chief of Engineers. U.S. Army. Sept. 8. 1910.

APPENDIX A
PLATE. 7.

WAR DEPARTMENT.

CORPS OF ENGINEERS, U.S. ARMY.

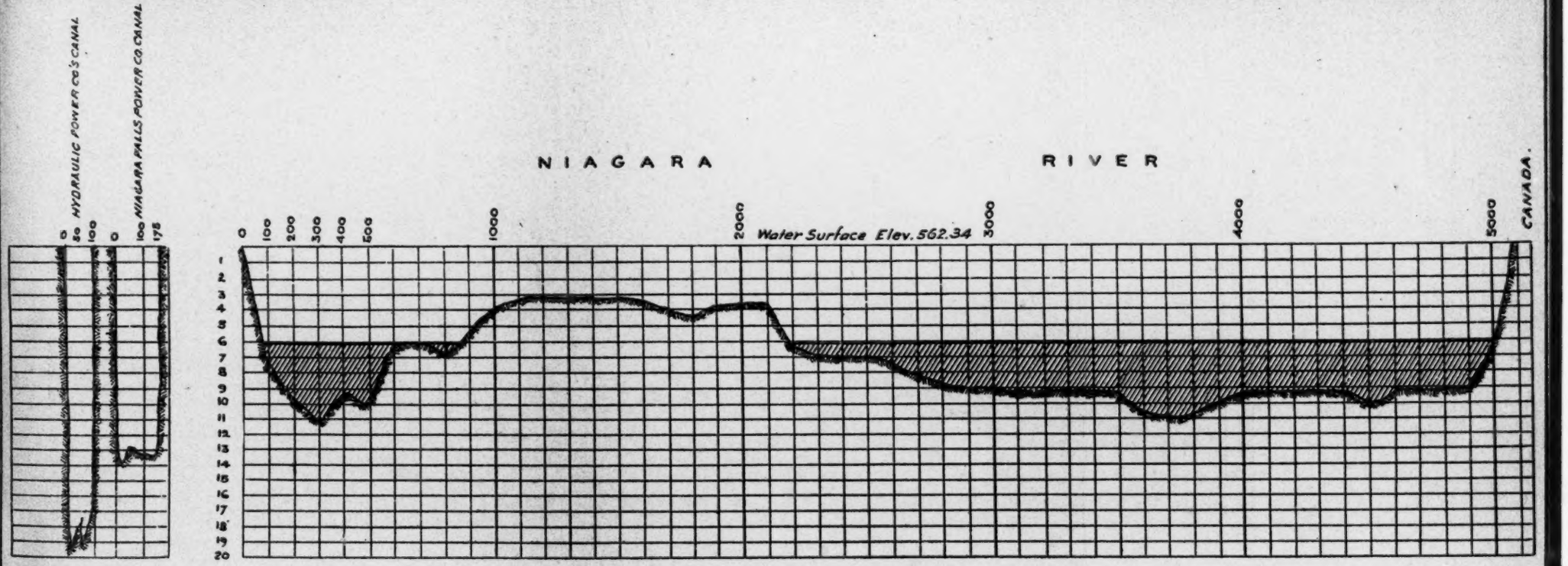


THE HOBBS PETERS CO. WASHINGTON D C

House Doc. No. 762 ; 63d Cong., 2d Sess.

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY.



Note · Water surface Elevation 562.34 is equivalent to Lake Erie Elevation 573.26.

HYDRAULIC POWER CO.

CROSS-SECTION OF RIVER

BELOW PORT DAY AND CHIPPEWA.

SHOWING PROPOSED COMPENSATING WEIRS.

ALSO

CROSS-SECTION OF POWER CANAL

ON AMERICAN SIDE.

HOR SCALE: 1" = 500'

VERT. " 1" = 8'

JOHN L. HARPER, CHIEF ENGINEER.

APPENDIX. A.

PLATE. 9.

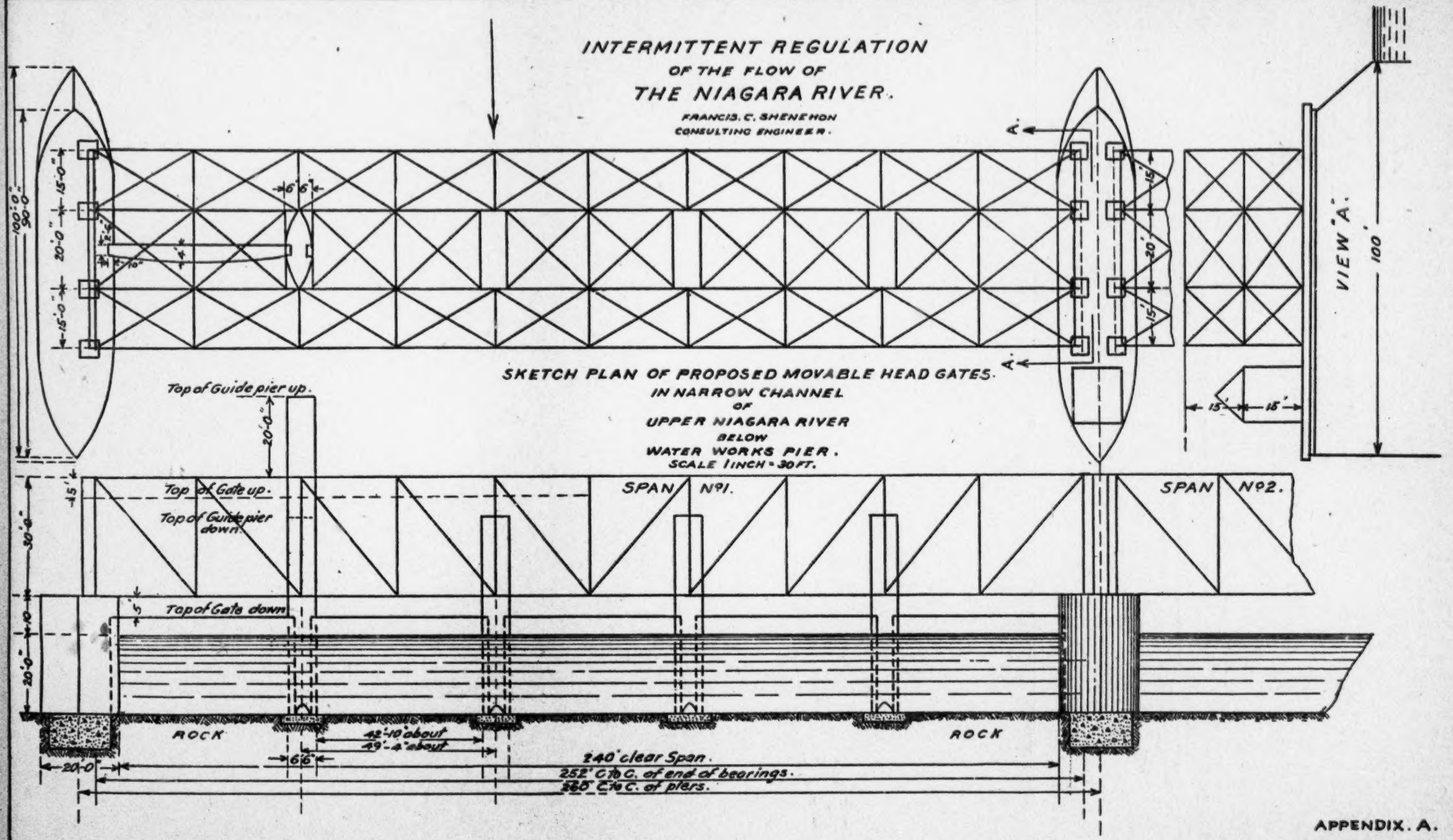
House Doc. No. 762 ; 63d Cong., 2d Sess.

WAR DEPARTMENT.

CORPS OF ENGINEERS U.S. ARMY.

INTERMITTENT REGULATION OF THE FLOW OF THE NIAGARA RIVER.

FRANCIS C. SHENEHON
CONSULTING ENGINEER.



SKETCH PLAN OF PROPOSED MOVABLE HEAD GATES
IN NARROW CHANNEL
OF
UPPER NIAGARA RIVER
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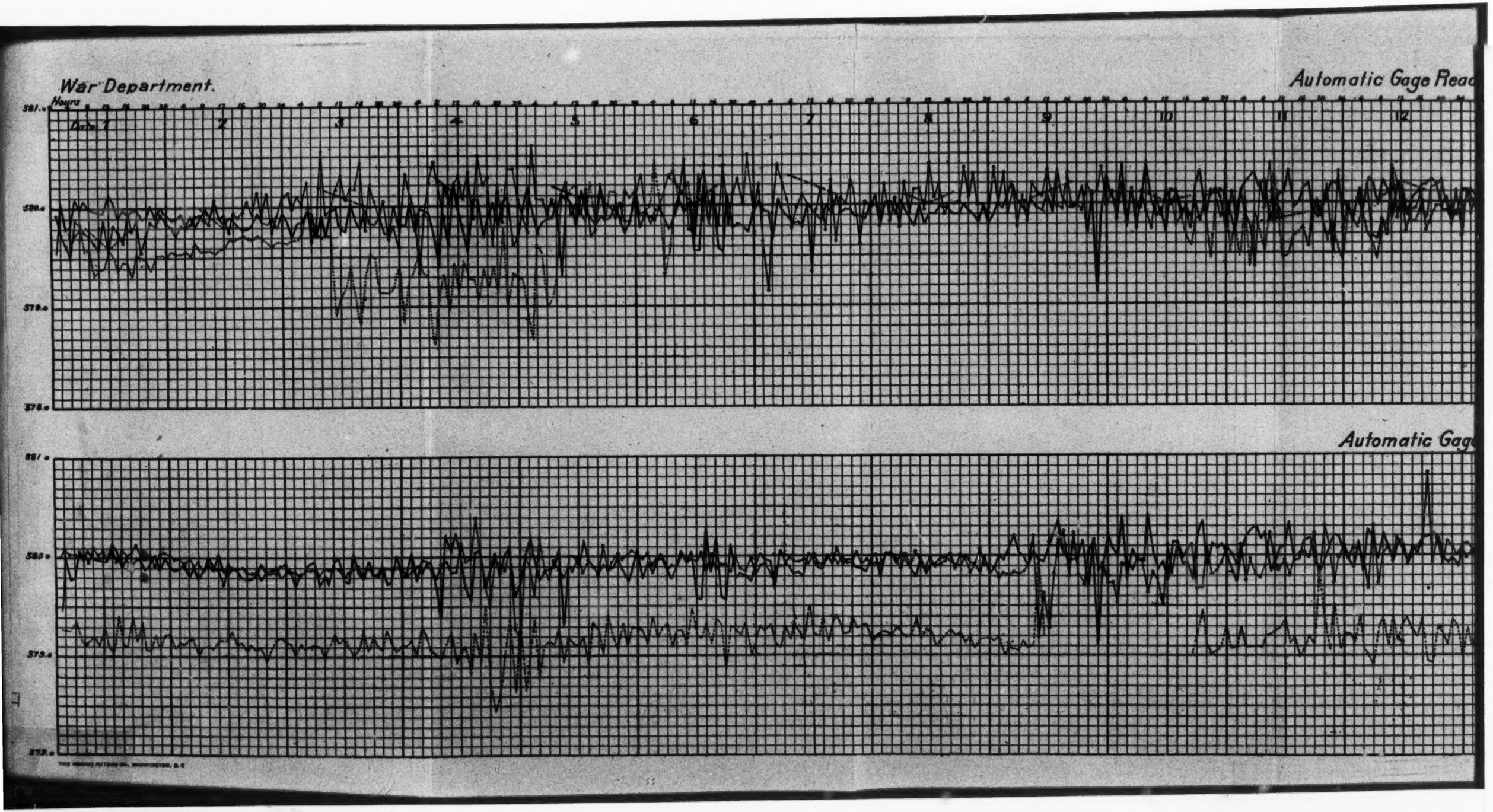
WATER WORKS PIER.
SCALE 1 INCH = 30 FT.

APPENDIX. A.
PLATE. 10.

THE HARRIS PETERS CO., WASHINGTON D. C.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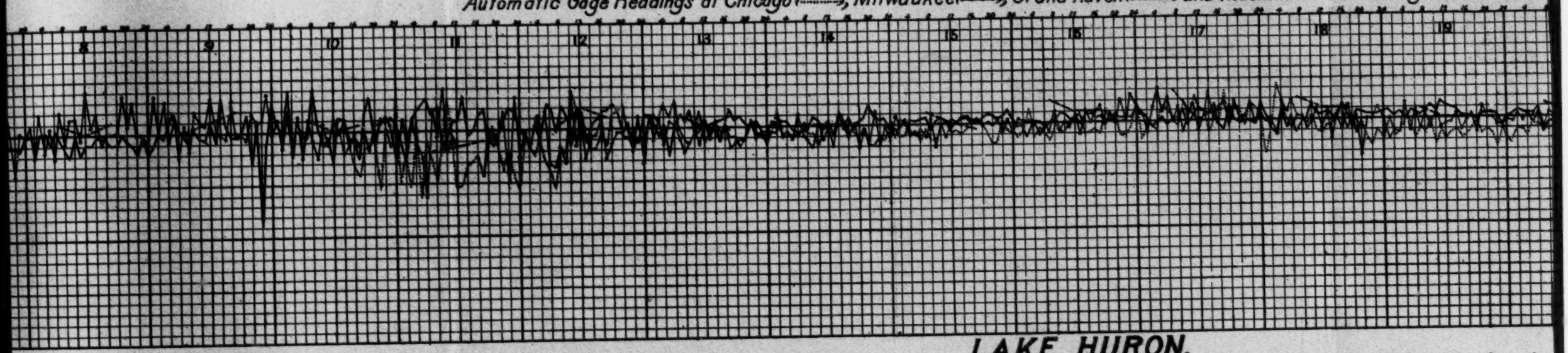
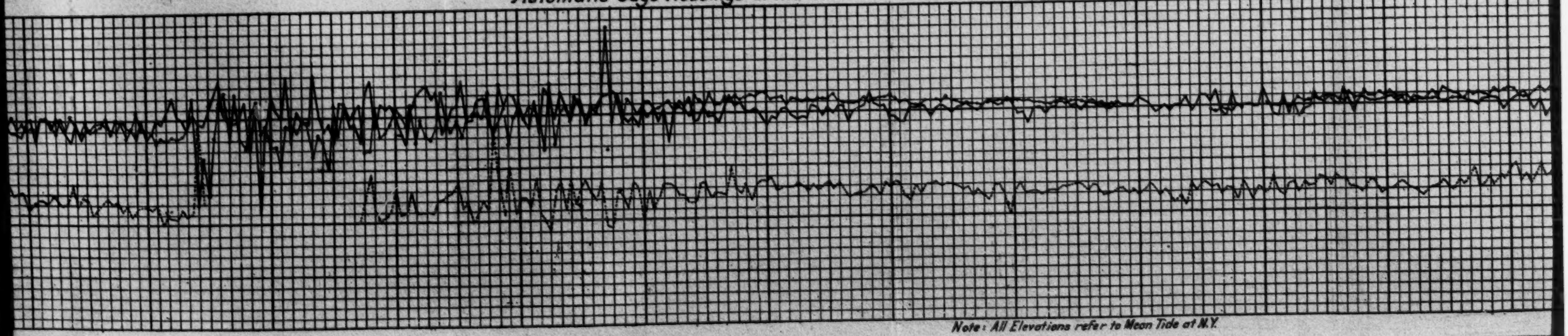
LAKE MICHIGAN.

Automatic Gage Readings at Chicago (·····), Milwaukee (– – –), Grand Haven (Staff Gage) and Mackinaw (——) during the Month of



LAKE HURON.

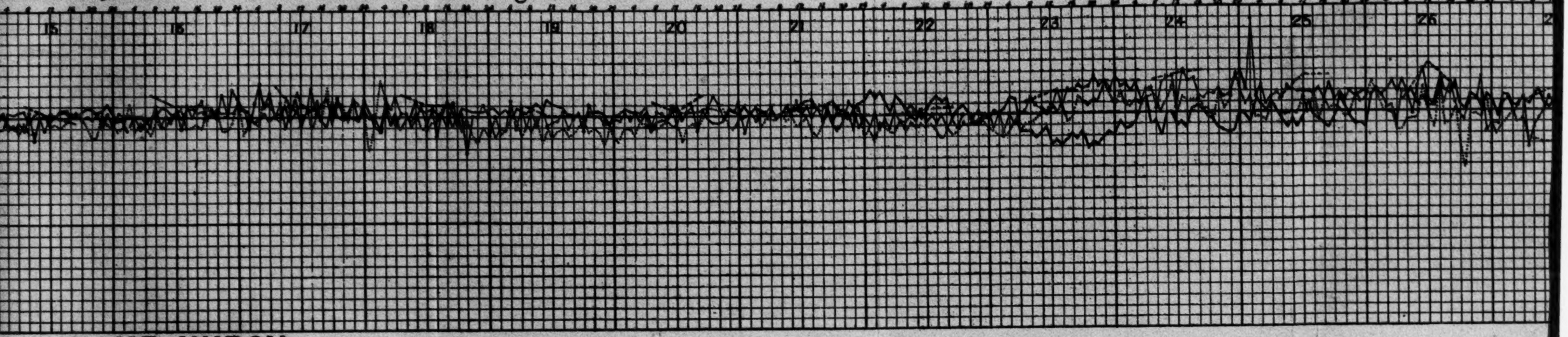
Automatic Gage Readings at Mackinaw (——) Harbor Beach (– – –) and Port Huron (——) during the Month of Jun



Note: All Elevations refer to Mean Tide at N.Y.

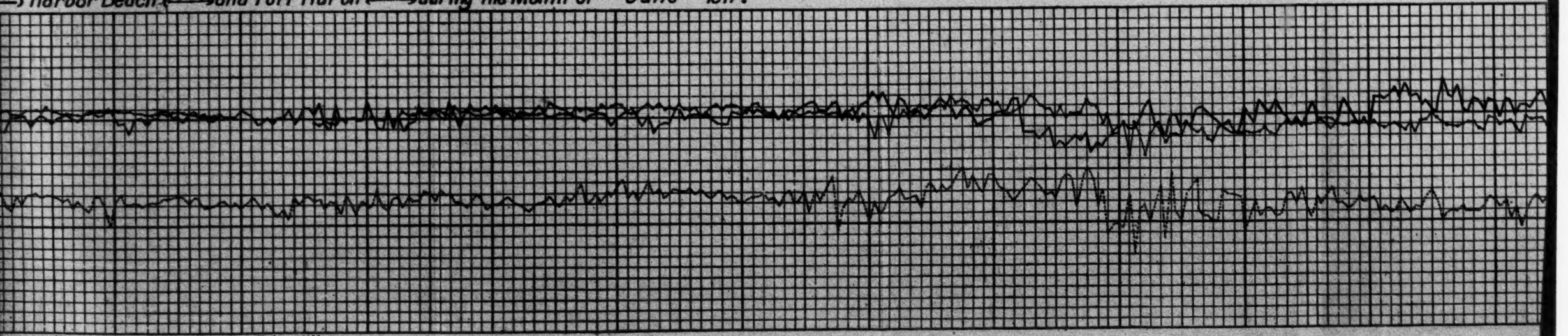
LAKE MICHIGAN.

aukee ←→ Grand Haven ←→ and Mackinaw ←→ during the Month of June 1911.



LAKE HURON.

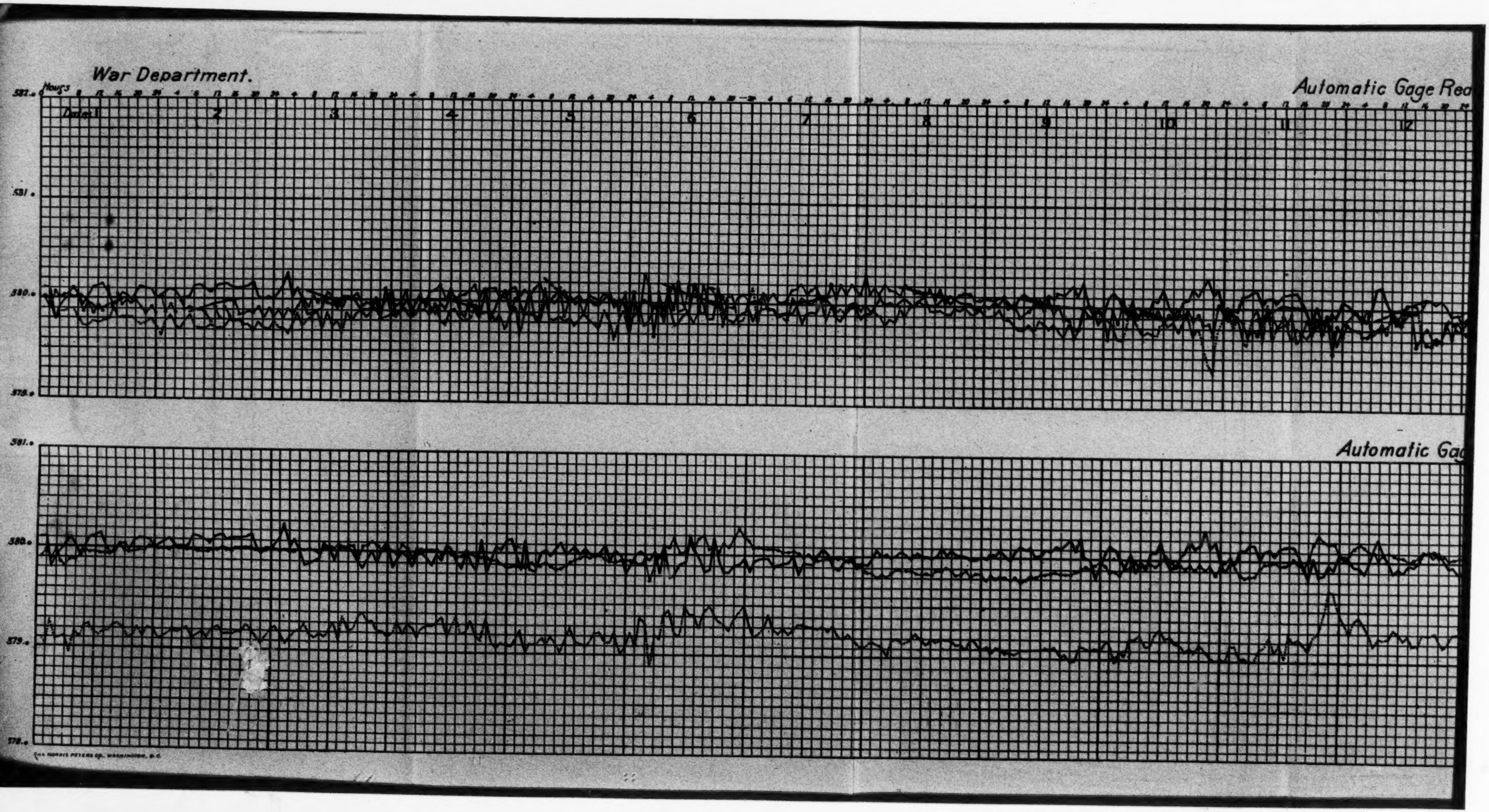
→ Harbor Beach ←→ and Port Huron ←→ during the Month of June 1911.



Note: All Elevations refer to Mean Tide at N.Y.

Corps of Engineers, U.S.Army.

Appendix C, Plate V.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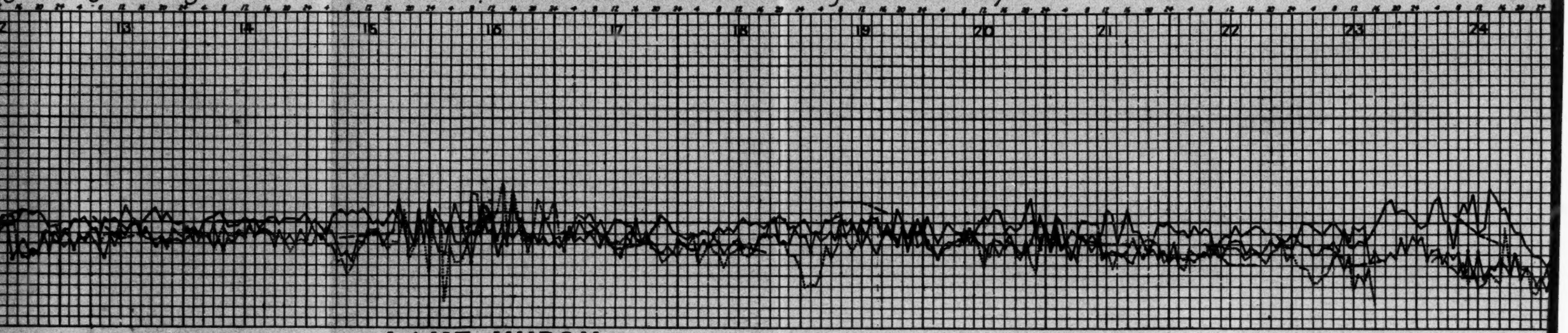
LAKE MICHIGAN

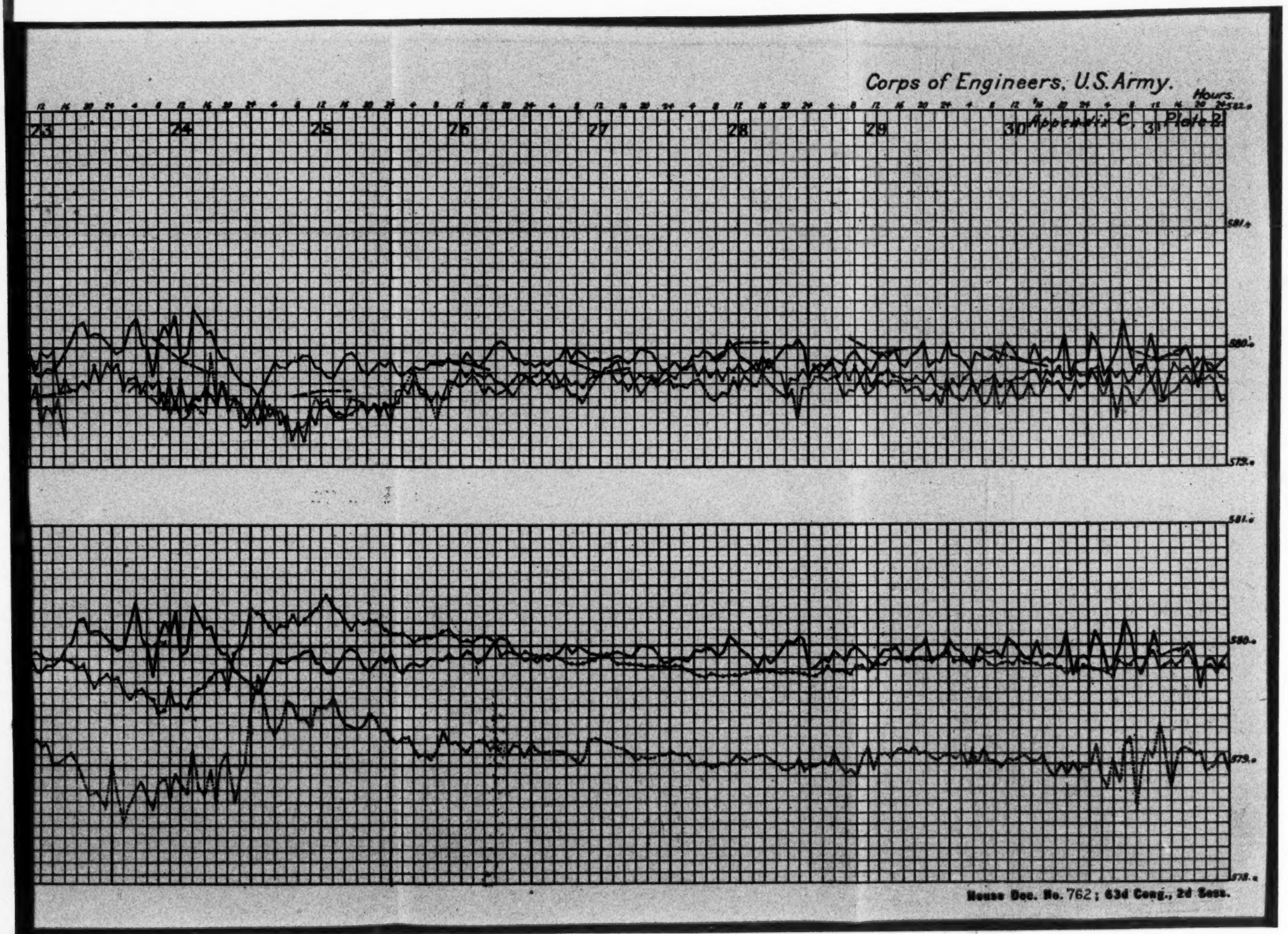
Gage Readings at Chicago (.....), Milwaukee (- - -) Grand Haven (Mail Boat) and Mackinaw (——) during the Month of July 1911.



LAKE HURON

Static Gage Readings at Mackinaw (——), Harbor Beach (- - -) and Port Huron (.....) during the Month of July 1911.

Note: All Elevations refer to Mean Tide at N.Y.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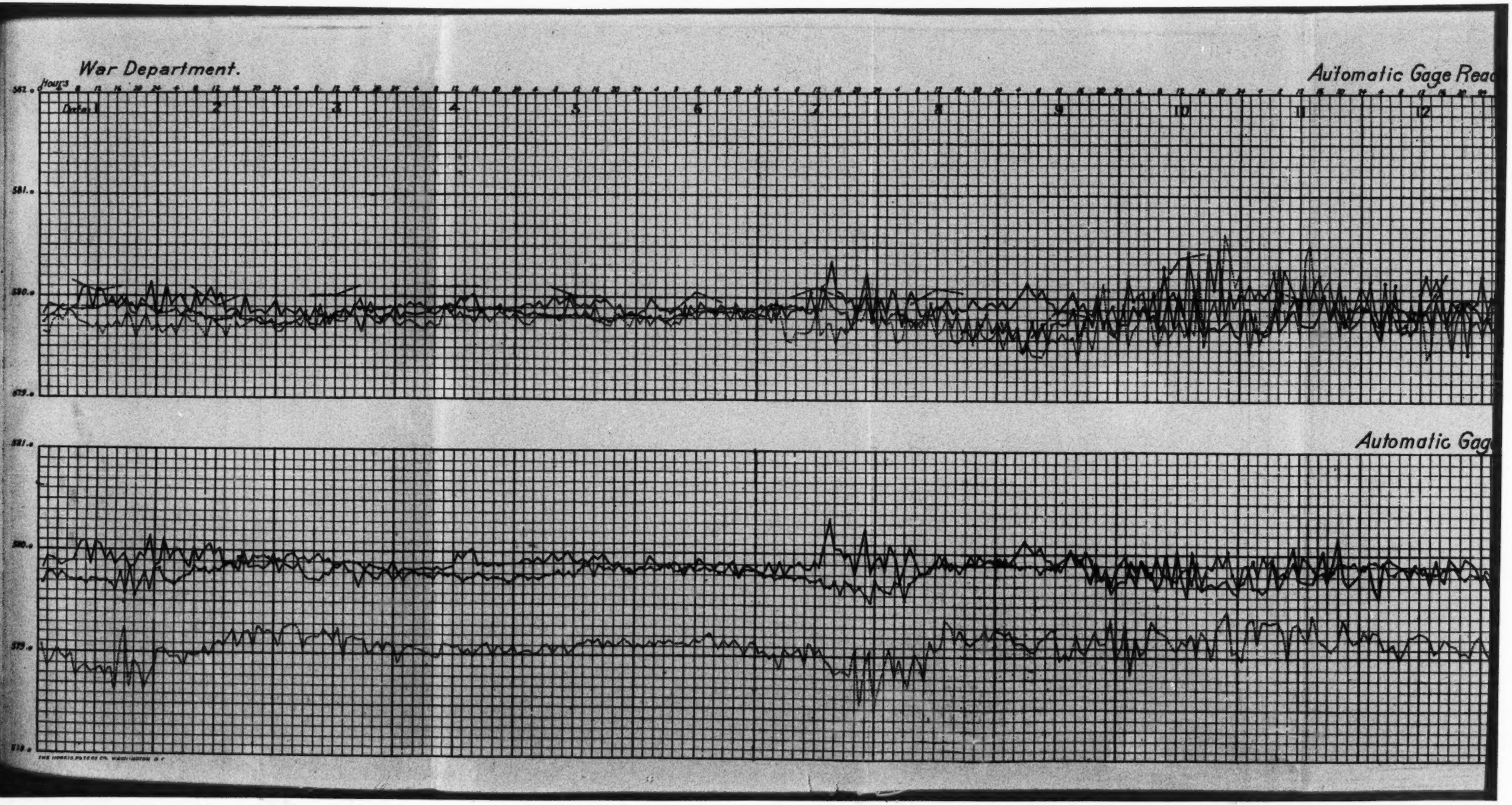
House Doc. No. 762; 63d Cong., 2d Sess.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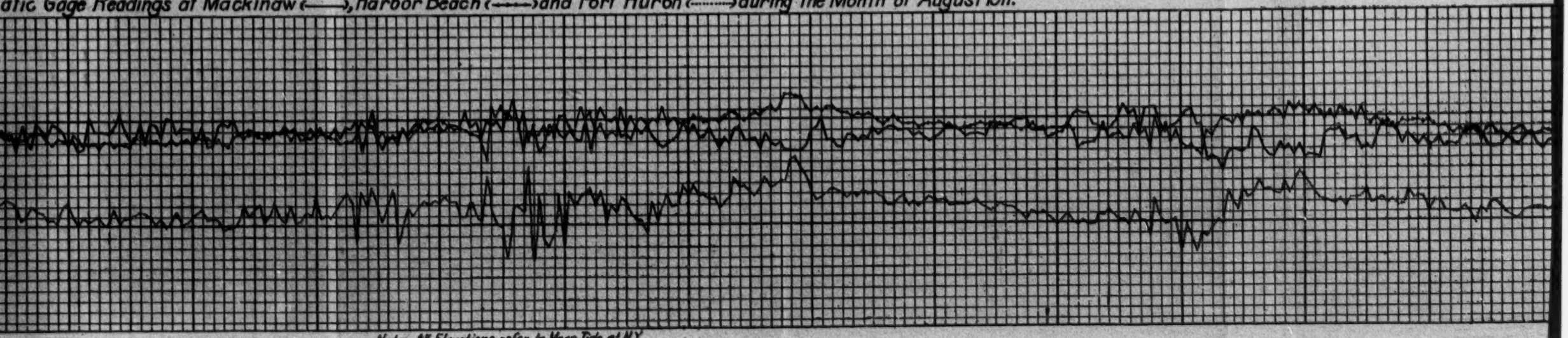
LAKE MICHIGAN

Gage Readings at Chicago (.....), Milwaukee (- - -), Grand Haven (Staff Gage) and Mackinaw (——) during the Month of August 1911.

LAKE HURON

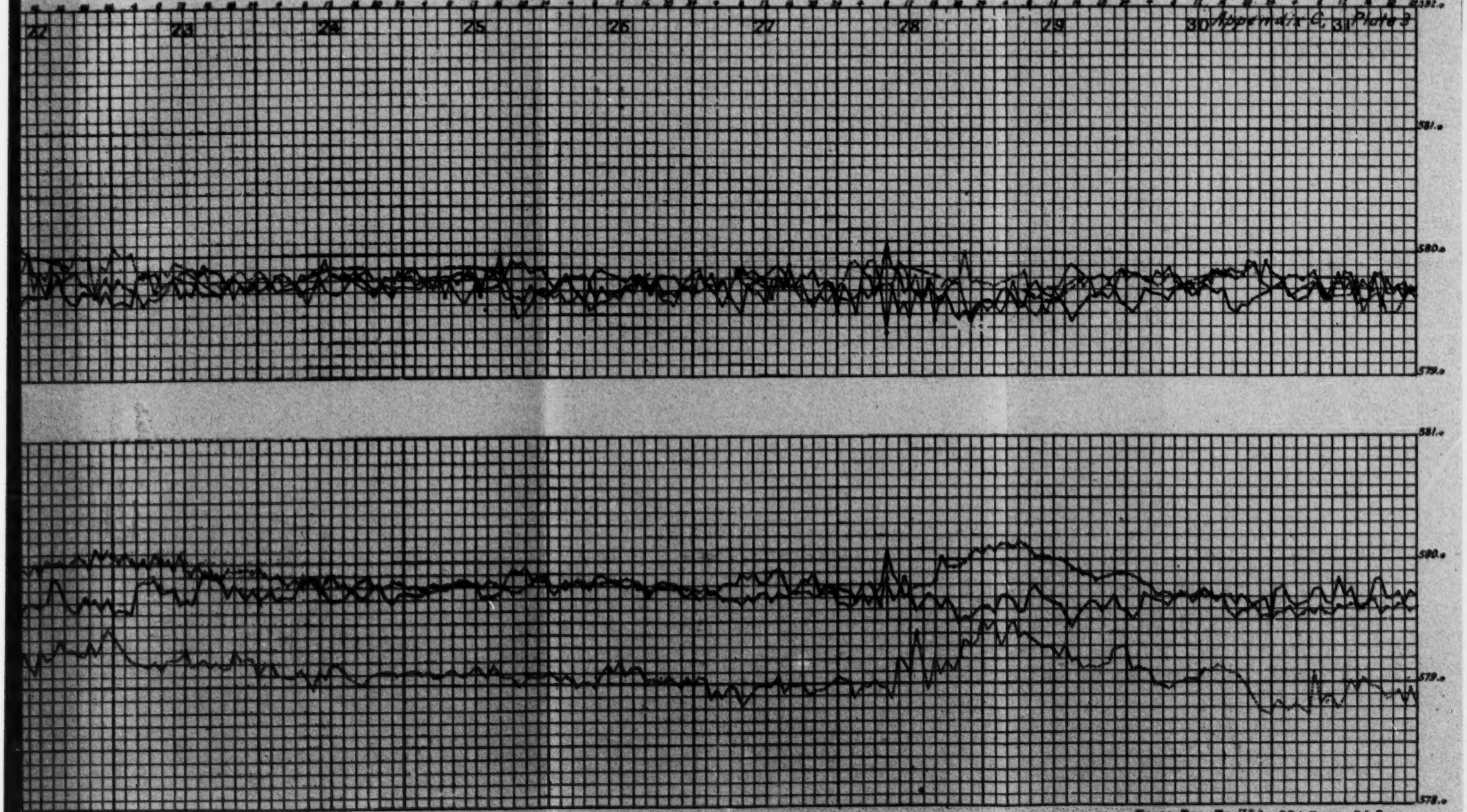
atic Gage Readings at Mackinaw (——), Harbor Beach (- - -) and Port Huron (.....) during the Month of August 1911.



Note: All Elevations refer to Mean Tide at N.Y.

Corps of Engineers, U.S.Army.

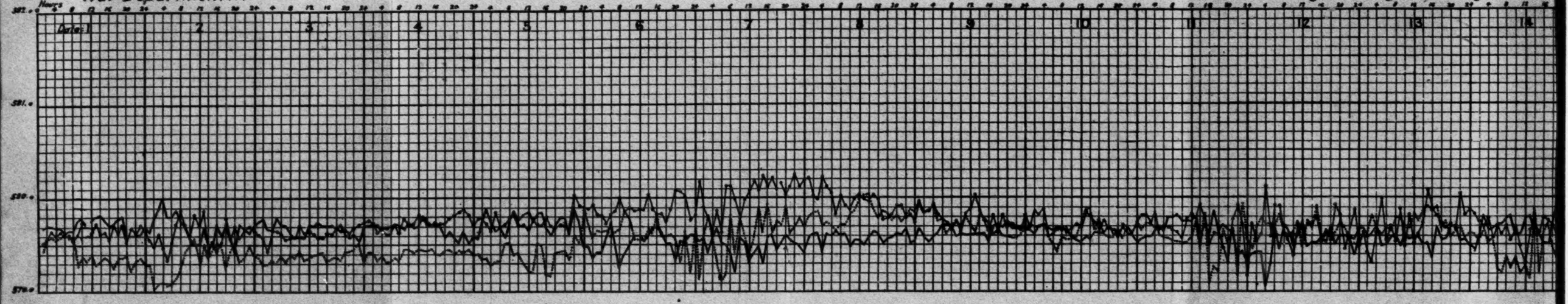
Appendix C, 31 Plate 3



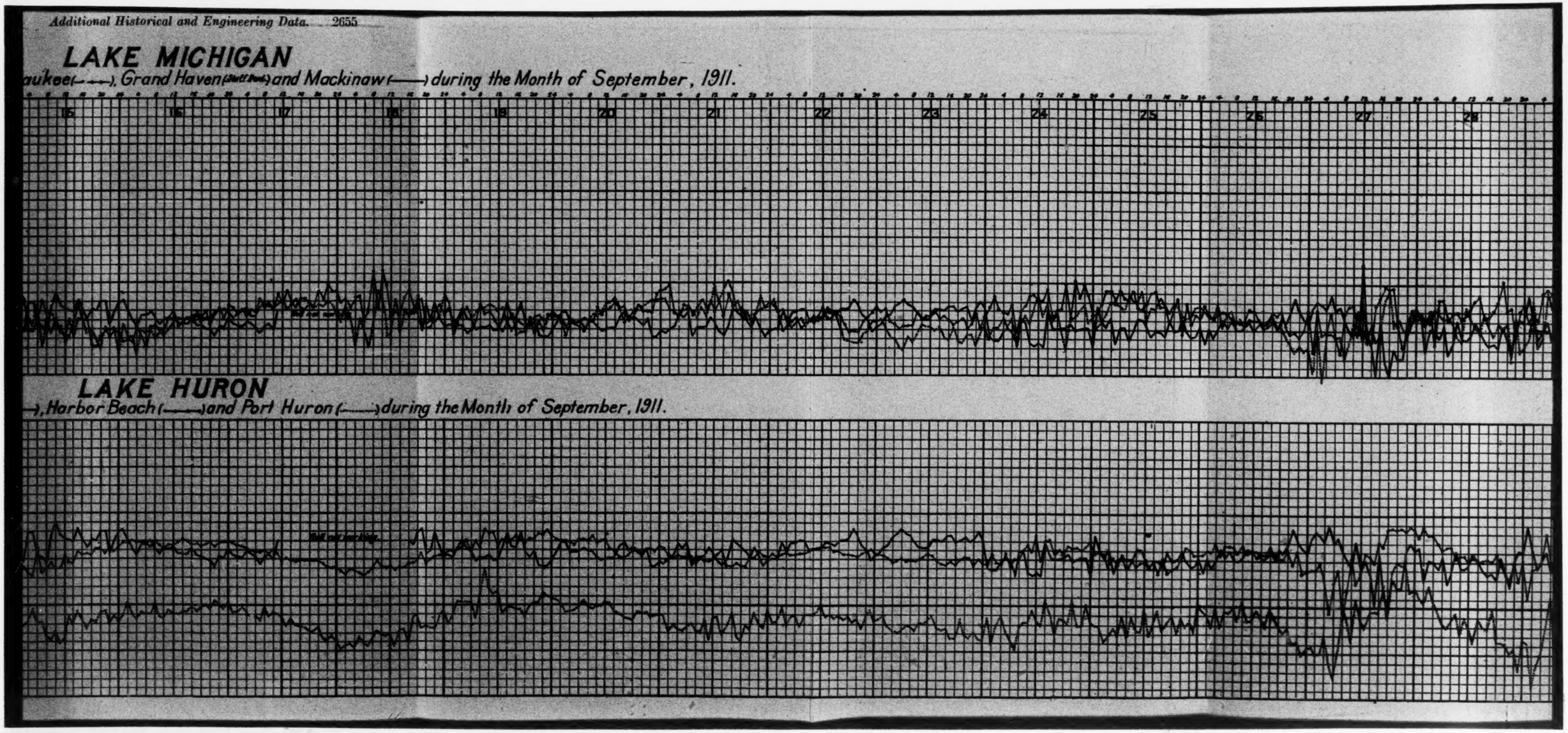
House Doc. No. 762; 83d Cong., 2d Sess.

War Department.

Automatic Gage Readings at Chicago (.....),



Automatic Gage Readings at Mackinaw


LAKE MICHIGAN
aukee(- - -), Grand Haven(Std. Time) and Mackinaw(——) during the Month of September, 1911.
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LAKE HURON
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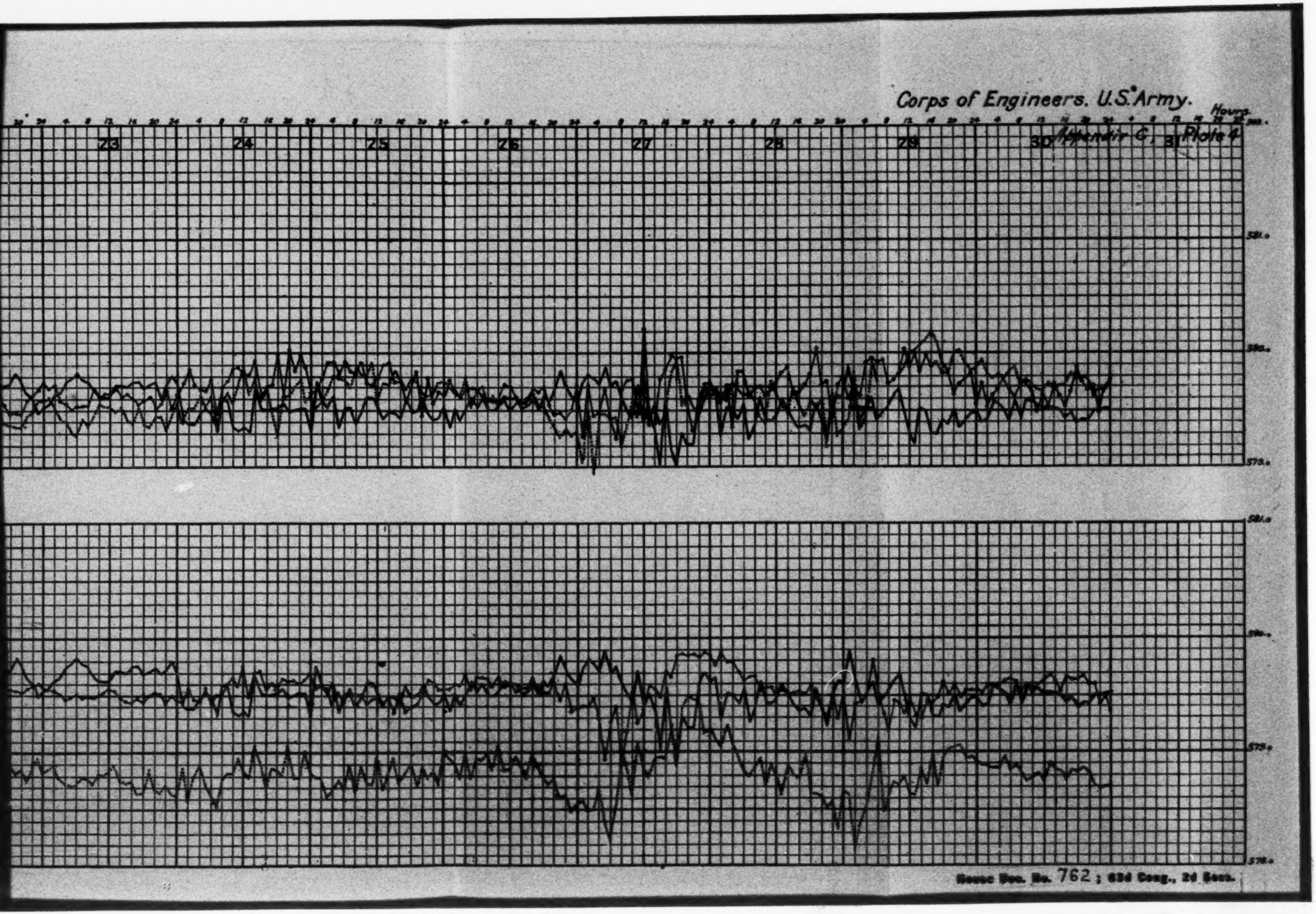
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House Doc. No. 762; 63d Cong., 2d Sess.

EXTRACT FROM THE STATEMENT OF THE SANITARY DISTRICT IN SUPPORT OF ITS APPLICATION FOR PERMISSION TO REVERSE THE CURRENT OF THE CALUMET RIVER, PENDING BEFORE HON. WM. H. TAFT, SECRETARY OF WAR, ON WHICH APPLICATION THE SECRETARY ACTED ON MARCH 14, 1907, APPEARING ON PAGES 8 AND 9 OF THE ANSWER OF THE SANITARY DISTRICT:

"While we are asking permission to thus reverse the flow of the Calumet River, we do not thereby concede that we have not the right to do so as a matter of right under the State law. * * *

That while insisting upon the right as a matter of right, we are entitled, nevertheless to a permit from the Secretary of War to evidence that there exists between the two governments that 'spirit of harmony and conciliation' which, in the words of Chief Justice Marshall, in *Gibbons* v. *Ogden*, 'ought always to characterize the conduct of governments standing in the relation which that of the Union and those of the States bear to each other'; and to further evidence on the part of said governments that 'frank and candid co-operation for the general good' spoken of by Justice Johnson in the same case, 'which should always take place where there is a seeming blending of the power of the two governments and an apparent conflict.'

EXTRACT FROM STATEMENT OF SANITARY DISTRICT IN SUPPORT OF ITS APPLICATION FEBRUARY 5, 1912, TO HON. HENRY L. STIMSON, SECRETARY OF WAR FOR PERMISSION TO INCREASE THE AMOUNT OF WATER TO BE WITHDRAWN THROUGH THE MAIN CHANNEL OF THE SANITARY DISTRICT TO 10,000 CUBIC FEET PER SECOND UPON WHICH APPLICATION THE SECRETARY OF WAR RENDERED DECISION JANUARY 8, 1913, APPEARING ON PAGE 15 BILL OF COMPLAINT.

"While we are entitled to the use of the waters of Lake Michigan as a matter of right, we also believe that we are entitled to this permit from the Secretary of War, in order that there may be evidenced that 'spirit of harmony and conciliation which ought always to characterize the conduct of governments standing in the relation which that of the nation and those of the States bear to each other,' as expressed by Chief Justice Marshall in the case of *Gibbons* v. *Ogden*, 9 Wheaton, 1; and also to make manifest that which was referred to by Mr. Justice Johnson in the same case as that 'frank and candid co-operation for the general good which should always take place where there is a seeming blending of the power of the two governments, and an apparent conflict.'"

EN 5

VOL. 5

United States of America,
Northern District of Illinois, } ss.
Eastern Division.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,019, and Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

Mr. James H. Wilkerson,
United States Attorney, and
Mr. Albert L. Hopkins,
Assistant United States Attorney,
For Complainant.

Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
For Respondent.

1914
The Gunthorp-Warren Printing Company
Chicago

VOL. 5

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UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS,
EASTERN DIVISION. } ss.

IN THE

District Court of the United States

UNITED STATES OF AMERICA,
Complainant,
vs.
THE SANITARY DISTRICT OF CHICAGO,
Defendant,

C. C. No. 29,019.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the Federal Building, Detroit, Michigan, beginning on Tuesday, February 3, 1914, at 10:30 A. M.

Present:

Mr. James H. Wilkerson and Mr. Albert L. Hopkins, representing the Government.

Mr. Edmund D. Adcock and Mr. Alfred S. Austrian, representing the Sanitary District.

TESTIMONY IN REBUTTAL ON BEHALF OF THE GOVERNMENT.

EUGENE E. HASKELL, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Haskell, you testified in this case before in February, 1909?

A. I did.

Q. Since that time, what further qualification have you had, in connection with hydraulic engineering?

A. I have been connected with the question of regulation of lake levels, in connection with my duties as a Commissioner of the International Waterways Commission.

Q. What has been your business since your last testimony?

A. I have been engaged with one of the Canadian members upon the completion of the report which the Commission put out, the title of which is the "Regulation of Lake Erie."

Q. You are connected with Cornell University still?

A. Yes.

Q. In what capacity?

A. Director of the College of Civil Engineering.

Q. And that includes what?

A. I have supervision of all departments of the college.

Q. With reference to the laboratory?

A. All of them; the hydraulic laboratory is a department of the college.

Q. Have you had any further employment since that time, that you have not mentioned?

A. I have mapped out a course of procedure for the Canadian Government, this last summer, to enable them to obtain some data in relation to the hydraulics of the St. Lawrence between Montreal and Quebec.

Q. Since your testimony in February, 1909, have you learned that there have been other measurements of the Niagara River?

A. I have; other measurements made by the United States Lake Survey.

(Chart produced and marked Haskell's Exhibit 1, February 3, 1914, for Identification.)

Q. I show you this chart marked Haskell's Exhibit 1 of this date for Identification, which purports to have on it all of the measurements made by the Lake Survey of the Niagara River, including 118 observations, which you did not have before you when you gave your former testimony. Assuming that the plat is correctly plotted, and assuming that the observations were taken correctly, do you wish to make any further statement in regard to the degree of correctness of the measurements of the Niagara River flow? Assume further, Mr. Haskell, that the 118 measurements were taken at the International Bridge Section, in the years 1907 and 1908?

Mr. Shenehon: This chart shows plotted the individual observations made at the International Bridge Section of the Niagara River; 101 observations made in 1898 to 1900, inclu-

sive, and 118 individual observations made in the years 1907 and 1908, as reported in the report on the Preservation of Niagara Falls, and already referred to in this case.

In addition to the plotting of these individual observations, there is indicated by a black square the mean volume of flow and mean gage level of 121 measurements on the Niagara River made at the Open Section, and already in evidence in this case. Those were made in 1899 and 1900.

In addition, indicated by a black triangle are shown the ten measurements of the Third Section made during the year 1913, the summer of 1913.

Mr. Adcock: What do you call that section?

Mr. Shenehon: We have spoken of it as the Third or Split Section. It is the mean of the measurements.

Mr. Hopkins: Q. Now Mr. Haskell, incorporating the statement just made as to what the plat shows into the question, and assuming it has been correctly plotted and the observations were made correctly, do you now wish to make a further statement with reference to your former testimony as to the degree of accuracy of those measurements?

A. Yes. The additional observations extend our knowledge of the discharge of the Niagara. They confirm the previous observations, and I would consider it perfectly proper to reduce the limits of error which I gave in my previous testimony.

Q. In coming to that conclusion, do you take into consideration the checks between the various sections?

A. Yes.

Q. What are those checks?

A. The Bridge Section and the Open Section agree within about 1 per cent. These new observations made on the Split Section fall between those two, agreeing within about ½ of 1 per cent of either of the other.

Q. Is that indicated on the chart?

A. They are indicated on this chart.

Q. What is your conclusion as to the accuracy of the work?

A. Why I should state that we knew the position of this center of gravity of the observations here within ½ of 1 per cent.

Q. You mean by that do you that we know the volume of flow of the Niagara River within the percentage that you have indicated?

A. For that particular point, for the stage which corresponds to that.

Q. Taking into consideration the three sections in that?
A. The three sections.
Q. What increment is shown by that?
A. It is given on here as 21,900 per foot.
Q. What degree of precision do you think that increment represents?
A. For this particular river, I should say it was within 2 per cent.
Q. What elements do you consider in making up your mind as to that degree of precision of the measurements of the Niagara River; for instance, first, as to cross section?
A. Why the determination of the cross section could be made with great accuracy.
Q. Within what percentage would you say?
A. Easily within ½ of 1 per cent.
Q. Now the co-efficient work?
A. That can easily be determined within ½ of 1 per cent. The records will show that.
Q. What is your opinion as to the degree of accuracy of the straight line method as adopted on that chart?
A. Why that represents the observations very closely indeed within the range given here.
Q. Are you acquainted with the volume of flow as measured by the Lake Survey in the St. Clair River?
A. I have seen the results of the observations which have been made there.
Q. Do you know what sections were measured in the St. Clair River?
A. I understand that they have recently measured discharges up in what is known as the Gorge Section near the head of the river; and that they have also measured the discharge in the several outlets in the Delta.
Q. Do you know how closely those various sections check?
A. Why they check very closely indeed, I believe.
Q. Can you give it in percentage?
A. No, I don't know that I can give it. As I recall it, it was within a very small percentage.
Q. Do you understand it is within 1 per cent?
A. Yes, I should say it was within 1 per cent.
Q. Now, do you have an opinion as to the accuracy with which we know the volume of flow in the St. Clair River?
A. For the center of gravity of those observations, for the stage corresponding to that, I should say we knew the flow within 2 per cent.

Q. Are you familiar with the various measurements of the St. Lawrence River?

A. I am not familiar with them excepting those that were made in the early days, 1900, 1901.

Q. Having those in mind, do you have an opinion as to the accuracy with which the Lake Survey knows the volume of flow in the St. Lawrence River?

A. Within the center of gravity of those observations that were made by Mr. Shenehon, while he was in charge of that party, I should say that we knew the position of that point within 3 per cent.

Q. In your work on the International Waterways Commission, did you have occasion to compute an increment for the St. Clair River?

A. Yes.

Q. What was the increment computed for mean lake stage?

A. For mean stage, 18,900.

Q. Do you still think that is correct?

A. I see no reason to change my opinion in that regard.

Q. How long have you been engaged in and studying the measuring of streams?

A. Thirty years this next summer.

Q. What is your opinion as to the practicability of measuring large streams?

A. They can be measured with great accuracy.

Q. Within what degree of accuracy?

A. Easily within 1 per cent, if you are willing to put the necessary labor on them.

Q. Do you have an opinion as to whether or not large streams can be measured as accurately as small streams?

A. I should say equally so.

Q. Within what degree of precision can the area of a cross section be determined?

A. Within ½ of 1 per cent.

Q. Within what degree of precision can the velocity coefficient be determined?

A. Within ½ of 1 per cent.

Q. With what degree of precision does the Haskell Meter register?

A. In Open Channel work, easily within ½ of 1 per cent.

Q. Suppose the water is highly perturbed, what effect do you think that would have upon the registration of the Haskell Meter?

A. It would undoubtedly under-register.

Q. To what extent?

A. Very small per cent.
Q. Can you give it more definitely?
A. I should say within 1 per cent.
Q. Is that the highest state of perturbation?
A. Well, there are cases where in a high state of perturbation of the water no meter has applicability.
Q. Take the conditions in the Niagara River, within what degree of precision will the Haskell Meter register there?
A. Within 1 per cent.
Q. Will you just explain further what you are taking into consideration in the Niagara River itself, in saying that it will be within 1 per cent; first, is it with reference to the International Bridge Section?
A. Do you refer to cross section, is that the point you wish to bring out? Or do you mean all of the processes right straight through, by which we arrive at the discharge?
Q. Take the Open Section, as we have spoken of it, with what degree of precision do you think the Haskel Meter would register in that Open Section?
A. In measuring velocities? Within ½ of 1 per cent.
Q. Take the Bridge Section?
A. The same is true there.
Q. And the Third Section?
A. The same is true there.
Q. What effect does an oblique current have upon the meter?
A. The velocity measured would be too large.
Q. So that if there were an under-registration of the meter, if the currents were all oblique, they would tend to compensate?
A. That would be the tendency.
Q. Are you acquainted with the Niagara River, and the condition of the water in the Niagara River?
A. I am.
Q. Specifically at the Bridge Section, will you describe the conditions there?
A. The International Bridge lies within ⅛ of a mile of the center of a two-mile stretch that is very uniform in width and the flow is very regular through that reach.
Q. With reference to the regimen of the river, is it good or bad for measuring?
A. It is good.
Q. And with reference to the piers of the bridge, what effect do they have?
A. The piers, of course, divide the water at those par-

ticular points as it comes down, and there is a tendency to create eddies next to the piers, on both sides.

Q. To what extent do you think that that eddying water will affect the whole result of the measurement, in percentage if you can give it?

A. Oh, not to exceed ½ of 1 per cent.

Q. Are you acquainted with Mr. Shenehon's report of 1900, in regard to that measurement?

A. Yes, I am.

Q. Do you think that his allowance for the eddying around the piers was proper and accurate?

A. I think it is a very fair allowance.

Q. Did you personally put some time in on that work?

A. At the beginning of those observations?

Q. Yes.

A. I began that work on the Niagara River in 1897.

Q. Did you examine those sections prior to their selection for this purpose?

A. Yes.

Q. You selected this section for measurements at the bridge, didn't you?

A. I did.

Q. Who was with you at the time?

A. Mr. George Y. Wisner.

Q. Both of you agreed that that was a proper section for measurement?

A. We did.

Q. Will you describe generally the Open Section in reference to its being a proper place for measurement?

A. The Open Section is about 1,800 feet below the bridge and in a very good reach of river for discharge work.

Q. Is there any turbulence or degree of perturbation that would affect the work?

A. There is none.

Q. Now have you seen what we call the Split Section on either side of Grand Island, where the river measurements by Mr. Richmond were made?

A. I visited that section on the 5th of January with Mr. Shenehon.

Q. Will you describe the conditions at those two sections?

A. The two sections are very good ones indeed. When there we took some photographs. Here is a photograph of the section on the west side of Grand Island, taken from the west side of the channel, looking east across the section.

(Witness producing photograph.)

Q. There is a curve there, isn't there?
A. The river is curving.
Q. What effect does that have on the location?
A. Practically nothing; the curve is of too long a radius.
Q. Now do you know the condition in either section above this place with reference to a sand bar?
A. In the east channel there is a bar above the section.
Q. What effect do you think that would have upon the section measured, as to whether it can be accurately measured?
A. Practically nothing, if the vertical curves were determined with the accuracy that they should have been.
Q. What effect does the rating of the meter have in this measurement of rivers?
A. We have to rate a meter in order to get the equation for converting revolutions per minute or per second made by the wheel into velocity.
Q. How important is the accurate rating of the meter?
A. The meter has to be accurately rated, in order to get accurate results.
Q. What is the most accurate way of rating a meter?
A. By drawing it through still water.
Q. How about using colored water in the stream that you are measuring?
A. For testing the accuracy?
Q. As a test of the accuracy?
A. It is the most accurate way that I know of for getting a comparison.
Q. Are you acquainted with the tests made by Mr. Shenehon in the Detroit River?
A. I am.
Q. What was that done for?
A. For the purpose of ascertaining how accurately the meters indicated the truth.
Q. What was the result?
A. That they were very accurate.
Q. What percentage do you mean when you say "very"?
A. That is less than ½ of 1 per cent; the results, as shown by his report upon that work and published in Senate Document Number 105, 62nd Congress 1st Session, in the paper, "The Preservation of Niagara Falls."
Q. Do you know of some tests made of the Haskell Current Meter by Doctor Mendenhall?
A. I do.
Q. Will you tell us what those tests were?
A. During the fiscal year 1890, 1891, while with the Coast

and Geodetic Survey, I was engaged in ascertaining deep sea depths and temperatures upon the coast survey steamers; and we used two different types of meters, that is the Haskell-Ritchie Direction Current Meter, and what is known as the Pillsbury Meter, which was a cup meter. The results obtained by the two did not agree, and Doctor Mendenhall, then superintendent of the Coast and Geodetic Survey, wanted to satisfy himself as to the reliability of those observations, he arranged for a test which was made from the Coast and Geodetic Survey steamer Blake in Vinyard Sound, in July or August, I won't be certain which, in 1891.

The method used by Doctor Mendenhall was that of determining the velocity of the current, which was a tidal one, by means of floats. The current meter was run for an interval of ten minutes at a five foot depth, and during that time at intervals of a minute each can float was run at the same immersion, and the velocity as derived from the mean of the ten floats was used to check the meter. The meter used had been rated some two months before that test, and the results of that rating are given in this pamphlet I hold in my hand, on page 8.

(Pamphlet identified by the witness was here marked Haskell's Exhibit 2, February 3rd, 1914, for Identification.)

Q. This is a pamphlet entitled: "Ritchie-Haskell Direction-Current Meter and the Haskell Current Meters"; and you are referring to what page?

A. That is page 7.

Mr. Austrian: Is that a government document?

A. No. The results of that comparison, of a part of the observations are shown on this page, the marked paragraph on page 8.

Mr. Hopkins: Just read the part you have in mind.

A. These observations are in feet per second, and are arranged in the order of float, meter; that is the velocity given by the float followed by that given by the meter: 1.04, 1.05; 1.29, 1.28; 1.55, 1.55; 1.94, 1.96; 2.56, 2.59; 2.65, 2.64; 2.76, 2.74; 2.80, 2.82; 3.08, 3.11.

Q. Now were there some tests made of this meter in Philadelphia?

A. The city of Philadelphia used them a number of years ago in determining the efficiency of some new pumps which they had contracted for.

Q. What test did they make and with what result?

A. They built a canal into which to discharge the capacity of the pumps, and in that canal placed a weir for measuring

the volume of the flow, and they also measured the volume of flow with these meters. The results of the two gave an agreement within, as I recall it, about 1 per cent. It has been some time since I have seen those figures.

Q. Are you familiar with an article by Mr. B. F. Groat, published in the proceedings of the American Society of Civil Engineers?

A. I have read it.

Q. With reference to this meter?

A. With reference to this meter, yes, sir.

Q. What is your opinion as to the soundness of the opinions given by Mr. Groat?

A. I think it is an admirable paper.

Mr. Hopkins: This article is already in and has been read from many times; it is in evidence.

Mr. Austrian: Q. What year was that?

A. December, 1912.

Mr. Hopkins: It is paper number 1259, page 819 of Volume 66.

Mr. Austrian: And the date?

Mr. Hopkins: 1913.

Q. Are you acquainted with Mr. Schoder and Mr. Turner of the engineering department of Cornell University?

A. I am.

Q. What is their position at Cornell, and their relation to you in that regard?

A. They are both assistant professors in the department of hydraulics. Mr. Turner is an assistant professor of the First Grade, and Mr. Schoder is an assistant professor of the Second Grade.

Q. Is their work in the laboratory under your direction?

A. It is.

Q. Have you read their testimony in this case?

A. I have.

Q. Did you take any part in the tests made by them?

A. I did not.

Q. Do you have any comments to make upon the results obtained by them, as appears in that testimony?

A. I should not be willing to accept them.

Q. What probable errors occurred in that rating and testing?

A. *Why they attribute everything to the meter.* They claim to know the discharge of that standard weir within 1 per cent. I doubt it. I think if it is known within 2 or 3 per cent, it is as close as is safe.

Q. In the question of the rating of the meter, what error do you think might occur there?

A. I should think it might well happen that there is an error of 2 per cent in the rating of that meter.

Q. Why?

A. I base my estimate on that upon the time at which all those observations were made.

Q. How about the number of observations in the rating?

A. I don't know how many were made, but I doubt very much indeed enough having been made to give a true determination of the rating.

Q. How about the experience of the men in the work they were doing?

A. The only experience that they have had is simply that in connection with student instruction in the laboratory, and in a few occasions they have gone out and measured open channels, so as to give students a little further knowledge of work of that character.

Q. Mr. Turner did some work with the Lake Survey, didn't he?

A. Mr. Turner was the Recorder of the Lake Survey for a little over a year, when I was Principal Assistant Engineer.

Q. Did you notice in that testimony that Mr. Schoder said that he had measured certain streams, one of which, I think was the Susquehanna, and the length of time that they took in the measurements? What is your opinion as to the accuracy of any such work as that, within the time mentioned?

A. It would take a month to get anything like a determination of the flow of that stream at that particular stage, which was a very low stage.

Q. Now, returning to the canal, what error if any might occur in the measurement of the area of the cross section?

A. It would be a difficult matter to determine the area of the cross section accurately in that perturbed water.

Q. Having in mind the photographs which are exhibits to their testimony, what degree of precision do you think they could reach in measuring the cross section?

A. In the perturbed water which is shown just below the baffles in Exhibits 4 and 5, 2 and 3, 6 and 8 and 9 and 10, it would be very difficult to determine the accuracy within 5 per cent.

Q. What was the depth of the water, as you understood?

A. Somewhere in the neighborhood of 3½ feet.

Q. Now with reference to determining the co-efficients of

the work as testified to by Mr. Schoder and Mr. Turner, what is your opinion as to the error that might occur there?

A. Oh, they could easily be in error 2 or 3 per cent in the determination of those.

Q. Any more than that?

A. Well, there might be more than that. It would depend entirely upon the time that was devoted to it.

Q. About the turbulence of the water in that canal, in comparison with the water in the Niagara River, or any other of the rivers we have been considering, the St. Clair, the Detroit and the St. Lawrence, at the sections which have been measured, what have you to say?

A. There is nothing in common between the two; that is in this case the perturbation is caused by the water dropping over a weir. The standing weir there is 9¼ feet high. There is nothing of that kind in connection with any of the discharge sections on the several lake outlets.

Q. The mere fact that there are baffles in there would not smooth it out?

A. It of course helps to still the water.

Q. How would you describe the condition of the water in the canal itself, as shown by the photographs?

A. Up near the baffles there, it is very much disturbed.

Q. It is practically a rapids?

A. Yes, practically a rapids.

Q. What is your opinion as to the applicability of the conclusions reached by these gentlemen, Mr. Schoder and Mr. Turner, with reference to the measurements that have been made by the Lake Survey in the Niagara, St. Clair and St. Lawrence Rivers?

A. I do not know that I quite get your point.

Q. (Question read.)

A. They are not at all applicable.

Q. Did you see the exhibit of Mr. Turner with reference to vertical curves in the St. Marys River?

A. I saw that blue print which you have here.

Q. Do you know whether that is an authentic record of the Lake Survey?

A. No, I do not.

Q. What is your conclusion as to that exhibit, with reference to the point it is introduced for?

A. There is nothing in it at all.

Q. Why?

A. He undertakes to compare two vertical curves and to point out the discrepancy between them, and attribute that to

the meter. We know there is a discrepancy even greater than what is shown there in the determination of vertical curves, and particularly vertical curves determined under the ice, as those were.

Q. With reference to their being at the same or different times?

A. Why, you see the two which he tries to compare were taken at entirely different times. They are not comparable at all.

Q. With reference to velocities, whether they were the same or different?

A. The velocities, I think there is some little difference in that.

Q. Was the method used there as referred to by Mr. Turner the same as that used in the Niagara?

A. No, it was not. That work in the St. Marys River through the ice all depends upon one meter, that is the use of one meter in determining all of the vertical curves and all of the discharges. In the later work, we used two or more meters so as to have a check.

Q. Do you have your former testimony before you, Mr. Haskell?

A. I have a copy of it here.

Q. Referring to that part of your testimony which appears on page 67 of the corrected paging with reference to dependence to be placed upon data of evaporation, in the light of further study, do you wish to change that?

A. I see no reason for changing it. Nothing has happened, so far as I know, to throw any greater light on that problem.

Q. What is your opinion as to the propriety of taking certain data in reference to percentage of run-off from areas in Massachusetts, Western Pennsylvania and New York, where the conditions are either hilly, sandy or wooded, and applying them without change to the Lake Erie basin, with reference to run-off and evaporation and so on?

Mr. Adcock: I object to that. I do not think the conditions incorporated in the question have been shown.

Mr. Hopkins: Q. First I will ask you then, what is your opinion as to the propriety of taking conditions of run-off in any locality, and applying them to another?

A. It certainly would be open to great uncertainty.

Q. And then if your data are taken from a territory as described in the prior question—are you familiar with the Lake Erie run-off basin?

A. Why, yes; with all of them for that matter.

Mr. Hopkins: Then I ask for an answer to my first question in reference to that.

Mr. Adcock: My objection to that was that the condition stated in your question does not appear in any part of the record.

Mr. Hopkins: Read the question.

(The question was read.)

Mr. Wilkerson: Your objection is it does not appear what kind of territory that is?

Mr. Adcock: Yes.

Mr. Wilkerson: Assuming that the conditions are as stated in the question.

Mr. Adcock: That is all right.

Mr. Austrian: As stated in what question; assuming the conditions are as incorporated in what question?

Mr. Hopkins: The question just read.

Q. Assuming the conditions of the districts named are as I have stated, either hilly, sandy or wooded, then what is your opinion as to the propriety of taking that data and applying it to the Lake Erie basin?

A. I do not think you could apply the data with any degree of certainty or accuracy.

Mr. Wilkerson: On that question, we might as well settle it right now, is there any dispute as to the physical characteristics of the territory in which these measurements of run-off were made; any dispute about the physical characteristics of New England?

Mr. Austrian: Each one was described.

Mr. Adcock: Each one was described, the conditions were described.

Mr. Hopkins: As far as that is concerned, let it stand. Mr. Stearns describes it.

Mr. Adcock: Do you want to ask him about that?

Mr. Hopkins: He has not read it.

Mr. Wilkerson: Then it is straightened out, because the testimony of Mr. Stearns is in accordance with the assumption in Mr. Hopkins' question.

Mr. Adcock: No, I do not think so.

Mr. Wilkerson: That is a matter of argument.

Mr. Adcock: If the assumption made in the question were in accordance with the testimony, it might apply.

Mr. Wilkerson: If the facts are already in the record, it is a matter of argument.

Mr. Austrian: That is if the witness knows the facts upon which Mr. Stearns based his testimony.

Mr. Wilkerson: The witness has based his answer on the question assuming the facts are as stated.

Mr. Hopkins: Q. Mr. Haskell, referring again to Mr. Groat's tests, just what were his tests of the meter, and what is your opinion as to his method?

A. So far as I can gather from his paper, I think the test a perfectly fair one, and a good one. That is the water dropped through the turbines into the tail race, and he had stilling racks above the sections which he was measuring; and his results are set forth in his report, in his paper I should say.

Q. Will you refer to the details of this particular test, as they appear in that report?

A. Yes, I will. I should refer to this paragraph marked "6," in his paper.

Q. What page?

A. It is page 821 in the report which has been referred to, referring to Proceedings of the American Society of Civil Engineers, Volume 38, number 10, of December, 1912, page 1663.

Mr. Adcock: What was that reference, page 821?

Mr. Hopkins: That was in a different book, same article.

(Paragraphs 3 and 6 in paper referred to are as follows:)

"3." "In the foregoing sense, a cup meter is affected relatively to a much greater extent than a screw meter. In the tail races at Massena, as an average, the cup meter was affected to the extent of 6 per cent, while the Haskell Meter was affected mostly by less than 1 per cent. In boilers of considerable violence the cup meter may easily over-register by 25 per cent, while the screw meter will under-register by not more than 3 or 4 per cent.

"6." The average corrections thus obtained for the Haskell Meter when run with the Gurley-Price Meter in the tail races at Massena varied from 0.5 to 0.9 of 1 per cent, while the corresponding corrections for the Gurley-Price Meter were about six times larger. Comparisons with the Pitot Tube furnished the same corrections substantially as those obtained by comparison of the meters."

The Witness: Mr. Groat's conclusions are set forth in that paragraph, and he refers to them again on page 1671, where he has a table, and gives his conclusions in regard to the observation shown in that table.

(The conclusions referred to by the witness are as follows):

$$\text{Average error of Gurley meter} = 6/7 \times \frac{2.16}{33.21} = 5.6 \text{ per cent}$$

$$\text{Average error of Haskell meter} = 1/7 \times \frac{2.16}{33.21} = 0.93 \text{ per cent}$$

Q. What is your opinion as to the propriety of deriving an increment from the ratio of fluctuations from one lake to another, as for instance, from Erie to Lakes Michigan-Huron?

A. I could not consider it as anywhere near as accurate as the method of actually determining the discharges of the outlets.

Q. Why?

A. The factors involved are not known, or cannot be determined with anything like the accuracy with which we can make the measurements which give us our discharge.

Q. What are some of the factors that you have in mind?

A. Why, evaporation, rainfall, run-out.

Q. How about ice?

A. Ice, of course, upsets conditions in several of the lake outlets nearly every winter, so that winter conditions are entirely different from those of the open season.

Q. What effect does the ice have upon Lakes Michigan-Huron?

A. It dams up the St. Clair River and thereby holds the water, impounds it in Lakes Michigan-Huron, to the detriment of Lake Erie.

Q. And Lake Erie falls?

A. Lake Erie falls. There are plenty of cases in the gage records which show that.

Q. Does that in your opinion interfere with the ratio of fluctuations as compared with open season flow?

A. Certainly.

Q. In general, what are the ice conditions on the St. Lawrence, and what effect do they have upon Lake Ontario?

A. The ice blocks several of the channels, as you get down among the rapids, and the tendency of course is when those channels are blocked for the water to rise in Lake Ontario.

Q. What is the ice effect upon Lake Erie, with reference to the other lakes?

A. There is practically little or no ice effect on Lake Erie; that is so far as the Niagara River is concerned.

Mr. Hopkins: That is all.

Cross examination reserved.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the offices of the Sanitary District, Chicago, Illinois, beginning on Wednesday, February 25, 1914, 10:30 A. M.

Present:

Mr. Albert L. Hopkins, representing the Government.
Mr. Edmund D. Adcock, representing the Sanitary District.

EUGENE E. HASKELL resumed the stand for cross examination by Mr. Adcock and testified as follows:

Q. Since 1906, you have been Dean of the College of Civil Engineering at Cornell University, Mr. Haskell?
A. That is director of the college, my title is.
Q. Director?
A. Yes, Dean of the College Faculty.
Q. Just what does that mean? You are the head of the college, aren't you?
A. Head of the college; the representative between the college and the Board of Trustes.
Q. And prior to that time you were with the Lake Survey?
A. I was with the Lake Survey from the spring of 1893 to 1906.
Q. When you left the Lake Survey, you were Principal Assistant Engineer, were you not?
A. Yes.
Q. From what time?
A. From the spring of 1893.
Q. And your duties were similar to the duties of the present Principal Assistant Engineer?
A. Yes, sir.
Q. When was the Lake Survey proper organized?
A. You mean the present organization?
Q. Yes.
A. The old Survey closed its doors in 1882 and the Survey was re-organized in 1893.
Q. And prior to your connection with the Lake Survey, what work were you doing, Mr. Haskell?

A. For the eight years previous to my going with the Lake Survey, I was with the Coast and Geodetic Survey at Washington, D. C.

Q. How long altogether were you in the Government service?

A. In the Government service?

Q. Yes.

A. With the exception of about six months in 1880, I was with the Government service from July, 1879, up to my going with the University in 1906.

Q. What were your duties as Principal Assistant Engineer of the Lake Survey?

A. Supervising the field work, and the work of the field force.

Q. During that time, you had charge and direction of the measurements of the St. Clair, Niagara and St. Lawrence Rivers, did you not?

A. From the time that investigation started.

Q. And the measurements were made under your direction?

A. They were.

Q. Mr. Shenehon had, under you, charge of the Niagara measurements, didn't he?

A. He did.

Q. And Mr. Sabin the St. Clair measurements?

A. The St. Clair measurement.

Q. Mr. Blanchard made some measurements on the St. Marys River?

A. Yes.

Q. And also on the Detroit?

A. Yes.

Q. And Mr. Shenehon also made measurements on the St. Lawrence River?

A. Yes.

Q. You devised the method by which the measurements, the discharge measurements, should be made, did you, Mr. Haskell?

A. Substantially so.

Q. And under your instructions, the measurements were made?

A. They were.

Q. Did you have anything to do with the selection of the

gaging section or the hydraulic section where the measurements were made in the different rivers?

A. That is only in a general way, where the party was sent into the field direct from the office.

Q. Then they advised with you as to the proper place, after they had made surveys, did they?

A. Yes.

Q. Will you describe the work on the St. Clair River, the early work which was done by Mr. Sabin?

A. By Mr. Sabin?

Q. Yes.

A. Mr. Sabin was sent to Port Huron for the purpose of making an examination and locating a cross section for the discharge work of that river, and he selected a section which we have always called Dry Dock; which was near or just below the old Dunford-Alverson Dry Dock.

Q. Did Mr. Shenehon use the same methods generally in measuring the discharge of the Niagara River that were used by Mr. Sabin on the St. Clair?

Mr. Hopkins: I make a general objection to all this line of testimony as not proper cross examination.

A. Why the methods are in general similar. There may be a little difference as to carrying out the details, which are not at all vital to the success of the work.

Q. Were there more than two meters used on the St. Clair work in the co-efficient work, by Mr. Sabin?

A. You say more than two?

Q. Yes.

A. I think not, although I would not be positive of that.

Q. Where was the multiple meter set used?

A. In the Detroit River.

Q. Those measurements were made when, what year?

A. I shall have to refer to the report to definitely locate it. My recollection is that we worked there in 1901.

Q. In 1901?

A. (Referring to report.) In 1901 I find it. The discharge measurements on the Detroit River were made in 1901-1902.

Q. I call your attention to page 5369 of the Report of the Chief of Engineers for 1900, and I will ask you whether that refreshes your recollection as to whether or not a multiple meter set was used in the co-efficient work on the St. Clair River?

A. It does. It was used on the St. Clair River. The work was started there.

Q. That was the work done by Mr. Sabin?
A. That was the work done by Mr. Sabin.
Q. Was that method used on the Niagara River?
A. On the Niagara?
Q. In the work done by Mr. Shenehon?
A. No.
Q. What were your duties as director of the college of civil engineering at Cornell?
A. My duties as director?
Q. Yes.
A. They are largely executive.
Q. What do you mean by that?
A. Why I look after all matters pertaining to the college, with the President, with the Board of Trustees and with the University Treasurer; see that the schedule of work for each department of the college is properly looked after; that it has the proper and requisite teaching force.
Q. In case it has not the requisite teaching force, you see to the employment of men?
A. See to the employment; make recommendations to the President.
Q. If any member of the teaching force were not qualified, you would discharge him, would you?
A. That is arranged there; that is a full professor is appointed for life. That is a man who has been tried out and has reached such a stage of efficiency that they think he is worth while. He is appointed for life, and is not removed without cause or without he chooses to resign. An assistant professor has an appointment for five years, and he is tried for five years, and recommended finally, or tried five years more as the case may be.
Q. And he may be removed at any time during the five years for cause?
A. For cause.
Q. And I presume one of the causes would be incompetency, wouldn't it?
A. Incompetency, certainly. We have what we call the grade of instructors. They are men who are employed, with the exception of the second grade, by the year; reappointed every year. I should have said that the third grade of instructors are appointed for two years instead of one.
Q. Is the second grade of professors and instructors higher or lower grade than the first?
A. It is higher.
Q. It is a higher grade?

A. It is a higher grade, the second is.

Q. There is a meter called the Haskell Meter, I believe. I presume it gets its name from the fact that you invented the meter or designed that meter?

A. Designed that particular meter; it does.

Q. You have the A, and B, meters, haven't you?

A. Yes, and three others.

Q. And three others. The A is substantially like the B, except that it has a direction attachment?

A. Direction attachment.

Q. Which do you consider the better type of meter?

A. That is for measuring the velocity of water, there is practically no difference between them.

Q. Which was used by you in your measurements of the different rivers, the A or the B meter?

A. The B meter was used largely. The A meter was used in a number of instances. It was used from the International Bridge at Buffalo for a time, and if I remember correctly it was also used in that multiple meter set. Those were so long ago that the details—

Q. That was the A meter?

A. That was the A meter.

Q. Was the B meter used?

A. The B meter was used also. In fact that was used more than the A.

Q. You, of course, consider the Haskell meter the best meter on the market, do you, Mr. Haskell?

A. That is rather a personal question.

Q. That is it will measure accurately, perhaps more accurately than any other current meter?

A. That is the feeling I have, Mr. Adcock. I do not suppose I should have invented a meter had I not been able to find fault with the ones that went before.

Q. From your work and experience, I presume you are familiar with the generally accepted laws governing the flow of waters in closed and open channels?

A. Yes, sir.

Q. What are the factors entering into a formula for the flow in an open channel?

A. That is the velocity of the current and the area of the cross section; and the stage of the river.

Q. You mean by that the fall?

A. The fall?

Q. Yes. Does the length of the channel have anything to do with the factors in determining the flow?

A. Only in a general way.

Q. I think that you probably misunderstood my question in that your answer was as to the flow as it passed a certain section. My question was, what are the factors entering into a formula for the flow in an open channel?

A. Well, length really is of no importance.

Q. Is the fall between the ends of the section of a channel considered of any importance?

A. Why we aim to locate a cross section for discharge work, so that the two ends of it are practically of the same elevation.

Q. I am not talking about the laying out of a section for current meter measurements, but I am speaking of the factors which enter into the formula for the flow in an open channel. Isn't the area of the cross section of the channel, the length of the channel, the fall between the ends of the section of channel considered, and the co-efficient to be determined by experiment, aren't those the different factors that enter in?

A. Certainly.

Q. And the most common formula, the one commonly used is the Chezy formula, isn't it?

A. Yes, that is one of them, the most common one.

Q. What are the different terms of that formula?

A. It is so long since I have bothered with those; I seldom ever have use for the formula, so I make no effort to remember it. V equals C into the square root of R S.

Q. I presume V means velocity?

A. Velocity.

Q. C is what?

A. The co-efficient.

Q. The constant?

A. To be determined by experiment.

Q. And the R is the hydraulic radius?

A. R is the hydraulic radius and S the slope.

Q. S is the slope?

A. Yes.

Q. Has C been determined, the value of C?

A. It has been determined by a number of experimenters in the past.

Q. How does the value of C change, does it change for different velocities in the same channel?

A. I believe so.

Q. Suppose the velocity should be changed, say 10 per cent, how much change would you expect in the value of C in this formula?

A. Will you ask that again, Mr. Adcock?
Q. (Question read.)
A. Really that is—
Mr. Hopkins: Objected to as not proper cross examination.
The Witness: It is a line in hydraulics that I have not been into in years, so to speak.
Q. (Question re-read.) In the same channel?
A. It would be a very small change indeed.
Q. What in general causes water to flow in a channel?
A. Gravity.
Q. That is the fall?
A. The fall, yes.
Q. In the Detroit River the flow is caused by the excess elevation of Lake St. Clair above that of Lake Erie, is it not?
A. It is.
Q. And if Lake Erie should rise to the same level as Lake St. Clair and remain level with Lake St. Clair as the latter changed, there would be no flow through the Detroit River. That is true, isn't it?
A. If Lake Erie—
Q. If Lake Erie should rise to the same level as Lake St. Clair and remain that way, then there would be no flow through the Detroit River?
A. The discharge of the St. Clair River would have to go somewhere. If Lake Erie were to fill up to the level of Lake St. Clair, of course, it would mean that the St. Clair River was emptying directly into a lake at the elevation of Lake St. Clair.
Q. And at least for a time, there would be no flow in the Detroit River?
A. For a time.
Q. And your proposition is that in time Lake St. Clair's flow, or the flow of the St. Clair River rather would raise Lake St. Clair, so that there would be a difference in the elevation of St. Clair and Erie, and thus there would be a flow through the Detroit River. Is that correct?
A. Yes.
Q. And there are no elements that produce flow in a channel other than the head or fall?
A. Are you speaking with regard to fresh water streams?
Q. Yes.
A. Certainly that is the case. It is not true with tidal streams, however.

Q. What is a sharp-edged weir, as distinguished from other weirs?

A. It is where the crest is narrow and worked off to a sharp edge.

Q. How is the discharge of such a weir obtained?

A. By the head of the weir.

Q. Who have made the principal investigations on the flow of water over such weirs?

A. The late James P. Francis made very extensive observations on the flow of water over weirs; also Fteley and Stearns, and Bazin.

Q. They derived formulæ for the flow, did they not, over such weirs?

A. They did.

Q. What is the most commonly accepted form of weir formula?

A. I should say that of Francis.

Q. What is that formula, do you remember it?

A. I could not give it. It has been so long since I have been testing with these problems as referred to weirs.

Q. Is it Q equals C L H, exponent 3 over 2?

A. It is very close to it. That is the formula.

Q. In that formula Q equals the discharge?

A. Yes.

Q. The length of the weir crest?

A. Yes.

Q. H equals what?

A. The head of the weir.

Q. The head of the water above the crest?

A. Yes.

Q. And the C equals the co-efficient determined by experiment?

A. Determined by experiment.

Q. How was C determined, the co-efficient?

A. By actually determining the volume that flowed over a weir for various stages?

Q. That is volumetrically?

A. Volumetrically.

Q. From Mr. Francis' experiments, what value of C was adopted for general use?

A. I have forgotten the value.

Q. Was it 3.33?

A. 3.33, something like that.

Q. Still speaking of a sharp edge crested weir?

A. Yes.

Q. That is your understanding?

A. Yes.

Q. Did the value of C in Mr. Francis' experiments change with the different weirs used by him?

A. I should say yes, although it is a long time since I have read those experiments. I do not recall the details of them.

Q. Do you know through what range as a mean for each type?

A. It seems to me it was about 1.6 feet.

Q. Through what range as a mean for each type; that is the co-effiicent change?

A. Well, I have forgotten. It would be mere guess work on my part to make any statement in regard to it at this time.

Q. Do you remember through what range the head changed?

Mr. Hopkins: You are still speaking of Francis' experiments?

Mr. Adcock: Yes.

Mr. Hopkins: Objected to on the ground he is not qualified to testify as to what the other man did.

Mr. Adcock I assume that these are well known experiments. The calibration of a certain weir was criticised by Mr. Haskell, in the course of his direct examination.

A. I have forgotten the details of those observations. My general impression is that it was somewhere around two feet, the range of head on the weir which Francis used.

Q. I will refer you to page 122 of Lowell's Hydraulic Experiments, and ask you if that will refresh your recollection; the author being—

A. Mr. Francis.

Q. Mr. Francis?

A. Yes, James P. Francis.

Q. I will ask you to refresh your recollection by examination of that. Also refer to the pages following (handing witness volume referred to).

A. 1.56 feet seems to be the maximum given here.

Mr. Hopkins: Let it appear that you are reading from the book just handed to you, Mr. Haskell.

The Witness: Yes.

Mr. Adcock: I do not think it need appear that way at all. I have asked the witness a question as to what it was, and I have given him a book to refresh his recollection.

Mr. Hopkins: Is your answer based upon your knowledge independently of the book or is it what you read from the book, Mr. Haskell?

A. It is what I read from the book.

Mr. Adcock: Q. Is this work of Mr. Francis considered an authority by hydraulic engineers?

A. It is.

Q. One of the standard works?

A. One of the standard works.

Q. Through what range did the co-efficient vary by individual experiments in Mr. Francis' work? You still have Mr. Francis' work there, have you not?

A. I have.

Q. You can refer to it if you wish to refresh your recollection.

Mr. Hopkins: To all questions based upon the book, if it does refresh your recollection so that you can testify from that recollection, say so; if not, say you are reading from the book.

A. The range here is from 3.36 to 3.31, that is the co-efficient.

Mr. Adcock: Q. What page are you referring to, Mr. Haskell?

A. Page 123.

Q. That was for the groups that you stated, was it not?

A. I take it that that is—

Q. The group means?

A. No; they are in the right hand column, the group means—yes, that would be true.

Q. For group means?

A. For group means, it would be true.

Q. For individual experiments?

A. I did not catch that last question.

Q. What was the range of co-efficient by individual experiment?

A. I find 3.3 to 3.36.

Q. What percentage would this be each way from a mean value of 3.33? It would be about .9 of 1 per cent, would it not?

A. I should say so.

Q. The Mr. Stearns that you referred to as collaborating with Mr. Fteley was Mr. Frederic P. Stearns?

A. Frederic P. Stearns.

Q. In the experiments of Fteley and Stearns on the Farm Pond Gate House Weir, what were the dimensions of the weir used?

A. I don't remember them.

Q. These experiments are recognized as authoritative experiments among hydraulic engineers, are they not?

A. They are recognized as good experiments.

Q. For the purpose of refreshing your recollection, I will refer you to Transactions of American Society of Civil Engineers, Volume 12, page 69, and ask you if you can give us the answer to that question after making reference to the book and page mentioned?

Mr. Hopkins: I think I will make an objection to this testimony as to experiments by other people, not cross examination, not competent; and I want it to appear whether the witness is testifying from his own recollection or from certain books that are handed to him.

Mr. Adcock: Q. You knew what those experiments were at one time, did you not, Mr. Haskell?

A. Yes, I have been familiar with them. I have read these experiments over, sometime ago, and was familiar with them at that time. I have not had occasion to use them for several years and so have forgotten many of the fine points that are given here.

Mr. Adcock: Does the counsel for complainant wish to protest further?

Mr. Hopkins: Just simply as to the form of your question. You say refresh his recollection. When he is simply reading from a book, he is not refreshing his recollection.

Mr. Adcock: Then you do not wish to protest further?

Mr. Hopkins: I will take care of that when we get to it. I am simply making these objections now so that you may know what I have in mind as to form. Anything else I have to say as to substance, we can take up later, anyway.

Mr. Adcock: I considered that your objection perhaps was more to the substance.

The Witness: Will you ask that question again, Mr. Adcock?

Mr. Adcock: Q. In the experiments of Fteley and Stearns on the Farm Pond Gage House Weir, what were the dimensions of the weir used?

A. The length of the weir is given as 18.966 feet.

Q. And the height of the weir?

A. Depth of channel below crest of weir was 6.55 feet.

Q. This weir was considerably larger than the weir used by Mr. Francis?

A. I believe so.

Q. Do you recall the dimensions of Mr. Francis' weir?

A. No, I do not.

Q. It is your belief that it was larger, is it not?

A. Yes, it is.

Q. What was the range of C in the formula Q equals C L H, exponent 3 over 2, and how many experiments are included in the Fteley-Stearns derivation?

A. Ten experiments are given in this table, the lowest value of C being 3.304, and the highest 3.327, practically.

Q. Isn't the range from 3.29112 to 3.3040 for ten experiments?

A. It is for the ten experiments.

Q. The percentage variation from the mean value of say 3.2976 was less than .2 of 1 per cent, was it not?

A. It was.

Q. What was the range of discharge measured, was it from 20 c. f. s. to 130 c. f. s.?

A. It was, according to this table.

Q. Referring to the Large Basin experiments with a weir approximately five feet long and 3.17 feet high, what was the range of C, in the formula mentioned, excluding 3 defective experiments?

Mr. Hopkins: Have you referred to the Basin experiments before?

Mr. Adcock: That is another weir.

Mr. Hopkins: Describe it in detail. Tell us in your answer what you are referring to and where you got your information.

A. That is in Table 14, opposite page 56.

Mr. Adcock : Q. These were the experiments of Fteley and Stearns, were they?

A. Yes. The largest one which I see given here is 3.428 and the smallest one is 3.340.

Q. You are referring to page 56, are you?

A. To the table opposite page 56, Large Basin Experiments.

Q. That is showing the Fteley-Stearns experiments as published in the Transactions of the American Society of Civil Engineers?

A. Yes.

Q. How many experiments do these cover?

A. Sixteen are recorded here.

Q. There were three defective experiments excluded, were there not, and the range which you have just mentioned there covered 13 measurements or experiments, did it not?

A. There are three observations in that—

Q. So that the range covered 13 experiments?

A. The range covered 13 experiments, rejecting those three; 16 altogether, 3 of which were rejected.

Q. What was the range of discharge?

A. Not counting the rejected experiments, 2.078 to 12.750 cubic feet per second.

Q. What was the maximum percentage error from the mean value of the co-efficient of say 3.384?

A. Less than 1 per cent.

Q. Now, Mr. Bazin made some experiments, didn't he?

A. Yes.

Q. He was a Frenchman?

A. He was a Frenchman.

Q. And they are recognized as authority among hydraulic engineers, are they not?

A. They are, for the types of weirs upon which he experimented.

Q. What dimensions of weir did Mr. Bazin use?

Mr. Hopkins: Same objection to questions in regard to his experiments as was made to the others.

Mr. Adcock: Those experiments of Mr. Bazin are familiar to you, are they not?

A. Why I have read them, but it has been several years since and I am not familiar with the details.

Q. You recognize those experiments as authority, don't you, for the type of weir used?

A. Upon the type of weir upon which he experimented, they are considered as authority.

Q. He made experiments with a sharp edged weir, or sharp crested weir?

A. Yes, he made experiments on a large number of types. I do not recall the individual ones.

Q. I have handed you a book. What is it called?

A. Number 52 of the Annals des Ponts et Chaussees. The paper is entitled: "Experiences Nouvelles Sur L' Ecoulement en Deversoir, Par M. H. Bazin, Inspecteur General des Ponts et Chaussees."

Mr. Adcock: With your permission, perhaps Mr. Williams can assist the witness, as I understand he is familiar with the French language.

Mr. Williams: I think Mr. Haskell has all the information necessary for him to proceed.

Mr. Hopkins: Let it appear that Mr. Williams is telling what is in that book.

Mr. Adcock: Q. What dimensions of weir did Mr. Bazin use?

A. He evidently started with a weir two meters in length.
Q. What was the size of the weir that he later used?
A. Observations are shown here in the table labeled "Series Number 2," in which he used a weir one meter in length.
Q. What was the height of the different weirs?
A. The height of the weir is given as 1.135 meters above the bottom of the channel.
Q. How many experiments did he make on the largest weir, was it 67?
A. 67.
Q. What was the range of his co-efficients?
A. The first one seems to be the largest. His co-efficient ranged from 0.4225 to 0.4440.
Q. What is the maximum percentage variation from a mean value of say 0.4332?
A. About 1 per cent.
Q. Less than .2 of 1 per cent, wouldn't it be?
A. Yes, less than .2 of 1 per cent.
Q. Assuming a weir constructed in all particulars like the 19 foot weir of Fteley and Stearns, how accurately would you think it possible to determine the discharge of water over it by using as a basis the experiments of Fteley and Stearns on their 19 foot weir?
Mr. Hopkins: Objected to as not proper cross examination.
A. There are other qualifications to come in there.
Mr. Adcock: Q. What is that?
A. There are other qualifications.
Q. What are they?
A. That is the weirs should be identical.
Q. That they should be identical. In all particulars alike?
A. Yes, all particulars alike.
Q. You mean of exactly the same size or what?
A. Not necessarily the same size but—
Q. Similar in dimensions?
A. Similar in dimensions and similar in construction.
Q. Assuming that they were in all particulars the same?
A. I should say within 1 per cent.
Q. Would it be less than 1 per cent?
A. Not much less.
Q. Wouldn't it be approximately a quarter of 1 per cent?
A. It would depend entirely on the amount of labor that you put on the observations, as to whether it would be that accurate or not.
Q. Assume that Fteley and Stearns got their co-efficients

to agree within .2 of 1 per cent, what would you say then as to the accuracy of measuring water under the conditions mentioned, measuring the discharge under the conditions mentioned?

A. For that particular weir, I should say within that percentage.

Q. Assuming the weir to be 6.65 feet instead of 6.55 feet in height, what difference would that make?

A. Practically no difference.

Q. Assuming a length of 16 feet instead of 19 feet, would the discharges be proportional to the length?

A. Yes.

Q. What other forms of weirs are there?

A. Flat crested, round crested; in fact, a large variety of forms.

Q. Is the same formula applicable to other types if the coefficient be changed?

A. Yes.

Q. Can any obstruction in a stream of flowing water, such that the level of water on the downstream side is below the level of the top of the obstruction when water is flowing over it, be considered as a weir?

A. Yes.

Q. Does the discharge of all overfall weirs vary as the 3-2 power of height above the crest of the surface of still water upstream?

A. Substantially so.

Q. You are familiar with the St. Marys River at Sault Ste. Marie, are you not?

A. Yes.

Q. You made some discharge measurements there?

A. I did.

Q. And they were carefully and accurately made?

A. They were.

Q. You are familiar with the discharge observations made in 1896 at the Spry Dock Section?

A. I am.

Q. They were made by you?

A. They were. That is the winter of 1895-1896, those were made by me.

Q. You are also familiar with the discharge measurements on the St. Marys River at the International Bridge about 1902?

A. I am.

Q. They were made by Mr. W. E. Wilson?

A. He made the observations, I believe, at that time. There were some made previous to his by Mr. Russell; also by Mr. Johnson.

Q. You have already stated that you are familiar with the discharge measurements made on the St. Lawrence and Niagara Rivers by Dean Shenehon, haven't you?

A. I have.

Q. Are you familiar with the measurements made on the St. Marys River at Section Brewery in 1905?

A. I am.

Q. They were made by whom?

A. Mr. Murray Blanchard had charge of the party.

Q. Who else?

A. No one else.

Q. Was Mr. Turner, Professor K. B. Turner, in the party?

A. Mr. Turner acted as recorder in the party.

Q. Do you know whether he did anything else beside acting as recorder?

A. Why that is all he was supposed to do. His duty was that of a recorder to that party.

Q. You sent him up there as a recorder?

A. As a recorder to that party.

Q. Do you believe the measurements on the St. Marys River to be more or less accurate than those on the St. Lawrence and Niagara?

A. They are less accurate than those on the Niagara.

Q. What percentage?

A. From 2 to 3 per cent, I should say.

Q. The measurements made on the St. Clair River in 1899, 1900, 1901 and 1902, were made by Mr. Sabin and Mr. Blanchard, under your direction, were they not?

A. They were.

Q. What is your opinion as to the correctness of the discharges obtained from those measurements on the St. Clair, as compared with those on the Niagara and the St. Lawrence by Professor Shenehon, under your direction?

A. I should give the individual measurements equal weight. That is, I should consider those made on the St. Clair just as accurate as on the Niagara.

Q. What about the measurements on the Detroit River as to their relative accuracy?

A. The individual measurements, I should place nearly the same precision on them.

Q. Mr. Quintus made some measurements on the Niagara River, did he not?

A. He did.

Q. He was an assistant engineer in the United States Engineers' Office at Buffalo.

A. At Buffalo.

Q. The results of his measurements are published in the report of the Chief of Engineers for 1893, part 6, page 4371, are they not?

A. I think that is correct. It was about that time.

Q. Just when and where were those measurements made, do you remember?

A. As I recall it, they were made just below the International Bridge.

Q. How far?

A. As I recall it, very close to what we have called the Open Section.

Q. About 1,800 feet below the International Bridge?

A. About 1800 feet below the International Bridge.

Q. That was near Mr. Shenehon's section?

A. Near Mr. Shenehon's section.

Q. Is there on file a cross section of the river, showing the soundings he took?

A. I have forgotten whether it is in his report or not.

Q. What increment did Quintas get for the Niagara River?

A. An absurd one.

Q. What is that?

A. An absurd one.

Q. Was it 21,000?

A. I have forgotten his figures. When I said an absurd one, I was referring more particularly to the form of the curve, the discharge curve which he worked out.

Q. When did he make his measurements?

A. It was somewhere in the early nineties. I have forgotten the exact year.

Q. About 1893, was it?

A. Somewhere about that time. It was some two or three years previous to the beginning of the investigation of lake levels by the Lake Survey.

Q. Mr. Quintas was not connected with the Lake Survey?

A. No, he was an assistant engineer in the United States Engineers' office at Buffalo.

Q. What was the matter with his curve?

A. The trend of it was in the wrong direction.

Q. What kind of a meter did he use?

A. He used a cup wheel meter, known as the Price Meter.

Q. You would not give much weight to Mr. Quintas' measurements then?

A. No, I should not. They gave approximate results.

Q. How about his increment?

A. I should not give much weight to that.

Q. Have you any idea as to the percentage of accuracy of Quintas' increment and discharge measurements?

A. I should not care to express any idea.

Q. Didn't he make his soundings right, or accurately?

A. My recollection of that matter is that those observations were very hurried, and the methods followed throughout were crude as compared with those under which the Lake Survey observations were made.

Q. He got his cross section, didn't he?

A. Oh, certainly.

Q. And then he had gage readings, didn't he, showing the water levels at the times?

A. Certainly.

Q. And he measured the velocity of the current?

A. Yes, and as I recall—

Q. At the hydraulic section?

A. And as I recall it, without anchoring their boat from which they worked. The boat ran her wheel to keep up on the range, while the observations were in progress.

Q. And you think that the meter was not immersed exactly on the section, on account of not anchoring the boat?

A. It might not have been.

Q. And that would make considerable difference?

A. There is a chance for error to come in, from the operation of the wheel of the tug.

Q. That is the tug churning her wheel there would create a disturbance which might throw the meter off?

A. That is it might influence the meter.

Q. How far away was the tug wheel from the place where the meter was submerged?

A. Oh, I don't recall the details of that work.

Q. Do you remember approximately?

A. Why it was customary on the Mississippi River, where Mr. Quintas worked on discharge work for some time, to lower the meter about 12 feet from the side of the boat, and the exact distance on these particular observations I do not recall; don't know that I have ever known that.

Q. From the middle of the stern or the bow of the boat?

A. It was customary to work from the stern of the boat with the meter.

Q. You think that any eddying which might be caused by the churning of the wheel of the boat, or from any other cause, would have some effect on the meter, then?

A. On velocities measured at the surface or near the surface.

Q. At what point was the meter placed in the water with reference to the water surface, the depth?

A. I don't remember, but I think he used mid depth.

Q. Instead of .4?

A. Instead of .4.

Q. Was the mid depth used in the work on the St. Clair River by Mr. Sabin?

A. I believe Mr. Sabin did use mid depth.

Q. Suppose that we had an open channel similar to the St. Lawrence or the lower Mississippi River, and at a certain period the fall over a certain length was 5 feet, and suppose that at some other time the fall was still 5 feet, but the water was, say, 1 foot lower at both ends, about what would be the effect upon the discharge in the second case, as compared with the first?

A. It would be less.

Q. How much less, what ratio?

A. That depends entirely on the size of the stream at that particular point.

Q. Would it be in proportion to the mean cross section?

A. In proportion to the cross section and velocity.

Q. (Question read.)

A. It would be less, the discharge would be less.

Q. In what proportion would it be less?

A. In proportion to the cross sections.

Q. Would there be a further decrease due to decrease in hydraulic radius?

A. A further decrease?

Q. Yes?

A. (Answer deferred until after recess.)

Recess to 2:20 p. m.

After Recess, 2:20 p. m.

EUGENE E. HASKELL resumed the stand and testified further on cross-examination as follows:

Q. (Question read as follows: "Would there be a further decrease due to decrease in hydraulic radius?")

A. Yes.

Q. Suppose in the same channel at another time the fall was only 4.5 feet and the elevation of the water at the upstream end was still 1 foot lower than in the first case, how would the discharge compare with that of the original condition, that is would it be more nearly equal to it than in the last case considered or otherwise?

A. That is the discharge would be less.

Q. Discharge would be less?

A. Yes.

Q. What is your opinion as to the run-off from the drainage areas of the Great Lakes and the precipitation on their surfaces, as to whether the total amount of inflow from all sources is increasing or decreasing?

A. I do not believe we have any reason to believe that it is any less than it used to be.

Q. Is it any greater?

A. Why we have no reason to think that it is any greater. That is, I am speaking now of a long period of time. Of course there are annual variations.

Q. But you consider it to be about the same in the later period as in the former periods?

A. Yes, that is the mean.

Q. Taking it over a long period?

A. Taking it over a long period, yes.

Q. Is it your opinion that the inflow into Lakes Michigan and Huron has been greater or less during the last 20 years than it was during the period from 1860 to 1880?

Mr. Hopkins: Objected to as not proper cross-examination.

Mr. Adcock: Is it your objection that it is not within the scope of the direct examination of the witness?

Mr. Hopkins: Yes. I did not go into anything of that kind.

A. I should say there were periods in that last 20 years when it was less.

Q. But take the average, the mean for the last 20 years as

compared with the average, the mean for the period from 1860 to 1880.

A. From 1860 to 1880—

Mr. Hopkins: Did this involve the run-off?

Mr. Adcock: I presume it would; it is inflow into the lake.

Mr. Hopkins: It was not precipitation alone?

Mr. Adcock: No.

The Witness: I should state that they were substantially the same.

Q. If you had two reservoirs of different size with their water surfaces at certain elevations with a certain inflow and outflow, and for a given time the flow into both should be increased an equal amount, assuming that both had discharge openings exactly similar as to discharging capacity for equal changes of head, would you expect the water to rise by a greater amount in one than in the other?

A. Yes.

Q. Which one?

A. In the smaller one.

Q. On account of the difference in storage?

A. Not necessarily that, the difference in evaporation.

Q. Would the storage have no effect?

A. Certainly, that is if an equal quantity were flowing into both lakes.

Q. And one was greater than the other?

A. Certainly.

Q. The water would rise higher in the smaller lake?

A. In the smaller lake.

Q. Than it would in the larger one?

A. Yes.

Q. And one reason would be because of the difference in the storage capacity?

A. Yes.

Q. And you say that another reason would be because of the difference in evaporation?

A. That is that might be the case.

Q. It might be the case?

A. It might be.

Q. That would depend, I presume, upon conditions?

A. Depend upon conditions.

Q. If the inflow to the smaller were greater in the same given time than that to the larger and the water in the two reservoirs raised by the same amount, what would that indicate as to the relative outflow per unit change of height of the two outlets?

A. I have not got that question clear in my mind yet.

Q. (Question read.)

A. If I understand the question correctly, I should say that the increment in the larger reservoir, the increment from the outflow in the larger reservoir would be the greater.

Q. (Question re-read.)

A. It would be greater in the smaller reservoir.

Q. Is the increment of the Detroit River greater or less than that of the St. Clair?

A. It is greater.

Q. Upon what do you base your conclusions stated in the last answer?

A. By virtue of the additional supply which comes in between Lake Huron and the Detroit River.

Q. That is over the St. Clair River?

A. The St. Clair River Basin, or the Lake St. Clair and St. Clair River Basin.

Q. Would that same conclusion be applicable, a comparison between the Niagara and the Detroit Rivers and between the Niagara and St. Lawrence Rivers?

A. Not necessarily so.

Q. Will you state your reasons, Mr. Haskell?

A. For certain seasons of the year, it would, and for other seasons of the year, when the evaporation was greater, I should say it would not be so.

Q. What seasons of the year?

A. The summer months.

Q. That is it would not hold in the summer months, that is your conclusion?

A. Yes.

Q. Do you believe that an increment can be derived for the St. Clair River that will be applicable to the varying conditions of the period from say 1884 to 1908, from the observations made from 1899 to 1908, inclusive?

A. I do.

Q. Can an accurate increment be derived from those observations without involving in the equation of discharge, the position of Lake St. Clair?

A. Yes, I believe one could be worked out.

Q. If you had a reservoir into which a quantity of water was flowing at the same time that water was flowing out, and the water was rising in the reservoir at a known rate, and a change should be made in the outlet such as to cause a less rapid rise in the reservoir, what would that indicate as to whether the outlet had been enlarged or restricted?

A. If I understood that correctly, it would indicate an enlargement of the outlet.

Q. If the inflow and outflow continued under the last condition until the water in the reservoir ceased to rise, would it have reached a higher or a lower level than in the case no change had been made in the outlet?

A. It would have reached a lower level.

Q. And if when the outlet was changed its area had been decreased, would the water then rise more or less rapidly in the reservoir, the inflow remaining the same?

A. It would have a tendency to rise.

Q. It would rise more rapidly, wouldn't it?

A. It would rise more rapidly.

Q. I hand you here, Mr. Haskell, a paper which I ask to be marked Haskell's Exhibit A, for Identification, February 25th, upon which there appears certain figures in columns I, II, III, IV, V, and VI, and ask you to examine it, and suppose that for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo and Niagara, for a period of years the elevation of the water at the upstream end had been as shown in the first column, and the fall through the channel had been as shown in the second column? And suppose that it were desired to obtain a discharge curve for this section that would represent the discharges of the period referred to the head at the upstream end, and suppose that there had been made a series of 27 observations under the conditions of columns III and IV, and that there was also available a series of 23 observations made with equal care under the conditions shown in column V and VI, which in your judgment would give a discharge curve the more closely applicable to the assumed conditions of columns I and II; columns I, III and V, representing the elevations and columns II, IV and VI, representing slope?

Assuming further that the elevations shown are at the head of the river.

(Table handed to witness in connection with the foregoing question was marked Haskell's Exhibit A, February 25, 1914, and is as follows):

I	II	III	IV	V	VI
247.77	6.46	245.66	6.27	245.84	5.95
247.55	6.10	245.48	6.00	245.57	5.79
245.30	6.03	245.85	5.95	245.51	5.70
247.04	6.00	245.19	5.92	245.71	5.67
246.50	6.00	245.57	5.79	245.63	5.67
247.35	5.87	245.51	5.70	245.28	5.60
245.88	5.79	245.71	5.67	245.20	5.58
245.62	5.59	245.63	5.67	245.24	5.56
245.50	5.59	245.28	5.60	245.00	5.56
245.72	5.56	245.20	5.58	245.45	5.55
245.72	5.21	245.24	5.56	245.38	5.55
245.16	5.50	245.00	5.56	245.15	5.54
244.42	5.47	245.45	5.55	245.11	5.51
245.07	5.42	245.38	5.55	245.32	5.46
245.74	5.42	245.15	5.54	245.07	5.43
245.81	5.35	245.11	5.51	244.96	5.38
244.96	5.33	245.32	5.46	244.84	5.34
244.93	5.30	245.07	5.43	244.65	5.34
246.71	5.28	244.96	5.38	244.91	5.32
244.89	5.23	244.84	5.34	244.77	5.29
245.09	5.23	244.65	5.34	245.09	5.25
245.01	5.23	244.91	5.32	244.43	5.19
245.09	5.12	244.77	5.29	244.67	5.06
244.19	5.08	245.09	5.25	.....	....
.....	....	244.43	5.19	.....	....
.....	....	244.67	5.06	.....	....
.....	....	245.38	4.97	.....	....
Aver.					
245.71	5.548	245.20	5.54	245.16	5.49
Max.					
247.77	6.46	245.85	6.27	245.85	5.95
Min.					
244.19	5.08	244.43	4.97	244.43	5.06
Change of Fall.					
.....	1.38	.....	1.30	.....	.89
Change of Elev.					
.....	3.58	1.42	....	1.42	....

A. I understand all of these gage readings were taken at the head of the river?

Q. Yes.

(Question read.)

Mr. Hopkins: I object to that question on the ground that it assumes theoretical conditions which do not appear in evidence in the case, both in regard to the presence or absence of the falls and rapids, and in regard to the channels assumed, elevations and so on.

A. I must say that I do not understand the question here.

Q. (Question read.)

A. We would undoubtedly get a more consistent result by using the slope.

Mr. Adcock: That is not the question.

(Question repeated.)

A. An engineer would naturally take that second group, the third and fourth and fifth and sixth, where he had the slope.

Q. Columns three and four?

A. Because he had the slope there.

Q. You have the slope in both cases?

A. Yes.

Q. Which would you take, three and four?

A. I should take three and four.

Q. If the elevations in columns I, III and V should have been 200 or 300 or 400 or any number of feet higher in every case, would your answer be the same?

A. Certainly; that would make no difference.

Q. Suppose that at two sections of a large river separated by say 5,000 feet, a series of discharge measurements covering at least 50 different discharges at each section should be made, in the usual manner and with the care that you use in the United States Lake Survey, including all preliminary work, and the range of head should be identical at both sections, but the observations at the two sections should be made on different days, and suppose that the mean elevation at which the observations were taken at each section were the same, and suppose that the mean measured discharges at the two sections agreed within 1 per cent, with what degree of accuracy would you say the discharge had been measured, for the center of gravity of the observations?

A. Within 1 per cent.

Q. Suppose that in a certain channel there were two weirs within 400 feet of each other, that the weirs were of different heights but of approximately the same length of crest, and assume that all the water which passed over one must pass over the other, except a small leakage which was collected and

measured and found to be less than one-tenth of one per cent of the quantity of water flowing, and assume that the quantities of water discharged over the two weirs in a series of at least 100 observations on each, when computed for the two weirs by any of the three principal weir formulae agreed within 1 per cent for each observation, the heads ranging from 1 to 3 feet, what would you say as to the accuracy of the measurements?

A. I should say they were very accurate.

Q. Within what percentage of accuracy?

A. Under those suppositions, considerably less than 1 per cent.

Q. What would you say as to the accuracy of the calibration of the weirs for the range in question if one weir was within 1-10th of a foot of the same height and within 3 feet of the same length as, and was similarly constructed to, the large weir used by Fteley and Stearns in their volumetric calibrations on the Boston Aqueduct?

A. I should say it was very accurate.

Q. Within what per cent?

A. Within less than 1 per cent.

Q. What would you say as to the accuracy of calibration if the agreement as before were within ½ of 1 per cent?

A. That it would be accurate within ½ of 1 per cent.

Q. In the float observations in Vinyard Sound, which you mentioned in your direct testimony, was the velocity uniform in the upper five feet of the current?

A. Yes, sir.

Q. Then why was the meter immersed 5 feet in that case?

A. No particular reason; it could have been two feet or three feet.

Q. How was the velocity of the submerged float observed?

A. Of the submerged float?

Q. Yes.

A. The submerged float was connected to a small copper float on the surface by a piece of fine wire and the velocity of the copper float was observed.

Q. Was the velocity of the lower float accelerated or retarded by the surface float?

A. No.

Q. How was it known that the sub-surface float remained at a uniform depth of 5 feet?

A. The sub-surface float was made of such a weight that it would partially sink the surface float, keep it in position.

Q. How do you know that the velocity was uniform in the upper 5 feet?

A. The sub-surface float was made of such a weight that it would partially sink the surface float, keep it in position.

Q. How do you know that the velocity was uniform in the upper 5 feet?

A. My recollection is that we measured the velocity at several depths from the surface down.

Q. How many?

A. I would not attempt to state that accurately.

Q. Did you measure it at the surface?

A. At the surface, and usually over five feet.

Q. How close to the surface?

A. For surface velocity when the water is perfectly smooth, the meter is usually run at one foot depth.

Q. Do you know what the velocity was at the surface, the actual surface of the water?

A. It is substantially that given in that pamphlet.

Q. How did you determine that?

A. In a tidal stream where the water is deep the vertical velocity curve is practically a straight line for considerable depth.

Q. Is it a straight line in the upper six inches of the surface?

A. If there is no wind blowing, it would be.

Q. What was the condition on that day, was there no wind?

A. Perfectly calm.

Q. The water surface was perfectly smooth?

A. Perfectly smooth.

Q. Is there no retardation due to the air when there is no wind blowing?

A. In a case of that kind it would be so small that we could not measure it.

Q. How do you know that, Mr. Haskell?

A. From experience.

Q. Would you be willing to state what experiments you have made in that connection?

A. Made a good many observations in the Gulf Stream, in the winter of 1890-91 that would confirm that.

Q. What were those observations and how were they made?

A. They were made with a current meter from the Coast and Geodetic Steamer Blake in the Gulf Stream off the coast of Florida.

Q. How close to the surface was the meter read?

A. Some days it would be run as close as a foot; and some

days not as close as that, depending upon the surface conditions.

Q. What did you make as to the distribution of velocities in the upper foot?

A. In the upper foot we practically—we did not measure anything in the upper foot.

Q. Then if that is true, Mr. Haskell, how can you say that the velocity did not change in the upper foot?

A. That is the projection of the curve, from having measured velocities below, that would have a tendency to show that there was practically no difference in that other foot.

Q. You simply projected the curve?

A. We projected the curve.

Q. You projected the curve from measurements made below the foot?

A. Yes.

Q. Below the upper foot?

A. Yes.

Q. Assuming that there was a difference in the velocity at the surface, and it was a perfectly still day, would the velocity at the surface be greater or less than the velocity at the five-foot depth?

A. Theoretically—the velocity at the surface you are referring to?

Q. Yes.

A. Theoretically it would be less because of the friction of the atmosphere.

Q. And if it were less, then the indication of the float velocity would be too small, would it not? If it were less, the indication of the velocity by the float would be too small?

A. Theoretically.

Q. Therefore if the float velocity were too low and the meter agreed with the float, the meter would under register, wouldn't it?

A. In that case.

Q. You mentioned a comparison of a meter and a weir made at Philadelphia. How accurately do you think that weir was rated?

A. That I can't say further than the work was done by engineers of the Bureau of Surveys of the city.

Q. You don't know how the weir was constructed?

A. Nothing further than what is given in a report which they made upon the subject.

Q. Did you have any experience and training in the meas-

urement of streams before entering the employ of the United States?

A. No.

Q. At how frequent intervals in the vertical are current meter measurements taken in the so-called co-efficient work?

A. Velocity measurements are made at the tenths of depth.

Q. Suppose a vertical to be so measured ten times at the same elevation of water surface, how closely would the river velocity at that vertical be determined?

A. Within ½ of 1 per cent.

Q. Suppose one-fifth depths had been observed instead of one-tenth depths, would the determinations have been more or less accurate?

A. I should say less accurate; that is as a general answer to that question.

Q. What percentage of less accuracy?

A. Oh, less than 1 per cent.

Q. Suppose that 1-20th depths were used, would the determination have been more or less accurate?

A. A general answer to that question would be that it would be more accurate.

Q. What would be the percentage of accuracy?

A. Oh, the vertical curve would be determined within less than ½ of 1 per cent, that is the true vertical curve.

Q. That is it would be more accurate than if the observations were taken at the 1-10th depth, is that right?

A. Generally speaking that would be the case.

Q. Would you say about 1-16th of a per cent?

Mr. Hopkins: Does that assume the same number of traverses?

Mr. Adcock: Yes.

A. I take it for granted you were referring to the same number of measurements of the curve.

Q. Would you say 1-16th of 1 per cent?

A. Oh, say within a quarter.

Q. Then with reference to the observation taken at the 1-10th depth, you think it would be less than ½ of 1 per cent?

A. Yes.

Q. What would you say as to that, within say 5-16ths of 1 per cent of accuracy, or ⅞ths of a per cent?

A. Why I should say that we knew the curve with an accuracy of less than ½ of 1 per cent.

Q. Couldn't you get closer than ½ of 1 per cent? That is quite a ways off?

A. Individual results might turn out less than that. You

might have certain curves where it gave less than ½ of 1 per cent

Q. I presume it is assumed that the velocity measurements were made with the Haskell meter when you give those values. Is that correct, Mr. Haskell?

A. Any good reliable meter, Mr. Adcock, will give you the same results.

Q. But you would prefer the Haskell meter, if you were going to get down as close as ½ of 1 per cent?

A. Certainly I should.

Q. Have you ever made observations using the 1-20th depths?

A. I have not.

Q. Have you ever calibrated a weir?

A. Never have had any occasion to.

Q. Have you ever used a weir in measuring water?

A. I don't believe that I have.

Q. You would prefer the Haskell meter to the weir? That is to measure the water?

A. For measuring such streams as the lake outlets.

Q. Have you ever compared a discharge measured by current meter with the same discharge determined by volumetric or gravimetric measurement?

A. No, I have not.

Q. Do you know of anyone who has?

A. No, I do not.

Q. Have you ever compared the discharge measured by current meter with the same discharge determined by an orifice, nozzle or weir?

A. No, I have not.

Q. If in determining the mean velocity in a certain vertical, two series of measurements were made, in each of which the velocities from surface to bottom were observed ten times, and in one series they were observed at the 1-10th depths and in the other at the 1-20th depths, which series in your opinion would give the more accurate determination of the ratio between the mean velocity in that vertical and the velocity at the 4-10ths depth point?

A. The greater number of observations you can have in determination of the vertical curve, the more accurately it is determined, generally speaking.

Q. So that the ratio between the mean velocity in that vertical and the velocity at the 4-10ths depth point would be more accurately determined, assuming that it was measured

at the 1-20th rather than at the 1-10th depth, wouldn't it?

A. Your two determinations might agree absolutely.

Q. But assume you did not have any other?

A. Generally speaking, that would be the case.

Q. You would think the 1-20th would be perhaps more accurate than the 1-10th?

A. Yes.

Q. Did you ever make any current meter measurements on the St. Clair, Detroit, Niagara or St. Lawrence Rivers, to investigate the question as to whether or not the rate of travel of the crest of a rise of lake coincided with the rate of travel of the increased discharge corresponding to that stage of lake?

Mr. Hopkins: Objected to as not proper cross-examination.

A. No.

Mr. Adcock: Q. Do you know whether it does or not?

A. No, I do not, definitely.

Q. Suppose that the velocity had been observed at ten points in each vertical of a gaging section, and that this had been repeated ten times at the same stage, within what degree of precision would you say the discharge was known at that stage?

A. Within ½ of 1 per cent.

Q. Well how much less than ½ of 1 per cent, materially less?

A. No, I should think that that covered the range. When we get as close as that, we think we are getting things pretty accurate.

Q. In your direct examination, you stated that the most accurate method of rating a meter was by drawing it through still water. In what other ways have you rated meters?

A. By rating them in running water.

Q. How?

A. Both by running them against and with the current, combining them in pairs, and by comparing the meter to be rated with another one, the rating of one of which is known, in close proximity to each other in the same current.

Q. When the meter is passing through still water, is it operating under conditions the same as the conditions which exist when it is used in determining velocity in a river like the Niagara or St. Lawrence or St. Clair Rivers?

A. We assume that it is.

Q. That is it is running along at an even velocity in the still water?

A. Yes.

Q. And the Niagara River, the threads of the current of the Niagara River are even, a uniform velocity at all times?

A. No, there is a slight variation in the velocity.

Q. So you would consider that the Niagara River, the conditions there were similar to the conditions that exist when rating the meter in still water?

A. We assume that that is the case.

Q. Do the hydraulic engineers of the country agree with you on that proposition?

A. There are lots of them who do not.

Q. Then there is a difference of opinion?

A. Difference of opinion.

Q. In other words, some think that the Niagara River is not a very slow or smooth moving river?

A. Of course it depends upon what part of the Niagara you take.

Q. Take a place like the Bridge Section, with the piers and so forth in there, they disturbed the current to some extent?

A. That reach of the river is a fairly regular one.

Q. Right around the pier?

A. No, there is eddying caused by the pier.

Q. Do all hydraulic engineers agree that you should pick out a section at a bridge where there are bridge piers in the stream as a gaging section?

A. If the conditions are good for measuring the discharge at a Bridge Section, we take that for the reason that observations can be made there more cheaply than where we have to fit up with a boat.

Q. Are you familiar with the statement made on page 5332 of Appendix III, of the report of the Chief of Engineers for 1900 as follows:

"The wetted perimeter of the Bridge Section as developed by the soundings is so broken and irregular, and the water so perturbed and deflected by the bridge piers, and by a caisson that escaped during construction and lies across a portion of span 6, that the validity of results derived from such a section may be questioned," and do you know by whom that statement was made?

A. Yes, that statement was made by Mr. Shenehon in his report upon Niagara observations.

Q. That was the section selected by you and Mr. Shenehon for the 1898, 1899 and 1900 measurements?

A. We began the work of measuring the discharge in 1897, under the Board of Engineers on deep waterways, and having

done considerable work on that section, the Lake Survey continued it.

Q. That was the gaging section selected at that time, was it?

A. At that time.

Q. And that has been used ever since by the Lake Survey?

A. No, since they have measured the discharge at the Open Section below, and recently at a Split Section further down.

Q. At the Split Section they made ten complete discharge measurements, didn't they, in the year 1913?

A. I have forgotten the exact number.

Q. Well, do you consider the statement made by Mr. Shenehon in the report mentioned as a correct statement of the conditions of the Bridge Section?

A. That last statement?

Q. Do you consider the statement made by Mr. Shenehon as a correct statement of the conditions that exist at the Bridge Section on the Niagara River?

A. It is an exaggeration of the conditions.

Q. Did he want to show the difficulties under which he measured within ½ of 1 per cent the exact discharge of the Niagara River, when he made that statement?

A. Why it is natural for the Chief in making a report to describe the conditions as he saw them.

Q. But not to exaggerate them, would he?

A. No, he should not exaggerate them.

Q. Unless it were to show how accurately he could work under very difficult conditions?

A. Why he was attempting to describe conditions as he saw them.

Q. But you say you thought he had exaggerated the conditions?

A. Yes.

Mr. Hopkins: I object to the question as to what the man wanted or thought when he wrote it. Mr. Haskell cannot know what the writer thought. I object to it on that ground, as asking what another man meant or wanted.

Mr. Adcock: Q. You said you thought he had exaggerated the conditions?

A. The conditions, yes.

Q. I am asking you why you think he would exaggerate them. He was under your direction, working under your direction?

A. That was Mr. Shenehon's first experience in discharge

work, and some of those things appeared to him of greater magnitude than they would today.

Q. Mr. Moore made some measurements in 1907 and 1908, did he not, Mr. Sherman Moore, which agreed also with that high degree of accuracy of the true discharge?

A. I believe so.

Q. He had never made any measurements before, had he?

A. I don't know whether he had made any discharge measurements previous to that time or not.

Q. If he stated that he had not made any measurements before that, you would consider his statement true, wouldn't you?

A. What is that question?

Q. I say if he had stated on examination in this record that he never had made any measurements before that you would consider that statement true?

Mr. Hopkins: Objected to as not competent, not properly stating the evidence.

A. That is the natural supposition.

Mr. Adcock: Q. What do you understand by the "Diurnal fluctuation" of a B meter?

A. Diurnal fluctuation of a B meter?

Q. That is the B Haskell meter? I am not referring now to the A meter. That may not have such a fluctuation.

A. I do not know what that can be.

Q. Well, would it be your opinion that there would not be any diurnal fluctuation?

A. It would.

Q. I find on page 5334, Appendix III of the report of the Chief of Engineers for 1900, this statement: "The B meter is credited with a somewhat greater range in its diurnal fluctuations, but it has a remarkable record for the pertinacity with which it clings to a mean rating." What do you understand from that statement?

A. You are calling to mind now by referring to that matter that I did not catch in the previous quesion. That is a daily change in the rating?

Q. Yes.

A. That daily change is so small, and there are only times when it occurs, so that it is negligible so far as any practical results are concerned.

Q. How small is that, Mr. Haskell?

A. I should say in figures it did not amount to more than 2-10ths of 1 per cent.

Q. Is it always within that degree of accuracy?

A. Yes, I should think so.

Q. That is you mean one day the fluctuations will be different from another day, is that correct?

A. It is largely a matter of care of the meter, as to how well it is cared for and how clean it is kept. You see if the meter is kept perfectly clean every day as it should be, and run under absolutely the same conditions, why that diurnal change is very small.

Q. When you say absolutely clean, what care do you refer to? Do you mean it should be kept in a glass case?

A. Oh, no; for instance in certain streams, it may be necessary to clean the meter two or three times in the course of a day.

Q. If you stop work say at night and start in the next morning, will there be a change in the rating between the night before and the next day, when you start in work?

A. It is customary in good work to clean the meter thoroughly as soon as the day's work is done and to oil it, and then it is ready for service the next morning.

Q. Then I take it that it would under register if it got dirty, wouldn't it, on account of friction and so forth?

A. It might, yes. That would be the tendency.

Q. That would be the natural tendency?

A. It would be the tendency.

Q. What is the range? Is that from the mean fluctuations, diurnal fluctuations, is that .2 of variation, or is it between the high and low?

A. Between the high and low.

Q. Then what would you say the variation from the mean might be?

A. One-half of that.

Q. .1 of 1 per cent. Might be less than that?

A. Might be less than that.

Q. Or it might be more?

A. Yes, it might.

Q. But not probable?

A. Not probable.

Q. What reason do you give for saying that it is not probable that it would be more?

A. That depends entirely on the care. We do not consider the meter fit to use unless it is properly cared for day by day and hour by hour, so to speak.

Q. So that a great deal depends upon how often it is cleaned, doesn't it?

A. Principally, yes.

Q. If it was run along for several days without being cleaned, it might under register very materially, might it not?

A. It would depend on how dirty it got.

Q. Upon what did you base the statement in your direct testimony that "There is practically little or no ice effect on Lake Erie; that is so far as the Niagara River is concerned."

A. Why the ice seldom ever blocks the Niagara appreciably. There have been instances when it has been known that it has interferred with the flow for short periods of time.

Q. Did the Lake Survey ever have anyone whose duty it was to make investigations and report as to the conditions of ice in the Niagara River?

A. That was the duty of the party stationed at Buffalo.

Q. What report did he ever make?

A. All that is said in regard to that matter is given by Mr. Shenehon in the 1900 report. I do not recall.

Q. He made those observations with reference to ice, at the time he was working on the Niagara River making the discharge measurements on the preservation at Niagara Falls?

A. No, that was previous to that.

Q. Prior to that?

A. That was prior to that.

Q. Mr. Shenehon was not stationed all the time at Buffalo, was he?

A. That was his headquarters during the investigation.

Q. During the measurements?

A. During the measurements.

Q. How many measurements did he make during the winter there at the Niagara River?

A. I do not recall.

Q. He did not measure there more than during one winter, did he?

A. The records will show that. I think there were parts of two winters that that party worked.

Q. Then it is your belief that no ice gorges occur in the Niagara River?

A. No. Ice gorges do occur in the Niagara River.

Q. That retards the flow, doesn't it?

A. It depends upon where the gorge occurs.

Q. Well, if the gorge occurred in a part of the channel so as to decrease the cross section, it would decrease the discharge, wouldn't it?

A. Certainly. An ice gorge occurred in the Niagara River below the Falls here just a year or two ago. That certainly would not have any effect on the flow from Lake Erie.

Q. Not unless it filled up to the height of the Falls?
A. To the height of the Falls?
Q. You never heard of it doing that?
A. No.
Q. But you have heard of ice gorges, haven't you, above the Falls, which would decrease the cross section of the river?
A. Only on that reach of the river which we consider as the Rapids, which approach the Falls on the American side.
Q. How about ice cover at the Niagara River retarding the flow?
A. It would have a tendency to retard the flow by the friction on the under side of the ice while the stream was frozen over.
Q. Who prepared the portion of the report of International Waterways Commission on the regulation of Lake Erie, 1910, embraced in pages 7 to 22, inclusive, being signed by you, I believe, Mr. Haskell?
A. You referred to this part of the report (indicating)?
Q. Yes.
A. That was written by General Ernst.
Q. That report was signed by you, wasn't it, Mr. Haskell?
A. It was.
Q. You subscribe to everything stated in that report?
A. I do.
Q. Referring to page 19 of this report and paragraph 33, as follows:

"Title: Ice Jams. During every winter ice jams form on Horseshoe Reef at the head of Niagara River. The ice in the lake is blown toward the outlet by a southwest wind and is piled upon the shallow reef where it forms an ice jam extending from near the bottom to several feet above the surface of the water.

In some instances the bergs have been 20 to 30 feet high. The proposed regulating works being placed about a mile below Horseshoe Reef would aggravate the difficulty. The neck of the outlet might become so effectively blocked with ice that the flow of the river would be materially decreased as was the flow of the St. Clair River in the winters of 1901 and '02. If those conditions should exist, a severe southwesterly storm, such as has occurred on numerous occasions, would inundate the lower part of Buffalo. These ice jams seriously interfere with navigation. The average date of opening navigation in the spring at Buffalo is April 9, while at Cleveland the average date is March 23. The difference of 17 days in the dates of opening of the two Lake Erie ports

is due to ice jams. It is probable that it would be materially increased by the construction of the regulating works. It is to be observed that the ice jams would make it difficult to maintain the works." Was the statement made there true with reference to ice jams in the Niagara River?

A. Yes.

Q. You consider, do you, that they would retard and decrease the flow from Lake Erie through the Niagara River?

A. The effect of those jams upon Horseshoe Reef is very small on the flow of the river.

Q. How do you know?

A. Because they are outside of the main entrance to the river.

Q. Don't they decrease the cross section at that point?

A. The cross section at that point is so large that a good portion of it could be cut off and the river still have nearly its full capacity.

Q. How would Buffalo become inundated, as stated in this report, if the flow of the Niagara River were not decreased?

A. That is the case when the dam is in there. That depends upon the dam being placed in that location, and causing an ice jam against the dam.

Q. Have you ever observed the condition of frazil or anchor ice in the Niagara River?

A. No, I have not.

Q. Isn't it a fact that there is considerable of that character of ice, which retards the flow?

A. Not above the Falls.

Q. Frazil or anchor ice in a river will retard the flow, will it not?

A. Certainly it can become of such quantity.

Q. You don't know whether there is any there or not, do you?

A. I never have seen any above the Falls.

Q. Did you ever look for any?

A. Yes.

Q. When and to what extent?

A. During the time in which those observations were going on.

Q. It was only during that time?

A. That is all, during the years with which I was connected with the work.

Q. I call your attention to page 24 of Mr. Shenehon's work entitled "Preservation of Niagara Falls, Senate Document Number 105, 62nd Congress, First Session as follows:"

"From January to May, ice conditions serve to impede the outflow so that the volume is sometimes 10 per cent less than the summer discharge for the same lake level, and in the mid-summer, the growth of aquatic plants in the river bed diminishes the clear channelway and increases the resistance above that of the smooth bottom. For the same level, the river passes approximately 1 per cent more water in May than in September."

Having in mind this statement which I have just read, what would you say with reference to whether there is practically little or no ice effect on Lake Erie, that is so far as the Niagara River is concerned.

A. It is all of short duration.

Q. That is from January to May?

A. Yes.

Q. Of each year?

A. You can't say it occurs each year.

Q. You don't know whether it occurs each year at that point?

A. I know there are some years in which it does not occur.

Q. The same as there are some years in which it does not occur on the St. Clair River?

A. Exactly.

Q. Suppose that on any of the rivers connecting the Great Lakes there has been made with the supposed care of the Lake Survey 147 measurements of discharge covering a range of lake stage of 0.76 feet, with what degree of accuracy would you say the discharge of the river in question was known corresponding to the mean of the elevations at which the discharges were observed; and I assume that this is with the Haskell meter?

A. I should say we knew the discharge within 1 per cent.

Q. No closer than that, Mr. Haskell?

A. That is close enough for all practical purposes.

Q. I understood you to say that if you only had ten, you would get within ½ of 1 per cent. That was in the Split Section of the Niagara River?

A. I will make that ½ of 1 per cent.

Q. Within ½ of 1 per cent?

A. Yes, within ½ of 1 per cent.

Q. You don't know whether it would be materially less than that or not?

A. No.

Q. Suppose that on any of the rivers connecting the Great Lakes there had been made with the usual care of the

Lake Survey 126 measurements of discharge covering a range of lake stage of 1.42 feet, with what degree of accuracy would you say the discharge of the river in question was known corresponding to the mean of the elevations at which the discharges were observed?

A. Within the same percentage, ½ of 1 per cent.

Q. And you would give the same answer, assuming that on those rivers there had been 57 observations made covering a range of lake stage of 0.76 feet, wouldn't you?

A. Yes.

Q. Suppose that on the same river we had 150 similar observations to those referred to in the preceding questions, covering a range of lake stage of 0.98 feet, not included in the preceding group, how accurately would you say the discharge was known corresponding to the mean of the elevations at which the discharges were observed?

A. Within the same percentage.

Q. And your answer would be the same, assuming in the same river there were 102 observations, covering a range of 2.50 feet?

A. 2.50 feet. At the center of gravity? I should say it was within ½ of 1 per cent.

Q. You would give the same answer, assuming that there were 36 observations, covering a range of lake stage of 1.67 feet?

A. 36, that is reducing the number quite a little. I should not expect quite as high an accuracy.

Q. Well then you would say it would be about ½ of 1 per cent?

A. About ½ of 1 per cent.

Q. Suppose that you knew the discharge of a certain river at a certain elevation within ½ of 1 per cent, and suppose that you also knew the discharge at another elevation of the same river within ½ of 1 per cent, and assume that the discharges were 203,382 cubic feet per second and 187,082 second feet, within what percentage of accuracy would you know the difference between them?

A. It ought to be by the same accuracy.

Q. Is it not the difference between the discharge?

A. Between the two?

Q. Yes.

A. Well, it would be one-half of that.

Q. Do you want the question read again?

A. Yes.

Q. (Question read.) That is between the discharges of the two elevations?

A. Substantially within ¼ of 1 per cent.

Q. Suppose under the same conditions the discharges at one elevation was 220,820 cubic feet per second, at another elevation it was 191,846 cubic feet per second, within what per cent of accuracy would you know the difference between them?

A. I think I misunderstood the question.

Mr. Hopkins: Difference between what, discharges?

Mr. Adcock: Yes.

(Question read.)

A. Within 1 per cent, if I have got that question right.

Mr. Hopkins: Do you wish to correct your other answer?

Mr. Adcock: Q. Why do you say within 1 per cent?

A. The error between the two might be on opposite sides.

Q. But by the theory of probabilities which you refer to here, it might be one side or the other in one case and one side or the other in the other case, and one might offset the other?

A. It might.

Q. So there would not be any difference?

A. There might not be any difference.

Q. You might know it within 100 per cent of correct?

A. You might know it exactly; the error might be 1 per cent.

Mr. Hopkins: That was the second question you were answering. I understand you did not understand the first question also?

A. Yes.

Mr. Adcock: You want to answer 1 per cent to the other?

A. Yes.

Q. What would you say the probable per cent of accuracy would be? You say it might be as great as 1 per cent, the difference?

A. The probable percentage?

Q. Yes.

A. About 1-10th of 1 per cent.

Q. Now suppose that you knew the discharge of a certain river at a certain elevation within ½ of 1 per cent, and suppose that you also knew the discharge at another elevation of the same river within ½ of 1 per cent, and assume the discharges were 249,046 cubic feet per second, and 216,600 cubic feet per second, within what per cent of accuracy would you know the difference between them?

Mr. Adcock: If Mr. Haskell thinks he does not understand the question, I would like to have him state what his under-

standing of the question is in his own words. There has been some suggestion made that he does not understand the question. I presume that is from the answer that has been given. When I say "question" I mean the three questions that have been propounded with reference to substantially the same situation, but using different discharges for different elevations.

A. I should make substantially the same answer to this as I did to the previous question, as I understand it.

Q. That is that the possible inaccuracy would be 1 per cent?

A. 1 per cent.

Q. And a probable inaccuracy would be 1-10th of 1 per cent?

A. Approximately that.

Q. If the difference in elevation between the first two discharges considered was 0.57 feet, assuming the conditions of the preceding questions and the answers thereto, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. With the same precision.

Q. If the difference in elevation between the second two discharges was 1.31 feet, assuming the same conditions presented in the previous questions and your answers thereto, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. Within the same precision.

Q. If the difference in elevation between the last two discharges considered was 1.11 feet, assuming the conditions mentioned in that question and your answer thereto, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. Within the same precision as I see it. Maybe I did not understand the question.

Q. That is there might be an error of 1 per cent and a probable error of 1-10th of 1 per cent?

A. Yes.

Q. What is the meaning of the term increment as used in this case?

A. The meaning of the term increment?

Q. Yes.

A. That is it is the increase in discharge per unit—

Q. You know we have not had a real good definition of increment by complainant's witnesses so far. I would like to have you give a comprehensive definition, so that the Court will understand it.

Mr. Hopkins: I object to the statement of counsel. It does not involve the facts. I move it be stricken out.

The Witness: I have answered that question once, Mr. Adcock.

Q. Have you?

A. Yes.

Mr. Adcock: It is not a comprehensive, specific statement.

Mr. Hopkins: Do you want him in giving the definition of increment to repeat what he said before, or do you know that already? Or do you want him to add to it anything to make it more comprehensive?

Mr. Adcock: Just assume that I do not understand what increment is.

Mr. Hopkins: You are entitled to ask the question over again.

Mr. Adcock: I am perfectly willing to ask it over again, if it has already been asked before, which I do not admit.

The Witness: Shall I go ahead?

Mr. Adcock: Yes.

A. By the increment of discharge in current meter work, we mean the increase in volume of discharge per unit of rise of the lake or the river at the particular point. We usually speak of that as the increase per foot, and divide it up into the tenth of a foot if a person is more concerned with the smaller unit, speaking of it as the tenth; or sometimes it is in inches, in which case it would be the increment per foot divided by 12.

Q. You say in current meter work?

A. In discharge work and in current meter work.

Q. It does not mean anything different in work of other kind?

A. Oh, no, it is a term that has grown out of discharge measurements of rivers, open channels.

Q. You may have an increment of population per year in a city?

A. Yes.

Q. The same thing?

A. Same thing.

Q. What I want to understand is, you said current meter work; it has not any different meaning in current meter work than in any other kind of discharge work?

A. Oh, no, it is the increment.

Adjourned to Thursday, February 26, 1914, 10:00 a. m.

Thursday, February 26, 1914, 10:00 a. m.

EUGENE E. HASKELL resumed the stand and testified further as follows:

Mr. Hopkins: I understand that Mr. Haskell wants to make some corrections in regard to his answers to the questions yesterday in reference to the error in those differences of discharges, referred to in the last questions when we adjourned yesterday afternoon. Do you want to make some corrections, Mr. Haskell?

The Witness: Yes.

Mr. Adcock: Q. This is after further consideration of the questions?

A. After further consideration of the questions.

Mr. Hopkins: Let the Commissioner read them to you if you want.

Mr. Adcock: Do you want them read to you, or do you have in mind the corrections that you wish to make in your answers to the questions?

A. I think I have in mind the point that I want to bring out and that is in regard to the error in the increment. That might be anywhere from ½ of 1 per cent to 10 per cent, that is approximately.

Q. You mean the difference between the discharges?

A. The error in that difference.

Q. The error in that difference?

A. Yes.

Q. That would be within the points which you mentioned?

A. Yes.

Q. And it might be as low as 1-10th of 1 per cent, which you mentioned?

A. No, ½ of 1 per cent.

Q. ½ of 1 per cent?

A. ½ of 1 per cent.

Then I want to make a correction in regard to the statement which I made when you read to me that passage from Mr. Shenehon's report on the Niagara River. I stated that that was his first piece of discharge work. I was in error about that, because Mr. Shenehon did assist in the observations which were made at Sault Ste. Marie the winter of 1895-'96; and also assisted in the computations which were made at that time. I had forgotten those.

Q. What did Mr. Shenehon do at that time?

A. He assisted in making the observations. There were three of us concerned directly with the making of observations, and he made observations a part of the time; Mr. Sabin a part of the time and myself a part of the time on the Spry Dock Section.

Q. What was his position?

A. Mr. Shenehon's?

Q. Yes.

A. Mr. Shenehon was assistant engineer in the U. S. Engineer Office at that time.

Q. What were his duties in connection with the making of discharge measurements on the St. Marys River, that you mentioned?

A. The work that winter was the question of preliminary work, or starting really in the investigation of lake levels, and there were several of us concerned in it, and were on duty from time to time in connection with the work in the river.

Q. That is when you say interested in it, you mean interested in making those particular measurements, or connected with making those measurements?

A. He assisted in making those measurements.

Q. What particular thing did he do in connection with making the measurements? Did he read the meter at the soundings?

A. He made the observations, that is the observations for velocity.

Q. He didn't have anything to do with the soundings?

A. Not that I recall.

Q. Or were any soundings made?

A. Yes, the soundings were made by what was known as the river party of the Engineer Office. It was a party that was fitted up purposely for the making of soundings.

Q. The current was slow there, was it?

A. Yes.

Q. Was this party that did the sounding connected with the Lake Survey?

A. No, they were connected with the river work or improvement work.

Q. That was the Engineer Office?

A. That was the Engineer Office.

Q. At the Soo?

A. At the Soo.

Q. Would the Lake Survey take the records of soundings

made by another engineer office of the United States Government?

A. Yes, where they were made as carefully as those were.

Mr. Hopkins: Did you want to make any further correction in regard to the range, in connection with that percentage coming from two discharge observations?

A. Really I think I have taken care of that in this matter. I think it answers that question.

Mr. Adcock: Q. These were not necessarily two single discharge observations that the questions embraced, were they?

A. No, I think not.

Q. They were the mean?

A. Yes.

Q. Of a number of observations?

A. Yes.

Q. Is it your proposition that the difference between the discharge at a certain mean of a group of observations at certain elevations and the discharge corresponding to the mean of another group of observations would be from ½ of 1 per cent to 10 per cent in error?

A. It might.

Q. Why do you limit it to ½ of 1 per cent, might it not be absolutely accurate?

A. Yes, it might be absolutely accurate. We simply state that as a lower limit, indicating good work, indicating precision.

Q. In your previous answers to questions as to the percentage of accuracy of the measurements with reference to flow, when you stated it was within ½ of 1 per cent of accuracy, you meant, did you not, that it was between zero and ½ of 1 per cent?

A. Yes.

Q. So now, on the same reasoning, and with reference to your answer as to the percentage of accuracy in the determination of the difference between the discharges of two elevations mentioned, you mean between zero and ten per cent?

A. Yes, that is the range might be so small as to—

Q. When water flows around a curve in a river, does the current follow the axis of the channel, or does the water tend to impinge on the concave bank?

A. It tends to impinge on the bank.

Q. That is pile up on that side?

A. Pile up on that side.

Q. Then would the current be oblique to a section normal to the axis of the channel?

A. Partially so.

Q. What is the result of the water piling up along the concave bank?

A. A tendency to increase the head at that point.

Q. What is the effect as to creating a reverse cross current in the bottom of the stream?

A. It would have the tendency to deflect the current from that bank and to send it toward the center of the channel.

Q. Or the convex bank?

A. Yes.

Q. Then the direction of the current at the top and bottom of the stream would make different angles with the axis of the stream, would it not?

A. The section might be such that it would.

Q. Wouldn't it be so on any curve in a river?

A. As to magnitude of that effect, it would depend upon the velocity. That is if the current were feeble that action would not amount to much of anything. If it were strong, it would amount to considerably more.

Q. If it were necessary to correct for that condition at the top, for the current at the top of the water, wouldn't it be necessary to make similar correction for the current at the bottom?

Mr. Hopkins: I make an objection to all this line of questioning, as not proper cross-examination.

Mr. Adcock: Not for the purpose of arguing the proposition, but merely so it may appear in the record, I will call your attention to the fact that the witness in direct examination testified with reference to the effect of an oblique current at certain hydraulic sections or gaging sections. I do not know whether counsel wishes to protest further or not.

The Witness: Shall I answer the question?

Mr. Hopkins: Yes.

A. It might be necessary to make the correction; that is the angle might be so great as to make it necessary to make the correction to the bottom velocities as well as to the surface.

Mr. Adcock: Q. At a point near mid depth, would or would not the two motions blend to produce a flow nearly axial?

Mr. Hopkins: I insist that the question be explained.

A. It would approximate to normal to the cross section. That would be the tendency.

Q. That is there would not be as great an obliquity at mid depth as at top or bottom?

A. That probably would be the case.

Q. Was there any obliquity of current on the split sections on the Niagara River?

A. Not to any appreciable extent.

Q. Was that your understanding when you testified on direct examination as to the accuracy of those measurements?

A. It was.

Q. If it should appear that the obliquity was determined by floats approximately 14 feet long and the depth of the river was something over 30 feet, and a correction was made for such obliquity, then the correction probably would be too great, would it not?

Mr. Hopkins: You mean at that place?

Mr. Adcock: At the Split Section.

A. I see no reason why it should be too great.

Q. Then how do you reconcile that conclusion with the former answers to the previous questions, with reference to the effect of an oblique current?

A. I do not see that it needs to be reconciled.

Q. Well, will you explain why you think it is unnecessary to reconcile it?

A. In this case of using the float, you get the direction of the current with respect to the plans of the cross section, and you make a correction for that.

Q. But you only get the obliquity at the top?

A. At the top.

Q. How about the obliquity at the bottom, that you mentioned a little while ago, in a reverse direction?

A. The correction might be the same or it might not. It would depend entirely upon the cross section.

Q. How about the portion of the stream where the current would be axial or normal to the cross section?

A. Normal to the cross section? That would not require any correction.

Q. And if you corrected that, you would reduce the discharge in that section, wouldn't you?

A. Yes.

Q. Then you did not remember, did not have this source of error in mind, when you testified as to the percentage of accuracy of these ten discharge measurements at the Split Section on the Niagara River?

A. Yes, I did have that in mind.

Q. But did you know that there was a correction made for the obliquity of the current?

A. On that section?

Q. On that section at that time?

A. I don't recall.

Q. Then it must follow that you did not take it into consideration at that time?

A. I took into consideration—or took for granted that that work was done with the same precision with which all of the Lake Survey work had been previously done.

Q. Which you consider to have a very high character?

A. I do.

Q. And the methods used and laid out for that work are precise?

A. We try to make them as precise as possible, to get at the truth as nearly as it was attainable.

Q. Was there ever any correction for obliquity of current at any other gaging sections upon any of these rivers?

A. Yes, correction was applied to the observations made from the International Bridge at Sault Ste. Marie. I do not recall whether it was applied at any other section or not.

Q. Did Mr. Shenehon correct for the obliquity of the currents created by the eddies around the International Bridge piers, at the International Bridge Section of the Niagara River?

A. It has been so long since I have seen those computations that I could not recall.

Q. If he did not, should he have done so?

A. He should have done so if they were of a magnitude to be of importance.

Q. That would depend upon his personal opinion at the time that he made the measurements, wouldn't it?

A. And the observations which he made.

Q. And his conclusions drawn from the observations as he made them?

A. Yes.

Q. Do you believe the equations of discharge shown on pages 3546 and 3547 of the report of the Chief of Engineers for 1912, to be applicable to the conditions existing between 1860 and 1890? That refers to all the rivers in controversy.

Mr. Hopkins: Objected to as not proper cross-examination. He has not testified to the Lake Survey equation. He gave his own.

A. (After referring to equations indicated.) This is the first time I have ever seen these equations.

Q. (Question read.)

Mr. Hopkins: I object to the question again as not cross-examination. It is not a matter that the witness has testified concerning, and there appear to be complications there that I do not think he ought to be called on to answer. He can use his own discretion, as to whether he understands it.

A. I should say that they were applicable so far as the St. Clair and the Niagara Rivers are concerned. I should not care to express an opinion in regard to the St. Marys River and the St. Lawrence River until after I have had time to read the report in full.

Mr. Adcock: Q. If the equation for the St. Lawrence River represents the present conditions and if a proper correction were made for the effect of the Gut Dam, then would you think the equations applicable to the St. Lawrence River for the period mentioned?

Mr. Hopkins: Same objection to that as to the prior question. In other words, does that additional matter in that question change your former answer?

A. No, I should prefer to stick by my former answer. Canadian Channel improvements in the North Channel, have undoubtedly had some effect upon the discharge of the St. Lawrence River, and those were made after 1890, if I remember correctly.

Mr. Adcock: Q. What were they, Mr. Haskell, that would affect the discharge of the St. Lawrence River?

A. You see the Canadian Government cut what is known as the North Channel, which would have a tendency to increase the discharge at that particular point.

Q. Do you remember just when that was done?

A. I do not. It was some time as I recall it in the latter part of the nineties and the first part of 1900-'01, it was a contract continuing over several years.

Q. Was that before or after the construction of the Gut Dam?

A. That was before.

Q. Is that the channel above the Galope Rapids?

A. Yes.

Q. Was it constructed at the time of the original discharge measurements on the St. Lawrence River?

A. I imagine it had been completed.

Q. That is it was not opened at that time?

A. That is my recollection of it.

Q. So that at the time those discharge measurements were made, there was no effect from this channel, the North Chan-

nel that you speak of; no effect apparent upon the discharge of the St. Lawrence River?

A. If the work had been completed, of course the discharge formula which is given would represent the conditions after the completion of the work, and as to just when that work was finished, I could not say. I remember it being in progress.

Q. If it were opened afterwards, then there would be no effect of it upon the earlier discharge measurements, of course?

A. No.

Q. Then if you corrected this equation to correspond with the conditions of the river during the earlier measurements, you would provide for the effect of this channel and the Gut Dam also, would you not?

A. Yes.

Q. Assuming the corrections to be made, then would the equation for the St. Lawrence River shown in the report mentioned, pages 3546-7, be applicable to the conditions existing between 1860 and 1890?

Mr. Hopkins: I again object to that line of questioning. It is eminently unfair. The witness has stated that he has not read the report; and without reading the report, he cannot know the conditions taken into consideration in forming that equation, wherein it is stated that there is probably an uncertainty and inaccuracy in the measurements of the St. Lawrence; also that the range of stage of the observations is much less than the actual range of stage, and many other conditions in the report itself to affect that equation. And I do not think the witness ought to be called upon to answer.

Mr. Adcock: I wish to protest against the form of objection made, as it is evidently made for the purpose of instructing the witness as to what counsel thinks his answer to the question should be.

Mr. Hopkins: I simply object to making a witness answer, who seems to be willing to answer on a report that he said he does not know anything about.

Mr. Adcock: Q. Then if you will examine the report, take all the time you want to examine the report and answer the question.

Mr. Hopkins: It is not proper cross-examination. I instruct him not to take the time to do it unless counsel wants to wait for him to do it; and move to strike out the whole deposition.

Mr. Adcock: The witness testified in direct examination

that he had examined and was familiar with the later discharge measurements made, and he gave an opinion as to the accuracy of those measurements.

Mr. Hopkins: He did not testify to that equation in that report.

Mr. Adcock: The equation is the reduction of the observations.

Mr. Hopkins: I suggest, Mr. Commissioner, that we adjourn to give the witness time to read the report.

(Question read.) "Assuming the corrections to be made, then would the equation for the St. Lawrence River, shown in the report mentioned, pages 3546-7, be applicable to the conditions existing between 1860 and 1890?"

A. They would be within the range of the observations used in the discharge work.

Q. What do you mean by within the range of the observations used in the discharge measurements?

A. That is the conditions previous to 1890, where the stage of Lake Ontario was above that at which discharge measurements were made, it might not be applicable.

Q. How great an error would result therefrom, assuming that condition?

A. It is hard to say.

Q. Would it be 50 per cent?

A. Not at all likely.

Q. Ten per cent?

A. It might be as great as 10 per cent.

Q. Do you think it would be as great as 10 per cent?

A. I should not care to express an opinion.

Q. Is that based on the proposition that the increment of the St. Lawrence River is best expressed by a curve rather than a straight line?

A. Yes.

Q. I refer you to table XXIII, appearing upon page 53 of the Report of the International Waterways Commission entitled: "Regulation of Lake Erie," wherein the increment of the St. Lawrence River is shown for various stages; and I will ask you, after examining that table, to state whether you consider the statements made there accurate?

A. (After examining table referred to.) They are substantially so, and are based upon the data that we had up to the time of making this study.

Q. They are based upon the Lake Survey measurements, aren't they?

A. They are.

Q. Didn't you say in your direct examination that you thought the increment was expressed about as well by a straight line as a curve?

A. I don't recall having made that statement, but within certain limits it is practically true.

Q. Well, what are the limits?

A. For small changes of stage, say of a foot.

Q. In other words, would you change the increment every foot?

A. Yes, I think that is substantially the form upon which these equations were derived.

Q. You have made a very careful study of the discharge measurements made by the Lake Survey upon these different rivers, and you have taken occasion in the testimony to express an opinion as to the accuracy of the discharge increments, as to the accuracy in the increments which have been derived from those discharge measurements, within very close limits. I wondered if you could not give us a closer estimation of the applicability of the equation for the St. Lawrence River mentioned to different elevations, elevations beyond the range of the measurements, closer than the 10 per cent which you have mentioned. For instance, you have stated that the discharge measurements of the Niagara River were within less than ½ of 1 per cent of true, the discharge. That is a very small percentage, isn't it?

A. It is.

Mr. Hopkins: Just a moment. Have you stated that correctly, Mr. Adcock, as to his testimony?

Mr. Adcock: Can you answer that? Can you give us a closer estimation than the 10 per cent which you mentioned in accuracy at other elevations?

A. I should be willing to stand by the results as given in here (indicating report referred to) for the probability of that increment beyond the stages of the observations.

Q. Within what per cent?

A. Oh, within 10 per cent.

Q. You cannot give it to us any closer than that?

A. No, I should not care to express an opinion any closer than that.

Q. Is this because of the difficulties of measurement on the St. Lawrence River?

A. No, it is because we have no observations beyond that point, and we are simply predicting as to what we think is the case beyond those limits.

Q. Then it is your opinion that the law of a curve as estab-

lished by the discharge measurements is not correct beyond the range of those discharge measurements, or the limits?

A. It may be an error beyond those limits by as much as 10 per cent.

Q. You think it is?

Mr. Hopkins: This is referring to the St. Clair and Niagara Rivers, I understand?

The Witness: The St. Lawrence River.

Mr. Adcock: Q. I assume in that connection that you are basing your answer upon the records of discharge measurements and gage readings, and so forth, in the Lake Survey?

A. From the Lake Survey data.

Q. (Question read.)

A. Yes.

Q. Assuming the mean open season elevation of Lake Huron, from 1860 to 1883, inclusive, to be as shown in Williams' Exhibit 34, Table XVIII, 581.99, and the mean of Lake St. Clair similarly, 576.39, what was the average discharge for this period?

A. 222,400.

Q. Assuming the mean open season elevation of Lake Huron from 1890 to 1901, inclusive, to be similarly 580.565, and that of St. Clair 575.155, what was the average discharge for that period?

A. 193,000.

Q. Assuming the average open season elevation of Lake Erie for the former period to have been as similarly indicated, 573.14, what was the mean discharge of the Niagara River for the period, by the equation on page 3547?

A. 221,591.

Q. Assuming the average open season elevation of Erie from 1890 to 1901, inclusive, to be, similarly, 572.175, what was the mean discharge of the Niagara River for this period?

A. 200,800.

Q. Assuming the average open season elevation of Lake Ontario for the early period, similarly, was 246.72, and referring to the increments used in Table XXIII of the report of the International Waterways Commission on the regulation of Lake Erie, 1910, and making such corrections as may be necessary, if any for the Gut Dam and the North Channel referred to, what was the mean discharge of the St. Lawrence River from 1860 to 1883, inclusive, by the International Waterways Report?

Mr. Hopkins: I object to all this line of questions as not

proper cross examination, and also on the ground that he has not named any correction to be made for the Gut Dam and the North Channel referred to. It does not appear in evidence what correction should be made by him.

Mr. Adcock: I will amend that question. Making such correction as you think necessary.

Mr. Hopkins: Same objection.

Mr. Adcock: Q. Do those equations appearing in the International Waterways Commission Report, Table XXIII, refer to the conditions before the Gut Dam?

A. They do.

Q. So there would be no correction for the Gut Dam or North Channel?

A. There would be no correction.

Q. Then with that in mind, will you answer the question which is pending?

A. You want me to compute it?

Q. Yes.

A. Will you put that in terms of the Ogdensberg gage, for which the formula is given here?

Q. Assume in the preceding question that the corresponding Ogdensberg gage is 245.80?

A. It will take two hours to compute this, if not more. The St. Lawrence River in the period from 1860 to 1883, inclusive, would be 280,000 flat.

Q. Assuming the average open season of Ontario, similarly, from 1890 to 1901, to be 245,635, and referring to the International equations, mentioned in the International Waterways Commission Report, what was the mean discharge of the St. Lawrence River for this period?

A. That would be 243,600.

Q. By how much did the flow of the St. Clair exceed that of the Niagara in the earlier period?

A. The St. Clair was 222,400, the Niagara 221,600; 800 cubic feet per second.

Q. By how much was the St. Clair discharge less than that of Niagara in the second period?

A. The difference is 7,800.

Q. How was the excess of water in the former period, coming from the St. Clair River, amounting to 7,800 cubic feet per second, plus 800 cubic feet per second, making a total of 8,600 cubic feet per second, as compared with the later one, disposed of after reaching Lake Erie?

Mr. Hopkins: I object to that. The former comparisons were upon certain assumptions, which had in some of them

degrees of error. Therefore, there is no foundation for that question.

Mr. Adcock: If counsel wishes to prompt the witness as to the answer to a question in the form of an objection, I see no way to stop him except by protesting in the record.

Mr. Hopkins: In answer to that statement I insist upon my objection that the other questions were purely hypothetical, and now he asks a question as to what did become of it in fact. The question is improper and unfair.

Mr. Adcock: I wish to make the same statement as to the last statement of counsel. I think my observations apply to a greater extent to the last statement than to the former statement made by counsel.

Recess to 2:00 p. m.

Thursday, February 26, 1914, 2:00 p. m.

EUGENE E. HASKELL resumed the stand for further cross-examination by Mr. Adcock and testified as follows:

Q. (Question read as follows: "How was the excess of water in the former period coming from the St. Clair River amounting to 7,800 cubic feet per second, plus 800 cubic feet per second, making a total of 8,600 cubic feet per second, as compared with the later one, disposed of after reaching Lake Erie?")

A. In my judgment that water did not reach Lake Erie; there is an error in the increment as applied to the St. Clair River; that that as given in this Lake Survey Report for 1912, is too high.

Q. In other words, Mr. Haskell, your St. Clair increment will not compare favorably with the Niagara increment?

A. State that again?

Q. (Question read.)

Mr. Hopkins: You mean the one of the Lake Survey?

Mr. Adcock: The Lake Survey increment for the St. Clair River will not compare favorably with the Niagara increment?

The Witness: That one, as given there, I should say was too large, as compared with the Niagara River.

Q. How many discharge measurements were considered by the Lake Survey on the St. Clair River, in determining their increment for that river?

A. I have forgotten those.
Q. About 400, wasn't it?
A. I do not think as many as that on the St. Clair River.
Q. Well, approximately that. Was it more or less than 400?
A. I should say it was less.
Q. How much less?
A. I had got it in mind that it was somewhere in the neighborhood of 200. Those are figures that I do not carry around in my head.
Q. I will ask you if, as a matter of fact, there were not 297 separate discharge measurements at the Dry Dock Section?
A. 297.
Q. And about 180 measurements at the Gorge Section?
A. I had forgotten the figures. I would not attempt to give them. They are a matter of record.
Q. And on the Niagara River there were approximately 218 on the Bridge Section, the International Bridge, and about 121 on the Open Section?
A. That would make 339.
Q. As against about 500 in the measurements on the St. Clair River?
A. On the St. Clair River.
Q. And it is because this increment of the St. Clair River will not check with the increment of the Niagara River that you say that it should be lower than the amount stated by the Lake Survey?
A. Lower than the amount stated by the Lake Survey in that report. You see the International Waterways Commission, we made that 18,900.
Q. How did you get that?
A. It is from the reduction made in the office of the Commission from the observations that existed up to the time of the report, our report.
Q. There have been a large number of observations made since then, haven't there?
A. There have.
Q. And I believe you stated that the discharge measurements and the work in connection with making the discharge measurements, gage readings and so forth, and the computations necessary to derive an increment on the St. Clair River, were as accurately done as the same character of work on the Niagara River?
A. I assumed that.

Q. I presume you assumed also that the Niagara River is an easier river to measure than the St. Clair River?

A. No easier to measure. The complications there are less.

Q. On account of passing boats and things like that?

A. No, I didn't have reference to that. I had more particularly reference to the question of back water.

Q. Well, what investigations have you made with reference to the effect of back water upon the derivation of the increment of the St. Clair River?

A. Well, I have made none myself further than watching computations which were made in regard to that work. Mr. Russell produced a report upon it and Mr. Sabin produced a report upon it.

Q. You put considerable weight on Mr. Russell's report, did you, and Mr. Sabin's report?

A. Certain parts of Mr. Russell's report, I think, are excellent.

Q. And certain parts of Mr. Sabin's?

A. Yes. In fact I could accept Mr. Sabin's report more in whole than I could Mr. Russell's.

Q. You approved Mr. Russell's report, didn't you?

A. I did.

Q. What was that report called, do you remember, and when was it published?

A. That was in 1904, Lake Survey Report, I think.

Q. Well, these measurements on the Dry Dock Section and on the Gorge Section checked, did they not?

A. Yes, I think within reasonable limits.

Q. That was one of the tests, or the test, which you used to determine the accuracy of the results obtained?

A. Yes.

Q. In the discharge measurements?

A. Yes.

Q. I refer you to the report of Mr. Thomas Russell, Assistant Engineer, dated Detroit, Michigan, May 18, 1904, which begins at page 4069, Report of the Chief of Engineers for the year 1904, and ask you to point out what portions of that report you agree with and what portions you disagree with (handing witness same)?

A. I agree substantially with the increment, as given here by Mr. Russell in his figures.

Q. What was that?

A. It worked out here substantially 20,700.

Q. How was that worked out?

A. It comes from the figures which he gives here.
Q. What page are you referring to?
A. I was referring then to page 4078.
I should also agree with Mr. Russell in the conclusions which he has reached, which are expressed in his paragraphs 22 and 23, on page 4131.
Q. Relative to what?
A. Relative to the effect on Lake levels.
Q. That is based, I suppose, on the increments that he derived?
A. That he has derived in his reports.
Q. And only on that?
A. Certainly. I have not read all of those through.
Q. You haven't pointed out anything that you disagree with yet, Mr. Haskell?
A. I should hardly agree with Mr. Russell in regard to paragraph number 4, where he refers to the discharge of the St. Clair and Detroit Rivers considered as one in terms of height of Lake Huron and Lake Erie.
Q. Considered as what?
A. That is on page 4129.
Q. You say you hardly agree with him?
A. That is he bases his formula upon the stages in those two lakes, leaving out of the question Lake St. Clair. I should not agree with him on that point.
Q. At all?
A. No, I should say—
Q. He was all wrong on that?
A. No, I would not say he was all wrong, but it would not be my way of attacking the problem, because I think Lake St. Clair cuts something of a figure in that.
Q. Well, does he get substantially the result from that, or how much is he in error?
A. I see that Mr. Russell limits it here himself, in a further sentence which I did not notice before. He said "The formula is only applicable for mean values covering a considerable period, at least one month."
Q. Then you would agree with his statement?
A. Well, I see he qualifies that.
Q. Having in mind this qualification of Mr. Russell's, you agree then with paragraph 4?
A. Yes, so far as any agreement is needed.
Q. Is there anything else you disagree with?
A. I find nothing in a preliminary examination. Possibly

if I were to study it closely in detail I could raise some questions.

Q. That is in some of the details?

A. Some of the details, mainly.

Q. But the general conclusions which he reaches, you agree with, do you?

A. Substantially so.

Q. What is the difference in the discharge of the St. Lawrence River between the two periods mentioned?

A. That was given as 280,000 for the period 1860 to 1883, and is 243,600 for the period 1890 to 1901, giving a difference of 36,400.

Q. A range of what?

A. It is a range of 1.08 feet.

Q. What increment would that show?

A. That would show an increment of 33,700.

Q. Assuming the increment used by Mr. Russell, which you have just stated, what would be the discharges of the St. Clair River, mean discharges for the two periods mentioned?

A. That is you refer to the previous figures which we had on the St. Clair, for the period 1860 to 1883?

Q. 581.99.

A. That was 222,400.

Q. Using Mr. Russell's equation, which you say you agree with, see what you get then?

A. I do not see the point to the question there.

Q. (Question read.) For the difference of discharge of the two periods?

Mr. Hopkins: I object to the form of that question; the part "which you agree with" is a question of record, and the attorney ought not to repeat the record.

A. 28,860 for the 1.43 feet; for the increment per foot there would be 20,100.

Q. What were your discharges?

A. 218,660, and 189,800.

Q. How much did the flow of Niagara exceed the flow of St. Clair during the earlier period, according to more recent computations?

A. The Niagara is 3,000 greater.

Q. What is the situation with reference to the second period?

A. 11,000.

Q. Then how was the excess of water in the former period coming from the St. Clair River amounting to 11,000 cubic

feet per second, minus 3,000 cubic feet per second, making a result of 8,000 cubic feet per second, as compared with the later on disposed of after reaching Lake Erie?

A. I should say that water did not get to Lake Erie.

Q. You think that water did not get to Lake Erie?

A. No.

Q. Then what became of it? Where did it go?

A. It is in Lake Huron-Michigan.

Q. Still?

A. It may be.

Q. Well, then, you do not agree with Mr. Russell's increment, is that right, or his equation?

A. Mr. Russell's increment is based upon the observations which he used in there, and I think that that could be enough in error to account for this difference.

Q. How much in error would it have to be, Professor?

A. Less than ½ of 1 per cent of the discharge.

Q. How about the increment?

A. Let me correct that last statement there. That would be 4 per cent. It would be nearly 40 per cent for the increment.

Q. The discharges would be in error 4 per cent and the increment 40 per cent?

A. Yes.

Q. How much evaporation do you think there is from Lake Erie per year?

A. From Lake Erie?

Q. Yes.

A. I think Mr. Wheeler's paper gives very satisfactory values on that question.

Q. Is that Eben S. Wheeler?

A. Yes. For 1903 you asked for the evaporation from Lake Erie?

Q. Yes.

A. He gives as the mean annual evaporation 26.1 inches.

Q. Well, how much do you think that varies from year to year?

A. Oh, it might vary 20 per cent.

Q. You say might vary? What is the probable variation?

A. You see that depends on so many conditions.

Q. What is the chief factor promoting or influencing evaporation?

A. Why the principal factors are temperature and wind and the humidity of the atmosphere.

Q. What is the chief factor?

A. (No response.)

Q. Temperature is generally considered the chief factor, isn't it?

A. Temperature is the large factor. It was just a question in my mind which was the larger of the two, this humidity or the temperature.

Q. You say that temperature of the water is the chief factor?

A. Yes, I should say the temperature was the chief factor.

Q. What is the evaporation from Michigan-Huron?

A. As given by Mr. Wheeler's observations, or his deductions rather, from the Lake Huron-Michigan Basin, the mean annual evaporation was 20.56.

Q. The Ontario Basin?

A. For the Ontario Basin 23.82.

Q. His investigations of the evaporation for the Huron and Ontario Basin were equally as accurate as those for Erie, St. Clair and Erie Basin?

A. I should say so.

Q. Assuming that there was an excess of 8,000 cubic feet per second more water delivered to Erie in the earlier period, that is from 1860 to 1883, than in the later period from 1890 to 1901, inclusive, as shown by the previous computation, assuming that it was disposed of by evaporation, how much evaporation does this represent on Lake Erie?

A. About three inches, I should say. It would be a case of taking time to compute it.

Q. Then, as I understand it, your conclusion, Professor, is that the evaporation from Lake Erie is about the same as the evaporation from Huron and Ontario?

A. It is a little greater, according to these figures.

Q. Any substantially greater is it?

A. Why, these means give Erie as 2.3 inches greater per year than Ontario; and 5.5 inches greater on Erie than on Huron-Michigan.

Q. Do you agree that failure of the increments of St. Clair and Niagara to check—I refer to the increments deduced by the Lake Survey under their equations of 1912—should be ascribed to a greater evaporation on Erie, or do you consider that the St. Clair increment is too large and should be reduced in order to check with the Niagara increment?

A. I should attribute it to both.

Q. Then when you say that the 8,000 cubic feet of water per second, or the 8,600 cubic feet of water per second, that did not get to Erie, that is not entirely true, is it? Wouldn't

you say some of it might have gotten there and evaporated?

A. Yes, I admit that.

Q. That is possible?

A. Yes.

Q. What is the effect of cold upon oil?

A. Cold?

Q. You use oil in your meters, don't you?

A. Yes.

Q. What is the effect of cold upon oil as used in those meters?

A. It thickens it.

Q. If a meter were freshly oiled and used in water at say 33 degrees Fahrenheit temperature, would or would not the cold water cause the oil to affect the rotation of the propeller?

A. To a very small extent.

Q. Have you ever made any experiments to determine to what extent?

A. Why, that matter would be told by rating—by comparison of rating of meter when it was rated in the summer time with when it was rated in the winter time.

Q. And a meter under these conditions would register less accurately and too low, wouldn't it?

A. To the extent of any effect that that might have.

Q. Did you ever make any tests? You say that you might determine what the effect would be. Did you ever make any tests of your meter to determine that proposition?

A. That particular point, no.

Q. Would a variation of the amount of oil used between moving parts make a difference in the registration in cold water?

A. No, I don't think so.

Q. What provision, if any, is made to ensure the same amount of oil on the meter shaft during the observations?

A. We always aim to put in enough oil to fill the space between the shaft and its bearings, that is the whole chamber, so that after the wheel is put back in place, oil fills the whole space.

Q. How much of a variation have you known or observed in a meter's registration in a single day?

A. I do not quite see the point of that question. The only test that I know of is that one made by Mr. Shenehon, and which he gives in his report on the Niagara River. Yesterday, when testifying, I had forgotten about that test.

Q. Was that in the report on the Preservation of Niagara Falls?

A. No, my recollection is it is in his report on the discharge measurements at the International Bridge.

Q. That was the early measurements?

A. Yes.

Q. Is that the early measurements?

A. Yes.

Q. When did Professor Shenehon make those tests?

A. While making the discharge measurements from the International Bridge.

Q. That was in 1897, was it, or 1898?

A. 1898-1899.

Q. Do you know what tests he made?

A. It was the comparing of two meters.

Q. Did he make a correction for that?

A. In his discharge work?

Q. In his computations, yes.

A. Why, naturally so. The point was to determine everything that had any bearing on the accuracy of the results, and apply it if it warranted.

Q. That is he did make a correction for those variations, diurnal or daily variations?

A. I think so, although I am not absolutely positive. It is some time since I—

Q. You think he should have done it if he did not?

A. Yes, if it warranted it.

Q. How large a variation have you heard of?

A. I think he speaks of about 2 per cent.

Q. About 2 per cent?

A. About 2 per cent.

Q. Do you know how Mr. Shenehon determined that this difference was due to the meter?

A. By comparing two meters.

Q. Might it not be that instead of correcting the meter he would be correcting the velocity, the actual velocity of the river, and that the meter was right and Mr. Shenehon was wrong?

A. Oh, I should not think so.

Q. It depended largely upon the personal equation, didn't it?

A. Yes.

Q. How is the change detected when the meters are in use, say six to eight hours a day?

A. They begin to skip in the registrations.

Q. What is the area of the circle swept through by the wheel of a Haskell A or B meter, in inches?

A. The area of the circle?

Q. Yes.

A. Those wheels are 7½ inches in diameter.

Q. Approximately what would be the area?

A. About 44 square inches approximately. My recollection is it is a little over that.

Q. In gaging the Niagara River at the International Bridge Section, how great an area of the stream actually came in contact with the meter blades? It would be infinitesimal, would it not?

A. Why, yes; it would be small, yes.

Q. And the same answer would apply to the co-efficient work, wouldn't it?

A. Well, it would be larger. It would be ten times as much or eleven times as much.

Q. It would be larger, but still it would be infinitesimal?

A. It would be small.

Q. Referring to the meter and weir test at Philadelphia, do you think the city engineers could have been more particular in their calibration of the weir than Professor Schoder has been at the Cornell Hydraulic Laboratory?

A. I think they made more observations at Philadelphia.

Q. How many more measurements?

A. I could not state the number.

Q. With what did they compare the weir?

A. At Philadelphia?

Q. To establish its rating?

A. I don't know.

Q. Did they compare it with anything, do you know?

A. Why, I suppose—I take it that they constructed a weir which represented as nearly as possible the Francis Sharp Crested Weir.

Q. You don't know about that, do you?

A. I don't know anything about it further than what is in the report which was made.

Q. Where is that report?

A. It is published in a paper of the Engineers Club of Philadelphia.

Q. What page?

A. July to September, 1897, beginning on page 107.

Q. How does the Susquehanna at Binghamton compare with the Niagara at the Split Section as to size?

A. I am not familiar with the Susquehanna at Binghamton, except in a general way.
Q. In a general way as you know it?
A. It is very much shallower.
Q. Is it wider?
A. No, I should say it was narrower.
Q. How much?
A. Oh, it would be a mere guess on my part. I should say it was not more than half the width.
Q. Do you know what the width of the Split Section was, or the width of the river at the Split Section?
A. I don't recall the figures.
Q. Wasn't the Wickwire Section about 2,200 feet, and the Oakfield Section about 1,900 feet?
A. I don't remember.
Q. Or vice versa?
A. I don't remember those figures.
Q. Assuming that to be correct, how much narrower would you say the Susquehanna is at Binghamton than the Niagara River at the Split Section?
A. I should not say it was over half the width of either one of those channels.
Q. Either one? Then probably 1,000 feet wide, something like that?
A. That is a mere guess on my part.
Q. A mere guess. It may be smaller than that?
A. Yes, it may be smaller than that.
Q. May be a little greater?
A. Yes.
Q. Would it be more or less difficult to gage the Susquehanna at Binghamton than the Niagara at Split Section?
A. More or less difficult?
Q. Yes.
A. Really there would be no difference as far as that goes.
Q. As to time?
A. As to the time it was required?
Q. Yes.
A. Oh, really there would be no difference. That is it would take less time to gage the Susquehanna.
Q. That is there would be less verticals?
A. Fewer stations, fewer vertical curves.
Q. And take less time to make the discharge measurements, too, wouldn't it?
A. Yes.

Q. Well, what percentage would you say of time, getting things down to percentage?

A. It would be in proportion to the number of stations.

Q. Well, say about a quarter of the time?

A. Oh, I would not put it in that way. It would depend entirely upon the number of stations. The time required for the observations at a particular station would be substantially the same in each instance.

Q. If it were deeper water, it would take a little longer, wouldn't it?

A. A little, but that would be very small.

Q. Are you familiar with the Drainage Channel, Mr. Haskell?

A. The Drainage Channel here in Chicago?

Q. Here in Chicago, yes.

A. I have been down it; know it in a general way.

Q. Do you know in general how that channel is constructed? It is an artificial channel, isn't it?

A. It is an artificial channel, yes.

Q. Do you know something about the rock section?

A. Why, I know there is a rock section on it.

Q. With comparatively smooth sides and smooth bottom?

A. Yes.

Q. And for a great number of miles it is perfectly straight, is it not?

A. I believe so.

Q. Do you know what the velocity of the current in that channel would be with a flow of about 7,000 cubic feet per second?

A. Why, no. It would be a matter to be computed after getting the figures.

Q. You don't know whether it would be approximately a foot and three-quarters per second?

A. Oh, I don't know. It depends.

Q. Did you examine Mr. Moore's work?

A. No, I did not. I did not pay any attention to it.

Q. You say it is possible to measure the flow of the Niagara River, the St. Clair and St. Lawrence Rivers within ½ of 1 per cent of accuracy?

A. That is to determine the center of gravity. That is provided you are willing to put in the necessary amount of labor.

Q. You are assuming the work that has been done by the Lake Survey, aren't you?

A. Yes.

Q. Would it be your opinion that one could measure more accurately the discharge of the Drainage Channel than the discharge of the Niagara River for instance?

A. Why, I should think they would be substantially the same. The Drainage Canal, of course, would be the easier stream to gage.

Q. Well, how much more accurately could the discharge of the Drainage Channel be measured than the discharge of the Niagara River, say?

A. I should say with equal accuracy.

Q. Well, would the conditions be better or worse on the Niagara River than on the Drainage Channel?

A. They would be worse. It would take more time, more labor.

Q. On the Niagara River?

A. Yes.

Q. Was there less opportunity for errors on the Drainage Canal than there is on the Niagara River?

A. Undoubtedly.

Q. Then assuming all those conditions, wouldn't you naturally say that you could measure more accurately the actual discharge of the Drainage Channel than the Niagara River?

A. No, I should put it wholly on the ground of the amount of labor you are willing to put on each stream.

Q. To overcome the difference?

A. To overcome the difference.

Q. And you have taken into consideration in that the fact that the Drainage Channel is regular in cross section, no disturbance, and that the Niagara River is a river which has very high velocity, about 5½ feet per second or more, and there are obstructions in the river in the shape of bridge piers and so forth at the Gaging Section?

A. Yes.

Q. And you are assuming also that all these difficulties which were mentioned that would be encountered on the Niagara River would be overcome?

A. Overcome by the extra amount of work you would naturally put on it if you wish it to reach the same accuracy.

Q. That is, one would naturally put on?

A. Yes.

Q. Assuming also that in the work on the Drainage Channel you would put on all the work that one naturally would?

A. Yes, all that was necessary to derive all of the coefficients.

Q. The same care and so forth?
A. Same care.
Q. Now, Mr. Haskell, you have given certain values to the increment of the Niagara, St. Clair and St. Lawrence Rivers. You have also stated the effect, your opinion on the effect on lake levels of a diversion at Chicago.
A. Yes.
Q. And you have given certain opinions as to the discharges of the different rivers?
A. Yes.
Q. Has your conclusion in regard to that been based entirely upon the records of discharge measurements in those different rivers and the records of the gage readings as made by the Lake Survey and referred to in this case?
A. It has.
Q. You stated in your direct examination that the rainfall evaporation absorption of the run-off in the drainage basin of the lakes or the inflow from the St. Marys River are neither increased nor decreased by the diversion at Chicago. You stated that in your direct examination earlier in this case, I think on February 17, 1909.
A. Yes.
Q. What do you mean by that statement, Mr. Haskell?
A. I do not see that has anything to do with the question of the diversion at Chicago or vice versa.
Q. Upon what do you base that statement?
A. The rainfall, evaporation and absorption of the run-off of the drainage basins of the lakes or the inflow from the St. Marys River, increased or decreased by the diversion at Chicago, I do not see any relation between the two at all.
Q. That is you do not think the run-off would be decreased by the diversion at Chicago?
A. No.
Q. Or that the rainfall would be increased?
A. Would have nothing to do with the rainfall.
Q. What do you think determines the amount of rainfall on the St. Lawrence basin?
A. The amount of rainfall?
Q. Yes, and run-off. I assume that your answer to the question put there would require a consideration of that question or problem?
A. No, not at all. I do not see that it has any bearing on the problem at all.
Q. But the question was asked here, as I remember it: "Was the rainfall, evaporation, absorption of the run-off in

the drainage basin of the lakes, or the inflow from the St. Marys River increased or decreased by the diversion at Chicago?" Now, wouldn't you, in answering that question—you answered "neither"—have to take into consideration the question or the problem as to how the amount of rainfall on the drainage basin is determined, or what effects it?

A. Why, the fact that you are diverting water at Chicago has nothing to do with rainfall, or nothing to do with evaporation.

Q. What I am trying to get at is how you figure that out?

A. I don't see any point to the question, Mr. Adcock.

Q. I presume that the water that flows down into the ocean gets back on the land some way, doesn't it?

A. It certainly comes back to give us our rainfall.

Q. In the shape of precipitation?

A. Certainly.

Q. And that varies from year to year to some extent?

A. Yes.

Q. And your proposition is it would not be affected in any way by the diversion?

A. I do not see that it has any bearing at all.

Q. Now, you have been a member of the International Waterways Commission for some time, haven't you?

A. Since 1906, the summer.

Q. And they have made several reports, two reports on the regulation of Lake Erie?

A. Yes.

Q. You believe, don't you, Mr. Haskell, that with the expenditure of comparatively a small amount of money the levels of Lake Erie may be raised or regulated?

A. To the extent set forth in that report.

Q. And without injuring, materially injuring anyone?

A. To that extent, as given there.

Q. And that the raising of the levels of Erie would affect the levels of Michigan-Huron?

A. Yes.

Q. And they would be raised?

A. To a small extent. The figures are given for that in that report.

Q. And Lake St. Clair, and the water levels of the St. Clair River, Detroit River and their channels would be raised an intermediate amount?

A. Yes.

Q. The Gut Dam has had the effect of raising the level of Ontario, hasn't it?

A. It has.

Q. Have any series of current meter measurements been made in large streams by anyone other than the Lake Survey?

A. The Mississippi River Commission has been engaged upon the discharge measurements of the Mississippi, Ohio, Tennessee, Cumberland and other streams ever since 1879.

Q. Has any consistent claim ever been made by anyone who made measurements of streams with current meters that the accuracy of the measurements were within ½ of 1 per cent of the actual discharge, except the Lake Survey?

A. No, I don't know that there has; but don't understand me as saying that you could gage the Mississippi with that precision, for the Mississippi River is an entirely different problem.

Q. Well, there are other rivers, aren't there, besides the Mississippi?

A. Yes, sir.

Q. And gaging work has been done on other rivers besides the Mississippi and the St. Clair and Niagara and St. Lawrence Rivers?

A. Yes.

Q. And streams also?

A. Yes, sir.

Q. With reference to those other rivers, has anyone ever made or claimed that they had determined the discharge by current meter measurements of rivers gaged within ½ of 1 per cent?

A. Not so far as I know.

Q. They do not usually make a claim of accuracy of more than 10 per cent, do they?

A. Seldom if ever made any claim at all.

Q. Except the Lake Survey?

A. They never make any claim at all. I don't know of any piece of work to which the care was given that the gaging of the lake outlets was given.

Q. I presume the measurements have been made of streams in rivers other than the St. Clair and Niagara and St. Lawrence and Detroit Rivers, and the St. Marys River, the persons making the measurements desiring to obtain the actual discharge, the law of the discharge of that river as accurately as they could do so and use the natural methods, the natural care, would they not?

Mr. Hopkins: I object to that as argumentative; and an

assumption based upon nothing in this record, unless he knows of the case?

Q. (Question read.)

A. I don't know of any case where there has been an attempt to determine the accuracy that was desired in the case of the work of the survey of the lake outlet.

Mr. Adcock: Q. Well, in measuring the rivers other than the ones I have mentioned, they would not do the work carelessly, would they?

A. Oh, no.

Q. They would use the natural care?

A. Certainly.

Q. And that care which would naturally occur to one who was experienced in that kind of work?

A. Yes.

Q. Now, you spoke of 3 per cent error in the discharge in the St. Lawrence River as determined by the Lake Survey. What is that due to?

A. That is, I think, we know the discharge of the St. Lawrence within the limits of the observations.

Q. Within 3 per cent?

A. I mean by that the center of gravity of those positions within 3 per cent.

Q. Why do you say 3 per cent of accuracy for the St. Lawrence and ½ of 1 per cent for the Niagara River?

A. There was a great deal more work done on the Niagara and the observations there cover a much greater range.

Q. We are speaking of the range of the observations in each case, the center of gravity?

A. Yes.

Q. Did you consider in this connection the perturbation that has been spoken of by persons who made discharge measurements of the St. Lawrence River, this perturbation being at the bottom of the river, in determining this 3 per cent of accuracy of those measurements?

A. I don't think there is any perturbation on the Three Point Section.

Q. At the bottom?

A. At the bottom.

Q. What investigations have you made to determine that?

A. I have not made any myself; just a case of the records.

Q. That is the records of the Lake Survey?

A. Records of the Lake Survey; the soundings that were made in that locality, and the general configuration of the stream.

Q. Assume that there was considerable perturbation at the bottom of the St. Lawrence River, what would you say as to the effect of that perturbation upon the determination of the discharge?

A. Why, it would have to be very large to be appreciable in the discharge.

Q. What comparison have you made in the discharges with the current meter, discharge measurements made with the current meter in smooth flowing water, as compared with those in perturbed and fast moving water?

A. None.

Q. Then upon what do you base the statement that it would take a large perturbation, in order to have any effect upon the discharge or the validity of value of the discharge measurements?

A. We base the accuracy with which we can gage a stream upon such work as that in the Niagara where, for instance, we had the Bridge Section and the Open Section.

Q. You base that entirely upon the check?

A. Upon the check.

Q. Between the two sections?

A. Between the two sections.

Q. In the particular river?

A. In the particular river.

Q. Did you have the difference in velocity, the probable difference in velocity between that of the Drainage Channel and that of the Niagara River when you stated that the Niagara River could be measured, the discharge of the Niagara River could be measured as accurately as the discharge of the Drainage Channel?

A. Yes.

Q. In other words, it would not make any particular difference how great the velocity was?

A. Oh, yes; the velocity could be so high that it would be out of the question to use the meter in it at all.

Q. What would be the limit?

A. Why, really, when the velocity goes above 7 or 8 feet per second, it becomes a very difficult matter to use a current meter in deep water.

Q. And that even with the Haskell Meter?

A. No difference what the meter was.

Q. How about the Price Meter?

A. It would not make any difference.

Q. The Price Meter would not operate as well, would it, at high velocity?

A. The Price Meter is a good meter under certain conditions; an excellent one, under certain conditions.

Q. Do you consider the Haskell Meter will operate better under all conditions?

A. That is the result of my experience, Mr. Adcock.

Q. You say that George Y. Wisner was with you at the time that you looked over the gaging section at the Niagara River?

A. That is my recollection of the matter.

Q. He was not then connected with the Sanitary District in any way?

A. It was not this Mr. Wisner. That is this Mr. Wisner's father.

Q. And he never was connected with the Sanitary District to your knowledge, was he?

A. No so far as I recall.

Q. In your direct examination you read from a pamphlet which was marked Haskell's Exhibit 2, February 3, 1914, entitled: "Ritchie-Haskell direction-current meter and the Haskell current meters. Instructions in their use by E. E. Haskell, C. E. E. S. Ritchie & Sons, Brookline, Massachusetts, Manufacturers. Washington, D. C. Gibson Brothers, Printers and Bookbinders, 1892." What I have just read appearing on the front page?

A. Yes.

Q. That pamphlet was distributed by E. S. Ritchie & Sons, Brookline, Massachusetts, manufacturers of the Haskell Meters, is that correct?

A. E. S. Ritchie & Sons and myself.

Q. What did you have to do with the circulation of that pamphlet?

A. One of them was given to each purchaser of a meter.

Q. This is a pamphlet which was used by you and the Ritchie Company in connection with the sale and use of the meter?

A. Yes; to give purchasers instructions as to how to use them, how to rate them.

Q. I presume the Ritchie Company issued other papers or advertising matter, didn't it?

A. They issued a small catalog, regular sales catalog, giving a description of the meters and the price.

Q. How long has Professor Schoder been connected with Cornell University, the Engineering Department?

A. Ever since I have been there, and for a few years

previous. I don't know just the date of his graduation. Mr. Williams will recall that.

Q. Probably about 1902, wasn't it?

A. He came there as a student in 1902, according to Mr. Williams' statement.

Q. Professor Schoder has had charge of the hydraulic laboratory at Cornell University since 1904, has he not; and under the title of Assistant Professor of Civil Engineering?

A. No.

Q. What was his title?

A. His title when I went there was that of Engineer in Charge, I think, of the hydraulic laboratory.

Q. What is his title now?

A. Assistant Professor of the College of Civil Engineering.

Q. He has moved up some since then, has he; he had been promoted?

A. He has received one promotion since then.

Q. Do you take part in any of the experiments made at the hydraulic laboratory at Cornell University?

A. It is seldom, if ever, that I do.

Q. Are you ever there when experiments are being made?

A. Yes.

Q. How often?

A. Oh, frequently.

Q. Well, how many times a month?

A. Why, there are certain times when we are making no observations whatever, so far as experiments are concerned.

Q. Well, how many times a year?

A. That is, as a rule, I am at the laboratory say two or three times a week.

Q. And you observed Professor Schoder's work there, you do observe it, do you?

A. I have seen it going on.

Q. You have observed it since 1906?

A. Since I went there in 1906.

Q. You have also observed the work of Professor Turner, haven't you?

A. Yes, Professor Turner has been assistant largely to Doctor Schoder.

Q. How long has he been there?

A. He has been there since 1906.

Q. Now, under what conditions are experiments made by Cornell University in hydraulics?

A. In hydraulics?

Q. Yes.

A. A request comes from a person or company or corporation asking for certain experiments to be made; and those are usually turned over to Professor Schoder and to Professor Turner to work out. I haven't the time that I can devote to it.

Q. And they have made a great many experiments in hydraulics in that laboratory since 1906, have they not?

A. Oh, no; not a great many.

Q. Well, several?

A. Yes, several would fit it. We have only had a very few problems.

Q. They made experiments in connection with their school work there, too, didn't they?

A. Well, that would come under the head of instruction.

Q. But they make experiments for the benefit of the different classes?

A. Certainly.

Q. In hydraulics?

A. Certainly.

Q. Did you ever calibrate the weir by which the water was measured that passes through the canal at the hydraulic laboratory?

A. No.

Q. Do you know who has calibrated that weir?

A. Doctor Schoder and Professor Turner have made some observations upon it.

Q. Don't you know that Mr. Gardner S. Williams calibrated the weir when he was there?

A. That weir has been entirely rebuilt since Mr. Williams was there.

Q. The lower weir?

A. Lower weir, both of them. We rebuilt both of them in 1908.

Q. What changes were made?

A. The main change has been made in the baffles.

Q. How far are the baffles from the lower weir?

A. From the lower weir?

Q. Yes.

A. Which ones do you refer to, which baffles?

Q. The lower end of the canal?

A. From the lower weir to the first baffle is 326½ feet.

Q. What was it before?

A. The same.

Q. How are the baffles changed?

A. The baffles in there now are made up of planks running horizontally.

Q. How were they arranged before?

A. Vertically.

Q. When?

A. I found them that way when I went there. I don't know when they were put in.

Q. How would that affect the discharge over the lower weir?

A. Really would have no appreciable effect upon that.

Q. Then the baffles would have nothing to do, or the location or the form of the baffles would have nothing to do with the calibration of the weir?

A. Not of that particular weir.

Q. The water that went over the lower weir was the same amount as that that went over the upper weir, was it not, in that canal?

A. Certainly.

Q. So, if you knew how much went over the lower weir, you would know how much went over the upper weir?

A. Over the upper weir.

Q. Did you ever go over the experiments made in connection with the calibration of the lower weir or the upper weir?

A. No, I have not.

Q. Then you would hardly be in a position to express an opinion as to whether or not that weir had been calibrated carefully and accurately, would you?

A. Just from general observation, the way I see work done around the University, around the laboratory.

Q. That is in general?

A. In general.

Q. What do you mean by in general? You mean that the work of the particular persons who had to do with the calibration of the weir—

A. Not that altogether, but general conditions.

Q. What conditions? I don't understand.

A. Our canal is not in first class shape for experimental work.

Q. You mean the weirs or the canal itself? I am speaking of the calibration of the weir?

A. Yes.

Q. You stated in your direct examination that the calibration of that weir was 3 or 4 per cent off?

A. No.

Q. Three per cent?
A. From two to three, I think I said.
Q. More than three, didn't you?
A. No.
Q. Two to 3 per cent? Well, upon what do you base that statement?
A. My recollection of the matter is that the standard weir was calibrated by comparison with a small weir in the laboratory, and not by comparison with the lower weir on the canal.
Q. How would that affect the calibration of the weir, the lower weir or the upper weir?
A. The canal in the laboratory is a small one and the water in getting in there has to pass through a gate where there is some obstruction to its free flow.
Q. Did you consider the various formulæ which you mentioned yesterday, various weir formulæ, in arriving at your conclusion that the calibration of the weir might be 2 to 3 per cent off?
A. I usually think of the Francis formula as the standard one.
Q. You didn't use any of the other formulæ?
A. No.
Q. Did you use the Francis formula? That is in arriving at your conclusion?
A. No, that statement is based upon the general care with which I have seen work done around the laboratory.
Q. Then you would not advise people to ask the University to make any experiments in hydraulics?
A. It would depend upon what they were.
Q. That is if they wanted accurate work done?
A. I should want to know whether we could meet the requirements or not, certainly.
Q. You say that your opinion as to the calibration of the weir is that it is 2 or 3 per cent inaccurate, and you base that conclusion upon the general work of the University, general conditions there?
A. No, not of the University.
Q. I assume the general conditions would apply to other tests which you have made or to other apparatus which the University might have there, with which to make experiments?
A. The amount of apparatus which we have there for making experiments is comparatively small.
Q. Well, do you consider that Mr. Schoder and Mr. Tur-

ner are not competent to make experiments in the laboratory, with the apparatus which you have?

A. That they are not competent?

Q. Yes.

A. Oh, no; no.

Q. You don't know any reason why Professor Schoder or Professor Turner would desire to color any experiments that they might make, one way or the other?

A. Oh, no; I should not say that; we—

Q. You have always been on good terms with Professor Schoder and Professor Turner?

A. Certainly, so far as I know.

Q. And they have a high opinion of you and you of them, haven't you?

A. I could not state their opinion of me.

Q. So far as you know, then; a high opinion of you and you have a high opinion of them?

A. Yes, I regard them as two excellent young men.

Q. You have no reason to believe that they would desire in the course of any experiments with the Haskell Meter to in any way carry on the experiments inaccurately, or in a manner which would injure you or the Haskell Meter?

A. Oh, no; I should not accuse them for a moment of any such intent.

Q. What did you mean, Professor, when you said in your direct examination that they were inclined to lay everything on to the meter, all mistakes to the meter?

A. Well, that point, that they assumed a higher accuracy for the measurements over the weir than I think they can justly claim. And I should certainly want to see the observations before I would be fully convinced of that matter.

Q. And you would like to see the observations and also see the work in connection with the calibrations, the experiments with the calibrations of the weir, before you would like to express an opinion as to the accuracy of Professor Schoder and Professor Turner's experiments with the current meter in that canal, wouldn't you?

A. Certainly.

Q. And you haven't seen those up to the present time?

A. I have not seen them at all; no.

Q. You do not believe, Professor, that Professor Schoder and Professor Turner would lay any inaccuracies to the meter if they did not honestly believe that it was due the meter, the Haskell Meter?

A. Oh, no; oh, no.

Q. You think the Haskell Meter presents a cure for most all difficulties that arise in connection with the determination of a discharge of rivers or streams?

A. I do not like the word "cure."

Q. Well, panacea, or something like that?

A. I think it is as good a meter as can be found on the market today.

Recess to 7:00 p. m.

After Recess 7:00 p. m.

EUGENE E. HASKELL resumed the stand and testified further as follows:

Re-direct Examination by Mr. Hopkins.

Q. Mr. Haskell, do you regard Mr. Schoder and Mr. Turner as having had sufficient experience in the matter of current meter work to make tests of the meters such as they testified to, with a high degree of accuracy?

A. No; I should not.

Q. You were asked yesterday as to certain weir tests made by various authors. Do you yourself have any personal knowledge of those tests?

A. No; I have not.

Q. What is the source of your knowledge in regard to those tests?

A. The reading of the reports made upon them.

Q. You were asked as to whether or not a change in the supply of water into the Great Lakes in an earlier period, say 1860 to 1883, compared with a later period. Do you want to make any further statements in regard to that?

Mr. Adcock: He made certain answers with reference to questions along that line. Do you want to add that?

Mr. Hopkins: Yes.

Mr. Adcock: Ask him if he wants to make any change in his answers to that?

A. Will you read that question?

Q. (Question read.)

Mr. Hopkins: Q. Do you want to make any additions or changes to the answers which you made to that question and similar questions?

A. Why, I might possibly describe it a little more fully.
Q. I wish you would.
A. For instance, the gage records beginning with 1860 and continuing up to about 1872 or 1873, are not as reliable as they are since that period. That was a matter that when General Comstock took charge of the survey in 1870, he went into with considerable care, and from about the time mentioned gage records were taken and preserved with greater care than previous to that time.
Q. Now, with regard to the supply of the Great Lakes, do you think cultivation and deforestation has anything to do with it?
A. Certainly, deforestation and cultivation, and increases in use of water for domestic purposes, such as sprinkling of lawns, and possible geologic changes may have some effect upon it, and it is probable that the dredging operations that have gone on have had a small effect upon it.
Q. Upon the levels of the lakes?
A. Upon the levels of the lakes. And undoubtedly there has been some change in the regimen of the various rivers that would have a small effect upon their stage.
Q. To what extent?
A. It would be a very small extent.
Q. Can you give it to us in tenths of feet, an outside limit?
A. Oh, I should say a quarter of a foot.
Mr. Adcock: What is that, the dredging?
Mr. Hopkins: Change in regimen.
The Witness: It may be that the dredging has caused that much of a change.
Q. Now, when you said that the equations in the 1912 report for St. Clair might be applicable to a prior period of 1860 to 1883, with what precision, do you think they are applicable with the earlier period, and why?
Mr. Adcock: Do you mean accurate instead of applicable?
Mr. Hopkins: Applicable; with what degree of precision are they applicable?
Mr. Adcock: I think that is an unintelligible question. I think the witness is entitled to have a question propounded to him that is intelligible.
Mr. Hopkins: Q. Do you understand my question, Mr. Haskell?
A. I would like to have it read to me.
Q. (Question read.)
A. I should think there might be differences of 10 to 15

per cent due to possible changes which I have mentioned, and of which we really have no direct measure.

Q. You mean in the increment, Mr. Haskell?

A. Yes, sir.

Mr. Adcock: Q. How about the discharge at the mean elevation during those periods?

A. For those periods?

Q. Yes.

A. I should think it would be somewhat questionable during that period of 1860 to about 1872 that I spoke of, an accurate knowledge of the stages of the lakes during that period.

Mr. Hopkins: That could be within 3 or 4 per cent, though, couldn't it?

A. Why, I think so.

Mr. Adcock: Q. Assuming you had an accurate knowledge of the stage, how accurately would you know the discharge?

A. Within the range of the observations, I should think then we knew it with the precision substantially which I have stated before.

Mr. Adcock: Half of 1 per cent?

Mr. Hopkins: Q. That does not take into consideration any change in regimen?

A. No; I did not consider that raised in that question.

Q. Mr. Haskell, you were asked yesterday as to whether or not you knew of any tests whereby the velocity of water at the surface could be compared with the water six inches or a foot below the surface?

A. Yes, sir.

Q. Has your recollection been refreshed as to any such tests?

A. Yes; I recall since testifying yesterday those observations made in the Detroit River by coloring the water for the purpose of testing the accuracy of the meters.

Q. That would be a way of testing it?

A. That would be a way of testing it.

Mr. Adcock: Q. Was that in tidal streams?

A. No, not in tidal streams, the Detroit River.

Mr. Hopkins: Q. In speaking of the ice in the Niagara River, you stated that there was no ice to amount to anything above the Falls. Do you wish to qualify or explain that answer?

A. Why, if I said the Falls yesterday, I meant above the Rapids, which approach the Falls.

Q. Now, as to the ice effect in the Niagara River as affecting the discharge of the river, in comparison with the St. Clair River, what is your opinion?

A. The ice effect in the Niagara River is of short duration. I don't know of any case where it extends over but a very short interval.

Q. What do you mean by a short interval, Mr. Haskell?

A. A week.

Q. You were asked as to the effect of cold water or cold temperature in general upon oil? When you took measurements in cold water were your ratings made in the same season of the year?

A. Why, as a general rule.

Q. And what kind of oil was used in your meter?

A. We used watch oil, a special grade that was made for cold weather.

Q. You were asked a number of hypothetical questions, assuming certain ranges and discharge measurements within a degree of accuracy given as to what percentage of error there would be in the difference of discharge. And then you were asked the question as to what percentage of error an increment would have based upon those same assumptions. You answered that the percentage of error of the increment would be the same percentage as the error in the difference between those discharges. Do you wish to make any correction of that answer now? You understand my question, Mr. Haskell? Did you catch my question?

A. Yes, I think so.

Q. All right, answer it?

A. I had thought since thinking the matter over that I misunderstood that question yesterday, and I should state that the error in the increment would be equal to the error in the difference divided by the range.

Q. You were asked certain questions in regard to a report of 1904, in which Mr. Russell made a report which appears in the appendix. I wish you would refer to that report, Mr. Haskell. Just how many pages of that report does that article of Mr. Russell's take up?

A. I believe there are 60 odd pages of it.

Q. When was the last time you read it?

A. I don't think I have read in since it was published.

Q. Did you ever study it with any great care?

A. Oh, I read it, of course, before it was published, and read it over quite carefully at that time.

Q. Now referring to the conclusions reached by Mr. Russell beginning on page—

A. Of the summary here, on page 4129.

Q. 4129. Before I ask that question: When you say you approved of it, just what does that mean, Mr. Haskell?

A. Why it means that I considered the report worth publishing.

Q. Does it mean that you agreed with the conclusions reached in there?

A. No, not necessarily with all of them, but that I did feel there was data in it to make it worth while to publish it.

Q. Now referring to the summary just referred to, on page 4129, is it?

A. 4129.

Q. Will you go through those summaries and tell us if there are any that you disagree with, which you did not mention today; and if you do not recall which ones you mentioned today, go through them all and tell which ones you disagree with. Take Number 2.

A. In regard to Number 2, I do not feel that we know the laws governing the flow of the Detroit River accurately enough to say that the formula which Mr. Russell derived here is an entirely satisfactory one.

Q. Number 3.

A. In Number 3, Mr. Russell states that the height of the water surface of Lake St. Clair in relation to heights of Lakes Huron and Erie is given by a certain equation there, in which he gives the co-efficient of the first term as .602. It is my understanding that later observations have increased that to .66.

Q. Go ahead and point out any others?

A. I think I spoke about, in fact, I am sure I spoke of Number 4 today.

Mr. Adcock: You refer to certain qualifications in 4 that you had not noticed when you made your first answer?

A. Mr. Russell makes a statement there, and then he qualifies it, and I should agree with his qualification.

Mr. Hopkins: All right, take Number 5.

A. The value of C in the Chezy formula there which Mr. Russell gives, I should regard that as questionable.

Q. How was the Chezy formula made up, in the first place, Mr. Haskell?

A. It is an empirical formula. The constant C is dependent upon observations to determine it.

Q. How about the work of measuring rivers in the Lake Survey, with reference to determining formulae of its own?

A. That has been a primary object in all of the Lake Survey work, was to make a determination of all of the coefficients needed for the reduction of the work.

Q. And would you regard those experiments just as accurate as the application of some such formula as the Chezy formula?

A. I should be inclined to say more so.

Q. Now continue as to the summaries.

A. I see no objection whatever to 6. I should question 7.

Mr. Adcock: What does that relate to?

A. Mr. Russell states, "The difference of 4,700 cubic feet per second adopted in the datum discharges of the St. Clair and Detroit Rivers is derived by taking it to be a part of the discharge of the Niagara River proportional to the Lake St. Clair drainage area as compared with the whole drainage area of the lakes above Niagara River." I should hardly hold that it was applicable. I see nothing in 8 to disagree with. I see nothing in 9 to question. I should not agree with 10.

Mr. Adcock: What does that relate to?

A. That relates to substantially the same thing that is set forth in 7, with which I did not agree.

Mr. Hopkins: Q. And 11 is dependent upon 10, isn't it?

A. Yes, 11 is dependent upon 10.

Mr. Adcock: Q. What does that have reference to, same thing?

A. Substantially the same thing, Mr. Adcock.

Q. You mean you question his mathematics or you question his assumption?

A. Question his assumptions.

Q. Of course, the mathematics is all right?

A. The mathematics, there are no question about.

Q. From my understanding, Mr. Russell is a very good mathematician?

A. He is an excellent mathematician, splendid computer.

Q. But you do not agree with all of his hydraulic conclusions?

A. No, there are very few of us that do agree on all these fine points.

Mr. Hopkins: Q. With reference to Number 11, do you consider the result reached by Mr. Russell as too high or too low, that .6 run-off?

A. I should say it was too high.

Mr. Adcock: What, per square mile?

A. Per square mile. This is the rainfall, reference to rainfall, is of the rainfall.

Q. Does not refer to the run-off?

A. Does not refer to the run-off per square mile; 12 is a little questionable, I should think.

Mr. Hopkins: Q. In what respect, Mr. Haskell?

A. That is he states there that "the adopted datum discharge for the St. Clair and Detroit Rivers are possibly too large and the discharge of the Niagara too small by very considerable quantities." I should not be inclined to put quite so much emphasis on the quantities. I should agree substantially with 13 and with 14.

Q. Where do you think the error in 15 would be more likely placed?

A. I am not willing to express an opinion in regard to that. I have some doubts about it.

Q. Take 16.

A. 16 is correct.

Q. Take 17.

A. I could not agree with 17.

Q. In what respect?

A. I think the quantity which he states as .8 of a foot is too great; 18 is unimportant in regard to this case.

Q. 19?

A. I should have no occasion to question 19.

Q. Now 20, take that.

A. I don't think Mr. Russell's statement in regard to 20 is quite correct. I do not see why the rise in Lake Erie for a foot rise in Lake Huron if continued should not be substantially the same. Nothing to question in 21; that is just purely a case of mathematics.

Q. How about the exact values as given in 22?

A. I made a statement in regard to those today. They are substantially correct. They are a little low for Erie. I think in my original testimony I answered that question and gave a little higher value than is here given for Erie; 23 is substantially correct. In regard to 24, I should not care to make any statement. That would be merely a question of computations.

Mr. Adcock: You would assume the computations were made correctly by Mr. Russell?

A. Unquestionably his computations are right. That is the data with which he started might be a little different from what I should use, if I were to go into the problem. In re-

gard to 25, Mr. Russell, in speaking of evaporation there, I should agree with those conclusions, and I think the figure which he gives for the evaporation from Lake Superior agrees very closely. Mr. Wheeler's figures are smaller than that by about four inches; and Mr. Russell's figures for the evaporation on Lakes Michigan-Huron are about approximately an inch greater than that given by Mr. Wheeler. In 27, I should question again that statement of .6 of the run-off being .6 of the rainfall, and his statement for evaporation is nearly ten inches higher than that given by Mr. Wheeler, which I would question.

Q. For what lake is that?

A. For Lake Erie. That is all in Mr. Russell's conclusions that have any bearing on the question.

Mr. Hopkins: Q. Mr. Haskell, in your direct examination you said that for Mr. Schoder to get an accurate measurement of the Susquehanna River, you thought it would take about a month. What did you take into consideration in giving that opinion?

A. I took into question the determining of all of the co-efficients, that is, the measuring of the vertical curves for all of the current meter stations, and going through the regular process of deriving all of the co-efficients that entered into the problem.

Mr. Adcock: Q. Was this with the Haskell meter?

A. Does not make any difference.

Mr. Hopkins: Q. Is that considering his experience and his equipment?

A. Certainly.

Q. I believe you said that the stream was at low stage at that time. Would that make a difference?

A. It would make a little difference.

Q. In a shallow wide stream would there be a different problem than in a deeper stream?

A. Why we have the feeling that we can get better results in a stream of reasonable depth than in one where it is so shallow that you practically have to wade it to do anything.

Q. And in getting at the precision of measurements in a shallow stream the percentage of the volume that is nearer bottom is greater, too, isn't it?

A. The friction on the bottom of course amounts to more. It is a larger percentage.

Re-cross Examination by Mr. Adcock.

Q. For what purpose are the contributions by the Lake Survey made in the Engineer's Reports?

A. I do not understand your question exactly, but the point of this investigation, of course, was made in the interest of navigation.

Q. Yes, but a lot of things are published in the Engineers' Reports from year to year, reports are made by the Lake Survey are they not?

A. Yes.

Q. What is the purpose of publishing those reports?

A. For the purpose of putting before the people concerned the data that has been gathered up to that time.

Q. One of the duties of the Principal Assistant Engineer, is it not, is to pass upon the reports prepared by Engineers in the office of the Lake Survey, as to whether those reports should or should not be published?

A. Certainly.

Q. Of course, the Principal Assistant Engineer brings to the office which he holds his experience and knowledge that he has gained in long years of work in the Lake Survey, doesn't he?

A. Certainly.

Q. And he determines what reports are accurate and are of value, does he not?

A. He does.

Q. Isn't it the purpose to present conclusions in such reports which are accurate, and to which the Principal Assistant Engineer subscribed?

A. That is the purpose.

Q. And it certainly is not the purpose to publish inaccurate statements of work done, or inaccurate or improper conclusions made from experiments or work done by the Lake Survey?

A. No.

Q. With reference to conclusion 20, in Mr. Russell's report as follows: "A rise of 1 foot in Lake Huron if continued would eventually produce a rise .727 foot in Lake Erie," I understood you to say it would produce a rise of 1 foot in Erie?

A. I should say approximately 1 foot.

Q. Then you would disagree with Mr. Russell's report in that connection?

A. In that connection.

Q. Do you know how deep the Susquehanna River is at Binghamton?

A. Only by hearsay.

Q. You stated in your cross-examination that you didn't

know, but that you thought it was shallower than the Split Section of the Niagara?

A. I should say that just simply from general information of the river, that is all.

Q. So you don't know whether the Susquehanna can be waded at Binghamton?

A. No, I would not make any positive statement in regard to that.

Q. If that impression might be gained from your re-direct examination, you wish to correct it in that regard?

A. I wish to correct it, certainly, because I have had nothing to do—

Q. Now this Chezy formula, that is a formula which is considered as a standard formula, isn't it, used by all hydraulic engineers?

A. Yes, it has been used very extensively.

Q. And no one has ever questioned the accuracy of that formula, have they, as representing approximately the results?

A. Oh, no.

Q. What experiments did you make with this oil that was used?

A. What experiments?

Q. Yes.

A. None. We adopted that oil because the makers of it claimed that temperature had little effect upon it. It was a brand of oil which they made— .

Q. You accepted the statement?

A. It was a brand of oil which they make especially for timepieces that are to be carried in cold climates.

Q. You accepted the representations made by the seller?

A. Certainly.

Q. What effect does deforestation have? You mentioned some effect in your re-direct examination. I did not understand whether it was to increase the supply of water or to decrease it.

A. That is where the timber is cut off.

Q. Then the cultivation of various areas of land, too, you mentioned?

A. Yes, where the timber is cut off, of course water gets to the streams more rapidly, and evaporation becomes a more important factor than it does in a timber country. The same is true of cultivated land.

Q. Then you think the lakes would probably be at a higher

level than during the period when the forests were upon the different areas?

A. At a higher level now?

Q. Yes.

A. No, I would say it anything the reverse.

Q. The deforestation and cultivation of the large areas of land would have the effect of decreasing the amount of water that would go into the lake proper?

A. No, it would bring about a different distribution; that is the time at which the water reached the lake would be earlier, for instance, than in the case where the country was timbered.

Q. When is the usual high water time during the year?

A. You see, that varies in the different lakes.

Q. Well, take Michigan-Huron, that is a pretty good example?

A. High water in Michigan-Huron comes the latter part of June.

Q. About the beginning of navigation, a little after the beginning of navigation?

A. After the beginning of navigation.

Q. You think it would probably under these new conditions be a little bit earlier than June?

A. That is, the tendency would be for it to come earlier.

Q. Very much, do you think?

A. Why, it is hard to say. We really haven't any data. Theoretically it looks as if that would be the case, but we haven't data sufficient to make an absolute solution of it and say that it is so.

Q. You spoke of the inaccuracies of gage readings during the earlier period, say along from 1860 to 1873, or '74, as I remember it?

A. Yes.

Q. How much would you say the mean of the gage readings from 1860 to 1883 was likely to be in error?

A. From 1860 to 1880?

Q. 1883.

A. 1883. Oh, in the mean it might be possible to be in error between 1-10 and 2-10 of a foot.

Q. Do you think Mr. Schoder and Mr. Turner had had more of less experience in current meter work and hydraulic work than Mr. Shenehon had had when he took charge of the measurements, discharge measurements of the Niagara River at the Bridge Section?

A. I should say less.

Q. They had had less or that Mr. Shenehon has had less?
A. No, Mr. Schoder had less.
Q. You have read Mr. Schoder's and Mr. Turner's testimony, have you not?
A. Why, yes, I read it through.
Q. I believe Mr. Shenehon had been on the gaging work of the St. Marys River at the Spry Dock Section, hadn't he?
A. Yes.
Q. That was the only work he had done before he commenced on the Niagara?
A. That is, as far as my recollection goes.
Q. That is true?
A. That is true.
Q. One of the difficulties in getting an increment, isn't it, Professor, is the connecting a discharge measurement to the proper stage of the lake, or to the stage of the lake that corresponds to the condition of the river at the gaging section when the discharge measurement is made?
A. No, that is not difficult at all.
Q. That is one difficulty you have, isn't it?
A. One difficulty?
Q. Yes.
A. I don't look upon that as a difficulty. That is we refer the discharge measurements usually to a gage at the section or close by the section, and if we want to transfer it to some other locality, we make the transfer by gage relations.
Q. But you take an interval of time, don't you, between the gage at say the controlling point and the time when you make your discharge measurement?
A. No, you can make them entirely independent of that.
Q. How was it done on the Niagara River? Was there any transfer of gages there?
A. I think in the case of the Niagara River they did determine the time interval between a rise for instance on the Buffalo Gage, and the rise on the gage at the section.
Q. And that was about eight minutes, wasn't it, time interval?
A. Why, something like that; just about eight minutes, I think, as stated in the report.
Q. But if you could take the measurement say of the discharge, 100 measurements of the discharge of the Niagara River when Lake Erie was at a constant stage, say 572, running over a period of several days, and you could also take 100 discharge measurements of the Niagara River when Lake Erie was at 573, running over a similar period of time, you

would have a better condition, you could determine the increment better for such measurements than you could from a number of measurements running over the same range of stage where the meter was at intermediate heights, the lake level was at intermediate heights.

A. No, I should not say so.

Q. Would it be just as accurate?

A. The observations which you made under the conditions which you named would have a much smaller range. They would come much closer to the center of gravity or to the true discharge curve.

Q. That is under the conditions which I assumed?

A. Yes.

Q. Than if the dicharge measurements were made when the lake was at a stage intermediate to 572 and 573?

A. Yes, you see a discharge measured on a rising river gives us, as we say, a mean velocity that is too great and on a falling river a mean velocity that is too small, and, of course, our range there becomes greater.

Q. Assuming the conditions which I first mentioned there, would you consider the increment obtained in that way as accurate as an increment which was obtained by a similar number of discharge measurements over the same range of stage where the stage of the lake was changing?

A. Yes, I should.

Q. You stated that the increment derived from the discharge observations of the Niagara River might be in error 2 per cent, didn't you?

A. I think that was my figures.

Q. And you also stated that the error of the difference between the mean discharge at a mean stage of the lake and the mean discharge at another mean stage of the lake would be approximately 10 per cent under conditions assumed in the cross-examination with reference to that subject matter?

A. That it might be possible.

Q. The increment would be ten per cent in error?

A. It might be possible, but hardly likely in the case of Niagara.

Q. Under those conditions?

A. Under those conditions.

Q. Now assume that you had 100 measurements of the discharge of the Niagara River when the lake state was exactly 573, you would know the discharge of the Niagara River within ½ of 1 per cent for that stage, wouldn't you?

A. I should feel that way.

Q. And if you had 100 other measurements made when the lake stage was exactly 572, you would know the discharge at that stage within ½ of 1 per cent, according to your figures?

A. Yes.

Q. What would be the error in the difference between the mean discharge at the elevation 573 and the mean discharge at 572? That is the error of the increment?

A. That is as between those two limits?

Q. Those two points, and assuming 100 observations made—

A. At each point?

Q. Yes, at each point, when the lake stage was exactly at that point?

A. I should say we knew it very closely, indeed.

Q. How closely?

A. Within that half of 1 per cent.

Q. Why do you make a distinction between that case and the other instance, the other comparisons?

A. Because the conditions which you gave are ideal, extreme accuracy for the two points.

Q. You simply have the stage the same, don't you?

A. But you have made 100 observations at each point under ideal conditions so that in that range—that is you must know the form of the curve very closely indeed.

Mr. Hopkins: I do not believe that he understands the question. It is exactly the same question asked yesterday.

Mr. Adcock: I think it is.

Mr. Hopkins: That you asked yesterday, where the difference was given at ten per cent.

Mr. Adcock: Q. How much might it be in error then, Professor Haskell? Might it be in error ten per cent, the increment?

A. In this particular case which you state here?

Q. Yes.

A. I should say no.

Q. How much might it be in error?

Mr. Hopkins: Those 100 observations are taken at absolutely the same point.

Mr. Adcock: Same stage.

Mr. Hopkins: Same stage; and exactly the same question was put yesterday; assuming a degree of accuracy at the mean discharge at a certain stage within ½ of 1 per cent, another discharge at another stage within ½ per cent, what would be the possible percentage of error in the difference given between zero and ten per cent. This is exactly the

same question as I see it, because you have got your 100 readings, understand, Mr. Haskell, at exactly the same point, so that your degree of accuracy of ½ per cent is just the same as the degree of accuracy of the other. If you want to change your whole opinion on the same thing, that is one thing, but it is exactly the same question. You may want to change your whole opinion. (To Mr. Adcock): He may want to change the whole thing.

The Witness: To me, the question is different entirely.

Mr. Hopkins: In both cases they assume a degree of accuracy at one point of ½ per cent. That is where they start from in both cases. All these other furbelows do not,—

The Witness: He states conditions that are absolutely ideal, and says that he has got 100 observations under ideal conditions; no change in stage. That gives him that point at 573, and he makes similar conditions for his 572.

Mr. Adcock: Do you consider you can make a discharge observation more accurately at one stage than at another?

A. No.

Mr. Hopkins: Let it go ahead either way. Mr. Haskell says he wants to read his testimony at more leisure.

Mr. Adcock: Q. Here is the proposition: If he answers one way, I am going to lead up to another question.

Mr. Hopkins: Go ahead.

Mr. Adcock: If his answer stands.

Mr. Hopkins: He may want to change it. My point was it seemed to me it was the same question, but if he thinks it is different all right; he is testifying, not me.

Mr. Adcock: Q. You would give greater weight to a series of observations made, of continuous observations made when the lake level was more or less at an even stage, would you, Mr. Haskell?

A. No. The resulting observations, as I stated before, would show a less range.

Q. I am taking a range of 1 foot here?

A. Yes, and your statement, the conditions which you supposed were substantially the fixing of those two points with an absolute certainty.

Q. If you had a series of observations made say when the lake stage was approximately 572, and several of them, and a series of observations made when the lake stage was approximately 573, or another elevation, you would give more weight to those observations than you would to a similar number of observations made when the lake stage, lake level was at a

stage intermediate to 572 or 573 as the case might be, wouldn't you?

A. No.

Q. Then as I understand it you give more weight to observations made running over a period of several days when the lake stage is exactly at 572 or at an even stage than you would to observations made when the lake stage was changing, but at some mean? The mean of the lake stage being the same for the last series of observations.

A. (No response.)

Q. Assuming that there were the same number of observations in each series and running over the same period of time?

A. Observations which were taken at a time when the lake was at a uniform stage and remained that way, of course, we would get a smaller range in our observations and they would be taken under more ideal conditions and the tendency would be to give them greater weight than the others.

Q. You would be closer to the true discharge, wouldn't you?

A. Those individual observations would be closer to the true discharge.

Q. The mean of the several observations taken would be nearer accurate than the others, is that correct?

A. Substantially so.

Q. And an increment derived under conditions where the lake level was more or less at an even stage would be more accurate you think than an increment derived from discharge measurements where the lake was changing around, assuming the same variation between mean elevation of the two centers of gravity used?

A. Yes.

Q. Suppose that you took 50 pairs of discharge observations and derived an increment from each of the 50 pairs and then took the mean of the increment derived from those 50 pairs, what would be the accuracy of the resulting increment?

A. That to my mind gets right back to the other condition of affairs.

Q. Well, what do you think would be the percentage of accuracy?

A. It might be anywhere between zero and say 10 per cent.

Q. Take 100 pairs?

A. It would not make any difference. That is, we would have the feeling that the 100 pairs would get a little closer to the truth. The more the observations, why—

Q. How much closer, in percentage?
A. In percentage?
Q. Yes. Or what would be the percentage of error in that case?
A. In the case of 100 pairs?
Q. Yes.
A. I should think we were getting very close to ½ of 1 per cent; that is on the true positions of the points of the centers of gravity.
Q. And the increment? I am asking about the increment, percentage of accuracy of the increment?
A. I should say it might be anywhere within the limits, as I have stated before, of zero and say ten per cent.
Q. Suppose you had 25 pairs?
A. I should say we did not know it as accurately.
Q. Within what percentage of error?
A. Your statement was 25 pairs?
Q. Yes.
A. Twenty-five pairs, that is getting down to a small number of observations to fix anything of that kind.
Q. What do you think it would be?
A. Oh, it might be ten per cent, may be more.
Q. Then it does not make a great lot of difference whether you have 10, 25, 50 or 100 pairs of observations?
A. Certainly it does.
Q. I thought you gave substantially the same percentage of error?
A. No. I may have given substantially the same for your 50 or your 100; that is in the first place you have got 100 observations fixing a certain point. At another stage, you stated that you had another 100 observations. That ought to fix those points very accurately.
Q. I am speaking now, Mr. Haskell, of taking 100 pairs and deriving an increment from each pair?
A. From each individual pair?
Q. Yes.
A. Oh.
Q. And then taking the mean of the increments thus derived?
A. Oh, that, I should want to see the observations before I expressed an opinion about that.
Q. Assuming they were made by the Lake Survey and assume in that connection that the observations composing the pair were not less than .5 of a foot apart, as far as lake stage is concerned?

A. I think you would fall into a greater error.
Q. How much?
Mr. Hopkins: I shall move to strike out all of this examination on the same grounds given before, that it is not re-cross examination. We have not gone into it at all?
Mr. Adcock: Is that a warning, or a protestation?
Mr. Hopkins: Simply that it may appear.
The Witness: That is the increments taken at equal intervals ½ a foot apart?
Mr. Adcock: We assume that no pair is used where the observations are closer together than ½ foot in elevation?
A. Closer together?
Q. No pair is used where the observations are closer together than ½ foot in elevation. That is purely an assumption.
A. Any answer that I make would be more or less of a guess.
Q. If it is not too much trouble, Mr. Haskell, I would like to have your opinion as to that. I appreciate we have had a long day.
A. You wanted that in percentage?
Q. Yes, what would be the percentage of error of the increment thus obtained, if any?
A. It might be within the same limits.
Q. Assuming 25 pairs, Mr. Haskell?
A. 25 pairs?
Q. Yes.
A. The limit certainly indicated would be greater.
Q. It might be some more than 10 per cent?
A. Yes, might be double that.
Q. What would the probable error be under each condition, with the 100 pairs?
A. The probable error with 100 pairs?
Q. Yes.
A. Why, you would have to have the observations to work that out.
Q. Assume you had observations made by the Lake Survey covering range, stage, say a foot and a half, each pair not being less than a foot and half apart?
A. You have got to have the observations themselves before you can make out a probable error.
Q. What do you think probably would be the error of the increment?
A. You are referring now to the 25 pairs?
Q. No, to the 100 pairs.

A. I should say it might be anywhere within the limits of zero to 10 per cent.

Q. But probably, what would the error probably be?

A. Oh, say half of that.

Q. Then for 50 pairs, you would have the same answer, would you?

A. Of course, theoretically it would be a little greater than that.

Q. But not appreciably. Practically it would not amount to much?

A. Why, it would depend upon the observations; might not amount to anything.

Q. Then 25 pairs?

A. When you begin to cut down your observations, of course you haven't got the position of your line determined as well.

Q. Now take all the observations that have been made by the Lake Survey as to the discharge of the Niagara River and the increment which they have derived, what do you consider to be the possible error, what might the error be of the increment that has been derived for the Niagara River, 21,900 cubic feet?

A. The possible increment?

Q. The possible error of that increment, what might it be?

A. I certainly don't believe it could be greater than 5 per cent.

Mr. Hopkins: How many, all the observations?

Mr. Adcock: All the observations made by the Lake Survey upon the Niagara River as to the discharge of the Niagara River; what do you think might be the error of the increment derived from those discharge measurements?

A. I should say 5 per cent.

Mr. Adcock: I think that is all.

Adjourned subject to notice.

CHARLES Y. DIXON, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Charles Y. Dixon.
Q. What is your business?
A. Civil Engineer.
Q. By whom employed?
A. United States Government, under the War Department.
Q. Will you just give us your training, education and experience in your line of work?
A. I graduated from the University of Michigan in 1887, in the prescribed course in Civil Engineering. I was in railroad work for 3 or 4 years; and began work with the government under the Engineer Corps, River and Harbor Improvement at the Soo, in 1892. In 1896 I was transferred under the same office to the Detroit River work; and I have been located in Detroit and vicinity ever since.
Q. In a general way, what has been the nature of your work connected with the United States Government in the river mentioned?
A. The preparation of specifications and making of surveys with the idea of improvement of channels.
Q. How long have you been at work on the Detroit River?
A. 18 years.
Q. Will you just tell us in detail what work has been done by the United States Government in the Detroit River?
A. Since I have been here?
Q. Do you know the work before you came here?
A. I know it as a matter of record.
Q. Well, give us all of it.
A. The first channel improvement on the Detroit River was made in 1877 at Lime Kiln Crossing; and until 1890 it was carried on, not every season, but as the money was appropriated; it was not continuous; but in 1890 the project at Lime Kiln Crossing, that they had in mind, was completed for a width of 440 feet. Later on a more general project was adopted, and work has been continuous since 1892 on the De-

troit River at different localities; not of course all in one place.

Q. What was the work done in 1870 at the Lime Kiln Crossing, what result was accomplished?

A. That of course was before my connection with it.

Q. I understand.

A. The original depth there was about 12½ to 13 feet, but the work that they did under those contracts, (there were several of them) provided for a depth of about 18½ feet at the midsummer stage which prevailed at that time. And the general average face of excavation, average depth of material removed, was perhaps about 2½ to 3 feet over the area that was improved at that time.

The length of the channel improved was about 2500 feet, and 440 feet wide, to the maximum face say about 6 feet.

Q. What was the nature of the excavation?

A. At that point it was rock.

Q. Was it rock?

A. Yes.

Q. Loose or in place?

A. There were a few overlying boulders.

Mr. Adcock: That was in 1870?

A. I am speaking of the work that was done prior to my going there. It is a mere matter of record. There were a few loose boulders overlying the bottom, but the matrial was mainly rock in place.

Q. What was done with the material?

A. It was deposited in the river. The greater part of the material that was excavated prior to 1890 was deposited just below but to the west of Stony Island; that is below Stony Island but a little bit west of Stony Island.

Q. What was the depth of the water in which the material was deposited?

A. About 12 feet generally, and the depth over the dumping ground as left would be from 4 to 5 feet. It would be very irregular however.

Q. Originally, was there any current in this channel where the material was deposited?

A. Yes, some.

Q. How about since that deposit?

A. There is still a perceptible current there.

Q. What effect did that depositing of material have upon the current?

A. Well, it would reduce the cross section at that point, of course.

Q. Did it have a compensating effect as far as the lowering of Lake St. Clair is concerned?

A. It did, yes.

Q. Now coming on down later, you say there was quite a little excavation about 1890. Just where and what was that?

A. In 1892, I think the work was resumed again at Ballard's Reef. From then for several years, there was work done in that locality.

Q. What was the nature of that work?

A. That was mainly rock, although in places there was earth and boulders overlying the rock to a depth of 2 or 3 feet; in some places more, but generally rock in place had to be removed in order to secure the improvements.

Q. Some of that work you say was in boulders and fragments of rock?

A. Yes.

Q. And what was done with the material?

A. Most of the material taken out of Ballard's Reef was deposited along the eastern shore of Grosse Isle; that would be north of Stony Island.

Q. Did that depositing of material have a compensating effect upon Lake St. Clair?

A. It tended to obstruct the flow in the river, yes.

Q. That was the purpose of depositing it there?

A. The purpose of depositing it was to get rid of it of course.

Mr. Austrian: I do not think you ought to put quite every answer in the witness' mouth.

The Witness (continuing): The material of course was excavated and we had to get rid of it, but in the depositing of material, the dumping grounds were so selected as to compensate as largely as we could for the excavation, and of course we had to be governed by the depth of water that was available, too. We could not always select perhaps the point that would compensate the most; but we had that in mind in choosing the dumping grounds.

Q. Any subsequent work that was done?

A. The work following that work at Ballard's Reef?

Q. Yes?

A. Well the work at Ballard's Reef was completed in 1899, the original project. Later on another project was adopted for an increased depth that required the entire area

to be gone over again and deepened about a foot and a half or two feet more.

Mr. Adcock: When was that?

A. That was started along about 1902, and in fact that project is not yet completed. It is completed with the exception of a little work at Ballard's Reef which is now nearing completion.

Q. What was done with the material in those cases?

A. It was deposited in the same general localities as I have indicated.

Q. Is there any other work that you have not mentioned?

A. The Livingstone Channel I have not mentioned.

Q. Go ahead with that?

A. That project was adopted in 1907, and the work of excavation was started in 1908; and the Livingstone Channel was completed and opened to navigation in 1912. This route is a straight channel, leaving the old channel at Ballard's Reef, and going straight to the mouth of the river, to the Detroit River. Light house, at the mouth of the river, going to the west Bois Blanc Island. It is 300 feet wide through the greater part of its length in the river. At the mouth of the river it widens to 800 feet. In the 300 feet portion, the material is mainly rock. There was a length however that was surrounded by dams and excavated in the dry, and that portion of the channel instead of being 300 feet wide is 450 feet wide. That is opposite Stony Island.

Q. In that case, was the material deposited in the river?

A. It was, excepting some of the material that was excavated in the dry, that was dumped off in piles on each side, and subsequently some of it has been taken to Detroit and crushed for commercial purposes. It has been excavated with a dredge. They are removing all the material that is there.

Q. Is there any other dredging in the Detroit River that you have not mentioned?

A. I think I have covered it.

Q. What effect has all of this dredging had upon navigation?

A. It has increased the navigable depth from what it was originally at Lime Kiln Crossing, about 12½ feet, as the records show to, at the present time a depth of about 19½ to 20 feet. In the Detroit River, there would be 21 feet navigable depth, if it were available elsewhere.

Q. Through the whole length of the Detroit River?

A. Yes, sir.

Q. Has there been any other material dumped into the Detroit River, other than that you have mentioned as being dredged in the river itself?

A. Well, there has been some excavation here in Detroit that has been deposited in the river, but it does not amount to a great deal. It is only a small amount.

Q. How about the river Rouge?

A. Yes, there has been excavation in the river Rouge and also excavations for buildings in Detroit; I believe some of that was taken down the river.

Q. Do you know how much was excavated in the river Rouge and dumped in the Detroit River?

A. No, I could not tell you that.

Q. What is your opinion as to the effect of all this work in the Detroit River upon the level of Lake St. Clair?

Mr. Adcock: Objected to.

Mr. Hopkins: If you object to the form of the question I will change it. I will withdraw that question.

Q. Has any other work been done in the Detroit River to compensate for that dredging?

A. A portion of the material that was excavated in channel improvement was, as I briefly stated, deposited so as to form a dam to surround a portion of the channel area, which was excavated in the dry. Those dams, of course, served to compensate. In those dams, an excavation has been made through them for the channel, of course, which is 300 feet wide, the dams have been removed for an opening of about 380 feet.

Q. How long were the dams themselves?

A. The area enclosed by dams was about 5800 feet long and about 1500 or 1600 feet wide.

Q. What is the length of the dam crossways of the current?

A. It would be about 1200 feet perhaps abreast of Stony Island.

Q. Do you have an opinion as to what effect all of this work in the Detroit River has had upon the elevation of Lake St. Clair?

A. I have an opinion, yes.

Q. What is that opinion?

A. Well, I do not think our improvements have affected the level there any more than to the extent of 1/10th of a foot anyway; not more than that.

Mr. Austrian: Q. Up or down?

A. It may be lowered perhaps 1/10th.

Mr. Hopkins: Q What are the ice conditions in the Detroit River?

A. The ice occasionally forms dams at the head of Fighting Island, and also at the head of Grosse Isle on the main Michigan shore, and at the head of Bois Blanc Island on the Canadian shore, in the narrower portions of the channel.

Q. How about ice cover?

A. The river in a severe winter is usually covered from Detroit to Lake Erie with ice; the ice being anywhere from a six inches thick to a foot and a half foot, in places.

Q. What effect does that have upon the volume of flow?

A. It retards it.

Q. How frequently does that sealing over of the river occur?

A. Well, we have not had it this year, and we had it last year only for a short time. Last winter was very mild, as it has been this winter; but with the ordinary winter the river is covered with ice, perhaps about six weeks I should say.

Q. What has been your experience in soundings?

A. In carrying on our work, we have made surveys every year during my work for the Government, for the past twenty odd years.

Q. With what degree of precision can you make soundings as for instance when you are trying to determine the area of a cross section?

A. I should say within 1 per cent. I would expect more accuracy in earth bottom than in a rock bottom. In rocky bottom, it is more or less uneven.

Q. What depth of water do you refer to?

A. I am speaking of depths of water from perhaps 15 to 25 feet. That is what I had in mind.

Q. And a current such as in the rivers you have mentioned?

A. Yes, sir.

Mr. Austrian: What rivers?

Mr. Hopkins: He has been speaking of the Detroit river and the other rivers which they mentioned, which happened to be the St. Marys or the Soo.

Q. A current such as the Detroit River, I will put it?

A. Yes, sir I had that in mind.

Recess to 2:30 P. M.

After Recess 2:30 P. M.

CHARLES Y. DIXON, resumed the stand and testified further as follows:

Mr. Hopkins: Q. Will you explain further your answer in regard to the degree of precision that you can get in soundings?

A. Our work in making surveys has been in depths of water ranging generally from 10 to 25 feet. In such depths, and in the current in the Detroit River, I would expect to get within 1/10th of a foot at least of the accurate depth.

Q. In 20 feet of water, what precision would that be as a percentage?

A. Well, that would be 1/10th of the difference, 1/2 of 1 per cent.

Q. How would it be in 30 feet of water?

A. I would expect within a tenth of a foot.

Q. So that your percentage in that case would be 1/3rd of 1 per cent.?

A. Yes, sir.

Mr. Hopkins: That is all.

Cross-examination reserved.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner, at the Lake Survey Offices, Detroit, Michigan, commencing on Tuesday, February 17, 1914, at 11:00 A. M.

Present:

Mr. Albert L. Hopkins, representing the Government.
Mr. Edmund D. Adcock, representing the Sanitary District.

CHARLES Y. DIXON, recalled for further examination testified as follows:

Cross-Examination by Mr. Adcock.

Q. Prior to 1905, Mr. Dixon, who determined where the spoil coming from excavations, should be dumped; speaking of the channel in the lower Detroit River?

A. Between 1896 and 1905, I did that, mainly at least; it was approved by the Engineer Officer in charge, always.

Q. It was on your recommendation, was it not?

A. Usually, yes, sir.

Q. Where was that spoil usually dumped with reference to the excavation area?

A. In what particular?

Q. As near the place where it was excavated as possible?

A. Yes, we usually tried to avoid a long haul to the dumping ground.

Q. What calculations did you make to determine where the spoil should be dumped?

A. You wish me to state how we arrived at the locality?

Q. Yes?

A. As to the dumping ground?

Q. Yes?

A. Well, we inspected the chart to determine the locality of available depth where it would not interfere with probable future improvements, or be objected to by property owners on shore, of course having in mind the compensation of the dumping ground, also.

Q. What calculations did you make to determine the compensation effect, if any?

A. We made none at that time.

Q. That is prior to 1905?

A. Yes.

Q. Since 1905, who determined where the spoil should be placed?

A. The same way.

Q. And you followed the same method?

A. Same method.

Q. In what depth of water was the spoil usually dumped?

A. Usually not less than 10 or 12 feet. That would be governed by the amount of water that the loaded dump scows would draw.

Q. That was the determining factor was it?

A. Largely, yes, sir. That would vary with the contractor's plant.

Q. You have done considerable sounding?

A. We have, yes, sir.

Q. To get a precision of, say one per cent., in the area of a cross section, as testified to by you in your direct examination, how frequent in your judgment should be the sounding?

A. Our soundings are taken at the corners of ten foot squares over most of our work.

Q. That is ten feet apart?

A. Ten feet apart, both ways.

Q. That is across the river?

A. Across the river and up and down stream also.

Q. Up and down stream also. Can soundings of the same depth be made more or less accurately in swift flowing than in slow flowing rivers?

A. In slow flowing rivers.

Q. On rock bottoms are abrupt changes of depth of, say one or two feet, likely to occur in the cross section?

A. They are occasionally found, yes, sir; more frequently in rock bottom than in earth bottom.

Q. You spoke of the Livingstone Channel Improvement, the cofferdam, in connection with your direct examination. How much of the material composing the old cofferdam was the contractor authorized to remove?

A. None excepting that which crossed the channel, for a width of—

Q. There has been some controversy, hasn't there, between the government and the contractor as to his right to remove this material?

A. Not the dumped material. That was the excavated material that was piled up on the side of the channel.

Q. I mean the spoil that was piled up there?

A. That matter was referred to the department in Washington, and they decided that the material belonged to the contractors, and they are now engaged in excavating all that material.

Q. Just state what material that is they are now engaged in excavating, taking out?

A. Those are the piles of rock that are on each side of the channel.

Q. That is of the new Livingstone Channel?

A. That is of the new Livingstone Channel, that were deposited there within the cofferdams.

Q. In case all that material is removed, the material that you have mentioned, what effect will that have upon the flow of the river at that point?

A. It would increase the flow slightly, but the area is still surrounded by the original dam and a portion of the dump pile will not be removed, because it is being removed for commercial purposes, and for about a thousand or 1200 feet at the south end of the area where those piles are, there is

considerable earth mixed in with the rock, and there it becomes of no value to them for their purpose.

Q. When this work was finished, was there considerable material that was removed from the Livingstone Channel piled above the surface of the water?

A. Yes, sir, there was.

Q. Of course that would have no compensating effect?

A. No.

Q. What is the depth of the Livingstone Channel now?

A. The clear depth within the dams is 23 feet. Outside of the dams it is 22 feet. The actual depth of excavation is somewhat greater than that.

Q. Do you know about how much that is?

A. Within the dams, it would be something less than a foot greater.

Q. A foot greater?

A. Less than a foot greater. It would vary somewhat. Outside of the dams, it in places would be two and perhaps three feet greater than that.

Q. What would be the depth of the water in the lower Detroit River, testified to by you as having been 12½ or 13 feet; that is originally before excavation was made; having in mind the present elevation of Lake Erie?

A. It would be slightly less than that which you have stated.

Mr. Adcock: That is all.

Re-direct Examination by Mr. Hopkins.

Q. Is any of this material that is being taken away by the contractor above the water level?

A. It is, yes.

Q. What part of it is above the water level?

A. The height of the pile above the water level varies from seven to perhaps 20 feet, and it comes to a point at the top.

Q. How deep are they going below the water?

A. The depth of water where the pile was dumped varies from perhaps about four feet at the least depth to about twelve or thirteen feet at the greatest.

Q. Are they attempting to take it all?

A. They are taking all that they can excavate with a dredge. It is doubtful if they can excavate that which is in the shallowest water. They have not yet done that. In fact,

their operations were stopped at the place of least depth last season.

Q. In your judgment what effect has this taking away of the material by the contractors had upon the compensation work in the river?

A. I think it has very little effect.

Mr. Adcock: Q. That is the material that was taken away up to date?

A. Yes.

Q. At the present time?

A. (No response).

Mr. Hopkins: I think that is all.

Re-re-Cross Examination by Mr. Adcock.

Q. When the material was originally placed there on the side of the Livingstone Channel, it was claimed by the Government, was it not, that the Government owned that material?

A. I understood so. At least it belonged to the contractor during the life of his contract and then reverted to the Government. That was my understanding.

Q. And the Government had the right to designate the place where the material should be dumped?

A. Yes.

Q. Or placed?

A. Yes If you will permit me to explain more fully—

Q. Yes.

A. That question was afterwards referred to the department at Washington, and they decided that the material belonged to the contractor even after the expiration of the contract.

Q. Has the Government taken any steps to purchase the material from the contractor, or acquire it in any way?

A. No.

Re-re-direct Examination by Mr. Hopkins.

Q. When did the contractor start taking away this material?

A. My recollection is early last season.

Q. Did you have that in mind when you testified before that the effect on the level of Lake St. Clair, in your opinion, was not to exceed one-tenth of a foot?

A. I did not take that into consideration at that time. It was our records that I had in mind at that time, they did not cover the—

Q. Now taking into consideration this, what is your opinion as to the effect on the level of Lake St. Clair?

A. I would not change my former testimony.

Further Re-cross Examination by Mr. Adcock.

Q. That is as to the conditions at the present time?

A. Yes, sir.

Q. What calculations have you made, Mr. Dixon, to determine the effect on St. Clair, Lake St. Clair, of the excavation that the Government has made there in the Detroit River?

A. I have made a study of the records of the water levels since the records have been kept; and have made some deductions. Will you permit me to consult my notes on that?

Q. Yes?

A. In making some of these deductions, reference was made to the water levels at Lake Huron, the water gage at Harbor Beach; that of Lake St. Clair at St. Clair Flats Canal, and Lake Erie at Cleveland; and prior to the improvement there were 20 monthly means selected, which agreed nearly with 20 monthly means after 1904, after the greater part of the improvement was made.

Q. Did you follow in that connection substantially the same method that Mr. Ray followed?

A. In this case, yes. The mean of the Lake Huron levels for the first period was 581.45.

Q. What years did you take?

A. I can't give you the months, but they were in the years from 1865 to 1879; 20 of the months. And in making these deductions, the yearly means were taken for the months from May to November inclusive, so as to avoid any obstructions due to ice jams. As I stated, the elevation of Lake Huron for that first period was 581.45.

Q. That is the entire period?

A. For the first 20 months prior to the improvement and for the 20 months after the improvement, the elevation of Lake Huron was 581.37; that is a difference of .08 of a foot.

Q. That is prior to 1879?

A. 581.45 was prior to 1879; 581.37 was after 1904.

In the first period, the fall in the St. Clair River is 5.45

feet; in the Detroit River 3.15 feet, making a total fall between Lakes Huron and Erie of 8.6 feet. After the improvement, the fall in the St. Clair River, that is the difference between the Lake St. Clair and Lake Huron levels, was 5.52, and between Lake St. Clair and Lake Erie 3.07; making a fall between Lake Huron and Lake Erie of 8.59 feet, showing that for corresponding elevations the slope in the two rivers,—tht fall in the two rivers remained practically unchanged; and if there was any change in one stream, there was a corresponding change in the other.

I also made some deductions based upon the areas of the cross sections in the vicinity of Lime Kiln Crossing. The only portion of the stream that has been changed as the result of the improvement is that portion of the channel between Stoney Island and the Canadian Shore.

From the early surveys, as shown on the charts, the cross section of what was called the Lime Kiln Crossing channel prior to the improvement was 47,400 square feet. After the Lime Kiln Crossing improvement and before the Livingstone Channel improvement, the area was 55,300. After the Livingstone Channel Dam was built, the area east of the dam, between that and the Canadian shore, was 37,400, being a change of nearly 18,000 square feet. As the result of the building of that dam, the elevation of Lake St. Clair was raised nearly .3 of a foot. That our records show.

After the Livingstone Channel was opened, the cross section of the two channels then between Stoney Island and the Canadian shore was for the Livingstone Channel 12,000 square feet and for the easterly channel 37,400 square feet as it was before. So that the area of the two channels east of Stoney Island is now about 2,000 square feet greater than it was before there was any improvement at all.

If a change of 18,000 square feet has caused the change in level of .3 of a foot, a change of 2,000 square feet would not be near as great, of course. It was less than one-tenth of a foot. That computation is necessarily only approximate, but it gives results that may be relied upon.

Q. In making the comparison which you mentioned between the 20 months in the two periods, did you take into consideration or compare the precipitation on the Michigan-Huron area and the Erie Basin?

A. No, sir.

Q. Did you make any investigation of the change, if there was any, in the so-called hydraulic radius?

A. No, sir.

Q. How much material was taken out before you began work on the Livingstone Channel? I believe you stated that the cross sectional area was 47,400 square feet, didn't you?

A. Before improving.

Q. What was that?

A. That was before improvement.

Q. After the improvement and before the work on the Livingstone Channel, you say it was 55,300 square feet?

A. That is it, yes, sir.

Q. And about how many yards of material were taken out?

A. In that vicinity, in that stretch of the river?

Q. Yes?

A. I can give it to you only as applied to the contract covering that stretch of the river. There were three contracts covering practically the same stretch of the river, about half a mile long or a little more; and the amount of material removed from that area prior to 1890, was about 112,000 cubic yards.

Later, between 1906 and 1908, under other contracts there was 357,000 cubic yards removed. The work prior to 1890 covered a length of channel of about 2500 feet and a width of 440 feet. That later covered a length of channel of about 4300 feet and a width of 600 feet. The later work consisted in deepening the former channel, and in taking in some additional area.

Q. Have you finished your answer?

A. I have.

Q. Do you consider that there was any lowering effect from these improvements prior to the commencement of the work on the Livingstone Channel?

A. Slightly, I think, yes.

Q. About how much?

A. I would think not to exceed one tenth of a foot. I think we are about back now where we were before; that is the dams of the Livingston Channel raised the water.

Q. I am speaking of the time prior to the work on the Livingstone Channel, was there any effect?

A. I think not to exceed .1 of a foot.

Q. The cross sectional area there was increased about 8,000 square feet, was it not?

A. It was.

Q. And the reduction of that area by the Livingstone Dam by 18,000 feet, they raised it 3/10ths of a foot?

A. Approximately.

Q. How long was the dam in there?

A. The dam was started in 1908 and completed about mid-season of 1909. It was opened so far as the channel area is concerned in July, 1912.

Q. That is the dam was there from 1908 to some time in 1912?

A. That was it.

Q. Well, do you consider that the full effect of the dam would be shown on the St. Clair in that period, three years?

A. I think so.

Q. How about Lake Huron, was there any effect in Lake Huron?

A. The effect on Lake Huron would be somewhat less than on Lake St. Clair.

Q. And would the full effect be shown in change of stage of Huron? Would the full effect be reflected on Huron in three years?

A. I think so.

Q. Has the full effect of removing the dam been shown on these two lakes?

A. I would not want to say as to that. Our records are not complete enough. In fact our records for 1913 have not yet all been reduced.

Q. In your judgment, without reference to the records, what do you say?

A. It might not be entirely felt yet, but I think there would not be much change from now on.

Further Re-direct Examination by Mr. Hopkins.

Q. How long in your opinion would it take the full effect of the removal of the dam to appear in Lake St. Clair?

A. I would not want to state positively. I would expect it to occur in a season nearly, although it might not.

Q. What is the present fall in the river, in the stretch where this excavation work has been done?

A. We have a water gage at about a half mile above the dam, and one on the Canadian shore nearly abreast of the foot of Bois Blanc Island. The fall between those two gages is something like 1.1 feet.

Q. What is the distance in miles there?

A. Something like four miles.

Q. What is the distance between Lake St. Clair and the lower gage?

A. About 23 or 24 miles, something of that kind.

Q. When was the improvement work on the Lime Kiln Crossing resumed after 1890?

A. The first contract—there were two contracts later—the earlier one of those two was completed in 1906. I think it was started in 1904 or 1905.

Q. What amount of material was removed between 1890 and 1905?

A. None at Lime Kiln Crossing.

Further Re-cross Examination by Mr. Adcock.

Q. Did your last answer include the entire lower Detroit River?

A. Just the Lime Kiln Crossing. There was work at Ballards Reef during that interval.

Q. Did you include Ballards Reef?

A. No, I did not.

Q. Was there some work done between 1890 and 1905 near Ballards Reef?

A. Yes, sir.

F. G. RAY, recalled in rebuttal on behalf of the Government, having been previously sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Ray, you have already testified in this case, haven't you?

A. I have.

Q. When did you testify?

A. I believe that was in the spring of 1909.

Q. Since that time what further experience or qualification have you had in this engineering work?

A. I was promoted to the position of principal assistant engineer with the Lake Survey in the fall of 1909, since which time I have had direct supervision of all field work and office reductions, in connection with the work of the Lake Survey.

Q. Whom did you succeed?

A. Mr. Shenehon.

Q. What was the occasion of your succeeding him?

A. Mr. Shenehon resigned and left the position vacant.

Q. What have been your duties in this new position?

A. I have acted under the direction of an Army Officer and have had, as I stated before, direct supervision of the field work and office reductions, in connection with the work of the Lake Survey; and have outlined field and office work and have prepared instructions under which the different field parties worked.

Q. What experience have you had in observations and in the reduction of observations, during all of your experience?

A. I started in government service with the Mississippi River Commission in 1892. The work on which I was engaged with the Commission was very similar to that of the Lake Survey. In 1901, I was transferred to the Lake Survey and have been employed by them since, and during the entire time have been engaged in field work and office reduction pertaining to the field work. That covers topography, triangulation, hydrography, magnetic observations and various other work of that nature.

Q. In all of that work you have had to do with the reduction and treatment of observations, have you?

A. I have had to do with the reduction and treatment of observations practically since the beginning of that period.

Q. And as to soundings?

A. I have personally had charge of parties engaged in soundings over a period of perhaps 15 years in the aggregate, a part of which time was on the Mississippi River.

Q. About how much time have you been on board ship on the Great Lakes, so that you could observe the conditions of the lakes?

A. I have been on board a vessel continuously during the field season, from 1901 to 1909 inclusive.

Q. How many months make a season?

A. Average of about 6½ to 7 months.

Q. What contact have you had personally with the hydraulics of the Great Lakes and the rivers connected therewith?

A. I had practically no experience in the hydraulics previous to 1909, other than to be familiar with the reports and methods of field work and office reductions, but not directly connected therewith.

Q. How about since 1909?

A. Since 1909, I have had supervision of the field work, including all of the hydraulic work of the Lake Survey.

Q. Since 1909, what has been the work of the Lake Survey, over which you have had supervision?

A. In the late fall of 1909, the hydraulic party was engaged on a measurement of flow in the St. Marys River, and also in the St. Clair River. There was one additional season of hydraulic measurements in 1910, on the St. Clair River.

In 1911, the hydraulic party was engaged on measurements on the St. Lawrence River, and again in 1913. Also in 1913, the Third Section or Split Section in the Niagara River was measured.

Q. What was your personal connection with this work? To what extent did you yourself supervise it, come in contact with it?

A. I drafted the instructions covering this work, usually after conference with the other assistants familiar with the hydraulic work, and with the supervision of field work as it progressed.

Q. Did you visit the work in the field?

A. Frequently.

Q. To what extent did you follow the detail work?

A. I consider that I followed it quite closely; that is as far as I had time consistent with the other duties of the office.

Q. Did you become familiar with the results and conclusions of these observations that were taken under your direction?

A. I did. I followed them very closely.

Q. Have you followed the reduction of the observations?

A. I have.

Q. From all of your experience and knowledge, from whatever source, have you reached a conclusion as to the precision of the work of the Lake Survey during that time?

Mr. Austrian: Objected to unless the witness states what the source of his information is; "Whatever source" must be a source in evidence.

Q. (Question read.) Including, of course, your knowledge of the work to which you have just testified, and if you have had any other knowledge aside from that, tell us what it is?

A. Do I understand you want—

Q. Referring specifically to the St. Clair, the Niagara and the St. Lawrence River measurements?

A. From my knowledge, I judge the hydraulic work on these three rivers to be probably the most accurate measurements in large streams that have ever been done.

The precision of measurement, considering the weighted

mean observation I believe to be within 2 per cent. of the exact result.

Q. Now, referring particularly to the St. Clair River, upon what do you base your opinion?

A. Upon the care with which the work was done, and upon the results that were obtained at three different sections on the river; all of which agree extremely close.

Q. Will you state what those three sections were, and what the conditions were in each one of them?

A. The original section was at Dry Dock, the so-called Dry Dock Section, where the flow was smooth and below the average velocity of most of the measurements that have been taken by the Lake Survey. The Gorge Section at the head of the river had—

Q. First, what was the velocity in the first section you mentioned, roughly?

A. I have in mind about 2 to 3 feet per second; I am not positive.

The Gorge Section was located in the narrow portion of the St. Clair River near its head, and the velocities on this section were practically nearly double those on the Dry Dock Section. The third measurement was taken in the delta at the mouth, and this consisted of six separate streams. The sums of the measurements of these streams were compared with the results obtained at the head of the river.

Q. What was the check between sections?

A. There was no precise method of check between the Dry Dock and Gorge Sections, owing to their being some little difference in stage, and the two lakes, Huron and St. Clair, not being in the same relative elevations, with respect to each other. The centers of gravity of the two sections were very close together however, and indicated a check of about 1 per cent.

Q. Now, as to the Niagara River?

A. I believe the precision of result there, the weighted mean result, is correct within 2 per cent.

Q. What is that based upon?

A. That is based upon the large number of observations that have been taken and the fact that measurements were taken on three separate sections, where the conditions were considerably different.

Q. What was the degree of check between those sections?

A. The check between the Open Section and the Bridge Section was about 1½ per cent. The Third or Split Section fell between these two.

Q. Now as to the St. Lawrence?

A. I believe that the precision with which we know the flow of the St. Lawrence is not as exact as that of the Niagara or St. Clair Rivers, and this is not due to any greater percentage of error in the measurements themselves, but there, so far, has been some little indecision in regard to the stability of the gages.

Q. What is your opinion as to the percentage of error in the St. Lawrence, possible error?

A. The possible error in the weighted mean flow there is in my opinion about 3 per cent.; that is the maximum.

Q. Speaking of the instability of gages, to what gages do you refer? Do you refer to the Ogdensberg gage?

A. I have more in mind the possibility of a change in the conditions at the gages rather than the instability of the gage. There seem to be some slight discrepancies in comparison of the local gages, and particularly the lock gages with reference to the gages on Lake Ontario.

Q. When the readings of observations are referred to the Ogdensburg gage, do you not have rather stable condition or do you?

A. The conditions are seemingly stable, with the possibility of very slight change in the Ogdensburg gage.

Q. Is there enough in that to account for the 3 per cent. of error that you mentioned?

A. No, I consider that the 3 per cent. error includes all sources of error.

Q. You mentioned certain work done in the St. Lawrence in 1913. By whom was that work done?

A. That was done by Mr. Richmond.

Q. Was that done under your direction?

A. It was.

Q. Prior to 1913, by whom was the work that you mentioned done?

A. Mr. Richmond also took measurements on the St. Lawrence River in 1911.

Q. Was that under your direction?

A. It was.

Q. During that work, was the cross section re-determined?

A. It was. It was re-sounded and the horizontal measurement was also checked.

Q. How did that check with the original cross section of Mr. Shenehon?

A. There was practically no difference.

Q. Did they re-determine the vertical curve?

A. They re-determined the vertical curves on certain of the stations in mid-stream, covering a large percentage of the total volume of flow.

Q. How did that check with the vertical curves that were obtained formerly?

A. I don't recall the exact figures, but the check was very close.

Q. All of these measurements by M. Richmond were since the Gut Dam, were they?

A. All of them.

Q. Would that have any effect upon the relation between the elevation at Ogdensburg and the flow at the section measured?

A. It would. The Gut Dam is between Ogdensburg and the Section, so that the relation of the Ogdensburg gage to the discharge measurements would be changed by the construction of that dam.

Q. Does that make the situation more complex?

A. It makes it more complex in attempting to relate the recent measurements to the measurements before the construction of the dam.

Q. Do you have an opinion as to what the increment is, say first of the St. Clair River?

A. The reductions of the St. Clair River measurements, as made under my supervision give an increment of about twenty-one and a half thousand. This is referred to Lake Huron elevation of 580. The formula which we derived was not a straight line formula, so that this increment varies somewhat for the different stages.

Q. In the percentages of error which you have given as to the discharge measurements of the various rivers, on which side, if either would they occur?

A. It would be liable to occur on either side.

Q. It is just as likely to be on one side as on the other?

A. (No response.)

Q. What is your opinion as to the precision of the increment you have just given in the St. Clair?

A. I believe that increment may be in error from 10 to 15 per cent.

Q. On which side?

A. I would believe that, if anything, the error is on the large side.

Q. That is that the real increment is smaller than the one you have given?

A. The real increment is smaller, if anything.

Q. Upon what do you base that, Mr. Ray?

A. More on comparison with the increment of the Niagara than anything else.

Q. Why do you give such a wide degree of error?

A. The St. Clair River is the most difficult to measure and refer to lake stages of any of the rivers connecting or flowing out of the Great Lakes. The reason for that is that the flow depends upon the stages in both Lake Huron and St. Clair. It is practically impossible to cover a very wide range on either lake without the other lake moving with it, and it makes a rather complex problem to separate the backwater increment from Lake St. Clair and the headwater increment for Lake Huron.

Q. Do you think that the true increment is a straight line or a curve, the true line of the increment?

A. I believe the true line is a curve.

Q. And with reference to low stages of the lake, how would the increment be, higher or lower than the increment at mean stages?

A. The increment would be lower on lower stages.

Q. You gave us an increment awhile ago at mean stage of the lake. How many feet were you speaking of then in the stage of the lake? What is the mean stage in other words?

A. The increment that I mentioned was between 580 and 581, referred to the Harbor Beach gage?

Q. Take a lake stage 1 foot lower than that, what do you think the increment would be?

A. In answer to your question, the increment for 1 foot lower stage would be, as I compute it, 20,700; that is in round numbers about 900 less than for the foot above.

Q. That is between 579 and 580?

A. Between 579 and 580.

Q. Now what is the increment of the Niagara River?

A. The discharge formula for the Niagara River as computed by the Lake Survey, the more recently derived formula, is a curve. The increment between stages 569 and 570 on Lake Erie is 19,540, and at the top of the curve, between 574 and 575, it is 23,510.

Q. What is it at elevation 573?

A. About 22,000.

Q. Is that about mean stage, or what is mean stage in feet?

A. Mean stage in feet is 572.55; that is for the 53 years from 1860 to 1912 inclusive.

Q. What is the increment for that stage Mr. Ray, mean?
A. That is almost exactly 22,000.
Q. What is your opinion as to the accuracy of the Niagara River?
A. I believe that increment is correct within 5 per cent.
Q. Why do you give the higher degree of precision to that increment?
A. On account of the small range from that line, from the line which that formula represents; and also for the reason of the large range in stage covered by the observations.
Q. Is that the increment derived at the International Bridge Section?
A. That is.
Q. How close does the increment of the Open Section compare with the one you have given?
A. The increment at the Open Section is, at stage 572.50, 21,720.
Q. The increment at the Open Section is a little lower than that at the Bridge Section?
A. A trifle lower than the increment shown by the Bridge Section.
Q. What is the general condition of the Niagara River itself, with regard to it being favorable or unfavorable for determining the increment with reference to lake stages?
A. I consider that the conditions are extremely favorable, principally on account of the fact that the sections were measured near to the headwater reservoir, and there was practically no backwater effect.
Q. The headwater reservoir you refer to is Lake Erie?
A. Is Lake Erie.
Q. Now what is the increment of the St. Lawrence?
A. The discharge equation derived for the St. Lawrence River by the Lake Survey is also a curved line formula, and has a varying increment. The increment at stage of 243 on the Oswego gage is 21,125, and for a stage of 248 is 25,045.

I wish to say further in regard to the increments just given, that those are derived from a formula which was deduced in the Lake Survey Office in 1912, from all observations taken previous to that time. That did not include the discharge measurements taken during the past season, and as I stated previously, there was some little question in regard to the gages on the St. Lawrence River, and the proper way to relate the discharges to the gages. All measurements taken during this past season seem to indicate that the increments just given are too large. No new reduction has been made to

include the last year's measurements, as it is considered necessary to continue the measurement of flow in this river, to obtain an accurate discharge curve.

Q. What is the degree of precision, in your opinion, of that increment?

A. I believe that the increments that I gave are correct within 10 per cent.

Q. On which side?

A. I believe I have just stated the measurements of the past season seem to indicate that the increments derived from the previous equation are too large.

Q. Is the Niagara the only river in which the increment was determined from measurements at two different sections?

A. The measurements on the St. Clair River were taken at three sections; also three separate sections on the Niagara River.

Q. Do you understand that the increment of the St. Clair was derived from measurement on three different sections?

A. No, I do not. That was derived at the two sections at the head of the river.

Q. In this work which you have testified about of measuring these rivers and deriving the increments, about how many engineers have taken a part in it, particularly in the computations, getting the results to which you have testified?

A. In what period of time? Mr. Moore and Mr. Richmond have both had charge of field parties engaged on hydraulic work, aside from the principal assistant engineer. They have had technical assistants on the work who have helped in the reductions.

Q. About how many technical assistants would they have?

A. Usually only one, that would be considered as an engineer.

Q. Mr. Ray, have you read Mr. Williams' testimony?

A. Practically all of it.

Q. Have you read the part that deals with his method of reduction of the observations?

A. I have.

Q. What is your opinion of that method of computation of observations?

Mr. Austrian: I object to that; that is not a subject that you can call for the conclusion of an expert upon. I submit you can ask him wherein he does not agree with anyone, but you cannot ask him for his conclusions on the result.

(Question withdrawn.)

Q. Do you have any comments to make upon his method of reduction of these observations?

A. I have not checked any of the reductions made by Mr. Williams. The principal thing that attracted my attention in regard to this matter was the use of a long period of time, long periods of lake stage to relate the various observations to.

Q. Just in detail, explain the method you are speaking of now?

A. As I recall, discharge observations on the Niagara River were selected during certain periods. I am not quite clear as to why these periods were selected; and the mean gage during a certain period was related to the discharge measurements, each one being given a certain weight according to the number taken on that day, or according to the number of days between the observations. Where two observations were taken on a day during mid-week, a weight of one-half was given to the observations providing the observations had been taken on the preceding and following days; and in case of Sundays, additional weight was given to the observations taken on Saturday and Monday.

Q. How long does it take the effect—

Mr. Austrian: He has not made any comment upon that method. He has not finished his answer.

Mr. Hopkins: If you want it, we will let him go ahead.

Mr. Austrian: Certainly, I do want it.

Mr. Hopkins: All right, go ahead Mr. Ray.

Mr. Austrian: I want him to finish his answer.

Mr. Hopkins: Q. Go ahead, commenting on the method.

A. I have given this method of reduction some thought since I read the testimony of Mr. Williams, and I fail to see any reason for taking a mean stage during a long period of time, and referring a single observation or a series of observations to this stage. I see no reason for considering that the stage of a previous day has any bearing on the discharge measurement that was taken, for instance on Monday; I see no connection between the Sunday stage and the Monday discharge measurement. The period of time between Lake Erie stages as measured at the Buffalo gage and the stage at the Bridge Section, I believe is about eight minutes.

Q. Any further comments, Mr. Ray?

A. It would seem to me that observations related to mean gage in this manner would on the whole, covering a long period of time, give a close approximation to the relation of the mean stage and the mean discharge covering that time.

But the tendency in that manner of relating the gages and discharges would be to increase the increment. It would tend to smooth out the lake stage and give a smaller range of stage during the observations than the correct one.

Q. When you say would give a greater increment, you mean greater than what?

A. Greater than the true increment.

Q. How much in advance of the observation did Mr. Williams take his gage in hours, at the beginning of a particular period?

A. I have not compared all these. I find the first one I notice is about 36 to 38 hours ahead of the actual observations.

Q. What do you regard as the true time that should have been taken in advance of the observation?

A. I regard as the true time the time in which the observation was taken, corrected by the time interval for a crest of stage to advance from the Buffalo gage to the Section, which I believe is about eight minutes.

Q. What in your judgment is the value of the conclusion reached by referring the observations to a gage 12 hours or 36 hours before, in the particular instance?

A. I cannot conceive that the stage for any considerable period, such as 12 to 36 hours before, has any effect or any bearing on the discharge at the time it was taken.

Q. Would its tendency be to bring error into the reductions or not?

A. As I stated before, the weighted mean discharge for a considerable period related to the mean stage for the same period would be substantially correct in all probability, but the range of stage to which the discharges were related would be considerably smaller than that occurring at the times of the discharges; and the error of this method of measurement in my opinion would tend to increase the increment over the true one.

Q. What is your opinion as to weighting the observations by time interval, where a Sunday intervenes or something of that kind, as it appears in Mr. Williams' testimony?

A. I fail to see any virtue in that method of reduction.

Q. What would be the result of that?

A. I am not quite sure what the result would be. It would depend on the fluctuation of the stage during the discharges. I believe I would have to take specific instances before I would arrive at any conclusion as regards that.

Q. Do you see any impropriety in that method?

A. I must say that I believe it is an incorrect method, if it is intended to derive a correct increment from the data.

Q. Do you understand how many observations Mr. Williams actually used, out of those available in the Niagara River?

A. I did at the time I read the testimony. I have forgotten.

Q. Do you have in mind about what percentage?

A. I do not now.

Q. Do you know whether the 118 observations of 1907 and 1908 were used?

A. I believe not.

Q. What are your views as to the rejection of observations?

A. I do not consider that it is proper to reject observations, except under very extreme cases where they are known positively to be in error.

Q. Are you acquainted with the 219 observations that were made at the Bridge Section?

A. I had nothing to do with making the reductions. I am familiar with the results of the reductions, and familiar with the method of work during the field observations.

Q. Do you know of any reason why any of them should have been rejected, consulting Haskell's Exhibit 1, for Identification, of this date?

A. I know of no reason why any of the observations should be rejected, in deriving the increment or in deriving the volume of the flow.

Q. What is your opinion as to the derivation of an increment by the ratio of fluctuations from one lake to another?

A. I believe that that method of comparing increments would be very good if there was an unobstructed flow between the lakes, and if we knew the relative local supplies to these lakes.

Q. What obstruction if any are in the particular lakes or rivers that we have in mind, that might interfere?

A. The principal obstruction to the flow, considering the flow 12 months in the year, is the ice effect during the winter months.

Q. How would that affect the relative fluctuations between Michigan-Huron and Erie?

A. The relative fluctuation would not bear a direct relation to the increment of flow if the connecting waters were obstructed during a portion of the year. The tendency, in

my opinion would be to raise the upper lake. There would be extra storage in Lakes Michigan and Huron, and also the increment of flow which we have determined for open season conditions would not hold through the winter months and would not represent a mean increment for the 12 month period.

Q. As compared with the method of deriving an increment in, say the St. Clair River, by actual measurement of volume and referring it to a known gage, what is your opinion of the method of deriving an increment from ratio of fluctuations?

A. The increment as determined from measurements of discharge would be far superior in accuracy to any determined by relative fluctuations of the lakes.

Q. What are your reasons for that?

A. There are a great many intangible elements affecting the stage of water in the two lakes, so that it is impossible to determine accurately what the effects of the various causes, such as rainfall, run-off, evaporation and so forth contribute towards the variation of stage.

Q. What is your opinion as to the possibility of accuracy determining the local supply?

A. I would not care to state the degree of accuracy. I think the results obtained by the use of such data would be somewhat inaccurate.

Q. Would it be more in the nature of an estimate than a determination?

A. I think so, decidedly.

Q. Suppose an increment determined by this method of ratio of fluctuations for a whole year, and no consideration is given to ice effect, but is based entirely upon the conditions during the open season, would such an increment be higher or lower than an increment which took into consideration the ice effect?

A. If we proceeded from the increment of the Niagara River to that of the St. Clair River, the derived increment for that river would naturally be too large, if the effect of ice was neglected. The reason for that is that the increment of flow at the time when the river is partially obstructed with ice is less than when the river is open. And this is borne out by observations of the Lake Survey, which were made from 1899 to 1902.

Q. What bearing would that have upon a lowering caused by a diversion, say at Chicago through the Drainage Canal?

A. The mean increment for the year, considering or including the ice effects would be smaller than the increment during the open season; and assuming that the Chicago diversions were uniform throughout the 12 months, the effect would be greater than shown by the open season increment.

Q. Now to what lakes does that refer?

A. That refers particularly to Lakes Huron and Michigan. There is also some ice effect on the St. Lawrence River, which partially obstructs the flow from Lake Ontario, and in a similar manner decreases the mean annual increment somewhat below open season increment.

Q. What is your opinion as to the degree of precision that can be made in soundings and in determining the area of a cross section, in such sections as have been used in the measurement of these rivers that you have mentioned?

A. I believe the results are correct within 1/2 of 1 per cent.

Q. On what do you base that, Mr. Ray?

A. Upon the accuracy with which soundings can be taken, and also the length of the section.

Q. Are you familiar with the conditions on the Niagara River at the Bridge Section and at the Open Section as to the condition of flow?

A. Not except what I have seen from the shores and from the bridge.

Q. Is it any great degree of perturbation?

A. I didn't observe any.

Q. What is your opinion as to the consistency of the three rivers, taking into consideration the measured volume of flow of each of them?

A. You mean the mean volume of flow?

Q. You mean, yes?

A. I have failed to find any reason for believing that they are inconsistent. I have made some analysis of the supply (local supplies to the lakes), and applying the derived quantities to the discharges, they showed results which are in accordance with each other to a degree that was satisfactory, considering the data that we had in regard to the supply.

Adjourned to Wednesday February 4th, 9:30 A. M.

Wednesday February 4th, 9:30 A. M.

F. G. RAY resumed the stand for further direct examination by Mr. Hopkins and testified as follows:

Q. Mr. Ray, are you familiar with the method used by Mr. Williams, as it appears in his testimony for computing the increment for the St. Clair, the Niagara and the St. Lawrence Rivers?

A. I have looked over the methods that he has used. I have not checked any of the computations.

Q. Will you state generally what that method is?

A. As I understand the computations that he has made, he has selected certain observations, or certain periods during which observations were taken, and grouped these observations and determined the mean of each group, and the mean of the daily mean gage readings covering a certain period, which in some cases begins from 24 to 38 hours or such a matter previous to the first observation in this group, and ending about a day before the final observation in the group.

Q. Now take the reference to the St. Clair, what was his method?

A. On the St. Clair River, he has taken selected groups of observations and determined the mean discharges, or rather the weighted mean discharges of each of the various periods into which these selected observations are divided, and has referred these to the stages of Huron and St. Clair determined by mean daily gage readings; the Huron stage covering the days in which the observations were taken; the St. Clair mean determined from the daily mean stages commencing one day previous to the first observation in the group, and ending one day previous to the last observation in the group.

Q. What paper or document are you referring to?

A. I am referring to Williams' Exhibit 34, Table XXVIII.

Q. In what respect if any does it differ from the Lake Survey Method?

A. In referring the discharge observations to the gage heights, and in the reduction of formula by the Lake Survey, it has been customary to refer to the mean height of local gages, and by that I mean the gages in the immediate vicinity

of the discharge section, covering only the time of the discharge work. These gage heights are then transferred to Huron elevations and St. Clair elevations by means of water level transfers, or in other words comparison of gage heights, the gage relations determined over a long period of time.

Q. Just what do you mean specifically when you speak of the time or times of the observation?

A. The periods during which observations were actually being made.

Q. You mean the two or three hours?

A. Yes, the period covered by the observation.

Q. That is the time covered by a particular observation?

A. Covered by each individual observation.

Q. How long would that be on the St. Clair?

A. I don't know as I can give that very closely. The time varied considerably between the work on the Dry Dock Section and the Gorge Section. The Gorge Section was the shorter section, and measured in less time.

Q. Can you give that roughly?

A. Roughly I should say two or three hours.

Q. Now what was the method at Niagara used by Mr. Williams?

A. Referring to Table XLVa, of Williams' Exhibit 34, I find that he has followed a similar process in selecting observations covering certain periods; that he has taken the weighted mean of the discharges during each of these periods and has referred them to stages of Lake Erie as determined at Buffalo from daily mean gage readings covering a period including the day previous to the first observation in each group, and including the last day covered by the observations.

Q. Now as to the weighting of the observations there?

A. The weight given to the observations is determined apparently from the number of observations taken during the day, and is inversely as the number of these observations. In cases where observations are not taken during any one day in these periods, the observations of the previous and following days are given additional weight.

Q. Suppose that four observations each day were made, on three consecutive days, what weight would be given to the observations on the middle day?

A. I do not find such a case exactly, but I judge that a weight of .25 would be given to each observation in such case.

Q. That is the four observations would be treated as a single observation?

A. The four would be treated as a single observation, and would be given a weight of one.

Q. What effect would the Lake Survey give to those four observations, what weight?

A. Each observation would be given a weight of one. In other words they would all be weighted equally.

Q. Now referring to Table XLI, what is Mr. Williams' method in regard to the St. Lawrence?

A. I judge by an inspection of Table XLI that the discharge measurements on the St. Lawrence River have been grouped similarly to those on the St. Clair and Niagara Rivers and weighted in the same manner. There the weighted mean discharge determined from each group is referred to the stage at Ogdensburg, determined from daily mean water levels on that gage and covering a period including one day previous to the first observation in each group, and ending one day previous to the last observation in each group.

Q. How long does it take the influence of the level of the water at Ogdensburg to be felt at Three Point Section?

A. Something over two hours; my recollection is about two hours and a quarter.

Q. Somewhere between two and three hours?

A. Between two and three hours.

Q. How many hours did Mr. Williams take?

A. The center of gravity would be 24 hours to the observation.

Q. Of what value in your opinion is this method of Mr. Williams in deriving the true increment?

A. It is my opinion that this is not a correct method; that it introduces, or may introduce stages of water which have no influence whatever on the discharge, at the time that the observations are being taken.

Q. Have you made any study of the effect, or as to whether or not there has been any effect upon the level of lakes Michigan-Huron by government improvements in the St. Clair and Detroit Rivers?

A. In 1909, I prepared a report for a Board of Army Engineers analyzing the probable effects on water levels of the construction of the Livingstone Channel.

Q. Please identify the report.

A. The report was published in document number 676, 61st Congress 2nd Session, House of Representatives.

Q. What is your opinion now as to the effect if any of the work in those rivers on the level of Michigan-Huron?

A. In further answer to your previous question, I will say that in making this analysis I undertook to derive an equation representing the stage of Lake St. Clair in terms of Lake Huron and Erie, as a basis for determining the effect of the Livingstone Channel. The solution from which this equation was derived came out exceedingly satisfactory and indicated to me that Lake St. Clair had retained its normal position between Huron and Erie during the period covered by gage observations on Lake St. Clair.

While it practically held the same position, the indications are that the change if any did not exceed 1/10th of a foot during this time. I also made some further studies in regard to the relative elevations of Huron and Erie, independent of St. Clair. The stages of these two lakes can be grouped in various ways and comparisons between the various groupings indicate a relationship covering a considerable range; I believe something between 60 and 90 per cent. variation on Erie for 1 foot variation on Lake Huron.

This solution is not very satisfactory owing to the fact that it gives different values for different manners of grouping. Some of these groupings indicate decreased fall in the two connecting rivers amounting to .1 to .3 of a foot.

The previous analysis that I speak of would indicate that if there had been a change in regimen or a decreased fall in either river that it also occurred in the other.

A further examination of the fall from Huron to Erie was made by comparing the stages during the earlier periods of record with those during the most recent period, and—to obtain stages that were directly comparable,—I took a grouping of the five lowest stages on Lake Huron and corresponding stages on Lake Erie out of the first 15 years of lake level records. The mean stage on Lake Huron for this period was 580.95. The mean stage on Lake Erie for the same period was 572.33, showing a fall between Lake Huron and Erie of 8.62 feet.

During the last 15 years of record, up to 1908, the five highest annual mean stages on Lake Huron were selected, and the mean of these gave a stage for Huron of 580.95, identical with the mean of the five taken during the earlier period.

The mean stage for Lake Erie during the same years was 572.36, showing a fall between Huron and Erie of 8.59 or .03 of a foot less than determined by the group in the earlier

period. The only reason for selecting these years, as was done, was to get a stage that was comparable. The latter period was taken up to and including 1907 but excluding the years later than that during which construction work on the Livingstone Channel was in progress.

This analysis would indicate to me that there has not been any great disturbance in the regimen of these two rivers.

Q. A little more in detail, what do you mean by no great disturbance in the regimen, in tenths of a foot, or in inches.

A. This analysis indicates that there is no appreciable change in the fall from Huron to Erie; that if there is actually a change it is too small to be determined in this method of analysis.

Q. Would your method of analysis detect a change as large as half a foot?

A. This would indicate to me that the change if any had not exceeded one or two tenths of a foot.

Mr. Austrian: Can we not get an answer to your question? I would like an answer to the other questions, too.

Mr. Hopkins: All right, answer my question, and let this answer stand.

Q. (Question read as follows: "Would your method of analysis detect a change as large as a half a foot")?

A. Yes, it certainly would.

(Chart produced and marked Ray Exhibit 1, February 4, 1914.)

Mr. Hopkins: We offer this in evidence.

(Charts produced and marked Ray Exhibits 2 and 3, February 4, 1914.)

Mr. Hopkins: Q. Is it possible to determine the increment at Niagara in any other way than the way indicated by you yesterday?

A. It is possible to eliminate the Buffalo gage from the problem by referring the discharge observations to any other gage on the Niagara River, or a gage in close proximity to the discharge section, and then relating that gage to some other gage on Lake Erie, this relation being determined by comparisons of gage readings at the Niagara River gage and the Lake Erie gage, covering a period long enough to determine a definite relation between these two gages.

The relation of discharge measurements on the Niagara River, with respect to these other gages on that river will determine an increment of the critical section measured by any such gage. And then introducing a factor determined

by the relation of that gage to a lake gage, the increment can be transposed into the increment for Lake Erie.

Q. Is that a correct method of proceedure?

A. I would consider it correct, but the determination of increment would probably not be as good as the one determined by reference directly to the Buffalo gage, as it would require two steps instead of one.

Q. I show you Ray's Exhibits 1, 2 and 3 of this date, and ask you to tell what those exhibits are, what they show. Take first Exhibit 1; get them in order?

A. On Exhibit 1 are plotted monthly mean gage readings at Cleveland and at Suspension Bridge gage on the Niagara River. These monthly means are plotted with elevations on Suspension Bridge as ordinates and elevations at Cleveland as abscissa. A line is drawn through the center of gravity of these monthly means, and I will say that these monthly means cover 12 months, July, August, September and October 1906, June, July, August, September and October 1907, June, July, August, 1908.

They cover a range of about 3 feet on Suspension Bridge gage. A line is drawn through the center of gravity representing the mean of the 12 months, and this line represents the relationship between the two gages. Assuming that this plot is correct and that the reduction indicated hereon is also correct, the line shows a fluctuation on Suspension Bridge of 2.334 times the fluctuation on the Cleveland gage.

There is also plotted on this same sheet for the same months the monthly mean stages at the Whirlpool gage on the lower Niagara River against the similar monthly means at Cleveland, and the line through the center of gravity of these points as shown hereon represents the relationship between these two gages, and the factor representing the relation of fluctuations is 2.611.

Exhibit number 2, shows a plot of the 118 discharge measurements made in 1907 and 1908, at the Bridge Section and these are plotted with respect to the stage at Suspension Bridge. These observations are combined into groups of ten each, excepting the last, which contains only eight. The line through the center of gravity of these observations, and trending along the plottings of the various groups represents the discharge curve of the Niagara River with respect to the Suspension Bridge gage.

Assuming that the plot is correct and that the reductions are also correct, the increment is shown to be 9,445 cubic feet

per second for 1 foot change of stage on Suspension Bridge gage.

There is also shown on this exhibit a computation of the increment for Lake Erie, applying to the increment for the Suspension Bridge gage the ratio of fluctuations between the Suspension Bridge and Cleveland gages. This computation shows an increment for the Cleveland gage of 22,000 cubic feet per second.

Exhibit number 3, shows a similar treatment of the observations with respect to the Whirlpool gage. On this sheet there are only shown 108 discharge measurements grouped in groups of ten in order of stage, excepting that the last group contains only eight.

The line representing the discharge curve through these observations indicates an increment on the Whirlpool gage of 8,585 cubic feet per second. Applying to this the co-efficient representing the relationship between the Whirlpool gage and the Cleveland gage, namely 2.61, determines an increment for the outflow of Lake Erie with reference to the Cleveland gage of 22,400 cubic feet per second. The results obtained by these two analyses eliminate entirely the Buffalo gage.

Q. Mr. Ray, assuming that the observations on Exhibit 1, just mentioned were correctly plotted, in your opinion does the line on those exhibits substantially represent the law of fluctuation?

A. I believe it does so far as the law of fluctuations can be determined from that number of comparisons.

Q. Now referring to page 31, of "Preservation of Niagara Falls," Senate Document number 105, do the figures on those exhibits as to ratio of fluctuation substantially check those referred to in that report?

A. The ratio of change shown in the table you have referred to, comparing Suspension Bridge with Lake Erie, is 2.29, and in the comparison on the exhibits is 2.33. The ratio of fluctuation for Whirlpool, is stated in the report as 2.47, and the determination on Exhibit 1 is 2.61.

Q. If you were to use the ratio of fluctuations as indicated by that table in the report referred to, what effect would that have upon the increment derived for Lake Erie?

A. In both cases the increment would be determined to be less than indicated on the exhibits.

Q. By how much, approximately?

A. In the case of Suspension Bridge, the difference would

be about 2 per cent., and in the case of Whirlpool, between 5 and 6 per cent.

Q. Now referring to Exhibits 2 and 3, assuming that the observations on those two exhibits are correctly plotted, do the lines there substantially show the law of relationship between the gage and the discharge?

A. I consider that they do, very closely.

Q. What effect do these three exhibits and what they show, as you have testified to, have upon the increment, or your opinion of the increment as given yesterday of Niagara River?

A. I consider that they are a very close check and are corroborative of the increment determined from the Buffalo gage by the Lake Survey.

Mr. Hopkins: I offer those three exhibits in evidence.

Q. In your testimony yesterday you said that you thought the increment of the Niagara River was more properly represented by a curve than a straight line. Now does that check with Haskell's Exhibit 1?

A. The increment by the straight line shown on Haskell's Exhibit 1, is 21,900. The increment determined by the curve line formula for the stage representing the center of gravity of all observations on the Niagara River is 22,010; a difference of about 110 cubic feet per second, per foot.

Q. Mr. Ray, do you know what work is going on at the Welland Canal?

A. I am informed that the improvement of the Welland canal is in progress, or at least that a number of contracts have been let for deepening the canal, and for the construction of new locks. The canal when completed under the present plans is to have 25 foot depth through the prism, and a depth over the lock sills of 30 feet.

Q. The Welland Canal is a canal connecting Lake Erie and Lake Ontario, isn't it?

A. It is.

Q. Now, since your former testimony, what has been the tendency in regard to the size of boats on the Great Lakes?

A. The tendency has been to build larger, longer and deeper draft boats.

Q. A little more in detail, Mr. Ray?

A. I saw a statement in an official report not long ago, and I don't know the date of the report, but the statement is a recent one and shows that in 1904, there were no boats on the Great Lakes over 500 feet long. Now, there are 139

boats over 500 feet long, 12 of which are over 600 feet. The increase in draft of the recently built boats is also noticeable; that is the provision for greater draft.

Q. About how many tons do those large boats carry per inch of draft, say, after they are loaded to 19 feet?

A. Somewhere about 90 tons per inch of draft.

Q. Mr. Ray, for a diversion of 10,000 cubic feet at Chicago, what would be the effect in inches upon the level of Lakes Michigan and Huron, Erie and Ontario, and the harbors and channels of those lakes?

Mr. Austrain: That is, what will be the effect in his opinion?

Mr. Hopkins: Yes, in your opinion

Mr. Adcock: As based upon these observations and records?

Mr. Hopkins: No, leave it as it is: What in your opinion will be the lowering in inches?

A. As determined by the Lake Survey discharge formulas, the lowering of Lakes Huron and Michigan for a diversion of 10,000 cubic feet per second would be 5½ inches; on Lake Erie about the same, and on Lake Ontario the lowering would be between 5½ and 5⅝ inches; and these lowerings that I have given are determined by using open river increments. The effect of ice gorges in the rivers is to reduce the increments, the mean increments for 12 month periods, and accordingly the effect of the diversion would be greater than indicated.

Q. Will that same effect occur in each of the harbors of those lakes?

A. The same effect would be felt throughout the lakes and harbors.

Q. How about the rivers, St. Clair, Detroit, Lake St. Clair?

A. The lowering in the St. Clair and Detroit Rivers would be approximately the same as the lowerings in Huron and Erie.

Q. How about Lake St. Clair?

A. The same would apply to Lake St. Clair.

Q. How about the entrance to the Welland Canal, and the entrance to the Erie Canal?

A. The effect would be the same in the entrances to these canals, as far down as the level of these canals were approximately the lake levels.

Q. It would be the same as what?

A. Same as the lowering on Lake Erie, about 5½ inches.

Q. And for Ontario, the entrance of the Welland Canal into Lake Ontario?

A. The effect on the entrance to the Welland Canal from Lake Ontario would be essentially the same as for Lake Ontario.

Q. Suppose instead of 10,000, the diversion at Chicago were 4,000 or 8,000 cubic feet, would the lowering be in the same proportion as for 10,000?

A. The lowering would be in direct proportion to the amount diverted.

Q. And as to 14,000?

A. The same would apply as to 14,000.

Q. Now with reference to navigation, is there any importance in the depth of the whole length, the whole lake, as distinguished from a particular channel?

A. The lowering of the whole lake would be the same as the lowering in the harbors and the channels.

Q. With reference to navigation, do boats confine themselves in all cases to a particular channel, or do they need more room at times?

A. The lowering would not be injurious to navigation on the open waters of the lakes, where the waters were deep. As the boats made use of shoaler waters, the effect of the lowering would be injurious to navigation,—providing the shoaler depths produced a limit to the draft of the boats.

Q. In times of storm and fog, the vessels do get off the channels, do they not?

A. They do.

Q. What knowledge do you have of the water power development at Niagara Falls?

A. I have a general knowledge of the power development situation, through having had to do with the supervision of the power companies at Niagara Falls and the measurement of their diversions.

Mr. Austrain: Q. As a government officer or individually?

A. Officially.

Mr. Hopkins: Q. Will you go ahead and tell us as to the measurements made in the diverting canals, and what horse power is developed per cubic foot of water and the values per horse power?

A. The Lake Survey has made measurements of flow in the diversion canal of the Niagara Falls Power Company and in the canal of the Hydraulic Power Company, in connection with the supervision of operations of these companies; the

purpose being to determine the relation between diversion and output in electrical horse power. The object of determining this relation was to expedite and make more convenient the process of supervision of the companies, placing limitations on their output which represented the diversions that were allowed them by law.

Q. How are the measurements made as to what they shall divert?

A. The measurements were made with the Haskell Current Meter in the diversion canals of these companies.

Q. Any check upon that measurement, with reference, first, to the Pitot Tube?

A. In measuring the flow through the diversion canal of the Niagara Falls Power Company, these measurements were made on two entirely independent sections in the canal, and the results obtained by these two series of measurements checked within about ½ of 1 per cent.

Mr. Austrian: Q. When were those measurements made?

A. 1907 I believe.

Mr. Hopkins: It was in 1909, wasn't it?

A. Additional measurements were made in 1909; the first measurements in 1907. The 1907 measurements were made to determine the amount of diversion then being made by the company; those in 1909 were made to determine the efficiency of the generating units and turbines in the two power houses, with an idea of constructing an efficiency curve representing the efficiency of development for different operating conditions.

The Niagara Falls Power Company at that time were operating the two power houses, numbers 1 and 2. The turbines in these two power houses were of a different type, and were developing at different efficiencies. The measurements determined the efficiency of development for each of the power houses independently.

In 1910, the Niagara Falls Power Company started rebuilding the generating units and installing new turbines in power house number 1, with an idea of increasing the efficiency of this station. The company made representation at that time to the government that it was increasing the efficiency of its plant, and desired a new determination of the efficiency of the reconstructed units. The Lake Survey at that time co-operated with the Niagara Falls Power Company in measuring the efficiency of one of the reconstructed units, and these measurements were made by the use of a

Pitot Tube in the penstock. At the same time, similar measurements were made in one of the old penstocks to determine the relation (as measured with the Pitot Tube) between the reconstructed and the old units. The results obtained with the Pitot Tube in the penstock of one of these old units in power house number 1, were directly comparable with the determinations made with the current meter in the canal of the power company.

The efficiency curve as determined with the Pitot Tube checked with that determined by the current meter in the canal within about 1½ per cent. The current meter indicated in this check the flow of water 1½ per cent. larger than that determined by the Pitot Tube.

Q. Will you describe a little further this Pitot Tube, and the accuracy of tests made with that, in comparison with the Haskell Meter?

A. The Pitot Tube is one built especially for the work by the Niagara Falls Power Company, and it was constructed so as to offer the least possible resistance to the flow of water in the penstock, and so that it could be operated without any bars or obstructions in the penstock. The Pitot Tube was rated in still water previous to and following the measurements in the penstock. The results obtained with the Pitot Tube were very accordant and indicated that the results were to be depended on as being of a high degree of precision.

Q. Does the Power Company accept the measurements of the Lake Survey?

Mr. Austrian: Object to that as incompetent.

A. They have accepted the measurements without protest and are operating, have been operating until the expiration of the Burton Law, under the limitations that were prescribed by the Lake Survey.

Mr. Austrian: I move the answer be stricken out as incompetent, irrelevant and immaterial; not responsive to the question.

Q. Now as to the efficiency of the turbines,—perhaps to put it better: Have you determined the horse power per cubic feet of water per second?

A. The present development of the Niagara Falls Power Company is about 10 electrical horse power per cubic foot of water diversion.

Q. What would you say as to the turbine efficiency?

A. The efficiency in power house number 1, was determined to range from about 34 per cent. at 50 per cent. gate opening up to 57 or 58 per cent. at full gate opening. In

power house number 2, the efficiencies over this range were from 53 to 72 per cent. and these efficiencies represent the determination of the relation between diversion in the canal and the output on the switchboard. Included in the amount of water used in this determination were also the wastes and the amount used for excitation.

Q. Go ahead and explain further your answer?

A. This efficiency is determined in power house number 1, for a head of 136 feet; in power house number 2, 140 feet, and this is the head between the canal and the wheel pit. In the case of power house number 1, the units in this station had no draft tubes, and the head of 136 feet represent the fall from the canal to the outlet of the turbine.

Q. Are those high or low efficiencies?

A. They are particularly low in power house number 1, and I believe somewhat below the efficiency of development now obtained by recently built turbines. These efficiencies must be understood to include all wastes and the use of water for various purposes around the plant.

Q. What is the market value per horse power of this electrical power for commercial uses at Niagara?

Mr. Austrian: We object to that; has no relation to this case.

Mr. Adcock: Furthermore the witness has not been shown to be qualified to answer that question.

Mr. Hopkins: Are you acquainted with the market value of power in and around Niagara Falls?

A. I have very little definite information—

Mr. Adcock: Objected to on the further ground that counsel cannot prove a witness' fitness to answer as an expert on a question of that sort, by asking whether he is qualified.

Mr. Hopkins: Go ahead, tell what you know about it.

A. I am not very well qualified to discuss the market value of electrical power at Niagara Falls. The situation is rather complex there. The power is handled in various ways by distributing companies, and to commercial factories. I am informed that the commercial power at Niagara Falls is about $18 a horse power per year.

Mr. Adcock: I move the answer be stricken out, as regards the statement of the horse power at Niagara Falls.

Mr. Hopkins: Q. Mr. Ray, are you acquainted with the Drainage Canal at Chicago?

A. Not from personal observation except that I have seen the canal. I have crossed the canal at times. The Lake Sur-

vey recently made measurements in the canal. Mr. Moore had charge of the measurements and these measurements were made under instructions drafted by myself, and I am familiar with the work done and with the results obtained.

Q. Mr. Ray, suppose a canal from Lake Michigan to Lockport, Illinois, or rather a canal from Robey street, Chicago to Lockport, Illinois, and from Lake Michigan to Robey street, the Chicago River about six miles, of sufficient size to carry 8,000 cubic feet of water at a mean velocity of a mile and a quarter per hour; from Robey street for eight miles the canal is 110 feet wide on the bottom, and 210 feet wide on the top. The next five miles it is 202 feet at the bottom and 300 feet at the top. The next 15 miles it is 160 feet at the bottom and 162 feet at the top, making a total of 34 miles to the controlling works; then it is 2 miles from there to the power house where there are other controlling works, making a total of 36 miles from Lake Michigan. Assuming that the depth in the Chicago River is 26 feet and the depth in the canal, which is the lower 30 miles of this channel, is 24 feet substantially.

Supposing further that there is a flow through that channel from Lake Michigan to Lockport of 4167 cubic feet per second, and suppose that at the controlling works at Lockport the canal is opened, or gates opened to a capacity of 14,000 cubic feet per second, how long would it take the effect of that opening to appear throughout the entire length of the channel, even to Lake Michigan, so that 10,000 cubic feet would flow towards Lockport and not into Lake Michigan?

A. In my opinion the time required to set up the flow through the canal to Lake Michigan would be between 2 and 3 hours, not exceeding 3 hours.

Q. That is a flow of 10,000 cubic feet in the direction of Lockport?

A. That is correct.

Mr. Hopkins: That is all Mr. Ray.

Cross-examination reserved.

Friday, February 20, 1914, 10:00 A. M.

F. G. RAY, resumed the stand and testified further as follows:

Cross-Examination by Mr. Adcock.

Q. You are Principal Assistant Engineer, are you not, at this office? (Lake Survey.)

A. I am.

Q. And have you held that position since 1909?

A. Since the fall of 1909.

Q. What are the duties of your position?

A. I have had general supervision of the field and office work of the Lake Survey, under the direction of the Army Officer in charge, and have had charge of the care and repair of floating plant; and in fact all operations of this office.

Q. What do you have to do with the preparation of the annual reports to the Chief of Engineers?

A. I have had considerable to do with the preparation of the reports of this office.

Q. Do you approve all reports that are made by this office to the Chief of Engineers?

A. Subject to the approval of the Officer in Charge.

Q. But all reports that are made to the Chief of Engineers are approved by you, are they not?

A. I believe they have been since I have been here, but not necessarily so.

Q. What if anything did you have to do with that part of the report for 1910, appearing on pages 1043 to 1050 of Appendix GGG?

A. I made a draft of that portion of the report, but I am not positive that it stood as it was originally drafted.

Q. The substance was the same?

A. The substance was practically the same. This is the report of the Chief of Engineers. The draft was prepared in this office, and revised in the office of the Chief of Engineers.

Q. What did you have to do with that part of the report for 1911, appearing on pages 3011 to 3018, being section headed "Surveys" in Appendix FFF of the Report of Chief of Engineers for 1911?

A. I prepared that report, and I believe it was published as prepared by me.

Q. What did you have to do with the section headed "Surveys and Investigation of Lake Levels" appearing on pages 3535 to 3548 of Appendix FFF, of the Report of the Chief of Engineers, for 1912?

A. I also wrote the draft of that report.

Q. On page 3547, of Appendix FFF, report of the Chief of Engineers for 1912, there are given certain formulae for the discharge of St. Clair, Niagara and St. Lawrence Rivers. Are those formulae correct ones to apply to these rivers, in your opinion?

A. I believe those are the best formulae that we had at that time, derived from all the hydraulic data.

Q. That is based upon the records of measurements of those rivers and the gages, etc.?

A. These formulae are the results of new reductions of all of the hydraulic data then on hand, and are the best representations of the data at that time that we could prepare.

Q. And simply referred to the data that you had on hand then, that is all

A. Yes, necessarily so.

Q. Are they the same as those referred to by various witnesses for the complainant in this case, upon which exhibits Complainant's Exhibits 1, 2, 3 and 4 are based?

Mr. Hopkins: I think you ought to name more definitely what witnesses you are talking about.

A. The witnesses, Haskell, Noble, Ernst, Curtis MacDonald, Townsend, Wheeler?

The Witness: Considering when these were made, I can tell you definitely they were not.

Q. (Question read as follows: "Are they the same as those referred to by various witnesses for the complainant in this case, upon which exhibits Complainant's Exhibits 1, 2, 3 and 4 are based"?) Do you know of your own knowledge?

A. The formulae published in the 1912 report, were prepared or derived after the testimony to which you refer was given; with the exception that the discharge formula for the Niagara River was not changed from the curved line formula that had been used previous to the time of the witnesses' testimony.

Q. You have Complainant's Exhibits 1, 2, 3 and 4, before you there, haven't you?

A. I have copies.

Mr. Hopkins: You have what was handed you and alleged to be copies?

A. Alleged copies.

Mr. Adcock: Do you know whether the formulae referred to on page 3547, Appendix FFF, report of the Chief of Engineers, 1912, are the same formulae as those upon which the exhibits, Complainant's Exhibits, 1, 2, 3 and 4, are based?

A. They are not.

Q. Do these equations give the same results?

A. They do not give precisely the same results.

Q. Are these equations the same as those given in the report of the International Waterways Commission on the Regulation of Lake Erie under date of 1910?

A. They are not.

Mr. Hopkins: When you say "these equations," which ones do you refer to, the exhibits 1, 2, 3 and 4 of FFF, the equations contained in them?

Mr. Adcock: FFF. (Q) Do they give the same results?

A. They do not.

Q. In the report of the Chief of Engineers for 1911, Appendix FFF, page 3013, there is the following statement: "A few relations of gage heights have been derived, and the observed discharges have been compared graphically with former values, both indicating an increase of about 3 per cent. in the volume of flow through the St. Clair River at mean stage since the determinations of 1899 to 1901. This change is attributed to the effect of recent dredging in the upper river." At the time that statement was published, was it approved by you?

A. It was.

Q. It was?

A. It was.

Q. By whom was the dredging done, and where was the dredging done that is referred to in that report?

A. I am not positive by whom the dredging was done. There was some dredging—

Q. I do not mean the contractor. Was it done by the United States Government or by John Smith?

A. It was not by the United States Government.

Q. It was not?

A. It was not.

Q. Do you remember by whom it was done?

A. The dredging at that time was being done by private companies, dredging gravel from the bottom of the river.

Q. Where was that dredging?

A. That was mostly between the Gorge and Dry Dock Sections and near the head of St. Clair River.

Q. Was it done under authority of the United States Government?

A. I am not sure. There was some controversy in regard to the dredging there, and I believe it was finally stopped by the United States Government.

Q. An increase of three per cent. in the discharge of the St. Clair River would lower the level of Lake Huron by how much in your best judgment?

A. About a quarter of a foot.

Q. Has anything been done to replace the dredging or the material dredged, or to compensate for it?

A. There has been no artificial compensation for that dredging.

Q. How much material was taken out, do you know?

A. I do not.

Q. Approximately, can you state?

A. I don't even know approximately. I never investigated. There was considerable gravel taken out of the bed of the river, and some quite deep holes dug.

Q. More or less than a million cubic yards?

A. I have absolutely no idea.

Q. For what period of time has the dredging been carried on?

A. There has been more or less gravel removed from the upper St. Clair River, for a great many years.

Q. When you stated that the effect upon the levels of Lake Huron would be about a quarter of a foot, you based that entirely upon the records of discharge measurements and the gage readings which have been referred to in this case, on the St. Clair River?

A. I believe, if I understand what you mean, the three per cent. increase in flow would be equivalent to between five and six thousand cubic feet per second, which would have an effect of somewheres in the neighborhood of a quarter of a foot.

Mr. Adcock: Will you read that question?

(Question read as follows: "When you stated that the effect upon the levels of Lake Huron would be about a quarter of a foot, you based that entirely upon the records of discharge measurements and the gage readings, which have been referred to in this case, on the St. Clair River?")

Mr. Adcock: Made by the Lake Survey.

Mr. Hopkins: Objected to as unintelligible.

A. A change in flow of three per cent. would be equivalent to a change in stage of about a quarter of a foot.

Q. And that is based upon the increment which you have derived from the records of discharge measurements and gage readings?

A. It is.

Q. Made by the Lake Survey?

A. It is.

Q. Would the filling in on the deep sections of the St. Clair River to leave a depth of say 35 feet be an obstruction to navigation?

A. It would be no obstruction to the present navigation.

Q. You don't wish to speculate on the—

A. I don't wish to speculate just now on what effect it would have on the current velocities.

Q. In the report of the Chief of Engineers for 1912, Appendix FFF, page 3545, at the bottom of the page is given a formula for the discharge of the St. Clair River, in which there is a term *Y*. What does that *Y* represent?

A. That formula is purely an empirical formula, in which *Y* represents in a way the mean bed of the river.

Q. In what way does it represent it?

A. The elevation.

Q. At the bottom of the page referred to, the Chief of Engineer's Report, are given the values of *Y* for certain years. What was the elevation of the river bed in 1899?

A. That was not the elevation of the river bed. It is an empirical formula in which that term *Y* may be taken as representing the regimen of the river, elevation of the river bed.

Q. What is the value of *Y*?

A. The value given is 567.44.

Q. And in 1900?

A. 567.58.

Q. According to that, the river had filled up about two inches, hadn't it?

A. Those are the values that fit in this formula more closely to the observations.

Q. Doesn't the formula indicate such a filling?

A. That variation in the value of *Y* for the different years includes changes in regimen of the river. It may also include slight changes in gages; and may also include some slight difference in the discharge measurements taken by different field parties and under different conditions, and with the different instruments.

Q. It was necessary to adopt this elevation, in order to make the formula fit the observations, was it not?

A. The elevations were derived by mathematical solution, and are the values which most closely agree with the observations.

Q. Was the method of least squares used in the derivation?

A. It was.

Q. What was the elevation in 1901?

A. 567.33.

Q. According to that, the river had scoured out approximately 3 inches?

A. Possibly.

Q. What was the elevation in 1902?

A. 567.64.

Q. And it had filled up nearly four inches?

A. It had.

Q. If the bottom of the river had raised an average of .31 of a foot, how much was the cross section decreased at mean stage?

A. I don't know as I understand your question.

Q. Would it be about 700 feet approximately?

A. I don't believe that it is possible to answer that question. The value there is derived for certain formulae, and may represent the average bottom of the river. The effect on the cross section would depend upon the width, and the river is of variable width.

Q. Do you know the average width?

A. I don't know offhand the average width of the St. Clair River?

Q. Approximately?

A. I would have to consult a chart.

Q. Isn't it approximately 5,000 feet?

A. (No response.)

Q. Assuming that the average width is about 2,000 feet, how much was the cross section decreased then at mean stage, if the bottom of the river were raised an average of .31 feet.

Mr. Hopkins: Q. Do you assume further that the width remained at the same place?

A. If the bottom was raised uniformly .31 feet, it would decrease the cross section at least 620 square feet.

Mr. Adcock: Q. Do you consider the average width to be about 2,000 feet?

A. I presume it is somewhere near that.

Q. How much was the so called hydraulic radius reduced by this change of the bottom?

A. The hydraulic radius would be decreased about the same.

Q. What would be the effect upon the discharge of reducing the hydraulic radius by the amount mentioned, the so-called slope remaining the same?

A. The discharge would change proportionately to the square root of the hydraulic radius times the area.

Q. Then it would be decreased?

A. It would be decreased.

Q. By that much?

A. Yes, by an amount in proportion to the square root of the hydraulic radius times the area.

Q. Would a reduction of the cross sectional area reduce the discharge, the slope remaining the same?

A. It would.

Q. Would the raising of the bottom of the St. Clair River in the amount mentioned raise or lower the level of Lakes Michigan and Huron for any given discharge?

A. It would, if it remained in such new position long enough for the backwater effect to be felt.

Q. It remained long enough to affect the discharge measurements?

A. These values were derived from the discharge measurements.

Q. Then the discharge measurements must have been affected by this change, must they not?

A. If the change is due to change in regimen, it would be.

Q. How much would this filling of the river of .31 feet raise the level of Lakes Michigan and Huron at mean discharge?

Mr. Hopkins: Assuming the width remained the same?

Mr. Adcock: Making the assumptions which have been made heretofore in connection with this proposition.

A. In answering your question, I wish to explain that I do not accept those values as being entirely due to changes in the bed of the river. In making a new reduction of the discharge measurements of the St. Clair River, we found that there seemed to be a difference between various years at the same stage. Whether or not that was entirely due to change in regimen, we do not pretend to know, but the new reduction was made separating the various years, for the purpose of deriving a better value for the increment; and it was done for that purpose only.

The change between the discharge values of the 1901 and the 1902 groups, as determined by this formula, was about 6,000 cubic feet per second, which is equivalent to a change in stage on Lake Huron of about a quarter of a foot.

Q. Then if no such change occurred in the river's bottom, your formula is incorrect, is it not?

A. No, I would not say that.

Q. Then the enumeration of the constants of the formula is incorrect?

A. The constants are derived by grouping each year separately; and the use of these constants in a formula makes the formula fit most closely to each group separately.

Q. And in the formula you give Y a certain value, do you not?

A. I do.

Q. And you say in the report:

"In applying this equation as first solved to the observed quantities, it is found that residuals were grouped by size or signs for the various years. Assuming that this variation of discharge for the different years of observation is due to change of regimen, the second solution was made in which the constants K and A were determined from all the observations, and Y which represents the elevation of the mean river bed, was determined for each separate year." Do you not so state?

A. That is correct.

Q. And in that you stated that Y represents the elevation of the mean river bed?

A. I do so state.

Q. When was it discovered that this change had taken place?

A. The new reductions of discharge that were made following the 1910 observations showed that there was some constant difference between various years.

Q. Was that about 1911 or 1912?

A. That was in 1910 and 1911.

Q. 1910 and 1911?

A. I would like to correct that. I think we finally derived the later values in 1911 and 1912.

Q. In establishing the fact of these changes of elevation of the bottom of the St. Clair River in 1899, 1900, 1901 and 1902, were any physical data made use of, obtained subsequently to January 1st, 1909?

A. The derivation of this formula included all observations of discharge from 1899 to 1910 inclusive.

Q. To what extent was the value of *Y* affected by any physical data secured after January 1st, 1909; that is the value of *Y* for the years 1899, 1900, 1901, 1902? You say the reductions were made in 1911 and 1912. Now I would like to find out what data, physical data was made use of that was obtained subsequently to January 1st, 1909, in making these reductions for the four years in question.

A. We used the discharge measurements made in 1909 and 1910.

Q. To what extent did these discharge measurements made in 1909 and 1910, which you speak of, affect the value of *Y* for the years mentioned, 1899, 1900, 1901 and 1902?

A. They would not affect the value of *Y* unless the increment was also affected. The value of *Y* is derived for these different years, and its manner of solution assumes that the line of increment is parallel in the groups of the different years. The observations in 1909 and 1910, added greater weight to the derived value of the increment.

Q. To what extent did they affect the value of *Y* in the percentages for those earlier years; was it an appreciable percentage?

A. That manner of solution was never applied to those previous years separately.

Q. If it had been, how great a difference would you have obtained?

A. It would take a week to figure that out, if you want an answer.

Q. You say it would take some time to figure it out. I will see if I can get at it in another way. What relation would this change have to the increment?

A. The manner of solution assumed that the increment was constant for each year, and the values of *Y* are derived on that assumption. If that assumption was not made, there would be a different increment derived for each year.

Q. In the event the discharge capacity of the St. Clair River had changed, wouldn't the increment change?

A. I doubt if the change in increment would be appreciable. The change would be less than the errors of observation, errors of determination.

Q. Wouldn't the increment change in the same proportion as the discharge capacity was changed?

A. Not necessarily.

Q. Would it change more or less?

A. I should say that it would change less than the change in capacity of the river.

Q. Are you positive about that, when referred to the St. Clair River?

A. I think so.

Q. In other words, if the capacity of the St. Clair River were, say 200,000 feet, discharging capacity; and that discharging capacity were afterwards reduced to 175,000 cubic feet per second, what would be if any the change in the increment?

A. Would that change in capacity be in depth or breadth or slope?

Q. Anyway, discharging capacity. Any way except widening of the channel at the water surface.

A. I would say that the increment would increase with an increased capacity, and the increase in increment would be slightly greater in proportion.

Q. I assume a decrease of the discharging capacity, Mr. Ray, in my question; assuming a fixed lake level.

A. (No response.)

Recess to 2:00 P. M.

After recess, 2:00 P. M.

F. G. RAY resumed the stand and testified further on cross-examination as follows:

(The testimony before recess was read to the witness, beginning with the question: "In other words if the capacity of the St. Clair were say 200,000 feet etc.")

A. I believe that generally speaking the increment would be less for the decreased discharge of the river. I am not sure that that would apply to the St. Clair River, unless all the conditions were known definitely.

Mr. Adcock: Q. Assuming that the discharging capacity was increased, would the increment increase?

A. I believe it would, slightly.

Q. Would it increase in as great a proportion as the discharging capacity was increased?

A. Approximately so.

Q. How near? When you say approximately, do you mean the same or—

A. To give a definite answer to that question, it would be necessary to know exactly how the capacity of that river was increased. It might be increased by enlarging the size of the channel at any point, or any short stretch along the entire length of the river.

Q. Suppose it were increased by lowering the average elevation of its bed?

A. I would expect to find that the increment increased nearly in proportion with the increased capacity.

Q. Do you think it would increase at a greater rate than the increase of the capacity?

A. I would not care to give a definite answer to that until I had time to work it out. That is a hydraulic problem which I have not worked with lately.

Q. You never have investigated that question in connection with your studies of the hydraulics of the Great Lakes?

A. Not in exactly that way.

Q. In what way have you studied that question, Mr. Ray?

A. (No response.)

Q. (Question read as follows: "Do you think it would increase at a greater rate than the increase of the capacity"). That is the increment. You say you never have studied it in that way. Now I ask you in what way have you studied the question as to the increase of the increment, proportional as the increase of the discharging capacity?

A. I have made some studies of the varying increments for different stages of the St. Clair River, as determined by the formula in the 1912 report.

Q. That is the formula which we referred to, in which *Y* was given certain values?

A. That is the same.

Q. Assume that *Y* were given a value of 5 feet less than is given in any one of the formulae, what effect would that have upon the discharge, the other conditions remaining the same?

A. It would materially increase the discharge for the same stages of the lakes.

Q. And the increment?

A. I am quite certain that the increment would be increased also.

Q. In a greater or less proportion than the discharge?

A. If the value of *Y* in the discharge formula for the St.

Clair River was decreased, the volume of discharge as derived by this formula would be increased and the increment would also be increased, in a less proportion.

Q. Then if the increment of a certain river were increased, that would indicate that the discharging capacity of that river had increased in a greater proportion?

Mr. Hopkins: Understanding all the time this is based upon the assumptions of the whole line of questions.

Mr. Adcock: We limit it to being increased by no change of width in the stream. That is all that is necessary.

The Witness: Generally speaking, an increase in the increment would accompany an increase of discharge.

Q. That is you mean by a greater percentage; that is the discharge would be increased by a greater percentage?

A. I would not care to say that. It would depend on the conditions by which that increase of flow was effected.

Q. Under what conditions then would it not be true? Are you ready to answer that question?

A. Only so far as I answered it before that a change in discharge or in capacity of the river, without changing the width would be accompanied also by a change in increment. If I understand your question correctly, I would say that the increment does not increase in proportion as fast as the volume of discharge.

Q. Is there any relation between the annual fluctuation of a lake and the increment of the outlet?

A. Do you mean whether there are any relations, definite relations between the annual fluctuations and the open river increment?

Q. And the increment of the outlet?

A. I think there would be.

Q. What is that relation?

A. A body of water which was dependent wholly for its supply upon another body of water would show a fluctuation in direct relation to the fluctuation on the supply basin, providing the channel between was unobstructed.

Q. And would you assume also that the increment—

Mr. Hopkins: That is the annual fluctuation you speak of now?

Mr. Adcock: Yes, I am speaking of annual fluctuation.

Q. Suppose that the increment of the St. Marys River, which is the outlet to Lake Superior, were 15,000 cubic feet per second, and that the increment of that river were decreased to 10,000 cubic feet per second, what effect would

that decrease have upon the annual fluctuations of Lake Superior? When I say "annual fluctuations," I mean the variations of annual stage.

A. If the outflow from Lake Superior were unobstructed by ice, the fluctuations would increase with the decreased increment.

Q. Suppose that it were obstructed by ice?

A. The change in annual fluctuations would then become indeterminate.

Q. Will you explain why?

A. The normal increments as expressed would not apply to the flow of water through the St. Marys River throughout the year in that case, and it would be practically impossible to determine the increment or at least we haven't that data during the time when the river is partly obstructed.

Q. But I am assuming in the question, Mr. Ray, that the increment is determined at 15,000 and there is a decrease to 10,000?

A. Is that the annual increment or the open river increment?

Q. That is the annual increment.

Mr. Hopkins: That assumes no ice.

Mr. Adcock: It assumes that that is the increment.

A. If the increment is assumed to apply to the annual flow, the fluctuations would change inversely as the change in increment.

Q. What change occurred in the elevation of the mean river bed of the St. Clair River from 1900 to 1901, as shown by the value of *Y* on page 3545 Appendix FFF, Report of the Chief of Engineers for 1912?

A. If *Y* is assumed to represent the mean river bed, the change shown is a lowering of .25 of a foot.

Q. That would be three inches, approximately three inches?

A. That would be three inches.

Q. This lowering produced a change in the formula for accurately computing the discharge of the St. Clair, did it not?

A. Those two values are values derived by a solution to fit the equation most closely to the center of gravity of the observations during the two years.

Q. And that solution was made by the method of least squares?

A. It was.

Q. And it was necessary to take account of it to get a

formula which would accurately fit the discharge measurements of 1901, was it not?

A. A single discharge formula for the observations of the St. Clair River did fit more closely to all of the observations; but as explained in the report, the residuals determined from a single equation were grouped by size or signs for various years, and it was believed to be better, to give a better determination of the increment by separating the yearly groups.

Q. You separated them and in your opinion gave a better determination?

A. A better determination of the increment.

Q. Were these changes in the river bed near the head of the river, do you know?

A. I don't think so; and I don't think that these values, different values of Y, are wholly due to change in regimen.

Q. Don't you consider that the waves drifted gravel and so forth into the head of the river, which was ultimately washed out at some other time?

A. I believe there has been some scouring and refilling of the bed of the river at various times.

Q. Near the head of the river?

A. At any place along the river, various places.

Q. So that it would change the mean river bed?

A. It would change the critical section of the river.

Q. Where is the critical section of the St. Clair?

A. The critical section is the entire length of the river. An obstruction in the river at any point between Lake Huron and St. Clair would change the flow through the river for fixed stages.

Q. Its discharging capacity?

A. It would change the discharging capacity.

Q. Have there been any recent surveys of the Niagara River, in the vicinity of Buffalo and the International Bridge?

A. There have.

Q. What was the occasion?

A. There was a new survey of the upper Niagara River from just above the Falls to Lake Erie made for charting purposes.

Q. What do those surveys indicate regarding the elevations of the bottom of the river as to whether or not there had been any changes discovered from the conditions existing at the time of the former survey?

A. The data of the upper Niagara River surveys have not

yet been plotted, and I am not able to answer that question.

Q. You spoke of ice in the St. Clair River in your direct testimony. Just what observations have you made personally with reference to that?

A. I have not made any.

Q. In the Lake Survey, have you any Engineer making observations with reference to the ice conditions in the St. Clair, who reports in writing to you?

A. Not to me.

Q. Who does he report to?

A. I don't recall that anyone has made observations on ice effects since 1909; that is anyone connected with this office.

Q. Is anyone connected with the Lake Survey making investigations, or anyone who has made investigations with reference to the ice in the Niagara River, who reports in writing to this office?

A. Not since 1909.

Q. For how many years prior to 1909 did the condition exist?

A. What condition?

Q. The making of reports with reference to ice conditions in the Niagara River?

A. I know of no reports concerning ice conditions, since the measurements that were made by Mr. Shenehon.

Q. And that was in the year 1899, 1900?

A. Yes.

Q. For how many years prior to 1899, did Mr. Shenehon make report with reference to the ice conditions in the Niagara River?

A. I don't recall that he made any report previous to that.

Q. And the same conditions were true with reference to the St. Clair River, were they not?

A. The observations during ice conditions on the St. Clair River were made by Mr. Sabin.

Q. At what time?

A. 1899, to 1901.

Q. For what length of time did Mr. Sabin observe the conditions of ice on the St. Clair River?

A. He made a determination of the ice effects for the winters of 1899-1900; 1900-01; 1901-02.

Q. In what cases did he actually measure the flow?

A. Mr. Sabin made actual measurements between January 2 and April 26, 1901.

Q. Did he make any actual current meter measurements of ice effects at any other time?

A. I believe not.

Q. Did anyone else connected with the Lake Survey?

Mr. Hopkins: You mean current meter measurements.

A. On the St. Clair?

Q. On the St. Clair?

A. I don't recall any.

Q. Wasn't the year 1901 a year of abnormal ice conditions?

A. It was.

Q. You gave in your direct testimony values of the increment of the St. Clair, Niagara and St. Lawrence Rivers, and you also stated that in your opinion a diversion of 10,000 cubic feet of water at Chicago would have a certain effect upon the levels of Lakes Michigan-Huron, St. Clair, Erie and Ontario. Were those conclusions as to the increment and the effect of diversion based entirely upon the reduction of the records of observations, records of discharge measurements and records of gage readings made by the Lake Survey, and referred to in this case?

A. They were.

Q. You stated that you visited frequently the field work of the hydraulic parties, since you have been Principal Assistant Engineer. Will you state just how frequently or how many times you were in the field during the measurements?

A. To the best of my recollection, I visited the hydraulic party when it was at work on the St. Clair River twice; while on the St. Lawrence River once; and once I visited the party engaged in measuring the discharge in the diversion canal at Niagara Falls.

Q. You say you followed the work closely? I presume you mean by that the work also of reducing the observations, don't you?

A. I do.

Q. What did you have to do with that work of reduction?

A. I supervised generally the reduction of the work and advised in regard to methods used, and also in regard to the form of the formulae to be derived, and consulted frequently with the men who were making the actual computations.

Q. You spoke of the value of water power at Niagara, a

certain value per horse power per year. Have you ever bought or sold any power?

A. I have not.

Q. You never bought or sold any electrical energy at Niagara Falls?

A. I have not.

Q. Did you ever try to buy or sell any?

A. I never did.

Q. You stated in your direct testimony that it would take about three hours to produce a uniform flow through the drainage channel from the power house to Lake Michigan (which includes the Chicago River) from a flow of 4167 cubic feet per second. What was that based upon?

A. That opinion was based on the time of travel of the wave set up by increased flow as observed by Mr. Moore, and the fact that the increased velocities traveled with that wave, or nearly so.

Q. Do you think that law would apply to the rivers as well as to the drainage channel?

A. I believe that the change in velocities would travel practically together with the change of stage.

Q. In rivers, the same as in the drainage channel?

A. In rivers, the same as in the drainage channel.

Q. Did you consider that the section at Lemont, which was selected by Mr. Moore, to measure the discharge of the drainage channel, was a good section?

A. It was not an ideal section, on account of an apparent obstruction somewhere above the section. That was not detected until after the measurements were under way.

Q. Do you consider that it would be more difficult to measure the flow of the drainage channel than that of the Niagara River?

A. The actual amount of labor involved would be less on the smaller stream. The percentage of accuracy I believe would be somewhat less than on the river.

Q. On the drainage channel than on the river?

A. Yes.

Q. Then you, in your opinion, could not measure the flow of the drainage channel as accurately as you could measure the Niagara River?

A. The actual flow could be measured much more closely in the smaller channel. In percentages, I believe it would be very difficult to attain the same percentage of accuracy as that attained in the large rivers.

Q. Will you give your reasons?

A. The sources of error are greater in percentage in the smaller stream. The indeterminate effects of the sides and bottom are greater in proportion. The percentage effects of stage perhaps are larger.

Q. Assuming that this section were in the rock cut, with smooth sides and smooth bottom; and also assume that for a long stretch both above and below the section the channel was straight and of regular cross section?

A. Do you also assume in that the flow is uniform, or nearly so?

Q. That would be the absolute discharge?

A. I believe it would be possible to obtain the absolute discharge with as great accuracy in the canal as in the rivers, but I do not believe this could be done with the large type current meter.

Q. You mean the B type, the B. Haskell Meter?

A. Yes.

Q. What would you use?

A. I would use a smaller type current meter and observe the curve of velocities closer to the sides and bottom with some other device, such as the Pitot Tube.

Q. Do you consider that you could measure more accurately the flow of a river half a mile wide with an average depth of 50 feet than a river a mile wide and 100 feet deep, average depth; other conditions being equal, same velocity?

A. With those dimensions, I don't believe there would be very much difference in the percentage of accuracy; while the larger river would be more difficult to measure, with respect to the amount of labor involved.

Q. But you believe that you could measure the flow of that river with the same percentage of accuracy that you could measure the other river?

A. The amount of difference would not be material, in my estimation.

Q. Then the larger the river the more accurately you could measure it, is that right? That is the percentage of error would be less?

A. That is not in conformity with my answer. I stated that there would not be an appreciable difference in the percentage of accuracy.

Q. Now you assumed in connection with your answer as to the length of time it would take to change the flow from 4167 cubic feet per second to 10,000 cubic feet per second

through the channel uniformly, that the change of discharge followed the change of stage immediately, did you not, or coincided with it?

A. A change in stage and change in velocity would not be proportional for different changes in the amount of flow. The increase of discharge following the change in stage, I believe might be greater or less than the final established uniform flow.

Q. Then am I correct in understanding that in your opinion the change in discharge does not coincide with the crest?

A. From what analysis I have made of that, I would say that they are not exactly simultaneous.

Q. How much variation?

A. The variation would be very small.

Q. In the Drainage Canal, a matter of how many minutes would it be, assuming that it takes three hours for the crest to travel from the power house to Lake Michigan?

Mr. Hopkins: You will fit the testimony better if you assume the three hours is for the full effect to be felt; if you want to fit the testimony.

A. The observations on the Chicago Drainage Canal do not show any appreciable interval of time between the change in stage and change in discharge.

Q. Do you think that is the general rule?

A. I do.

Q. Was the discharge of the Chicago Drainage Canal measured at two different points, two different sections?

A. It was not.

Q. You have there Mr. Moore's table showing the discharges at Lemont on December 20th, which is I believe approximately 9 miles from the power house?

A. I have such a table.

Q. And according to Mr. Moore's testimony, which you heard this morning, did you not, it was stated that the highest discharge, greatest discharge at Lemont was observed by him at 9:28 or 9:58 in the evening?

A. That is the largest discharge shown in the tables.

Q. Assume that it were shown beyond a doubt that the greatest discharge at the power house during December 20th was at 4:30 in the afternoon, would you wish to modify your conclusion as to the length of time that it would take to establish a uniform flow of 10,000 cubic feet per second through the channel, from a flow of 4167 feet per second?

A. With that assumption, there would be nothing to cause me to change my opinion.

Q. Why not?

A. There appears to be an interval of 33 minutes between five and 5:33 P. M. of that day, on which no observations were taken; and this is about the period at which this discharge corresponding with the flow that you have assumed would reach the Lemont Section.

Q. Then I take it there was no data in Mr. Moore's examination, appearing in Mr. Moore's report, on which you could base a conclusion as to the change of discharge?

A. The interval of time from the power house to the section would not be shown at that particular time. There were other observations, however.

Q. What other observations?

A. There was a sudden break in the amount of discharge on the morning of December 21, which was observed; and there was also another sudden break on December 22.

Q. What time?

A. Shortly after five o'clock P. M.

Q. In the morning or afternoon?

A. P. M.

Q. Referring to table 2, sheet 4, showing the discharges for December 22, doesn't it appear that the maximum, greatest discharge occurred between 5:49 and 6:21, greatest discharge measured at that date?

A. It does.

Q. What streams have you gaged with the current meter, Mr. Ray?

A. I have never made any discharge measurements myself with the current meter.

Q. From whom did you receive instructions with reference to the method of determining discharges of rivers?

A. I have never received any instructions in regard to discharge measurements, except a very brief training that I had in college.

Q. You have made studies of the work of other men, haven't you?

A. I have studied the work of other men.

Q. You studied the work of Mr. Shenehon?

A. Yes, sir.

Q. Mr. Sabin and Mr. Haskell?

A. Yes.

Q. The Haskell Current Meter was used by the Lake Survey when you became Principal Assistant Engineer?

A. It was.

Q. And has been used for several years?

A. We have made very little use of any other meter.

Q. The first gagings that were made on the St. Clair, Niagara and St. Lawrence Rivers were made with the Haskell Meter?

A. They were.

Q. Professor E. E. Haskell, was Principal Assistant then, was he not, of the Lake Survey?

A. The first discharge measurements on the rivers were made before the Lake Survey was a separate office.

Q. I am speaking of the work done by the Lake Survey in 1899?

A. There was no separate office known as the Lake Survey in 1899.

Q. What was Mr. Haskell's position at that time?

A. He was Assistant Engineer of the U. S. Engineer Office.

Q. Was he Senior Assistant?

A. I believe he was, although the work of that office was divided into various departments. The Engineer Office at that time had charge of improvement work at the Soo; on the Detroit River and on Lake Huron.

Q. What did Mr. Haskell have charge of at that time?

A. I believe Mr. Haskell had supervision of the operation under the appropirations for Lake Survey work.

Q. He had charge of the measurements of these rivers, did he not, gaging at that time?

A. That is my understanding. I was not here at that time.

Q. Is there any reason why the elevation at a certain point in the bottom of a stream should control the elevation at another point five feet away.

A. No.

Q. If in a stream 2,000 feet wide, you have located by sounding the position of the bottom at 100 points in the cross section, do you then know the actual elevation of the bottom at 99 other points midway between them?

A. You don't know the precise elevation of the points between.

Q. Is there any reason why the other 99 should give the same average elevation as the original 100?

A. There is a reason why they should give about the same average.

Q. What is that reason?

A. On the law of averages, the 100 points might be assumed to give the same average depth as the other 99. There

is no reason to believe that the other 99 points would be uniformly higher or lower.

Q. Did you ever sweep a river bed?

A. Not in a river.

Q. Did you ever in the lakes?

A. I have.

Q. Have these river beds ever been swept?

A. Portions of them.

Q. And at the gaging sections?

A. I don't recall now that they have.

Q. What is the purpose of sweeping?

A. In the open lake?

Q. Anywhere?

A. The purpose of sweeping is to determine the least depths and also to determine the presence or absence of obstructions between the lines of soundings, or within the area swept.

Q. Do you believe that you can take five years from the period between 1860 and 1874 and have the conditions of local supply on both Lakes Michigan and Huron and on Lake Erie the same as in any other five years selected from the period between 1893 and 1907?

A. I do not.

Q. In the five years selected by you as given in your direct testimony from the earlier years, were they low or high water years?

A. They were low water years.

Q. And to those in the later period, were they high or low water years?

A. They were high water years.

Q. Do you expect the conditions of local supply to be the same in high water as in low water years, on Lakes Michigan-Huron as compared with Erie?

A. The local supplies would not necessarily be the same.

Q. Would variations of the local supply influence the elevations of the lake, mean annual elevation, or the elevations during the open season?

A. The local supply would be one of the elements affecting the elevations of the lakes.

Q. You selected during the earlier period of years 1866, 1868, 1869, 1872 and 1873, did you not, subject to correction?

A. I selected the five years of lowest stage on Lakes Michigan-Huron.

Q. And which were the years mentioned by me in my question were they not?

A. Those years were 1866, 1868, 1869, 1872 and 1873.

Q. And the years selected in the later period were 1904, 1905, 1906, 1907, and 1908, were they not?

A. The years selected out of the later period were 1894, 1904, 1905, 1906 and 1907.

Q. Referring to Williams' Exhibit 34, Table XLVIII, Sheet 1, will you read the precipitations there given for Huron-Michigan basin, as determined by the mean of the precipitations at Milwaukee and Detroit for the years in the first period and tell us what is the average for the five years.

A. The precipitation as shown by this table for the years named are as follows, in chronological order:

33.95
31.08
35.85
29.18
33.31

The mean of which is 32.67 inches.

Q. Referring to the same exhibit and table and sheet, will you read the precipitation of the St. Clair-Erie basin, as determined from the mean of precipitations at Detroit, Cleveland and Buffalo; and I will ask you if the mean is not 37.51 inches?

A. I got a mean of the same, 37.51.

Q. The difference then is 4.84 inches, isn't it?

A. Correct.

Q. Now referring to Sheet 2, of the same table, will you give us the precipitation for the Huron-Michigan basin for the years in your later period and tell us what the mean is?

A. The mean precipitation for Michigan-Huron as shown by this table for the five selected years of the later period, is 30.52 inches.

Q. Referring to the same years in the same table and exhibit sheet, what was the precipitation on the St. Clair-Erie basin for the later period, what is the mean?

A. The mean is 32.67.

Q. What is the difference in precipitation on the two basins?

A. Difference of 2.15 inches.

Q. What would be the effect of an excess precipitation on the St. Clair-Erie basin of 2.69 inches in raising or lowering Lake Erie relatively to Lake Huron? It would raise Lake Erie, wouldn't it?

A. All other things being equal, the additional precipitation on Lake Erie should give a higher stage for that lake.

Q. Would Lake Erie occupy its normal position relative to Lake Huron, or the same position relative thereto, when its precipitation exceeded that of Huron-Michigan by 4.84 inches that it did in a series of years when the precipitation on its drainage area exceeded that of Huron by only 2.15 inches?

A. Assuming that the effect of ice, run-off and evaporation were the same, the increased rainfall on Lake Erie should raise that lake to a higher stage in its relative position.

Q. When you made your comparison, did you assume or did you take into consideration the possible effects of ice?

A. I did not.

Q. Then does your comparison of the two five-year periods show anything conclusive as to the changes in fall between Lakes Huron and Erie, under average conditions?

A. That was taken as simply one method of comparing the lakes. The years were selected merely to get a comparable stage, and I do not believe that this comparison is conclusive. It is simply one of many comparisons that can be made.

Q. It ignores one important element doesn't it, precipitation or local supply on the two lakes?

A. It ignores the causes for the stages, whether those causes were during those current years or preceding those years. It is simply a method of comparing the difference of stages for the same elevation.

Q. Will you state, Mr. Ray, just how, given a number of discharge measurements say of the Niagara River or the St. Lawrence, how do you derive the increment?

A. The discharge measurements are plotted with respect to stage and the increment determined graphically; or it may be a mathematical solution to determine the formula of discharge related to the stage, and increment derived from that formula.

Q. Do you group the discharges with reference to stage, in either process?

A. It is not necessary; it may be done.

Q. What did you do?

A. The discharges have been grouped for a graphical representation of the increment. I believe in all cases—

Q. According to what?

A. Have been grouped according to stage.

Q. According to stage?

A. In the mathematical determination of the formulae, I

believe in all cases the independent observations have been used.

Q. Then an observation made one year might be placed with an observation made another year?

A. Providing the stage overlapped in the two years.

Q. What do you mean by overlapped?

A. If the range in stage during one year passed above or below the limits of the stage during the preceding year, that would be called overlapping.

Q. Now you occasionally take two observations a day, don't you?

A. Or more.

Q. What?

A. Two or more.

Q. And Lake Erie fluctuates or oscillates from time to time during the day, doesn't it?

A. It does.

Q. Several feet at Buffalo in one day?

A. Very seldom to that extent.

Q. But it changes to a considerable extent, does it not?

A. It does.

Q. So that you might take a discharge measurement, say in the morning when the stage was low, and another discharge measurement in the afternoon when the stage was high, might you not?

A. That might occur.

Q. And the discharge measurement made in the morning would be grouped with a discharge measurement made at some other time, say the month before or the year before, when the lake was at the same elevation approximately?

A. If they were grouped with respect to stage that might happen.

Q. And that was the method that was used, was it not, in getting the graphical representation of the increment?

A. It was.

Q. Over what period of time was the lake elevation used with each discharge observation; that is to correspond to each discharge observation?

A. Over the time in which the observations were being made.

Q. That is you would take the mean of the lake stage for the two or three hours that was consumed in making the observation?

A. That was usual. That is a weighted mean; those were weighted means.

Q. You took weighted means, you say. How were they weighted?

A. They were separated by panels, and the result was essentially a weighted mean.

Q. That is you would ascertain the time when you were making your discharge measurement in a certain panel, would you?

A. I believe that is right.

Q. And take the level of Erie in the case of Niagara, for what time during the discharge measurement of one panel, for what length of time?

A. The discharges during the measurement of each panel were referred to the corresponding stages, and that in effect gave a weighted mean for the discharge.

Q. For the time during which you measured that particular panel, or each panel. Is that the idea?

A. That is my understanding.

Q. Now how were they weighted?

A. It was essentially the same as weighting, in using the stages for the separate panels, deriving the discharge separately for the various panels.

Q. Is each panel given an equal weight, or how do you do that?

A. I thought I explained that.

Q. Was the water level during the taking of the discharge measurement of each panel given equal weight?

A. The discharge of each panel was computed with respect to the stage prevailing at the time the measurement of that panel was taken.

Q. In referring your discharge to the lake elevation, what weight was given to the mean elevation during each panel gaging; was it given the same weight or different weights?

A. It is my understanding they were weighted according to the volume of discharge through that panel.

Adjourned to Saturday February 21, 9:30 A. M.

Saturday, February 21, 9:30 A. M.

F. G. RAY resumed the stand and testified further as follows:

Re-direct Examination by Mr. Hopkins.

Q. Mr. Ray, you spoke of some dredging in the St. Clair River, on your cross examination. What ultimate effect do you think this has had or will have upon the regimen of the river?

A. That dredging, as I explained, was all dredging done by private companies for gravel in the upper St. Clair River, and surveys in that locality have shown from time to time that there is no material change, although this dredging has continued for a great many years.

Mr. Adcock: I did not understand. Did you say surveys in that locality?

A. Surveys in that locality. Dredging was continued for many years on the shoal at the mouth of the Black River; a great deal of material was removed, although I am not able to state how much. The surveys have shown that the shoal is not materially different in size now than at the time of the original surveys.

Mr. Hopkins: Q. What is the nature of the excavation in the stream itself. In other words what kind of a hole does it leave?

A. Why the dredging has been largely with clam shell dredges, and it has left sort of pot holes in the bottom of the river, which naturally fill up in a very short time. There is known to be lots of material moving down the river, particularly after Northeast storms in Lake Huron.

Mr. Adcock: Q. You say "known to be." Did you see it, or what information have you?

A. I have observed the material moving there at the head of the river myself during surveys on Corsica Shoal, and these matters have been reported upon by the hydraulic parties that worked on the Upper St. Clair River.

Mr. Hopkins: Q. You spoke in your cross-examination of the fact that there has been no artificial compensation for that dredging. Was there any other kind of compensation?

A. Such as I have just spoken of, the natural compensa-

tion. The river seems to fill up naturally to its normal bed following these dredging operations.

Q. Referring to the reports of 1910 and 1912, which were referred to in cross-examination, will you tell us again a little in detail what that letter *Y* in your equation represents?

A. *Y* in the discharge formula for the St. Clair River, as given in the 1912 report, may represent the mean bed of the river. The object is using this method of solution for the discharge equations was to determine a better value for the increment of that river.

As I stated in the cross-examination, there appeared to be some discrepancies between the observations for various years; when solved for a single formula covering the entire set of observations, the residuals were apparently grouped by size or sign for the various years, and showed that these yearly groupings were not directly comparable, for some reason or other.

It was stated in the report that the various values for *Y* might be considered to represent a change in regimen, although it was realized at the time, and it is believed now, that the difference in the values of *Y* also includes the errors in gages, the difference that might be shown by different ratings of the meters in the various years, and also includes any difference due to personal equation of the different observers.

Q. Then when questions were asked you in cross-examination in regard to a three per cent. change, was that from the maximum to the minimum, or was that change to the mean?

A. That was the range between the maximum and the minimum. The greatest difference from the mean curve was about 1.7 per cent.

Q. Was it also assumed in those questions that the entire change, or the entire *Y*, was due to change in regimen?

A. If the measurements during the various years were absolutely correct, the difference in *Y* would represent a difference in regimen.

Q. But in the hypothetical questions asked you, where there was an assumption that the bed of the river had been raised or lowered, they assumed that the entire value of *Y* was due to the change of regimen.

Mr. Adcock: I want to object to that question. The question referred to by counsel speaks for itself, as to what was assumed.

A. It is not unreasonable to believe that the difference in *Y* is largely due to change in regimen, but it may contain differences due to these other causes, which I have stated.

Mr. Hopkins: Take a period of ten or eleven years, and base on the 1912 equation, what change of regimen is indicated?

A. If the value of *Y* actually represents a change in regimen and nothing else, this change between 1899 and 1910 would be equivalent to a change of .07 of a foot in the mean river bed. This would amount to about three-quarters of one per cent. in the discharge.

Q. Which way was that?

A. The 1910 value would show a higher bed of river than the 1899 value.

Q. And what effect does that have on the discharge?

A. Somewhat lessens the discharge.

Q. In one of the reports, there is some reference to a three per cent. variation. Will you explain how that is?

A. (Referring to same.) In explanation of the statement on page 3013 of Appendix FFF Chief of Engineers Report for 1911, in which it is stated that the observed discharges of 1910, when compared graphically with former values indicate an increase of about three per cent. in the volume of flow through the St. Clair River at mean stage since the determinations of 1899,—'01, I will state, that that is the result of a preliminary comparison. The final reduction had not then been made.

Q. Does it so state in the report that it is a preliminary reduction?

A. It states that a graphical comparison was made with former values and this comparison indicated an increase in flow of about three per cent. The comparison was made by plotting the new observations with respect to the curve determined or published in the 1904 report.

In making the final analysis, it appeared that the observations of the earlier period were not on the same stage as those in 1909 and 1910, and that a line passed through the earlier groups did not strike the more recent observations.

Grouping the later observations to establish a graphical curve through those, this curve was found to come very closely to the center of gravity of the earlier observations. In other words, the two curves were not parallel. In following this analysis, the reason for this appeared to be that there was a constant difference or error between the yearly groups, and

that the formula derived in the 1904 report was not the best derivation of the increment.

In making the new analysis of all of the observations, this apparent difference of three per cent. largely disappeared. There is still left differences between certain years as large as three per cent., as I have stated, between the maximum and the minimum.

Q. How much from the mean?

A. The largest discrepancy from the mean is about 1.7 per cent.

Q. You were asked on cross-examination if any written reports had been made to you, or to this office, in regard to ice conditions in the St. Clair, except those made by Mr. Sabin. What other evidence do you have of retardation of flow due to ice than reports made? What evidence have you aside from current meter measurements of volume of flow?

A. The effect of ice jams on the flow of the St. Clair River was determined by Mr. Sabin in 1901, between January and April of that year. In making this determination, Mr. Sabin found a relation between the discharge under ice effects and the fall at the head of the river. By using this relation and applying it to the gage readings at G. T. R. and M. B. R. gages, for other years, it is possible to determine what the effects have been during such periods. These gage records have been examined for the entire period during which the gage at M. B. R. was in operation, and included the time from 1900 to 1906 inclusive.

The retardation in flow in the St. Clair River during these seven years, when reduced to an average for an entire year are as follows: For the winter of 1899-1900, the retardation is equivalent to a flow of 12,400 cubic feet per second distributed over 12 months.

The next year, this retardation is—

Q. What year was that?

A. 1900-01, is equivalent to 21,000 cubic feet per second for 12 months.

1901-02, is 10,600.

For 1902-03, the records are missing at the M. B. R. gage and it is impossible to determine the ice effects.

1903-04, the retardation is equivalent to 14,200 cubic feet per second for 12 months.

1904-05, the retardation is 20,000 cubic feet distributed over 12 months.

1905-06, is 9,900; or an average for the six years of 14,700 cubic feet per second.

Q. Mr. Ray, is it possible to determine the ice effect from the comparison of the discharges of the St. Clair and the Detroit Rivers in the winter time?

A. It might be possible to determine ice effects if the ice blockades occurred either in one or the other river exclusively, but where there is a possibility of ice blockades in both rivers at the same time, I can see no way of determining what those effects are from the discharge formula.

Q. What is the actual fact in regard to whether or not there is ice effect in both rivers at the same time?

A. It is often reported that ice jams occur in both rivers during the same periods.

Q. General ice conditions exist, do they not?

A. The same general ice conditions would exist on the two rivers; if it was a severe winter, you would expect to find plenty of ice in both rivers at the same time.

Q. Mr. Ray, will you explain a little more in detail, why it is possible to measure a large stream with as great a percentage of accuracy, or greater accuracy than small streams or canals?

A. Some of the sources of error in measuring any streams or canals are constant or nearly so, and the sources of error are generally larger in percentage in a small stream than in a large stream. This is true of the determination of the cross section, and is also true of the determination of the vertical coefficients. In the determination of coefficients in the small streams, it is not possible to get as closely to the bottom in percentage of depth as in the larger streams; and it is therefore impossible to determine the trend of the vertical curve as closely.

Q. You said that your opinion as to the length of time it would take a wave to travel in the Chicago Canal, and the velocity, was based upon Mr. Moore's observations. Will you just explain what observations he made, that you base that on?

A. That opinion was based on the gage records that were made at Lemont and Willow Springs incidental to the work of measuring the flow of the Chicago Drainage Canal, using the time interval between the two gages.

Q. It was not then the time interval between Lemont and the power house?

A. It was not.

Q. Is the maximum flow in that canal the same at Lemont as it was at the power house at the same time, or allowing for the time to travel?

A. Not necessarily so. All observations at Lemont show that the stage continued to fall at Lemont and at Willow Springs after the increased flow had reached there. The flow through the power house for a time would include an additional amount necessary to deplete the storage in the canal between Lemont and the power house, so that the maximum flow through the power house might not coincide with the maximum flow at Lemont, and certainly the two would be different in amount.

Q. Is there any general formula with reference to the travel of wave velocity?

A. I only recall one formula, that given by Merriman, in which the velocity is equal to the square root of g x d, d representing the depth.

Q. What does g represent?

A. Acceleration of gravity.

Q. And from that formula what is the conclusion as to the length of time it would take the velocity to travel from the power house to Lake Michigan as compared with the observations?

A. The two values agree very closely. They are corroborative of each other.

Q. Mr. Ray, you were asked to compare certain years between 1865 and 1875, with certain years since 1890, with reference to rainfall. The rainfall data in the question was taken from Williams' Exhibit 34 in this case. What reliability is to be placed upon the rainfall data back in those early years?

A. The rainfall data for those earlier periods is not understood to be very reliable, and not comparable with the rainfall data of recent years.

Mr. Adcock: I object to that and move to strike out that portion of the answer which states, "understood to be unreliable."

Mr. Hopkins: Q. What is your opinion as to the reliability of it?

A. My opinion is that it is not as reliable as recent data.

Q. What is your opinion as to whether or not it is comparable with rainfall data of recent years?

Mr. Adcock: He has already stated his opinion. He has already compared it.

Mr. Hopkins: He said "It is generally understood." I am asking for his opinion.

Mr. Adcock: He has already stated his opinion. I submit that he has answered the question.

Mr. Hopkins: Answer it.

A. Furthermore, I don't believe that rainfall data at two stations such as Milwaukee and Detroit would represent the actual precipitation on the entire drainage area or the entire lake surface of Michigan and Huron.

Q. How about Detroit, Cleveland and Buffalo as to the precipitation on the drainage area of Lake Erie?

A. That might possibly be somewhat better, but in the former case you have no data for the upper end of the lakes and the rainfall in those regions might be considerably different.

Q. Why did you direct the third or the split section of the Niagara River to be measured last year, Mr. Ray?

A. The question of measuring another section on the Niagara River had been discussed in this office for several years, but the reason for making the measurements this last year was on account of the testimony which had been introduced into this case, with an attempt to throw doubt upon the results obtained by the Lake Survey in the Niagara River measurements.

Q. Any further comment upon the reason for these measurements or the results of them?

A. Another reason for making the measurements was to determine the discharge on a section which was materially different in condition from the sections at the bridge and in the open section; and to verify or determine what possible error there might be in the former measurements.

Q. In the new equations of 1912, how does the volume of flow at mean stage compare with the volume of flow as shown in Complainant's Exhibits 1, 2, 3 and 4, at approximately the mean stage of the observations?

A. There is no material difference in the amounts determined for mean flow or mean stage during the times of observations.

Q. Now the same question only as to increments instead of volume of flow?

A. The increments were changed somewhat for the St. Clair and St. Lawrence Rivers.

Mr. Adcock: Q. Up or down?

A. The increment for the Niagara River was not changed at all. The same equation—

Q. The St. Lawrence River? That was reduced, was it not?

A. The increment for the St. Lawrence River was reduced.

Q. And that for the St. Clair also?

A. Yes, it was.

Q. That was in 1912?

A. The 1912 equation determined smaller increments for St. Clair and St. Lawrence Rivers.

Mr. Hopkins: Mr. Ray, what is the source of your information in regard to the cost of power at Niagara Falls?

A. The price that I named in the direct examination was merely hearsay, and was supposed to represent the price to the large consumers at or in the vicinity of Niagara Falls.

Mr. Adcock: What was that price?

A. $18.

Mr. Hopkins: Q. Didn't the Secretary of War take some bids, if you know?

A. I think the Secretary of War received proposals from various companies by advertisement to import power from Canada. The proposals were received upon a competitive basis, one of the items for consideration being the rates of charge to the consumers. The rates submitted in these proposals by the companies all operating at Niagara Falls were the same as the rates then in existence. I have some of the rates which they submitted at that time. They are public.

Q. What are some of the rates to the consumers in those bids?

A. The rates proposed are rates to so-called small consumers at Niagara Falls. This rate for firm power ranges from $35 per horse power per year, in lots less than 10 horse power, on a 24 hour basis, to $20 per horse power per year for energy of 500 horse power and upwards.

The rates at Buffalo under the schedule of demand rate ranges from $36 per electrical horse power per annum, when not exceeding 100 horse power to $27.50 per electrical horse power per annum when the demand equals or exceeds 500 horse power.

Mr. Hopkins: That is all.

Re-cross Examination by Mr. Adcock.

Q. Do you know of any company that is buying electricity down there, and the price they pay?

A. I don't know any of the rates to the large consumers.

Q. Where was this electricity that you speak of delivered?
A. These are published rates for consumers, small consumers at Niagara Falls and Buffalo.
Q. Where is the power measured?
A. On the consumers' premises.
Q. That is after all the transmission expense and everything like that has been taken care of?
A. Yes.
Q. Don't you know as a fact that the Ontario Paper Company is producing horse power from the Ontario Power Company at an average price of $8 per horse power per year?
A. I don't know that.
Q. Was this 24-hour service?
A. It was so stated on the schedule of rates.
Q. To whom was this horse power that you speak of sold for $18 per horse power per year?
A. I have been told that there are contracts in existence at Niagara Falls with the large consumers.
Q. Do you know of any?
A. I do not.
Q. You do not know of anyone buying it at that price?
A. No.
Q. Were any of these proposals which the Secretary of War invited accepted?
A. They were not. These rates that are quoted here are rates that are in existence in Niagara Falls and Buffalo, and power is being sold at those rates.
Q. That is measured at the consumers' premises, is that right, and those are small consumers that you mentioned there, aren't they?
A. They are.
Q. What was the average percentage of the effect of six years' record of ice? It was about eight per cent., wasn't it, as you stated?
A. About that.
Q. This was based on Mr. Sabin's report, was it not?
A. This was based on the relation between discharge and fall at the head of the river, as obtained by Mr. Sabin in his discharge measurements.
Q. Has anyone else made any computations of ice effects, comparing it with Mr. Sabin's report?
A. Mr. Russell made some computations of ice effects.
Q. Who is Mr. Russell?
A. Mr. Russell is an assistant engineer in the Lake Survey office.

Q. How long has he been with the Lake Survey?

A. He has been with the Lake Survey for a great many years. I would have to look up the record to give a definite answer.

Q. Has he been connected with the Lake Survey longer than anyone else who has testified in this case?

A. He has.

Q. He is very familiar with conditions around this locality, and on the St. Clair and Detroit Rivers, isn't he?

A. I am not sure that he is familiar with the conditions. He is familiar with the records of the office.

Q. And various reports, records of measurements and computations and so forth that have been made?

A. I judge that he is familiar with those.

Q. How do his computations compare with Mr. Sabin's referring to page 4107 of the report of 1904, Chief of Engineers?

A. The ice effects determined by Mr. Russell are for the year 1901, and are smaller than those determined by Mr. Sabin, except for the month of May.

Q. What is the average for the five months?

A. The average for the five months, as determined by Mr. Sabin, is 49,620 c. f. s., and as determined by Mr. Russell is 26,930; the difference between the two being 22,690 cubic feet per second.

Q. What percentage of Sabin's is Russell's?

A. About 54 per cent.

Q. If Sabin's per cent. was 8 per cent., then Russell's was about 4 per cent., wasn't it?

A. About that.

Q. This report of Mr. Russell's, and the computations that he made, were after those of Mr. Sabin, were they not?

A. They were.

Q. And after certain discharge measurements were made on the Detroit River?

A. They were.

Q. And Mr. Sabin did not have before him, at the time he made his computations, the records of the discharge measurements on the Detroit River, did he?

A. Mr. Sabin did not need to have the records of the Detroit River.

Q. I am asking you the question. Will you kindly answer it?

A. He did not have the records.

Q. Mr. Russell's report was approved by the principal assistant engineer of the Lake Survey, wasn't it?

A. I don't know just how fully that report was approved. I presume it was approved or it would not have been published.

Q. Well, the Chief of Engineers must have approved it, or he would not have published it, would he?

A. That is a report of this office, and it would be published—

Q. If it were approved by the principal assistant?

A. If it were approved by the principal assistant.

Q. So the principal assistant must have approved it. Isn't that true?

A. I presume it was approved.

Q. That was the custom in the office, wasn't it?

A. That was the custom.

Q. Customary to approve?

A. It was customary. It was understood that the report was approved.

Q. Do the gage records indicate the presence of ice jams in the Detroit and St. Clair Rivers?

A. I stated in the re-direct examination that they might indicate the ice effects, but not necessarily so.

Q. That is what gages?

A. The relation between the gage readings at Harbor Beach, St. Clair Flats and Cleveland.

Q. On how many occasions in the last ten years have gorges occurred simultaneously on the two rivers, the Detroit and St. Clair Rivers?

A. We have no definite records.

Q. If the discharge capacity be reduced by say 8 per cent., the increment must be reduced by less than that per cent., according to what you said yesterday, so that the effect of this ice on the increment would be more than 8 per cent., and according to Mr. Russell's figures is probably about 4 per cent. Isn't that true?

Mr. Hopkins: That is the total increment for the year.

Mr. Adcock: Yes.

A. The retardation of flow might be eight per cent., and the effect on the increment greater than eight per cent.

Q. Will you explain how?

A. The mean increment for the year, taking into account the ice effect would depend upon the increment during the time that the rivers were partly blockaded. If the increment

during the open season, say eight months, was 22,000 and the increment for the remaining four months of the year was 10,000, the mean increment for the year would be about 18,000, which is less than the open season increment by upwards of 20 per cent.

Q. What decrease of discharge would you have to have, to compare with an increment of 10,000?

A. I can't see that the increment during the ice blockades has any relation to the amount of retardation of flow.

Q. Will you state why you believe that?

A. As an illustration, the effect of ice during four months of the year might possibly be the same, regardless of the stage on Lake Huron; in which case the increment of flow for those four months would be zero, and would bear no relation to the amount of retardation.

To make my meaning clear, I will add that I mean by that that the amount of water flowing past this blockade of ice is assumed to be the same regardless of the stage.

Q. Could that possibly exist?

A. It is possible but not probable. It is simply an illustration to show that the increment during the winter months bears no relation to the amount of retardation.

Q. Do you mean to say that given a certain ice jam and Lake Huron rises a foot, there would be no change in the flow through the St. Clair River?

Mr. Hopkins: He didn't say that.

A. I do not mean to say that, but the increment of flow would not be the same as during the open season.

Q. Did you assume that Lake Huron remained at the same stage during the ice jam, during the time of the ice jam, when you said the increment would be zero?

A. In that illustration, I was assuming that the ice jam for two different stages of Lake Huron allowed the same amount of water to pass, which is possible but not probable.

Q. That is the same ice jam, or a different ice jam? In other words, is it your proposition that if Lake Huron during this period when there was an ice jam rose a foot, there would be no increase of flow through the St. Clair River?

A. That assumption could be made for the same ice jam, or it could be made for ice jams of different years.

Q. You mean that it is probable that the ice jam would increase as the lake level rose, so that there would be no increase in flow? I just want to get what you mean, Mr. Ray. You say there would be no increment of flow?

A. I do not intend to claim that the amount of water flowing through the St. Clair River would be the same regardless of the stage of Lake Huron. The illustration that I gave was merely to show that there was no relation between the increment during the ice jams and the stage on Lake Huron.

Q. But I understood you to say that during ice jams, it would be possible that the increment would be zero. If the increment were zero, it would necessarily follow there would be no increase in discharge for a rise of a foot in Lake Huron?

A. I believe that the increment would be something more than zero, but it would not bear any relation to the amount of retardation.

Mr. Sabin in his report states that the increment during his observations was more or less indeterminate; that as near as he could determine during that period the increment was about 10,000.

Q. That was because of the change in the jams or change in retardation?

A. He simply found that during the ice stage there was more water flowing down the river past the ice blockades, and that that was approximately 10,000 cubic feet per second per foot of rise.

Q. Now assuming that at a particular instant while there was an ice jam, Lake Huron should rise a foot, would there be any increase in the discharge?

A. The measurements indicated that there would be.

Q. Did the measurements cover a condition of that kind? Did the measurements of Sabin cover a condition of jam and a rise or fall of lake as assumed in the question?

A. The measurements were taken during a range in stage on Lake Huron, and while this range was not large enough to give a definite determination of the increment during the period of measurements, the nearest indication was that the increment was about 10,000 cubic feet per second during those measurements.

Q. Weren't the ice jams changing during the course of these observations?

A. They probably were.

Q. And the section was therefore changing in its carrying capacity?

A. Not the section on which the measurements were taken.

Q. Well, say at the jam?

A. He did not measure at the jam.

Q. And the discharging capacity of the river as a whole was changed by the jam?

A. It was.

Q. Now the change in the discharging capacity would make a change in the increment, wouldn't it?

A. Probably would.

Q. When you say "probably," does that mean that you have a doubt?

A. The determination of increment on the observations of Mr. Sabin covered the full period of the time of those observations and naturally represented the increment during the mean condition.

Q. (Question read.) Now, will you direct your attention to the question, as to whether you have a doubt?

A. The change in the carrying capacity of the river would necessarily make a change in the increment.

Q. Would the proportionate change in increment be as great or greater than the change of discharging capacity of the river?

A. That is indeterminate from the data.

Q. That is your opinion it is indeterminate?

A. That is my opinion, it is indeterminate from the data.

Q. In your discussion of the equation in which the value of Y was given as the elevation of the bed of the river, do you wish us to understand that the term "change of regimen" is synonymous with the term "change of the bed of the river"?

A. Generally speaking it is.

Q. When you say "generally," what do you mean. Can you give us a more definite idea?

A. This equation is purely empirical and the value of Y in that equation may represent the mean river bed, may be considered to represent the mean river bed, and a change in the value of Y would therefore be considered a change in regimen.

Q. If there were during the day a maximum discharge at a certain time at the power house on the end of the drainage channel, ought there to be at some time later a maximum discharge at the section at Lemont, as compared with other discharges at Lemont during the day?

A. If there was a sharp peak in the load in the power house at Lockport, there would be a peak on the discharge at Lemont sometime later.

Q. Ought they to be equal in amount?

A. Not necessarily equal.

Q. What do you mean? The discharges would not be equal in amount?

A. The maximum momentary discharge would not be the same as the maximum momentary discharge through the power house.

Q. Would it be greater or less?

A. If this peak load were sharp and the load were suddenly withdrawn again, the discharge through the power house would be greater than the maximum flow past Lemont.

Q. Suppose that Lake Michigan should suddenly go up two feet and then recede, would the discharge at the mouth of the Chicago River coincide with the discharge at Lemont at a later time; the discharge at the power house remaining the same during the period?

A. If the discharge at the power house remained the same, —I don't understand your question.

Q. No, if Lake Michigan should go up two feet and should then recede, would the discharge at the mouth of the Chicago River coincide with the discharge at Lemont at a later time, assuming that the Bear Trap Dam or the regulating works at the end of the canal were unchanged during the period of time?

A. I would say that the maximum discharge at Lockport would not be as great as the momentary maximum flow into the canal at Chicago.

Q. If the water were free to escape over a weir at Lockport as soon as there was a rise in the canal at that point, a rise of the water level in the canal at that point, would that make any difference in your answer to the preceding question?

A. It would not.

Q. Assuming that Lake Michigan-Huron should suddenly rise three feet and then recede by the same amount, would the maximum discharge at the head of the river coincide with the discharge at the Dry Dock Section at a later time on the St. Clair River?

A. The wave proceeding down the river from a sudden fluctuation on Lake Huron would be somewhat flattened out, and while the amount of water entering the head of the river must necessarily pass the Dry Dock, the maximum velocity would not represent the maximum inflow from Huron by a small difference.

Q. You spoke of an equation here, V = square root of g × d. Just what does that mean; I did not quite understand it from your redirect examination?

A. That is a theoretical equation representing the velocity of tidal waves.

Q. Did you use that equation in working out the conclusions with reference to the establishment of a uniform flow of 10,000 cubic feet per second through the canal at all points, from a flow of 4,167 cubic feet?

A. I did not.

Further Re-Direct Examination by Mr. Hopkins.

Q. Mr. Ray, you were asked a question, assuming that there was a sudden rise on Lake Huron and then a sudden drop, whether or not the entire effect would be felt at the Dry Dock Section.

Q. Do any such conditions as are assumed in that question exist in fact?

A. Not to my knowledge, and I don't believe it is possible.

Q. Taking the conditions as they do exist, what would your opinion be as to the same question, that is the effect of elevations of Huron on the flow at Dry Dock Section?

A. The sudden fluctuations on Lake Huron are a great deal less than those in the hypothetical question, and occur both in the general manner stated and also in the inverse. That is that there is a drop and then a rise during the observations, so that the effect of relating the discharges to the gage heights at the head of the river would be compensating.

Q. Yesterday you were asked certain questions about change in flow due to elevation in the bed of the river. It was assumed in all those questions that there was no change in the width. That was as you understood it?

A. It was.

Q. Is that comparable with obstructions by ice as they exist?

A. It is not.

Q. Why?

A. For the reason that the ice blockades may and generally do narrow the discharging section of the river.

Q. How about surface obstructions in the ice conditions, the ice cover?

A. There is a retardation of flow due to ice cover, the

under side of the ice causing friction and consequent retardation.

Q. Now, you say that during the ice period, the increment is indeterminate? With reference to the increment in the open season, is it greater or less?

A. It must necessarily be less.

Q. You mean less under ice conditions?

A. Under ice conditions, yes.

Q. Did Mr. Russell make any observations himself in regard to ice conditions?

A. Not to my knowledge.

Q. He used Sabin's observations, didn't he? Just what was Mr. Russell's method, the results of which are reported in that 1904 report?

A. The ice effects as determined by Mr. Russell were computed from the discharge equations of the two rivers, the effect being determined by the differences as shown by the gage heights, and the discharge equations.

In Mr. Russell's comparison shown in the 1902 report, he has compared the ice effects as determined from the discharge equation with those given in the 1902 report by Mr. Sabin, which effects determined by Mr. Sabin were actually measured and were not theoretical.

Q. Are there any indeterminate elements in the winter determinations made by Mr. Russell?

A. If I understand your question, the ice effects as determined by Mr. Russell depend upon gage relations introducing the stage of water in Lake St. Clair and comparing the discharges as determined by that gage for the Detroit and St. Clair Rivers. If there was any retardation or blockade in both rivers at the same time, his derivation in this method could not be correct.

Q. As a matter of fact didn't he use open season equations for this determination of the flow of the two rivers?

A. He did, and in that method assumed that one or the other river was flowing freely and openly.

Q. What knowledge have we of the equation of discharge of the Detroit River under ice conditions?

A. None whatever.

Further Re-Cross-Examination by Mr. Adcock.

Q. Who was the Principal Assistant Engineer when Mr. Russell made his report?

A. Mr. E. E. Haskell.

Q. How many observations did Mr. Sabin make?

A. I derive from the records that Mr. Sabin made 61 discharge measurements during ice conditions.

Q. What time was occupied in making each discharge measurement?

A. It would take a week to answer that.

Mr. Hopkins: Objected to on the ground that the witness did not make them.

Mr. Adcock: Q. What was the average time?

Mr. Hopkins: If you know of your own knowledge?

A. I don't know of my own knowledge. It is a matter of record.

Q. Have you any records of it?

A. The records of Mr. Sabin's measurements are in the office.

Q. Would it take two days to make each discharge measurement?

A. No.

Q. Would it take one day?

A. I presume not.

Q. Would it take 12 hours?

A. I don't know.

Q. Well, would you say more or less than 12 hours in your opinion?

A. I should say less than 12 hours.

Q. As much as six hours less than 12 hours?

A. I have already stated that I don't know.

Q. You are Principal Assistant Engineer, and I am asking for your judgment as to how long you think it would take Mr. Sabin under those circumstances to make a discharge measurement.

Mr. Hopkins: That is objected to as incompetent and immaterial, how long it would take Mr. Sabin to do anything. You do not need to answer that, anyway.

Mr. Adcock: Go ahead.

A. I am not familiar with the conditions under which Mr. Sabin had to work during the ice measurements.

Q. Have you made any computations yourself from the records that Mr. Sabin has made?

A. I have not.

Q. Then you don't know the conditions, actual conditions under which Mr. Sabin made those measurements, do you?

A. Only so far as they are stated in his reports.

Q. In the report of the Chief of Engineers?

A. Yes.

Q. You don't know what length of time was covered in making a single discharge measurement?

A. That is a matter of record in the office.

Q. I say you do not know personally?

A. I do not.

Q. How many discharge measurements were taken each month during the period of ice conditions mentioned?

A. Ten measurements were taken in January, 16 in February, 21 in March and 14 in April, all 1901.

Q. Do you consider that the conditions would be favorable for making discharge measurements during the winter of 1900-'01, in the month mentioned?

A. I know of no reason why they were not favorable.

Q. Well, compare them with the conditions in the open season?

A. I see no reason why the results should not be good. The conditions under which the work was performed was less favorable.

Q. Although you did not know the conditions?

A. I do not know them, no.

Q. How many times has the St. Clair River been measured in open season; I mean years, how many different years were series of measurements made?

A. Seven years.

Q. There was considerable discussion about the effect of ice, wasn't there, at the time Mr. Sabin made his measurements?

A. I was not here at that time.

Q Well, the reports of the Chief of Engineers show that, don't they? Mr. Sabin made a report on this; Mr. Russell made a report about it, and it is referred to in various reports and in this testimony.

A. It has been, yes.

Q. No other discharge measurements of the St. Clair River during ice conditions have been made, except those of Mr. Sabin's, have there?

A. Not to my knowledge.

Q. You say that the total reduction discharge of the St. Clair River, during the five months mentioned in the winter of 1901, January, February, March, April and May, was approximately 50,000 cubic feet per second, wasn't it? If the flow of the St. Clair River were retarded in that way, it would raise Lake Huron, would it not?

A. It would.

Q. And lower Lake Erie, wouldn't it?

A. It would for the time being, yes.

Q. How much would Lake-Michigan-Huron be raised; how much would Lake Erie be lowered?

A. If ice jams such as occurred in the winter of 1900-1901 continued each winter indefinitely, the effect—

Q. No, I think the question is, Mr. Ray, as to what was the effect in 1901 upon Lake Erie and Lake Huron of the retardation mentioned for those months?

A. The backwater effect of the ice jam of 1900-'01 on Lake Huron would be about four inches.

Q. How do you compute that?

A. The retardation of flow shown by Mr. Sabin is equivalent to a retardation of approximately 21,000 cubic feet per second for a year; and at the end of twelve months, about 44 per cent. of the backwater effect would have been consummated.

Q. How much would have been consummated at the end of six months, say on June 1st, 1901?

A. .36 of a foot.

Q. Michigan-Huron would be raised .36 of a foot?

A. That would be the tendency, due to the ice effect.

Q. That would be about how many inches?

A. It would be a little over four inches.

Q. How much would Erie be lowered at that time?

A. The effect on Lake Erie at the end of a year—

Q. I think I asked the question say June 1st?

A. July 1st, you stated.

Q. June 1st, I think?

A. You want it for June 1st?

Q. June 1st.

A. The lowering effect on Lake Erie considering that the flow in the Niagara River is not seriously obstructed by ice during any of the winter months would be 16 inches approximately.

Q. How about 1901?

A. I understood you asked for July 1st on Lake Michigan.

Q. I asked for June 1st on both?

A. The rise on Lake Huron on June 1st would be about 5½ inches.

Q. And the lowering effect of Erie would be how much?

A. Sixteen inches.

Q. On June 1st?

A. It is subject to uncertainties due to ice effects in the late winter on both the Niagara and the St. Clair outflow.

Q. How great is the result you reached in percentage, what percentage of accuracy?

A. I would consider that those amounts were subject to inaccuracies of 20 or 25 per cent.

Q. The error might be either way?

A. It might be.

Q. Now, you are considering the actual conditions as determined by Mr. Sabin, are you not, in his report for the month that he measured?

A. I am.

Q. Will you turn to Mr. Sabin's report, and I will ask you to examine that report and state the amount Huron is raised and the amount Erie is lowered according to that report during the months mentioned for 1901?

A. I do not find that Mr. Sabin has made any statement here regarding the effect at any stated time, such as June 1st.

Q. Don't you find on page 2837, Appendix EEE, Report of the Chief of Engineers for 1902, under the heading "Difference or Effect of Ice for the Months of January, February, March, April and May, 1901," that Lake Michigan was raised during January .06, during February .18, March .11, April .14, May .02, making a total of .52 of a foot; that the depth of Lake Erie being minus was lowered in January .28, February .81, March .51, April .62, May .11, which, if added up, would make a total of 2.33 feet? The figures that I read are from Mr. Sabin's report with reference to his observations during the ice conditions in 1901, is that correct?

A. Those effects are the immediate effects and are not the effects that would be shown on June 1st or any time after the period in which the ice effects occurred. The increased stage caused by the ice on Lake Huron would cause a temporary increase of flow, which would tend to bring back the normal stage on Lake Huron. The same would be true on Lake Erie. Conversely the decreased flow of Niagara River due to the decreased stage would allow Lake Erie to fill again, so that the effects on June 1st would be about as stated.

Q. Then you disagreed with Mr. Sabin's statement?

A. I do not. The backwater effects shown by Mr. Sabin are not intended to represent permanent effects.

Q. Where is it so stated in his report?

A. I don't know that he stated that.

Q. What was the mean elevation of Huron in December, 1900?

A. The elevation of Lake Huron as observed in December, 1900, at Harbor Beach was 580.46.

Q. What was the mean elevation of Erie during the month?

A. 571.45 at Cleveland.

Q. What is the difference?

A. The difference is 9.01 feet.

Q. What was the mean elevation of Huron during the month of June, 1901?

A. 580.91.

Q. And the mean elevation of Erie for the same month?

A. 571.72.

Q. What is the difference?

A. 9.19 feet.

Q. Take the same for May also, Huron and Erie and the difference?

A. The elevation of Lake Huron in May, 1901, was 580.81. Lake Erie in the same month was at an elevation of 571.31. The fall between the two lakes was 9.50 feet.

Q. Take November, 1900?

A. In November, 1900, the average monthly elevation of Lake Huron was 580.66 and of Lake Erie was 571.49. And the fall between the two lakes was 9.17.

Q. According to the actual elevations of Michigan-Huron and the elevations of Erie in the records which you have there, how much did Erie fall between January 1st, 1901, and June 1st, 1901?

A. The water levels of Lake Erie rose about .12 of a foot from January 1st to June 1st.

Q. It rose?

A. Yes.

Q. How many inches is that?

A. 1½ inches.

Mr. Adcock: I think that is all, Mr. Ray.

Further Re-Direct Examination by Mr. Hopkins.

Q. Mr. Ray, suppose there had been no ice effect during the time mentioned in the previous questions from between January 1st, 1901, and June 1st, 1901, what would have been the elevation of Lake Erie as compared with what it was at the time?

A. The elevation of Lake Erie would have been something over a foot higher on June 1st than it actually was, if it had not been for the ice effect.

Q. In answering the question as to what increased elevation there would be in Michigan-Huron, due to the ice effect from the data that you have, did you take into consideration local supply of Huron and Michigan?

A. I did not. The statement of ice effect as given by me was intended as the backwater effect from the ice, and this effect would be to make Lakes Michigan-Huron higher than it would have been without the backwater. The actual change is not represented by the figure given.

Q. And was not intended to so represent the actual figure?

A. It was not intended to represent the actual change in the elevation of Lakes Michigan-Huron.

Q. And as to the effect of the ice on Lake Erie during that year, did you take into consideration local supply on the Lake Erie basin, including Lake St. Clair?

A. I did not. The value that I gave for the lowering effect on Lake Erie of the ice in the St. Clair and Detroit Rivers was simply the effect of ice and did not consider the local supply and did not consider the normal change in the elevation of the lake.

Q. Between January 1st and June 1st, the lake does normally rise, doesn't it, speaking of Lake Erie?

A. The average curve for Lake Erie does so rise between January 1st and June 1st.

Q. In your judgment is that due to local supply?

A. It is.

Q. How about the increased flow from Lake Huron after the ice has gone out?

A. There would be an increased flow due to the ice stage in Lake Huron. The effect of this increased flow would be to draw down the elevation, the abnormal elevation which had been caused by the ice.

Q. Is it your present opinion that Mr. Sabin's results as to ice effect are correct, so far as the volume of flow is concerned?

A. I believe they are so far as the data warrant.

Further Re-Cross-Examination by Mr. Adcock.

Q. Doesn't Mr. Sabin's figure show a retardation of flow into Erie to the effect of about 2.33 feet of lowering of elevation on Erie?

A. The effect on elevations on Lake Erie would be about 2.33.

Q. What would be the rainfall on the Erie basin to produce a run-off or an increase of local supply, so that Erie would raise 2.45 feet?

A. On what assumption were those figures given?

Recess to 2:45 P. M.

After Recess 2:45 P. M.

F. G. RAY resumed the stand and testified further as follows:

Mr. Adcock: (Question read as follows: "What would be the rainfall on the Erie basin to produce a run-off or an increase of local supply so that Erie would raise 2.45 feet") Assuming no change in the discharge of outlet or inlet, that is assuming that there is no change, no flow?

A. A depth of 2.45 on Lake Erie as I compute it is equivalent to a rainfall over the entire land and lake drainage basin of Lake Erie of about 7¾ inches.

Q. That is on the assumption that all the precipitation went into the lake; that amount went into the lake?

A. It is, yes.

Further Re-Direct Examination by Mr. Hopkins.

Q. Mr. Ray, do you want to explain one of your answers in regard to that 2.33? Just read the question and answer.

(Question and answer read as follows: "Doesn't Mr. Sabin's figures show a retardation of flow into Erie to the effect of about 2.33 feet of lowering of elevation on Erie? A. The effect of elevations on Lake Erie would be about 2.33.")

A. In further explanation of what that 2.33 is, I understand it to be the depth of water over the surface of Lake Erie that is equivalent to the retardation as measured by Mr. Sabin during the five months, in 1901.

SHERMAN MOORE, a witness called in rebuttal on behalf of the Government, having been previously sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Moore, you have been sworn, and have testified in this case before, haven't you?

A. I have.

Mr. Austrian: When was that?

A. That was in May, 1909.

Mr. Hopkins: Q. Since then what further qualification have you had in regard to your work as an engineer?

A. Since that time I have been employed on the Lake Survery, in charge of field parties and general survey work, and also in some hydraulic work. In 1909 I made measurements in the canal of the Niagara Falls Power Company to calibrate the turbines under various gate openings and determine the amount of power which they could develop under varying conditions, without exceeding the amount of water allotted by the Secretary of War.

I also made measurements in the canal of the Hydraulic Power Company at the same time. In the fall of 1909 I made discharge measurements in the St. Clair River, and in that winter reduced all of the velocity co-efficients for Section Gorge.

In 1910, I made measurements during May and June on the St. Clair River on both Section Gorge and Section Dry Dock, located and laid out the sections in the Delta and made some measurements on them.

In December, 1911, I made measurements in the canal of the Hydraulic Power Company for the purpose of determining the amount of power which they could develop without exceeding the amount of water specified by their limitations.

In December, 1912, I made measurements in the Chicago Drainage Canal at Lemont.

Q. 1912 or 1913?

A. 1913. During the winter of 1912 I made a complete re-reduction of all discharge observations of the Lake Survey, deriving new formula where it seemed necessary.

Q. I believe you have already testified that you made certain measurements in the Niagara River in 1907 and 1908?

A. I have.

Q. Any further measurements, particularly with reference to the St. Lawrence?

A. I made measurements on the St. Lawrence River in 1908; that was covered by my previous testimony.

Q. Now, in this work you say you did in 1912 of re-computing the discharge formula for the rivers, just give that a little bit more in detail, what you did?

A. I took up each of the rivers connecting the Great Lakes; examined all of the observations for possibilities of error, and made some changes and alterations in gages and meter readings, which seemed indicated by the observations and by our further knowledge of the subject, and wherever necessary I derived new equations expressing the law of flow in terms of the controlling gage.

Q. What result did you get with reference to the increment at Niagara?

A. The increment of flow on the Niagara River was not changed by the new reductions.

Q. What changes did you make if any in the gages at Niagara, or rather the Buffalo gage?

A. There were no changes whatsoever in the controlling gages on the Niagara River.

Q. About the rating of the current meter, what have you to say?

A. Those were not changed.

Q. The cross sections?

A. The cross section was not changed from that determined in 1907. The observations made in 1907 and 1908 appeared to fall exactly on the line determined in 1906, and no changes whatsoever were indicated as being necessary in the equation of 1906 to express the true relationship in 1912.

Q. What was the purpose of these further measurements that you have mentioned, and these new computations, that is checking over the computations?

A. The purpose of the measurements was to determine whether or not there had been any change in the regimen of the river. The purpose of the reduction was to get for our office record a complete and systematic classification of the various data, a comprehensive treatment of the whole subject.

Q. In cubic feet per second, what is the increment of the Niagara River, as finally determined by you?

A. Between 21,000 and 22,000 cubic feet per second.

Q. Have you examined Ray's Exhibits 1, 2 and 3 of this date?

A. I have.

Q. Did you hear Mr. Ray's testimony?

A. I did.

Q. Do you concur in the conclusions reached by Mr. Ray in regard to those exhibits?

A. I do.

If not, in what respect do you differ?

A. I concur with Mr. Ray in his testimony.

Q. What effect, in your opinion, do those exhibits have upon the increment as derived by you at Niagara?

Mr. Adcock: Or determined, you mean?

Mr. Hopkins: Yes, the increment as determined?

A. They are an excellent corroboration of the increment as determined by the observations with respect to the Buffalo gage.

Q. Those exhibits eliminate the Buffalo gage, do they?

A. They eliminate the Buffalo gage.

Q. Now give us specifically any further conclusions that you have reached in regard to the St. Clair River?

A. I made measurements of flow on the St. Clair River in 1908, '09 and '10, establishing a new section; and in the spring of 1911 I established the Third Section in the Delta. The agreement between the sections, as I know it, is very close.

Q. Within what per cent.?

A. I believe within 2 per cent.

Mr. Adcock: Q. What agreement, cross section agreement?

A. The agreement of the discharge, the mean discharge, and there is no apparent discrepancy in the increment of flow by the upper two sections. The observations on the lower section were not sufficient to determine an increment. They do not cover a great enough range of stage.

Q. What is your conclusion as to the increment of the St. Clair?

A. The latest reduction by the Lake Survey shows an increment at mean stage of about 21,000 cubic feet per second. That, in my opinion, may possibly be in error by as much as 20 per cent.

Q. On what side do you think that error would occur?

A. In my opinion it is more likely that the increment derived by that equation is too large.

Q. Did you derive an increment from your measurements at the Gorge Section?

A. I derived an approximate increment in the winter of 1909, before we had the present number of observations on that section. The observations were not sufficient to derive

the increment with accuracy, but showed an increment between 18,000 and 19,000 cubic feet.

Q. What effect, if any, have your later observations had upon that increment?

A. There has been no reduction of those observations by themselves, and I could not say what effect the further observations had upon the increment.

Q. What in your opinion is the maximum possible error in that increment that you have just given?

A. Not to exceed 25 per cent. maximum possible error.

Q. What do you think the probable error is?

A. I stated about 20 per cent. That statement of 20 per cent. as a probable error is not technically correct. The term "probable error" is not used mathematically.

Q. Give us, then, the range, what is correct, the range in feet; what would be the maximum and the minimum increment?

A. I believe personally that the increment in the St. Clair River lies between 17,000 and 22,000.

Q. Now, Mr. Moore, what increment did you derive for the St. Lawrence River?

A. About 23,000 cubic feet per second.

Q. For what lake stage is that?

A. That is for stage of 245 feet on Lake Ontario, by the Oswego gage.

Q. Is that mean?

A. Somewhere near it, I think.

Q. What is the increment for a foot lower elevation?

A. 22,000.

Q. In your opinion is the increment of these rivers more correctly represented by a curve, or a straight line?

A. I think there is very little difference between the accuracy of a straight line and a curve. One seems to represent the law of flow about as well as the other.

Q. Within what degree of accuracy do you think the volume of discharge of the three rivers has been measured, taking first the St. Clair River?

A. For the St. Clair River I should say that we knew the volume of flow at the stage representing the mean of the observations within 1 per cent.

Q. Now the Niagara?

A. For the Niagara River, probably within ½ of 1 per cent.

Q. The St. Lawrence?

A. For the St. Lawrence River, within 5 per cent.

Recess to 2:00 P. M.

After Recess 2:00 P. M.

SHERMAN MOORE resumed the stand and testified further on direct examination as follows:

Mr. Hopkins: Q. Mr. Moore, what is your opinion as to the degree of accuracy with which large streams can be measured?

A. I believe large streams can be measured with an accuracy of at least 1 per cent.

Q. In arriving at your conclusion, what specific things do you take into consideration, as for instance cross section?

A. The cross section of a large stream can be determined accurately within ½ of 1 per cent. The velocity co-efficients can be determined within 1 per cent. The velocities, absolute velocities, are practically exact.

Q. How are they determined?

A. With the current meters.

Q. In the measurement of these streams how many meters were used?

A. In the more recent practice of the Lake Survey, it has been customary to use four meters.

Q. Will you explain just how you use them, and how they are rated and checked and so on?

A. Each meter previous to the observations, and at short intervals throughout the observations, is rated carefully on a still water base. The meters are watched very carefully throughout the observations in order to detect any changes from the rating; and there is a systematic interchange of meters in the work, whereby any little eccentricities in individual meters are eliminated from the mean result.

Q. How frequently are ratings made?

A. It has been the practice in more recent work to rate the meters on an average of about once a month.

Mr. Austrian: Will you ask what he means by the more recent work?

Mr. Hopkins: Q. What do you mean by the more recent work?

A. The work since 1906.

Q. Isn't that also true as early as 1900?

A. I believe that the ratings in 1900, and those about that time, were not quite so frequent. There were, however, very frequent still water ratings made.

Q. With reference to the accuracy of current meter meas-

urements, did you make any tests in the power canals at Niagara?

A. The canal of the Niagara Falls Power Company was measured in two sections with an agreement of ¼ of 1 per cent. between the two. The canal of the Hydraulic Power Company was measured in two sections, with an agreement of less than 2 per cent.; and in addition there have been measurements made in the penstocks of the turbines with a Pitot tube, which have checked the current meter measurements.

The efficiencies of the turbines were determined originally by current meter measurements in the canal, and later Pitot tube measurements in the penstock of the turbines were made, as a comparison of the two methods. The check was exceedingly good, about 1½ per cent., I think.

Q. Which was higher?

A. The volume of flow by the current meter was the largest.

Q. The two different sections that you checked, the measurements were made with the current meter?

A. On both sections.

Q. And then a check with this Pitot tube?

A. Yes.

Q. Do you know how many horse power per cubic foot per second on the electrical switchboard are generated at the Hydraulic Power Company's plant, say power house number 3?

A. I have no figures which would show the number of horse power generated by one cubic foot in power house number 3. In the two power houses, numbers 2 and 3, the Hydraulic Power Company develop about 19.2 horse power per cubic foot of water. The efficiency of power house number 3 is very much higher than that of power house number 2; and it is probable that the horse power per cubic foot would be considerably larger in that power house, although I have no figures to show it.

Q. Did you yourself make any soundings in the Niagara River at the Bridge Section?

A. I made soundings at the International Bridge, in spans 1, 2, 3 and 4.

Q. Did you find any evidence of a boulder strewn bottom?

A. There was no evidence whatsoever shown by the soundings. The soundings ran uniformly, and indicated an absolutely smooth, hard bottom.

Mr. Austrian: Q. In what year were those soundings made?

A. I think it was 1907.

Q. Do you know anything about the bottom on the Canadian side, span number 8?

A. The bottom of the river is visible in spans 8 and 9 on the Canadian side, and consists in smooth bed rock limestone rock in place.

Q. What is the nature of the bottom in spans 1 and 2?

A. In spans 1 and 2, the bottom is largely composed of silt.

Q. What is the nature of the bottom of the river further upstream, say at the Buffalo water intakes?

A. That is ledge rock.

Q. Do you know of a certain part of the Niagara River where the bottom was uncovered for a while, where they were doing some construction work?

A. On the western side of the rapids, immediately above the Horseshoe Falls, the Ontario Power Company uncovered quite an area of the bottom by their divertors; that is to say in the vicinity of and immediately below the first cascade in the rapids.

Q. Just go on and tell what the condition was at that time?

A. The area unwatered lay at the head of the rapids in a portion of the river of exceedingly high velocity and very broken currents. The water was exceedingly rough. The fall in that stretch of the river is about 55 feet in about a mile. It is exceedingly broken water, and very rapid.

Q. What effect would that condition have upon the bottom?

A. If the bottom was composed of soft limestone, as I believe it was—as I know it was—the rapid current and the turbulence of the water would cause large erosion on the limestone, probably following seams, and resulting in fissures and cracks of considerable magnitude. This was actually shown when the bottom was uncovered.

Q. Do you understand that that is the portion of the river referred to in Mr. Freeman's testimony, when he said there was a portion in the Niagara River uncovered for a while?

A. I am not familiar with Mr. Freeman's testimony.

Q. Is the condition at that place any indication of the nature of the bottom at the Bridge Section or the Open Section, which were measured by the Lake Survey?

A. So far as I can see it bears no relation whatsoever to the nature of the bottom at the International Bridge.

Q. Or the Open Section?

A. Or of the Open Section. The conditions are entirely different.

Q. Or of the Third or Split Section?

A. No. The conditions in all three cases are entirely different.

Q. What is the condition of the Niagara River at the gaging sections, with reference to turbulence?

A. At the International Bridge Section, there is a certain degree of turbulence around the bridge piers resulting from the placing of the piers in the current. It does not extend to any great distance either side of the piers. The turbulence on the bottom can be judged by the eye in spans 8 and 9. In those two spans, the water appears to be running absolutely smoothly and evenly over the bottom, with no eddying or boiling whatsoever. The indications of the current meters are that there is no eddying or boiling, or any great perturbation in the mid-spans, or near the edges outside of this certain narrow zone of disturbed water. At the Open Section, so far as I am able to judge, there is no turbulence whatsoever. The water appears to be running very smoothly and evenly. I am not familiar with the Split Section.

Q. Does the current meter give any indication of turbulence?

A. Not at the points at which I made observations; the registration is perfectly uniform and steady.

Q. I mean if there were any turbulence, would the current meter indicate it?

A. The current meter would indicate turbulence.

Q. How?

A. By an unsteady registration. We found that condition existing in the canal of the Hydraulic Power Company. The meter in that case would slow up, almost stop and then speed up; the registration was very irregular. In all of the large rivers in which we have made measurements, in which I personally have made measurements, I have found nothing of that kind whatsoever. The registration has been perfectly uniform and regular.

Q. That includes the St. Clair, the Niagara and the St. Lawrence Rivers?

A. That includes those three rivers.

Q. How is the Gorge Section of the St. Clair River as to turbulence?

A. There is no indication of turbulence at the Gorge Section, that I have ever been able to detect. There undobutedly

exists a slight perturbation close to the bottom, but it is very slight and is not extreme. The bottom of the Gorge Section is visible over the first 100 feet on the western side. The bottom consists of a rather fine, compacted gravel, and there is no sign of turbulence there whatsoever.

On the eastern side, the bottom is also visible. There it is smooth sand. There is no sign of any turbulence there. The registration of the meters at the bottom point in mid-stream where the depth is in the neighborhood of 65 feet was, as near as could be determined by ear as regular as it was in any other portion of the stream.

Q. How about the bottom of the St. Lawrence?

A. The bottom of the St. Lawrence is rougher. And if there is any turbulence in any of the rivers, it probably occurs there more than it does in the other stream. I have made no measurements near the bottom of the St. Lawrence; I could not say in that matter.

Q. Have you determined the time of the lag from the Buffalo gage to the Bridge Section where the measurements were made in the Niagara River?

A. I have.

Q. What is the time?

A. As I determined it in 1907, the time from the Buffalo gage to the Section, as I remember it, was eight minutes. It was in exact agreement with the time determined in the earlier observations; and that same time has been used in the reduction of all observations.

Q. What was that time, Mr. Moore?

A. I think it was about eight minutes. That is my recollection of it.

Q. How do you determine that?

A. By a comparison of the elevations on the gages with the automatic record. The stage line on each gage appears as a wavey line on the gage record. Peaks will appear on both gages, and the time between those peaks is scaled off the record. It is very determinate.

Q. What is the time from the Buffalo gage to the Open Section?

A. I should judge that to be about ten minutes. I have never made any measurements there.

Q. Have you read the testimony of Mr. Schoder and Mr. Turner in this case?

A. I have.

Q. Do you have in mind the tests that they say they made of the Haskell current meter?

A. I have, yes, sir.

Q. What is your opinion as to the value to be given to those tests as testified to by them, as a criticism of the Haskell current meter?

A. Judging by the photographs in evidence I should say that they were exceedingly lucky in obtaining an agreement between the weir and current meter anywhere near as good as they did. The sections as indicated on these photographs are sections which are absolutely unfitted for current meter measurements. Any person with experience in stream measurements with a current meter would never attempt to determine the flow of a stream in that condition, with a meter. According to Mr. Turner's testimony, the meter was vibrating both in a vertical and in a horizontal plane.

The measurements on the lower sections should have been in closer agreement to that determined by the weir, provided the error lay in the current meter. The fact that it does not would be an indication to me that the error lay in other elements than in the current meter.

The determination of the cross section under conditions of, that kind where as Mr. Turner testified the fluctuation of the water surface in the form of waves amounted to as much as .2 of a foot, would be exceedingly difficult, and might easily be in error by as much as 10 per cent. The determination of velocity co-efficients in a stream only 3 feet deep, is practically out of the question.

The indications as given by the weir, I do not believe show the actual, true flow. That is I would say I believe there is a possible error in the weir due to the method of calibration, and to the uncertainty of weir measurements in general. The observations, as I see them would tend to throw no discredit whatsoever on the meter measurements, but rather should add credit to the performance of the Haskell meter.

Q. Upon what in detail do you base your statement that you think there may be error in the weir measurements?

A. The weir was calibrated, as I understand it, by comparisons with another weir, by indirect comparisons with another weir, through a third weir, and the introducing of those two steps with an uncertainty in the calibration of the original weir would introduce further error into the determination of the weir used in determining the volume.

Q. Did you state whether or not there was any greater

precision in those tests further down stream where the water was in better condition than there was up near the baffles?

A. I stated that if the error lay in the current meter, those measurements down stream should show a more close agreement with the weir than those up stream. Judging by the photographs the water there was not in quite such a high state of perturbation. Mr. Schoder's testimony is to the effect that there is no appreciable law between the discrepancies shown in the distance from the baffles, and that appears to be the fact, in looking over the tests.

Q. I call your attention to vertical curves introduced by Mr. Turner of certain observations in the St. Mary's River. In your opinion do those curves and the deductions that he drew from them, have any effect upon the accuracy of the Haskell current meter or of the processes of river gaging?

A. The deductions drawn by Mr. Turner from those curves which he presents appear to me to be entirely unjustified by the observations. The curves which he has shown are plotted as absolute velocities, and there is no data to show that the discharge of the river when those curves were measured,—when each curve was measured, was the same; the indications are that it was not. The change in the flow of the river would of necessity change the absolute velocity, and the curves should show a divergence. The use of a second meter, which is customary in all the more recent work, and much of the previous work; in fact I believe it was only on one or two sections of the St. Mary's River that one meter only has been used, would have brought these curves together, undoubtedly.

If these curves should be reduced as percentage velocities instead of absolute velocities, it will be found that they do come together, by dividing each observation by the velocity at any one point on the curve, preferably the four-tenths and five-tenths depth.

The fact that the curves do diverge is merely the result of plotting velocities instead of percentage velocities, and it has no bearing on the accuracy of the work done on any of the other rivers or in the St. Mary's River at this particular station.

Q. From your study and work in the St. Clair River, do you have any opinion as to whether or not there has been a change in regimen in the St. Clair River?

A. I believe there have been minor changes in the regimen of the St. Clair River, since measurements were first

made there, but I do not believe that those changes have been of sufficient size to affect appreciably the volume of flow, or the increment as derived from the observations.

Q. Do you believe any large change of regimen occurred about 1890?

A. I can see no evidence of any large change of regimen in 1890 or in any of the years preceding, so far back as our records go.

Q. Have you been present and did you hear all of Mr. Ray's testimony?

A. I did.

Q. Did you hear his statement of the methods used by Mr. Williams in computing an increment from the observations?

A. I did.

Q. What is your opinion as to those methods?

A. I am unable to see how the stage preceding an observation by 24 or 36 hours or the stage following an observation can have any bearing whatsoever on the volume of flow at the time that the measurement was actually made. The fluctuation of the lake during that period, in my opinion, would be sufficient to render that method entirely erroneous. The result of the method would be to flatten the elevation at the lake, that is to reduce the elevation at the lake corresponding to the higher discharges, and to raise the elevation of the lake corresponding to the lower discharges, and hence to give an increment which would be larger than that shown by the observations.

The method of weighting the observations it seems to me is an entirely arbitrary method. I am unable to see any justifications for it. The weighting of observations tends to eliminate observations. Observations can be weighted to produce almost any result desired, if the weights are sufficient.

Q. What in your opinion is the relative value of an increment determined by a ratio of fluctuations between the lakes and an increment determined from a measurement of the river which empties the lake in question?

A. The determination of an increment from the relative fluctuations of the lakes is in general a rough check on that determined by actual observations in the outflow river, but in my opinion it is nothing more than a very rough check, and should not bet substitued for actual observations.

It is a deduction based on facts which are complicated

by various causes, and the result reached from a consideration of these facts cannot be compared in accuracy with that determined by actual observations.

Q. You have already testified as to a method of determining an increment at the Niagara River with reference to gages at the Whirlpool and Suspension Bridge; and in so doing you use a ratio of fluctuations, do you not?

A. Yes, sir.

Q. In what way are they different from the ratio of fluctuations from lake to lake?

A. The fluctuations of a gage in the Niagara River, or in the St. Lawrence River, are the result of the fluctuations in the elevation of the lake surface. The elevation of the lake surface determines the flow through the river, and the flow of the river determines the elevation of the gage on the river, on the lower pools.

In the case of the relative elevations of two of the lakes, the water surface elevation on one lake is only indirectly a function of the elevation on the other lake. The peak on Lake Erie is not caused by the peak on Lake Huron, because it occurs earlier in the year. It is probably the result of local supply.

In the case of a river, the local supply is infinitesimal in its effect on the gage relation. In one case the relation is well defined and definite, and in the other it is at best uncertain.

Q. In determining the ratio of fluctuation in the rivers themselves, that is only in the open season too isn't it?

A. Only the open season is used in determining the relationship between gages on the rivers, because ice effect would interfere with the law of relationship in the winter time.

Q. Now could you do the same thing, use the open seasons as between the lakes?

A. It would be possible to use only the open seasons between the lakes. There is a question as to whether you would gain very much from it on account of the large time interval probably existing. The knowledge of that is a theoretical consideration, which has been satisfactorily worked out, but it is still theoretical, and the relationship cannot in any way be anywhere near as intimate as it is in the case of a gage on a river in which there is no local storage, or anything of that kind.

Q. That is the reservoir effect of the lake?

A. Yes.

Q. When you say that it is a question whether you would gain much by taking the open season, do you mean gain much from taking the whole year as between the two lakes?

A. I mean that there would be a question in my mind at least as to whether the mean of the open season on two lakes expressed a true relationship between the lakes any better than a mean of yearly means.

Q. My point is whether you were comparing the open season with the whole year on the lakes, or whether you were comparing the open season on the lakes with the open season on a river?

A. I was comparing the open season on the lakes with the full year on the lakes.

Q. Having in mind the measurements of discharge of the three rivers, St. Clair, Niagara and St. Lawrence, do you see any inconsistencies in those measurements?

A. From what study I have given to the subject, I can see no large inconsistencies in the volume of flow of the three rivers.

Q. Now, Mr. Moore, calling your attention again to your work on the Sanitary District Canal near Chicago in December, 1913, just what did you do?

A. I measured the amount of water flowing through the Sanitary Canal at Lemont from the Stevens street bridge, between December 16 and December 22.

Q. How was the flow in the canal distributed?

Mr. Austrian: I move the answer be stricken out. It is a conclusion of the witness and not stating facts; upon the further ground that the answer is not responsive to the question.

Q. For how long a period of time were you engaged in that work, Mr. Moore?

A. We made observations on six days, usually from about nine o'clock in the morning until five in the afternoon. On one afternoon, the work was continued until seven o'clock; and on one night, the work was continuous throughout the night.

Q. About how many observations a day did you make?

A. The measurement of flow was practically continuous. The observations have been grouped covering periods of about 30 minutes, into 96 observations.

Q. With reference to the time of day, was there any difference in the flow?

A. The flow during the day time was decidely less than it was during the night hours.

Mr. Austrian: I move the answer be striken out as irresponsive, as stating a conclusion of the witness.

Q. How much difference was there, in a general way, Mr. Moore?

A. Roughly, about 1500 cubic feet per second.

Mr. Austrian: I move the answer be stricken out as stating the conclusion of the witness, and embodying a qualification not known to the law.

Mr. Hopkins: Q. Did you make any tests in that canal to determine the lag, or the time within which a crest would travel in the canal?

Mr. Austrian: I object to the form of the question as calling for the conclusion of the witness. I have no objection to the witness stating what he did; but asking whether or not be made any tests calls for a conclusion.

Mr. Hopkins: My question is did you make any, yes or no?

A. Yes.

Q. Just what did you do?

A. I read two gages, one at Lemont and one at Willow Springs, and compared the resulting elevations with respect to the time at which abrupt changes in the elevation took place.

Q. How far apart were those points?

A. About 7.8 miles.

Q. What was the result of your experiments?

A. The change in elevation was felt at Willow Springs about 30 minutes after it was felt at Lemont, due to changes below Lemont.

Mr. Austrian: Q. Mr. Witness, did you read both of those gages yourself?

A. I did not.

Mr. Austrian: I move that the testimony of the witness be stricken out as hearsay testimony.

Mr. Hopkins: Q. Would that same rate apply to other distances in that canal?

A. I believe it would.

Mr. Austrian: I move the answer be stricken out, as the witness has shown no knowledge on the subject, but gives his belief.

Mr. Hopkins: Q. Who was with you in that work?

A. Junior Engineer, A. B. Jones, of the Lake Survey and Recorder Harry Whittelem of the Lake Survey.

Q. Now in making these experiments as to the lag, that you have just mentioned, just what individuals took part in that, and what did each one of them do?

Mr. Austrian: I object to the form of the question, unless it is shown he was present and observed each one of the parties in question.

Mr. Hopkins: Q. Just who did the different things?

A. The gage at Willow Springs was read by Mr. Whittelem. The gage at Lemont was read by myself and by Mr. Jones.

Q. Were you in charge of this work?

A. I was.

Q. Was it done under your instruction and under your supervision?

A. It was.

Q. What caused these changes in elevation that you have spoken of?

A. The changes in the load on the power house at the lower end of the canal, and changes in the waste gates.

Q. Were the results of those observations put into a report by you and turned over to your superior officer?

A. They were.

Mr. Adcock: I move that be stricken out as immaterial.

Mr. Hopkins: Q. Is it a part of the records of the Lake Survey Office?

A. It is.

Mr. Adcock: I move that be stricken out as immaterial.

Mr. Hopkins: Q. Have you got that record?

A. Not here.

Q. Where is it?

A. It is in the files of the Lake Survey Office.

Q. Have you got a copy of that?

A. I have a portion of it.

Q. Have you the portion covering these observations with reference to lag?

A. I have.

Mr. Hopkins: Mr. Adcock, is there any objection on the gound that it is a copy rather than the original?

Mr. Adcock: No, if it is a complete copy.

Mr. Hopkins: Q. Have you a complete copy of the report as far as it pertains to these observations in reference to the lag?

A. I have.

Mr. Hopkins: Is there any objection on the ground that he is testifying to a copy rather than the original? If there is we will send down and get the original.

Mr. Adcock: No, not on that ground. I make the objection to the report going in. He can testify as to what was done in connection with that work.

Mr. Hopkins: Q. Will you refer now to the copy of the report that you have with reference to this particular matter, and tell us what results you obtained?

Mr. Austrian: I would like to ask the witness a question with reference to the report before he answers.

Mr. Hopkins: Go ahead.

Mr. Austrian: Q. Mr. Witness, the report that you refer to that was made, went to your superior officer after the completion of the work?

A. Yes, sir.

Q. That pertained to the Drainage Canal, between December 16 and 22, 1913?

A. Yes.

Q. And was all done pursuant to the direction of your superior officer that you referred to in your testimony in this connection?

A. It was.

Q. It was all a part of the same general direction and instruction referred to?

A. Yes.

Q. That is all the work you did pursuant to that direction and instruction?

A. Yes.

Q. And the entire report that you made to your superior officer was made shortly after you returned from that inspection and measurement and performance of the duty that you have just referred to?

A. Yes.

Q. And the entire report bears upon the whole observation, experiments, etc., taken in that connection, does it not?

A. No, it does not.

Q. Does it refer to anything other than the Drainage Canal of the Sanitary District of Chicago?

A. No.

Q. It all refers to the Sanitary District of Chicago, and was made to incorporate your observations, and the experiments that you have testified to?

A. Those were incorporated.

Q. What else was incorporated?

A. There were certain recommendations in regard to future—the best method of doing work in the future, provided we were called upon to do it.

Mr. Hopkins: Q. As appears in the report that you made in connection with those observations, which is a part of the record of the Lake Survey Office, what results did you obtain from the observations with respect to the lag from Willow Springs to Lemont, or vice versa, between those points?

A. Between 25 and 30 minutes.

Q. In your opinion will that same rate apply to the entire length of the Sanitary District Canal?

A. It will.

Q. Suppose the Sanitary District Canal is flowing 4,167 cubic feet of water in the direction of Lockport, and it is desired to open it to an extent so that it will take care of 10,000 cubic feet a second and flow it towards the town of Lockport, in what length of time can it be done?

A. The observations show that the change travels about a mile in four minutes. Applying this to the length of the canal would indicate that the effect would be felt at Lake Michigan in about 2 hours and 25 minutes. It is probable that the full effect might be a little behind this, but it is very certain that the time would not exceed three hours.

Q. You are familiar are you not with the canal itself?

A. I am.

Q. And the regulating gates down near Lockport?

A. I am.

Q. You had that in mind when you gave that opinion?

A. I did.

Q. Now in this work at Lemont, what was the area of the cross section which you obtained?

A. Approximately 4,000 square feet.

Q. And what instruments did you use in measuring the velocity?

A. I used two Haskell meters.

Q. Do you have there your blue prints showing the results you obtained, showing the volume of discharge?

A. I have, yes, sir.

Mr. Hopkins: I offer in evidence as Moore's Exhibits, 1, 2, 3, 4 and 5, the blue prints showing discharge measurements; the first four showing discharge measurements and the fifth showing the mean daily discharge.

(Whereupon blueprints offered in evidence were marked Moore's Exhibits 1, 2, 3, 4 and 5, February 5, 1914.)

MOORE'S EXHIBIT 1, FEB. 5, 1914.

Table 2.
In 4 Sheets.
Sheet 1.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter.
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.500
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
1	Dec. 16	15:23–15:46	15-B	1.64	1.49	4015	5982	580.04		576.99	3.05		SW	8
2		15:47–16:18	15-B	1.71	1.55	4023	6236	580.04		577.04	3.00			
3		16:18–16:49	15-B	1.65	1.49	4024	5996	580.04		577.05	2.99			
4	Dec. 17	10:06–10:36	10-B	1.86	1.68	3585	6527	579.84		576.19	3.65			
5		10:36–10:58	10-B	1.84	1.67	3558	6493	579.84		576.21	3.63		W	20
6		11:37–12:07	10-B	1.82	1.65	3901	6437	579.74		576.29	3.45		W	20
7		13:14–13:34	15-B	1.68	1.52	3964	6025	579.78		576.68	3.10			
8		13:38–14:09	15-B	1.65	1.49	3974	5921	579.84		576.74	3.10			
9		14:09–14:46	15-B	1.70	1.54	3982	6132	579.95		576.79	3.16			
10		15:16–15:39	10-B	1.68	1.52	4013	6100	580.04		576.98	3.06		W	8
11		15:40–16:05	10-B	1.82	1.65	4023	6638	580.04		577.04	3.00			
12		16:07–16:27	10-B	1.68	1.52	4029	6124	580.04		577.08	2.96			
13		16:27–16:47	10-B	1.60	1.45	4032	5846	580.04		577.10	2.94			
14	Dec. 18	9:21– 9:43	10-B	2.06	1.87	3725	6966	580.19		575.20	4.99		N	6
15		9:50–10:13	10-B	1.97	1.78	3751	6677	580.24		575.36	4.88			
16		10:16–10:39	10-B	1.93	1.77	3772	6676	580.25		575.49	4.76			
17		10:47–11:08	10-B	1.89	1.71	3793	6486	580.24		575.62	4.62		NW	2
18		11:09–11:26	10-B	1.83	1.66	3813	6328	580.20	576.21	575.74	4.46	0.47		
19		11:37–12:01	10-B	1.75	1.58	3841	6069	580.15	576.32	575.92	4.23	0.40		
20		12:02–12:23	10-B	1.71	1.55	3867	5994	580.10	576.40	576.06	4.02	0.32		
21		13:31–13:56	15-B	1.65	1.49	3940	5871	580.20	576.90	576.53	3.67	0.37	N	4
22		13:57–14:21	15-B	1.71	1.55	3961	6140	580.26	576.96	576.66	3.60	0.32		
23		14:35–14:57	15-B	1.76	1.60	3976	6322	580.32	577.06	576.75	3.57	0.33		
24		14:58–15:20	15-B	1.70	1.54	3988	6142	580.38	577.17	576.83	3.55	0.34		

Sherman Moore.

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MOORE'S EXHIBIT 2, FEB. 5, 1914.

Table 2.
In 4 Sheets.
Sheet 2.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter.
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 96—601.560
U. S. P. B. M. 114—604.121
U. S. P. B. M. 120—602.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
25	Dec. 18	15:23-15:45	15-B	1.67	1.51	4010	6055	580.40	577.24	576.96	3.44	0.28	N	4
26		15:46-16:05	15-B	1.64	1.49	4023	5994	580.44	577.33	577.04	3.40	0.29		
27		16:06-16:24	15-B	1.62	1.47	4038	5923	580.44	577.38	577.08	3.36	0.30		
28		16:24-16:45	15-B	1.62	1.47	4036	5933	580.44	577.46	577.12	3.32	0.34		
29	Dec. 19	9:58-10:23	10-B	1.79	1.62	3917	6346	579.98	576.79	576.39	3.59	0.40	SW	12
30		10:23-10:49	10-B	1.71	1.55	3938	6104	580.02	576.86	576.52	3.50	0.34		
31		10:50-11:27	10-B	1.78	1.61	3940	6343	580.04	576.96	576.53	3.51	0.43		
32		11:28-11:56	10-B	1.78	1.61	3943	6348	579.88	576.97	576.55	3.33	0.42		
33		12:06-12:36	15-B	1.53	1.39	4011	5575	579.78	577.27	576.97	2.81	0.30		
34		13:37-14:01	15-B	1.51	1.37	4016	5502	579.74	577.28	577.00	2.74	0.28		
35		14:07-14:30	15-B	1.54	1.39	4032	5604	579.78	577.37	577.10	2.68	0.27		
36		14:30-14:55	15-B	1.53	1.38	4037	5571	579.90	577.42	577.13	2.77	0.29		
37		15:01-15:20	15-B	1.48	1.34	4047	5423	579.94	577.46	577.19	2.75	0.27	SW	8
38		15:21-15:34	15-B	1.48	1.34	4062	5443	579.94	577.53	577.28	2.66	0.25		
39		15:58-16:21	15-B	1.50	1.36	4073	5539	579.94	577.60	577.35	2.59	0.25		
40		16:22-16:37	15-B	1.49	1.35	4076	5503	579.94	577.64	577.37	2.57	0.27	SW	4
41	Dec. 20	9:10- 9:33	10-B	1.88	1.70	3838	6525	580.16	576.37	575.90	4.26	0.47		
42		9:34-10:01	10-B	1.92	1.74	3854	6706	580.22	576.44	576.00	4.22	0.44		
43		10:14-10:29	10-B	1.89	1.71	3875	6626	580.31	576.57	576.13	4.18	0.44		
44		10:30-11:05	10-B	1.82	1.65	3886	6412	580.40	576.64	576.20	4.20	0.44		
45		11:14-11:47	15-B	2.04	1.85	3883	7184	580.44	576.73	576.18	4.26	0.55		
46		11:50-12:24	15-B	2.04	1.83	3886	7189	580.44	576.74	576.20	4.24	0.54		
47		13:44-14:16	10-B	1.37	1.24	4045	5016	580.44	577.25	577.18	3.26	0.07		
48		14:17-14:40	10-B	1.36	1.23	4066	5001	580.39	577.45	577.31	3.08	0.14		

Sherman Moore.

Table 2. In 4 Sheets.
Sheet 3.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter.
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.560
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
49	Dec. 20	14:40-15:07	10-B	1.32	1.20	4097	4916	580.34	577.62	577.50	2.84	0.12	N	6
50		15:07-15:34	10-B	1.30	1.18	4122	4864	580.34	577.77	577.65	2.69	0.12	N	6
51		15:35-15:59	10-B	1.49	1.35	4123	5566	580.34	577.91	577.66	2.68	0.25		
52		16:01-16:25	10-B	1.46	1.32	4131	5453	580.34	577.93	577.71	2.63	0.22	N	10
53		16:25-16:51	10-B	1.44	1.30	4156	5403		577.98	577.86		0.12		
54		16:55-17:00	10-B	1.88	1.70	4117	6999		578.06	577.62		0.44		
55		17:33-18:06	15-B	1.97	1.78	4071	7246		577.98	577.34		0.64	N	8
56		18:06-18:37	15-B	2.06	1.87	4065	7602		577.80	577.30		0.50		
57		18:37-19:13	15-B	2.03	1.84	4045	7443		577.75	577.18		0.57		
58		19:13-19:44	15-B	1.99	1.80	4031	7256		577.59	577.09		0.50		
59		19:44-20:15	15-B	2.03	1.84	4021	7399		577.56	577.03		0.53		
60		20:15-21:08	15-B	2.04	1.85	4005	7409		577.46	576.93		0.53		
61		21:28-21:58	10-B	2.15	1.95	3972	7745		577.30	576.73		0.57		
62		21:58-22:31	10-B	2.14	1.94	3961	7684		577.26	576.66		0.60		
63		22:31-23:04	10-B	2.11	1.91	3951	7546		577.20	576.60		0.60		
64		23:04-23:33	10-B	2.10	1.90	3941	7488		577.11	576.54		0.57		
65		23:33-24:04	10-B	2.08	1.88	3933	7394		577.05	576.49		0.56		
66	Dec. 21	0:04- 0:35	10-B	2.06	1.87	3928	7344		577.01	576.46		0.55		
67		0:35- 1:05	10-B	2.06	1.87	3919	7329		576.95	576.40		0.55		
68		3:04- 3:35	15-B	2.18	1.97	3890	7663		576.80	576.23		0.58	N	10
69		3:35- 4:06	15-B	2.14	1.94	3885	7537		576.79	576.19		0.60		
70		4:06- 4:37	15-B	2.17	1.97	3885	7653		576.77	576.19		0.58		
71		4:37- 5:08	15-B	2.12	1.92	3876	7442		576.74	576.14		0.60		
72		5:08- 5:39	15-B	2.14	1.94	3875	7518		576.73	576.13		0.60		

Sherman Moore.

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MOORE'S EXHIBIT 4, FEB. 5, 1914.

Table 2. In 4 Sheets. Sheet 4.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter.
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 90—591.560
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
73	Dec. 21	5:29- 6:10	15-B	2.13	1.93	3872	7473		576.72	576.11		0.61		0
74		6:10- 6:42	15-B	2.13	1.93	3868	7465		576.68	576.09		0.59		
75		6:42- 7:03	15-B	2.12	1.92	3867	7425		576.68	576.08		0.60		
76		7:03- 7:14	15-B	1.70	1.54	3928	6049		576.70	576.46		0.24		
77		7:14- 7:24	15-B	1.48	1.34	3980	5333		576.70	576.78		—0.08		
78		7:24- 7:46	15-B	1.18	1.07	4024	4306		576.92	577.05		—0.13		
79	Dec. 22	9:46-10:12	15-B	1.86	1.68	3961	6654	580.43	577.00	576.66	3.77	0.43		0
80		10:13-10:39	15-B	1.95	1.77	3953	6997	580.45	577.12	576.61	3.84	0.51		
81		10:39-11:05	15-B	1.95	1.77	3951	6993	580.44	577.12	576.60	3.84	0.52		
82		11:07-11:31	15-B	1.98	1.79	3953	7076	580.42	577.13	576.61	3.81	0.52		
83		11:31-11:58	15-B	1.98	1.79	3953	7076	580.38	577.12	576.61	3.77	0.51		
84		13:03-13:24	15-B	1.56	1.41	4045	5703	580.20	577.45	577.18	3.02	0.27	S	4
85		13:25-13:43	15-B	1.58	1.43	4040	5777	580.17	577.48	577.15	3.02	0.33		
86		13:47-14:08	15-B	1.62	1.47	4050	5954	580.14	577.53	577.21	2.93	0.32		
87		14:09-14:40	15-B	1.66	1.50	4060	6090	580.14	577.59	577.27	2.87	0.32		
88		14:44-15:03	15-B	1.64	1.49	4065	6057	580.14	577.62	577.30	2.84	0.32	S	4
89		15:04-15:37	15-B	1.57	1.42	4073	5784	580.14	577.66	577.35	2.79	0.31		
90		15:50-16:16	10-B	1.60	1.45	4091	5932	580.14	577.75	577.46	2.68	0.29		
91		16:17-16:47	10-B	1.55	1.40	4102	5743	580.14	577.80	577.53	2.61	0.27		
92		16:49-17:03	10-B	1.53	1.39	4102	5702	580.14	577.86	577.53	2.61	0.33	NNE	8
93		17:03-17:16	10-B	1.73	1.57	4100	6537		577.87	577.52		0.35		
94		17:17-17:49	10-B	2.20	2.07	4010	8301		577.74	576.96		0.78		
95		17:49-18:21	10-B	2.38	2.16	3969	8573		577.45	576.71		0.74		
96		18:21-18:53	10-B	2.26	2.06	3956	8170		577.34	576.69		0.65		

Sherman Moore.

MOORE'S EXHIBIT 5 FEB. 5, 1914

U S LAKE SURVEY

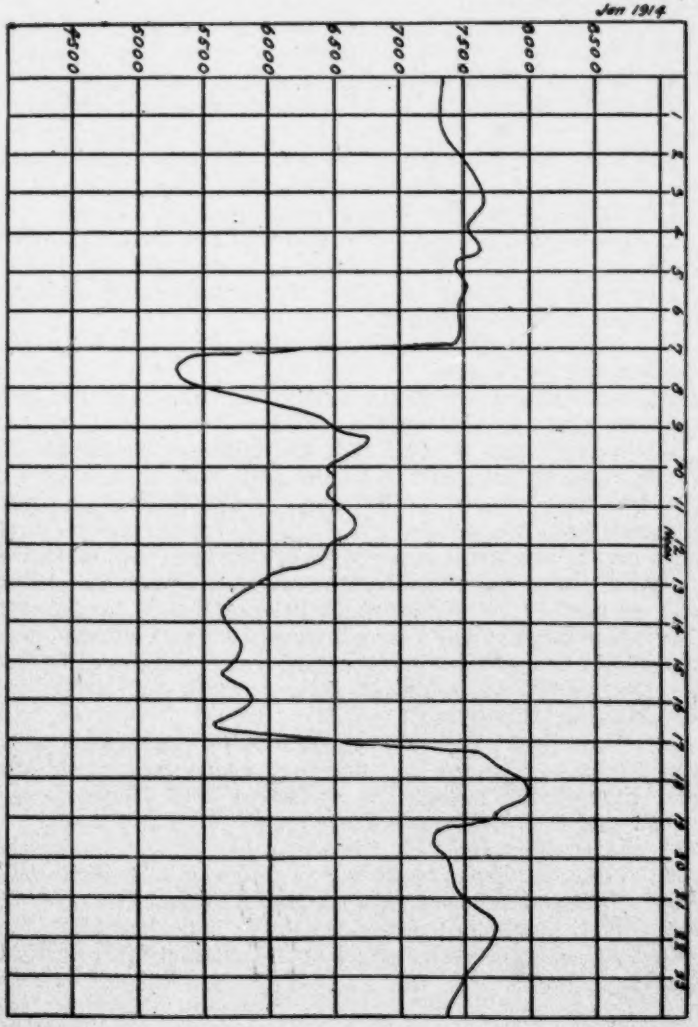
Plate 4.

CHICAGO DRAINAGE CANAL

Mean 24 Hour Curve of Flow

Lemont, Ill.

SHERMAN MOORE, Jun. Engr
Jan 1914.



Mr. Hopkins: Q. Mr. Moore, what do those exhibits show?

A. Exhibits 1, 2, 3, 4 are a tabulation of the measurements made in the Drainage Canal at Lemont in December. The first column is the number of the observation.

The second column is the date on which the measurements were made.

The third column shows the time of day on which the measurements were made.

The fourth column shows the number of the current meter used.

The fifth column gives the index velocity in feet per second.

The sixth column gives the mean velocity in feet per second.

The seventh column gives the area of the section in square feet.

The eighth gives the flow in cubic feet per second.

The ninth column is the elevation of Lake Michigan at Chicago.

The tenth column is the elevation of the water surface of the canal at Willow Springs.

The eleventh column is the elevation of the water surface of the canal at Lemont.

The twelfth column is the fall in the water surface from Lake Michigan to Lemont.

The next column is the fall in the water surface from Willow Springs to Lemont. And the last two columns give the direction and velocity of the wind at the time of the measurements at Lemont.

Exhibit 5, is a graphical representation of the flow through the canal during the week that measurements were made there, with respect to its distribution through the 24 hours.

Q. Mr. Moore, will you tell us in inches what the lowering effect upon Lakes Michigan and Huron, Erie and Ontario, as you compute it, would be of a diversion of 10,000 cubic feet of water at Chicago?

A. The effect of the diversion of 10,000 cubic feet at Chicago would be to lower the surface of Lakes Huron and Michigan about 5 1/5 inches; the surface of Lake Erie about 5½ inches, and the surface of Ontario about 5 inches.

Q. How about Lake St. Clair?

A. Lake St. Clair would be lowered about 5½ inches.

Q. How about the St. Clair and the Detroit Rivers?

A. They would be lowered about the same amount.

Q. Would it have any effect in the channel up towards the St. Mary River?

A. It would have an effect in the channel as far as the locks.

Q. And to what extent?

A. The lowering in the lower reaches of the St. Marys River would be the same as it on Lake Huron, 5½ inches. The lowering would diminish slightly as you went up the river.

Q. What do you think it would be at the locks approximately?

A. Probably in excess of 4 inches.

Q. For any other diversion at Chicago, from 1 to 14,000 cubic feet, would the lowering in the places mentioned be in the same direct proportion?

A. It would be directly proportionate.

Mr. Hopkins: That is all.

Cross-examination reserved.

SHERMAN MOORE, recalled for further examination, testified as follows:

Cross-Examination by Mr. Adcock.

Q. You received the degree of Civil Engineer in the University of Wisconsin in 1907?

A. Yes, sir.

Q. And you were graduated, I presume, from the Academic Department in 1902?

A. Graduated from the Civil Engineering Department in 1902, with the degree of Bachelor of Science in Civil Engineering. I received the master's degree of civil engineer in 1907.

Q. And from 1902 on, you were connected with the Lake Survey?

A. I have been connected with the Lake Survey since 1902.

Q. That is immediately after you graduated from college, you came with the Lake Survey?

A. I did.

Q. And the first work, first measurement of streams you did was in 1907 and '08 on the Niagara River. Is that correct?

A. That is right.

Q. Prior to that time you had been doing what? What were your duties?

A. In 1902, I had charge of the triangulation on the St.

Lawrence River, in connection with a resurvey of the river; and also did a large amount of topographical surveying.

In 1903 and 1904, and part of 1905, I was connected with the primary triangulation from the Straits of Mackinaw to Lake Erie, and did all of the reconnaissance work and station building.

In the latter part of 1905, I made topographical surveys including some triangulation, on Sandusky Bay and the Portage River. And in 1906, I assisted on the resurvey of the Niagara River, having charge of the triangulation the redetermination of the crest line of the falls and soundings above the rapids.

Q. In your triangulation work, did you have charge of the party?

A. I did not have charge, technically.

Q. Who was your superior, immediate superior?

A. On the primary triangulation, Mr. H. F. Johnson.

Q. And in 1907 and 1908, you assisted in the gaging on the Niagara River?

A. In 1907, and 1908, I had charge of all of the hydraulic work, the investigations on Niagara Falls.

Q. And that consisted partly in gaging the Niagara River?

A. In part.

Q. At the International Bridge Section?

A. In part.

Q. And the Open Section?

A. No.

A. Not at the Open Section.

Q. Not at the Open Section?

Q. That was the first work you did in connection with stream gaging?

A. The first work I did in connection with stream gaging was to measure the flow through the canal of the Hydraulic Power Company.

Q. That was in the same year?

A. That was in the same year.

Q. And you had charge of that work as well as the work on the Niagara at the bridge section?

A. I did.

Q. Was anyone else connected with you in that work?

A. Mr. Richmond was my first assistant.

Q. What was your title then?

A. Junior Engineer.

Q. What was the next work you did in stream gaging?

A. May I ask after what?

Q. The next?

A. After what?

Q. What we have been talking about. The work at the Niagara River, that is the last thing we have talked about.

A. The last thing we talked about was something else.

Q. No, it was not. It was the Niagara River, Bridge Section?

A. In the fall of 1908 I made measurements on the St. Clair River.

Q. Where?

A. Section Gorge and Section Dry Dock.

Q. And then what was your next work in stream gaging?

A. In 1909, I measured the flow in the canal of the Niagara Falls Power Company, determining the efficiencies of the turbines and deriving the limitations under which they operated.

Q. You had charge of that work?

A. I had charge of that work.

Q. What was the next work you did in connection with stream gaging?

A. That same summer, I measured the flow through the canal of the Hydraulic Power Company and determined the maximum output for their plant under the limitation of water prescribed by the Secretary of War. In the fall of that year I continued measurements—

Q. On the same river?

A. I continued measurements on the St. Clair River. I neglected to state that in 1908, I made measurements on the St. Lawrence River.

Q. Instead of the St. Clair?

A. In addition.

Q. And the last work you mentioned on the St. Clair River, where was that done?

A. In both Sections Gorge and Dry Dock.

Q. What was the next work you did in connection with stream gaging?

A. In the spring of 1910, I resumed measurements on the St. Clair River at both Section Gorge and Section Dry Dock, and established the hydraulic sections in the Delta, making some measurements on them. I had charge of the work in 1910, until the first of July, when I was transferred to other work.

Q. Since that time, have you done any stream gaging?

A. In December of 1911, I made measurements in the canal of the Hydraulic Power Company and determined the maxi-

mum output under the conditions under which they were then operating.

Q. That is at Niagara?

A. The Hydraulic Power Company at Niagara Falls.

In December of 1913, I measured the discharge of the Drainage Canal at Lemont.

Q. And in all this work of stream gaging, you had charge of the work, as I understand it, since 1907, when you commenced on the Niagara River?

A. In all of the stream gaging that I ever did, I had charge of the work.

Q. What is your title now?

A. Junior Engineer.

Q. That is the Lake Survey?

A. United States Junior Engineer.

Q. From whom did you receive instructions as to the method of gaging streams?

A. My knowledge of the methods which I employed in gaging streams has been derived from a study of the method employed by Mr. Shenehon on the Niagara and St. Lawrence Rivers, by Mr. Sabin on the St. Clair River; by the Geological Survey, and various other sources.

Q. Did you receive any instructions, while you were obtaining your master's degree, and B. S. degree?

A. Very slight instruction.

Q. That is while in college, or in your work at Wisconsin?

A. Very slight instruction.

Q. What instruction did you receive or what studies did you make at that time?

A. I don't believe that I can remember very definitely what was done. I remember of rating the Haskell meter, rating the Price meter and measuring in a rather crude way the flow of a small stream there. The instruction was about that given by most engineering schools, which is very slight.

Q. What did you learn from the study of the Geological Survey work?

A. I have employed their methods to some extent in certain work in connection with work in power canals. It has influenced to some extent the method which I have developed.

There is one matter that I omitted in my answer to that question in regard to the measurements I had made. I neglected to state that in 1909 I measured the flow of the St. Marys River from the International Bridge at the Soo, and the flow through the three power canals there.

Q. Do you remember the name of the stream in Wiscon-

sin which you measured before you entered the Lake Survey?

A. I believe it is called the Yahara River.

Q. That is the only work that you had done in that connection?

A. That is the only work that I did there.

Q. Or in measuring streams, before you entered the Government service?

A. Or measuring streams before I entered the Government service.

Q. What was the size of that stream? Do you remember?

A. I don't remember exactly. It was somewhere in the neighborhood of 40 or 50 feet wide and 1 to 3 feet deep, I believe.

Q. In your stream gaging, you have used the Haskell meter?

A. In the larger part of my work, I have used the Haskell meter, because I believe it the only accurate meter on the market to-day. I have also used the Price meter, under certain conditions.

Mr. Adcock: I move to strike out that portion of the answer which states: "Because I believe it to be the only accurate meter in use to-day." It is not responsive to the question.

Q. Now, you say in fitting yourself to measure streams, you studied the work of Mr. Shenehon and Mr. Sabin?

A. I did.

Q. Did you study the work of anyone else outside of them, in connection with the Geological Survey that you mentioned?

A. I do not recall any names. I am familiar with a large part of the work done by the Geological Survey.

Q. I asked you outside of the Geological Survey?

A. I misunderstood your question.

Mr. Adcock: If you will follow the questions, we may get along better, Mr. Witness.

Q. What type of Haskell meter did you use in connection with your work in stream gaging?

A. Principally the B type, although I used the A type to some extent.

Q. To what extent?

A. I used an A meter in the measurements from the International Bridge at Buffalo, and in the first two seasons work on the St. Clair River; I believe it was the first two seasons; in the first season anyway. I am not certain about the second.

Q. And since that time, you have not used the A meter?
A. I have not used the A meter.
Q. What tests did you make of the Haskell meter before you entered upon your work of gaging the Niagara River at the bridge section?
A. I don't understand what you mean.
Q. How did you happen to use that meter?
A. I used that meter because that meter was furnished me by the Lake Survey.
Q. Did you make any soundings in the St. Clair River at the Gorge Section?
A. I have.
Q. You used the same apparatus that Mr. Richmond described that he used in his work?
A. Substantially the same.
Q. In what particular was it different?
A. Simply in minor particulars, which I do not recall at the present time, unimportant particulars.
Q. Did you use the same weight?
A. Used the same weight.
Q. Same size?
A. Same size.
Q. Did you observe the inclination of the sounding wire at the Gorge Section?
A. I did.
Q. Did you do any soundings in the Niagara River?
A. I made soundings in the Niagara River.
Q. Where?
A. At the International Bridge and spans 1, 2, 3 and 4 on the American side.
Q. How frequently were the soundings made?
A. I don't remember.
Q. Well, was it two feet apart?
A. I don't remember.
Q. Have you any notes with reference to that?
A. There is a record in the office.
Q. Could you get hold of those notes and refresh your recollection?
A. I can in about an hour's time, probably.
Mr. Adcock: I presume that you will have to get them, then, and have them here.

Recess to 2:15 P. M.

February 19, 1914, 2:15 P. M.

SHERMAN MOORE, resumed the stand and testified further, as follows:

Mr. Adcock: Q. How frequently as an average were soundings made on the Bridge Section?

A. The soundings at the International Bridge Section were on the average about 20 feet apart in the resounding. No attempt was made to determine definitely the new cross section. The idea was simply to determine whether there had been any scour, and a few soundings were taken at intervals of about 20 feet across each span.

Q. In what panels were those?

A. Panels 1, 2, 3, and 4.

Q. What was the greatest depth?

A. The greatest depth was about 48½ feet.

Q. What stage was that referred to?

A. 567.24 at the section gage.

Q. In what panel was this deepest point, 48½ feet?

A. The middle panel in span 4.

Q. About the middle of the panel of 4?

A. It occurred in the middle panel in span 4.

Q. What is the number of the panel?

A. The index point I believe was known as 4 6/12ths.

Q. The index point? Read the question.

Mr. Hopkins: What does that 4 6/12ths mean?

A. It means that the index point for that panel was in the fourth span and 6/12ths of the distance across the span.

Mr. Adcock: Q. But you did not number the panels?

A. No.

Q. What was the inclination of the sounding wire?

A. That I could not say at the present time. I have not found that notebook yet.

Q. What have you got?

A. I think I can answer what you want to know in regard to the St. Lawrence River.

Q. You are still searching for your other records, are you?

A. Yes.

Q. You can take that up later then? Did you do any soundings in the St. Lawrence River?

A. I made soundings on the St. Lawrence River from stations 4 to 14, inclusive.

Q. And there were 17 in all, were there?

A. There were 17 in all, I believe.
Q. On what section?
A. Section Three point.
Q. Same place that Mr. Shenehon sounded in his early work?
A. Practically the same.
Q. When you say "practically," what do you mean?
A. There was some slight uncertainty in reproducing the section. Some of the old monuments were not definitely found. The soundings were probably within two or three feet of the old section.
Q. What was the depth, maximum depth?
A. The greatest sounding when reduced was about 56 feet.
Q. That was referred to what stage?
A. 225.88 by Mr. Shenehon's level reduction. I believe that is about .06 of a foot different from the 1903 reduction.
Q. What was the weight used?
A. Cast iron sounding weight of 140 pounds approximately.
Q. What was the inclination of the sounding wire at that point?
A. 13 degrees.
Q. What was the mean velocity in that vertical, or the index velocity if you have it, either one?
A. I haven't the mean velocity, but it is about 5½ feet per second.
Q. That is the mean?
A. That is somewhere in the neighborhood of the mean.
Q. Have you the index velocity?
A. That is the index velocity.
Q. What was the inclination of the meter cable at that vertical?
A. About 30 degrees.
Q. Is that the .9 depth or bottom?
A. That is .4 depth.
Q. What was it at the .9 depth?
A. I made no observations there.
Q. You did not do any co-efficient work there?
A. No.
Q. What was the meter used?
A. The meters used were type B, Haskell meters, with 40-pound leads.
Q. That was the same weight that was used by Mr. Richmond at the Gorge Section at the St. Clair?
A. It was not. Mr. Richmond used 140 pound weights.
Q. And the same weight that you used on the Niagara?

A. It was the same weight.
Q. Which was the 140 or the 40 pound?
A. 40 pound.
Q. Have you a vertical there where you made soundings, and the deflection of the sounding wire was approximately 10 degrees?
A. (No response.)
Q. Did you use the same size sounding wire on the Niagara and St. Lawrence that was used by Mr. Richmond, that he described yesterday, in connection with the Gorge Section?
A. I believe so.
Q. And similar to the one that he used in the Split Section?
A. I believe so.
Q. Do you know whether Mr. Shennehon used the same size wire, sounding wire?
A. I don't know that he used the same size wire, but I believe that he did, wire that was closely comparable.
Q. That is your best recollection?
A. Yes.
Q. (Question read as follows: "Have you a vertical there where you made soundings and the deflection of the sounding wire was approximately 10 degrees.")
A. That seems to be the case on vertical 8.
Q. What was the depth there?
A. 50 feet.
Q. What was the deflection of the meter cable at the .4 depth?
A. Approximately 28 degrees.
Q. What was the index velocity?
A. About 5½ feet per second.
Q. That was approximately the same as the other vertical that you just mentioned?
A. Not materially different.
Q. How nearly correct is that index velocity that you gave?
A. That index velocity that I gave is the velocity to the nearest half foot which I happened to pick off of a certain discharge measurement.
Q. Can you give any more accurate statement as to the index velocity at that point?
A. I can average these 30 discharges, or I can give you the actual velocity when the angle was 28 degrees.
Q. All right, give us that?
A. I will have to get the rating tables to do that.

Q. What was the size of the meter cables used in these different places?

A. The size of the meter cables vary. At certain places it was one size and at other places it was another.

Q. Did you use the same size on all the meters on the St. Lawrence gagings?

A. I could not say. There is no record kept of the size of the cable.

Q. How about the Niagara gagings?

A. There was no record kept.

Q. Or the St. Clair gagings?

A. There has never been a record kept of the size of the cables.

Q. Did you use a different sized cable on the A meter from what you used on the B meter?

A. I am unable to say. No record was kept. There was no intention to use a larger cable on the A meter than there was on the B meter.

Q. You had charge of the St. Lawrence gagings and the Niagara gagings, did you not?

A. I did.

Q. Have you any recollection about that?

A. My recollection is that there were two sizes of cables in use. They would be used indiscriminately with the meters. The meters would be used first on one side and then on the other. The size of the cable would vary every time a new core wire was put in, and the matter seemed to have so exceedingly little importance that no record was ever made of it.

Q. Did you ever make any investigations as to that question, as to the importance of the meter wire, size of it?

A. No, I never did.

Q. You don't consider then that the size of the meter cable would have anything to do with the deflection of the meter cable when the meter was submerged?

A. The size of the meter cable probably would influence to some extent the angle of deflection at the surface, but the influence would not be sufficient to change the correction to the depth by an appreciable quantity.

Q. And to what extent would it be influenced at the surface?

A. To a very much less extent.

Q. How many discharge measurements did you make on the St. Lawrence?

A. About 25 measurements.

Q. Take vertical 8, for instance, did you read the deflection of the meter wire, each time you took a velocity observation?

A. I did not.

Q. How many times did you?

A. I could not say. I find the record here of one or two times but they were not always recorded.

Q. How many records have you of meter wire deflections at that vertical?

A. I only find three such.

Q. You find three?

A. I find three.

Q. Give the deflections that you find there, and the index velocities corresponding to the deflection?

A. I believe there are more than three here. I find here five observations of the deflection of the meter cable on Station 8.

Q. Have you the index velocities corresponding?

A. With an index velocity of 5.40, there was an observed angle of 28 degrees. With an index velocity of 5.55, there was a deflection angle of 30 degrees. With an index velocity of 5.54, there was a deflection of 30 degrees. With a velocity of 5.50, there was a deflection of 30 degrees. With a velocity of 5.63, there was a deflection of 27 degrees.

Q. All with the B meter, were they?

A. They were all B meters. They were not the same meters.

Q. The same Haskell meter, B Haskell meter?

A. Same design of meter.

Q. And the same weights on each meter?

A. Same weight on each meter.

Q. What was the number of the vertical where that was 56 feet?

A. Vertical 9.

Q. Referring to vertical 9, give us the same information as to that?

A. I find four observations of the deflection angle at station 9. Wtih a velocity of 5.64, the deflection was 32 degrees. With a velocity of 5.76, the deflection was 31 degrees. With a velocity of 5.60, the deflection was 31 degrees. With a velocity of 5.85, the deflection was 32 degrees.

Q. Have you another vertical there besides the one you

have mentioned, where the deflection of the sounding wire was 10 degrees?

A. I see no other vertical at which the deflection was exactly 10 degrees.

Q. How near?

A. There is one here 9 degrees, vertical 7.

Q. Give us the same information as to the deflection of the meter wire, and the index velocity, on vertical 7; and also the depth?

A. I find five observations of the deflection of the meter cable on station 7. With a velocity of 5.48, the deflection was 25 degrees. With a velocity of 5.57, the deflection was 26 degrees. With a velocity of 5.64, the deflection was 27 degrees. With a velocity of 5.79, the deflection was 27 degrees. With a velocity of 5.60, the deflection was 26 degrees.

Q. What was the depth?

A. The depth at station 7, reduced to stage of 525.88, by the section gage was 43 feet.

Q. How frequently did you make soundings on the St. Lawrence River in this section?

A. Every 10 feet.

Q. What evidence of boulders did you find on the St. Lawrence Section, Three Point?

A. The soundings showed no evidence of any large boulders. There are occasional differences in the soundings of one and two feet in which the intermediate sounding is less than those on either side, which may indicate boulders.

Q. What evidence did you have as to the condition of the bottom of the Niagara River, as to whether there were boulders or other irregularities at the bottom of the Niagara River?

A. The sounding weight was moved about a foot on either side of the exact point; in some cases more than that, without showing any sudden increase or decrease in the depth. On the Canadian side of the river, the bottom is visible and appears to be smooth.

Q. On the Niagara River, you sounded about every 20 feet?

A. Soundings were made about every 20 feet.

Q. Did you make any soundings above or below the section?

A. I did not.

Q. The soundings that you made were as near as you could make them right on the section, were they not?

A. I will modify that statement slightly. Soundings were made below the section in spans 3 and 4.

Q. How far below?

A. I should judge about ten feet.

Q. How often?

A. Every 20 feet.

Q. You stated that there was no turbulence of the water on the Niagara River?

A. There is turbulence around the bridge piers; a short distance away from the bridge piers the water is running smoothly and evenly.

Q. How was it at the bottom?

A. On the western side where the bottom was visible, the current appeared to be very smooth and regular.

Q. How deep was it there?

A. The depth where the bottom was visible ranged from zero up to about 10 to 12 feet.

Q. How far did that extend?

A. My impression is it extended part way into the second span from the Canadian side. I don't remember exactly how far it extended.

Q. At the depth of ten feet that you speak of, how would the turbulence appear at the bottom to the eye, if there were any turbulence?

A. I believe that if the current was in a perturbed condition that particles of sand and silt which were being carried along would make the turbulence visible.

Q. I understood you to say it was a rock bottom?

A. It is a rock bottom. There was more or less sediment at times going down the river.

Q. If there were very much sediment, you could not see that deep?

A. There were times when it was impossible to see the bottom on account of the sediment.

Q. Then it must have been turbulent at that time?

A. Not necessarily.

Q. Have you your data here with reference to the Niagara, that you were going to try and get?

A. Yes, I have. I think I have what you desire.

Q. You mentioned a vertical where the depth of the water was 48½ feet. What was the inclination of the sounding wire at that point?

A. The deflection of the sounding wire was 13 degrees.

Q. That was in span 4, was it not?

A. That was in span 4.

Q. What was the inclination of the meter cable and the index velocity, that you have records of?

A. At that point?

Q. At that point, yes, at that vertical.

A. I find no record in the discharge book of any deflections of the meter cable. They were apparently not recorded.

Q. You have no records of any deflection at any vertical?

A. I have no record of any deflections at any vertical.

Q. Were those deflections read?

A. I believe they were.

Q. What year did you do your work on the St. Lawrence?

A. On the St. Lawrence in 1908.

Q. And this work on the Niagara was done in 1907?

A. 1907, and 1908.

Q. Well, what is your recollection about that? You say you think they were. Do you have any recollection as to whether they were read or not?

A. According to my recollection they were. I would not want to say that they were, and yet as I remember it they were.

Q. Whose duty was it to take those observations?

A. The deflection might be read by any member of the party. They were not read at every measurement, by any means, but I believe they were read occasionally.

Q. There were 118 discharge measurements?

A. 126.

Q. 126 discharge measurements made by you at that time in the Niagara?

A. Yes.

Q. And the only co-efficient work that you did was on the St. Clair River, wasn't it?

A. That is the only large river in which I have done co-efficient work.

Q. And Mr. Richmond was in your party was he?

A. He was.

Q. You testified before in this case on May 25, 1909, did you not?

A. I believe that was the date.

Q. You then described the method and apparatus used by you in making soundings on the Niagara River, did you not?

A. I believe I did.

Q. I call your attention to your testimony, as it appears

on page 413 of the record, in answer to the question: "How did you make those soundings? Will you give us the method Mr. Moore?" I will ask you to read your answer to that question, and I will then ask you to state if that correctly states the method used?

A. (Reading) "The soundings were made by means of a cast-iron weight, which was of the projectile type, a sphere drawn out into cones on each end, with a wooden tail to hold the nose of the weight in the line of the current. The weight used there was 135 pounds. It was suspended with steel piano wire, a little less than 1/10th of an inch in diameter. This wire was carried on the drum of a reel which rested on the chord of the bridge. The circumference of the drum was exactly three feet, and the depth was determined by the revolutions and partial revolutions of the drum. In spans 3 and 4, the velocity of the current was so great that in order to bring the weight to the bottom in the plane of the section it was necessary to cause the wire to enter the water at about four feet above the line of the section. This was done by a heavy weight which carried a hook which engaged the sounding wire. The auxiliary weight was suspended from the downstream chord of the bridge and a guy line was run to the upstream chord of the bridge, so that the weight and the sounding wire could be pulled back upstream any desired distance. The angle of inclination of the wire did not exceed 18 degrees; it was usually much less. The weight was lowered to the water surface, and the readings of the circumference of the drum was taken with the weight just touching the water surface. Then it was lowered to the bottom and a second reading on the drum was taken. The weight was then raised just clear of the bottom, and the angle which the wire made with the vertical was measured. The difference between the two readings, corrected for the inclination of the wire was the sounding; gave the depth of the water. It was referred to a fixed plane by the readings of a gage on the shore."

The statement of the method used is correct.

Q. Is that the same weight used on the St. Lawrence soundings?

A. Same type of weight.

Q. These sounding weights were made from the same mold, were they?

A. Yes.

Q. And they were as near the same size as could be obtained?

A. Yes.

Q. How accurately in your opinion was the depth of the Niagara obtained at the point where soundings were taken?

A. I believe that individual soundings were correct as a rule within seven or eight-tenths of a foot.

Q. What would be the per cent. of error that you speak of?

A. In 40 feet of water, about 2 per cent.

Q. Were the soundings repeated in the same position?

A. They were.

Q. How many times?

A. In the soundings that I made from the International Bridge, every alternate sounding was determined by two observers independently. I don't know how often the original soundings were repeated but it has been quite customary to make soundings more than once.

Q. What percentage of accuracy does that give to the soundings at any one point?

A. I stated that one sounding might be in error by about two per cent.; two soundings, the error of the depth determined by two soundings, would be approximately one-half of that.

Q. That would be about 1 per cent.?

A. Somewhere in that neighborhood. Individual soundings might show greater discrepancy than I was speaking of.

Q. Greater than two per cent.?

A. Greater than two per cent.

Q. How many soundings were taken then at one point?

A. Didn't I just answer that question?

Q. I don't think so. You stated that every alternate sounding was—

Mr. Hopkins: He said he didn't know how many, in some cases more than one.

Mr. Adcock: Q. Were made by two independent parties. Now, are we to understand from that that there was some place or were some places where there was only one sounding made?

A. In some places.

Q. And in others there were two soundings made?

A. In my work on the Niagara River, at some points there was one sounding and at each alternate point there were two soundings.

Q. And on the St. Lawrence River?

A. I believe that on the St. Lawrence River there was

but one sounding made on a point, with the exception of a portion of the area which was sounded the second time.

Q. There was some portion of the area sounded the second time?

A. I believe so.

Q. What was the reason for that?

A. The reason for the second sounding was to get a check on the work.

Q. And in the St. Clair, what were the conditions?

A. Section Gorge was sounded either three or four times, I don't remember which.

Q. What was the reason that you sounded so many times on the Gorge as compared with the number on the St. Lawrence and the Niagara?

A. There appeared to be some slight uncertainty in regard to the exact location of the sounding as determined by the transit angles, and as the bottom of the river on the west side is exceedingly steep, the soundings were repeated until we were certain we had positive results.

Q. Were they repeated all the way across the number of times which you mentioned?

A. No.

Q. How far across?

A. They were taken all the way across twice, and more than half way across I think four times.

Q. In lowering the weight by the method which you spoke of, if the drum made ten revolutions before the weight struck bottom and you were in still water, what depth would that indicate?

A. Approximately 30 feet.

Q. And if it were in water with a mean velocity of 6 feet per second, what would be the depth?

A. I don't know what the depth would be without the angle of inclination of the wire.

Q. Knowing the angle of the inclination of the wire, how would you determine the depth?

A. The problem of determining the curve taken by the wire in the current is a mathematical problem which is capable of solution on several assumptions, all of which give practically the same results. Those computations have been made for various deflection angles, and tables computed showing the correction to be applied to the amount of wire reeled off the drum.

Q. Did you use the table in the making of that correction,

which is shown as table number 1, page 5330, report of Chief of Engineers for the year 1898?

A. I did not.

Q. For 1900 rather?

A. For the work on the Niagara River, and for the sounding on the St. Clair and St. Lawrence Rivers, I did use table 1, on page 5330 of the report of Chief of Engineers for 1900.

Q. How was that table computed?

A. The table is computed by considering the pressure of the water against the wire over each tenth of the depth as determined by the velocity of the water, the variation in velocity being determined by typical vertical velocity curve.

Q. Was the velocity considered uniform from top to bottom in the computation of this table?

A. It was not. It was considered as varying, as shown by typical velocity curves.

Q. How near 30 feet would that wire be unwound to the extent of ten revolutions?

A. In still water, it would be 30 feet corrected for the diameter of the reel.

Q. If the circumference of the reel were exactly three feet as you stated?

A. If the circumference of the reel were exactly three feet, in still water there would be no correction.

Q. If you wind a wire .1 of an inch in diameter around a drum having a circumference of exactly three feet, and unwind the wire through ten complete revolutions of the drum, what length of the wire have you released?

A. It depends on the size of the wire.

Q. I have stated, one-tenth of an inch in diameter?

A. I would have to make a computation of that.

Q. You stated, however, 30 feet, did you not?

A. I misunderstood your question. The circumference of the reel is measured on the center line of the wire in practice. In that case it would be 30 feet.

Q. Then you want to correct your statement made previously, do you not, as to the circumference of the reel?

Mr. Hopkins: Just add to it that the circumference was determined as you just stated. That is what you want, isn't it?

A. If the circumference was measured as is customary in our work at the center of the wire, or of the cable on the reel, my answer will be correct.

Q. Did you always use a wire of the same size .1 of an inch in diameter?

A. Ordinarily.

Q. Suppose you had measured a channel about 16 feet in width with vertical walls, and found it to be just 16.13 feet wide, and that over half of the area at each side a facing coat of mortar had scaled off to an average depth of 1 inch causing a depression of that depth in the walls which you had not taken into account, how great an error would be introduced into your measurement of width?

Mr. Hopkins: I object on the ground that the hypothetical question is not based on testimony in the record.

A. I believe the error in width would be about ½ of 1 per cent.

Q. That is the area used would be about .955 of the true area, is that correct?

A. The width would be about that.

Q. Yes, the width. Suppose the bottom of a section were smooth and the center of it were ½ inch higher than it was at the sides and that you assume the elevation at the center to be the average elevation, if the water were 2.62 feet deep, how great an error would be introduced?

A. Provided the bottom consisted of two straight lines intersecting at a point in the center ½ inch higher than it was at the edges, the assumption of the depth at the center as the true depth of the section would introduce an error of about .8 of 1 per cent.

Q. Suppose at the top of the water there were waves .2 feet high, the water being 2.62 feet deep, and in determining the depth of the water, the measurement was taken to the trough of the wave instead of to the mean between the trough and crest, what in percentage would be the error in the depth so obtained?

A. Assuming that the area of the section were measured to the trough of the waves, the difference in the cross-section would be about 4 per cent. from what it would be if it were measured to half way between the crest and the trough.

Mr. Hopkins: I object to that question unless the kind and nature of the wave is stated, too.

Mr. Adcock: Q. Are there any other measurements of elevations necessary to be taken, in order to arrive at the area of a water section in the canal mentioned?

A. I do not believe that the product of the depth as de-

termined in that manner multiplied by the width would of necessity give the effective cross section.

Q. What other measurements of elevations do you think would be necessary to be taken into consideration in determining the water section?

A. I know of no other measurements which could be made under those assumptions to increase the accuracy of the cross section.

Q. Including all the sources of error which has been mentioned, what is the total error of the determination of the cross section?

A. The cross sectional area with those assumptions would be in error about 5.3.

Q. You read the testimony of Mr. Schoder, did you not?

A. I did.

Q. There was not any depth stated by him shallower than 2.62 feet of water in the canal that he described, which was measured by him?

A. I see none.

Q. The other depths were from 2.73 to 7.44 feet were they not?

A. They appear to be.

Q. With a depth of 7.09 feet, at which the meter showed a deficiency of 9.5 per cent, what would have been the percentage of error due to cross section, on the assumptions above mentioned?

A. I believe it would be about 1½ per cent.

Q. At how frequent intervals in the vertical are current meter measurements taken in your co-efficient work, say for instance on the St. Clair River. That was the only one that you did any co-efficient work on, isn't it?

A. We measured each tenth depth.

Q. Suppose a vertical to be so measured ten times at the same elevation of water surface, how closely would the river velocity at that vertical be determined; that is at .1 depth?

A. I should say within two per cent.

Q. Suppose 1/5 depth had been observed, instead of 1/10th depths, would the determination have been more or less accurate?

A. It would be less accurate.

Q. What percentage less, or within what percentage of accuracy would it have been?

A. Probably within five per cent.

Q. If 1/20th depths had been used, would the determination have been more or less accurate?

A. With the same number of observations, I should think there would have been practically no difference.

Q. You mean with ten observations at the 1/20th, each 1/20th depths?

A. The accuracy would probably be about 1 per cent. in that case.

Q. In other words it would have been twice as great as the 1/10th depth?

A. Roughly, yes.

Q. You never have made any observations at the 1/20th depths, have you?

A. I never have.

Q. Have you ever calibrated a weir?

A. To a very limited extent only.

Q. Where was this weir?

A. In the hydraulic laboratory of the University of Wisconsin.

Q. How large was it?

A. My recollection of it is that it was about 12 inches.

Q. And that was done simply to determine the method, at that time?

A. It was done as a laboratory experiment, in connection with the college course.

Q. And merely to instruct you as to how it might be done?

A. That was the only purpose of it.

Q. Had no practical benefit?

A. No.

Q. You never have used a weir in measuring water, have you?

A. I have not.

Q. Or you never have compared a discharge measured by a current meter with the same discharge determined by volumetric or gravimetric measurement?

A. No.

Q. Do you know of any one who has?

A. I don't recall any one at present.

Q. Have you ever compared the discharge measured by a current meter with the same discharge determined by an orifice or nozzle?

A. I have not.

Q. You stated that you made in 1912, a reduction of all discharge measurements, did you not?

A. I did.

Q. That you made changes in meter ratings and alterations in gages. Just what did you mean by that?

A. I made a new study of the observations with respect to gage heights and with respect to cross section and meter ratings, and reached somewhat different conclusions in regard to them than were reached in the original reductions. Those changes appeared to be justified by our further knowledge of the hydraulics of the stream in question and the observations were corrected.

Q. What changes did you make?

A. In the discharge of the St. Mary's River, in certain measurements at the International Bridge, the gage which was used was in the canal of the Chandler-Dunbar Power Company, at pier 3, and the elevations of that gage had been referred to the elevations at the automatic gage at Southwest pier by a parallel correction.

The observations indicated that the correction was not the same for all stages, and I applied a correction which was proportional to the stage. I derived new laws for the measurements made in the broad shallow stretch of the river below the rapids by using the increment of flow as determined at the Bridge Section. The increment on the lower sections was indeterminate on account of the small range in stage and large variations in power diversion.

On the Niagara River I made a new tabulation of all discharge measurements, bringing all measurements into a single tabulation. I examined the meter ratings the cross section and the velocity co-efficients, and decided that they could not be improved upon.

Q. That is you mean you examined the data and records and so forth?

A. I do.

Q. You did not re-rate the meters?

A. Oh, no. On the St. Lawrence River I made similar examinations, and there I made certain changes in the ratings used in the computations of the discharge, which seemed to be more logical than those originally used. I also introduced other measurements made by a second meter, which had not been included in the original measurements.

Q. Were those the records compiled by Mr. Shenehon, that you examined on the St. Lawrence?

A. I examined those compiled by Mr. Shenehon.

Q. What did you mean when you said that you changed the meter ratings?

A. The meters were rated at more or less frequent intervals throughout the work, and Mr. Shenehon had used a mean rating for his measurements, being a mean of certain other ratings made during the season. A comparison of the results by the two individual meters indicated that the choice of individual ratings covering certain fixed periods of time would bring the results by the two meters into harmony, and therefore to my mind was more logical than the use of the mean rating covering a season.

Q. That is the mean for the entire season. What did you do down there, take the mean for a certain portion of the season?

A. I took single ratings and applied them to the observations which they logically covered.

Q. When you say logically covered, just what do you mean by that, that were nearest in time?

A. The nearness in time was one consideration.

Q. What was the other consideration?

A. The other consideration was the consistency in the volume of discharge shown by the two meters running abreast, which was done in each measurement.

Q. You mean by running those meters abreast as you did, together, that you could discover when one meter would get off of its rating?

A. That is what I mean.

Q. And that was one of the things that you took into consideration in making your corrections?

A. It was.

Q. What else did you take into consideration?

A. Those were the only two factors.

Q. The two factors of time, and the performance of the meters?

A. Yes.

Q. Now what did you do with the St. Clair River gaging records?

A. I do not find my report now. To the best of my recollection, we simply listed the discharge measurements.

Q. Did you make any corrections in the meter ratings?

A. I made no corrections to the discharges whatsoever.

Q. Did you follow the same plan that you did with reference to the St. Lawrence?

A. I did not. The subject of the St. Clair River at that

time was being handled by Mr. Richmond, who was doing the same work for that river that I had done for the other rivers, and I accepted his results.

Q. Do you know whether he made any changes in the meter ratings?

A. I could not say.

Q. Now on the Niagara River what changes did you make?

A. I made no changes on the Niagara River discharge measurements.

Q. Neither at the Open Section nor the International Bridge Section?

A. At neither section.

Q. How about the meter ratings?

A. I made no changes in meter ratings, or any others.

Q. Did you make the same examination of the meter ratings with reference to the time and as to other performance of the meters, that you did with reference to the St. Lawrence ratings?

A. I did where it was possible to do so. The method used at the International Bridge Section was somewhat different from that used at the other section.

Q. It was difficult to check it then, is that the situation?

A. On the International Bridge, during a portion of the work, a single meter would be used. There would be no comparison between two meters during a portion of the work.

Q. That was single meter work you used, entirely?

A. No, it was not single meter work.

Q. But they did not run the two meters together, simultaneously?

A. Each discharge measurement depended on a single meter, while at the other sections each discharge measurement depended upon the mean of two meters.

Q. How about the co-efficient work on the Niagara?

A. That depended on two meters, the same as the other rivers.

Q. Has there ever been any co-efficient work done on the Niagara except what Mr. Shenehon did in his early work, and except what Mr. Richmond did on the Split Section?

A. I believe not, by the Lake Survey.

Q. Then in 1907 and 1908, discharge measurements that you made on the Niagara River, you used the co-efficients which Mr. Shenehon had derived?

A. I did.

Q. That was when?

A. Those co-efficients were derived in 1889, I think, mostly.
Q. 1899?
A. 1898 to 1900.
Q. Now you made certain changes you spoke of. What was their effect upon the increment, do they reduce it or increase it in the St. Lawrence River?
A. They reduced the increment.
Q. How about the changes that were made in the St. Clair gagings, records?
A. I made no changes of the St. Clair records.
Q. Mr. Richmond's changes, did they increase or decrease the increment?
A. I am not prepared—
Q. Did Mr. Richmond report his results to you?
A. Not of his reduction, no.
Q. You don't know what they were then?
A. I know the formula that he derived.
Q. You also know that there was an increment derived before, don't you?
A. I know that there was in existence before that a formula, several formulae of the St. Clair River.
Q. You made certain measurements on the Chicago Sanitary Canal this last year, in 1913, you stated. From whom did you receive your instructions as to making those measurements?
A. I received my instructions from Principal Assistant Engineer F. G. Ray, for and in the absence of Colonel Sanford.
Q. What instructions did you receive? Were they in writing?
A. They were.
Q. Have you got a copy of them?
A. I have here the original of the instructions which I received.
Q. Will you read it into the record?
(Witness produces letter which is as follows):

"United States Lake Survey Office

Old Custom House

Detroit, Michigan, Dec. 13, 1913.

From: District Engineer Officer
To: Sherman Moore, J. E.
Lake Survey Office, Detroit, Michigan.
Subject: Discharge measurements, Chicago Drainage Canal.

1. You are instructed to proceed, together with Junior Engineer A. B. Jones, and Surveyman Harry E. Whittelem, to Joliet, Illinois, or to any other point that you may determine as more advantageous, and from there conduct a series of measurements of the flow of water through the rock cut of the Chicago Drainage Canal, this work to be carried out in the manner authorized by the Chief of Engineers in Department letter received this date. (E. D. 91911.)

You will make a careful determination of the flow, using methods similar to those heretofore used by the Lake Survey on similar work in the diversion canals of the Niagara Falls Power Companies. The object of the measurements is to determine the amount of flow during the periods covered by the work to the highest degree of accuracy that is obtainable by observations extending over a period of approximately one week. In connection with the discharge measurement, gages should be operated at or near the mouth of the Chicago River, at the discharge section, and at some point in the vicinity of Willow Springs or Summit, Ill. These gages should be referenced to bench marks of the Illinois River Survey, or with bench marks of the Coast and Geodetic Survey net.

2. Owing to the lateness of the season and the possibility of ice in the canal in the near future, it is desirable to push this work as rapidly as possible, and accordingly you will begin your measurements without delay. As soon as convenient after the work is under way, you will notify the officers of the Chicago Sanitary District concerning the operations that you have in hand, and invite them to be present personally, or by representative, during the operations, if they desire to do so.

3. Upon completion of the work herein outlined, you will return with your assistants to the Detroit Office, and plan to rate meters and reduce the observations as soon as possible thereafter.

For and in the absence of Lt. Col. Sanford,
(Signed) F. G. Ray,
Principal Asst. Engineer."

Q. Have you the letter which you sent to the Chief Engineer of the Sanitary District pursuant to those instructions?

A. I have not.

Q. Have you a copy of it?

A. I have not.

Q. There is a letter referred to from the Chief of Engineers in the letter you just produced dated December 13, 1913, from Mr. Ray, Principal Assistant Engineer to you. Do you remember what that stated?

A. The letter as I recollect authorized the measurements.

Adjourned to Friday, February 20, 10:00 A. M.

Friday, February 20, 1914, 10:00 A. M.

SHERMAN MOORE resumed the stand for further cross-examination by Mr. Adcock and testified as follows:

Q. Did you receive any other instructions than was contained in the letter that was referred to from Mr. Ray?

A. No definite instructions.

Q. What do you mean by "definite instructions"?

A. Mr .Ray and I discussed informally the best methods of work and the best point at which to work, and various things in connection with the work, entirely informally. Those were the only instructions I received.

Q. Do you remember the contents of the letter that you sent to the Sanitary District?

A. It was a very brief letter written hurriedly at the hotel one night in which I notified Mr. Wisner that we were making operations there, making measurements there, and requesting a permit to visit the power house.

Q. That is to the best of your recollection the complete contents of the letter?

A. I could not repeat the contents.

Q. That is you could not repeat it word for word as it was written, but that is substantially the contents?

A. That is substantially the contents.

Q. You stated in your direct testimony that there would be a certain effect upon the levels of Lake Michigan-Huron, Lakes St. Clair, Erie and Ontario, by a diversion of 10,000 feet at Chicago. You also stated, gave certain increments for different rivers. Were your conclusions as to the increments and as to the effect upon lake levels based entirely upon the rec-

ords of the observations and measurements of flow of the St. Clair, Niagara and St. Lawrence Rivers?

A. They were.

Q. You also stated that you had made certain experiments to determine the lag, the travel of the crest between Lake Erie and the Bridge Section of the Niagara. Just what experiments did you make?

A. I made a comparison of the records of the automatic gage at Buffalo and at the foot of Austin Street, and comparisons between readings with a staff gage at the International Bridge and the automatic gage at Austin Street.

Q. You ascertained, in your judgment, from those experiments, that when the Buffalo gage rose, for instance, in eight minutes there would be a corresponding rise of the gage at the Bridge Section. Is that correct?

A. I did.

Q. Did you make any experiments to determine how soon the discharge at the Bridge Section would change so as to correspond to a rise or fall of Lake Erie?

A. I made no such experiments.

Q. What is your opinion as to the time within which the discharge would change to correspond to a rise or fall of Lake Erie, as between the two points?

A. In my opinion, the flow of the river at all times is a function of the gage height about eight minutes preceding.

Q. In other words, the flow of the river corresponds or changes as the stage changes, is that correct?

A. That is correct. That is what I mean.

Q. Or eight minutes later. That is the level, the water level at the Section Point?

A. Yes.

Q. You never made any experiments to work that out?

A. I never have.

Q. Upon what do you base that opinion?

A. On experiments made by Mr. Shenehon in the Niagara River, and experiments made by Mr. Sabin in the St. Clair River.

Q. What were the experiments that Mr. Shenehon made? Also state those of Mr. Sabin; describe what they did?

A. In both cases, the meter was run continuously at the section and the velocity as given by that meter was compared with the elevation as given by the gage at the head of the river.

Q. Do you know for how long the meter was run?

A. I could not say.

Q. Did both Mr. Sabin and Mr. Shenehon use the same method?

A. Substantially so.

Q. Mr. Shenehon's experiments were on the Niagara?

A. Yes, sir.

Q. Mr. Sabin's on the St. Clair?

A. Yes.

Q. Did you ever make any experiments of your own, Mr. Moore, on any channel or river?

A. I can't recall ever having made any.

Q. Do you base your opinion upon any work that you did on the Sanitary District Channel of Chicago in the year 1913, in December?

A. That work was corroborative of the fact, although the conditions existing in that canal are not similar in all respects to those existing in a river.

Q. What would be the difference, what conditions are different?

A. In a river, the change in flow is the result ordinarily of a change in the elevation of the lake at the head of the river. In the Drainage Canal, the change in flow was the result of a sudden change in the flow at a point below the section.

Q. What effect would that have?

A. The change of flow in the canal was very large in proportion to the flow, much larger than any change taking place in the elevation of a lake in the same time; and the effect would be complicated by storage capacity in the canal, which I do not believe would enter into the case of a river where the changing stage is very much slower and the river has an opportunity to at once adjust itself through the critical sections to the new conditions.

Q. How about the River St. Clair? Don't you have a change of the stage of Lake St. Clair, which may affect the flow of the St. Clair River?

A. The change in stage of Lake St. Clair is in the open season the result of changes in the flow of the river; and perhaps in that case the comparison is a little better between the river and the canal, although the changes are slow, a long time in taking place.

Q. Do you think the effect would be greater in the case of a large change than in the case of a small change?

A. May I ask just what you mean by "effect"?

Q. The effect at the point observed, that is the point in the river, the discharge section?

(Original question read.)

Mr. Hopkins: Do you mean "quicker"?

Mr. Adcock: "Quicker," rather than "greater."

A. I believe that in the case of a large change, the time required to establish normal conditions throughout the channel might be slightly greater than for a small change.

Q. How does the St. Marys River compare with the conditions in the Sanitary District Canal?

A. They are entirely dissimilar, so far as I can see.

Q. In what way?

A. The St. Marys River corresponds with the Niagara River in the fact that the flow of the river is a function of a single gage above the Rapids.

Q. Doesn't the gage below the Rapids affect the flow in the river?

A. It does not, in the case of the St. Marys River.

Q. Do you mean that to apply to the portion of the river below the Rapids?

A. I mean that any changes in the water surface elevation below the foot of the Rapids will have no effect upon the flow of the river.

Q. You mean that statement to apply to the lower river, to any point in the river and every point in the river?

A. I mean that statement to apply to any point or every point in the river below the foot of the Rapids.

Q. You stated in your direct testimony, I believe, that it would take approximately two hours and a half to three hours to cause a uniform flow of approximately 10,000 cubic feet per second through the entire length of the Drainage Channel and Chicago River from a flow of approximately 4,167 feet, did you not? That was your conclusion?

A. I believe I did state that.

Q. Did you make any experiments in the channel to determine what the length of time would be?

A. I made no experiments for that purpose.

Q. You made approximately 100 measurements in the channel during December, 1913?

A. My results have been reduced in the form of 96 measurements.

Q. The Chicago Engineer Office made certain measurements of flow there, did they not, in that channel?

A. They did.

Q. And they made some measurements simultaneously with you?

A. They did.

Q. Their discharge for the same stage was approximately 10 to 14 per cent. higher than the discharge which you found, was it not?

A. Their discharge at the same time was approximately 10 per cent. greater than what I found.

Q. You state in your report, which was referred to by you on your direct examination as dated January 16, 1914, referring, Mr. Moore, to page 7: "That the maximum flow at Lemont came about six o'clock in the afternoon and corresponds to the overlapping of the day load and the night load at the power house. As a time interval of about 30 minutes between the power house and Lemont is shown by the observations, this load actually occurs about 5:30 P. M."

You also state further down: "The afternoon flow was probably all through the power house, except for small leakages." Did you ascertain just at what time the peak load went on that day?

A. I did not.

Q. Did you ascertain by examination of the flow at the power house the time when the flow was changed to take care of the peak load?

A. I was present when the load on the power house was changed, on one occasion.

Q. But were you present on the day that you refer to in this report?

A. I was not.

Q. So that your statement, then, as to when the peak load occurred, at 5:30 P. M., is based upon what?

A. That statement must not be considered as an actual expression of fact. It is simply a statement of the probable causes for the variation in the load as shown by the measurements at Lemont. The figure of 30 minutes there stated, which is approximate only, was derived by taking the time at which the flow increased at Lemont and the time at which the last generator was synchronized and thrown into service on Sunday afternoon. The operator stated to me that that was the customary time of throwing that load on.

Q. That was what time?

A. I believe the last switch was thrown on that afternoon at 4.45. I have no definite record of that time.

Q. That was Sunday, wasn't it?

A. That was Sunday.

Q. They would not have a day load to carry?

A. They had no day load at that time; that is they had a

small day load. I do not believe it was as large as their ordinary day load.

Q. The time referred to in your report and the portion that I just read, was December 20th, was it not?

A. There is no reference made to any date in the report. It is a general statement of probable conditions.

Q. That was the day, was it not, that you ran your meters all day and all night?

A. On December 20 I ran the meters all day and all night.

Q. Was that the only day that you ran them under those conditions?

A. On December 22 I ran the meters until the load had apparently become uniform in the evening.

Q. What time was that?

A. About 7:30 as I remember.

Q. On the other days how late did you run the meter?

A. About 5:00 o'clock ordinarily.

Q. Will you refer to your notes and your table and give me the exact time that the maximum flow took place at Lemont on December 20?

A. The observations show an absolute maximum flow between 9:48 and 9:58 P. M. The increase in flow at that time over other observations is so small that it may easily be due either to slight errors in the meter or—

Q. How much is the difference in the change?

A. The difference in the flow at that time from what it was at six o'clock is about 5 per cent.

Q. Wasn't that flow some place between 6:06 and 6:37 P. M. in the afternoon of December 20?

A. The maximum flow, as shown by the observations, occurred, as I stated, between 9:48 and 9:58 P. M.

Q. Will you refer to your table attached to your report?

A. The table does not show the maximum single observation.

Q. You have them grouped there in 20 minute periods or half hour periods, and doesn't the maximum flow appear to be between 6:06 and 6:37? When I say maximum, I mean the greatest amount immediately prior to 9:30, that you spoke of?

A. The measurements as grouped in the table between 6:06 and 6:37, show the largest flow recorded to be at the observation made between 21:28 and 21:58.

Q. Just reduce that 21:58 to English?

A. 9:28 to 9:58.

Q. What is the distance between the power house and Lemont?

A. About nine miles, I think.

Q. That is about a quarter of the distance, is it not, from the power house to Lake Michigan?

A. Yes.

Q. Do you think the increase in discharge would travel through the entire length of the canal at the same rate that it traveled between the power house and Lemont?

A. I believe it would, approximately the same rate.

Q. During the time that you were making measurements on the Drainage Channel, did you get the discharge of the channel at Lemont for every hour of the day and night, that is the 24 hour day?

A. No, I didn't.

Q. So that your conclusion as to the daily flow may not be correct; it may be too small?

A. On December 20th, there was an interval of about two hours from 1:00 A. M. to 3:00 A. M. in which no measurements were made. The amount of water flowing at Lemont was practically the same at 1:00 A. M. and at 3:00 A. M. The load on the power house was probably constant. In view of these facts, I believe that the observations show the true amount of water within the limits of the observations flowing through the canal on that one day. There is a possibility, of course, that something happened in those two hours, and that the flow was either diminished or increased. It does not seem to me likely.

Q. You don't know of your own knowledge what happened during that time?

A. I don't know of my own knowledge what happened.

Q. Mr. Richmond spoke in his cross examination about a table of meter corrections for correcting the position of the meter. Have you that table?

A. Mr. Richmond referred to several tables. I don't believe I understand exactly which one you refer to.

Q. He referred to a table that you gave him in connection with his work on the St. Clair at the Gorge Section.

A. I may possibly have that table. I will look and see.

Q. You can look for it after we get through here and give it to us.

A. I don't know that it is in existence.

Q. You don't know that it is in existence?

A. No; it may be.

Q. How was it made up, Mr. Moore?

A. The corrections to the reading of the reel were derived from a consideration of the mean deflection observed over a

considerable period and a table prepared by Mr. Ray showing the amount of correction corresponding to that angle of deflection and compared with the table by Mr. Shenehon, in his 1906 report.

Q. Did that take into consideration the size of the cable?

A. It did not.

Q. The computations to make up this table which you speak of?

A. It did not.

Q. Did it take into consideration whether the cable was rough or smooth?

A. It did not.

Q. Did it take into account the character of the meter at the lower end of the cable?

A. It did not.

Q. Whether it was a A meter or a B meter?

A. It did not.

Q. Assuming that during a certain period of time, say for instance a day, all the water flowing through the Drainage Channel at the Lockport power house passed through the water wheels, and that there was a meter showing the amount of electrical energy, electrical output generated by those wheels; and that at a certain hour it appeared by this meter showing the amount of the electrical output, that it was at a maximum, would that indicate that the maximum flow of water through the power house occured at that time?

A. I think it would.

Q. With the measurements that you have made, and the gagings that you made on the Drainage Canal and Lake Michigan, do you think it would be possible for you to calculate the slopes for various flows through the canal and river?

A. I am very certain that what data I obtained is not sufficient for that purpose.

Q. You state in your report, page 3, paragraph 7, as follows: "When the Lake Survey party left Detroit, it was intended to secure some observations of flow before the officers of the Sanitary District were aware of the work, in order to insure results during normal operating conditions." Did you receive any instructions from Mr. Ray with reference to that, or from Mr. Shenehon?

Mr. Hopkins: Objected to as immaterial.

A. I received no instructions, no definite instructions in regard to that matter. Mr. Ray and I discussed it, and it appeared to be merely precaution such as we have always taken to insure that our results—that is not exactly what I

mean—to have evidence that there was no manipulation of the flow during the time that observations were made.

Q. You didn't have any evidence that there would be any manipulation?

A. We had no expectation that there would be.

Q. You stated also in your report in the same paragraph as follows: "Mr. George M. Wisner, Chief Engineer for the Sanitary District, was at once notified by letter of the purpose of the Lake Survey, so that if he desired he might observe the operations, either in person or through a representative."

Q. Did you notify Mr. Wisner to co-operate or be present by representative, while you were making these observations?

A. There was no specific invitation. I did not consider that such was called for. If he knew the operations were in progress, I expected that if he desired to be present he would feel at liberty to do so.

Q. Did you "notify them (The Sanitary District) to be present personally or by representative, during the operations"?

A. I certainly did not.

Q. You say also in your report: "A representative of the Sanitary District was present during a part of the work"; when was he present?

A. I have no records to show when he was present.

Q. As a matter of fact, did not some one from the Sanitary District appear at the section or near the section where you were gaging for Lemont, for the purpose of making measurements, the very last day you were there?

A. Mr. Blanchard was present at various times, from the start of the observations until the finish of the observations.

Q. How long was he present?

A. I am not certain that he was present every day, but he was present at times for three or four hours at a time.

Q. Mr. Blanchard happened to be at this point when you went there, didn't he?

A. Mr. Blanchard had a party at that point when I went there.

Q. Did you consider that the notification that you gave Mr. Wisner, about which you have testified, a carrying out of the instructions contained in your letter?

Mr. Hopkins: Objected to as immaterial.

A. I so considered it.

Q. You state in the last page of your report, paragraph 31, as follows: "With the possibility of having to calibrate the

power house at Lockport at some future time, for the purpose of supervision of the flow, a reconnoissance of the lower reaches of the canal, and an inspection of the power house was made." Was that contained in any of your instructions?

A. It was contained in no written instructions.

Mr. Adcock: That is all.

Re-direct Examination by Mr. Hopkins.

Q. Mr. Moore, will you explain those inclusive figures given by Mr. Richmond in his testimony as to deflections of the meter cable, which he read from your note books?

A. On one day in the note books, the deflection of the meter cable set down opposite each position of the meter shows a range in value of 4 or 5 degrees, or thereabouts. Those figures are not actual observations. At that time, I was attempting to determine the outside range within which I could expect the angle to fluctuate. I had at that time with me a list of all the observations observed previously, and as each station was occupied, I noticed the inclination at that time, compared it with previously measured inclinations.

Mr. Adcock: Q. At the same station?

A. At the same station, and instructed Mr. Richmond to set down in the note book these figures which to me represented the maximum and minimum deflection which could be expected at that point. Those were used as a basis for determining the correction to the depth of the meter.

Mr. Hopkins: Q. In your opinion, are the cable deflections as testified to by Mr. Richmond from your note books actually observed, any measurement of velocity?

A. The deflection of the cable is an indication in a rough way of the velocity. It is not a measure of the velocity. It cannot be used as a measure of the velocity, because it depends on a great many elements other than the velocity. The depth at the particular time of observation affects the deflection. The size of the wire was not uniform. It was varying constantly. Cables wore out and were replaced by new ones, not always of the same size. The core wire, that is the electric wire on the interior of the cable, carrying the electric current to the meter, was frequently renewed.

Each time this core wire was renewed, the strands of the cable were loosened. For a short period, the cable would probably be larger, and would pull down in use.

There are minor differences in the meters used, and to my

mind the deflection may legitimately be expected to vary over four or five degrees for the same velocity at the same point.

Mr. Adcock: Q. Same size cable?

A. No. To some extent, possibly with the same size cable. Errors of observation also enter into these deflections, which were never determined with any great degree of accuracy. It was considered that an error of two or three degrees in the deflection made absolutely no difference in the positions of the meter, so far as results were concerned.

Mr. Hopkins: Did you ever make anv tests for deflections of a sounding wire to show whether or not Mr. Ray's table was correct, the table you said you used?

A. I have made such experiments under the most extreme conditions.

Q. Tell us about those tests?

A. In off shore sounding, that is in sounding in water over 66 feet deep on the lakes, with a steamer, it had been my practice to limit the deflection of the sounding wire to about 30 degrees, believing that the table was not accurate beyond that point.

I was informed that other parties of the Lake Survey were using angles as high as 45 and 50 degrees, and I questioned the accuracy of results obtained under those conditions; but as the difference between 30 degrees and 45 degrees represents several square miles in a day's work, I made some observations to determine whether the corrections as derived from the table were correct with these large deflection angles. On a smooth, sandy bottom, in about 150 feet of water, with the steamer running at a practically uniform speed, with a deflection angle of about 45 degrees, the soundings would show a variation of only one or two feet from one sounding to the next. Under those conditions, I stopped the steamer in the shortest possible distance, which probably was within 200 feet, and observed the depth with a zero deflection. The depths as read off of the sounding scale, indicated somewhere in the neighborhood of 175 feet. The correction, as taken from the tables, amounted to between 20 and 25 feet. After this correction was applied to the soundings, they agreed within a foot or two of the depth observed with the zero deflection.

There are also in our work cases, a good many cases where lines run with a high angle of deflection crossed lines running at a much lower angle of deflection, but so far as I know, in every case there is no discrepancy appearing in the soundings.

Q. What percentage would that one or two feet be, where you were making that test?

A. A discrepancy of 2 feet in 150 feet would be a little over 1 per cent.

Q. Now suppose your angle of deflection is within the limits used in the soundings for current meter measurements, would there be any such percentage of error, in your opinion?

A. In my opinion the percentage of error would probably be smaller. The observations under extreme conditions show that the theory of the curve taken by the wire is approximately correct, and with smaller angles of deflection of lesser depths, the actual errors would be very much smaller.

Q. In your cross-examination, you spoke of a sounding, an individual sounding at one particular place in the Niagara River, which you thought might be 2 per cent. in error. Am I correct in saying that that 2 per cent. was as to an individual sounding at an individual point?

A. That 2 per cent. was given as a limiting value on the error of an individual sounding.

Q. What is your conclusion as to all of your soundings in the cross section, the percentage of error in spans 3 and 4 at the International Bridge Section in the Niagara River?

A. The mean of the seven soundings in span 3 or of the 11 soundings in span 4, is undoubtedly correct within less than ½ of 1 per cent.

The difference between the soundings made by me and the soundings made by Mr. Shenehon in 1900, at the same points, show a mean percentage change in span 3 of 1/10th of 1 per cent., and in span 4 of 4/10ths of 1 per cent.

Q. Referring to your testimony in regard to certain measurements made by Mr. Schoder and Mr. Turner on the canal at Cornell University, you said that there might be an error of 10 per cent. in the cross section. On cross examination, on certain assumptions, you totaled up the percentage of error in the cross section to 5.3 per cent. Does that change your opinion as to the percentage of error of the cross section, as given in your direct testimony?

A. I still believe that in the determination of the cross section the error might easily be an error of 10 per cent.

Q. On cross examination, you were asked if you ever made any tests of current meters. Do you want to correct that?

A. I assisted in the tests of current meters made in the Detroit River in the spring of 1906, by Mr. Shenehon.

Q. In your cross-examination, you were asked a question as to whether or not the level of Lake Huron had any effect

on the lower St. Marys River. Do you want to say anything further in regard to that?

A. When I speak of the discharge of the St. Marys River, the flow of the river through the Rapids and through the Power Canals is the thought in my mind. Changes in the elevation on the lower river below the Falls, or in Lake Huron, would affect for a short time the actual flow through the portion of the river below the Falls, by changing the amount of storage. That is with the falling stage at the lower end of the river, a certain amount of storage would be withdrawn from the lower stretches of the river and would increase the flow while that was in progress. Similarly, rises would check the flow by increasing the amount of water which went into storage.

The effect for any considerable period would be negligible, and the effect would not be felt on the river above the Falls or above the Rapids.

Q. Now, referring to the Chicago Drainage Canal, do you know how the engineers from the Chicago office did their work? Just explain their method of measuring?

A. I was present while an engineer from the Chicago office made measurements of the flow of water through the canal at Lemont, and he stated to me that that was his customary method.

Observations of velocity were made at .4 depth at points 10 feet apart across the stream. The Engineer Office at Chicago furnished me with a copy of their reduction of these measurements; and from the copy it appears that they assumed that the velocity as determined by the current meter at the .4 depth was the mean velocity in the vertical. They took the mean measured velocity and multiplied it by the cross sectional area to derive the discharge.

Q. Did you determine the vertical co-efficients in the canal?

A. I did.

Q. What percentage of the index velocity, as measured at the .4 depth, represented the mean velocity as to the whole canal, all of the vertical curves?

A. On the Lemont Section, the mean velocity in the vertical was 90 per cent. of the velocity at the .4 depth practically.

Q. What effect would that have upon the total discharge, comparing your total discharge to that made by the Chicago Engineers, United States Engineers?

A. The failure to use the vertical co-efficient would result

in the measurements as made by the Engineer's Office in Chicago, being about 10 per cent. larger than those made by me.

Q. How did their current meter work check with yours as regards measure of velocity?

A. A current rating was made of their meter, in comparison with one of ours, and showed a discrepancy of less than 2 per cent., from which I would judge that their measurements of velocity were probably good.

Q. In cross-examination, you said something about the maximum in the Chicago Drainage Canal, at one period of the day being about 5 per cent. over what it was somewhere around 6 o'clock of the same day; and the difference might be indicated by the current meter. Will you explain that a little bit more fully?

A. It is a fact which is well known to this office, which was pointed out by Mr. Shenehon as far back as 1899, that a current meter is subject to daily variations, which may amount to as much as 2 per cent. The difference between the maximum load as pointed out on that day and the load at 6 o'clock was stated to be 5 per cent. If you assumed that the meter at that time was giving velocities 2 per cent. in error, the actual flow through the canal at this period which was pointed out would be 3 per cent. larger than it was at 6 o'clock, and it would not be larger than at other intermediate times. I simply chose 6 o'clock as a convenient comparison. The 5 per cent. difference is partly difference in flow.

Q. Mr. Moore, your observations as to the rate of travel of waves, as I understood, were from Lemont to Willow Springs. That is correct, isn't it?

A. I base my testimony concerning the time necessary for the wave to proceed from the power house to Chicago on the interval shown between the gages at Lemont and Willow Springs.

Q. Not from Lmont to the power house?

A. Not from Lemont to the power house.

Re-cross Examination by Mr. Adcock.

Q. This Chicago Office that you speak of that made the measurements on the Drainage Canal, is the U. S. Engineer's Office at Chicago, isn't it?

A. It is.

Q. The men in that employ?

A. (No response.)

Q. They used a Price meter, didn't they?
A. They used a Price meter.
Q. In your opinion, their work was not accurate?
A. In my opinion, their measurements of velocity were accurate.
Q. But they did not know how to gage a stream, that is the proposition?
A. They neglected to apply one correction which I believe should be applied.
Q. And in that you differ evidently with the Engineer Office at Chicago?
A. I do.
Q. Now you made some tests with Mr. Shenehon of the current meter in the Detroit River. Just what did you do? Was that where you put fluid into the water and calculated the time and so forth as compared with the velocity shown by the meter?
A. Those were the experiments.
Q. That is simply to determine whether or not the current meter indicated the time during which this colored fluid traveled a certain distance?
A. Whether the current meter indicated the same velocity as that indicated by the movement of the colored water.
Q. Where was that? How far in the water was the current meter suspended, immersed?
A. If you want an accurate statement of that, I will have to look it up.
Q. Just approximately?
A. My recollection is it was about 2 feet.
Q. You were not present when Mr. Turner and Mr. Schoder determined the cross section of the canal at Cornell, were you?
A. I was not present.
Q. You spoke of a table that was prepared by Principal Assistant Engineer Mr. Ray. When did he prepare that table?
A. I don't know.
Q. When did you make the tests?
A. I made the tests last summer.
Q. Mr. Ray was still Principal Assistant Engineer?
A. He was.
Q. You referred to a table just now in your testimony, of the deflections of the meter cable at various points, as I understood, in the cross section, from which you made these entries of 9 to 14 degrees, etc. Have you that table?

A. The entries of from 9 to 14 degrees and so forth were made in a note book. The correction was entered in a table.

Q. You said that you had a list of deflections, showing the deflections at the various points on the verticals that had been observed there, giving the range, and that this was a transcript of those arrangements, as I understood your testimony. If there is such a table, we would like to see it?

A. I don't believe I understood just what you want.

Q. (Question and answer read as follows: "Mr. Moore, will you explain those inclusive figures given by Mr. Richmond in his testimony as to deflections of the meter cable, which he read from your note books?

A. On one day in the note books, the deflection of the meter cable set down opposite each position of the meter shows a range in value of 4 or 5 degrees or thereabouts. Those figures were not actual observations. At that time I was attempting to determine the outside range within which I could expect the angle to fluctuate. I had at that time with me a list of all the deflections observed previously, and as each station was occupied I noticed the inclination at that time, compared it with previously measured inclinations."

The Witness: That list of deflections referred to was merely a temporary list and was destroyed as soon as the computations were made. The reason for entering the maximum and minimum deflection in the note book was to permit of destroying the list.

Q. How often were these meter cables renewed during a gaging like you did on the St. Clair River?

A. The electric wire in the center of the cable was renewed whenever the insulation became imperfct. It might be two or three days or a cable might last a month, possibly six weeks. It all depended on whether or not the insulation happened to be broken in getting the wire into the interior of the cable.

Q. What was the difference in the size of the cables used in the St. Clair work?

A. One cable was 3/8ths of an inch, as I remember it. That is, it was of the size sold commercially as 3/8th of an inch, and the other one a quarter of an inch.

Q. Which one did you use on the B meter and which one on the A meter?

A. To the best of my recollection, no distinction was made between them. It might be the A meter—

Q. You endeavored, didn't you, to use the same size cable all the time?

A. We did not.
Q. So far as you could?
A. We did not.
Q. You just interchanged from one size to another?
A. Yes.
Q. Just as you happened to have wire around?
A. As we happened to be able to buy the cable.
Q. Do you consider the difference in the size of the wire made any great difference in the deflection?
A. The size of the wire might make some difference in the deflection. I would not care to say how much. I have never made any experiments or computations to show what it would be; but I can conceive of its being as great as two or three degrees easily. It might be more. It is possible it was less.
Q. Then you haven't any very definite idea as to what the difference might be?
A. I have not a very definite idea.
Mr. Adcock: That is all.

Re-re-direct Examination by Mr. Hopkins.

Q. Do you consider the deflections made any great difference in the results of the measurements?
A. The deflections of the meter cable within five or six degrees would have a very small effect upon the actual position of the meter, and the small change in the actual position of the meter would have an infinitesimal effect on the measured flow.

Further Re-cross Examination by Mr. Adcock.

Q. So it was not very important just where the meter was immersed, was it?
A. It was not at all important, within certain limits.

Adjourned subject to notice.

WALDEMAR S. RICHMOND, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Waldemar S. Richmond.
Q. Where do you live, Mr. Richmond?
A. Detroit, Michigan.
Q. What is your business or profession?
A. Civil Engineer.
Q. By whom employed?
A. United States Lake Survey.
Q. What education, training and experience have you had?
A. I was graduated from the Massachusetts Institute of Technology in June, 1905. I worked, directely after that, one month for the Pennsylvania Railroad at Pittsburg; eight months with the Widell Finley Company of Chicago, in Dakota and Illinois; two months as assistant instructor in civil engineering at the Massachusetts Institute, and since May, 1906, with the United States Lake Survey.
Q. What training and experience have you had in the measurement of rivers and streams of various kinds?
A. I was for three years ranking Assistant to Mr. Moore, and was with him in all of his hydraulic work except the measurments in December, 1911, and December, 1913.
I had full charge of the hydraulic party for about two months in the fall of 1909, during Mr. Moore's illness; and since July 1st, 1910, I have had full charge in field and office of the hydraulic party of the Lake Survey.
Q. The work that you say you were not engaged with Mr. Moore in, in December, 1913, what work was that?
A. That was the measurement of the Drainage Canal.
Q. And in December, 1911?
A. Measurements of the hydraulic canal at Niagara Falls.
Q. What rivers have you measured, or taken part in the measurement of?
A. St. Marys, St. Clair, Niagara and St. Lawrence.
Q. Now take the St. Clair; how many sections have you been engaged on?
A. On measurements on two river sections and on all the six sections in the Delta.
Q. What sections are they?

A. Near the head of the river, there is Section Gorge; further down, Section Dry Dock, and the six sections in the Delta are named to correspond with the names of the channels.

Q. When was each one of those measurements?

A. Sections Gorge and Dry Dock, I made measurements of in 1908, 1909 and 1910, and the channel sections in 1910.

Q. With reference to what gage were each of these observations made, or were the observations at each of these sections made?

A. In 1910, 11 self-registering gages were maintained. Do you mean what gages were used in final reductions?

Q. Explain in detail just how the work was done?

A. In 1910, the 11 self-registering gages were maintained as I have stated. These were located partly at Port Huron near the head of the river, and along the length of the river as far as Lake St. Clair. Discharge measurements were made at Section Gorge and at Section Dry Dock during practically every month of the seven months of the field season; and on each of the six Delta Sections at five different periods, a little more than a month apart.

Q. To what gage were your discharge measurements referred?

A. In the final reduction, the measurements were referred to a gage right at the foot of Lake Huron, called Ft. Gratiot Lighthouse gage, and to a gage at the foot of the river on Lake St. Clair called St. Clair Flats gage, but through the relation of those two gages to the upstream gage, and gage at Dry Dock.

Q. What do you mean by the upstream gage?

A. The Ft. Gratiot Lighthouse gage.

Q. What was the purpose of these new measurements that you made?

A. They were to increase our knowledge of the hydraulics of the river, to ascertain as definitely as possible whether or not there had been any change of regimen in recent years, and whether or not there was any seasonal change in regimen.

Q. What precautions did you take to insure the correctness of your work; as to gages, for instance?

A. Gages were maintained in the customary manner, all the precautions which I had learned from former work being observed, and in addition extra precaution was taken, in that practically every gage was referred to at least two different bench marks, and levels were run at least three times during the season; that is at the beginning of the work, and

sometime in mid-summer, and again near the close of the work. The gages were very frequently inspected by a trained assistant, who was particularly careful with his watch; the idea being to get the time on the records within one or two or perhaps three minutes; that is as accurately as possible. Unusual precautions were taken in leveling, to the reference points of the gages. An umbrella was used over the level if there was any sun, or was used as a wind shield, if there was the slightest breeze. A spherical rod level was used with the rod. The target was always set, and it was read independently by two persons. Further, an improvement was made in the small type of gage, so that there was no possibility of the record paper slipping.

Q. Now, what precautions were taken as to other elements of the work?

A. All known precautions were observed. In regard to the meter work, some refinements were introduced. In rating the meters, they were suspended two at a time, a thing which has frequently but not always been done by the Lake Survey, so that any irregularity that appeared in one and not in the other was at once noted.

The meters were rated at least twice, you might say, during each rating; that is, when one pair had been about half rated they were taken out; the other pair was half rated, and the first pair was then returned to the water, but in opposite positions, so that the meters had received a cleaning and oiling, and were interchanged in position, during the two halves of the rating.

The same base wire, which is the standard of length that determines the distance factor in the rating, was used in all these ratings, the same identical wire, and the distance between the two marks on it was determined in position at least once during each rating, with a good steel tape.

In measuring velocities in the stream, or discharge measurements, two meters were always run abreast at the 4/10ths depth points as heretofore, but after the completion of a single discharge measurement one meter was invariably changed and the other meter was cleaned and oiled, so that if more than one measurement was made during the day, we had a current rating, a current comparison of the performance of two meters against one other one. The meters were always attended to by myself or my assistant, Mr. Jones; nobody else being allowed to clean them or oil them or have anything to do with the wheel part of the head of the meter.

The contact pins were never changed during the entire season.

The pivot was never molested between two still water ratings. In case of wear, when the wheel began to rub at any point on the meter, the part that was rubbed was immediately filed down, so that the rubbing could not continue. That would not be a part of the bearing.

Mr. Adcock: I move to strike out the portion of the answer which states that he used all precautions that he obtained from other work. It states an improper conclusion of the witness, that he used extra precautions, because that encroaches upon the province of the court, and then that he used unusual precautions, in running levels, the same point with reference to that statement as to the previous one; and that he used all known precautions with reference to certain ratings of the meters. And that a man was selected who was careful with his watch, we object to that as unintelligible.

Mr. Hopkins: Mr. Richmond have you read Mr. Moore's testimony in this case, taken in 1909?

A. I have.

Q. Are you acquainted with the precautions which he said in that testimony he used?

A. I am very familiar with them.

Q. Did you take all of those precautions?

A. I did.

Q. And those that you have mentioned to-day in your testimony?

A. I did.

Q. Who is this Mr. Jones that you spoke of?

A. Mr. Albert B. Jones is a Junior Engineer with the United States Lake Survey. He has been my ranking assistant since July 1st, 1910.

Q. Have you had opportunity to check on his work?

A. I am perfectly familiar with practically all of his work.

Q. Is he a college graduate?

A. He is a graduate of the University of Michigan, class of 1910.

Q. In civil engineering?

A. In civil engineering.

Q. Is his work accurate?

A. It is.

Q. Who were the individuals—

Mr. Austrian: I haven't any objection to your asking if

in the witness' opinion his work is accurate. I do not think you have a right to ask him that.

Mr. Hopkins: I think everything he says is really that.

Mr. Austrian: I do not think you have a right to ask him whether his work is accurate.

Mr. Hopkins: It is a question for you to argue. He said that he had seen all of his work; was very familiar with it.

Mr. Austrian: Will you change your question? It is not a proper question. Otherwise you substitute the witness' opinion for the court's.

Mr. Hopkins: That is you best judgment as to his work, is it?

A. Yes.

Q. Who were the individuals that handled the watch in connection with the gage that you speak of?

A. As a matter of fact I handled the watch myself while Mr. Moore had charge of the party, until the first of July.

Q. What year?

A. 1910, and thereafter Mr. Clarence Theurer, a surveyman with the United States Lake Survey attached to my party made the inspection and handled the watch.

Q. What precautions do you take as to the accuracy of your watch, in discharge work? As to the time elements, what precaution is taken?

A. Watches were compared with standard time as given by some clock in Port Huron, almost daily during the year of 1910, in the endeavor to keep the watches actually used at least within three minutes of correct central standard time.

Q. In discharge work, what precautions are taken to insure the correctness of the time element?

Mr. Adcock: I object to that unless you refer to the Lake Survey work.

A. Time intervals during the velocity observations were ordinarily 120 seconds. These were customarily determined with an ordinary watch with a second hand; but a good stop watch was occasionally used to check the determination by the common watch.

Q. Mr. Richmond, did you investigate for error in the breaking of the electrical circuit?

A. I have never made any experiments to show what the error in making and breaking of registration circuit was, but it can be accurately deduced theoretically. There is a constant error in the registration as practiced in our work. It amounts in the ratings to approximately 1/3 of 1 per cent.

The velocity observations tend to eliminate it, and in certain velocities it is entirely eliminated. There is, however, a residual error in all the discharge work, and it amounts on some sections to as much as .2 of 1 per cent of the discharge.

Q. In which direction is that error?

A. The discharge as recorded is too small, due to that error.

Mr. Adcock: That is your opinion?

A. That is the result of computation.

Mr. Hopkins: Q. What would it be, that same error, in the Third Section or Split Section of the Niagara River?

A. On the portion of that section in the West Channel, it amounts approximately to 1/10th of 1 per cent.; and on the other it is the same.

Mr. Adcock: Q. Do you correct that error in making the computations?

A. It has not been corrected.

Mr. Hopkins: Q. Would that error have any effect upon an increment determined from those observations?

A. Inappreciable.

Q. Now what measurements have you made upon the Niagara River?

A. Upon the Niagara River, I assisted Mr. Moore in his measurements from the International Bridge in 1907 and 1908, and this past summer, I directed the measurement at the Third Section.

Q. Was the work at this Third Section or Split Section done with the same degree of care that you have described as to your late work in measuring the rivers?

A. Yes.

Mr. Adcock: That does not apply to the former work?

Mr. Hopkins: The question was only as to the latter work. The other was already in the record.

Q. I show you Exhibit C, October 8, 1913, consisting of four pages. What is that exhibit?

A. This exhibit appears to be a blue print copy of a letter submitted by me to the District Office of the Lake Survey, being a preliminary report on the hydraulics of the Niagara River of 1913.

Q. What does it contain in detail?

Mr. Adcock: I object to that question as to what it contains. That is shown by the paper itself.

Mr. Hopkins: Q. Describe in a general way what is in there?

A. This letter contains data relative to the measurements on the third Section of the Niagara River.

Q. By whom was it written?

A. By myself.

Q. Does it contain the correct data as discovered by you in the work at the Third Section?

A. Yes.

Q. Does it give the volume of discharge?

A. It does.

Q. What else does it give?

A. It gives certain data about the conditions at the sections, and in general the methods employed in making the measurements.

Mr. Hopkins: We offer that in evidence as Richmond's Exhibit 1, February 4, 1914.

(Document identified by witness was offered in evidence and marked Richmond's Exhibit 1, February 4, 1914.)

Mr. Adcock: I want to object to that, as it appears to be merely a preliminary report; the final report should be produced showing the complete document. It is objected to on the ground it appears to be merely a part of a report.

Mr. Hopkins: Have you made any further report?

A. I have not.

Mr. Adcock: Does that report contain all the data which you have with reference to that measurement?

A. It contains all except the tabulation of the daily mean water surface elevations at the gages.

Q. Does it contain the details of the soundings and coefficient work?

A. It does not go into great detail.

Mr. Hopkins: Q. So far as results are concerned, is it final?

A. It is.

Mr. Adcock: I withdraw the objection that was made.

Mr. Hopkins: I show you Exhibit D of October 8, 1913 (handing witness same), what is that?

A. This appears to be a photographic reproduction of a chart prepared by me showing the relations of revolutions per second to velocity in feet per second, which are the ratings of the four meters used.

Mr. Adcock: That was on the Split Section?

A. Yes.

Mr. Hopkins: That is offered in evidence as Richmond's Exhibit 2 of this date.

(Document identified by the witness and offered in evidence was marked Richmond's Exhibit 2, February 4, 1914.)

Q. I show you Exhibit E of October 8, 1913 (handing witness same). I will ask you what that is?

A. This is a similar reproduction of a chart prepared by me showing the final results of discharge measurements on the two portions of the Split Section, with their relation to elevations at the Buffalo gage, Lake Erie.

Mr. Hopkins: That is offered in evidence as Richmond's Exhibit 3 of this date.

(Document identified by witness and offered in evidence was marked Richmond's Exhibit 3, February 4, 1914.)

Q. I show you another paper, Richmond's Exhibit 4 of this date. Tell us what that is.

A. This is a reproduction of a chart prepared by me showing the cross section of the bottom profile and the transverse curve of velocities at .4 depth for Sections "Wickwire" and "Oakfield," the two portions of the Split Section.

Mr. Hopkins: I offer that in evidence.

(Document offered in evidence and identified by witness, was marked Richmond's Exhibit 4, February 4, 1914.)

Q. Mr. Richmond, will you go into detail as to what you did in the measurements at this Split Section, and what precautions as to accuracy were taken, and just explain in your own way how the work was carried on.

A. These sections having been selected and approved by my superiors, the first work was to determine horizontal distances.

Mr. Adcock: State who approved of it?

A. Mr. F. C. Ray, Principal Assistant Engineer. The first work was to measure horizontal distances, in order to obtain the length across the river and the location of certain signals with respect to this line. In making these horizontal determinations, a good 100 foot steel tape was used to measure a base line about a half a mile long. A system of triangulation was laid out, all angles being read by repetitions, so that each angle was known within a few seconds of arc; and by trigonometric computation, the distances were determined. As a check on these distances, connection was made with the triangulation system of the International Waterways Commission.

This connection on Section Oakfield gave a discrepancy of about 1/10th of a foot in a line nearly half a mile long, and on Section Wickwire the agreement was not quite as good.

The system of ranges was then planned, and the positions of the ranges determined in a similar manner so that definite points on the river could be occupied, by sighting across the ranges which defined the section itself, and another pair which gave a line intersecting. The intersections of the two lines defining any position in the river were never sharper than about 35 degrees, I believe.

On each section, two sets of cut-off range systems were established, one on each shore. In sounding the sections, the Lake Survey steel catamaran was used. A 140 pound, fish shaped iron sounding weight was suspended by a steel wire, about a tenth of an inch in diameter. This was wound on the drum of a reel, by the indications of which, depths to the nearest tenth of a foot could be read. This catamaran was swung in position on a long mooring line, in the customary manner. The sounding wire entered the water exactly on section, and its position on the section was determined by angles from a transit on shore. Deflections above the water of the sounding wire from the vertical were observed. These soundings were reduced in the customary manner, the necessary corrections for deflections, diameter of reel and fluctuation of stage being applied.

Mr. Hopkins: Q. What possible error might come in the distances, that is length of section and so on?

A. The length of either section would not be in error by one-half a foot.

Q. What is that as a percentage?

A. Not over .03 of 1 per cent.

Adjourned to Thursday, February 5, 9:30 A. M.

Thursday, February 5, 1914, 9:30 A. M.

WALDEMAR S. RICHMOND, resumed the stand and testified further on direct examination as follows:

Mr. Hopkins: Q. With what degree of precision, in your opinion, did you get the area of the cross section at the Split Section?

A. Within ¼ of 1 per cent.

Q. Is that true as to both of them?

A. For each section.

Q. In your sounding, did your weight go down plumb, or was there a deflection; if so about how much?

A. The mean deflection was 1 degree from the vertical; the maximum three degrees.

Q. That is in the sounding wire?

A. That is the deflection of the sounding wire.

Q. Now your velocity co-efficient, with what degree of precision did you ascertain that?

A. The mean of the co-efficients was within ½ of 1 per cent.

Q. Your velocity as ascertained by the current meter or meters?

A. Average velocities were good within .2 of 1 per cent.

Q. What in your opinion is the degree of precision of the whole work, the measurement of discharge, of the volume of flow?

A. I believe the final result to be good within 1 per cent.

Q. You mentioned something about undertaking new measurements for the purpose of further refinements if possible. What were your results in that regard; and what effect if any did it have on the final result?

A. The result, the final result was not appreciably better, in spite of the attempted refinements.

Q. How was this indicated in the Niagara River, with refernce to other measurements, or in comparison with the former measurements?

A. I should say that the close agreement of results was a good indication of this.

Q. Do you know what care of refinements were taken in the earlier measurements in the Niagara River?

A. I have read carefully the records of that work, and I am fairly familiar with the refinements taken.

Q. What were they?

A. Without going into detail, they were fairly similar to those of the later work.

Q. Now you said you had made some measurements in the St. Lawrence River. When did you do that work in the St. Lawrence River?

A. In 1911 and 1913.

Q. With what degree of precision do you think the Lake Survey now has the volume of discharge of the St. Lawrence River?

A. For the mean stage of observation, within 3 per cent.

Q. I don't believe I asked you this question: What was the condition of the water at the Third Section of the Niagara, with reference to your measurements?

A. The surface water was smooth, and the indications were that there was no particular perturbation in the flow.

Q. Did you make any examinations for that? First, what was the character of the bottom?

A. The bottom was mostly gravel or clay, on each section.

Q. There is a certain sand bar some little distance above this section, isn't there?

A. Yes, there is a bar in the neighborhood of half a mile above each section.

Q. Did you know that at the time you selected the section?

A. I knew that.

Q. What effect in your opinion does that bar have upon the condition of the water where you measured it as to perturbation?

A. I believe it would have no appreciable effect at the sections.

Q. Was there any curvature in the stream at those places?

A. There was a rather flat curvature at each section.

Q. What effect would that have upon the section with reference to your measurements?

A. I think the effect would be inappreciable.

Q. Do you have any way of knowing whether there are perturbations in the water beneath the surface, by indications of the meter or any other way?

A. Yes, there is a very good way.

Q. Just what is it?

A. It is the indication of the electric register of the meter.

Q. Were there any such indications in these places?

A. On the bottom runs, the registers indicated some irregularity.

Q. How about the 9/10ths depth?

A. The 9/10ths depth did not show much if any.

Q. What in your judgment would be the effect of that condition near the bottom on the whole work, as to the whole volume of flow?

A. The whole volume of flow might be indicated slightly smaller than the true volume.

Q. What do you mean by slightly, in percentage?

A. I don't think it would amount to a quarter of 1 per cent. of the river flow.

Q. You take that into consideration in giving your opinion that the whole work was accurate within 1 per cent.?

A. I do.

Q. Did you take into consideration in giving your opinion of the 1 per cent. error of the whole work, the make and break of the electric current?

A. I did.

Q. Did you state which way the error was?

A. It might be either way.

Q. Mr. Richmond, what in your opinion is the increment of the Niagara River?

A. At mean stage of observation 21,500.

Q. Just what work have you done, in connection with the increments of these various rivers, and what study have you made?

A. I derived the more recent equations for the St. Clair River, and have done some computing on the derivations for the Niagara River; have derived the later equations for the St. Lawrence River.

Mr. Adcock: Q. The increment is based upon your computations and the computations of others?

A. Yes, sir.

Q. From the measurements in evidence here, the records of measurement?

A. (No response).

Mr. Hopkins: Q. Have you studied the work of the other men in the Lake Survey Office, in this matter of increment?

A. I have.

Q. And compared that with your own observations and computations?

A. Yes.

Q. And the increment you have given for the Niagara is the result of all of your knowledge in connection with that matter?

A. It is.

Mr. Adcock: What I wanted to ask you is whether or not your statement as to what you believe the increment of the Niagara River to be is based alone on the observations or records of observations and measurements in the Niagara River that have been referred to in the evidence?

Mr. Hopkins: Q. Mr. Richmond, just tell us what it is based upon, your opinion as to the increment?

A. It is based upon my knowledge of what the observations were, what the results were and what the computations were, having myself assisted in making some of those computations.

Q. Referring to Haskell's Exhibit 1, February 3, 1914, how does the increment as it appears on that exhibit from the plotted observations compare with the one you have given?

A. The increment given here is 21,900.

Q. In your opinion Mr. Richmond, is the line showing an increment a straight line or a curve, that is for the Niagara River?

A. For the Niagara River I believe there is practically no difference.

Q. You say that you yourself have computed an increment for the St. Lawrence River?

A. I have.

Q. What is that increment?

A. For a stage of 245 at Oswego, about 21,000.

Q. What elevation was that?

A. 245.

Q. Is that mean?

A. That is the nearest even foot from the mean.

Q. What range of stage did you get in the St. Lawrence approximately?

A. A little over two feet for mean measurements.

Q. Is this increment from your own measurements?

A. It is.

Q. In your opinion within what degree of precision is the increment that you have given in the Niagara River?

A. I believe it to be within 5 per cent. of the truth.

Q. And the increment of the St. Lawrence River?

A. Within 8 per cent.

Q. You say you have computed an increment, too, for the St. Clair River?

A. I did.

Q. What is it?

A. For a stage of 579 at Lake Huron, 20,300; for a stage of 581, 22,700, with normal conditions in Lake St. Clair.

Q. That would indicate that the increment in the St. Clair is more correctly represented by a curve than a straight line?

A. I believe it is.

Q. Now on the St. Lawrence?

A. In my opinion a curve fits the observations a little better than a straight line for the St. Lawrence.

Q. Now, Mr. Richmond, these increments are all derived from open season conditions, aren't they?

A. They are.

Q. What would the increment for the entire year be as compared with the increment you have given?

A. It would be somewhat less, due to ice effects in the rivers.

Q. What rivers do you refer to in that particularly?

A. I believe the St. Clair and Detroit Rivers to be affected much more than the others.

Q. How about the St. Lawrence?

A. There is some effect. I don't know how great it is.

Q. For a given diversion say at Chicago, which continues all the year around, in your opinion would the effect upon the lakes as far as level is concerned, be greater or less when the whole year is considered than the increment you have given?

A. The effect would be greater because the increment must be less.

Q. Now in your work at the St. Clair, that you have conducted, what did you do with reference to passing boats?

A. I made practically no velocity observations when passing vessels were on or near the sections.

Q. Were there a good many boats passing?

A. Yes.

Q. How about the Niagara and the St. Lawrence in that respect?

A. There are comparatively few boats passing on the Niagara. On the St. Lawrence, the condition is somewhat intermediate between the Niagara and St. Clair.

Q. What is the length of time it takes for a crest at the Fort Gratiot Lighthouse to affect the Gorge Section in the St. Clair?

A. Approximately one minute.

(Table entitled: Time interval required for change of Lake Stage at Ft. Gratiot to be felt at various gages and sections is set out below:)

From Fort Gratiot Lighthouse Gage.

Gage or Section	Miles	Time	Time to Nearest 10 Minutes	Minutes per Mile.	Section from Channel Entrance Miles.
		h min			
Section Gorge	0.45	1			
G. T. R.	0.80	2			
M. B. R.	2.45				
Dry Dock (Dunford)	4.65				
Dry Dock (Section)	5.10	16	20	3.14	
St. Clair	13.8	44	40	3.19	
Marine City	21.6	59	1:00	2.73	
Roberts Landing	25.6	1:09	1:10	2.69	
Section Sny	27.4	1:14	1:10		0.3
Section Bridge	30.8	1:32	1:30		0.8
Herson Island	32.4	1:37	1:40	2.99	
Salt Block (gage)	33.7	1:41	1:40	3.00	
Section M. C.	33.9	1:42	1:40		1.5
Section Salt Block	34.6	1:44	1:40		
Section Bassett	34.7	1:44	1:40		0.3
Section S. E. Bend	34.9	1:45	1:40		
St. Clair Flats	39.4	2 Approx	2 Approx	3.05?	

Q. Referring to table above, just describe that?

A. That is a table showing the distance along the thread of the stream from Ft. Gratiot Lighthouse down the St. Clair River, and the corresponding time intervals of wave propagation down the river.

Q. Suppose the level of Lake Huron at Ft. Gratiot Lighthouse should rise 1 foot. How long would it take that effect to appear in the St. Clair River at various gages along the river?

A. At the G. T. R. gage—

Q. That is the Grand Trunk Railroad gage is it?

A. Yes—two minutes; at Section Dry Dock gage 16 minutes; at St. Clair 44 minutes; at Marine City 59 minutes; at Robert's Landing 1 hour and 9 minutes; at Herson Island gage 1 hour and 37 minutes; at Salt Block gage 1 hour and 41 minutes, and at St. Clair Flats gage approximately 2 hours.

Q. At what places were measurements made there of flow?

A. I mentioned the automatic gages.

Q. Which one is the Gorge Section?

A. The one that was mentioned previously, as taking 1 minute.

Q. Which one is the Dry Dock Section?

A. 16 minutes.

Q. What was the name of it?

A. Section Dry Dock gage.

Mr. Hopkins: Q. And the Third Section where you made measurements?

A. The intervals to those gages were determined by proportion from the nearest self registering gages.

Q. What is the time approximately?

Mr. Adcock: Are those the gages on the gaging section at the Delta you speak of?

A. Yes. At Section Sny in the Chenal Ecarte 1 hour and 14 minutes; at Section Bridge in the Blind Channel 1 hour and 32 minutes; at Section Bassett in the Bassett Channel, 1 hour and 44 minutes; Southeast Bend Section in the South Channel, 1 hour and 45 minutes; at Section M. C. in the Middle Channel 1 hour and 42 minutes; at Section Salt Block in the North Channel, 1 hour and 44 minutes.

Q. What is the rate per mile in the transmission of this wave effect?

A. Approximately three minutes to the mile.

Q. In your judgment does the velocity effect closely follow that?

A. I believe it does.

Q. What was the time interval on the St. Lawrence River between the Galops Rapids and the Three Point Section?

A. Between the Ogdensburg and section gages you mean?

Q. Yes?

A. The interval is two hours and 20 minutes.

Q. Did you determine that yourself?

A. That is the interval determined by Mr. Shenehon. I have re-determined it to be 2 hours and 15 minutes.

Q. What is the distance?

A. About 17 miles.

Q. What is the rate per mile?

A. That is about eight minutes to the mile.

Q. Why is that slow as compared with the St. Clair?

A. It must be due to the presence of the rapids in that reach of the river.

Q. Mr. Richmond, in your opinion with what precision can large streams be measured as to volume of flow, as compared with small streams?

A. Large streams can be measured at least as accurately as small streams.

Q. Have you read the testimony of Mr. Schoder and Mr. Turner in this case?

A. I have.

Q. Do you have in mind the tests made by them of the Haskell current meter, as testified to by them?

A. Yes.

Q. In your opinion do those tests show that the current meter is inaccurate?

A. No.

Q. Why not?

A. The tests were made under conditions such as never prevailed at gaging sections used by the Lake Survey. The meter is said by Mr. Turner to have vibrated both horizontally and vertically. In all my use of a current meter, I have never seen any such vibrations. The perturbation at the sections, as judged by the photographs is very much greater than at any section the Lake Survey has ever used. It is not comparable at all.

Q. Do you think that it is possible to determine with accuracy the cross section in that canal that they testified about under the conditions that appear in their testimony?

A. It was testified that waves of at least .2 foot amplitude were occurring on these sections. I do not see how the cross sections, at least of the shallower sections, could have been determined within about 2 per cent.

Q. How about the portion of the water nearest the bottom and the sides?

A. Meter measurements were not taken closer than ½ foot to the sides and bottom of the canal.

Q. How about the velocity coefficient?

A. I don't understand that coefficients were used, but if they were, I do not see how they could have been determined very accurately under those conditions.

Q. I suppose that in a large river you would have a wave effect of as much as two inches or more, wouldn't you?

A. Never during the determination of a cross section. That work is always done on a day when the river surface is perfectly smooth.

Q. But suppose you had a river of a depth of 30 feet as compared with a canal of 3½ feet, what would be the difference?

A. The percentage of error in the smaller channel would be very much larger.

Q. Why?

A. The size of waves on the river would have to be comparable with the size of waves in that canal. The waves would have to be—

Mr. Adcock: Assuming a depth of 30 feet?

Mr. Hopkins: Yes, assume a depth of 30 feet.

A. The waves would have to be considerably larger. I could not state just how much.

Q. Can you give it roughly? Is it your opinion that the wave would have to be about 2 feet high to be comparable?

A. It would have to be in that neighborhood.

Q. How about the weir measurements themselves in these tests?

A. There is some doubt as to the accuracy of the weir, inasmuch as it was calibrated by a double transfer from a smaller weir.

Mr. Adcock: Q. Mr. Richmond, do you know how it was calibrated?

A. As given in the testimony by Mr. Schoder and Mr. Turner.

Mr. Adcock: I move that the statement of the witness be stricken out as to conclusions regarding what the testimony of Mr. Schoder and Mr. Turner shows. The court will determine that.

Mr. Hopkins: Q. Is your statement in reference to the weir Mr. Richmond based upon what was in the testimony as to the way they determined the accuracy of the weir?

Mr. Adcock: I object to that.

Mr. Hopkins: Q. Upon what was your statement as to the weir based?

Mr. Adcock: You can ask him a question assuming that it was calibrated. I do not want the witness to state what Schoder's and Turner's testimony shows.

Mr. Hopkins: Assuming that the weir was calibrated in the manner stated in the testimony of Mr. Schoder and Mr. Turner.

Mr. Adcock: I object to that.

Mr. Hopkins: What is your opinion as to the accuracy of the weir measurements?

Mr. Adcock: I object to that question on the grounds stated.

Mr. Hopkins: Now go ahead.

A. I do not see how the weir could be assumed to be accurate.

Mr. Adcock: I move that answer be stricken out.

Mr. Hopkins: Q. Do you recall a part of Mr. Schoder's testimony—

Mr. Adcock: You can ask him a question assuming that the weir was calibrated in a certain way. If your assumption corresponds, in the opinion of the court, with what Mr. Schoder and Mr. Turner stated in their testimony, then your answer is all right.

Q. (Question read) —wherein he is speaking of the precision of observations at various sections, and speaks of having made more observations at some sections than at others?

A. Yes, at a section 41 feet below the baffles, he measured discharges number 6 and 9. The discharge as given by the standard weir differed only about 1 per cent. in those two measurements.

The mean depth at the section differed less than ½ of 1 per cent. There was a difference by the current meter measurement of approximately 7 per cent. This, Mr. Schoder attributes to the difference in precision of the current meter measurements. He measured velocities at more points in the section on discharge number 9, but did not measure any closer to the sides or bottom. This discrepancy, amounting to about 7 per cent., is much greater than the discrepancies found in Lake Survey measurements, and seems to me to indicate a lack of precision in his work.

Mr. Adcock: You say it seems to have shown lack of precision; you mean he did not do his work accurately, is that right?

A. Yes.

Mr. Hopkins: That is all.

Cross-examination reserved.

Wednesday, February 18, 1914, 9:30 A. M.

WALDEMAR S. RICHMOND resumed the stand and testified further as follows:

Mr. Adcock: Q. On the Oakfield Section, Mr. Richmond, the hydraulic section, what was the width of the river at that point?

A. About 2,200 feet.

Q. How many panels?

A. There were 11 panels, in addition to the two end areas.

Q. You sounded that section in the same way you did the Wickwire Section?

A. Practically the same.

Q. Every 7½ feet?

A. The soundings were a little closer together, averaging 5.6 feet apart.

Q. About how often were they?

A. 5.6 feet.

Q. Is that the closest, or the average?

A. That is the average in the 11 panels.

Q. What is the greatest depth?

A. 37.7 feet.

Q. What was the greatest inclination, maximum inclination of your sounding wire?

A. Three degrees.

Q. Where was that found?

A. At the maximum depth.

Q. How many days did it take you to do the soundings on both sections?

A. As I recall it, soundings were made on four different days on Section Oakfield, only part of the day being used each time. On Section Wickwire, the sounding was completed on one day, I believe in about half a day.

Q. On the Oakfield Section, were those days consecutive days?

A. They were not.

Q. How far apart were they?

A. I haven't the record of that. I could not say exactly.

Q. Was there the same condition of wind and water and so on as to turbulence, at the time you made the soundings?

A. Practically the same.

Q. Did you have any record of the conditions on the day the soundings were made?

A. In the field books, I believe there are records of the weather conditions, and with reference to the quietness of the surface water.

Q. What was the index velocity in the vertical, where the maximum deflection occurred on Oakfield?

A. It was about three feet a second. I haven't the exact figures.

Q. Was the water the greatest depth at that point?

A. I do not think any vertical came at the point of maximum depth on the section, exactly.

Q. How near the maximum depth was the nearest vertical?

A. I should say offhand within one or two feet.

Mr. Hopkins: Q. Do you mean one or two feet in depth or one or two feet laterally from the deepest point?

A. I mean difference in depth between the maximum depth and the depth on the vertical nearest to it.

Mr. Adcock: Q. What would be the effect of this additional depth that you speak of on the velocity?

A. Do you mean what difference would there be in the mean velocity at the point of greatest depth and at the vertical?

Q. Yes, and at the nearest vertical?

A. I should think the mean velocity would be slightly greater at the deepest point.

Q. I presume that there is some point in a river where the mean velocity is greater than the mean of any other point?

A. In the vertical, yes.

Q. Is that usually at the greatest depth, or do other conditions enter in?

A. It is influenced somewhat by other conditions, mainly whether that greatest depth continues upstream and downstream at the same point.

Q. Do you know whether that was the case here at this point of the river?

A. I do not know, within that small limit.

Q. What was the vertical where the greatest deflection occurred; that is the number of the vertical so that we can have it for reference?

A. I haven't that exactly, but I believe it would be one of the central verticals.

Q. You numbered the various verticals, didn't you?

A. They were numbered.

Q. I didn't know but perhaps you might know the number of the vertical, where the greatest deflection occurred?

A. I haven't that here so that I could give that.

Q. Was it vertical eight?

A. I don't believe so.

Q. What was the vertical where the deflection of the sounding wire was two degrees, and what was the depth at that point on the Oakfield Section?

A. I could not state that without reference to the original data. I have no record of it here.

Q. You can't answer that question without referring to your notes?

A. Without consulting the field books, and I am not sure I could then.

Q. On Oakfield, what was the number of the vertical where the greatest deflection in the sounding wire existed?

A. Vertical five was about 18 feet from the point of maximum sounding and maximum sounding deflection.

Q. What was the depth at that point?

A. At vertical five, for the stage of this plot, the depth was 36.4 feet.

Q. What was it at the deepest point, 37?

A. 37.7.

Q. What was the stage to which you refer?

A. 2.40 on section gage.

Q. What was the deflection on vertical 5?

A. Sounding deflection?

Q. Yes?

A. It was between two and three degrees. The deflection was not measured actually at that point.

Q. And the deflection at the deepest point was three degrees?

A. Three degrees.

Q. What was the deflection on vertical eight?

A. Between zero and one degree.

Q. What was the depth on that vertical?

A. About 21.9 feet at gage 2.40.

Q. What is the actual elevation to which 2.40 corresponds?

A. It has not been referred to actual elevation.

Q. What was the index velocity on vertical five for the elevation mentioned?

A. 2.99 feet per second.

Q. What was it in 8?

A. 2.54.

Q. Referring again to vertical 8, how many times was vertical 8 traversed by the meter, current meter?

A. Eight times.

Q. How many times were the verticals traversed at the other stations?

A. Four times on each except vertical 9, which was traversed six times.

Q. Why were eight traverses used at vertical 8?

A. Because, owing to a slight uncertainty in the smoothness of the bottom, the results by four traverses were not quite as good as on the other verticals, so that more traverses seemed desirable.

Q. That was your determination, was it?
A. Yes, it was.
Q. At the time you made these different traverses?
A. Yes.
Q. What percentage of the index velocity was the mean velocity by the first four traverses on vertical 8?
A. I don't think I ever computed that. I haven't those computations now.
Q. Then how did you compare the individual results with average results?
A. A plot was made in the field of the mean of those first four traverses, and from an inspection of that plot, as I recollect, I determined that more observations were desirable; but I do not think that the coefficient was computed.
Q. That is you compared this plot with the plot of other verticals, did you?
A. Yes.
Q. Did you think there was any greater inconsistency in 8 than there was in 4?
A. Yes, there was.
Q. You are sure of that statement, are you?
A. Yes, I feel sure of that.
Q. From calculations that you have made or from what?
A. Simply from inspecting the plot, and noting the amounts by which individual points did not fall on the smooth curve drawn.
Q. Take vertical 6, what do you say as to that?
A. Vertical 6 was measured with four traverses only, and it was considered satisfactory.
Q. Did you consider that the agreement of traverses in 6 was as good as that in 8?
A. The final result at 8, does not seem to me to be quite as good as on 6.
Q. Are you referring to the first four traverses or all eight traverses?
A. I was referring to all eight.
Q. Will you refer to the four in answering the question?
A. It would answer for that also.
Q. What is that?
A. It would answer for that also.
Q. Compare that with one vertical.
A. Compare 6 with one of 8?
Q. 8, the first four traverses of 8?

A. I should say the result of the first four traverses on 8 was not as good as on 1.

Q. Will you compare the results of the first four traverses on 8 with the results of the second four traverses on vertical 8?

A. From an inspection of the data here, I should say the last four were a little more harmonious among themselves than the first four.

Q. What was the difference in percentage of the coefficients?

A. That has not been computed.

Q. Wasn't it approximately two per cent.?

A. I could not say very accurately without computing. I do not think it would be that great.

Q. How great do you consider it would be?

A. It looks to me as if it might easily have been 1 per cent.

Q. Might it have been two per cent. approximately?

A. I could not say definitely, without making a computation.

Q. How long will it take you to make a computation?

A. An hour, perhaps.

Q. Assuming that the difference between the results of the first four and the second four traverses has been approximately two per cent., how far would that adopted average have been from the mean of the first four?

A. It would have been in the neighborhood of half of the two per cent.

Q. Approximately 1 per cent.

A. In that case, approximately 1 per cent.

Q. Suppose that eight traverses had been made on all the other verticals, and the result had been to make a similar change in the percentage for all of them, how much would the discharge have been changed?

A. Assuming the condition you state, the total discharge would have been changed 1 per cent.

Q. If the difference was .9 of 1 per cent., the answer would be the same, is that correct?

A. The vertical coefficient enters as a direct factor.

Mr. Hopkins: Q. Mr. Richmond, that 1 per cent. as to all of them, was that assuming that that one per cent. of error would be on the same side in every one of them?

A. That was what I understood from the question, the assumption that they made, that the coefficient should be 1

per cent. smaller or larger in each case. That of course is not the case.

Mr. Adcock: Q. What was the vertical where the deflection of the sounding wire was approximately two degrees?

A. The deflection seems to have been practically two degrees at verticals 3, 4, 5, 6 and 7.

Q. What was the depth in each one of these verticals, referring to the 2.40 mentioned?

A. Those depths scaled from the chart are: Vertical 3, 32.4; vertical 4, 35.1; vertical 5, 36.4; vertical 6, 34.8; vertical 7, 33.8.

Q. What was the index velocity in each vertical? I think you have stated the index velocity of 5?

A. Vertical 3, 2.9 feet per second; 4, 3.0; 5, 3.0; 6, 3.0; 7, 2.9.

Q. If you wished to obtain the ratio of the mean velocity to the index velocity in any vertical, by arithmetical computation, what weights would you give to the observation at each point in the vertical?

A. If I understand your question rightly, in this case a single one of my observations at the bottom was given the weight of ½, and the others practically a weight of 1.

Q. Did you make any distinction between the weight of .2, .4, .7, .8 depths?

A. I think not.

(Question and answer immediately previous to last one read.)

Mr. Hopkins: Include in your answer what you understand the question to mean?

The Witness: I don't believe I understood the question.

Mr. Hopkins: Answer the question. Strike out the answer.

A. My answer was based on observations. I simply meant that I took a weight of one-half for the bottom observation, because there were two observations and the mean was used as against single observations on the other points.

Mr. Adcock: Q. You understand—

A. I would not attempt to do it the way I understand from your question, because I don't think it could be done accurately.

Q. That is by arithmetical computation?

A. Yes.

Q. Did you ever try it that way?

A. I never did.

Q. How great an error would result if the observations were properly weighted by this arithmetical computation?

A. If they were weighted with due regard to the form of a

smooth curve drawn through the plotted points, I don't see why a fairly accurate computation could not be made.

Q. Taking into consideration the form of the curve, what weights would you give to the different observations at different points?

Mr. Hopkins: That is a question on the arithmetical feature.

Mr. Adcock: Yes.

Mr. Hopkins: I object to that on the ground he said he would not determine it that way.

Mr. Adcock: No, we are asking him by arithmetical computation.

Mr. Hopkins: That is the form of my objection. He said he would not determine it that way.

Mr. Adcock: If he wants to express the opinion this is not as good a way as some other way, that is another proposition.

Q. (Last question read.)

A. It seems to me that the weights would have to vary with the individual curve, and that method of computation in the end would amount to the same thing as the method I have used.

Q. Do you mean that you would weight them differently in each vertical?

A. Yes.

Q. On what theory would you do that?

A. Because each vertical is of different depth from every other one, and the bottom run is always at a certain distance from the bottom and, therefore, the percentage difference, on a shallow vertical, comes considerably higher up the curve than on a deep one.

Q. How much difference would that make in the result for changes of depth from 20 to 30 feet?

A. As practiced by the Lake Survey, the bottom depth in a 20-foot vertical would be at a point about 93 per cent. of the depth from the surface, and in the 30-foot vertical about 95 per cent.

Q. How much difference would that make in the discharge, if both were given the same weight?

A. If I understand the question, there would be very little difference.

Q. How great an error would result if you gave the surface a weight of 1; .2 depth a weight of 2; .4 a weight of 2; .6 a weight of 1½; .7 a weight of 1; .8 a weight of 1; .9 a weight of 1, and the bottom ½?

A. For the average condition on Section Oakfield, I think

the error in the co-efficient would be in the neighborhood of 2 per cent.

Q. If all verticals were treated in this way at a single section, would a comparison of the results indicate the relative values of the ratio of mean to index velocity?

A. I think not, because the depths differ so much, and this error would change rapidly with change in depth. It would be fairly accurate for verticals of the same depth.

Q. How great changes occur at a single station? Confine your answer to a single vertical?

A. Confining my answer to a single vertical and dealing with the separate traverses of it, that seems to me to be a fair method of comparison.

Q. What is the ratio of the mean velocity to the index in the several verticals of the Oakfield section?

A. For vertical 1, .934; vertical 2, .908; vertical 3, .909; vertical 4, .918; vertical 5, .912; vertical 6, .918; vertical 7, .917; vertical 8, .911; vertical 9, .915; vertical 10, .914; vertical 11, .860.

Q. What is the mean of the scalings of each vertical?

A. The mean abscissa for each curve constructed is as follows: Vertical 1, .9250; vertical 2, .9044; vertical 3, .9062; vertical 4, .9223; vertical 5, .9097; vertical 6, .9172; vertical 7, .9148; vertical 8, .9133; vertical 9, .9147; vertical 10, .9138; vertical 11, .8716. Those are not really the mean of the scalings as the question states. I tried to state it so as to show that. They are the areas divided by the depths.

Q. And to reduce this to the co-efficient, this has to be divided by the scaling at the .4 depth?

A. Scaling at the .4 depth.

Q. Now, in these observations you used the Haskell current meter?

A. I did.

Q. That is the meter that the Lake Survey has used in their work?

A. I had four Haskell meters of the B type.

Q. What is the B type as compared with the C type, or some other type?

A. I don't recollect having seen any but the A, B and E types. The A meter is a larger meter arranged for determining directions of the current as well as velocity. The E meter is similar to the B, but smaller.

Q. Has the A meter a larger wheel?

A. No, the wheel is the same.

Q. What is it that is larger about the A meter?

A. The body is longer, and the central part is expanded to form a chamber in which a mechanism is located for determining deflections when the meter is out of sight, down in the water.

Q. That is the A meter?

A. That is the A meter.

Q. The B meter is not what is known as a direction meter?

A. No, the A is the direction meter.

Q. And the B meter is the meter that was used in this work, as well as on the other work of the Lake Survey, in connection with the gagings of the different rivers mentioned?

A. The A meter has been used, but it was not in this work that I am speaking of.

Q. When was the A meter used?

A. It was used by Mr. Shenehon in his Niagara River gagings; by Mr. Moore in his Niagara and St. Clair gagings.

Q. Have all the observations on the St. Clair and Niagara River been taken with the A meter?

A. Partly with the A, and partly with the B.

Q. What proportion of them were taken with the A meter?

A. Less than one-third on the St. Clair River. On the Niagara River about one-half of Mr. Shenehon's observations, I believe, were taken with the A meter.

Q. Did he use both meters at the same time; both types in his work?

A. Yes.

Q. Does the A meter indicate the direction in the vertical plane?

A. It can be used to indicate direction.

Q. How would you mount it to indicate direction in the vertical plane?

A. There is no change in the mounting; simply a matter of connecting up the electrical mechanism and operating it.

Q. Were those connected up for that purpose and so used in the work on these different rivers mentioned?

A. Not as far as I know.

Q. Did you misunderstand the question as to whether it indicated direction in the vertical plane?

A. Apparently I misunderstood your question.

Q. Do you wish to explain or correct your answer as to whether it would indicate direction in the vertical plane?

A. This meter will not indicate any deflection which means a pointing up or down.

Q. How was this meter suspended, in your co-efficient work

and in your other work on making these observations on the Wickwire and Oakfield Sections?

A. The meters were suspended in a similar manner to the sounding weight as already described, except that a quarter inch steel table was used.

Q. How heavy a weight was on the bottom of the meter?

A. On Sections Wickwire and Oakfield, the regular 40-pound weights were used with the meters.

Q. On all the verticals?

A. On all velocity measurements.

Q. Could you see the meter as it was suspended in the water at the time you were taking your velocity observations?

A. I could see the meter down to a depth of perhaps 6 feet; not below that.

Q. Would that be at the .1 depth, say, in the deeper sections?

A. That would be below the .1 depth.

Q. But not down to the .2, would it?

A. I could not say, but I doubt if we saw the meter at the .2 depths.

Q. Did you observe the deflection of the wire upon which the meter was suspended?

A. We did.

Q. What was the greatest deflection?

A. The greatest deflection I find is 12 degrees on vertical 5 for the bottom and .9 depths.

Q. For the bottom and .9 depths?

A. Yes.

Q. That is at Oakfield?

A. Section Oakfield.

Q. That was the deepest panel, wasn't it, deepest station?

A. That was the deepest.

Q. At the other stations, what was the deflection for the bottom and .9 depths?

A. The deflections were as follows: Vertical 1, 2 degrees; vertical 2, 4 degrees; vertical 3, 7 degrees; vertical 4, 10 degrees; vertical 5, 12 degrees; vertical 6, 10 degrees; vertical 7, 10 degrees; vertical 8, 5 degrees; vertical 9, 3 degrees; vertical 10, 1 degree; vertical 11, no degrees.

Q. That was at what depths, 9/10ths depth?

A. 9/10ths depth and bottom.

Q. Did you have any method by which you were able to keep the meter when it was submerged in the water in the proper direction?

A. The meter itself is constructed so as to point in the direction of the current.

Q. That is it has a tail to it?
A. It has.
Q. And that is intended to keep the wheel towards the current?
A. Yes.
Q. How accurately did you consider you could place your meter, say in the vertical at the .4 depth?
A. I believe that it was always within .2 of a foot of the proper depth.
Q. Did that apply to all positions in the vertical?
A. I think it would, yes.
Q. The deflection which you mentioned here, was that the deflection in the co-efficient work observed?
A. It was observed, yes.
Q. And the deflections which you gave were the deflections observed in the co-efficient work?
A. Yes, and at the bottom depths.
Q. And at the bottom depths. Did you observe the deflections after you had made the co-efficient work and in taking the velocity observations in the various verticals?
A. These deflection angles were observed usually during the first traverse of the vertical.
Q. In each case?
A. In each case.
Q. When you took a velocity observation at a particular station, you submerged your meter at the .4 depth, did you not?
A. You mean in measuring discharge?
Q. Measuring the discharge. I am not now referring to the co-efficient work?
A. Yes, in discharge measurements, both meters were suspended at the .4 depth.
Q. That is two meters were suspended?
A. Two were used abreast.
Q. How far apart?
A. They were four feet apart.
Q. In your co-efficient work do I understand you to say that you observed the deflection in each traverse of the vertical, or just the one traverse?
A. Usually only during the first traverse, I think.
Q. So you did not compare the deflection during the first traverse with the deflections during other traverses of the vertical, in co-efficient work?
A. Sometimes, but not as a general rule.
Q. Did you in this work out here at Oakfield or Wickwire?

A. As I recall it, we did compare some of the deflection angles on the deeper runs, but I do not see it recorded in the records.

Q. When you made a discharge observation at a station, or in making the discharge observations at the various stations, did you place the meters at the same point in the panel, each panel?

A. The steering wheel of the catamaran was held on station, this bringing the positions of the two meters practically in the same location.

Q. Each time you made a discharge observation?

A. Each time, yes.

Q. Was this point assumed to be the center of each panel, or the middle?

A. Not in all cases.

Q. Well, what determined the position or the point in the panel?

A. The station was located either in the middle or near the middle of each panel and was marked out in the river by intersecting range lines from the shore.

Q. How close to the middle was this point where you submerged your meter?

A. In the panels which were 100 and 200 feet wide, the station was in the middle. In the panels whose width was 150 feet, the station was 70 feet from the mid-stream side of the panel.

Q. What panels were 100 feet and 200 feet and what were 150 feet, at Oakfield?

A. Panels 1, 10, 11, were 100 feet wide. Panels 2 and 9, 150 feet, and panels 3 to 8, inclusive, 200 feet wide.

Q. Did you submerge the meter at any time in any other points in these different panels than the points where you mentioned? A. No.

Q. So you don't know what the velocity was during the time that you were taking these discharge observations at other points in the panels than the ones where you submerged your meter, as you have stated?

A. Not by actual measurement.

Q. How accurately was the steering mechanism held on the vertical?

A. I should say it was very infrequent that the steering wheel was more than 2 feet from the station position.

Q. How long did it take you to do the co-efficient work on Section Oakfield?

A. About five days.

Q. How long would it take you to make a discharge observation at Oakfield, or how long did it take you, an average?

A. About two hours and a quarter.

Q. Did you observe the deflection of the wire when you were making a discharge observation?

A. No.

Q. At .4 depth?

A. No.

Q. You didn't calculate that deflection at all?

A. No.

Q. When did you compare the deflection when you were making one discharge observation at a given station with the deflection while you were making a similar discharge observation at another time on the same station?

A. It was not observed or compared; it was too unimportant.

Q. That is, you considered it unimportant?

A. I did.

Q. Did you ever do that in your work?

A. Not on those sections?

Q. In any section?

A. Frequently in other sections where it becomes a matter of importance.

Q. But in your judgment, in doing this kind of work, in view of the conditions at this particular point or in this particular section, you thought it was not necessary, is that correct?

A. The correction would have been less than .01 of a foot, an amount that we could not set off on our apparatus.

Q. How far were the meters from the steering wheel of the catamaran?

A. Fifteen feet forward of the steering wheel.

Q. Upstream or downstream?

A. Upstream.

Q. How much would the catamaran swing with the wind at 35 miles an hour?

A. I don't believe I understand your question.

Q. Well, if the wind during the making of an observation was, say, east, northeast, 35 miles an hour, what effect would that have on the catamaran in the Oakfield Section, as to its parallelism with the axis of the stream?

A. I think the catamaran when held on station would point very slightly differently from what it would if there was no wind; I think that difference would be a very small amount.

Q. About how much would it affect the position of the meter?

A. I do not believe it would affect it a foot.

Q. What anchors did you use?

A. I didn't use the side anchor at all.

Q. Just had the single anchor?

A. But on the two stations nearest the end I used side lines to the shore. The central stations, we swung on the head anchor, and kept on position by the steering mechanism. It is a very simple matter.

Q. Now the method which you have outlined here, which you used in the Split Section of the Niagara River is substantially the same method which was used on the St. Clair, Niagara and St. Lawrence Rivers?

A. Substantially, yes.

Recess to 2:15 o'clock P. M.

After Recess 2:15 P. M.

WALDEMAR S. RICHMOND resumed the stand and testified further on cross-examination as follows:

Mr. Adcock: Q. You have some sheets there which show the percentage discharges of the various verticals, I believe 21 in all, in the Oakfield and Wickwire Sections?

A. Percentage velocities, yes.

Mr. Adcock: I would like to get copies of those. I ask that they be identified as Richmond's Exhibit A, consisting of 21 sheets.

(Percentage discharges of verticals, consisting of 21 sheets, marked Richmond Exhibit A, February 18, 1914.)

Q. Was the co-efficient work done at the same time that you made your discharge observations?

A. The co-efficient measurements followed the discharge measurements immediately.

Q. Immediately followed them. Then the co-efficient work and the discharge observations on Wickwire and on Oakfield Sections were carried on between July 30th and August 12th, all done in that time? Is that correct? That is 1913.

A. Did you say on both sections?

Q. Yes?

A. Between July 30th and August 27th.

Q. What was the range of the stage of Lake Erie during that period?

A. From 572.2 to 573.3.

Q. How long does it take to do the coefficient work on a particular vertical?

A. Something like two hours for all the work.

Q. Have you determined coefficients in other sections on other rivers?

A. I have made the measurements and determined coefficients on other sections, yes.

Q. What ones?

A. I did a part of the work for Section Gorge on the St. Clair River; most of the work for the six Delta Sections on the St. Clair River, and remeasured some verticals on Section Three Points on the St. Lawrence River.

Q. What were the maximum depths at these several sections?

A. The maximum depth on Section Gorge was 62½ feet; Section Sny, 28 feet; Section Bridge, 8½; Section Bassett, 31; Section Southeast Bend, 56; Section M. C., 35½; Section Salt Block 46½; Section Three Points, 60.

Q. Have you observed any difference in the coefficients as to whether they were in deep or shallow water?

A. Yes, there is some difference.

Q. Just describe the difference?

A. In deeper water the vertical curve follows a more vertical direction into the eight and sometimes nine-tenths depths, so that the mean velocity is a greater percentage of the index velocity. The resulting coefficient for .4 depth is larger for the deep curves.

Q. In a particular vertical, then, if there is a change in stage, the coefficient would change, would it not, if the stage of the water level was higher there would be a change in the coefficient?

A. It would not change appreciably within the range of observations we observed.

Q. You are speaking now of the Oakfield and Wickwire Sections?

A. Of any vertical that I ever measured.

Q. Suppose a change of three feet in a 30-foot depth, what would you say as to that?

A. I believe theoretically there would be a change, but I believe it would be smaller than could be used in our observations.

Q. How small a change could be used, then, in your observations?

A. We record our coefficients to tenths of one per cent.

Q. Is it your belief that a change of three feet in a 30-foot depth would not change the coefficient .1 of 1 per cent.?

A. I don't think it would.

Q. Have you ever made any calculations?

A. I have never made any calculations myself.

Q. Assuming that there would be a change in the coefficient, the use of a common coefficient for all elevations would give a smaller discharge at the high elevations and a larger discharge at the low elevations, is that right?

A. Assuming those conditions, that would be the tendency, I would say.

Q. Did you do any sounding in the Gorge Section on the St. Clair River?

A. I did.

Q. How often was that sounded?

A. The average distance between the final soundings, I believe would have been between five and ten feet.

Q. What was the width of the river at that point?

A. On Section Gorge 1010 feet.

Q. What was the deflection of your sounding wire at the 62½ feet depth, which you said was the greatest depth?

A. 20 degrees.

Q. What was the size of the wire and the weight?

A. The wire was the regular steel piano wire used by the Lake Survey, about .1 of an inch in diameter. The weight was the standard 140-pound castiron sounding weight.

Q. What was the index velocity, that is the velocity at the .4 depth?

A. About 6 feet a second.

Q. Give us the percentage velocities for the different depths observed in this vertical?

A. I haven't that data. I could not give that.

Q. Have you got it here in the office so that you could get at it?

A. I have the following percentages, which I have scaled from a blueprint copy of the plot of this vertical four Section Gorge. For the surface observation: 98.6; at .1, 100.4; at .2, 100.8; at .3, 100.3; at .4, 100.0; at .5, 98.1; at .6, 98.1; at .7, 95.0; at .8, 93.4; at .9, 85.3, and bottom 60.5.

Q. Have you a 15-degree deflection there in the sounding wire on the Gorge Section?

A. It was probably as much as 15 degrees.

Q. Where the deflection is 15 degrees?

A. The deflection of the sounding wire would probably have been as great as 15 degrees.

Q. What is the deflection of the meter cord at that station four?

A. I presume you want the greatest deflection, at the bottom.

Q. Greatest deflection?

A. 29 degrees.

Q. That was the .9 and the bottom?

A. No, that is the bottom.

Q. What was the weight on the meter?

A. 140 pounds.

Q. Was that at the station where you had your 15-degree deflection or where you had your 20-degree deflection of the sounding wire?

A. That was at vertical four.

Q. The sounding wire deflection was 15 degrees at that point?

A. I said I thought it would be about that.

Q. This was where you had a sounding deflection of 15?

A. Approximately.

Q. What was the greatest depth in that panel?

A. (No response.)

Q. These velocities you gave us were on Station Four?

A. Those were on Station Four.

Q. What station was this where you had 62½ foot depth and a 20-degree deflection?

A. That was 25 or 30 feet west of the vertical four.

Q. What vertical was it?

A. There was no vertical observed at that point.

Q. The velocity was not measured at that point?

A. No.

Q. How near that point was the velocity measured?

A. On vertical four.

Q. What was the depth of vertical four?

A. 61.9 at stage 580.

Q. Then there was a difference of five degrees in the sounding wire between 62½ feet and 61.9?

A. I didn't say that. You asked if the deflection was in the neighborhood of 15 degrees, and I said I thought it was that great.

Q. No, I asked you what was the greatest deflection of the sounding wire on the Section Gorge, and I understood you to say 20 degrees?

A. Yes.

Q. And that was the deepest point, 62½ feet?

A. Yes. Then you assumed this 15 degree deflection on

vertical four for the sounding wire, which I said was probably somewhere near right.

Q. No, I did not assume that. Then what was the deflection of the sounding wire at vertical four?

A. I have no record of that, but I should say it was between 15 and 20 degrees.

Q. Then if at 62½ feet it were 20 degrees, at 61.9 it would be very close to 20 degrees, in your opinion would it not?

A. That sounds reasonable.

Q. Now have you got a vertical there where the deflection was 15 degrees, on the Gorge Section?

A. I could not say as to that. I haven't the data at all.

Q. It is available here, is it not?

A. I think I can find it. It will be quite a task; we have to find the sounding and computation books both.

Q. (Question read as follows: "Now have you got a vertical there where the deflection was 15 degrees on the Gorge Section"?)

A. The sounding wire deflection was 15 degrees on verticals 3, 5 and 6.

Q. What was the depth?

A. For stage 580 on vertical three, the depth was 54½ feet; vertical five, 55½ feet; on vertical 6, 47 feet.

Q. How many verticals did you have on that hydraulic section?

A. Ten.

Q. What was the index velocity on these verticals, at the stage mentioned?

A. Vertical 3, about 6.2; vertical 5, 6.1; vertical 6, 6.5 feet per second.

Q. What were the percentage velocities at the several depths on each vertical, 3, 5 and 6?

A. I have these percentages scaled roughly from the blue print. They are as follows:

For vertical 3, surface 96.7; .1, 98.7; .2, 100.7; .3, 101.0; .4, 100.0; .5, 97.5; .6, 94.6; .7, 89.4; .8, 85.0; .9, 74.8; bottom 61.6.

Vertical 5: Surface 101.0; .1, 102.0; .2, 101.8; .3; 100.9; 4, 100.0; .5, 98.6; .6, 96.9; .7, 95.5; .8, 93.1; .9, 83.9; bottom 64.8.

Vertical 6, surface 96.4; .1, 97.8; .2, 98.8; .3, 99.9; .4, 100.0; .5, 99.9; .6, 98.8; .7, 96.7; .8, 91.4; .9, 82.4; bottom 57.2.

Q. How many traverses did you make of the verticals on this hydraulic section?

A. What amounted to about 18 traverses on each vertical.

Q. What was the deflection of the meter cable in verticals 3, 5 and 6, that is the greatest deflection?

A. For the bottom depth on Station 3, 23 degrees; station 5, 27 degrees; station 6, 17 degrees.

Q. What was the weight, 140 pounds?

A. 140 pound weight.

Q. How do you account for such a difference in the deflection between those different verticals, when the deflection of the sounding wire was substantially the same in each vertical?

A. I think it is due largely to the difference in conditions between the action of the current on the sounding weight and wire and the action on the meter and the wire. It is due partly to the fact that these observations were made at different times, and presumably at somewhat different stages, and are averages.

Q. That is the degrees of deflection are averages. Is that the point?

A. Yes.

Q. Well what are the conditions that you think will operate on the meter that would not operate in the same way on the sounding wire or sounding apparatus?

A. On vertical 6, the observed velocity at the bottom is less than that on 5 and 3, and consequently the action on the meter tending to swing it downstream would be somewhat less.

Q. Is it probable that the velocity was the same, substantially the same at that point, when the sounding weight was submerged?

A. I could not say; if the sounding was not taken on the same day, the distribution of velocities would be about the same, but the actual velocities in the vertical plane would be somewhat different and the sum total result on the length of wire submerged might be a little different.

Q. Well then, on different days, the deflection of the meter wire might be different?

A. It would be a little different.

Q. That would mean then a difference in distribution of velocity, wouldn't it, over that vertical?

A. No, I don't mean that.

Q. Can you explain your answer a little further and state just what you do mean?

A. It seems to me that the effect of the current on the wire and the cable is not due directly to the distribution of

velocities. The impulse acting on the wire or cable at any point varies probably more as the square of the velocity than the velocity itself, and for different depths and different inclinations of the wire, we have the uncertainty due to the fact that the current does not strike the wire or the cable normally.

Q. Well, do I understand then that the current would strike the cable to which is attached the sounding weight differently than the cable to which is attached the meter, causing this difference?

A. It seems reasonable to me that even for the same inclination, the effect on a twisted wire cable might be somewhat different from that on a smooth cylindrical wire.

Q. To the extent of approximately 50 per cent. difference?

A. But I think that this discrepancy you speak of is partly due to errors of observation.

Q. Well then within what degree of accuracy do you consider that the deflections were observed?

A. For the bottom velocities at this section, I think there might be an error of two or three degrees.

Q. That would be approximately 15 per cent. then?

A. That would be something like 15 per cent. It might be in either direction.

Mr. Hopkins: That is 15 per cent. of the angle?

A. Of the angle.

Mr. Adcock: Q. Now take these same verticals, 3, 5 and 6, what was the deflection of the meter wire at the index points, .4 depth?

A. At .4 depth on vertical 3, the deflection of the meter cable was about 7 degrees; on vertical 5, about 9 degrees, and on vertical 6 about 7 degrees.

Q. That was the first traverse?

A. No, that was the average of several values that I just found in the book.

Q. How many times did you observe the deflection on vertical 3, at the .4 depth?

A. I could not say. It was observed a good many times and was not always recorded.

Q. Have you any records there of different observations of the deflection of the meter wire at .4 depth on the vertical?

A. I find in this note book three records of the deflection of which we are speaking.

Q. That is on vertical 3?

A. That is on vertical 3.

Q. What were the deflections?

A. Two of those were measured with one of the B meters, and they are each 7 degrees. The other was measured with an A meter and it is 12 degrees.

Q. What was the velocity observed at the time the meter was submerged at the .4 depth and the deflection was 7 degrees in both cases?

A. The velocities recorded are for the A meter, 6.2 feet per second, for the B meter, 6.6 and 5.8.

Q. That is the B meter was where the deflection was 7 degrees?

A. Two cases of 7 degrees; one velocity is 6.6 and the other 5.8.

Q. Can you give me similar information as to verticals 5 and 6?

A. For vertical 5, I find five records of the deflection as follows:

12 degrees, velocity 6.2. 12 degrees, velocity 6.1. 9 to 14 degrees, velocity 6.4. 10 degrees velocity 6.3. 5 degrees velocity 6.2.

For vertical 6, the following:

10 degrees, velocity 6.8. 10 degrees, velocity 6.2. 7 to 11 degrees, velocity 6.2. 7 degrees, velocity 6.7.

Q. What do you mean by 7 to 11 and 9 to 14 degrees?

A. That is what is recorded in the bock.

Q. You mean that the deflection was somewhere between 9 and 14 degrees? It might be 9 and might be 14, or 7 to 11 as the case might be?

A. I don't recall the circumstance and I doubt if I made the observations, but my interpretation would be that the deflection varied during the measurements there, and it was watched by some observer.

Q. What period of time would be taken up in making the measurement?

A. That would cover a period of about five minutes.

Q. So it is probable that the wire was swinging back and forth between 9 and 14 degrees deflection?

A. I would not say that it swung back and forth. It probably swung from 9 to 14 or from 14 to 9.

Q. 9 to 14 and from 14 to 9, back?

A. One way or the other; might not have reversed at all. I don't know.

Q. And it might have?

A. It might have for all I know.

Q. What would that indicate in your opinion, that is that condition of the wire moving about as you suggest?

A. There might have been some unsteadiness in the catamaran at that time. I don't see what else would do it.

Q. What unsteadiness of the catamaran would cause such a condition?

A. The catamaran might have started to move from position and it would have been brought back with a sudden turn of the wheel.

Q. Might there have been a change in velocity? That is at that point, at that time, which would cause that condition?

A. There is some change in velocity, but not enough to account for it on that theory.

Q. Have you examined the records of that measurements so that you are able to state that, or do you state it from general belief and experience?

A. That was a general belief. That one reading is a mere incident out of hundreds of readings.

Q. There was a similar reading in vertical 6 recorded, wasn't there?

A. Not quite as wide.

Mr. Hopkins: Q. As I understand, Mr. Richmond, this is all based upon your guess as to what that 9 to 14 and 7 to 11, is, isn't it?

A. I do not recall the observations, and I doubt if I made them. They are simply given—

Q. Of your own knowledge, you do not know what that means then?

A. I don't know exactly, no.

Mr. Adcock: Q. Now these deflections that you have stated and the velocities were observed during the coefficient work, were they not?

A. Some of those were during the coefficient work and some during discharge.

Q. How many were observed during the coefficient work. I mean approximately; you do not need to figure it up?

A. On Section Gorge, discharge work was almost always carried on simultaneously with coefficient work, and probably on about half of these coefficients were being measured.

Q. Were all the observations that were taken at the .4 depth used for discharge measurements?

A. As I recall it, they were.

Q. So the observations for the coefficient work were not taken separately from the observations to determine discharge?

A. Not except in one or two instances.

Q. Was the same type of meter used?

A. As I remember, we had three B meters and 1 A meter in that work, and they were interchanged in various ways.

Q. What was the weight of the B meter and its apparatus as compared with that of the A meter and its apparatus?

A. Roughly 30 or 40 pounds.

Q. The difference?

A. Yes.

Q. In favor of which one?

A. The A meter is heavier.

Q. Does the A meter furnish greater resistance to the water than the B meter?

A. In my opinion, it does.

Q. The wheel is not any larger, is it?

A. The wheel is the same size and same shape.

Q. What is the particular thing that would furnish greater resistance?

A. The body of the meter previously described, in which the deflection mechanism is encased.

Q. Was there a heavier weight on the A meter than there was on the B meter?

A. I believe the weight was about the same. I am not sure on that point.

Q. Have you ever made any experiments to determine whether the A meter furnished greater resistance than the B meter?

A. No.

Q. Do you know of any experiments?

A. I do not.

Q. How many discharge measurements did you make on Section Gorge?

A. About 180 complete measurements were made while I had charge of the party.

Q. If the A meter furnishes a greater resistance to the current and would drive further downstream as a result when submerged than the B meter, you would have to use a different table would you in determining the position of the A meter than in determining the position of the B meter?

A. Not within the accuracy with which we set depths.

Q. How accurately do you set the depths?

A. We attempted to set them to the nearest tenth of a foot. They were probably always within two or three tenths.

Q. How about 60 feet of water?

A. The bottom depths were rather easily set because it was customary to lower the meter until it touched bottom and then raise is about .3 of a foot so that it was just clear.

Q. How near did the depth as indicated by the meter, lowered in the manner you just described, coincide with the depth as determined in your sounding operations?

A. Depths could not be determined as accurately by the sounding with the meter as with the sounding wire.

Q. Within how closely did they agree?

A. I never have examined the data to see how closely they did agree.

Q. You have tables, haven't you, showing the percentage velocities and index velocities for each traverse of the vertical in all the sections on the Gorge, all the verticals on the Gorge, similar to those that you furnished on Oakfield and Wickwire?

A. Such tables are supposed to be in the office files, but recently I was unable to locate them.

Q. Would you try and produce them tomorrow for us?

A. I know I cannot produce them. Mr. Ray has made an extended search for them and cannot find them.

Q. Did you participate in any of the discharge measurements on the Niagara and St. Lawrence Rivers, in addition to what you have mentioned?

A. I don't understand that question.

Q. (Question read.)

A. Yes, as already stated.

Q. Were the discharge observations on the St. Clair River as accurately made as those upon the Niagara and St. Lawrence Rivers?

A. I believe they were.

Q. Referring to the Niagara River, do you think they were just as accurately made as they were on the Niagara River?

A. I think the St. Clair work was as accurately done as the Niagara.

Q. It was the same class of work?

A. It was supposed to be the same class of work as nearly as we could do it.

Q. How did the sounding work on the St. Clair River compare with that on the Niagara River, as far as precision is concerned?

A. I am not familiar with the sounding on the Niagara River, except on the Split Section.

Q. You know that the soundings on the St. Clair were done accurately, don't you?

A. I have every confidence in them.

Q. You do not know about that on the Niagara. What percentage of error do you believe to exist in the soundings on the St. Clair River?

A. I believe that the cross section of Section Gorge was determined within 1/2 of 1 per cent.

Q. In what direction is this error?

A. I have never thought but what it could be in either direction.

Q. It is liable to be too small or too large?

A. That is my present opinion.

Q. Take the width of the section, was that determined accurately on the St. Clair, the Gorge Section?

A. Very accurately, yes.

Q. You think as accurately as that of the Niagara?

A. Yes.

Q. Do you think there is any percentage of error in the determination of the width of the section on the St. Clair, Gorge Section?

A. It would be considerably less than .1 of 1 per cent.

Q. In which direction?

A. In either direction I should think.

Q. .1 of 1 per cent. would be how much? That is about 1100 feet there.

A. Well, it would be about 1 foot.

Q. How is this width determined?

A. By triangulation from a base line measured on shore with a steel tape.

Q. Well, possibly the court might not know much about triangulation. Suppose you just explain what you mean by that.

A. In determining the width at Section Gorge, as I recall it, a station was established on the line of the section at a point perhaps 100 feet from the shore. From there a line was measured in a northerly direction with a 100 foot steel tape.

Q. Northerly direction, what did that bear to the axis of the river?

A. The river was flowing nearly due south at that point. I do not remember whether that base line was measured with a fifty meter wire or a 100 foot steel tape, but the line meas-

ured was about as long as the distance across the river. Signals were erected at both ends of this line and at a point on the west shore of the river right near the waters edge. Transit angles were then read by repetitions at the two stations on the east shore and from the two measured angles and the included base line, the triangle lengths were computed by trigonometry. Then for a given stage the distance to the waters edge from the points on the section on each side of the river were measured. The sum of these deducted from the side of the triangle along the section gave the width of the section at the water surface.

Q. Were the meters or meter ratings accurately made in the work on the St. Clair that you mentioned, the Gorge Section?

A. They were accurately made, yes.

Q. And you consider as accurately as the meter ratings on the Niagara?

A. Yes, I think they were.

Q. Was there any percentage of error in those ratings?

A. I don't know to what you refer, unless to the constant error of registration of which I have already testified.

Q. In which direction is that constant error? Do you mean to say that the ratings have an accuracy of 100 per cent., except for the constant error that you mentioned?

A. I do not mean to say that the ratings are perfect. That is what your question assumes.

Q. Within what degree of accuracy are they made?

A. I believe that the rating curve at any point is within .3 of 1 per cent. of the true line.

Q. Which way is that error?

A. That error is likely to be one way or the other.

Q. There is no greater error in the ratings of the meters on the St. Clair gagings than on the Niagara, is there?

A. I don't think there is.

Q. How about the coefficient work, was that as well done on the St. Clair River as on the Niagara, in the gagings?

A. I believe it to be as well done.

Q. What percentage of error do you believe exists in the coefficient work on the St. Clair?

A. I believe the weighted mean coefficient for Section Gorge to be within 1/2 of 1 per cent.

Q. Which direction is that error in the coefficient work?

A. It might be either way.

Q. Now referring to the observations constituting a gag-

ing on the St. Clair River, were they as accurately made as upon the Niagara?

A. I believe they were.

Q. Do you believe any error to exist in those observations?

A. Only within the limits of accidental errors, as I have already stated.

Q. What is the amount?

A. If the various elements entering—

Q. I mean the error of the individual observation, that is the velocity determination?

A. I don't believe I understand your question.

Q. Well, you submerged your meter to a .4 depth, didn't you at each vertical, in making a gaging?

A. You mean how much error might there be in a single discharge observation?

Q. Yes, in the various verticals, or in the average of a large number of verticals, considering the discharge work as separate from the coefficient work. You have told us what the error might be in the coefficient work. That enters into your final result—

A. I can't say whether you are talking about the final discharge or the actual velocity observation during the discharge measurement?

Q. The actual velocity observations made during a single discharge observation, leaving out all question as to error in the coefficient work, error in the soundings, error in the determination of the width of the Section, and the other errors which you have mentioned heretofore; that is a single discharge observation?

A. I believe that the average velocity in a discharge measurement was determined within less than one-half of 1 per cent.

Q. In which direction is that error?

A. I think I have made a mis-statement in that.

Q. If you have, just strike out the answer, if you want to state it over again.

A. I would rather change that statement to 2 per cent. either way.

Q. Two per cent. either way?

A. Yes.

Q. That is the average velocity of a series of observations?

A. No.

Q. Just state what you mean the two per cent. error to apply to?

A. I believe that the average velocity measured during a single discharge measurement is within two per cent. of the truth, either way.

Q. You mean a complete discharge measurement that you have spoken of, that takes a couple of hours or so?

A. Yes, I mean what ordinarily would be two, 2 minute runs on each of the ten index points.

Q. That is the .4 depth?

A. That is the average of 20 observations ordinarily.

Q. That is you believe that the average would be within 2 per cent. of accuracy at the .4 depth?

A. For one single discharge measurement.

Q. And you are referring to the Gorge Section here, are you not?

A. I was referring to the Gorge Section.

Q. Where you had 11 verticals?

A. 10.

Q. What would be the error of 50 discharge observations on that section, made in the same manner that you mentioned?

A. I believe the observations, as I stated, would tend to balance, and the mean of 50 would be very close to the truth.

Q. Within what degree of accuracy?

A. My opinion at the present time is that the average result would be within .1 of a per cent.

Q. .1 of 1 per cent.; and that might be either way?

A. Either way.

Q. Now in that connection, you mean the average velocity, don't you?

A. Yes.

Q. You mentioned the observations made of the gagings in connection with the St. Clair observations in your direct examination. Were those observations carefully, accurately made?

A. They were.

Q. And as accurately as you think in connection with the Niagara gagings?

A. I believe they were.

Q. Do you believe there is any percentage of error in connection with the gage readings?

A. There is some error. I don't think that individual readings would often be more than .05 or .06 of a foot in error, and of course thousands were taken.

Q. In what direction?

A. Either way.

Q. Now were the reductions of the St. Clair observations carefully made?

A. They were carefully made.

Q. And as carefully made as those of the Niagara observations?

A. I believe they were.

Q. What percentage of error do you believe to exist in the reductions of the St. Clair observations, if any?

A. You mean how much error do I believe there might be in the final discharge of the St. Clair River?

Q. Due to the reductions alone; that is error in your office work here, in calculating, using the slide rule or whatever apparatus you used?

A. I believe that error is so slight as to be negligible, in comparison with the errors of observation.

Q. What percentage of error would be introduced due to error in gage reading

A. In what?

Q. As they were introduced into the computations?

A. I don't understand that question.

Q. (Question read as follows: "What percentage of error would be introduced due to error in gage reading"). You said individual gage readings might be .05 or .06 of a foot in error.

A. What I meant was that an individual reading of the gage did not represent the water level at that instant at that point within .05 or .06.

Q. But none of your measurements are tied up to a single gage reading, are they?

A. They are not.

Q. In the gage readings as they occurred in a series of 50 discharge measurements, what percentage of error would be due to them in your result as connecting the discharge with the gage elevation?

A. I think the percentage would be so small as to be negligible.

Q. Are there any other sources of error or inaccuracy in the St. Clair observations and discharges known to you, other than the ones which you have pointed out?

A. No.

Q. You say you graduated from the Massachusetts Institute of Technology, I believe?

A. Yes, sir.

Q. In 1906?

A. 1905.

Q. And you were for about nine months with, what was the name of the concern? Who were you with before you came with the Lake Survey?

A. Directly before, I was at the Boston Tech, as Assistant Instructor.

Q. From whom did you receive instructions in the methods of operation in your stream gaging work?

A. Practically all my knowledge has been gained from my work on the Lake Survey, although I received in the Institute a brief course in stream gaging.

Q. From what particular individuals in the Lake Survey?

A. I have learned mostly from Mr. Shenehon and Mr. Moore.

Q. And you received no instruction from anyone except the persons in the Lake Survey?

A. No direct instruction, no.

Q. I presume you studied at some college did you?

A. As I say, I had a brief course in stream gaging in college.

Q. Did it cover the methods used by the Lake Survey

A. No, it took up current meter work in a small way in canals.

Q. What meter did you use?

A. Personally I used the Fteley Meter on one occasion, and I saw a Price Meter and a Haskell Meter operated.

Q. That was in connection with your college work?

A. Yes.

Q. Did you ever make any measurements of small streams, discharge measurements?

A. I assisted Mr. Moore in measuring three canals at Sault Ste. Marie, the two power canals at Niagara Falls, the rivers tributary to the St. Clair River.

Q. What one?

A. The Black, Bell and Pine.

Q. When was that done?

A. In 1910. I do not now recall any other.

Q. How extensive were the measurements of these small streams?

A. The measurements in the power canals were very extensive.

Q. I am speaking of the rivers or streams?

A. Just a very few measurements.

Q. Did you endeavor to determine an increment?

A. No.

Q. Did you ever observe with a current meter the velocities at points nearer together than .1 of the depth?

A. I don't now recall that I ever did.

In further answer to that previous question: We gaged the power canal of the International Paper Company at Niagara Falls.

Q. The gaging of these canals that you mentioned, that was done while you were with the Lake Survey?

A. Yes, under Mr. Moore's supervision.

Q. You used the Haskell Meter?

A. Haskell Meter, yes.

Q. Did you ever make a comparison of the coefficient of a vertical when points were observed at the one-fifteenth or one-twentieth depths, with that for .1 depth observations?

A. I don't recall that I ever did.

Q. You spoke of a weir. Will you just describe a weir, how it is used to measure water?

A. A weir is essentially a notch through which water is allowed to pass and spill over in a free overfall. Usually they have sharp edges on the upstream edge. They are frequently rectangular, sometimes trapezoidal, sometimes triangular. The head is variously measured by a gage placed at a suitable distance upstream from the crest of the weir.

Q. How and by whom have they been calibrated?

A. What weir do you mean?

Q. Any weirs?

A. They have been calibrated by Bazin, James B. Francis, Alphonse Fteley; I believe by Frederic P. Stearns and Mr. Gardner S. Williams and other notables whom I do not now recall.

Q. Have you ever measured water by means of a weir?

A. I can recall but one occasion, and that was during my instruction in the Massachusetts Institute.

Q. What were the dimensions of the weir, what was the head of the water and purpose of measurement?

A. I don't recall except that it was a small weir, and I believe it was in the tail water coming from a small turbine and that we were attempting to derive a value for the efficiency of the turbine at a certain speed.

Q. How large was the weir?

A. I could not say now, but it was a very small affair.

Q. Ten inches or ten feet?

A. Nearer ten inches.

Q. Then you never have compared the volume of water

measured by a Haskell Meter with the measurement of the same volume by any other device?

A. By the Price Meter.

Q. Give the particulars of that measurement?

A. I have used the Price Meter and the Haskell Meter side by side at Section Dry Dock in the St. Clair River.

Q. How closely did they agree?

A. They agreed very closely in calm water; not so well if there were waves on the surface of the river.

Q. How deeply were the current meters submerged?

A. At the Section Dry Dock, discharges were always measured with the meters at mid-depth.

Q. What was the difference between the Price and the Haskell Meter in the perturbed water that you speak of?

A. You mean when there were waves on the surface?

Q. Yes?

A. The divergence on one occasion was ten per cent.

Q. In your opinion, do you believe that the water was disturbed in the vicinity of the meter at half the depth?

A. The reason for that divergence was that a moderate swell was running on the river, and the catamaran was moving up and down somewhat. That motion is well known to cause the Price Meter to over register considerably.

Q. Have you made any other comparisons?

A. I made a few comparisons between the two meters on one of the still water rating bases.

Q. Have you made any comparison between the Haskell Meter and any other device for measuring water, the flow of water?

A. Not that I now recall.

Q. And you have never been present when any comparisons were made?

A. I can't think of any now.

Q. If in determining the mean velocity in a certain vertical two series of measurements were made, in each of which the velocities from surface to bottom were observed ten times, and in one series they were observed at the .1 depths, in the other at the one-twentieth depth which series in your opinion would give the more accurate determination of the ratio between the mean velocity in the vertical and the velocity at the .4 point?

A. I believe there would be practically no difference.

Q. Then in your opinion ten observations are as good as 20? Is that the result we are supposed to reach from your answer?

A. I don't believe I understood your question then. There were ten observations at each point, at one-twentieth depth in one case and at .1—oh, twice as many observations in the second case?

Q. Yes?

A. I wish to modify my statement. It seems to me that other conditions being equal, somewhat greater accuracy would be obtained in the second case.

Q. That is where it was observed at the one-twentieth depth?

A. Not because of observing at the one-twentieth depth, but because there were a good many more observations.

Q. How much better would you think it would be?

A. That would depend on various conditions. I believe that such relation can be obtained under good conditions in a large stream very accurately in the first case.

Mr. Hopkins: That is at .1 depths?

A. Ten observations each at each tenth of the depth.

Mr. Adcock: Q. Have you ever made any experiments in that connection?

A. I can't recall them.

Q. Did you ever make any current meter measurements on the St. Clair, Detroit, Niagara or St. Lawrence Rivers, to investigate the question as to whether or not the rate of travel of the crest of a rise of the lake coincided with the rate of travel of the increased discharge corresponding to that stage of the lake?

A. I never made any direct measurements of that matter.

Q. Do you know whether it does or not?

A. I have several reasons for believing that it does.

Q. State your reasons?

A. In the first place, it seems natural to me that a change in velocity should take place quickly with the change in slope.

In the second place, assuming that change in velocity did travel with the change in stage, the discharges in the Delta Sections of the St. Clair River were referred to Lake Huron and Lake St. Clair stages; and these results check almost exactly the results obtained by direct measurements at Section Gorge and Section Dry Dock.

In the third place such experiments as you state have been made, I understand, by Mr. Shenehon. I have seen some charts that he plotted from his results, and it seemed to me that those experiments proved it.

In the fourth place, Mr. Moore observed that very thing

on the Drainage Canal at Chicago, recently. In view of those considerations, I do believe that the change in velocity follows closely the change in stage.

Q. That is you mean that the full change of velocity would follow the change immediately?

A. I am not certain that the full change of velocity does, but I believe that by far the greater part of it does.

Q. Well, how immediately, how closely does it follow; how closely does it coincide with the crest?

A. As I recall Mr. Shenehon's experiments, there was no difference in time that could be scaled in the plots. In Mr. Moore's, the observations were such that when plotted, there seemed to be a slight lag of the velocity behind the stage, as I understand the plot. But within the error of observations apparently the full velocity or very nearly the full velocity change occurred within 30 minutes or so of the first break in the stage.

Q. That is you are referring to Mr. Moore's experiments?

A. To Mr. Moore's observations on the Chicago Drainage Canal.

Q. What about Mr. Shenehon's observations?

A. I don't know as I can state anything further about his than I have already stated.

Q. Do you know where Mr. Shenehon made his observations?

A. I understood they were made either at the bridge or at the Open Section on the Niagara River.

Q. How did he make it?

A. My understanding was that a meter was suspended at some depth of the river and allowed to run continuously for a long while, its registration being noted frequently and the corresponding velocity deduced.

Q. How would he know whether the full change of velocity had been reached, to correspond to the change of stage? Where else did he measure his velocity?

A. I am not thoroughly familiar with Mr. Shenehon's work, and I do not think I could state anything further in regard to it.

Q. What was the range of velocity at the Delta Sections, and at the Gorge and Dry Dock Sections?

A. I have here the mean velocities on each of those sections and the approximate maximum.

Q. Just give us that?

A. I could not give the range from maximum to minimum.

Q. From mean to maximum would do just as well; the mean and the approximate maximum?

A. At Section Gorge, the mean velocity was about 5.6, the maximum about 7. At Section Dry Dock, the mean was 3; maximum 4.4. Do you want that separately for the various—

Q. No, have you got it combined there?

A. The mean velocities for the six Delta Sections was in the neighborhood of 1.8 feet per second and the maximum velocity observed on any section was about 2.8.

Q. Then as I understand it Mr. Richmond, assuming that Lake Michigan should rise a foot suddenly, then as soon as the crest reached, say the Gorge Section, there would be a change in discharge at the Gorge Section to correspond to the change in stage immediately upon the crest reaching the Gorge, is that correct?

A. I believe that condition would take place within a few minutes.

Q. And that would be true on down the river?

A. As I understand your question, it would. I do not mean to say that the river would be in equilibrium, however.

Q. But you mean that the quantity of water flowing would correspond with the stage of lake?

A. I believe that the quantity of water passing any section on the river would depend on the stage at that section and the differential slope at any time.

Q. (Last question read) At a given point, at the time the crest reached that point as the result of the change in stage?

A. I do.

Q. In other words what we want to get at is whether the river is discharging, at the Gorge Section say, the amount of water which would correspond to the stage at the time the crest reaches the Gorge?

A. As far as Lake Huron is concerned, I believe it is, but the discharge at the Gorge depends partly on the stage downstream, and until that crest has traveled away down the river and the conditions have come to equilibrium, we would not find the discharge agreeing with the headwater and the back water in its proper relation.

Q. Assume the same conditions with reference to change of stage etc. on the Niagara River that we have assumed with reference to Lake Huron and the St. Clair River, and taking the point, for instance the International Bridge Section?

A. I believe the same thing that I have attempted to state

with respect to the St. Clair River prevails, but the back water cuts a much smaller figure on the Niagara River.

Q. Then you consider that in the case of the Niagara River it would not be necessary for it to reach a condition of equilibrium all the way through corresponding to the change of stage?

A. Not as necessary.

Q. It would have then some effect, you think?

A. A very small effect.

Adjourned to Thursday, February 19, 10:00 A. M.

Thursday, February 19, 1914,
10:00 o'clock A. M.

WALDEMAR S. RICHMOND testified further on cross-examination as follows:

Mr. Adcock: Q. Have you records showing the index velocity for each traverse of the verticals in the Split Section work; also water elevation during each traverse of the vertical, and copies of the plotted mean vertical curves in the Split Section?

A. I have in the records, I believe, the velocity at the index.

Q. For each traverse of the vertical?

A. Yes. That is in the note books. I have no gage readings that I recall during the measurement of verticals, but I have plots of the mean vertical for each station.

Q. Would you furnish us with a memorandum table showing the index velocity for each traverse of the vertical, and copies of the plots of the curves?

A. I believe the office would be willing to furnish those, yes.

Mr. Adcock: I will ask that they be marked, when furnished, Richmond's Exhibit B, for Identification.

Q. Will you state how you placed the meter, say at the .7 or .6 depth in the depth of 60 feet on the Gorge Section work, in the coefficient work?

A. The meter was set at the .6 depth by paying out enough cable to lower the meter by the vertical amount necessary and also by the extra length required by the curve taken by the cable. That correction for extra length was derived from observations of deflection, as already stated.

Q. That is you used a table or formula?
A. That was tabulated and we used a table.
Q. What table was used in that?
A. Those corrections were derived by Mr. Moore, and I believe are based on Mr. Shenehon's theory in regard to corrections. Mr. Moore derived the corrections and I simply used what he had derived.
Q. Have you a copy of the table?
A. The table I used was on a filing card and I do not know where it is now.
Q. That table is used in the office here, is it, in your work?
A. The table based on Mr. Shenehon's theory?
Q. Yes?
A. That is in his 1900 report, Army Engineers. But I used a table constructed presumably from that and the deflection angles by Mr. Moore, and written on an index card. I don't know where that card is.
Q. Was it a different table than the one which was used by Mr. Shenehon?
A. I don't know just how it did differ.
Q. Who made up the table that you used?
A. Mr. Moore made the table that was on the card.
Q. Go ahead and explain further, if you have any further explanation, as to the method by which you determined the position of the meter at the .7 depth?
A. I don't know that I can add anything further than that the proper length of cable was paid out in that manner.
Q. And according to this table that you have?
A. According to this table, which was compiled in 1908, and verified in 1909.
Q. What did that table show? Can you give us any idea of it further than you have stated?
A. As I recall, it gave a tabulation of corrections to be added for each different tenth of depth for each vertical and the straight proportionate depth for a given stage.
Q. Was it in feet?
A. Feet and tenths.
Q. Tenths of feet?
A. Yes.
Q. How near was the meter placed to the .7 or .6 depth in your coefficient work in deep water?
A. I have already stated that I believed vertically those positions were within .3 of a foot.
Q. That is at the .7 and .6 depth, in 60 feet of water?

A. I think they were within that.

Q. Well, your opinion is based entirely upon the method by which you did the work and the accuracy of this table, isn't it, as to the position of the meter?

A. My opinion is based on the fact that I know this table was satisfactory to me. It was based either on Mr. Shenehon's theory or Mr. Ray's, I am not positive which; and those two theories agree almost exactly in final results for any depths and deflections we have ever used.

Q. Assuming that that table is correct then, which you have not verified—

A. I did verify it and I believe I am sure.

Q. How did you verifv it?

A. I know I was satisfied—I cannot recall the calculations I made—but I was satisfied that it was correct.

Q. What I am trying to get at is: Were you satisfied from your own calculations or experiments that you made, or were you satisfied from the fact that you believed that Mr. Shenehon and Mr. Ray or Mr. Moore, perhaps all of them, had the correct theory, and did their work correctly in making up this table, which was it?

A. From experiments, I don't know,—in other words I have never made any experiments to derive such corrections; but I have compared and studied the theories of Mr. Shenehon and Mr. Ray, one being based on the variation in velocity in the flowing water; the other being based on still water, assuming the velocity the same at every point of the wire.

Q. You have used that table then—

A. And I have used both theories and have found that within the limits of depths and deflection angles that I have used, those two theories gave practically the same correction.

Q. Does that table take into consideration the fact that an A meter at the same position on the table as a B meter, and at the same depth in practically the same velocity causes the deflection to change from 7 degrees to 12 degrees?

A. I do not think any different correction was applied to the A meter than the B, but as I recall it the A meter was used at the index only, where the correction in any event would be a very small amount. On the vertical and in the deeper depths, I believe the B meter only was used.

Q. Then there was no method by which you could deter-

mine the direction of the meter at the deeper depths; that is if you used the B meter in your coefficient work?

A. No.

Q. Or the direction of the current at the deeper depths in the position of the meter at the .7, .6 or .9 depths?

A. No determination was made at the deeper depths.

Q. Do you know whether Mr. Shenehon's table was made up on the assumption that the horizontal force acting on the meter had no effect?

A. I understand Mr. Shenehon's table was based on that, but Mr. Ray's was based on the opposite assumption, and the two theories give almost identical corrections.

Q. Do you know whether Mr. Shenehon's table is used outside of the Lake Survey work?

A. I don't know.

Q. Am I correct in understanding that your conclusion, as you stated yesterday, as to the coincidence of the discharge in crest due to a given change of lake elevation is based mainly on the results of Mr. Moore's work on the Drainage Canal in December last?

A. It is also based on Mr. Shenehon's experiments as I know them; and it is based on what seems to me common sense, that nothing could intervene but the inertia of the water, and that change in inertia can be accomplished by the forces acting, in a very few minutes.

Q. What weight do you give to Mr. Moore's observations, in reaching your conclusions?

A. I give them great weight.

Q. Equal weight with Shenehon?

A. I give them more weight, because I know them better.

Q. Do you consider the results obtained on the Drainage Canal applicable to the cases of the St. Clair, Niagara, St. Lawrence and Detroit Rivers in this particular, with reference to the lag and the discharge being coincident with the travel of the crest, etc.?

A. I believe they are sufficiently applicable for the discussion in hand.

Q. In Mr. Shenehon's observations on the Niagara River in this connection, did he measure simultaneously the discharge at two places in the river?

A. I don't think he did but I am not positive.

Q. You think he did?

A. I don't think he did.

Q. Assuming that he did not measure the discharge at two

places simultaneously, do you think he could be sure that the discharge at one place coincided with that of another at any particular time?

A. Within reasonable limits, yes, because rivers flow under definite laws, and when the velocity at one point in a section is affected, there is in general a corresponding effect at every other point in the section.

Q. That is you mean in the discharge or in the elevation?

A. In both, if it is due to the effect of change in the lake stage.

Q. Within what per cent. of accuracy?

A. I should say closer than 10 per cent. The best data I have on that that I now recall is in regard to measurements in the power canal of the Niagara Falls Power Company, where discharge was observed at perhaps 10 stations, and another meter was run simultaneously at one point in the canal further upstream. A general coefficient was derived for the single meter, and by means of it the discharge could be determined within a few per cent., for any condition of operation that was observed.

Q. Did you have the discharge at two points determined simultaneously?

A. Determined at a general index meter not on that section; and determined in the standard manner by observations at the index points on the section.

Q. Within what percentage of accuracy could it be determined in that way?

A. I don't recall the figures exactly, but I believe that no single discharge differed more than six or eight per cent.

Q. Do you think the single meter indicated the discharge within six or eight per cent?

A. That is my recollection. It may have been even better.

Q. How far apart were these two sections?

A. The single meter was at the upper end of the canal where the section was the same depth and perhaps twice as wide, and I think possibly 300 feet upstream from the section measured.

Q. What was the change of elevation between the two stations 300 feet apart, as you stated?

A. I have not much idea. It was considerably less than half a foot.

Q. How wide was the canal?

A. At the section, as I recollect, it was about 180 feet wide.

Q. And where the single meter was, how wide was it?

A. Roughly I should say about twice as wide. I am not very certain about that.

Q. What weight do you give to those observations in reaching the conclusion which you have stated?

A. I give that simply as an illustration of my point that rivers and canals flow according to definite laws, and if a change is noted at one point in a section or in a nearby section, we may reasonably expect a corresponding change in other points of the section.

Mr. Hopkins: You mean over a definite period of time?

A. Yes, within a brief period of time.

Mr. Adcock: Q. Don't you think these two sections that you speak of on the power canal were too close together to give accurate results?

A. No, there was another condition entering. Between the upper meter, which was the solitary meter, and the section, the intake of the International Paper Company branches out from one side, which would seem to me to introduce an element of uncertainty, so that the conditions there might be even worse than between points on the same section in a river.

Q. Have you any data in the office here which shows the results obtained there?

A. I believe that data must be here. I am not particularly familiar with it.

Q. Would you be willing to furnish it to us at the proper time, or when you can find it?

A. Mr. Moore is more familiar with that than I am. I believe I can furnish it.

Q. What has been the effect of the Gut Dam on the level of Lake Ontario?

A. The presence of the Gut Dam has caused a rise in surface of Lake Ontario.

Q. About how much?

A. I believe between .3 and .4 of a foot.

Q. For a given discharge of the St. Lawrence River under present conditions, how much higher would Lake Ontario be than for the same discharge before the construction of the Gut Dam?

A. By my own computations, practically .32 of a foot.

Q. Do you consider that the sounding work, coefficient

work, the discharge observations, meter ratings, gage readings were as accurately done in the work upon the St. Lawrence River as upon the Niagara River at the Bridge Section?

A. I believe that the observations were all as accurately made, but that certain conditions entered which made the final results considerably more discrepant.

Q. What are those conditions?

A. In my opinion one condition is that the bottom of the river is much rougher, making it impossible to determine the cross section quite as accurately.

Another condition is that the river is gorged just below the section; the velocities are accelerating very rapidly past the section, and it becomes of much greater importance to observe velocities exactly in the same section in which soundings are taken; and I believe that that was not always absolutely done. That is I believe velocities were sometimes measured a little upstream or a little down stream from the section sounded, and because of the rapidly accelerating velocities, there was a residual error in the discharge.

Q. That latter difficulty was not on account of the inaccuracy of the work done by the men on that section, but because of the conditions?

A. Because of more difficult conditions.

Q. These that you mentioned?

A. And which were not fully realized, perhaps, at first.

Q. Then in your opinion this section, Three Point Section, was not a good section to measure?

A. I would not say that. It was a more difficult section in some respects to measure.

Q. Then the results were not such as might have been obtained on other sections?

Mr. Hopkins: In the same river?

Mr. Adcock: In the same river.

A. I doubt if a better section could have been chosen in the St. Lawrence River.

Q. Have you made any survey of the river to determine that question?

A. I have never made any surveys, but I have made more or less of a reconnoissance of the river and have studied the charts very closely; and I have decided that it was a very difficult matter to chose an excellent section, and that probably no better section for gaging with Haskell meters could have been selected than Section Three Point.

Q. I presume the choice of a section, etc., depends largely

upon the judgment of the person who is making it, doesn't it?

A. Largely, yes.

Q. And the value of the work or the results obtained depend upon his judgment?

A. To some extent, of course.

Q. What is the percentage of error in the work on the St. Lawrence River due to the rough bottom?

A. That is not known, because the same determination of cross section has been used in all the computations.

Q. So you could not give any percentage of error, as you have in other instances?

A. I re-determined the area of Section Three Point and Mr. Moore re-determined it. It was first determined by Mr. Shenehon. In my opinion, we all three sounded slightly different sections, not very different. The outside discrepancy was less than half of 1 per cent. in the three measurements.

Q. You all, I presume, intended to sound the same section?

A. What is that?

Q. You all intended to sound the same section, didn't you?

A. I don't think so if I understand your question. The method of working used by Mr. Shenehon, as I understand it, was to keep the steering wheel of the catamaran on section, and he suspended his sounding wire from an overhang on a pulley somewhat forward of the steering wheel; and I believe he suspended one of his meters from the same wheel.

Q. At the same time?

A. Later, bringing the meters and sounding weight except for the difference due to deflection in the same section. Mr. Moore did the same thing, but I believe that his overhang was nearer the steering wheel; that is down stream from that used by Mr. Shenehon, bringing his section a little down stream where the section is perhaps a little smaller and the velocities a little greater.

In my work, I sounded exactly in the plane of the section, but in measuring velocities I kept my steering wheel on the section and allowed the meters to be suspended somewhat upstream. But in all the reductions, the cross section determined by Mr. Shenehon has been used.

Q. Is there any record in the office showing how these sounding wires were suspended, as you have mentioned, or do you know this from conversation with Mr. Shenehon and Mr. Moore, as to the method they used?

A. There is full record about my own work, and fairly complete record about Mr. Moore's; less complete about Mr.

Shenehon's. I have gained some of my knowledge of the conditions during his work from conversation with him and his assistants.

Q. Then Mr. Moore's gagings and your gagings have all been referred to a different section than the one that you measured?

A. Not that at all. My meters were in every case suspended, as nearly as I can find out, in almost exactly the section sounded by Mr. Shenehon; and Mr. Shenehon suspended his meters in that same section sounded in 1900. It is my personal opinion that in 1901, Mr. Shenehon's meters were suspended a little further down stream, and that Mr. Moore's meters were suspended in about the same position.

Q. What was the mean velocity on the St. Lawrence at this section?

A. Mean velocity of Section Three Point is about 4½ feet a second.

Q. What is the depth? What is the greatest depth?

A. Maximum depth, 60 feet.

Q. How many stations or panels did that cover?

A. There are 17 panels.

Q. In how many was the depth 60 feet approximately?

A. Vertical 9 was about 60 feet deep.

Q. That was at high water, wasn't it, high elevation of the lake?

A. It is not high water as I recall. That is for a stage of about 226 I believe—no, 230; that is for stage 230 at the section.

Q. What was the minimum velocity and the maximum velocity in that vertical? What was the number of that vertical?

A. Number 9 is the deep vertical.

Q. What was the minimum and maximum velocity that you observed at the index point .4 depth?

A. I could not say that without about an hour's search in the books. I could give the mean.

Q. Have you got the maximum and the mean?

A. The mean index velocity is about 5.2 per second.

Q. Have you a record there of the maximum?

A. I haven't here, no.

Q. Do you remember approximately what it was?

A. It would vary about in proportion to the variation between high and low discharge, roughly.

Q. Could you ascertain that for us from the records, without too much trouble?

A. I could look that up, yes. The maximum and minimum?

Q. Yes?

A. Index velocity that has been observed on vertical 9.

Q. Yes. When did you do your work on the St. Lawrence River?

A. I had charge of the work there in 1911 and 1913; and I worked there under Mr. Moore in 1908.

Q. How many discharge measurements did you make, approximately?

A. Mr. Moore made 26 in 1908. I made 62 in 1911 and 35 in 1913.

Q. Have you tables showing the index velocities and the percentage velocities in each of the 17 verticals in Three Point Section that you measured the same as you had and furnished, and the same as were marked Richmond's Exhibit A, for Identification, in connection with the work on the Split Section on the Niagara River?

A. You are speaking now of vertical curves?

Q. Yes, of your own observation. (Question read.)

A. I re-determined coefficients on 6 of the 17 verticals and I have such computations for that.

Q. I presume in connection with that, in connection with your sounding work, you have the records showing the inclination of the sounding wire and the inclination of the meter wires in those different verticals?

A. Those records are in the office.

Q. They are in note book form. On what verticals did you re-determine the coefficient?

A. Verticals, 7, 8, 9, 10, 11 and 15.

Q. Those were where the water was the deepest?

A. With the exception of 15. Those verticals represented 56 per cent. of the discharge.

Mr. Adcock: That is all.

Saturday, February 21, 2:45 P. M.

Re-direct Examination by Mr. Hopkins.

Q. Mr. Richmond, in speaking of the Oakfield Section of the Niagara in vertical 8, you said that the coefficient of that vertical might have a possible error of 1 per cent. On what side might that error be?

A. I believe I stated that I thought it might be either way.

Q. And what effect would such an error as that have upon your total coefficient work, in your opinion?

A. I stated that I believed the weighted mean coefficient for all the work to be within 1/2 of 1 per cent.

Q. That opinion is not changed?

A. No.

Q. What were the surface conditions at that section, as well as the Wickwire Section, during the soundings?

A. The surface was smooth on the days when soundings were taken.

Q. Did you make any correction for the direction of the current?

A. Yes.

Q. Just tell us how?

A. The direction of the current was determined by running rod floats which were 14 feet long, and locating them by two transits on shore. The paths of these floats were plotted, and the amount by which the stream lines diverged from the perpendicular to the section scaled from the plot was used as representing the current deflection for the various panels.

Q. Did you, and would you use an arithmetical method of computing mean ordinates or coefficients, as suggested by Mr. Adcock in his questions on your cross-examination?

A. I did not, and I would not.

Q. Mr. Richmond, where your panels were 200 feet wide and you measured velocity at one point in the panel, what error do you think would come into your total velocity work when not measuring in between the stations?

A. I considered that the error would be smaller than I need consider in making those observations.

Q. That is on the total volume of flow?

A. Yes.

Q. What is that based upon, in your opinion?

A. That is based upon my general knowledge and experience in regard to streams. Where we have a smooth section if we know the velocity at two points 100 feet apart near the center of the stream, we know that there is no wide deviation from that at a point in between.

Q. Suppose there were an obstruction which interfered with the velocity at some point there, could you and would you in such measurements as you have made in, say the Niagara River, detect it?

A. If there was an obstruction which would cause a detrimental effect on the measurements, I believe it would be detected by the measurements at points arranged in that manner in a stream.

Q. Would your soundings help tell it?

A. Of course the soundings would help very materially.

Q. Would the surface indications help to tell you of such a perturbance?

A. Yes, they would help.

Q. And if you find such a point of perturbation, do you make measurements at that point?

A. In case such a point was found, special care would be taken and extra measurements made, to be sure the proper corrections would be applied.

Q. Now referring to deflections of cable wire, did you make any corrections for that, so as to bring your meter to the proper elevation?

A. Yes, as already stated in cross-examination, I believe, the corrections which I considered proper were always made.

Q. In an ordinary river, where the flow is comparatively even, would it make any difference in your velocity measurements if your meter were a little bit downstream from the section?

A. I do not consider it would make any practical difference.

Q. What conditions would make a different result?

A. If we had a section at a point in the stream where velocities were rapidly accelerating or retarding, it would be important to keep the meter exactly in the proper plane.

Q. I believe you said that you thought there was an acceleration in the St. Lawrence below the section?

A. At Section Three Point, yes.

Q. To what extent do you think this would affect your velocity work at that place?

A. I have only a few experiments on that, but I am now

of the opinion that that difference is sufficient to account for the discrepancies which have been noted among various measurements at that section.

Q. Were there any such conditions of acceleration or retardation in the other rivers besides the St. Lawrence, at the sections where you made measurements?

A. At all the other sections there were not such conditions as at Section Three Point.

Q. In your cross-examination, in stating certain degrees of deflection at certain points in the St. Clair River of the cables suspending the meter, you gave some testimony as to degrees of deflection which were changing from 7 to 11 or some other figures. From whose notes were you testifying as to that?

A. I was testifying from Mr. Moore's record.

Q. Have you found out anything further as to whether they did indicate what you said they did?

A. Mr. Moore has informed me that I did not understand those figures.

Q. Do you wish to take out or change that part of your cross-examination based upon Mr. Moore's notes?

A. The two values that I gave as varying from, for instance perhaps 7 to 11 degrees, seem to have been a record of computations by Mr. Moore rather than observations.

Q. Those inclusive values then were not actual measurements, so far as you know?

A. That is the information Mr. Moore has given me.

Mr. Adcock: You would better state just what figures it was that you mistook in these note books.

Mr. Hopkins: Q. Just what figures were they, designate them. You mean the two inclusive figures, 7 to 11, and another one?

A. There were two figures giving inclusive deflections. One as I recall was 7 to 11 degrees, and the other I believe was 9 to 14.

Q. You want to withdraw those two?

A. Yes, I apparently did not understand those figures.

Mr. Adcock: We might just as well clear that up as we go along. (Q.) What was the true record of the deflection?

A. Apparently there was not a true record. Mr. Moore states that that was a record which he calls a computation and really not an observation. They were not my records and I could not state—

Q. A computation of what deflection?

A. It was the deflection of the meter cable when the meter was suspended at the index points on a certain vertical at Section Gorge.

Q. But there was no observation of it made, no actual observation made, or was it merely a calculation as to what the deflection ought to be?

A. As I understood from Mr. Moore, it was a record which to his mind represented the outside deflections he had observed at various times at that point, but I could not clear it up any further than that.

Q. In other words, ranging over a number of immersions of the meter at the .4 depth at that point, there had been a variation of deflection from 7 to 11 or 9 to 14 degrees, is that the proposition?

A. That is the idea I got from it.

Mr. Hopkins: Q. In your cross-examination, you were asked if you thought that the measurement of the discharge in the St. Clair River was as accurate as that of the Niagara. How about the increment of the St. Clair, in comparison with the Niagara?

A. I do not believe the increment has been derived as accurately as that for the Niagara River.

Q. Why?

A. Because the conditions from which it must be derived are much more difficult. We have on Lake Huron an outside range of stage of about 2.1 feet for all the observations ever made. A similar range on Lake St. Clair, and for any given stage on Lake Huron, only a very small fluctuation on Lake St. Clair, making it exceedingly difficult to separate the back water effect from the head water effect and derive any increment.

Q. What is your opinion as to the possible error in the increment as derived by the Lake Survey of the St. Clair River?

A. I would not want to say we knew the actual increment closer than 15 per cent. either way.

Q. You think that might be either way?

A. Yes.

Q. Did you ever make any tests of meters in rough water, the Haskell and Price meters?

A. I used the Haskell and Price meters side by side at Section Dry Dock in measuring certain discharges in 1909.

Q. Under what conditions?

A. Under favorable conditions for some measurements, and under conditions of wave motion on the river for others.

Q. Tell us what were the results of those tests?

A. When there was wave motion, the results by the two meters differed, and on the day of the greatest wave motion the results were most discrepant, being about ten per cent. apart.

The results by the Haskell Meter, however, plotted close to the line of discharge law in every case; the error apparently being in the Price meter, which is known to over register under such conditions.

Re-cross Examination by Mr. Adcock.

Q. What portion of the cross section at Oakfield and Wickwire was occupied by the meters in making a single discharge measurement?

A. The meters were run at the index points only in making those measurements, there being 11 index points on Section Oakfield and 10 on Section Wickwire.

Q. What proportion of the cross section was actually occupied by the meter?

A. You mean the cross sectional area of the meter wheel in proportion to the section itself?

Q. Yes?

A. Almost infinitesimal.

Q. Did you ever in your gaging find a point of perturbation lying between verticals as laid out by you on your gaging section which you measured?

A. I recall one instance in a power canal.

Q. You never noticed any on the rivers, though?

A. I do not recall any.

Mr. Adcock: That is all.

BAMLET KENT, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Bamlet Kent.
Q. Where do you live?
A. In Detroit.
Q. You are an engineer, are you?
A. Yes, sir.
Q. In what service?
A. In the Engineer Service of the United States.
Q. What was your education and training Mr. Kent?
A. My training was at the Michigan College of Mines.
Q. What experience have you had in your work?
A. About 19 years, between 18 and 19 years.
Q. Have you been that long with the Government?
A. About 18 years with the Government.
Q. What has been the nature of your work with the Government?
A. Triangulation work, taking soundings, looking after dredging, and looking after construction work.
Q. Have you done much dredging work in the Great Lakes and the rivers connecting them?
A. I have, yes, sir. Looked after it.
Q. In what lakes and rivers and places have you done such work?
A. In Portage Lake, Portage Lake Canal, Portage Lake River, St. Clair River, foot of Lake Huron; and the head of the Detroit River.
Q. Referring to some work in the Rouge River, just what did you do there?
A. We have removed there altogether, since the Government has taken charge of it, about 820,000 yards.
Q. That is cubic yards of earth?
A. Cubic yards.
Q. Where did you deposit that?
A. Deposited it in the Detroit River in 30 feet or over, in front of the mouth and below the mouth of Rouge River.
Q. Are you familiar with the dredging that has been done by the United States Government in the St. Clair River?
A. Yes, sir.

Q. Will you just tell us what has been done, either by you or under your supervision?

A. The Government has removed from the Black River at Port Huron 443,034 yards.

Q. When you speak of yards you mean cubic yards?

A. Cubic yards. This was taken out of the Black River and deposited about a mile below the mouth of Black River in St. Clair River. The Government removed 82,978 cubic yards from Pine River and deposited it almost directly in front of the mouth of the river in 30 feet or over of water. From the Bell River at Marine City, the Government removed 168,326 cubic yards and deposited that in 30 feet or over, directly in front of and a little below the mouth of the river.

At the mouth of Black River, the Government removed from close to the docks and along in front of the docks 353,484 cubic yards, which also was deposited about a mile below the mouth of Black River in about 30 feet or over of water.

Opposite Port Huron, on the middle ground, the Government removed 231,498 cubic yards, which also was deposited below, about a mile below the mouth of the Black River.

The Government removed from the vicinity of Stag Island about 219,000 cubic yards and about 106,000 cubic yards from various other shoals, such as opposite St. Clair, opposite Marine City and Squirrel Island. This material was all dumped in the St. Clair River.

Q. Any work in Lake St. Clair?

A. There was removed in Lake St. Clair at the canal by hydraulic dredge 2,044,801 cubic yards.

Mr. Adcock: Where was that placed?

A. That was placed to the east of the St. Clair Flats Canal in Lake St. Clair—to the west of St. Clair Flats Canal in Lake St. Slair. Besides that, there was 1,024,540 cubic yards removed by dipper dredges. That was deposited in Lake St. Clair. That was deposited in 14 feet of water or thereabouts east of the St. Clair Flats Canal.

In Lake St. Clair at the lower end, and at Grosse Point Channel, there was removed 5,664,263 yards.

Mr. Hopkins: Q. Where was that?

A. That was taken out of Lake St. Clair and deposited in Lake St. Clair.

Mr. Adcock: Right near the place?

A. That was deposited east of the channel along Lake St. Clair, the big bulk of it being at the Grosse Point dumping grounds.

Q. Was that by hydraulic dredge?
A. No, that was dipper dredge.
Mr. Hopkins: Mr. Kent, the earth deposited in Lake St. Clair itself, does that have any effect upon the flow from Lake Huron to Lake Erie?
A. I hardly think it would have; if so it would be very small.
Q. As the result of this work by the Government, what has been the effect upon the navigation channel, with reference to whether it has increased the depth or width and so on?
A. It has increased the width and increased the depth.
Q. What is the depth throughout the channel?
A. There is practically a navigable channel of about 21 feet.
Mr. Adcock: That is through Lake St. Clair?
A. Through Lake St. Clair.
Mr. Hopkins: How about the river?
A. Probably a maximum draft of about 22 feet.
Q. Through the river?
A. Yes.
Q. What was the navigable capacity before this Government work was done?
A. Before any Government work was done, about 9 feet I should judge.
Q. When was that?
A. I could not say, preceding 1860.
Q. Do you know the intermediate stages of the improvement of that channel?
A. I know them but I have not got the data in my mind.
Q. Now what has been the effect of depositing this earth in the St. Clair River?
A. There has been more material deposited in the St. Clair River from the rivers than has been taken out of the river.
Q. In your opinion, has this work of the Government had any effect upon the levels of Lake Huron?
A. I believe it has had none whatever as the material was all dumped—or not all dumped but the bulk of the material was dumped pretty much in one place in the cross section of the river, tending to shoal the entire cross section of the river below where the shoals were removed.
Q. In that way compensated for the dredging in other parts?

A. Yes, sir.

Q. Was it in Lake St. Clair or the river itself that they changed the navigable capacity from 9 feet to 21 feet?

A. It was in Lake St. Clair.

Q. In the approach to what channel was that?

A. From Lake St. Clair to the St. Clair River, through the old channel?

Q. Is that known as the South Channel?

A. That would be the South Channel.

Q. How many channels are there?

A. There are at present 3 main channels.

Mr. Adcock: That is in Lake St. Clair itself?

A. Distributaries of the St. Clair River.

Mr. Hopkins: Now what do you know of ice conditions in the St. Clair River?

A. Nearly every year, whether the river freezes over solid or not, if there is floating ice, invariably there are ice jams that form in the St. Clair River in the vicinity of Russell Island, from that above.

Q. That is there are ice jams from Russell Island on up?

A. Up.

Q. How about an open winter like this one?

A. Well, an open winter, ice jams take place just the same. Ever this year the small quantity of ice we have had, we have had one jam there this year, a short distance above Roberts Landing.

Q. Does that still exist?

A. I believe not. I believe that went out a short time ago.

Q. Was that a big jam or not?

A. It was a jam such that it brought the water up pretty close to the railroad track and also flooded a good deal of the low land above it; that is the main current was blocked, or at the middle ground at Port Huron.

Q. What effect did that have upon the flow below the jam?

A. It diminishes the flow.

Q. In the river?

A. It diminishes the flow in the river.

Q. A little more particularly about how much would you say?

A. At times, the jam is such that instead of having a current of upwards of five miles at the gorge between Ft. Gratiot and Point Edward, the current is practically not noticeable, the water being dammed back to such an extent that it is practically slack water.

Q. About how much of the time in the course of a year is the flow of the St. Clair retarded by ice?

A. I should judge that in average years the current is retarded at least about four months, between three and four months taking the average season; about three months say.

Q. Now does the river freeze over?

A. It does, the entire length.

Q. What effect does that have upon the flow?

A. It retards it and diminishes it, both.

Q. Seriously?

A. It does.

Mr. Hopkins: That is all.

Cross-examination reserved.

Adjourned subject to notice.

BAMLET KENT, recalled for further examination testified as follows:

Cross-Examination by Mr. Adcock.

Q. Is the deposit of material in 30 feet of water in the St. Clair River to a depth of one or two feet considered an obstruction to navigation?

A. No, sir.

Q. If a channel were built so that the water remained at all times not less than 30 feet deep, at all points, where you had that depth previous to the filling, would that constitute an obstruction to navigation?

A. All parts less than 30 feet filled?

Q. Yes?

A. No, it would not be.

Q. You testified with reference to certain excavation work that was being done in the St. Clair River and in Lake St. Clair. Who determined where the material that was excavated should be done?

A. The Engineer Officer in charge.

Q. The Officer in charge?

A. Yes.

Q. Upon whose recommendation?

A. Well, the Engineer Officer in charge is the army officer that is in charge of the District; the District Engineer decides.

Q. Do you know who it was?

A. It depends on what officer was here when the work was being performed.

Q. And who recommended it?

A. He himself chose that arbitrarily, the army officer?

Q. The army officer. Didn't he have anyone working under him who made recommendations?

A. He gave instructions to the inspector of engineers under him, and his instructions were carried out.

Q. Was the material dumped usually near where it was excavated?

A. Depending on whether the dumping ground had been assigned for the material near to the work or not. It depended on that.

Q. Was the dumping ground assigned usually near the excavated area?

A. If there was deep water, or if there were places away from the channel, it was assigned near where the work was.

Q. Did you personally have anything to do with the determination of where the material should be dumped?

A. Nothing, except following the orders of the Engineer Officer in charge.

Q. Do you know what investigations or calculations he made to determine the spoil area?

A. He took it from the sheet of soundings showing the depths, that was what decided where the dumping was to be done, where the soundings showed.

Q. In the past ten years, on how many occasions have you known ice jams to form in either the St. Clair or Detroit Rivers, or both of them?

A. I have known three definite ice jams; one during the week of February 8th; how long preceding that I don't know, but it was there on February 8, and for the next eight or ten days, 1904. It was there eight or ten days after February 8, 1904.

In February, 1909, there was another; and I think the latter part of January, 1911. That jam lasted for a considerable length of time, probably two or three months.

Q. Was that on the St. Clair River?

A. On the St. Clair River.

Q. Where?

A. The jam took place from Russell Island to Roberts Landing, or a little above.

Q. Was there any in the Detroit River?

A. That I could not say.

Q. How long did these ice jams last, that you mention in the St. Clair River? Take the first one that you mentioned?

A. I don't know exactly the length of time. I happened to see them at different times. From the gage readings at the time I should judge that the one in 1911 probably lasted between two and three months, about three months I should judge. The one in 1904, I know was solid for at least a month, but whether the full maximum stoppage of the water took place for that length of time I do not know, but I know it lasted upwards of that time.

The one in 1909, I believe lasted in the neighborhood of about a month, somewheres about that time.

Q. How long have you been connected with the St. Clair River, in your work?

A. Since 1903, April, 1903.

Q. Did you make any reports with reference to the condition of the ice?

A. Nothing but verbally except the one in 1904. And I gave them the thickness of the ice below Russell Island to about three miles out in St. Clair.

Q. How thick was it, do you remember?

A. The thickest we found was 44 inches. The average was somewheres in the neighborhood of about 32.

Q. Did you have any instruction from your superior officer as to making observations of this kind?

A. I was taking soundings for the new St. Clair Flats Canal, and consequently I was taking several hundred soundings a day with the men.

Q. Making the report with reference to the ice conditions there was incidental to your work in making those soundings?

A. We did give the depth of ice in each day's report, the depth through which we were boring holes.

Q. Is there anyone else here in the service who was detailed to make reports as to ice conditions in different years?

A. I believe not.

Q. Well, these statements then, with reference to the ice conditions are the result of simply casual observations that you made?

A In 1904, we were making a survey for the new St. Clair Flats Canal; and on February 8, I believe it was, Pere Marquette Ferry Number 14, left Detroit for Port Huron. When she struck the first jam immediately below Russell Island, she grounded on ice; there was ice underneath her all around. She had trouble in backing away, and finally did work her way

through. She again grounded above Algonac about two miles, on ice, and more or less ice underneath her until she got to Roberts Landing.

Q. Well, these observations with reference to ice conditions which you mentioned were the result of the facts that you happened to see, in connection with other work, isn't that true?

A. Yes, sir.

Q. When the ice jam breaks, is the flow greater or less than before it was formed?

A. It is greater.

Q. Does this increased flow tend to compensate for the reduced discharge during the existence of the jam, in your opinion?

A. What was the question again?

Q. (Question read).

A. The increased flow would take place immediately when the jam was broke but would not be increased except the head would increase. It would only increase the amount which the head was increased. It would increase for the time being. When the jam broke, that jam going out would cause the water to flow faster until it gets its natural slope again.

Q. You stated in your direct examination that during the time these jams existed there was no current in the gorge in the St. Clair River?

A. Didn't I state no visible current; didn't I say visible current in my original testimony?

Q. I understood you to say there was practically no current?

A. I believe I said practically no visible current; I believe that is what I said, because there is a current there but it is not visible to the eye, because it takes considerable current for you to notice it as you casually look over water. There is a current but it is practically not visible.

Q. For how long a time did that condition which you mentioned with reference to the current exist?

A. That I don't know.

Q. You didn't make any observations with reference to that?

A. No, sir.

Q. You just noticed it as you came in contact with the jam, as you have mentioned?

A Yes, sir.

Q. Was that each jam that you mentioned or just on one occasion that you noticed it?

A. I have only noticed it on one occasion in regard to the current. The other is hearsay in regard to the current, hearsay from other men.

Q. There was water flowing through the river, wasn't there, at that time?

A. There certainly must have been some, yes.

Q. In the event the discharge of the St. Clair River is reduced by ice, will that reduce the discharge of the Detroit River, assuming that there is no ice jam in the Detroit River at that time?

A. In the St. Clair River, you say there is?

Q. Yes, if there is a jam in the St. Clair River and there is no jam in the Detroit River, and the jam in the St. Clair River reduces the discharge of the St. Clair River, will the Detroit River discharge be reduced?

A. It certainly will if Lake St. Clair is reduced; as soon as the head is reduced, the discharge will be reduced.

Q. Has there been any scouring in the channels in Lake St. Clair?

A. In parts of it there has been considerable.

Q. That is the channels are deeper than they were when originally excavated, is that right?

A. Yes, sir.

Q. And wider also?

A. In places, yes.

Q. Do you know to what extent the scour has taken place and the channel has been widened in Lake St. Clair?

A In about the center of Lake St. Clair, the channel probably is about 800 feet wider than it was formerly.

Q. How much deeper?

A. That will vary from practically nothing on the sides, to between one and two feet.

Q. In the center?

A. Well, yes, in the center of the channel.

Q. And that exists all the way through these channels?

A. No, wherever there is much sand, there has been no scouring, wherever there has been sand. The scouring has taken place only where there has been clay.

Q. What causes this condition of scouring?

A. By deep draft boats causing the milky substance from the clay to go into suspension, and it is carried away by the current.

Re-direct Examination by Mr. Hopkins.

Q. These ice jams that you speak of in 1909 and 1911, are all the jams that you yourself saw?

A. Well, I saw each of those jams.

Q. You do not mean to say those were the only jams that were?

A. Oh, no, not by any means. They happen to be the ones where I was there personally and saw them myself.

Q. Wasn't there one there this year, or hasn't there been one?

A. There was but I didn't see that. That was hearsay.

Q. How about other years?

A. I believe there have been jams every year that there has been any ice whatever; I believe there have been jams.

Q. At least until this month, this was considered an open year, wasn't it?

A. Yes, it was considered a very open year until the beginning of this month.

Q. And when was this jam that you speak of?

A. The jam took place I believe either the latter part of December or early in January. I believe it was in January, come to think of it, in January.

Q. Now after the jam breaks and this increased flow takes place immediately, it lasts about how long?

A. Until the river assumes its regular slope again.

Q. That is until Lake St. Clair fills up?

A. Yes, sir.

Q. About how long do you think that would take?

A. Well, I should think that Lake St. Clair would adjust itself in the course of probably a week or ten days.

Q. Now this scour, you say that the wheels of the vessels stir up the fine clay, and it is in suspension. As a matter of fact doesn't most of that float out to the sides?

A. It deposits in other parts of the lake undoubtedly.

Q. It is not a wash so much as it is a stirring up of the—

A. No, it is purely a stirring up by the boats. There is no current to cause a scouring.

Q. When you spoke of dumping of one or two feet in 30 feet of water, that that did not interfere with navigation, you meant navigation as it is at the present time?

A. Yes, sir.

Q. Do you know to what depth the Welland Canal is being built

A. 30 feet.

Mr. Hopkins: That is all.

Recess to 2:15 P. M.

After Recess, 2:15 P. M.
February 17, 1914.

WALDEMAR S. RICHMOND, resumed the stand and further testified as follows:

Cross-Examination by Mr. Adcock.

Q. You made some measurements of the flow of the Niagara River in 1913, did you not?
A. Yes.
Q. That was at what is called the Split Section?
A. That has been called the Split Section.
Q. It has been called that in the testimony so far?
A. Yes.
Q. What is the reason you called it the Split Section?
A. I presume because it is in two parts, one on each side of Grand Island.
Q. The river is divided at that point?
A. The river is divided at the head of Grand Island.
Q. About how far is that from the International Bridge?
A. The sections, or the head of Grand Island?
Q. No, the section which you measured, the gaging section?
A. They are 4 3/4 miles from the foot of Squaw Island.
Q. I asked you how far it was from there to the International Bridge Section?
A. That would be between 5 and 5 1/2 miles.
Q. When did you do your work there, what time of the year?
A. It was in July and August.
Q. From whom did you receive your instructions?
A. From the officers of the Lake Survey, mostly from—
Q. Mr. Ray?
A. Mostly from Mr. Ray direct.
Q. What was the purpose of making the gagings there?
A. The purpose was to have a third measurement of the river which was entirely independent of the previous measurements, to see what the agreement would be.
Q. Did Mr. Ray tell you that was the purpose?
A. I believe he told me that.
Q. When was it first determined to make observations there at that point by the Lake Survey?
A. It was talked about in the spring; was finally decided upon in June I believe.

Q. What time in the spring if you remember, was the first talk? That was the spring of last year?

A. I should say March or April.

Q. Did you have any talk with anyone who was not an employe of the Lake Survey, about making measurements, connected with the Lake Survey?

A. I don't recall that the matter was talked of outside of the Lake Survey.

Q. That is no one who was not then connected with the Lake Survey?

A. I don't believe I quite get your question.

Q. Did you talk with anyone about making measurements, who was not then connected with the Lake Survey?

A. Not that I remember.

Q. What were your instructions?

A. My first instructions were to make a reconnoissance of the upper river with a view to selecting suitable gaging sections, preferably in slow water, and after making such reconnoissance and making recommendations to the office, I was instructed to proceed with the measurements of the adopted section.

Q. Who was in the party that made the measurements?

A. My ranking assistant was Mr. Jones. The other technical assistant was a Surveyman appointed for the summer temporarily.

Q. Who was that?

A. A Surveyman. The other members of the party were the ship's crew, and deckhands attached to the party.

Q. How many altogether?

A. At that time I believe the entire party was ten men including myself.

Q. Which section did you measure first?

A. They were measured as nearly simultaneously as possible.

Q. Was the party divided for that purpose?

A. No.

Q. When you say as near simultaneously as possible, just what do you mean? Do you mean that the meters were run at the same time on each section?

A. Oh, no. No, one section was laid out and prepared for measurement and then the other one. When it came to velocity observations, they were taken first on one section and then on the other, usually not observing more than two days on one before going to the other section.

Q. Two what?

A. Two days before going to the other section.
Q. How many observations would you make a day on each section, velocity observations?
A. For discharge measurement do you mean?
Q. Yes?
A. The greatest number of discharges measured in one day was three.
Q. Did you make observations during July and August, each day?
A. Oh, no.
Q. How many did you make altogether?
A. Altogether ten complete discharge measurements were made on each section.
Q. The same number on each section. Covering what period of time?
A. July 30 to August 12 inclusive.
Q. How wide was the Section Wickwire; how wide was the river at that point?
A. About 1950 feet.
Q. How many panels were there?
A. There were ten panels, in addition to what we call the two end areas.
Q. You made soundings, did you, at that point?
A. Yes.
Q. What area did you sound?
A. The entire area.
Q. How far up the river and how far down the river?
A. For this work the soundings were exactly in the plane of the Section.
Q. That is on a line?
A. On a line across the river.
Q. You did not sound above or below that line?
A. Not at that time.
Q. Well, did you do it before?
A. I sounded the entire upper river within the last two years.
Q. How frequently were the soundings made?
A. I believe as close as 75 feet apart.
Q. Is that an average?
A. On the average.
Q. You mean that some of them were closer than that, closer than 75 feet?
A. Some were undoubtedly closer.
Q. How much?
A. I could not say now exactly.

Q. Well, was it close to 50 feet?

A. In shallow water soundings from a row boat or small launch, we frequently went at a very slow speed and soundings were taken about as often as they could be recorded.

Q. And where the water was swift, it was not sounded so frequently?

A. It was not as frequent as that.

Q. What was the greatest distance between soundings?

A. I do not think there was ever 400 feet between soundings.

Q. Now in making your soundings here, in connection with the work that you did on the Wickwire Section, how frequently did you make your soundings?

A. Soundings on Section Wickwire averaged 7.6 feet apart.

Q. What kind of an apparatus did you use to make soundings?

A. The standard sounding weight was a 140 pound fish shaped weight suspended by a plough steel piano wire, about .1 of an inch in diameter. That was wound on the drum of a reel, which was supported on a steel catamaran.

Q. What was the diameter of the drum?

A. The diameter was such that the circumference was about five feet.

Q. When the weight struck the bottom in the course of these soundings, could you see it?

A. You could not see the weight, no.

Q. Did you know where it was with reference to the line of the section?

A. Very nearly.

Q. How did you determine that?

A. Because the wire never deflected from the vertical more than three degrees, above water.

Q. How did you measure that?

A. That was measured on a deflection scale which was fastened under the sheave over which the wire passed.

Q. Well now, maybe the court would not just understand just how that was done. I wonder if you could tell us in the language of the layman about that?

A. The wire in passing from the drum of the reel went over an iron pulley, and descended down into the water from the pulley.

Q. The pulley was on the line of this section was it?

A. The pulley was on the section.

Q. How was that determined; how did you determine whether it was on the line?

A. By standing by the pulley and looking at the side ranges, on one bank or the other.

Q. Go ahead and describe how you measured the inclination?

A. Below the pulley, a board was fastened horizontally and on this board were marks so arranged that as the wire hung vertically the mark denoting zero was right by the wire, and if the wire deflected down stream three degrees, the line marked three would be almost against the wire.

Q. What was the diameter of this weight on the bottom?

A. About eight and a half inches.

Q. How closely was the inclination of the wire read?

A. To the nearest degree.

Q. Where was the maximum inclination of the wire, what point in your soundings on that section?

A. In degrees?

Q. No, where on the section?

A. The deepest part.

Q. How deep was that?

A. The deepest sounding on Section Wickwire was 29 feet.

Q. What was the inclination of the wire at that point?

A. As I recall, it was 3 degrees from the vertical.

Q. Where was the minimum inclination of the wire observed on that section?

A. Near the shore.

Q. What was that?

A. Zero.

Q. You kept a record, did you, of the inclination of the wire at the different sounding points?

A. It was observed on every sounding, I believe.

Q. Did you keep a record of it?

A. It was recorded.

Q. Who read the deflection?

A. I believe I read the deflection myself.

Q. Were there any other deflections observed than the ones that you have mentioned?

A. Not in connection with the soundings.

Q. I suppose it was some place between zero and three degrees, at the different points?

A. Oh, well I stated that the deflection was read on practically every sounding.

Q. What was the depth of the sounding, and what was the

corrected depth in each case, and where were they located? Have you the data here so that you can answer that question?

A. I don't know as I understand your question. We made 218 soundings on Section Wickwire. Every sounding was corrected.

Q. Every one of them?

A. Every one.

Q. You would not correct the zero, would you?

A. There were other corrections.

Q. What corrections would you make?

A. The soundings were all reduced to a common stage. They were all corrected for error in the reel. I do not recall that any other corrections were necessary.

Q. You then say that the corrections which you have mentioned are in your opinion the only ones that were necessary. Is that correct?

A. That is all I can think of now.

Q. What corrections would you make for error in the reel? What do you mean by that?

A. The scale on the reel indicated that five feet of wire had been paid out for each revolution. As a matter of fact, a little less wire was paid out. The correction was determined by measuring 50 and 100 foot lengths of wire on shore, winding them on the reel, and noting the distances by which the beads failed to meet at 10 and 20 revolutions of the drum.

Q. What was a constant correction that you would make in each case?

A. That gave a constant percentage correction.

Q. And with reference to this deflection, you would make correction for that, would you?

A. We would if they had been necessary. The greatest computed correction was .01 of a foot and was accordingly neglected.

Q. You mean by that that when this weight struck the bottom it was only .01 of a foot out of line?

A. I do not. I mean that the length of wire submerged was only .01 of a foot greater than the straight distance from the water surface to the bottom.

Q. How much would the weight be off of the line, off the section line?

A. I could not say exactly.

Q. You never made any calculations?

A. I never calculated. We could give limits beyond which it could not have deflected.

Q. What would be the maximum limit, in your opinion?

A. I make it 1.5 feet.

Q. That is at the deepest point, at 29 feet there that you were speaking about?

A. In that depth, the weight could not have been as much as 1½ feet down stream from the section.

Q. While you were making these soundings, I presume you were on some kind of a boat, were you not?

A. Working from the Lake Survey Catamaran.

Q. Can you describe that catamaran of the Lake Survey?

A. The catamaran is composed of two airtight pontoons of steel, each one about 28 feet long and of 5 foot beam. These are fastened together, or rather held apart by steel trusses, so that the two pontoons are abreast and sixteen feet apart, center to center.

On top of the trusses there is a deck of wood. The catamaran when loaded for work draws about 1½ feet.

Q. How was this catamaran held in place while you were making the soundings?

A. It is moored by a galvanized wire from a float about a half a mile upstream; the float in turn being anchored to the bottom of the river.

Q. Was there any movement of the catamaran at the time you were making these soundings?

A. The catamaran was steadied while making each sounding; then moved—

Q. How?

A. By movements of the steering wheel.

Q. How was this board that you speak of kept in a horizontal position?

A. It was fastened firmly in the horizontal position.

Q. At the time you read the deflection, how did you know that it was in a horizontal position?

A. Because the catamaran is so steady that the tilting would not amount to anything appreciable in reading single degrees.

Adjourned to Wednesday February 18, 1914, 9:30 A. M.

Depositions in the above entitled cause taken before the Commissioner on the 8th day of April, 1914, at 10:30 A. M. at Room 606 Federal Building, Chicago.

Present:

Mr. Albert L. Hopkins,
On behalf of the Government.
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
On behalf of the Sanitary District.

SVEND K. EMERSEN, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. Svend K. Emersen.
Q. Where do you live?
A. 3727 Lyndale Street.
Q. What city?
A. City of Chicago.
Q. What is your business?
A. Lake Captain.
Q. By whom employed?
A. Pickand, Mather & Company.
Q. How long have you been a captain on the lakes?
A. The season of 1913, full season; and off and on, taking somebody's place you know, but one full season you might say.
Q. How long have you been navigating the Chicago River?
A. Well last summer practically off and on, and then years before that when I was sailing lumber schooners and barges out of Chicago.
Q. About how many years altogether have you been navigating the river in lumber schooners or otherwise?
A. About three years in lumber schooners and last season in the big fellow.
Q. Last season what size boat did you have?
A. What do you mean, the size boat?
Q. The length?

A. 348 foot length and 48 foot beam.
Q. What draft?
A. All we can get in the Chicago River. We load down to 20 feet, if we can get the water.
Q. What can you draw in the Chicago River?
A. 18 foot 6 is recommended at the present time.
Q. What is the effect of the current in the Chicago River on the navigation, from your experience?
A. That all depends on where you are.
Q. Go ahead, tell us where it does affect navigation?
A. All through the bridges, down in town, down through town; all the way up there, I should judge the current is 2½ to 3 miles an hour. Of course out to the pier you won't get so much current as you do down through the narrow places.
Q. What is the width of the river along about between Madison Street and 12th Street?
A. Oh, all the way from 80 feet and up. I got stuck there last summer; met a boat down here at one of the bridges. We were 48 feet beam and he was 42. One had to get out of the way for the other to get through the bridge.
Q. What place in the river is the current greatest?
A. Well, what you call here around Jackson Street Bridge and all the way up into them narrow places there.
Q. What are the conditions down about 12th Street?
A. Well, there is another hard place.
Q. How many tugs do you use in coming into the river, how many did you use with your boat you had last summer?
A. Two tugs.
Q. Could you come in without tugs?
A. No, they will not let us go up with one tug. You could not handle her with one tug.
Q. Suppose the current in the river were greater, in your opinion what effect would it have on navigation in the river?
A. Close up the Chicago River and make a boulevard out of it. Of course if you are going to have more current there, navigation would be impossible.
Q. What is the name of your boat?
A. Venus.
Q. Where does that boat hail from?
A. Fairport, Ohio.

HERMAN JAENKE, a witness called on behalf of the Government in rebuttal, being first duly sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. What is your full name?
A. Herman Jaenke.
Q. You live in Chicago?
A. Yes, sir.
Q. What is your business?
A. Lake Captain.
Q. How long have you been a lake captain?
A. I have been sailing for 12 years steady; last 12 years, captain.
Q. What is your boat?
A. The George N. Orr.
Q. Who owns that boat?
A. The Canada Atlantic Transit Company.
Q. What has been your experience in the navigation of the Chicago River? How long have you been navigating the Chicago River?
A. On and off for the last 30 years; last 16 years steady.
Q. What has been your experience as to the effect of the current in the Chicago River on navigation?
A. Well I should judge the current in the river is about from 2 to 3 miles and we have very much difficulty in going with the current, principally.
Q. What is the difficulty?
A. Well, it interferes with the navigation. For instance, I say, going with the current if they don't give you the bridge, all we can do is reverse our engines and we lose control of the boat entirely.
Q. How about the docks?
A. Well, striking the dock or anything. We have to strike something.
Q. Can you stop without striking the docks?
A. Can't do it. You lose control of the boats, when the current gets—
Q. How many tugs do you use?
A. One, one tug.
Q. What is the size of your boat?
A. We are 326 foot keel.
Q. What is the beam?

A. Beam 42 feet.

Q. How about coming down the river when you meet another boat?

A. Well, for instance between Adams and Van Buren, if you meet a good size boat, we can't pass. There is only one place we can pass and that is right at the elevator, they call it the Manhattan.

Q. Why not?

A. The river ain't big enough; won't let us go by. You cannot go through Adams, Jackson Boulevard, Van Buren.

Q. When you have two boats in the river along there, what effect does that have on the current?

A. Well, you get a whirlpool out of it; about 8 or 10 miles. I had an experience coming in last year. I got stuck in Madison Street, drawing about 17 foot 6; and another steamer tried to pass by in the other draw, in the west draw, and it was impossible for them to get through.

Q. How about damage to the boats, to the docks?

A. Our boats are dented; the bows are all dented in; every one of the package freighters. They are steel. They are all dented in through the momentum. If you are loaded and the current gets hold of you you can't stop; there is no tug can stop you. You are bound to swing into the abutment.

Q. What is the name of the boat you got stuck in the draw with?

A. One of the Lehigh boats; she was the Tuscarora.

Mr. Hopkins: That is all.

No cross-examination.

J. P. MINSKEY, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. Will you state your full name?

A. J. P. Minskey.

Q. Where do you live?

A. I live on Orchard Street, 2464.

Q. What is your business?

A. I am a sailor man; been Master Mariner for a good many years, if that is what you call it.

Q. What has been your experience in navigation?

A. Well, my experience in navigating in the Chicago River is confined to two years ago this winter. I have been in a

company that all their business has been from Lake Erie to Lake Superior for 25 years, all only a year ago last winter.

Q. What other work have you done?

A. That was the Gilchrist Transportation Company.

Q. What work did you do for the Gilchrist Transportation Company?

A. I had charge of the steamers we had here that were loading storage grain from the 1st of August up until the following spring. We had 15 ships. They were in Chicago, and they ranged in size from 5,000 tons to 10,000 gross tons.

Q. Are you familiar with the conditions in the Chicago River as to current?

A. Yes, sir.

Q. And its effect on navigation?

A. Through that winter I got very familiar with it, because I had a lot to do with it, every day moving boats. We had a good many boats laying along the South Branch, and in fact both branches of the river; but we did not have a ship lying to the dock in the South Branch that we did not have from 1 to a half dozen bills of damage against them. That is every boat that would go by would damage us, mostly.

Q. What caused that?

A. That was caused from the current in the river; the boats being large and heavy, every boat that would go along by, they would hit them, rub them and the current would catch them on the bow and shove them right head first down into us.

Q. What were the names of those boats that you had charge of?

A. There was the steamer Gilchrist, I think I had six damage bills on her. The steamer Lake Shore, I had several damage bills on; the steamer Neptune, several damage bills. I could not say how many on each one without I had a book and looked it up; but the Mars, the Saunders, and the Oglesby.

Q. What were some of the other boats in that 15 you had charge of? Do you remember the names of the other boats?

A. Oh, I could not call them all right offhand.

Q. Where were these boats lying?

A. These boats that I speak of were lying in the South Branch.

Q. Where?

A. Well one was lying just above Taylor Street, between Taylor Street and the Little Railroad Bridge. There was another lying just below 18th Street.

Q. Which one lay at Taylor Street, just above Taylor Street?

A. The Neptune.

Q. Go ahead.

A. The Gilchrist laid at 18th Street, and the Saunders laid just below 18th Street. Well now, there is this about that: We were moving them. There was not one of those boats in this time we did not load and unload from 2 to 3 times, 4 times some, and we were moving them.

Q. In a general way we want to know where they were lying when damaged?

A. This Gilchrist laid just above 18th Street Bridge, on the east side of the river. You come down and come through the Pennsylvania Railroad Bridge, you know and we were lying right down on the east side of the river there between the Pennsylvania Railroad bridge and 18th street bridge on the east side of the river above 18th Street, south of 18th Street. I speak of this above and below as I used to know it 25 years ago. They have got the damn current running uphill now and I am liable to call it up when it is down, maybe.

The Mars laid below 18th Street Bridge on the west side of the river awhile. Then she laid up the river awhile, up above 22nd Street.

Q. Any damage to it?

A. She got damaged up there, yes, sir. She got damaged so that the plate that comes up to the angle iron that forms part of the deck, the deck comes on, turned the whole thing over, stanchions and timberheads, and a lot of stuff, turned them over there for, oh 50 feet. There was a lot of damage; cost us a lot to get that fixed up.

Q. Would you consider it dangerous now to navigate the Chicago River?

A. It surely is. You can't go up and down this river. Now I did not move a boat, not one of those that winter, without having more or less damage on them; when in the South Branch; the North Branch not so bad.

Q. How many tugs did you use?

A. We used from two to six on a boat.

Q. Did you ever get stuck in the river?

A. Yes, sir, I was stuck with the Steamer Lake Shore in the Pennsylvania Railroad Bridge. We came down, we laid at one of the elevators, the Santa Fe I think, but we came down there and stuck. We had two tugs, one tug ahead and one tug astern. We went into the draw of the bridge and I

was stopped, and bye and bye you could see the water rise up ahead of her, where she blocked it up. And bye and bye she backs, went and backed right up, the river—

Q. Just when was that?

A. I should say it was in March.

Q. Of what year?

A. 1912, two years ago this winter.

Q. What draft did you have?

A. We tried it twice and could not get through. We laid her to the dock and waited a day. I notified our agent here, Mr. Sullivan, and we waited a day and we thought we had a fine time, the water was high. He thought maybe we were on the bottom, but I told him we could not—that could not be because we only were about two thirds loaded. We tried it again, and this time we had two tugs ahead,—the second day, I think we waited two days and the second day we had two tugs ahead and a tug on each quarter, and she did the same thing with us. That time, we only tried it once. I said that was expense enough, we would back out. The second day following, they shut down the Drainage Canal or checked the water so that one tug took us over and brought us down.

Q. One tug?

A. Yes.

Q. What was she drawing at that time?

A. She was drawing about 16 feet.

Q. Can you draw 20 feet in the Chicago River?

A. No, sir; at least they said it was not safe to load over 18½ feet and I did not load any of the boats over 18½ feet. We had one of them through mistake, that loaded at the Santa Fe, the Saunders, I left a ship keeper and the man in the elevator to load her and they got her down to 20 feet. She got on the bottom up in the end of the slip when she was drawing 20 feet. When we got out and had steam on again we went down again and they lightered it for us without charging any extra, because the elevator man said it was his fault. We lightered her to 18½ feet, and we came down with it in the end.

Q. Is the river at least 200 feet wide?

A. I never measured the river. It would be only a pure guess, or guess work on my part, to say how wide it was. I know our big boats that are 54 or 55 or 56 feet seem to fill it up pretty well.

A little later in the season, I took the Steamer Neptune from Taylor Street to take her up to the North Branch to

unload her; and we were all day at Washington Street, while they were building that new bridge. The cofferdam, a little of the river got shut off on the other side, filled in some dirt along on the cofferdam, and she was only loaded with oats, light draft, probably less than 16 feet. But we were all day there trying to get her across the pinch in the river where it had been narrowed up. The current was so strong, and we had at one time, on this day that we worked there, we had four tugs on her, a tug on each quarter and two tugs ahead. The tug ahead was the Towing Company's tug, and they got another Towing Company to help them. The tug after, it was steering us, it was a Towing Company tug; and a Dredging Company's big tug dropped along on one quarter, and he said he could push us over alone. But we didn't get over. And I took a brand new cable, and then Captain Bob Young, he was up there bossing his tug and I was bossing the job and Mr. Sullivan's man from his office was down there to help us out. And we did not get over. I had a brand new cable that I had borrowed from one of our bigger ships, 10,000 ton boat, one inch and an eighth cable, a new one. I took a bight of that and put it over a clump of spiles they had to protect this cofferdam. I was going to keep her there and block the river all night; but she pulled the clump of spiles down and I thought it was not safe to stay, so we had to back up the river a half mile to get a place to stay over night. The next day they shut down the Canal again and we got over the next day.

Q. When was that?

A. This was the same winter, I think in March, later in March.

Q. 1912?

A. When we got over, we got over so fast that we took a sheer and went into the West Approach to Lake Street Bridge, and they have no spiling around it at all and we took the wheel strakes off of her. They sheared one of the angle irons off of the stone work and put a big dent in the bow you could walk into, on the stonework of the West Approach. The boys thought she was not going very fast and she cuts the protection on the bridge.

Q. Would there be any difficulty in navigating the river if the current was a mile and a quarter an hour?

A. Why I would not think so. I would not think it, a mile and a quarter. That is all guess work on my part, for I am not an expert on this current business. But I should think

we ought to navigate it without much trouble, if it were not higher than that.

Q. Do you navigate the river in Cleveland?

A. Yes, sir, I have been up the Cuyahoga River a great many times. We go up there sometimes without a tug. I have been up there a good many times without a tug. It is a good deal narrower than our river here, a good deal crookeder, a good deal crookeder, and a good deal narrower. There was one place where it ain't more than a length of a ship, from here (indicating) right across to two parts of the bridge, a regular oxbow, right around. We would navigate it and go up and go to the furnace without damage, because there is no current. We can stop the boat. We can go slow; if we can't steer her, we would heave out a cable on one side and a cable on the other and pull her up to that part or pull her back. And we would usually have a tug ahead, but in case where we have had tug strikes we have been up there without a tug. I have been up there twice without a tug and come down again. That would be as far as it would be from the forks of our river up—well, as far as the river goes, the Santa Fe Elevator. And we have no trouble to navigate it and do it without damage. And lots of the places there is not room for three boats abreast, that is for the boat on each side; you can't get your boat through between, lots of places in it.

Q. In your opinion, what is the current in the Chicago River?

A. Well, I have seen it over ten miles when we have been trying to get through these bridges; as I tell you, going alongside of you like a mill tail, when a man could not run and keep up with it.

Q. You have it partly dammed up?

A. You have it partly dammed up. But I should think in the least calculation it is five miles in those bridges all the time, in those close places. While they have been building that Pennsylvania Railroad, I would say it averaged five miles an hour in the draw of that bridge.

Q. Did you ever test it by dropping things in and trying to walk with it?

A. Yes, sir, I had a man undertake to walk up a ladder with a box of provisions, and the ladder broke and he went into it and we came darn near losing him by sucking down under the boat, we just fished him out and that is all we did do.

Cross-examination reserved.

ARNOLD GREEN, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name please?
A. Arnold Green.
Q. What is your business?
A. Lake Captain.
Q. How long have you been a Lake Captain?
A. Since 1887.
Q. What company are you connected with?
A. Have been with the Chicago Steamship Company up to last fall.
Q. What boat did you navigate?
A. City of London.
Q. What is the size of the boat?
A. 297 feet keel and 41 feet beam.
Q. How much experience have you had in navigating the Chicago River?
A. Well, for 34 years I have been on this river.
Q. What is your opinion as to the effect of the present current in the river upon navigation?
A. Well, it is dangerous to navigate the river; has been since the current came here.
Q. What is your opinion as to what the current is?
A. Well, that varies; depends upon where you take it.
Q. Take the narrow places?
A. At Halsted Street and Pittsburg Ft. Wayne Bridge and 12th Street, and this place down here between Van Buren and Jackson, that is the most difficult places.
Q. What do you think the current is at those places?
A. Oh, they go three or four miles an hour any time, I should judge, the way it looks to us.
Q. What would be the effect if you had any greater current in the river?
A. Could not navigate at all as far as I could see.
Q. Have you ever had any trouble?
A. O, lots of it.
Q. Have you ever been stuck?
A. No, I never was stuck.

Q. What kind of a boat do you have, as far as power is concerned?

A. It is a powerful boat.

Q. What speed can you make?

A. Oh, about 11 miles an hour loaded.

Mr. Austrian: Q. What tonnage?

A. 2,000 tons gross tonnage; carry three thousand tons of freight.

Mr. Adcock: Q. What is your draft?

A. 18 feet.

Mr. Hopkins: Q. What do you consider the worst place in the river?

A. Oh, for handling a boat 12th Street is a bad place, on account of the cross current there.

Q. Just how does that operate on a boat?

A. It will catch one end of the boat and swing it around you know, long boats.

Q. There is a turn there, is there?

A. Yes, there is a turn there; coming down the river it will catch your stern and you will swing into the bridge, and going up it will swing the bow the other way and swing the stern into the bridge.

Q. Do you use a tug?

A. Yes, use a tug always going up the river with the current, have to.

Mr. Adcock: Q. With the current?

A. Yes.

Mr. Austrian: Do you use it coming down?

A. Once in a while if I am drawing 18 feet or more.

Q. If you are drawing what?

A. If I am drawing 18 feet of water, I usually take a tug.

Cross-examination reserved.

W. D. HAMILTON, a witness called in rebuttal on behalf of the Government was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. W. D. Hamilton.
Q. Where do you live?
A. 2431 South Lincoln Street, Chicago, Illinois.
Q. What is your business?
A. Ship Master and Marine Superintendent.
Q. Are you familiar with conditions in the Chicago River?
A. I am.
Q. Who are you working for?
A. Edward Hines Lumber Company.
Q. What is your experience with the Chicago River, how long, and what have you done?
A. I have been sailing in here for about 34 years, since 1879.
Q. What is the width of the river?
A. The width of the river will vary from—in my estimation from 80 feet to about 240 in the narrowest place.
Q. What was the narrowest place?
A. 80 feet, in that neighborhood. I might be a few feet out of the way there, not much.
Q. At Jackson Street there is a draw, isn't there?
A. Yes.
Mr. Adcock: Q. Where is that narrow place?
A. The narrow places would be at Jackson, Adams and Van Buren Street and the Metropolitan Railroad Bridge, the narrowest part of the river.
Mr. Hopkins: Just what effect does that draw at Jackson Street have?
A. Well, it is a very narrow place. I do not consider it the worst place in the river.
Q. How about the by-pass there, there is a by-pass?
A. The by-pass carries but very little water through it. I have visited that proposition several times and looked at it and noticed that the current through the by-pass is very much slower than it is through the main body of the river. In fact very little water moves through the by-pass.
Q. What is the current in the river.

A. I should think it varied from two miles in the widest part of the river to up as high as 3½ to 4 miles in the narrow places.

Q. Where would you say it was 3½?

A. Along—well, take Polk Street Bridge for instance and at 12th Street. Understand I do not mean that this current would be that speed for the full width of the river, but where it strikes these corners and goes around these corners it is much faster and a much more dangerous proposition. It forms a strong cross current and takes absolute control away from the ship entirely.

Q. Is that the part of the current that affects navigation?

A. That is the part of it that affects it the most. The cross currents is the worst thing we have to contend with. If the river was the same width all through, so that we had the same current to contend with at all points, it would not be quite as difficult to navigate as it is now.

Q. What effect does that current have upon navigation?

A. Why it makes a ship practically unmanageable and if she was of any size at all and she didn't have considerable tug service attached to her, she would be unable to do anything. She would go across the river.

Q. The boats you have charge of are usually small boats?

A. Smaller type.

Q. Lumber boats?

A. Lumber boats from 156 feet long to 230 feet long.

Q. What beam?

A. Beam from 28 to 40 feet.

Mr. Adcock: What is the draft?

A. Draft, extreme with us would be about 16.6.

Mr. Hopkins: Q. You do not navigate the North Branch?

A. Yes, sir, we go all over the river; go north to deliver lumber, to any lumber docks in the city; several loads last year to the Hettler Lumber Company.

Q. What do you consider the worst place in the river?

A. 12th Street is a very bad place and Halsted Street is very bad; the current there at 12th Street, a fellow going up the river if he gets—

Q. When you say up the river you mean away from the lake?

A. Going south, when a ship gets clear of the abutment, the current will generally catch the stern and drag it over to the west bank, unless he has got a tug to hold it. And when

he is coming down the river or going north, the same thing applies to the bow. It catches the bow in entering the draw. We invariably go through the east draw; it will catch your star board bow and drag you into the abutment. We had one boat, the smallest boat we got, we had three damage jobs in one season. That was at 12th Street, all on the same spot on that account.

No cross-examination.

JOHN SIMONS, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your full name?
A. John Simons, 6348 Maryland Avenue, Chicago.
Q. What is your business?
A. Lake Captain.
Q. How long have you been a lake captain?
A. Seven years.
Q. For what company?
A. Canada Atlantic Transit Company.
Q. What is your boat?
A. Arthur Orr.
Q. Sister boat to the George M. Orr.
A. Yes, sir.
Q. How long have you been navigating the Chicago River?
A. 20 years. Well, I have not navigated it that long. I have went up and down it for 20 years.
Q. What is the rate of the current in the Chicago River?
A. Oh, I should say around 2 or 3 miles an hour. Sometimes more. I do not think there is any time it is below that.
Q. What is your opinion as to whether or not it is dangerous to navigate the Chicago River under present current conditions?
A. I think it is dangerous, to avoid damage in navigating it. Anybody navigating the Chicago River, to my estimation, are in danger of damaging their steamboat every time they go up.
Q. What are the chief difficulties and where?
A. Why, the biggest part of the current, or the worst

place, is take it from Jackson or Madison Street to Van Buren, and then take it at 12th Street and then again at 16th Street, the railroad bridge; then again at the Pennsylvania Bridge and also at Halsted Street.

Q. What kind of freight do you carry?

A. Package freight, merchandise, and flour and feed also—

Q. Give us the dimensions of your boat?

A. 334 feet long, that is clear; 40 foot beam.

Q. What draft?

A. Carry about 4500 tons on 18 foot draft.

Q. What draft can you load to?

A. Well, about 18 feet, load of grain.

Q. If you had all the water you wanted, could you load deeper than that?

A. Very little deeper we could load. I could load 19 feet, full load of wheat. That is all.

Cross-examination reserved.

Recess to 3:00 P. M.

After recess, 3:00 P. M.

ARNOLD GREEN, resumed the stand and testified further as follows:

Cross-Examination by Mr. Austrian.

Q. Captain, I understood you to say that you had navigated the waters of the Great Lakes for 34 years?

A. Yes.

Q. You began in 1880?

A. Yes.

Q. Will you indicate please just what part of the Great Lakes you navigated?

A. From Chicago to Buffalo, Duluth, Kingston, Oswego.

Q. Through the Soo Locks?

A. Through the Soo Locks and through the rivers.

Q. And by reason of that occupation for that length of time, you were at that time and continuously since have been very familiar with the waters referred to?

A. Yes.

Q. In 1880 and for some years thereafter, what was the size of the boat or boats which you navigated or took part in navigating?

A. Oh, they were about three or four hundred ton.

Q. Three or four hundred ton?
A. Yes.
Q. When did you undertake to navigate a boat of the size of the one you are now navigating, some 2,000 tons?
A. About 12 years ago.
Q. 12 years?
A. 11 years ago, rather.
Q. What was the size of the boat that you navigated in 1900, and immediately prior to that?
A. Oh, about 400 tons, four or five hundred tons.
Q. What length?
A. Oh, 140 feet.
Q. What draft?
A. About 12 feet.
Q. Did you have occasion to observe the conditions in the Chicago River prior to the opening of the Sanitary District Canal?
A. Yes, sir.
Q. Do you recall at or about what time that was opened?
A. Yes.
Q. When?
A. When the Canal was opened?
Q. Yes?
A. In 1900.
Q. 1900?
A. Yes.
Q. You passed up and down the river and made deliveries of freight and picked up freight during the course of the years immediately preceding that, did you not?
A. Yes.
Q. What was the condition of the Chicago River with reference to its navigability for the years preceding 1900?
A. Oh, it was bad.
Q. It was bad?
A. Yes.
Q. How bad?
A. Well, there was no water in it.
Q. No water in the Chicago River prior to 1900?
A. To speak of. Always had trouble with the water.
Q. Speak a little louder please.
A. Always had trouble with the deep drafted boats.
Q. What were the bridge conditions prior to 1900?
A. Well, they were pretty near all center pier bridges of course.

Q. Hard to navigate by reason of those center pier bridges, wasn't it?

A. Yes.

Q. What was the condition of the river with reference to its depth, what effect did that have upon navigation?

A. Well, you would get aground of course, stuck.

Q. When did you begin to see improvement in the conditions of the Chicago River with reference to its navigability?

A. I can't tell that; it comes so slow.

Q. Approximately when?

A. I could not say that.

Q. Sir?

A. I could not say that; that would come so slow that I could not say what time.

Q. Were they better after 1900 than before?

A. In the line of depth of water, yes it was.

Q. And clearance, in width of the river?

A. Well, I can't say that.

Q. You have seen no widening of the Chicago River?

A. Oh, yes, I have seen that all right enough.

Q. To what extent?

A. Well, it is probably—I don't know how much wider but considerably. It was 50 to 75 feet in some places.

Q. In mostly all of the places where it was theretofore very narrow, the river has been considerably widened since 1900, has it not?

A. Yes.

Q. And have you noticed any improvement in the conditions of the river with reference to its navigability due to the removal of center pier bridges?

A. Yes.

Q. Have you noticed any improvement Mr. Green with reference to the odors, the smells in the river?

A. Yes, sir.

Q. What was the condition in the Chicago River prior to 1900, with reference to its sanitary affect?

A. Bad.

Q. How bad?

A. Well, it was smelling.

Q. How bad was it smelling?

A. Well, that I could not say.

Q. It was enough almost to nauseate you, make you sick, wasn't it?

A. Yes, sometimes.

Q. What has it been since 1900?
A. Pretty good in the south branch.
Q. Also as good as in the lake, isn't it?
A. Yes. Today it is very bad, the river.
Q. With reference to the way it looks or smells or what?
A. Don't smell; it looks bad.
Q. The lake looks bad too, doesn't it?
A. I guess so.
Q. It is roiled up?
A. Yes.
Q. On account of the winds and the storms?
A. Yes, on account of what they dump out there.
Q. What they dump in the lake?
A. Yes.
Q. What are they dumping in the lake?
A. Dump all they dig out of the river, I guess.
Q. They dump into the lake?
A. Yes.
Q. Mr. Green, the United States Government has been dumping into the lake in furthering of its work in excavation and so forth, has it not?
A. Probably is.
Q. Prior to 1900, how frequently were there collisions in the navigation in the South Branch of the Chicago River?
A. I could not say.
Q. You have had a lot of experience there, had a lot of observation?
A. Yes, but I could not say how frequent. There was not as much damage as after the opening of the canal. There was not as much, not as serious.
Q. Were they any?
A. Oh, yes, there were some of course.
Q. Quite frequently?
A. Well, I guess so.
Q. Sir?
A. Probably.
Q. Prior to 1900, the great occasion for collision and so forth, was due to the fact that the river was narrow and ships used to bump into each other in navigating the North Branch?
A. Yes.
Q. Since then the collisions you have heard of and that have been spoken of were collisions that were due to a boat swinging into a pier abutments or bridge abutments?

A. Yes.
Q. Is that right?
A. Yes.
Q. How many times would you say you have passed up and down that river in your steamboat, or in other steamboats on which you were, on an average per year in the last 20 years, Captain Green, 10 or 15 times a year?
A. Yes, at least.
Q. 25 times a year?
A. No, not that many.
Q. 15 or 20 times a year would be a fair average would it?
A. Yes.
Q. How many times have you seen boats stuck in any portion of the river in any of those trips you have made since 1900?
A. That I could not say.
Q. Give us your best judgment?
A. I could not judge of that.
Q. Well, as many as three times?
A. No, more than that.
Q. As many as 13 times?
A. Probably about that.
Q. About 13 times in all your experience. How many collisions would you say you have knowledge of or known about that occurred in the 14 years before the Sanitary District Canal opened?
A. I could not say.
Q. How many vessels did you see stuck in the river prior to that time?
A. I could not say that.
Q. Many?
A. I could not say that.
Q. You don't remember at all?
A. No.
Q. The vessels now are very much larger too than they were then?
A. Yes.
Q. The draft is very much deper?
A. Yes.
Q. The beam is very much wider?
A. Yes.
Q. And the tonnage capacity is very much greater is it not?
A. Yes.

Q. When you first started to navigate in the Chicago River in 1880, there was rarely a boat if any that came into the Chicago River that had as much capacity or was of as great a size as the one you are now operating. That is correct, isn't it?

A. Yes.

Q. And the boats that are navigating in the river now, referring to the freighters, Captain Green, are nearly all as large or larger than the boat you operate?

A. Yes.

Q. You spoke of some bad places in the river. You spoke of Van Buren Street, Jackson Boulevard, Madison Street, 12th Street, Pennsylvania Railroad Bridge at Stewart Avenue and Halsted Street?

A. Yes.

Q. Those are the only bad places you know of, or the worst of the bad places you know of. Is that correct?

A. Yes.

Q. Do you remember operating on the Chicago River in 1892, at the time they had the big storms?

A. Yes.

Q. That is when you got flows towards the lake, the river flowed toward the lake then?

A. Yes.

Q. What was the condition of the river with reference to navigation during those freshets and storms during 1892, in 1892?

A. Well, could not navigate. They stopped, tied up everything.

Q. Navigation stopped for a long period of time, didn't it?

A. For a week or so I guess.

Q. And those storms and freshets were so bad, and such a torrent rushing in the Chicago River that it is a matter of common knowledge that boats were rubbed off by the storms from their moorings at the docks?

A. Yes.

Q. Carried out into the lake and smashed against the bridges and so forth?

A. Something like that.

Q. And all by the flow of current and flow of water in the Chicago River?

A. Yes.

Q. How many like conditions do you remember since that time?

A. Well, that would be pretty near all the time now; water running the other way, that is all the difference.

Q. While the river was flowing into the Lake, how many like conditions were there?

A. What?

Q. How many like conditions do you remember before the water was turned in 1900?

A. How many times before?

Q. Yes, or since?

A. Since. Oh well,—

Q. Before 1900? Many?

A. No, I don't remember any. The way I look at it, it is as bad just now as it was then in them freshets.

Q. I am coming to that. It is even worse now than then?

A. Practically the same.

Q. I am coming to that in just a minute, but I want to know how many of those similar conditions occurred within your recollection before 1900?

A. Before 1900?

Q. Yes?

A. Three I think.

Q. Three. When navigation was completely stopped?

A. Yes.

Q. Captain, how fast would you say that the water was pouring down the Chicago River into the Lake during those freshets and storms that you speak of prior to 1900?

A. Well, four or five miles an hour I should judge.

Q. Will a current of four or five miles an hour in the Chicago River tear a boat away from its moorings and away from the dock where it is tied?

A. It might if it is striking the right way.

Q. I am talking about in the Chicago River where the boats are lined up parallel to the flow of the river, and properly secured, a current of four or five miles an hour—

A. I don't know of any boats that broke adrift, I don't remember that.

Q. You don't?

A. No.

Q. You want us to understand that at the time of the freshets the current in the river towards the lake was only four or five miles an hour?

A. Well, something like that.

Q. Something like that?

A. Yes.

Q. But still boats could not navigate?

A. No, they would not take us down, would not tow or anything.

Q. Would not tow. You could not get down by your own steam pressure?

A. No.

Q. How many times since 1900, have those conditions arisen, where they would not tow you and you could not go by your own steam pressure?

A. You would tow and do the damage—

Q. No, please answer the question: How many times have similar conditions arisen where you would not be towed down the river and you could not get down by your own steam?

A. I don't remember.

Q. You don't remember any, do you?

A. No.

Q. Sir?

A. I don't remember any—yes, I remember once.

Q. Tell us about that?

A. Well, that was in the spring of 1908.

Q. Yes.

A. I done a lot of damage that day so I ought to remember it. That was in the North Branch.

Q. You did a lot of damage that day?

A. Yes.

Q. The current was very strong in 1908?

A. Yes.

Q. Due to the Sanitary District Canal and the opening of the Canal?

A. I don't know, due to the cloud burst I understand. I was not around when it happened, and came in during the night. There was no current in the river, in the main branch, but there was a big current in the North Branch.

Q. You never found any current in the North Branch due to the Sanitary Canal?

A. Not to affect navigation.

Q. Not to affect navigation at all?

A. Except at that time.

Q. You heard after you got out it was due to a cloud burst?

A. Yes, to a cloud burst.

Q. You don't want to charge that against the opening of the Canal do you, the cloud burst?

A. No.

Q. What?

A. No.

Q. Now Captain, I believe you testified on your direct examination in reply to the question put to you by the learned counsel on the other side that the current in the Chicago River since the opening of the canal was in the open places from 1½ to 2 miles. Is that correct?

A. I think I said 3 miles, in some narrow place.

Q. I am talking of the open places?

A. Open places?

Q. 1½ to 2 miles in your judgment. Is that correct?

A. Yes. I think I said 3 miles in narrow places.

Q. I am talking about the open places?

A. Open places, that may be.

Q. How much will you say now the current was or is in the open places?

A. Well, it is hard to say that. It is difference in the current. I know it has been running 3 miles an hour sometimes in the open places.

Q. As much as 3 miles an hour?

A. Yes, sir.

Q. At other times less than that?

A. Yes.

Q. At other times I am talking about, not at other places?

A. Yes.

Q. How much less than that at other times?

A. 1 or 2 miles.

Q. Other times less than a mile?

A. Yes, I seen it dead.

Q. What was the most you ever heard of its running in the open places?

A. Oh, I never measured it so I could not say.

Q. You never measured it when you concluded it was running 3 miles an hour?

A. I kind of guessed that.

Q. I want you to guess the same way at the other time, give us the same sort of a guess?

A. How fast it had been going?

Q. Yes?

A. Well not over five miles.

Q. You heard some witnesses testify here it was going as much as 10 or 12 miles an hour, didn't you?

A. I guess I did, yes.

Q. Did you ever see it run as much as 10 or 12 miles an hour anywhere?

A. No, I could not say that.

Q. Ever see it run as much as 8 miles an hour anywhere?

A. No, I could not say that either.

Q. Did you ever see it run as much as five miles an hour in your opinion, anywhere?

A. Yes.

Q. Where?

A. Well, in the narrow places.

Q. Tell us where?

A. Well, that would be Halsted Street and them bridges we name.

Q. The places I named, the bridges?

A. Halsted Street, Pennsylvania Bridge.

Q. Have you seen any widening in your observations of those narrow places?

A. No, you can't widen them.

Q. Can't widen them on account of the bridges?

A. Yes.

Q. What width are those places you indicate as narrow places immediately North and South of the bridges?

A. They are regular width of the river.

Q. Regular width of the river. What is the regular width of the river?

A. I don't know, something 150 to 200 feet.

Q. Do you know any place where it is less than 200 feet since the Sanitary Canal has been opened, except just at the bridge abutments?

A. 200 feet?

Q. Yes?

A. I don't know how wide it is at the Pennsylvania Railroad Bridge. It is not very wide there, West of it.

Q. I don't mean the bridge. I mean immediately North or South of the bridge.

A. West of it there. I don't think it is over 150 feet.

Q. The bridges, places other than at the bridges, the river is at a uniform width practically isn't it? The South Branch I am talking about?

A. No, not all over. There is places where it is narrower.

Q. Substantially all it is one width?

A. Yes, there is places where it is narrower.

Q. But substantially, the great length of the south branch of the river, it is substantially 200 feet or over is it not?

A. It may be.

Q. And the narrow places you speak of are the sections we will refer to as the Bridge Sections of the river, where the bridges are placed?

A. Yes.

Q. That is by reason of the fact that the abutments are there, you haven't got quite as wide a stand to navigate the river. Is that correct?

A. Yes.

Q. Prior to the Sanitary District making these improvements, you had a number of tunnels under the river too, didn't you?

A. Yes.

Q. Where you could only draw something like 15 or 16 feet of water?

A. 16, I guess.

Q. And those have been removed?

A. Yes.

Q. And prior to the Sanitary District making these improvements, the river at many places was not over 16 or 17 feet deep at that time?

A. That is all.

Q. Since then the river has been widened and deepened to an extent of 26 feet, hasn't it?

A. No.

Q. No?

A. 18½ or 19 feet.

Q. Where is it only 18½ feet?

A. Well, where we get—there might be some deep holes some places, but there isn't that much water.

Q. There isn't that much water. You can't point out any place where the navigable part of the river is not 26 feet deep can you?

A. No, I cannot.

Q. Have you ever gone aground anywhere?

A. Yes.

Q. Tell us where?

A. I have been aground in the North Branch many places.

Q. I am talking about the South Branch?

A. Well, that Pennsylvania Bridge, several times.

Q. That is at the bridge?

A. Through the bridge.

Q. Of course you know you can't deepen that river there without loosening the abutments of the bridge until they remove the bridge, you know that, don't you?

A. Yes, I guess so.

Q. And they are removing the bridge, aren't they?

A. Probably are; maybe that will be a long time.

Q. What other place or spot have you found the water shallower than 26 feet?

A. At the Rock Island Elevators, there is no water at all sometimes.

Q. You mean next the dock?

A. Well, quite a distance out, south of 12th Street there.

Q. South of 12th Street?

A. Yes.

Q. Don't you know that there is no place in the navigable part of the river less than 30 feet deep, and prior to the opening of the Sanitary District Canal there was no place that was deeper than 16 feet?

A. No, that is not so.

Q. That is not so?

A. I have been aground in the forks a couple of times.

Q. We will get to the forks after while. We are only at the spoons.

A. Right next to the bridge.

Q. We will get to the forks in a little while. Mr. Green, is the water as deep now at the Rock Island Elevator as it was in 1911?

A. I don't know.

Q. You don't know?

A. I know that bridge, once in a while of course we can get that.

Q. I am not talking about the exceptions. I am asking you whether as a general proposition is the water as deep at the Rock Island elevator now as it was in 1911?

A. I don't know.

Q. I will ask you whether or not immediately opposite the Rock Island elevator, the depth of the water was not 27.2 feet in the middle of the stream, or approximately the middle of the stream, immediately opposite the south part of the elevator; 26.4 feet immediately opposite the middle part of the elevator and 29.9 and 27.4 feet immediately opposite the North end of the Rock Island elevator. Can you answer that question?

A. No.

Q. You don't know?

A. I don't know.

Q. Now you spoke about Van Buren Street being a bad spot and that you had been stuck at Van Buren Street. Is that right?

A. No, I was not stuck, but I needed all the power I could get through there.

Q. You neded all the power you had to get through?

A. Yes.

Q. Prior to the opening of the Sanitary District Canal in 1900, what depth of water was there at Van Buren Street?

A. 16 feet I suppose.

Q. How much is there now?

A. I don't know. It is more than 18 feet anyway.

Q. It is more than 18?

A. Yes.

Q. If I should tell you it was 26 feet, would you think that my statement was incorrect?

A. Yes, I would think it might be a deep hole there, but it would not be for any distance.

Q. Not for navigation purposes?

A. I mean not for any great distance. It might be a hole, of course.

Q. There would not be much sense in digging a hole to improve navigation?

A. No, but those holes were probably formed by the current.

Q. If I said to you Mr. Green that the depth through the draw at Van Buren Street at its shallowest spot is 20 feet and at its deepest spot is 24.1 feet, would you say in your opinion my statement was incorrect?

A. Oh, that may be so.

Q. And that at the 200 foot point immediately south of the bridge, the depth at no point is less than 22.7 feet, would you say that statement was incorrect?

A. No, I could not say one thing or another.

Q. And immediately north of the bridge at no point was it less than 24.9 in the navigable part, would you say that statement was incorrect?

A. I don't believe that.

Q. You don't?

A. No.

Q. Have you ever had occasion to think, since the opening of the canal, it was less than that?

A. Well, I have been rubbing on the bottom there. It may be now.

Q. Since the Van Buren Street tunnel was out?

A. I believe so.

Q. When was the Van Buren Street tunnel removed?

A. I don't remember now.

Q. You don't remember?

A. It is not very long ago.

Q. I beg your pardon?

A. It is not very long ago but I don't remember what year it was.

Q. You haven't any recollection of having rubbed the bottom since then at Van Buren Street?

A. How long ago is it now since it was?

Q. Mr. Wisner says he thinks it was 1910 or 1911.

A. Maybe not since then.

Q. Now Mr. Green, if the bridge span at Van Buren Street is enlarged, it being now only 94 foot opening, would that in your opinion greatly improve the opportunity of good navigation at that spot?

A. How much do you say, how much difference?

Q. If the 94 foot opening was enlarged say to 180 feet?

A. Sure, alter conditions altogether.

Q. Alter conditions altogether? And the open span at Jackson Boulevard, the place you say was dangerous to navigation is only 92 feet?

A. Yes.

Q. That is about your understanding of it?

A. Yes.

Q. If that span is enlarged to make it between 160 and 170, would that remove 1 of the dangers you have referred to?

A. Yes.

Q. And the Metropolitan Bridge the same way?

A. Yes.

Q. You know the Government has condemned the Metropolitan Bridge, and that is in the process of being removed?

A. Yes, kind of slow in moving it.

Q. And the city bridge at Jackson Boulevard is in the process of being removed?

A. Yes, I seen something of that.

Q. Those improvements will greatly improve the navigability of the Chicago River?

A. Oh yes, sure.

Q. And if the—

A. The building south of Van Buren Street, what are you going to do with that?

Q. The building south of Van Buren Street? And that in the improvement that is now under way will be removed also and the river widened?

A. That is a dangerous place.

Q. You mean the Loop power house building?

A. I guess that is a power house.

Q. You know that already steps have been taken to condemn that property and enlarge the river at that point?

A. Yes.

Q. You know Captain, do you not that the river has been widened each side of the Union Loop Power House? You have seen that, haven't you?

A. Yes, I seen that; yes, south and north.

Q. South and north of it, to 200 feet?

A. Yes.

Q. That has all been done since the opening of the canal?

A. Yes. I just was wondering why that building was there. Everybody asked me that question.

Q. At the Madison Street Bridge, you say that was another dangerous point?

A. There is one.

Q. A 60 foot opening on the west side and a 55 foot opening on the east side?

A. Yes.

Q. You know that is a center pier bridge, you remember that?

A. How much water is in that draw, may I ask?

Q. Yes, 21 foot.

A. Yes.

Q. How much do you think is in that draw?

A. I didn't think it was over 18; may be now.

Q. You go through with a 18½ foot load?

A. We go through; that is all too.

Q. We will come to that in just a minute.

A. Make no headway.

Q. If I told you that in the middle of the stream between the west abutment and the center pier the depth runs from 24 to 26 to 20 feet, and the east side from 28 to 26 to 18 immediately next to the dock line, would you say that I was misstating the fact, or don't you know about it?

A. In the Madison Street?

Q. Yes?

A. The east draw?

Q. 28.6 and 26.6 in the navigable part of the river.

A. Now?

Q. In 1911, 14th day of December 1911, and immediately next to the dock line 18.1 feet, would you say that was not correct?

A. I don't think so, I don't think so.

Q. How much less would you say it was?

A. Somewheres around 18 feet I would think it would be.

Q. Have you ever had occasion to take the depth there?

A. No, but the boat sticks you know, you think something is the matter; you think it is the bottom.

Q. Did you ever get stuck there?

A. Pretty near not quite but we may have rubbed something in the sides.

Q. You have rubbed on the sides?

A. The bilge.

Q. You spoke of the 12th Street Bridge, that is a center pier bridge there is it not?

A. Yes.

Q. The west draw is about 58 feet?

A. That is never used.

Q. That is never used and the east draw is 63 feet. That is the one that is used?

A. Yes.

Q. Do you remember prior to the Sanitary District Canal making those improvements what the draft permitted was or the depth of the river in the navigable part?

A. 16 feet.

Q. 16 feet. Since then how much is it?

A. Well, it is 18½ or 19; 18½ I guess is about as deep as they get.

Q. If I told you it was 20 feet, you would not want to gainsay that would you?

A. No, that may be.

Q. Do you know to what extent the river has been widened immediately north and south of the 12th Street Bridge since the Canal Project was undertaken?

A. North of 12th Street Bridge?

Q. Yes, north and south of the 12th Street Bridge?

A. I don't know of anything North of it. It was widened south of it.

Q. It has been widened south to 220 feet or about that?

A. Widened the river that much?

Q. No, so that it is 220?

A. No, that may be. It is not widened north of it.

Q. Not widened north?

A. No, not on the south side of the river; may be widened a little on the west side, where it is no good to anybody.

Q. If that center pier old bridge is removed and the water is at a depth of 20 feet so that you would get a span of between 160 and 180 feet, would that in your opinion improve navigation, to remove one of the obstacles you have been fearful about?

A. Yes, sir.

Q. Mr. Green, I show you a map entitled "Sanitary District of Chicago, map showing Chicago River improvement from 12th Street to 18th Street; scale 200 foot to one inch," and I draw your attention to that part of the plat which upon its face is indicated as 12th Street?

A. Yes.

Q. There appears there the center pier of the bridge at 12th Street, does there not?

A. Yes.

Q. I will ask you to look on the west side of the river?

A. Yes.

Q. And ask you to state whether from the track numbered 15 on lot 5, that is this point here (indicating) there has been any widening of the river to improve the conditions of navigation?

A. Yes, all that is there shown.

Q. All that is there shown colored a deep blue?

A. Yes.

Q. And that is carried all the way down here to the St. Charles Air Line Bridge, that is correct?

A. Yes.

Q. Has that removal of all of that adjoining soil improved the conditions of the navigation?

A. Greatly.

Q. And has reduced the dangers of navigation and the currents, hasn't it?

A. Yes.

Q. And then if the 12th Street center pier bridge is removed, and a newer type of bridge leaving a much larger span for navigation, for a 200 foot opening, if that is installed, that will still further greatly improve the conditions?

A. Yes, it will be all right.

Q. It will be all right. Now you spoke of the Pennsylvania Railroad Bridge at Stewart Avenue, I believe you said?

A. I guess that was it.

(A map was here identified and marked Exhibit for Identification 1, shown to Witness Green.)

Q. I will ask you to look Captain at the plat marked: "Sanitary District of Chicago, Map showing the Chicago River Improvement from 18th Street to Halsted," and I draw your attention to the point on the map indicated as 18th Street. That is removed is it not?

A. Yes.

Q. And a large bascule bridge with a wide opening there?
A. Yes.
Q. Has that improved navigation any at that point?
A. Yes.
Q. Greatly?
A. Yes. If they only would open the bridge, it would be all right.
Q. If someone would open the bridge. That is when the steamboats come down and blow the whistle, if the man in charge of the bridge would open the bridge, your troubles would be removed, is that it?
A. Yes. I ran into the draw of the bridge once. They did not open the bridge.
Q. You know the Sanitary District does not open and close bridges. You want to go over to the City Hall to raise that question. I want to draw your attention, going south or in a general direction southwest from the new bascule bridge at 18th Street to the part of the map indicated in dark blue, starting with the numbers, 1, 2, 3, 4, 5, opposite the words "Coal Dock"?
A. Yes.
Q. You remember that was a coal dock?
A. Yes.
Q. That has all been taken out?
A. Yes.
Q. That land or earth there has all been taken out down to the heavy blue line between the dark blue and the white passing through the letter "K" of the word "dock"? That has all been removed by the Sanitary District Canal?
A. Yes.
Q. Has that improved conditions?
A. Oh yes, greatly.
Q. Very much?
A. Yes.
Q. Then you get down to the Pennsylvania Railroad bridge which is at Stewart Avenue and immediately adjacent to the figures "48"?
A. Yes.
Q. Now the improvement that I have just drawn your attention to, by the removal of this dark blue dirt and earth, and the opening of this large bascule bridge, you haven't got the full benefit of it, on account of this Pennsylvania Railroad bridge?
A. That is right.

Q. If that Pennsylvania Railroad Bridge was out of there, then you would get the full benefit of it, wouldn't you?

A. Yes.

Q. And the Pennsylvania Bridge is a center pier bridge?

A. Yes.

Q. And as long as that is there, the widening of the river and the putting of this bascule bridge in has not helped you as much as it would otherwise?

A. No, that is right.

Q. When that Pennsylvania Bridge is out, and you get a wide open span bridge there, then you will be all right, won't you?

A. Yes.

Q. You know that the Government has condemned that Pennsylvania Bridge and is making them remove it; it is being removed now?

A. I believe it is. It has been many years.

Q. The Government moves very slowly. You want to go to Washington and make complaint about that.

A. (No response.)

(Map shown to witness was marked Exhibit Green Number 2.)

Q. Now, beyond the Pennsylvania Bridge going South and West, you have no trouble at all except at Halsted street, is that correct?

A. Yes.

Q. The depth of the river at Halsted street prior to the opening of the canal was much less than it is now, wasn't it?

A. Yes, I guess so.

Q. You have no trouble with the depths at Halsted street at all, do you? You have no trouble with the depths at Halsted street?

A. No.

Q. If that bridge that is now at Halsted street is widened, the open span is widened from 105 feet to 180 feet say, that will improve the conditions of navigation very materially, will it not?

A. Yes.

Q. You know that the river has been widened at Halsted street immediately north and south of the Halsted street Bridge?

A. Yes.

Q. Sir?

A. Yes, I know that.

Q. That widening has helped navigation, has it not?
A. Oh, yes.
Q. Now, beyond Halsted street, south and west, you have had no trouble at all?
A. Oh, yes, we have more or less trouble on account of the current.
Q. You have more or less trouble because you navigate a big ship?
A. More so where there is a current in a narrow place like the Chicago River.
Q. But no difficulty as compared with those you have indicated?
A. Oh, no.
Q. And those were ones that you encountered due to the narrowness of the river, often without a current, if there was no current, prior to the opening of the canal in 1900, were they not?
A. No, I could not say that.
Q. You had other difficulties, then, didn't you?
A. We had others, but many more now.
Q. You have more now?
A. Yes.
Q. But after these improvements were made, with the greater depth of water and with the wider openings of the bridges along the lines that I have indicated, navigation will have been greatly improved in the Chicago River?
A. It will help some.
Q. It will help materially, won't it?
A. Oh, yes, if you do not increase the current.
Q. Sir?
A. If you do not increase the current.
Q. The current that you have noticed in the river has been noticeable where the river was wide, most noticeable where the river was wide and where it suddenly narrowed? I mean narrowed into a pass or by-pass, which was made by the abuments of the bridges?
A. Yes.
Q. That is where you have noticed the heavy current?
A. Yes.
Q. Where you have spoken about the dangers of being jammed into piers or abutments of the bridges, that was at or about the place where the river was 200 feet wide or about 200 feet wide and suddenly was narrowed into a bridge opening of 90 or 100 feet, is that correct?
A. Yes.

Q. And thus created the dangers to navigation that you have referred to?
A. Yes.
Q. Sir?
A. Yes, some of them.
Q. The greater part of them, isn't that correct?
A. Yes.
Q. Captain, what depth do you navigate in the locks at the Soo?
A. About 18 feet, 18½.
Q. You are notified, it is a matter of public record to what depth you can load there?
A. Yes.
Q. What is the depth to which you can load to go through the Soo Canal?
A. Well, it is up to 19 feet, 19.6 I believe sometimes.
Q. Sometimes as low as 18.6?
A. Yes, less than 18.
Q. Sometimes less than 18? You have got to take that into consideration when you load from the Chicago River to go up the lakes?
A. Yes.
Q. Sir?
A. Yes.
Mr. Austrian: That is all.

Re-direct Examination by Mr. Hopkins.

Q. Those maps that were shown you, you don't know whether or not they are accurately made as to the amount of feet it shows, do you?
A. No, I could not say.
Q. You haven't checked up the maps or anything of that kind?
A. No.
Q. Do you happen to know the amount of tonnage that comes into the Chicago River now as compared with the time before the opening of the Drainage Canal?
Mr. Austrian: Objected to as incompetent, irrelevant and immaterial; has nothing to do with this case.
A. I don't know exactly. I know it is less.
Q. You know it is less?
A. Yes.
Q. Is there any other harbor on the Great Lakes where

you have as much difficulty with the current as you have in the Chicago River?

Mr. Austrian: Same objection.

A. No, it is the worst.

Re-cross Examination by Mr. Austrian.

Q. How about Port Huron, the Huron River, St. Clair River?

A. That is all right. That is wide, big, lots of room.

Q. Do you have any trouble there?

A. No.

Q. Captain, do you know that the class of small vessels has been affected by the building of great steamships by the steel trust and other combinations? Have you ever heard of that fact?

A. I have read something about it.

Q. Yes. Do you know that they have created and built vessels carrying from 10 and 12 to 15,000 tons capacity?

A. 12,000.

Q. 12,000 tons capacity. And can put as much freight in one of those as they could put in six boats of your capacity?

A. Yes.

Q. And that they have diverted that freight from the Chicago River to the places that they control the railroads to get cheaper carrying, have you ever heard anything about that?

Mr. Hopkins: I object to what he has heard.

Mr. Austrian: You asked him what he heard with reference to diversion of freight to the Chicago River.

Q. Have you heard any such talk as that?

A. No, but I have seen it of course.

Q. You have seen it and read about it?

A. Read about it.

Q. And the great steamships on the Great Lakes are now owned by the Pittsburg Steamship Company, aren't they, most of them?

A. Most of them, yes.

Q. And the Pittsburg Steamship Company, do you know who owns that?

A. I suppose the people in general.

Q. The Steel Corporation?

A. They own stock all over the country.

Q. Where do they carry their freight to?

A. To their furnaces wherever they have them.
Q. Where?
A. Well, it is in—
Q. Pittsburg?
A. From Erie to South Chicago.
Q. South Chicago. And they do not go through the river to go to their plants at South Chicago and Gary, do they?
A. No.
Q. They have built canals by which they can carry their steamers right in from the lake to their mills at Gary and South Chicago, right direct from the lake without going up any branch of the Chicago River, haven't they?
A. Yes.
Q. Sir?
A. Yes.
Q. And they used to have a plant on the south branch, a rolling mill plant or furnace plant on the south branch of the Chicago River and on the north branch of the Chicago River?
A. I know they had one up north but I didn't know they owned that south; I didn't know.
Q. There was a plant there?
A. There was a plant there, two plants.
Q. And the lake carriers used to bring the ore in a crude state, and the coal to operate those furnaces and plants into the south branch of the river and into the north branch of the river, didn't they?
A. Yes.
Q. But since the formation of the steel corporation, they have been closed down, haven't they?
A. Yes.
Q. And there was a big plant down at Bridgeport, too, that they used to operate before the steel corporation was formed?
A. That is what you had reference to?
Q. Yes.
A. They shut down before that time, I guess.
Q. Just before that?
A. Many years before that.
Q. These big steamers that are owned by the Pittsburg Steamship Company, they only carry, so far as you know they only carry ore for the United States Steel Corporation?
A. Yes.
Q. Not for anyone else?
A. No.

Q. They do not carry other kinds of freight so far as you know, do they?
A. Carry coal once in a while.
Q. They carry coal to their plants?
A. Well, to outsiders, too.
Q. Where?
A. Well, docks around the lakes, small docks, small boats.
Q. The small boats?
A. Yes, they carry coal around.
Q. That is when they carry coal up north, it is on the return trip that they carry the ore south?
A. Yes.
Q. Have you known of them to charter tonnage to carry the ore south?
A. Yes, they charter other boats, I know that.
Q. They charter other boats to carry the ore?
A. Yes.
Q. From the mines down?
A. Yes.
Q. Do you know or did you know of their sending any coal up with a chartered tonnage?
A. I don't know.
Q. Who asked you to come here to testify, captain?
A. Mr. Sullivan.
Q. Who is Mr. Sullivan?
A. He is vessel agent for the city.
Q. Who is he agent for?
A. He is agent for any boat he can get.
Q. But principally who is he the agent for?
A. I think for his own fleet of boats; he has got his own fleet of boats.
Q. Isn't he the agent for the Pittsburg Steamship Company?
A. Maybe; I don't know.

SVEND J. EMERSEN, resumed the stand and testified further, as follows:

Cross-Examination by Mr. Austrian.

Q. I understood you to say you had been a master mariner or captain for one year. Is that correct?
A. Yes, sir; but I have been captain off and on taking charge for a trip or so; but I do not include that in.

Q. And that you have navigated the Chicago River for three years?
A. Well, yes, off and on. That is not steady.
Q. Not steady?
A. No.
Q. When were those three years?
A. Oh, that was on an old schooner here 18 years ago.
Q. On a schooner 18 years ago?
A. Yes.
Q. Since 1896? That is 18 years ago?
A. Yes.
Q. Since 1896, how much, if at all, have you navigated the Chicago River?
A. Well, I navigated up and down then a couple of years, off and on.
Q. What years were they?
A. That was the two years after that.
Q. From 1896 to 1898, is that correct?
A. That is correct.
Q. That is before the canal was opened?
A. Before the canal was opened, yes. My experience than was not what it is now.
Q. You have more experience now than then?
A. Yes.
Q. Certainly. You and I are about the same age, about 21?
A. About that.
Q. This boat you had occasion to run up and down the Chicago River from 1896 to 1898, was that a steam craft or sailing craft?
A. No, a barge towed by steamboat.
Q. Towed by steamboat?
A. It was towed by steamboat.
Q. The conditions in the Chicago River in 1896 and 1898 when you were there, you don't remember very distinctly?
A. No.
Q. You don't remember the conditions very well?
A. Not very well, no.
Q. Do you remember the smell?
A. Indeed I do. I don't remember any current though.
Q. Your mind is on current; my mind is on smells just now. So you just direct your mind where mine is; it is easier to remember. I am asking you, Mr. Witness: Do you remember the smell?
A. Yes, I do.

Q. You don't remember any current?
A. No, sir.
Q. You have not been up here when there were any freshets or storms?
A. No.
Q. You haven't any recollection about any of those?
A. No, I haven't any.
Q. Of course I only want to know what you remember?
A. Yes.
Q. I am not trying to trip you, and you are not trying to trip me?
A. That would not do.
Q. Mr. Emerson, I understood you to say on your direct examination that in operating on the Chicago River in the last year—and I understand that is the only time you have operated since 1898?
A. Yes, since 1898.
Q. —you have noticed a current that went at times from 2½ to 3 miles an hour. Is that correct?
A. Yes, sir.
Q. Where was that current noticeable?
A. Well one time I came in here last summer.
Q. I mean at what place in the river?
A. I was going to give you, down to the pier, down to the coal dock down here at West Pier, or South Pier, these two piers.
Q. What bridge?
A. That is before you get around to the mouth of the river.
Q. It is east of the bridges is it?
A. Yes, outside the bridges altogether.
Q. East of the bridges?
A. Yes, east of the bridges.
Q. You saw a current through there?
A. Quite a current there one time.
Q. That is at one time. Where have you noticed this heavy current that you speak of that is from 2½ to 3 miles an hour?
A. There is one place down there at the coal dock; and Jackson, and Adams, 12th street and also Halsted street.
Q. At the coal dock you refer to, the river is about 300 feet wide, isn't it?
A. Yes, I guess it is, probably a little better than that.
Q. A little wider. You read those names of the places

you noticed the current from a little memorandum book just now, didn't you?

A. Yes.

Q. When did you write those in the memorandum book?

A. In my log book on the steamboat.

Q. In your log book on the steamboat?

A. Furthermore, because I do not recollect the names of those bridges. All I have to do when I operate my steamboat is to watch my boat. I don't take notice of them bridges, but by inquiring what is the name, so and so bridge.

Q. When did you write those names down?

A. I wrote them down to-day.

Q. You wrote them down to-day?

A. Yes, so I could tell you where the places were.

Q. You told Mr. Hopkins where they were before you told me.

A. I told him that yesterday.

Q. I mean to-day, you told him right here in this room.

A. Yes.

Q. That is all right.

A. I had them down then.

Q. When did you write them down, yesterday or the day before?

A. I wrote them down to-day.

Q. You wrote them down to-day? I thought you said you wrote them down yesterday so you could tell me?

A. To-day I told you?

Q. You told me to-day?

A. Yes.

Q. You wrote them down to-day?

A. Yes.

Q. Who came to see you about testifying in this case, or who asked you to come here?

A. Captain D. Sullivan.

Q. The same Mr. Sullivan that the previous witness referred to?

A. Yes.

Q. Did you talk to him about your testimony?

A. Why he got the testimony from me last summer.

Q. You talked about your testimony to him then, did you?

A. Well, different places where I had any troubles, yes.

Q. Did you write it down?

A. Why, he got our record over there, yes.

Q. He got a statement from you?

A. Yes. Of course, you must remember we don't write to

the office how much current we have here, how much current there. That is to be carried by ourselves.

Q. You have to carry that in your mind?

A. Yes.

Q. You have no independent recollection, have you, of any particular time of month or day in the month or month in the year that you saw this current of 2½ or 3 miles?

A. Yes, we came up here in June.

Q. Last year?

A. 1913. And I have been up here in August; and I was up here last November; the first part of December, rather.

Q. Then you were here in June, in August and the first part of December last year?

A. Yes, December.

Q. Those were the three times you were in the Chicago River last year?

A. Yes.

Q. That is you made three trips into the river?

A. Yes.

Q. In June where did you go; where did you land your boat?

A. 35th street.

Q. In August where did you land your boat?

A. 35th street.

Q. In December where did you land your boat?

A. Lehigh Coal Dock between North avenue and Fullerton, I think, aboue North avenue.

Q. When you went up to the Lehigh Coal Dock, did you strike any currents there?

A. Not after I got through the forks, I did not, through Kedzie street.

Q. You found no currents in the North branch?

A. No.

Q. Then the only two trips you had since 1898 in the Chicago River, in the South Branch, were in June and August of 1912?

A. 1913.

Q. I mean 1913?

A. Yes.

Q. And the observations concerning which you have testified were made on those two trips?

A. Yes, sir.

Q. And that is all you know about it, isn't it?

A. That is about all I know about it.

Mr. Austrian: That is all.

Mr. Hopkins: That is all.

J. P. MINSKEY, resumed the stand and testified further, as follows:

Cross-Examination by Mr. Austrian.

Q. What are your initials?
A. J. P.
Q. Mr. Minskey, I understood you to say that two years ago this winter you were in charge of some boats that were operating or stationed on the Chicago River, is that correct?
A. Well, yes, I had charge of the boats, but we were not what you call operating on the river. We were holding them here for storage; that is we were holding grain for storage.
Q. That was in 1912?
A. Yes.
Q. There was supposed to be a corner in the grain market in 1912?
A. I guess you might call it that, for they put the oats in some of these boats for about 35 cents, and sold them out for 80 in the spring.
Q. There was a shortage of warehousing space?
A. Shortage of warehousing.
Q. So those who had purchased the grain, the oats whichever it was, had it brought here, and instead of putting it in warehouses they put it into empty bottomry.
A. Put into these vessels.
Q. And those vessels tied up at certain docks along the river?
A. All along the—
Q. The South Branch?
A. Both branches.
Q. South and North Branch?
A. Mostly in the North Branch.
Q. There were some 15 vessels in number, weren't there?
A. Why, I think so.
Q. I mean under your charge or supervision?
A. Yes.
Q. That is instead of having the vessels earn no money after the close of navigation, your company or your associates had an opportunity of leasing the bottomry for warehousing purposes to store grain; and they took advantage of that and stored them in the Chicago River?
A. Yes, the season was rather poor in the coarse freight trade. The company I was with at the time were not con-

nected with the Iron Company so that—and coarse freight being very scarce, the boats were chartered in the last of August and September and put into this storage here and South Chicago.

Q. When you say that your line was not affiliated with any iron industry or ore industry, you mean it did not carry any of the ores from the mines down to South Chicago or to the Pittsburg industries, and hence the season was poor. Is that correct?

A. Yes.

Q. The Pittsburg Steamship Companies' boats were operating as usual that summer?

A. I think so; not alone the Pittsburg, but there was a good many others that is connected with the iron business, that is in the same—

Q. The observations that you made with reference to the condition along the Chicago River you made principally while you were in charge of those 15 boats?

A. Yes.

Q. During the winter of 1912?

A. Yes.

Q. Navigation at that time was closed on the river?

A. Well, not when I began.

Q. You began in September, wasn't it?

A. Yes, last of August.

Q. Last of August?

A. And September, the boats—I think my boat ran that year 72 days, and we started in the early part, June, maybe and ran 72 days, and then I was sent here and took charge of these boats.

Q. Do you remember when your boat was taken off?

A. Just the day?

Q. Well, approximately the day?

A. Oh, it was in August, the last of August that I was laid up.

Q. And did you immediately come here?

A. Immediately came here.

Q. And the boats were all tied up?

A. Some were and some were not.

Q. When did you begin to make observations as to the condition of the Chicago River?

A. As soon as I took charge of them.

Q. Where, at what point in the river did you take charge?

A. I had charge of all of them.

Q. Did you travel around from one boat to another?

A. I traveled around from one boat to another every day; went aboard every boat every day.

Q. You were a sort of inspector, were you not?

A. Yes.

Q. To see the condition of the grain?

A. See that the grain was taken care of.

Q. Kept dry?

A. And see the boats was not damaged, or if there was damage who done it and what the circumstances was.

Q. It will be necessary for you to tell us where your boats were located.

A. I could not locate them all; we moved them so many times I could not do that. We had one that laid a long time right above 18th Street Bridge; one laid—

Q. Is that where you made the principal observations?

A. Well, as much as any probably there.

Q. Right above the 18th Street Bridge?

A. Between 18th Street and the Pennsylvania Bridge.

Q. Between 18th Street Bridge and the Pennsylvania Bridge?

A. Yes.

Q. Where else did you make the observations you have testified to principally? I don't care what you saw walking across the bridge, but you have testified as to certain conditions that you observed at the places where these boats were located.

A. I said—

Q. Tell us the next one?

A. I think you are mistaken about that.

Q. I may be wrong. I am not infallible; I am not like the Government.

A. The damage, I think the boat that laid there got the most damage maybe of any.

Q. All right.

A. And another one that laid below the bridge, and maybe a length below the bridge.

Q. That is below the 18th Street Bridge?

A. Yes, she had a good many damages. She was between, about half way between the railroad bridge and 18th street, below the bridge there.

Q. That is north, isn't it?

A. Well yes, north of 18th street.

Q. North of 18th?

A. That 16th Street bridge there is a railroad bridge. We

laid,—one boat laid this side of the bridge and the other laid the other, and I think those two boats got more damage than any other that I had, that I was looking after. You see the river crooked and the flow made a bend you know, and rubbed you.

Q. Now Captain, do you know how these damages occurred, did you see it?

A. No, I don't think I saw one.

Q. You didn't see any damage to the boat?

A. Only saw the damage.

Q. Saw the result?

A. Saw the damage but didn't see the collision.

Q. Didn't see the collision?

A. No, it was boats rubbed them.

Q. You didn't see the collision, or how the damage occurred upon any boat that you had?

A. Oh yes, I did.

Q. Tell us one?

A. Well, the steamer Lake Shore, when we were jammed in the Pennsylvania bridge.

Q. The steamer Lake Shore?

A. We have a law suit on her that we haven't got settled yet.

Q. The steamship Lake Shore, when you were jammed—

A. We were trying to get through it at the time.

Q. At the Pennsylvania bridge?

A. Yes, and could not.

Q. At the Pennsylvania Bridge?

A. Yes.

Q. Who did you sue there?

A. I think the company sued the Tug Company.

Q. The Tug Company was the company that was hauling the boat?

A. Towing the boat.

Q. You sued them for negligence, didn't you?

A. I think so.

Q. Because they had not drawn you through properly, is that right?

A. Well, because we received the damage in going through the bridge, or trying to get through the bridge.

Q. Because you contended they operated the tow negligently or carelessly, is that right?

A. Well, as far as I was concerned, I didn't think it was carelessly.

Q. Still you sued them?
A. Well, the damage came there and our company wanted to recover if they can.
Q. Why didn't you sue the Sanitary District?
A. What?
Q. Why didn't you sue the Sanitary District?
A. I give it up, partner. I ain't a lawyer for the firm and won't boss that, and I don't know. If I was the lawyer for the firm, maybe I would have sued the Sanitary District, but as I was not—
Q. Did you collide with one of the Rock Island boats?
A. With what?
Q. With one of the Rock Island boats?
A. Rock Island boat?
Q. Yes?
A. Have they got any boats?
Q. I dont' know. I am asking you.
A. Not that I know of.
Q. Did you collide with any boat in this current you have just testified to at the Pennsylvania Bridge?
A. No.
Q. You just collided with the bridge?
A. Just collided with the—
Q. With the abutment?
A. With the approach of the bridge.
Q. It would not get out of your way?
A. It would not get out of the way.
Q. Now then, did you see any other accident, that you have referred to?
A. Yes, at the time I was trying to get the Neptune past Washington Street Bridge, I had ahold of her and saw her run into the approach to the Lake Street Bridge.
Q. That is the occurrence of this Neptune damage; that is the occurrence that you speak of when you had difficulty getting over Washington Street?
A. Yes.
Q. They had been doing some repair work in the river at Washington Street?
A. Yes, they were—
Q. Sinking a caisson, weren't they?
A. Putting a foundation in for the bascule bridge.
Q. There was a lot of work going on there, and you had difficulty in getting through?
A. We tried to get over and that is the place I had four

tugs on the job and they could not get her over, there was so much current.

Q. You finally did get her over?

A. They shut down the canal for us and the next day we got over and then we did the damage on the bridge.

Q. You got over so fast that you went two whole blocks?

A. We went over slow for a long time. When she did start, the tugs didn't stop quick enough, stop pulling quick enough. We were going pretty fast.

Q. There was no current there at all that day?

A. Oh yes, rather strong current.

Q. Strong current?

A. Yes.

Q. The current was against you?

A. The current was against us.

Q. Still you got over the Washington Street Bridge, and you went from Washington to Lake Street, bumped into Lake Street and that was all on account of the Sanitary District Canal being open?

A. Now as I told you, we went slowly past the bridge, but as she passed it, after she got by it they didn't stop pulling quick enough and we did the damage.

Q. Do you blame that on the Sanitary District?

A. We blamed it on the tug and we were trying to recover from the tug.

Q. You are trying to recover for what happened on that occasion?

A. If I had thought, I would have put a letter in my pocket and showed it to you.

Q. If the current had not been there, if it had been down the river you would have gone still faster?

A. We would not have done any damage because we would have been going slow.

Q. You would have been going slow?

A. Yes.

Q. You sued the Tug Company for that negligence?

A. I didn't sue.

Q. The company did?

A. The company is suing on that.

Q. With the exception of the Lake Shore incident that you sued the Tug Company for and the Neptune incident you sued the Tug Company for, you observed injuries to your boats occasioned at the 18th Street and Pennsylvania Railroad

bridge, and immediately north of 18th Street. Is that correct?

A. Yes.

Q. Now Captain, did you ever navigate the Chicago River?

A. Did I ever navigate it?

Q. Yes?

A. Yes, sir.

Q. As part of your business I mean?

A. I have not for 25 years. Previous to that 25 years, before, I navigated it very often.

Q. I must admit the soft impeachment, that is too late for me. Captain, I show you the map which has been identified as "Witness Green Number 2," and point out to you 18th Street as indicated upon this map, so labeled. Can you see Captain without your glasses?

A. I could not see it without my glasses, boy.

Q. All right, I am with you. That (indicating) is 18th Street?

A. Yes, sir.

Q. Here (indicating) is the Pennsylvania Bridge?

A. Yes.

Q. That is indicated?

A. That is here.

Q. Yes, right there. You say your boat was lying between 18th Street—

A. And here.

Q. That is your boat was lying on the West side of the river?

A. On the South.

Q. This is West?

A. Oh, I thought this was the river.

Q. This (indicating) is the river.

A. I had a boat lying here (indicating), on this side.

Q. That has been widened. The river is there (indicating) now. This soil has all been taken out; the deep blue is all out.

A. That may be, yes.

Q. There (indicating) is the river bank. This heavy blue line is the river bank.

A. When did they take this out? It seems to me there was a crook right there (indicating) and we were right down here (indicating).

Q. That is the crook?

A. It was more than that there, boy.

Q. They have taken that out—

A. The last two years?

Q. Oh no, it has been taken out many years ago, the deep blue has been taken out many years ago.

A. All right.

Q. Since the canal was opened.

A. I won't dispute you, boy.

Q. That is a fact.

A. My recollection of the river was a sharp bend, and our stern stuck just a little by it, and there is no center in this.

Q. That is out too?

A. And they came in and butted us right there. I had another one right over in here.

Q. You had one on the East side and one on the West side?

A. I had to move away. I didn't leave her there only a week and I had to move her.

Q. When did this accident occur on the West side?

A. Oh, I had a half a dozen ones.

Q. When did the accident you are talking about occur to the boat on the West side?

A. The bruise at the dock?

Q. Yes, on the West side of the river, on this side of the river, the West side?

A. Why it was along in the river; I could not tell you; or early in the fall. I had five or six damages on this one here (indicating).

Q. That is on the West side?

A. It is.

Q. That is West; West is over there, East here, North there and South here.

A. East over there?

Q. Yes. I want to know when the damage occurred to the boat that was lying on the West side?

A. Oh didn't have one there only about a week.

Q. When did the accident occur, or the damage occur to the boat on the West side?

A. I said I didn't have one there but a little while. I don't know, I said we had any accident on the one on the West side. I said they didn't leave her there but a few days, less than a week and then took her back, loaded her to an elevator, steamed her up there out of the way.

Q. Now Captain—

A. I had four or five accidents on this boat, while she was lying here (indicating).

Q. On the West side or the East side?
A. The East side of the river.
Q. That is on this side (indicating). Here is the Indiana elevator right here.
A. Well, that is all right, yes.
Q. You laid her up near the elevator, did you?
A. This is the elevator they tore down, didn't they?
Q. I don't know.
A. This is above the 18th Street, South of 18th Street?
Q. This is South of 18th Street.
A. Yes sir, south.
Q. There is 18th Street, there is the Pennsylvania Bridge.
A. She was laying where this old elevator was and laid there for—she laid there for three months.
Q. Three months?
A. Yes, and in the time—
Q. From August to September?
A. From probably September sometime up until in January when we moved her, when we tried to—
Q. About January?
A. Yes.
Q. And she had several bumps?
A. She had several bumps there, yes.
Q. Was there any ice in the river?
A. Oh, not so very much.
Q. In 1912?
A. Oh yes, there was drift ice in the river but it never froze up so but what they could move boats.
Q. There was drift ice in the river?
A. There was drift ice in the river all winter.
Q. And there were boats navigating in the river beyond and beside your boat you had tied up at the Indiana Avenue elevator?
A. The damages all came on this boat before the close of navigation.
Q. Before that?
A. I think so.
Q. You don't know whether they did or not, do you Captain?
A. Yes, I do.
Q. You know these ten or twelve damages you got all came before navigation closed in 1912?
A. Well now I don't think all of them came because some we got moving them ourselves, so we were moving them later

in the year; but the damages came in the fall, while the boats were running, before navigation shut down.

Q. The damages came while the boats were running?

A. Not these boats were not.

Q. But other boats in the river?

A. Yes.

Q. You know boats were running in the river all winter that year, weren't they?

A. Well, not very much.

Q. Some?

A. Oh yes, some, of course, but then they are smaller boats and don't cut so much figure.

Q. Then I want you to tell me Captain when that boat that was lying at the Indiana elevator was damaged, and how often it was damaged and how it was damaged?

A. Well she had a damage forward that came, I could not tell you the boats that damaged that; and she had four damages on her after end.

Q. Four?

A. Yes.

Q. Within what period of time?

A. Just hit against the rail and pushed them in and broke the stanchions along from the mid ship's side.

Q. Within what time did these four damages occur?

A. Within four months, three months I should say.

Q. Within a period of three months?

A. Yes.

Q. That is three months intervened between the first collision—

A. I should think she was lying there three months.

Q. What space of time intervened between the first damage to her and the last damage to her, while lying at the Indiana Avenue elevator?

A. I could not tell that without going to the Company and getting the damage from each boat.

Q. I am only talking about the one that was lying at the Indiana elevator.

A. Yes, I know; that boat laid there from the time I took charge of her until she was unloaded sometime in the winter.

Q. You said about January. You said she laid there from September to January?

A. I should think it was somewhere about January, maybe later than January.

Q. You said she was damaged four times while lying there?

A. She was damaged while lying there.

Q. Four times?

A. I think so.

Q. I am asking you now what period of time elapsed between the first damage and the last damage, while she was lying there?

A. I think you are asking something I could not tell you without getting my accounts from the company.

Q. Your reports from the company?

A. Yes, my reports that I sent into the company.

Q. Where is your company's office, Captain?

A. It is in Cleveland.

Q. Those reports that you sent into the company, you retained no copies of?

A. No, the company went into bankruptcy. They were under a receiver's hands at this time.

Q. They were not connected with the Pittsburg Steamship Company?

A. And they were sold out a year ago in February; all the boats were, and the company has three little boats left.

Q. It would be rather hard to get your reports now?

A. I should rather think so. I had this letter from these—from the attorneys, and wanted me to look them up some witnesses, some more witnesses than I had given, and send them.

Q. Yes, but Captain you remember—

A. In this same ship.

Q. You remember visiting the ship every day?

A. Every day.

Q. Were those four accidents within a period of 30 days?

A. Oh no, it was longer than that.

Q. Within a period of 60 or 90 days?

A. Yes, it won't more than that.

Q. You would say between the 1st and the last?

A. Yes.

Q. Must have been 90 days elapsed?

A. Yes.

Q. And that boat was not put there until about the first day of September?

A. It was in September, I think.

Q. All right, September you think. So the last accident must have occurred in or about the first day of January?

A. Somewhere along in the winter, first of the winter.

Q. Or in December, instead of January?

A. Oh my dear boy, that is two years ago you know. I have so many of those accidents that same winter that to define just what time an accident happened on one of the boats—

Q. I am not asking you to define it; I am only asking what space of time intervened between the first and the last accident to the boat at the elevator?

A. I should think it would be at least three months probably.

Q. Three months; then that last accident must have occurred after navigation closed?

A. Practically probably.

Q. Navigation didn't stay open until December that year, did it?

A. Well, I guess it never closes before December 1st.

Q. Never does?

A. No, the insurance lasts until the 1st of December.

Q. 10th of December.

A. 10th of December.

Q. Captain, how long after you put the boat there did you have your first accident?

A. I don't think it was only a few days. You see it is almost impossible to find places in the South Branch to tie up the boats.

Q. Because the boat is about 40 feet wide, one of the big boats, at least, 40 foot beam?

A. 52 foot beam.

Q. 52 foot beam. That is a pretty wide boat to block up a river with?

A. Yes, and we were laying in a bad place there, but we could not find another place. They were tearing down this elevator at the time.

Q. You were lying in a bad place?

A. We were lying close to 18th Street bridge, close to the bridge, and then afterwards backed up further, and it was impossible to find places to lay those boats.

Q. You don't consider that because you had accidents lying at a bad spot like that in the river, that that was a very unusual thing do you, Captain?

A. Some day you would think it was because it was right in a hollow there, but they had to turn and make this railroad bridge just above this bridge (indicating), turn and make that and then the other way, so that—

Q. You were in a jammed place?
A. In a jammed place.
Q. If you were going to pick out a spot to lay a boat up three months in the Chicago River, that would have been one of the last places you would pick?
A. If we had to lay up in the South Branch, I don't know one more spot.
Q. You were right between the 18th Street Bridge and the Pennsylvania Railroad Bridge?
A. Yes.
Q. And the Pennsylvania Bridge was a center pier bridge and there was a very severe turn immediately south of the 18th Street bridge? That is correct?
A. Yes.
Q. A sharp turn between the two bridges and you were lying on the low side, but still the sharp turn was there?
A. Yes.
Q. And the boats went through the North Draw of the Pittsburg Bridge, didn't they?
A. Yes.
Q. So that made it a very delicate spot to lay a boat up?
A. Yes. You could not go through the other draw.
Q. You could not go through the other draw. You know the Government has ordered the Pennsylvania Railroad to remove that bridge, don't you?
A. Well, they were removing it that winter.
Q. They were removing it that winter?
A. They started to build the—
Q. The new bridge?
A. The new bridge, that winter.
Q. That clogged up the river some too?
A. Yes.
Q. That made it still worse?
A. That is one thing why we could not get through because they blocked it up, made so much current they could not get through. We laid just above the bridge with this same ship some four or five days and there was so much current we could not get tugs enough to pull her through.
Q. That heavy current was due to the Pennsylvania Railroad clogging up the—
A. It was due to the Drainage Canal in the first place.
Q. But increased by their closing up one-half of the river at that point and building the new bridge?
A. Part of one-half.

Q. Part of one-half?

A. Yes. You know I have nothing against the Drainage Canal.

Q. You think it is a good thing, don't you?

A. How?

Q. You think it is a good thing?

A. Why—

Mr. Hopkins: Objected to.

A. It is a good thing, sure, if they don't make so much current that they spoil our waterway.

Q. You are more interested in that than anything else?

A. Than I am in anything else.

Q. That is your livelihood?

A. Yes. For instance the Cuyahoga River at Cleveland is a much crookeder river than our South Branch. It is a much narrower river. At the same time we have no difficulty in going up that even as far as our Santa Fe elevator would be here. We go up there to the upper furnaces with boats that are 500 feet long. I can't say without trouble, because it is, but we can go slow; we can get up without doing damage.

Q. Now Captain, just stop a moment: I understood you to say that sometimes you saw a terrible current in the Chicago River, regular rapid.

A. If you would have been on the Lake Shore when we were trying to get through that bridge, you would have seen it yourself.

Q. But that is the Washington Street accident?

A. No—

Q. The Pennsylvania?

A. Yes.

Q. That is where they had clogged up the river in building the bridge. They built a dam there, didn't they?

A. Well, I don't know as it was a dam.

Q. It was a cofferdam?

A. It was narrow and when the boat got into it, it increased it.

Q. Still narrower

A. So it would run by just like this (illustrating).

Q. The time you refer to is when they were re-constructing the Pennsylvania Railroad Bridge south of 18th Street, is that right?

A. They had just started it.

Q. Just started, and they had built a cofferdam in the south draw of the Pennsylvania Bridge, hadn't they?

A. Yes, they had just started it.
Q. To build the cofferdam?
A. Just started to build it that winter.
Q. And then your boat came in to the other draw?
A. Came into the north draw.
Q. Into the North draw, and your boat was 52 feet beam?
A. Yes.
Q. The center piers of the bridge were there in the middle of the stream?
A. Yes.
Q. And the cofferdam was in the west of the stream, so there was not very much space left in the river to carry the water, was there?
A. Well, there was not so very much, but we got all the way we could get with four tugs on the boat.
Q. Answer my question please. There was not very much—
A. I beg your pardon; I meant to do it.
Q. There was not very much space left in the river when your boat got in that draw?
A. No.
Q. This is the place you saw the current you testified to on your direct examination?
A. Sure, that I said it was going ten miles an hour.
Q. Yes?
A. I think it was going every inch of it.
Q. Of course if they built a dam across the river at any spot in the river and left not more than 25 or 30 feet, you would see a very heavy current there too?
A. I guess you would.
Q. Captain, you said it was very difficult to get a tying up place in the south branch of the Chicago River that winter. Why didn't you tie up in the north branch?
A. It costs money where you load a boat away out at the Santa Fe elevator to turn around and tow her up to the north branch to get a place to lay it; costs quite a penny.
Q. There were no elevators in the north branch?
A. How?
Q. There were no loading places in the north branch?
A. Yes.
Q. Did you load any?
A. We had three or four elevators there that we loaded boats.
Q. In the North Branch, did you load them there?
A. Yes, loaded them in the North Branch.

Q. You had no trouble in the North Branch?
A. No.
Q. But the rest of the boats—
A. What boats we had in the South Branch, we had a lot of trouble.
Q. You tied them up in the South Branch?
A. We tied them sometimes. We didn't tie them all. When we loaded close down this way, where we could get them to a safer place, we took them there.
Q. You spoke about an accident at the 18th Street and Pennsylvania Bridge other than this one above 18th Street. You had a boat between 16th and 18th Street Bridge?
A. Yes, she was on the lower side of the river.
Q. On the east side?
A. On the east side, yes.
Q. I show you Green's Exhibit 1, Exhibit for Identification. This is 18th Street as indicated in print. And here is the 16th Street bridge indicated on the map.
A. Yes.
Q. That is a railroad bridge (indicating).
A. This is the east side.
Q. This is the east side, the right side the way you are looking is the east side. Will you indicate where you had that boat tied up?
A. (Indicating).
Q. This is 16th; this is 18th?
A. Tied up right along here (indicating).
Q. You had that boat tied up right at the bend—
A. It is very near straight here and just—
Q. That has been cut off between here somewhere?
A. This is wider now.
Q. Yes. This is where the docking used to be; here (indicating) is where it is now.
A. We had her lying here (indicating) for some time.
Q. That is you had her between 16th and 18th Street?
A. Yes. She didn't come right down to that slip. Right here (indicating) is a railroad dock where they handle package freight and we were close to that, a little warehouse along in there, we were close to that and laid up along this way.
Q. That was right in the bend of the river between 16th and 18th Street?
A. The bend here. Very little of this river but what you will find bends in, 300 or 400 feet—
Q. That was in the bend between 16th and 18th Streets?

A. Yes, on this side.
Q. On the East side?
A. Yes.
Q. How many accidents did you have there while your boat was tied up?
A. I think that boat had two accidents there.
Q. That was due to the fact that some boat bumped into you and scraped you?
A. Bumped into us and rubbed us; one hit us on this bow here (indicating), and one bumped her on the stern.
Q. You didn't see either of those accidents? You don't know how they occurred?
A. I didn't see either. All I know is what the ship keeper told me when I came up there. And then I seen one of the men that did the damage and he came down there with some one, settled it, same as fixed up.
Q. The 16th Street Bridge, that is a center pier bridge?
A. Yes, sir.
Q. That has not yet been changed. They only used the draw on the East side, didn't they?
A. They used both sides of that.
Q. For the big vessels?
A. Why I should think so. I never have used it. We always go down this side (indicating); but it seems to me there is room enough.
Q. The vessels you have seen go down there always went down the east side?
A. The vessels I have seen go down there always went down the east side.
Q. Coming from the east side then they have to necessarily approach close to your vessel, wouldn't they?
A. Well, there is plenty of room there, if it was not for the current.
Q. They would have to approach near your vessel, wouldn't they?
A. Oh yes, yes.
Q. Did Sullivan talk to you about testifying in this case?
A. How?
Q. Did Mr. Sullivan talk to you about testifying in this case?
A. No, sir.
Q. Who asked you to come here?
A. Who asked me to come? I had a letter from the District Attorney asking me to come.
Q. Did anyone speak to you—

A. He said Captain Sullivan—
Q. Had given him your name?
A. Had given him my name, though I hadn't spoken to anybody.
Mr. Austrian: That is all.
Adjourned subject to notice.

Deposition of witness taken before the Commissioner on the 10th day of April, 1914, at 3:00 P. M. at Room 606 Federal Building.

Present:
Mr. Albert L. Hopkins,
On behalf of the Government.
Mr. Edmund D. Adcock, and
Mr. Alfred S. Austrian,
On behalf of the Sanitary District.

JOHN F. HAYFORD, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Hopkins.

Q. State your name?
A. John F. Hayford.
Q. Where do you live Mr. Hayford?
A. Evanston, Illinois.
Q. What is your business or profession?
A. Civil Engineer and Director of the College of Engineering, Northwestern University.
Q. How long have you been connected with the Northwestern University in that capacity?
A. Since 1909.
Q. Before that time, what was your work or business?
A. From 1898 to 1909, I was in the Coast and Geodetic Survey, Government Survey, first as expert computer and Geodesist two years and then 1900 to 1909, as an inspector of geodetic work and chief of the computing division.
Q. Where did you have your training, and what was your training, education and so on?
A. Cornell University, graduated with degree of civil engineer.
Q. When, what year?
A. 1889.

Q. What was your work from 1889 to 1898?

A. From 1889 to 1895, I was connected with the Coast and Geodetic Survey as computer, and then on the field force, detailed two of those years on the survey of the boundary between the United States and Mexico.

Q. From 1895 to 1898 what were you doing?

A. During those years I was instructor in civil engineering in Cornell University, teaching mainly mechanics, surveying and astronomy.

Q. A little more in detail, what has been the nature of your work during the last 11 years, or during the 11 years you have been in the Geodetic Survey work?

A. During those 11 years, 1898 to 1909, I was in charge of the triangulation and leveling and the astronomical work, both in the field and the office. That is I was responsible for the method used in the field work, for seeing that those methods were properly carried out as to the general conduct of the field work in those lines, and responsible also for all the office work, the computations of those same groups of observations.

Q. Were you in charge of or did you have anything to do with the reduction of observations?

A. Yes, during those years in charge of the office work, was of course primarily in charge of the computations; had a force there which varied from 15 to 20 engaged entirely in computations in those classes of work.

Q. What is the geodetic work of the United States Coast and Geodetic Survey, and what is its extent?

A. So far as the interior of the United States is concerned, the survey, it is the precise leveling of the whole country, carries the astronomic work throughout the whole of the United States. Then for all of the Coasts under the jurisdiction of the United States, the Coast Survey has the making of the charts; including in the making of the charts everything from the surveys themselves through to the printing of the chart. That is for all coasts under the jurisdiction of the United States. Of course not including the Great Lakes in that.

Q. Tell just what you did Mr. Hayford?

A. It was land work, and of course the triangulation was for the control of the charting work which is charting of water as well as land; but the work itself was land work primarily.

Q. I understand that you did some field work, didn't you?

A. Yes, sir, during those 11 years I was responsible both

for the field and the office work in those lands. I was responsible from the beginning of the making of the plans of the field work to the publication of the results. That involved getting out engineering work, seeing how the work was done; being entirely familiar with the field and office, I was as much responsible for the field work as the office work in those lines. That is that was triangulation, leveling and astronomical work.

Mr. Adcock: Q. The astronomical work was to locate yourself as to stars where you were working?

A. Yes, and getting the true directions.

Mr. Hopkins: Just following that, what was the purpose and what were the duties of the Coast and Geodetic Survey?

A. To furnish, so far as the coast work is concerned, to furnish reliable charts for the benefit of navigation, to make navigation safe; and so far as it is part of the interior work of the United States, so far as that is concerned, it is to help furnish the framework on which reliable maps of the whole country may be drawn. That is it is responsible, as far as the interior is concerned, for the framework only, the triangulation and the precise leveling. On the coast work of the Survey, it has to do the whole thing, furnish the detailed chart.

Mr. Adcock: That is on land or water?

A. Water; and the land near the water, in sight of the navigator from his ship; the fringe of land along the coast.

Q It is the location of the shore, in other words?

A. The shore, and such portions back of the shore as may be seen from the deck of the vessel and therefore might be needed by the navigator.

Mr. Hopkins: Q. In connection with that, did you have anything to do with water levels, observing water levels, tides and things of that kind?

A. Yes. Of course precise leveling is started from tidal observations to get the connection with sea level; also it happens that a necessary part of the precise leveling of the United States was the connection with the water levels through the Great Lakes; and therefore I was brought in touch with the water levels through the lakes, which were used as a part, in reality, of the precise level net.

Q. You have had a good deal of experience have you not with the reduction of observations made by engineers in the field?

A. Yes, sir, throughout that whole service. You see the office part of the work done under my direction was largely just that matter of reducing the observations, finding the

correct conclusions from the observations which had been made by the field parties.

Q. Is there any difference between the way the computations of field work are made in that kind of work and those made by hydraulic engineers in the measurements of rivers?

A. Why the general methods, of course, are the same for the computations. The details of the methods necessarily differ with the material that is being handled.

Q. You went directly to the Northwestern University when you left the Coast and Geodetic Work?

A. I did, yes.

Q. What is your work at Northwestern?

A. It is mainly administrative work, as director. I have a teaching schedule which is less than one-third of the regular schedule, so it is mainly administrative work.

Q. Do you have any outside work?

A. I have during those years been doing other outside things, at the same time that I was doing the work as director.

Q Have you had any special work during this time, in addition to the experience you have already given?

A. This is during the time I have been at Northwestern?

Q. Well, during the whole time.

A. Well, in those years at Northwestern, I in the first place, for two of the years, 1909 to 1911, I was still continuing the computations and writing for the Coast and Geodetic Survey, completing the work that had been begun while I was in their service. Then from October 11, to July 13, I was a member of the Commission of Engineers on the Costa Rica-Panama Boundary Arbitration.

Q. By whom were you selected?

A. Appointed by the Honorable E. D. White, Chief Justice of the United States. And the third piece of work I did during those same years, work still in progress, is an investigation of the evaporation and the stream flow, made under a grant from the Carnegie Institution of Washington.

Q. That is evaporation any particular place?

A. The purpose of the investigation is to determine the laws of evaporation from large water surfaces; and the line of investigation is to treat each one of the Great Lakes as an evaporation pan. Therefore the study is directly connected with the Great Lakes; that being the line of attack which was outlined in my application for the grant and the line of application which is being followed.

Q. Have you done any work on the Alaska and Canadian boundary lines?

A. Yes. In connection with the surveys for the Coast and Geodetic Survey, the Superintendent of the Coast and Geodetic Survey being a commissioner in connection with those surveys, my control of the triangulation brought me in touch with those boundaries and therefore I had full knowledge in regard to that and was responsible for certain parts of the work on the Alaska boundary surveys and the surveys of the boundary between the United States and Canada.

Also I was on the Alaska Boundary Survey before the arbitration, one summer season, in the Coast and Geodetic Survey.

Q. Just a little more in detail, what does that boundary work involve; as far as you were concerned, what did you have to do?

A. In the Alaska and Canadian Boundaries, you refer to?

Q. Yes, any of the boundary work, what is your work?

A. Well, to go back to the Mexican boundary, the two years there, I did all of the astronomical work on that boundary from El Paso to San Diego; that is the determinations of the latitudes and azimuths, true directions; running out also 230 miles of the boundary on the ground, running it out for the United States.

On the Alaska boundary, the one summer season I was up there simply on the astronomical work; but later in connection with the Alaskan boundary and the Canadian boundary, I was in charge of certain parts of the triangulation and in charge of certain parts of the computations in connection with the triangulation. It was the computation largely in those later years that I had charge of, in connection with that work.

Q. All of this work involved the taking of observations and making computations and reductions from them?

A. Yes. It has been so in all parts of my service in the coast survey and on these other surveys each has involved computations continuously; that is involved having charge of the computations; not directly in the making of them individually, of course.

Q. Will you state under whose direction or by what institution this investigation of evaporation is being made?

A. Made under the Carnegie Institution at Washington.

Q. Why was that undertaken?

A. I believed that our knowledge of the evaporation from

large water surfaces, the knowledge which is now in the hands of the engineering profession, was very weak and inaccurate; and I believed that there was a line of attack by way of the Great Lakes which would improve that knowledge. I so stated to the Carnegie Institution, and the grant was made because I convinced them that I was probably right in that view.

Q. What are the present methods in regard to evaporation on the Great Lakes, and why are they likely to be inaccurate?

Mr. Austrian: Do you mean his methods?

Mr. Hopkins: No.

Mr. Austrian: Methods other than yours?

The Witness: Yes, practically all of our knowledge, the knowledge of engineers of evaporation at the present time is derived from observing evaporation from small pans with a water surface of a few square inches, or at most a few square feet; and what is really desired, what is really needed is the evaporation from large water surfaces such as a water reservoir or a lake.

Now it is my belief that the change in condition from that at the pan where the observations are made to an open lake is such an extreme change that when one reasons from the pan to determine what occurs in the lake, that reasoning is very defective; that the difference in conditions is so great that the conclusion as to the evaporation from the reservoir or a lake is a very weak conclusion. The conclusion may be in error in the tens of percentage.

Q. Have you come to any conclusion yet?

A. On the evaporation? No, sir, the investigation has not progressed far enough.

Mr. Austrian: How long have you been at it?

A. It is about two years, but it has been done in fragments of time, when nothing else was on hand to do. And according to my estimate for the Carnegie Institution I should be much less than half done at the present time.

Q. That is you figured it would take about five years?

A. I told them it would take from three to ten years.

Q. From three to ten?

A. Yes, that was the original estimate of the time it would take me.

Q. You are much less than half through. You have kept your promise, I take it?

A. Yes, sir.

Mr. Hopkins: Q. Mr. Hayford, you have made certain

studies of the measurements made by the Lake Survey of the Niagara River, have you not?

A. Yes, sir.

Q. What has been the source of your information, and what have you studied, just tell us?

A. First the document known as the Preservation of Niagara Falls.

Q. Do you have the date of that?

Mr. Adcock: That is the same thing we have heard about before.

Mr. Austrian: That is the one prepared by Professor Shenehon I take it?

Mr. Hopkins: Prepared by Mr. Shenehon.

The Witness: Yes, sir. Second the portions of the Lake Survey Reports, 1900 to 1902, which deal with the discharge of the Niagara at the Niagara gagings there.

Mr. Austrian: Q. Those are in evidence, I take it?

The Witness: Then three blue prints which I have here, three sheets showing the measurements of discharge at the International Bridge Section.

Mr. Hopkins: Which are in evidence in connection with Mr. Shenehon's testimony as to the observations taken at the International Bridge Section and the Open Section. I am stating that. You can check it up, Mr. Williams.

Mr. Adcock: Let us see if we cannot refer to that a little more specifically.

Mr. Hopkins: I have not the exhibit numbers.

Mr. Austrian: Don't they show on the face, the exhibit numbers?

Mr. Adcock: It is Williams' Exhibit 24. When you refer to those, they are Williams' Exhibit 24.

The Witness: There are three sheets for the International Bridge Section and two sheets for the Open Section. They are all in one exhibit.

Mr. Adcock: They are all Williams' Exhibit 24.

The Witness: Next, five sheets of a computations made on the Williams' Three Point Method; a computation which I understand was made by Mr. Shenehon.

Mr. Hopkins: Is that in evidence, Mr. Shenehon?

Mr. Shenehon: That was referred to in the cross-examination of Mr. Williams, and pronounced correct by Mr. Williams.

Mr. Williams: Five sheets, you say?

Mr. Adcock: Just a minute—

Mr. Williams: I have no recollection about it from this—

Mr. Adcock: We will not admit that those were introduced or offered in evidence or identified.

Q A part of the things you considered then were five sheets which I now hand you, which we will ask to have marked Hayford's Exhibits 1, 2, 3, 4, and 5 of this date, April 10. Those are offered for identification.

(The five sheets above referred to were here marked for identification Hayford's Exhibits 1, 2, 3, 4 and 5, April 10, 1914.)

A. Next is four blue prints, each showing three curves of elevation at Buffalo; the discharge of the Niagara River and the elevation at Suspension Bridge.

Mr. Shenehon: That is the three sheets, what has been called the Three Curve Series.

The Witness: Four sheets.

Mr. Shenehon: Four sheets.

Mr. Hopkins: Identified on Williams' cross-examination as Exhibits F, G, H and I, Government's Exhibits.

Mr. Williams: October 9, 1913.

Mr. Hopkins: Q. What else, Mr. Hayford?

A. And three blue prints one curve each, showing a discharge of the Niagara River.

Mr. Shenehon: Those are Exhibits J. K and L, of the same date?

Mr. Hopkins: That is subject to correction.

Mr Adcock: By us, after examination.

Mr. Hopkins: As to whether or not it is a correct copy.

Mr. Williams: I have a copy of the blue print. I haven't a copy of this.

Mr. Hopkins: Q. What else, Mr. Hayford?

A. One blue print showing the discharge of the Niagara River and the elevations at Suspension Bridge and Whirlpool.

Mr. Hopkins: What is that exhibit?

Mr. Shenehon: That has never been put in.

Mr. Hopkins: I would like to have that marked Hayford's Exhibit 6, of this date.

Mr. Adcock: For identification?

Mr. Hopkins: For identification.

(Blue print referred to by witness was marked Hayford's Exhibit 6, April 10, 1914.)

Mr. Hopkins: Q. Anything else?

A. One blue print of the discharge curve for the Open Section.

Mr. Shenehon: That has never been put in the testimony and may be identified.

The Witness: It is the blue print from this tracing (indicating).

Mr. Hopkins: We have the tracing, and I would like to have it marked as Hayford's Exhibit 7, of this date, for identification.

(Tracing referred to by witness was marked Hayford's Exhibit 7, April 10, 1914.)

The Witness: Finally a similar one for the Bridge Section.

Mr. Hopkins: Which is here referred to and marked for identification Hayford's Exhibit of this date.

(Document identified by witness was marked Hayford's Exhibit 8, April 10, 1914.)

Mr. Hopkins: Hayford's Exhibit 8 is a reproduction of the curve shown on Haskell's Exhibit 1, of February 3d, 1914.

Q. Just in a general way, Mr. Hayford, what are these things you have studied; first the five sheets, the blue prints?

Mr. Adcock: I object to that on the ground it is impossible for him to answer it.

Mr. Austrian: What do they purport to be? Unless they are an accurate reproduction, they are nothing.

A. They show the measured discharge of the Niagara River, 340 measurements other than a few made under ice conditions, but 340 that were used; and they also show the corresponding stages of the lake at Buffalo, and some other information connected with the observations, wind velocities, etc.

Mr. Austrian: Q. You had nothing to do with the making of the observations or the plotting of them, did you?

A. I did not.

Mr. Hopkins: Q. What do the other documents that you have referred to show in connection with those measurements—or purport to show, Mr. Hayford?

A. The Three Curve and One Curve blue prints show the portions of the same information in other forms, in graphical form. The two discharge curves show the observations again in another form, and also show lines based upon those observations, conclusions drawn by some other person, conclusions drawn from the observations; and the remaining blue prints, of course, have other information in regard to the elevation of the water surface at Suspension Bridge and Whirlpool with a little information with regard to elevation at Cleveland of the water surface.

Mr. Austrian: Q. You had nothing to do with making those observations or plotting them upon these various maps?

A. I did not.

Mr. Hopkins: Mr. Hayford, from the study of those things that you have just referred to, can you tell whether or not the observations shown there were accurately made?

Mr. Adcock: Just a minute; I object to that question on the ground that the witness has not shown that he is qualified to answer that question.

Mr. Hopkins: Go ahead.

Mr. Austrian: Do you mean accurately made upon the maps or plats?

Mr. Hopkins: No, the observations taken, the man who was the observer.

A. I believe the degree of accuracy of the observations and of the results can be and has been determined from the data.

Q. Well, in this case, what is your opinion as to the accuracy of the observations?

Mr. Austrian: That is all of them, all of the exhibits that you have referred to?

Mr. Adcock: I object to that on the further ground that it is impossible for him to tell from those papers that are presented whether the measurements were taken accurately or that the observations are accurate.

Mr. Austrian: Your question is not quite specific.

Mr. Hopkins: My question was, from what he has studied, whether or not he can tell that the observations which are plotted there—

Mr. Austrian: On all the exhibits that he has referred to.

Mr. Hopkins: Yes.

Mr. Austrian: That is five or six, or eight or ten of them?

Mr. Hopkins: Whether they were accurately observed; and if not wherein there is any variation.

Q. Go ahead and explain in your own way whether from that data alone you can tell, form an opinion as to the work of the engineers in the field.

Mr. Adcock: You mean without regard to his knowledge as to whether the observations were taken accurately or whether he knows anything about the conditions existing at the time, or anything like that?

Mr. Hopkins: He will give us his reasons.

A. From the data, and from the printed documents, from the general literature of the subject; from the examinations I

have made, in the manner I would like to state fully later, the degree of accuracy of the observations, and the conclusions from them have been determined. I have made such an estimate of the accuracy which I believe to be reliable within certain limits.

Mr. Adcock: I move to strike out that answer on the ground he has taken into consideration other things than the papers and documents which have been presented to him.

Mr. Austrian: And other things than the documents in evidence.

Mr. Hopkins: Q. In addition to the things you enumerated awhile ago, that you have studied, is there anything else that you took into consideration, Mr. Hayford, in that matter; and if so, what?

A. In getting the sidelights on the whole matter, why, of course, I read other articles like Hoyt & Grover's book on stream measurements, dealing with the general matter of current meters; a recent article by Grote in the American Society of Civil Engineers, treating of current meters again.

Q. Which is in the record in this case? That is the article by Grote, referred to by Mr. Freeman.

A. (No response.)

Q. Go ahead, Mr. Hayford, what else did you identify?

A. And other published reports by the Lake Survey, in connection with other stream gagings, to determine the general methods used and the results obtained in other cases; that is for general information as to the methods and their reliability.

Mr. Adcock: Q. What stream gagings do you refer to, made by the Lake Survey?

A. To the St. Lawrence and the St. Clair River, St. Marys River and those—

Q. Niagara River?

A. Niagara River; of course that is all included.

Q. Including the Detroit River?

A. Some measurements in the Detroit River and some experiments on current meters at Detroit.

Q. Do they appear in the reports of the Chief of Engineers, United States Army?

A. Yes, sir.

Q. Only?

A. No, other articles in regard to these same matters in other places, as I utilized all of the engineering literature I could get time for to be well posted in this matter.

Q. I am referring particularly to the Lake Survey report. Did you refer to any other reports of the Lake Survey than the ones which appear in the Chief of Engineer's Report, United States Army, with reference to the stream gaging of the rivers which you have mentioned?

A. It is the Lake Survey, yes, in the Chief of Engineer's reports.

Q. That only?

A. Only for the Lake Survey work, yes, but I referred—this document on the preservation of Niagara Falls is already referred to, of course. It involves work done under the direction of the Lake Survey.

Q. That report on the Preservation of Niagara Falls was made by Mr. Shenehon?

A. Yes.

Q. Of the Lake Survey?

A. Of course the earlier gaging at Niagara Falls, at Niagara River rather, done by Mr. Clinton B. Stewart, was published in the transactions of the Western Society of Engineers. I looked that up also.

Mr. Hopkins: Mr. Hayford, these other things you have referred to are matters of general literature on river measurements that you have used to qualify yourself?

A. Yes, sir, on river gagings, and on the use and the performance of the current meters, especially the Haskell current meter.

Mr. Adcock: Is that the A or B meter?

A. Both, and quite a number of meters; not simply two. Of course there had been many Haskell current meters used in various parts of the work.

Q. By the Lake Survey?

A. By the Lake Survey; by other organizations. I am familiar also with the use of that meter in the Coast and Geodetic Survey. It has been used in the Coast and Geodetic Survey for many years.

Mr. Hopkins: Q. Now from all of that information that you have mentioned, do you have an opinion as to the accuracy with which the observations were actually made?

A. I do.

Q. State your opinion and the reason for it.

Mr. Austrian: That is the observations indicated upon the various maps and plats and tables you have just introduced in evidence for identification. Is that correct?

Mr. Hopkins: All that he has referred to.

Mr. Austrian: Yes, that he has referred to here in evidence. He has referred to a lot—

Mr. Adcock: I want a further objection there.

Mr. Hopkins: That he has referred to, which are in evidence, or which we identified, marked for identification today. I refer to these blue prints in evidence and William's Exhibit 24, five blue prints.

Mr. Adcock: I make the further objection he has not shown that he is qualified to answer that question.

Mr. Hopkins: All right, go ahead; what is your opinion as to the accuracy, Mr. Hayford, and why?

A. It is my opinion that those observations—I think I can state the accuracy best by stating the conclusion drawn from them, from my investigation of the accuracy of the conclusions, and then come back to the individual observations.

I believe those observations establish that the discharge of the Niagara River, when the elevation of the lake surface at Buffalo is 572 feet even, is 195,740 cubic feet per second; and as to the accuracy of that conclusion, that it is an even chance that this value is within one half per cent. of the truth, and it is practically certain that it is within 2½ per cent. of the truth.

Then the observations also establish that the increment of discharge corresponding to one foot of increase in the elevation of the water surface at Buffalo, is 21,860 cubic feet per second. Now, as to the accuracy of that increment, it is an even chance that said value is within 1 per cent. of the truth, and it is practically certain that it is within 5 per cent. of the truth.

Now, as to the individual measurements of the discharge, the greatest error occurring in any one of the 340 measurements already referred to is 4½ per cent. That is about 9,000 cubic feet per second. Now, all other observations of the 340 observations have smaller errors than that.

As to the general line followed in reaching those conclusions: First, taking the 340 observations—the one qualifying statement that I ought to enter in there in regard to the discharge at the 572-foot level is, of course, that refers to the discharge under the average actual conditions in the Niagara River, when there is no ice in the river. Now, then, as to the line of attack in reaching these conclusions: First, I took the 340 observations. They stand in two groups; one in the Bridge Section, one in the Open Section. For the Bridge Section, I took approximately the first half of the ob-

servations, those made from July 16, 1898, to May 19, 1899, and made a complete and very thorough computation by the least squares method of the mean discharge and the increment of discharge from those.

I took them the latter half of those observations; that is, 118 observations made between October 21, 1907, and August 6, 1908, the dates inclusive, of course, made a similar computation from those. Then, taking the measurements on the Open Section, I divided those into two groups approximately equal. These groups are in their order of time; they are simply chronological groups; took the first 58 observations from August 30 to October 31, 1899; made a complete computation on that group. Next I took the group of 63 observations on the Open Section from November 1st, 1899, to July 24, 1900, and made a complete computation on those. That made four computations.

Then I took the whole 219 observations on the Bridge Section, as a single group; made a complete computation with those. Similarly, I took the 121 observations on the Open Section and made a complete computation. That made six computations each on a part of the observations.

And, finally, I combined the last two computations named and derived from the whole group, these 340 observations, what I believe to be the best values now determinable from these observations on the discharge and the increment of discharge for the Niagara River.

Now, then, from those computations, by comparison of the six computations with each other and a comparison of each one with the final computations which included them all, I could get some evidence as to the reliability of the results.

I also went over carefully all of the internal evidence afforded by those computations, the internal evidence being that given by the disagreement of the observations from each other; and also in studying that internal evidence, I studied very carefully the relation between each of the observations and such of the surrounding conditions as I could find recorded in these various sources of information. And next I took the certain other computations which had been made, using this same data, or parts of it, and compared the results with those other computations with the computations I had made. The other computations were, first, this determination of the discharge and the increment made by stretching a thread, as I understand it, over a plotted sheet—

Mr. Adcock: A string?

The Witness: I am not certain whether it was a thread or a string.

Mr. Adcock: It might be either one.

The Witness: It might be either one. It was a straight line, portable straight line, stretching it over a plot. There was such a determination shown on one of these blue prints before me; a determination based on the 219 observations at the Bridge Section. A second one made in the same way on the 121 observations at the Open Section.

Q. Was that with a string, too?

A. With a string also. Then I found in the Lake Survey Report, 1912, Appendix FFF, on page 3547, a statement of the discharge of the Niagara River in terms of the elevation of the lake surface at Buffalo. That is the result of a similar computation. The details of that computation I don't know, but I took out the result from the publication, for comparison with these other results.

I compared also with those computations two results shown in Appendix III of the Chief of Engineers, report for 1900, page 5361, two computations made by Mr. Shenehon, or under his direction; one from 86 observations at this Bridge Section, being a part of the observations of the 219; and also a computation made under his direction from 63 of the observations on the Open Section. That is on the Bridge Section, they were observations from September 10 to December 10, of 1908, the earlier part of the series. In the case of the Open Section, they were observations from October 4, 1899, to June 30, 1900; again the earlier part of the observations.

I also compared with the computation made from observations of the discharge at the International Bridge by Clinton B. Stewart and published in the Western Society of Engineers' transactions. And, lastly, I compared with the computations on the five sheets introduced in evidence on the Williams Three Point Method.

Mr. Hopkins: That is Hayford's Exhibit 1, 2, 3, 4 and 5 of this date?

A. Yes, that is a computation made by the Three Point Method, using the 219 observations at the Bridge Section.

Now, those were then seven different computations based on various sets of observations; all computations giving the discharge of the Niagara River in terms of or as related to the water level at Buffalo. Those different computations, in comparison with the comparisons I have made, served also

to indicate the accuracy, the degree of reliability of the various conclusions; served as checks.

Mr. Adcock: Q. Was this on the internal evidence?

A. These other computations are in part external evidence, inasmuch as they included in some cases other observations and also inasmuch as they were computations made by other methods.

And finally, after that line of attack, then I undertook to study the methods of observation and the computations very carefully to determine, if possible, or as far as possible, the source of the various unavoidable errors in this work, and in all such work traced back the errors to their source, so as to be able to determine what effect various conditions had on the accuracy and reliability of the final result. That was a study in detail of the different sources of error. I have a list of those sources of error and the—

Q. Go right ahead and state them.

A. The accuracy or size of the errors which could be traced back to those causes.

Q. What are those possible errors and what effect do you think they would have?

A. First, as to the effect they might have on the computed discharge, and then I would like to state later the effect each of these sources of error might have on the completed increment. The two effects will be different, expressed as percentages.

First, as to the effect of those different errors on the computed discharge at a mean elevation of say, at the elevation of the lake surface, 572 feet, which is practically the mean elevation. First, as to the measurement of the area of the cross section of the stream at the point where the gaging, stream measurements were made, I estimate that the maximum error in this final divided result due to that cause is 1 per cent.; that is the maximum. It is the maximum in each case I propose to state.

Mr. Adcock: That is the discharge?

A. No, cross section. That is the error in the discharge due to errors made in determning the cross section. Of course, it includes errors of sounding, which is a part of the work of getting the cross section.

Now, the errors in the mean discharge, coming from the ratings of the meters, that is the current meter, the meters

used, the maximum in that case is 1 per cent., maximum possible error in the final derived value of the mean discharge.

Q. Did you consider that they used a Haskell meter in that connection?

A. Yes.

Q. A or B meter?

A. Both, several meters. That is, I traced up, studied the details as to what meters they used and how they were rated. In the determination of the velocity ratios, the errors due to errors in the determination of velocity ratios is a maximum of ¼ of 1 per cent. in that mean discharge.

Mr. Williams: Just what do you mean by velocity observations?

The Witness: In the determination of the ratio of the velocity at various points in the cross section and the velocity at the index station.

Next, the maximum error in the mean discharge, which may arise from the effects of turbulence in the stream, including the pulsations, is 1/10th of 1 per cent.

Next, the maximum error in the mean discharge which could arise from the effects of winds, is ¼ of 1 per cent. Remember, this is the mean discharge under the average actual conditions.

Mr. Adcock: Q. Of the 340 measurements, that is all the measurements?

A. Yes, the error in the mean discharge under actual conditions due to the accumulation and the removal of weeds, removal by the current by natural causes, I mean, I find to be negligible so far as the mean discharge is concerned. Also so far as the mean discharge is concerned, the errors due to lag effects and to backwater effects, I find to be negligible. When I say negligible I mean it is well under 1/10th of 1 per cent. And finally—

Mr. Adcock: Q. You did not compute the error closer than 1/10th of 1 per cent.?

A. Yes, that is when I satisfied myself that the error was well under 1/10th of 1 per cent., I called it negligible.

Now, the maximum error in the mean discharge, which could arise from errors in the determination of the direction of flow at the current meter was 1/5th of 1 per cent.

And, finally, I studied the matter to ascertain whether there was a possible error in this computed mean discharge due to

any possible difference in the discharge on disturbed days as contrasted with quiet days; meaning by disturbed days either the days when there was a high wind velocity at or near Buffalo, or days on which the water surface at Buffalo was rapidly fluctuating. And I found that there is no relation discoverable between disturbed days in either of those senses and the discharge itself. When I say no relation between disturbed days and the discharge, I mean between discharge on a disturbed day that is found in that way, or the day after. That is, it is conceivable possibly that if you had a disturbed day it might disturb the flow for some hours thereafter. Therefore, I examined the matter not only to see whether the day itself on which the observation was made was disturbed, in the sense defined, but also examined the record for the preceding day.

Mr. Hopkins: Q. Is that all, Mr. Hayford?

Mr. Adcock: Q. There is nothing there, it is neglible.

A. No relation between the discharge and the disturbed days.

Q. There is no error?

A. No error due to that cause.

Q. You marked that, "winds negligible"?

A. Yes, you might put it so.

Mr. Hopkins: Q. You mean, Mr. Hayford, that there is a direct connection between the stage at Buffalo and the discharge, regardless of whether or not the lake is quiescent or fluctuating?

A. Yes. That is, it is the mean level at Buffalo, there is a direct connection between the mean level at Buffalo during the time when the discharge observations were made and the discharge itself.

Q. And in getting that result you took into consideration a series of observations?

A. I took into account all of these 340 observations and the evidence as to the lake surface at Buffalo. The lake surface, of course, was shown by continuous curve of lake levels shown on these blue prints which have been introduced here in evidence.

Q. Mr. Hayford, what is your final conclusion, then, as to the maximum error in the volume of flow?

A. You mean the maximum error in any single observation, or the maximum possible error in the final deduced result?

Q. Of the 340?

A. Well, my conclusion is that from the 340 observations studied fully the discharge of the Niagara River corresponding to 572 feet even for the lake level at Buffalo is 195,740 cubic feet per second; and that it is an even chance that that value just stated is within ½ per cent. of the truth, and it is practically certain that within 2½ per cent. that is so far as the discharge is concerned at that elevation, which is practically the mean elevation.

Q. What would you say as to the probability of it being the maximum, the 2½ per cent.?

A. It is practically certain that the error is less than that maximum.

Q. The probable error is ½ of 1 per cent.?

A. Yes, ½ of 1 per cent.; that is, it is an even chance that the value stated is right within ½ of 1 per cent.

Q. Did you compute an increment of discharge for a foot difference in the level?

A. Yes. That computation, or that determination, is a part of the same computation.

Q. What increment did you derive?

A. I found the increment corresponding to 1 foot increase of elevation in the lake surface at Buffalo was 21,860 cubic feet per second; and as to the accuracy of that conclusion, that it is an even chance that that value is within 1 per cent. of the truth. It is practically certain that it is within 5 per cent.

In regard to that value of the increment, I may say that I studied these separate sources of error in the same way, as to their effect upon increment that I have already outlined in connection with the mean discharge, so if you care for it I could give you the possible errors in the increment due to these various sources.

Q. Go ahead, Mr. Hayford.

A. Now, as to the possible maximum, possible errors which may arise from these various sources in the computed increment from the measurement of the cross section including the soundings, the maximum possible error in the increment so produced might be 1 per cent. The maximum possible error in the increment due to errors in the rating of the meters, ½ of 1 per cent. I am following the same order in the statement that I did before, for the different items.

The maximum error in the increment which could arise

from errors in the determination of the velocity ratios, ¼ of 1 per cent., from the determination of velocity ratios. The maximum error in the increment which could arise from the effects of turbulence, including pulsations, 1/10th of 1 per cent.

Mr. Adcock: Q. That is the same as the other?

A. Yes, on certain items, for instance on that particular item they are the same, but not all the way through. The maximum error in the increment which may possibly have arisen from the effects of winds, ½ of 1 per cent.

Q. That is more, isn't it?

A. Expressed as a percentage, yes. The maximum error in the increment which might arise from the changing of the condition as to weeds, 3 per cent.

Q. That was negligible before?

A. Yes. The errors from lag, back water and from the determination of the direction of flow at the meter, neglible.

Q. That was ½ of 1 per cent. and negligible as to lag and back water in the other, wasn't it?

A. (No response.)

Q. There is another one, disturbed days.

A. Now, the effect of the disturbed days defined as already stated, I find that there could be no error, no appreciable error in the increment from that cause.

Q. That is negligible, too?

A. Negligible, yes. Now, each of these estimates are estimates of—

Q. Did you get the ratings and cross section as to increment?

A. Yes, those were stated.

Q. What were they as to increment?

A. As to increment, measurement of cross section 1 per cent.

Q. 1 per cent.?

A. And the rating of the meters ½ of 1 per cent.

Mr. Hopkins: Go right ahead.

A. Each of these estimates are estimates of the maximum which could come from the causes. Of course as these errors are not necessary, in fact it is pretty certain they cannot all be of the same sign and that you could not have a maximum possibly occurring on all of them, the total error would not be obtained by adding up those quantities. The total error is —I have already estimated as 5 per cent.

Mr. Adcock: Five per cent.?

A. As the maximum possible in that increment; that is, it is practically certain that the stated value of the increment is correct within 5 per cent.

Mr. Hopkins: Q. What are the probable errors?

A. For the increment?

Q. Yes?

A. One per cent. That is, it is an even chance that the increment is right within 1 per cent.

Mr. Adcock: Q. That is, you changed the signs on some of them?

A. The errors from these separate sources, some of them may be of one sign, some of another. Moreover, in all of those you will not have a maximum possible error occurring on all of them. Some of them will be less than the maximum.

Mr. Williams: Not at the same time.

A. Not at the same time, and these are estimates of the effect on final result.

Mr. Adcock: That must be a difficult matter to get it, isn't it, then, to determine the signs for each one, and to determine the 1 per cent. probable error?

A. Certainly it is a difficult matter.

Q. Mr. Hayford, what effect would the diversion of 10,000 cubic feet per second at Chicago have upon the level of Lake Erie?

Mr. Adcock: You are only stating that from these things—

Mr. Hopkins: From the conclusions you have reached.

Mr. Adcock: And the papers you have before you?

A. Yes, from these observations. That the loss of level of Lake Erie, corresponding to a loss of outflow of 10,000 cubic feet per second, is 5½ inches. That comes from converting the increment into a loss of level.

Mr. Hopkins: Q. Mr. Hayford, now from that data that you have, and that you testify you have used, from the observations that are set out before you, assuming that they are correctly copied and handed to you in those documents you have referred to, can you tell whether or not the observer did his work carefully and accurately?

A. I can.

Q. How?

A. From the lines of evidence and the lines of examination that I have outlined. From the internal evidence of the computation; from the comparison of different computations with each other, and from the study of the details of the methods.

Q. Suppose they were careless in their observations, how would it appear in the results which you have before you?

A. It would appear by there being larger disagreements between the observations than I actually find. It would appear by there being large discrepancies between the different computations when they were based on parts of the observations in turn, as I have indicated in the six different computations.

Q. And in that number of observations, 340, what would be the tendency of any error of observation?

A. That is as the number of observations increased, or is increased, of course there is afforded a greater opportunity for the errors of observations and errors due to varying conditions to cancel themselves out, to eliminate each other, so that in a large number of observations the error in the final result based on all of them will be, of course, smaller than the error of any one result or in the average result.

Q. Mr. Hayford, your main study was from these tabulations found in Williams' Exhibit 24, was it not?

A. Yes, the five blue prints.

Q. And the charts or maps you referred to, and the plats were used to check with it, were they?

A. Exactly. The figures used in the computation were taken from these tables.

Q. You assumed that those charts were correctly plotted, did you?

A. Yes, and also checked them up in parts by comparison with these tables as the originals. In certain parts I did check them, so that I didn't have to take the plots entirely on faith.

Q. Have you given us all of the study or reading that you have done to qualify yourself upon the question of reduction of observations of river measurements? In other words, did you study hydraulic engineering in college?

A. I did. I think I may answer that question in this way: I have given you all of the reading which I did for this specific purpose; but in college, of course, as a part of a civil engineer's training, I necessarily read and studied along this line, and also in connection with the Coast Survey work, with this evaporation investigation. Also long before I was called on in connection with this case, I had read along these same lines at various times. I have not given you those readings, of course.

Mr. Adcock: Q. That was all your hydraulic experience?
A. I don't understand your experience.
Q. Was that all of your hydraulic experience?
A. I think I have indicated in a general way all of it.
Q. That was in college?
A. (No response.)
Mr. Hopkins: Q. Would you consider, Mr. Hayford, that your experience in reduction of engineering observations through all of that period qualified you to reduce the observations of an hydraulic engineer, just the same?
Mr. Austrian: Objected to on the ground you cannot prove that the witness is qualified as an expert by asking him whether or not he is an expert.
Mr. Hopkins: Read the question.
(Question read.)
A. I do. I have been practically continuously since I graduated, since 1889, working on computations and in general charge of them.
Mr. Adcock: I move that answer be stricken out as not responsive to the question.
Mr. Hopkins: Q. Will you now state just what work you have done in connection with the reduction of observations, what qualification you have had, and how that is applicable to the work which you have just done in connection with this matter?
Mr. Austrian: The first part of that I think he has answered already.
Mr. Hopkins: Maybe he has, but let us repeat.
A. In all of the work which I have already outlined in the Coast and Geodetic Survey, and in connection with other surveys, especially in the Coast and Geodetic Survey, while in charge of their computing along certain lines, I was dealing with the general problem always of deriving the correct and reliable conclusions from field observations. That problem is the universal problem. That is the same problem everywhere, regardless of what kind of observations you are dealing with. At least there are many features of the problem that are the same. It is that general training which I believe qualifies me to derive the correct conclusions from field observations and to determine the reliability of the conclusion, degree of reliability, degree of accuracy after it is derived.
Mr. Adcock: I move to strike out all after the words "it is that general," etc., on the ground it is within the province

of the court to determine whether he is qualified, and not for the witness to determine.

Mr. Hopkins: Q. In other words, it is purely a mathematical question, isn't it, Mr. Hayford?

A. The determination of the relation between the discharge of the Niagara and the lake level at Buffalo is in part a purely mathematical question, a method of computation. It is in part, of course, an engineering question, a study of the data and the methods.

Q. What is your opinion as to the applicability of the method of least squares?

A. To this problem?

Q. Yes?

A. It is my opinion that that is the best method of computation to be used to get the most reliable conclusions out of these measurements or any other extensive set of measurements.

Q. Now how about the three point method?

A. The three point method, as shown in the computation which has been put in evidence, I have compared with the least square method. It is my opinion that the three point method as so applied in this case ignores or excludes about ½ of the evidence given by the 340 observations.

(Answer of witness read.)

The Witness: I should correct that: The three point method, as applied here, was to 219 observations, not 340.

Q. As a general proposition the three point method would bring about that result?

A. Yes, the three point method, as applied to any case, will exclude a considerable portion of the evidence given by the observations. It may be more or less than ½, but it will always exclude a considerable portion of the evidence.

Q. Do you regard it as a correct mathematical method to use in the reduction of observations?

A. Well, it will give an approximation to a correct result. The method is incorrect only, or mainly, in that sense that it utilizes a part only of the evidence given by the observations. If you chose I can indicate further how it excludes a part of the evidence.

Q. Yes, go ahead.

A. As applied to this particular case, for example, the three point method was applied by first deriving the mean elevation of the lake at Buffalo corresponding to the 219 observa-

tions. That mean elevation was 572.549 feet. Now, then, all of the observations which were made when the lake at Buffalo was above that elevation were placed in one group, which I will call group 1 for convenience, and all of the observations made when the elevation at Buffalo was less than that value were placed in another group, which I will call group 2. Then the mean elevation and the mean discharge were computed separately for each of those two groups. That gave two mean elevations and two mean discharges. And finally the increment was derived by dividing the difference of the two discharges by the difference of those two elevations, the mean discharges and mean elevations.

Now, such a method of computation ignores evidence in this way: If you take the second group, it includes the third observation made on October 24, 1907. And it also includes the first observation made on November 10, 1898. They both fell in group 2. Now, the lake elevation corresponding to the first of these observations was 572.54, and the second observation was 570 even, differing by 2.54 feet; the lake level being lower during the second observation.

Now the measured discharges were for those two observations, for the first one 209,230 cubic feet per second and for the second observation 154,100 cubic feet per second. Those two differ by 55,000 cubic feet per second, the second one being the smallest.

Now, these two differences, the difference in elevation of the lake at Buffalo in the two cases and the difference in the two discharges, are entirely included in the three point method, because you have simply included both those observations in getting the mean for the second result group, and the result of that mean is identical with what it would have been if you have the large discharge, 209,230 cubic feet per second, with the small elevation, 570 feet, and vice versa if you had the small discharge with the larger elevation.

In other words, if you interchanged the discharges and let the elevations stand, your computation, the final result of the computation from the three point method, will be unchanged. Therefore, that method of computation ignores the evidence that when the lake surface dropped 2.54 feet that that discharge diminished by 55,000 cubic feet per second.

Every one of such differences that are within the second group are ignored as a part of the evidence. And similarly any pair of differences like that that is in the first group is

ignored. Evidence of that kind, the internal evidence of each group by itself, is entirely ignored in the three point method; and as applied to this case, that is about ⅓ of all the evidence, is ignored, so that the fact that the three point method gave a result nearer the result from the least squares method of computation merely goes to show that the errors of observations and the errors due to the variations in conditions are small.

Of course, if the evidence in any case is all accordant, or closely accordant, then you can reject a part of it and get nearly the same conclusion that you would if you took in all the evidence; and that is the nature of the reason why the three point method, as here applied, gives nearly the correct result.

Q. Now, how about using a thread, Mr. Hayford?

A. The method of stretching a thread over the plot of the values, that method takes into account all of the evidence shown on the plot; that is, if the plot is made with the individual observations, then it will take in the evidence and all of it from all of the observations; it takes it into account, however, with some inaccuracy on account of the fact that the man is using his judgment, his eye simply, and not making a careful computation; and, of course, it involves the judgment of the individual man stretching the thread. But it does take all of the evidence into account.

Q. It depends somewhat, then, upon the skilfulness of the man who did the work?

A. The skilfulness of the men and the judgment used in selecting the scale, both scales, vertical and horizontal, of the plot.

Q. In this particular case, Mr. Hayford, an increment derived by a thread showed 21,900 cubic foot. What would be your opinion as to whether or not that method of using a thread was approximately correct?

A. It would necessarily, as applied to this case and with these particular plots give a close approximation to the correct result. All of the valuations, values, are, which were secured from two applications of the thread method.

Q. Without going into any great detail, are they almost identical?

A. Yes, very nearly identical with my derived value; one on one side, one on the other.

Mr. Adcock: Q. I suppose the judgment of the observer was used there in getting the result, is that so, is that true?

A. I take it he had to use his judgment to get a result.

Q. He could get about what he wanted to?

A. I didn't make that statement.

Mr. Hopkins: Q. Mr. Hayford, you did not take into consideration, in the results that you have given, any measurements made at what we have called a third section down near Grand Island?

A. No, I did not.

Mr. Adcock: The Split Section.

The Witness: I did not take that into account. I had no information in regard to that further than that there had been some measurements made, but I had none of the records of those measurements.

Mr. Hopkins: Q. Suppose, Mr. Hayford, that ten observations were made at another point in the river, that is known in this case as the Split Section, under the same general conditions as to care of the observer as appears in the other sections, the results of which you have before you, and in regard to which you have testified, by an engineer in the Lake Survey Office, and the results obtained by him checked within 1 per cent., a little over 1 per cent. of the results at the Open Section and the International Bridge Section, which you have examined, falling between the two. What effect, if any, would that have upon your opinion as to the accuracy of the volume of flow which you have already testified to?

Mr. Adcock: I object to that on the ground it assumes a condition which does not appear in the record in this case.

Mr. Hopkins: Specify, Mr. Adcock.

Mr. Adcock: I do not need to specify.

Mr. Austrian: Condition or state of facts.

Mr. Adcock: Condition or state of facts not in evidence, and not appearing in the case.

Mr. Hopkins: Q. Do you understand the question? Will you answer it, please?

A. That would simply, to my mind, confirm the reliability of the conclusions I have drawn as to the accuracy of the mean discharge as computed from the Bridge and Open Sections; from the measurements in the Bridge and Open Sections; that is, a close agreement of that kind would confirm conclusions I have already stated.

Mr. Adcock: Q. Then, would you reduce the error, percentage of error, that you formerly computed?

A. No, on simply that evidence I would make no change in these estimates.

Q. I take it you state your conclusions there as to the percentage of error with a great deal more assurance, is that the idea, after the hearing of these other measurements?

A. Yes, when I have additional evidence which confirms evidence already in, I feel my conclusions to be still safer than before.

Q. But you would not reduce the percentage?

A. No, I would not; not simply on that amount of additional evidence. It was too little to change the conlcusion.

Cross-examination reserved.

Adjourned subject to notice.

JOHN F. HAYFORD was recalled as a witness on behalf of the Government and testified further as follows:

Cross-Examination by Mr. Adcock.

Q. Have you ever made any so-called current meter gagings or measurements of discharge of rivers, with a current meter?

A. I have not.

Q. Have you ever been present when such gagings were made?

A. I have not.

Q. Did you ever use a current meter?

A. No, I never did.

Q. You are connected with the Northwestern University School of Civil Engineering?

A. Yes, School of Engineering.

Q. Of engineering?

A. Yes.

Q. We have called it civil engineering; I do not know whether there is a difference?

A. That covers the whole field.

Q. I suppose there is a mechanical engineering department, something like that, is there?

A. It is all included within the same college; therefore it is called the College of Engineering, rather than Civil Engineering.

Q. Your institution has to do with hydraulics, hasn't it?

A. It has.

Q. Have you got a Haskell Meter at your College?

A. No, we have not.

Q. You have a Price Meter though, haven't you?

A. Yes.

Q. In analyzing and testing the accuracy of the discharge observations on the Niagara River, did you apply any criteria other than purely mathematical ones?

A. I did.

Q. Give us the details of what you applied, other than mathematical criteria?

A. I made a study of the details of the methods of observation and of computation that were used in connection with the measurements of discharge of the Niagara River, and other similar measurements.

Q. What did you apply in that study to prove the accuracy of the measurements, other than mathematical calculations?

A. I necessarily applied my knowledge of the methods. It was not simply a mathematical study. Necessarily, there are questions of judgment involved all the way through, in both the observations and in the methods of computation; therefore it is not purely—

Q. You used personal judgment as to making certain reductions there, did you?

A. Yes, sir, also judgment—

Q. When you say "methods of making the observations," you refer to the manner, the method followed in taking the discharge measurements?

A. Yes.

Q. That is you considered the various methods used, did you?

A. Yes.

Q. And then you formed an opinion as to whether the methods which were used in making those measurements were proper methods, did you?

A. Yes, were methods which would secure the facts.

Q. From a mathematical standpoint?

A. No, I should say from an engineering standpoint. That is, it is far from being purely mathematical, as it involves many other things than simply mathematics.

Q. Upon what did you base your opinion as to the method used?

A. On the various printed records and also, of course, the information given in the exhibits that have already been referred to in my direct testimony.

Q. You made a study of the methods used in making discharge measurements, for the purpose of testifying and forming an opinion as to the accuracy of that method, did you?

A. Yes, sir, I made a special study, of course of it, in addition to the general information which I had on the same subject, of course, before.

Q. You did not have any practical experience as to the use of the methods, did you?

A. No, not in the sense of having made any measurements myself.

Q. I hand you three sheets, blue prints, on which there appears certain figures, which blue prints I ask be marked Hayford's Exhibit A, cross examination. (Blue prints so marked.) This exhibit upon its face purports to show corrected discharge measurements of the Niagara River, Open and International Bridge Sections. Assuming these measurements to have been made under the same circumstances and

conditions as the 340 measurements concerning which you testified on direct examination, what do you find the mean discharge to be at elevation 572, and what do you find the increment to be for 1 foot change of lake level for the 340 of these measurements at elevations corresponding to those previously considered by you?

Mr. Hopkins: That question is objected to. It is not based upon evidence in this case, and will involve an unreasonable amount of time to work out, perhaps will require from ten to twenty days to answer; and therefore we will insist upon the objection. And instruct the witness at this time not to answer.

Mr. Adcock: The witness has attempted to qualify as an expert computor. We insist that this question is a proper question to test the witness' ability to make calculations, such as he attempted to make in his direct examination; and it has to do with ascertaining the methods of arriving at results from discharge observations, and the materiality of the opinion given by the witness in direct examination.

It is also suggested that this question was submitted to the counsel for the Complainant, and read into the record at a hearing some three or four weeks ago, so that the witness has been advised of the character of the question which would be asked, and has had an opportunity to make the calculations, and to answer the question which has been just now asked. The question was submitted on Wednesday the 15th of April.

Q. Will you now answer the question, Mr. Witness?

Mr. Hopkins: I will add to the record the statement of the fact that counsel for the Government notified counsel for the Sanitary District that they would not ask the witness to answer the question until the source of the figures was put in, and the facts upon which the question is based were made a part of the record. So far as that is concerned, I again instruct the witness not to answer at this time.

Mr. Adcock: In other words you now instruct the witness?

Mr. Hopkins: May I ask the witness another question, before that? (Q) Mr. Hayford, about how long would it take to answer that question; or could you answer it with any degree of accuracy?

A. I think it would take approximately 20 days, and so far as I understand this, it seems to me that then the answer could not be well founded unless there is more information furnished than is given on those sheets. I have not seen the sheets yet. There is not sufficient information, in my opinion,

given on those sheets to make it possible to return an answer corresponding to the answer in the direct testimony.

Q. What additional matters, Mr. Hayford, ought to be there?

A. The same information as to the methods of computation of these figures as is available in the case of the other figures. In the case of the other figures, the full information is given as to the method of computation leading up to the results. It seems to me to return an answer corresponding to the answers given in the direct testimony, I must have that full information in regard to these figures.

Mr. Adcock: Q. What computations do you refer to?

A. Computations connecting the observations made in the field with these figures, which purport to be the discharge at particular times. That information is given quite fully in the other case.

Mr. Hopkins: I wish to incorporate—

Mr. Adcock: Just a minute: Q. Have you read the question which has been put to you, and the assumptions that were to be made in connection with these discharge measurements?

A. I have; yes, I heard it.

Q. You observe you are to assume that the measurements were made under the same circumstances and conditions under which the 340 measurements were made, concerning which you testified on direct examination?

A. Yes, but the blue prints, these blue prints, of course are results; they are not the measurements. The measurements are the readings taken in the field; and it is the connection between the measurements actually made and these figures which purport to be discharges that is missing, in my opinion.

Q. In answering the question put to you with reference to 340 measurements, what field notes did you see?

A. I did not see any of the original field notes.

Q. Did you see any copies of field notes?

A. No.

Q. Then you necessarily did not take the field notes into consideration in arriving at your results testified to in your direct examination, did you?

A. No, I did not have the field notes.

Mr. Adcock: I submit for the record, in connection with this question, that in the course of the cross-examination of the witnesses, both for the complainant and the defendant, questions have been asked which have required the making of computations; and that this is the first time that any objection has ever been made upon that score.

I also submit that it is perfectly proper to ask an expert witness a question of this kind, a question which may require a considerable amount of work in connection with making the answer. Do I understand that the counsel for the Government still instructs the witness not to answer the question?

Mr. Hopkins: I wish to incorporate in my objections to the question the reasons given by the witness himself as to the impropriety of attempting to answer the question. I do still instruct the witness not to answer the question at this time, but will take the matter before the court at the most convenient time, and submit it.

Mr. Adcock: The defendant insists upon the witness' answering the question submitted. And for the purpose of the record, I want to state that upon an answer being given to the question which has been asked, I will ask two other questions based upon the same conditions: With what degree of precision is each certainly correct, and a further question: And within what degree of precision is it an even chance that the error of each is greater or less?

Mr. Hopkins: The same objection is made to the other questions, it being understood that as to all questions, there is still reserved the objection of materiality and competency. And I instruct the witness, in the same way, not to answer the two last questions, at this time.

Mr. Adcock: That is all, Mr. Hayford.

Re-direct Examination by Mr. Hopkins.

Q. When you said something was missing, Mr. Hayford, did you make it clear just what you meant, in regard to field notes, or just what did you mean?

A. What is missing in this data?

Q. In the question that is offered to you to-day.

A. Yes. In order to enable an opinion to be formed, the connection between the field notes on the one hand and these discharges, or what purport to be discharges on the other hand, that method of computation in detail is the thing which is the missing element.

Q. And without that, you do not think you could answer the question?

A. No.

Re-cross Examination by Mr. Adcock.

Q. I will amend the hypothetical question asked, and will ask you to assume that the discharges shown are the actual,

positive, certain discharges for the elevation shown. Then, Mr. Hayford, is there any reason why you could not make the computations which you are asked to make in that question?

A. It would seem to me that would beg the question. The discharge is the thing which must be measured. The question is the accuracy of the measurement. Therefore we must have the methods of the measurement, and of arriving at the figures, the final results from the measurements, in order to know what the accuracy is.

Q. Then you are assuming something which I have not asked you to assume in my question, aren't you?

A. No, I don't think I am.

Q. I am asking you to assume certain conditions here. You are an expert witness. Assuming that the elevation and the discharge were the two things that were observed, and that there were no intermediate steps.

Mr. Hopkins: In others words, you wish to bring in a matter purely of mathematical computation.

Mr. Adcock: Yes.

Mr. Hopkins: And we make the same objection, same instruction; further, that it is not fair to ask our witnesses to do computing for the Defendant.

Mr. Adcock: That is all.

FRANCIS C. SHENEHON, a witness recalled in rebuttal on behalf of the Government, having been previously sworn, testified as follows:

Direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, you testified in this case, in June, 1909, didn't you?

A. Yes.

Q. Since that time, what have been your professional activities, connections and so on?

A. In September, 1909, I resigned from the Government service, and became Dean of the College of Engineering of the University of Minnesota, at Minneapolis.

Q. What is your work in that connection?

A. My work is mainly administrative, as Dean of the College. I am also head of the department of civil engineering and a lecturer to the post-graduate, the fifth year civil engineers on the subject of rivers. harbors and canals.

Q. Have you during that time been engaged in any private practice?

A. Yes, I have given a certain portion of my time to consulting practice as a civil engineer.

Q. You were an expert for the United States Government in the case of United States against the Chandler-Dunbar Power Company?

A. Yes.

Q. You have also been engaged as expert and have been working on this case have you not, Mr. Shenehon?

A. Yes.

Q. Just to what extent have you worked on this case?

A. I have given perhaps six months or more of my time, mostly in the last two years, to this case.

Q. Just in that connection, what in detail have you done in this case?

A. I have attended most of the hearings in which testimony has been taken. The testimony which I did not hear before the Commissioner, I have for the most part read. I have not read the testimony of the six masters of vessels that was recently taken. Aside from that I believe I have read all the testimony.

Q. Have you given any special study to the testimony in this case?

A. Yes, I have given very extensive study and consideration to the testimony in this case and to the elements entering into the hydraulic situation of this case, as well as other elements.

Q. In reading the testimony of defendant's witness, Williams, did you also read and study the exhibits that were put in evidence in connection with it?

A. Yes, I have given some considerable study to the exhibits, as well as to the verbal testimony of Mr. Williams.

Q. I show you chart market for Identification "Exhibit 3, Williams' Cross-Examination" and ask you to tell just what that chart is; what it shows; who made it and how?

A. This chart was made by me, and upon it are plotted 219 discharge observations made on the Niagara River at the International Bridge Section. In the vertical scale indicated on the left hand side of the chart is the elevation of Lake Erie as indicated by the Buffalo water gage. Plotted, and increasing towards the right is the volume of flow. The scale is shown at both the top and the bottom of the chart; the volume of flow in cubic feet per second, or the discharge in cubic feet per second.

The statement or title on this chart indicates that it is discharge measurements of the Niagara River plotted from the records of the U. S. Lake Survey. The measurements of 1898, 1899 and 1900, are shown by black circles, 101 measurements in all. The measurements of 1907 and 1908, are shown in crosses or with a plus sign. There are 118 of these measurements in 1907 and 1908.

The center of gravity, or the mean of all of these 219 measurements, is shown by a star. There are two lines threading these observations. I withdraw the word "two". There is one line threading these observations and a second line which I will refer to later. The line threading the observations was drawn by Mr. Gardner S. Williams, Advisory Expert to the Sanitary District in this case, and the method employed was to stretch a thread. This line was drawn by Mr. Williams, having in view the star representing the center of gravity of all observations.

Q. I believe you said Mr. Shenehon that this on its face purported to be a plot of observations made by the Lake Survey. You made it, didn't you, the plot?

A. The plot was made by me and was not made by the Lake Survey, but from the records.

Q. Is the plot what it purports to be?

A. Yes, and it has been very carefully checked, and I believe it to be accurate.

Now, the second line which does not thread the observations, but passes through the center of gravity represents a law of discharge in which the increment is 34,000 instead of what I believe to be the true increment of the Niagara River, 21,900.

Mr. Hopkins: I offer that document in evidence and ask that it be marked Shenehon's Exhibit A of this date.

(The document identified by the witness was marked Shenehon's Exhibit A, April 15, 1914.)

Mr. Hopkins: It was understood that a photograph will be substituted for this exhibit.

Q. I show you a chart marked "Haskell Exhibit 1, February 3, 1914," and ask you who made that chart and what it is?

A. This chart was made under my direction and corresponds in part with the chart just described, to the extent that the 219 observations before mentioned are plotted on this chart. These are all plotted in solid circles. The scale is the same as the chart just described.

Q. That is Shenehon's Exhibit A, of this date?

A. It also has a star, representing the mean volume of discharge and mean Lake Erie elevation for the 219 observations shown.

In addition, there is plotted, in the form of a black square, the mean of 121 measurements at the Open Section of the Niagara River.

There is also plotted, in the form of a black triangle, the mean of 10 measurements at the third or Split Section of the Niagara River. The equation of discharge indicated by the heavy black line threading the observations is indicated as $Q = 153{,}300 + 21{,}900\ (H_B - 570.00)$. In this equation the quantity or volume of outflow in cubic seconds feet is represented by "Q." "H" sub "B" indicates the height or elevation of the water surface of Lake Erie at the Buffalo gage. The increment of flow for a rise of 1 foot, is 21,900 cubic seconds feet.

The statement is made on this chart that the loss of level of Lake Erie for loss of outflow of 10,000 cubic seconds feet is 0.457 feet or 5 1/2 inches; for loss of outflow of 14,000 cubic seconds feet is 7 11/16ths inches.

Mr. Adcock: I did not know that that statement was on that chart. I object to it on that ground.

Mr. Hopkins: Q. Is that shown on the chart?

A. That is shown on the chart, yes.

Mr. Adcock: Have you offered it in evidence?

Mr. Hopkins: No, I have not offered it in evidence.

Mr. Adcock: All right.

The Witness: On the right hand side of the chart are certain lines with indicated Lake Erie elevations in figures at the left of it. The uppermost of these indicates the mean Erie level at Cleveland for June, 1908. And is so stated on the plot.

It is further stated that 10 observations for discharge volume are shown thus: The symbol to the right of "thus," being a solid circle. The other lines and solid circles indicated are self explaining. The object of this was to make a detailed study of the observations themselves by utilizing a blueprint with various colors shown on the circles indicating the observations.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit B, of this date.

(Whereupon document referred to was marked Shenehon's Exhibit B, April 15, 1914.)

The Witness: I wish to make one additional explanation:

In addition to the heavy black line threading the observations are three lines on either side. These lines indicate the limits of the percentage variations of volume of flow. This is stated on the lines themselves, and I believe is self explaining.

Mr. Hopkins: I renew the offer.

Mr. Adcock: As I understand, the statement as to the effect of a diversion of 10,000 and 14,000 cubic feet per second as appears on that chart is a mere statement of what the chart itself shows that to be, isn't it?

The Witness: The lowering for Erie, as indicated on this chart, is based upon the assumption that the increment indicated, 21,900, is the correct increment.

Mr. Adcock: And the statement of the lowering of the levels of Lake Erie is simply a conclusion from that chart itself. In other words, in admitting this in evidence, we do not want to agree that that is the actual lowering. The words there that are used as to stating the effect of the diversion of different amounts on the lake levels is a statement as to what that chart itself shows.

The Witness: Let me just add something.

Mr. Adcock: Yes.

The Witness: I wish to state further that the increment indicated on this sheet and the line representing the law of discharge are the same as the increment and line on U. S. Exhibit number 3, introduced earlier in this case. And the conclusions drawn from that increment are the same as indicated by the scale on the left-hand corner of that earlier exhibit.

Mr. Adcock: This statement here: "The loss of level of Lake Erie for loss of outflow of 10,000 cubic seconds feet, is 5½ inches; for a loss of outflow of 14,000 cubic seconds feet, it is 7 11/16ths inches," that is a conclusion from the chart itself, isn't it; that is what the chart shows?

A. It is a conclusion drawn from the observation and demonstrated by the chart itself, and in my judgment is a correct deduction.

Mr. Adcock: I want to object to the offer of that on account of the statement which is made on the chart, unless it is admitted by the Government that the statement as to the effect of the diversion is simply a conclusion from the chart itself.

Mr. Hopkins: I understand that the statement as to the loss of level of Lake Erie, as it appears on the chart, is a

result or a conclusion from the results obtained from the chart itself.

Mr. Shenehon: That is true.

Mr. Hopkins: All right.

Q. I show you another chart marked Shenehon's Exhibit C for Identification of this date. Will you just tell who made that chart, Mr. Shenehon; what it is and what it shows?

A. This is a chart on which certain selected discharge observations of the Niagara River are plotted on the same scale as to lake elevation and as to volume of discharge as Exhibit B, just indicated.

Mr. Adcock: That applies to Erie?

A. It applies to the Niagara River at the International Bridge Section.

Mr. Hopkins: Q. Just what observations are plotted there?

A. 30 observations, selected by Mr. Gardner S. Williams, Advisory Expert of the Sanitary District in his study of the Niagara River, are plotted in solid black circles. In addition, in solid triangles, are plotted 10 observations of discharge of the Niagara River taken in the winter season when ice conditions prevailed.

Q. What do the lines show?

A. The heavy central black line threading the solid circles indicates the law of discharge the same as on Exhibit B, using the same equation, which involves also the same increment 21,900.

A statement is made on this chart below the title: 30 measurements selected by Mr. Gardner S. Williams, expert witness, on behalf of the Sanitary District, from a total of 101 measurements in 1898 and 1899, shown thus: That is the solid black circle. It further states: Mr. Williams neglected 118 measurements in 1907 and 1908, and by oversight included 10 winter measurements when ice conditions prevailed. These are shown thus: the symbol being a triangle. The increment used by U. S. is 21,900.

Q. Just what does that chart show?

A. This indicates that out of 219 observations available, Mr. Williams selected 30, as representing the most quiescent conditions, as he saw them of Lake Erie, and as I have before stated the ten observations during the winter, which crept in by oversight.

A point I wish to make in presenting this exhibit is that if an increment be drawn from the 30 observations selected by

Mr. Williams, it will be less than 21,900. If the quiescent observations are the ones from which we should determine the increment, an increment drawn through the 30 selected by Mr. Williams will be less than 21,900; I should say as little as 21,000. I have not computed it.

Q. Does that include the ten winter observations?

A. No, that excludes the ten winter observations. In Mr. Williams' earlier testimony on this subject, which was the basis as I understand it of the testimony of Mr. Freeman and Mr. Stearns, the winter observations were used and an aggravated or enlarged increment determined by reason of that, and by reason of other erroneous, as I see it, methods of reduction.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit C of this date.

(Chart offered in evidence was marked Shenehon's Exhibit C, April 15, 1914.)

The Witness: I should state that this was made under my direction and has been very carefully checked.

Mr. Hopkins: Q. I now show you another chart, Shenehon's Exhibit D, of this date, which is also marked Hayford's Exhibit 7, for Identification, April 10, 1914, and ask you the same questions in regard to that chart?

A. This is a chart of the discharge observations at the Open Section of the Niagara River. The scale is the same as already described for Exhibits A, B and C. 121 measurements taken in 1899 and 1900, are shown by solid black circles. In addition, the 219 measurements of the flow of the Niagara River at the International Bridge Section are shown by a solid square; and the ten measurements taken at the Third or Split Section of the Niagara River are shown by a solid triangle.

The solid heavy line threading the observations indicates the law of flow, as shown by the observations. This line passes through the mean of all the observations, which is indicated by a star as on the other exhibits A and B, already described. The lines on either side of the heavy black line show the limits of the percentage variation from the law indicated by the heavier line. Certain statements concerning the elevation of the lake for the individual observations, or for the groups of observations for months, are indicated on the right-hand side much the same as in Exhibit B.

The equation of discharge indicated on this chart is: $Q = 151{,}000 + 21{,}640\ (H_B = 570.00)$. The meaning of the

terms used, Q and Hв, are the same as indicated for Exhibit B.

Q. Was that made under your direction and checked?

A. This chart was made under my direction and has been very carefully checked and I believe it to be accurate.

Mr. Hopkins: I offer it in evidence as Shenehon's Exhibit D, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit D, April 15, 1914.)

The Witness: This contains a statement of the loss of level indicated by the increment used, which is 21,640.

Mr. Adcock: That is as shown on that chart?

The Witness: Deduction from the increment.

Mr. Adcock: As shown on the chart.

The Witness: As shown on the chart.

Mr. Hopkins: Q. I now show you this chart, Shenehon's Exhibit E, of this date, which is also Hayford's Exhibit 6, of April 10, 1914, and ask you the same question in reference to this chart.

A. This is a chart which contains two different illustrations. On the left-hand side is given the volume of discharge of the Niagara River plotted with respect to the elevation of the water surface at the Suspension Bridge. This is in the gorge of the Niagara River, this gage, just above what are known as the Whirlpool Rapids, in the still, deep water at that point. The scale on the left hand indicates the elevation of the water surface in feet and hundredths. And the scale at the top indicates the volume of discharge in cubic seconds feet. The solid black circles indicate groups of discharge observations. Each of these groups contains four observations and these four observations were each made on a single day. This is in a way selected observations, because no day was utilized that had less than four observations. These observations are those already in evidence, made at the International Bridge of the Niagara River, in 1907 and 1908.

The black open circle shows the center of gravity or mean of the 16 groups, containing 64 discharge observations altogether. The solid line threading these observations indicates the law of discharge, or the relation between the water surface elevation and the volume of flow; and the equation at the bottom of the plot indicates this relationship.

Q. Was that chart made under your direction?

A. This chart was made under my direction, and has been very carefully checked and I believe it to be accurate.

A statement is made at the bottom showing that the derived increment for Lake Erie is 21,860. On the right-hand side of the chart is a similar plot for the water surface in the whirlpool of the Niagara River. 60 observations are used in this and the groups are of 4 observations each; each of the four observations being the work of a single day.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit E, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit E, April 15, 1914.)

The Witness: The increment as deduced for Lake Erie from Whirlpool gage is indicated as 22,440.

Q. I now show you a chart, Shenehon's Exhibit F, of this date, which is also marked Ray's Exhibit 2, of February 4, 1914; and ask you to tell under whose direction it was made, and what it shows?

A. This chart was made under my direction, and has been very carefully checked. It shows the volume of discharge of the Niagara River, plotted with respect to the elevation of the water surface in the Gorge at Suspension Bridge. It differs from the Exhibit E, in the fact that it utilizes the 118 observations available and printed in the document known as the "Preservation of Niagara Falls."

Q. What increment is derived from that?

A. The increment for Lake Erie at Cleveland deduced from this chart and from certain data referred to in this chart is 22,000 cubic second feet.

Mr. Hopkins: I offer that in evidence as Shenehon's Exhibit F, of this date.

(Chart offered in evidence, marked Shenehon's Exhibit F, April 15, 1914.)

Q. I show you chart, Shenehon's Exhibit G, of this date, also marked Ray's Exhibit 3, of February 4, 1914, and ask you to tell us under whose direction that was made and what it shows, what it is?

A. This chart was made under my direction and very carefully checked. It is similar to Chart F, just described, except that the water surface to which the volume of flow is referenced is that at the Whirlpool gage in the Whirlpool of the Niagara River. The increment deduced for Lake Erie is 22,400.

This is 108 observations taken in groups of ten, except that one is taken in a group of eight. The data used in making this chart is indicated in a table at the upper left hand corner.

Mr. Adcock: Q. Is there any statement of the lowering effects there?

A. Yes.

Q. I assume the statement is simply a conclusion from that chart, isn't it The same admission is made with reference to that statement that was made with reference to the other?

A. Yes, sure.

Mr. Hopkins: I offer this in evidence as Shenehon's Exhibit G, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit G, April 15, 1914.)

Q. I show you chart marked Shenehon's Exhibit H, of this date, also marked Ray's Exhibit 1, of February 4, 1914, and ask you the same questions in regard to that?

A. This is a chart showing two different lines, with the observations plotted in solid black circles, which would determine the trend and position of these lines. The scale on the extreme left hand side shows the elevation of the water surface at the Suspension Bridge in the gorge of the Niagara River already referred to.

The scale on the right hand side indicates the elevation of the water surface at the Whirlpool gage in the Niagara River. The scale crosswise of the chart as indicated, indicates the elevation of the water surface at Cleveland, at the water gage of the United States, at Cleveland. The lines indicate the relation or law of fluctuations; the left hand one, the movement of the water surface in the gorge of the Niagara River, for a foot change, or for any change of Lake Erie; and the one on the right hand side, the similar relation for the Whirlpool.

This is derived from monthly mean observations as indicated by the tabulation of data in the extreme left hand corner and the right hand side above the title.

The conclusion reached from this data and from this chart is that the water surface at Suspension Bridge has a movement of 2.334 for a change of 1 foot of Lake Erie surface at Cleveland, considered as monthly means; and that the water surface in the Whirlpool has a movement or fluctuation or change of 2.661 for a foot change at Cleveland, as determined by monthly mean elevations of these water surfaces.

This chart has been used in connection with Exhibits F and G, in deriving the increment of the Niagara River with reference to the water gage at Cleveland. These three charts

reach an increment of the Niagara River in entire accord with the previous increment, at the same time eliminating completely any use of the Buffalo gage.

Mr. Hopkins: I offer the chart in evidence as Shenehon's Exhibit H, of this date.

(Chart offered in evidence was marked Shenehon's Exhibit H, April 15, 1914.)

Q. I show you a chart marked Shenehon's Exhibit I, of this date and ask you the same question in regard to that that I have as to the others?

A. This was made personally by me and has been carefully checked. It represents the relative fluctuations of the water surfaces of Lake Huron at Harbor Beach and Lake St. Clair at the Flats. Each observations shown by a solid circle which indicates the mean elevation of the water surfaces referred to for the months June to November, inclusive, each year. The mean of the 24 groups is shown as a star. The line threading these observations is the law of relationship between these two water surfaces of Lake Huron and Lake St. Clair as indicated by the United States Lake Survey, in its report of 1912, page 3546.

Q. Has that chart been used in this record before?

A. This chart was used in the cross-examination of Mr. John R. Freeman, and possibly other witnesses.

Q. Do you know whether it was marked for Identification at that time?

A. It was used in the form of a blueprint on which a certain number of observations after 1889 were colored red, so as to show a distinction between those prior and those after. It was used in investigating the matter of any possible change in the regimen of the St. Clair River.

This was used in the cross-examination of John R. Freeman as Exhibit 13, October 8, 1913.

(Chart identified by witness was marked Exhibit I, April 15, 1914.)

Q. I now show you a chart, Shenehon's Exhibit J, of this date and ask you the same questions in regard to that.

A. This was used in the cross-examination of Mr. Freeman in the form of a blueprint and was marked at that time U. S. Exhibit N.

Q. Who made this chart?

A. This was made under my direction and indicates the relative water surface elevations of Lake Erie at Cleveland and Lake Ontario at Oswego. The solid black circles repre-

sent the annual mean elevations prior to and including the year 1903. Beginning with the year 1904, and all other years up to the year 1912, the observations are shown by solid red circles.

This chart is designed to show the characteristic change in the relationship of Lake Erie and Ontario coming with a definite known change of regimen in the St. Lawrence River, due to the building of the Gut Dam. A black line threads the observations for mean elevations for the years prior to 1904, and a red line after that time.

Mr. Hopkins: I offer that chart in evidence as Shenehon's Exhibit J.

(Chart offered in evidence was marked Shenehon's Exhibit J, April 15, 1914.)

Q. I show you four photographs of charts, Shenehon's Exhibits K. L. M and N of this date, which were referred to in the cross-examination of Gardner S. Williams, and marked respectively Complainant's Exhibits F, G, H and I; and ask you to state under whose direction these were made and what they show?

A. The original charts of which these are photographs were made under my direction, and every pains taken to ensure their accuracy. This series of charts has been referred to in this case as the Three Curve Series, and consists of four sheets marked 1, 2, 3 and 4. These sheets show the observations of discharge for the Niagara River taken in the years 1907 and 1908, 118 observations in all. These observations are plotted in solid black circles on a scale of volume in cubic second feet.

The waving dotted line which passes near or through these observations in this is the center of the three continuous broken lines shown on each sheet, indicates the computed volume of flow from the water surface elevation at the Buffalo gage, Lake Erie.

Q. Using what equation?

A. The equation used is stated on each of these sheets and is the same as that used in U. S. Exhibit 3; also the same as that used on U. S. Exhibit, Shenehon's B and C of this date.

The upper waving line indicates the elevation of Lake Erie at the Buffalo gage as shown by the scale on both the left and right-hand sides. This is plotted for each hour of the day and is the basis of the volume of flow indicated by the dotted line.

In other words, knowing the elevation of Lake Erie at Buf-

falo, and having an equation which will give us the discharge or volume of flow, the dotted line indicated is easily represented.

The bottom waving line on these sheets indicates the elevation of the water surface in the Gorge pool of the Niagara River at Suspension Bridge gage. This is also plotted for each hour of the day. The information given by this series of sheets is very considerable, and the use of the waving line at the Suspension Bridge gage gives very definite conclusions as to the time which it takes a change in Lake Erie to travel the distance between the Gorge pool and the Buffalo gage; or, conversely, the Buffalo gage and the Gorge Pool.

Q. What does it show that time to be?

A. Rather elaborate investigation of this matter indicates that the lag or time of travel of the crest or the valley between the Buffalo gage and the Gorge Pool is about three hours and a quarter.

Mr. Austrian: How far is it?

A. The distance is approximately 25 miles.

A. I wish to state that in the original blueprint used in this case, one observation was not plotted. It was omitted and a third checking of the series revealed its absence. It has since been plotted on the original and is reproduced in these photographs. That refers to the observation first on August 5th. The scales and other matters connected with these sheets, I believe are self-explanatory.

Mr. Hopkins: I offer these in evidence as Shenehon's Exhibits K, L, M and N, of this date.

(Documents so offered in evidence were marked Shenehon's Exhibits K, L, M and N, April 15, 1914.)

Q. I now show you three charts marked Shenehon's Exhibits O, P and Q of this date, which were also used in the cross-examination of Gardner S. Williams, and which have been referred to by various witnesses in this record as Complainant's Exhibits J, K and L, and ask you to state who made them and what they show?

A. These three charts or photographs are from original charts made under my direction, sheets 1, 2 and 3. These sheets have been referred to in this case as the One Curve Series. The waving dotted line indicated shows the water surface elevation of Lake Erie at the Buffalo gage. It shows at the same time by the relationship or equation previously referred to and used in the Three Curve Series, the discharge observations made at the Open Section in 1899 and 1900. This

series utilizes only those observations where we had a self-registering gage to give us the elevation of Lake Erie at Buffalo. This is beginning on August 30, 1899.

A statement is made on sheet number 1, of this series, and applies to the three sheets, that these observations on the Open Section have been adjusted so as to show the equivalent volumes as measured on the International Bridge Section.

By this I mean to say that to each observation taken in the Open Section, the values indicated on the lower right-hand corner of Sheet number 1, have been added. In plotting the continuous dotted line, the hourly elevations at the Buffalo gage have been utilized. This shows very definitely the change of Lake Erie level at Buffalo prior to and during the taking of the discharge observations, as well as after the taking of the discharge observations.

Mr. Hopkins: I offer those in evidence as Shenehon's Exhibits O, P and Q of this date.

(Documents offered in evidence were marked Shenehon's Exhibits O, P and Q, April 15, 1914.)

Q. I now show you a chart marked Shenehon's Exhibit R, of this date, referred to in the cross-examination of Gardner S. Williams, as Complainant's Exhibit A, and ask you to tell us who made it?

A. This was plotted under my direction and carefully checked.

Q. State what it shows?

A. It shows in broken lines the annual or yearly mean elevations of Lakes Michigan-Huron, Lake Erie and Lake Ontario. These are the solid black lines shown as a series of steps in the three profiles of the chart; the top one being Michigan-Huron, the middle one Erie and the lower one Ontario. The gages utilized are for Michigan-Huron, Milwaukee, Erie, Cleveland, and Ontario, Oswego.

At the right-hand side is shown the same form of profile except that the observations of elevations are grouped in five-year means, except the last period 1910 to 1912, which is of three years. At the right-hand side of each of these is a pronounced scale of inches.

Referring to the top profile on this chart, there appears certain dotted horizontal lines. These indicate the elevation of Michigan-Huron computed from the elevations for Lake Erie, as shown on the middle profile. The equation by which this is computed is indicated on the chart.

Where the actual or observed elevation of the lake is above

the computed elevation, the areas between the solid black line and the dotted horizontal line are shown in blue. Where the observed elevation of the lake is below its computed elevation this area is shown in red. The significance of the red may be that when the lake is lower than it is computed to be, it is dangerous.

A similar procedure is shown in the middle profile and for the bottom profile. Lake Ontario in the bottom profile shows, computed elevations from Erie by an equation indicated and the computed elevations for Lake Erie are derived from the elevation of Lakes Michigan-Huron. This has been referred to in this case as the red and the blue chart.

Mr. Adcock: Can you produce a letter written by Mr. Shenehon to Mr. E. E. Haskell, who was principal assistant engineer of the Lake Survey, written in 1899, or about that time?

Mr. Shenehon: Yes, the Lake Survey has got that. I told them it was all right to put it in.

Mr. Adcock: It was about 1899, in which there are some criticisms made by Mr. Shenehon of the measurements of the Niagara River. We have asked—Mr. Williams has asked for a copy of that letter, and I understand it has not been produced. We would like to use it in cross-examination of Mr. Shenehon.

Mr. Hopkins: I will answer in the morning.

Mr. Adcock: I understood it was referred to the United States Attorney here whether we could have a copy. The request was made about the 23rd of March, this year.

Mr. Hopkins: I offer in evidence this chart as Shenehon's Exhibit R, April 15, 1914.

(Chart offered in evidence marked Shenehon's Exhibit R, April 15, 1914.)

Adjourned to Thursday, April 16, 1914, at 10:00 o'clock A. M.

April 16, 1914, 10:00 A. M.

Parties met pursuant to adjournment.

Present same as before.

FRANCIS C. SHENEHON, resumed the stand and testified further on direct examination as follows:

Mr. Hopkins: Q. I now show you a chart marked Shenehon's Exhibit S, April 15, 1914, also marked Government's Exhibit O, for Idenification, and referred to in the cross-examination of Frederic P. Stearns, and ask you to tell what that chart is and what it shows?

A. This chart is a record of the United States Lake Survey and contains three curves, two being or representing the laws of discharge of the St. Lawrence River for the period prior to the building of the Gut Dam, and the other for the period after the building of the Gut Dam on the St. Lawrence River. These are discharge curves of the St. Lawrence River. The discharges plotted on this sheet are with respect to the water level of Lake Ontario at Oswego as represented by a scale on the left-hand edge of the sheet.

On the right-hand side is also a scale of the water surface elevations at Ogdensburg, so that the volume of flow may be taken off for either the elevation of Lake Ontario or the elevation of the St. Lawrence River at Ogdensburg. The third curve is the discharge of the St. Lawrence River referred to the depths on the old sill of lock number 25, which as I recollect it is at the foot of the Galops Canal.

The title and explanation in the lower right-hand corner indicates that this was made in 1912, by Mr. Sherman Moore, Junior Engineer; and that it was compiled under the direction of Lieutenant Colonel C. S. Riche, Corps of Engineers, U. S. A.

Mr. Hopkins: I offer the chart in evidence as Shenehon's Exhibit S, April 16, 1914.

(Chart offered in evidence was marked Shenehon's Exhibit S, April 16, 1914.)

Q. I now show you a table, Shenehon's Exhibit T, of this date, which is referred to in the cross-examination of John R. Freeman as United States Exhibit M. I will ask you who

made that table, what it is, and from what sources it was made?

A. This was made by me personally, and is an analysis of the consistency of the flow of the St. Lawrence River as compared with the flow of the Niagara River for 16 years, beginning in 1891, and ending in 1906. The table itself indicates the sources of the data. The St. Lawrence River outflow was taken from the curves shown on Shenehon's Exhibit S, which was at that time the best available data in my judgment as to the outflow of the St. Lawrence River. Perhaps I should make the reservation: The best available compiled data. At that time, some additional observations had been taken on the St. Lawrence River, but not reduced.

The flow of the Niagara River is taken from United States Exhibit Number 3, and to that, as indicated by the tabulation itself, 2,300 cubic seconds feet has been added for the flow of the Niagara River, on account of the Erie and Welland Canals.

The local supply and storage for Ontario is taken wholly from the tabulation of Stearns Exhibit Number 1.

The conclusion indicated by this table is that the Niagara River and the St. Lawrence River are in accord within 4,600 cubic seconds feet, or about two per cent.

Mr. Hopkins: I offer that table in evidence as Shenehon's Exhibit T, of this date.

(Table offered in evidence marked Shenehon's Exhibit T, April 16, 1914.)

The Witness: I think I should state that this indicates that the actual discharge of the Niagara River as computed from discharge measurements is less by 4,600 feet than deduced discharge; the deduced discharge in this case being that derived by taking the observed flow of the St. Lawrence, as computed from the discharge measurements of the St. Lawrence, and subtracting from it the local supply and storage for Ontario, as shown by Mr. Stearns in his Exhibit 1. It may also show that the volume of flow of the St. Lawrence is too great by two per cent., or any combination of errors in the local supply and the discharges of the two streams, which will serve to bring about this result.

Q. Now Mr. Shenehon, I show you some papers, Shenehon's Exhibits U1, U2, U3, U4 and U5, which are also marked Hayford's Exhibits 1, 2, 3, 4 and 5 for Identification, April 10, 1914; and ask you to state who made those and what they are?

A. This is a computation by Mr. Williams' three-point method of the law of discharge indicated by the 219 measurements of discharge of the Niagara River at the International Bridge Section. This computation was made by me personally and was checked by my assistant, and later in the cross-examination of Mr. Williams was referred to him for confirmation of the correctness of the computation, and the result derived, and returned as O. K. by him.

The conclusion is stated in the evidence, in Mr. Williams' cross-examination, and this shows that the increment of the Niagara River at the International Bridge is 21,860, as derived by this computation, while the Government's Exhibit Number 3 indicates an increment of 21,900.

Mr. Hopkins: I offer those sheets in evidence as Shenehon's Exhibits, U1, U2, U3, U4 and U5.

(Sheets so offered in evidence were marked Shenehon's Exhibits, U1-U5, April 16, 1914.)

Q. You say you have read and studied the testimony of Gardner S. Williams, Frederic P. Stearns and John R. Freeman in regard to methods of determining increments for the St. Clair, Niagara and St. Lawrence Rivers, Mr. Shenehon?

A. Yes, sir.

Q. And their conclusions and opinions as to those increments?

A. Yes.

Q. Will you just state in a general way the method used by those witnesses in determining an increment; and comment on it?

A. In the derivation of the increment of the St. Clair River, Mr. Gardner S. Williams used a variety of methods. Starting with the groups utilized in the U. S. Exhibit Number 1, Mr. Williams makes reduction by the method of three points instead of the method of least squares. This has the effect, as I recollect it, of slightly increasing the increment. I may state here, however, that the method of three points as opposed to the method of least squares makes no large difference in any conclusion reached in this case for the increment, no large difference.

I wish to state in passing also that the increment as shown on U. S. Exhibit Number 1, which is a discharge curve of the St. Clair River, was computed by the method of least squares and was not gotten by the stretching of a thread or string. So far as the use of the three-point method, or least squares is concerned, or even the method of stretching a thread, the

indications of the increment, of the Niagara River, as an illustration, shows that the line shown on U. S. Exhibit Number 3, giving an increment of 21,900, differs but slightly from the increment derived by the three-point method as used by Mr. Gardner S. Williams; the latter being 21,860.

Mr. Williams in stretching a thread over the observations at the International Bridge of the Niagara River determines an increment of 21,600. It would appear that whatever method is used in determining the increment from the observations in the three cases of the St. Clair, the Niagara and the St. Lawrence, has little bearing on the issues in this case in my judgment.

A reservation should be made to this statement, that when you leave the straight line equation and begin to deal with curves, the three-point method no longer applies, and Mr. Williams' own statement in his testimony is that the method of least squares under these circumstances is the best method used.

I might add that in the case of the Niagara River, the very close check between the use of the three-point method and the method of least squares and the stretching of a thread comes from the fact that there is such a multiplicity of observations, and such excellent accord, that it does not make much difference what method you use in deriving the line indicating the law of discharge. I should add moreover that the range of four feet makes the trend of this line unquestionable within five per cent.

Now I have departed somewhat from the matter of the derivation of the increment of the St. Clair River by Mr. Williams. Mr. Williams then goes into the matter of the inclusion of the discharge work of the year 1901, which was not utilized in the computation of the increment of the St. Clair, as shown on U. S. Exhibit Number 1.

Mr. Williams corrects the observations of 1901 for the backwater effect or the lack of backwater effect of Lake St. Clair, and makes a computation in which he uses these. I do not know whether it is necessary for me to go into detail and indicate the increments derived by Mr. Williams.

Q. Not all of them, just the general method, and then in detail as to the one that he finally gives as being the correct one in his opinion.

A. Mr. Williams then gets out increments by the method of taking sets of observations in which Lake St. Clair is reasonably constant in stage, while Lakes Michigan-Huron is va-

rying, and in that way he determines, or attempts to determine an increment for the St. Clair River due to the stage or elevation of Lakes Michigan-Huron alone.

Mr. Williams then reverses the process, and taking reasonably constant elevations of Lakes Michigan-Huron, he finds what the effect, or attempts to find what the effect of the level of Lake St. Clair is in retarding or accelerating the outflow. While this method, which I believe was employed by Mr. Sabin, and I myself accept as a method of deriving increments, the application and detail of computation used by Mr. Williams are in my judgment not defensible.

I think I might refer to the table, in which Mr. Williams shows his derivation of individual increments, and in his summation and mean.

I wish to refer to Table 25, in Williams' Exhibit 34, in which he is discussing, by the method already stated, the increment of the St. Clair River for the changes in the elevation of Lake Huron at the head of the St. Clair River. These are from the observations of 1908 and 1910. The first increment derived utilizes as the data three discharge observations and the mean elevation of Michigan-Huron by the three discharge observations is 580.34. The center of gravity—or the elevation of one of the observations is evidently 580.32, and the extreme range of Huron level indicated by the center of gravity of the three points considered is .03 of a foot.

The second derivation of increment in the same table—

Q. Just on that one, what effect does that range or lack of range have upon the result?

A. I think no engineer, even Mr. Williams, would wish to state that there was any consequence whatever in an increment derived with a change of lake elevation of .03 of a foot.

Q. Why not?

A. The precision of the increment is proportional, other things being equal, to the range in the level of the lake between the observations. If one should take a set of observations with ten in each group,—two sets of observations with ten in each group, and there was a foot difference in elevation in the lake stage between the two, the error in the increment would be likely to be as much as ten per cent. or more; and where you took only .03 of a foot instead of a foot, why the increment is likely to be several hundred per cent. in error. By taking a large number of stages, the error in the result would be considerably diminished, but the method in

my judgment, the method of applying this treatment is not the proper one.

Q. That is because any error in your observations referred to that small range of stage would give a much greater percentage?

A. Yes. I wish to point out that in the increments derived by Mr. Williams in this table number 25, they range all the way from 7,500 up to 74,060.

In other words the range of the deduced increment itself, in the latter case, is nearly 10 times the increment derived in the former case. The variation of the increments derived by this method is all the indication necessary that the method itself is a trivial one. When I say that I mean the treatment, as Mr. Williams has given it.

On the following page, table 26, of the same Exhibit 34, the backwater increment for Lake St. Clair is indicated, and I find that in some of his derivations here, the increment is plus instead of minus. By this I mean that when Lake St. Clair rises, it increases the volume of outflow of the St. Clair River, which is contrary to all hydraulic laws, and contrary to Mr. Williams' own conclusion in the case. These increments vary, the backwater increments of Lake St. Clair, from 15,830 with a plus sign to 90,000 with a negative sign. This range of the derived increments is sufficient indication of the weakness of the method pursued.

I have mentioned only two of the tables in which Mr. Williams has used that particular treatment, and those did involve the observations of 1908 and 1910. In earlier tables he uses a similar treatment for the observations of 1899 up to the observations of 1908 and including the observations of 1908.

In table 22, Mr. Williams uses the observations of the years just mentioned and I note that his extreme range in one set of observations—and when I say extreme range it is the range of the three points in the three-point method of reduction—is 12/100ths of a foot. That is the top line of table 22, with 15 observations utilized. In a group of four observations in the middle of this table, the range between the extreme groups of the three-point method is 12/100ths, again.

Q. In general, I understand Mr. Shenehon, that Mr. Williams got an increment for the St. Clair by a certain method; another one for the Niagara and another one for the St. Lawrence; and then starting with those increments, checked them or re-determined, starting from one to the other by what is called the consistencies or inconsistencies of the rivers, the

ratio of fluctuations, taking into consideration local supply, and reached a final conclusion a little different from the one he had started with. Is that correct in general?

A. You refer to the method of fluctuations, what has been called in this case method of fluctuations, passing from one river to another, to determine an increment.

Q. Yes. But he first got certain increments in the way you have stated it?

A. I had not completed my statement in that particular.

Q. He first got some increments from the measurements themselves, didn't he?

A. Yes.

Q. You were engaged in explaining how he got his increments in the first place, to start with?

A. Yes.

Q. All right.

A. I believe the method that Mr. Williams finally concluded as the best method for his purposes, because he utilized it in the case of the Niagara and the St. Lawrence as well as the St. Clair was the method of taking groups of observations selected at times when the conditions were quiescent, or at least his attempt was to select groups of observations at quiescent periods of the lake.

Now, in carrying out this method on the St. Clair River, Mr. Williams selected 12 different periods; and combined the observations for the mean lake level of Michigan-Huron and St. Clair for each of the periods concerned, except that he advanced the date of the St. Clair observations for elevation or level of the lake by one day.

Mr. Williams in addition to that weights the observations, in proportion to the time interval between the observations as observed. For the earlier period prior to 1908, I believe it is, in these 12 groups, Mr. Williams selected 80 observations. By this method of weighting, he created four more observations making what he calls the weighted observations 84. Now this method of treatment assumes that the flow in the river, as I understand it, is so uncertain and so much out of equilibrium that it is necessary to take a considerable number of days in order to have static conditions, or conditions of even flow.

The fact however, as indicated by the observations themselves, is that the flow in the river is determined by the elevation of the lake at the head of the river at the time of the observation, or a few minutes preceding that time. This is

clearly demonstrated in the observations of the St. Clair River and in the observations of the Niagara River.

The method used assigns as part of the reason or cause of the flow in the St. Clair River a certain number of hours in advance of any individual observation or a certain number of hours after that particular observation, and the effect of this is to flatten out the elevation of the lake surface, which really controls the discharge. In other words, when we are observing for discharge, the lake varies to some extent on either side of what may be the mean level of the lake at that particular time. There will be some observations for flow in which the lake is above its mean level, and some observations in which the lake is below its mean level. Now, for the top or group of highest elevation, the effect is this: That the volume of discharge is referred to an elevation which is below the elevation of the lake which created it, and for the bottom observation, the bottom group of observations, the lake is referred to a mean elevation which is above the elevations which really created the discharge.

Now, I have not as a matter of fact analyzed the grouping in the St. Clair River, and what I speak of now refers more particularly to the Niagara River. The effect of this is to keep the volume of flow as observed by the United States Lake Survey while decreasing the change of lake elevation between. That is it diminishes, lessens the divisor in the fraction by which we determine the increment; the increment being the difference in volume of flow dvided by the difference in lake elevation. Of course this has the effect of making the increment appear larger and making the loss of level due to any diversion in the lake less.

Now, Mr. Williams' treatment of Lake St. Clair by advancing it 24 hours, I think has no bearing on the case, no tangible bearing on the case and his method of beginning at midnight for instance on the day on which his group of observations begins, puts in at least eight hours of Lake Huron elevation, which has no bearing, in my judgment, on the volume of outflow.

I wish to speak a little bit more about Mr. Williams' method of weighting observations. Mr. Williams gives a weight of unity, or one, to the observation of a single day, whether there are five observations on that day or whether there is one. That of course is destroying observations. On the other hand, if he happened to have an observation on Saturday and Sunday comes along and there are no observations there,

possibly none on Monday but there are some on Tuesday, then because there has been a time interval between these particular single observations, a time interval which has been included in determining the element, he gives a reward of merit to these observations for the falsification which has been put into them. In other words he has used something that has nothing, in my judgment, to do with the discharge, and rewarded the observations by giving them increased weight. In other words creating observations in the same process.

I see no justification whatever for a treatment of that kind. Now, Mr. Williams reaches by this particular method of reasoning and computing, a conclusion that the increment for the St. Clair is in the neighborhood of 29,000 cubic seconds feet.

Q. Is that same general method used in all the rivers, by Mr. Williams?

A. I wish to go into the difference in method in the Niagara and St. Lawrence a little more. And in his final testimony, Mr. Williams states his best judgment that 29,000 is the best increment for the St. Clair as applying to the issues in this case, and that it may be ten per cent. greater than that.

I wish to show what this method of weighting, what it actually amounts to in Mr. Williams' treatment of the 1908 and 1910 observations. He makes seven groups out of those observations. Mr. Williams starts with 161 observations, and by his method of weighting he destroys 88 of them and finally utilizes 73. Now, in his totals Mr. Williams, according to weights, has used 157 observations out of 488 that are now available and have been used by the United States Lake Survey in determining the increment which has been put into this case by Mr. Ray and other engineers of the United States Lake Survey. This increment, as I recollect it, is in the neighborhood of twenty or 21,000.

Now, in the case of the Niagara River, Mr. Williams assumes without any basis of authority in any observation, so far as I am aware, and in contradiction of the observations as indicated themselves, and as finally admitted in the cross-examination by him,—he assumes that the discharge of the Niagara River is dependent on the elevation of Lake Erie at Buffalo for some hours in advance of the measurement of the discharge observation itself.

Mr. Williams, in selecting his groups in the Niagara River

includes the gage elevation, the mean daily gage elevation of the day preceding the observations in his group, preceding the first observation of those in his group. He includes the last day up to midnight, the mean elevation of the last day on which observations are taken in any particular group. Now the effect of this is to put into the elevation which he takes to control or cause the outflow from Lake Erie through the Niagara River, 31 hours in advance of an observation that might begin on eight o'clock in the morning of the first day on which observations were made.

It is a matter of fact, as determined by observations, that the elevation of Lake Erie at Buffalo gage is the cause of the outflow of Lake Erie, with a time lag of 8 to 10 minutes.

Q. At the gaging—

A. At the gaging section, at the Open Section of the Niagara River.

It is a further fact that the time interval for change in conditions of the river between the Buffalo gage and at Chippewa, which is about 20 miles down the river, is approximately 2 hours, and that at the Suspension Bridge gage, which is a couple or three miles further down the river, the time interval is a little over three hours.

Mr. Williams has himself in his testimony accepted his error, as I understand, in this record, and I do not, in the case of the Niagara River, need to dwell on this any further. I do wish to say however that in the case of the Niagara River Mr. Williams has rejected observations and neglected observations, and put them in in a way that is hardly helpful in securing a result in a scientific investigation.

I understand that the direct testimony of both Mr. Freeman and Mr. Stearns, so far as the Niagara River is concerned, depends on Mr. Williams' earlier testimony, in which these rejections, and in which these observations neglected, and in which this improper intrusions of winter observations was contained. Specifically, out of 219 observations available for the International Bridge Section, and in the record in this case at the time Mr. Williams testified, he utilized 30 at the International Bridge Section. Through an oversight, he included some winter observations. These winter observations had the effect of increasing the increment. In the case of the Open Section, Mr. Williams utilized 89 out of 121 observations.

Now, it goes without saying, I think, that if a man is free to accept and reject observations, he can reach almost any

conclusion he may wish. It is a most dangerous thing to put in the hands of an observer, the right or ability to reject observations without ample cause.

In the case of the St. Lawrence River, Mr. Williams in his method of chronological periods and weighting of observations, utilizes the day before the observations began, and does not use the day on which the observations were ended, in deriving the mean elevation of the water surface in the river at Ogdensburg, which determined the flow. Here, in the St. Lawrence, Mr. Williams used the same freedom, a freedom of rejection, and in his selection of quiescent periods included those that are very far from quiescent. The method of deriving an increment in this way has always, as Mr. Williams has used it, gotten a bigger increment than the increments indicated by the exhibits 1, 2, 3 and 4 of the United States in this case.

I want to return to the St. Clair River and its increment, as indicated by Exhibit Number 1, just referred to. In that exhibit, the increment was shown as 23,820. In my direct testimony, I stated that I believed this might be in error as much as 25 per cent., indicating that the increment would lie somewhere between 18,000 and 24,000 roundly. The values of the Lake Survey utilizing the 488 observations in making the determination indicate an increment somewhere in the neighborhood I believe of 21,000, confirming my original view.

The time of travel between the Ogdensburg gage and the gage at the three-point section on the St. Lawrence, was approximately two hours and 40 minutes. The distance is about 16 miles.

Q. Mr. Shenehon, Mr. Williams, also Mr. Stearns and Mr. Freeman checked on some of these increments and reached new and similar opinions in regard to the increments by taking into consideration what we have spoken of as the ratio of fluctuations and the lack of consistency between the rivers in reference to the Government's increments. Will you simply explain just what method was used and with what result?

A. When the mean annual elevations of the lakes Michigan-Huron, Erie and Ontario was plotted, Michigan-Huron with respect to Erie, for instance, the observations aligned themselves to a certain extent, indicating that there is a certain relation in the fluctuations of the two lakes concerned. In the case of Lakes Michigan, Huron and Erie, for instance, as indicated by Shenehon's Exhibit R, Erie appears to fluctuate about 70 per cent. of Michigan-Huron. Now this rela-

tion of lake surfaces, or the adhesion to this relation by the lakes themselves, is not very close for particular years, but taken in five-year means, it shows a very substantial adherence to the ratio indicated.

Now in my earlier testimony, I touched on this same matter and I was asked why Michigan-Huron fluctuated one foot for Erie's fluctuating only .7 of a foot; what was the reason of it, and I answered because it was running that way. What I mean is, what Mr. Williams himself has stated in his testimony, that this is an empirical relation. It is not like the relation of fluctuations which we have on a river like the Niagara, where it is most determinable from day to day, and is a hydraulic relationship. This ratio of fluctuations between great reservoirs like the lakes themselves, is only in part due to the increments of the outflow rivers.

Now, if the St. Clair River and the Niagara River and the St. Lawrence River were free of ice all the year around, we would have in my judgment a very close approximation to a rational relationship between these rivers, when you take into account the change in the supply coming into each reservoir. But we have this condition on the St. Clair River in particular: During the winter season, ice gorges form at times shutting off half the flow of the river. This means that Michigan-Huron must rise because the water is being impounded, and that Lake Erie must fall, because the water impounded in Michigan-Huron is denied to Lake Erie, so during the periods each year, and in certain years during long periods and in large percentages, this abnormal relation exists. It follows then that the relation of fluctuations of Michigan-Huron, Erie must take into account the ice periods, and for that reason the relationship is an empirical one, depending in part on the increments of the rivers, and more particularly that would be during the open season, and then falsified or changed to a certain extent by this condition entering in from the winter flow. This means that Michigan-Huron is always at an artificially high stage and Erie is always at an artificially low stage. Now you may argue by the law of fluctuations from the increment of one river to another, but not with any certainty whatever. And the determination of an increment by this method is crude and inaccurate, in my judgment, compared with the method of deducting the increment from the discharge observations themselves.

The methods used by Mr. Williams and reiterated by Mr. Stearns and Mr. Freeman were to start on the St. Clair with

an inflated increment, in other words an increment derived by methods that in my judgment are inaccurate, and therefore which has been enlarged beyond its proper size; doing the same thing on the St. Lawrence, and by a method of fluctuations determining an increment for the Niagara River. This increment I believe is 34 or 35,000 as finally determined, and shows a line that appears to bear no intimate relation to the discharge observations. After Mr. Williams' conclusion that the Niagara River was really too turbulent to be considered in this case so far as deriving an increment from the discharge observations is concerned, Mr. Williams gives 34,000 or 35,000 as his best judgment as an engineer of the increment of the Niagara River.

Now, Mr. Stearns had a method of deriving an increment also. Mr .Stearns starts with the St. Lawrence and creates by putting in the local supply between the St. Lawrence and the Niagara, he creates the volume of flow in the Niagara River. And in a similar way he deduces from the St. Clair and putting in the intermediate supply, he deduces again the discharge of the Niagara River and with it and these various volumes of flow as indicated by his mean determinations, he derives an increment in that way. I believe on the face of it, this method of derivation is so uncertain, or in other words it is so certain to give erroneous results, that it needs little comment. When I come to the matter of discussing the supply, the runoff and so on as determined by Mr. Stearns and Mr. Williams, I think it will become very apparent that the actual amount of the runoff, the local supply of any one of these lakes is a quantity that is too indeterminate and has such different dimensions when gotten out by the different witnesses for the Sanitary District, and I may include in that Mr. Thomas Russell of the Lake Survey itself, that it is not safe to determine the trend of a line that really requires very accurate measurements by any such inaccurate method.

Mr. Adcock: What do you mean by that?

A. You read your own testimony and you will strike that. It has certainly been referred to by your own witnesses, both Williams and Stearns, and Freeman.

Q. You said "including Thomas Russell of the Lake Survey."

A. Yes, sir.

Mr. Williams: If you would include the report of Thomas Russell, I think you would be all right.

Mr. Hopkins: As referred to in this testimony?

The Witness: As referred to in this testimony, and as indicated by his report of 1904, already referred to in this case.

Mr. Austrian: Q. That is he is in the same position as the others. I understand his conclusions—

The Witness: I will discuss that a little later.

Mr. Austrian: I would like to get something—

Mr. Adcock: Q. You are referring to the report of Thomas Russell of 1904, are you not?

A. Yes.

Q. That has been referred to in evidence?

A. Yes, I so stated, Mr. Adcock.

Q. You said including Thomas Russell. I did not know whether you referred just to the report, or something else he might have said.

A. I did correct that.

Mr. Hopkins: Q. Mr. Shenehon, how did the witnesses for the defendant determine their increment, using the ratio of fluctuations; what stream did they begin with and just how did they reach their conclusions, in a very general way?

A. The Niagara River increment as determined by the ratio of fluctuations began, started with the inflated increment of the St. Clair, and producing an increment by the ratio of fluctuations, and the change in supply between the two rivers, utilizing Mr. Williams' ratios, I believe, of fluctuations; and then starting on the St. Lawrence with an inflated increment and proceeding by the law of fluctuations with the change in supply between the St. Lawrence and the Niagara.

Q. Have you determined an increment by the same or a similar method, beginning with the Niagara River increment as determined by the Lake Survey? If so, what result did you get?

A. Yes, I started with the increment of the Niagara River of 21,900. I believe in this discussion I called it even 22,000; and proceeding by the same methods as used by Mr. Williams, I derive for the St. Clair an increment of 14,600, and in doing this I use the ratios indicated on Shenehon's Exhibit R; that is the relation between the Michigan-Huron, Erie as 70 per cent. and between Erie and Ontario, 135 per cent.

For the St. Lawrence, I derive by this method an increment of 18,800. Now, for reasons already stated, I have shown that this method of deriving an increment is an approximation only and is subject to the error in the co-efficient or ratio

utilized. This is not the true hydraulic ratio, but is an empirical ratio which involves ice effect, local supply, run-off, rainfall and so on and is a rather crude approximation.

There is a reason however that the all the year around increment of the St. Clair River is smaller than the increment derived during the open season because the ice conditions are likely to cause a lower increment during the ice period, so that the all the year around increment must be taken in connection with the ice period, as well. The increment for the whole year is a thing that would determine the lowering due to such a diversion as that at Chicago.

In the case of the St. Clair River, we have extreme ice conditions, as indicated by our records of rivers in the Lake Survey, and in the case of Lake Ontario the ice conditions are less pronounced, so far as the retardation of flow from Lake Ontario is concerned.

Here again on the St. Lawrence, however, there is the chance or probability that the winter increment is a little less than the summer increment and that the all the year around increment is less than the values given by the discharge observations and the loss of level for both Ontario and Erie is likely to be somewhat in excess of the values derived from open season increments.

Now it appears to me the most reasonable method of procedure to start on the river that is midway of the series, the series being St. Clair, Niagara and St. Lawrence, and derive the increments for the other two rivers. It appears to me reasonable also and proper, because the increment, in my judgment, of the Niagara River is the best established of the increments of the three rivers concerned.

Q. Why is that so?

A. I stated this in my earlier evidence in 1909. I stated that in my judgment the increment of the Niagara River was known within 5 per cent.; the increment of the St. Lawrence, within 10 per cent., and the chart, U. S. Exhibit number 1, showed an increment for the St. Clair that might be in error 25 per cent. The increment for the Niagara River covers a range of lake stage of nearly four feet, 3.92 at the International Bridge. It is a case where we have the increment of the river corroborated, the increment of the river at the International Bridge Section corroborated by the increment of the river at the Open Section. These are very definitely indicated by Shenehon's Exhibits B and D.

The increment is further corroborated by the derivations

taken out for the Gorge Pool and Whirlpool as shown by Shenehon's Exhibits E, F, G and H.

Q. How about the number of measurements in the Niagara River, number of observations?

A. There are 340 observations, for discharge, utilized in Exhibits B and D, already referred to.

Q. Is there any backwater effect in the Niagara River?

A. No, the conditions hydraulically are the simplest of any of the rivers considered. The increment of the St. Clair on the other hand is the most complex problem, so far as the derivation of an increment is concerned that we have in this case, and Mr. Gardner S. Williams so states in his testimony. I think I am correct in that. I can refer to his words if you wish.

The backwater effect from Lake St. Clair has made the problem an exceedingly difficult one, and it was for that reason that I indicated in my earlier testimony my judgment that the increment might be 25 per cent. in error.

We have at the present time, however, 488 observations on the St. Clair and we are getting closer to the increment certainly, and as I before stated it is in the neighborhood of 20,000 or 21,000. But we have always had, as indicated by the various reports, on the St. Clair a big range in our increment. It has ranged anywhere from 16,000 up to 24,000, and Mr. Williams runs it up to 29,000, so the thing is very indeterminate. Perhaps I should exclude Mr. Williams determinations in this case.

In the case of the St. Lawrence, we have not a very good range of Lake stage during the observations; just two groups of observations, with 93 discharge observations; range of a little over two feet, extreme range. The proper method of procedure, therefore, in my judgment, is to begin on the Niagara River and by the method of fluctuations proceed to the increments of these two rivers in which the increments are less well known.

Q. How many of the observations on the Niagara River were made by you and how many by other men in the Lake Survey Office?

A. I myself, personally, handled the instruments on a very small percentage of the observations, probably less than 10 per cent. The observations, however, were made under my direction and under my planning, in conjunction with Mr. Haskell, as principal assistant engineer of the Lake Survey. We utilized, however, 19 observations, I believe, which were

made by the Board of Engineers on Deep Waterways, by Mr. C. B. Stewart. While I was in charge of the Buffalo office at that time, I did not interfere in any way with the measurement of the volume of flow. Mr. Stewart had been working on that in conjunction with Mr. Haskell, and he proceeded under the methods in use at the time that I reached Buffalo. That was a period of two months that I was there.

Q. Did you hear the testimony in this case of Mr. Richmond, Junior Engineer, United States Lake Survey Office?

A. Yes, sir.

Q. Are you familiar with the section which he measured, he testified he measured?

A. Yes.

Q. Known as the Split Section?

A. Yes, I have visited the section, or the two sections on either side of Grand Island.

Q. What are the general conditions there as to turbulence, and as to being proper sections for discharge measurements and so on?

A. I regard the sections as excellent ones, speaking of the two individual channels. The current velocity is lower than I myself prefer to select for a discharge section, but for the corroboration or the check on the sections further up the river, this is a most valuable deviation from the rule that I myself have made in selecting more rapid currents. It gives a bigger variety in the sections measured. There was no indication whatever of any turbulence in the water.

The whole reach of the river from the head of Grand Island, or even further up, from a little below the International Bridge, the whole reach of the river is reasonably placid. Perhaps I might make that from the foot of Squaw Island to the vicinity of Niagara Falls, the river is running placid and serene; and during the summer season it is a place where a large number of pleasure craft of all kinds are in operation, launches, row boats. It is one of the play grounds or play rivers of the people of Buffalo. I regard it as an excellent selection of a section. And as I say, I visited the section and observed the condition of the river, and the flow at that point, or those two points.

Q. You referred to the difficulties in determining the run-off in making up the local supply, say of Lakes Erie and Ontario. There have been three different computations introduced in evidence as to this run-off, or referred to, one by Mr. Williams, one by Mr. Stearns and one that of Mr. Rus-

sell in the Lake Survey, referred to. Will you just tell what those various methods were, beginning with Mr. Russell's, and the relative values of the methods or results obtained by each.

A. The method of reaching a generalization as to the run-off used by Mr. Russell was to assume that the yield or contribution of the Lake Erie basin, including the land area and the lake itself, was in the same proportion to the supply or yield of the basins of Lake Superior and Michigan-Huron.

Under this assumption the Lake Erie basin should contribute 30,100 cubic seconds feet.

Using this generalization the yield per square mile of territory is the only consideration. It ignores in every way the topographical conditions, and the geological conditions, the conditions as to forestation or cultivation, and simply makes this broad generalization. Of course this is not a determinate method of arriving at the solution of this very important factor in the case.

Mr. Russell in other places in his report of 1904 speaks of the run-off as six-tenths of the rainfall. As the rainfall is about 34 inches for the year this would give a run-off approximating for the year 45,000 cubic seconds feet.

Q. Does he in determining the run-off take into consideration rainfall or evaporation, at all?

A. No, not in that generalization. He treats the evaporation from the lake surface as a separate affair.

Q. And in trying to determine the run-off of one part of that big drainage area of the Great Lakes, as against another part, is there any value in the method used?

A. As indicated by the conclusions of Mr. Gardner S. Williams in this case, which I regard as the only professional conclusion reached in the matter of run-off in this case, Mr. Russell is widely in error.

Q. Now what is Mr. Stearns' method of determining the run-off?

A. Mr. Stearns' method, as I understand it, was to work out a formula from certain drainage basins in New York State, Massachusetts and Pennsylvania, and then proceed to apply this formula to the drainage basins of the Great Lakes. I think it is generally conceded that run-off is a very complex thing. Mr. Stearns, as I understand it, did not give any large considerations, or give any consideration to the topographical or geological conditions of the two drainage basins concerned. And Mr. Stearns' values may be regarded

as estimates reached by a formula derived on water sheds that are not comparable, in my judgment, to those of Lake Erie and Lake Ontario.

Q. What was Mr. Williams' method?

A. Mr. Williams examined such data as was available of the stream flow, the streams entering Lake Erie and entering Lake Ontario. In the case of Lake Erie, he examined the flow for a period of years of streams in Lake Erie, amounting to about 33 per cent. as I recollect it of the run-off basin; and in the case of Ontario, 37 per cent.

Now we have not, so far as I am aware, in any engineering literature, any statement of the run-off that has the professional scientific basis that the conclusions reached by Mr. Williams have. It is a contribution to our knowlege of the Great Lakes.

Q. Now taking the values given by Mr. Williams for the run-off, and taking the evaporation and rainfall as given by either Mr. Williams or Mr. Stearns, what is the consistency between the rivers, as measured by the United States Engineers?

A. I would like to state first certain conclusions, as I understand them, derived by these three men mentioned. As I understand it, Mr. Thomas Russell makes the summer run-off of Lake Erie about 45,000 cubic seconds feet. During the months, June to November, inclusive, Mr. Gardner S. Williams makes the run-off 7,640. During the same months, June to November, Mr. Stearns mades the run-off for Lake Erie 16,230. Mr. Stearns' figures are more than twice those of Mr. Williams, and Mr. Russell's are somewhat in excess of the figures of either of them. I am not certain that Mr. Russell's figures are not for the full year.

In the case of Lake Ontario, Mr. Gardner S. Williams' figures are 23,800 cubic feet per second and Mr. Stearns' figures 15,260.

Now, I don't know what Mr. Russell's are for Lake Ontario. I have not looked them up. Having in mind these values—

Q. Did Mr. Russell make any observations whatever in regard to these determinations?

A. I understand Mr. Russell's generalization is a matter of judgment taking .6 of rainfall for year, somewhat less for summer.

With these wide variations in the generalization of Mr. Russell, the estimate of Mr. Stearns and the determination of

Mr. Williams, the danger of attempting to produce an increment for the Niagara River by starting at the St. Lawrence or starting at the St. Clair, to my mind becomes very evident.

While on this matter, I want to take up another thing where Mr. Russell has been quoted in this case; his 1904 report has been quoted by Mr. Williams. That is his reference to 81 inches of evaporation on the surface of Lake Erie. This 87 inches, as I understand it, is a deduction from the guess as to the run-off of the Lake Erie basin, and Mr. Williams in particular, with his knowledge of the run-off, might be regarded as unjustified in referring to this conclusion reached by Mr. Russell in this case, in that report referred to.

Now, I myself, have made a determination or computation with a view of investigating the question of whether or not these three rivers, the St. Clair, the Niagara and the St. Lawrence, are consistent and in accord. That is if you start with the St. Clair and put in the local supply and reach the Niagara, whether or not you reach a value that is consistent with the observed value. And then proceeding on down to the St. Lawrence, or starting at the St. Lawrence and coming back to the Niagara, you get consistent results.

In this determination, we have certain things that have been subject to criticism, but I am willing to pass those by because none of us has any very accurate knowledge as to the evaporation of the lake surfaces. We have no very valuable information as to the rainfall on the Great Lakes, and when I say this, I mean as to the absolute quantities. We may know the relative values of these things tolerably close, but as to the absolute quantities we haven't any very definite information. So, I am willing to accept the values put into this case by Mr. Stearns in his Exhibit Number 1, as being sufficient for the purposes in hand. I refer to the lake surfaces in mentioning evaporation and rainfall.

Now, starting with the St. Clair River, using the Lake Survey equation as indicated in the report of 1912, which I regard as the best value we have for the volume of flow for the St. Clair River, and confining this investigation to the months of June to November, inclusive, used by Mr. Stearns in his Exhibit 1, and taking a series of years beginning in 1891 and ending in 1906—I take that series for three reasons: One is that it is alleged in this case that there was a change of regimen in the St. Clair River about 1889-'90, so I begin with the year 1891, and I terminate with the year 1906,

because that is as far as Mr. Stearns carried it, and I wish to use his values as derived in his Exhibit 1. That is one reason. The other reason is because the years are fairly symmetrical, around the earlier discharge observations, at least. And another reason is because we have a more definite knowledge in these later years both of rainfall and elevations of lake surfaces than we had in the earlier years. The local supply and storage which is indicated on Table B, column 6, of Mr. Stearns' report I change only by substituting Mr. Williams' value for the run-off, 7,640, instead of the mean value, 16,230, used by Mr. Stearns. The local supply, as I make it, is 15,100, that is, local supply and storage. I accept Mr. Stearns' figures for the storage because I checked him and know that his figures are accurate. That is an easily determinable thing. The deduced value by adding the local supply and storage to the volume of flow of the St. Clair River is 211,100 for the flow of the Niagara River. The flow as indicated by the equation of the Lake Survey, Government's Exhibit Number 3 in this case, is 206,500. This shows an accord, an agreement between the flow of the St. Clair River and the Niagara River of 4,600 feet, which is about 2 per cent. The value derived from the observations of discharge on the Niagara is 4,600 smaller than the deduced value by adding the intermediate supply and storage.

Now, starting on the St. Lawrence River and coming to the Niagara River, I refer to Shenehon's Exhibit T. This is self-explanatory, I believe. It takes the value of the St. Lawrence River from the Lake Survey report of 1912, and takes the same value for the Niagara River as computed from the discharges as just indicated as coming from Exhibit 3, U. S. Exhibit 3.

The conclusion appearing from this sheet is that the St. Lawrence checks the Niagara within 4,600 feet; and in this case the actual value of the discharge derived from the discharge observations is 4,600 feet less than the value derived by interpolating or deducting the intermediate supply of Lake Ontario.

I wish to state in this Exhibit T, the run-off for Lake Ontario is taken from Mr. Stearns' Exhibit Number 1. Now, as I believe that Mr. Williams' values for the run-off are much to be preferred over those of Mr. Stearns, which are more or less estimates, I have proceeded to make an analysis starting with the St. Lawrence, using the same value for the mean flow of the 16 years as used in Exhibit T, using the same local

supply and storage as determined by Mr. Stearns except that the run-off is taken from the values given by Mr. Gardner S. Williams in his Table 59A, Exhibit 34.

This shows that the Niagara River as deduced by subtracting from the St. Lawrence the intermediate supply and storage, checks the volume of flow indicated by the discharge observations within 4,000 cubic seconds feet; and this indicates that the value of the flow derived from the discharge measurements is 4,000 feet too large as compared with the St. Lawrence.

Now, it should be noted that in the analysis, utilizing Mr. Stearns' run-off, the check is within about 2 per cent., but on the other side, Niagara being indicated as too small, while using Mr. Williams' figures for the run-off, the Niagara is indicated as about 2 per cent. too large.

That is the value of the flow shown by the discharge observations is too large. As an inference or corollary from these statements, if we use Mr. Gardner S. Williams' figures, the St. Clair and the St. Lawrence River checked each other within about three to four per cent. indicating for the whole series an excellent corroboration.

Recess to 2 P. M.

After Recess 2 P. M.

FRANCIS C. SHENEHON, resumed the stand and further testified as follows:

Mr. Hopkins: Q. Mr. Williams in his testimony gave some opinions in regard to the consistency or lack of consistency of rivers, using those elements of local supply you were speaking of this morning. Just what was his method and wherein is it fallacious, if at all?

A. As I understand the analysis made by Mr. Williams to determine the consistency or the converse of the three rivers, St. Clair, Niagara and St. Lawrence, Mr. Williams chose the years 1900 to 1904, inclusive, and proceeded to write out the volume of flow from the St. Clair River without taking into consideration or including the retardation of the ice period.

Mr. Williams then introduces the intermediate supply much as in the case indicated by my testimony this morning in

the physical analysis, except that he uses the full year, that is, taking the run-off from the Erie Basin, taking the rainfall on the lake surface and the evaporation from the lake surface; then the volume of flow of the Niagara River, giving no correction for any possible small ice conditions that might prevail.

He then takes the local supply of Lake Ontario including the run-off, the rainfall on the lake surface, the evaporation from the lake surface and finally the volume of flow of the St. Lawrence River during the full year, without making any deductions, as I understand, for the retardation by ice coming in the winter months.

Now, in my judgment it is an erroneous method in the fact that Mr. Williams did not make any correction for the flow of the St. Clair River by reason of the ice periods. The particular years used by Mr. Williams include the years 1900, 1901, 1902, in which years Mr. Louis G. Sabin made observations and deductions as to the ice effect.

Sabin's report on this subject is shown on page 2837 of the Lake Survey Report of 1902. As an inference from the retardation shown in the years 1900 to February 1902, inclusive, it appears that the mean retardation due to ice spread over the full 12 months of the year for the three years concerned averages 14,200 cubic seconds feet. Should this average be present also in the years 1903 and 1904, it would seem to me that Mr. Williams should make a correction, in other words, cut down the volume of flow of the St. Clair as indicated in his statement by from 12 to 14,000 cubic seconds feet.

Now, I believe it to be a matter of fact that the retardation of the Niagara River by reason of ice is exceedingly small. That is, the retardation of the outflow. The ice troubles in the Niagara River are those in the vicinity of the Falls. The power companies sometimes have considerable difficulties with ice, but the ice is of a kind that has very little effect on retarding the outflow of the Niagara River; the position of the ice in the lower river at Chippewa, has a very small effect.

The ice effect in the St. Lawrence River is known to have some considerable dimension. That is discussed in my own report of 1902, where the methods used are not entirely conclusive, but it has some considerable value I think in showing the retardation from ice in that river, but the principal case where ice is a big factor so far as the retardation of the outflow is concerned is in the St. Clair River.

I believe also Mr. Williams neglected the change in outflow in the St. Lawrence due to the building of the Gut Dam in 1903. That, however, would involve only the year 1904, and part of the year 1903, and the error entering on that account would be not large.

I believe Mr. Williams also neglected the change of storage, but the error coming from that I think would be small. I am not certain as to that change of storage. It is immaterial; the change of storage would probably be very small.

Q. I call your attention to plate 10 of Williams' Exhibit 34, which purports to show dredging in the St. Clair River, Lake St. Clair and Detroit River; and call your attention to the two large white portions which are supposed to indicate the amount of dredging. I wish you would tell just where those are, and what effect, if any, that dredging would have upon the outflow from Huron to Lake Erie.

A. This plate 10 is misleading, as all profiles are likely to be where a large distance is squeezed up, relatively, and elevations are shown on a large scale. Glancing at this chart casually, I should be inclined to think that some very important dams have been removed at the head of the St. Clair River, at the foot of the St. Clair River, at the head of the Detroit River and in the lower reaches of the Detroit River.

Q. Just where were those removals? Take first the one shown above Fort Gratiot?

A. Now, what appears on this profile, or what looks to me like a dam with two points on it, two crests at the lefthand side, is the dredging done on what is known as the middle ground which is about a mile and a half out in Lake Huron. As I recollect it, the dredged cut there is about a thousand feet wide and the material was dumped alongside, so that any material taken away is redeposited in their regular dumps alongside. But the lake there—I am stating this somewhat at random, but it is my belief—at right angles to the sailing course is two to three miles wide. I believe therefore that the removal of this material could have had no influence whatever on the outflow conditions of the St. Clair River.

Now, the dam, or what appears on this plate to me to be a dam at the foot of the St. Clair River, is in part across the bar at the Delta of the St. Clair River, extending in a straight line the south channel.

Now, as a matter of fact this has removed some material, most of it being in the lake itself, and I am not sure that it is not practically all of it in Lake St. Clair where there is

such a considerable width that the effect on the volume of flow is very inconsiderable.

The amount of water that flows through this particular channel, in acordance with the report of Mr. Richmond in this case is about 30 per cent. of the volume of flow of the river at that point. The other chanels, so far as I am aware, are in their natural condition, including the old meandering course of the south channel. As a matter of fact, I believe 12-foot navigation did pass through the south channel prior to this excavation in the early days, possibly with some little excavation. I should wish to refer to the chart to verify that statement, but in the meandering course of the old south channel, which is not before me as I testify, there is a considerable depth, and when I say considerable depth, I refer to nine to twelve feet, with a possible correction on looking at the chart.

I believe that the outflow of the St. Clair River is not appreciably assisted by the removal of this material at the head of Lake St. Clair; and a similar statement should be made regarding the removal of the third dam of this series, which appears at the foot of Lake St. Clair, at the head of the Detroit River. This appears to be about two miles above the Windmill Point Lighthouse, which is the real head of the river, and therefore in Lake St. Clair material, as I recollect it was dumped alongside and had a retarding influeence that would probably take care of any little lowering effect that might come from the excavation.

The little peaks shown in the lower Detroit River appear to be from less than 1 foot to about 3 feet in depth of excavation. While the removal of these, unless compensation was complete at that point—and I understand there was some material dumped in the river that must have had some conserving effect—must have had a very small influence, as it appears to me on the elevation of Lake St. Clair, and with the small influence on Lake St. Clair, the effect of Michigan-Huron as to lowering must have been very small indeed, so far as plate 10 indicates this.

Q. I call your attention to Table 40 of Williams' Exhibit 34, and will ask you whether or not Mr. Williams took into consideration ice effect in getting those results?

A. This Table Number 40 appears to be a statement of the volume of flow of the St. Clair River by the defendant's equation by months for the years 1900 to 1907, inclusive. It appears to me that the values for the discharge, aside from

the erroneous equation used are in error further by the fact that no consideration is taken of the retarding influence of the ice, which has previously been discussed. The volume of flow for January, February and March appear to depend on the elevations of the lake surfaces, Lake Huron and St. Clair, flowing just as if the stream were entirely unimpeded, as it flows in the month of July, for instance.

Q. Mr. Shenehon, what is your opinion as to the accuracy with which large rivers can be measured, as compared with measuring small streams?

A. I should not attempt to measure a small stream; and by that I mean a stream with a volume of flow of perhaps 500 cubic seconds feet or less, with current meters of the types used in the river gaging of the Lake Survey on the rivers of the Great Lakes. I refer to types A and B. I would not expect to get a precision much better than 5 per cent.

Mr. Adcock: That is A and B of the Haskell meter?

A. Yes, the large meter I am speaking of now.

Mr. Hopkins: Q. Why not?

A. The meter seems out of proportion to the size of the channel that I have in mind. I am thinking now of the canal at Cornell, and with a depth of perhaps three and a half feet. I do not see myself how any vertical curves can be determined in a canal of that kind or in a stream of that depth with a meter of that size, that would mean anything in the final precision of the work better than five per cent. If the observer should from some other experience set down that the ratio of velocities in the vertical to the mean velocity or to some velocity measured might be 90 per cent., that might help matters.

I think I can illustrate this in this way: The wheel 7 inches in diameter in a stream of say 3½ feet in depth would correspond to a wheel of a diameter of 10 times 7 inches, 70 inches, or about 6 feet, in a stream 35 feet deep.

Mr. Adcock: Q. That is it occupies too much of the cross sectional area?

A. It occupies too much of the cross sectional area and prevents your getting the trend of the vertical curve close to the bottom or the transverse curve close to the side of your canal, in the case of the canal, so the objection on my part is that there is a lack of proportion between the size of the meter and the canal that would prevent any work of a finer precision than five per cent.

I think what appears to be good practice in the measure-

ment of small streams, to take a meter, current meter on a rod and wade out in the stream indicates that the observer does not expect a precision much better than 5 or 10 per cent., because the observer himself walking into the stream is distorting the currents; that is, he is forming what corresponds to a bridge pier, and it is a movable pier, a pier that is one place at one time, and is taken out. What the original condition of the stream flow was without the observer's interference is not determined, I should judge, by gagings of that kind.

Q. With what degree of accuracy do you think large rivers can be measured, rivers like the Niagara, St. Clair and St. Lawrence?

A. In my judgment, we have determined the volume of outflow at mean stage of the observations within 1 per cent. on the St. Clair and the Niagara Rivers, and possibly with a little less precision on the St. Lawrence River.

Q. There has been a great deal said in this record about the violence of Lake Erie changes at Buffalo. Just what changes do take place there in the elevation, and how long do they last and what are they?

A. (No response.)

Mr. Austrian: Mr. Shenehon, I would like to have you tell us with what precision in your opinion you could measure small streams, such as the Chicago Sanitary District Canal, the Illinois River, the Chicago River?

A. Well, I am not familiar with the conditions of the Illinois River. I should say a canal like the Drainage Canal could be measured with a precision better than 2 per cent. And I have in mind water power canals at Niagara Falls where the water used by the power companies is determined by the United States Lake Survey, and my belief is that the precision with which the flow is measured there is about 2 per cent. or a little better.

I may say that in my practice in the gaging of streams on the Great Lakes, we did not attempt to measure with current meters the volume of flow in the end areas, back of the terminal cribs on the Niagara or the St. Lawrence, believing that we could in those little areas get better results and sufficiently good results by running a line of floats down.

Q. (Last question by Mr. Hopkins read.)

A. I refer, in answering this question, to Shenehon's Exhibits K, L, M, and N, which is known in this case as the three curve series. During the observations of 1900, 1907

and 1908, of the Niagara River, it is rarely that the fluctuation, or rise or fall, of Lake Erie exceeds two inches in an hour, or one-half inch in 15 minutes. The gradual rise as it comes in the majority of cases during the discharge observations, or the corresponding fall of the lake is so almost imperceptible that it may not be regarded as violent fluctuations.

Of course there are cases where the fluctuation per hour is somewhat greater than I have stated, but there are so many observations during the periods when the fluctuations are at the lesser rate, or even below that, that we do not need to consider as a cause of inaccuracy in the Niagara River work, as opposed to the accuracy of the other two rivers, this matter of lake fluctuations.

Q. How do the observations when the level is changing rapidly compare with the observations when the level is changing more slowly?

A. With the rising stage, there is an increased flow of perhaps 1 per cent.; with a falling stage, a decreased flow of perhaps the same amount, and in the end the effect of the fluctuation is balanced in a series of observations. The final inaccuracy in the result and in the increment is exceedingly small.

Q. There has also been a great deal said about the turbulence of the Niagara River and the difficulty of measuring the discharge of that river. What is your opinion as to that?

A. The difficulty of measuring the discharge of the Niagara River, the physical difficulties were somewhat greater than the ordinary river that an engineer is called upon to measure the volume of flow; these are the depth of the stream, the velocity of the current. But in the end, the sections above the International Bridge, and the Open Section and the Third Section have permitted measurements of the highest precision, as I view it.

The facts as regards the International Bridge Section have all been stated by me, and I concluded, after an investigation of the error due to the eddies around the bridge piers, that one-half of 1 per cent. would in all probability measure that.

As regards the Open Section, I have made an investigation on the assumption that there may be some perturbation of the water close to the bottom. I assumed for the purpose of this computation—not as a matter of fact, but for the purposes of this computation,—that the perturbation for the

bottom 20 per cent. of the cross sectional area, bottom 20 per cent. in depth of the cross sectional area was what Mr. Groat in his paper refers to as violent boilers; and I assumed that his mean value of the under registration of the Haskell Current Meter of 3 to 4 per cent.—I took 3 1/2 per cent. as an average, and applying that even though there were an under registration of 3 1/2 per cent. in this whole area, the final effect on the volume of flow would only be 1/2 of 1 per cent., and if the conclusions of Mr. Groat are correct, would make a lesser value by 1/2 of 1 per cent. due to that cause.

While I am touching on this, I would like to state one other thing that has been brought into this case; that is the matter of the direction of flow. If the very small correction for what is known as the direction of the flow, that is the water not passing through the cross section at right angles with the section, if that has not taken into account all the deviations from the right line, then any error coming from this omission would be that we have measured the flow too great; in other words the current meter measures the volume of the flow, and the direction correction is to make it smaller. In other words this too great volume of flow indicated by an erroneous or too small direction correction tends to compensate and offset any error coming from under registration.

Q. One of the criticisms made of the work of the Lake Survey at the Niagara River has been concerning the difficulty of relating the discharge to the stage of Lake Erie. What have you to say as to that?

A. I had intended to speak, in answering the question regarding the perturbation, of what knowledge we have as to whether there is perturbation in the lower stratum of the water; and I have made a very complete study of the vertical curves, that is the relation of the velocities beginning at the surface down to the bottom in the various streams considered in this case; the St. Clair River as gaged by Mr. Sabin at the Dry Dock Section, the Niagara River in the Open Section, the Niagara River at the Bridge Section, the St. Lawrence River at the Three Point Section and the vertical curves observed by Mr. Richmond in what is known as the Split Section of the Niagara River.

In these examinations for the St. Clair River and for the Open Section and Split Section of the Niagara and the Three Point Section of the St. Lawrence, I took the ten stations

which appeared to have the bulk of the flow, or more than 50 per cent. of the flow in each case and combined them into a single vertical curve, and superimposed these composite curves one on another. These curves were on a percentage basis of depth and velocity, and the curve of the Open Section of the Niagara River so closely overlaps and covers the curve of the St. Lawrence that they are scarcely distinguishable from each other. The curve of the St. Clair River shows towards the bottom a somewhat higher velocity, indicating a smoother bottom. The third section almost exactly duplicates the Open Section of the Niagara, and the St. Lawrence curves, except that where the composite curve the line strikes bottom, there is a little less velocity. These as a series indicate that one section as compared with another is not largely influenced by perturbation; that if there is any perturbation, it is common to the whole group.

Q. (Last question read.)

A. This matter was investigated by me, and the conclusions reached are shown by means of Shenehon's Exhibits E, F, G and H. In this series, the volume of flow is related to sheltered gages in the river, instead of relating it directly to the Buffalo gage. The relations between the fluctuations of the particular river point chosen, the elevation of water surface in the gorge, and Suspension Bridge and the elevation of the Whirlpool are referred by water levels transfers to the Cleveland gage and to the Buffalo gage both on Lake Erie.

I find that in the case of the use of the Cleveland gage and the ratio of fluctuations established between that by monthly mean water surface elevations and the water at the Suspension Bridge and the water in the Whirlpool that the increment derived by the direct reference to the Buffalo gage is almost exactly reproduced. In other words, the increments derived are all in the vicinity of 22,000. This to my mind is a complete verification of the work of directly relating the volume of flow to Lake Erie level at Buffalo. I believe the demonstration is most complete.

I may add that the observations used in this work are those of 1907-1908, because we did not have these lower river gages for the earlier work. These charts I believe are self explanatory, and the method employed in reaching these conclusions I believe to be a correct one.

Q. You made certain meter tests by comparing the registration of the meter with colored water, and testified in regard to that in the original testimony?

A. Yes.

Q. What is your opinion as to the accuracy of that test, having in mind that the colored water is near the top, as to whether that gives any indication of the waters below the surface.

A. Well, in connection with what I have said about the precision with which the composite vertical curves in one river will reproduce those in another, I believe that the velocity indications of the current meter, with ratings on a still water base, are applicable for other depths than the surface depths. I believe no error of any magnitude has entered into this work for the reason that the current velocity indicated in the river is rendered incorrect by a still water rating of the instrument used for measuring the velocity of flow.

Q. Mr. Shenehon, did you and the engineers in the Lake Survey take into consideration the back water effect of Lake St. Clair, in determining the increment of the St. Clair River?

A. That is in U. S. Exhibit Number 1, as originally put in this case.

Q. And in all your determinations, that was considered, was it?

A. In the recent Lake Survey determinations, and by that I refer to the report of the Lake Survey, 1912, this has been very fully considered, in the reduction of 488 observations.

Mr. Adcock: Was it considered before that?

A. In connection with the U. S. Exhibit Number 1, the period covered by the observations was taken as being sufficiently long so that Lake St. Clair would maintain its proper relative position with respect to Lake Huron. I have investigated the fact as to whether or not this is true for the years 1898 to 1908, inclusive, excluding 1901, and I find that they were nearly in accord with the relation shown by the Lake Survey and indicated on an exhibit in this case. I take my evidence from Williams' Exhibit Number 34, where he has made a reduction covering this point. The exhibit referred to is Shenehon's Exhibit R.

I might refer, as I mentioned Mr. Williams' Exhibit 34, to table 16. At the bottom of the table, the values given are for the weighted Huron and Erie elevations, 580.608, and for Lake Erie, 572.115. I have taken off values from this curve and I find that the relation that should exist between Michigan-Huron and Lake St. Clair, in accordance with the law expressed on Shenehon's Exhibit R, would indicate 580.61 for Michigan-Huron, and 572.11 for Lake St.

Clair. It may be objected that this contains the year 1908, but the year 1908 was plotted on the curve in Exhibit Number 1, and appeared to be in general consonance with the other observations. Lake St. Clair appears to have been about 0.06 low by Mr. Williams' table VII.

Q. Wasn't that one of the reasons assigned by Mr. Freeman for the rejection of the Lake Survey's increment

A. Mr. Freeman's reasons, as I recollect them, for rejecting the—giving more weight to the increments as derived by Mr. Williams than to those of the Lake Survey, as indicated by the direct testimony, was that I think he spoke of: Shenehon did not take into account the elevation of Lake St. Clair. Another reason was that: Shenehon did not use the three point method. Another was, that volumes of flow of the St. Clair River and the Niagara River did not check up, when you pass by interpolating intermediate supply from one to the other.

In the end, as regards the Niagara River, he regarded the perturbations or turbulence of the river as a factor to be considered. In his early statement he did not have in mind the third section, because it had not yet been measured at that time.

I wish to make a statement regarding Mr. Freeman's testimony on turbulence, and the nature of the bottom of the Niagara River. Mr. Freeman was employed, as I understand it, by the Ontario Power Company of Niagara Falls, Ontario, and had to do with the un-watering, or at least viewed the space unwatered by their divertors in the rapids. Now the rapids just above the cataract at Niagara Falls make a descent of about 60 feet in something like 3/4 of a mile. The Ontario Company's intake, where the bottom was unwatered, in order to put in the permanent diverting weir, was one of the most ragged pieces of bottom one could expect to find, with the great descent—I think the water descends about 20 feet in that distance, under the earlier condition—and the great rapidity of the water, the cascades entering there, the bottom was doubtless cut up with pot holes in the solid rock, and it is a position where ice carrying boulders would drop the boulders, the ice being broken up by its descent over the first cascade, so there is no comparison whatever, so far as I am aware, of the nature of the bottom there and the Niagara River from Chippewa up to the head of the river itself at Lake Erie.

I wish to speak of one other thing regarding the head of the river. The first descent of five feet from Lake Erie down

to the vicinity say of the Open Section, in the upper reach of this, the water is traveling at a fairly high velocity but there is no rapids there, there is no breaking water. On a still day, this flow of the water is perfectly smooth. There are no white horses, no riffles indicating a rapids, anything of that kind.

I am very familiar with that river because I maintained water gages there getting the slope of the river under the Board of Engineers on Deep Waterways, and for two months made almost tri-weekly inspection of these gages, and testify regarding this with very intimate knowledge of the actual conditions.

Q. What is your present opinion as to the increment of the St. Clair River, what it is, and its accuracy in the light of all this study that you have made, the testimony that you have read, the recent measurements and observations of the Lake Survey?

A. I believe the increment of the St. Clair River is in the neighborhood of 21,000 cubic seconds feet, and the precision is probably within 10 to 15 per cent. In making this statement, I may wish to qualify this by reference to a Lake Survey document, which is not here at the present time. I am basing this on my recollection of certain increments gotten out separately from the Gorge Section and the Dry Dock Section at different times.

Q. The same question as to the Niagara River?

A. 21,900, with a precision of five per cent.

Q. The same question as to the St. Lawrence River?

A. 22,000 approximately, with a precision possibly of 20 per cent.

Q. Why do you give the precision of the Niagara greater than the St. Clair?

A. There are two reasons why I give the precision of the Niagara higher than the St. Clair. One is the fact that in the Niagara we have approximately 4 feet of range in our discharge observations, 4 feet in the range of the elevations of Lake Erie, from elevation 570 to 573.92, more accurately. This long range of our observations gives a more accurate trend of the curve. In other words the precision of the observations, other things being equal, is proportional to the range of lake stage which is secured from the discharge observations.

Another reason why I count the increment of the Niagara River as of high precision is the fact that the Open Section increment checks so very closely the increment of the

Bridge Section. The increment derived entirely independently on the Open Section is 21,640. That of the Bridge Section 21,900. Then on the Niagara, we have the opportunity of checking the increment by referring it to other gages as at the Suspension Bridge and in the Whirlpool, and I may add at Chippewa.

Q. And there is no backwater there?

A. Another reason is that the observations of the Board of Engineers on Deep Waterways, while somewhat restricted in number and range are reasonably corroborative of the increment derived by the Lake Survey.

Another reason still is that the hydraulic conditions are the simpliest in the Niagara River of any of the three rivers considered.

Q. In what respect?

A. The Gaging Section is very close to the Buffalo gage at the head of the river. There are no backwater effects that need any consideration in the open season flow; and the corroboration of the three sections, which are so very different in their physical conditions, adds strength, not only to the mean volume of flow but to the increment as well. In speaking of these divergent or differing physical conditions, the measurements of the Niagara River were made in one place at the Open Section, where we get the whole river flowing in a single stream. In the case of the International Bridge, we have the whole river flowing in nine different streams. In the case of the Split Section we have the river flowing in two different streams, and we have a wide range of velocities as well.

The reason I give a lower precision to the St. Lawrence is because of some little doubt that has arisen in the late investigations of the Lake Survey as to the observations of 1900-1901. The range of stage was so little on the St. Lawrence that a slight inaccuracy in the group of observations the second year would vary the line quite considerably, and there appears from Mr. Richmond's investigations to be a slight inaccuracy in the second season's work. The reason of it is not very clear yet, but it has been considered.

In the case of the St. Clair River, the complexity entering from the backwater effect of Lake St. Clair is a thing which is likely to make the increment less determinable, and again in the case of St. Clair River the lack of a long range of lake stage. I believe it is a little over two feet there.

Now, the St. Clair River and its increment has the corroboration of very close checks in the three sections meas-

ured, and they are quite different so that my view of the lesser precision of the increment of the St. Clair grows out of that fact that I have mentioned, or the several facts I have mentioned. The mean volume of flow at the mean stage of the observations is doubtless one of the most accurate we have in this series of observations, in my judgment.

Q. What effect if any did your personal supervision at the Niagara River have upon your opinion, Mr. Shenehon?

A. I was, of course, intensely interested in the problem of measuring the flow of the Niagara River, and very much pleased at the close confirmation of the measurement in the Bridge Section as shown by the volume of flow of the Open Section. But when I went to the St. Lawrence River, which was also under my immediate charge, I had had all the experience of the work on the Niagara River in addition to my former work in river measurement and other forms of hydraulics. I had reached what appeared to me a little better method of work, and in gaging the three point section of the St. Lawrence, I regarded that as my masterpiece, if I may speak of it in that way. I believe the Section itself and the methods used there in many respects are excellent.

Mr. Austrian: What year was that?

A. That was in the year 1900. The reason why the final results in the St. Lawrence are not of the same precision, in my judgment, as those of the Niagara River, is simply the fact that we did not get the range of Lake stage or river stage at Ogdensburg. That was a matter of gaging only over a short period, and we did not have a duplicate section, you understand, there, except as the winter section at Nevins Point already referred to is considered. That winter section at Nevins Point on the St. Lawrence was only a partial corroboration of the accuracy. It was not as full as the corroboration we have of the Open Section and the Third Section on the Niagara.

I do not know that any statement in detail concerning that winter section has ever been put in this record. From the treatment at that time of the observations on the same principles that they were treated in my 1902 report for winter observations, the gage tender's gage at the Galope Rapids was used as the basis of judging whether the flow corresponded to the summer flow or not; and on that basis the two sections were in accord within somewhere in the neighborhood of 1 per cent., as I recollect it. But that corroboration is nowhere near as good as the corroboration of the Third Section of the Niagara River, and of course the Open Section

is a complete corroboration of the International Bridge, volume of flow. So I had all the direct supervision on the St. Lawrence that I had on the Niagara, and with all my experience there is a further advantage in the latter work.

Q. Did the Board of Engineers on Deep Waterways make any observations on the Niagara?

A. The observations made by the Board of Engineers on Deep Waterways derived a volume of flow and an increment for the Niagara River. During the last two months of the operations of that Board of Engineers, I was in charge of their Buffalo office, and Mr. C. B. Stewart was making the discharge observations, without any particular supervision or direction of mind. That was in the year 1898, July to September 1898.

Now the volume of flow as indicated by the measurements of the Board of Engineers was about 4 per cent. greater than the volume of flow indicated by my own measurements at the Bridge Section.

The main reason for the difference was in the measurement of the cross sectional area. As the area was sounded by the Board of Engineers, they used an 80 pound weight on a sash cord, throwing the weight upstream much as you sound with a lead line, and letting the weight and the line drop downstream with the current. The cross sectional area was, as I recollect it, about three per cent. in error. Aside from that, the error of coefficients and all other elements entering was simply 1 per cent.

In speaking of the Board of Engineers on Deep Waterways, I would like to read a statement from Mr. Haskell as to the difference in the volume of flow as indicated by the work of the Lake Survey and that of the Board of Engineers. This is on page 5323 of the report of the United States Lake Survey for 1900, Appendix III; and is the report of Mr. E. E. Haskell, assistant engineer.

Mr. Adcock: That is the Chief Engineer's report is it?

A. Yes, report of the Engineer, Appendix III, on the Northern and Northwestern lakes.

> "It will be observed that the results obtained by Mr. Shenehon for the discharge of the Niagara are somewhat smaller than those given by the Board of Engineers on Deep Waterways, as published by Mr. C. B. Stewart in his paper on discharge measurements of the Niagara River read before the Western Society of Engineers in December, 1899."

This report of Mr. Stewart was afterwards printed in the report of the board of engineers on Deep Waterways.

"The greater part of this difference comes from our having very much more data upon which to base the determination of the coefficients used in the reductions. The remainder comes from the smaller values used for the cross section, that is having been measured with more elaborate appliances by Mr. Shenehon, and hence with greater precision than I could obtain with the outfit at my disposal when I started to work for the Board. I mention this so there can be no misunderstanding regarding the values obtained by the Board and those published by this office."

Mr. Hopkins: That is all at the present.

Adjourned subject to notice.

FRANCIS C. SHENEHON, a witness recalled on behalf of the Government, testified further as follows:

Cross-Examination by Mr. Adcock.

Q. Suppose that for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo and Niagara, for a period of years, the elevation of the water at the upstream end had been as shown in the first column and the fall through the channel had been as shown in the second column of Haskell's Exhibit A, for Identification, February 25, 1914. And suppose that it were desired to obtain a discharge curve for this section that would represent the discharge of the period referred to the head at the upstream end, and suppose that there had been made a series of 27 observations under the conditions of columns 3 and 4, and that there was also available a series of 23 observations made with equal care under the conditions shown in columns 5 and 6, which, in your judgment, would give a discharge curve the more closely applicable to the assumed condition of columns 1 and 2?

A. I should not wish to answer that question without plotting the observations and investigating them in detail.

Q. You can do that by the next hearing can you not?

A. Yes.

Q. You testified first in this case in 1908, did you not Mr. Shenehon?

A. June, 1909.

Q. 1908, was the last time you made any measurements on any of these outlets, was it not?

A. I was Principal Assistant Engineer of the United States Lake Survey at the time the measurements in the Gorge Section of the St. Clair River were made. The measurements on that section were initiated at the time that I was Principal Assistant Engineer of the office.

Q. How much better qualified are you now to judge of the precision of a series of discharge measurements made by you on a large river than you were in 1908?

A. Well, I have given some considerable thought to things connected with river measurements, in connection with this case mainly, and in connection with my practice as a consulting engineer.

Q. How much more nearly correct would you consider your present estimate of the error of a series of measurements made by you at this time than it would have been for a similar series made by you in 1908?

A. I think that my judgment of the precision of the measurements made on the rivers of the Great Lakes has much to assist it at the present time. Let me say what I mean:—

Q. I hope you will confine your answer to your own measurements, the measurements you made yourself.

A. I can hardly do that, because my judgment is affected by the reports and conclusions that have been made and reached by the other men of the Lake Survey, and by computations made from those measurements by myself.

I was going to say that the reason I have a greater certainty as to the precision of these measurements now comes from the close corroboration of the volume of flow in the Gorge Section with that in the Dry Dock Section; those two sections checking within 1 per cent.

Q. I wish—

A. Just let me go on with this answer. In addition, we have the check of the sections made by Mr. Richmond in the delta of the St. Clair, which are within 1 to 2 per cent.

In addition it has been testified to, and I believe is correct, that the measurements in the Detroit River are in full accord with the measurements already made in the St. Clair River.

In addition, by interpolating the local supply for Lake Erie

as computed by Mr. Gardner S. Williams, there is full accord between the St. Clair River measurements and the Niagara.

In addition, the Third Section of the Niagara River has been measured, and this checks within 6/10 of one per cent., or within 1 per cent., let us say, of the prior sections, on the Niagara River.

In addition, the corroboration of the measurements of the Niagara River, which after interpolating the supply of Lake Ontario as computed by Mr. Gardner S. Williams, or Mr. Frederic P. Stearns, check within two per cent. the volume of flow in the St. Lawrence River. So that my judgment has been much assisted in reaching a conclusion that these measurements are of the highest precision.

Mr. Adcock: I will move to strike out all the answer of the witness, and I will ask the witness to answer the question which I asked him; and not discuss the measurements of particular rivers. I will ask the Commissioner to read the question.

(Question read as follows: "How much more nearly correct would you consider your present estimate of the error of a series of measurements made by you at this time than it would have been for a similar series made by you in 1908?")

A. Do you mean, Mr. Adcock, if I should go out now and make a new series of measurements?

Q. Yes, measurements of a river, made by yourself?

A. I should expect to better the prior work very little. I believe all this does affect my judgment, and would affect my judgment in going out to measure a stream myself; that the Lake Survey has bettered the methods that were used, in some little details.

Q. Suppose that you went out to measure the Mississippi River now, how much more acurrate would your judgment of the error be of those discharge measurements made at the present time than your judgment as to the discharge measurements made in 1908 of the same river?

A. I think if it were the Misssissippi River, I should not expect to get the precision we have gotten on the rivers of the Great Lakes.

Q. I am speaking of the Mississippi River?

A. I should not expect to get the same degree of precision on the Mississippi.

Q. I am asking you for your judgment of the percentage of error of the discharge measurements?

A. On the Mississippi River?

Q. Yes?

A. Under flood conditions?

Q. 26 measurements made at the present time as compared with measurements that you might have made in 1908?

Mr. Hopkins: Which he might have made in 1908, on the Mississippi River?

Mr. Adcock: Yes.

A. I think there would be very little difference in the precision; that is, with my present knowledge as compared with my knowledge in 1908.

Q. Then you mean to say, do you, Mr. Shenehon, that your estimate of the precision of the discharge measurements made in 1908 is as good as your estimate would be to-day?

A. No, I do not.

Q. Well, how much difference would there be, what per cent. better?

A. Let us understand what we are getting at here. Perhaps I do not quite understand it. Do you mean by that my precision of the Niagara River—

Q. No.

A —in the light of my present knowledge, as compared with what my estimate of the precision might have been in 1908?

Q. No, any river of the magnitude, say, of the Niagara River. I want your opinion as to how much better you are able to judge now than you were in 1908?

A. I feel that I judge with a higher degree of certainty now than I would in 1908.

Q. How much higher?

A. I can't state that in figures. I think my view at that time was that we could measure these streams within 1 per cent., and I do not feel that we can do much better than that on the streams of the Great Lakes; and the chances are in such rivers as the Mississippi, under the silt conditions, that the precision might be a little lower there. I have not, however, had any experience in a silt bearing stream, so my view of that is somewhat speculative.

Q. Well, would you say that your judgment was 50 per cent. better now than it was then?

A. I am afraid I can't measure my judgment in percentages.

Q. Well, maybe you could measure it in this way. How much more money would you spend on your judgment now than you would in 1908, if the question as to whether you would

speid the money were based upon your judgment as to the predsion of measurements?

A I am afraid I can't help you on that.

Q You can't help me. Do you consider that Mr. Richmond, a wtness for the complainant, is better qualified to judge of the accuracy of a series of discharge measurements made by himself, than you are now able to judge of a series made by yourself, at this time?

A You are getting into psychology now.

Q I am asking for your opinion as to Mr. Richmond's judgment of the accuracy of his measurement, as compared witl your judgment of the accuracy of measurements made by you now,—a comparison?

A I regard Mr. Richmond as a man of excellent judgment, andhe has made very full investigations. I should regard his judgment as very high.

Q. Do you consider that he is better qualified, or that you are better qualified, to judge of those things?

A. I do not like to pass on my qualifications, in matters of this kind.

Q. We know the qualifications of Mr. Richmond?

A. Yes.

Q. And we know your qualifications; it is in evidence in this case.

A. Of course I am an older man, with possibly wider experience than Mr. Richmond; and I think that should be considered in answering the question.

Q. You would say the same thing as to Mr. Moore, wouldn't you? He is a Junior Engineer in the Lake Survey, the same as Mr. Richmond?

A. Yes, Mr. Moore is a man who has the experimental mind, I think, and is an investigator, and has excellent judgment I think; perhaps not quite as deliberate as Mr. Richmond in some ways; perhaps not having quite the judicial mind of Mr. Richmond; perhaps I could put it in that way.

Q. Taking them both together, do you consider that Mr. Richmond and Mr. Moore are better qualified in their combined judgment as to the accuracy of discharge measurements made by themselves than you were to judge of the accuracy of similar measurements made by yourself in 1908?

A. I should think it would be about an even thing.

Q. About an even chance?

A. I should think so.

Q. In this case, one equals two ?

A. I do not think you can put it in mathematical form, Mr. Adcock. The assumption of course is that a jury of 12 men give a better decision than a judge, but it is not always so.

Q. What length of time do you consider a proper one to allow for between the reading of the Buffalo gage and the corresponding discharge measurement at the International Bridge?

A. Eight to ten minutes.

Q. What did you use?

A. In the case of the International Bridge, I believe no time correction was made for lag. In the case of the Open Section, either eight or ten minutes; I am not certain.

Q. And the Open Section would be eight or ten minutes?

A. Yes.

Q. And the Open Section is about 2,000 feet—

A. Abouth 1800 feet below the International Bridge.

Q. Below the International Bridge?

A. Yes.

Q. What as to the Split Section?

A. Somewhere in the neighborhood of an hour, or possibly a little less.

Q. How do you establish this time?

A. The time interval between Chippewa and the Lake is about two hours, and I believe this is a little less than half way down the river; that is the location of the Split Section.

Q. And for the International Bridge and Open Sections, how do you establish that?

A. That was established by observations made from the International Bridge, in which current meters were run continuously in connection with the water gages, the Buffalo gage and the Section gage, and the curves of velocity and elevation of water surface of the Section and at the Buffalo gage plotted, in order of time.

Q. How many current meters did you run continuously?

A. My recollection is that we ran one.

Q. Where did you run it?

A. About mid stream of the International Bridge, as I recollect it. You understand, you are asking me questions concerning things that happened something over 15 years ago.

Q. Did you do that yourself, Mr. Shenehon?

A. I believe I started the observations, yet I am not positive of that.

Q. How long was this current meter run?

A. About half a day. Now, I have not seen those curves,

as I recollect it, since that time. I would need to refresh my memory of these things by actually getting out the curves and seeing them. They are in the records of the United States Lake Survey Office.

Q. Did you make any discharge measurements simultaneously at different places on the Niagara River?

A. No.

Q. To determine the travel of the discharge?

A. No.

Q. The change of discharge for change of elevation?

A. That depends on the fact that a meter running at a single station is an index, in a large way, of the volume of flow clear across the river. You could observe on a single station, one of the important mid river stations, and knowing the relationship of the various stations, you could write out in rather a crude way the discharge, possibly within 5 per cent.

Q. Would it have been as satisfactory a way to determine this change of discharge for change of lake stage to have run a series of meters at different points between Chippewa and the head of the river, simultaneously?

A. It would have been a scheme that would have been helpful, yes.

Q. As an engineer, do you consider that would have been a correct way for determining the change of discharge?

A. Let me say something else: You asked me if we had measured the discharge simultaneously several places on the Niagara River, would that have been as satisfactory, and I answered yes. Now, by calibrating the weir in the Whirlpool, and calibrating the weir at Suspension Bridge and that at Chippewa, we have measured simultaneously by weir measurements the flow of the Niagara River in four places at the same time; at the International Bridge, referred to the Buffalo gage, the Chippewa gage, the Suspension Bridge gage, and the Whirlpool gage.

Whenever the water is at a certain elevation at Chippewa, there is a certain amount going over the Falls, so it is just as good as having a current meter measurement there, since the weir is calibrated. Whenever Lake Erie has a certain elevation, there is a certain amount of water going down the river. When it is a foot higher, there is around 22,000 cubic feet more; and we have corresponding elevations on the weir at Chippewa, so that we have the two simultaneous measure-

ments of out-flow suggested by you, so that we get the time of travel in that way.

Q. When you say you know the discharge of the Niagara River, you know it from these so-called measurements you have put in evidence, current meter measurements?

A. We have the current meter measurements of the International Bridge Section, the Open Section, and the Split Section, and we have the simultaneous gage readings corrected for lag at these other points I have just mentioned, so in the end we arrive at a discharge equation for the four different points; elevation at Erie; elevation at Chippewa; elevation at Suspension Bridge, and elevation at Whirlpool.

Q. How about the accuracy of those calibrations?

A. Practically exact, as indicated by the curves put in, in this case. When I say exact, I mean with the accuracy that we have for the discharge at Buffalo, with possibly a little trace of inaccuracy coming from the transfer, but it is very little.

Q. Then if a rise should occur at the Buffalo gage of, say, .2 of a foot, you would expect the full effect would be felt at the Bridge in about eight minutes, is that correct?

A. I think the "full effect" is not quite a correct statement. There would be a little reservoir effect in between the Bridge and the—

Q. What percentage of the effect?

A. I can't state that as to percentage.

Q. Nine tenths?

A. A pretty large percentage of the effect.

Q. About .9?

A. That would depend, Mr. Adcock, on the length of time during which the rise took place. If this .2 rise took place in two hours, you would probably have substantially the full effect. If it took place in 20 minutes, you would get a little less. I could not give the exact percentage.

Q. But you assumed, in deriving an increment there, that the full effect was obtained in eight minutes, didn't you?

A. I do not think that is involved. We were probably in error a little, one way or the other; and it would not be substantial in the end whether we made any time correction or not.

Q. Then your proposition is there was no use at all of making any correction there for the lag, is that right?

A. I think it added very little value. The correction of ten minutes probably decreased the residual a very slight

amount. It probably had no effect whatever on the final conclusion.

Q. Then am I to understand it did not make very much difference where the lake level was with reference to the time the discharge measurement was made?

A. No, I do not mean that.

Q. In deriving the increment?

A. No, within the limit of ten minutes, it made very little difference.

Mr. Hopkins: Q. Did you mean increased the residual or decreased it?

A. If we did not observe this little lag of ten minutes, the residual would be a little bigger there; the residuals are a little bigger on the Bridge Section on that account, but the conclusion in the end would be the same, substantially.

Q. The Buffalo gage is about three miles from the Bridge, isn't it, or the Bridge is about three miles from the Buffalo gage?

A. Somewhere in that neighborhood.

Q. And the Chippewa gage is about 20 miles from the Buffalo gage?

A. Yes.

Q. Assuming that there was a sudden lowering of say two tenths of a foot at a point an equal distance down stream from the Bridge, and the Buffalo gage remained stationary, how long would you expect it to be before the full effect reached the Bridge?

A. That is three miles down from the Bridge? Oh, I should imagine in the neighborhood of ten minutes.

Q. That is it would be about the same as the effect from the rise at the Buffalo gage, is that correct?

A. I suppose so; I should think so.

Q. There would not be any difference. You heard the testimony of Mr. Sherman Moore, a witness for the Complainant, relative to his observations of discharge in the Chicago Sanitary and Ship Canal, did you not?

A. Yes.

Q. Do you consider his gagings accurate and reliable, that is the gagings he made on the—

A. I have not given any detailed study to the gagings of Mr. Moore in the Sanitary Canal.

Q. Knowing Mr. Moore's work, what would you consider it to be?

A. I should expect it would be accurate, good work.

Q. Within what percentage?

A. I should think Mr. Moore could get the discharge of the Sanitary Canal within 2 per cent., and possibly a little better than that.

Q. Do you think he did get it within 2 per cent.?

A. I don't know. I have not examined his observations sufficiently to know.

Q. You were present and heard him testify about them did you not?

A. Yes.

Q. And the methods that he used?

A. I do not recollect now just how many measurements he did make. It was not an exhaustive, long piece of work.

Q. You heard Mr. Ray comment upon those measurements, didn't you?

A. Yes.

Q. The fact that Mr. Moore considered them reliable and accurate, would that have anything to do with your judgment?

A. Yes, Mr. Ray is a man of very excellent judgment, as I view it.

Q. Did he determine the time of travel of an increase of discharge from Lemont to Willow Springs, as you remember?

A. Yes.

Q. What was the time, and how did he determine it?

A. It was determined by the gage readings, as I recollect it. I am not certain whether the change in volume of flow with a change of gage openings at Lockport was involved. I have not given any large consideration to this with a view to testifying. It was not testified to in my direct testimony.

Q. Do you remember the time from the power house to Lemont, as stated by Mr. Moore?

A. I believe it was at the rate of about a mile in three minutes.

Q. That would be about 30 minutes, assuming it was ten miles?

A. Yes.

Q. Do you think the methods which Mr. Moore used to determine the length of time for a change of discharge was accurate?

A. Well, it should always be understood that in a case of that kind, the gage will not give you the full value in the change of flow. In other words, we have the same condition in any stream; the first thing that must be done on opening the

gates at Lockport is to draw off a certain volume of water; the reservoir effect comes in. And the same thing comes in the Niagara River and the St. Clair River and the St. Lawrence. The lower gage will not show for a sharp change in Lake Erie, for instance, the same relative change below, because part of the water has been used up in reservoir effect, either plus or minus.

Q. That is the same general principle would be applied to the conditions on the Niagara, St. Clair and St. Lawrence Rivers that would be applied here on the Drainage Canal?

A. Oh, yes.

Q. That is am I to understand that there would be a crest which would give a change in the stage of the water, and that the discharge would follow at some time after that corresponding to the change in elevation, at a certain place either up or down from the point you are making your gaging?

A. I stated in answer to your question concerning the Bridge, that the length of time in which the water is rising has some considerable influence on that. If you have a small rise in a relatively long time you get, at the intermediate point, practically the full value in discharge of the gage rise.

Q. Assuming for instance that the Buffalo gage should rise a foot, the elevation of the lake should change, so that it should be a foot higher. Now, there would be a crest that would travel down to the International Bridge in about eight minutes, wouldn't there be?

A. Yes.

Q. How soon would there be a change of discharge at the International Bridge, to correspond with the elevation of the lake at the Buffalo gage for this changed elevation?

A. If the rise was at the rate of an inch an hour, something of that kind, the discharge would be practically undiminished. That is the elevation of the gage at the International Bridge would correspond to the volume of flow under quiescent conditions.

Q. That is the discharge would change just as quickly as the crest?

A. In a very slow rise.

Q. As the gage would rise?

A. Where the lake was rising slowly. If however, there was a seiche that came up, where it rose a foot in a short time, the volume of flow at the beginning would be a little greater, of course, at the International Bridge, due to the increased

slope. And as it traveled down the river, the reservoir effect would come in and that would be lessened. So when you got to Chippewa—

Q. Suppose there would be a sudden change of three or four inches. That is quite usual, isn't it, at the Buffalo gage?

A. You mean in an hour or two?

Q. Say in 20 minutes.

A. Well, under those circumstances you would have a higher velocity, a higher flow than you would get for a slower rise, on account of the increased slope.

Q. That is at the time that the crest reached the International Bridge, the discharge would be greater at the International Bridge than it should be according to the elevation of the lake, is that it?

A. The general proposition is that a rising stage gives a little higher volume of flow at the up-stream or initial weir. I believe the observations will show that; the rising stages will show a little higher discharge than the falling stages.

Q. Do you think they will show a higher discharge than a continuous stage of the Lake?

A. Yes, a rising stage would show a slightly higher volume of flow than a quiescent stage, or falling stage. These are very small quantities, you understand.

Q. I am not asking you about that.

A. I think in my original testimony, I indicated perhaps 1 to 2 per cent. Possibly that is on the large side.

Q. Now the method which Mr. Moore used with reference to determining the travel or the lag was similar on the Drainage Canal to the method which was used to determine the same thing with reference to the Niagara River. Isn't that true?

A. I rather thought that he used the gages rather than current meter measurements. And yet, I am not sure. That is his continuous gage record, I believe, does parallel the line of the volumes of flow.

On examination of the plot made by Mr. Moore entitled: "Elevations and flow in Chicago Drainage Canal from measurements of December 16, to 22, '913," being (Moore's Exhibit 5 of Feb. 5, 1914) I find that the volumes of flow are also plotted for the different hours, as well as the gages or the gage readings at Lake Michigan, Willow Springs and Lemont.

Q. The question was: Was it a similar method to the one which was used in the Niagara River to determine lag?

A. Yes, the method is similar.

Q. Now you said it would take how long for the crest to travel to the Split Section from Buffalo gage?

A. That is an estimated value, and I had in mind Mr. Richmond's statement of one hour.

Q. One hour?

A. Yes.

Q. Assuming that the elevation of the lake at the Buffalo gage should rise a foot, the crest would be apparent at the Split Section in one hour, would it not, about that, approximately one hour. Would the discharge at the Split Section correspond, at the time the crest arrives at the Split Section, to the change of the stage of the lake?

A. I think there would be a little lesser discharge under those circumstances, that is assuming a fairly rapid change.

Q. The discharge would not be as great as it should be according to the change of stage at Buffalo gage, is that right?

A. A portion of the water is being used up in reservoir effect in between. And if the gage were going down, the converse would be true; and the effect is a compensating one, so far as the volume of flow is concerned.

Q. If an allowance of time were made for the amount required to fill the storage, is it then your opinion that the discharge at the Split Section would correspond to that due to the elevation of the Buffalo gage, with the time interval indicated by the transmission of the wave, plus this period of storage?

A. I should not care to answer that without some consideration. I do wish however to say right here that no correction was made in the Niagara River for reservoir effect. That was a point that came up in Mr. Williams' testimony, in which he suggested that he assumed that we had made corrections for reservoir effect. That is not so. The correction for reservoir effect would make the residuals a trifle smaller, but would have no influence on the final result.

Q. What percentage of the full effect would be felt in an hour in the discharge?

A. I could not tell you that, Mr. Adcock. I have some curves in my trunk which will give some information on that point, in which the gage in the Gorge and at Suspension Bridge is the basis, so that we can find the time of travel and the percentage of flow, the lessened percentage of flow that comes with sharp rises, or in falling water the converse. I

would be very glad to bring those up; then we can discuss that intelligently.

Q. In getting your increment, in deriving your increment, do you determine the percentage of the full effect that is felt at the time that the wave reaches the gaging section?

A. The error coming in an individual measurement from this cause is plus in one case and minus in another, and in the aggregate in the many observations which we have, it is eliminated, compensated. This shows very clearly in the observations plotted in the Gorge and at the Whirlpool for single days. The observations themselves show that the volume of flow passing over the rapids, through the Whirlpool Rapids and the Lower Rapids, is very exact as compared with the volume of flow passing out of Lake Erie; that is for an eight hour stretch, eight or ten hour stretch. So that it is a little thing except as you regard the lag coming from a fairly sharp rise.

Q. You assumed that those errors offset one another in the number of gagings, that is your theory is it?

A. Oh yes, I am very positive of that.

Q. That is it would be impossible for you to use words that would really express how positive you are, is that true?

A. (No response.)

Q. You are aware, Mr. Shenehon, that yesterday Lake Michigan at the Chicago gage changed about 5 feet in 20 or 30 minutes, the stage of the lake?

A. That fact has been mentioned to me. I have no observations indicating that, but I understand there was a seiche at this end of the lake that had very considerable value. I have never heard of one as large as this one, which I heard spoken of as about 5 feet, I mean at such short intervals.

Q. There are changes of that character in the stage here and at other points of Lake Michigan, Huron and Erie, in perhaps not that short a time but in an hour or so, aren't there?

A. Yes.

Q. Quite frequently?

A. I should expect this to be a very unusual phenomenon. Mr. Cooley I believe, mentioned this seiche in this vicinity as of short period, but of rather slight rise, magnitude. I should imagine that the records of the Sanitary District must be full of information as to the travel of such a seiche down the canal.

Q. On Lake Erie there are sudden changes of greater magnitude than that, aren't there?

A. I don't recall any seiche of this short period. The

Lake Erie seiche is something like eight hours long as I recollect it; that is from end to end of the lake.

Q. That amounts sometimes to 10 or 15 feet, doesn't it, 10 to 12 feet?

A. That is very exceptional. There are I think records where the lake has gone up as much as 8 feet, but it is not within my experience. I had great difficulty in securing a range of a little less than 4 feet, which we secured in the Niagara River during the time that I was observing there.

Q. That was at the Buffalo gage?

A. That was at the Buffalo gage. That includes the years 1898 to July 1900, inclusive. That is the open season, and it includes also the periods in 1907 and 1908. We were looking for just such seiches of that kind, with full equipment ready to take advantage of them, and they didn't come along very frequently.

Q. When you speak of the mean of a series of discharges measured at certain mean elevations of the lake being in error a certain per cent., do you assume that the elevation of the lake is also in error by some further amount, or do you consider that the elevation is corrected and all the error is represented in the discharge as referred to that elevation?

A. The error in the gage—and I speak now of the Buffalo gage—is exceedingly small. In the mean of a number of observations, it is probably not greater than one to two hundredths of a foot. That would be a quarter of one per cent. of the outflow. I know of no reason why it should be persistently of one sign rather than of the other; just as likely to be plus as minus.

Q. So they would offset; in the end you would obtain accuracy because the errors would be offset, is that correct?

A. Yes, it is compensating. Of course the matter of the error of the gage seems to me very conclusively settled, when I consider the eliminating of the Buffalo gage entirely, as was done in the exhibits put in by me in this case. We took the gage at Suspension Bridge and the gage in the Whirlpool and eliminated the Buffalo gage, and by water level transfers got our increment out with respect to Cleveland. So I feel that the error in the gage is an exceedingly small thing; needs no large consideration.

Mr. Adcock: Now Mr. Reporter will you read the question?

(Question read.)

A. Let me give a specific case: When we say that the volume of outflow of the Niagara River is 219,000 cubic sec-

onds feet at elevation 573.00, it involves the gage as well as the volume of outflow.

Q. What per cent. of error do you ascribe to the gage elevation?

A. Well, we regard the gage as a fixed thing; 573 means 573. We regard the gage as accurate and throw all the error in the discharge. The errors of individual observations are so great compared with the error in the gage that this seems to be the proper procedure.

Q. Is that what you had in mind when you stated that the St. Clair increment was likely to be less accurate than the Niagara River, on account of the shorter range of Lake elevations?

A. No. If you had observations of equal precision, and in one case you had a range of lake stage of two feet, and in the other case you had a range of four feet, the precision would bear the same ratio as the range. In other words it would be twice as precise; any error would be half as great in the case of the four foot range.

Q. You give that as one of your—

A. (Interrupting) I wish to add a little something to that: I do not mean to say that is all in the case of the St. Clair. We have this intricate, complex situation of the outflow being governed by Huron's elevation, as well as a backwater effect from Lake St. Clair, so we have there an exceedingly complex condition. It is not alone the range of two feet; it is this other complexity added, that had made the difficulty in the St. Clair River.

Q. You do believe that the lesser range of lake stage has an influence upon the accuracy of the increment in the St. Clair River, as compared with Niagara?

A. You mean that is one of the elements, the lack of range as compared with the Niagara, for instance? Oh, yes.

Q. You are again positive about that, are you, Mr. Shenehon?

A. Yes.

Q. What was the range of Lake Huron stage at Harbor Beach during the St. Clair measurements?

A. It was a little over two feet, as I recollect it. Is that what you mean, the elevation corresponding to the observation?

Q. Yes. Suppose that on any of the rivers connecting the Great Lakes there had been made by the Lake Survey 147 measurements of discharge covering a range of lake stage

of 0.76 feet, with what degree of accuracy would you say the discharge of the river in question was known, corresponding to the mean of the elevations at which the discharges were observed?

A. So far as the compensating errors entering into this group of 147 observations are concerned, it would be very little, probably not over one-tenth of one per cent.; but the fixed error, of course, due to cross section, due to velocity coefficients, due to any fixed inaccuracy of the meter measurements should be added to the accidental or compensating error.

Mr. Adcock: Will you read the question Mr. Reporter, and see if we can get an answer to the question.

Q. (Question read as follows: "Suppose that on any of the rivers connecting the Great Lakes there had been made by the Lake Survey 147 measurements of discharge covering a range of Lake stage of 0.76 feet, with what degree of accuracy would you say the discharge of the river in question was known, corresponding to the mean of the elevations at which the discharges were observed.)" Assuming that the measurements were made by the Lake Survey, and they used in those measurements the accuracy which they claim to use, and which you probably think they do use?

A. Is that a question?

Q. That is a question?

A. I thought I answered your question. Haven't I answered that question?

Q. No, because I assumed that they probably have determined the cross section and all those other things, and they rate their meters, and all those things.

A. Well, are you asking for some particular river now, or any river?

Q. I am asking you about any river?

A. Well, I should say that we know the discharge for that group within 1 per cent.

Q. Suppose that upon the same river—

A. I would like to qualify that statement a little bit. We have in the Niagara and in the St. Clair what is known as the "slope cycle," due to growth of weeds; and a group of observations made at some particular time might include that; might be the time when the weeds were the greatest, or might be in the time when the weeds were in the least development, so that there is a possibility of error coming in there; and I am assuming in this answer that this 147 contains all normal weed conditions.

Q. Suppose that upon the same river we had 150 similar observations covering a range of lake stage of 0.98 feet, not included in the preceding group, made by the same Lake Survey that we speak of?

A. Same number of observations?

Q. No, 150.

A. Approximately the same.

Q. And the same assumption as to the supposed accuracy?

A. Practically the same, 1 per cent. say.

Q. That would be 1 per cent.?

A. That was a range of 0.98 on that last one?

Q. Suppose that you know the discharge of a certain river at a certain elevation within 1 per cent., and suppose that you also know the discharge at another elevation of the same river within 1 per cent., and assume that the discharges were 203,382 and 187,082 cubic feet per second, within what per cent, of accuracy would you know the difference between them?

A. What is the difference of elevation between the two?

Q. We haven't that yet, just the difference.

A. These were determined from the number of observations given, 147 and 150?

Q. Yes. Assume you knew each of them within 1 per cent. (Question repeated.)

A. If it be assumed that the 1 per cent. in this answer is just as likely to be on one side as the other, the error may be as great at 25 per cent. That is of the difference there, it may be greater or less by 25 per cent. I should not expect however the 1 per cent. to be of an accidental kind so that it would not be as great as that, the error.

Q. That is the maximum would be 25 per cent.?

A. Yes, assuming that the whole error of 1 per cent. in these observations is of the accidental kind. It may be just as likely on one side as the other, then you would have a maximum of 25 per cent.

Q. Didn't you limit that kind of an error to one-tenth of 1 per cent.?

A. No, the limitation to one-tenth of 1 per cent. was on the basis of the residual of 1 per cent., a mean residual of 1 per cent. in the observations, and that does not mean necessarily that is all eliminated.

Q. What do you consider to be the most reasonable error? You have given the maximum of 25 per cent.

A. You haven't given the range have you between these two groups?

Q. Not yet. We are asking about the accuracy of the difference. We have not got to the increment.

A. Well, the error, under the assumption of the full error being of the accidental kind, would be somewhere between 1 per cent. and 25.

Q. What would you say it would be nearer, the 1 per cent. or nearer the 25 per cent.?

A. Well, I think I would wish to know what particular place you were talking about.

Q. I am speaking of the difference?

A. Is there a question?

Q. Yes? Would it be nearer the 1 per cent. or nearer the 25 per cent.?

A. I don't believe I can answer that definitely without knowing the particular location. You asked me concerning gages a little while ago. I am not quite free to say that in two groups on the St. Clair, for instance, that we know our gage relations quite as accurately as we do in such simple cases as we had on the St. Lawrence and the Niagara.

Q. I am not asking you to assume any inaccuracy for the determination of the gage?

A. You are reaching a point now where you have a difference.

Q. Yes, I am asking for the difference. I am asking for the per cent. of error in the difference, per cent. of accuracy in the difference, rather.

A. Well, I should say it would be an even thing whether it is 1 per cent. or 25 per cent., and either side.

Q. If the elevations were 580.92 and 580.35, and the difference in elevation between the two discharges was 0.57 feet, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?

A. Well, you would divide the error which I have just given by this quantity, 0.57.

Q. That is you would divide 25 per cent. by that?

A. That is if you are securing the increment, if that is what I understand you to mean. You want to know what the increment would be?

Q. We have asked what the increment would be for a change of 1 foot?

A. The error of the difference would not be any greater whatever the interval between them; that is already determined.

Q. I do not get that?

A. I have already given you the percentage of the error of the difference between two quantities.

Q. Yes. Now I am asking you within what degree of accuracy would you know the change of discharge for change of elevation of 1 foot, assuming that the range between the two—

A. That is my answer. That becomes an increment, under those circumstances, under our definition in this case. It would be 1 divided by 0.57 to 25 divided by 0.57. It would be from say 2 per cent. to 44 per cent.

Q. Would it be nearer 2 per cent. or nearer 44 per cent.?

A. It is an even thing.

Q. It might be one or the other?

A. Yes.

Q. That then would be the error in the increment, is that correct?

A. Under those circumstances I should think so.

Q. (Question read as follows): "If the elevations were 580.92 and 580.35 and the difference in elevation between the two discharges was 0.57 feet, within what degree of accuracy would you know the change of discharge for a change of elevation of 1 foot?"

A. I wish to make this reservation: What I have stated thus far is on the assumption that the error of 1 per cent. we are talking about here is an accidental error, just as likely to be on one side as the other, which is not true for the most part of the observations with which we have to do in this case.

Q. How much would you want to reduce it, having in mind the observations which have been referred to in this case?

A. If I were speaking of the Niagara observations, I think I would divide that by about four, possibly by a bigger divisor.

Q. How about the St. Lawrence? We would like to hear from you on that?

A. The St. Lawrence River has had a change of regimen since the original observations, and I myself have not investigated the observations since the building of the Gut Dam. The building of the Gut Dam changed the outflow by about 5½ per cent., and changed the increment, I presume, in some measure, probably by about the same percentage.

Q. When you say outflow, you mean capacity?

A. The volume—

Q. The capacity of a river?

A. Yes. That is the building of the Gut Dam in one of the three channels at the Galops has changed the conditions of flow as measured by me in 1900 and 1901. We had I believe

only 93 observations and those were in two groups, the lower ones being in one season and the upper ones in the second season. It appears at the present time that an error did enter there. This is still in the melting pot, and we don't know our increment as accurately, or we did not know our increment as accurately on the St. Lawrence as indicated by my original testimony; that is, that is the indication from the present investigations.

Q. And you are willing to take those indications now and testify to them?

A. The new increment, as derived by the Lake Survey.

Q. When it gets through the melting pot, then you may have another opinion, is that correct?

A. My opinion as to the increment under present conditions of the St. Lawrence is based on two things; one is the testimony of the Lake Survey men in this case, the men who have been engaged upon that work, and the other is the investigation by the methods of fluctuations which indicates an increment between eighteen and nineteen thousand. While this method of fluctuations has distinct limitations, is a rough check on the increment and is not to be entirely disregarded.

Q. That is the St. Lawrence River?

A. I am speaking of the St. Lawrence now.

Q. That is the increment there is between eighteen thousand and nineteen thousand?

A. No, I think it is about twenty one thousand. I think the testimony indicates about twenty-one or twenty-two thousand.

Q. And the error that crept in there was an error that may result from a somewhat disturbed condition in the bottom of the river?

A. No, it is not charged up to that.

Q. Error in the determination of the cross section?

A. No, the cross section checked almost exactly on the second determination.

Q. Wasn't there some question as to whether you got on the right line when you first measured?

A. That does not enter.

Q. That does not enter?

A. No.

Q. Then is it in the determination of the coefficients?

A. They checked almost exactly, the second determination with the first.

Q. Just what error did creep in?

A. There seems to be a little acceleration of the section;

that is, that is the indication. As I say, that is in the melting pot, so that the second season's observations may have been taken a little further downstream, not using the overnangs as we used them in the first season's work, and using lighter weights, and that is what appears to be the cause of the error of possibly 1 per cent. in the second season's observations. Whether it is so, I do not know.

Q. The melting pot is the so-called regular army that was mentioned by Mr. Wilkerson the other day?

A. That is that very distinguished body of men known as the Lake Survey.

Q. Such as Mr. Richmond, Mr. Moore?

A. Mr. Ray.

Q. With very large experience in engineering affairs?

A. I know of no men who have had better experience in river gaging than the gentlemen you are speaking of, unless I should indicate Mr. Haskell, and other men who have been connected with the Lake Survey.

I believe the error in the St. Lawrence increment as originally derived, and as finally derived, is somewhere in the neighborhood, that is the difference is somewhere in the neighborhood of 10 or 15 per cent. The original increment was stated with respect to the Ogdensburg gage. It was also stated on our Exhibit Number 2, U. S. Exhibit Number 2, that the Gut Dam has since been built, which would reduce the increment about 5½ per cent. The change from Ogdensburg to Oswego means two per cent. more. That is 7½ per cent. My own estimate of the error of the increment was ten per cent. Take that as negative, and you are pretty close to the new increment derived, testified to by the Lake Survey.

Q. You prepared the original exhibits of the complainant in this case, did you not, Mr. Shenehon? You prepared the original exhibits 1, 2, 3 and 4 in this case, didn't you?

A. Yes, they were prepared under my direction.

In answering a preceding question, I stated that the error of the difference of two quantities was between 1 and 25 per cent. This would be also the error of the increment under these conditions, instead of the 2 to 44 per cent. previously stated.

Q. Then you were in error when you said the percentage of accuracy of the increment was dependent on the difference of elevation considered. That is what I gather from your correction?

A. No, I don't wish to be interpreted as making that statement.

Q. I call your attention in this connection, Mr. Shenehon to a statement made on page 2804 of your direct examination in which you were asked this question:

"Q. What effect does that range or lack of range have upon the result?" (You are speaking of the increment.)

"A. I think no engineer, even Mr. Williams, would wish to state that there was any consequence whatever in an increment derived with a change of lake elevation of .03 of a foot.

"Q. Why not?

"A. The precision of the increment is proportional, other things being equal, to the range in the level of the lake between the observations. If one should take a set of observations with ten in each group,—two sets of observations with ten in each group, and there was a foot difference in elevation in the lake stage between the two, the error in the increment would be likely to be as much as ten per cent. or more; and where you took only .03 of a foot instead of a foot, why the increment is likely to be several hundred per cent. in error. By taking a large number of stages, the error in the result would be considerably diminished, but the method in my judgment, the method of applying this treatment is not the proper one?"

A. That statement that you have read is correct. I need to think this matter out a little bit, here. There is a little question between the original percentage of the total volume applied in each case, and then the final percentage of the increment itself.

If the volume of flow is ten times as big as the increment, the percentage error in the increment would be ten times that of the volume of flow; twice ten times, if we had errors of opposite signs; then you would divide that error by the range to get the precision of the trend of the line itself.

This question you have asked me is a little confusing, and I wish time to straighten that out.

Mr. Adcock: Certainly.

The Witness: My statement in my original testimony is correct.

Mr. Adcock: I simply called your attention to it to refresh your recollection, that is all.

The Witness: It is correct.

Mr. Adcock: I assumed you still wanted to abide by your testimony.

The Witness: Oh yes, that is correct in my original testimony.

Mr. Adcock: I am asking you now with reference to

whether you were in error when you said a little while ago that the percentage of accuracy of the increment was dependent on the difference of elevation considered?

A. That is true, it is dependent on the difference in elevation considered.

Q. Assume that at a certain mean elevation the mean discharge of a large number of measurements is 300,000 cubic feet per second, and assume that this might be in error 1 per cent., then the true discharge might be anything between 303,000 and 397,000 cubic feet per second, might it not?

A. Yes.

Q. Assume that at another mean elevation the mean of a large number of discharges was 200,000 cubic feet per second, and that this might be 1 per cent. in error, then the true discharge might be anything between 202,000 and 198,000 cubic feet per second, might it not?

A. Yes.

Q. Assuming that these mean elevations were 1 foot apart, what would be the maximum, minimum and mean values of the increment?

A. That is 300,000, starting?

Q. Yes, 300,000 and 200,000?

A. That would be about 2 per cent.

Q. No, I am asking you the maximum, mean and minimum values of the increment?

A. What is the range?

Q. 1 foot?

A. That would be 1 per cent.

Q. I want the quantities?

A. That would be 105,000.

Q. That would be the maximum.

A. 100,000.

Q. That would be the mean.

A. And 95,000.

Q. What is the maximum percentage error of the increment?

A. 5 per cent.

Q. Assume the elevations were .5 feet apart, what would be the maximum, minimum and mean values of the increment?

A. (No response.)

Recess to 7:00 P. M.

May 12, 1914.

After Recess, 7:00 P. M.

FRANCIS C. SHENEHON resumed the stand and testified further on cross-examination as follows:

Q. (Question read as follows: "Assume the elevations were .5 feet apart, what would be the maximum, minimum and mean values of the increment?")

A. The increment would be 210,000, 200,000 and 190,000 as extreme under these conditions.

Q. Respectively?

A. Respectively.

Q. What is the percentage error of the increment?

A. Five per cent. on either side.

Q. That is the same answer as to the question where the range was one foot, isn't it? Five per cent. on either side?

A. If you take your difference, a certain fixed quantity and have your error a certain percentage of that, then the percentage of the increment is the same. But that is not the case we have in the rivers of the Great Lakes?

Q. I am asking you whether this is the same percentage error you had when the difference was 1 foot. It is, is it not? That is 5 per cent on either side?

A. It would not make any difference, if you start with a certain difference, the percentage error in that; it is independent of the range, but that is not the case we have on the Great Lakes.

Q. You are still positive about that, Mr. Shenehon?

A. Yes. Perhaps I would better illustrate that, so as to make it quite clear, and to make it quite clear that my statement in my direct testimony concerning this .03 of a foot is corroborated. May I state it?

Q. Certainly. We are always ready to receive information.

A. I want to take a case where the volume of flow is say 200,000 cubic feet per second, and the error, we will assume is 1 per cent., or 2,000 feet. I would like to keep that 2,000 fixed, for simplicity.

Q. 2,000 what?

A. 2,000 cubic feet. Now, when the lake under these conditions has gone up one tenth of a foot, we have a difference of 2,000, according to our increment, but our error is 2,000, so the error is 100 per cent. of the difference. And if we

should derive an increment, the error of that increment would be 100 per cent.

Now, when the lake has gone up another tenth, two tenths in all, the difference is 4,000, while the error is 2,000. We have an error of 50 per cent., and the error in the increment from that would be 50 per cent., and so on until we reached 220,000, the lake having gone up a foot, the error being 2,000 and the increment 20,000; the increment is then in error 10 per cent.

If, instead of the lake going up one tenth of a foot it had only gone up .03 of a foot, we would have had an increased quantity there of 600, while our error is 2,000, so we would have had an error of 333 per cent. in our increment. That is the case, except the values of the increment are different as referred to in my direct testimony. The increment, I believe, in that case was a larger one, so the percentage of error would be a little smaller.

Q. You are assuming in that instance, Mr. Shenehon, that your error of discharge is always 2,000 cubic feet per second?

A. Yes; it is approximately 1 per cent. of our base quantity. If we regarded it as 1 per cent., it would not be that, growing a little bigger as we increased the volume of flow. But to illustrate the case, this does it very simply, and to my mind very satisfactorily, indicating that the error, the percentage of error in the increment is substantially as the range considered. That is if you have a range of 1 foot, and you have a certain error in your increment, when the range is four feet, you have one fourth of it, and it comes about in just that way.

Q. How do you apply that to the situation which was presented here in the hypothetical question which I asked you?

A. Well, the reason is because you have taken a big difference.

Q. I have taken .57 of a foot.

A. No, a big difference in the volume. You have taken a difference there in the volume of so much that the 2,000 or the 1 per cent. becomes a relatively smaller quantity. Having established your percentage quantity, then of course dividing by your range does not alter that fact.

Q. Assume that your discharge at a certain elevation was 200,000 cubic feet and the error was 1 per cent.?

A. Yes.

Q. At another elevation the discharge was 190,000.

A. And the same error, 1 per cent.

Q. What would be your maximum, minimum and mean values of the discharge in the first case?

A. Well, assuming one per cent., that would be 200,000 for absolute, 202,000 maximum, 198,000 minimum.

Q. And in the second case?

A. 190,000, 191,900 and 188,100.

Q. What results do you get?

A. 10,000, 13,900 and 6100. Those are the differences.

Q. Those are the differences?

A. Those are the differences, yes.

Q. Assume these mean elevations were 1 foot apart, what would be the maximum, minimum and mean values of the increment?

A. The increment would vary between plus 39 per cent.—

Q. No, I am asking you for the values of the increment?

A. This would be the values of the increment.

Q. Just indicate it?

A. Between 13,900 and 6,100.

Q. What is the percentage error of the increment?

A. 39 per cent. From plus 39 per cent. to minus 39 per cent.

Q. Suppose these mean elevations were 0.5 of a foot apart, what would be the maximum, minimum and mean values of the increment?

A. The percentage error has already been determined by the difference of 10,000, and the assumed percentage, so it does not vary with the range, in the particular way in which you ask the question. It is dependent on the range, as indicated by the smallness of the difference.

Q. Then the range has no effect upon the value of the increment?

A. The percentage error of the increment varies substantially as the range, as previously stated.

Q. Then how do you make that out in the assumed case?

A. Because the 10,000 indicated here, the difference is a value depending upon the range. For instance, if your increment is 20,000, the 10,000 indicates that your range is half a foot. That is the thing that determines the percentage error in your increment; the relative size of the difference, and the quantity which is the error. If the difference is 10,000 and the error 2,000, you see that it is a relatively big percentage of the difference, and that is how the increment is dependent for its precision on the range.

Q. I am a little dense: I wish you would explain further?

A. It is this way: Take the case I cited where the volume of flow is 200,000. One per cent. of that is a relatively large quantity, and 2,000 compared say to the difference coming with half a foot change in stage, say 10,000, so if you divided the 2,000 by the 10,000, you see you have got right there a 20 per cent. error indicated; and if that may be either side, of course the range of values doubles up; so that is the reason. It is the size of the difference as compared to the size of the percentage of a big quantity which is the volume, that is what determines it.

Q. The difference which you used in the last instance here was small as compared with that in the first instance, wasn't it? That is the 100,000, and 10,000?

A. Yes, and we found in the case where we had the big quantity indicating a large range that the error of the increment is 5 per cent., between plus and minus 5 per cent.

Q. But the percentage of error in the increment is the same for a foot as it was for 0.5 of a foot, as you worked it out, wasn't it?

A. With 100,000 as a difference, we have an indication right there of between 4 and 5 foot range.

Q. I know, but on the basis of the second assumption?

A. I think you are—

Q. That is it was the same percentage of error where the difference was one foot as it was where it was five tenths of a foot?

A. As I stated, the size of the difference in relation to the quantity discharged, percentage error; that is in the case above there the size of the 100,000 as compared with the error of 1 per cent., 3,000 or 2,000 for the smaller quantity. That is what determines the thing.

Q. Mr. Shenehon, you have submitted certain charts showing gage relations between Buffalo gage and other gages on the Niagara River. Just what was it your purpose to prove by those charts? What do you understand them to show?

A. Will you specify as to the particular charts you have in mind, Mr. Adcock? Is it the one between Buffalo and the Whirlpool, and Buffalo and the Suspension Bridge; that is a single chart.

Q. Was it the regimen of the river that you attempted to establish there?

A. I think there is only one exhibit, Shenehon's Exhibit H, which is the relative fluctuations of the water surfaces in the Whirlpool and the Gorge Pool plotted with respect to Lake

Erie at Cleveland. Is that the one you have reference to, Mr. Adcock?

Q. Well, there were several charts put in.

A. Shenehon's Exhibit E, is the volume of discharge of the Niagara River related to Whirlpool and Suspension Bridge gages. Shenehon's Exhibit F, of April 15, 1914, is the volume of discharge of the Niagara River related to Suspension Bridge gage. And Shenehon's Exhibit G, volume of discharge of the Niagara River related to the Whirlpool gage.

Q. You had some purpose in mind in offering those exhibits, did you not?

A. Yes.

Q. What I wanted to get was what you considered that they showed?

A. The volume of flow of a river like the Niagara may be referred to the controlling gage at Buffalo, known as the Buffalo gage. It also may be referred to other gages in the river, so that we may write out an equation, a discharge equation, in terms of the height of the water surface at Chippewa gage for instance, or at the Suspension Bridge gage, or at the gage in the Whirlpool; so that we have volume of flow referred to those particular gages.

Then we may, by water level transfer, relate the fluctuations of the Chippewa gage or the Suspension Bridge gage, or the Whirlpool gage, with the gage at Cleveland, the Lake Erie gage at Cleveland; or to the gage at Buffalo. And then by the ratio of fluctuations write out the increment, deriving an increment, first, of course, for these river pools; then write out an increment for the water surface of Lake Erie at Cleveland and Buffalo.

It is a simple, legitimate process of open season transfer of water levels. In the end, the object of this is to answer the criticism made in the testimony as to the Buffalo gage or to the fluctuations of Lake Erie. But these criticisms are that Lake Erie fluctuates so rapidly, and in time of storm the waves may have such an effect on the gage elevations or on the gage pipe, that we doubt the conclusions of that gage. That is the criticism, you understand. But this process is to relate the volume of flow to quiescent places in the river itself where storms do not roughen the water to any large extent, and in this way the Buffalo gage as an element in the derivation of the increment disappears; it is not necessary. When I say that, this relates of course only to the 1907 and 1908 observations, because we did not have these other river gages during the times of the earlier measurements.

Q. How are these gages related to the discharge measurements?

A. The times of the individual discharge measurements are known, and the length of time which it takes to make an observation, so in this process the elevation of the water surface at Suspension Bridge, for instance, was taken at the third even hour after the beginning of the particular discharge observations, and as a rule four of these hourly readings of the gage were taken, taken from these scaled sheets; and then these observations themselves were formed into groups of ten, or in perhaps a few cases there are less than ten in a single one of the groups. The sheets themselves show that.

Then these are plotted with respect to the gage concerned, the volume of flow as shown by the measurements related to the height of the water surface, and the line is computed indicating the law of relationship. From that an increment is derived for this particular pool, for instance the Gorge at Suspension Bridge. And then by this relation of fluctuations between Lake Erie and the particular pool, as the Gorge, we have a multiplier in the relative movement of the Gorge Pool to convert the increment there to the increment referred to Lake Erie at Cleveland, or at Buffalo.

I did not explain the difference in these curves. I believe Shenehon's Exhibit E, took the discharges on days when there are four discharges, and in that case I believe that the ten hour period was utilized, beginning I think at ten o'clock in the morning; in other words endeavoring to put a lag of about 3 hours between the measurement and the water surface elevation in the Gorge. And the same for the Whirlpool. I believe in that case, there were ten even hours taken from these Lake Survey gage sheets for the four measurements of the day, and only those days where four measurements were taken were utilized in making this curve.

This curve, however, was succeeded by the other curves mentioned, where all of the observations available for 1907 and 1908 were utilized in groups of ten, in order of stage.

Q. Why do you use four hours there, Mr. Shenehon? You spoke of the fact that the gage was read for a period of four hours, hourly?

A. Well, we took the nearest four hours after making a time correction, you understand, of three hours. The lag is a little over three hours; so we used the nearest, the third hour after the time of beginning discharge measurement and then the three succeeding hours, including four hourly readings in all to cover the 3-hour period.

Q. Did your gagings last for a period of four hours?

A. Not as a rule. They lasted two hours and possibly a little over. We sometimes took four in a day. That would indicate possibly a little better speed than two hours.

Q. That is you would travel across the river on your gagings taking the observations at various stations, would you?

A. Yes.

Q. And what would you do, take the mean of the four hours to determine the elevation for the period, for your discharge measurements made?

A. Yes.

Q. Did you make any calculations for the time that you were making observations at stations in mid-stream where the percentage of—

A. You mean weighting the mid-stream?

Q. Yes?

A. No, that would not be applicable for a gage so far downstream, I think, or not necessary. The weighting of observations in that way, in the end, is a refinement that tends to reduce the residual a little bit, make the observations a little more accordant among themselves, and has no substantial effect on the final result. That seemed to be a logical, proper method—

Q. There are about 340 discharge measurements made there, aren't there?

A. That is in the Niagara River, we have 219 at the International Bridge in this case and 121 at the Open Section; and 10 at the Split Section, which are not included in the 340 mentioned.

Q. Did the lake remain fairly constant during the period of each of these discharge measurements?

A. That is a matter of record.

Q. It was probably fluctuating during the four hours, wasn't it?

A. Some flunctuations, yes.

Q. And there were certain spans of the International Bridge there where the largest percentage of the water flowed, weren't there?

A. Yes.

Q. You did not make any observations or refer the discharges obtained for those particular spans where the percentage of the water going through was greatest to the elevation of the lake at that particular time, as I understand it, at the time the observations were made at those stations?

A. You are referring now to these reductions for the Gorge and Suspension Bridge?

Q. No, I am referring to the measurements made at the International Bridge?

A. Oh, yes, in the measurements made at the International Bridge where they were referred to the Buffalo gage, they took account of the elevation of the gage at the particular time the station was occupied.

Q. That is at the instant, or for a time before that, eight minutes?

A. In the case of the Open Section that correction was made, and I had an impression it was in the Bridge Section; and I am inclined to think it was in the later observations. But I notice in the 1900 report a statement that it was not considered at the Bridge Section, that ten minute to eight minute lag.

Q. Then as I understand it, at the time you observed at a certain station, you would connect with that observation the elevation of the lake at that particular time, at the time you made the observation?

A. Or with a time preceding by eight to ten minutes.

Q. But you don't know now whether you made any allowance for the time interval on the measurements at the International Bridge?

A. It states in the 1900 report that the observations at the Bridge Section did not take into account this eight or ten minutes lag. In the Open Section it did, but, as I say, in the reduction of the 1907-'08 observations, it is my impression that the lag was taken into account.

Q. You want to state it as a fact that the lag was taken into account in the 1907 and 1908 observations?

A. I state it as my belief. I could not state it as a positive fact.

Q. Did Mr. Moore make those observations, or did you?

A. Mr. Moore made those observations.

Q. You think he introduced that refinement into the observations?

A. It had been rather a customary practice beginning, I think with the—I rather think that was begun in observing the St. Marys River.

Q. When was that done?

A. That was in the Nineties, 1895, 1896.

Q. You overlooked that in your 1898, 1899 and 1901 measurements?

A. On the Niagara?

Q. Yes?

A. I reached Buffalo in July, 1898, and took charge for two months of the office of the Deep Waterways Board of Engineers, and at that time the observations had been in progress for some time, and they were continued for a couple of months by Mr. C. B. Stewart and from that time until July—

Q. I am referring to the Lake Survey measurements that you had charge of on the Niagara River.

A. The Lake Survey measurements began in September, 1898, under my direction and charge, and immediate supervision; and continued until July, 1900.

Q. I just wondered why you did not take into consideration the time interval there, Mr. Shenehon? You state that in the St. Marys River measurements in 1895, that that time interval was taken into consideration, and I understand that those measurements were made by the Lake Survey in the St. Marys River. Did you consider it—

A. We had another thing in the St. Marys River, that was not repeated. That is we corrected for reservoir effect in those earlier measurements, and that appeared to be a refinement that was not necessary, not warranted, and was not used in any of the later observations that I am aware of. This eight or ten minutes is not a very essential thing, Mr. Adcock.

Q. I wondered why Mr. Moore differed with you. You understand that he saw fit to use the time interval there?

A. You mean in his 1907 and '08 measurements?

Q. Yes?

A. He would have my full approval, and I presume it was discussed with me, his doing that on the Bridge Section in 1907 and '08. It would be very natural that the 1907 and '08 work coming later should utilize that correction.

Q. Then your opinion changed as to the propriety of making allowance for the time interval between the early observations—

A. My opinion is now it is a logical, proper thing to do; that in the final result it has very little bearing on either the volume of flow or the increment.

Q. And that was a matter of judgment which you exercised in 1898, when you started in on these measurements for the Lake Survey on the Niagara River, and your judgment has not changed?

A. No.

Q. Notwithstanding the fact that Mr. Moore cited that to you, that refinement in his measurements?

A. No, I should have O. K.'d and possibly I did O. K. his doing that.

Q. Now, after you took these observations, referred the observations which you made at a particular station to the elevation of the lake at that time, or as Mr. Moore did eight minutes before, the Buffalo Gage, what happened to the observations? That is, so far as those particular things were concerned, did you make allowance for the amount of water passing through each station and weight the observations according to that?

A. Now you are getting at this point that some stations, for instance, have ten per cent. of the flow and some have one per cent. of the flow; the gage that prevails during the time of one per cent of the flow, that is the actuating cause of that flow, is given the weight of one. The gage prevailing, the height of the Lake prevailing during the measurement of that station which is ten per cent. of the flow is given a weight of ten. I am making this rather arbitrary, these weights. That is what you have in mind.

Q. Yes, assuming those were the facts. Upon these charts, and in the information that has been presented here in this case, you have an elevation given and the discharge of the lake according to that elevation, have you not?

A. Yes.

Q. Is the elevation given the mean for the four hour period which you mentioned?

A. You are referring now to the Whirlpool and the Gorge?

Q. No, to the International Bridge. What is that elevation that is shown, how do you get the elevation?

A. It is a weighted mean. We find out that in each station there is a certain percentage of flow.

Q. I am speaking of the elevation now?

A. Yes, I understand. I am showing how we get the weight. As I stated before, these stations, one may have a weight of one, another two, another five, another seven, another ten. As we proceed with reference to our Buffalo gage, the gage height that corresponds to the time of the observation, where the weight was ten, was given a weight of ten. It is the weight of the elevation.

Q. That is the particular station?

A. Yes, and the gage elevation is a weighted mean. But whether we had taken a simple mean for the time of the ob-

servation or had taken a weighted mean, in the final result, would have made no difference.

Q. Then you went to a lot of work for nothing, didn't you?

A. It seemed a logical, proper thing to do. Sometimes you do things that possibly have a limit, too much refinement in them. Sabin, I believe, did not weight in the same way.

Q. He took the simple mean, the actual mean?

A. That is my recollection.

Q. His judgment in that connection differed from yours?

A. Not in any substantial measure, not widely.

Q. Perhaps he was trying to follow the path of least resistence, not putting himself to any unnecessary burden, is that the idea? You say it didn't make any difference whether they were weighted or not?

A. I say it made no substantial difference. I had already explained it would probably reduce the residuals a little bit; that is the individual observations would be a little bit more accordant.

Q. Does the fact that you used that method in your discharge measurements of the Niagara River induce you to say that they are better than the St. Clair measurements?

A. No.

Q. That does not have anything to do with the determination of that question?

A. Not any. But I am not certain that you have heard me say that the Niagara River measurements are better than the St. Clair River measurements. I say we were able to get an increment that is determinate and reliable for the Niagara River, where we have a margin of variation in the St. Clair. I have stated in my testimony that I believe the volume of flow of the St. Clair is—

Q. I am speaking with reference to the elevation of the lake.

A. The determination of an increment, of course, is another matter. They had some gage difficulties on the St. Clair that we did not have on the Niagara.

Q. What I was trying to get at was whether the fact you used the method which you have just described had anything to do with your forming an opinion as to the relative accuracy of the discharge measurements?

A. No, I should say it had no bearing whatever on the increments nor on the volume of flow, taken as a total.

Q. Then if you were going to make discharge measurements again for the purpose of determining an increment, or endeavoring to determine an increment, you would not

use the method that Mr. Moore used, or that you used in the Niagara discharges, the weighting and so forth?

A. Yes, I think I would.

Q. Notwithstanding the fact that in your opinion it would not make any difference?

A. There is an advantage in lowering your residuals a little bit; you have your observations in line a little bit better.

Q. What did Mr. Richmond do in his measurements at the Split Section?

A. I believe he did not so weight his gage. I think I would agree with him on that, on account of the distance from the Buffalo gage.

Q. What did you do on the St. Lawrence River?

A. On the St. Lawrence River, we weighted them I believe, although it is a distance there that makes it of rather doubtful propriety. Possibly it was following out a scheme that had been used before.

Q. The distance was greater on the St. Lawrence than it was at the Split Section?

A. Yes, the justification on the St. Lawrence would be less than on the Split Section, for that.

You understand this is a very trivial thing; whether you do it or not make little difference in the final result.

Q. You spoke of the St. Lawrence measurements which you considered threw some doubt on the increment which you had obtained for the St. Lawrence period. Would you just explain what that error was that crept in?

A. I don't know.

Q. You don't know?

A. Mr. Richmond made some observations that appeared to indicate that the water was accelerating at a fairly rapid rate as it crossed the section; and that if our meter was a little further up or downstream it made some little difference, and he appeared to feel that was the reason why there seemed to be this discrepancy between the increments, that seemed by the later measurements less than the earlier increment.

Q. When you testified the other day, you took all the indications which you thought appeared in the later observations and gave the increment which resulted from that?

A. Yes. My testimony on the increment of the St. Lawrence is simply a reflection of the testimony of the Lake Survey men in this case, their independent investigation. It is, as I stated, however, indicated by an investigation through fluctuations, that the increment is between eighteen and nine-

teen thousand; and while this is a crude method, as I stated before, it has influenced my judgment to a certain extent. The relationship between Erie and Ontario is very much better than that between Michigan and Huron and Erie, and there is a reason for that.

Q. Then you are not convinced that the increment which was given as 21,000 for the St. Lawrence River is really the true increment?

A. Not ultimately, no.

Q. You would not want to be understood as staking your professional reputation in this case upon the fact that 21,000 is a true increment?

A. No, my testimony on that must have all the reservations of the witnesses of the Lake Survey on that point.

Q. Then you assume that the opinion given by Mr. Richmond and Mr. Moore, as to the increment being 21,000 may not be the correct opinion?

A. Yes, I think that is subject to a variation of 10 to 15 per cent. either way.

Q. Either way?

A. Yes.

Q. It might be as low as 18,000 or as high as 24,000?

A. Yes, and the indications of the fluctuations would be that it is closer to the down side, although I do not think that is ultimate.

Q. And the increment which you gave in 1909 for the St. Lawrence River in this case was 50 per cent., might be 50 per cent. in error, might it not?

A. No. Let me figure it for you. On U. S. Exhibit Number 2, the increment of the St. Lawrence for the time prior to the building of the Gut Dam, and referred to the gage at Ogdensburg is 28,900. Correcting by 5½ per cent. for the building of the Gut Dam and 2 per cent. to transfer to the Oswego gage gives an increment of 26,870. Then my statement was at that time this might be 10 per cent. in error. Subtracting that gives an increment of 24,180, which is a proper deduction from my earlier testimony. Now I say that the increment may be 21,000 or 22,000, I believe my testimony was.

Q. It might be 18,000, about?

A. I hardly think it is as small as that, probably not smaller than 20,000.

Q. Then your statement that it might be ten or fifteen per cent. either way is not entirely correct?

A. That is a little bit rough, I should say.

Q. Did you make a correction in Exhibit 2, for the Gut Dam?

A. It is noted, yes, both the correction for the Gut Dam and for the Oswego gage. Both those are made in the form of a note.

Q. You said that the period for a change of discharge to pass from the Buffalo gage to the Chippewa gage was two hours for a distance of 20 miles; and from Buffalo to Suspension Bridge, three hours for a distance of 22 or 23 miles. Why, in your judgment, does it take an hour for the effect to travel the last two or three miles?

A. I think the statement for Chippewa is a little over two hours, and the statement for the Suspension Bridge gage is a little over three hours, about three hours and a quarter as I recollect it. That makes an hour's difference. The travel of the water over the rapids, about three-quarters of a mile of the cataract rapids, of course, is very slow.

Q. Is it slower than it is in the river?

A. Doutbless; it is a function of the depth under those circumstances, the travel of an increment of that kind; then the accumulation of water in this Gorge Pool, and the distance I believe from Chippewa is from three to four miles instead of two, as you stated.

Q. What is the cross-section of the river over the rapids?

A. Which rapids? That is somewhat variable. At the head of the rapids, my recollection is it is about three quarters of a mile wide or a little more.

Q. What is the depth, mean depth?

A. May I see the Preservation of Niagara Falls Report? (Referring to same.) Well, the depths pretty well down towards the first cascades from Plate Number 12 on the Report of the Preservation of Niagara Falls are all the way from two and a half, two, three, five and four-tenths, three, four and four-tenths, six and six-tenths, six and six-tenths, six and six-tenths, five and three-tenths, eight and four-tenths, seven and eight-tenths. And on a line across from Chippewa to the entrance of the Hydraulic Power Company's canal, the depths range from 2.3 down to 11.6. The bulk of the way it is less than 9 feet.

Q. How would the velocity there compare with the velocity at the International Bridge?

A. It would be inversely as the depth; that is the shallower water and the width, of course, taken into account; for equal width that would be.

Q. Would the water get through that section faster than

it would through Sections like the International Bridge, or the Split Section or the Open Section?

A. The velocity is faster, yes.

Q. Then it does not take the water longer to get through?

A. The general formula for the travel of a crest or increase in depth going down the river is as the square root of the depth, so the greater the depth, of course, the more rapidly the wave advances. In great depths, of course, they go at pretty high speed; the change of condition.

Q. Are you speaking of the passage of a wave; the change of discharge or change of elevation?

A. Both. I think we have the same condition on the St. Lawrence, the passing of the water over the Galops Rapids.

Q. In connection with the gage readings at the Suspension Bridge and the Whirlpool, were there any measurements of discharge made at those points?

A. At the Suspension Bridge?

Q. Yes?

A. Or the Whirlpool?

Q. Yes.

A. There were no velocity measurements made.

Q. You mean no discharge measurements. By velocity measurements. you mean discharge measurements?

A. I mean at the head of the Whirlpool Rapids, which is the foot of the Gorge, there were no velocity measurements made in connection with the gage reading at the Suspension Bridge gage. The measurements of velocity were made at the International Bridge in 1907-'08.

Q. That was the only place was it, Mr. Shenehon?

A. Yes, in those years.

Q. Then if the measurements heretofore considered in this case are in error as indicated by the testimony of Defendant's witnesses, the indication of these charts would also be similarly in error, would they not?

A. You are referring now to these exhibits that have to do with the Suspension Bridge and Whirlpool gages?

Q. Yes.

A. So far as the volumetric part of the observations is concerned; but the object of these exhibits was to indicate that we could eliminate the Buffalo gage and not regard that as an element of error in the observations.

Q. You wanted to predict the gage height at some other point, passing from the Buffalo gage, is that the object?

A. No, we can predict that from the Cleveland gage, as is done in one of these exhibits.

Q. How closely?

A. Mr. Williams' evidence is full of the closest—

Q. I am asking you.

A. I refer to that, because there are some figures given there which are pertinent, and I haven't in mind the exact coincidence. It is shown on the exhibit, if we can get it, an exhibit that has Chippewa indicated.

Q. I am asking you generally how closely as to time, etc., and as to stage?

A. Monthly mean elevations of the two water surfaces were utilized in the transfer from Cleveland, during the open season, of course, and preferably during the quieter summer months.

Q. That would not have anything to do with your discharge measurements, would it?

A. The relation of two water surfaces, such as the surface of Lake Erie and the surface of the water in the Whirlpool for instance, or in the Gorge, taken over a certain period of time, is fixed; they are very definitely related.

Q. Take the Cleveland gage, say for instance you had a daily reading mean daily Cleveland gage, could you predict from that mean daily a daily mean for the Chippewa gage?

A. Oh, no.

Q. It only relates to monthly?

A. You must take, I should say, as long a time as a month to have any good results, but you can from the Buffalo gage, from day to day, you can predict the Chippewa gage with great precision.

Q. Can you predict the Chippewa gage by hourly readings at Buffalo?

A. Not with the same precision. No, there are some fairly wide divergencies in hours. They will not exactly track.

Q. With reference to what length of time, what period of time would you think it necessary to cover that, in order to predict the Chippewa gage?

A. I should say three or four hours would possibly give a reasonably close relationship. I wish to state in regard to the Chippewa gage that that gage is subject to some fluctuations due to the water in the power canals at Niagara Falls, so the relationship there is not quite as good, taking in a short period like a few hours, as it would be in a day; and of course in a month it is more accurate.

Q. Suppose you had a rise at Buffalo, sudden rise within a half an hour of a half a foot, could you predict what the elevation of the Chippewa gage would be from that?

A. A rise of a foot in half an hour, is that the point?

Q. Yes.

A. No, I should not attempt to predict the elevation.

Q. Suppose you had a rise of a half a foot in an hour?

A. No, I should not attempt to predict very accurately. When I say that, that is within an inch of the elevation of the Chippewa gage. I am not sure but what I could within an inch.

Q. Within an inch?

A. Yes, I think so.

Q. What proportion of the change at the Buffalo gage is the corresponding change at Chippewa?

A. A foot at Buffalo is followed by .56 of a foot.

Q. That is 56 per cent.?

A. 56 per cent.

Q. I show you some exhibits that were introduced in this case, showing the hourly records of the Buffalo and Chippewa gages for November 1st to 6th, 1906, referring to Williams' Exhibit Cross Examination Number 4, two sheets, what hour do you find the first maximum on the Buffalo gage, and what is it?

A. One minute: Has this to do with the lag between Chippewa—

Q. I don't know yet. I am asking you the question. We will use it for whatever purpose we can.

A. The reason I ask you that is that I have tabulations in which the lags are taken out consecutively with a determination that I think has more accuracy than any little picking of these hours might have in this cross-examination. I would be very glad to put those in evidence.

Q. I am asking you, Mr. Shenehon, the question. I will endeavor to use the testimony in the best way possible.

A. The question is to find the crest on the first day, is it?

Q. Yes?

A. Is this confined to the first day?

Q. Confined to the first day.

A. I find that during the whole day, the change of elevation of the water surface at Chippewa is only three-fourths of an inch, and it is very difficult under those circumstances to pick out a crest.

Q. I am asking you as to the Buffalo gage, Mr. Shenehon?

A. This is the Chippewa gage, I had before me. (Referring to another exhibit.) The first crest I find is on the

third hour, a rise of .06 of a foot or three-quarters of an inch.

Q. That is 3:00 A. M., isn't it?

A. That is 3:00 A. M.

Q. The elevation is what, 571.92?

A. 571.92.

Q. How much of a change in one hour?

A. From the hour before?

Q. Yes?

A. 5/8th of an inch, .05 of a foot.

Q. But it is .06 down, isn't it?

A. Yes, on the fourth hour it goes down to .06, or 3/4ths of an inch.

Q. Do you find a corresponding summit at Chippewa?

A. At Chippewa between the third and the fourth hours, we have a rise of .02 of a foot, and it runs level between the fourth and the fifth, and between the fifth and the sixth it shows a rise of 1/8th of an inch.

Q. How long after?

A. That is the next hour.

Q. The next hour?

A. Yes.

Q. You would not consider that that rise had anything to do with the summit that you just spoke of at 3:00 A. M.

A. I think we are getting down to rather little quantities to look for duplication of a crest.

Q. What do you find as to that, Mr. Shenehon?

A. I can read these off.

Q. No, I am asking you if you find a summit at Chippewa to correspond with the summit which you just mentioned as occurring in the third hour?

A. No, not a well marked crest.

Q. What and when is the following low point on the Buffalo gage?

A. The 12th hour, we have an elevation of 571.72.

Q. Do you find a corresponding minimum at Chippewa for that?

A. We have 562.39 for the 14th hour, which is a little below the readings of the hours preceding. The 12th hour is 2.42, the 13th 2.40. This is 2.39, a drop of 3/8th of an inch in the three hours readings there.

Q. For what hour is that?

A. That is down to 14, at the 14th hour; figuring on a two hour lag, we have 2.39. The 15th hour it gets down to 2.38.

Q. What per cent. is that of—
A. Of the change at Buffalo?
Q. Change at Buffalo?
A. At Buffalo, between the 11th and 12th hours it drops down to 0.05 of a foot, and at Chippewa between the 13th and the 14th hours it drops down 0.01 of a foot. That is 20 per cent.
Q. You ought to have predicted that about 56 per cent.?
A. No, I don't think any one of us would have predicted that with these little movements. The effect of the power companies would doubteless be in excess of the quantities at Chippewa indicated here.
Q. When and what is the following summit at Buffalo?
A. We have 1.96 at the 19th hour.
Q. 1.96 what?
A. That is 571.96, 571 is not indicated.
Q. What is the rise from that depression, previous depression?
A. That is .14 of a foot—no, .24 of a foot.
Q. Do you find a corresponding summit at Chippewa?
A. On the 20th hour we have 562.41 which is .03 of a foot over the 15th hour, which was 562.38.
Q. Do you consider that a summit to correspond with the summit at Buffalo?
A. Well, that 15 hours there, that 2.38 is the low corresponding to 1.72, I should say, 571.72 at Buffalo, and the 21 and the 22 hours are 562.42, each of them.
Q. Isn't there a summit on the Chippewa gage?
A. The last observation at 24 o'clock shows 562.44.
Q. What does it show between two and three A. M. of the second day?
A. That goes up to 562.45.
Q. Isn't that the highest following the summit of the Buffalo gage that you just referred to of .24 of a foot?
A. Yes.
Q. What is the interval there?
A. Well, I think these quantities are such that we can hardly take off intervals.
Q. Well, there was a summit at Buffalo wasn't there?
A. I might say that a little more draft in the power house, at the Ontario Power Company, a little more draft in the Niagara Falls Power Company's plant, a little more or less in the Hydraulic Power Company's plant would have a much wider effect than that indicated by the whole range of the Chippewa gage.

Q. Would the draft of these power companies be the same?

A. I think if you are looking for crests you are pursuing an improper method. Or if you are looking for time intervals, you are not pursuing a proper method.

Q. Would a draft on the power house create a summit at Chippewa?

A. A lessened draft.

Q. I thought you said a draft?

A. I suppose we can think of those as plus and minus.

Q. Change of draft?

A. A change of draft, perhaps that is a better statement.

Q. As a matter of fact there is a seven hour interval between the crest at Buffalo where the depression was .24 of a foot and the summit at Chippewa.

A. No, I see no evidence of that fact.

Q. Isn't it a fact that the highest is 7 hours?

A. I state very positively that the pettiness, the littleness of the quantities you are dealing with here are sufficient to obscure the object, if we are looking for the lag.

Q. I am asking you, Mr. Shenehon, as to—

A. That is my answer.

Q. I am asking you as to what those gage readings show at Buffalo and Chippewa?

A. I say that the movement there is reaching the limits of observation and the physical indication is not a conclusion that may be drawn as to the lag.

Q. Then you would not want to take those figures or those records of observations of the elevations at the Buffalo gage and Chippewa as indicating anything that appears on those exhibits. Is that right?

A. I regard this as an improper method of attempting to get the lag out of these little changes in gage elevations, just as I regard the method of getting an increment out of 0.03 foot range on the St. Clair River in the same category.

Q. I am asking you what appears from these exhibits?

A. I am endeavoring to give you as accurate an answer as is possible under the circumstances. You are endeavoring to get a statement as to what the lag is. I say it is not to be gotten out of that day's record.

Q. So that you could not tell anything about the lag from the exhibits I have just shown you?

A. There is nothing determinate as to the lag in that little change indicated on that sheet.

Q. But as a matter of fact the interval of time between

the summit that you have just referred to at the Buffalo gage, seven to eight P. M. of the first day, and two to three A. M. of the second day is seven hours, isn't it?

A. I do not dignify those by the term summits.

Q. They have the highest record, highest gage readings there, the highest elevation shown by that exhibit for that day?

A. We have on the Buffalo gage at the 19th and 20th hours 571.96 and we have on the Chippewa gage the highest elevations, 562.45, on the second and third hours of the following days.

Q. Now there are seven hours between that, aren't there?

A. Yes.

Q. Twenty-four one hundredths of a foot, is how many inches? About four inches, isn't it, three inches?

A. Yes, a little less than three inches.

Q. And you do not consider that that is a change of elevation that amounts to anything?

A. No, I do not state that.

Q. I misunderstood you then. You said it was a trivial, insignificant, small change that would not be indicated anywhere, could not be taken into consideration.

A. I am speaking of your crests at Chippewa now, what you call a crest at Chippewa.

Q. Yes, and we are speaking of a change of elevation at the Buffalo gage in Lake Erie.

A. Yes.

Q. What change of elevation—

A. I have explained also, but perhaps I ought to go into that a little more in detail, that the Niagara Falls Power Companies are lowering the water at Chippewa by a considerable amount, in the neighborhood of four inches; and the change of draft on those plants is sufficient to account for some little irregularities in the Chippewa gage. When it comes to the matter of daily draft, they are so nearly uniform that you may make the prediction with considerable certainty.

Q. What would you consider to be a sufficient raising or lowering of Lake Erie to have any effect or be of any material consequence, so far as this is concerned, determining the same?

A. Whenever Lake Erie goes up one-tenth of a foot, approximately 2,200 cubic feet of water would go down the river. If it is a case of rise, a portion of that will be absorbed in

the reservoir effect as it goes down, and in the end there will be a reflection at Chippewa, but part of that may go through the turbines. It is not necessary to have all of it go through the turbines, and where water is going through the turbines you have a diversion effect that lowers the water; just as the Chicago Drainage Canal lowers the lakes, so we have that condition coming in there.

Q. Well, that rise of .24 of a foot would have some effect on the discharge at the International Bridge, wouldn't it?

A. Yes.

Q. And it would have its full effect in eight minutes?

A. Yes.

Q. It would not make any difference in the discharge at the International Bridge whether that rise had continued down through the river, would it, in your opinion, the full length, so that the river had established its regimen according to the change of stage?

A. You do not understand me to state that a little rise on Lake Erie is going to be indicated for instance in the Gorge by any large rise there, especially if that rise is followed by a fall, do you?

Q. I don't know. I am trying to find out about it. I am looking for information.

A. I stated I would be very glad indeed to present some computations of lag, some tabulations, if you are really looking for that.

Q. We are trying to ascertain just what the travel is there according to these—

A. I can help you very materially if you will permit me to present certain tables.

Q. —according to these sheets which you have presented. I am asking you for those. Now, take the next, what is the change at Chippewa from the last minimum?

A. The last minimum being the 21st hour at Buffalo of the first day.

Q. The last minimum at Chippewa was on the 17th I think.

A. What is your question, Mr. Adcock?

Q. What is the change at Chippewa from the last minimum?

A. Will you state the hour to which you refer, the 21st hour of the first day on the Buffalo gage?

Q. No, I am speaking of the Chippewa gage.

A. The minimum preceding the last maximum.

Q. Yes?

A. The minimum at the 17th hour of the first day.
Q. Yes. What is the change?
A. From what?
Q. From the maximum, from the minimum to the maximum?
A. The maximum I see above there is 562.43. That would be .05 of a foot, 5/8ths of an inch.
Q. Is that the maximum?
A. Yes, I think so.
Q. What happened the next hour, does the gage go down or go up?
A. The minimum as stated is on the 15th hour; goes up one hundredth the next hour and goes down one hundredth the next hour, that is the 17th and goes up one hundredth the next hour; and on the 19th it goes up another hundredth. The 20th is 562.41, the 21st is 562.42.
Q. What is the change?
A. The 22nd is 562.42, the 23rd 562.42, and the 24th is 562.44.
The first hour of the second day of the month,—that is the month of November, 1906—is 562.44; the second hour is 562.45. It continues—I mentioned that before—the third hour 562.45; there is .07 of a rise there.
Q. Seven hundredths of a rise?
A. Yes.
Q. What is 56 per cent. of the Buffalo gage, when do you start on the Buffalo gage?
A. The Buffalo change on the first day of the month is from 571.72 to 571.96 on the 19th hour. That was .24. Is there a question?
Q. Yes, what is 56 per cent. of the Buffalo change?
A. That would be about .13.
Q. Then the observation at Chippewa was five hours late and about 50 per cent. too small, wasn't it?
A. According to the indication of these other changes, yes.
Q. When and what was the following minimum at Buffalo?
A. On the sixth hour of the second day we have 571.72.
Q. What was the change from the last to maximum?
A. That would be the same thing that we had before, a drop of .24.
Q. Do you find a corresponding minimum at Chippewa?
A. On the 8th hour we have 562.38 which is a drop of .07 from the maximum preceding.

Q. When and what is the following summit at Buffalo? In that last, by reason of the fact that Chippewa did not change to correspond, is there another change of draft on the power house?

A. I will not attempt to explain the difference.

Q. You gave that as something that probably happened with reference to the other—

A. We are working with rather a short base here.

Q. We will take another one; we will get a little larger base. When and what is the following summit at Buffalo? Look at 15 o'clock. 572, wasn't it?

A. The following summit?

Q. Yes?

A. The 11th hour on the second day 1.93.

Q. Summit at Buffalo?

A. Yes, 571.93 on the 11th hour of the second day.

Q. What is the corresponding change at Chippewa?

A. There is a rise of 0.01 by the 13th hour and .02 by the 14th, and the highest is shown on the 18th, 572.43.

Q. How long after is that?

A. Seven hours.

Q. Won't you have to find another summit there about two hours previous for the Buffalo gage?

A. I think we are working on a rather short base here.

Q. We are trying to find a larger base. We are trying to get these intervals as they show on that exhibit. How much was the change from the preceding minimum on the Chippewa gage?

A. .05.

Q. That happened at 18 o'clock, didn't it?

A. 18 o'clock.

Q. Look for three hours previous at the Buffalo gage, what do you find? You find 572, don't you?

A. Yes, 572.00.

Q. And the change from the preceding minimum on the Buffalo gage is .28 of a foot, isn't it?

A. .28, yes.

Q. Would it be your opinion that the summit at 18 o'clock on the Chippewa gage corresponded to the summit at 15 o'clock on the Buffalo gage?

A. I should prefer to get better marked changes, in order to work out this lag.

Q. .28 of a foot is a little over 3 inches, isn't it?

A. Yes. Of course, we have a range, you know, on the Buffalo gage of 4 feet.

Q. Do you think there is another draft on the power house there, from the power house?

A. I am very positive that the draft for this power is going on very constantly, and I presume there are some fluctuations.

Q. What percentage of the total flow is the draft?

A. Somewhere in the neighborhood of 20,000 cubic second feet at the present time.

Q. About ten per cent.?

A. Yes.

Q. How much of a change would you anticipate there might be, or variations from this?

A. The lowering due to that is somewhere in the neighborhood of five or six inches. I am not quite certain as to that.

Q. How much is the change of draft variation in the flow?

A. I can't give you that; I haven't the power curves of the company. The Niagara Falls Company has a light and traction load, and some little variation in the lead. The Ontario Company I believe also furnished power for light and traction on the American side.

Q. On what do you base your statement as to the change of draft?

A. General knowledge of power companies.

Q. But you don't know what the variation of flow is?

A. No.

Q. You don't know whether there is any variation at all as a matter of fact?

A. Yes, I know as a matter of fact there is.

Q. You know the percentage of 24-hour power these people consumed, don't you?

A. I think it is all sold as 24-hour power, or practically all; and yet when I say that I am not certain as to the Ontario Power Company load.

Q. Do you know the load factor?

A. No; I know the Hydraulic Power Company's is pretty nearly the 100 per cent. factor, so the variation is rather small.

Q. According to that, the change at Chippewa was one hour late and about 70 per cent. too small, wasn't it?

A. Well, it was late and small.

Q. 70 per cent.?

A. Some large percentage. I don't remember.

Q. You think that might be because of the change of draft in the Power Company?

A. I state that as one of the uncertainties, and I am—

Q. We will take the next. When is the next minimum at Buffalo? Look at 21 o'clock, elevation 571.78.

A. 21 o'clock?

Q. Yes.

A. 571.78.

Q. What is the change?

A. From the 572 above is .22.

Q. Do you find a corresponding minimum at Chippewa? When you look for a corresponding minimum, what time interval do you take there?

A. I look for about two hours. The drop is .04 between the 18th hour, the last summit at Chippewa, and the elevation is 562.39.

Q. There is about four hours there on the Chippewa gage where it was absolutely steady, wasn't it, following that summit?

A. Yes, there are five hours.

Q. Five hours there wasn't any change?

A. No.

Q. So you do not find any depression to correspond to the almost three-inch change at the Buffalo gage?

A. There is no well marked corresponding change.

Q. If you were plotting that, you would have a straight line, practically for that?

A. The five hours.

Q. For five huors would be a straight line, horizontal line?

A. Yes.

Q. When is the next summit at Buffalo? Look at 2 A. M. the third day.

A. On the third day at two o'clock we have 572.04.

Q. Is there a corresponding summit at Chippewa?

A. Yes, the gage rises a few hundredths; on the fourth hour it is 562.43, a rise of .04.

Q. It remained stationary there for about four hours?

A. It runs stationary for four hours.

Q. If you plotted it, you would have a horizontal line, wouldn't you for four hours?

A. Yes.

Q. And the change at Buffalo is a little over three inches, isn't it?

A. Yes, one-eighth of an inch over three inches.

Q. When is the next depression at Buffalo?

A. On the eighth hour we have 571.74, a drop of .3 of a foot.

Q. That is about eight o'clock, isn't it?

A. Yes, that is eight o'clock.

Q. From seven to eleven, it runs practically steady?

A. Well, we have a drop between the peak at the seventh hour there at Chippewa, we run down to—

Q. I am speaking of the Buffalo gage?

A. Yes, that runs steady, pretty nearly steady for four hours there.

Q. That is a pretty good length of time?

A. Yes.

Q. And the change was very near four inches, wasn't it?

A. Between that and the 572.04 recorded above?

Q. Yes?

A. Yes.

Q. Where does this appear at Chippewa, at what time, if at all?

A. Chippewa shows a drop down to 572.36 by the 12th hour, from 572.43.

Q. Isn't it the 13th hour?

A. It runs down to .34 on the 13th. That is the minimum, 562.34.

Q. It stays pretty regularly there from 13 o'clock to 16 o'clock, doesn't it?

A. Yes, it is fairly steady there.

Q. How much is the change at Chippewa?

A. The drop was .07 of a foot.

Q. What would be 56 per cent. of the Buffalo change?

A. About .17 of a foot.

Q. The actual was .07, wasn't it?

A. Yes.

Q. So—

A. I think there is one thing I ought to call your attention to as we—

Q. You may be asked that on re-direct. What was the interval, six hours about?

A. It is a little difficult to tell where these are so flat in both the Buffalo gage and the other one.

Q. This was approximately four inches, the change?

A. It runs pretty flat down for several hours, as you mentioned in your question, five hours there we haven't well defined peaks there.

Q. There is a change from Buffalo of pretty near four inches, isn't there from the—

A. Less than four inches.

Q. A little less?

A. Yes.

Q. Nearer four than three inches?

A. About 3¾ths to be accurate.

Q. It is .295 of a foot, isn't it? What was the interval there?

A. These observations are of such a nature that it is very difficult to determine the interval. Sharp, well marked peaks are necessary to determine an interval. These are running flat here for five or six hours.

Q. Now, you have here at seven o'clock, the depression commenced at Buffalo, did it not, and it remained that way until about 11 A. M.

A. It would appear to me, Mr. Adcock, that these observations speak for themselves. I do not see any crest on a level running along here at Buffalo, 571.75, .74, .75, .74. I must confess my determination of a lag would hardly depend on any such series of observations as you are picking out.

Q. The gage was falling, was it not, and it ceased to fall at a certain time and remained practically stationary for four hours at Buffalo?

A. A limitation should be placed upon this, where the movement is so little, that these are hourly scalings, and there may be a variation at Buffalo, there may a little valley between the hourly readings, and this form of determination would hardly follow. When you get a well marked peak, then it is different.

Q. It fell four inches in about three hours, didn't it?

A. Between the second hour and the seventh hour and the third we have a fall of—

Q. Fell pretty steadily, pretty fast?

A. Nearly .3 of a foot.

Q. How much quicker would you want it to fall in order to have it show, indicated at Chippewa?

A. Well, I would be very glad to present the tables which will show—

Q. I ask you now from these gage readings to tell.

A. I would suggest, moreover, that we have the readings

plotted in the three-curve series, in which Buffalo and the Whirlpool are indicated and the lag indicated between—also the Gorge, that the lag indicated between the Gorge and Buffalo must be greater than the lag between Chippewa and the Lake, and it is a clear inference, there is a large well marked movement there, with no water power complications, and there the interval is about three hours and fifteen minutes.

Mr. Adcock: I will move now to strike out the witness' answer to the question, and ask the reporter to read the question; see if the witness will answer the question asked.

Mr. Hopkins: I object to the general line of inquiry. I have not made any objection, but this is simply asking him to state the contents of a document which is already in evidence, in the first place, and making computations on matters inquired into on the witness stand. And the third reason is he has testified it does not give any results because of the very small range in the limitations, among other things, that makes it of no value.

Mr. Adcock. I assume counsel supposes there is not anything to be considered in this case but the witness' opinion. We have the right to cross-examine the witness upon the facts about which he has testified concerning gage readings. He has presented himself as Chief Expert for the Government. I do not think it comes with very good grace from the Government to try and limit the cross-examination of its Chief Expert. Now read the question.

(Question read as follows: "How much quicker would you want it to fall in order to have it show, indicated at Chippewa?")

A. I should like to see changes in the neighborhood of a foot at Buffalo, and with reasonable sharpness of crest so as to accent the influence well. We have in our exhibits what is known as the Three-Curve Series, which gives rather conclusive results. It has been testified to by—

Q. How quickly do you want that change to take place at Buffalo?

A. Oh, in three or four hours.

Q. That would be rather unusual, wouldn't it?

A. Yes.

Q. I understood you to say so a little while ago?

A. Yes, and yet we can find cases where this change is accomplished.

Q. There would not be a great many of those, would there?

A. The Three Curve Series is illuminating along this line.

Q. I am asking you the question; am asking how many you can find?

A. I will be glad to refer to these curves. That will make me better able to answer your questions.

Q. How many in a week? How often would that change take place?

A. I would have to refer to curves.

Q. But Mr. Shenehon, you are very familiar with the Niagara River?

A. Yes.

Q. You have written a work here entitled: "The preservation of Niagara Falls," and you examined the river at all points. You are familiar with the stage of the lake as shown by the gages at Cleveland and Buffalo, the fluctuations, and I assumed that you would be able to give us an idea of how often you would find a change of 1 foot in three hours at the Buffalo gage?

A. Have you any objection to my referring to the documents in this case?

Q. You have the right to refer to them, certainly. I am asking you for the information.

A. (Examining exhibits.) I examine sheet number 1, of Shenehon's Exhibit K, in which the water surface elevation of Lake Erie at the Buffalo gage is shown from October 21, to November 8, in the year 1907. I find one case where the change in the elevation of Lake Erie was 1 foot in about seven hours. That is, the rise and fall is accomplished in that length of time.

Q. That is the Three Curve Series, Mr. Shenehon, is it?

A. Yes, sheet number 1, of the Three Curve Series.

Q. And that is the only change, only instance where the change—

A. No, there are cases where the lake has either lowered or raised substantially a foot in four or five hours.

Q. How substantially, what percentage of a foot?

A. There is one about .9 on the 24th.

Q. In how long?

A. In about five hours, and the fall on the following day is accomplished, a foot in probably the same length of time. On the 25th, there is a rise of nearly a foot in about six hours.

Q. What percentage of a foot?

A. It is pretty close to a foot. We can call it roundly a foot.

Q. But minus?

A. That is rising; on the falling—on the down drop there is a foot fall, a little bit over a foot accomplished in about eight hours.

Q. You only find on that Three Curve Series there one instance that really meets your conditions, as a matter of fact?

A. No, on November 2nd, I find that the lake rose nearly two feet in the time, about five hours?

Q. What year is that?

A. That is the year 1907. And I find well marked peaks corresponding to these on the lower curve of this sheet, showing elevations in the Gorge of the Niagara River.

Q. Have you got the Chippewa gage on that?

A. No, the Chippewa gage is not plotted on this.

Q. Did you get the relation of the Chippewa gage from those observations?

A. The lag in the Chippewa gage was gotten out by my assistant, Mr. Souther, from the gage sheets.

Q. What gage sheets?

A. Similar to the sheets that you put in my hands here for inspection.

Q. But those are the ones which you presented to Mr. Williams on cross-examination, are they not?

A. Yes.

Q. Why did you take others?

A. I rather think these are among the sheets that we utilized. The Lake Survey Office has been open to Mr. Williams, and all its records, so far as that is concerned, to choose any other particular sheets.

Q. What did you use to determine this lag, or the relation of Chippewa to 56 per cent. of the Buffalo change?

A. In that determination, the daily mean elevations of the Buffalo gage and the Chippewa gage were used and computed, not for one year alone, but for at least two, and the results are printed in the report on the Preservation of Niagara Falls.

I may add also that in this same river pool, across the river from Chippewa on the American side, what is known as the Grass Island gage gives substantially the same amount. This thing is so well established that one year's result checked within 1/8th of an inch of another year.

Q. How then did you determine the lag from the daily means to be two hours? How could you introduce that refinement into the daily mean observations?

A. The lag was determined from the hourly gage sheet.

Q. Just as we are trying to do here. That is what I asked you first, Mr. Shenehon, as to how you determined the lag?

A. Well, the method used by you is the proper method, except that you should select days where there is a fairly large movement instead of these days of smaller movement.

Q. Have you got the plottings by which you determined the lag in the hourly mean of hourly readings?

A. I find two sheets here on which the lag is determined both for rising and falling water, July, 1908, and November, 1907. I rather think there are some more; and the results on these surprise me a little. They appear to have been in error. The mean lag for July, 1908, in well marked high water is 2.6 hours. That is between the Buffalo gage and the Chippewa gage, and the well marked low water lag is 2.55, or two hours and 33 minutes.

Q. What are your well marked low water and high water and so on there?

A. The days are given on these sheets.

Q. Is that hourly readings?

A. These are from hourly readings, the hour from which a well marked low point is indicated at Buffalo is set down and also that at Chippewa, and the difference is taken out and these are summed up and the mean taken out.

Q. What are you referring to, the exhibits in this case?

A. This is not an exhibit at this time. I rather think I have some more of these Chippewa sheets. I think in this derivation of the lag at Chippewa, we found the same difficulty that you gentlemen are discovering to-day; and that an inference from the lag determined at the Whirlpool is probably better value than attempting to get it out of Chippewa.

Q. You considered it was necessary in order to determine the relation of the Chippewa gage to the Buffalo gage to take the daily mean?

A. Yes.

Q. Did you ever take a daily mean discharge measurement of the Niagara River?

A. No.

Q. Never did?

A. You mean continuous 24 hour measurement?

Q. Yes?

A. No.

Q. You never took a discharge measurement of the Niagara River when the gage at Buffalo and the gage at Chippewa for 24 hours were at equilibrium, did you?

A. We took 340 observations, and during this period we may safely assume that the normal relations existed between Lake Erie and the elevation of the water at Chippewa, and that sometimes at Chippewa it was a little too low, and sometimes it was a little too high, and therefore we have these residuals to which I have referred. That is one discharge measurement shows a little to the right of the line, indicating it is a little too big; another one a little to the left, showing it is too small, and these are the errors of observation that are present in all work, all the best work as well as other kinds.

Q. And you have given your judgment as to what percentage the error is, all those things?

A. Yes. Understand me that the residual, the final error in the result coming in from the elevation of the water at Chippewa, is in my judgment, zero, in other words it is an effect that is entirely compensated in the result.

Q. Mr. Shenehon, in testifying with reference to lag, you referred to two papers here, which you have just kindly allowed me to look at, entitled: "U. S. v. Sanitary District of Chicago, determination of lag between Buffalo and Chippewa gages, time required for change in Lake Erie to reach Chippewa. Only days of well marked changes used in determination." There are two sheets, and they cover the period where there are apparently some gage readings that were made in 1907 and some others in 1908 used. You have columns there; a column where you say "lag hours" "comparison with Buffalo and Chippewa." I see cases where the lag is 4.5 hours; others where it is 5 hours; others where it is 1 hour; others where it is intermediate; one 5 1/2, another where it is zero, 3.5 hours, 5 1/2, and another one at zero; various estimates put down as to lag. How do you account for those discrepancies?

A. The water movement is very small at Chippewa compared to Lake Erie.

Q. How did you then reach the conclusion that it was 2.6 hours?

A. By averaging, summing them up, average.

Q. You took a number of these different gage readings from Buffalo and Chippewa, etc., and used your judgment about picking them out?

A. No, I didn't use my judgment. I put it in the hands of a very capable assistant.

Q. And he used his judgment?

A. He used his judgment.

Q. And then to get the time interval you took an average of all these?

A. Yes.

Q. Including the zero?

A. Yes.

Q. And the one hour, and everything else?

A. Yes.

Q. And upon that you are willing to make the statement that the lag there is 2.6 hours?

A. It appears from that particular table. I don't mean to state that as an ultimate conclusion. I wish to put in the lag as derived on well marked gages in the Gorge where the movement of the water is 2.29 that of Lake Erie, where it is well determined, where there is no water power complication, no large water power complication entering.

Q. Two per cent. you say?

A. 2.29 is the ratio of movement between the water in the Gorge at the Suspension Bridge gage, and Lake Erie.

Q. Before making any statement—

A. It seems to be a certain thing that the lag at Chippewa is less than the lag at the Suspension Bridge, because the water must pass over the rapids after it leaves Chippewa, a travel of three or four miles.

Q. Then before you would like to leave this case with the statement that the lag there is 2.6 hours, you would want to make further investigation, wouldn't you?

A. Yes. I recollect now that in our earlier measurements —I had forgotten it, and this is not very clear yet in my recollection, either—that we did have a time interval of two hours and forty minutes; and I don't know how I got it in my mind recently that it was two hours.

Q. There isn't anything else you think you would like to study more carefully before you want your opinion to go into the record?

A. Yes. I am going to give you the statement of the lag at the Suspension Bridge through the Whirlpool.

Q. Are there any other opinions you have given in this case that you feel you would like to make further study concerning the basis of the opinion, the method of arriving at it?

A. You mean correctly figured.

Q. No, method of correctly arriving at the results. You

say here you do not want to stand by your opinion as to the 2.6 hours.

A. I had an impression that the lag was about two hours. I think that was my earlier statement, and I wish to fortify or confirm my error, if it is more than two hours. I had not in mind these tables that I have here, and I think there are other tables of the Chippewa gage that may not be quite in accordance with these.

Q. You will look them up in the meantime will you, and if you have any papers from which you determined this lag, you will bring them so that we can examine them?

A. Yes. Of course in the end, you must understand that the lag is very clearly shown between Buffalo and the Gorge Pool which is four miles below Chippewa roundly, by the Three Curve Series. It is there for inspection, and may be made out by anyone concerned, and it is not necessary to take this—

Q. Mr. Shenehon, we will no doubt reach that famous Three Curve Series in due time; but I am concerned about this lag.

A. You were asking for my assistance, weren't you?

Q. Yes.

A. In reaching a really accurate conclusion that will be helpful to the court in this matter.

Q. That is right.

A. That is what I am attempting to give you.

Q. And I hope we may have an opportunity to look at the figures or papers by which you refresh your recollection as to the determination of the lag.

A. I shall give you the best knowledge I have, I assure you, in that and every respect.

Adjourned to Wednesday May 14, 10:00 A. M.

Wednesday May 14, 1914, 10:00 A. M.

FRANCIS C. SHENEHON, resumed the stand and testified further on cross-examination as follows:

Mr. Adcock: Q. Have you got any of those sheets this morning that you mentioned you had last night?

A. I haven't any more sheets than the two I had last night.

Q. That is with reference to the lag?

A. I have sheets concerning the lag in the Gorge, at the

Suspension Bridge gage and in the Whirlpool, which are pertinent in this discussion.

Q. You haven't any more sheets concerning the lag between Buffalo and Chippewa?

A. Only the two I had last night.

Q. Now, Mr. Shenehon, we were talking about a depression at Buffalo, which occurred about seven o'clock and lasted until 11:00 A. M. on the third of November; and the change from the previous peak was .295 feet. And we also spoke of a depression at Chippewa, which occurred at 13 o'clock and lasted until about 16 o'clock, in which I believe you stated that if you plotted those gage elevations it would be approximately a horizontal line, and the depression at Chippewa, or change, was .07 foot. You also stated that 56 per cent. of the Buffalo change would be .165 feet. Then I asked you as to the interval between the depression at Buffalo and the depression at Chippewa, which apparently would be six hours. Is that correct?

A. This is on the third, you are speaking of now? And on the Buffalo gage it is from the 7th hour to the 11th hour?

Q. Yes?

A. Substantially.

Q. Yes.

A. 13th to the 18th it keeps on going further. The level is so flat there at Chippewa that it is rather difficult to state what the time interval would be.

Q. It would not be less than six hours, would it?

A. I would not attempt from these observations to determine the lag.

Q. What is the change at Chippewa? The marked change is about six hours, isn't it?

A. There does not appear to be any very sharply marked change.

Q. Would it aid you any if we showed you a plotting of that? (Handing witness same.) I will ask the Commissioner to mark for Identification certain blueprints showing plotting of the gage elevations of Chippewa covering November 1st to 6th, inclusive, of the year 1906. These plottings were made from the gage records appearing upon Williams' Exhibit cross-examination number 4, being two sheets presented to Mr. Williams on his cross-examination by the counsel for the Government, and prepared, I believe for such offer by the witness. Mark them Shenehon's Cross-Examination A and B.

Whereupon plottings handed to witness, were marked respectively Shenehon's Cross-Examination A and B.

A. I would like to ask whether or not the Buffalo gage has been corrected for the hourly readings as indicated by the note on Williams' Exhibit Cross-Examination Number 4? I understand Mr. Williams to say that this correction has not been applied.

Q. Would it make any difference in the relative elevation of the Buffalo gage?

A. No, it would make a difference when you come to predict the Chippewa elevation from the Buffalo, to see whether or not my statement was conservative that we could come within an inch in the time of four or five hours in the prediction.

Q. Would it make any difference so far as the plottings are concerned, and the fluctuations at Buffalo?

A. No, so far as the fluctuation of the lag is concerned, it is not pertinent.

Q. It is not pertinent?

A. No.

Q. So the inquiry which you made was also not pertinent, is that right, to the question which is before the court?

A. My inquiry had to do with the general proposition of the relation between the Buffalo and the Chippewa gages.

Q. Yes, but so far as the determination of the lag is concerned, the purpose for which these exhibits were prepared, it would not have any materiality?

A. No. Now, if I can get the question, I will endeavor to answer it.

Q. (Question read as follows): "What is the change at Chippewa? The marked change is about six hours, isn't it?")

A. This relates to the third and has to do with the tenth on the Buffalo gage and the sixteenth hour on the Chippewa? Yes, that appears to be about six hours.

Q. Then the time is three hours and four-tenths late, and 50 per cent. small, basing this upon your correction of last night with reference to the lag, you stating now you believe the lag to be 2.6 hours?

A. Well, I didn't make that as a final statement. I stated that a sheet which was presented indicated that, and my original statement, of course, was that it was two hours and fifteen minutes; and even under that statement it would be about two hours and thirty-four minutes, the mean of these

two columns, the rising and the falling water. The conditions are such at Buffalo that we get a large error of observations.

Q. It would be 50 per cent. small too, wouldn't it, to change at Chippewa?

A. I presume that is an inference from the figures. I don't recall substantially.

Q. When is the following summit at Buffalo, Mr. Shenehon?

A. I am referring now to the blueprint. I assume the blueprint is correct.

Q. Look at 16 o'clock.

A. Well, there is a subordinate summit at 13 o'clock and another one at 16 o'clock on the Buffalo gage on November 3.

Q. The change there is .235 feet?

A. .24, I make it on the Buffalo gage.

Q. Does this appear at Chippewa?

A. There is very little change indicated at Chippewa in this column. There is about .02 indicated at Chippewa.

Q. Which is really insignificant?

A. Insignificant.

Q. And the change at Buffalo was approaching three inches, was it not, very near three inches?

A. Yes.

Q. When is the next minimum at Buffalo?

A. On the fifth hour of the fourth day, November 4th.

Q. Isn't it two to three A. M.?

A. Well, we have a rapidly vibrating condition at the Buffalo gage, where we have evidently a seiche running back and forth, with a range of two or three-tenths within a couple of hours. And I think that really in this discussion we have to take a mean line passing through those seiche points.

Q. What is the lowest point there?

A. The lowest point is on the fifth hour, at five o'clock.

Q. Five o'clock. And what is the change?

A. The difference is .98 of a foot, a little less than a foot.

Q. That is approximately a foot, isn't it?

A. Yes, a quarter of an inch less than a foot.

Q. When does this appear at Chippewa?

A. Two hours later.

Q. What is the amount of the change at Chippewa?

A. .28 of a foot as I make it.

Q. That was a rather gradual change wasn't it at Buffalo?

A. Yes.

Q. It was quite a change too, wasn't it?
A. Yes, that is a well marked change.
Q. What is the per cent. of the Buffalo change at Chippewa?
A. Roundly 28 per cent.
Q. 28 per cent.?
A. Yes.
Q. That is about 50 per cent. small, isn't it?
A. Yes.
Q. Do you think you have really got the depression at Chippewa which corresponds to the Buffalo change?
A. Yes, I think so.
Q. How do you account for its being only 28 per cent.?
A. Error of observation.
Q. Error of observation?
A. Yes.
Q. Then it is something that might be pretty difficult to tell what it is?
A. I am inclined to think if you will take the mean of say four or five hour elevations at Buffalo, and compare them, without picking or selecting your observations with the corresponding elevations at Chippewa, you will find this relation holds within the limits I stated, as a general thing.
Q. You cut it down to minutes, two hours and thirty-four minutes a while ago?
A. I am speaking of the relationship, 56 per cent. relationship in fluctuation. That is a very well determined thing.
Q. How long was it from the time the water began to fall at Buffalo until it began to fall at Chippewa?
A. About five hours is the interval indicated. The Chippewa showing declines about five hours after the change.
Q. That was a steady fall running over quite a little time?
A. Yes.
Q. As shown at Buffalo?
A. And yet on the Chippewa gage you have this flat elevation, level water indicated for five hours there, any point of that may be considered the peak, I suppose, of that particular high.
Q. You would not expect the change at Chippewa to occur in no time at all, would you?
A. No.
Q. That is after a change at Buffalo?
A. No.

Q. That is you would not expect Chippewa to change as the Buffalo gage changed?

A. No.

Q. You would not expect it to change within one hour, would you?

A. I had in mind before two hours, and I have not quite decided where that impression came from. It appears from this sheet it is over two hours.

Q. Would it be reasonable at all for an engineer to expect the change at Chippewa to be within one hour after the change at Buffalo?

A. Oh, yes, it would be reasonable.

Q. It would be reasonable?

A. Yes.

Q. You think you would work it out that way, would you?

A. I think we are still within the limits of reason when we call it one hour.

Q. You certainly would not expect Chippewa to change at the instant Buffalo changed, would you?

A. No, indeed.

Q. Why do you use the zeros here in these—

A. You are touching on a fundamental fact in observational data.

Q. I hadn't quite finished the question. In determining this lag, why did you use the zeros? These sheets that were prepared by Mr. Souther, and which were handed you yesterday entitled: "United States vs. Sanitary District, determination of lag between Buffalo and Chippewa." And then I find on that you state the lag to be zero in three instances on the first sheet, and one hour in several instances, and you say the way that they determined what the lag would be or was, was by taking the mean of those determinations from individual instances?

A I started to say this represents—

Q. Just a minute: Do you think that is a fair thing to do, to take the zeroes there into consideration?

A. I think my explanation must proceed, in answer to a question of that kind. The zero does not represent an ultimate fact. It represents a conclusion with a minus residual. In other words, you will find some of the observations show a lag that is longer by a couple of hours or three hours than the actual lag, and others will show three hours too little. And this is a characteristic thing in all observations. The zero simply means that the error of observation is on the minus

side. If we should eliminate the zero by selecting observations, which is not in my judgment a good practice as a rule, we would also eliminate the 5.5 because it is too big in the same proportion that the other is too small.

Q. Why do you eliminate the minus three hours to which you just referred? Isn't it just as unreasonable to suppose that the change at Chippewa would be at the same instant as the change at Buffalo as that Chippewa would change before Buffalo?

A. If you will understand, the taking off of these things is subject to an error of two or three hours in any particular case, or may be subject to the error, and the error may be too small by two hours or three hours or it may be too big, an even thing. If you take out your zeroes, you must also take out all your large observations. In other words you retain them all. And understand, while this appears to be an inconsistent thing that the time interval is only zero, or nothing, it is also inconsistent that it is 5 1/2 or 6 hours, and these two things balance each other in the final result. That is a well known illustration of the compensating error of observations.

Q. You say it is inconsistent it should be 5 or 6 hours and yet we find numerous instances where the Chippewa change was 5, 6 or 7 hours after the Buffalo change, do we not?

A. In selecting well marked changes, those should be incorporated as a portion of the observations, but you should not select those that are big, and not include also those that are little, unless you have a predecided view as to what you wish your lag to be.

Q. You have just referred to one here where the change was a foot, haven't you quite a well marked change?

A. Yes.

Q. That you speak of?

A. Yes.

Q. I also asked you to look on those exhibits which I handed you and ascertain how long after the Buffalo gage began to fall, the Chippewa gage began to fall, and you stated it was five hours.

A. Yes. That would be a very proper observation to incorporate in here (indicating exhibit). And I point out to you that there are on this sheet one observation in which the lag is shown as 4½ hours, another 5½, still another 5½, another 3½. Now, these observations of 5½, assuming that the lag is about 3 hours, let us assume it is 3 hours, the five hours and a half bear about the same relation on the big side that

the zero does on the small side. One is too big and the other too little, and the average of the two, zero added to 5.5 divided by 2 is 2.75, or 2¾ hours. So the average of those, taking the big and the little ones, gives pretty close to what appears to be the correct result by this computation.

Q. If you were going to eliminate 5.5 hours, you should also eliminate the zero. Is that correct?

A. I would not do either as an observer, understanding some of your quantities would be too big, some too little. I do not feel at all concerned about a zero lag on the one side and 5.5 hours on the other.

Q. So you would eliminate both of them?

A. No, I would eliminate neither. I would leave them both in just as I have done. The elimination of observations is a very dangerous thing.

Q. If you were going to eliminate either one of them at all, which would you eliminate?

A. I would eliminate both in that case. I would get out my mean first, and say this is so big it does not correspond with the mean, and this is so little it does not correspond, so cut them both out.

Q. Which is the more unreasonable, the zero or 5.5 hours?

A. It is about an even thing from the point of view of the observer, understanding how some observations strike too little and some strike too big. It is an entirely reasonable conclusion that an observation may appear to have a zero lag, when the error of observation may be one or two or three hours.

Q. Doesn't one of these waves or crests travel at a regular speed?

A. You mean all of them?

Q. Yes?

A. I think the gage records here indicate considerable concerning that.

Q. As an exact fact, would not two similar changes in elevation travel down to Chippewa in about the same time, within a minute? In other words, if you had two, one change say of a foot—

A. Yes.

Q. And then you could determine exactly how long that took. You had another change of exactly a foot at another time, wouldn't you expect the two to travel in exactly the same time?

A. No.

Q. How much difference?

A. I can't state that. The observations indicate the range was between zero and 5½ hours. And the mean indicates about 2½ hours there on that particular sheet.

Q. I am asking you as to whether you think there would be certainly any difference in the travel between two exactly the same changes?

A. I am inclined to think for you to get exactly duplicate conditions would be rather difficult.

Q. But if you had those conditions?

A. If we had exactly similar conditions at exactly the same time of year, exactly the same stage of the river, exactly the same state of affairs as to wind and weed growth and other conditions, I should expect one to duplicate the other very closely.

Q. What effect would the weeds have on the current, how much would they detain the travel?

A. Very little.

Q. What per cent.?

A. I could not state it as a percentage.

Q. How many minutes?

A. I could not state it in minutes.

Q. Would it be three minutes?

A. I should say as much as three minutes.

Q. Would it be as much as five minutes?

A. I am not prepared to define it.

Q. Would it be as much as an hour?

A. No.

Q. Half an hour?

A. No, I think not.

Q. Would it be as much as 15 minutes?

Q. You are getting down to pretty fine limits. I am not prepared to say. I should say it would be less than 15 minutes.

Q. It would be less than 15 minutes?

A. Yes, I should say so.

Q. Well, what effect would the wind have?

A. Very little.

Q. What would be the effect from that in minutes?

A. An upstream wind has a little retarding effect, a downstream wind a little accelerating effect, but that is extremely small so we do not need to give that any large consideration in this lag effect.

Q. Would it be less than ten minutes?

A. Yes, I think so.
Q. Might be less than five?
A. I would not like to define it.
Q. Probably less than five?
A. I would not wish to define it any more closely.
Q. What other things might affect the travel of that crest?
A. The elevation.
Q. How much would the elevation affect it?
A. That is the depth of the water. That varies as the square root of the depth. There would be a little change coming in that.
Q. How much, how many minutes?
A. Suppose we had five feet in the one case—
Q. We are taking the ranges here, we are taking one foot. That is a well marked change, which you have reference to.
A. I think I can get at that. I should say five minutes would be an extreme, not over five minutes, I should say.
Q. Is there any other influence?
A. Of course, barometric pressures enter in a slight degree in this.
Q. How much effect would they have?
A. I could not make a statement concerning that.
Q. Would it be an appreciable effect in minutes?
A. It would not be much. Mr. Williams in his testimony indicated between the Buffalo gage and the Section about .05 of a foot, that is in a distance of two to three miles say. In these other distances proportional to that, you would have quite a considerable effect. Of course in the end it is a thing that balances out, just as Mr. Williams, I believe, testified himself, as between the Section and the Buffalo gage. So, while individual observations may show it for a short time, the large number of observations utilized in making a determination would eliminate it in even a small number of hours. I do not conceive of any large barometric change lasting over five hours.
Q. Well, if add altogether, your weeds, your barometric pressure, your winds and everything like that retarding the crest, it would not amount to 20 minutes, would it, the difference?
A. No, I should say not. I don't know that the barometric pressure has a great deal to do with the travel of the crest. I am speaking now of the consistency of the two gages.
Q. You mentioned barometric pressure, and as I do not know anything about it, I assumed that it had something to

do with it. Of course in asking you the question, I want you to take that into consideration.

A. Of course if it passes from one grade to another it must traverse the length of the river. I do not think it is a thing that needs any large consideration.

Q. What is the approximate average depth of the Niagara River from the Buffalo gage to Chippewa?

A. I should say in the neighborhood of 20 feet. I am not positive of that. I would need to take it off from the chart. (Examining same.) I should say 16 might be a fair value, approximate value, 16 feet.

Q. Well, what is it from the Buffalo gage to the Bridge?

A. It is deeper for the most part. The question was from the Buffalo gage to the Bridge?

Q. Yes?

A. I should say a little deeper, probably 20 feet.

Q. You still think do you, Mr. Shenehon, it is just as unreasonable to suppose the lag would be 5.5 hours between Buffalo and Chippewa as to suppose it would be zero?

A. I think you misunderstood me. I say that as an observation, an observation is just as consistent where it shows zero as where it shows 5½, where the mean of a large number of observations, is about 2½ hours.

Q. Why do you take zero into consideration?

A. I simply take zero as an observation in which the error is on the minus side. In other words it is too small, and the other one is too big, and these things balance each other.

Q. But physically, zero is entirely impossible, isn't it?

A. Yes.

Q. Do you say physically 5.5 hours is impossible?

A. No.

Q. Would you say physically 7 hours was impossible?

A. No.

Q. Would you say physically 8 hours was impossible in the lag there?

A. I would not wish to set any particular limits to the lag. I should determine the lag from what the observations indicated on the stream itself. After I had reached a determination, as I have, somewhere in the neighborhood of two or three hours, then I should regard with suspicion a lag of 8 hours or 7 hours in any particular observations.

Q. But, Mr. Shenehon, I am asking you for your opinion as an expert?

A. Yes.

Q. And as an engineer, and I appreciate you have given

great study to this proposition, and I would like to have your opinion as to whether or not you consider 9 hours physically impossible for the lag there?

A. You mean as a final conclusion?

Q. I am asking you for your opinion?

A. As a final conclusion that the lag is eight hours?

Q. No, I am asking you for your opinion as to whether physically it would be impossible for the lag to be eight hours on any observation?

A. I don't know what conditions might be superimposed to bring a lag of eight hours, as great a lag as that.

Q. Then do you say it would be physically impossible for it to be eight hours between Buffalo and Chippewa?

A. In my judgment the lag itself is not eight hours.

Q. It is not what?

A. It is not eight hours.

Q. Would it be impossible for it to be eight hours?

A. In my judgment it is not eight hours, and I don't think in any case in which we showed a clearly marked relationship it would be eight hours.

Q. You have stated that it is physically impossible for the Chippewa gage to change at the same instant as the Buffalo gage?

A. Yes, that is true.

Q. You have also stated it was physically possible for the lag to be one hour, haven't you?

A. It is physically possible?

Q. Yes?

A. Yes, I think it might.

Q. Now I am asking you whether you think it physically possible that the lag would be eight hours?

A. No, I don't think so.

Q. You do not?

A. No.

Q. You would say the same thing with reference to nine hours?

A. I think an observation might show it, but I should regard it as the error of observation.

Q. Would you include such an observation in determining this mean?

A. Yes, I would.

Q. Would you discard a nine hour lag if you had an observation showing it?

A. I might begin to scan the observations, unless they

were so well marked as to be very determinate, if they showed any such lag as that.

Q. Would you discard a minus 1 hour at Chippewa?

A. No, I think not.

Q. A minus two hours?

A. No.

Q. Minus three hours?

A. No, I don't think so.

Q. You would not discard a zero?

A. No.

Q. Although you know it would be physically impossible to have a zero?

A. You are going outside the limits of the error that appears in the observations here, well marked observations.

Q. You have based your increments in the various rivers in this case upon the consideratin of the lag between the controlling gage and the discharge section, haven't you?

A. Not to any large degrees; no, I should say it is almost independent of the lag, so far as the Niagara River is concerned, for instance, and so far as the St. Clair River is concerned. In the St. Lawrence, I think there is a chance that the lag does enter in the original determination of the increment there.

Q. Then I take it you treat it as inconsequential whether the river is in equilibrium at the time your gaging is made. Is that correct?

A. Yes, the observations are taken and recorded as the river is flowing and as the gages indicate, and we have eliminated, so far as I am aware, no observations for conditions where the river may not be in equilibrium.

Q. That is you have eliminated the observations?

A. No, we have not eliminated the observations; we have included them all.

Q. Now, you would include observations which were physically impossible with observations which were physically possible, in determining your average for the lag?

A. You mean this lag determination?

Q. Yes?

A. I would include the zeroes, if that is what you mean.

Q. You would include a minus 2, a minus 3?

A. There appear no minus 2's or minus 3's.

Q. I am asking what you would do?

A. I think I would give the matter some consideration before determining that. I imagine the young man who went through these did not select any where that condition ap-

plied. You will notice the honesty with which he did work, in putting in the zeroes. That is evidence to my mind that he worked with entire honesty in carrying out the task which I gave him: "Now, find out, Souther, what is the lag between these various gages; take these gage sheets, pick out the well marked lows at the Buffalo gage and the well marked lows at the Chippewa gage and the Gorge and the Whirlpool, and set down the time interval, and reach a conclusion."

Q. On these two sheets, you find the mean lag shown at the bottom of the pages, 2.6 hours, 2.55 hours, 3.31 hours?

A. Yes.

Q. 3.5 hours?

A. Yes.

Q. Would you say that the mean of all those was 2.6 hours or was two hours and 34 minutes, or two hours?

A. From those sheets, the mean of the four would be the most probable value, but you will notice these are in pencil and were not regarded as sufficiently determinate to reach a conclusion on the lag. These were never inked in and used. I am not sure whether I have a set that was inked in, or was used. But if the lag indicated here was greater than the lag indicated four miles below in the river, where the thing is well determined and sharp, I should say this was in error, and it is in error just from this difficulty of picking out the highs and the lows with the small range of fluctuation above the falls. That is the point.

Q. What is the mean of all those lags?

A. A little under three hours.

Q. Just three hours minus a little, isn't it?

A. Yes.

Q. Now these sheets were evidently prepared for this case, weren't they, "United States vs. Sanitary District of Chicago, determination of lag"?

A. Yes.

Q. There is a formal heading?

A. Yes. Some others were prepared also.

Q. It bears date September 24th, 1913?

A. They were initiated with a view of use in this case, as we are now using them.

Q. Now after you have taken into consideration the mean of the totals there, would you want to change your answer in any way as to the statement that it would be as unreasonable to expect a lag of 5.5 hours as to expect that there would be no lag at all?

A. Those very nearly balance. I am not going to give

you a final answer on that until I give you the lag as determined at Suspension Bridge, because that is pertinent.

Q. Mr. Shenehon, I am asking you about these gage records appearing in Williams' Exhibit Cross-Examination Number 4, and on these sheets which you have produced entitled, determination of lag between Buffalo and Chippewa.

A. I understand you want my best judgment as to what the lag is.

Q. I am asking you with reference to these observations?

A. The mean value indicated by these sheets is—

Q. Just a minute.

A. —substantially 3 hours.

Q. Do I understand you to say still that a lag of 5½ hours is as questionable as a lag of zero?

A. Practically.

Q. That there would be no lag at all?

Mr. Hopkins: He never said the lag was that, but the observations of lag.

The Witness: I think you understand that, that the observation in a particular case is subject to error, and the error appears to be as large as two or three hours, and when the error is on the negative side, if three hours is the correct lag, zero appears as the observation value.

Q. Will you explain how that record could come in? These records are from automatic recording gages, as I understand. Those gages you have described, and they are a continuous record, the level being shown at every second and minute by means of continuous lines drawn in pencil on a sheet of paper, when the water rises and falls?

A. The small movement of the water at Chippewa is an element in that that I do not find in examining the Suspension Bridge gage, residuals or errors of observation of quite the same magnitude and the fact that with sharp changes—and these are likely to be the kind that are picked out in well marked changes—the full effect is not shown at Chippewa where Lake Erie is rising. There would be a less important effect indicated at Chippewa; where the lake is falling, there would be a lesser fall; that is would be lesser rise and lesser fall; that is sharp, well marked changes.

Q. What is the error of observation of a recording gage?

A. Extremely small.

Q. About one-tenth of 1 per cent.?

A. It is hard to express it in percentages.

Q. Define how it may creep in?

A. Well, the Chippewa gage, as I understand it, was a

gage of the small type, recording on a scale of three inches to the foot. At the point of reverse, there is a chance for a little error of a few hundredths to come in.

Q. Few hundredths of what?

A. .03; .03 or .02 of a foot.

Q. How about time?

A. There is a chance for a little error of time. I think the clocks are so cared for that the error in those little gages is not very big, and yet there has been a time when the slipping of the paper would introduce some little errors. Whether or not they are present in these gages or not, in this particular record or not, I am not certain.

Q. Would it be five minutes?

A. I could not say as to that.

Q. Would it be two hours?

A. Oh, no, I do not think there is any error of that kind that would come in.

Q. Would it be half an hour?

A. I do not think there would be errors of half an hour.

Q. Ten minutes?

A. I don't know that I could define that.

Q. You would not expect it to be ten minutes, would you?

A. No, I should say not. I think the main reason is the small movement that was probably present at the time of these changes.

Q. Now on this sheet entitled "United States vs. Sanitary District, Determination of Lag," etc., you have here well marked high water at Buffalo and at Chippewa?

A. Yes.

Q. What changes were included in those observations?

A. They are indicated by the date shown in the first column.

Q. Just a minute. You don't know what the changes were that are included in those papers referred to, which you produced yesterday, do you? You don't know the amount of the changes at Buffalo?

A. No, from the sheets themselves, one of these is November, 1907. The days on which well marked changes occurred appear, and the dates in the first column, and a reference to the gage at Buffalo for those dates will indicate the change, and the hours themselves are given so it can be determined from this sheet.

Q. When you say "well marked," you don't know whether those are what you would call well marked changes or not, do you, referred to on those sheets?

A. This was an investigation submitted by me to an assistant, and it is dependent upon his conclusion as to what were well marked. I did not very carefully supervise his work.

Q. When you say "well marked," you simply mean that the paper states that they are well marked changes, is that right?

A. Yes.

Q. What instructions did you give Mr. Souther with reference to preparing them?

A. Simply to make a determination of the lag by selecting the well marked changes; where those changes were crests, put those in the one column, and where they were lows or valleys put them in the right hand column, so as to see whether or not when the water was going down we had the same lag as when the water was going up, as a comparison. I must say that it appears that this series is incomplete; that for the Suspension Bridge, the Gorge and the Whirlpool, I used five different sheets, and I appear to have only these two at Chippewa at the present time. My files at Minneapolis doubtless contain other sheets concerning the Chippewa gage.

Q. How large changes did you tell him to take?

A. I didn't give him any definite instructions on that, as I recollect it.

Q. You just left it to his judgment to pick out well marked changes?

A. Yes.

Q. Now proceeding, Mr. Shenehon, when is the next summit at Buffalo?

A. A summit appears on November 5th, at the fourth hour.

Q. At four A. M. on the 5th, the elevation was 572.01, wasn't it?

A. The change appears to be about .99 of a foot between the low for that day and this high.

Q. You would call that a foot change, wouldn't you?

A. It is within one per cent. of a foot, 99 hundredths, as I said.

Q. You were speaking of well marked changes yesterday?

A. Yes, I would regard that as a well marked change.

Q. Do you find this change at Chippewa?

A. The corresponding change appears above five hours afterward.

Q. What was the change?

A. Change from extreme low at Chippewa to high is .28 of a foot.

Q. What is 56 per cent. of the Buffalo change?

A. Practically .56, which is practically half of that.

Q. Half of it?

A. Yes.

Q. 50 per cent., yes, wasn't it?

A. The change is less than it would figure by the 56 per cent, relation, yes.

Q. It is also some hours late according to your proposition, isn't it?

A. It is five hours indicated here.

Q. That is not very far from 5.5, though?

A. At Chippewa the crest does not appear really well marked here.

Q. So it is probable that there is not any crest shown at Chippewa, isn't it, marked crest for the change at Buffalo?

A. When the Buffalo gage went up this little sharp peak and dropped down again, that is not very clearly shown at Chippewa. A real sharp, quick change at Buffalo is not very fully reflected throughout the river, that is at Chippewa.

Q. How long did this change at Buffalo take?

A. It went up about .07 in an hour.

Q. How long did it take to go up the foot?

A. I am in error about that. I must make a correction for that; it went up a foot in eight hours.

Q. Eight hours?

A. Yes, but it dropped very quickly.

Q. How long?

A. In one hour—it went up about one tenth and dropped down again in the second hour following, about one-tenth.

Q. How long was it up?

A. Well, we have a single observation there indicating that high point.

Q. How long did it take it to drop?

A. It reaches another valley or low point in six hours.

Q. I am asking how long it took to drop to the low point?

A. That is what I am trying to give you.

Q. Seven hours?

A. This point here (indicating) six hours.

Q. That was a very rapid change, wasn't it?

A. No, the fall is not very big there. That is a fall of only .3 of a foot in six hours.

Q. What happened at Chippewa?

A. We have a fall of about .01 of a foot there, following that by four hours.

Q. Now when is the next summit at Buffalo?

A. That is on the 16th hour of November 5th.

Q. And what is the change, about .31 of a foot?

A. About .3 of a foot.

Q. That is about four inches, isn't it?

A. A little less than four inches. It is pretty close to four inches.

Q. Does this appear at Chippewa?

A. Yes.

Q. When?

A. Four hours later.

Q. What is the Chippewa change?

A. .04 of a foot.

Q. And 75 per cent. small, wasn't it, based on the 56 per cent. basis?

A. It is a very large percentage small, yes.

Q. And two hours late, according to your statement of the lag between Buffalo and Chippewa?

A. Something over an hour late, yes.

Q. Do you now say that the lag is two hours or three hours?

A. I will give you a statement on that: 111 determinations, individual determinations of the lag at Suspension Bridge have well marked high water—

Q. You have spoken of the Suspension Bridge and the Whirlpool and so on. Just as you go along and make your statement with reference to them, give us the geography.

A. I believe my early testimony does give this, but to review it, what is known as the Suspension Bridge gage is just above the old Suspension Bridge across the Niagara River, the Railroad Bridge at what used to be known as Suspension Bridge, New York. It is just above the head of what is known as the Whirlpool Rapids, and this is below the cataract.

Q. When you speak of the cataract, that is what we commonly call Niagara Falls, isn't it?

A. Yes.

Q. The fall of water over the ledge of rock there?

A. Niagara Falls, of course, consists of the rapids above the cataracts themselves, and the small cascades that come in there. And I suppose it really refers to that whole region, including the rapids and the Whirlpool.

Q. I am speaking of what the sight-seers see when they go to see the Falls.

A. The Cataract is a well recognized name applied to these particular large falls of water which you have reference to. This Suspension Bridge Gage records the elevations and fluctuations of the water in this Gorge, this big still pool that is sunk down 200 feet below the general level of the country there. And the gage, as I have said, is near the head of the Whirlpool Rapids, where the water makes a descent to the Whirlpool. Then the Whirlpool gage is in the Whirlpool itself, which is that circular basin at the foot of the Whirlpool Rapids and at the head of what is known as the Lower Rapids; and in each of these pools the fluctuation of the water is very large for a change of a 1 foot at Buffalo. Of course the fluctuation is caused by the added water sent down by the additional foot at Buffalo, and the rise in the Gorge pool and in the Whirlpool. Now, this big range of stage there makes these changes very well marked indeed, so that it is fairly easy to pick them out and get excellent determinations. And at the Suspension Bridge Gage, this determination is for the months of October and November, 1907, June, July and August, 1908. The days selected were those when there was well marked change, and in the various months—

Q. What were the changes at Buffalo?

A. Those will appear on the Three Point Series of curves.

Q. I am asking you what were they?

A. It is not set down in the tables. They are well marked changes.

Q. That Three Curve Series, or Three Point Series, is it—

A. That will show the particular hours.

Q. You discussed that yesterday, didn't you?

A. Yes, I mentioned it yesterday.

Q. All right.

A. Now, during the month of October, there were 23 days utilized. During the month of November there were 23 days; during the month of June, 21 days and during the month of July 23, and during the month of August 21, making 111 different determinations of the lag. And the mean for marked high water is three hours and six minutes. This is three to four miles below Chippewa. The mean for a well marked low water is three hours and 18 minutes. The Whirlpool is still another mile or so down the stream, and there the mean of 113 observation or determinations shows a lag of three hours and nine minutes. That is for well marked high water, and for well marked low water, three hours and 26 minutes.

Now it goes without saying, I think, that the lag at Chippewa must be less than the lag at either of these places, so that it, in my judgment, is well determined that the lag at Chippewa is less than three hours.

Q. It is minus three hours?

A. It is three hours, and that earlier relation that I spoke of yesterday that came, I think, in the determination back in 1903, as I recollect it now, is two hours and 40 minutes. I have an impression that was mentioned in this report on the Preservation of Niagara Falls. I am not sure whether it is. So, that is not far from the truth as I see it.

Q. About three hours?

A. Two hours and 40 minutes.

Q. In other words, in the three or four miles, you think it would take about 40 minutes to make the travel, do you?

A. Yes, we have a different condition coming in there, the passage of the water over the Rapids, the sheer fall.

Q. You made the statement in your direct examination here that the lag between the Buffalo gage and Chippewa was two hours, and I believe also other witnesses, Mr. Moore and Mr. Richmond and Mr. Ray made the statement that the lag between Buffalo and Chippewa was two hours. Do you now wish to correct your testimony with reference to that, if you made such a statement, and do you now consider that Mr. Moore and Mr. Ray and Mr. Richmond were in error when they made that statement in their examination?

A. I think my statement was somewhere in the neighborhood of two hours and fifteen minutes.

Q. Well then, do you wish—

A. You understand that now with the absence of or in completion of the observations at Chippewa—I have only a partial record here, and my recollection is that it was somewhere in the neighborhood of two hours and fifteen minutes.

Q. That was your statement that the lag was?

A. Yes.

Q. Now do you wish to correct that statement?

A. I think it is somewhere between two hours and 15 minutes and two hours and 40 minutes.

Q. You gave the minimum then didn't you?

A. In my earlier testimony?

Q. Yes?

A. I have an impression that was based on something, and possibly it is the other sheets of this series that helped me to form an opinion. It may have been it was formed from conclusions from these sheets I have just quoted.

Q. You don't want to be understood now as giving any opinion as to what the lag is between Buffalo and Chippewa?

A. You mean definitely, down to ten minutes?

Q. No.

A. Yes, you can put me down definitely as saying not to exceed two hours and 40 minutes, and possibly as little as two hours and 15 minutes.

Q. When you made the statement it was two hours, or two hours and 15 minutes, you did not want to be understood as stating it was an exact—

A. Oh, no.

Q. An exact fact?

A. Oh no, this matter of lag is subject to a little variation.

Q. As a matter of fact you don't think now, do you, that you have made a sufficient study so that you can give a definite opinion as to what that lag is?

A. Not within 10 minutes. I would not wish to be tied to the nearest ten minutes.

Q. How about the Lake Survey witnesses, do you think they have made any further study than you have made?

A. I am not aware of what they have done. Mr. Moore has done considerable work on the Niagara River, and they have later gage records that have not been consulted by me.

Q. You don't think they have gone any further than you have with reference to these investigations?

A. They have later records and have made reductions of them but I should not expect them to change that very much outside the limits I have given.

Q. Two hours and 15 minutes?

A. Between that and two hours and 40 minutes.

Q. If you were asked the question as to what the lag was, you would not give the minimum would you, two hours and 15 minutes?

A. It would depend upon the purpose of the statement.

Q. Of the examination. If I asked you now what the lag was between Buffalo and Chippewa, you would not say it was two hours and 15 minutes, you would not give me the minimum, would you?

A. I think the fairest kind of statement would be to give you the range, yes.

Q. I take it you will inform the Lake Survey of this error, or perhaps failure to make complete investigation with reference to that, so that they will not put this matter in any of the reports of the Chief of Engineers, won't you?

A. Well, I might seek further illumination myself as to the lag as they have determined it. I think we have the lag very well determined indeed for the Gorge and for the Whirlpool. That I think is an excellent determination, over 100 points.

Q. When is the next depression at Buffalo?

A. We have a depression at Buffalo on the 21st hour on November 5; and it is continuous for about four hours with a little jag in between.

Q. What is the change?

A. The drop from the prior summit or peak is .28 of a foot.

Q. That is about three inches and a half?

A. 3⅜ inches.

Q. Close to three inches and a half?

A. Yes.

Q. Wasn't that drop from 572.01 to 572.04?

A. That is wrong; I am wrong about that. The scale doubles up here. It is .36 of a foot.

Q. .36 of a foot?

A. Yes.

Q. When does that appear at Chippewa?

A. It appears at Chippewa at the third hour of the next day.

Q. What is the time?

A. As a mean for that whole depression there, it would be about four hours later; five is a better value.

Q. Five hours. What was the change at Chippewa?

A. .06 of a foot.

Q. How much low, about 80 per cent., wasn't it?

A. Yes, very much low. I will give you that more exact; 70 per cent. low.

Q. 70 per cent. That is it is 70 per cent. less than it should have been according to the 56 per cent. determination?

A. Yes, of course the 56 per cent. is not applicable to these changes of this particular kind.

Q. I see. We understand, I think, your position on that, Mr. Shenehon. That is that you should have determined it from daily changes.

A. Yes, a portion of the rise at Buffalo is absorbed in the reservoir effect of the river.

Q. And extra draft, you haven't forgotten that extra draft from the power house. That is another thing.

A. That is a thing that is compensating, and is just as likely to be one way as another, and in an individual case it

may distort the thing in daily means; on a large number of observations it eliminates it. I do not think that is a very large thing anyway, that variation.

Q. And it was about an hour and 45 minutes late too, wasn't it, that change?

A. Yes.

Q. According to your minimum?

A. A little more than that I guess.

Q. An hour and 15 minutes, according to your maximum?

A. I think I stated a difference of five hours, wasn't it?

Q. Two hours and 20 minutes.

A. Yes, you ought to get the full value of these things in.

Q. What is the next summit at Buffalo? That .37 of a foot change there at Buffalo was something over four inches, wasn't it?

A. .36, yes it is a little over 4¼ inches.

Q. 4¼?

A. Yes. The next summit at Buffalo, the well marked peak is on the 10th hour of November 6, and shows a rise at Buffalo of .36 of a foot.

Q. That is a little over four inches too, isn't it?

A. Yes, same as you had before.

Q. Do you find this at Chippewa?

A. This peak at Buffalo is a fairly flat one, because there are little variations of tenths or so and there are several hours approximately the same elevation, within a tenth or two of the same elevation, so that I should judge there would be about a two hour difference there. As a matter of fact, if you should take that extreme peak at Buffalo and the starting of the peak at Chippewa, we would have zero difference. It would be better to take, say, the center of those two groups and that would indicate about two hours—it would be about four hours.

Q. About four hours?

A. Yes.

Q. What was the change at Chippewa, what per cent. of the change at Buffalo?

A. Let me correct that last statement. That would be a little over three hours. The question was the rise at Chippewa.

Q. Yes, how much?

A. .05 of a foot.

Q. What per cent. of the change at Buffalo?

A. 75 per cent.; does not conform with the 56 per cent.

relationship within 75 per cent.

Q. Within 75 per cent.?

A. Yes. I would expect that.

Q. You would expect it?

A. Oh yes.

Q. What is the next depression at Buffalo?

A. There is a depression which is indicated at its minimum at the 14th hour. The lake drops .24 of a foot.

Q. That is an even three inches, isn't it?

A. Yes, a little less than three inches, and we have .03 drop at Chippewa coming about two hours later.

Q. What is the per cent. of the Buffalo change?

A. It is about 25 per cent., in error 75 per cent., if it should be assumed that the 56 per cent. relationship would hold, which of course we would not assume in a case of this kind.

Q. Now Mr. Shenehon, when we started to-day here to ask you about the depressions at Buffalo and the summits at Buffalo, compared with the summits at Chippewa and the depressions at Chippewa, you protested about our going into it didn't you because you didn't think it would have any value in the determination of the lag, but we have at least done this: We have caused you to make an examination of your papers, and go over the records here with reference to those gage readings, so that you think that perhaps your opinion as to the lag was incorrect, as given in the re-direct examination. Is that correct?

A. It was rather roundly stated as two hours and fifteen minutes. I am not sure I did not use two hours; I rather think I did.

Q. You did?

A. Yes, it was a round statement.

Q. Do you remember whether you said approximately two hours?

A. No.

Q. What is the Chezy formula?

A. It is a formula for the flow of water in open channels.

Q. What is it?

A. Velocity equals C times the square root of RS.

Q. I notice you give that very readily. It is a formula that every engineer should know, every hydraulic engineer should know?

A. I presume a great many hydraulic engineers do not carry in their minds formulae. I carry very few myself.

Q. Isn't that one usually carried by hydraulic engineers?

A. It is like the fundamental formula for the velocity of water issuing from an orifice, or in general—

Q. You imagine that it might be a good deal like the maxim of the law that persons must come into equity with clean hands?

A. Yes, I have heard that.

Q. You heard the testimony of Mr. Hayford in this case didn't you?

A. Yes.

Q. In fact you assisted him in the preparation of his testimony, didn't you?

A. Well, I do not think it goes quite to the point of assistance. I placed in his hands certain documents and explained what they were.

Q. You told him what you wanted to prove by him, didn't you?

A. What investigations he should make.

Q. That is the ultimate facts which you wished to arrive at?

A. Yes. Investigate the precision of the work from all points of view.

Q. And after he had made that investigation, you went over the results of his investigations with him, didn't you?

A. On the occasion of his testimony.

Q. That is before he testified?

A. I do not think in detail. I did know his results prior to his testimony.

Q. And you knew the general results, didn't you?

A. No, I do not think that I knew until his testimony.

Q. When you say detail—you said you didn't know the detail?

A. Yes.

Q. What did you mean by that? Now you say you did not know anything about what he would testify to before he went on the stand?

A. I believe I had gathered the impression, and I am not sure just how, that his determination was that the observations were precise. But the exact figures I did not know.

Q. Did you know anything about his determinations with reference to the percentage of error, various percentages of error that he mentioned there in his direct testimony?

A. I do not quite understand that.

Q. For instance, the percentage, the error that might result from the rating of the meters or from the velocity, weeds turbulence, and things like that?

A. Now the question, what is the form of the question?

Q. (Question read as follows): "Did you know anything about his determinations with reference to the percentage of error, various percentages of error that he mentioned there in his direct examination"?

A. No, not prior to his testimony, I had not gone over those in detail with him.

Q. But you knew that he had reached a conclusion as to the precision of the work?

A. Yes, I knew his views of conclusions as to the precision, prior to his testifying.

Mr. Hopkins: I enter a general objection to this, as not cross-examination.

Mr. Adcock: Q. Do you recall his explanation of the criticism of the Three Point Method, wherein he said (page 2730 typewritten record; printed record 3102, 3103, and 3104) "In other words, if you interchanged the discharge and let the elevations stand, in your computation, the final result of the computation from the Three Point Method will be unchanged," do you remember that?

A. Yes, I remember he discussed that. I do not remember the exact wording.

Q. You remember the substance?

A. Yes.

Q. What I have stated is the substance?

A. I think so.

Q. If such a transposition were made, would the observations then fall approximately in a straight line with the rest?

A. I do not know; I have not given full consideration to the case cited.

Q. You have understood, have you not, that in the use of the Three Point Method by the Defendant's witnesses in this case, it has been restricted to the discussion of observations which did fall approximately in a straight line?

A. No, I do not think that to be a fact.

Q. I take it you understand that the St. Clair observations of discharge and elevation and so forth, and the St. Lawrence River observations do not fall in approximately a straight line?

A. No, that is not a conclusion to be drawn from my statement.

Q. You got the application of the Three Point Method, did you not?

A. If Mr. Williams will plot the groups that he chose for the Niagara River—

Q. I am speaking of the St. Lawrence and St. Clair, Mr. Shenehon. Perhaps Mr. Williams did not consider the Niagara observations were worth plotting?

A. Yes, I think he reached a premature conclusion of that kind. I have in mind also the case of the relations of the lakes. If you will plot those lines, they do not come in very accordant straight lines. For instance the relation between Michigan-Huron and Erie and the—

Q. I am not asking you that.

A. If those were plotted, the observations used by Mr. Williams, they will not fall in very accordant straight lines; but the Three Point Method was used in reaching a conclusion, reaching not only one conclusion but two conclusions as to the relationship.

Q. With reference to the observations of discharge, how did you do that, for those two rivers?

A. The method used by Mr. Williams in his chronological period scheme threw the observations off from the straight line. In other words the relationship between the lake and the flow was aggravated, made to fall further from a straight line.

Q. Did you plot those to determine whether they fell in a straight line?

A. I plotted Niagara, and there we have the case of observations that to start with fall in very accordant straight lines, as indicated by Shenehon's Exhibits B and D.

Q. I am asking you about the St. Clair and St. Lawrence Rivers?

A. No, I did not plot those.

Q. So you do not know whether they fell within a reasonably straight line or not, do you? Is that true?

A. Well, from the methods used—

Q. I refer you, Mr. Shenehon, to Plate 6, of Williams Exhibit 34, with reference to the St. Lawrence River and ask you to look at that and state whether that refreshes your recollection with reference—

A. The six groups plotted on that chart appear to line up fairly well in a straight line. I refer to Plate 5, in which eleven groups of the St. Clair River are plotted and the observations are extremely discrepant, do not fall on the straight line.

Q. They are affected by the level of Lake St. Clair, aren't they?

A. Plates 6 and 5, differ, so far as I recollect it, in the fact that one is of one set of years—no, plate 6, is of the St.

Lawrence River. There, there was not very much variation, according to the method used by Mr. Williams.

Q. Plate 5, what is that?

A. Plate 5, is the St. Clair.

Q. That was with reference to the elevation of Lake Huron, wasn't it?

A. Yes, and yet my recollection is that those are corrected for the backwater effect of Lake St. Clair. This I think is the final increment of Mr. Williams regarded as his best increment, 28,872.

Q. What proportion of the discharge of Lake Erie is due to the local supply on the average?

A. Do you mean the amount that is contributed by its watershed and by the rain falling on the lake less the evaporation? In my statement concerning that, I took the run-off as computed by Mr. Gardner S. Williams over a term of 16 years; assuming a mean rainfall for those 16 years, or a rainfall corresponding to that shown in Table LIXa, I think, of Williams' Exhibit 34. That represented something like 7,400 cubic second feet as the yield of the watershed, during the months June to November inclusive.

Q. Did you agree with Mr. Williams on his determination in that regard?

A. I had made no determination of the run-off myself, for the reason that it appears to me good. There are two reasons; one is Mr. Williams attacks the thing in the proper manner, that is making an investigation of so much of the stream flow of the watersheds themselves as was available, and the other reason is that when you utilize Mr. Williams' figures, it puts in accord the flow of the St. Clair River, the Detroit River and the Niagara River. And when you utilize either Mr. Williams' figures or Mr. Stearns' for Ontario, it puts the St. Lawrence in accord very closely, within two or three per cent.; two per cent. I think it is, with the Niagara.

Q. What proportion of the annual discharge of Lake Erie is due to the local supply, on the average?

A. Mr. Williams' figures indicate .66 of a cubic foot per second per square mile of drainage basin. When you come to the full year, the analysis is complicated, and in the end unsatisfactory, unless you make a correction for the ice conditions in the St. Clair River.

Q. Now Mr. Shenehon, I am not asking you for an analysis of the testimony of the witnesses in this case. I am asking you to assume from your experience, and give us an opinion as to what you believe to be the proportion of the annual dis-

charge of Lake Erie that is due to the local supply on the average?

A. My answer is: The best evidence I have, as to what it is is the testimony as to run-off given by Mr. Gardner S. Williams. I have never made any independent investigations.

Q. You never made any attempt to ascertain what that was, independently?

A. No. That is true.

Q. And when you determined the increments for these various outlets of the lakes, you did not think it necessary to determine that question, is that right?

A. No, I did not.

Q. You were willing to rely entirely upon your observations made with the current meter used by the Lake Survey. Is that true?

A. Don't understand me to say that I do not regard an investigation of that kind as desirable. I think it should be extended to include the rivers that Mr. Williams did not include in his examination.

It was a missing link in the physics of the Great Lakes; and it had been surmised and guessed at or estimated before; and Mr. Williams' method of attack is the one that should lead to the best methods. Of course his method is subject to considerable percentage of error, so far as that is concerned.

Q. Do you think it is as desirable to use some method of that kind in determining a correct increment as it is to determine the lag or to use the eight minute interval between the Buffalo gage and the International Bridge?

A. Well, I don't see any relation between that and the derivation of the increment.

Q. I know, but when you give your opinion as to what an increment is, you would like to know whether that increment is correct; you would like to test it, make various tests, wouldn't you to determine that question?

A. Yes, the tests that we applied on the Niagara, for instance, were duplicate sections, the increment being substantially the same in each; and it was tested by referring the measurements to the gage in the Gorge.

Q. Also at Chippewa, wasn't it?

A. And also at Chippewa, yes.

Q. You were willing to rely upon simply those tests, the agreement between the Open Section and the International Bridge Section, were you?

A. Yes, and yet when you open up the whole line of the rivers and the individual supply, that is additionally valuable

and I do not wish to discount that in the least. It is proper to test mean volume of flow.

Q. What is the percentage of the discharge of Lake Erie due to local supply on the average, the annual discharge?

A. In answering that question, I might assume the evaporation and the rainfall on the lake surface balancing. I have not gone into that, so I am not prepared to state—

Q. I am not speaking of local supply.

A. The local supply is involved in the evaporation and in the rainfall on the lake surface itself, as well as the run-off. I do not wish to make any assumptions involving the evaporation on the lake surface. I think it is a thing that we have not determinate information about.

Q. You stated a little while ago you thought the local supply from Lake Erie was approximately 7,000 feet?

A. I stated that as the run-off given by Mr. Williams, without raising any question as to the validity and correctness of rainfall observations or evaporation used by Mr. Stearns, I use that value for the run-off and Mr. Stearns value for the evaporation or rainfall, and it places this whole chain of lakes in consonance, that is the discharge of the various rivers.

Q. I am asking you what your opinion is as to that percentage due to the local supply?

A. Not knowing the evaporation, in other words the water that flies off or flows away through the air from the lake surface, I am unable to give you a statement of that.

Q. Then you don't know?

A. I don't know.

Q. You never made any independent investigation?

A. No.

Q. Of your own?

A. No.

Q. You don't know from any of the investigations that have been made in this case?

A. I have Mr. Stearns' figures as to the evaporation.

Q. But you say all those are in accord, these conclusions, Mr. Williams' conclusions are in accord with the general physical conditions, your various increments and so on; and yet you do not want to give an opinion as to what the local supply is. Is that true?

A. Well, I should say it was very close to the amount indicated in my analysis.

Q. What percentage of the discharge of Lake Erie is the local supply?

A. Perhaps three or four per cent. Now I am speaking of the months June to November, inclusive.

Q. We are talking about the whole thing?

A. I do not know.

Q. You do not know about the whole thing?

A. I have not made any analysis which involves the whole thing. I do not know whether Mr. Williams' figures, I have no means of knowing whether Mr. Williams' figures for the whole year are correct or not. That includes the winter season when the flow of the streams would be somewhat in doubt and the precipitation of snow, water in the form of snow, being somewhat in doubt. I do not know.

Q. By what per cent. does this local supply vary from year to year?

A. I have made no investigation of that.

Q. You do not know anything about it. What proportion of the discharge, according to your best judgment, is the evaporation from Lake Erie on the average?

A. I do not know.

Q. You do not know that. By what per cent. does the evaporation vary from year to year?

A. I do not know.

Q. Do you consider the evaporation to vary in a greater or less proportion than the rainfall, from year to year?

A. I would not wish to make any statement on that.

Q. Does it vary less?

A. It would depend on the other elements, the temperature and distribution of the rainfall, general humidity; and I could not reach any conclusion concerning it.

Q. What is the variation of rainfall from year to year on the drainage of Lake Erie?

A. That is indicated in tables printed by Mr. Wheeler in his 1903 report; tables I believe given in Mr. Williams' Exhibit 34, which will indicate that. I could refer to those tables.

Q. Well, to refresh your recollection, the mean rainfall as given by Mr. Wheeler was 34.08 inches, wasn't it?

A. I had it in mind as 34 inches as an average rainfall.

Q. And the range was 40.23 inches in 1890, to 28.41 inches in 1895, wasn't it? That is 24 per cent. to minus 25 per cent.?

A. In Mr. Wheeler's table on page 2879 of the report of the Chief of Engineers for 1903, the annual rainfall is not summed up by Mr. Wheeler, but I see pencil figures placed here, which I may assume to be correct. These were made by Mr. Gardner S. Williams. The average appears to be

34.14; the maximum is 40.23, and the minimum is 28.41. That is the year 1895, when the lakes were so low.

Q. That would be 24 per cent. to minus 25 per cent. variation, wouldn't it, or 25 per cent. in both directions?

A. A little less than that. That is taking 34.14 as the base, 40.23 is 6.09 greater; divided by 34.14, that would be about 17.8 per cent.

Q. That is the variation?

A. That is the variation for the maximum from the mean.

Q. It is practically the same for the variation from the minimum?

A. Yes, very close to the same for the minimum.

Q. Assuming that there was an excess of 8,000 cubic feet per second more water delivered to Erie in the period from 1860 to 1882, than in the period from 1890 to 1901, as shown by the computation of Mr. Haskell, on page 2259—105 of the typewritten record (printed record page 2734), and assuming that it was disposed of by evaporation from the surface of Lake Erie, how much evaporation would this represent on Lake Erie measured in inches, if distributed through the Open Season?

A. During the six months, June to November, it would represent about five inches; that is the 8,000 would correspond to five inches.

Q. Wouldn't it be seven inches?

A. No.

Q. Then you disagree with Mr. Haskell's answer to this question?

A. I do not remember Mr. Haskell's answer to this question.

Q. Wherein he said it was three inches, which he finally corrected to four inches, as appears on page 2259-108 (printed record page 2736).

A. I am simply figuring it this way: Having 8,000 cubic second feet of water to dispose of in 183 days or six months, June to November, inclusive, the lake would be lowered five inches in disposing of that water, below five inches.

Q. Did you not at the time Mr. Haskell gave his answer check his computation and agree with it? You were present were you not?

A. Yes, I was present. I am not certain.

Q. You do not remember that. In your direct examination you stated that in deriving the Niagara increment, the witnesses for the defendant in this case started at the St. Lawrence with an inflated increment, did you not?

A. Yes.

Q. How was that inflated?

A. By Mr. Williams' chronological method of grouping the observations.

Q. How much was it inflated?

A. From 28,900 roundly to 30,300. I am not quite certain of the last figure.

Q. What per cent.?

A. That is not quite an accurate statement that I gave there of 28,870. That should be the figure I got out yesterday, 24,000.

Q. Wasn't the 28,870, the increment that was given by the Government witnesses in this case for the St. Lawrence River?

A. That was for the St. Lawrence River at Ogdensburg, ant that should be corrected by two per cent. The 30,300, was for Oswego for Lake Ontario.

Q. You said it should be corrected for Oswego, Mr. Shenehon. Didn't you say in your testimony early in this case that that increment which was given was substantially correct for Oswego?

A. I think the U. S. Exhibit Number 2 covers that.

Q. I am asking about your testimony?

A. I have no recollection of making any such statement. It is within two per cent. of correct, so if you wish to call that substantially correct, that would be 7.1 per cent., as I make it, of inflation. I reduce that to Oswego, which gives an increment for Oswego of 28,300. That is correcting by two per cent.

Q. You say that is seven per cent.?

A. A little over seven per cent. I make it 7.1.

Q. You change the increment then, you reduce it two per cent. for Oswego, do you?

A. Yes.

Q. But you stated in your direct examination, didn't you that that increment was substantially correct for Oswego?

A. I am not aware of that fact. I think I stated the increment as indicated on U. S. Exhibit Number 2, where it appears for Oswego you must reduce the increment two per cent.

Q. Well now you stated in your examination, re-direct examination, that this increment for the St. Lawrence River might be ten per cent. in error, didn't you?

A. Yes.

Q. You are also aware that Mr. Williams in arriving at

the increment which he used for the St. Lawrence River made certain calculations, aren't you?

A. Yes, which I regarded as erroneous, and in the absence of knowledge as to the lag or time interval in the river, he set his gage elevations ahead, as you recollect.

Q. But the seven per cent. which he used for the increment, which he used, was within the ten per cent.?

A. Yes, that is true.

Q. Which you described as being in error, didn't you?

A. Yes, that is true. Of course my present opinion is that the error was on the other side. It was greater than the ten per cent. indicated.

Q. That the increment was greater. Did you indicate that in your direct examination?

A. No, that was not stated.

Q. And it was not your opinion at that time, was it?

A. I think I had not made any further investigation by the method of relative fluctuations to—

Q. Yet you say that Mr. Williams' determination there from those discharge observations which was within the ten per cent. as you stated that the increment might be in error, was still an erroneous conclusion?

A. His method of treating the observations, to my mind could reach no other—did reach no other conclusion than an erroneous result; that the method was vitally and fundamentally wrong.

Q. And not based upon any logical reasoning at all, as an engineer?

A. Based on an ignoring of the facts.

Q. And as a foolish and unnecessary calculation, is that correct?

A. I do not like to characterize Mr. Williams' work.

Q. I am asking you with reference to Mr. Williams' computations as an engineer there?

A. The investigation and the method used by Mr. Williams, in my judgment, are not those that would be used by an investigator with full knowledge of the facts.

Q. And still his determination is within the ten per cent. which you stated?

A. Yes, within seven per cent., roundly.

Recess to 2:00 P. M.

After Recess 2:00 P. M.

FRANCIS C. SHENEHON resumed the stand and testified on cross-examination further as follows:

Mr. Adcock: Q. Now, Mr. Shenehon, I asked you a question, which I think was the first question beginning with the cross-examination yesterday, and you stated that you would not like to answer that question until you had an opportunity to plot up the observation shown upon Haskell's Exhibit A, of February 25, 1914. I understand that those observations have been plotted, and I will now ask you if you will answer the question first put to you?

A. I have before me a plot of the observations which were presented to me, and this plot is in three parts corresponding to the three series indicated by the tabulation forming part of the question.

Q. You understand that that plotting was made by Mr. Murray Blanchard, don't you?

A. This plot was made by Mr. Murray Blanchard, an engineer in the Sanitary District Engineer's Office, and I am assuming it is correctly plotted.

I find that the observations in columns 1 and 2, when plotted, show that the discrepancies indicate no very clear cut law of relationship.

I find that the observations in groups 3 and 4, columns 3 and 4, in which there are 27 individual observations, are in fair alignment, but not in alignment with the observations of groups 1 and 2. And I find the observations of groups 5 and 6, align themselves fairly well along a line, and that line is not in accord with the line indicated for columns 1 and 2. The choice, under these conditions, I think would rest with groups 3 and 4, on account of the greater number of observations and somewhat greater range in the fall. The choice, however, is not a very clear cut one. I am not sure that the question itself is entirely comprehensible, after plotting these observations.

We have three groups of observations, and neither one of the groups appears to be in accord with the other group. I hardly see how a clear cut determination may be made as to which of the two groups may be chosen to get the condition represented here, unless I state neither.

Q. Your choice lies between 3 and 4?

A. I cannot see that there is any very close relationship

between the observations in 1 and 2, with those of 3 and 4, or 5 and 6.

Q. You think that neither one of those groups is applicable to the assumed conditions of columns 1 and 2?

A. The assumed conditions of columns 1 and 2 are somewhat remarkable. We have, for instance, from a mean line which I have drawn, which is of course only approximate, I did not take out centers of gravity,—I have stretched a line and the observations are such that the bearing of the line cannot be very accurate, the observations themselves are so discrepant; I speak of observations in columns 1 and 2 now. For instance, we have a residual in groups 1 and 2 of approximately a foot and a half from the mean line; and if we take the residual in the other direction, it is about .7 of a foot. We have other residuals approaching that in size.

Q. You think it would be improper Mr. Shenehon, I understand it is your opinion, to derive a discharge curve from either set of observations, to be applied to the conditions of columns 1 and 2?

A. The question itself is really incomprehensible to me. I confess my inability to get a clear comprehension of the thing. We have three sets of observations shown and columns 1 and 2, represent real conditions, actual conditions, as I understand. Just what these observations are, I don't understand where they come from, if they are not real conditions.

Q. They are real conditions also. Mr. Haskell seemed to be more alert than you?

A. Mr. Haskell is a very alert man.

Q. He considered it was possible to form an opinion with reference to the very identical question I asked you.

A. Mr. Haskell, I believe, did not see the observations plotted.

Q. But from the records shown on the Exhibits there, he was able to form an opinion, wasn't he?

A. I think the testimony indicates that. I don't remember what his conclusion of the matter was.

Q. And you have no choice then as to which column—

A. I say the thing is incomprehensible to me.

Mr. Hopkins: Are those figures in evidence?

Mr. Adcock: Yes.

Q. Now, do you wish to devote any further study to that question, Mr. Shenehon?

A. I might take it under advisement, see if I can really comprehend the thing.

Q. Mr. Haskell answered the question very quickly, readily. He grasped the words, the expressions—

Mr. Hopkins: Objected to. We cannot know what another man grasped or understood.

Mr. Adcock: Q. Now, can you make any choice as between columns 3 and 4 and columns 5 and 6, as to which one is more applicable to the conditions indicated in columns 1 and 2?

A. I have stated that columns 3 and 4, have a greater number of observations. That is an advantage, and there appears to be a greater range in the difference in elevation, or difference in fall. So as far as those elements are concerned they appear to favor 3 and 4; the observations appear to be a little more accordant in 5 and 6. Viewing them that way, that appears to be a group of observations that align themselves well with a little less length in the fall, or height in the fall. The trend of the line for the 5th and 6th, is nearer parallel to the trend of the line for the group 1 and 2.

Q. Which do you choose, then?

A. I do not make any choice. I give you the elements in each, the advantages in number in one case, a little better in accord than the other, a little better accord with the line.

Q. Mr. Shenehon, the court will not know anything about these reasons you give. You are an expert witness and we are asking for a conclusion, and I am asking you to give me your choice between columns 3 and 4 and 5 and 6.

Mr. Hopkins: Objected to as already answered. He has no choice.

The Witness: I have given my answer that the question is an incomprehensible one to me; and I have pointed out that we have groups of observations here with certain peculiarities. I do not wish to make any choice.

Mr. Adcock: Q. I know, but you have mentioned certain things which might lead you to make a choice.

A. Yes; they are not sufficient to permit me to make a choice.

Q. Then you haven't any opinion as to which one?

A. I should prefer to make no choice.

Q. Would you as an engineer, use one group as readily as another?

A. For what purpose? I cannot see the relation of groups 1 and 2 to the other two.

Q. For the purpose of making a choice?

A. I cannot see any relation. I can't see the rationale of what we are attempting to get at.

Q. I am asking you to suppose that you desired to obtain

a discharge curve for this section at which the observations in columns 3 and 4 and 5 and 6, were made, that would represent the discharge of the period referred to the head at the up-stream end?

A. What is the relation of groups 1 and 2? That is what I can't make out.

Q. (Continuing.) Assume it is made at the same section, same river. You have three groups, in the same section and the same river. If you will read the question, you will find that the conditions are all assumed there.

A. You mean I am to choose between the three groups?

Q. No, between the two?

A. I can't see the relation between groups 1 and 2.

Q. Between columns 5 and 6, and columns 3 and 4?

A. Well, I repeat that I do not comprehend the question.

Q. In other words you want us to state to you what the next question will be. Is that right?

A. I want you to make the thing comprehensible to me.

Q. I am asking you to answer the question as it has been put to you, to give your opinion as to the choice that you would make between the groups of observations there as applicable to the conditions assumed in columns 1 and 2?

A. You mean assuming three groups of observations, I am to say which group I regard as the best?

Q. No, just read the question? (Question read as follows:) "I am asking you to assume that suppose for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo, and Niagara, for a period of years the elevation of the water at the up-stream end had been as shown in the first column, and the fall through the channel had been as shown in the second column," do you understand what that first and second column represents?

A. Yes.

Q. (Continuing.) "Suppose it were desired to obtain a discharge curve for this section that would represent the discharge for the period referred to the head at the up-stream end, and suppose that there had been made a series of 27 observations under the conditions of columns 3 and 4; and that there was also available a series of 23 observations made with equal care, under the conditions shown in columns 5 and 6. Which in your judgment would give a discharge curve the more closely applicable to the assumed conditions of columns 1 and 2?

A. I believe I can't answer that question.

Q. On what ground?

A. I have already stated that each of these lines has some elements that appear to be superior to the other. The upper one, which is 5 and 6, the trend of the line appears to be a little nearer in accordance with the trend of the line in 1 and 2, but the observations in 1 and 2, are so discrepant that they cannot have any great value.

The range in 3 and 4 in the backwater effect or the fall there is greater than in 3 and 4; and more nearly in accord with the line in 1 and 2. The range in each, I believe, is pretty nearly the same, that is for the elevation, so there is not any great choice there. In 3 and 4, we have the more observations. In 5 and 6 we have a little better accord. I would have great difficulty in choosing between those.

Q. Now Mr. Shenehon, you have stated various facts concerning the different groups there?

A. Yes.

Q. I am asking you to weigh those considerations which you have mentioned and give me a conclusion as to which group, columns 3 and 4, and 5 and 6, are most applicable to the condition assumed in columns 1 and 2?

A. I think I have given you the best answer I can, Mr. Adcock.

Q. If you had to use one or the other to obtain a discharge curve, which one would you use?

Mr. Hopkins: Objected to as already answered; that he has no opinion.

A. What I can't comprehend is what 1 and 2 represent.

Q. That is not the question, as to what you comprehend about that.

A. Then I can't answer the question, can I?

Q. If you were going to obtain a discharge curve for that section of that river, which would you use, the group in columns 4 and 5 or columns 5 and 6?

A. You have attached to your question certain assumptions in columns 1 and 2. I do not comprehend that.

Q. I am asking you to assume: Suppose for a certain channel similar in magnitude to those connecting the Great Lakes, but without such rapids or falls as occur at the Soo and Niagara, for a period of years the elevation of the water at the up-stream end had been as shown in the first column, and the fall through the channel had been as shown in the second column. Those are certain assumptions to make, with reference to columns 1 and 2.

Mr. Hopkins: Same objection. The witness says he has no opinion.

Q. And I am asking you to suppose that you desire, as a hydraulic engineer, to obtain a discharge curve for this section that would represent the discharge of the period referred to the head at the up-stream end, and suppose that there had been made a series of 27 observations under the conditions of columns 3 and 4, and that there was also available a series of 23 observations made with equal care under the conditions shown in columns 5 and 6. Now, which in your judgment, would give a discharge curve the more applicable, more closely applicable to the assumed conditions of columns 1 and 2. I want you to make a choice. You have stated various reasons that might enter into making such a choice. If you were going to obtain a discharge curve as indicated in the question, would you use either one of them?

Mr. Hopkins: Same objection. He says he would not.

Mr. Adcock: Q. You may use one or the other, is that the point?

A. I am not sure I would wish to use either of them.

Q. If those were the only observations you had and it was necessary to obtain a discharge curve, which one would you use as between columns 3 and 4 and columns 5 and 6?

A. I have stated that the thing is rather incomprehensible to me, and I have not any very clear cut choice. The greater number of observations there appeals to me, with the greater range, and if you wish a mild choice, I might say 3 and 4 is preferable.

Q. Do you consider the observations shown in 3 and 4, equally applicable, at least as applicable as those shown in columns 5 and 6?

A. Yes, or a little more so on account of the greater number under greater range.

Q. And you make your choice as between the two, columns 3 and 4?

A. Yes. You understand this is not a very clear cut choice, and I am not sure in the end that either of those is entirely applicable to the conditions shown in 1 and 2. The thing is rather obscure, you understand, in my mind.

Q. Do you wish to make the statement that neither one is applicable to the conditions assumed in columns 1 and 2?

A. In columns 1 and 2, as I stated before, the discrepancy of certain observations from any line, the scattering of them is so wide, that it is rather difficult to make a statement along this line.

Q. I am asking you for your opinion. I know it is difficult. There are lots of difficult questions about this case, and I appreciate also, Mr. Shenehon, that you want to be very careful about your answers.

A. Yes.

Q. And that you are cautious and everything like that, but we would like to have you answer the question as to your choice.

Mr. Hopkins: Objected to. The witness has already answered.

Mr. Adcock: Q. I mean as to whether either one of them is applicable to the conditions assumed in columns 1 and 2?

A. I should wish to make further computations to see whether or not a line derived from groups 1 and 2, would coincide very closely with lines 3 and 4. They do not appear to in the lines that I have drawn, by stretching a thread, or a string, to speak more accurately. They do not appear to coincide. They appear to be of fairly wide divergence. The law of relationship is not the same for 1 and 2, as it appears, as that in 3 and 4.

Q. Do you think you could obtain more accurate results if you used a thread than the string that you did use in this case?

A. I do not think that would change the thing very much, but it would be well to take out the center of gravity and put the thread through that at least. But where you have discrepant observations, as you have in columns 1 and 2 here, a thread has its difficulties as well as the Three Point Method, and even the method of Least Squares.

Q. You now wish, Mr. Shenehon, to obtain the center of gravity and show that center of gravity, before you attempt to use it?

A. That center of gravity, in the Three Point Method and Least Square Method, they both pass through that point, on the assumption it is a straight line.

Q. In the latter exhibits which the Government has presented in this case since Mr. Williams has testified, you have shown the center of gravity on the exhibits, haven't you?

A. Yes.

Q. That was not shown on the previous exhibits?

A. I think Mr. Williams has contributed the center of gravity to be set as a central pivotal point where we have a straight line relationship. It confirms the stretching of a

thread with a little higher precision and it is, as I say, a point on the Least Squares derivation.

Q. Notwithstanding your opinion of some of Mr. Williams' methods in analyzing the observations that have been presented in this case, you think he has made some contribution to the Lake Survey in their work in determining the discharge curve?

A. I am very glad indeed to acknowledge whatever Mr. Williams has contributed. I am delighted always to have a chance to acknowledge anything of that kind.

Q. He might be a valuable adjunct to the Lake Survey, might he not?

A. (No response.)

Mr. Hopkins: Objected to.

Q. If the elevations in columns 1, 3 and 5, should have been 200, 300, or 400 feet, or any number of feet higher in every case, would your answer be the same?

A. Yes.

Q. That is axiomatic, is that right, Mr. Shenehon?

A. Yes.

Q. You are willing to make answers with reference to any question which involves an axiom in the engineering profession?

A. In so an intelligent a court as this, axiomatic conclusions need not be set down.

Q. 8,000 cubic feet per second equals how many feet in one year?

A. That would be 252,288,000,000.

Q. What is the area of Lake Erie in Square feet?

A. Including Lake St. Clair?

Q. No, Lake Erie?

A. In computations concerning this, we generally include the two.

Q. Include it if you wish?

A. That would be, Lake St. Clair included, 292,964,000,000 square feet; with 1 foot depth, would be cubic feet.

Q. What depth of water in inches would have to be evaporated during the year to dispose of an inflow of 8,000 cubic feet per second?

A. That has been already given as a little over five inches.

Q. No, I am asking you to figure that from what you have learned?

A. The statement of five inches included six months.

Q. How much would have to be evaporated to do it in six

months, to take care of 8,000 cubic feet per second inflow in six months?

A. Well, a continuous flow?

Q. If 8,000 cubic feet of water per second annually came into that lake, that had to be gotten out by evaporation, and you were going to evaporate it in six months—

A. My answer to the question where I stated five inches in depth on the surface of Lake Erie and Lake St. Clair, if it was disposed of in six months, would be equivalent to a flow of approximately 8,000 cubic second feet.

Q. Now, I have asked you to figure what 8,000 cubic feet per second would represent in cubic feet in one year. I asked you to take the area of Lake Erie including that of Lake St. Clair. Now, I ask you to state what depth of water in inches would have to be evaporated during the year to dispose of an inflow of 8,000 cubic feet per second annually. You have the cubic feet of water and the area of the lake surface, St. Clair and Erie. Now, isn't it a simple proposition that you would divide 252,288,000,000 by 292,964,982,600 and that you would get as a result about .75 of a foot?

A. It would be about .86 of a foot, a little over 10 inches. It would be just twice the amount that I stated before. I said a little over five inches; this would be a little over ten inches.

Q. Then do you wish to correct your statement?

A. My answer before was based on the flow at the rate of 8,000 cubic second feet over a period of six months, equivalent to a depth of five inches. That same amount flowing for a year, of course, would be twice as great; ten inches.

Q. If you had to dispose of this amount of flow in six months, would the evaporation be any less?

A. Well, are you assuming now that you have fixed conditions at the outflow, or if we have a higher elevation of the lake we have a higher outflow.

Q. Assuming the conditions as they existed, that there was 8,000 cubic second feet of water throughout the whole year to be disposed of by evaporation from Lake Erie, we ask what depth it would be. Mr. Haskell answered three inches. We called your attention to his figure and you checked it?

A. The ten inches appears to be correct. If however, you assume an 8,000 cubic second feet inflow and take into account the higher elevation and therefore the difference in condition at the outflow, you might reach a different conclu-

sion if it was an element in the question, which I understand it is not.

Q. Not an element?

A. Simply getting the relation between depth on the lake surface and the cubic feet per second over a certain length of time.

Q. Assuming as you testified this morning that the average depth of the Niagara River from the Buffalo gage to Chippewa was 16 feet—

A. That is an approximation gotten bv glancing at the map.

Q. If you want to glance again and change the figure, all right. Do you wish to change your statement made this morning?

A. If any material change were made, I would wish to spend two or three hours in making a more elaborate computation. This for approximate purposes may be sufficient.

Q. Continuing the question: And from the Buffalo gage to the bridge, it was 20 feet?

A. Yes.

Q. And that the rapidity of translation of a change at Buffalo would vary as the square root of the depth, as you also testified today and yesterday, what percentage of the time of transmission to Chippewa would be represented by the time of travel to the bridge?

A. I would have to scale off the distances accurately, in order to reach a conclusion.

Q. You stated I believe, in answer to a question, that the distance from the Buffalo gage to the International Bridge was 3 miles?

A. Those are round numbers. I will endeavor to get that a little more accurately. (Examining chart.) 3 4/5ths miles.

Q. 3 4/5ths miles from the Buffalo gage to the Bridge, is that correct?

A. That is correct.

Q. The distance as you have scaled it from the Buffalo gage to Chippewa is what?

A. An average of 16 miles—not from Buffalo gage, from the Bridge to Chippewa is 16 miles, and 3 4/5ths, 3.8.

Q. That would be how many miles from Buffalo to Chippewa?

A. That is an average of 19.8 from Buffalo gage to Chippewa. We have spoken of it roundly as 20 miles. It is a little

more by the American channel, and a little less by the Canadian channel.

Q. Now, having done the scaling which you said was necessary in order to answer the question, will you answer the question which I answered you?

A. Will you read the question?

Q. (Question read as follows: "Assuming, as you testified this morning, that the average depth of the Niagara River, from the Buffalo gage to Chippewa was 16 feet, and from the Buffalo gage to the Bridge it was 20 feet; and that the rapidity of translation of a change at Buffalo would vary as the square root of the depths, as you also testified today and yesterday, what percentage of the time of translation to Chippewa would be represented by the time of travel to the Bridge"?)

A. I make the time of translation from the Buffalo gage to the Bridge 14 minutes and from the Bridge to Chippewa—

Q. No, the percentage?

A. I will give you the percentage after stating the quantities.—62 minutes. The aggregate time is 76 minutes.

Q. Wait a minute: I am asking you as to the percentage?

A. I am about to figure that now, after having expressed the factors entering into the determination. 18 per cent. and 82 per cent. are the two percentages.

Mr. Hopkins: The time to the bridge is 18 per cent. of the time to Chippewa?

A. Yes. Of the whole time between the Buffalo gage and Chippewa; 18 per cent. is consumed in travel to the Bridge, and 82 from the Bridge to Chippewa.

Mr. Adcock: Q. Now assume that the time required for a change to travel to Chippewa is two hours, how long will it take this change to reach the Bridge?

Mr. Hopkins: You mean upon the same assumption?

Mr. Adcock: Yes, based upon his answer.

Mr. Hopkins: Based upon his answer to the former question?

A. About 21 minutes, based upon that percentage relationship.

Mr. Adcock: Well, assuming it is 2 hours and 15 minutes, which is the minimum you stated this morning, how long would it take the change to travel?

A. About two minutes and a half longer; it would take about 24 minutes.

Q. And if it were 2 hours and 40 minutes?

A. About 29 minutes.
Q. If it were 3 hours?
A. About 32½ minutes.
Q. Four hours?
A. That would be about 43 minutes.
Q. And 5 hours?
A. Let us see where we are on this: That is from the Buffalo gage down to the Bridge, on the assumption that it took—
Q. On the assumptions of your answer to the previous question?
A. I would like to recast those answers. Give me your various times, first, 2 hours?
Q. 2 hours and 15 minutes, 2 hours and 40 minutes, 3, 4, 5 and 6 hours?
A. Now let me answer these consecutively.
Q. Use any order you choose.
A. Proportionally, or the proportion of time from the Buffalo gage to the Bridge under the assumptions made, if the total time between the Buffalo gage and Chippewa were two hours, it would be 21 minutes to the International Bridge; if 2 hours and 15 minutes, 24 minutes; if 2 hours and 40 minutes, 29 minutes; if 3 hours, 32 minutes; if 4 hours, 43 minutes; if 5 hours, 53 minutes; if 6 hours, 61 minutes.
Q. Now Mr. Shenehon, how about that eight minute interval that you used,—which you did not use and Mr. Moore used in connection with your measurements, what value was that?
A. I believe it is a sufficient value for getting at the volume of flow with no error chargeable on this account, if this would appear in the end to be the correct interval instead of the eight minutes or ten minutes used, and so far as the increment is concerned, a similar statement follows?
Q. You might just as well say 2, 3 or 4 minutes, any number of minutes, make a guess at it, mightn't you?
A. I have already made a statement, whether the ten minutes was used or was not used, in my judgment, has no bearing on the conclusion as to increment and volume of flow of a group of observations. A single observation would probably be a little closer if you observed the time interval.
Q. But the value that you used there for the travel was 300 per cent. wrong almost, wasn't it?
A. No, I do not regard this as conclusive. We have as-

sumed roughly the depths. We have assumed a formula that is a theoretical one.

Q. That is based on the two hours, isn't it?

A. No,—

Q. If the calculations are correct, the facts which you have stated in your testimony, and from which you have drawn these conclusions here, and you assumed at the time of travel between Buffalo and Chippewa is two hours, which you stated, you are almost 300 per cent. wrong on the time of travel?

A. Assuming these figures we have just made to be absolutely correct.

Q. How much do you think they are off?

A. Well, I would expect to make a rough statement of the depth in the two cases, take a mean length of channel as we have done on the both sides of Grand Island, I should expect to have some variation if this were done more carefully. In the end, I would not expect the text book equation to be entirely applicable.

Q. What better methods have you used to determine the eight minute travel?

A. Observations.

Q. On what?

A. At the International Bridge made with the—

Q. For how long a time?

A. I think I stated half a day, and yet I am rather hazy whether it might have been a day or half a day.

Q. What do you consider it would be by taking a week at Chippewa?

A. Well, I consider that the cases are very different. The changes between the Buffalo gage and the International Bridge are exceedingly intimate. They are close together, fairly deep water between.

Q. You think a half a day would be sufficient to determine that?

A. Yes, for the substantial accuracy that is required in the lag. In fact I stated if we did not observe the lag at all, as Mr. Sabin did not in the St. Clair River, I think we would not get any error.

Q. If you were three or four hundred per cent. wrong, or five hundred or six hundred per cent. wrong on your calculations as to the travel, it would not make any difference?

A. When you get into these small quantities and talk about big percentages, you are rather distorting the thing.

Q. If the real time of travel between Buffalo and Chippewa were five hours as the figures this morning indicated, going over the gage records from November 1st to November 6, 1906, covering a week, then you were 500 per cent. wrong, weren't you?

A. You do not understand that I accept the conclusion drawn from your figures given this morning? I have put into the record the lag at Suspension Bridge and the Whirlpool which are well below Chippewa in the river, where we get this out with excellent determination, and the maximum lag at Chippewa, in my judgment, does not exceed two hours and 40 minutes.

Q. Does not exceed that?

A. No.

Q. You think you could determine that lag between the Buffalo gage and the International Bridge in half a day, but you could not determine it in taking the observations running over a week as to Buffalo and Chippewa, is that right, determine the lag at Buffalo and Chippewa?

A. Our examination indicated that Chippewa was not a favorable place to determine the lag. It is hard for me to conceive as a physical fact that the lag is greater between Chippewa and Buffalo than between the Gorge and the Whirlpool, which are down the river three or four miles further.

Q. We will go on a little bit further. Maybe we can contribute something more to the Lake Survey. In how many instances was the observed lag to the Suspension Bridge as shown on sheets which you presented this morning, numbered 1, 2, 3, 4 and 5, and entitled "United States v. Sanitary District of Chicago, determination of lag between Buffalo and Suspension Bridge gage, time required for change in Lake Erie to reach Suspension Bridge; only days of well marked changes used in determination," in how many instances was that equal to six hours?

A. You are asking now with respect to the Suspension Bridge gage?

Q. Yes. That is the nearer gage, isn't it?

A. Yes, that is the one—

Q. It is immediately below Chippewa?

A. Three or four miles below Chippewa. I find in the month of October, 1907, out of 23 determinations on high water and 22 on low,—I do not find any lags in excess of 5.5.

Q. Will you answer my question: I am asking you with reference to six hours. How many were six hours?

A. On the sheet marked November, 1907, in which 23 determination of marked high water are shown and 21 of marked low water, I find—

Q. Do you find one, just calling your attention to sheet number 1, under date of the 12th of October, 1907?

A. The answer should be, 1 on the first sheet; on the second sheet I find 2. On the third sheet, I find 2; on the fourth sheet I find 1. On the fifth sheet, I find 4, one of these being seven hours. I understood your question to be six hours or in excess of six hours?

Q. Yes? How many five hours to 5½ hours?

A. Would you prefer to have me count these up and simply give the results?

Q. Yes?

A. How many did you make for six hours?

Q. 10.

A. I find 2.

Q. Between five hours and five and a half hours?

A. I misunderstood the question. I will recount that: 21.

Q. How many were there four to four and a half hours?

A. I get 55.

Q. How many altogether, Mr. Shenehon, that were four hours or more?

A. 86 is my count.

Q. You had, I believe, 111 observations, didn't you?

A. Twice that many, roundly.

Q. What?

A. Twice that many; 111 on the high water and approximately the same on the low water. I counted both the well marked high water and the well marked low water.

Q. Now, at the Suspension Bridge and the Whirlpool, there are recording gages, aren't there?

A. Yes, those were self-recording.

Q. There was one at 7 hours, I believe, was there not Mr. Shenehon?

A. Yes, one at 7 hours.

Q. They are all automatic, self-recording gages?

A. Yes.

Q. How many zeroes do you find?

A. I don't find any.

Q. How about the sheet number 1; observation on the 11th for falling water?

A. Yes, there is one on the 11th, that is right.

Q. How many where there is one hour given as the lag?

Mr. Hopkins: You mean less than one?
Mr. Adcock: One or less.
A. You want me to count the zeroes in that?
Q. No, between zero and 1, ignoring zero?
A. I find seven of 1 hour.
Q. Seven of 1 hour?
A. Yes.
Q. How many between 1 and 2 hours?
A. I find 58 between 1 and 2.
Q. How many between 2 hours and 2.5 hours, or including 2.5 hours?
A. You mean including the 2 also?
Q. Yes, better include the 2.
A. That has already been included.
Q. Did you include the 2?
A. I included 2 and 2½.
Q. What?
A. It included 1½ and 2.
Q. Did it include anything between 1—?
A. No, did not include 1; 1½ and 2.
Q. How many have you got at 2 hours and a half?
A. Fourteen.
Q. That makes altogether how many 2½ or less than 2½?
A. That makes 80.
Q. Eighty?
A. Yes.
Q. Do you think it would be physically possible for a change at Buffalo to appear at Chippewa before the Buffalo change took place?
A. Not as a matter of causation, no.
Q. Do you think it would be physically possible for the same thing to take place at the Suspension Bridge?
A. In advance of the cause?
Q. Yes?
A. In the outflow of Lake Erie?
Q. Yes?
A. No.
Q. Do you think it physically possible for a change to take place at the Suspension Bridge at the same time that a change took place at Buffalo?
A. No.
Q. Do you think it physically possible for a change at the Suspension Bridge to take place within 1 hour after a change at Buffalo?

A. I think we are now getting into the region of possibilities.

Q. You think it could be physically possible?

A. Yes, I could understand the condition, I think, where it might happen that way.

Q. What would accelerate the travel so that it could possibly travel from Buffalo to the Suspension Bridge in one hour?

A. An exceedingly sharp rise might have the effect of sending the stream in a virtual bore down the river more rapidly than ordinarily.

Q. That is if the rise is very sudden, you consider that the travel of the crest is faster, do you?

A. I don't wish to—

Q. You base your answer upon that?

A. I could give an illustration: We had the breaking of the Johnstown Dam, at one time, in which a wall of water traveled down through the valley at an exceedingly rapid rate. Let us duplicate that situation at the head of the Niagara River. You have an exceedingly rapid rate; I would not be willing to state the lower limits of the time that might be taken.

Q. Do you think it would be more rapid than under ordinary circumstances?

A. Yes, I should think so.

Q. You feel very sure of that?

A. Yes, I think the rate of travel of a bore of that kind might be more rapid than the ordinary slower rise of the water.

Q. Have you got any observations?

A. No, I haven't anything to support that.

Q. Just an opinion?

A. Yes.

Q. You think it would be fairly possible for a change to take place at Suspension Bridge within an hour and a half after the change at Buffalo, do you?

A. Yes.

Q. And within two hours?

A. Yes.

Q. And within two hours and a half?

A. Yes.

Q. And that there might be conditions which would so accelerate the travel, so that the crest could travel from Buffalo to the Suspension Bridge in two hours and a half?

A. Yes, I could imagine extraordinary conditions.

Q. Then you think it would be fair, as an engineer, to include these 80 observations, do you, where the travel was less than two hours and a half?

A. Yes, I would include the one, and have included also the one in which the travel is indicated as zero, for the reason given this morning, that is an individual observation subject to the error of observation; and it would be ridiculous to reject your observations because they happen to be on the small side, and retain the observations that happen to be on the large side, because you have got to have the small ones in order to balance out the effect of these that are unusually large, and so we have the error of observations coming in.

Q. You selected what you call marked changes, didn't you?

A. Yes.

Q. "Well marked" you call it?

A. Yes.

Q. And in selecting those, you plot them, don't you so as to show a line?

A. No.

Q. Or you compare the elevation?

A. They were selected directly from the gage sheets.

Q. You did not use the care with reference to that, then, that you did this morning with reference to plotting the observations shown on Haskell's Exhibit A. You wish to have these plotted before you give any opinion?

A. That is a matter of the variation of a line showing a relation. It is quite a different affair.

Q. But when you found a crest at Buffalo, which you say indicates a well-marked change—

A. Yes.

Q. —it is your desire then to find something at the Suspension Bridge that will correspond with that in some way, isn't it?

A. The procedure is to follow down picking out the hours. You understand I did not do this myself.

Q. Did you leave that to Mr. Souther?

A. That was done by Mr. Souther, my assistant.

Q. He is the same gentleman who prepared the other two papers entitled somewhat the same way, with reference to Chippewa?

A. Yes, I may say—

Q. Did he prepare any other papers used in this case?

A. Yes.

Q. What?

A. He was my assistant in the preparation of a great many of these papers.

Q. Did you check over his figures?

A. Yes, usually.

Q. Did you check these?

A. No, these particular figures have never been checked by me.

Q. Now, the procedure is to pick out well marked changes during the day, at say, for instance you have here October 1st, 1907, you would pick out the change at the Buffalo gage which is well marked during that day, would you, or would he?

A. That I believe was the procedure, follow down pick out the—

Q. What hour—

A. Let me state my recollection of how this was done. I think he picked out for each day the low point and the high point.

Q. That is at Buffalo?

A. Where there was a wavering in the line, so that that was not well marked, that day was not included. You will notice in these tabulations that there are perhaps 23 out of 31 days utilized, and pursuing a similar procedure in regard to the Suspension Bridge gage, and setting down the times, you have the relationship.

Q. And then if a crest—

A. Answering the question you propounded a short time before: These all have been plotted and are shown in what has been mentioned as the Three Curve Series, so these tabulations are subject to corroboration by reference to the Three Curve Series. The dates and the times of day indicated on here are such that the particular time chosen may be checked by you, if you care to do that.

Q. Now, as I understand it, Mr. Souther, would check over a day, go over one day, for instance November 1st, 1907, and he would find a well marked change, perhaps a crest at Buffalo. Then the same day he would look at the gage readings for the Suspension Bridge, wouldn't he?

A. Yes.

Q. And if he found a crest there, he would put that down, would he, is that right?

A. That is—

Q. Without regard to the time when the crest appeared at Suspension Bridge, as compared with the Buffalo gage?

A. Yes.

Q. And as a matter of fact, the crest at Suspension Bridge

might have been due to some fluctuation or rise of the Buffalo gage the day before, might it not?

A. No. If you will refer to this Three Curve Series, you will see that the curves are very characteristic.

Q. I am trying to ascertain how Mr. Souther got at those figures.

A. I will be very glad to explain everything I can.

Q. I am trying to get at it. If you will just answer my questions I think we will get along. If, for instance, on November 1st, 1907, there was a crest at Buffalo at 1.00 A. M., and there was a crest at Suspension Bridge at 1:00 A. M., and that was the only crest appearing at the Suspension Bridge for that day, you would not say that the crest at 1:00 A. M. at the Suspension Bridge was due to any crest which he had observed for that day at Buffalo at the same time, would you?

A. These things are sufficiently characteristic, so that the relation—

Q. Will you answer my question? Would you expect that?

A. Won't you please read the question?

Q. (Question read.)

A. If these two corresponded, that would be set down as an observation, if they were well marked.

Q. Set down as zero?

A. As zero.

Q. If you will answer my question, would you say that the crest observed at Suspension Bridge was due to the change of elevation or the crest, which was shown at 1:00 A. M., the same hour, at Buffalo?

A. I should say it was due to the error of observation.

Q. Might it not have been due entirely to a crest appearing at Buffalo the preceding day?

A. No.

Q. Why not?

A. Because the relation is so definitely established. And I refer you again to the Three Curve Series on this point. The relation is so definitely established that we know definitely, and as stated by your own witnesses in this case, Mr. Freeman among others,—

Q. But, Mr. Shenehon, the crest at Suspension Bridge, was not due to any crest at Buffalo that same day, was it?

A. It contains what is known as the error of observation. That is the same error that makes another observations 7 hours, another one 6.

Let us give you an illustration in this case, where a similar rejection was made by Mr. Stearns in his physical analysis,

in which he finds the years 1895—6 abnormal, because there was less water in those years.

Mr. Hopkins: I think if you read the question again, the matter you have in mind is not involved in it. He assumes those things as absolute, not as observations.

Mr. Adcock: There is a zero here—

Mr. Hopkins: They are not taken as observations but as absolute facts.

Mr. Adcock: No.

The Witness: These are observations that must be understood to be subject to the error of observations. I have I think explained that as fully as I can.

Mr. Adcock: All right, we will go ahead. I think we understand your position. (Q.) Now, what time in your opinion does it take a crest or change of elevation at Suspension Bridge to appear at the Whirlpool?

A. Well, a very few minutes later, according to the observations.

Q. How many minutes?

A. The indications here are for 3 hours and 6 minutes, Suspension Bridge; 3 hours and 9 minutes at the Whirlpool.

Q. That would be about three minutes afterwards, wouldn't it?

A. Yes, that is for the marked high. For the marked low it is 3.18 at Suspension Bridge and 3.26 at the Whirlpool. That is a difference of eight minutes. Eight and three are eleven; about six minutes appears to be the time.

Q. Now, Mr. Shenehon, will you examine sheets number 1, 2, 3, 4 and 5, of the papers which you produced this morning entitled: "United States vs. Sanitary District of Chicago, determination of lag between Buffalo and Whirlpool gages, time required for change in Lake Erie to reach Whirlpool. Only days of well marked changes used in determination." Now will you refer Mr. Shenehon to the first sheet, the October 1st, 1907, data. You find in the column marked lag, hours, with reference to well marked high water at Buffalo, Whirlpool, you find that the lag between Buffalo and Suspension Bridge is two hours, do you not?

A. Yes.

Q. The first observation sheet 1?

A. Yes, for Suspension Bridge, the lag for the first observation—

Q. Is two hours?

A. Is two hours.

Q. And for the Whirlpool is what?

A. Three.

Q. Three hours for the same days and the same lag is it not?

A. Yes. You will note on this these are even hours, and with the exception of the fact that the half is sometimes put in, it is difficult to determine where the particular peak was. The peak is not always sharply defined, you understand.

Q. We will go along. Do you think it physically possible that the lag should have been an hour between the Suspension Bridge and Whirlpool?

A. That is not so indicated there. The error of observation enters there, individual observations.

Q. What is this error of observations?

A. Where you are taking the nearest hour on these observations, and simply getting your data from a sheet in which the hourly ordinates are scaled, it does not follow at all that—the individual minutes not appearing—the difference should be in smaller units than hours.

Q. Take the one on the 2nd of October, there was a difference there of an hour, wasn't there, as shown there for October 1st?

A. Yes.

Q. Between Whirlpool and Suspension Bridge?

A. Whirlpool shows 1 hour later.

Q. For October 2nd, it is two hours to the Suspension Bridge and two hours to the Whirlpool, is it not?

A. Yes.

Q. That is another error of observation, isn't it?

A. Yes.

Q. And on the 3rd, it was two hours and a half to the Suspension Bridge and two hours to the Whirlpool wasn't it?

A. Yes.

Q. That was the travel of the crest?

A. You are—

Q. In other words the crest got to the Whirlpool a half an hour before it got to the Suspension Bridge, didn't it?

A. After you take care of the error of observation, the absolute fact is not inconsistent. The error of observation is sufficient to take care of this burden, because we are taking these out from hourly scalings.

Q. Let us take the next, October 5: The lag to Suspension Bridge was three hours, wasn't it, and to the Whirlpool was half an hour later, three hours and a half?

A. Yes.

Q. And on the 6th, it was two hours to the Suspension Bridge and three hours to the Whirlpool?

A. Yes.

Q. Making a difference of an hour?

A. Yes.

Q. The 7th, it was one hour to the Suspension Bridge and two hours to the Whirlpool, wasn't it?

A. Yes.

Q. An hour later at the Whirlpool, which you say takes about three minutes?

A. No.

Q. Six minutes?

A. Takes about six minutes.

Q. On the 8th, the lag to the Suspension Bridge was 5 hours and a half, wasn't it?

A. Yes, that is the observation.

Q. And 4 hours to the Whirlpool?

A. Yes.

Q. An hour and a half difference?

A. Yes.

Q. In other words it got to the Whirlpool an hour and a half before it got to the Suspension Bridge.

A. I think you are ignoring the fact that you have not a sharp, stacatto point in which you pick out a particular clear cut thing, and the error of observation I have mentioned already must be borne in mind by you.

Q. It would be hardly reasonable to expect that the crest would travel to the Whirlpool an hour and a half quicker than it would travel to the Suspension Bridge?

A. No, that fact is not indicated by the observation.

Q. It is not indicated?

A. Not when you take into account the error of observation, the fact that you are dealing with a quantity where you must pick out by judgment what is the crest of a rounded point, where several hours may be nearly the same.

Q. Then you do not mean error of observation entirely?

A. Yes.

Q. Don't you mean error of judgment?

A. That is a part of the error of observation always.

Q. So that you refer also to the error of reading the gage, do you?

A. No.

Q. And the error of judgment of the man who is picking out these various crests and valleys and so forth, is that it?

A. That does enter in this. As I have stated already, the crest at a particular time may not be represented by a sharp clearcut point.

Q. Wouldn't you think a man had committed a very serious blunder if he had assumed that the change in elevation at Buffalo would be shown at the Whirlpool an hour and a half quicker than it would be at the Suspension Bridge?

A. I should say he was honest, using very honest methods in his determination, setting these things down as they appear, and that there is no accumulating error in the thing; it is eliminated by the two hundred and odd observations we have in getting the lag.

Q. In other words you go out and you get anything, and because you get a great number, you think that any error would be eliminated?

A. No, I take exception to you going out and getting anything that is not within well defined limits.

Q. Take for instance the 10th, the lag for Suspension Bridge was four hours and for Whirlpool was four hours, wasn't it?

A. Yes. When I say the lag, what is set down here as the even hour, representing the nearest hour; ordinarily the half hour is used where it seemed to be an even thing between the two hours.

Q. Should they have used any half hours at all?

A. The half hour is the least unit used in here, in any place.

Q. Then the time error could not be more than 30 minutes in any instance?

A. That does not follow.

Q. Take the 11th, you have the lag to the Suspension Bridge 2½ hours and to the Whirlpool 3 hours?

A. The 11th?

Q. Yes?

A. Two hours and a half to Suspension Bridge and Three hours to the Whirlpool.

Q. On the same day at the 19th hour, you have one hour at Suspension Bridge and two hours and the Whirlpool, do you not?

A. Yes.

Q. Might not the peak which is indicated at Buffalo at 13 o'clock, correspond to the peak at the Whirlpool at 21 o'clock? That is seven hours.

A. I think a reference to the Three Curve Series would be illuminating on that point.

Q. We will endeavor to illuminate the Three Curve Series at the proper time, Mr. Shenehon.

A. All right.

Q. Take the 12th, you have the lag to the Suspension Bridge two hours, and the Whirlpool three hours, haven't you?

A. Yes.

Q. And on the 13th you have the lag at the Suspension Bridge three hours, and it appeared at the Whirlpool two hours later, five hours is that right?

A. Those are the figures indicated.

Q. And on the 14th, you have another instance where it is two hours, don't you, at the Suspension Bridge, and three hours at the Whirlpool?

A. Yes.

Q. And on the 15th, it appeared an hour earlier at the Whirlpool, which is three hours lag than it did at the Suspension Bridge which was two hours, is that right?

A. That is the indication by the observations.

Q. Take the 21st, it was two hours at both places, wasn't it?

A. Yes.

Q. And on the 26th it appeared at the Whirlpool in four hours, or one hour earlier than it did at the Suspension Bridge, which was five hours, is that right?

A. Suspension Bridge indicated five and Whirlpool four.

Q. And on the 30th, it appeared at the Whirlpool an hour earlier than it did at the Suspension Bridge, four hours at the Whirlpool and five hours at the Suspension Bridge, is that right?

A. Five hours Suspension Bridge, four hours Whirlpool is indicated on this sheet.

Q. And on the 31st it appeared two hours earlier at the Whirlpool than it did at the Suspension Bridge?

A. That is the indication.

Q. Three hours at the Whirlpool and five hours at the Suspension Bridge, is that right?

A. That is the indication

Q. On the 15th, the falling stage, it was five hours to the Suspension Bridge and four hours to the Whirlpool, wasn't it?

A. Yes, that is the indication on the sheet.

Q. On the 11th, Mr. Shenehon, it took an hour to get to the Whirlpool, and it got to the Suspension Bridge in no time, instantaneous change, is that right?

A. No, you do not mean it got there, you mean the error—
Q. The indication shows that.
A. The time it got there less the error of observation is zero, as indicated by the sheet?
Q. The observations show similar conditions all the way through, do they not, as to what I have stated here?
A. You mean that individual observations will show discrepancies?
Q. Discrepancies of the character which I have mentioned?
A. Yes, you would expect them to, the nature of the observations is such.
Q. Several hundred, or two hundred per cent. sometimes, is that right?
A. I think to express it in percentages is distorting the truth.
Q. You like to express some things in percentages, don't you, for instance ½ of 1 per cent. being the error of discharge and so forth?
A. In this case, you take a short base with a relatively large error of observations, it sounds very large when you state it in percentage.

Adjourned to Saturday, May 16th, 1914, 9:30 A. M.

Saturday, May 16, 1914, 9:30 A. M.

FRANCIS C. SHENEHON resumed the stand and testified further on cross-examination as follows:

Mr. Adcock: Q. Suppose that in the case of the St. Clair River referred to on Tuesday the discharges for two elevations were 203,382 cubic feet per second and 187,082 cubic feet per second respectively, and suppose that the lower discharge was too small, and in error one per cent. and the upper discharge was also too small and in error .902 of 1 per cent., what would be the difference of their corrected discharges?
A. The differences in those two cases are substantially the same, the difference of the former quantities given being 16,300 cubic feet; subtracting the error from each of these quantities, the resulting difference as I make it is 16,340.
Q. Cubic feet per second?
A. Cubic second feet.
Q. What is the difference of the original discharges, the same, wasn't it?

A. 16,300; I gave that.

Q. Then on Wednesday, Mr. Shenehon, when you said the range of error of the difference of these discharges was from 1 to 25 per cent., you were in error weren't you?

A. The range would be from plus an error 25 per cent. to minus 25, and may be anywhere within those limits, and therefore passes through zero.

Q. It would be a more correct statement to say it would be from zero to 25 per cent.?

A. Well, between plus 25 and minus 25 of course includes that. Your statement here, however, does not quite cover that case because you have not taken 1 per cent. error in each of the quantities. You have .9 of 1 per cent. in one case and 1 per cent. in the other.

If you make each one 1 per cent., which was the proposition as I understood it when discussing it before, this would show an error of 1 per cent. in the increment, assuming that the 16,300 is an increment.

Q. Would the error be from 1 to 25 per cent., or from zero to 25 per cent.?

A. Well, under the assumption here, assuming 1 per cent. error and on the same side, it would be 1 per cent. of error. If you were assuming it to be plus, it would be 1 per cent. in error on the upper side, on the large side. If you assumed it to be minus, it would be 1 per cent. in error on the lower side. But in the range of possibility, we have all the way from the extreme plus quantity to the extreme minus. Of course in passing between there, it would pass through the value zero. I think that is the point you have in mind.

Q. Yes? If the change of elevation was .57 feet, what would be the percentage of error of the increment, zero to 25 per cent.?

A. Please read that question.

Q. (Question read.)

A. Yes. Having gotten a percentage of error in the increment from a difference in this way, dividing by that it is independent of the range after you once reach that conclusion, as I explained in my testimony the other day.

The littleness of the difference between two quantities, where the range is small, is large in proportion to the error of the volume of flow concerned; and that is the thing that makes the error in the increment dependent on the range, as it is.

Q. Referring to the report of the Chief of Engineers for 1912, Table Number 1, page 3546, do you accept the figures

there given as correctly representing the discharge of the St. Clair River?

A. I have never checked those figures.

Q. What is that?

A. I have never checked these figures; I so stated in my testimony, that my conclusions in regard to the St. Clair River are dependent on the testimony of the men of the Lake Survey in whom I have confidence, and does not depend on an individual or detailed examination of the later conclusions, or an analysis of the later observations.

Q. Then we are to understand, I assume, that the testimony you have given with reference to the discharge of the St. Clair River is based entirely on the testimony of the men of the Lake Survey who have testified in this case?

A. Yes. Originally it is based on confidence in Mr. L. C. Sabin, and upon knowledge of his good judgment and careful observing. The later conclusions are based on the observations of Mr. Richmond and Mr. Moore, and of the conclusions and computations made by them, as well as Mr. Ray, principal assistant engineer of the United States Lake Survey. And my testimony in this respect simply reflects my confidence in these men.

Q. The fact that you have testified, then, with reference to the discharge of the St. Clair River, is to be taken rather as a commendation of their work by you, is it not?

A. Yes, of their work as observers, and their careful studies and reductions, and so far as the later increment of the St. Lawrence is concerned, the same reservations were put in my testimony.

Q. Of course the St. Lawrence was a little bit different. There you had made measurements yourself on that river?

A. Yes. I am speaking of the later measurements and the later conclusions on the St. Lawrence with the new condition of the river after the building of the Gut Dam.

Q. I understand you have not measured the St. Clair River?

A. Oh, yes, I was in charge of the original measurements.

Q. I said the St. Clair?

A. You say I personally?

Q. Yes?

A. The work at the Gorge Section was initiated while I was Principal Assistant Engineer.

Q. But you did not have personal charge of the work?

A. I was in general supervision of the office, and directed the choice of a section there. I did not very largely super-

vise either the observations in the field or the reductions. I did not visit the work.

Q. Those were the measurements in what year?

A. 1908.

Q. I think you have explained why you were willing to take some of the conclusions which were reached by Mr. Moore and Mr. Richmond with reference to the St. Lawrence, in your previous testimony didn't you, on cross-examination?

A. Yes.

Q. These measurements showed a different increment than your earlier measurements did?

A. Yes, a change having taken place, you understand, in the regimen of the St. Lawrence river between those times; that is the building of the Gut Dam, introducing a new condition.

Q. I think you have stated the effect of the Gut Dam upon the increment to be 5¼ per cent., is that right?

A. Yes, that was my estimate of the change.

Q. Does the difference between consecutive numbers on horizontal lines represent the back water effect of Lake St. Clair for the .1 foot changes in its elevation?

A. I so understand it, yes.

Q. At the International Bridge Section, what meter was used to traverse the vertical?

A. Meter L. S. 2 B.

Q. What is that?

A. L. S. 2 B, for the observations of the United States Lake Survey.

Q. The L. S. is a new term used here?

A. That is Lake Survey 2 B.

Q. That was not the Haskell meter?

A. Yes, the particular meter—

Q. I didn't know but what we had a new name for it now?

A. No, I think you will find in the tabulations—

Q. That is the number of the meter?

A. I refer to the summary of discharges table number 1, of F. C. Shenehon, Assistant Engineers, 1906. The rating number was meter L. S. 2 B, meter L. S. 4 A.

Q. What does the 2 mean?

A. That is the type of the meter.

Q. Is that the type or the number? B is the type and 2 is the number of the meter in your equipment, isn't it?

A. Yes, B is the type and 2 is simply the one in our equipment.

Q. That is you give it a number in your office, don't you?

A. Yes, these numbers as I recollect it were stamped on the meters when received. That is with a metallic stamp on the lead as I recollect of the meter.

Q. How close together were the two meters run in the Niagara River work, when the traversing meter was checking with the index meter?

A. Three to four feet.

Q. What is your opinion as to the relative accuracy with which the flow of large and small streams can be measured, say streams of 200,000 cubic feet per second, and streams of two to ten per cent. as much?

A. I should say the percentage precision of the larger stream is somewhat greater, although you have reached a point now where there is not a large difference. A canal flowing 10,000 cubic second feet, as I stated, should be within 2 per cent. if very carefully gaged, and a stream of 20,000 might have a little better precision than that.

Q. Don't you claim a great deal better precision in your measurements of the Niagara River, about ½ of 1 per cent. of the discharge, something like that?

A. Within 1 per cent. is my conclusion as to the precision.

Q. I was under the impression some of the other witnesses connected with the Lake Survey gave it as half of one per cent., didn't they?

A. Yes 1 per cent. is my figure.

Q. But they had a figure of ½ of 1 per cent., about?

A. Yes.

Q. Then you don't agree with their figure?

A. Within the limits stated by you, that appears to be the fact.

Q. Just why do you differ?

A. I per cent. is my judgment of the precision of the work.

Q. I wondered if you had any reason, or was it just a kind of feeling you had. You know you engineers have feelings with reference to certain things?

A. Oh, it is better than that. I think possibly it was originally derived from the agreement between the Open Section and the Bridge Section on the Niagara River. And this is further strengthened by the agreement of the Third or Split Section; and it is further strengthened by the agreement of sections on the St. Clair.

Q. I am trying to get an understanding why you think those measurements are so accurate?

A. You understand, the man who feels that the precision, or has reached the conclusion that the precision is ½ of 1 per cent. may be right and I may be in error. I am simply giving my judgment in the matter.

Q. Well, what I was trying to get at is why you differ from Mr. Richmond and Mr. Moore. You are more or less responsible for the conquering of the Niagara, and I wondered just why these men who were under you felt that the work was better than you felt it was?

A. I can't help you in your explanation.

Q. These discrepancies and so forth are somewhat confusing, and I would like to get your opinion as to why you say 1 per cent. and they say ½ of 1 per cent.?

A. I think possibly the term "error" is stated in different ways. Mr. Hayford, for instance, gave ½ of 1 per cent., as I recollect, as the probable error of the volume of flow.

Q. What did he state?

A. My recollection is ½ of 1 per cent. I can confirm that (referring to memoranda) yes, the probable error as derived by Mr. Hayford for the volume of flow is ½ of 1 per cent. And he concluded that it is practically certain that the error cannot exceed 2½ per cent., but what is stated there, is I suppose, the reason why we differ; not a statement of this particular thing. The one per cent. that I speak of is not the mathematical probable error. It is a judgment—

Q. You had formed your conclusion as to the probable error there before Mr. Hayford had solved this mathematical problem, hadn't you?

A. Yes, my statement was in the earlier testimony in 1909.

Q. And his conclusions there were simply the results of mathematical computations, weren't they?

A. In part. He investigated pretty fully the methods and processes used, the checks, the rating of current meters, the various conditions, by looking into the literature on the subject, so while the ½ per cent. is a probable error, that is a mathematical quantity. The maximum error stated contains his judgment, as well, as I understand it, based on examination of all the elements entering into the case.

Q. Then this 1 per cent. of error which you say there may be in the increments, the volume of discharge determined, is the result of your judgment, is it?

A. Yes, that is true. You understand—

Q. You could not give any particular reason for it?

A. You understand with figures before me—for instance

a long line of plotted observations indicating for the most part a precision within 1 per cent., or two per cent. in the individual observations, the accord of the observations among themselves, the knowledge I have of the care with which all processes were scrutinized and carried out, and the check of independent sections, these things of course have all come in to help me reach a conclusion as to what I regard as the precision of 1 per cent. When I say that, you understand the Split Section had not been gaged at the time I made my original statement in 1909.

Q. You haven't changed it now, have you?

A. No. I should not wish to say that we reached a precision higher than 1 per cent., that is in my judgment. The probable error shows a little higher than that, but my judgment is there ought to be a leeway there of ½ of 1 per cent.

Q. These people who surely do not know as much about the gaging of the Niagara as you do have reached apparently reached the conclusion that the work was closer than you have yourself?

A. Mr. Hayford, with my explanation here—

Q. I am speaking of Mr. Ray and Mr. Moore.

Mr. Hopkins: Objected to.

Q. Mr. Richmond?

A. I should wish to refer to their testimony. I do not understand that they—

Q. Then you don't know whether they stated the precision was within ½ of 1 per cent.?

A. I am of the opinion that Mr. Ray didn't make that statement. I should wish to refer to the testimony.

Q. Perhaps Mr. Moore or Mr. Richmond did?

A. I should wish to refer to their testimony.

Q. Would you be surprised if you should find in the testimony that they had stated that it was within ½ of 1 per cent.?

A. I should be surprised if I found Mr. Ray had made that statement.

Q. You think he is more conservative than Mr. Richmond or Mr. Moore or both of them, do you? Is that the reason that you would be surprised?

A. I should wish to read the testimony before answering that question to refresh my memory as to the exact way in which they made their statement.

Q. I know, but you say you would be surprised if Mr. Ray made the statement, implying you would not be surprised if Mr. Moore or Mr. Richmond stated it?

A. I had in mind that Mr. Ray stated two per cent. I may be in error about that.

Q. I am asking you why you would be surprised?

A. A matter of memory.

Q. Entirely?

A. Yes.

Q. Not because of your judgment of the men?

A. No, I should not in these matters prefer Mr. Ray's judgment to my own.

Q. But between Mr. Moore, Mr. Richmond and Mr. Ray?

Mr. Hopkins: I object to the question. He cannot know what other people know. It is entirely unfair; it is incompetent for one man to tell in this sort of a situation what the ability and competency of another man is.

Mr. Adcock: Q. I am asking you why you would be surprised; why you state you would be surprised if you should find that Mr. Ray stated that?

Mr. Hopkins: Objected to further,—

Mr. Adcock: Q. Had made the statement that it was 1 per cent.?

Mr. Hopkins: Objected to.

Mr. Adcock: The error was 1 per cent.

A. May I refer to the testimony.

Q. Implying you would not be surprised if Mr. Moore or Mr. Richmond had made the statement.

Mr. Hopkins: I object further to the question as having been answered.

A. It is dependent on my recollection of the testimony.

Q. Only?

A. Yes. I think we ought to spread out this testimony in front of us, so that a witness may refer to matters coming up. The testimony is so voluminous that I do not carry in mind every figure that has been stated by a witness.

Q. Mr. Ray did say 2 per cent., Mr. Shenehon, page 2276?

A. Referring to the testimony of Mr. Ray on page 2276 of the testimony in manuscript (printed record, page 2791) I find that he makes the following statement:

"From my knowledge, I judge the hydraulic work on these three rivers to be probably the most accurate measurements in large streams that have ever been done. The precision of measurement considering the weight mean observations I believe to be within 2 per cent. of the exact result." He is there, of course, speaking of all three rivers.

Q. On page 2331, Mr. Moore stated: "For the Niagara, probably within ¼ of 1 per cent."

A. You are referring to the Canal of the Niagara Falls Power Company.

Q. No, the Niagara River?

A. Mr. Moore's statement there is what is known as the probable error for the Niagara River, ½ of 1 per cent., agreeing with Mr. Hayford on that.

Q. Then you do not agree with either Mr. Ray or Mr. Moore on that?

A. The mathematical probable error is in the vicinity of ½ of 1 per cent. I allow myself a leeway of half of a per cent. for the possible constant errors that may enter, that are not eliminated in discussing the probable error.

Q. He says: "For the Niagara discharge probably within ½ of 1 per cent.?"

A. Yes. My statement of 1 per cent. has a little more to do with a nearer certainty rather than the probable error.

Q. You differ with both of them then?

A. No, the probable error is about ½ of 1 per cent.

Q. Mr. Ray stated it was within 2 per cent.?

A. He does not give that as the probable error. You are confusing the mathematical term "probable error" with the errors of a man's judgment, and that appears to be Mr. Ray's.

Q. You think Mr. Moore did not give his judgment then, just simply the mathematical probable error?

A. Yes, that appears that way. It is an even thing whether it is better than ½ of 1 per cent., or not quite as good. That is what probable error means.

Q. You spoke of the relative accuracy with which certain streams of different sizes could be measured, and you stated that a stream of 5,000 cubic feet per second could not be measured as accurately as one of 2,000 cubic feet per second?

A. That is other things being equal.

Q. Yes, I think that would be a general statement. How about one 2 per cent. of the larger stream, say 4,000 cubic feet per second?

A. In the vicinity of 2 per cent.

Q. Error?

A. Yes.

Q. Your judgment is that the error would be twice as great in the smaller stream than in the large stream that was mentioned?

A. Yes, it might be. That is, that was a conclusion I reached at the time we gaged the power canals at Niagara Falls; we might have an error as big as 2 per cent.

Q. Upon what grounds do you base your conclusion in that regard?

A. Of course there are quite a number of elements, but a large stream is the summation of a series of small streams. The 2 per cent. I speak of might be the error, it might be plus or it might be minus. When you sum up a number of small streams, as, for instance, you take the International Bridge as an illustration, there we have divided up the whole river into nine spans, if you wish to consider them that way, or 21 stations. Each of these stations, each of these small streams may have an error of 2 or 3 per cent., but the aggregate percentage of precision is much better than the precision of the individual small streams or stations. That is a principle coming in. That is one of the elements. The other one is of course in a deep stream like the Open Section of the Niagara River or the Bridge Section of the Niagara or the Third Section, or the Three Point Section of the St. Lawrence, or the two sections on the St. Clair you can determine very definitely the trend of your vertical curve where you could not do that with the same instruments in a shallow stream.

Then there is the relation also between the wetted perimeter and the cross sectional area, that needs some consideration.

Q. Does this apply, in your judgment, to a comparison of your gagings of the Niagara and the gagings of the Chicago River or the Drainage Canal?

A. Yes, I think the Chicago River was gaged, I believe I said within 2 per cent., or maybe that is the canal at Lemont, is what I have in mind.

Q. You stated that one reason why a small stream could not be measured as accurately as a large stream was because of the greater percentage of unexplored regions, did you not?

A. No, that is not quite a—I didn't use quite those words. I guess it amounts to about the same thing.

Q. Practically the same thing?

A. That is there are certain portions of the cross sectional area where your transverse curve or your vertical curve is changing very rapidly, that you cannot explore with your larger instruments in your smaller canal. I refer to the case of the canal at Cornell.

Q. How about the Drainage Canal or the Chicago River, a stream of 4 or 5 or 6,000 cubic feet per second?

A. The conditions there with the greater depth and the smooth sides represent fairly good conditions for gaging.

Q. Do you think they are as good as at the Bridge Section of the Niagara?

A. As I understand the conditions there in the section at Lemont, without having visited it, I should say the condition is better. Regarded as a single stream, it is better than the side streams, at least, in the Niagara River at the Bridge Section.

Q. Considering the whole Niagara River?

A. Oh, no; I adhere to and believe absolutely that a statement of 1 per cent. for the Niagara River is my judgment as to the precision obtained.

Q. And 2 per cent. for the canal?

A. Yes, that is a rough judgment, that 2 per cent.?

Q. Then that is based upon a greater portion of the regions near the walls of the canal and along the bottom that you mentioned?

A. Yes, you ought to get your transverse curve and your vertical curve very accurately in the Drainage Canal.

Q. You do not think you could measure the flow of the Drainage Canal as accurately as you could the Niagara River?

A. If we had the whole outflow of the Great Lakes such as we have at Buffalo through twenty drainage canals of the same dimensions and smoothness, we could probably measure with an equal precision.

Q. Considering simply the one by itself?

A. I have made my statement that 2 per cent. is about my judgment of the precision which we may secure.

Q. You stated that the section at Lemont on the Drainage Canal was better than the Bridge Section of the Niagara River, did you not?

A. It is better than some stations. That was my statement.

Q. But that on the other sections, the Open Section and the Split Section, you thought they were better than the Drainage Canal, didn't you?

A. Are you referring to individual stations?

Q. No?

A. Or to the aggregate?

Q. The aggregate?

A. You understand the aggregate, the sum total of volume of flow in the Bridge Section I believe to be better than the measurement on a single Drainage Canal at Lemont. That is clear, isn't it?

Q. But take the Bridge Section as a whole, how does it compare with the Section on the Drainage Canal?

A. Well, we have a number of stations, 21 in all. Each one has an error probably bigger than the two per cent. mentioned. When I say "all" not all of them, the mid-stream sections in spans 4, 5 and 6, probably have a better precision than the Drainage Canal, better than 2 per cent. individually.

Q. In view of the fact that the Split Section and the Open Section agree so well, as you say, with the Bridge Section, does that change your opinion any as to your comparisons with the three sections?

A. Oh no, no indeed.

Q. Take the Bridge Section altogether, it is a better section than the section at Lemont on the Drainage Canal, and the error of the Bridge Section would be half as much as that of the Drainage Canal?

A. Let me state that a little differently. If you should measure the volume of flow in the Drainage Canal in twenty different sections, or in a number of sections, you will get a precision higher than 2 per cent. on the Drainage Canal. So it is the aggregation of the number of measurements, the number of sections, where one may be a little large and the other may be a little small, and in the end the sum total has a precision higher than any one of them on the average section. That is the principle that enters in this matter, and is one of the reasons why we do get this high precision in the river measurements.

Q. The larger the river the greater the precision?

A. Yes. Just think of a mid stream section at the bridge, for instance, say the middle of span 4. Here is a considerable volume of water with a water perimeter on either side, if I may so speak of the 80 foot section, and simply the friction of the bottom, it has not the friction on the sides the same as your canal, so there is a condition that is very excellent and that is the condition we have in open river sections, a series of smaller streams flowing side by side. The error in one may be that it is a little too big and the error in the other a little small, and in the end the aggregate, balancing error against error, gives us a high precision such as we have shown in our triple gaging on the Niagara River and our triple gaging of the St. Clair River.

Q. That is because of the greater proportion of unexplored regions in the one, isn't it, than the other?

A. The unexplored region needs to be thought of as that region where you have sharp changes, as towards the bottom

or towards the side of the canal; or towards the bridge piers, in the case of the International Bridge.

Q. Which do you consider the more accurate, the Bridge or Open Section gaging of the Niagara?

A. The conditions at the Open Section are a little better than those at the Bridge Section, in my judgment.

Q. Which is the more accurate gaging?

A. A conclusion ought to be a little more accurate for the Open Section than for the Bridge Section; and yet the precision indicated by me has to do with the conclusion reached by the two, you understand. These two sections checked within 1.3 per cent.

Q. Take the Bridge Section alone, what percentage of error is there there?

A. You understand it is difficult to assign with the great exactitude which you would like to have me, the percentage of error.

Q. No, I do not agree with you on that. I am just trying to find out what you believe to be the percentage of error of the Bridge Section gagings, alone.

A. You understand my judgment of the precision depends to some extent on the agreement of sections; the agreement of the several gagings in the same river.

Q. Then if you did not have a section to compare with the Bridge Section, you would not know just what percentage of error to ascribe to that?

A. The analysis of the elements entering indicates that the precision must be very high.

Q. Then without considering the Open Section gagings at all, what do you say?

A. Of course it is difficult for me to answer that question, because I have in mind the various duplicate sections and triplicate sections that have been measured, and that has doubtless influenced my judgment in this matter.

Q. How close to the bottom were the velocities examined at the Bridge Section?

A. My recollection is about 18 inches.

Q. How close to the piers at the sides?

A. Within one to two feet.

Q. What proportion does the unexplored area at the Bridge Section adjacent to the bottom and the piers bear to the total area?

A. I would have to make a computation to determine that; and I would like to know what you mean by unexplored. You mean below that foot and a half, 18 inches at the bottom?

Q. Yes?
A. And within say the two feet?
Q. Yes? Did you get always right up to within two feet of the piers at the sides?
A. That is my recollection. The figures however will show that in detail.
Q. As a matter of fact, weren't you between two and six feet?
A. Well, I would have to follow that—
Q. Never less than two and sometimes as high as six?
A. It would depend on circumstances I think, in the particular case.
Q. I am asking you simply for the purpose of refreshing your recollection?
A. Yes.
Q. And directing your attention to that particular thing?
A. Yes. I may have figures by which that can be determined. I will be very glad to refer to them. You understand it is 15 years ago since these gagings were made, and my recollection may be a little dim on certain points.
Q. Of course it is not very long ago since you expressed an opinion as to the accuracy of the measurements there, and I assumed that perhaps you had all those things in mind?
A. No, that opinion was expressed in 1909.
Q. You still have an opinion with reference to it, stated I believe recently?
A. Yes, my recollection is that we in detail and in generalization throughout scrutinized the work and secured the results of the highest precision.
Q. Your opinion now then is based upon your remembrance of the conclusions that you reached then?
A. I have read some documents recently, the letter which I wrote to Mr. Haskell, and some other things that—
Q. I am referring Mr. Shenehon to your own individual ideas of the work that was done there. As I understand you did make most of those gagings?
A. Yes, I was in charge.
Q. Made most of the gagings?
A. Directed the gagings and made many analyses of the various points where error might enter.
Q. And your conclusion now is based upon your remembrance of the conclusion you gave in 1909, with reference to the percentage of error?
A. In part. Of course I have had this much under con-

sideration since. This case has rather brought up a great many things but in such matters as you refer to, whether I got two feet from the pier or four feet or six feet, that is a matter I need to refresh my memory on.

Q. When you gave your opinion recently as to the 1 per cent. of error there, you did not have in mind how close you were to the piers on the sides, you didn't have that in mind distinctly?

A. No, because it would not make any difference in the conclusion. I did have in mind however the corroboration of the various sections as indicated in my testimony, that have been made since then.

Q. You might make that computation with reference to what proportion of the unexplored area at the Bridge Section adjacent to the bottom and the piers, what proportion that bears to the total area?

A. Taking a value of two feet from the Bridge pier, and a foot and a half from the bottom, I get 2800 square feet. And at elevation 568, this corresponds to a little less than seven per cent., we will call it seven per cent. of the cross sectional area.

Q. How does this compare with the Chicago River, say at Loomis Street, where the width is 200 feet and the sides are practically vertical for 12 feet below the water line, when the bottom gradually slopes to a depth of 26 feet in 60 and 70 feet of width, and is practically level for 70 feet in the mid-channel, the area being about 4300 square feet?

A. I make the indeterminate area, as I believe we have before referred to this in the Chicago Drainage Canal—

Q. I am referring to a particular section.

A. In this particular section handed me, I make the indeterminate area 353 square feet in a cross sectional area of 4300, which is 8.2 per cent.

Q. Would an accurate, a closer computation of the Niagara, bring that percentage up to about 7½ per cent.?

A. The computation made by me is a little crude. There was some scaling in the computation, and I made it 6.8 and called it 7 per cent., because Mr. Williams' assistant makes it 7.4. I think 7 per cent. is a fair statement of the case. It does not make much difference, however.

Q. Then there is no special credence to be given to the Bridge Section measurements in comparison with, say a section on the Chicago River such as has been described, on account of the size of the section?

A. If we had twenty, the volume of flow of the Great Lakes flowing in twenty of these channels we would have the precision a little bit higher than the Bridge Section.

Q. But the percentage of unexplored area was equal?

A. Yes.

Q. In the Bridge Section and in the section of the Chicago River which has just been described, there is very little difference?

A. Yes, I should say in this unexplored area, as we have called the indeterminate area, about three per cent. of the flow of the river passes.

Q. What was the difference between the section as adopted by you and that used by the Board of Engineers on Deep Waterways?

A. Cross sectional area?

Q. Yes?

A. My recollection is that the Board of Engineers made it about three per cent. greater.

Q. That would give a greater volume of water then, wouldn't it, passing?

A. Yes, that would indicate a greater volume of water.

Q. How far would the position of the meter used in traversing the vertical be down-stream from the plane of the edge of the guard rail of the Bridge.

A. An endeavor was made to bring it practically under the guard rail, or a little bit below.

Q. How was it prevented from drifting?

A. A tackle was arranged in which an 80 pound weight was suspended with a pulley, over which the cable of the meter passed, or a snatch block, I guess is a more accurate term. Then the cable was pulled up-stream from the upper side of the bridge, from the upper chord of the bridge—not the chord, the outside member.

Q. Could you make a sketch on a piece of paper there which would show how you maintained the meter on the section?

A. Do you wish to put this in evidence?

Q. I do not know whether we will or not? Just a rough sketch.

A. (Witness makes sketch as directed.)

Q. How far up-stream was the cable drawn at the point of entering the water?

A. My recollection is 10 or 12 feet. That is for the extreme condition in span 3, the deep span.

Q. That is where it was deep and the water was swift?

A. Yes, that was computed for each position.

Q. You suspended your meter at the lower side of the bridge didn't you?

A. Yes, the North side which is the down-stream side.

Q. Down-stream side?

A. Of the bridge, yes, so the bridge itself forms a platform which may be utilized and was utilized.

Q. At a depth of 10 feet below the surface, how far down-stream from the guard rail would the meter be?

A. Substantially under the guard rail, perhaps a few feet down-stream, two or three feet.

Q. How many feet?

A. I can't give a statement of this.

Q. Approximately?

A. I do not care to approximate that. If you wish to give me half a day to make computations on that, I presume I could give you some statement that would be—

Q. Then you haven't any recollection at all as to that?

A. My recollection is that we placed the meter definitely through the vertical plane.

Q. And at 15 feet depth the same thing?

A. I make the same statement.

Q. 20 feet, 30 feet, 40 feet and 50 feet?

A. I do not wish to make any statements concerning the —you are speaking now, if the meter were free and not pulled up-stream?

Q. No, the position where it actually was during the gaging when you occupied a section.

A. Making a measurement of the discharge?

Q. The vertical?

A. Or taking a vertical curve?

Q. Taking a vertical curve?

A. The vertical curve in the swift water, tackle was used by the United States Lake Survey as I have sketched on this piece of paper.

Q. In making your discharge measurements?

A. The meter at the .3 depth in making the discharge measurement depended on the heavy weight, the 136 pound weight which was used on the meters.

Q. Then in making the discharge measurements you did not use this guy wire?

A. No, not in making the discharge measurements. The sag down-stream was very little for .3 depths. You understand the only sag of any importance was in, say spans 3 and 4. When I say any importance, I am referring now to

the discharge observations. The use of these big heavy weights prevented that possible down-stream sag of the meter, and the use of quarter inch cable, as light cable as we could possibly use under the circumstances.

Q. How much less do you think that sag was than in the case computed by Mr. Stewart when he made his measurements there for the Board of Engineers on Deep Waterways?

A. You mean for vertical curves?

Q. No, for horizontal?

A. You mean for discharge measurements?

Q. Stewart made a computation of the position of the meter on the chart and so on?

A. Mr. Stewart in certain of his observations also pulled the meter up-stream, but did not in all cases, I presume, get it under the Bridge chord.

Q. What different method or apparatus did you use from that used by Mr. Stewart?

A. Mr. Stewart used what are known as the sleeve weights on the cable, and used a heavier cable as I recollect it, in his observations with the 4a meter, and the sag down-stream indicated without any pulling up to offset that was quite a bit, probably twice as great or more.

Q. How much greater?

A. Perhaps I better refer to a chart. I refer to a blue-print which accompanied a certain letter sent by me to Mr. Haskell in 1899, in which I presented the scheme of using the heavy weights and illustrated the desirability of doing this by this plan. The distance downstream below the bridge chord indicated by this plan, when the weight is not pulled up-stream, would be 12½ feet in 50 feet of water, with a surface velocity of 6½ feet. And the same sag down-stream indicated for the 12a meter, with the lighter weight, with the sleeve weights used by Mr. Stewart, was 32 feet.

Q. That is at greater depth or same depth? You mean 32 feet?

A. Yes, this is shown for the same station.

Q. What station was that?

A. It is one of the stations—

Q. Of mid-stream?

A. Of span 3, which is the deepest water we have to contend with.

Q. How deep was the meter?

A. Approximately 50 feet, 49 perhaps.

Q. That is it was 32 feet down-stream from the gaging section, is that right?

A. 32 feet down-stream from the plane of that lower bridge chord, yes.

Q. That is your gaging section, isn't it?

A. Substantially, yes.

Q. You let out a line which you—

A. The section really differs very little. I sounded it in three sections, one below the bridge chord, perhaps 10 feet; another one under the bridge chord and another one substantially under the upper bridge chord, and the acceleration indicated normally, as I recollect it, is not considerable.

Q. Then your former statement that the meter was at all times on the line of the section, at all depths, was not entirely accurate, was it?

A. I think you misunderstand the statement I have made to you. The chart here does not indicate the situation where the 80 pound weight has been hauled up-stream. It indicates the position where it is hanging verticallv. There is a chance to pull it up-stream about 16 feet here.

Q. How do you get different results from my statement?

A. My results in coefficients; when you say that in all other elements—

Q. I mean as to the sag or drift?

A. The main thing is in the use of lighter cable, quarter inch cable which reduced the current pressure, and also the placing of the weight in such a position that it was in the lowest velocities for the meter, and it was also vessel shaped, compact. We did not catch the current pressure as the heavy weights used by Mr. Stewart did.

Q. How much would the cable reduce it?

A. From 80 to 54 pounds, as I recollect it, after reading a letter recently concerning the matter.

Q. How much would the cable reduce the drift?

A. I would not be able to say that.

Q. Your conclusion as to the drift was the result of experiment?

A. Yes, it is the result of the measurement of the pressure of the current at different velocities on the meters concerned with the light cables concerned. And I had in mind also the form of the vertical curve, that is the variation of velocities from top to bottom.

Q. Is it your opinion that a cable ½ inch in diameter would assume a different angle or curve hanging in the water from a similar cable a quarter inch in diameter?

A. You mean the form of the curve?
Q. Yes?
A. Provided the same relations were maintained?
Q. Same velocity of current?
A. In the weight, same section, same velocity of current?
Q. Same point.
A. Same resistance on the weight at the bottom?
Q. Leaving the weight at the bottom out, just the cable, considering it was a flexible cable?
A. I don't know that I entirely get your question. Let us assume that as the cable enters the water surface the angle is ten degrees measured in a straight line between the snatch block and the water surface. That is the maximum of the cable.

If I understand your question, it is if under the circumstances in this particular case here we had two cables and the angle at the surface is indicated say as ten or twelve degrees, and the relation between the weight and the cable is similar, they would be substantially—
Q. Leaving the weight out, leaving no weight except the cable?
A. I can't leave the weight out because the curve is dependent on the weight as well as the other elements. That is we have this condition: With a cable which sustains a weight, and the meter may be a portion of the weight, the trend of the cable under those circumstances would be substantially plumb at the meter and the angle above the water surface is read, and if it were 12 degrees, the two cables would substantially follow the same curvature. So far as length is concerned, it would be almost exact.
Q. Is it your opinion that in these two cases the angle above the water would be the same?
A. That is an observed quantity.
Q. I want to know whether it would be?
A. If you are using sleeve weights, for instance, you have one condition. If you are using a weight down in the slack water towards the bottom, you have another condition. If you will detail definitely all your conditions, I will be very glad to do all I can to answer the question, but I cannot intelligently answer it otherwise.
Q. Will you indicate to us the effect of the different elements introduced by you which created a different condition from that indicated by Mr. Stewart?
A. In the case of the apparatus used by Mr. Stewart, the

sleeve weights are a certain distance above the meter, clamped on the cable. These sleeve weights were 20 pounds each, and were cylinders of cast iron. They covered a length of nearly ten feet of the cable, and the bottom-most sleeve weight, as indicated on this drawing, is about 12 feet above the bottom of the river, so that these cylinders received a considerable current pressure, the velocity being higher there than it is at the bottom; and the form not being a vessel shape enters in. I have already stated that the difference in current pressure on the cable as between the 3/8ths cable, as we call it, and the quarter inch cable, is from 80 to 54 pounds, a considerable betterment due to that.

Q. You mean that was the change of the force?

A. If you put a bigger cable crosswise of the current, the pressure on it of course will be greater.

Q. Is this difference in weight of cable or force of current on the cable?

A. It is force of current on the cable.

Q. How far down-stream from the guard rail is the end of the pier at the water surface?

A. It differs in the different piers. I do not know that I could make any statement concerning that. The pier between spans 2 and 3, of course is the pier on which the draw bridge is located, and is the length of the two spans, or a little longer. The other piers are placed on caissons below the water surface. I should say they extended—

Q. At the water surface?

A. I should say the caisson extends 10 feet below the—

Q. Does the caisson come to the water surface?

A. In some cases it is a little above the water surface.

Q. In which cases?

A. I do not know that I can explain this. Those piers, particularly towards the Canadian shore, the caisson shows a little above the surface as I recollect it. The piers I refer to are those between spans 6 and 7 and 8 and 9. The caisson there comes above the water surface. In other cases I believe it is below, except on the pivot pier. I am not sure about the pier between spans 1 and 2?

Q. How far is the pier, lower edge of the pier, from the guard rail, that is referring to the pier at the water surface in the spans where you say the greatest amount of water was flowing?

A. I should say six to ten feet. There was sufficient clearance on the piers, outside of the truss work for a man to very

comfortably operate the transit. I recollect it that way, in particular. We made observations by transit from the down-stream coping of the bridge piers. And in the case where the caissons came in, it extended a little further down still.

Q. Do you know what the total length of the pier was?

A. No. Of course on the up-stream side, the breakwater runs pretty well up, possibly 12 feet above the bridge chord, or more; I should say more than that.

Q. I refer to a paper dated December 20, 1899, by Clinton B. Stewart, M. W. S. E. page 450, of the Journal of the Western Society of Civil Engineers entitled "Discharge measurement of Niagara River at Buffalo, New York," the following quotation:

"The bridge is a single track railroad bridge having a plank walk about four feet wide on each side of the track. This afforded a favorable opportunity for crossing the river quickly in discharge measurements, and ease in reaching any station for work on vertical or transverse curves. The bridge consists of nine spans, which were numbered from the American shore, and having the following water widths and pier widths.

Span number.	Water width Feet.	Width of Pier
1	151.5	19
2	154.1	35
3	156.2	13
4	234.2	13
5	235.8	13
6	235.3	13
7	186.9	9.5
8	184.3	10
9	138.3	17
	1676.6	129.5

Total width of river equals 1806 feet. The piers have a batter on the sides of about one in twenty-four, so that the width of the intermediate spans may be taken as constant. They have a length of about 35 feet with a cut-water on the up-stream end, the down-stream end being rectangular in form." Do you have any reason to disagree with the statements of Mr. Stewart just read?

A. You mean as to the 35 foot—

Q. Any of those statements?

A. No, I have no reason to disagree.

Q. In a drawing attached to this paper of Mr. Stewart's the width of the bridge outside the guard rail is given as 18.5 feet. Do you question that?

A. No, I presume Mr. Stewart is accurate in his statement. I would like to add a little something to that quotation from Mr. Stewart, on page 451 of his report.

Q. All right.

A. After speaking of the piers, the downstream end being rectangular in form, he goes on again: "Eddies are produced by the piers to some extent, but they do not extend more than about 5 feet from the pier, and in most cases the current remains practically linear and with about the same amount of fluctuations as near the middle of the span. It is thought that little error has been introduced from this sort."

Q. How do you determine whether the water is eddying and so forth at that point?

A. The surface indications, and if it comes from a submerged indication, why it will show a little further downstream, as in the case of the caisson in span 6.

Q. That is pretty clear water through there?

A. You can't see bottom in any great depth; perhaps at certain times eight or ten foot depth.

Q. If the water was muddy, if there were any disturbance, the indications would appear at the surface?

A. The water is very seldom muddy, it is a clear—

Q. If it were muddy?

A. Not always transparent, but the translucent water of Lake Erie.

Q. Did you ever see the railroad bridge over the Missouri River at Omaha, when the river is muddy?

A. No, I don't think so. I do not know.

Q. You never observed the eddying appearance of the Missouri River at this point around the bridge span?

A. No, I am not well acquainted with the Missouri River.

Q. You never observed the eddies around the bridge piers at that point on the Missouri River where there was a great whirlpool, the water was apparently going around and around. did you Mr. Shenehon?

A. No, I have never observed that.

Q. How far would station 4 and two-twelfths be from the pier?

A. About 37 feet.

Q. On page 5343 report of Chief of Engineers for 1900, you said in substance that on the Niagara River, the surface

indication of direction was taken as the direction at all depths, is that correct?

A. Yes, that is true. I may make one reservation that preliminary to establishing the Open Section, a series of floats were sent down the river and the direction of the current plotted.

Q. I call your attention to two photographic copies of records of the United States Lake Survey Office showing the observed direction of the current at various depths at the Bridge Section, and ask you how closely those observations agree with the above assumption? I ask that these be marked Exhibits Shenehon's C and D, cross-examination. I will ask you also to state in that connection what they show as to the disturbance being confined to within five feet of the pier.

(Photographic copies referred to were here marked Shenehon's Exhibits C and D, respectively, Cross Examination.)

A. These observations, I believe, were those made with the four A, or direction current meter, and made under the direction of Mr. Stewart in his investigations, evidently in 1897.

Q. Were those made by Mr. Stewart?

A. Whether these are the angles which the current makes with the bridge, or whether they are deviations from the North or from the magnetic North, I do not know. The indications of the A meter depend upon a magnetic needle and a repeating device in the instrument itself. That is likely to give some deviation from the true direction.

These were made in 1897, and the date shows that they were compiled by Mr. Harry H. Atwell, who was one of my assistants, February 21, 1899.

Q. They show variations in the direction of the current, do they not?

A. The observations show variations, and we can charge a portion of that up to the magnetic needle, I suppose, and a portion to the instrument itself; and some portion to the current.

Q. Did you make similar observations?

A. I made surface observations, and not with the meter.

Q. Not with the direction meter?

A. No. The measurements I made were made by suspending a float weighted down with chains from the upper part of the bridge and reading the angle indicated by the line which held it from floating down-stream.

Now, I would like to read from Mr. Stewart's report con-

cerning this, and I presume he is referring to these very sheets, or the data which these sheets contain. He says:

"Observations for the mean direction of flow of the river (page 463 of the report made by him, already referred to). In order to determine the mean direction of flow of the river, three discharge measurements were selected, in which the direction of the current for each of the meter stations had been observed and where the direction part of the meter had worked very satisfactorily." I interpolate that this indicates that there were times when it did not. (Continuing reading:) "This gave four sets of 21 readings each, and at distances apart of about 80 feet. The maximum range in direction of the current in any one of the sets was about 21 degrees.

The mean of the three sets gave an azimuth of 187 degrees from the magnetic south as the mean direction of the flow of the current. The variation of the mean direction at any point from the mean direction of the whole river would not exceed two or three degrees."

This appears, therefore to be a matter that does not have any large bearing on the volume of flow in this case.

Q. Did he say anything about individual variations?

A. No, the individual variations appear to be much as you would expect magnetic variations of that kind to be.

Q. What do these variations indicate? They indicate a disturbance in the water or eddying, don't they?

A. I think if you will watch a magnetic needle on a bridge, you will note that there are some disturbances that are not due to any current because it may not be immersed in the current.

Q. This gage was not on the bridge, was it?

A. Not at the time of observing in the current, but I am speaking now of an instrument that has some little movement as a current meter does, with the wheel turning and a magnetic needle incased in the same instrument. There are little fluctuations, you understand when it is entirely at the standstill. If you put a magnetic needle on a transit tripod and stand it up on a firm base, it will assume the magnetic north, but you would not expect an individual case—

Q. Does the repeater fluctuate?

A. The repeater?

Q. Yes?

A. The repeater is an instrument that simply goes on stopping for certain intervals until it is stopped by the magnetic needle itself, so the magnetic needle is the thing which determines what the repeater does. By many repetitions of

this form of observation, you doubtless get very good results, and I presume Mr. Stewart's statement of two to three degrees is a fair statement.

Q. Referring to station 4 and 6/12ths, I note that the surface is 190 degrees, and various points down show 280, 260, 250, 240, 245 degrees?

A. That is in span 6?

Q. Span 4 6/12ths.

A. Well, knowing the river there and knowing that is a mid-stream span of considerable depth and evenness of bottom and linear flow, I trust the river rather than the indications given by the instrument there.

Q. That is the largest discharge there, isn't it, the largest amount of water flowing through that particular span?

A. There is a little over 12 per cent. of the water flowing through that station 4 6/12ths. That is 12.23 of the volume of flow.

Q. Then you would not rely on the current meter indication on the direction?

A. I think a great many observations would doubtless give a value that would be so close to the truth that it would be sufficient as a mean, as Mr. Stewart has probably used it.

I wish to add in this matter of direction that any error which we have introduced into this work by reason of the putting in of too little direction correction means that we have made our discharge too great, which has a tendency to offset any error coming from the effect of turbulence making the discharge too small.

Q. Then if you have not considered the turbulence which is exhibited by these meter observations, you have failed to consider an important element?

A. But I have, and already testified to it. And I have shown how taking a very considerable portion of the cross sectional area, as I did, 20 per cent. of the depth in the open section, and assuming that the perturbation there was that of violent boilers referred to by Mr. Groat, and assuming that the current meter under registered 3½ per cent. through that area, the final effect of that would be if it did exist, which in my judgment it does not, would not be over ½ of 1 per cent.

Q. That is that there is no turbulence there?

A. No turbulence that would be denominated violent boilers, in my judgment, for any such depth as 20 per cent. of the depth.

I made an analysis of that also, Mr. Adcock, and it has

been referred to in this case in my 1900 report, so that has been very fully considered, and we have very definite information concerning it. I refer to the discussion of this matter on page 5332 of the report of the Chief of Engineers of the U. S. Army, for 1900, which is my report on the Niagara River. So we have given this the fullest consideration.

Q. Mr. Shenehon, in your direct examination, you referred to two observations by Mr. Sabin on ice effect in the St. Clair River, in the years 1900, 1901 and 1902. Will you point out to us what observations of ice effect Mr. Sabin made in either 1900 or 1902?

A. If you will refer to my testimony, you will see that my statement was, "Observations and Deductions."

Q. That is as to slope conditions?

A. If you will refer to my direct testimony, you will see that I did not speak of it as observations, but observations and deductions.

Q. Deductions?

A. Yes.

Q. What observations, I am asking about; I did not ask you as to deductions?

A. I beg your pardon?

Q. I did not ask you as to deductions. I asked as to observations. He made no discharge observations, did he?

A. During the ice conditions?

Q. In those years?

A. Yes.

Q. 1900 and 1902?

A. My answer was as to whether he made any discharge observations, the particular years?

Q. In those years?

A. He made observations of the slope of the river in those years, and from that deduced the effect of the ice. When I say he made deductions from the slope, I mean deductions, as I understand it, obtained from his prior discharge observations and the conditions that accompanied them.

Q. How long was the section over which the slope was measured?

A. I shall have to look up that matter. This is not entirely fresh in my mind as to just how he obtained the data.

Recess to 2:00 P. M.

After Recess, 2:00 o'clock P. M.

FRANCIS C. SHENEHON, resumed the stand and testified further on cross-examination as follows:

Mr. Adcock (Question read as follows): "How long was the section over which the slope was measured?

A. 4.4 miles from G. T. R. gage, to Dry Dock.

Q. Which would you expect to give more accurate results, the longer reach or the shorter reach? There was one from G. T. R. to M. B. R., two miles, wasn't it Mr. Shenehon?

A. Yes, the equation numbered two on page 2833, of the report of the Chief of Engineers for 1902, gives an equation depending on the fall from G. T. R. to Dry Dock, and equation number 3, on page 2824, is the fall from G. T. R. to M. B. R.

Q. Which would you expect to give more accurate results, the equation on the longer reach or the one on the shorter reach?

A. I have not sufficiently analyzed the situation to pass on it definitely.

Q. As an engineer, which would you choose, the longer reach or the shorter reach to determine the better results?

A. My answer to that would be that I should accept the conclusion Mr. Sabin reached in that matter after full analysis and intimate knowledge of the conditions involved, and so have accepted it in my testimony in this case.

Q. Whatever conclusion he came to you would accept?

A. Yes, on this matter of ice. That is the best conclusion I know of.

Q. That is the best information that you have?

A. That is my judgment, yes.

Q. So in the absence of any other information you would accept his statement?

A. I do not have any knowledge of any better determination, and when I say that, I have in mind the personality of Mr. Sabin, his ability and good judgment as an observer.

Q. How closely could you determine the discharge of the Niagara from the slope of the Buffalo gage to the International Bridge?

A. I could not answer that question without some investigation, or the plotting of the observations to see how they work out.

Q. Well, I suppose you have made calculations of this kind, haven't you?

A. In this particular position, the change of .1 at the Inter-

national Bridge, as I recollect it, has an influence about 2/3rds of 1 per cent. on the volume of flow, the backwater effect.

Q. I am speaking of the situation where you are simply taking your slope?

A. Yes.

Q. If you were asked to determine the Niagara from the slope between the Buffalo gage and the International Bridge, how closely do you think you could determine the discharge from such observations?

A. Well, I would have to know where the disturbance came from. That is if it were a backwater effect from the lower river it would be one thing, and if it is a change in the outflow conditions, that is the slope changing during unimpeded open flow conditions, then it would be another thing.

Q. Assuming it was a backwater effect?

A. With a sufficient number of observations, or considering a sufficient number of observations, I should say within 5 per cent.; just as likely to be on one side as another.

Q. Did you ever attempt to determine the flow of the Niagara River in that way?

A. Yes. The effect of the backwater on the Niagara River has been determined.

Q. Did you ever attempt to determine the discharge of the Niagara River from the slope relations?

A. No, I think not. I simply know within reasonable bounds the effect of backwater.

Q. What precautions were taken to prevent ice accumulating on the meters?

A. On the current meters?

Q. Yes, in the St. Clair River, by Mr. Sabin?

A. I should say that the ice does not accumulate on the current meter as a matter of fact. If you have a piece of ice on your current meter, and you immerse it in the water, the ice immediately disappears; the temperature of the water is such as to immediately thaw any film of ice that may be on the meter.

Q. Does it thaw the ice that is floating in the river?

A. I assume that Mr. Sabin was watching out for that very carefully, because he would lose his whole instrument if he allowed ice to accumulate on his meter. It would not only be a matter of interfering with the accuracy of the measurement, it would be a matter of stripping the meter from the cable.

Q. You don't know then exactly what precautions were taken?

A. No.

Q. The temperature in which Mr. Sabin was working was below freezing, was it not?

A. During the winter season, doubtless, but the water itself, the temperature of the water was above 32 degrees.

Q. And the meter would be colder than the water?

A. Yes. We had that condition at the International Bridge during the winter observations, the meter wheel in taking it out of the water would stop and be stiff. The minute you put it in the water again, the wheel falls out. When I say "the minutes," in a few seconds, the temperature of the water is immediately conveyed throughout the whole meter.

Q. Were there any other measurements made on the St. Clair River under ice conditions?

A. Measurements were made in 1898, two measurements. And measurements were made, eleven measurements in 1901, between January 2nd and February 2nd; and in February and March, 38 measurements; and then from March 25 to April 26, sixteen measurements. This was in the year 1901.

Q. Were those measurements for discharge?

A. Yes, those were measurements for discharge.

Q. How were they made?

A. By the ordinary methods. Those of 1898 were made at the Dry Dock Section, and the first 11 in 1901, at the Dry Dock Station, and then later Section Craig, was established, which I believe was a little further up-stream. The detail of these measurements is given on page 2835——

Q. Those are the same measurements you have been speaking of, aren't they?

A. On the St. Clair River, yes.

Q. Was 1901 an abnormal ice year?

A. Yes.

Q. Ice conditions?

A. Yes, it was one of the worst years we have any record of.

Q. So great that you rejected the discharge measurements on the St. Clair River in getting your increment, as appears on U. S. Exhibit 1?

A. Yes, U. S. Exhibit 1, shows the 1901 observations without correction for Lake St. Clair effect.

Q. If in February, 1901, the discharge of the St. Clair River was reduced to the extent of 85,900 cubic feet per second as indicated by Sabin's measurements, what became of the water that did not flow through the river?

A. It was doubtless impounded.

Q. In Lake Michigan?

A. Michigan-Huron.

Q. How much would that amount of water raise Michigan and Huron?

A. In the table number 7, the impounding value indicated for the year 1901, is .06 of a foot for January; February .18; March .11; April .14; and May .02, an aggregate of .52 feet or 6¼ inches. That answers your question I think, doesn't it?

Q. No. (Question read as follows: "How much would that amount of water raise Michigan and Huron"?) That is the amount of 85,000 cubic feet per second?

A. .18 of a foot would be the amount, the value. You understand when the lake goes up a little it also has an outflow value that compensates that in part.

Q. That was taken care of by Mr. Sabin in his reduced discharge, wasn't it?

A. I am not sure of that. Yes, that appears to be the difference between the discharge given by an equation and the winter condition derived by differences in slope.

Q. How much would a reduction of the supply to Erie by 85,900 cubic feet per second for 28 days lower the level of that lake?

A. The amount of value or the negative amount of flow would be .18 of a foot as indicated by this table of Mr. Sabin's.

Q. How much of that lowering would be compensated by reduced outflow at Niagara?

A. That question is a iittle complex. I think I can come somewhere near it: On the face of it it would appear to be about 9,000 cubic second feet.

Q. What change of level?

A. That would correspond to a half of the .81, or .4.

Q. What is that?

A. That corresponds to the difference in flow between an elevation, .8 or .81 lower or higher, half of that; half the difference of elevation.

Q. How much would it lower the lake? It would not lower the lake 4/10ths of a foot?

A. The effect would be just the converse of lowering of the lake; where the lake began to lower, of course it would shut off a certain amount of flow and that would be a quantity of a sign opposite to that of the sign of the lowering.

Q. It would be about .085 of a foot, wouldn't it?

A. You mean that amount of flow?

Q. Yes?

A. That is one month?

Q. According to your equations?
A. Yes, about an inch.
Q. About an inch?
A. Yes.
Q. Then other things being equal, Lake Erie should have lowered about .725 feet, is that right, during February 1901?
A. You mean that its elevation would be different than it would otherwise have been in the absence of this hold up?
Q. Yes?
A. That appears to be a fair deduction from the—
Q. Referring to the report of the International Waterways Commission on the regulation of Lake Erie, page 139, table 26, second column, what was the elevation of Lake Erie on February 1st, 1901?
A. (Referring to Table indicated.) On February 1st the elevation was 571.18; and March 1st, it is 570.94.
Q. How much had it fallen during the month of February?
A. The absolute fall appears to be about .24 of a foot.
Q. How much more should it have fallen according to the previous computation, .485 feet?
A. It depends on the local supply and run-off. That we cannot get out of this computation. We would have to go into the—
Q. At that point we launch into the realm of speculation, don't we?
A. At that point we launch into the realm of rainfall, run-off, melting of the snow and the other elements of that kind.
Q. How much does the local supply usually vary in the month of February?
A. I have no determination of that, but I should say for a particular year it would be a very difficult thing to state it; depending on the conditions towards the end of February; might have a very sudden fall that would give a large run-off one year and might—another thing, we have at that time the accumulation of the winter snows, and we are approaching the time of the breaking up.
Q. Suppose Mr. Shenehon, that during the month of February, as a matter of fact, in that time there were no rains to amount to anything, no thaws to amount to anything in the drainage basin of Lake Erie, what would be your answer then?
A. Well, I should not accept your assumption.
Q. I am asking you to assume that?
Mr. Hopkins: I object to a question based on a hypothesis impossible in fact.

Mr. Adcock: Q. Have you an answer now to that question?

A. What is the question?

Q. Assuming that there were no rains to amount to anything, and that there were no thaws of any considerable amount during that month on the drainage basin of Lake Erie?

A. You mean that the year was entirely normal?

Q. No, the month?

A. The month?

Q. Yes?

A. In that particular?

Q. Yes?

A. I can answer that question now: During the month of February Lake Erie normally rises 2⅝ inches, that is an average. Instead of that, in this particular year it went down as already testified to—

Q. About 3 inches?

A. Yes, three inches, so it appears to be abnormal to the extent of 5¼ inches, around there; that is it appears to be lower where the indications from the volume which we have assumed would be 9¼ inches. In other words our assumption of a normal year, of course may not be true, and we have that variation.

Q. How much rain would it take to raise Lake Erie five inches?

A. You mean on the lake surface itself?

Q. I assumed you could answer that question. On the drainage basin?

A. This is the month of February?

Q. Yes?

A. I should not expect a great deal of rain at that particular time. You mean precipitation, in whatever form it may be?

Q. Yes?

A. In what length of time, in one month? Let me get the question clear. What is the particular depth you are speaking of that I am to convert into rainfall?

Q. Five and a half inches?

A. A depth of 5½ inches over the whole drainage basin including the land and the Lake area for a month would amount to a flow of 5,500; that is assuming it all reached the lake, and is concentrated on the lake surface, 5,500.

Q. The question was how much rain would it take to account for that rise of the lake, 5½ inches? I understand from

your testimony the lake was 5½ inches higher than it would have been if this had been a normal year and Mr. Sabin's ice data had been corrected.

A. Let me make that clear: I referred to a mean annual curve of the movements of Lake Erie from month to month, derived from a large number of years. And I find that normally the rise of Lake Erie during that time was 2⅝ inches, during that particular month of February; and this particular year, with the abnormal ice condition, the lake went down three inches, it is a little less than three inches, so I made the aggregate 5½ inches.

Now, this would appear to me in excellent accord with the ice value as given by Mr. Sabin, because we cannot assume that for the particular month of a particular year that the run-off, precipitation, and the other factors are normal. We can take a long period of years and we can reach a fairly accurate conclusion, but when it comes to a particular month, I think we are all agreed that you cannot assume it a normal month. I think this is corroborative of the conclusions reached by Mr. Sabin. I see nothing to set aside the conclusion reached by Mr. Sabin.

Q. On the assumption that this was a normal year, then the effect of ice appears to have been less than 1/3 that deduced from Mr. Sabin's measurements, doesn't it?

A. No, the effect of ice would be about 60 per cent. of the actual computed value here; assuming the normal year would indicate that the ice effect was 60 per cent. of that indicated by Mr. Sabin.

Q. Do you know whether Mr. Sabin made any investigation to determine whether that was a normal year or not?

A. I do not. We haven't any basis for reaching a conclusion on that point for a single month.

Q. Of course his figures were made in 1901, in February and different months, weren't they, of that year?

A. I know of no expert in meteorology or run-off or rainfall, who can tell what happened in 1901 as to run-off.

Q. That is at the present time?

A. I do not think it is determinable.

Q. Wouldn't it have been possible—

A. It is not determinable from any measurements that we have.

Q. Wouldn't it have been possible to obtain observations as to that?

A. You mean of each stream in the run-off basin?

Q. Yes? That is for the month of February, and also the precipitation, take account of that on the lake surface?

A. I think we are reaching the realms of speculation, now.

Q. You could at least determine whether it was an abnormal year.

A. I believe this is an excellent check on the conclusion as to ice—

Q. I know what your belief is?

A. I am trying to give you the reason on which this belief is founded. You are endeavoring to discredit Mr. Sabin's work by assuming he can tell what the run-off is for a particular month, which I do not agree with.

Q. Wouldn't it have been possible to have determined whether or not the conditions were abnormal in February, 1901?

A. You mean as to the run-off?

Q. As to the run-off, as to whether it was abnormal so as to raise the lake 5½ inches. That would be an abnormal thing, an abnormal condition.

A. The lake did go down about three inches, at a time when normally it would go up 2⅝ inches.

Q. But in order that Mr. Sabin's work, figures, may be correct, there must have been that year an abnormal condition as to run-off or precipitation on the lake surface or the drainage area?

A. So far as any individual month or any individual year is concerned, we may regard it as abnormal. In other words it will not fit the mean. The chances are every year is an abnormal year, every month is an abnormal month. The actual amount of lowering of Erie checks the computed from Sabin's ice effect, 60 per cent. of it.

Q. As a matter of fact there must have been an abnormal condition that month, wasn't there, in order that Mr. Sabin's conclusions with reference to the ice conditions on the St. Clair River should be correct?

A. I have stated that in matters of the particular value of the run-off and the precipitation for a particular month, that we would not expect any month to fit a mean curve; and therefore the presumption always is that it is abnormal.

Mr. Hopkins: You do not mean it is abnormal, but just that it does not fit the mean?

A. I mean it will not fit the mean value.

Mr. Adcock: Q. Then the conditions were such that they did not fit the mean. Is that right?

A. Yes, that is true.

Q. They did not fit mean conditions?

A. Yes.

Q. As an average of ten years, for how many months is the surface of the St. Clair River covered with ice, how many months of the year?

A. I should say not to exceed three months as an average, and possibly a little less than that. The months of January, February and March, or possibly a little bit earlier, starting in the latter part of December, around Christmas time. Of course that varies from year to year. Where we have ice jams, they may last through April, and do. In this particular year in 1901—

Q. This ice proposition is more or less indeterminate, isn't it. You haven't had any observers out?

A. Any particular year you are speaking of now?

Q. You have never had any observers out there from the Lake Survey looking at the ice, have you, whose duty it was to make a report?

A. Sabin—

Q. Sabin made a report?

A. His report on ice is printed, and that of course you are familiar with.

Q. Yes?

A. The ice condition is reported by the weather department at Washington and bulletins are issued relating to ice conditions, but that has more to do with the opening of navigation, so that they may anticipate the date on which vessels may sail.

Q. But you people in the Lake Survey did not make any observation with reference to that except as Mr. Sabin did in 1901, that abnormal year?

A. You will remember on the St. Lawrence River I made certain deductions as to ice effect.

Q. I am speaking of the St. Clair.

A. You will remember on the Niagara I have certain conclusions and observations. But on the St. Clair, I think that we have mentioned here is the Lake Survey data as to ice conditions.

Q. There seem to be a lot of conclusions with reference to ice and so on, without very much actual basis as to observations made?

A. I have an impression from the testimony beginning with Mr. Freeman's—or beginning earlier with the testimony of the Government witnesses, and then including the very fine discourse by Mr. John R. Freeman, on ice conditions, par-

ticularly in the St. Clair and St. Lawrence Rivers,—then I had in mind the testimony of Mr. Kent on that point, and it appears to me that we know very definitely, and that we can pick out in the profile shown by Mr. Freeman the years when these ice effects are very pronounced.

While I am touching on this, I wish to reiterate a thing I have stated before that when Mr. Williams made his physical analysis of the lakes, through inadvertance I presume, he picked this particular series of years in which this large ice effect appears, and from which we may make deductions as to ice effects of other years, and then regarded is as annulled or balanced by ice effect in the other rivers, whichever way you wish to consider it.

Q. But there was no one in the Lake Survey whose duty it was each year—

A. No.

Q. Each month of the winter season to make observations as to ice?

A. That is true. I have in mind another case, however, where Mr. Graves was detailed to run some levels, read some gages, so as to determine the slope of the river, at the time of another ice jam; but I do not recall the year. But there has been, so far as I am aware, no regular observation year after year, winter after winter of the ice conditions of the St. Clair River, except as the weather gages may give some information on that point.

Q. What is the average thickness of the ice?

A. I could not tell you. I have never investigated the ice on the St. Clair River, that is the ice itself.

Q. Leaving out the question of ice jams, by what percentage does this ice cover reduce the discharge of the St. Clair River?

A. I could not answer that question.

Q. You don't know how much of an influence this would have on the annual discharge, do you?

A. Basing that on the years that Mr. Sabin discussed and his conclusions—

Q. I am excluding ice jams. I am speaking of ice cover.

A. Oh no, I should not expect that to be a very big quantity; might be somewhere between five and ten thousand second feet during the time the ice cover was on.

Q. For how long a time during an average of ten years, do the ice jams last in the St. Clair River?

A. That I cannot inform you upon.

I wish to make one other statement here that will clear up this matter of 5½ inches. When I state—

Q. I thought you had covered that subject?

A. No, I have not. There is one thing I think should be put in to make it quite clear that there is one little thing that we have not fully considered in making this confirmation.

I said that the normal rise of Lake Erie during the month of February was 2⅝ inches. That normal condition includes the ice effect. There is every year an ice effect possibly of 3½ inches or something near that, would be a possible average measure. So in the end, where we have stated here that we show only 5½ inches, we are entitled to add something to that for the average mean normal ice effect, which shows in the curve. So really our correspondence with Sabin's figures is very much closer than I stated before. That fact did not occur to me when I was discussing the matter; but that is quite pertinent.

Q. By what percentage on an average do the ice jams reduce the discharge of the St. Clair River?

A. I think our information concerning those is mostly summed up, so far as the exact figures are concerned, in Sabin's tabulations. Of course we can draw some inferences, with some reservations, from the relative elevations of Lake St. Clair and Lake Huron; the effect reflected from the Detroit River upon Lake St. Clair, which would be in the nature of a lifting up of the lake when ice jams were in the Detroit River, and a lowering effect in Lake St. Clair when the jam was in the St. Clair River. Those two things may occur at the same time, so that we see no ice effect when retardation actually does exist.

Q. Sabin showed an average for the five months of about 55,000 cubic feet per second, did he not, which was about 25 per cent. in the abnormal year of 1900-1901?

A. Sabin for the three years in which he has set down values, the three winters, is perhaps a better way of stating that, shows for 1900 a loss which spread over the whole year, the whole twelve months of the year, would amount to 12,510 cubic second feet.

Q. That would be about what per cent. of the entire flow?

A. Thinking of the flow as 200,000, would be about 6¼ per cent.

Q. Then for 1901 he made it about 50,000?

A. 1901, if it is spread over the whole year, it would amount to a flow of 20,640, for the year 1902—

Q. How much is that what per cent. is that, about ten per cent.?

A. That is about ten per cent., a little over. For the year 1902, spread over 12 months, he makes it 9,470, and the mean of these three years indicates about 14,220. That would be a flow that spread over the whole year would amount to 14,220 about seven per cent. of the flow.

Q. Russell, however, after further study of these conditions in 1904, reduced Sabin's estimate to 27,000 cubic feet per second?

A. With certain definite reservations.

Q. Or less than six per cent. for the entire year, wasn't it, for the year 1901?

A. Mr. Russell made a discussion, as I recollect it, that is based on the relative elevations of Michigan and Huron, or Lake Huron and Lake St. Clair, and Mr. Russell himself speaks of the indetermination of the method of procedure, as I have done in a similar discussion on the St. Lawrence River.

Q. Now, that year 1901, was an abnormal year, wasn't it?

A. Sure.

Q. That is the ice effect in an average year, or running over a period of ten years would be a good deal less than that?

A. Yes, I get an average of 14,220, covering the whole year for these three years. I should say it is less than that, probably eight or ten thousand, in the average year.

Q. You do not think much of Russell?

A. Mr. Russell?

Q. Yes?

A. I have great respect for Mr. Russell.

Q. I thought you spoke of him, not in the commendatory way that you have spoken of some of the other men in the Lake Survey?

A. No, Russell is a different type; he is a computor. That is his main work in the office of the United States Lake Survey, and he is a most excellent computor, a very valuable man, but a man whose judgment we do not always trust.

Q. Mr. Hayford was a computor too, wasn't he?

A. Hayford is of a different type. I do not wish in the slightest to discredit the work of Mr. Russell. I think what you have in mind is my judgment as to his considering the run-off of the Lake Erie basin as 60 per cent. of the rainfall. That of course I regard as a very serious misstatement and misjudgment, and on that are based the other things that

have troubled Mr. Russell in adjusting the flows of the various rivers.

This 81.4 inches of evaporation, as I understand it, grows out of that erroneous conclusion or generalization as to the run-off of the Lake Erie basin.

Q. According to the best information that you have, what is the average run-off per square mile of the Great Lakes Drainage basin?

A. The conclusions reached by Mr. Williams in his investigation of the streams should rank as the best determination we have, and he shows during the months June to November inclusive, a mean value of roundly a quarter of a cubic foot per second per square mile of drainage basin.

Q. Where?

A. Lake Erie basin.

Q. I asked for the whole drainage basin of the Great Lakes.

A. The whole drainage basin?

Q. Yes? I asked for the run-off per square mile of the drainage basin of the Great Lakes?

A. You mean the average?

Q. For the year?

A. Well, that could be gotten by taking the volume of outflow of the St. Lawrence River and dividing it by the drainage basin.

Q. Suppose you do it and tell us what it is. Refer to Table LVIII of Williams' Exhibit 34 (handing witness same).

A. Let me ask you a question: Is this a question as to the run-off of the land?

Q. No, the entire drainage area?

A. Including the lake surfaces?

Q. The entire drainage area. That is what Mr. Russell based his figure on.

A. I have divided the volume of flow of the St. Lawrence, which I have taken as 240,000 cubic seconds feet, by 287,700, which is the drainage area of the Great Lakes including the lake surface itself, and find that the average yield per square mile is .83 of a cubic foot per second per square mile of area.

Q. What did Mr. Russell take?

A. Mr. Russell took for Lake Erie 30,300, as I recollect it.

Q. About the same amount, wasn't it?

A. A little less .74.

Q. That was for the entire drainage basin of Lake Erie, including the lake surface, wasn't it? Now, what do you consider the average run-off per year on the Lake Erie basin to be, the drainage area I mean?

A. For the year? I have no better figures than those given by Mr. Williams, and his figure is 0.66 for Lake Erie.

Q. Mr. Russell took .684, didn't he?

A. The computation I have just given you would indicate 0.774.

Q. Is that a serious error, do you think, so much so that you would condemn Mr. Russell for it?

A. Yes, when used through the months of June to November inclusive, because Mr. Williams' figures for that time are practically 1/3 of those for Mr. Russell. In other words if Mr. Williams is correct during that period, and the method by which he derives his values would indicate that, then Mr. Russell was 200 per cent. in error.

Now, understand, this is not the volume of flow from the land basin as Mr. Williams' value is, so you have compared Mr. Williams' run-off from the land area with the yield of the whole basin including the lake, as indicated by Mr. Russell.

Let me go a little further on that: 60 per cent. of the rainfall, as I figure it, would be about a foot and a half, a cubic foot and a half per second per square mile of area, so where Mr. Williams gets .66 cubic foot per second, Mr. Russell gets a foot and a half, so Mr. Russell there, if Mr. Williams is correct, is over 100 per cent. in error.

Q. Do you know the common figures for the run-off of watersheds and percentage of rainfall?

A. I know some of them. I don't carry things of that kind in my mind. I happen to have in mind the figures for Minnesota. We think of four inches for run-off for 26 inches of rainfall.

Q. Well now Mr. Russell is the computor of the Lake Survey, is he?

A. Yes, a very excellent computor.

Q. He makes computations with reference to observations that are made in the field, does he?

A. Yes, and he has in the past made observations. Mr. Russell has done some of the geodetic work of the Great Lakes. He at the present time goes out and makes magnetic observations for the variation of the compass, and he made some measurements of flow of the St. Mary's River.

Q. He is in a good deal the same work that Mr. Hayford who testified here is in, the Geodetic Survey Work, isn't he?

A. I think Hayford's position was quite different from Mr. Russell's. Hayford was Chief of the Computing Division,

with a great many assistants, and Inspector of Field parties as well. His was an executive, supervisory, large position.

Now that you speak of Mr. Hayford, I would like to make a correction in a statement I made in my testimony. You asked me as to whether or not I knew what Mr. Hayford was to testify about. I told you not in detail; that I knew that he had found the results to be precise. But in looking over some of my records, I find that on the morning preceding his evidence—he gave his evidence on the afternoon of the tenth—in the morning I spent a couple of hours with him and we went over his testimony, and I did set down at that time the actual maximum and probable errors that he had derived; that is in discussing with him the testimony which he was to give in the afternoon; it was on the same day. I had in mind that I took that down as he testified.

Q. Did the Coast and Geodetic Survey have anything to do with the measurement of discharge of streams, determination of increments?

A. I believe not. I think I ought to explain however that in bringing Mr. Hayford into this case, under my recommendation, I had in mind the man who was most capable in my judgment of any man I know of in the world—

Mr. Adcock: I move to strike that out. I have not asked him any question as to that.

The Witness: (Continuing)—to discuss physical observations, and there was no other purpose on my part. Any conclusion he might reach would go into the case after he once started.

Mr. Adcock: I move that be stricken out as not responsive to any question put to the witness.

The Witness: Hayford has an international reputation as an observer, and a man who reduces physical observations and discusses them.

Mr. Adcock: I move that be stricken out as not responsive to the question.

The Witness: The question was whether Mr. Russell and Mr. Hayford were about of the same type.

Mr. Adcock: No.

The Witness: That was my understanding of the question.

Mr. Adcock: I didn't ask you that question. I asked you as to whether or not the Coast and Geodetic Survey made any measurements of the discharge of rivers and determined increments of any streams?

The Witness: I answered that question, and answered further in response to your prior question.

Mr. Adcock: You know Mr. Shenehon, I am perfectly willing—my objection along this line is simply to lead you on because you show your interest by going outside of the questions that I ask you, and to volunteer. But I would like you to confine yourself to the questions which I ask.

Mr. Hopkins: I object to statement of counsel in commenting on what the witness' manner shows. It is no part of counsel's business to do that.

Mr. Adcock: It is a part of counsel's prerogative.

Mr. Hopkins: The witness might say, showing every effort to tell the truth also.

The Witness: In my answers Mr. Adcock, I am assuming that on both sides—perhaps I am assuming too much in that—we are endeavoring to get the real truth before the court.

Mr. Adcock: We are endeavoring to get the truth certainly, and in a lawsuit we have got to confine ourselves to questions and answers, the answers being—

The Witness: So as not to get the wrong side of the truth.

Mr. Adcock: (Continuing) The answers being responsive to questions.

Q. Now, will you answer the question with reference to the scope of the work of the Coast and Geodetic Survey?

A. I think the testimony will indicate that I have answered that already.

Q. They do not have anything to do with that?

A. No, not to my knowledge. They do however make hydrographic examinations, geodetic and magnetic observations, a great many physical observations that require reduction.

Q. As a computer in the Lake Survey, Mr. Russell has had considerable experience with computations with reference to observations to determine discharge of rivers, and relate such discharge to elevations of the lake, hasn't he?

A. Yes, he even reached a conclusion as to the lowering caused by this Chicago diversion, which was a little over six inches in Lake Michigan, as I recollect it.

Q. Will you tell us what is the weight per foot and the horizontal force of the current per foot used by you in computing the position of the meter in the Niagara River work on the International Bridge?

A. The question is as to the pressure?

Q. Yes?

A. On the current meter?

Q. Yes?

A. And the pressure on the cable per unit of length for different velocities and for different depths?

Q. Yes?

A. I do not carry those values around with me. They are matters of record in the office of the Lake Survey; and I have a curve up at my office in Minneapolis that shows the relationship between velocity of flow and the wire, cables, I believe also. But we made definite, careful observations of those things, and our estimation of the meter and its approximately correct position in the vertical, and up-stream and down-stream was worked out with the full knowledge obtained by these observational data.

Q. Where is that data?

A. In the Lake Survey office as I recollect it, and yet some of those observations, I believe, were made by Haskell for the Board of Engineers on Deep Waterways, and the data may be in the archives of the Government in some other place. But those were very carefully made, and I believe we secured correct results.

Q. Do you know what the position of the meter was in those various depths in your coefficient work, with reference to the guard rail?

A. You mean up-stream or down-stream?

Q. Yes?

A. Oh, I suppose we may have been in error three or four feet.

Q. You may have been down-stream three or four feet?

A. Yes, I think that would be a possibility.

Q. Might it have been further down than that?

A. As I think of it, that would be about the limit of it.

Q. It would be about the limit?

A. Yes.

Q. How far up-stream could you draw your cable?

A. I don't remember the exact limiting amount. I have it in mind as possibly ten feet. I think that would possibly mark the limit.

Q. In deriving an increment for the St. Clair River from the observations at the Dry Dock Section, is it in your judgment possible to ignore the position of Lake St. Clair and arrive at correct results?

A. Not to ignore Lake St. Clair, that is not the right word.

Q. Ignore the position of Lake St. Clair?

A. Speaking of an individual discharge or a short series,

we need to take into account Lake St. Clair; and in the end, an equation that does not contain Lake St. Clair as one of the elements, the backwater effect there, could not be applied to individual observations.

In the chart, U. S. Exhibit Number 1, in this case, Lake St. Clair was not ignored; it was specifically stated on the chart—specifically stated in the evidence that the period of time over which the observations extended was such that I felt safe in not entering that term in the question.

Q. What is your opinion now?

A. I think it is better to have an equation that does take into account Lake St. Clair.

Q. Do you think it would be proper to use one that did not?

A. It would depend on the purpose.

Q. For the purpose of deriving an increment?

A. Well, when you say the purpose in this case—

Q. I didn't say the purpose in this case. I said for the purpose of deriving an increment.

A. I so understood.

Q. For the St. Clair River?

A. I think it is preferable to use an equation as has been done in later equations in which the two terms appear.

Q. You think it would be proper for you, from an engineering standpoint, to derive, attempt to derive an increment without taking into consideration the position of Lake St. Clair?

A. Oh, yes, as indicated by U. S. Exhibit Number 1, I think that was entirely justified, with the explanations in my evidence of 1909.

Q. At that time, you did not take into consideration the position of Lake St. Clair?

A. Yes, I took it into consideration by assuming that the time over which the observations extended was such that we could—

Q. The Lake Survey later in deducing their equations have taken into consideration the position of Lake St. Clair, have they not?

A. Yes, it is a very proper thing to do, and it is especially pertinent and proper where the curve is to be used for a physical analysis. It would have been improper to use this particular curve here in a physical analysis, that is seeing whether or not we could take the volume of flow and in-

terpolate the local supply and come to another river. That was an improper use of these curves.

Q. Then if we should take all of the discharge measurements on the St. Clair at the Dry Dock Section and refer them to the corresponding elevations of Lake Huron, as reported in the Government reports, and should determine by any accurate method the inclination of the average line represented by the whole series of observations, do you consider that a reasonably accurate increment would be obtained?

A. Yes, I should think so. The analysis of the Lake Survey has tended to show that each season has a little difference in the volume of flow.

Q. Suppose we just try that. Assume that the center of gravity of the upper group at elevation 580.92, was 203,382?

A. How many observations and elevations?

Q. Whatever there is in that group?

Elevation 580.92, all of the observations that would fall into that group, 147. And the lower group, elevation 580.35, discharge 187,082, 150 in that group, what is the increment?

A. That would give an increment of 28,600. I notice however that you have given me 297 observations where the Lake Survey has gotten an increment with 488 observations.

Q. Would you say that there are more than 297 observations at the Dry Dock Section?

A. No. That would include the Gorge Section.

Q. Have the discharge observations made since 1903 on the St. Clair River shown any change in the flow of the river from the conditions of former measurements?

A. A variation from year to year has been indicated by the observations; not only those since 1903, but the whole series as reduced by the Lake Survey.

Q. The later ones have shown nothing really new then?

A. The changes have been, not progressive, but back and forth.

Q. When you prepared U. S. Exhibit number 1, you believed the increment thereon shown of 23,820 cubic feet per second to be correct, did you not?

A. No, I so stated in my testimony, that I believed it was subject to a possible error of 25 per cent., and my judgment was that the increment was somewhere between 18,000 and 24,000.

Q. Were there any observations included in the derivation of your increment for the St. Clair, that were not used by Mr. Wheeler in the derivation of the increment of 25,300

cubic feet per second testified to by him on direct examination?

A. The observations are plotted on U. S. Exhibit Number 1, and in my evidence I stated, as I recollect it, that the year 1901, and the year 1908, were not used in computing the increment. But the observations of 1901, as adjusted for the abnormal stage of Lake St. Clair, appear to be in reasonable accord with the other observations.

Q. You haven't answered the question yet, Mr. Shenehon?

A. What is the question?

Mr. Adcock: Will you read the question?

(Question read as follows: "Were there any observations included in the derivation of your increment for the St. Clair that were not used by Mr. Wheeler in the derivation of the increment of 25,300 cubic feet per second testified to by him on direct examination?"

A. My recollection is that Mr. Wheeler did not use anything after the year 1902.

Q. All of the measurements were available, weren't they?

A. Just one minute, let me think about this: I am thinking of Mr. Wheeler's report of 1903. It is my recollection that Mr. Wheeler used the same observations, that is excluding 1908. I think he did not use any observations in 1908.

Q. He did not use any of those?

A. Not in making the computation, but I presume Mr. Wheeler did include the year 1901, yet I am not positive; I would need to refresh my recollection by reading over Mr. Wheeler's testimony.

Q. He got an increment somewhat different from you, didn't he?

A. 25,300.

Q. You did not use any observations that Wheeler did not use?

A. I say I would need to read over again Mr. Wheeler's statement concerning that before I could give you an answer to the question. I would be very glad to take the time to do that, if you care to have me.

Q. I would like very much if you would do that, but not now. You can do it some other time, and send the Commissioner the answer to the question.

A. All right.

Q. If the observations of 1901, had been included by you without correction, the increment would have been about 27,800 cubic feet per second, would it not?

A. I can't tell you.
Q. What is your best judgment on that?
A. I would not have any judgment without—
Q. You would have to plot them would you?
A. Yes, I would need to look into the matter.
Q. The improvement planes for Lake Erie were originally 9.03 feet below Huron, were they not; that is prior to 1893 or 1894 or 1895, along there?
A. The improvement planes, there are somewhat different elevations.
Q. I am speaking of the relation; the improvement plane for Erie, Huron?
A. I am not certain the improvement planes are just the same for all contracts.
Q. Were not the relations changed along about 1895?
A. Yes, at the time the 20 and 21 foot project was gotten under way, it is my recollection that the improvement plane was made nearer the low water elevation instead of a mean.
Q. At the present time, the improvement plane for Erie is eight feet below the improvement plane for Huron, is it not?
A. I should have to look up those figures. I do not carry them with me.
Q. Prior to about 1895, the improvement plane of Erie was 9.03 feet below the improvement plane of Huron?
A. I don't recollect the elevations of the improvement planes.
Q. You have not considered that proposition?
A. As I recollect the thing, the intent was to get as deep a channel as possible, and not only were the 20 and 21 foot projects gotten under way, but a little additional gain over that was gotten by referring to lower water.
Q. Why should they change the relation of Erie to Huron?
A. I am unable to tell you why they did this thing or that thing.
Q. It would be interesting if that were the fact, would it not?
A. I do not know. I presume the reports from the officer on one lake might have indicated that he would prefer that the improvement plane for Lake Michigan-Huron be so and so, and the officer on Lake Erie might recommend another, and this would be adjusted in the office of the Chief of Engineers.

Q. In that "melting pot" there is the Chief of Engineers' Office?

A. I have not struck that melting pot.

Q. You desire to obtain, do you not a depth of water substantially the same all the way along, so that there would be no object in having the water a foot or two deeper in the channels or harbors of Erie, whatever they may be, than in Huron?

A. As an illustration, they are building the Soo locks for a draft of about 24 feet of water, and the channels of the lakes are 20 to 21. Some harbors are dredged deeper, and there may be particular places that are dredged deeper still.

Q. Take it over a long period of years, Mr. Shenehon, the mean stage of the lake, any particular lake, is substantially the same as the stage of the same lake for another similar period of years, is it not?

A. It depends on the number of years considered.

Q. Well, what number of years would you say?

A. If you should take a series of years around 1895, you would find fairly low water.

Q. No, I am speaking of a number of years. What number of years would you consider necessary to make a comparison, so that the stage of the lake would be substantially the same in the two periods?

A. It would depend on my object in the investigation. That is specifically the object which you wish to obtain. I may be able to—

Q. Take for instance Lake Superior, or Lake Michigan—Huron, assuming the channels connecting the lakes are unchanged, say for 10 or 15 years, whatever it may be, assuming you find the mean stage of Lake Michigan-Huron, say, at a certain elevation and then you compare the stage with another period of years, you will find they are approximately the same, will you not?

A. Not necessarily. I think that is illustrated in the exhibit put in this case known as "the red and the blue," in which we show five year periods, show changes in the elevations of the various lakes.

Q. Take ten years?

A. No, the ten year periods will not show exactly the same for the same lakes.

Q. How near?

A. I should not be able to state.

Q. Assuming that the channels were not enlarged or decreased?

A. For Lake Ontario for instance, one ten year period as compared with another may show a difference in elevation of nearly a foot.

Q. How long periods?

A. Those were ten year periods.

Q. How about 20 year periods; two 20 year periods?

A. There would be a difference of half a foot, possibly more. I would be very glad to take specific periods, if you—

Q. What was the elevation of Lake Superior from 1860 to 1889?

A. 1860 to 1889?

Q. Yes, inclusive?

A. I refer to table number L of Williams' Exhibit 34, which I assume has been correctly worked out. The elevation of Lake Superior for that period, 1860 to 1889, is 602.27.

Q. Now, these lake levels bear certain relations, do they not, to one another? I believe you stated that you could predict the level of Erie from Huron, did you not, in your direct examination?

A. In five-year periods you can come very close to a prediction of what Lake Erie would be from the elevation of Lake Huron.

Q. What was the elevation of Michigan-Huron for 1860 to 1889?

A. I refer to table XIX, of Williams' Exhibit 34, which I assume to be correctly worked out. The elevation stated there for Huron, 1860 to 1889, is 581.91.

Q. The difference is what?

A. 20.36 feet.

Q. What was the difference between the elevation of Huron and Michigan, from 1890 to 1910?

A. I refer to the continuation of Table XIX, Williams' Exhibit 34, the second sheet, which indicates the elevation of Huron 580.48, that is, for the full year.

Q. What was the elevation of Superior for this period?

A. The elevation indicated in Table L, of Williams' Exhibit 34, sheet, 2, is 602.36.

Q. That is substantially the same as from 1860 to 1889, is it not, for Superior?

A. Yes, a little bit higher.

Q. A very small amount?

A. About an inch, I should say.

Q. And Michigan-Huron was about a foot and a half lower, wasn't it?

A. The difference between the elevation of Superior and the elevation of Huron for these latter years, is 21.88, and this indicates for the latter period as compared with the former, 1.52 lower.

Q. A little over a foot and a half?

A. Yes.

Q. What was the elevation of Superior from 1890 to 1900?

A. Of course I should call attention to the fact that the building of the International Bridge raised the level of Lake Superior about six inches.

Q. Will you kindly answer my question?

A. The elevation of Superior, as handed me by Mr. Williams, for the years 1890 to 1900, is 602.28.

Q. And you are stating that as the correct figure, are you not, Mr. Shenehon?

A. Subject to correction.

Q. The only thing is, we do not want to have any question in the record as to figures that you give. What was the elevation of Michigan-Huron from 1890 to 1900?

A. 580.34, is the figure which Mr. Williams gives me, which I state now, subject to checking and possible correction.

Q. The elevation of Superior and the elevation of Michigan-Huron, from 1890 to 1900, compares substantially with the elevation for the 20-year period from 1890 to 1910, does it not?

A. Yes, within an inch.

Q. And the difference in elevation is 21.94?

A. Yes.

Q. Now, the elevation of Superior from 1901 to 1910, is 602.46, is it not?

A. I set down that figure as given me by Mr. Williams, with the reservations made to the earlier figures.

Q. And the elevation of Michigan-Huron is 580.65, is it not?

A. 580.65.

Q. 1901 to 1910, making a difference of 21.81?

A. 21.81, I have that.

Q. That shows that from 1901 to 1910, Michigan-Huron were higher in comparison with Superior than they were from 1890 to 1900, does it not?

A. Yes. I should make a reservation, however, by stating that under an arrangement made by the Federal Govern-

ment with the power companies at Sault Ste. Marie, they were not permitted to lower the level of the lake below a certain point. In other words, that is a period where it has been under regulation, so that the power companies are compelled to shut down and cease to—

Q. When did this take place?

A. That is sometime about 1900, maybe a little later. I am not certain of that date.

Q. About 1900. 1907, wasn't it?

A. I have in mind the building of the power canal there. That was under way prior to my leaving the Soo in 1898, and it has been opened since about 1900, but I should need to look at the date.

The two spans of the International Bridge nearest the Canadian side had regulating gates put into place, which, however, have never been operated as gates. They simply block the flow, the portion of the flow in those channels, but I have the impression that the date of the building of those was earlier than the year 1902, which Mr. Williams tells me was the date of the washout under the power house at the Soo.

I should need to look up the dates to speak with any sureness on that point.

Q. You mentioned 1902, or about that?

A. Yes.

Q. The withdrawal of water from Superior was regulated, that is, through the power canal, was that true?

A. Yes, the power companies operated under a limitation. If the lake got below a certain level, they were compelled to shut down until it returned to that level.

Q. You do not think that the regulation affected the mean elevation of the lake materially, do you? That is, Lake Superior.

A. Yes, if the power companies had not shut down the water would doubtless have gone to a lower point. In other words, it would have the same effect as a diversion through an independent canal. They would have gone on draining off Lake Superior by adding to the natural overflow, the flow through the power canal. That is true of the Canadian side as well, and yet whether or not the Canadian Government imposed any restriction there or not I am not certain.

Q. In the elevation of Michigan-Huron as compared with the elevation of Superior from 1901 to 1910, and from 1890, to 1900, there is not much difference, is there?

A. No, under those conditions, a period of low water in

Lake Superior, Lake Superior would be maintained at the expense of the lower lakes, of course.

Q. Well, that would have led to the lowering of Michigan-Huron, wouldn't it?

A. Yes.

Q. But from 1890 to 1900, the relation was the same as it was from 1901 to 1910, practically?

A. Well, let me see, that is from 1890 to 1900?

Q. Yes?

A. That was the period in which Lake Superior was impounded for the building of the International Bridge. Lake Superior was raised six inches, and the water was impounded at the expense of the lower lake at that time.

Q. How much was it raised?

A. About six inches.

Q. And Michigan-Huron fell a foot and a half?

A. Then of course the period, 1900 to 1910, we have the Chicago Drainage Canal.

Q. But you do not see any effect from the Chicago Drainage Canal here, do you on the relation of the levels of Superior to Michigan-Huron?

A. I think under those conditions the thing would be masked.

Q. The relation of Huron to Superior for the last ten years is the same as for the ten years between 1890 and 1900?

A. As I have stated, it is a matter of compulsion to hold it there. The Federal Government saw to it that the lake did not go below a certain point.

Q. How do you account for the change in 20 years, that Michigan-Huron is a foot and a half lower the last 20 years, that is from 1890 to 1910, than it was during the period prior to 1889?

A. I do not try to explain a difference of that kind in detail, and closely.

Q. That is a physical condition?

A. I have already stated to you we have two things coming in the elevation of Superior there. Between 1890 and 1910, we had the building of the International Bridge which raised Lake Superior, as I have stated, about six inches, and during the same period we had the regulation of the power companies, which did not permit Lake Superior to go below a certain point.

Q. How much did the building of the International Bridge at Niagara raise Lake Erie?

A. I should say an inch, inch and a half, probably an inch and a half.

Q. You haven't accounted for this foot and a half yet.

A. No.

Q. Do you think that was caused by the dredging, etc., in the St. Clair River?

A. I think I am on record pretty fully on that point in this case.

Q. I know, but you have not taken that into consideration.

A. No, I think the effect of the dredging in the St. Clair River and Lake St. Clair and the Detroit River is a very little thing in accounting for the lowering of the lakes.

Q. But if the channels between Superior and Michigan-Huron, and Huron-Michigan and Lake Erie remained the same, the relations of falls between these lakes would have been the same?

A. Of course I take into account also the relationship between Erie and Michigan here and I find this falling of the lakes was a characteristic thing. It was not confined to Michigan-Huron, and was not confined to Erie; that the thing is in Ontario as well, so the dredging in the channels that you speak of, in the St. Clair and Detroit Rivers, which culminated in what has been called by Mr. Williams in this case, and I believe Mr. Stearns also, the sudden change in 1889 when the critical point was taken off the dam in the Detroit River, the Lime Kiln Crossing,—the same thing is occurring in Erie and Ontario, but we do not have any such critical dams removed in those lakes,—so this dredging, this taking away of the critical point which culminated in this lowering of 1889-90, these two years that have been rejected by Mr. Williams in his discussion, did not mean the increase in volume of flow passing through these other lakes, as far as I can make out, in an analysis; but we have the whole series of lakes, outside of Superior, at lower elevations in these later years.

You cannot charge that up to the dredging in the Detroit River and the St. Clair River and Lake St. Clair. An analysis of that indicates that the big bulk of the material removed was either outside the river, the bulk of it was outside the river in Lake St. Clair and Lake Huron, and that the portion that was dredged from the channels of the St. Clair and Detroit Rivers was, for the most part replaced, and additional material was brought in from other places and dumped in the St. Clair River and the Detroit River.

Q. There were certain improvements in the Niagara and also in the St. Lawrence Rivers, which affected Ontario, were there not?

A. Yes, but to my mind rather slightly. There has doubtless been some little lowering of Lake Erie through improvements, dredging of channels, but it is in my judgment very small. And the same is true of Ontario.

Q. Upon what did Mr. Noble base his testimony as to the effect of the lowering of Lakes Michigan-Huron, shown in Exhibit Number 1?

A. Mr. Noble based his testimony regarding Lake Erie on the observations made by—

Q. I asked as to Michigan-Huron?

A. Mr. Noble's testimony in that regard was as to the method employed of deriving the lowering, and I believe referred to U. S. Exhibit Number 1.

Q. In your recent testimony, you gave a value of 21,000 cubic feet per second for the St. Clair increment, did you not?

A. Yes.

Q. Then your earlier conclusions were in error? Is that a fact?

A. No, I think I gave a margin of possible error in the 21,000 as much as I did in my earlier testimony. I think my testimony was between 18,000 and 24,000 originally. The mean of those two quantities indicates 21,000.

Q. But your increment at that time was 23,800?

A. No, I think you are in error.

Q. Cubic feet per second, was it not?

A. No, I think you are in error about that.

Q. With an error of 25 per cent?

A. Reference to my testimony will indicate that I regarded the increment somewhere between 18,000 and 24,000 and the mean value between those appears to be 21,000; and the Lake Survey work is in confirmation of my conclusion at that time.

Q. You suggested that there might be an error either way of 25 per cent. in the St. Clair River?

A. I stated specifically my judgment was between 18,000 and 24,000.

Q. That is in the record. Now, Mr. Ray gave an increment of 20,700 cubic feet per second, did he not, for the St. Clair?

A. Yes, I would not quarrel with Mr. Ray about that other 300 cubic feet in the increment.

Q. Mr. Moore thought it might be anywhere from 17,000 to 22,000, did he not?

A. Mr. Moore in his testimony states: "I believe personally that the increment of the St. Clair River lies between 17,000 and 22,000."

Q. In your earlier testimony you stated your belief as to the possible effect of the diversion of 10,000 cubic feet per second was about five inches on Lake Michigan, did you not?

A. Well, no, I did not. I stated that U. S. Exhibit Number 1, indicated five inches. That would be for an increment of 24,000; but assuming an increment of 21,000, which appears to be the mean of the increments stated, it would be somewhat in excess of—a little less than six inches. An increment of 20,000 would give six inches for a diversion of 10,000.

Q. Mr. Noble stated the effect to be about five inches on Michigan-Huron, didn't he?

A. Mr. Noble testified from U. S. Exhibit Number 1, and took off the value of five inches, and his testimony is to the effect, as I understand it, that the method of deriving the lowering was a correct one, and U. S. Exhibit Number 1, showed that.

Q. He was asked to give his opinion, was he not?

A. Mr. Noble's opinion, as I understand it, would be based on U. S. Exhibit Number 1.

Q. Mr. Haskell, in his original testimony stated that the effect would be about six inches, did he not?

A. Yes, I think so. He used the International Waterways formulae or equations, which were independent of our own.

Q. And Mr. Wilson gave 6¼ inches on Lake Michigan?

A. That should be from the same data, and doubtless has to do with the different stage of the lake.

Q. And when Mr. Wheeler was asked his opinion, he gave 4.76 inches as the lowering?

A. Yes.

Q. For a diversion of 10,000 feet, on Lake Michigan?

A. I do not know,—we have still to look up what particular data Mr. Wheeler used.

Q. And Mr. Sabin stated that it was in his opinion from 5 to 7½ inches, did he not?

A. Yes, I remember the upper limit of 7½ inches used by Sabin.

Q. And Major Keller, gave five inches?

A. He used U. S. Exhibit Number 1, as the basis of his conclusion.

Q. But he was asked for an opinion, was he not, as to the effect of the diversion of 10,000 cubic feet?

A. Yes, as I recollect it.

Q. And he gave as his opinion five inches?

A. I may add that in the report of 1904, Mr. Thomas Russell would show it to be 6¼ inches, .52 feet.

Q. Mr. Russel has not been called by you?

A. He has been quoted by witnesses for the Sanitary District. His report is a thing that has been referred to frequently in the testimony.

Q. You did not consider Mr. Russell's opinion of sufficient value to call him?

Mr. Hopkins: Objected to as incompetent.

Q. Did you?

Mr. Hopkins: Mr. Shenehon does not call the witnesses in this case. It was entirely unnecessary; we had enough. Mr. Adcock? Q. Did you?

A. I regard Mr. Russell's judgment as very good on many points, and I have taken issue with him as to his conclusion of the run-off of the Lake Erie watershed.

Q. Not even as an expert computer was he called, was he?

A. I prefer Mr. John F. Hayford as a man of wider international reputation.

Q. You were looking for a man of reputation?

A. Yes, a man who stands among the highest of any men engaged at the present time in physical investigations.

Q. That is your opinion?

A. That is my judgment; and I think it is an accepted judgment.

This does not appear to be clear, in so much of Mr. Wheeler's testimony as I have looked over here. He reaches an increment of 25,200 second feet in the St. Clair. That would indicate a lowering of the level of less than five inches, about 4¼ inches.

Q. 4¼ inches was Mr. Wheeler's opinion, was it not?

A. Yes, that is substantially the value.

Q. Mr. Moore, gave an opinion of about five inches, didn't he?

A. No. You mean in the original testimony?

Q. Yes?

Mr. Hopkins: I understood that all of this concerning what other people gave is based upon your recollection of what their testimony is.

A. Yes. The testimony will show for itself, I think. Mr. Moore arrived at his values after many more investigations

and many more observations, as recently stated, of between seventeen and 22,000 for the increment. An increment of 17,000 would indicate a lowering of about seven inches, and 22,000 would be 5⅜ inches. Those are the limits between which Mr. Moore in his later testimony—

Q. But in his original testimony, he stated the effect was five inches.

A. Well, his information is now very much more extensive.

Q. One hundred measurements more, isn't it one hundred more observations, something like that?

A. No, nearly twice as many as were had originally, not quite. There were 253 originally and 488 now.

Q. Mr. Ray stated that it was 5¼ inches, did he not?

A. That would be based on an increment of 22,000.

Q. Mr. Moore gave another value of 5 1/5 inches, did he not?

A. I do not recollect.

Q. Mr. Richmond gave the St. Clair increment as 22,700 cubic feet and the effect from that as 5.28 inches, did he not?

A. 5¼ inches.

Q. Yes?

A. I imagine you are stating these things in accordance with the testimony of the witnesses.

Q. Mr. Haskell, when last on the stand, gave a value of 18,900 cubic feet per second as the increment and the effect of the lowering at 6⅜ inches, did he not?

A. Yes, I believe he gave a value from the International Waterways report, which does not of course contain all the later data.

Q. Then, among the witnesses for the complainant who have testified upon this subject, there is a range from 4.76 inches by Mr. Wheeler from his own computations to 7.5 inches by Sabin, from his computations, with 5.7 inches as your testimony and 6 and 6⅜ inches Mr. Haskell's estimate, showing a range of 57½ per cent. in the estimated effect based on Mr. Wheeler's value. Is that correct?

Mr. Hopkins: Objected to as entirely argumentative, and on the further ground that the record speaks for itself.

A. I think the proper method of getting at a matter of that kind would be to take the mean value between extremes, which is 6¼ inches, and make your percentage relation with respect to that.

Q. It is 57½ per cent. by Mr. Wheeler's value, isn't it, showing a range of 57½ per cent. by Mr. Wheeler's value?

A. Would you like me to figure that out?

Q. I am asking you the question. You can figure it out or guess at it or any way you want.

Mr. Hopkins: We will assume your figures are correct, if you state they are. That is the percentage based upon the lowest amount, what is it?

A. The difference between 7.50 and 4.76 is 2.74. Dividing that by 4.76 indicates 57½ roundly.

Mr. Hopkins: Q. What would be the percentage if properly computed from the mean?

A. If this percentage is computed from the mean, taking the extreme which is Sabin's 7½, and 6.1 as the average of the extremes, would indicate a percentage of 23 per cent.

Mr. Adcock: Will you read the question now, and I will ask the witness to answer it. I move to strike out his answer to the question as not responsive.

Mr. Hopkins: I put a question in there which was answered.

Q. (Question read as follows): "Then among the witnesses for the complainant who have testified upon this subject, there is a range from 4.76 inches by Mr. Wheeler from his own computations to 7.5 inches by Sabin from his computations with 5 inches and 5.7 inches as your testimony, and 6 and 6 3/8 inches according to Mr. Haskell's, showing a range of 57½ per cent. in the estimated effect based on Mr. Wheeler's value," is that true?

Mr. Hopkins: He has answered that question that it would be 57 per cent. of Wheeler's value.

Mr. Adcock: Q. Is that right?

A. Yes, I gave it in detail.

Q. It is 57½ per cent. as stated there. Is that right?

A. Yes, of Wheeler's computation, as indicated in my prior statement.

Q. Mr. Shenehon, has there ever been an occasion within your knowledge when discharge measurements were made at two different sections of the same river at the same time?

A. Not of the same river. We have made them in the same canal. That was done in the hydraulic power canal at Niagara Falls, and a similar process between what is known as the conveyor meter of one of the hydraulic sections in the Niagara Falls Power Company's canal. That was the method of comparing the precision of the sections.

Q. Are you familiar with the discharge measurements made under Col. Curtis MacD. Townsend, who formerly testi-

fied in this case, at Arkansas City, Arkansas, and Wilson's Point, La., in 1891 and 1892?

A. No.

Q. I refer you to a pamphlet compiled in the office of the Mississippi River Commission and printed under Government authority, entitled "Tabulated Results of Discharge Observations, Mississippi River and Its Tributaries and Outlets," pages 72 and 73 for Wilson's Point, and pages 65 and 66 for Arkansas City, and ask you to give the discharges there reported for Arkansas City and Wilson's Point for the period March 28th to April 4th.

A. How do you wish me to give this, individual dates and volumes of flow as indicated in this tabulation?

Q. Yes?

Mr. Hopkins: You are reading out of that pamphlet?

A. Yes, I am reading from the pamphlet referred to.

Date.	Arkansas City.	Wilson's Point.
March 28,	1,391,000	1,272,000
" 29,	1,419,000	1,288,000
" 30,	1,424,000	1,219,000
" 31,	1,409,000	1,201,000
April 1,	1,419,000	1,247,000
" 2,	1,406,000	1,276,000
" 3,		1,234,000

Q. The average there is 1,412,300 cubic feet per second at Arkansas City?

A. The average as indicated here in the computation made by Mr. Williams, for Arkansas City is 1,412,300 cubic feet per second, and for Wilson's Point 1,248,100, and the difference is 164,200 cubic second feet.

I, myself do not know the location of the two places nor whether the dates are coincident.

Mr. Hopkins: Q. Do you know anything about this work?

A. I know the volumetric measurements on the Mississippi River are not in the same class with the precision of the work in these clear fixed rivers of the Great Lakes.

Mr. Adcock: Q. These were current meter measurements, weren't they?

A. Yes, I made some statements in regard to the Mississippi River measurements in my cross-examination. In the Mississippi, with flood conditions, as I assume this must have been, there is an amount of grit and turbulence in the water that makes current meter measurements less precise than the results gotten in the clear waters of the Great Lakes.

Q. There was some precision obtained in these measurements, wasn't there?

A. I am not aware that the Mississippi River Commission attempts to work with any great degree of precision, for the reason that the river is fluctuating over very wide volumes of flow, and there appears to be no particular reason why they should get them down to the last refinement.

Q. At Wilson's Point, the average was 1,248,000 cubic feet per second, wasn't it?

A. As read.

Q. You say that they were not attempting to get close results. Is that true?

A. My understanding of the gaging of the Mississippi is that they do not work for any such precision as we have gotten in the rivers of the Great Lakes. The necessities do not exist for any such precision as that, and the difficulties are very much greater than any we had to contend with.

Q. You are familiar with the work called "Starling on Discharge of the Mississippi River"?

A. That is a paper that was read before the American Society of Civil Engineers, isn't it?

Q. Yes?

A. I would like a little information as to how far apart these two sections are, and whether the measurements coincide in every respect in time of day and so on, so that it may be in evidence.

Mr. Adcock: I refer you to page 371, of the transactions of the American Society of Civil Engineers for 1895 (volume 34), where it is stated:

"With all the precautions that experience has suggested, there are sometimes discrepancies or anomalies in discharge observations so great that they cannot be accounted for in any of the ways heretofore indicated. Instructive examples of this are to be found in the observations taken in 1891 and 1892 at Arkansas City and at Wilson's Point. Up to this time it had been impossible to check the observations at one point by those taken at another, owing to the intervention of tributaries, which introduced a disturbing element difficult to calculate. Thus Helena could not be checked by Arkansas City in 1884-85, because the White and Arkansas rivers poured out between the two stations a variable and unmeasured volume, which sometimes amounted to 300,000 cubic feet per second. In 1891, however, C. McD. Townsend, M. A. Soc. C. E., being dissatisfied like everybody else with the existing state of the

knowledge of discharges, had simultaneous gagings taken at the two places above named, 93 miles apart, and without any tributary or other disturbing condition between. The results showed the discharge at Arkansas City to be 150,000 to 200,000 feet more than at Wilson's Point. Had the difference been only for a day or two it might have been explained, well or ill; but it was continuous and persistent. At Arkansas City, from March 28th to April 4th, the records were 1,390,586, 1,419,422, 1,423,730, 1,408,553, 1,419,321, 1,405,641. At Wilson's Point they were: 1,272,440, 1,288,000, 1,219,436, 1,200,578, 1,247,445, 1,275,904, 1,234,182. Averages, 1,411,209, and 1,248,283. There was no crevasse or other disturbing influence between them. The same discrepancy kept up until April 23rd, after which date the difference slowly diminished. This unexpected result put the engineers to their wits' end. The meters were compared and exchanged. They had been several years in service, and their bearings were somewhat worn. They were rated frequently, and the rates of the same meter at different times were found to be very discrepant.

Captain Townsend considered the meters to be unreliable, and ordered two new ones. The next spring, 1892, a still greater flood developed, and high water discharges were taken at the same two places with the new instruments. The results were more discrepant than before. The discharges at Arkansas City from April 26th to May 9th, averaged 1,598,682; at Wilson's Point, 1,364,277. The instruments were compared, side by side, and meters and observers were changed, without affecting the result. There were no disturbing influences between the two places except the overflow of the foreshores outside of the levees, which increased only 1.7 feet during the interval of 13 days."

Then it takes up various explanations like, obliquity of current, vertical currents, other disturbing influences, the "flanking method," faults of method, etc.

What have you got to say now that you have heard the conditions under which the measurements were made there at Wilson's Point and Arkansas City?

Mr. Hopkins: I wish to object to this entire line of questioning, and this question in particular, because it is not proper cross-examination. The witness has not based any of his opinions upon the matter that has been read to him and therefore it is incompetent. I move that the question, and all this matter that has been read in, be stricken out.

Mr. Adcock: The witness is an expert measurer of dis-

charges, and I want to get his opinion as to these discrepancies that are found where they measure a river simultaneously at two different stations. That is something that was never done by the Lake Survey.

Mr. Hopkins: I want to object further on the ground that the witness states he has no personal knowledge of the work which was criticised by the author of the article read.

Mr. Adcock: Q. You know Colonel McD. Townsend, don't you?

A. Yes.

Q. He was one of the witnesses you produced in this case?

Mr. Hopkins: I object to "you produced"; let it be understood that the witness did not produce anybody; that the Government attorneys have run this case, and still insist that they are running it.

A. I am sure Colonel Townsend would object to being produced by anybody.

Q. I am assuming you are the General of this Regular Army, which Mr. Wilkerson spoke of in his opening statement in this case.

Mr. Hopkins: Objected to.

A. It is my recollection, as regards Colonel Townsend, that he testified as to the navigation of the Great Lakes; not the hydraulic question involved.

I take exception to the statement of counsel that we have not measured duplicate sections simultaneously. I have stated that we have; that we did in the case of the hydraulic power company at Niagara Falls, and that they checked within 2 per cent.

Q. I am speaking of the measurement of rivers.

A. The flow in an open stream, whether artificial canal or river amounts to the same thing, and demonstrates the validity of the results.

I wish to state further we observed under identical conditions as to the elevation of Lake Erie, for instance, in the Niagara River, on three different sections and we have checks within one, 1.3 and ½ per cent. That is a sufficient answer.

As regards the Mississippi River work, I should wish to know the whole personnel of the men handling the instruments, the methods used, the current meters used; all the conditions. If these are placed in my hands, including the observations themselves, and their methods of reduction, I should be very glad to pass on the conclusions.

Q. You were ready to accept the conclusions of Mr. Sabin without very careful study?

A. Yes. I know something of Mr. Sabin's methods, and I know the instruments he used. I know his equipment. I know the care used. I know the months over which the work extended. I know the clarity of the river in which he had to work, and know the permanence of conditions with which he had to deal; and I know that the Gorge Section which was measured in the St. Clair under my supervision as Principal Assistant, checked Mr. Sabin's work within 1 per cent.

I know that the Delta Section checked again within 1 or 2 per cent, so I have every reason for confidence in the work on the St. Clair River.

Q. You are not so familiar with the work of Mr. Townsend?

A. Mr. Townsend doubtless never handled —

Q. I beg your pardon, Colonel MacD. Townsend.

A. I feel very positive that Colonel Townsend handled none of the instruments; did none of the field work, and if he followed the procedure of engineer officers, it was pretty largely in the hands of his civilian assistants.

Q. You have confidence in civilian assistants, haven't you?

A. Not necessarily.

Q. Particularly where they are under the direction of army engineers?

A. Before you asked that question, I made certain statements regarding the Mississippi River—

Q. The Mississippi River also is a very large river, is it not?

A. Yes, that in a very few days measured a volume of flow five or six times, eight times bigger than the flow measured by us in many months.

Q. According to your theory, the larger the river the more accurately the discharge could be measured with the current meter? If that is so, they ought to have gotten within about 1/16 of 1 per cent.

Mr. Hopkins: The witness stated, if sufficient work were put upon it.

A. That is hardly a fair conclusion in itself, that the whole thing is dependent upon the size of the river.

Q. Now there are some diversions at Niagara Falls, aren't there?

A. Yes.

Q. There is a treaty between the United States and Canade, is there not, with reference to that?

A. Yes, Great Britain and the United States entered into a treaty—

Q. The Canadian power companies may divert 36,000 cubic feet per second?

A. Under the treaty, a limitation of 36,000 is placed.

Q. And on the American side there is a limitation of 20,000?

A. Yes.

Q. It is generally understood that that difference of limitation, or the less amount for the American companies, was because of the diversion at Chicago, the contemplated further diversion, is it not?

Mr. Hopkins: Objected to. The treaties speak for themselves; it is incompetent.

A. I have no evidence of that fact.

Q. It is a general feeling, is it not, that perhaps if the diversion were limited, the diversion at Chicago were limited, the American power companies might receive more water.

Mr. Hopkins: I object to the question in regard to the general feeling. Ask him as to his own feeling.

Mr. Adcock: The general understanding?

A. I do not think so. Let me perhaps clarify this a little.

Q. If you don't know anything about it, just say so.

A. I am going to say something concerning it. The American channel contains about five to seven per cent. of the total flow of the river. The International boundary is in the main rapids, and fairly close to Goat Island, so that probably 80 to 90 per cent. of the volume of flow is on the Canadian side of the boundary.

At Sault Ste. Marie, the bulk of the flow is on the American side of the boundary, and as I have understood those two facts were taken into consideration in adjusting the volume of flow at Niagara; 36,000 for the Canadian and 20,000 for the American companies.

Q. Now, you have been retained by the Hydraulic Power Company, have you not?

A. Yes, I was retained—I was engaged by the Hydraulic Power Company in the beginning of 1912, I believe it was.

Q. That is an American company?

A. Yes, that is the big American company, that has a head of 210 feet going over the bluff.

Q. You were retained, and under that engagement you

wrote a communication to what is known as the Special Board of Engineers on Waterways from Lockport, Illinois, to the mouth of the Illinois River, which had under consideration compensating works, etc., did you not, Mr. Shenehon?

Mr. Hopkins: I object to the question as not proper cross-examination; and we do not intend to have any matters in regard to compensation come into this case through our witnesses. It is a matter that involves an appropriation from Congress, whether it is large or small, and therefore it is not proper to be considered in this case. I instruct the witness not to answer.

Mr. Adcock: I have not asked him anything about compensating works.

Mr. Hopkins: You asked him if he wrote such a letter.

Mr. Adcock: I asked him if he wrote such a letter.

Mr. Hopkins: I instruct him not to answer.

Mr. Adcock: I am asking him with reference to a letter which he wrote to a Board which had under consideration that matter; and I want to say that this question has nothing to do with the compensating works. However, we do insist that the question of compensation is an important element in this case, but I am not asking the witness to—

Q. Did you write a letter on behalf of the Hydraulic Power Company of Niagara Falls, on October 12, 1912, to the Board of Engineers on Lakes to the Gulf Waterways?

Mr. Hopkins: That is all right.

A. I appeared before the Board of Engineers—

Mr. Adcock: Wait a minute.

Mr. Hopkins: The question is did you write such a letter?

Mr. Adcock: By this question, I do not wish to withdraw the question which I asked, which counsel has instructed the witness not to answer. I insist upon the witness answering the question which I asked him. At the proper time, I will take such advantage of counsel's instruction as may seem proper in this case.

Mr. Hopkins: I still instruct the witness not to answer the original question. In regard to the second question, whether he wrote a certain letter at a certain time, he may answer yes or no if he cares to.

A. Yes.

Mr. Adcock: Q. You wrote that letter did you not in behalf of the Hydraulic Power Company?

A. Yes.

Q. You didn't mention, when counsel asked you as to addi-

tional qualifications which you might have to testify in this case, you didn't make that statement—

Mr. Hopkins: Objected to.

Q. —make the statement as to the fact that you were employed by the Hydraulic Power Company since you testified in this case, did you?

Mr. Hopkins: It appears what he said.

A. I testified that I had a practice as a consulting engineer, which included that and other engagements not mentioned.

Q. You mentioned various engagements you had, did you not?

A. I mentioned when specifically questioned one engagement; that was my retention as expert in the case of the United tSates v. Chandler-Dunbar Company, and also the case of United States v. Sanitary District of Chicago.

Q. But you did not mention this particular employment?

A. No. Under advice of counsel.

Q. You did not mention it?

A. Under advice of counsel.

Q. Under advice of counsel. What did counsel say to you?

A. That the question of compensation would be objected to as immaterial, and therefore it would be well not to bring the matter in by specific reference to the thing.

Q. But you went into certain questions that had to do—

A. Let me add something more: I was very well aware of the fact that this pamphlet was in your hands at the time; and the fact of my service for the Hydraulic Power Company is a well-known one.

Q. Mr. Shenehon, there were various considerations, various matters which you took up in that letter which had to do with hydraulic questions, did they not?

A. Yes.

Q. And perhaps the study which you made in connection with the engagement for the Hydraulic Power Company might have additionally qualified you to testify in this case?

Mr. Hopkins: That is objected to. It is a question for counsel to determine as to what qualifications they desire to bring out.

Mr. Adcock: Q. Now when did you have this conversation with reference to this particular letter?

A. You mean with counsel?

Q. With counsel, yes.

A. I believe that was on Tuesday, April 14th.

Q. That was just before you testified in this case, was it?
A. Yes, just before my testimony. I testified on the 15th.
Q. With whom did you have that conversation?
A. With Mr. Hopkins and Mr. Wilkerson.
Q. This particular letter was discussed, was it?
A. Yes.
Q. Both letters?
A. The second letter was not presented on behalf of the Hydraulic Power Company.
Q. Whom was that presented on behalf of?
A. On behalf of myself.
Q. Did you consider that the letter you presented on behalf of yourself was in any way inconsistent with the employment indicated in the letter you presented on behalf of the Hydraulic Power Company?
A. The Hydraulic Power Company does not approve of any scheme of regulation in which movable gates of that form are used.
Q. Your second letter did not detract from the effect of the first letter, did it?
Mr. Hopkins: Objected to.
A. That I don't know.
Mr. Hopkins: He does not know.
Mr. Adcock: Q. What?
A. I do not know.
Q. It would be rather peculiar for you to write a letter on behalf of the Hydraulic Power Company advocating certain things, and then write another letter on behalf of yourself, which was inconsistent with the letter you wrote on behalf of the Hydraulic Power Company.
Mr. Hopkins: I object to the statement of counsel as purely argumentative.
A. I do not believe there is any inconsistency between the two, so far as that is concerned.
Q. If the second letter was of any benefit to the Hydraulic Power Company, you were perfectly willing that benefit should be obained by them, were you not?
A. Sure. The second letter presented a scheme that I believe is beneficial to all three elements considered; that is the power companies and the scenic grandeur at Niagara Falls, and navigation, with all three of which I have had to do.
Q. Do you consider that your employment by the Hydraulic Power Company has in any way increased the interest you have in behalf of the Government in this case?

A. I think a comparison between my evidence in 1909 and my evidence later will indicate that.

Q. I note that you used—

A. That my point of view is substantially the same now as then.

Q. You used very extravagant terms at different times in the course of your re-direct examination, in criticising the work of Mr. Williams and other witnesses in this case, that their conclusions were erroneous, and not based on good engineering tactics or principles, etc., and I wondered if your interest had anything to do perhaps with the language which you used concerning the conclusions?

A. No, I did not have a chance earlier to characterize some of the methods used by the experts, Mr. Williams in particular for the Sanitary District. My language, I think, might have been the same earlier, under like circumstances.

Adjourned to Monday, May 18, 1914, two o'clock P. M.

Monday, May 18, 1914,
2:00 o'clock P. M.

FRANCIS C. SHENEHON, resumed the stand and testified further as follows:

Re-direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, in your cross-examination you testified that the local supply of Lake Erie for the open season was about 3 per cent. of the Niagara discharge. What percentage is the local supply of Lake Erie for the whole year?

A. Based on the run-off values given by Mr. Gardner S. Williams in Table LIX A, of his Exhibit 34, the run-off for the full year is given as 0.664 cubic second feet per square mile of drainage area. That is the dry land portion of the drainage basin. Taking the area of the dry land tributary to Lake Erie and St. Clair as 30,300, this indicates a yield of 20,100; and this is 9.14 per cent. of a flow of 220,000 cubic second feet.

Q. What percentage of the entire drainage basin of Lakes Superior, Michigan-Huron and Erie, including the water surfaces is the drainage basin of Lake Erie, including the water surface?

A. 16 per cent.

Q. And Lake Erie has a notoriously small run-off in comparison to its size, in comparison with the other lakes, has it not?

A. Yes. Another point comes in there in the presumably greater evaporation of Lake Erie, so that we can possibly get no yield from the rainfall in the water surface, while on the upper lakes there is a possibility of receiving some yield from the rainfall on the lake surface itself.

Q. I show you a chart entitled: "Elevation of Niagara River, Chippewa gage," which I will ask to have marked Shenehon's Exhibit V. I offer the chart in evidence and ask you to tell what it is; who made it and what it shows?

(Chart so offered in evidence by counsel for Complainant, was here marked Shenehon's Exhibit V.)

A. This is a chart in which the hourly elevations of the water surface of the Niagara River at the Chippewa gage are plotted in the vertical for elevations and the hours in the horizontal.

The tracing cloth or sheet on which this is plotted is graduated, so that each hour may be indicated, and each tenth of a foot and half tenth of a foot are indicated by the vertical scale, so that the elevations may be plotted one one-hundredth of a foot. The dates are given across the top of the chart, showing that the chart begins on October 21, 1907, and continues on the top line through November 6.

Q. Were those the same dates in regard to which you were cross-examined?

A. No. The date on which I was cross-examined was November, 1906, as I recollect; the first few days, first to sixth inclusive, in 1906.

A second line is plotted in the form of a series of dots, forming a dotted line that follows along the solid black line; the solid black line being the elevations, the observed elevations at the Chippewa gage. The elevations shown by the dotted line are computed from the observed elevations at the Buffalo gage for the several hours concerned, assuming a lag of two hours. This computation is made by using an equation which is indicated on the chart.

Q. What is that equation?

A. The equation is $H_C = 561.23 + .557\ (H_B - 570.00)$.

Mr. Adcock: Will you translate that into English?

A. In this equation, H sub C is the height at the Chippewa gage, and is so stated on the chart. H sub B is the height

of Lake Erie at the Buffalo gage, and the elevations are in feet above sea level.

The first term of this equation, 561.23 indicates the elevation at Chippewa when the Buffalo gage is 570. Then as the Buffalo gage varies, for instance when it rises a foot at the Buffalo gage, it rises .557, or at that rate.

Mr. Hopkins: Q. You do not mean the Buffalo gage rises .557, you mean the Chippewa gage?

A. The water surface at the Chippewa gage rises .557. In other words the movement at the Chippewa gage indicated here is 55.7 per cent. of the movement at the Buffalo gage.

Mr. Adcock: Q. That is the purpose of the equation, isn't it, to show that?

A. Yes, that indicates the relative elevations of the water surface at the two gages. The lower line contains similar information for the days June 26th to July 12th, inclusive of the year 1908.

This chart was made under my direction in November, 1913, in investigating the relationships of the water surface elevations to the fluctuations.

Mr. Adcock: Q. Did your assistant have anything to do with it?

A. Yes, this was made under my direction by my assistant.

Q. That is the same gentleman you spoke of the other day?

A. Yes, his name appears as delineator on the chart, Mr. M. E. Souther. The statement is made on the chart that the lag used is two hours, and this chart in its designation is indicated as "Studies in River Hydraulics."

There is also an accentuated scale of inches, to assist in understanding the relations of the two curves shown.

Mr. Hopkins: I ask that that be marked Shenehon's Exhibit V of this date.

(Document previously so marked.)

Q. Have you made any further checks or computations showing the correspondence between the Buffalo gage and the Chippewa gage, taking daily means? If so with what result?

A. I have made an investigation, in which I have examined the relation between the elevation of water surface at Chippewa with respect to the elevation of the water surface at Buffalo gage. This was done by taking five hour periods at each of the gages, taking Chippewa gage three hours later than the elevations at the Buffalo gage.

Q. What was the result of that, in respect to whether you can predict the elevation at Chippewa, and how closely?

A. I chose the month of November, 1907, for this investigation, and took the first ten days. My object in chosing the month of November was to obtain what is the worst month of the year so far as storm conditions are concerned, and variation of the surface of Lake Erie. It will give a very excellent test of the relationship under the most adverse circumstances of wind and storm and barometric gradient.

Mr. Adcock: Is that November 1st, to 10th?

A. Yes, November 1st to 10th inclusive.

I chose the year 1907 for another reason. That was that I wanted to use an equation which was derived from a different year, so that the charge of "circular reasoning," I believe it has been called in this case, could not be made. In other words the equation was that of the year 1906, while the observations were those of the year 1907, which were not used in deriving the equation.

Q. You wanted to be relieved of any accusation that you were reasoning in a circle, is that it?

A. Yes. This gave forty individual sets of five hours each, and the mean of those indicates that in three cases we have exact agreement. In other words, the prediction of the elevation of the water surface at Chippewa from the Buffalo gage is exact, and in 12 cases the agreement between the predicated value and the actual value is ½ inch or less. In 21 cases of the 40, the agreement is within one inch or less.

In 30 cases out of the 40, the agreement is within 1½ inch or less; and in 38 cases out of the 40, the agreement is within 2 inches. And the largest discrepancy is 2.7 inches.

During this period we had a range of elevation in Lake Erie from 572.18 to 574.14, or a little less than 2 feet.

Now it would not be fair to let the ability to predict the elevation at Chippewa from the Buffalo gage rest on possibly the worst month in the year, and so I have taken also a series of readings in the month of August, 1906. In these readings, we cannot escape the accusation of circular reasoning, that could not be applied in the other case.

Mr. Adcock: Q. That was August? What days?

A. I was just about to state that. As the first and second days are incomplete in the record of the Chippewa gage, I began with the third day of the month and took the dates August 3rd to 12th inclusive.

There are 40 predictions in this series, each—

Q. That was five hour mean?

A. Yes, these are five hour means, with the same lag of three hours. The prediction was exact in four cases out

of 40. It was within one quarter of an inch in 16 cases out of 40.

Q. Within ¼ of an inch?

A. Within ¼ an inch in 27 cases out of 40, and within 1 inch in 37 cases out of 40. The greatest discrepancy, a single discrepancy, is two inches.

Now if we take the means of the 20 hours on each particular day—

Q. What was your range in this case?

A. The range of Lake Erie, as indicated by these sets of means of five observations is from 572.11 to 573.15, or a little over one foot.

Q. These ranges in both cases were for five hour means?

A. Yes. They are not the extreme ranges of the lake.

Q. You said something about the 20 hours?

A. Yes. I was about to indicate the closeness of the check where we consider the means of the 20 hours for each day.

For the month of August, in four cases out of ten, the check is exact, the prediction was exact. In nine cases out of ten, the prediction is verified in the observed values at Chippewa within ½ inch and in one case the discrepancy is a little less than one inch, approximately one inch.

I made a similar investigation of the 20 hour periods for the month of November. This indicates that six predictions out of ten are less than one inch discrepant, the maximum discrepancy being 1¾ inches.

Q. If you had taken 48 hours it would have been closer, would it not?

A. Yes. The longer the period within limits, of course the more closely the lower gage will correspond with the upper gage, although the 20 hour periods appear very accordant.

Mr. Hopkins: Q. You have never contended, or tried to make those gages check for a less period than daily means have you, so far as this case is concerned?

A. In the computations deriving the values as indicated by the equation which I read, the daily means were used; that is individual observations, as I recollect it.

Q. In your opinion, what is the value of a check by using individual observations between the Buffalo gage and the Chippewa gage?

A. It shows that for approximately half of the ten hour day which may be regarded as the working day—

Q. I say individual observations?

A. You mean single, hourly?

Q. Yes?

A. There is not any necessity, as I see it. We have discrepancies for single hours.

Q. How do you explain those discrepancies?

A. That comes from the fact that when Lake Erie is rising, for instance, fairly rapidly, a portion of the outflow caused by that rise is used in filling up the river between Buffalo and Chippewa, and that means that the full volume of flow does not immediately reach Chippewa. And when the lake is going down we have the converse condition entering. The Chippewa gage is still discharging the water accumulated in the river by the higher lake stage, so in that case we have the residual of error of the opposite sign.

Q. It is hard to tell just when the crest has reached Chippewa, is it not? It is more rounded than at Buaffo, as indicated by that chart?

A. Yes, this chart shows very clearly that in the determination of the lag, for instance, between Buffalo and the Chippewa gage, the roundness or flatness of the crest at Chippewa makes the task a more difficult one than where the movement of the water is greater and the crests are sharper.

This is very well illustrated on November 3rd, where a well marked peak appears from the computed Buffalo gage, and a rounded elevation shows for the Chippewa gage. One might choose through a range of at least three hours the crest at Chippewa corresponding to the crest at Buffalo; and where the movement is less pronounced than it was on that day, as it was nearly a foot there, the difficulty appears from an inspection of this chart.

Q. In other words the changes at Chippewa are not so extreme but last longer. Is that not true?

A. Yes, there is a tendency to a little greater stability there than indicated by the movement at Buffalo.

Q. Also in taking hourly observations, can you tell just when the highest point has reached a particular gage?

A. There is a difficulty coming in from the fact that between the hourly elevations there may be a slight rise in the Buffalo gage, for instance, that does not appear in this record, between the even hours, so that we may not in the hourly scalings get all the actual peaks or all the actual valleys that really occurred.

Q. So that in your cross-examination, when you were asked to pick the next crest or the next valley after a certain elevation or depression at Buffalo, you can only get those on the hour, and there might have been one that happened in

the meantime that would not appear in the evidence, is that right?

A. Yes, that is true. I think the difficulty of predicting in the way in which the matter was put up in the cross-examination appears from this sheet; where we take a great many dates and a great many observations, we can get a sufficient number to reach,—not a prediction, but a statement of the lag.

Q. Did you include that matter in what you termed error of observation, that is you were only observing once an hour, or rather taking observations once an hour?

A. Yes, that was intended to be covered by that term; that it had to do with all the elements that might cause in a particular instance an erroneous result for the lag; and in the end, you understand, the lag—

Mr. Adcock: Q. Those were hourly means, were they not?

A. No, they are hourly scalings, just as if a man were at the gage—

Q. I know, but on this exhibit, Williams' Exhibit whatever it was—

A. No. Those are actual individual scalings of the gage roll. They are not hourly mean elevations. It is just as if a gage tender visited the gage once an hour and got what the water surface was at that particular time.

Q. On this automatic gage?

A. The gage rolls are graduated in hours, and simply the elevation of the water surface where this graduation comes is scaled off and the mean of the 24 hours of the day gives the mean elevation for the day.

Q. But the peak any time within the hour would be shown on the roll, wouldn't it?

A. Yes.

Q. And that is what you are supposed to read?

A. Not in this investigation, as I pointed it out to you.

Q. You read it for a certain hour?

Mr. Hopkins: Q. Just what it would be at ten o'clock sharp, eleven o'clock sharp.

A. (No response.)

Mr. Adcock: Q. Is that what is read out, ten o'clock or eleven o'clock?

A. That is the point, just as if we did not know what was in between the hours. They are simply the elevations at these hourly periods.

Mr. Hopkins: Q. Does that same situation apply in re-

gard to the two Gorge Sections, that is the Whirlpool and the Suspension Bridge?

A. Yes, with this exception, that the movement of the water is so much bigger there that the peaks and valleys appear very much better accentuated, so that it is a simple task to determine the lag, and yet we have this other thing that you mentioned, this fact that at Buffalo there may be a peak which is sending down water at the half hour, for instance, and which appears on the scaling of the gage at Suspension Bridge and the Gorge, and does not appear on the Buffalo gage as from the hourly scaling, you understand that condition still obtains, so individual observations are subject to the small errors coming from that.

Q. In other words there may be peaks or valleys that pass Suspension Bridge or Whirlpool that are not in the record which was used in the cross-examination of you?

A. Yes.

Q. The elevations at Suspension Bridge and Whirlpool were also taken at one hour periods, and not as hourly means?

A. Yes, that is a general principle in scaling these gage rolls, for the preparation of the sheets similar to the one that Mr. Williams presented to me, or Mr. Adcock presented to me in the cross-examination on Saturday.

Q. Then in those questions that were asked you in regard to a peak, wherein counsel stated that a peak appeared at Whirlpool two or three hours before it did at Suspension Bridge, it might have been a different peak entirely, so far as that one case would indicate?

A. Yes. There is that chance, and that was considered among the errors of observation.

Q. Mr. Shenehon, would you agree with Mr. Williams in the following testimony given by him on cross-examination in this case: (Typewritten page 1222-354, printed page 897.)

"Q. That is to say from the mean elevation at Buffalo you have been able to predict the Chippewa gage within substantially a quarter of an inch?

"A. That is correct. * * * It indicates the establishment of a relation with a satisfactory degree of precision, so far as gage elevations are concerned.

"Q. And I understand that the period covered is 11 months?

"A. Yes." Would you agree with that, the parts that I have read?

A. Yes, the 11 months refers to the prediction from the

Cleveland gage which Mr. Williams was able to make with considerable precision, mostly within 1 inch.

Q. The two questions were referring to different gages?

A. Yes, the daily means with respect to the Buffalo gage and the monthly means with respect to the Cleveland gage.

Q. You stated in your cross-examination that in the ultimate result you did not think it made any substantial difference in deriving an increment for the Niagara River whether or not you allowed eight minutes for lag from the Buffalo gage to the International Bridge. Will you explain a little more in detail why that is so?

A. Whether we take the water surface elevation at Buffalo gage for a period of ten minutes preceding our observations or ten minutes after would have substantially no effect on our final conclusions. It may make the discrepancy of an individual observation a little greater.

I may say also if we should extend that under ordinary conditions, and were in error in our lag by an hour that we would introduce into the final result, in my judgment, no substantial error.

The individual observations in that case would show a little more discrepant and in examining the discrepancy of the observations themselves we have a measure,—we could charge up to the gage entirely the discrepancy and it would indicate that it is very small.

Q. Why not?

A. Because the lake in the most cases does not change largely in a period of an hour and sometimes the change is a little rise and sometimes the change is a little fall. Of course individual cases where the change is charged to the incorrect lag, in that case would show in a discrepancy; the individual observation would plot off from the line.

Q. So that in a great number of measurements of observations, it would practically give you an elevation of the lake remaining stationary long enough for your observations or your measurements, discharge measurements?

A. Yes, that is true.

Q. Well, how about a period of four or five hours or twelve hours or more?

A. When you get much beyond an hour, you are beginning to introduce errors that will show very large discrepancies and may in the end affect the substantial accuracy of your increment. And in the case of 10 to 12 or 24 hours of course

you have reached a condition where you might have very discrepant results.

Q. In your opinion, what percentage of the time it takes the lag to travel from Buffalo gage to Chippewa, does it take for it to travel from the Buffalo gage to the International Bridge at Buffalo?

A. My view of the lag at Chippewa, is, as I stated, somewhere between two hours and 15 minutes and two hours and 40 minutes, and the lag at the International Bridge is from eight to ten minutes.

Q. The 17 per cent. that you gave on cross-examination was simply an answer to the hypothetical question there given you?

A. Yes.

Q. And that was based upon a rough approximation of depths, as you took them from the chart?

A. Yes, it is utilizing a formula in conditions that may be quite different from those in which the formula was derived. That is the Niagara River varies considerably in depth from the International Bridge to Chippewa, and this appears to make the application of the equation or formula somewhat erroneous.

Q. You stated in your original testimony that you some years ago computed an increment for the St. Lawrence River of 28,900. I believe it was pointed out that there should be a correction of 5½ per cent for the effect of the Gut Dam and 2 per cent. for the change to the Oswego gage?

A. Yes, from the Ogdensburg gage.

Q. Are there any other reasons why you are willing to adopt the new increments suggested by the Lake Survey and testified to by you in your rebuttal testimony?

A. Yes.

Q. What are they?

A. The greater range secured in the later observations have some bearing on that; and as I stated, earlier, an investigation by the method of fluctuations indicates somewhere in the neighborhood of 19,000 for an increment, which tends to verify the later results of the Lake Survey.

Q. Also there are more observations?

A. Then the other thing, the weak point in the original increment was the small range secured, in the neighborhood of two feet.

Q. Also you have many more observations, have you not?

A. Yes.

Mr. Adcock: Q. How many?

A. I cannot state that without looking it up.

Mr. Hopkins: I show you a chart marked Shenehon's Exhibit D1, of this date. What is the chart, by whom was it made and what does it show?

(Chart referred to was here marked Shenehon's Exhibit D1, May 18, 1914.)

A. This is a chart which is similar to Shenehon's Exhibit D, of April 15, 1914, in the matter of graduations for elevation of Lake Erie and the horizontal graduations for volume of discharge, and in other respects that are apparent on inspection.

This is entitled: "United States vs. Sanitary District of Chicago; Discharge Measurements of the Niagara River Plotted from the Records of the U. S. Lake Survey, Open Section, Buffalo, New York. 89 measurements selected by Mr. Gardner S. Williams, Expert witness on behalf of the Sanitary District from a total of 121 measurements in 1899-1900, shown thus." And on this chart it is stated that the increment used by the United States is 21,640.

The object of this chart is to show the observations taken under quiescent conditions as selected by Mr. Williams will give an increment for the elevations corresponding to the volume of flow for individual observations taken from the records of the United States Lake Survey an increment as determined by the United States namely 21,640.

The heavy black line threading these observations represents the law of discharge 21,740, used by the United States in Exhibit Number 4, U. S. Exhibit Number 4.

In further explanation of this chart, I desire to state that the 89 observations are plotted exactly the same as the observations are plotted on Shenehon's Exhibit D, of April 15, 1914. The only difference between those two so far as the plotting of the observations is concerned is that the number is 89, and these are selected observations instead of the full 121 plotted on Shenehon's Exhibit D.

Mr. Adcock: Q. Have you taken the elevation for a period or just for the time?

A. I will state further, the elevations and values are those appearing in the tabulations of the observations which have already appeared in this case, prepared by the United States Lake Survey.

Q. Does the diversion of water by the Power Companies at Niagara, divert it permanently from the Great Lakes?

A. No. The water is diverted, in the case of the American Companies, above the Cataract Rapids and returned to the

Niagara River in the Gorge, and goes on down the Niagara River into Lake Ontario and remains in the system of the Great Lakes.

Q. How much navigation is there between the intakes and the point where it is returned to the Niagara River?

A. In the case of the American companies, boats run as far as Port Day, which is the entrance of the lower canal, the Hydraulic Power Company's canal, which is a few hundred feet below the intake of the Niagara Falls Power Company.

Q. What size of boats?

A. Small boats only, tugs and scows and vessels of that character. I may add that what is known as the dead line extends from Port Day, which is the entrance of the Hydraulic Power Company's canal to Chippewa, and below this dead line navigation does not venture. When I say that, I presume in dumping the scows, there have been cases where they dropped below the dead line.

Q. This navigation that does go as far as Port Day, what is the draft of the boats?

A. Not over 15 feet.

Q. What is the depth?

A. Depth of the water itself?

Q. Yes?

A. The limitation is, I believe, to 14 feet. I am not certain they can carry 14 as far as this point.

Q. Do you know what effect there is on navigation by virtue of the diversions at Niagara; if so what?

A. There has been a lowering caused by the diversions of the power companies at Niagara Falls, the two American companies and the Ontario Company which takes its water from the head of the Rapids or a little ways down in the Rapids. Investigations however indicated that the divertor of the Ontario Company had nearly compensated the lowering. Assuming that there was a diversion at Niagara Falls of 20,000 cubic feet, the corresponding lowering—

Mr. Adcock: Q. There is some from the Canadian side, is there not?

A. The diversion on the American side is limited to 15,100.

Q. What is the Canadian diversion?

A. I am assuming that to be about 5,000 in the Ontario Company. That is the only one that has any effect whatever on what is known as the Grass Island Pool. The Ontario Company is the only Canadian Power Company that affects the elevation of water in the pool to which we have been re-

ferring; that is the water in the navigable portion of the river.

Mr. Hopkins: Q. What effect does it have on navigation, what ships are likely to be affected so far as navigation is concerned in the Niagara River?

A. There is very little navigation in the Niagara River below Tonawanda which is some distance up the river. There is, however, a sufficient amount of navigation so that the Federal Government is in control of the diversions at Niagara Falls.

Mr. Adcock: I object to that; and move to strike out the answer as it is not responsive to the question; states a conclusion, and is improper for the witness to give such a conclusion.

A. The lowering caused by a diversion of 20,000 cubic second feet in this pool would be a little over half a foot, .51 of a foot.

Mr. Hopkins: Where?

A. At Chippewa and the Grass Island gages immediately above the rapids.

Q. Chippewa is below this diversion, isn't it?

A. Chippewa is across the river from the American Power Canals and above the Ontario Company's intake. I think you understand that the diversions at Niagara Falls have been permitted and limited by Congressional action, and the permits from the Secretary of War.

Q. You have a letter from Major Keller that you wanted to submit here?

A. When the Hydraulic Power Company in December, 1911, asked me to undertake certain investigations for them, I was a little in doubt as to the propriety of doing the work for a power company, after having made the investigations of all the conditions for the Federal Government and having made recommendations to it.

I may state, however, that the power company wished me to carry out for them certain recommendations as to ameliorating works made in my report which is known as the report on the Preservation of Niagara Falls. So I wrote to my friend and my superior officer in the Lake Survey.

Mr. Adcock: At that time you were not connected with the Lake Survey?

A. No, this was in December, 1911. It was something over two years after I had severed my connection with the Federal Government. So I wrote Major Keller, asking his views on this and he replied as follows, I put this letter in evidence:

United States Engineer Office.
"Rock Island, Illinois,
December 28, 1911.

Mr. Francis C. Shenehon,
Dean, College of Engineering,
University of Minnesota,
Minneapolis, Minn.

Dear Shenehon: I have yours of the 28th, and am sorry that you cannot join us on the Panama trip. Perhaps at some later day we may be able to get together on some similar undertaking.

In the meantime, I wish to answer your inquiry as to whether in my opinion there is any reason why you should not undertake the commission offered you by the Hydraulic Power Co. While I have some hesitation in offering opinions concerning questions that after all each man must decide in the light of his own conscience, this case seems so clear that I give you my opinin for the little that it is worth. There is in my mind not the slightest doubt that you are fully at liberty to accept the commission which has been offered to you. Your previous official knowledge of the matter will enable you to do fuller justice to the United States in case any interest of the United States should be involved, and I feel sure that should such interest become evident, you will be amply able to devise means of reconciling the private with the public good. It is an advantage to the United States to have someone with really expert knowledge of all the considerations involved to handle a matter of this kind, and I therefore feel free to wish you a long and successful engagement.

Very sincerely yours,
C. KELLER,
Major, Corps of Engineers."

Mr. Adcock: I wish to object to the introduction of that letter in evidence, on the ground it is entirely immaterial; it is incompetent and has no place in determining any of the questions involved in this suit.

The Witness: I wish to make a further statement concerning this letter, that Major Keller was Officer in Charge of the Lake Survey, at the time the Chicago Drainage Canal case was initiated, and it was through his recommendation that I have been continued as expert for the Federal Government in this case. So he has full knowledge of all the elements entering into my employment and I regard his advise as very sound, excellent.

Mr. Adcock: I move that the further answer of the witness be stricken out as immaterial and incompetent.

Mr. Hopkins: Q. Mr. Shenehon, does the fact that you have been employed by and are in the employ of the Power Company have any effect upon your testimony in this case?

Mr. Adcock: I want to object to that question as it is not competent for a witness to state what interests he may have in a law suit; conclusions in regard to what may affect his testimony. That conclusions is to be drawn from the facts. It is entirely improper on re-direct examination, or in any event, to ask a question of that kind.

Mr. Hopkins: You went into the question of his interest. No one knows about that better than he does.

Mr. Adcock: You cannot ask him a conclusion as to his interest. You can ask him the questions and bring out the facts.

Mr. Hopkins: Answer the question.

A. Not in the least.

Mr. Adcock: I move that the answer be stricken out.

Mr. Hopkins: Mr. Shenehon, in your opinion, would a diversion at Chicago cause any material effect on the Great Lakes?

Mr. Adcock: I want to object to that on the ground that it is incompetent, immaterial and irrelevant. It is improper to ask the witness a question which may be the issue in this law suit, or which involves one of the issues in this law suit; ask him a conclusion as to the ultimate fact or an ultimate fact. It is an attempt to invade the province of the court. That is for the court to determine from all the facts which may be presented.

Furthermore it is improper on an examination of this witness at this time in so called rebuttal.

Mr. Hopkins: I did not give you the amounts: Suppose 2,000, 4,000, 10,000 or 14,000 cubic feet per second?

A. The diversion as mentioned would unquestionably, in my judgment, have a substantially detrimental effect on the Great Lakes from the lower entrance of the ship locks at Sault Ste. Marie to Montreal.

Mr. Adcock: I move to strike out the answer of the witness for the reasons that I stated in the objection to the question.

Mr. Hopkins: That is all.

Re-cross Examination by Mr. Adcock.

Q. You say that on the drainage area of the Erie basin, there is a notoriously small run-off, do you?

A. I understand by the word "notoriously" one that is reputed to be of small yield.

Q. Have you ever computed the run-off yourself?

A. I have been very willing to accept the conclusions reached by Mr. Gardner S. Williams as indicated by his table LIXA, presented in this case, in which he derives a value for the run-off, from an examination and investigation, of 33 per cent.

Q. That is about 20,000 cubic feet per second?

A. Yes. I figure it 20,100; 20,000 is sufficiently close.

Q. That is slightly less than the 16 per cent. that you mentioned, somewhat less than the 16 per cent. of the total discharge of the Niagara River?

A. Yes.

Q. About 10 per cent.?

A. A little less than 10 per cent.

Q. As I understand it, figuring drainage areas, you calculate that there is a certain percentage of run-off for the amount of rainfall in a year, do you not?

A. That is one way of computing it, with a variation in the percentage with the amount of rainfall.

Q. That is as the rainfall varies, the run-off will probably vary, the precipitation?

A. Yes; that is I believe an accepted view.

Q. That is the larger the rainfall, the larger the per cent. of run-off?

A. Other things being equal.

Q. You have considerable data with reference to the average rainfall on the various drainage areas of the Great Lakes, have you not?

A. Yes, that is given in Mr. Wheeler's report 1903.

Q. And from that you can ascertain the relation of rainfall between the different drainage basins of the Great Lakes?

A. From the values given of the rainfall, we have some relative figures that will assist us in doing that.

Q. Isn't it a fact that relatively the rainfall upon the Erie drainage basin shown by these records is greater than on the other drainage basins, Michigan-Huron, for instance?

A. Mr. Wheeler, in his report of 1903, page 2861, gives the annual rainfall as a mean between 1882 and 1898, of 26.26 inches for Lake Superior; for Michigan-Huron, same period,

32.21; St. Clair-Erie, the value does not appear to be properly printed, but a deduced value is 34.08; and for the Ontario basin 36.87. This would indicate that the Erie rainfall is greater than the Superior and Michigan-Huron rainfall, as indicated in this tabulation, and less than the rainfall on the Ontario basin.

Q. That is about two inches less?

A. 2.8 inches less.

Q. If there is more rainfall on the drainage basin of Erie, it is reasonable to suppose that there is more rainfall on the lake surface than on the Michigan-Huron and Superior lake surfaces?

A. That would be a fair presumption. As the gages are on the shore line, just what the rainfall may be on the lake surface is not definitely known, that is the proportion it bears to the whole drainage basin.

Q. What data have you with reference to the evaporation, relative evaporation on the lake surfaces?

A. I think you know that I regard this matter of evaporation as a matter that our knowledge is not very definite about.

Mr. Adcock: I will ask the reporter to read the question. I move to strike out the answer of the witness.

Q. (Question read.)

Mr. Hopkins: If any?

Mr. Adcock: I didn't ask him that.

Mr. Hopkins: I have.

A. I will be very glad to read from these same tabulations of Mr. Wheeler.

Mr. Adcock: Q. I am not asking you to read. I am asking you what data you have with reference to the relative evaporation on the lake surfaces?

A. I read from page 2861—

Mr. Hopkins: He did not ask for that; he asked for your own knowledge.

Mr. Adcock: Q. I will add: Independent of discharge, so-called discharge measurements.

A. I should expect evaporation to be less on Lake Superior and Michigan-Huron, and less on Ontario than on Erie.

Q. You would expect it to be?

A. Yes.

Q. What data have you outside of your so-called discharge measurements? You know we do not want to get away from reasoning around in a circle, that you were so afraid of a little while ago?

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A. I have no independent data.

Q. You have no independent data?

A. No.

Q. What data is there outside of the deductions made from so-called discharge measurements?

A. Referring again to Table LIX A, of Williams' Exhibit 34, the full year run-off for Michigan-Huron is given as 0.866; Erie, 0.664 and Ontario, 1.440, indicating that Ontario is more than twice that of Erie.

Q. Mr. Shenehon, you are familiar, are you not, with the experiments on evaporation made by the United States Weather Bureau with reference to evaporation?

A. Well, not in detail. I have never felt that the conclusions that might be reached on the Great Lakes from any observations on tanks on shore, or the measure of the humidity, was conclusive evidence of the evaporation on the Great Lakes. I believe that is a thing yet to be solved.

Q. In other words, you have discarded those experiments entirely, have you? You did not think it necessary to study them in connection with this lawsuit?

A. In my evidence I think I said that in the physical analysis we could presume these values for the rainfall and evaporation to be sufficiently good to permit us to go on and test one river by interpolating in between. I used the values derived by Mr. Stearns in his tabulations.

Q. Do you understand that the evaporation from land drainage areas is subject to the same laws as evaporation from water surfaces?

A. Hardly.

Q. You have presented an exhibit here, Mr. Shenehon, has been marked Shenehon's Exhibit V. That was prepared I believe you said by your assistant, Mr. Souther on about November 19, 1913, in which the two hour lag was used, in preparing that exhibit. You do not think that is the correct value for the lag between Buffalo and Chippewa, do you?

A. The value I have more recently given is from two hours and 15 minutes to two hours and 40 minutes.

Q. And in connection with your preparation of certain figures here with reference to gage readings from November 1st, to 10th, 1907, at Buffalo and Chippewa, in which you took the mean of five hours, you used three hours as the lag?

A. Yes.

Q. As the value of the lag, Buffalo to Chippewa?

A. I had to choose in each case an even hour.

Q. You also used the same value for the lag in connection with the deductions from gage readings, Chippewa and Buffalo, August 3rd, to 12th inclusive, 1907, did you not?

A. Yes, on each of the two sheets which I presented today, I used a lag of three hours as the nearest even hour. In preparing these, I had the possibility of using both the two hour and three hour by including six hours altogether, but I thought it would be better in this investigation to compare five hours with five hours.

Q. The value of the lag is 50 per cent. more than the values which you gave earlier in your testimony, is it not?

A. Yes. They are each of them even hours; each of them is in error.

Q. You say that the readings are every hour, so that it is impossible to give us any intermediate time; but on those exhibits which were prepared by Mr. Souther, we found some instances where the lag was computed at two hours and a half, one hour and a half, five hours and a half, did we not?

A. Yes, and I can explain that I think. Where it was doubtful whether the peak was on a particular hour or the one following, he would take the mean of the two instead of taking either one.

Q. He exercised his judgment there, did he?

A. Yes.

Q. From the observations?

A. Yes.

Q. From the recorded gage readings?

A. Yes. There are very few of those, however.

Q. Now will you compute the Buffalo gage from the Chippewa gage, showing in a dotted line the computed Buffalo gage from the Chippewa gage and by a heavy line the actual elevation of the lake as shown by the Buffalo gage for the Three Curve Series?

A. You mean I am to prepare four sheets?

Q. Yes? You have the data, have you not from which the Three Curve Series was made?

Mr. Hopkins: For what period of time?

The Witness: I would protest against the method of determining the Buffalo gage in that way because it is inverting the order of things. The reason for the height of the Chippewa gage is the volume of flow caused by the elevation of the Lake Erie surface.

Q. As I understand from your examination previously, you stated that it was possible by this relation to predict the

height of the Buffalo gage from the Chippewa gage, did you not?

A. I may state right here that the 40 observations which I have indicated would indicate that you might predict the Buffalo gage from the Chippewa gage with a value which would be in the ratio of 1.00 to 0.56,—in other words you simply reverse the order in these statements I have made,—of course that means this would nearly double up, where you would be off a half an inch in predicting from Buffalo to Chippewa, in reversing the thing you would be off nearly an inch. Your predictions would bear about that relation?

Q. For the mean of say 48 hours at Chippewa, you could predict the Buffalo gage pretty closely, couldn't you?

A. Mr. Williams predicted the 24 hour means in many cases—

Q. I am asking you?

A. (Continuing)—within a quarter of an inch, and reversing the process, the Buffalo gage may be predicted by the same series of observations within half an inch, but of course in most cases it would be an inch or more.

You are using a short base line to get the larger quantity.

Q. I would like to have you make that computation that I asked you to make?

Mr. Hopkins: For what time?

Mr. Adcock: For the time covered by the discharge observations in the Three Curve Series.

The Witness: You mean hourly plottings?

Q. Yes?

A. (No answer.)

Q. Does the water abstracted by the Power Companies at Niagara Falls have any effect upon the level of Lake Erie?

A. A very minute effect.

Q. What would be the effect of the use of 56,000 second feet by the Power Companies upon Lake Erie? That is the amount I believe that under the treaty—

A. Let me understand exactly where you wish the diversion to be made.

Q. By the Power Companies.

A. There are two Power Companies at Niagara Falls whose diversions have absolutely no effect upon the elevation of Lake Erie; that is they take their water from well down in the rapids, below the cascades.

Q. Assume that it is above the cascades; assume that the additional quantity is above the cascades.

A. You mean the whole 56,000 is above the uppermost cascades?

Q. No, the excess of 56,000 over the present diversion is above the cascades.

Mr. Hopkins: In other words, what is the total present diversion?

A. About 20,000 cubic feet. I don't know exactly how much the Ontario Company is using.

Mr. Hopkins: I understand if an additional 36,000 is taken above the cascades.

Mr. Adcock: In addition to what is already taken.

Mr. Hopkins: I object to that question as not based on any hypothesis in the case. There may not be any 56,000 taken at that place rather than any other place.

A. I think there is no probability whatever of any such amount being taken above the uppermost cascades. If however, that amount were taken under the same conditions that the Ontario Company is taking its water, intercepting a sufficient amount of flow in the rapids and taking—

Q. I am asking you to assume that was taken under the same conditions as the American Company takes it.

A. If 36,000 second feet are diverted from the Grass Island-Chippewa Pool, under the same conditions as the two American Companies now divert their water, the effect on Lake Erie would be a lowering of approximately 2¼ inches.

Q. Plus or minus?

A. A lowering, I said, of 2¼ inches.

Q. The American Companies take about 15,000 feet now, do they?

A. 15,100. They are taking right up to their limit.

Q. They have lowered or will lower the level of Erie about an inch, will they not?

A. An investigation made and reported in the Preservation of Niagara Falls indicated that between my earlier measurements of 1898 to 1900, and the later measurements of 1907-'08, there had been no lowering whatever of Lake Erie from diversion at Niagara Falls; and the reason for that is that the Ontario Company had backed the water up a little by their divertor which was thrown out into the rapids.

Q. Assuming, as you stated, that 36,000 would lower it 2¼ inches, 15,000 would lower it a little over an inch, would it not?

A. Slightly less than an inch.

Q. How much would a diversion of 2,000 feet from Lake Michigan lower Lake Erie?

A. In the neighborhood of an inch, a little over an inch; 1.1 inches roundly.

Q. That is based upon your increments that you have been talking about heretofore. Is that correct?

A. Yes, that is having in mind U. S. Exhibit Number 3.

Q. When you took those longer periods, 20 hour periods in making your reductions to predict the elevation of Chippewa from the Buffalo gage, you did that to eliminate so-called oscillations of Lake Erie, did you not, sudden oscillations like those occurring in an hour or two hours?

A. The exactness of the prediction is the evidence of that; and an examination of the results I think should be rather conclusive on that point.

Q. It was for the purpose of eliminating the effect of the oscillations in Lake Erie, was it not?

Mr. Hopkins: The question is what was the purpose of taking the time?

A. The reservoir effect in the river between Chippewa and Erie due to changes—or, if you may wish to speak of that as oscillations in Lake Erie, is the reason why a 20 hour period gives more exact predictions than a five hour period. It tends to eliminate the effect of oscillations.

Q. If the Buffalo gage were at an even elevation for a number of hours, say 24 hours, and assuming a straight line as you might plot them, or horizontal line, approximately horizontal, and the Chippewa gage were in the same position, that is with reference to these horizontal lines, for a number of hours, you would then consider that the river was in equilibrium, would you not?

A. Yes. Where Lake Erie is quiescent over a period of hours and the flow in the river becomes a steady thing, then we speak of it as being in equilibrium.

I think I would like to speak of the back water effect due to say three inches abnormal elevation at Chippewa, the effect it would have on the floor. The backwater effect has a value of roundly 20 per cent.; now .25 of a foot, which is the decimal expression for three inches, would mean .05 of a foot on the Buffalo gage; and that is equivalent to 1100 cubic second feet, or ¼ of 1 per cent. of the normal outflow. And you will notice in the five hour periods that I took, in the worst month of the year, November, that there was just one case where the maximum deviation of Chippewa from its predicted value was as much as 2.7 inches.

Mr. Adcock: That is all, subject to the other question.

Adjourned to Wednesday, May 20, 1914, 10:00 o'clock A. M.

FRANCIS C. SHENEHON resumed the stand and further testified as follows:

Further Re-cross Examination by Mr. Adcock.

Q. On your previous examination, Mr. Shenehon, you were asked to make certain computations; that is to compute the elevation of Buffalo gage from Chippewa based upon the formula which you had derived as the relation between Buffalo and Chippewa. And I have before me four sheets which purport to be plats which I understand have been prepared by you, covering the dates named upon the so-called Three Curve Series. I ask that the Commissioner mark these papers Shenehon's Exhibits E1, E2, E3 and E4, Cross Examination. (Sheets so marked.) These papers that have just been marked, have been prepared by you, have they, Mr. Shenehon?

(Sheets referred to in above question were here marked Shenehon's Exhibits E1, E2, E3, and E4, Cross Examination.)

A. Yes, prepared by me personally except one sheet on which I employed a draftsman and I checked his work sufficiently to feel sure that it is correct, substantially correct.

Q. Now the curve which appears at the top of these different sheets as the black line is the observed elevation of Buffalo gage, is that correct?

A. Yes, and that means each hourly elevation is plotted and a scale made of height and time.

Q. And the red line is the computed elevation of Buffalo with reference to the Chippewa Gage, is that correct?

A. Yes, that is true.

In your question you asked me to plot that in the form of a dotted black line. I found that the predicted elevation and the computed elevation were interwoven so much that it was difficult to distinguish the black dotted line, and so plotted it in red. If you wish it done, I can go over that with a solid dotted line.

Q. The red line shows the computed?

A. That is the predicted, the computed elevation.

Q. From Chippewa gage. And you use there your law, the one that you have testified to?

A. Yes.

Q. What was that by the way? That is if Chippewa changes say one foot, you expect that Buffalo will change a certain amount?

If Chippewa changes .56 of a foot, Buffalo changes one foot. That is the ratio.

Q. That is the ratio?

A. Yes.

Q. Of course we can see can we not, Mr. Shenehon, whether this red line is so interwoven with the black line that it would be impossible to distinguish a dotted black line, can we not?

A. That may be done as you wish. I will point out specific cases where the difficulty appears.

Q. For instance at noon on June 29, or between noon and six o'clock on June 29, they would not be interwoven very much, would they?

A. There are cases where they are very sharply and clearly apart, and I imagine in cases they would be as much as six inches apart in lake elevation; those sudden changes, either rising or lowering.

Q. Referring, again, to October 22, about noon of that day, and in fact covering October 21, and October 23, the red line is not interwoven very much with the black line, is it?

A. October 21 and 22?

Q. 22 and 23.

A. Those are fairly distinguishable.

Q. That is you can see that the red line is some distance from the black line there, can you not?

A. Yes, it is 1/10th of a foot in lake elevation different in a good many cases on those three days. In some cases it is as much as .3 of a foot, nearly 4 inches.

I might call your attention however,—

Q. I will ask you further questions, Mr. Shenehon, if I may have those exhibits, all of them, after you get through.

A. You understand, Mr. Adcock, I can go over this with a dotted black line if you prefer to have it in that way, after you have investigated whether or not it is going to confuse the plot.

Q. It does not make any difference, Mr. Shenehon; a red line is just as good as a dotted black line. In fact, on the 26th and 27th of October, the 28th and 29th, the 30th and 31st, November 1st, November 2nd, the lines are not very close together, are they?

A. That was commencing October 30th?

Q. No, before that?

A. Yes, the lines on the 27th, they coincide over a period of about six hours, so that they would not be clearly distinguishable. The lines cross; that is the line of actual elevation is crossed by the red line, the predicted elevation, in a number of cases on the 29th.

Q. But you can see some space between, can you not?
A. In some cases they actually are superimposed.
Q. That is the six hours that you have mentioned?
A. Yes. And in other cases the lines cross, indicating that the predicted at that point is exact.
Q. Of course the court can see that too, can it not?
A. Yes.
Q. Then on August 4th, 5th and 6th, the red line and the black line are not very close together, are they?
A. There are considerable divergencies on the dates mentioned. That was the last sheet plotted by me, and there are sharp changes of elevation on those three days, which indicate a large movement at Buffalo, where the movement predicted from Chippewa would not indicate that.
Q. Well, the result of it is generally, is it not, from those plottings, that the computed elevation, the predicted elevation is lower at the high points and higher at the low points than the actual observed elevation?
A. Yes. That has been repeatedly stated by me I think in my testimony.
Q. You agree to that proposition, do you?
A. Oh, sure.
Mr. Adcock: There are a few questions I would like to ask Mr. Shenehon further on cross-examination.
Q. Over how long a period of time did your several current meter ratings last at the reservoir at Buffalo, and through the ice?
A. I should have to refer to the records to answer that question, Mr. Adcock.
Q. Have you any recollection at all as to the period of time?
A. We would spend two to three days at a time in ratings, and the ratings were perhaps a month or two apart. I should wish to refer to the report of 1900, for a specific statement concerning that. You are referring to the Niagara River now, or the general practice?
Q. The Niagara River?
A. (After referring to report.) I find that for the L. S. 2 B Meter, this was rated on a still water base in September, 1898; in July, 1899, at the reservoir in Buffalo; in September and October, 1899, same place; in November at the same place; also in February, 1900, at the reservoir at Buffalo.
I find for the L. S. 4 A Meter, that it was rated in July, 1899, at the reservoir at Buffalo; September, October, the same place.

Another equation is given for October, 1899, November, 1899, and February, 1900. Now my recollection as to the time would be anywhere from two to three, possibly four days. I hardly think it was as long, however, as four days, ordinarily.

Q. What table do you refer to, Mr. Shenehon?

A. I refer to table 4, summary of meter readings, on page 5339 of the report of the Chief of Engineers for the year 1900.

Q. Does that table indicate all the ratings of the meters that were made?

A. Up to the date, February, 1900. I am not certain whether another rating was made prior to leaving, in June or July of the same year, or not.

Q. But that includes all the ratings that were made up to the date of the report?

A. Those are all the still water ratings. Of course other ratings were made in the river itself, side by side, comparisons which are of a somewhat different nature.

Q. How frequently was the meter cleaned and oiled during the ratings, these two or three days that you speak of, that is each meter?

A. Why I should say as often as two or three hours. You must remember you are asking me something about what occurred 15 years ago, 14 years ago. I can't give you down to the last minute.

Q. How many revolutions, or how many feet of current travel was there between oilings in ratings, including both recorded and unrecorded revolutions?

A. That would be a different thing to get at. Roundly, 2.4 miles.

Q. That is between each of the oilings?

A. That of course is approximate.

Q. That is approximate?

A. I should add that if anything were wrong with the meter, as sometimes did happen, it was necessary to take it up, then it was generally oiled.

I wish to be understood however as saying that in my practice, very little oil was used; nowhere near the quantity of oil indicated by Mr. Haskill in his statement. Our practice was to put just a little oil on the very tip of the pivot, both in rating and in the river work.

Q. Did you take it apart to do that?

A. You have to take off the wheel, yes; that is the wheel is raised from the pivot.

Q. It hasn't any self oiling system?

A. Oh, no.

Q. How frequently was the meter cleaned and oiled during the Niagara gaging?

A. Why at the beginning and end of the discharge observations ordinarily. Sometimes, where anything went wrong in between, then the meter was also raised as in the rating and the wheel taken off, and any trouble investigated.

Q. How often did you have trouble?

A. Oh, it was not very frequent. In handling the two meters, I think ordinarily we would not pick up a meter during a discharge measurement for that purpose. I am thinking now of the work on the catamaran in the Open Section.

Q. How about the International Bridge?

A. There of course the meter was picked up between each measurement at the station.

Q. And oiled?

A. No, not oiled unless it was indicated. When I say indicated, the reason for oiling was ordinarily what is known as a skipping, a few too many registrations, coming from a little oil getting on the silver or platinum disc. And that was infrequent. That was the reason why I used so little oil, so that that should be infrequent.

Q. How often did you have trouble, every hour?

A. I should say not. I should say that was—

Q. Every two hours?

A. I should not think it would average over every two hours, possibly not as frequently.

Q. Would you oil it every time you had trouble?

A. Whenever we took off the wheel and wiped off the disc, it was customary to touch the cork of the watch oil bottle to the pivot, put a fraction of a drop of oil on the pivot.

Q. A fraction of a drop. What fraction?

A. You would not put what would drip from it. We would tilt the bottle up, and a little oil would remain on the cork that we would touch on the pivot of the meter.

Q. You did not use an ordinary oil can?

A. No, we used watch oil; used it in that way, worked right from the watch oil bottle.

Q. You oiled it by means of a cork, what little oil remained on the cork?

A. We upset the bottle, you understand, with the cork still in, and turning the bottle up, touched the cork with the adhering oil to the pivot.

Q. Did you ever run for a day without having any trouble?

A. In running for a day, the meter would be oiled at noon after the completion of a discharge observation.

Q. That is in case you had no trouble, you would oil at noon, and then again at night?

A. Yes, and if we were measuring discharges, if we got across the river and started back, we would ordinarily overhaul the instruments before starting back.

Q. That is between each discharge measurement you would oil the meters, is that correct?

A. Yes.

Q. In your gagings of the Niagara River at the International Bridge Section, how many miles of current travel were there past the current meter between oilings, including both recorded and unrecorded?

A. Well, it would be quite different on the Bridge Section from the Open section. You refer to the Bridge Section?

Q. I am speaking of the Bridge Section now, Mr. Shenehon?

A. On the Bridge Section; this statement must be approximate, of course.

Q. Certainly?

A. That would be about three miles.

Q. On the Open Section, what was it?

A. That might be a little more than three miles because I did not in that computation take account of the unrecorded. There should be a little more added to that.

Q. It would be pretty near double, wouldn't it?

A. No, I think not. No, it would be the time of lowering the meter and raising it, which is a very short time. No, I should say possibly 3½ miles would be a fair statement of that.

Q. That is in the course of making a discharge measurement when the meter would turn and there was no record made of its revolutions?

A. That would be the time that we are lowering the meter from the water surface down to the .3 depth.

Q. Down to the .4 depth?

A. In the International Bridge, it is .3.

Q. There were how many stations there, Mr. Shenehon?

A. Twenty-one stations.

Q. It is your proposition that in making the discharge measurement the meter would only run a half a mile, in lowering and raising it to the .4 depth at each of the 21 stations?

A. Well, I figured that we made two 2 minute observations, that is four minutes on the station where the meter is wound up. You see in the deepest point .3 is only 15 feet, and the meter is lowered fairly rapidly, and as soon as the observation is completed, it is raised very rapidly.

Q. How soon after the meter is lowered to the depth—.3 depth, is it not?

A. Yes.

Q —do you commence to take the record?

A. Immediately.

Q. That is on the instant?

A. I don't mean on the instant.

Q. It would be half a minute?

A. Let me figure this now: This is a statement that is made approximately. Let's see how much that would be. I said 3½ miles of which three were kept in the regular recorded observation. That would be, four minutes would be 240 seconds; 1/6 of that would be 40 seconds; that is the half mile is 1/6 of the three miles; that would be 40 seconds. That would be 20 seconds for lowering and 20 seconds for raising, which is reasonable. It is fairly close to that.

Q. 20 seconds for lowering and 20 seconds for raising; and also in the 20 seconds after lowering, you would have commenced to get your record too, would you?

A. Well, if we are going to make these corrections and make it with the utmost refinement, I should add something considerable to what I have given you for still water ratings. I have given the actual revolutions that were recorded. You see we made a run on each side of the base going both directions. I should add 50 per cent. at least to that. It was a 200 foot base. We begin at least 50 feet back and we would run at least 50 feet over the base, so where I stated a travel of 2.4 miles it should be 3.6 miles.

Q. What percentage of the time was the meter out of the water during the period of a single discharge measurement at the International Bridge?

A. About two hours was a normal time for discharge, and if we observed four minutes at each station, that would be 84 minutes; leaves 36 minutes for the raising and lowering of the meter and the move between stations.

If you wish to get this with all the revolutions of the meter, I am afraid I can't give it to you because sometimes there would be wind blowing while the meter was being raised from the water surface to the bridge, and the wheel would spin. That would be true also in rating, in our preparation of the meter. You see it is rather difficult to get a determinate, comparable statement of these things. I see what you are getting at, and I am going to help you all I can, but you see I can't tell you very exactly about that.

Q. You still maintain do you Mr. Shenehon, that the meter only ran half a mile?

A. I should think that was a fair estimate and we did not take into account any spinning in the air. There should be a little added for that.

Q. You are also considering the 21 stations at the Bridge Section?

A. Of course in the end it does not make much difference whether there is oil on the pivot or not, within a reasonable limit.

Q. What was the average current at the Index Point?

A. Well, I have, in this rough computation, taken four feet per second.

Q. You have taken four feet per second as the average, have you Mr. Shenehon?

A. Yes. I think that is on the low side.

Q. You think that is on the low side?

A. I think I should add about ¼ to that statement, bringing the velocity up to a mean of about 5 feet per second. Now let me see where that goes to; that would be 3¼ miles; ¼ added to that would be 4.37. Yes, that would be about 4.37.

Q. That is not allowing anything for the raising, for the time the meter was moving?

A. Yes, that is true.

Q. What is your estimate of the miles of travel of the meter, that is the recorded travel?

A. I make 4¼ miles the travel on the rating base and 5¼ miles the travel on the International Bridge Section in a discharge observation.

Q. How much was meter B pulled upstream at the International Bridge at depths of 10, 20, 30, 40 and 50 feet, in Spans 3, 4 and 5?

A. My recollection is in coefficient work that we pulled it up from 8 to 10 feet.

Q. At all these positions?

A. I don't recollect in detail what we did at a particular station. That amount of upstream pull would not be required, in my judgment, in more than a few of the spans, those deeper spans.

Q. How was it in gagings, discharge measurements?

A. In discharge measurements there was no pulling of the meter upstream. The meter with the heavy 136 pound weight dropped from the rail of the bridge, over the rail of the bridge.

Q. How many miles of travel were there, current travel,

between oilings of the meter in coefficient work at the International Bridge Section?

A. I can't give you definite figures on that, Mr. Adcock.

Q. Well, approximately?

A. I should say it was much the same as in discharge work; possibly a little more frequent.

Q. More frequent oilings. You had more trouble?

A. I say "possibly." No, we were using two meters at the International Bridge where we used one in the discharge work.

Q. I wondered why you oiled it more frequently in coefficient work?

A. I don't know that we did.

Q. Did you pull your meter out of the water and oil it before you got through a vertical?

A. Before we got through a single vertical?

Q. Yes?

A. Not ordinarily, no.

Q. How long would it take you to make your observations in a single vertical for coefficient work.

A. That was different lengths of time.

Q. Would you oil it before you went to another station?

A. Not necessarily, no.

Q. You did not have any regular practice about that in the coefficient work?

A. The meters were ordinarily always oiled before starting out in the morning and always in the afternoon.

Q. Before starting out after dinner?

A. If there was any reason why it should be overhauled between times, it was done.

Q. When you say if there was any reason why it should be oiled between times, you mean if there was any trouble?

A. Yes, sometimes the connection, you understand there was trouble with the connections.

Q. If there was not any trouble then you oiled it before going out in the morning and after dinner before commencing your work in the afternoon, is that right?

A. Yes, that was the regulation, to always oil the meter at those times and such other times as might be required. When I say "required," you understand that a meter is an instrument that is clicking just as intelligently to the observer as a telegraph instrument tells the operator what the message is. We know what is happening down in the water very accurately. We know when a little oil gets on the disc,

and we have the sharp double click breaking into the regular rhythm of the spinning of the wheel. We know when the water is turbulent. When we get into an eddy, we can tell immediately.

Q. You would not oil it when you got into an eddy?

A. No. I am explaining that there are reasons why we know we need to bring up the meter and overhaul it, and it is because this spinning wheel with the electric connection is telegraphing the message to us constantly.

Q. Then the operator would have to use his judgment as to when he should oil?

A. The same judgment that the telegraph operator uses.

Q. Now Mr. Shenehon in the Open Section, you said the time of travel between oilings was very different from that at the International Bridge, did you not? You mean it was shorter or longer time of travel?

A. That differed. Certain of the measurements in the Open Section were made while coefficient work was going on. In other words we would observe eight minutes on a station. In such a case, it would take longer to get across the river; and other times, of course, we made observations much the same as at the International Bridge, two 2 minutes runs. So which time do you refer to in your question; where we are taking coefficient observations at the same time?

Q. I wanted you to explain just what the difference was?

A. In the case of the Open Section, the meter would not be raised from the water between stations, so during the two hours or longer which it took to take a discharge observation the meter wheel would be spinning. If you can get the mean velocity of the current, that works out in that case. That might be a way to get at it.

Q. You testified as to the derivation of increments for the St. Lawrence and St. Clair Rivers, using the Niagara increment and the Lake Erie run-off. That was on your re-direct examination. When was that computation made?

A. I never have made any computation of that kind.

Q. What computation did you make then, using the run-off of the Lake Erie Basin?

A. I made a computation in which the consistency of the volume of flow of the—

Q. That is the discharge of the Niagara River?

A. Yes, as compared with that of the St. Lawrence River, by introducing the local supply as computed by Mr. Stearns in his Exhibit Number 1, I think it was, using 16 years; be-

ginning in 1891. Another computation was made in which I took the run-off as given by Mr. Gardner S. Williams in his Exhibit 34; that is an average.

Q. Sheet 5 of table 69e?

A. I have not the exhibit before me; 59, I think it is.

Q. 59?

A. Using table 59a, of Williams' Exhibit 34, and the period June to November. This gives the average run-off of 0.924 cubic feet per second per square mile of drainage area for Ontario.

Q. Did you examine table 59e, sheet 5, in that connection?

A. Sheet 5, of table 59e, pertains to the run-off of Lake Erie rather than Lake Ontario. Is that the one you wish to refer to?

Q. Yes?

A. I have this table before me. I have never very carefully examined the details of any of these sheets. The conclusions appear to be in consonance with the volumes of flow of the rivers and that appeared to me sufficient.

I should add, however, that the method of getting at the thing is to my mind the correct one, examining the run-off of the streams in the lake areas themselves, just as Mr. Stearns examined the run-off of the streams in Massachusetts, New York and Pennsylvania.

Q. I call your attention to the tabulated discharge of the Maumee River from July to November, shown on sheet 5, of table LIXc, Williams Exhibit 34. What is there shown as the area, drainage area above Waterville?

A. 6,111 square miles.

Q. What is the recorded run-off from this area for July, 1899?

A. 285 cubic feet.

Q. What is this per square mile?

A. That is 0.046.

Q. What is the run-off for August 1901?

A. 47 c. f. s.

Q. What is this per square mile?

A. A little less than 0.008 cubic feet per second per square mile.

Q. What is the run-off for September 1900?

A. 27 c. f. s.

Q. Or 0.0044 c. f. s. per square mile?

A. Yes, about that.

Q. That is pretty small per square mile, isn't it?

A. Yes.

Q. Hardly conceivable?

A. Well, I have lain at anchor in the Maumee River, with practically no current running.

Q. Was that in the canal or the channel of the Maumee River?

A. That is at Toledo, in the Maumee River.

Q. Did you ever lay at anchor in the canal?

A. No.

Q. Did you know there was a canal there?

A. At Toledo?

Q. No. In the Maumee River?

A. No.

Q. Paralleling it. What for September 1901, was the run-off?

A. 42 c. f. s.

Q. And per square mile that would be what?

A. About .007.

Q. For October, 1899?

A. 48.

Q. About .008 cubic feet per second?

A. That would be about .008.

Q. For October 1900?

A. 41. That would be about .007.

Q. And for October 1901?

A. 246.

Q. .04, is that right?

A. Approximately .04.

Q. And for November 1901?

A. 98 cubic feet per second, about .016.

Q. Do you think it possible that 6,111 square miles of drainage area on the Maumee River should only contribute from .0044 to .047 cubic feet per second per square mile, when the average of all the rivers, the Maumee included, as shown in table LIXa, is never less than one hundred and twenty-six thousandths cubic feet per second?

A. I imagine the error of observation enters into these observations, as all others.

Q. You said you did not know anything about the canal paralleling the Maumee River near Waterville, from which large quantities of water are used for power purposes?

A. No, I am not familiar with that.

Q. In view of this condition as to the run-off records from about 50 per cent. of the measured area of Lake Erie, upon which would you place the greater reliance, the records as

published by the United States Geological Survey and embodied in Table LIXa, Williams' Exhibit 34, or a run-off derived from rainfall observations as used by Mr. Stearns?

A. I think the best values we have for determining the relationship, that is the local supply of Lake Erie are from the finely gaged rivers, St. Clair and Niagara; and I think the best basis we have of determining the local supply for Ontario is the Niagara and the St. Lawrence Rivers. There are not any others comparable in precision to those, in my judgment. You are asking me a question regarding the local supply.

Q. I asked you a question, and I hoped that perhaps you might answer the question that I asked you. I did not understand that your counsel had asked you any question which would require an answer.

A. Will you please read the question?

Q. (Question read.) You told me something about comparing the Niagara discharge and the St. Clair discharge. I have not asked you anything about that. I am asking with reference to the run-off data as compared with the rainfall data.

A. I think it is understood that Mr. Stearns used a similar method to that used by Mr. Williams in getting out his formula which he applied to the Great Lakes, and made an estimate. Mr. Stearns, as I understand it, used such stream gagings in New England, Pennsylvania and New York as were available. Mr. Williams uses a similar method, only he uses the streams in the basin of the Great Lakes themselves, instead of alien streams, streams not in this basin.

Doubtless the streams used by Mr. Stearns were somewhat in error. I imagine that the final conclusions of Mr. Williams are likely to be in error possibly as much as 33⅓ per cent., and the error of observation is certainly present in all of these stream gages. Now, I believe Mr. Williams' method was a correct one.

Q. That is you would place greater reliance on that?

A. Even considering the little flow as indicated, pointed out.

Q. That is the extraordinary conditions shown on the drainage area of the Maumee River?

A. I rather persist in feeling that my earlier answer to your question was a correct one, because I must take into consideration all the things that do affect my judgment in these matters.

Q. I have asked you to take into consideration certain specific things. Then you place the greater reliance upon the

United States Geological Survey records, shown in table LIXa?

A. Yes. They check, from the results gotten out by Mr. Williams, they check very closely the volumes of flow of our records, and that really is the big test we have of the physics of the Great Lakes. What the local supply is is best tested by the flows of the rivers of the basin itself.

Q. When did you make that computation?

A. The first computation between the Niagara River and the St. Lawrence was made at the time of the cross-examination of Mr. Freeman, I believe. It was introduced, I think, in his cross-examination.

Q. You did not make a computation with reference to that matter until after Mr. Williams had testified in this case, did you?

A. No, that is true; until both Mr. Stearns and Mr. Williams had testified.

Mr. Adcock: I think that is all.

Further Re-direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, in these computations that were made from the Chippewa gage to the Buffalo gage, you were still taking the hourly observations were you not and plotting them according to the method requested by counsel for the defendant?

A. Yes, they are from the records of United States Lake Survey, the hourly readings at Chippewa used as a basis of deriving the elevation of Lake Erie; and I used in this connection a lag of two hours.

Q. You did not have the data showing the elevation of the 59 minutes between the hours, or for all the time between the hourly periods, did you?

A. No.

Q. And in your direct testimony in this matter, you testified that you could get a certain degree of accuracy using daily means, did you not?

A. Yes, 20 hour means, I think I used in a statement in my re-direct testimony, and then I used also five hour means, and of course those same predictions made of the elevation at Chippewa can be reversed by taking the reciprocal of 56 as a basis. In other words, where I stated that the check between Buffalo and Chippewa was 1 inch, where we are deriving Chippewa from Buffalo, it would be about 1.8 inches where we

reversed the process. That is the ratio of 1 to 56 is 1.78 roundly. It would be rather interesting to simply reverse those predictions for the months of November and August, that I put into my re-direct testimony. It would indicate that in five hour periods how fairly close you can predict the elevation of Lake Erie at Buffalo from the elevation of the water surface at Chippewa, which is 20 miles down the river in distance and is down about 10 feet in elevation. It is remarkable, and I should be very glad to compute those and put them into the record.

Mr. Hopkins: We will reserve any further examination.

Further Re-cross Examination by Mr. Adcock.

Q. You say you used a two hour lag?

A. Yes.

Q. I thought we convinced you sometime ago that it was not two hours exactly. Have you gone back to the two hours?

A. This matter of lag, the exactness of it has very little bearing really on the questions at issue. I believe I said that the lag, in my judgment, was somewhere between two and three hours, and two hours and 40 minutes seems to me a very good value.

Q. If I recollect Mr. Shenehon,—I may be mistaken; your memory may be more correct than mine,—but I understood you to say you put the minimum at 2 hours and 15 minutes; the maximum at 2 hours and 40 minutes?

A. Let me state one other thing—

Q. Is that a fact?

A. Yes, that is the truth. Let me add one other thing: In the exhibit which I put into this case, Shenehon's Exhibit V, on cross-examination, the lag was two hours on that, and in order to keep the series much the same, this you see is a reverse process of the same thing, it seemed wise to make that two hours.

Q. In other words two hours was your story, and you are going to stick to it?

A. I think the testimony is pretty full on that subject.

Further Re-direct Examination by Mr. Hopkins.

Q. Why doesn't the lag make much difference?

A. The changes are ordinarily so slow that whether you take 2 hours or 2 hours and 40 minutes, or 3 hours between

Buffalo and Chippewa, really is of little consequence. I think an examination of these exhibits which have been put into the case this afternoon will indicate that two hours is fairly close, and possibly it will indicate also that 3 would be a little closer; but it is not a matter of any large moment. It does not enter into any of the real issues of this case, in my judgment. You understand within these limits I am mentioning at Chippewa, whether we take two hours or three hours is of no great consequence.

Further Re-cross Examination by Mr. Adcock.

Q. You think if you had taken 3 hours instead of 2 hours, it would be somewhat more exact?

A. I think it would be a little closer but not very substantially.

Q. If you were going to make up a series of exhibits such as you have made up heretofore in this case, you would take 3 hours rather than 2 hours?

A. I think I would, yes. You remember that I remembered a thing that I had forgotten, that we had before used 2 hours and 40 minutes in some previous computations.

Further Re-direct Examination by Mr. Hopkins.

Q. Mr. Shenehon, what difference if any would it make whether or not a meter had been oiled after it ran two miles, three miles, four miles, five miles or six or any other length, within a reasonable period?

A. Referring now to these large Haskell meters, the A, and the B, types, where the wheel is a little over seven inches in diameter, and this wheel is spinning like a thimble on a needle, the pivot gives very little friction and running in the velocities, a mean velocity say of five feet such as we have been considering, the current is so powerful that that friction is really of little moment.

In my judgment there would be substantially no difference whether we had any oil on the pivot or not. The principal friction or resistance in turning comes in in the bearing of the contact pin on the disc that I have already spoken of. That has some moment. In other words, it is a little distance from the axis of revolution, and that is the real critical thing that determines a change in rating.

Further Re-cross Examination by Mr. Adcock.

Q. The meter is a pretty delicate instrument, isn't it?

A. Yes, but as I previously stated, it is a fairly strong one, also.

End.

VOL. 6

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS,
EASTERN DIVISION. } ss.

IN THE

District Court of the United States

UNITED STATES OF AMERICA,
Complainant,
vs.
THE SANITARY DISTRICT OF CHICAGO,
Defendant,

C. C. No. 29,019 and
Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

MR. JAMES H. WILKERSON,
United States Attorney, and
MR. ALBERT L. HOPKINS,
Assistant United States Attorney,
For Complainant.

MR. EDMUND D. ADCOCK and
MR. ALFRED S. AUSTRIAN,
For Respondent.

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UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS, } ss.
EASTERN DIVISION.

IN THE

District Court of the United States

UNITED STATES OF AMERICA,
Complainant,
vs.
THE SANITARY DISTRICT OF CHICAGO,
Defendant,

C. C. No. 29,019, and
Equity No. 114.

SUR-REBUTTAL EVIDENCE ON BEHALF OF THE DEFENDANT.

Depositions in the above entitled cause, taken pursuant to notice, before the Commissioner at the Federal Building, Chicago, Illinois, April 15, 1914, at 2 P. M.

Appearances:

Mr. Albert L. Hopkins, on behalf of the Government.
Mr. Edmund D. Adcock, and Mr. Alfred S. Austrian, on behalf of the Sanitary District.

DENNIS McCARDHY, a witness called on behalf of the Sanitary District, was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?
A. Dennis McCardhy.
Q. Where do you reside?
A. Chicago.
Q. What is your business?
A. At present I ain't in any business.
Q. Have you been connected in any way with the Chicago River, with navigation on that river?
A. Yes, sir.
Q. Will you state what your connection has been; what you have done on the river and how long you have been familiar

with the conditions there, and with what concerns you have been connected.

A. Well, I have been on the Chicago River, connected with it for 40 years. Now, for about 10 years, I was engineer on a dredge; for 30 years superintendent for different companies, working on the Chicago River dredging and docking and so on, etc.

Q. Have you been on towing crafts?

A. Well, I have superintended, that is having charge of the tugs towing crafts.

Q. In your occupation, you were brought in direct contact with the river, were you?

A. Yes, sir.

Q. During the navigation season about how many times during the day would you travel or navigate, go up and down the Chicago River?

A. Oh, sometimes once, sometimes five times, four or five times.

Q. For what space of years; how long did that continue?

A. Well, for 30 years.

Q. And when did you stop, along about the year 1912, was it?

A. That I resigned?

Q. Yes?

A. Yes, in 1912.

Q. Now, you were connected with the Chicago Towing & Dredge Company, were you for a time, dredging and towing company?

A. I was connected with the Chicago Dredging & Dock Company, the Lydon & Drew Company, and the Chicago Great Lakes Dredging Company.

Q. During what period were you connected with the company that you first named?

A. Well, it was in the eighties; I just don't recollect.

Q. Up until about the year 1896, was it?

A. Along about that, yes.

Q. Do you know about what year in the eighties it was?

A. Sir?

Q. Do you know about what year in the eighties you became connected with the Chicago Dredging & Dock Company?

A. Well, it might have been 1880 or 1881, or somewheres along there. I could not recollect the dates exactly.

Q. Were you superintendent then of their work?

A. Not when I first went to work for them. I was engineer of a dredge. About 1881 or '82, I became superintendent.

Q. What did their work consist of principally?

A. Dredging, docking, piledriving and foundations, bridge foundations and so on.

Q. And towing?

A. Towing their own—doing their own towing, such as mud scows, dredges, piledrivers and so forth.

Q. And your duties as superintendent made it necessary for you to traverse the Chicago River and its branches at different times during the navigation season, and each day?

A. Yes, sir.

Q. And you were familiar with the conditions of navigation upon the Chicago River?

A. Yes, sir.

Q. During that period?

A. Yes, sir.

Q. From 1896 until what time were you connected with the Lydon & Drew Company, or the Great Lakes Dredging & Dock Company?

A. Well, from 1896 until 1912.

Q. You were superintendent for them, were you?

A. Yes, sir.

Q. Of their work. Did they have anything to do with work upon the Chicago River itself, and its branches?

A. Yes, sir.

Q. Just state in general what work you did during that period?

A. Well, their work consisted of deepening and widening the river, docking, dredging, building piers for breakwaters, bridge foundations and so on, etc.

Q. And while you were superintendent for Lydon & Drew, or the Great Lakes Dredging & Dock Company, both, did you become familiar with the navigation conditions during that period on the Chicago River?

A. Yes, sir.

Q. And you traversed the Chicago River and its branches in the same way that you did before, did you?

A. Yes, sir.

Q. In your work for these various companies, was it necessary for you to tow scows up and down the river?

A. Yes, sir.

Q. Prior to 1900, what was the capacity of the scows that were usually towed?

A. Well, from 150 yards up to 180 yards.

Q. In recent years you have had larger scows, have you not?

A. Yes.

Q. What capacity are they?

A. Well, from 750 to 1,000 yards.

Q. You have had occasion to tow those scows, scows of that capacity, have you not?

A. Yes, sir.

Q. During what period was it that you towed the larger scows?

A. Well, let me see: I would say offhand the last six or seven years, seven or eight years; six, seven or eight years.

Q. When you speak of capacity, you mean that is the capacity of the scows carrying the mud or other material, cubic yards?

A. That was the yards, yes, sir, yardage.

Q. How were those scows towed; was there just one or two?

A. No, we could tow one to three. We have towed three.

Q. They were fastened together, one following another?

A. Yes.

Q. And they had a tug in front?

A. Yes, sir.

Q. And the motive power was steam?

A. Steam tugs.

Q. On the tugs. No motive power on the scows?

A. Not at all.

Q. How about the steering, as compared with boats that are towed in the Chicago River?

A. There is no steering of a scow. The tug has to control the—

Q. In your opinion is it more difficult to tow scows than an ordinary boat that is towed on the river?

A. Yes.

Q. Under those conditions?

A. Yes, I think it is more difficult.

Q. If there is difficulty in navigation, it would be more apparent in towing the scows that way than towing boats?

A. I would say it is more difficult to tow the scows, on account of no steering apparatus.

Q. And because they have no motive power of their own?

A. No motive power of their own.

Q. What has been the condition of the Chicago River since 1900, or since the work done by the Sanitary District in the deepening and widening of the Chicago River was commenced, and has been practically completed, with reference to navigation, as compared with the condition which existed prior to that time?

A. Well, now, you know that is a question that when we started, we did not improve the conditions; it took several years to go along and make—improve those conditions.

Q. The question I intended to ask you is this: Since the work has been practically completed?

A. Yes.

Q. The deepening and widening the river. As I understand it, Mr. McCardhy, before the Sanitary District commenced its work the Chicago River, the depth was about 16 feet, and they have deepened it now to approximately 26 feet. Is that correct?

A. Yes, that is correct; from 14 to 16 feet is the depth of the Chicago River.

Q. And the Chicago River has also been widened by the Sanitary District to approximately 200 feet at all points except points, certain places now under improvement, is that correct?

A. Yes. The United States Government also worked in widening the river some places.

Q. At the same time that the Sanitary District did, in conjunction with that work?

A. Yes.

Q. And the Sanitary District has put in or replaced a number of bridges with bridges having wider bridge openings, have they not?

A. Yes. In other words, they have taken away the center piers in a great number of bridges.

Q. Having those things in mind, how is the condition of the Chicago River, the main river, the South Branch and the West Fork to the beginning of the Drainage Canal, with reference to navigation, how does it compare now with the conditions which existed prior to the doing of that work which you have mentioned?

A. Well, I would say they are far better to-day. There is some improvements to be made yet, as I understand, that they are about starting at now. The Chicago River to-day, and has been for the last year, south of 12th street, south of 12th street with the exception of two railroad bridges which they are about taking out, why you could not improve it any more than it is.

Q. Do you consider that these particular improvements that have been made and that are now being made at the bridges, taking those improvements into consideration, do you consider that the conditions of navigation there will be good?

A. I do. I think they will be very good.

Q. You refer, do you not, Mr. McCardhy, to the Van Buren street bridge situation?

A. Yes.

Q. To the Jackson street bridge?

A. Yes.

Q. When you speak of the Van Buren street bridge, that is the Metropolitan and the city bridge there; there are two bridges there?

A. Yes.

Q. And the Madison street bridge?

A. The Madison street bridge.

Q. That is under improvement. The 12th street bridge?

A. Yes.

Q. The Pennsylvania bridge which has been ordered out?

A. Yes.

Mr. Hopkins: I think the witness ought to do the testifying. I object to leading questions.

Q. And the 16th street bridge, the Air Line bridge?

A. Yes.

Q. Which has been ordered out as you understand it, Mr. McCardhy?

Mr. Hopkins: I object to the question as leading.

A. The greater part of this is under way now. The greater part of this improvement is under way now.

Q. When the improvements referred to, now under construction, are made, what in your opinion will be the condition of navigation upon the Chicago River, the South Branch and the West Fork to the Drainage Canal?

A. Well, I would consider it a very navigable stream, the river, very easy to navigate.

Q. How will that condition compare with the conditions with reference to navigation that existed prior to the opening of the canal and the making of these improvements?

A. The conditions of these improvements made, and the condition of the river previous to when these improvements were started would be 500 per cent. ahead of what was there when they were started.

Q. Mr. McCardhy, the Government introduced some witnesses here last week, showing that there was a considerable current at certain points in the river. Have you come in contact with those points?

A. Yes, I have.

Q. What points?

A. Washington street.

Q. Did you have occasion to pass that spot frequently?

A. Yes.

Q. While there was a current?

A. Yes.

Q. What occasioned that current, if you know?

A. Well, they were putting in new foundations for the bridge and they had cofferdams in on each side of the bridge

which narrowed the stream up so much that it caused this current. Instead of the water passing through a 200-foot channel it was passing through a 100-foot channel, so it must have caused the current.

Q. That was merely a temporary blockade?

A. Yes, during the time of construction of the bridge.

Q. That has since been removed, has it not?

A. Oh, yes, that is removed.

Q. Has that current you refer to, disappeared?

A. The current has disappeared.

Q. What other, if any, points have you observed where there was a strong current at different times?

A. Well, at the Pennsylvania Railroad bridge.

Q. What was that occasioned by, if you know?

A. By the new construction they were putting in for the new bridge. They narrowed the channel up there with the piers, abutments.

Q. That was necessary for the purpose of making the improvements?

A. Oh, yes, it was necessary.

Q. Do you know who ordered that improvement?

A. Well, I don't know whether it was ordered by the United States Government or the Sanitary District, I don't know who it was ordered by.

Q. When that obstruction and those cofferdams are removed, which are necessary to rehabilitate or reconstruct that bridge, in your opinion that current will be removed?

A. Oh, there is no doubt about it.

Q. Any other spot you noticed that was particularly dangerous to navigation at any other time?

A. Well, there is another bad spot at, I guess at Congress street where that power house stands.

Q. That is under condemnation now as you understand it?

A. Well, I don't know.

Q. Immediately north and south of that power house, the river is 200 feet wide, isn't it?

A. Yes—well, it has been widened. I just don't know what width it is.

Q. The record in this case shows it is over 200 feet wide?

A. Yes.

Q. When that is removed, the obstruction occasioned by that power house, this current that you refer to will likewise be eradicated, will it not?

A. Yes.

Q. Have you observed the improvements made by the

Sanitary District with reference to straightening out any parts of the river?

A. Yes, sir.

Q. For instance, Mr. McCardhy, I draw your attention to a blueprint which on its face indicates: Map shown to Witness Green, number 2; particularly that part of the blueprint between 22nd street and Halsted street?

A. Yes.

Q. Will you state in what way the Sanitary District has caused the river to be improved for the benefit of navigation at those points between the two lines indicated, Halsted and 22nd street?

A. They cut off this pocket (indicating) and widened out the river there.

Q. They cut off the property from Dupont's Slip on the west side of the river to the lot marked 6 adjacent to the words "Lumber street"?

A. Yes.

Q. Do you know how much they took off at the widest part there?

A. Well, my recollection would say in the neighborhood of 100 feet there on the widest part.

Q. It tapered down as indicated on that plat?

A. The Sanitary District done some work there and also the United States Government.

Q. They worked in conjunction there, did they not?

A. Yes, they done some work.

Q. I draw your attention to the south bank, south and east bank of the river, mostly east, from Ogden Slip to 22nd street?

A. Yes.

Q. They likewise took out a great quantity of earth there, did they not?

A. Yes.

Q. Do you recall how much they took out?

A. I do not. I don't remember how much was taken out.

Q. It was a very large quantity?

A. It was, of course there was one wider place.

Q. Did they deepen the river from Halsted street to 22nd where that improvement was made?

A. Yes, sir.

Q. What effect did the improvements I have just referred to make on the navigability of the stream between Halsted street and 22nd street?

A. Well, it made easier navigation to commence with, and it done away with accidents that happened along there on account of this narrow river.

Q. What did they call the river between Halsted street and 22nd street prior to this improvement made by the Sanitary District?

A. The name that marine men called it and river men called it was "Collision Bend."

Q. I have drawn your attention not to those two improvements. There were many other improvements made by the Sanitary District of the same character?

A. Yes, sir.

Q. Along the river, were there not?

A. Yes, sir.

Q. Were you familiar in your travels with the question of the occurrence of accidents and collisions in the river prior to these improvements by the Sanitary District?

A. Yes, sir.

Q. Were there a great number of collisions, a large number of collisions occurring prior to that time?

A. Yes, sir, there was a great many collisions.

Q. What was the general character of the collisions that occurred in the river before it was widened, before it was deepened and before it was improved by the removal of center pier bridges?

A. Well, away back in those times before this was improved—

Q. By "this," you mean from Halsted street to 22nd street?

A. Yes. I judge that 80 per cent. of the boats passing through there at that time was sail vessels towed by tugs. Of course, they are gone up, and there ain't very many sail vessels towed by tugs any more, but at that time you would hear of 20 collisions such as vessels colliding and their jibbooms taken away, where you would not hear of one or two in a season, I don't believe you would hear of one in a season now. That was a common occurrence every day or two to hear of those collisions.

Q. Mr. McCardhy, in your travels up and down the river and working in and about the river between 1900 and 1912, or in the later years of the period 1900 to 1912, were collisions and accidents on the Chicago River greater in number than they were before, or less in number?

A. They were less in number.

Q. Was the Chicago River in your opinion and is the

Chicago River and the South Branch and the West Fork of the South Branch in 1912, and up to the present time easier of navigation than it was prior to the turning of the river, and prior to the making of the improvements that you have referred to?

Mr. Hopkins: All this examination about the comparative navigability of the river will be objected to.

Mr. Austrian: I will state for the benefit of the record that the objection, in my humble opinion, comes with poor grace from the counsel on the other side who introduced it into the record on the last hearing of the testimony in this case.

The Witness: Do you want me to answer that yes or no?

Mr. Adcock: Yes.

A. I say that south of 12th street, principally south of 12th street, navigation is far easier than it was those days. Now, there is several improvements to be made north of 12th street for to make the—

Q. North of 12th street it is easier than south of 12th street?

A. South of 12th street it is finished, that is completed except those two railroad bridges.

Q. Under process of reconstruction?

A. Yes. North of 12th street, there is several of them bad points to come out yet.

Q. And they are under improvement at the present time?

A. Well, that is what I understand. I don't know that.

Q. You haven't been down to look at it?

A. No.

Q. When those critical points that you have referred to are improved by the construction of new bridges and the removal of center pier bridges and the other improvements that you have referred to are made north of 12th street, how in your opinion will the Chicago River compare with reference to navigation in its present state as compared to its state prior to the making of these improvements by the Sanitary District, taking into account, if you please, Mr. McCardhy, the fact that the Chicago River is flowing away from the lake now, while prior to the making of these improvements it was flowing into the lake?

A. Well, I would say the improvements carried on north of 12th street as they have been carried on south of 12 street, that navigation would be 500 per cent. easier in these conditions than it would prior to 1900.

Q. And in making that statement Mr. McCardhy, have you

taken into consideration and account the fact that the vessels to-day are much larger and of greater tonnage, length and beam, than they were when this improvement was initially started?

A. Oh yes, I have, because we have followed that up ourselves in our own business. We have increased our scows and dredges and so on in size; and tugs.

Q. Nearly five times, have you not?

A. Yes.

Q. How did the navigation with these large scows in later years compare with the navigation of the smaller scows in former years? Is it harder or easier?

A. They are easier except I say at these bad spots.

Q. Where it is being improved?

A. Yes.

Q. In your experience in operating on the river, did you have occasion to come in contact with freshets or flood conditions prior to the reversal of the flow of the Chicago River?

A. Yes, sir.

Q. Will you state what those conditions were and what effect if any they had on navigation?

A. Well, there is one in particular that I recollect, and I could not exactly state the date of that. But my experience was this: That I was building a dock for the S. K. Martin Lumber Company on the Northwestern Railroad Company in Mud Lake, and I had pile drivers there, of course, working at it, and Saturday night we tied up for over Sunday, and Sunday I was called up and the water had raised in the neighborhood of seven feet, and my pile driver was up in the lumber yard. Now the dock was about 4 feet over water, well it took from 3 to 3 1/3 to float the pile driver. The water had raised that much, she had got up over the dock, floated up over the dock. It didn't last over maybe three days, two or three days, something like that. But the date of that I do not recollect now. It might have been—I don't know just what date it was.

Q. The evidence previously taken in this case shows it was in 1892 or 1893.

A. I could not say offhand the date.

Q. Mr. McCardhy, this place that you speak of, was that on the Chicago River?

A. It was on the Chicago River, yes.

Q. What were the freshet conditions, the water conditions that frequently occurred in the spring?

A. Every spring we had a freshet. I think this one I speak of was the worst one we had, but it was a common thing to

have the water raise three or four feet in the spring of the year.

Q. Did that create a current?

A. Oh my, yes, it was a regular—

Q. Did it have any effect on navigation?

A. They could not navigate, too costly.

Q. Since the opening of the Sanitary Canal and the making of these improvements, do you know of any such conditions existing?

A. No.

Cross-Examination by Mr. Hopkins.

Q. During your business experience you have been superintendent for these various companies you have mentioned?

A. For about 30 years.

Q. You are not a navigator as such are you?

A. No.

Q. You have no license as a commander of a vessel, anything of that kind?

A. No.

Q. You have never done any practical sailing yourself?

A. Oh I have, yes.

Q. What?

A. Well, I have often steered a tug up and down the river, but I am not a licensed man, don't you know.

Q. Now these scows that you have been using in recent years, your big ones, how long are they?

A. Well, from 125 to 135 feet long.

Q. How wide?

A. 40 and 41 feet; from 38 to 41 feet.

Q. What is the depth?

A. 12 feet.

Q. What draft do they carry, 12 feet?

A. They are about 12 feet draft, about 12 1/2 foot sides. We load them right down, decks too. We often have them draw 12 feet loaded.

Q. Now you say that a tug draws from 1 to sometimes 3?

A. Yes, we have had 3 on. 2 is about the average but we often have had 3.

Q. Have you had 3 loaded, carrying them against the current?

A. Yes, sir.

Q. What time of the day and when have you done that?

A. Well, the city passed a law here some years ago that we

could not carry—we should not tow 3 and since that we had to stop it. We were forced to.

Q. When was that passed?

A. It might be two years ago. The city won't allow us to tow three scows in one tow now.

Q. Two years ago?

A. Something like that, it might be two, but the city passed that law.

Q. Now so far as current is concerned, does it make much difference whether you tow one or two scows? Doesn't the first one break the force of the current?

A. The first one of course, the current from the tug wheel hits the first one, and also what other little current there is.

Q. What investigation have you personally made as to the depth of the Chicago River in recent years?

A. I have had the superintending of the dredging of it.

Q. You wish to state in this record that there is a depth of 26 feet all along that river?

A. I would not say that there is all along; there may be spots there is not. But our contract with the Sanitary District called for 26 feet of water. Now they had an inspector on there and if we did not get the 26 feet, we were notified that there was not 26 feet. Now, where the tunnels is, of course that is only in the latter two or three years when Van Buren street tunnel was lowered. Up to that time there was only, I think, 17 feet of water over Van Buren street tunnel, or somethink like that. Now there is 27 feet on top of the tunnel.

Q. Some of this dredging was done quite a long time ago, wasn't it?

A. No, there was some of it done in the last two or three years.

Q. I know, but some of it was done quite a long time ago, wasn't it?

A. Yes.

Q. Do you undertake to go the full length of the river every year?

A. No.

Q. So that some of those parts that was 26 feet eight, nine, or ten years ago, may have been much filled up since?

A. The river don't go eight or ten years without dredging. It is dredged oftener than that, but it is not dredged every year.

Q. In connection with your work, there is nothing that you do to check up on the depth every year. You really don't

know unless it is some particular place you happen to be working at?

A. The Sanitary District or the Governwment, or whoever it might be, gives us orders with specifications. Now it is my duty to instruct the men aboard that dredge what to do, whether to take 20 feet or 26, or whatever it is. That is what I always did.

Q. That is when you did the work?

A. Yes.

Q. After that, after you finished your job you don't know how much it has filled up?

A. No, did not care.

Q. Did you do the dredging for the width?

A. Yes, sir—well, maybe not in all cases, but the majority of places I done the dredging for the width.

Q. Aren't there a great many places along the length of that river where the width is less than 200 feet?

A. I could not say offhand to that. The width I would not say offhand what it is.

Q. You mentioned the Washington street place. What is the width there now since they have completed their work?

A. I don't know.

Q. What is the width at the Metropolitan Bridge?

A. I don't know.

Q. Is that the place where there is a by-pass around under the Pennsylvania Station?

A. Yes.

Q. Do you know anything about the current or the conditions in that by-pass?

A. I don't know how much current there was. I knew water passed through there.

Mr. Austrian: Through the by-pass?

A. Yes, but I don't know what current there was there.

Mr. Hopkins: Q. How long has it been since that by-pass was dug there?

A. Oh, I don't know. It might be nine or ten years ago. I don't know just when it was.

Q. That is covered over isn't it with a platform?

A. Yes.

Q. So that since it was dug, there has been no dredging whatever in that?

A. No.

Q. And the part of the river that is open there is less than 100 feet, isn't it?

A. The width I don't know. The width I don't know.

Q. So that you don't know what the width of the river is?

A. No, I don't.

Mr. Adcock: Mr. Hopkins, you understand that the Metropolitan Bridge has been ordered out by the United States Government. They have been directed to put in a wider bridge, a bridge with wider openings. Do you want us to produce the order of the Secretary of War, ordering that out?

Mr. Hopkins: No. If you want that fact in the record I am willing to admit it.

Mr. Adcock: Willing to admit it has been ordered out by the Secretary of War?

Mr. Hopkins: Yes.

Mr. Austrian: We are going to put a witness on to show all those things.

Mr. Hopkins: I don't know what the conditions are.

Q. I believe you said that you of your own knowledge don't know just what part of the river is under improvement and what is intended to be improved?

A. No, only what I hear. What I hear may not always be true.

Q. You spoke of some collisions in Collision Bend down there, and it is not so bad as it used to be in that place. At that time, they were mostly sailing vessels, weren't they?

A. Mostly—well, I would say 80 per cent. pretty near of the boats that passed there was sailing vessels towed by tugs.

Q. And down there in the river the tug had to do all the controlling, didn't it?

A. Yes.

Mr. Adcock: Q. They had steering—

Mr. Hopkins: Q. You had a great many vessels—

Mr. Adcock: Q. They had steering apparatus on the sailing vessels, didn't they, Mr. McCarhdy?

A. Let me understand the equestion there.

Mr. Hopkins: Which question?

A. The last question.

Q. I said they had a great many more vessels in the river at that time, didn't they?

A. Yes. I say that 80 per cent. of them was vessels, sailing vessels.

Q. I mean of any kind or shape, you had more ships in there?

A. More ships in there, yes.

Q. Whether sailing or steam or not?
A. Yes.
Q. As a matter of fact, there was more tonnage in the river then than now?
A. No, I would not say more tonnage.
Q. Do you know whether there is more or less since 1900?
A. I understand there is more tonnage now, in the river, than there was those days, but not the number of boats.
Q. Would it make any difference if you knew that there was less tonnage?
A. No, it would not make any difference but I say that was my understanding.
Mr. Adcock: Q. These sailing vessels of course had steering apparatus, didn't they?
A. Oh yes, yes.
Mr. Hopkins: Q. They also had long booms sticking out?
A. Yes.
Q. Things of that kind?
A. Yes.
Q. What was the nature of the accidents?
A. The river was very narrow, and it was not only narrow but it was going around a bend like this (illustrating) and if two boats met in that narrow places, some of them was going to collide. Now there was, for a long time, the boat coming this way (indicating), or the boat going this way (indicating), meet in that bend, whichever was the furthest away would have to stop until this boat got through. And we have had to stop thousands and thousands of times waiting for some boat to get through, running there with our scows.
Mr. Adcock: Q. That was before 1900?
A. I am talking of that now. I understand he is, Mr. Hopkins is.
Mr. Hopkins: Q. That was because of the narrowness of the river, was it?
A. Narrowness and the crookedness, both combined.
Q. Prior to the opening of the Drainage Canal, you speak of freshets, spring freshets. About how long did they last to an extent that they prevented navigation?
A. Well, I would say offhand from—oh, from three to four days, maybe five days.
Q. What month did they occur in Mr. McCardhy?
A. Well, as a rule it was in the latter part of March or April; it was in April; fore part of April.
Q. Before the season of navigation?

A. Before the season of navigation, yes.
Q. What current would there be in the river at that time which would interrupt navigation?
A. Oh really I could not say offhand how many miles.
Q. No way of estimating the miles per hour?
A. No, I could not say that.
Mr. Hopkins: That is all.

Re-direct Examination by Mr. Adcock.

Q. That freshets that you have spoken of occurred in May or June didn't it, that big one?
A. I could not recollect that. As a rule the freshets would occur in the last of March or April, as the snow and ice would melt out. If it was in May or June I could not say.
Q. That big freshet you speak of, that occurred during the navigation season did it not Mr. McCardhy, where the boats were torn away from their moorings?
A. Yes, but I could not say offhand now whether it was before navigation or whether navigation was opened. Of course boats tied to the dock, vessels laying over winter, would break their moorings and go adrift; but I can't say whether it was after navigation or not that the big freshet occurred.

GEORGE M. WISNER, a witness recalled in sur-rebuttal on behalf of the Defendant, having been previously sworn, testified as follows:

Direct Examination by Mr. Adcock.

Q. Mr. Wisner, you testified in your former examination with reference to the time that it would take to establish a flow of 10,000 cubic feet per second, assuming that the flow had formerly been 4167 throughout the channel. That is when I say 10,000 cubic feet, I mean uniform flow through the channel and the Chicago River. And it is my recollection you stated it would take from seven to nine hours to accomplish that change. Have you any further information, have you made any investigation since then which you wish to state in further explanation of your answer to that question?
A. Yes, sir.
Q. State what information you have, and what investigations you have made?

A. I was testifying at that time from my recollection as to how long after the controlling works at Lockport were changed from one elevation to another you would see the effect in the Chicago River. This was occasioned usually by vessels being caught upon one of the tunnels in the river, and we would shut off the water so as to raise it, and release the vessels from the tunnels.

Q. That is raise the water surface?

A. Raise the water surface at Washington Street or LaSalle Street; principally at Washington Street where most of the trouble was occasioned.

Q. When were those tunnels taken out?

A. Four or five or six years ago. My recollection was it would be from seven to nine hours after we changed the flow before the vessel could get off; and sometimes it was a little longer. I had made no measurements, discharge measurements, nor had I made any gage readings, that I remember of, along the channel; but simply by observing at the place where the vessel was aground. And my recollection was, as I stated, this was seven to nine hours. The only thing that we had to gage whether the water elevation changed was watching the boat as it was released from the tunnel and then afterwards when we turned the water on observing by the eye how long it was before the current started up again.

Since testifying previously, I have had two different tests made, one on February 22 and the other on March 8, to determine how much the discharge in the main channel and the Chicago River would change when the discharge at the Controlling Works was increased from approximately 4,000 cubic feet per second to 10,000 cubic feet per second.

Q. That is you established a flow for how long at 4167 cubic feet per second?

A. For the 12 hours preceding, that is approximately 12 hours.

Mr. Wilkerson: Just a moment: Do you think you have made that testimony competent? I do not want to be capitious in my objections, but I doubt whether under any rule that is competent.

Mr. Adcock: What do you mean?

Mr. Wilkerson: That is against the hearsay rule. He has not told how it was made.

Mr. Adcock: He is going to explain it in detail. You can have all the field notes and everything you want, or we will put them in.

Mr. Wilkerson: He was going ahead with conclusions.

Mr. Adcock: Yes.

Mr. Wilkerson: Without having given us—

Mr. Adcock: I understand he will state how the test was carried out and by whom. Also in connection with these tests he will submit for the examination of the Government the notes of the engineers who made the tests, or if you insist we can call the witnesses and have them testify concerning what they did, whichever way is satisfactory to the Government.

The Witness: For the 12 hours preceding the time at which the flow was changed from approximately 4,000 cubic feet to 10,000 cubic feet per second, we tried to adjust the flow of the canal so as to have as near as possible a uniform flow of 4,000 cubic feet through the channel. That is we reduced the flow somewhat from the amount we had been flowing.

Q. That was at the Controlling Works?

A. At the Controlling Works at Lockport.

Q. For how long a period did you maintain that flow of 4167 cubic feet?

A. For a little over six hours we had it going through the channel, on February 22nd.

Q. Go ahead and state just what you did in connection with that, what was done, Mr. Wisner?

A. And on March 8th, it was practically the same.

On the 22nd, the work was done under my direction, with Mr. Murray Blanchard in direct charge of the field operations. This is the same Mr. Blanchard who has been mentioned in the testimony as having been connected with the Lake Survey in the discharge measurements of the St. Marys River and the St. Clair River; and had charge, as I understand it, of the measurements for the Lake Survey on the Detroit River. He was in direct charge of the work. In addition, there were several engineers and helpers from this office. And we measured the water as near as we could at the Controlling Works by means of the dam, and the amount we thought was going through the power wheels; and then we had a current meter measurement at Lemont, Summit and Dearborn Street; the gages being read at those places.

Q. When you say you measured as near as you could the volume of water that was going through the Controlling Works, how closely did you ascertain that amount?

A. I imagine that we were within—outside limits—within 10 per cent. of it one way or the other. That is not a very definite quantity.

The section at Lemont was the same section as was measured by Mr. Moore of the Lake Survey, a section that we had been carrying on measurements at for some time. The method pursued was the same as that used by the Lake Survey, as I understand it. That is verticals were determined, and the meter immersed at one point and the coefficient determined for that particular point.

Q. On February 22, and 23, from six P. M. until about 5:30 A. M., we flowed as near as it was possible 10,000 cubic feet through the Controlling Works and measured the water, as I stated, at the other places by means of current meters. The gaged were also read.

The flow was increased at about 5:53 to about 6:10; took that long to increase the flow, manipulate the works; that is P. M. on February 22. And then we attempted to keep up as near 10,000 as we could. Generally, I would say throughout that time the flow according to the power house measurements probably averaged 200 cubic feet over 10,000.

The computations were worked up of the discharge at Lemont and at Summit and Dearborn Street.

The section at Summit was about four or five miles above Willow Springs. The discharge measurement at Lemont was taken by means of a Haskell Current Meter; at Summit we used the Price Meter; and at Dearborn Street a Haskell Meter. We only had those three meters available at that time.

I would have run this test longer but it was absolutely impossible to do it without absolutely breaking a lot of contracts that we had for the furnishing of power, and I could not run it at that time any longer than the 12 hours approximately, as testified to.

Q. What flow did you get at different times at the various sections which you have mentioned, on February 22?

A. The largest flow that we were able to get at Lemont was 9300 cubic feet per second.

Q. That is within that time?

A. Within that time, yes; within the whole time between six o'clock P. M. of February 22, and 5:30 of the next morning.

Q. And when did that maximum flow appear at Lemont?

A. There is a peculiar thing that seems to happen when this flow is turned on: There will be an indication of a large flow at Lemont about an hour and a half to an hour and 50 minutes after the flow was increased at Lockport.

Q. How far is Lemont from Lockport?

A. It is eight miles from the old Controlling Works in

round figures, and ten miles from the power house. That flow only keeps up for a very short time, and it drops off as though there were possibly an influence, an impulse set up in the water; and the water only being measured at one particular point, I am of the opinion you get a false indication of the discharge at that time, because the flow then did not go up again until about 3:30 the next morning.

Mr. Wilkerson: Q. What was that maximum?

A. 9300 Cubic feet per second.

Q. That is the figure for an hour and a half after the works were opened at Lockport?

A. That was an hour and a half afterwards. Then it dropped off to about 8200 cubic feet per second.

Mr. Adcock: Q. At what time?

A. It reached that at ten o'clock at night, when it raised gradually to 9300 and some odd cubic feet per second at 3:30 the following morning.

Q. That is you had 9300 flow twice?

A. So indicated by the meter, yes.

Q. And the first was at what hour?

A. About 7:30.

Q. About an hour and a half after—

A. We started to turn it on at about 5:50.

Q. You say it took until about 5:10 to fully change the works so that you had a flow of approximately 10,000 cubic feet?

A. Yes. That is the reason I answered it took an hour and a half to an hour and 50 minutes.

Q. Then it went down to about 8,000 cubic feet per second at about what time?

A. Between 9:30 and 10 o'clock that night.

Q. Then gradually rose?

A. To 9300 feet at about 3:30 the following morning.

Q. How long did it remain at 9300 cubic feet per second?

A. It was pretty close then to the end of the time we took in making the test, and my recollection is the meter got off at that time.

Mr. Wilkerson: Was the 8200 the lowest flow reported after the 9300?

A. That is the lowest flow.

Mr. Adcock: Q. It gradually fell to the 8200 is that correct?

A. Yes. At Summit, the first indication of the increase in the discharge came at seven o'clock, and it gradually rose so that at eight o'clock there was a flow of 7,000 cubic feet.

There was a gradual rise of the discharge at Summit then until about one thirty, when the flow reached 8200 cubic feet. From then until the end of the test, at about six o'clock the next morning, the flow ran practically 8,000 cubic feet.

Q. How far is Summit from the section that you previously mentioned?

A. It is 13 miles. It is about four or five miles above Willow Springs; that is about 12 or 13 miles above Lemont.

Mr. Hopkins: Making about 20 miles from Lockport, 22 miles?

A. 22 miles from the power house.

Q. The regulation was done at the power house?

A. Yes, that is the only place that we can regulate the flow.

Mr. Wilkerson: What is the maximum amount you can let through there, 14,000?

A. You can let that through for a short space, and then you pull it down so that you are not able to get it through there on account of the contraction of the channel above.

Mr. Adcock: That is in the earth section?

A. The earth section, and the Chicago River itself.

The measurements at Dearborn Street were carried on, as I stated, by a Haskell Meter and the flow had an increase, starting in about 8:30 that night, began to slowly increase and raised gradually to about 2:30 in the morning when there was a flow of about 5800 cubic feet per second.

It then gradually decreased to five o'clock in the morning when there was an indicated flow of 5500 cubic feet per second; and from five o'clock in the morning until six in the morning it increased, so that at that time there was approximately 6200 cubic feet per second passing Dearborn Street.

I would say in this connection that Dearborn Street being so close to the lake, it is influenced by the rise and fall of the lake.

Q. What was the condition of the Chicago gage at that time with reference to the rise and fall of the lake?

A. The height of Lake Michigan generally varied during February 22nd and 23rd, at the time of the tests, from plus .5 up to plus .9, in round numbers; but the elevation of the lake varied two or three-tenths within half an hour, at times.

Q. Were the meters run continuously during the period?

A. Yes, they were run continuously except possibly they were drawn out of the water occasionally to see that they were working as well as could be expected.

Q. State what you did on March 8, in connection with making tests?

Mr. Hopkins: What was the absolute gage elevation of the lake, have you got it? You said .5 to .9?

A. I have it plotted.

Mr. Wilkerson: About putting this data in, you can use your own judgment, but we will argue this case as finally made up.

Mr. Adcock: I stated in the beginning that we would submit to you any papers that were referred to, and all the field notes that have been made by the engineers; or if you want to encumber the record, we can call all these witnesses and have them testify.

Mr. Wilkerson: We have no disposition to encumber the record; only, if there is a conclusion stated upon a hypothesis which is not perfectly clear in the record, we shall insist to the court upon the adoption of the hypothesis most favorable to our side of the case, in the absence of absolute data.

The Witness: We made another measurement on March 8, as stated before. I did this to have a check upon the first one; and tried to make it under a little better conditions; used more current meters, more discharge sections.

Mr. Adcock: It was a more complete test, wasn't it?

A. Yes.

Q. And ran over a longer period?

A. Yes, it ran a longer period.

Mr. Wilkerson: What was the date of it?

A. March 8 and 9.

Mr. Adcock: The weather conditions were better, were they not?

A. The weather conditions were better.

Prior to increasing the flow, we tried to get as near uniform flow at about 4,000 cubic feet per second as was possible.

Q. When did you start in flowing 4,000 cubic feet per second?

A. We started in on that day. It was early in the morning of March 8.

Q. What time?

A. I said about four or five o'clock we started to change the flow to obtain this 4,000 foot flow. We did it as soon as it was possible, after our lighting load went off.

Q. You think that was about four o'clock?

A. That is my recollection.

Q. When did you have the Controlling Works completely

changed, so that the volume of 4,000 cubic feet per second would pass through those Works?

A. That was changed so that we seemed to have a fairly even flow there for some distance above the Controlling Works; and the flow was increased at 12 o'clock noon to 10,000 cubic feet per second.

Mr. Wilkerson: What was the flow when you commenced to cut it down?

A. I haven't that in mind, but I imagine it was in the neighborhood of 7,000 cubic feet per second.

Q. You cut it from 7,000 to 4,000; then increased it?

A. Yes, increased it from 4,000 to 10,000.

Mr. Adcock: Q. For how long did you maintain the flow at 4,000 cubic feet per second? That was about from three or four in the morning until twelve noon of March 8?

A. That was at the Controlling Works. Of course it took some time to get the rest of the channel flowing that amount. For instance, around the different gaging stations the flow seemed to vary between four and five thousand cubic feet per second, at the different sections, at twelve noon, when we changed the flow.

Q. That was before you changed it from 4,000 to 10,000 at Lockport?

A. Yes. The flow was put on at about 11:50 in the morning and at 12:00 noon, or shortly after that, there was 10,000 going through the Controlling Works and power house at Lockport; and the flow as indicated there got up as high as 10,500; but it ran at 10,000 or above until one A. M. of the following day.

Q. That was on March 9th.

A. At 3:30, it was 9500; that was as close as we got it. After that, the water had to be shut off. There were discharge sections at Dearborn Street, Loomis Street, Robey Street, Willow Spring, Lemont and at Lockport; the Lockport discharge section being about a half a mile this side, or towards Chicago, from the old Controlling Works in the Rock Section.

Q. Will you just name those the other way from Lockport up; first was Lockport?

A. First was the Controlling Works and then the Lockport discharge section; Lemont, Willow Springs, Robey Street, which is the junction of the Chicago River and the Canal; Loomis Street, Dearborn Street.

Q. Just give the distances if you will please?

A. Distance from where?

Q. From the Controlling Works to Lockport?

A. From the Power House to Lockport 13,000 feet; from Lockport discharge section to Lemont 37,200; Lemont to Willow Springs 39,200 feet; Willow Springs to Summit 28,400 feet; Summit to Robey Street, 40,100 feet; Robey Street to Loomis Street 5650 feet; Loomis Street to Dearborn 22450 feet; Dearborn Street to Lake Michigan 5400 feet. That will be more accurate than the answer in miles.

For the record here, we will submit a table giving this in feet and miles from the Power House to Lake Michigan.

Q. Give us the miles?

A. These are subject to correction: From the Power House to Lockport, 2.46 miles; to Lemont from the same place (I will give the distances every time from the Power House), 9.51 miles; Willow Springs, 16.93 miles; Summit, 22.30 miles; Robey Street, 29.90 miles; Loomis Street, 31.0 miles; Dearborn Street, 35.2 miles; Lake Michigan, 36.3.

Q. The flow at the Controlling Works averaged 10,000 cubic feet per second from 12:00 o'clock noon until 2:45 the next morning?

A. Yes, a time interval of 14 hours and 45 minutes.

Q. Will you state Mr. Witness what the flow was at the Lockport Station?

A. The flow at the Lockport discharge section was approximately 4,000 cubic feet per second when we started, and the indicated flow was 8,000 at about half past twelve, or half an hour later. At 1:50 to 2:00 o'clock, the flow at this station reached a little over 8900 cubic feet per second, and it ran approximately at that flow until 5:30 P. M. of March 8. It then increased to 10,000, which it reached at 7:00 P. M. of March 8.

The flow at this discharge section then varied from 10,000 to 10,400, and down to 9500 at 3:30 A. M. of March 9. That is the Lockport discharge.

Q. Now Mr. Witness, on all those sections that you have mentioned there, the vertical coefficients were obtained, and the work was done by Mr. Blanchard, was it not?

A. Under his direction, and most of it personally by him. These gage readings and measurements were made—

Q. And from 12:00 o'clock noon until about 5:00 o'clock the next morning, was it, at these different sections current meters were run continuously, and continuous readings were taken?

A. They were run continuously from about 10:00 A. M. of March 8, until 9:30 to 10:00 A. M. the next day, with the ex-

ception of the Dearborn Street Section, which was discontinued at 12:00 o'clock midnight on account of an accident to the meter; and also at Lemont. At those two places we had no record from 12:00 o'clock midnight, or 12 hours after the test started.

Q. Will you take the next station?

A. The next station is Lemont; and the flow at Lemont at about 12:00 o'clock varied between 4500 cubic feet per second and 5,000.

Q. That is 12:00 o'clock noon of March 8?

A. March 8. It gradually rose, so that at one o'clock, or one hour after the flow was increased, there was a flow of approximately 8500 cubic feet per second. It then gradually increased—

Mr. Wilkerson: When you say "gradually" you mean what?

A. Near a straight line; "uniform" would be better possibly. It increased uniformly from one o'clock to approximately two o'clock. In connection with the Lemont station, it did not start to increase until 12:20. At 2:00 o'clock it reached 9100 cubic feet, when it seemed to vary from a little above 9,000 to a little below 9,000, from 2:00 P. M. until 6:00 P. M. when there was a fairly uniform increase to 8:00 P. M., when the flow was 9600 cubic feet. It ran fairly uniform at this same discharge until about 9:30, and from 9:30 it increased uniformly to 10:00, when there was an indicated discharge at Lemont of 10,000 cubic feet per second. And it continued at approximately that discharge until 12:00 o'clock, when the meter, as I said, was damaged; got out of order.

Q. How long after the water was turned on?

A. It was ten hours after the water was turned on.

Q. That is after it was increased?

A. After the water was increased from 4,000 to 10,000, before we got a discharge of 10,000 cubic feet at Lemont.

At Willow Springs, the flow started to increase at about 12:45 P. M. From that time, it uniformly increased until 1:10 or 1:15 when the flow was 7,000 cubic feet per second. From this time until 4:00 P. M. the flow uniformly increased so that the discharge at Willow Springs was 7800 cubic feet per second. It ran practically at the same discharge until 6:10 P. M. when there was a discharge of 8,000 cubic feet per second. From 6:10 it increased uniformly until 9:30 P. M. when the discharge was 9,000 cubic feet per second. From 9:30, the increase was uniform to 3:50, when the highest discharge was reached, amounting to 9300 cubic feet per second.

Q. That is 3:50 the morning of March 9?

A. The 9th. From then on the water dropped slightly until 6:10 or 6:20, when there was a flow of 9,000 cubic feet per second. After that the discharge commenced to decrease as the water had been lessened at Lockport.

The next station where a discharge measurement was made was Robey street. The flow started to increase at 1:35 or 1:40, and at that time the indicated flow at Robey street was about 4600 cubic feet per second. That was at 1:35 when it started to increase, and it increased uniformly to 2:20 when the flow was 5900. From that time to 4:40 P. M., the flow as indicated was practically constant. There was a uniform increase from 4:40 to 5:40, the flow increasing to 6500. From this time, that is from 5:40 P. M. to 12:00 o'clock midnight, the flow increased fairly uniformly and the discharge was 7800 cubic feet. It ran fairly constant from this time to 4:00 A. M., the discharge varying between 7800 and 7900 cubic feet. Beginning at 4:00 A. M. the flow gradually increased so that at 6:40 to 6:50 it ran a maximum of 8400 cubic feet per second. From that point the discharge decreased. The change had been made at Lockport before that.

The next gaging was at Loomis street. At the beginning of the test, the flow at Loomis street as indicated by the meter was about 3800 cubic feet. The first indication of an increase of flow, that was at all marked, was at 2:00 P. M. From 2:00 P. M. until 3:20, there was a uniform increase and the flow was 5100. From this time to 12:30 A. M. of March 9, the flow increased fairly uniformly and there was a discharge of 7,000 cubic feet per second.

Q. What hour was that?

A. At 12:30.

Q. A. M.?

A. A. M. From 1:20 until 4:00 o'clock in the morning, the meter was out of service and was being repaired, and the record on that section was incomplete during that stretch; but at 4:20 the flow was 7,000 cubic feet per second and increased gradually to a maximum of 7200 cubic feet per second at 8:30 A. M., when the flow started to decrease.

In regard to Dearborn street, I wish it understood that this section and the discharge is affected by the lake which is only a mile away from it. The discharge at the beginning of the test, as indicated by the discharge measurement at this place, was about 4200 cubic feet per second. The first marked indication of a change in the discharge started at four o'clock

P. M. of March 8, when it uniformly increased, or practically uniformly increased, to the end of the test at 12:00 o'clock midnight, when the discharge amounted to 7300 cubic feet per second.

As stated before, the meter became damaged at that time, or out of order, and no further measurements were made at that section.

Mr. Hopkins: Q. What was the flow at 4:00 P. M. at Dearborn street?

A. 4350 cubic feet per second.

Mr. Adcock: Q. What was done with these meters as to rating them and where were they rated, if at all?

A. These meters were all rated in the testing flume at Ann Arbor.

Q. By whom?

A. By Messrs. Murray Blanchard and H. P. Ramey, one of the engineers under me. These were rated both before and after the tests were made.

Q. What meters were used?

A. On this last test, there were two Haskell and four Price meters.

Q. Were the men that read the meters experienced in that work?

A. I had an engineer in charge, a technical man in charge of each of the stations.

Q. That is civil engineers?

A. Civil Engineers, and they had all been drilled by Mr. Blanchard; and Mr. Ramey himself was on one of these sections, and he had had some experience.

Q. What section was he on?

A Robey street. Mr. Ayers of Mr. Williams' office was in charge of one of the sections.

Q. Which one?

A. Dearborn street.

Q. Where was Mr. Ramey?

A. Robey street.

Q. Who was at the Lockport station?

A. Mr. R. H. Burke, another assistant engineer working under me.

Q. Who was at Lemont?

A. Mr. George E. Haggis, of Mr. Gardner S. Williams' office.

Q. At Willow Springs?

A. Mr. Ripley, one of the assistant engineers of our office.

Q. At Summit?

A. That was only on the 22nd. We did not measure at Summit on March 8.

Mr. Wilkerson: Q. You said you had gages at all points.

A. Yes.

Mr. Adcock: Who was at Loomis street?

A. Mr. I. H. James, formerly of the Lake Survey Office but now working for Mr. Gardner S. Williams.

Q. Have these men experience in connection with reading current meters?

A. I so understand, yes.

Q. By whom were the reductions of the field notes and observations made?

A. Mostly by Messrs. Blanchard and Ramey.

Q. How many men were used on March 8, in connection with this test?

A. There were over 70 men employed upon this test, working practically continuously for 24 hours.

Q. You heard the testimony of Messrs. Moore and Ray with reference to the time it would take to change to a uniform flow of 10,000 cubic feet per second from 4167 cubic feet per second and the statement was made that it would take approximately 2½ to 3 hours. From these experiments that you made, do you think that would be possible?

Mr. Hopkins: The tests were not the same, because in the hypothetical question I assumed that the Lockport gates were opened to 14,000 cubic feet per second.

(Question read.)

Mr. Wilkerson: I object to that on the ground that there is an erroneous assumption in the question as to the testimony of the Government's witnesses; and that it appears from the experiments themselves alleged to have been made under the direction of the witness that it is impossible to reach a conclusion by the witness with reference to the matters about which he is assuming to testify?

A. It would be absolutely impossible.

Mr. Adcock: Q. What would be your estimate of the time it would take to establish this flow of 10,000 cubic feet per second throughout the entire channel from a flow of 4167 cubic feet per second?

A. I doubt if you could get more than 9/10ths of the total change in less than from 22 to 24 hours at Robey street.

Mr. Wilkerson: Q. That is to say your conclusion is that you would get 9/10th of the total change at Robey street in from 22 to 24 hours?

A. In other words it would take from 22 to 24 hours to set up a flow of 9,000 cubic feet per second at Robey street.

Q. At Robey street?

A. Yes, when the channel flow at Lockport has been increased from 4,100 to 10,000.

Q. And would the same percentages apply, if there were a greater maximum of flow at the Controlling Works?

A. You want me to answer that question now or on cross-examination?

Mr. Wilkerson: I will withdraw it.

Mr. Adcock: Q. You mean by that you would have approximately 9,000 cubic feet per second flowing past Robey street in 22 to 24 hours after the change was made?

A. Yes.

Q. How long before you would have 10,000 cubic feet?

A. That would be a much longer time, as in my opinion the increase would not be so rapid; it would flatten out. Just how long it would take, I do not know.

Q. In your direct testimony, Mr. Witness, I believe you testified as to how long it would take storm water coming from the Chicago River basin to concentrate in the Chicago River in cases of storm?

A. I believe I did.

Q. Have you made any additional study with reference to that matter since you testified?

A. Yes. We made a study by the gaging of several of the large sewerage districts, in which the sewage has been measured, and we have made a study of the time after the rain starts until the maximum discharge was reached. This study has been very careful and has been carried on in the 39th Street District, the Robey Street District and the Diversey avenue sewerage district. These are three separate and distinct areas about Chicago; one of them being on the South side, another on the West side and another on the North side.

Mr. Wilkerson: I object to this, on the general ground of incompetency; and on the ground that there is not sufficient basis shown for the statement of a conclusion at this time. And on the further ground that the testimony is improper in this case for any purpose, for the reason that this suit being an attempt to review the decision of the executive branch of the Government, data has no place in this record which was not submitted for the consideration of the Executive Officer who made the decision. That it is improper to be offered in court until it has been first considered by the War Department.

Mr. Adcock: With reference to the tests or calculations which were made in connection with the measurement of the sewage and storm waters in the various sewerage districts mentioned by the witness, I will submit for the examination of the Government the field notes made by various persons making the test. Or if counsel now desires, I will produce the witnesses who made the measurements and let them testify as to what they actually did.

Mr. Wilkerson: The witness may proceed to answer the question with the understanding that after an inspection of these things we may desire to make a motion to strike out assigning specific reasons which may appear from an inspection of the notes.

Mr. Adcock: I assume the counsel means, when he says he will make a motion to strike out, that it will be in the nature of a notification to us that he desires us to call witnesses or make further proof with reference to the measurements made.

Mr. Wilkerson: Yes; or it might be for reasons apparent on the face of the notes themselves. An inspection of the notes themselves might disclose some defect apparent on the surface of the observations.

Mr. Adcock: Which may be cured possibly by calling the witnesses.

Mr. Wilkerson: It might or might not be.

Mr. Adcock: Yes, depending upon the circumstances in each case.

Mr. Wilkerson: That is merely in order to facilitate the examination and to economize on time.

Mr. Adcock: And also to save the expense of taking the testimony, having it printed, etc.

The Witness: I would say in regard to these measurements that they were authorized by the Board of Trustees upon my recommendation, and have been carried on under my direction, and the results have been worked up under my direction.

Q. That is the Chief of Engineers was directed by a resolution or ordinance of the Board of Trustees to make these measurements?

A. To install weirs and measure certain discharges from certain well defined sewerage districts. From these studies—

Mr. Wilkerson: May I ask, so that we may have it in the record, whether with reference to these storm water measurements or the measurements in the river and the canal about which the witness has testified this morning, any notice was

given by the District to any of the Government Officials with reference to the making of either set of observations.

Mr. Adcock: I will say that no notice was given, nor did the Government give us notice of the measurement of the Split Section of the Niagara River, at the time they made that; nor at Lockport.

Mr. Wilkerson: I merely ask the question. There are two propositions involved as to notice, entirely different; the necessity for the notice in one case being based upon a fundamental legal proposition not in the other, as I conceive it.

Mr. Adcock: No notice was given by the Government with reference to the measurement of the canal at Lemont by Mr. Ray and Mr. Moore.

Mr. Wilkerson: The same observation applies to those measurements as to the other.

Mr. Adcock: I also make the offer to repeat these tests when a representative of the Government may be present, at the expense of the Government however, as we consider the tests that have already been made sufficient for our purposes and for the purposes of this case.

The Witness: (Continuing) From these studies as near as we can determine, the time of concentration of the storm run-off on the large sewerage areas upon the urban drainage area of the city of Chicago will be from 3 to 3¼ hours. The suburban district along the North Branch North of Lawrence avenue would take in the neighborhood of 24 hours to reach the maximum. The discharge of 10,000 cubic feet per second will occur, in heavy storm, in the neighborhood of 3 to 4 hours.

Mr. Adcock: Q. Where would that be concentrated?

A. I mean there would be that amount of water coming into the Chicago River South of Lawrence avenue.

Q. Would it be possible to so manipulate the Controlling Works at Lockport as to change the flow from 4167 to 10,000 cubic feet per second so as to prevent any of the storm water or sewage of the city of Chicago going into Lake Michigan?

Mr. Wilkerson: Same objection to that as to the other.

A. It would not.

Q. Will you state the reason?

Mr. Adcock: I assume all this is subject to objection as to materiality and relevancy, anyway.

Mr. Wilkerson: It is all subject to the same objection that I stated.

Mr. Adcock: I understand that all this testimony that has

been taken has been taken subject to objections as to materiality and relevancy, which objections may be made at the time the evidence is presented to the court on the hearing. Is that the fact? That was our original—

Mr. Wilkerson: As to those objections, yes.

Mr. Adcock: Materiality and relevancy. As to competency in matters of form, that is a different proposition.

Q. Why?

A. The engineer or executive in charge of this work of changing the flow from 4167 cubic feet per second to 10,000 cubic feet would have to anticipate every storm by at least from 20 to 21 hours in order to prevent the Chicago River from discharging partly into the lake. This means that every time there was the slightest indication that there might be a rainstorm, the flow would have to be increased so that if a heavy storm did occur, the Chicago River would not be reversed and discharged into Lake Michigan.

Another point is that it would be impossible to maintain a channel from Lake Michigan to Lockport that would ordinarily flow 4167 cubic feet per second and still be capable of flowing 10,000 cubic feet per second when needed.

Q. What is your reason for that?

A. For the reason stated in my direct examination that with such a slow velocity as would obtain with a flow of only 4167 cubic feet per second the channel would fill with sediment coming either from the solids of the sewage and street washings or from the sediment in the lake water itself. The result would be that during the slow flow the channel would be gradually filling up with sediment so that at the time you needed a larger flow there would not be a sufficient cross sectional area to permit the flow of 10,000 cubic feet per second through the canal.

Q. During these tests was the 39th street pumping station in operation?

A. No, except for sewage only.

Q. Except for sewage. Did the pumpage and flow of sewage in your opinion vary, that is in the sewers that emptied in the Chicago River, during the period of each test?

A. Practically not, that is to be of any moment as far as this test was concerned. There was no heavy run-off from the sewers.

Q. In your gaging of the Main Channel and the Chicago River, how long after the flow was changed at Lockport was the effect of this change shown upon the gage at Lemont?

A. The elevation of the water surface at Lemont started

to lower about 27 minutes after the change was made at Lockport.

Q. Take the intervals with reference to the other gaging stations.

A. At Willow Springs 47 minutes; at Summit an hour and 17 minutes; at Robey street 1 hour and 47 minutes.

Q. How about the discharges between those places?

A. The discharge, or the amount of water flowing by these sections, started to increase at the same time that the water surface showed a lowering on the gage, but the full effect of the discharge at Lockport, or at the Power House, was not felt at these different discharge sections until the time as indicated in my previous answer, being several hours later; and in the Chicago River itself it was not obtained.

Q. How do you account for the conclusions reached by Mr. Moore and Mr. Ray with reference to the time it would take to change the discharge?

A. The engineers of the Lake Survey Office measured the water at only one section, that being from the Stevens street Bridge at Lemont. They read the gages at Lemont and Willow Springs and obtained from the Government Office at Chicago, as I understand it, the elevation of Lake Michigan. They had no data as to what the flow at Lockport was. The only place they had an actual discharge measurement at any time was at Lemont from the Stevens street Bridge. The time of change in the level of the water surface at Lemont being observed and also at Willow Springs, and the distance known by them, they assumed that the discharge at Willow Springs changed as the water surface level changed and from this they computed the so-called lag throughout the entire length of the channel, and the Chicago River, and testified that the full effect would be felt in the channel from Lake Michigan to Lockport in not to exceed three hours, whereas this time simply represented a wave of translation and not a full effect of the change of the discharge at Lockport.

Q. Have you any data there showing the variation of the Chicago gage, that is the elevation of the water surface of Lake Michigan during the period of the test, March 8-9?

A. Yes.

Q. What were the variations?

A. The gage at Lake Michigan varied from twelve o'clock noon on March 8, from datum, to plus .3 above datum. There were variations of 1½ tenths in 15 or 20 minutes at times; and

a variation of that kind is sufficient to affect the discharge at Dearborn street somewhat.

Q. You have spoken of the interval of time required to create a change of discharge at various points. Was this in any way similar to the rise or fall of the water surface of a lake at the head or foot of a river, in its effect?

A. In my opinion it is, providing that the time of the change of the elevation of the water surface was comparatively short, and generally if the time of change was gradual or longer, the same general effect would obtain; that is a wave of translation would travel along the river and be indicated on the gages, but would not indicate the time of the full effect of the change of the discharge due to an increase or decrease of the water surface of the lake. In other words, to get the time of the full effect of the change of discharge, the river would have to be measured simultaneously at two or more points.

Q. How long have you been familiar with the Chicago River and the sewage problems connected therewith?

A. From July 7, 1892, to date. I went to work for the Sanitary District upon that date and was on the original survey of the South Branch of the Chicago River for a few months. From some time in September, 1892, until September, 1895, I did not have very much to do with the Chicago River as I was located at Lockport at that time. I was transferred back to Chicago at the latter date, and was more familiar with the river from that time on. And from 1897 to date, I have been in charge of the Chicago River improvement, either as assistant engineer at that time in charge of this improvement, or as assistant chief engineer and chief engineer of the District.

From 1897 until about 1903-4 or '05, I was in direct charge of all the improvements that were being made on the Chicago River.

Q. The depth of the South Branch of the Chicago River before the Sanitary District started work was approximately 16 to 17 feet, was it not?

A. Yes, sir.

Q. And it is now 26 feet?

A. It is now 26 feet except at a few bridge openings; that is the South Branch of the Chicago River?

Q. Yes?

A. From Lake street to the Canal.

Q. That is the central portions?

A. The central 100 feet of the stream is 26 feet in depth with a depth of 16 feet at the Dock lines.

Q. Now you have some maps there of the Chicago River, have you not Mr. Witness?

A. Yes. This map shows the main branch of the Chicago River from the lake to Lake street, showing the North Branch as far north as Kinzie street, and the South Branch of the Chicago River from Lake street to Ashland avenue. This is the stretch that was widened and deepened.

Mr. Adcock: I will ask that these maps produced by the witness, being 5 in number, be marked Wisner's Exhibits 7, 8, 9, 10 and 11, of this date.

(The maps referred to were so marked.)

Recess to 2:00 P. M.

After Recess 2:00 P. M.

GEORGE M. WISNER, resumed the stand and testified further as follows:

Mr. Adcock: Q. You have described have you Mr. Witness Exhibit 7, 8, 9, 10 and 11?

A. I have not described them.

Q. If you have not described them, will you describe the exhibits, and as you do so indicate from the exhibits just what improvements have been made by the Sanitary District in the Chicago River, the South Branch and other branches of the river that may be referred to in those exhibits.

Mr. Wilkerson: You mean by the District alone, on its own initiative?

Mr. Adcock: Yes.

The Witness: And the city of Chicago.

Q. Also indicate the time, so far as your memory serves you, when the improvements were made?

A. These five sheets are maps of the Chicago River from Lake Michigan through the main branch of the River, and South and West on the South Branch of the Chicago River to Ashland avenue, which is about half a mile east of the beginning of the canal.

The maps are drawn accurately to a scale of 200 feet to the inch and indicate the dock lines of the river, the bridges, and generally the physical characteristics of the banks of the river within a block or so—

Q. Is that before or after the improvement?

A. They indicate both, with the exception that it does not show the location of the old bridge piers and center pier protections of the bridges that were removed and changed from the swing type of bridge to the center pier—to the bascule type of bridges. It does indicate the type of bridge, and when it is completed, as stated on the map, for instance State Street Bridge, which was built by the Sanitary District is a Scherzer bascule, as indicated, "built by the S. D. of C." meaning Sanitary District of Chicago, completed 1903. So by looking at these maps at the different bridges, you can learn by whom they were built and when completed.

The lake is on the right hand side of the map, Wisner's Exhibit 7. When I say on the right hand side of the map, I mean to have it so placed that the words "Chicago River" in the part tinted blue reads right side up; that being to the East, and Lake Street being to the West.

The streets like 5th Avenue, LaSalle, Clark, State, run practically north and south, and streets like Kinzie and Lake run east and west. This first sheet shows the junction of the south and the north branches of the river.

On Exhibit 7, which is as I stated the main branch of the river, the improvements made by the Sanitary District consisted of the removal of the State and the Dearborn Street bridges, which bridges were of the center pier swing type such as now exists at Fifth Avenue and Michigan Avenue. These were replaced by the bascule type of bridge giving a wide center opening and doing away with the center pier and the center pier protection, which clogged up the river and interfered with navigation. The Sanitary District also dredged the river in the vicinity of these bridges to a depth of 21 feet.

On the main river, in addition to what was done by the Sanitary District, the city of Chicago removed the LaSalle Street tunnel, deepening the river at that place. The tunnel at LaSalle Street interfered with navigation; the boats at times being stuck on it and blocking the river.

Wisner's Exhibit 8 of this date consists of a map of the same scale extending south from Lake Street to 12th Street showing the docks on the river before and after improvements made by the Sanitary District. This stretch of the river has been widened practically throughout its entire length, the widening being indicated by the dark blue tint. By applying a scale to this dark blue tinted area, the amount of the widening can be determined at any place. Generally, it varies in width from nothing to approximately 90 feet. The part tinted green of which there are two places indicated on this

sheet are stretches along the river which have not as yet been widened for the reason that the property has not been acquired by the Sanitary District, but is included in the general project, and it is expected will be obtained and widened within the next year.

Q. Do you know whether any suits are now pending?

A. There are condemnation suits pending against both of these pieces of property.

Q. You are referring now to—

A. To the parts tinted green, one being on the east side of the river between Van Buren Street and Harrison Street and labeled "Union Elevated R. R. Co. Power House."

Q. That is what is called the Union Loop Power House?

A. That is called the Union Loop Power House. The other is indicated by "Tract Number 201," the 201 being in a circle and being just north of Taylor Street.

The Sanitary District has widened and excavated the river throughout this stretch to 26 feet in depth; has removed all of that part tinted a dark blue thus widening the river, and has rebuilt all the docks where the river was widened.

Q. What is the width?

A. The width where completed is at least 200 feet.

Q. That is all except those two points?

A. All except those two that have not yet been excavated. The District has removed a center pier bridge and built a bascule bridge at Randolph Street, which was completed in 1903.

The Washington Street Bridge and the tunnel thereunder were removed by the City of Chicago and a new bridge completed in 1913 at this street.

The Madison Street bridge, the one that now exists, is of the center pier swing type, and is to be removed by the city of Chicago.

Q. When you say "is to be removed," what do you mean?

A. It has been ordered out and plans and specifications are being prepared and it will be rebuilt within the very near future.

The Jackson Boulevard Bridge is now being removed by the Sanitary District, and is to be replaced by a bridge of the bascule type, having a wide opening.

Q. You spoke of the Madison Street Bridge and the Jackson Boulevard Bridge; they are to be rebuilt. What channel opening are they to have, and what cross section there?

A. The opening of the Jackson Boulevard Bridge will be

167 feet in width; the one at Madison Street, as I recall, is to be 180 feet, somewhere in that neighborhood.

Q. How does that compare with the bridges that are being removed?

A. The bridge openings there are only about 55 to 60 feet in width at the present time. At Jackson Boulevard, the opening is a little wider, I believe about 90 feet.

The next bridge to the south is the Metropolitan Elevated Railroad Company Bridge. This was ordered out by the Secretary of War.

Q. Do you know when under the order of the Secretary of War the Metropolitan Bridge was to be removed?

A. By December 1st, or 31st of this year, I have forgotten which.

It is part of the contemplated plan of the Sanitary District to remove and replace the Van Buren Street Bridge with a bridge having a 200 foot opening.

The Harrison Street Bridge, which was of the center pier type has been removed and rebuilt by the Sanitary District, being completed in 1905.

Polk Street Bridge which was of a similar character has been removed and was rebuilt by the City of Chicago, being completed in 1910.

Taylor Street Bridge which was of the center pier type was removed by the Sanitary District and rebuilt in 1900.

The railroad bridge just south of that and indicated as "B. & O. C. T. R. R." was of the center pier type and was built by the Sanitary District, being completed in 1901.

Twelfth Street Bridge has been ordered out by the Secretary of War and is to be rebuilt jointly by the city of Chicago and the Sanitary District, with an opening of 200 feet instead of the present opening of about 55 to 60 feet.

Wisner Exhibit number 9, is the third sheet of this set, being of the same scale, and is a map of the south branch from 12th Street to 18th Street inclusive. The part tinted a dark blue represents the river widening performed by the Sanitary District, and the part tinted green is a piece of property not yet obtained, but which is under condemnation; and in my opinion will be obtained within the next few months, when this whole stretch of the river will have been completed; so that from Lake Street to the beginning of the Drainage Canal, with the exception of the three pieces mentioned and the stretch of the river at the Metropolitan Elevated, the entire river has been widened to at least 200 feet and even to 26 feet or more, with

the exception of the bridge openings of the old center pier bridges.

The widening on this stretch of the river varies from zero to 80 feet in width. The river was redocked and deepened as stated.

The bridge marked "St. Charles Air Line" which is practically on 16th Street, is to be rebuilt by the Railroad companies. Plans are now being prepared, and this bridge is to be taken out and replaced with a 200 foot opening bridge.

The 18th Street bridge which was of center pier type was rebuilt and replaced with a bascule type bridge completed in 1905 by the Sanitary District.

Wisner's Exhibit 10 of this date is a continuation of this map and gives the Chicago River on the same scale, 200 feet to the inch from 18th Street to Halsted Street. The same general tinting indicates what has been done by the Sanitary District. The widening varies from nothing to nearly 140 feet in width at Collision Bend.

Q. Where did that get its name?

A. It got its name on account of there being so many collisions at this place before this widening was made; I mean collisions between vessels.

Q. What was the original width at the Bend?

A. A little over 100 feet. There was a narrow point on the river immediately south, or west of 18th Street, and at that place the Sanitary District widened it about 120 feet at the widest point. The old 18th Street bridge, on account of the narrow river and bend in it, the vessels were unable to use but one bridge opening, that one being on the east side of the river. By that I mean vessels of any size.

The bridge marked "P. Ft. W. & C. R. R." is a bridge owned by the Pennsylvania Railroad Company, and is now in the process of being removed; a new bridge having been built at this place with I think a 200 foot opening.

The Canal Street Bridge was built by the Sanitary District and completed in 1903. That was not of the center pier type, but was of a narrow opening type, known as a jacknife. It stood askew and was a very difficult place for navigation.

The 26th Street Bridge was of the center pier type and was removed; rebuilt by the Sanitary District, completed in 1906.

The next sheet shows in the same way the improvements made by the Sanitary District from Halsted Street to Ashland Avenue. The part near Ashland Avenue tinted brown is a turning basin that was built by the United States Government to facilitate the turning around of vessels after going up the

river. Generally, this river was widened throughout this stretch, throughout the entire length, to give a channel which is now at least 200 feet wide and 26 feet deep.

The Sanitary District removed a center pier bridge and rebuilt with a bascule bridge at Main or Throop Street, completing it in 1903. And one at Loomis or Deering Street, completing that in 1904; and one at Ashland Avenue completing that in 1903.

The river from Ashland Avenue down the West Fork to the beginning of the Canal was over 200 feet in width, and was simply deepened by the Sanitary District to 26 feet in depth.

At the lower end of this last sheet the water as indicated on the left hand side of the sheet is the west fork of the south branch, from which the canal starts at Robey Street.

The indicated water to the right of the map is the South Fork of the South Branch, the far end of which is known as Bubbly Creek, being located near the Stock Yards, and having been mentioned in this case several times.

The middle water stretch is the entrance to the old Illinois and Michigan Canal.

On Wisner's Exhibit Number 8, I neglected to mention that the City of Chicago had removed and rebuilt a tunnel under the Chicago River immediately North of Van Buren Street, and indicated on this map as "West Chicago Street Railway tunnel." This prevented the deepening of the river for some time, as the top of the tunnel was about, as I remember, 20 feet below the surface, 20 or 21 feet below datum.

Q. The Government produced certain witnesses known as lake captains, who referred to certain critical points or difficult points of navigation. They mentioned Van Buren Street, Jackson Boulevard, Madison Street, 12th Street, Pennsylvania Bridge, 16th Street Bridge, the St. Charles Air Line Bridge. Those are all bridges which have been ordered out by the United States Government, or are points where new bridges are being constructed, are they not?

A. Yes, sir.

Q. In your opinion, when those bridges are completed, the new bridges are completed with approximately 200 feet clear channel opening, will there be any difficulty in navigating the Chicago River at this point?

Mr. Hopkins: Objected to, the witness is not qualified to answer that. He is not a navigator. As I understand it at those bridges, it is not widened to 200 feet.

Mr. Adcock: Approximately.

Mr. Hopkins: 167 feet.

The Witness: They vary from that to 200 feet in width.

Mr. Adcock: Q. They vary from 167 feet to 200?

A. From the narrowest, about 140 feet, some of the first ones built, up to about 200 feet in width.

Q. But by-passes were arranged for those—

A. For the narrower openings.

Q. The narrower openings, so that you would have a cross sectional capacity of approximately 200 feet in width there?

A. Nearly that; some of them may be a little short of that.

Mr. Adcock: In view of the counsel's objection, still insisting that the witness is qualified to answer because of the facts stated in his previous examination, I will ask the witness to state what experience he has had in connection with determining the capacity of the Chicago River at various flows of water to determine the condition of navigation.

A. As stated, I have been in charge of this improvement, and have watched vessels going up and down this river for the past 21 years; and have been on them at times before the opening of the canal and afterward. And I know of my own knowledge that vessels can get through that river now, and do get through it that could not by any physical possibility have gone through prior to the improvements made by the Sanitary District.

Q. Have you considered the flowing capacity of the river, the current that may be created by various flows of water at different points in the river?

A. Yes.

Q. That is part of your duty is it not as an engineer, assistant engineer of the Sanitary District, and as Chief Engineer?

A. Yes.

Q. Go ahead and answer the question now.

A. In my opinion, there will not be any great difficulty in navigating the river after all these improvements are made, and in my opinion there is no great difficulty in navigating the river at this time, with the exception of the times when old bridges are being removed and new ones are being built, when from the nature of the structure that is to be built the river is more or less clogged by temporary works.

Q. Such as cofferdams?

A. Such as cofferdams, and maintaining traffic on the old bridge, during the construction of the new one.

Q. The Sanitary District has expended approximately how much money in deepening and widening the Chicago River and in building the bridges which you have mentioned?

A. Approximately eleven and one-half million dollars.

Q. Did you ever observe the Chicago River prior to 1900 when it was in flood?

A. Yes.

Q. What effect did the flood conditions have upon navigation in the Chicago River?

A. It prevented navigation during the excessive floods and created a current much in excess of anything that we have at this time. This occurred usually every year, sometimes two or three times a year.

Q. That is during the navigable season of the year?

A. Sometimes during the navigable season, and sometimes in what is known as not the navigable season; but as a matter of fact the Chicago River is always open to navigation. I never remember of having seen the South Branch frozen over.

Q. Do they have the same conditions now as to floods?

A. No sir, they are entirely done away with.

Q. One of the witnesses, one of the lake captains, I think it was Mr. Minskey, testified that certain boats under his charge were injured while lying in the vicinity of 18th Street in the year 1912, was it not?

A. I have forgotten the exact date, but at any rate it was since the improvements made by the Sanitary District at 18th Street, and the widening of the river between 12th and 22nd Streets.

Q. Do you remember the dimensions of the boats which he stated he had in the river at that time?

A. He stated that he had the steamer Gilchrist and Lake Shore, I think it was, and he gave the beam as being 52 feet. I looked it up in the Official Blue Book, as it is called, giving the dimensions of steam vessels on the Great Lakes, and found the steamer Gilchrist was 356 feet long by 50 feet beam, and the Lake Shore was a sister ship, of the same size.

Q. He stated that those boats were tied up in the vicinity of 18th Street. Would it have been possible to have boats of that size lying alongside the dock at the places indicated, if the Sanitary District had not widened and deepened at that point?

A. No, sir.

Q. How do you work that out?

Mr. Adcock: I hand the witness two sheets which I ask be marked Wisner Exhibits 12 and 13 respectively of this date, and ask the witness to describe the exhibits and state what is shown upon them.

(Documents handed witness were marked Wisner's Exhibits 12 and 13, May 20, 1914.)

A. Wisner's Exhibit 12, is an outline of the docks along the Chicago River from just North of 18th Street to just South or West of the Pennsylvania Railroad Bridge at Stewart Avenue; is drawn to a scale which is twice as large as Wisner's Exhibit 7 to 11; that is it is 50 feet to the inch, and is therefore four times the size of the other maps, but is accurate, and simply shows 18th Street. It shows the dock lines prior to the improvements made by the Sanitary District, and on the right hand side of the map, the line that follows to the right—

Q. Which is west?

A. Which is west, is the line to which the Sanitary District widened the river from 18th Street to below the Pennsylvania Railroad Bridge at Stewart Avenue. When I say the right, I mean the right when looking at 18th Street, and it reads right side up.

This would also be observed by the direction indication of the arrow showing North, East, South and West.

Upon this, in dotted lines, have been plotted the outlines of a boat which is 356 feet long by 50 foot beam. The one at the lower end of the map—

Q. Is that the size of the boat referred to?

A. That is the size of the Gilchrist, which Mr. Minskey testified he had lying between 18th Street and the Pennsylvania Railroad Bridge, on the East side of the river.

At 18th Street, there existed an old center pier bridge and protection; this protection being shown on this map by two horizontal lines and diagonal lines coming together which is practically in the shape of the protections as built. And in the East Draw of this bridge which was the only draw that could be used by the larger boats, is plotted the outlines of the boat Gilchrist to scale, showing that it was physically impossible for it to have gone through this bridge opening, if the old bridge existed there, for the reason that the boat would get aground at the stern and be against the center pier midships, and aground forward.

I have also plotted in dotted lines the same size steamer between the two bridges, although it could not have gotten through; and another one a little further on, showing that if that boat had been lying alongside of the dock it would have been physically impossible for another boat of the same size to have passed through.

Q. That is under the old conditions?

A. Under the old conditions.

At the place indicated as "Pennsylvania R. R.," meaning the Pennsylvania Railroad Company's bridge, there is plotted a boat of the same size showing that it would have been almost impossible for it to have gone through the draw. This bridge is now about to be removed.

On Wisner's Exhibit 13 of this date, to the same scale, is plotted the river as it exists today. And I have plotted on the east side of the river just south of 18th Street the steamer Gilchrist, indicated by the figures "356 by 50," meaning the size of the boat; and have also plotted a vessel 600 feet in length and 55 foot beam, showing that with this vessel lying alongside of the dock, a vessel of that size could have passed if carefully handled without necessarily damaging the boat lying alongside the dock.

These improvements have now been made, and it necessarily follows that the river has a larger navigable capacity now than it did prior to the improvements being made.

Mr. Wilkerson: You have not indicated in your testimony, but that was all done under the authorization of the War Department, was it not?

A. This was done under the General 200 Foot Project.

Mr. Adcock: Q. The largest portion of the work which you have mentioned, done by the Sanitary District, was carried out under what is known as the Sanitary District Project of 1900, was it not?

A. Yes.

Q. And a permit was obtained from the Secretary of War approving the plans of that project, was there not?

A. Yes, sir.

Mr. Wilkerson: Q. And from time to time your plans were submitted and approved by the War Department and the Chief of Engineers?

A. Only as far as the bridges were concerned. The widening was only submitted, as I recall it, at one time, the widening and deepening.

Q. That was a general authorization for that?

A. Yes.

Mr. Adcock: Q. And the permits with the applications therefor are attached, I believe to the answer of the Sanitary District to the bill of complaint last filed, being equity number 114. I believe that project was referred to by Mr. Cooley, in his testimony was it not, Mr. Wisner. Is that correct?

A. Yes.

Q. And he described it. How about the draft of boats now

as compared with those that could navigate the Chicago River prior to the work of the Sanitary District you described?

A. A boat drawing over 16 feet of water could not have navigated the Chicago River prior to the improvements made by the Sanitary District; at the present time they can probably navigate drawing 21 feet, the reason it is only 21 feet being that the Main Branch of the river was never deepened to more than that depth.

Q. Prior to the improvements made by the Sanitary District and prior to the opening of the channel, have you ever seen any boats stuck in the river?

A. Many times.

Q. How is the river now compared with the condition it was previouly to the improvements of the Sanitary District with reference to the tortuousness of the river?

A. It is much straighter.

Q. Is that any benefit to navigation?

A. Yes, indeed.

Q. Do you remember when the City of Chicago completed the Illinois and Michigan Canal on what is called the Deep Cut Plan, so that water could flow by gravity from Lake Michigan or from the Chicago River through the Illinois and Michigan Canal into the Des Plaines River?

A. I think it was in 1871.

Q. Do you know the capacity of the Illinois and Michigan Canal to withdraw water from Lake Michigan?

A. It was approximately 24,000 cubic feet per minute, 400 per second.

Q. In 1883, was it not, the City of Chicago installed pumping works at Bridgeport, and from that year the pumping works were placed in operation? Do you know what the capacity of the pumps was, and how much water was regularly pumped from the Chicago River into the Illinois and Michigan Canal, which water flowed into the Des Plaines River and thence into the Illinois River?

A. Generally, from 50 to 60,000 cubic feet per minute.

Q. Did the withdrawal of the water in 1871 and 1873, and from 1883 on, until the opening of the Drainage Channel, have any effect upon the force and current of the Chicago River during a considerable portion of each year?

Mr. Wilkerson: You do not contend he knows anything about that, do you?

Mr. Adcock: Yes, he is qualified.

Mr. Wilkerson: No, he said—down to what time?

Mr. Adcock: Q. You know the ordinary dry weather run-off of the Chicago River, do you, Mr. Wisner?

A. Yes. Exclusive of sewage?

Q. Yes?

Mr. Wilkerson: If he thinks he can answer all right. I do not think myself he is qualified to answer it.

Mr. Adcock: You may answer the question.

Mr. Wilkerson: We may have the quess of the witness. It is perfectly obvious it is a mere guess.

A. It had the practical effect of reversing the Chicago River during the dry weather seasons, and during the season when the snow was falling and not melting and running off; when there was a dry weather flow.

Q. When there was a minimum of run-off?

A. Yes.

Q. There was some suggestion made by counsel that perhaps you are not qualified to answer this question. Will you just state what facts it is necessary for an engineer to determine in order to state when the current of the Chicago River would be reversed in each year?

A. He would have to be acquainted with the Chicago River as to its characteristics during the dry season; with the approximate population, amount of pumping for the domestic supply, the drinking water; and be familiar generally with the amount of pumping and the amount of sewage that runs away; the different sewerage districts, in a general way. When I answer this, I do not mean to say it is absolutely correct, but I do know enough about it to know that there would be a substantial reversal of the flow in the Chicago River with the amount of water running off during the dry periods.

Q. That is the Chicago River, instead of flowing towards the lake would flow away from the lake during a portion of each year under those conditions. Is that it?

A. Yes, sir.

Q. And there would be some considerable amount of water extracted from Lake Michigan itself?

A. Bound to be.

Q. Mr. Witness, you stated this morning the results of the tests made on the Drainage Canal on February 22, and March 8-9 of this year, made under your direction; and in the course of your testimony you referred to certain charts upon which the discharge at various gaging sections was plotted. I ask that the six sheets which I now hand the Commissioner,

be marked Wisner's Exhibits 14 A, B, C, D, E and F. I will ask you to state what appears upon those exhibits, for the convenience of the court and counsel.

(Charts shown to witness were here marked respectively Wisner's Exhibits 14 A, B, C, D, E and F, May 20, 1914.)

A. Wisner's Exhibit 14A, represents graphically the discharge of the Sanitary District Canal at the Power House and Controlling Works on February 22 and 23, as plotted up from the records kept at that place.

In the left hand column is given the discharge in cubic feet per second. In the horizontal columns are the hours and the date. The figure in the lower right hand corner is the discharge from 6:30 A. M. on February 22, to 3:00 P. M.; and if the sheet had been large enough would be joined on to the same line on the left hand side of the page under "3:00 P. M." and opposite "3,000."

Wisner's Exhibit 14B, represents graphically the discharge on February 22 and 23, as measured at the Power House, Lemont, Summit and Dearborn Streets. The figures on the left hand side of the page being the discharge in cubic feet per second, and the time being plotted in the horizontal at the top of the page.

Wisner's Exhibit 14C, represents graphically the gage readings from Lake Michigan to the Power House from 6:00 A. M. on February 22d to 2:00 P. M. on February 23; there being ten different places as indicated in which gages were maintained and read, during the time this test was being carried on.

Wisner's Exhibits 14D, 14E and 14F, represent the same as the previous three sheets, being the test carried on during March 8 and 9.

Adjourned to Thursday May 21, 2:00 o'clock P. M.

GEORGE M. WISNER resumed the stand and testified further as follows:

Direct Examination Resumed by Mr. Adcock.

Q. Did the Sanitary District lower the Kampsville and LaGrange dams in the Illinois River at any time?

A. The Sanitary District lowered the Kampsville dam 2 feet and we attempted to lower the other one, but with the restrictions placed upon us by the Government we did not succeed in getting it down.

Q. When was that work done?

A. I can get that date for you.

Q. It was subsequent to April, 1904, wasn't it?

A. Oh, yes, it was 1905 or 1906.

Q. And that was done pursuant to a permit from the Secretary of War?

A. From the Secretary of War, yes.

Q. Are you familiar with the navigable capacity of the Illinois and Michigan Canal from Joliet to Chicago, or from Chicago to Joliet?

A. Yes.

Q. That portion of it?

A. Yes.

Q. When I say navigable capacity, I mean the width, depth, and capacity for admitting boats, large boats.

A. The size of boats that can go through it.

Q. Yes? Was the stretch of the Illinois and Michigan Canal from Chicago to Joliet, that is to what we call the upper basin, the same capacity as that portion of the canal from the upper basin below along the Des Plaines and Illinois Rivers?

A. To Peru.

Q. To Peru?

A. Yes.

Q. During the last 20 years, say?

A. Just the same.

Q. Just the same?

A. The locks are all the same size.

Q. The locks are all the same depth, the water is the same?

A. They vary a little bit, but practically the same.

Mr. Adcock: That is all.

Adjourned to Tuesday June 15, 1914, at 10:00 o'clock A. M.

June 15, 1914, 10:00 A. M.

GEORGE M. WISNER resumed the stand and testified further as follows:

Cross-Examination by Mr. Hopkins.

Q. In making these tests as to the rate of flow in the canal, you made every effort did you to get it as accurate as possible?

A. I employed the most competent men that I could obtain from our engineering force, and from some outside men.

Q. Do you consider that their work was accurately done?

A. I told them to follow as nearly as possible the methods pursued by the Lake Survey. This work was under Mr. Blanchard's charge, and my general instructions were to get as accurate results as possible with current meters.

Q. Is your opinion as to the accuracy dependent upon simply what they told you, or do you have opinions of your own in regard to it?

A. It was impossible for me to be at all those discharge sections. I was at one of them, or two or them, part of the time.

Q. On February 22, where were you?

A. At Washington and Dearborn Street, if I remember rightly.

Q. And on March 8, where were you?

A. Dearborn Street.

Q. What personal work did you do?

A. I did not do any of the personal work, simply that I gave orders to have this work done; and went over the results with them afterward, talked it over with them.

Q. Have you personally had any experience in measuring streams?

A. Oh, some, yes, sir.

Q. With the use of current meters?

A. Some, yes.

Q. Just what has been your experience in that connection?

A. You mean personally, where I handled the meter myself?

Q. Handled the meter and directed the work?

A. As I remember, I never handled the meter myself. I directed the work in the measurement of the Illinois River; and in some current meter measurements of the flow of water through big conduits.

Q. Do you consider then that the results say at Dearborn Street on March 8th, are reasonably accurate?

A. I would say that they were comparatively accurate.

Q. Compared to what?

A. Well, I mean this, that we knew how fast the current was going and we had the flows down and then afterwards we knew how fast it was going when the current had been increased; and as near as we could tell one compared with the other ought to give a fairly good idea of the amount of water that was flowing by this particular station.

Q. In your opinion what was the percentage of accuracy of the volume of flow determined at Dearborn Street during these tests?

A. I have not such a high idea of the accuracy of the current meter as a great many witnesses who have testified on the other side in this case.

Q. Well, what is your idea of the accuracy of these particular measurements?

A. It would be merely a guess, Mr. Hopkins.

Q. Don't you think in testifying as to these tests and what they would show that that would have an important bearing?

A. I suppose it would be an important consideration, but it is as accurate a method as we have for the measurement of large flows of water, with the possible exception of floats in a canal of the size and shape of the Drainage Canal. In my opinion, I think they were as accurate as current meters, possibly more so.

Q. Was this work accepted by you and the district as being as accurate work as Mr. Blanchard could do in this matter?

A. I told him to do just as accurate work as it was possible to do.

Q. And you think he did that?

A. I think he is conscientious and has had training extending over several years; and I have no reason to doubt that it was just as accurate as it was possible for him to superintend.

Q. You would not want to give a percentage of accuracy, say for Dearborn street?

A. No.

Q. Do you think you were within 20 per cent. of the true volume of flow?

A. Oh, I imagine it was within that percentage, all right.

Q. Would you say the same as to Loomis street?

A. I imagine as you went further down stream that the accuracy might be greater than at Dearborn street.

Q. Why at Loomis street?

A. Well, it is further away from the lake and less subject to sudden fluctuations in the lake level.

Q. What effect would that have other than to decrease the rate of flow?

A. Well, these sudden impulses coming from the lake, I have an opinion do not give an accurate discharge throughout the whole section, but simply have an effect on the meter that is not necessarily felt throughout the entire discharge section. That is my opinion.

Q. Did you have some of these sudden impulses at the time of these tests?

A. Why, the water surface, as I remember, varied three or four-tenths in a short space of time, the lake level; and Dearborn street is, I think, just about a mile from the lake.

Q. What influence in your opinion would .2 or .3 change in the elevation of the lake have at Dearborn street?

A. I would not know, but I think it has an influence, all right.

Q. Well, then you do not claim a high degre of accuracy in the work at Dearborn street?

A. It is as accurate as we could get under the circumstances, I think, and from a comparative standpoint, showing how long it took to increase this flow, it ought to give a result that would have some value in determining how long it would take to change the flow from 4,000 to 10,000 cubic feet.

Q. I am speaking of the volume of flow at the particular station?

A. How is that?

Q. (Question read as follows: "Well, then, you do not claim a high degree of accuracy in the work at Dearborn street?")

A. What do you mean by "A high degree of accuracy"? Then I can answer your question. Your idea and mine might be different as to what a high degree of accuracy is.

Q. Would you say within five per cent.?

A. I would not say it was closer than five per cent. It might be.

Q. Did I understand you to say awhile ago you would not say any better than 20 per cent.?

A. No, you did not understand me to say that. You asked me if it would be within 20 per cent., and I said I thought it would be.

Q. Between five and 20; do you have any further opinion?

A. It might be less than five, might be more.

Q. What is your idea as to the degree of accuracy at Loomis street, then?

A. Oh, I would not say. It might be within 5 per cent., might be more.

Q. What is your best judgment as an engineer, if you have any, as to that accuracy?

A. I would say I am not enough of an expert in the use of current meters to say how accurate they are. I simply have to judge by my general information.

Q. In the report made to you by the men that you had doing the work, did they give an opinion as to the accuracy?

A. Not that I recollect. I simply talked with Mr. Blanchard. My recollection is that he stated that the work was as carefully done as he knew how to have it done. These men were competent as far as he knew, the men that were in charge of his party, and that the results were as good as could be expected.

Q. You don't know what Mr. Blanchard's opinion as to the percentage of accuracy, say at Dearborn street is, as to the volume of flow?

A. No, I don't know, as he never expressed that to me.

Q. Mr. Blanchard was not personally present at Dearborn street, was he?

A. He was part of the time.

Q. What part of the time?

A. I don't know. I know that I was there with him at one time.

Q. What time was that?

A. That was on the day of the first test, I believe, along in the middle of the day sometime; possibly in the afternoon; I have forgotten, along maybe two or three o'clock, I should say.

Q. Now, what were the weather conditions on that day, on February 22nd?

A. The weather conditions were, it was quite cold.

Q. In fact there was a blizzard that day, wasn't there?

A. It was a bad day, yes. I think there was quite a snow storm.

Q. There was ice floating in the river?

A. There was some ice in the river, yes, sir.

Q. And you were not satisfied with the work that day so you made another test on March 8th?

A. No, I would not say that exactly. We did it more as

a check, and also on account of the test not being as long as we thought we could get on the second day.

Q. Do you think that the temperature of the water had any effect on the flow?

A. I would not be surprised if it did.

Q. Have you ever made any tests to determine in open rivers whether it makes any difference whether the water is cold or not?

A. It is my opinion from what I have observed on the canal that it does not flow as readily when it is cold as when it is warmer.

Q. What do you think that is due to?

A. Well, it is pretty hard to say, unless it is due to the fact that the water is a good deal lighter,—has the same tendency as molasses, and does not run as well when it is cold as when it is warm.

Q. Do you think fluidity is affected by cold?

A. I am of the opinion that it is.

Q. Just from the fact that it does not seem to flow as fast in cold weather as it does in warm?

A. That is all, and from what I have read in regard to flow of water through filters, over weirs.

Q. Would you take that into consideration in working out any engineering problem?

A. It might be taken into consideration, and I would regard it in this way: We are apt to have a flood come as we did on December 25, in cold weather, and the water would not flow as readily then as it would if we got a flood in June.

Q. If you were working at a particular problem, what effect would you give to the difference in temperature?

A. I do not know. I do not know as that has been determined; if it has I am not familiar with it.

Q. What was the temperature of the water on February 22nd, then?

A. I do not know. It must have been around freezing, anyway.

Q. Did you take that fact into consideration in estimating the flow through the power house and the dams at Lockport?

A. No, I don't know as there is any data available that would give you that. I know on this test we flowed over 10,000 cubic feet according to the records at the power house.

Q. Suppose the water had been at a temperature of 70

degrees under the same conditions, how much more do you think would have flowed?

A. Well, you would get more. What you actually lose is the slope; and it takes more slope, in my opinion, to get the same volume of water through the Chicago River and the Drainage Canal when the water is around 32 to 40 than it does when it is around 70.

Q. Do you have any opinion as to the amount of that difference?

A. Under what conditions?

Q. As between 70 degrees, and about freezing?

A. That would depend upon other things.

Q. What other things?

A. Oh, the amount of water being flowed.

Q. Assume that the other things are the same?

A. Well, then, this would vary with them.

Q. Do you know of any formula for the flow of water in open channels, where the temperature is an element?

A. There may be such a formula, but I have not seen it.

Q. Are you familiar with the formulae of flowing water in open channels?

A. I am familiar with some of them.

Q. Do you not think that most of that effect is due to the ice?

A. No, I do not.

Q. What effect do you think the ice had on February 22?

A. On what?

Q. The discharge, flow of the water?

A. I think it had a tendency to require more slope to get the water through the channel than it would have if the ice had not been there.

Q. That is a greater loss of storage?

A. It means that there would be more water drawn off in storage, yes; that is, more water that you might call storage in the channel would be drawn off.

Q. It would take longer for the effect to be shown, too, wouldn't it?

A. The effect of the—

Q. Take a certain distance, it would take longer for the effect to be shown?

A. Of the full discharge, to get a uniform discharge through the channel?

Q. Or increasing a discharge, take longer to have the effect felt?

A. So that you have a uniform flow through the channel from one volume to another?

Q. Yes?

A. Why, it would, to the extent of the difference in storage due to more head or slope being consumed in flowing the water if it is cold than if it was hot, or warm.

Q. That was in regard to ice, just the effect of ice in the channel?

A. I think my answer is intelligible.

Q. Regardless of the temperature of the water; I mean the floating ice?

A. You would not have floating ice in the water, unless the water was cold.

Q. I understand, but suppose it were just above freezing in both cases; in one case you have ice floating; in the other you do not?

A. There would be a little more slope, I think, due to the fact that the ice projecting above the water has more air friction than just the water surface; and possibly hitting against the sides of the channel. I imagine that there might be some theoretical effect requiring more slope through a long channel than if no ice were there, with the same temperature.

Q. Suppose there were a slope of five feet in the canal, what would be the difference in the volume of flow if the water were 70 degrees in one case and 32 degrees in another?

A. I would not know.

Q. Do you think it would be 5 per cent.?

A. I would not hazard a guess. It would not have any value to the court.

Q. There was quite a strong wind, too, on February 22nd, wasn't there?

A. At times, as I remember.

Q. From what direction?

A. We may have that information, but I do not remember right now.

Q. Have you got it before you?

A. No, I haven't anything before me. I asked you yesterday what you wanted, and you would not tell me.

Q. Did you give it consideration in giving your opinions formerly on the stand?

A. In what respect?

Q. Any respect?

A. Why, I gave it this consideration: I knew it was a very disagreeable day for men to work and to be exposed,

and that was one of the reasons why we carried on a second test. I rather expected that that might be brought up in cross-examination, so as to make this test appear as though it had no value.

Q. So that that was something that you did anticipate?

A. I rather expected that.

Q. Was that one of the reasons why you undertook a new test on March 8th?

A. That was one of them.

Q. Did you consider that the wind would have any effect upon the results as far as flow is concerned? That is in addition to the matter of cross-examination?

A. I know that wind has the effect of changing the elevation of Lake Michigan, for instance, and that it affects the flow through the Chicago River. Of course these current meters were installed at these different stations and were read continuously, and very great care was taken to get as accurate results at that time as was possible by the use of current meters.

Q. Did it have any effect as to the placing of your boat when you were measuring in the sections, where you were measuring from a boat?

A. The only place we measured with a boat on February 22, was at Summit, and the boat was tied tight in the middle of the stream, and held as near stationary as was possible, and I am informed that the boat was practically stationary all the while.

Q. What boat was at Summit at that time?

A. The Robert R. That is the boat that you gentlemen went down the canal on the other day.

Q. You had already determined the coefficient?

A. At Summit?

Q. At Summit?

A. That was done later.

Q. Who did that?

A. Mr. Blanchard did the coefficient work.

Q. Taking March 8th, do you have any more definite opinion as to the accuracy of the measurements at Dearborn street of the volume of flow?

A. I imagine that the ones on March 8th, should receive the benefit of any discrepancy between the two. The weather conditions if they had any effect at all were better, and I know that men work better and more efficiently when they are not exposed to such hardships as they were exposed to

on February 22 which, unfortunately, was a rather severe day and night.

Q. I believe you stated you thought the work was more accurate the further down the canal you went?

A. I am inclined to think so, other conditions being equal; and any effect such as the sudden variations, or variations in the lake level being obscured.

Q. Was there any snow on the ground on March 8th; not thinking of melting ice or snow on the sides?

A. I am speaking from memory; my recollection is there was not much snow on the ground. There was not much, if any, run-off due to thawing.

Q. You would consider the work at Willow Springs, Lemont and Lockport, fairly accurate, then?

A. I would pick Lemont as probably more accurate than the station at Lockport.

Q. Why?

A. Oh, it was a little closer to the dams, and we had done more work at Lemont and the section was probably better understood if I can use—

Q. You think the coefficient work was better determined there?

A. I would say so.

Q. And your cross-section?

A. I don't know about the cross-section, but probably with all the measurements, where we made a great many, better results could be obtained at Lemont than at Lockport.

Q. What is your idea as to the percentage of accuracy at Lemont?

A. I haven't any.

Q. What was the object of putting in the Lockport section?

A. I was anxious, while carrying on this experiment, to get as many sections along the river and channel as we had meters available, and as checks one on the other.

Now, in regard to the accuracy, I can only state that, take Willow Springs, Lemont and Lockport, and taking the storage into consideration, they check one with the other within five per cent. Whether there was an error all on one side or not, I don't know. That is approximately so, as I remember.

Q. How close did Willow Springs and Lockport check, taking into consideration the storage, say at one o'clock P. M.?

A. My recollection is that I would want time to figure that over, if you desire it accurately.

Q. Will you refer to your charts, if you have them?

A. The effect had not got to Willow Springs at that time.

I would like to state right there, it was very hard at that time when the discharge is changing very rapidly to get an accurate result on that. Possibly if you would go along further in the day I could do better, Mr. Hopkins.

Q. Give the best result you can there, approximate it?

A. I want to say that the discharge as indicated graphically is almost a vertical line at one o'clock, and you could make a great big error one way or the other if you did not pick that off. It is not a fair question, at that particular time; and I think Mr. Shenehon would agree with that statement if he would look at the flow in the discharge measurement at Willow Springs at one P. M. on March 8.

Q. You have a chart which you submitted that purports to state the flow at Willow Springs at that time, have you not, Mr. Wisner?

A. It indicates the flow graphically at that time.

Q. Wouldn't it give it within two or three hundred cubic feet?

A. It might not, as anyone could see by observing the chart that at one o'clock the flow is increasing so rapidly at Willow Springs that when it is platted the line is almost a vertical line.

For instance, the flow increased from 12:45, say to 1:10, from 4,600 cubic feet to over 7,000 cubic feet per second.

Q. Well, take 1:30?

A. At that particular time, 1:30, this change was being felt very much at Willow Springs, and the results would not be as good as later on, when the flow had become more nearly uniform. And I can only say that the Lockport discharge measurements checked with the storage run-off within about nine per cent.; Lemont, about one per cent.; and Willow Springs, where the change was then taking place very rapidly and the gages changing, as near as we could figure it was around twelve per cent.

Q. You understood my question was as to Willow Springs and Lockport?

A. That is the only way I can answer that question. Oh, you did not care for Lemont?

Q. It was not in the question.

A. Pardon me; you can cross that out if you wish.

Q. Willow Springs and Lockport check very closely, do they not?

A. I would not say, at that time. Figuring between the meter and the storage, there was a difference at Willow Springs of 12 per cent. and at Lockport of 9 per cent. at that time, when conditions were not good for making a comparison of that kind.

Q. Between the two there was a difference of 3 per cent.?

A. The difference between the measured flow at Willow Springs and what you would compute for the run-off of the storage was 12 per cent., and at Lockport 9 per cent.

Q. Were they on the same side?

A. The error was on the same side.

Q. So that as between the Lockport section and Willow Springs, there was three per cent. difference?

A. I don't know whether that follows or not. I could not say off hand, but possibly that was right.

Q. Now, what are the actual figures there from which you got that per cent.?

A. I just picked them off of this chart, and they may not be exactly accurate, but the measured discharge at Willow Springs, as I used it, was 7,250 cubic feet per second and the storage should have been 8,400. And at Lockport there was a measured discharge of 8,850, and the storage run-off should have been around 9,700. Of course that is assuming that the power house measurement is correct, and taking the difference in elevations as near as we could get it, and there were probably some inaccuracies in getting the gage readings at the same time, although we tried to get them as accurately as possible. But those errors are always bound to creep in in all measurements of this kind.

Q. Do you think that any inaccuracies or errors in the discharge measurements along the canal were as likely to be on the one side as the other?

A. That I do not know. We used all care in having the meters rated before and after, and of course these measurements did not extend over a great number of days and I would not venture an opinion as to whether they are as apt to be on one side as on the other or not.

Q. Do you know of any constant error that was in it?

A. No, I do not know of any constant error that was in this work. The only thing is that at Lemont where we had done more work, it checked better.

Q. Did you make a computation as to the one o'clock time, including storage? Awhile ago you expressed an opin-

ion that that was not worth so much, but did you make any computation?

A. I was judging that from the chart itself, Mr. Hopkins, where the line of discharge is practically vertical, so I did not make any computations at that time.

Q. Will you do so as nearly as you can get it, getting the flow from Willow Springs to the power house?

A. No, I will not, because it would not be a fair answer, and I could not give anywhere near an accurate answer.

Q. How near could you get?

A. It might be away off, at that time.

Q. Have you tried to see how it would come out?

A. No, I can tell by inspection. These show the way these are platted.

Q. Will you figure what it is at one o'clock from Lockport gaging station?

A. Figure what?

Q. What the flow would be at the power house and controlling works, taking into consideration the storage?

A. What is running through the power house is indicated by the flow, and at one o'clock it was 10,350 cubic feet per second approximately.

Q. I ask for an answer to the question?

A. If you will word your question so that I understand it, Mr. Hopkins, I will be glad to answer it, but you asked what the flow was at the power house considering the storage.

Q. Computed from the Lockport gaging station as measured by the current meters?

A. The flow at the Lockport discharge section was a little over 8,500 as I read it from the chart or diagram; between 85 and 8,600 cubic feet per second.

The flow at the Lockport section was 8,600 cubic feet per second, and there was a storage run-off in addition to that, which would be indicated at the power house, of 734 cubic feet per second, bringing it up to 9.334 cubic feet per second and the flow as indicated at the power house was about ten thousand three hundred and something, three hundred and fifty. The difference would be the error which would probably be less than ten per cent., but anyone can figure it.

Q. Will you take now two o'clock?

A. At the same place?

Q. At the same place?

A. It checked within between 7 and 8 per cent.

Q. What was the amount?

A. The amount as indicated by the power house and controlling works discharge was 10,400 cubic feet per second.

Q. My question is as to the amount from that computation, that is what I am trying to get at, the amounts and not the comparisons.

A. Read me the question.

Q. I want the amount of discharge at the power house and controlling works as computed from the Lockport gaging section, taking into consideration the storage at two o'clock P. M.

A. The only figuring that I have made on the storage has been to assume that the flow through the power house and controlling works is correct. And the answers I have given have been based upon that, when I have taken into consideration the storage.

Q. Isn't there another way to get the storage, and a better way?

A. The storage—

Q. From the difference in elevation of the gages?

A. The storage is figured that way, but in figuring back and comparing one with the other, I have used the discharge at the power house as being correct.

Q. That was not my question.

A. Then I have not understood your question, Mr. Hopkins. I have tried to.

Q. Do you think you understand it now, do you get the point?

A. No, I do not.

Q. (Question read as follows: "I want the amount of discharge at the power house and controlling works as computed from the Lockport gaging section, taking into consideration the storage, at two o'clock P. M.")

A. The discharge at the power house is 10,400 cubic feet per second. The measured discharge at Lockport was 8,950 cubic feet per second, and the storage run-off was 520 cubic feet per second bringing the corrected discharge at the power house up to 9,470 cubic feet per second based upon the Lockport discharge.

Mr. Hopkins: I move to strike out the first sentence as to what the discharge was at the power house and controlling works as not being responsive to the question.

Mr. Adcock: For the record, I should say that that sentence was entirely responsive. I have been listening to the question and answer, and I can't see but what it is responsive.

Mr. Hopkins: Q. Will you give us the computed discharge at the same place at three o'clock?

A. The measured discharge at the Lockport Section was 8,850 cubic feet per second, and the storage run-off was 520, bringing the discharge based upon that section at the Controlling Works up to 9,370, whereas the discharge as recorded at the Power House and Controlling Works was 10,500 cubic feet per second.

Mr. Hopkins: I move to strike out that part of the answer from "whereas" as not being responsive to the question.

Q. At four o'clock?

A. The measured discharge at the Lockport Section was 8,900, and the storage run-off below there was 550 cubic feet per second, bringing the total up to 9,450 cubic feet, but as measured at the Power House it was 10,300 cubic feet per second.

Q. Wasn't that 500 feet storage, rather than 550?

A. We add 550 in our computations.

Q. In your opinion within what degree of accuracy is that storage?

A. I have never figured that. I imagine the storage as computed was fairly accurate.

Q. Is that within five per cent.?

A. Oh, I think so.

Q. Now, take five o'clock?

A. The measured discharge was about 8,720 cubic feet per second. The storage was about 500, bringing the total up to 9,220, and the discharge at the Power House and Controlling Works was a little over 10,000 cubic feet, 10,080 cubic feet per second.

Q. Now will you give us the mean of those five hours, of the computed value?

A. As a mathematical proposition you add up those five discharges and divide them by five, which gives you about 9,370 cubic feet per second.

Q. Now will you make the same computations using Willow Springs instead of Lockport, beginning at one o'clock?

A. The average from two o'clock until five—

Q. Will you give each hour first?

A. At two o'clock it was 9,154 cubic feet per second basing the flow on the measured discharge at Willow Springs at two o'clock. At three o'clock, 9,625 cubic feet per second. At four, 9,570 cubic feet per second. At five, 9,560 cubic feet per second.

Q. What were your two items at five o'clock?

A. The two what?

Q. The items that make up that 9,560 at five o'clock, what was the discharge and storage?

A. The discharge was 7,900 cubic feet per second and the storage was 1,660 cubic feet per second.

Q. Isn't that storage, from your charts, about 1,600?

A. It varies somewhat, but I took it from figures from which the chart was made up.

Q. That shows 1,660?

A. That shows 1,660, yes.

Q. A little short of 1,600, on the chart?

A. I took these from the actual figures from which the chart was made.

Q. Wasn't that discharge at one o'clock at Willow Springs as measured 6,400?

A. That is hard to tell whether it was or not. It is not a fair thing to put that in there.

Q. Isn't it so on the exhibit which you put into this case?

A. The exhibit is an exhibit here, and any one can look at it. I only have to say that is not a fair—

Q. Will you look at it and see what it is?

A. It is not a fair thing to put that in because the water had not gotten to anywhere near a state of evenness of flow. (Referring to Wisner's Exhibit 14e.) The change was just being indicated at Willow Springs, and it would be impossible to get an accurate discharge at a particular time from a plat of this kind. I might make a mistake of seven or eight per cent. in reading off the chart.

Q. Was your current meter running at one o'clock at Willow Springs?

A. My information is that it was.

Q. Do you have the results showing what discharge was indicated at that time?

A. That indicated discharge was probably incorrect at that time.

Q. Then are there any other incorrect data in these exhibits that have been put in evidence?

A. Due to this particular fact, that there was an impulse traveling along the channel; that is simply my opinion. It is probable that the current meter indicated a discharge at the particular place where it was, but it is also probable that this would not give the true discharge, using this point as an index point, and afterwards computing your verticals and figuring

your coefficients. And this probably accounts for the errors in the measurements of the Great Lakes.

Q. How many other incorrect matters are there in those exhibits in your opinion?

A. There is no incorrect information in the exhibits.

Q. You seem to think that that one is incorrect?

A. Assuming that the discharge is as you stated 6,400 cubic feet per second, the storage is 3,191 and it brings the total discharge up to about 9,600 cubic feet per second.

Q. Well now, that is simply on the assumption that is made. Do you pretend to say whether or not that assumption of 6,400 is correct?

A. When the discharge is changing so rapidly, it is hard to pick out what the actual discharge was at a particular second or minute.

Mr. Adcock: Q. As I understand, Mr. Witness, your point is that at that time the line on that chart which shows the discharge was running practically vertical, is that correct?

A. Yes, sir.

Q. Whereas at other points it is more or less of a horizontal line?

A. Yes. You can pick with some degree of accuracy from the chart what the discharge was. As a matter of fact the indicated discharge at Willow Springs by the meter was 6,610 cubic feet per second, whereas this chart, in trying to read it, I read 6,400, as did Mr. Hopkins, which would bring that answer that I gave up 210 cubic feet higher, bringing the discharge up to 9,710 cubic feet per second.

Mr. Hopkins: Q. What was your storage, again?

A. 3,190.

Q. Wouldn't that be 9,590?

A. Pardon me, I read off the wrong number; 9,590.

Mr. Adcock: That is the first figure?

A. That is the first figure.

Q. The corrected figure?

A. The corrected figure would add 210 cubic feet per second to that, bringing it up to 9,800 cubic feet per second.

Mr. Hopkins: Q. What was the method of that correction?

A. That was the actual discharge as indicated by the meter at one o'clock.

Q. According to your plats, Mr. Wisner, your storage is about 3,000 instead of 3,190, isn't it?

A. Well, it would be read, as I stated, on account of this

line being so vertical, anywhere, so that you could get from probably 3,000 cubic feet up to 3,300 cubic feet per second.

Q. At one o'clock?

A. At one o'clock, taking the chart that I have here in front of me, yes, sir.

Mr. Adcock: Q. Why did you take 3,190?

A. I took that from the figures that we had.

Q. That is that shows the actual—

A. Those were the figures from which we attempted to plat this graphical representation of it.

Q. And the chart is made entirely from those figures, as I understand it?

A. Yes.

Q. There might be an inaccuracy of plotting?

A. Very apt to be; where you are trying to read two vertical lines, having only a slight angle of inclination one with the other, the width of the ink stroke would make an inaccuracy in reading.

Q. How do you get 3,300 from that chart?

A. Those two lines practically coincide from 7,000 cubic feet per second or even less up to about 7,400 cubic feet per second. And you could read it anywhere within that 400 cubic feet per second. On the chart, the width of the ink mark overlaps the other line.

Mr. Adcock: Q. Now you have taken the figures—

A. I have taken off of that the figures from which this chart was plotted.

Mr. Hopkins: Q. You attribute the discrepancy between the chart and the figures to errors in plotting?

A. There is no discrepancy. You cannot plat a line that has any thickness. The definition of a line is a thing that has one dimension.

Q. In all of the answers that you have given, the figures for storage are somewhat greater than they appear on the chart?

A. I would not say so. You may read them smaller. I doubt if any two men would take this chart and read it just the same. They might by accident.

Q. With the exception of this one at one o'clock at Willow Springs, didn't you read them all yourself as less than the amount of the figures we asked you awhile ago?

A. I don't remember that I did.

Q. Do you know any reason why any discrepancy in plat-

ting would always show that the storage in the plot is less than the storage from the figures?

A. I don't think that it would.

Mr. Adcock: Q. How much is the difference, as a matter of fact, of the percentage?

A. It would not amount to anything.

Q. Would it show materially on the line?

A. In this particular case, Mr. Adcock, where this line is practically running up and down, it is apt to be considerable, but at other places it ought not to amount to much in percentage.

Mr. Hopkins: What is the mean of your five hours at Willow Springs?

A. The mean is 9,542 cubic feet per second.

Mr. Adcock: Q. That is the computed at the Power House?

A. From Willow Springs to the Power House.

Mr. Hopkins: Q. So you consider it unfair to use the one o'clock at Willow Springs, although it has been put in evidence?

A. Possibly the word "unfair" is wrong. I should have said—

Mr. Adcock: I object to that question, the expression "although it has been put in evidence"; it is absolutely unintelligible. The question has been asked and has been answered. The witness gave the reason.

Mr. Hopkins: Q. Although the data from which the question has been asked has been put in evidence by the defendant in this case?

A. What is the question?

Q. (Question read as follows: "So you consider it unfair to use the one o'clock at Willow Springs, although the data from which the question was asked has been put in evidence by the defendant in this case?")

A. Possibly the word "unfair" is not a proper word to use, but as I stated before, the change was taking place so rapidly in the discharge at Willow Springs as indicated at the Index Point that it was pretty hard to get the actual discharge at a particular minute.

Q. What is your mean of your four, from two to five inclusive?

A. I think that is in, Mr. Hopkins, 9,480.

Q. How does that check with your Lockport computation, the figure you gave for the Lockport for the mean was 9,370.

A. One showed 9,370 and the other one 9,520.

Q. And the mean of those two is 9,450, isn't it?
A. I have not figured it.
Q. Will you verify that? What is the mean of those?
A. 9,455.
Q. What is the difference in percentage from the mean to each of these, the Lockport and the Willow Springs?
A. The difference would be the same.
Q. Difference in per cent. from each one to the mean?
A. Oh, a little less than 1 per cent. based upon the mean as the—
Q. Three-quarters of 1 per cent.?
A. Nine-tenths of one per cent.
Q. And the difference between the two would be about twice that in percentage?
A. One is as far from the mean as the other in percentage, and in figures.
Q. Then these two sections check within two per cent. Is that so?
A. I just said so.
Q. Now you seemed to think that the Lemont gagings are more accurate than the others. Why?
Mr. Adcock: I object to that question, because he has already stated several times in the record why he considered the Lemont gagings were more accurate.
A. More measurements had been made at this section, and I think that possibly on that account the work would be more accurate there.
There is this particular thing, which I think Mr. Shenehon will appreciate: We were rigged up there for making discharge measurements and the work was probably more accurate than any of the other stations.
Q. How did your coefficient compare with the coefficient as determined by Sherman Moore?
A. It checked.
Q. Did you use his coefficient, or did you determine one independently?
A. Determined one independently.
Q. How close was the check?
A. Only by platting. We did not have the actual figures, but by the platting the vertical curves checked.
Q. What was the coefficient used by you in this measurement?
A. .914.

Q. Did you have the data showing what Sherman Moore's coefficient was?

A. We got that by comparing his observed velocity with his corrected velocities, and as near as we could tell it was .91.

Q. How did your cross-section check with Sherman Moore's?

A. I don't know as you could tell exactly on that, because one was taken on one side of the bridge and the other on the other side of the bridge. There might be some variation so that you could not tell in percentage what the variation was, but generally as I recall, it checked very closely.

Q. Might not that have an effect, cause an effect on the coefficient if you took a different section?

A. I should think it would be very slight. That bridge is not, I should say from recollection, over 40 feet wide. This bridge spans the whole channel, part of it being, as you know, in the channel.

Mr. Adcock: Q. That is there is no obstruction at that point?

A. No obstruction from the bridge.

Q. Is it in the rock there?

A. It is in the rock section. The sides are practically vertical.

Q. And the bottom is uniform?

A. Practically level, yes, so built.

Mr. Hopkins: Q. Just what particular advantages did you have at Lemont that you did not have at Lockport and Willow Springs in the way of time, men, equipment and so on?

A. At Lemont, for instance, there was a bridge spanning the channel, and at Lockport we had to rig up a wire trolley across the channel.

Q. And at Willow Springs?

A. Willow Springs had the same advantage, but at Willow Springs the wide earth section was just entering into the narrower rock section. The work had been gone over, quite a number of discharge measurements had been made at Lemont, and this was not so at these other stations.

Q. How far below the beginning of the rock section was the Willow Springs discharge section?

A. I am speaking from memory; I should say five or six hundred feet.

Q. Then what effect do you think that would have, the fact that you were that near a little wider section?

A. It means that when the water got to Lemont, it had been flowing through what you might call a practically uniform section from Willow Springs to Lemont, a distance of approximately eight miles. And it would seem as though the water would have a fairly even flow throughout the section, other things being equal; whereas, this funnel shaped opening into the narrower channel might cause some eddies and it might affect the discharge measurement; but the principal thing is that we did more work at Lemont and were fitted up for it at this particular station better than at any other place.

Q. Did you do more coefficient work or more sounding?

A. Yes, I think both of them.

Q. Were there any eddies at Lockport?

A. Personally I did not see that section. I do not know as there were any eddies, but it was rather close to the Bear Trap Dam and as I stated before there was not a bridge at this place. The work had to be done from the stream itself.

Q. How far from the Bear Trap Dam was that?

A. About 3,000 feet, but the channel starts to widen out about 2,500 feet above the Bear Trap Dam.

Q. With the dam open that distance below, and the canal beginning to widen, that would really facilitate the flow, wouldn't it at Lockport? If it had any effect at all, wouldn't it make it easier?

A. I was talking about the accuracy of the discharge measurement, not about the facility of the flow in the channel.

Q. Why did you choose these sections?

A. We wished to get down as close to where the channel widened out as possible.

Q. Even at the expense of inaccuracies?

A. Oh no, I would not say that. That is an unfair question.

Mr. Hopkins.: Not that it makes any difference, but I do not think it is the province of the witness to comment on the character of the examination. If the attorney wishes to say anything to the court, that is his business. Outside of the record, he can say all he desires to.

Q. In your opinion as a hydraulic engineer, what percentage of inaccuracy could come or did come from the selection of these sections, one about five or six hundred feet below a somewhat wider stretch of canal and the other one about, say the same distance above a wider section?

A. I have never given that any thought. I would not want to answer that without going into it.

Q. Do you really think that it made any difference?

A. I am of that opinion.

Q. Weren't they very good sections for discharge work, both of them?

A. I would say they were better than those that you got on the Niagara or the St. Clair River.

Q. How were your measurements made at the Power House and the Controlling Works?

A. Those were simply made I think, as I testified, by the amount of water flowing over the dams and from the rating of the amount of water that flowed through the wheels. This was based upon the tests made upon these wheels at Holyoke, Massachusetts. The wheels acted practically as a meter.

Q. What was the temperature of the water when those tests were made?

A. That I do not recall.

Q. Do you know the time of the year?

A. They were made at different times.

Q. I believe you testified on your direct examination that those measurements at the Power House and Controlling Works might be inaccurate as much as 10 per cent.?

A. I said they might be. I did not know.

Q. How did you measure the water over the dams?

A. That is by a weir formula which was developed in this office to fit that shape dam as near as we could tell from experiments that had been made at other places.

Q. What is your idea of the degree of accuracy of that?

A. If I recollect, these were checked by some rod float measurements made in the channel.

Q. At what point in the Chicago River does the sewer nearest Lake Michigan empty?

A. I think at the foot of Michigan avenue. There may be some smaller ones east of there coming from concerns located along the bank of the river.

Recess to 2:15 P. M.

June 16, 1914, 2:15 P. M.

GEORGE M. WISNER resumed the stand and testified further on cross-examination as follows:

Mr. Hopkins: Q. Mr. Wisner, in comparing the computed results this morning of Willow Springs with Lockport, do you think that it is better to make the comparison without using the one o'clock reading at Willow Springs?

A. Well, as I said before, the discharge is changing so rapidly at Willow Springs that it might be very difficult to get what the actual discharge was there at some particular minute. Most of these discharge measurements, as I understand, extended over about five minutes' duration.

Q. What would be your computed mean, omitting the one o'clock computation at Willow Springs?

A. 9,480 cubic feet per second.

Q. What do you think of the accuracy of the Robey street measurements as compared with the accuracy say at Willow Springs and Lockport?

A. The section there was not quite as good as at Willow Springs. It was measured off of a boat and undoubtedly was not as good as the measurement made at Lemont.

Q. How about as to Willow Springs and Lockport?

A. The section is better at Willow Springs than Lockport, and any variation in the level of Lake Michigan would affect the discharge measurement more at Robey street than it would at Willow Springs or Lockport. Willow Springs, as I stated before, was measured off of a bridge. Lockport was measured from a cable and Robey street from a boat.

Q. Do you think that the Robey street measurements are as accurate as the others?

A. I would say not as accurate as Lemont. In regard to the others, I would not know because we just made these measurements on those two days, and there were not enough of them made to show the relative accuracy of the measurements.

Q. Do you think there was any constant error at Robey street, so that it would be over or under the others?

A. I would not have an opinion on that.

Q. Do the men who made the measurements, and who are present in the room, have any opinion on it? I understand you are testifying a good deal from their data, so just consult with them.

Mr. Adcock: Of course it is understood, I believe, that Mr.

Wisner's direct examination should show the names of the different persons who had to do with the measurements at different points; and I believe I stated to counsel for the Government that we would produce any one witness, or all, for cross-examination, if the Government wished to ask them any questions.

Mr. Hopkins: As I understood, it was suggested that Mr. Wisner, the Chief Engineer, should give the results of the entire test for all of them; but as to certain details, in fact all of the details, he seemed not to be familiar with; and Mr. Blanchard, who had charge of the field work, is present here, as well as Mr. Ramey, and my suggestion is that the witness get these matters of accuracy, which he does not have any opinion on himself, from these gentlemen.

Mr. Adcock: Yes, the understanding being that we could better facilitate the inquiry into the facts by that method.

A. In reply to the last question, the section at Robey street is not as good as at Willow Springs or Lockport. There was more coefficient work done at those two sections than at Robey street or Loomis street.

Q. Do you think that that would make the result at Robey street less or more than the others?

A. I think the chances are that it might make it less. The further away you get from the outlet, any error that you make in computing the storage would be accumulated.

Q. How about the accuracy of the measurements at Loomis street?

A. The same general criticism would hold in regard to them as at Robey street, uneven bottom, not as good a section, the bottom being soft and hard to get the area, which did not obtain in the rock sections.

Mr. Adcock: You mean hard or harder to get the area?

A. The bottom is softer and it is harder to get it, for the reason it is difficult to locate the surface of this rather soft mud which accumulates in the bottom of the Chicago River.

Mr. Hopkins: Q. A little difficulty in getting the exact cross-section?

A. I would say so, in the Chicago River.

Q. How is Dearborn street?

A. Dearborn street would be the same way, and then that is obstructed somewhat by the bridge.

Q. There is a great deal of storage between Dearborn street and Robey street though, is there not?

A. Not so much.

Q. The North Branch and the South Fork and the slips, the turning basin?

A. On the superficial area, you would be right, but there is not much of a drop due to the storage being drawn off. There is some storage, of course.

Q. Do you think the Dearborn street working results were as accurate as at Loomis street or Robey street?

A. As I stated before, I think the results at Dearborn street may have been affected and were more affected by fluctuation in Lake Michigan than were the others as you went down-stream.

Q. Now similarly to the method used this morning, will you compute the discharge at the Controlling Works and Power House from the Robey street measurements, taking into consideration the storage?

A. At the same hours?

Q. Beginning at two o'clock?

A. We will begin at one o'clock, why not?

Q. Beginning at two o'clock?

A. I am going to begin at one.

Q. I insist upon an answer to the question.

A. I will put your two o'clock in. At one o'clock, it was 10,000 cubic feet; two o'clock, 8,574; three o'clock, 9,285; four o'clock, 8,920; five o'clock, 8,800.

Mr. Hopkins: Now you will read please the question to the witness, beginning at two o'clock. I move the one o'clock be stricken out as not responsive to the question.

Mr. Adcock: You have prepared figures similarly, have you not?

A. To what we were asked this morning at the other stations, yes. Two o'clock—

Mr. Hopkins: As I understand, no one in this case contends that any effect would be felt from the Power House to Robey street within one hour. I do not think any one has any justification for that except facetiousness.

The Witness: You can read the answer, what it is in there from two o'clock on .

Mr. Hopkins: Q. Will you give us the means of those computations from two to five inclusive?

A. About 8,900 cubic feet per second for those four.

Mr. Adcock: Q. You are leaving out the one o'clock?

A. Yes.

Mr. Hopkins: Q. Do you think there is any greater percentage of error in the storage as shown at Robey street than the others?

A. I would say so, yes; much more.
Q. In percentage?
A. Yes, in percentage, quantity or any other way?
Q. Why?
A. Well, from Willow Springs down, or to Lockport and to the Power House on the other side, the walls are practically vertical, whereas above there the side slopes, and the slopes have caved in some and we have no accurate way of telling just what the area is—we have not as accurate a way of telling what the area is as the water gets lower.
Q. Would that fact make your storage too big or too little?
A. It might make the storage either way; might make the error either way.
Q. Will you give us the same computed values computed from Loomis street, from two to five inclusive?
A. The average or mean for that is about 8,250 cubic feet per second, the average of the four.
Q. That is Power House and Controlling Works now, computed from Loomis street?
A. Yes.
Q. What is it for two o'clock, three, four, five?
A. Two o'clock, 7,677; three o'clock, 8,265; four o'clock, 8,560; five o'clock, 8,520.
Q. I presume you would not expect anything like as accurate results at Dearborn street by that method of computation as at the other places, because of the greater storage and length of time?
A. Well, the greater storage, and the further fact that as you get up to this end of the works, the beginning of the channel, a slight error in the reading of the gages would make quite a large percentage error in the amount of storage drawn off, and then Dearborn street, as I stated before, is affected by variations in lake level.
Q. Just how much difference in the accuracy, percentage of accuracy of storage do you think there is between say Willow Springs and Robey street?
A. It would simply be a guess on my part, and there is no way that I know of—
Q. Where you have no sloping sides, and slope washed in, one way or the other.
Mr. Adcock: Mr. Witness, you may finish your former answer before answering that question.
A. (Answer of witness read as follows: "It would simply be a guess on my part and there is no way that I know

of—") —of accurately or anywhere near accurately estimating how much more accurate one is than the other; but I can say that in the earth sections which have been washed considerably by the passage of boats, it might make quite a little difference. We simply had to figure this on the theoretical section as built. We have no additional data, and it was an approximation of the amount of storage above Willow Springs, more so than below.

Mr. Hopkins: Q. Could you give any outside limits, when you say it would be a mere guess?

A. No, I would not attempt to do that as it would be, might be misleading.

Q. The canal is about 200 feet wide at the surface along through there, isn't it?

A. There is one stretch of it that is 202 feet wide on the bottom, with side slopes. The other was built 110 feet wide on the bottom and side slopes of two horizontal to one vertical. A part of that stretch has since been widened, I think about 70 feet.

Q. So that a few feet variation on the sides from place to place would not make very much difference in the storage?

A. It might make considerable difference when you consider the long distances and also further, as I stated, that any little inaccuracy in the reading of gages at this end, would amount to considerable.

Q. Do you think it could be ten per cent. in error?

A. I would not hazard a guess. You are just as well able to guess on that as I am.

Q. To what extent then has it washed, or changed its capacity?

A. There are places where the canal has probably widened at the surface, the water surface width is 40 or 50 feet wider than we dug it.

Q. Possibly at other places it has caved in?

A. And narrowed?

Q. Yes?

A. At the water surface? I think not.

Q. Do you think it would average 40 feet?

A. No, I don't think so.

Q. Do you think it would average 10 feet?

A. I imagine it would average more than that.

Q. Do you figure that in getting the storage?

A. No, we figure the storage and the theoretical widths as actually dug. We did not have the other measurements.

Q. Would you consider that there is an average of 20 feet?

A. I would not guess on that.

Q. Well, that possible error could not do much more than account for the difference as computed say between Robey street and Willow Springs, could it?

A. Well, taken in connection with any gage readings that were not accurately made, there might be a considerable error there.

There was one other thing that might affect the storage, I am informed by Mr. Ramey, and that was that he did not include in these storage quantities the water that would drain down from the North Shore Channel.

Q. That would only affect the computations from Dearborn street, would it not?

A. That would not affect it except at Dearborn street.

Q. There is no reason why the storage as given in these charts or in your tables there in the Rock Section should be on one side rather than the other, larger or smaller than the correct amount, is there?

A. If there is, I do not think of it at this time.

Q. In other words, you do not have the canal widened at the surface as you had it in the earth section?

A. No, except to a small percentage.

Q. Is there any constant error that you know of in that storage as submitted by you in your direct testimony?

A. I do not remember that I submitted it in my direct testimony.

Q. It is in these exhibits?

A. On those exhibits, yes.

Q. (Question read) "Is there any constant error that you know of in that storage as submitted to you" in the exhibits from which you testified in your examination, copies of which were submitted to the Government for examination, as showing the results of those tests, referring to plate 34A.

Mr. Adcock: I do not know that those were offered in evidence.

Mr. Hopkins: I said which were submitted. I offer in evidence chart 34. Is there any objection to it? If so I will try to identify it by the other people. Let it appear that 34A is a chart submitted to the Government by the Chief Engineer of the Sanitary District, the witness, as showing certain results obtained in tests made under his direction March 8 and 9, 1914; and is attached to and to be taken in connection with Wisner's Exhibits—

Mr. Adcock: They were not attached to it. The exhibits which we offered in evidence are bound together.

Mr. Hopkins: Do you object to the admission of this chart in evidence, the one which has been submitted to us, or shall we ask the man who made it—

Mr. Adcock: It has not been the custom to object on those grounds?

Mr. Hopkins: With the idea of reserving the objection. I do not want it to come later.

Mr. Adcock: No, I understand there is no reserved objection as to any question of form. It is only objections as to substance that are reserved in this testimony.

Mr. Hopkins: Q. Mr. Wisner, will you refer to Table 34A, and tell us what that is? By whom was it made and tell us what it shows.

A. It was made under my direction by Mr. Ramey and it shows that assuming the discharge at the Power House and the Controlling Works as correct, and substracting from that the storage drawn off between the different points, shows what the discharge would have been at the other stations as indicated on the plat, Lockport, Lemont, Willow Springs, Robey street, Loomis street, Dearborn street.

Q. How were these various values for storage derived?

A. By taking, as I stated before, the area of the surface, and how much the water was reduced in elevation between the gages; that is for instance if the water was reduced a foot in height from Willow Springs to Lockport, we took the length times the width, times I foot, and that gave the number of cubic feet that the storage was reduced in a certain time.

Q. Is that a correct chart, correctly plotted and so on?

A. I presume it is approximately correct.

Mr. Adcock: Q. That is as near as you can plot?

A. As near as we can plot.

Q. And I also understand Mr. Witness, that you have the figures here from which that plot was made, and those were among the various things we offered to produce for the benefit of the Government upon request?

A. That is correct.

Mr. Hopkins: I offer that chart in evidence as Wisner's Exhibit 14G. of this date.

Whereupon chart identified was marked Wisner's Exhibit 14G, June 16, 1914.

Q. Now Mr. Wisner, the discharge at the Controlling

Works and the Power House, showing an average of 9,370 from one until five, as computed from the gage readings at Lockport, and the storage from Willow Springs an average of 9,480 from two until five, Robey street 8,950 from two to five, and Loomis street 8,250 from two to five, taking into consideration your former statement that the measurements at the Controlling Works and the Power House may be in error ten per cent., is it now your opinion that the gage readings at Lemont are nearer correct than all the rest of these?

A. I take it you mean discharge measurements at Lemont.

Q. Yes.

A. I would say so Mr. Hopkins.

Q. Then all the rest are out of step but this one?

A. I would rather base my judgment upon the measurements made at Lemont.

Q. Although there is consistently a lower amount at the other four stations?

A. That might be, but there were more measurements made there, and the work was really more carefully done for the reason we were making discharge measurements there for another purpose, and Mr. Blanchard was employed particularly to make those measurements as accurately as it was known how to make them.

Mr. Adcock: That is the other measurements?

A. At Lemont.

Mr. Hopkins: How about the others, wasn't he to make those as carefully as possible?

A. Yes, but there were only a few of them made; and if I understand work of this kind, you have to make a great many measurements in order to get at a fair discharge for a stream of this kind.

Q. Do you know any reason why all of these should show so much lower than Lemont?

A. No, I do not, unless possible sewage coming in from the sewers at this end may have had some effect, and we did not get it as storage when it was really storage or supply.

Q. How many sewers are there coming in below Robey street?

A. There is one at Western avenue, a big sewer at Western avenue and this one at the Corn Products Company; that is a big one; a big one at Kedzie avenue, and maybe some others.

Q. How many below Willow Springs?

A. There is quite a little leakage comes in from the Des

Plaines River. I do not know of any sewers. There may possibly be some further down but I do not recall them now.

Q. How much in cubic feet per second do you think comes in between Robey street and Lemont in sewers?

A. I never measured it.

Q. How much came in during this particular test, have you any idea?

A. No, I do not know.

Q. Would it be 1,000 cubic feet per second?

A. No, I doubt it.

Q. Or 100 or 10?

A. Oh, it would be more than 10, probably more than—I am merely guessing—I should say there was more than 100 cubic feet per second, a great deal.

Q. That could not account for the difference?

A. No, that might simply be accounted for in the inaccuracy of getting the correct area of the storage or the measurements may be in error. They were simply made on these two days.

Q. What kind of a meter did you use at Lemont?

A. I think that is all in the direct testimony. I am willing to put that in again if you want.

Q. Yes, I want that.

A. Haskell meter at Lemont.

Q. At Lockport you used a Haskell meter?

A. Haskell at Lockport.

Q. A Price meter at Willow Springs?

A. Yes.

Q. As far as the meter work is concerned, there is no reason why Lemont should be any more accurate than the other two?

A. Not as far as I know as regards the meter itself, except the inconvenience of handling it. It was much more convenient at Lemont than at Lockport.

Q. You did not have any inconvenience at Willow Springs?

A. No, but at Willow Springs that was another kind of meter. Willow Springs, as far as the section was concerned, the convenience of handling the meter was concerned, and Lemont were practically the same.

Q. Then you consider the Haskell Meter gives better results than the Price Meter?

A. I am not an expert on that, Mr. Hopkins.

Q. You mentioned the fact that they were different meters?

A. They were.

Q. Is that supposed to have had any effect on the results?

A. That I would not know.

Q. If you are not sure that your gagings were accurate or any of the discharge measurements were reasonably accurate, then your test is not worth quite so much, is it?

A. I did not say that I was not sure that they were reasonably accurate. You said that.

Q. What do you say?

A. I say considering what was done, I think the work was well done and with a degree of accuracy that you would expect under the circumstances.

I further say that the work at Lemont was the best work, and should be entitled to more credit than the others.

Q. Although it is out of harmony with four others, omitting Dearborn street because of the difficulties there, though it is out of harmony with four others you still insist that was the best result?

A. It is out of harmony but, I explained, to a reasonable extent.

Q. When you speak of "well done," can you give us some idea from which we can judge that in figures or percentages, either in cubic feet per second or any other way, so that we know what it means?

A. In making measurements of the kind that we made to get comparative results where sections, discharge sections were not continuously measured over a long number of days, I would say if on one measurement on one place and another one at another place, if they agreed within 10 per cent. with some place that was accurately made, you would be doing work pretty carefully, because the law of averages does not enter into offset errors that may come into a measurement of this kind; and there were only a few measurements made at any station except at Lemont.

Q. Lockport, Robey and Willow Springs agree much closer than 10 per cent., do they not?

A. They may. I have not figured within what percentage they do agree.

Q. Will you refer to your chart there, at six o'clock—

A. Which chart do you refer to?

Q. I think it is your 14e, as introduced in evidence. Will

you compute the amount at the Controlling Works and the Power House from Lockport, at six o'clock?

A. A little over 10,000 cubic feet per second.

Q. How about Willow Springs?

A. Basing it on Willow Springs?

Q. Yes, basing it on Willow Springs?

A. That is a little over 10,000 cubic feet per second, too.

Q. Take the same two stations at seven o'clock?

A. Based on Lockport it is 10,750, and on Willow Springs, 10,950.

Q. Doesn't that look as though there was quite an increase in the flow between five and six o'clock at the Power House?

A. There was an increase in the flow at the Power House as indicated between 5:30 and 6:30, of about 400 cubic feet a second.

Q. And the flow at Lockport and at Willow Springs shortly thereafter conforms very closely to it, does it not, in those computations, taking into consideration the storage each time?

A. I do not quite understand, Mr. Hopkins, what you mean when you say conforms very closely to it.

Q. To the flow as shown on the Power House and Controlling Works line?

A. I would not say that it conforms very closely to that; probably off 600 or 700 cubic feet a second right there.

Q. Does it not take into consideration the storage?

A. We were taking into consideration the storage.

Q. But it is much closer than it was from one o'clock to five o'clock, is it not?

A. I would have to plot that on here to see that. I do not remember what those figures were at one o'clock, now.

Q. From one to five for Lockport was 9,370, an average. Take your average?

A. Well, generally between one and five there is a little more discrepancy than there is from seven to eight or nine o'clock in the evening. That is assuming that the records at the Power House were correct.

Q. About 5:30 you were changing from your Bear Trap Dam to your turbines.

A. Yes, that is true.

Q. Is it not possible that more water would get through the turbines than you estimate, and that there may be an error in the amount as determined at the Power House between one and five?

A. I think undoubtedly those wheels are underrated in

the amount of water they take. That is particularly so, Mr. Hopkins, working under a low head.

Q. At what time were you working under the low head?

A. The head had gotten down pretty well at five to six o'clock in the evening, and from then on until the end of the test.

Q. Don't you think it is possible that the amount shown on Chart 14e, for the Power House and Controlling Works between one and five o'clock was too high?

A. It checks very closely with the Lemont measurements up to five o'clock.

Q. But in all cases it is more than the Lemont measurements, is it not?

A. The discharge at the Power House?

Q. Yes?

A. Is more than the Lemont discharge?

Q. Yes?

A. From one to five? Yes.

Q. As computed with the storage, too? That is taking into consideration the storage.

A. Well then, taking into consideration the storage from one o'clock until five, the two check very closely. For instance at one o'clock, taking the storage into consideration, based upon Lemont, the discharge is 10,400, and at one o'clock from the records it was 10,350 cubic feet per second.

At two o'clock, the records at the Power House show a discharge of about 10,400, and computed from Lemont it is 10,200. At three o'clock it checks within about 300 cubic feet per second. At four o'clock, within about 200 cubic feet per second, and at five o'clock it is about 50 or practically the same.

Q. There is a sewer you say at Michigan avenue?

A. Yes.

Q. About how much does it discharge in cubic feet a second, an average?

A. I would have to look that up for you, Mr. Hopkins. I do not know now.

Q. How much during the time of this test on March 8th?

A. I suppose we could get some sort of an estimate but I haven't it in mind.

Q. What is the total amount of sewage that goes into the canal, or that discharges from sewers?

A. In dry weather it is about 250 gallons per capita.

Q. Can you give us that in cubic feet per second?

A. As near as we can tell from the gagings we have made, the dry weather flow amounts to about 300 gallons per capita. This includes seepage that comes into the sewers, and on that basis, if my calculation is right, the total run-off would be in the neighborhood of 1,150, between 1,150 and 1,200 cubic feet per second.

Q. How much of that is below Robey street, between Robey street and the Power House?

A. I do not know. I could not answer that offhand, Mr. Hopkins.

Q. About 10 per cent.?

A. There is a big sewer comes in at Western avenue. I do not know; I would say offhand I do not think it amounted to 10 per cent.

Q. How was that flow distributed; is there much of it between noon and midnight, is that when most of it comes, or vice versa?

A. With the long sewers, it takes a longer time, and with the short ones a shorter time to get to the river.

Q. What proportion of that 1,150 cubic feet per second comes into the North Branch of the river?

A. I would have to look that up. I could not answer that offhand.

Q. Can you give roughly what it is?

A. I would not think there was 30 per cent. of it. I may be in error; I am simply guessing.

Q. How about the South Fork, the Stock Yards?

A. There is quite a big population drains into that.

Q. As much as 40 per cent., you think?

A. I do not want to go into this and then be checked up on the percentage. If you want a table prepared, I would be very glad to do it.

Q. I thought perhaps you could get it roughly. Have you got the information where you could get at it and give us this more or less offhand or approximately correct?

A. That would take some little time to get it approximately correct.

Q. There is a very small percentage of that amount coming into the river between Lake street and the lake, is there not?

A. I would not say there is very much that comes in between Lake street and the lake, although there is a big run-off, dry weather run-off from the so-called Loop District. In fact it is more than the storm run-off.

Q. Where does that go into the river, south of Lake street?

A. Pardon me, I thought you said between Lake street and the lake.

Q. Yes. I just wanted to know where it goes into the river?

A. It goes in at all the streets, I think there is a sewer on every street from Michigan over to Lake street.

Q. Is there a sewer running on the east and west streets?

A. There is on some of them. I am not sure about all.

Q. Lake, Randolph, Madison, Washington?

A. There is a big long sewer on North Clark street that comes in from the north. At Randolph street, my recollection is there is not a very large sewer on the east side of the river.

Q. Now what is the area of the watershed of the Chicago River?

A. My recollection is it is 307 square miles.

Q. 307. Just in a general way what are its boundaries?

A. Well, it goes from Lake Michigan west to the ridge between the Des Plaines River and the Chicago River.

Q. How far north?

A. It goes north away up into Lake County.

Q. Skokie?

A. The Skokie is all in that drainage area, yes, sir.

Q. And how far south?

A. Well, it goes south practically the whole length of the Drainage Canal, you might say, but that was not included in those figures. As I remember, those figures only go down as far as Summit.

Q. How far south along the lake?

A. We divide that where the sewers come north from the Calumet River, that is about 87th street.

Q. About how often in the course of a year would there be a storm of 10,000 cubic feet per second?

A. That would depend upon the year.

Q. Contributing to the canal. Take an average year.

A. That is a rather difficult question to answer, for the reason that the number of days in the year that this will happen will increase as this drainage basin becomes more filled up and improvements are made by which the water, for instance from the Skokie drains off faster; but I would say that you might get a maximum a flood here of 10,000 cubic feet per second possibly on an average of once or twice a year through a number of years.

Q. How long would that rate of flow last?

A. That would depend upon the stream. They had one in 1892 in May, and one in June, that lasted for several days, as I recall it. We have had them since then where they kept up, as near as I can recall, two or three days. When I say that, I do not wish to be understood as meaning that there was 10,000 cubic feet all the while, but it was a heavy run-off. The discharges were not measured.

Q. And in order to have that big a run-off, that rainfall has got to cover a large part of the drainage area, has it not?

A. I should say that you might have what you call a local storm and still cover that area, which is not very large.

Q. I know, but what I have in mind is you could not get a 10,000 cubic foot run-off from just the territory adjoining the Chicago River, within a mile or two of it each way?

A. I would say probably you could. When I make that answer, I have in mind that there was a local storm of that kind, which I think I testified to, which occurred on Hickory Creek, which is a stream that runs into the Des Plaines River at Joliet. I presume it is nowhere over 40 miles from the City of Chicago, and at places closer. That storm occurred, and it flooded out the City of Joliet, went over the railroad tracks at that time where the Santa Fe depot was located. Since then the tracks have been elevated. And at that time there was a heavy rain storm in the City of Joliet itself, but it occurred east and north of the City of Joliet, and did not, according to information that I had at the time, cover a very large area.

Q. What is the area of the City of Chicago?

A. I think it is 195 square miles.

Q. Of course the Desplaines River and the river valley is not included in this 307 square miles?

A. No.

Q. Did you ever know of a case where you had 10,000 cubic feet of water in the Chicago River from a storm, where the rain did not cover more than 100 square miles?

A. I haven't any data of that kind, Mr. Hopkins. No, that would be almost impossible information to get, as to just how much a severe storm would cover. My opinion would be that if you have a rain storm that would produce 10,000 cubic feet per second, it would probably cover the whole of Chicago River. It would be raining in all parts of the district except in a particular case like I mentioned that happened around Joliet. As I understood, you asked me if

that were possible to occur, and I have stated this particular thing which occurred within 40 miles of Chicago.

Q. In other words, then, it would take longer than the two or three hours that you mentioned in your direct testimony for the full 10,000 cubic feet of water to get in the Chicago River, that is, the South Branch of it, and the canal, because you have got to give time for some of it to come in from the suburban districts, have you not?

A. I think it would be entirely possible for it to get into the Chicago River within the time stated in my direct testimony.

Q. What is the shortest time, not possible but probable, as the existing conditions are in this community, when a storm of 10,000 cubic feet a second would get into the South Branch of the Chicago River or the canal?

A. That would depend entirely upon the condition of the ground and previous rains, amount of snow upon the ground; whether the ground was saturated or not, and general conditions of that kind?

Q. What is the shortest time that you could get 10,000 cubic feet into the river from a rain storm in the ordinary course of nature, not just a possible downpour?

A. I think the range I gave in my testimony would be the shortest time.

Q. What was that?

A. My recollection was, I can look those notes up, but I think it was three to four hours, as I remember it.

Q. How did you determine that?

A. We just determined that from measurements we had made on different sewerage districts or sewers, one of which was located on the North side, one upon the Southwest side and one down on the South side.

Q. What test did you make?

A. Took the time when the rain started and when we got the maximum run-off from the sewers and from that we made an estimate as to how long—

Q. Where did you make your measurements of the run-off in the sewers?

A. At the outlet.

Q. Where were these outlets located, say on the North side?

A. The one on the Southwest side was at Robey street, the other one was at 39th street pumping station, and the other on the North side, Diversey boulevard, I believe. We

took these three separate districts, so as to get a kind of general idea what would happen in the whole city.

Q. Then your determintion was how long it would take to get into the Chicago River, including its various branches?

A. No, that was when it would be poured into the Chicago River like for instance you pour several streams into a bowl and it was overflowed and it would start to run out.

Q. This time of three or four hours, where did you get the water to in that time?

A. That is from the time the rain had gotten a good start until we got the maximum or concentrated high load.

Q. At the mouths of the sewers?

A. Yes.

Q. And at various distances from the South Branch to the Drainage Canal?

A. Well, Diversey boulevard empties into the North Branch.

Q. How far is that from the lake by way of the river?

A. Diversey boulevard?

Q. Yes?

A. That sewer must be three or four miles north of the river, and the river is about a mile and a half long; three and a half miles north and a mile and a half over.

Q. About five miles?

A. Yes, about five.

Q. Robey street is how far, seven miles?

A. That is about six miles from the mouth of the river.

Q. And the 39th street outlet?

A. Well, that is pumped into the 39th street conduit and it comes into the river at Halsted street.

Q. 39th and Halsted?

A. 39th and Halsted.

Q. Was that where you made your measurements in this case?

A. No, we measured it as it came into the pumping station.

Q. On the lake?

A. On the lake, yes, sir.

Q. Around by way of that pumping station to the lake is about ten miles at least, isn't it?

A. It may be in the neighborhood of eight or nine miles.

Mr. Adcock: Q. Around to the lake?

A. Yes, from the pumping station around.

Q. What has that got to do with it?

A. Nothing.

Mr. Hopkins: Q. It takes some time for water to go seven miles even if it were going towards the lake, doesn't it?

A. Yes, sir.

Q. And even after you got it into the river, it would take it some time if it were flowing towards the lake, would it not?

A. Yes, sir.

Q. To what capacity can you open up the Controlling Works and the Power House at Lockport, both of them, the whole works at the Power House?

A. That would depend on how high the water was at the Power House and the Controlling Works.

Q. Assuming a mean discharge of 4,167 cubic feet a second?

A. That that has been flowing right along steadily?

Q. Yes?

A. Assuming also that the lake is normal. I suppose we could open up for a short time, you might get a large flow. I would not attempt to say what it would be without computing it. And it would be some little job to do that, but I doubt if you could flow over 14,000 for a very short time.

Q. Haven't you got some blank spaces in the old Controlling Works that could be opened up and make it more?

A. Oh, we could knock out the end of the canal, and for a short time you would get a larger flow than 10,000 cubic feet per second, but it would not last very long unless the rest of the channel were enlarged.

Q. At those places at the power house reserved for a lock, if a dam were put in there, you could let through 20,000 or more, could you not, if you had the water there? I am speaking of the capacity to flow it through there?

A. I know, but the point is simply this, you might temporarily have a large flow there, but could not keep it up any length of time.

Q. Because you have not got the water there to run through it?

A. You would not have the water there. I have often said when people have brought up the question of flooding at Joliet, if the Controlling Works broke, what damage it would do, and I have been of the opinion it would not do much damage. It would simply soon draw itself down and you would not be able to get through the channel any more water than the capacity of the channel.

Q. What capacity could you open it for at that end?

A. I am trying to tell you, at the start you might be able to get 20,000 cubic feet a second through for a short time, but it would gradually decrease on you.

Mr. Adcock: Q. For how long?

A. I would not attempt to say; it would be simply a guess and figuring on the storage. I have not figured it.

Q. It would be a very short time?

A. I should say so.

Mr. Hopkins: Q. As far as what would become of water that is contributed along the canal, you would have your slope down so that any water contributed along the canal would go with that?

A. That would go with that, yes.

Q. You would not need to be actually flowing 20,000 at that end, if you have the capacity for it, that would throw what water you got that way, would it not?

A. I don't think you made that clear to me.

Q. (Question read.)

A. You mean I could create a hole in the reservoir and let it fill up down there? You could do that for a short period, but I think it would be some considerable time, if that is what you are getting at, before you could get 10,000 cubic feet of water going through the Chicago River at Robey street.

Q. Through the Rock Section, you have a capacity of 14,000 cubic feet?

A. Yes.

Q. Above that you have a little—

A. That is assuming, Mr. Hopkins, that the rest of the channel above there has been improved to the same capacity.

Q. That is what I was going to ask you about.

A. Yes.

Q. You are starting some dredging around Summit now?

A. We have been dredging there, yes.

Q. You are widening the canal there?

A. Yes, sir.

Q. To what width?

A. We are widening it, I think it amounts to about 50 feet.

Q. And that makes it what capacity?

A. I do not know that.

Q. Take the entire canal from Robey street, what is the maximum amount you can flow through?

A. I have never tried to flow the maximum amount through it for any considerable length of time except in times of

storm to prevent the water from the Chicago River from going into the lake, and there the source of supply was rather general.

It is pretty hard to tell what the maximum capacity of that channel would be if we would open it up real wide. The best evidence we have are these tests you have seen here where we flowed 10,000 cubic feet for some ten hours, as I recall.

Q. Then what will be the dimensions of your canal at the narrowest place, when you get through with this dredging?

A. This is merely a progressive dredging. The intention was to take off at this time just sufficient to provide the dilution water for the present population; and at some future time to widen still further.

Q. What is the dimension now at the narrowest point?

A. The narrowest point there now is 110 feet wide on the bottom, 2 to 1 side slopes.

Q. How deep, 26 feet?

A. No, I think about 24.

Q. You are going to widen that 50 feet on one side or both sides?

A. My recollection is about 50 feet on one side.

Q. That will make it 160 feet wide?

A. About that, yes, sir.

Q. And 24 feet deep?

A. Yes, sir. I would like to qualify that answer a little bit as to width. Before when the channel was dug, it was dug in the dry and the sides were sloped up two horizontal to one vertical. When you come to dredge it, you cannot make a slope of that kind, and we have simply dug into the bank on the north side of the channel about 50 feet and come up pretty near straight with the dipper bucket; the result being that when you get through you hardly have available 50 feet additional width that we are dredging, because the ground above the water surface is some 14 or 15 feet high, and that caves in and takes up the available cross section for the free flow of water.

Q. The cross sectional area would be over 5,000 square feet would it not?

A. In reply to that, I would say the cross section, taking into consideration the caving, I doubt if it would be much over 4200 square feet.

Q. It would not be a very difficult matter to get a section there of 5,000 cubic feet?

A. It is a matter of expense. You could get one of 20,000; it is not difficult.

Q. It would not be any very great expense to make it 5,000 from what you have now with a similar amount of dredging, say, on the other side?

A. If I make those figures right, it would probably cost in the neighborhood of $130,000 a mile.

Q. You mean to widen it to that extent?

A. To widen it, yes.

Q. This dredging that is going on now on the North side, is costing that much?

A. It is costing more than that.

Q. What are you doing with the dirt?

A. It is being used on public improvements, filling the lake front park, building the piers out here for the new harbor that the City of Chicago is building, and in front of which the United States Government is to build a break water.

Q. What is that dirt worth?

A. It is a liability as far as we are concerned.

Q. But is considered in getting rid of it in that estimate you made?

A. I was assuming that it was taken away and placed in the lake somewhere.

Q. Now if you had 10,000 cubic feet of water from the Government, you would still want this channel widened to the extent of digging it through there, wouldn't you?

Mr. Adcock: I object to that question, as the assumption is improper and also impossible. The Government already has the water.

Q. (Question read.)

A. You would want to have the channel of a large enough capacity to get the 10,000 through.

Q. Whether you had 10,000 cubic feet a second or not, if you could help keep water out of the lake in flood times by increasing the width of the canal, it would probably be wise to do it, would it not?

A. I do not think you could maintain it, Mr. Hopkins.

Q. Then why is it being widened now?

A. So as to get water through it.

Q. The same way with the Sag Canal that is being dug, it is going ahead increasing the expenses regardless of the determination of the water rights?

A. That is hardly an engineering question, is it?

Q. Now suppose you did have the canal widened all the way to accommodate a flow of 10,000 cubic feet a second, and

you were to open your Controlling Works to between 14 and 20,000 cubic feet a second, wouldn't it draw off the storage much more quickly in the canal?

A. Oh, that would draw the storage off quicker, yes.

Q. So that you would have an increased slope the length of the canal?

A. That would increase the slope. That is what it does.

Q. And any water that ran into the canal or ran in say along Robey Street, Ashland Avenue, all of that neighborhood, would pile up where the elevation is highest and still further increase the slope towards Lockport, would it not?

A. Yes, and it might increase it towards the lake to such an extent that there would be a peak and run both ways.

Q. In three hours you would have your storage in the lower end of the canal practically drawn off, would you not?

A. I do not think so. 14,000 flowing, you mean?

Q. An opening of 14,000 or more.

A. My recollection is that I figured that with 14,000 flowing at the lower end, if it were possible to so stop up the canal that an increased flow would not be coming in from the lake, it would take in the neighborhood of six hours to draw off the storage.

Q. All the way?

A. Yes, that is assuming—

Q. That is all the way to the lake?

A. That is assuming up to Dearborn Street, I believe I just gave you that, Mr. Hopkins, because I did not have a definite answer to the other one, and I did have that.

Q. What would it be in your opinion about Robey Street?

A. To draw that storage off would take about five hours and 20 minutes; that is assuming that it does not increase any from water that would naturally run in; assuming no flow into the canal from above Robey Street.

Q. That is 14,000 from Lockport up to Robey Street?

A. Yes.

Q. Five hours and 20 minutes?

A. Yes.

Mr. Adcock: That is 14,000 at Lockport?

Mr. Hopkins: Yes.

Q. It takes only 40 minutes from Robey Street to Dearborn Street?

A. Less than that if I have it correct.

Q. Now in three hours, would you not have the larger part of that storage up to Robey Street drawn off? You would have nearly all of it down at the lower end, and the fore bay

and down there and would you not have the larger part up as far as Robey Street?

A. In three hours, you would have about 6/11ths of it drawn off.

Q. You think that is uniform in the length of time?

A. That was your assumption as I understood it.

Q. No, I didn't assume anything?

A. You assumed, as I understood you, in your question that there was a flow of 14,000 through the lower end of the canal.

Q. Open it up to that capacity?

A. Yes. That means a uniform flow, as I understood it, out at the end of the canal, 14,000 cubic feet a second.

Q. Your 6/11ths is the ratio of 3 to 5½?

A. Yes, it is.

Q. Do you think that drawing off the storage is uniform, taking a particular point along the line?

A. No, in answering your question, I understood you to ask me how long would it take to draw the storage off, and I assumed no water would be coming into the canal this side of Robey Street, from the lake or anywhere else, except what was flowing through with the 4167 cubic feet. I assumed that that was a constant.

Q. Would not the storm water itself tend to dam the water that was coming from Lake Michigan?

A. Yes, and carry the sewage out into the lake.

Q. Then it would tend to dam the water, would it?

A. The water coming in—if you can speak of a water dam, which is rather absurd.

Q. All right, you use some other word that will express it. You know what I am trying to get at.

A. I do not mean to criticise you Mr. Hopkins, but as I see it—

Q. If you have then a storm and from six to 10,000 cubic feet of water is contributed to the river along three or four or five or six or seven miles from the lake, would that not in itself tend to stop the water coming from Lake Michigan?

A. The tendency would be for that water to go into the lake.

Q. Do you understand my question? Do you think my question calls for that answer or do you just want to keep reiterating that?

A. I think it does, Mr. Hopkins.

Mr. Adcock: It seemed to me that the answer was responsive.

Mr. Hopkins: I move the answer be stricken out as not responsive.

Q. Suppose then that only 4,167 cubic feet is your storm and it all comes in through the South Fork and runs into Ashland Avenue, where would that go?

Mr. Adcock: When?

A. If you were flowing a constant amount through the lower end of the channel of 4167 cubic feet per second and the water was supplied from the sewers on the South Branch, as I conceive of it the main branch would be at a stand still, providing the lake did not vary in elevation which it usually does in times of storm, and there would not be any water coming in from the lake, if that were possible.

Q. Now suppose that a greater amount comes in at various places along the way, it tends to pile up the storage and would stop water coming from Lake Michigan, would it not?

A. To pile up and run out into the lake, because you cannot—

Q. Would it stop water coming from Lake Michigan?

A. It would if your supply coming from sewers and runoff of the Chicago Drainage area were greater than what were flowing through the channel at Robey Street, then it would stop the supply of it coming from Lake Michigan, reverse the current and go into the lake. I cannot make my answer any more responsive than that.

Mr. Hopkins: You just keep saying something that I do not ask for; you suppose it may be, or it is something else, which I think your counsel can take care of.

Mr. Adcock: May be the witness does not say just what you want him to.

Mr. Hopkins: No, the witness insists on answering something I did not ask him, because he wants to get that into the record.

Mr. Adcock: I do not agree with you on that. It seems to me the witness is following your question very closely.

Mr. Hopkins: Yes, he understands it, but he is answering something else.

Mr. Adcock: No, I disagree with you on that.

I think the record will show.

Adjourned to Wednesday, June 17, at 10:00 A. M.

Wednesday, June 17, 1914, 10:00 A. M.

GEORGE M. WISNER resumed the stand and testified further as follows:

Cross-Examination Continued by Mr. Hopkins.

Q. What is the width of the draw at Michigan Avenue?

A. I can get it for you in just a few moments; I haven't it in mind. The width of the two draws?

Q. Yes, of all the bridges along the river.

A. You want them all?

Q. Yes? The bridge at Michigan Avenue is known as the Rush Street Bridge, isn't it?

A. Yes, that is the one at the foot of Michigan Avenue. I have information before me as to the width of the openings at Michigan Avenue. The width for nagivation in one draw is 72 feet, and in the other one 73 feet.

Mr. Adcock: Which ones?

A. I do not know; they are practically the same. For the passage of water it would be greater, the bridge being askew. That is simply the width of a boat that could pass through this draw.

Mr. Hopkins: Q. What is the width for passage of water?

A. That I haven't so accurately, Mr. Hopkins. In reply to that question, by scaling, which is approximately correct, it is 90 feet in one draw and 84 in the other; and on one side of the bridge there is a by-pass between a pier and the abutment or dock line, which is 7 feet wide on the bottom and about 10 feet wide at the water line.

Q. Does that part of the river which is not used for navigation have the same depth as the other?

A. I would so so, generally. It is simply on account of the bridge going across the river askew, that you can't get such a wide boat through it.

Q. Is that bridge at right angles to the direction of flow?

A. I would say at that particular point that it is, but the river has quite a crook in it. It is substantially correct. The by-pass is on the north side of the river.

Q. Do you know the depth of the by-pass?

A. I do not. I never had occasion to look that up.

Q. What is the width of the draw at State Street?

A. It is 140 feet clear for the passage of boats. That is between protections. There are two by-passes, one on each side of the river, and the opening for the passage of water is a little greater than this 140 feet.

Q. What is the dimension of the by-pass? You have it there in square feet, area of the by-pass?

A. Yes, with the water assumed to be at datum. Of course if the lake is higher than that there will be a little added; 180 square feet in each by-pass.

Q. There is more or less obstruction to the by-pass at State Street, is there not, some piles in around there?

A. I did not notice the other day when I was there whether in front of the by-pass there were piles or not. When we built it, we aimed to keep the piles behind the masonry work, and not in front of the openings to the by-pass.

Q. At these places there is not very much current, is there?

A. Well, we never have a swift current in the river.

Q. Compared to the current in the middle of the river, there is not much current?

A. It is somewhat slower, Mr. Hopkins, necessarily.

Q. What volume of flow do you think passes through those by-passes?

A. I never measured that.

Q. How long has that by-pass been there?

A. Since the State Street bridge was built.

Q. When was that?

A. That is already in evidence on that exhibit that was put in here. It is on these maps if you want to go into that again.

Q. Yes, if you have it before you.

A. It is on that exhibit.

Q. I would like to have that. When was that State Street Bridge put in?

A. 1903.

Q. If there were any piles or other obstruction in those by-passes, that would tend still further to obstruct the flow through there?

A. If that were so that would be true, but there were none left in the by-pass.

Q. Has there been any dredging in the by-pass, since the bridge was constructed in 1903?

A. No, nor in the river that I know of.

Q. So that if there is any filling in, in the by-pass, it would still be there?

A. Unless the current scoured it through. If it were filled in, of course it would be there.

Q. Do you know whether there is any filling there?

A. No, I do not. I have not made any personal examination of that. I know of none having been made.

Q. With the velocities of flow that obtain in those by-passes, is there likely to be any filling up?

A. I should not think so. My recollection is that the sewers are built so as to discharge on the down stream side of the bridge. I doubt if there would be any filling coming from the solids in the sewage. When I say the down-stream side of the bridge, I mean the west side of the bridge.

Mr. Adcock: The west side of the bridge?

A. Being the side away from which the current strikes the bridge.

Q. Some of the witnesses have referred to the down stream side as being towards the lake; others away from the lake.

A. When I refer to down stream, I refer to that side away from the lake.

Mr. Hopkins: Q. Now what is the width at Dearborn Street?

A. It is 142 feet for the passage of boats between protections, outside of protections.

Q. Any by-pass there?

A. Yes, sir, two, each having a net area of 175 square feet.

Q. Are the conditions there as to by-passes the same as at State Street?

A. My same answer would apply to Dearborn Street as to State. I understand that this particular by-pass,—these by-passes have been filled in. That bridge was built, if you wish that information, in 1907, completed in 1907.

Mr. Adcock: You do not know that there is any filling in at State Street?

A. No, I do not know that.

Q. There is no evidence that you have heard of, that there is any filling in?

A. No.

Mr. Hopkins: Q. How do you know that there has been any filling in at Dearborn Street?

A. Because we had that investigated.

Q. You have made soundings?

A. Yes.

Q. Clark Street Bridge is a swing bridge?

A. Clark Street is a swing bridge.

Q. What are the widths of the two draws?

A. 78 feet and 68 feet, for the passage of boats. The open-

ing for the passage of water is practically the same. It may be a few feet wider but I haven't the information.

Q. Now Wells Street or Fifth Avenue. What is the name of that bridge?

A. Wells Street Bridge.

Mr. Adcock: Is that a swing bridge?

A. Swing bridge. The channel width for navigation is 65 feet and 71 feet. My recollection is that there are by-passes there, but I have not the information.

Q. Do you have any idea what their dimensions are?

A. No, I have not, Mr. Hopkins. There may be also by-passes or a by-pass at Clark Street, but I haven't that information. We did not have anything to do with those bridges. Those that we have had anything to do with I can give you accurate information in regard to them.

Q. How about Lake Street?

A. Lake Street is now being removed. Let me correct that; they are now building a new bridge at Lake Street.

Q. What kind of a bridge?

A. Doing away with the center pier and building one of the bascule type similar to the ones at Dearborn and Randolph Streets.

Q. What will be the openings?

A. This bridge is being built by the City of Chicago. It is about 209 feet at the water line and a couple of feet less at the bottom of the channel.

Mr. Adcock: Q. That is the opening for Lake Street?

A. There is a slight batter on the piers at Lake Street.

Mr. Hopkins: Q. Take Randolph Street?

A. It is 141 feet 2 inches in the clear, and two by-passes each of 204 square feet area.

Q. About how much wider in total width would that make it, the 408 square feet additional area?

A. About 25 feet.

Q. What is the depth in those by-passes?

A. About 16 feet as I recall.

Q. Making a total width then not to exceed 167 feet?

A. In that neighborhood.

Q. Washington Street?

A. 170 feet 6 inches.

Q. Any additional opening there?

A. I think not.

Q. Madison Street?

A. Madison Street is a swing bridge, and it has been or-

dered out by the Secretary of War and is to be rebuilt by the City of Chicago as soon as the new bridge now being built at Jackson Boulevard is completed; and is to have a clear opening of 180 feet.

Q. Adams Street?

A. On the west side is an opening 60 feet wide and on the east side about 83, varies from 82 to 85½ feet.

Q. Any by-pass there?

A. There is no by-pass at that place. It is a swing type.

Q. What about the width of the new bridge at Jackson Boulevard?

A. The opening there for navigation would be 168 feet wide and for the passage of water about 174, plus a by-pass area of 384 square feet.

Q. What is the depth of the by-pass?

A. 18 feet.

Mr. Adcock: That is the same depth, that is on each side of the by-pass at the dock line.

A. It will be that depth in front of the by-pass.

Mr. Hopkins: Q. What is the proposed plan for the Metropolitan bridge?

A. That is ordered out by the Secretary of War and is to be removed by the 1st of December of this year.

Q. What is the next bridge below Jackson, Van Buren?

A. Van Buren.

Q. What is the width of that?

A. 98 feet in the clear and a by-pass of 800 square feet.

Q. What is the depth of the by-pass?

A. Minus 17; that would be 17 feet deep with the water at datum. That 98 feet width is for the passage of boats, and there is probably eight feet, 6 to 8 feet more for the passage of water.

Q. What would be the width of the by-pass?

A. It is 50 feet in width and the area is 800 square feet based upon the bottom being at minus 16, but as a matter of fact, it is at minus 17, which would give an area of about 850 square feet instead of the one I gave.

Q. You have got a total width there of not over 156 feet?

A. About 156 feet. That bridge is an old bridge; has been in there since before the World's Fair year.

Q. What is the next bridge, Harrison Street?

A. Harrison Street.

Q. What is the width of that?

A. About 175 feet.

Q. Is there a bridge at Polk Street?
A. Polk Street yes; 160 feet.
Q. Taylor?
A. 140 feet with two by-passes of 137 square feet each.
Q. What is the depth of the by-passes?
A. The bottom of the by-pass is on an incline. It varies at the dock from about 6 or 8 feet in depth to out next the pier where it is about 18 feet.
Q. What is the average width of the two by-passes?
A. 16 feet.
Q. Each?
A. Yes.
Q. At the water surface
A. Yes, sir, at the water surface.
Q. So that the water surface has a total width of 172 feet?
A. That would be right.
Q. How about the other bridges down below, are there any others that are along 175 feet or less for the flow of water, total width? If so what are they?
A. You ask me for any less than 175 feet total width?
Q. Yes?
A. 12th Street, you know there is an old bridge there that is to be removed. It was ordered out.
Mr. Adcock: By the United States Government?
A. By the United States Government.
Mr. Hopkins: Q. What is the width there now?
A. For navigation it is 53½ and 61.3 feet. I think it is somewhat wider for the passage of water.
Q. How much?
A. I do not know, Mr. Hopkins. I haven't that information.
Q. How about the St. Charles Air Line bridge?
A. That is to be re-built by the railroad companies, with 200 foot opening. It is now a swing bridge with two draws. It has openings for navigation of 55½ and 59½ feet.
Mr. Adcock: Q. That is being built, isn't it?
A. They have not started it yet.
Mr. Hopkins: Q. Are there any others of a width less than 175 feet?
A. Halsted Street.
Q. What is that width?
A. That exact information I have not, but it is approximately 120 foot opening and there are two by-passes.

Q. What is the nearest approximation you have to the by-passes?

A. They are about 25 to 30 feet in width.

Q. Each?

A. Each.

Q. You do not know what their cross sectional area is?

A. I haven't that, Mr. Hopkins.

Q. Between Halsted Street and say Rush Street, the width of the river aside from the bridges, you say is about 200 feet.

A. It is 200 feet or more with the exception of four places along the river where the widening has not yet been completed.

Q. Those you have already named?

A. Yes.

Q. How much wider in the wide places is it than 200 feet between Halsted Street and Rush Street?

A. Oh, I presume there are places where it is 400 or 500 feet wide.

Q. Does that include slips?

A. On the main river there are places where it is over 300 feet in width and at the junction of the two branches of course it is over 500 feet wide, the junction of the north and south branch. There are places on the south branch where it would be as wide as 280 feet.

Q. In the season of navigation, boats are lying from place to place along that stretch of the river, are they not?

A. Not very many; very few.

Q. Where do they tie up?

A. Mostly out beyond Rush Street, towards the lake from Rush Street. There are some small boats that go down to the lumber yards, go into the slips. Occasionally you will see a boat tied up in the main river west of Rush Street. On the south branch, once in a while there is one at Randolph Street.

Q. Some passenger boats dock at Clark Street?

A. Passenger boats come up close to Clark Street.

Q. The South Haven boats are on the north side of the river and west of Clark Street, are they not?

A. I do not remember about that.

Mr. Adcock: Q. They are not there for very long at a time, are they?

A. I know generally the most of those passenger boats are west of Rush Street. There are some that come up there occasionally and go out, boats doing an excursion business in the summer time, that come through the State Street bridge I think.

Q. What is the width of the river from Rush Street out, say for the next two or three hundred feet?

A. 300 to 270 feet.

Q. What is the width of the river between Rush and State Streets?

A. It runs around 220 feet, except at one point.

Q. The Goodrich boats dock in there, do they not?

A. I think they do, just east of Rush Street.

Q. Just west of Rush Street?

A. West of Rush Street, no, the Graham and Morton are west of Rush and the Goodrich east.

Mr. Adcock: Q. These passenger boats do not lie at the docks very long, do they?

A. Not ordinarily, no.

Mr. Hopkins: Q. Don't they usually lie in Chicago about 12 hours?

A. I didn't think they were here that long.

Q. Boats that get in early in the morning do not go out until evening?

Mr. Adcock: No.

A. They go out and coal up.

Mr. Adcock: They come in the morning and go out in the morning, make a day trip?

Mr. Hopkins: That is just the excursion boats.

The Witness: They make two trips a day in the busy season.

Q. That is the Michigan City boats?

A. I think across the lake, St. Joseph.

Q. How about the Northern Michigan Transportation line?

A. Where do they go?

Q. They go to Ludington, Manistee, Frankfort, and other northern ports?

A. I don't know. I can't answer; I am not familiar with that.

Mr. Adcock: They only have a few boats here anyway.

The Witness: I do not know how many boats they have, Mr. Adcock.

Mr. Hopkins: Do you have any measurements in the Chicago River showing a greater velocity than a mile and a quarter an hour?

A. Not that I know of. I am speaking now outside of the narrow bridge openings, where bridges have not been—

Q. No, that is what I am speaking of. Have you any measurements?

A. I haven't any measurements there but I believe the current probably in some of those old draws is faster than that.

Q. You have no measurements of them?

Mr. Adcock: For what volume of flow?

A. The only measurements that I have in the bridge openings are those that we took at Dearborn Street when the mean current was about a mile and a quarter an hour.

Mr. Adcock: Q. Was that the mean, or the maximum for the tests there?

Mr. Hopkins: Q. What was the current at your index point there?

A. It was 2.4 feet per second, around about there.

Mr. Adcock: Q. Was that the maximum?

A. That is at the index point.

Q. I know, but when the flow was at the maximum during that test?

A. Just about the maximum.

Q. It was about 10,000?

A. That is what we were flowing through the Controlling Works.

Mr. Hopkins: Q. What was the flow at Dearborn Street at that time?

A. Between 6500 and 7000 cubic feet a second.

Q. Did you just have one section at Dearborn Street and one index point?

A. There was practically just one index point.

Q. Did you take into consideration those by-passes in getting the volume of flow there?

A. Those were taken into consideration.

Q. What is the slope of the canal, when it is covered with ice?

A. I never saw it covered with ice.

Q. Do you have much floating ice in the canal?

A. At times, there is quite a little at this end of the canal; very seldom—

Q. Does it take any more water to flush that out? How do you handle it at the lower end?

A. It never gives us any bother there, except once I think we had a slight trouble, that was one winter a few years ago that was very severe, and at that time we did not have much trouble with the ice. I believe we let down the dam and let it pass over the top.

Q. Where do you measure the amount of water that you are taking through the canal?

A. At the lower end.

Q. Do you take any less water in the winter time than you do in the summer time?

A. I think we do as a general thing.

Q. You have longer periods in the day for lighting purposes have you not?

A. Yes.

Q. How about your head, is it higher or lower in the winter?

A. The water surface is usually lower in the winter than it is in the summer, because the lake rises in the summer time.

Q. But to generate that power, you need more water in the winter?

A. I do not waste as much in the winter though as I do in the summer.

Q. Do your records show that you take less water in the winter time than the summer?

A. I think they do. I am speaking generally now.

Q. How much less?

A. I am pretty certain that was so this last winter.

Q. How much less?

A. I would say 50 or 60,000 cubic feet a minute, may be more.

Q. Why did you take less this winter?

A. Well, it is simply that they were building up their head, as we call it at the lower end, on account of the low water during the winter; and for the reason that we do have a big demand for a short time during our peak load for water. In order to carry through that, we would shut down the flow and would let the water fill up in the lower end of the channel to give us additional head when our peak load came on.

Q. If you had 10,000 cubic feet of water per second, would there be any occasion to take any less in the winter time than in the summer time?

A. It might be advantageous.

Q. It is a question of your convenience down at the power house and the lower end as to how much you would take is it not, between seasons?

A. I don't quite understand what you mean by that question, Mr. Hopkins?

Q. You have control as to how much you would take. It

would be a matter of your own convenience whether you took more or less water any particular time?

A. We have so far had control of the amount of water that passes through the channel.

Mr. Adcock: Q. It is not any matter of convenience?

A. It is not a matter of convenience.

Q. We are contracted to flow a certain amount for the population?

A. Yes.

Mr. Hopkins: Q. Are you contracted to flow more in one season of the year than you are in another?

A. No.

Q. Is it not somewhat a matter of discretion for the people in charge of the works there whether they shall take a little more to-day, and a little less to-morrow?

Mr. Adcock: That is within reasonable limits.

A. I think that would be a good answer, within reasonable limits. I think we should be allowed also some discretion, as long as we conform to the spirit of the law.

Mr. Hopkins: Q. You are speaking of what you call the State law?

A. Yes, sir.

Q. The fluidity of the water then does not make any difference, whether you take more or less in the winter time?

A. It does not up to a reasonable amount. As I told you yesterday, I thought it would require more slope or head to get the same amount of water through the channel when the water is cold than it does when it is warm.

Q. If you were measuring it at Lockport as to how much you want and how much you were going to take, the fluidity would not make any difference would it? You might require a little larger opening if the fluidity had any effect?

A. We might make a mistake in the amount of water we are flowing, by the formula that we have, for the passage of water through these wheels, and to some extent possibly over the dams.

Q. Did you ever take into consideration the difference in the fluidity of the water at different temperatures, in regulating the amount of your flow at Lockport?

A. I never thought that that refinement was necessary.

Mr. Hopkins: I want to state for the record that in view of the fact that there is a motion pending before the court as to the materiality of what has been called the sanitary phase of this question, we reserve the right to further cross-examine this witness, and before the court, in case that point is de-

cided adversely to the Government. We also reserve the right, which has been offered to us, to call the witnesses who actually made these tests, and questioned them as to the detail of the tests and the accuracy of their work.

Mr. Adcock: This seems to be a different plan from that which the Government has followed heretofore. We have put on several sanitary experts, or sanitary engineers, with reference to various questions involved, and the Government has cross-examined upon that point; and furthermore I believe the witness has been cross-examined by the Government with reference to the so-called sanitary phase of this case, about which he testified on direct examination.

Mr. Hopkins: As I understand, there has no witness testified in regard to this feature since that motion has been taken under consideration by the court, and he said that in case that he did rule adversely to the Government he would give permission to introduce evidence.

Also in view of that contention of the Government that it is entirely immaterial, we have not regarded it as necessary to make an elaborate study to adequately cross-examine the witness; and I will say also that the witness' disposition to avoid the questions has something to do with it.

Mr. Adcock: The cross-examination upon that feature has been closed. The witness has been produced on re-direct examination with reference to matters entirely different from that, and has testified in that regard.

The Witness: I rather resent the statement made by counsel there that I have avoided answering the questions.

Mr. Adcock: Just wait a moment: As to the counsel's statement with reference to the manner in which the witness has answered the questions, it seems to me entirely unnecessary; it is an improper statement, and it is not borne out at all by the record. The witness has very carefully endeavored to answer the question which has been put to him, as the record will disclose. And I hope that the counsel's statement is not made on account of any difficulties that might have occurred between the witness and counsel. I assumed that he was above such idea.

Recess to 2:30 P. M.

After Recess, June 17, 2:30 P. M.

GEORGE M. WISNER resumed the stand and further testified as follows:

Re-direct Examination by Mr. Adcock.

Q. You were asked yesterday Mr. Wisner, to compute the discharge at the Power House on March 8, 1914, during the time that the test was made under your direction by the Sanitary District, from the gaging station at Lockport, Willow Springs, Robey and Loomis Streets, taking into consideration the storage for the hours beginning at 1:00 P. M. to 5:00 P. M. inclusive. Was there any condition existing at that time which would make a computation of the discharge at the Power House in those hours difficult, or where there might be inaccuracies creep in? And if so, how would those hours compare with the conditions of flow from 6:00 P. M. until 12:00 midnight?

A. Taking the first hours when a sudden change had been made in the discharge out at the end of the channel from approximately 4167 cubic feet per second to over 10,000 cubic feet per second and this change accomplished in a few minutes, it leaves the whole channel which is 30 miles long, and the Chicago River in what you might call an unstable condition. In other words, this sudden change might set up, and probably does, a pulsation through the canal, and measurements which you get from current meters would probably be unreliable until the stream had gotten into some sort of a quiescent state or a state of gradually increasing its flow. That was particularly so I think, as I pointed out yesterday, as far as one o'clock was concerned at the Willow Springs discharge section, where the change was taking place rapidly; that is the flow was varying rapidly, and to make a comparison on those hours—

Q. You mean the flow or the velocity?

A. The velocity was changing. To make a comparison of those hours, I do not think would be as fair or the results as reliable as though you would pick out say from 5:30 that evening until 1:00 o'clock in the morning when the canal was assuming a state of equilibrium or trying to adjust itself to the changed condition of flow at the lower end.

Q. You stated on your direct examination, I believe, that the flow was changed about noon of the 8th?

A. It was.

Q. From 4167 cubic feet per second at the Power House to something over 10,000 cubic feet as shown by the record there?

A. As near as we could tell.

Q. Have you made any computations, taking into consideration the matter of storage and the flow at the Power House at different hours beginning at 6:00 P. M. until 1:00 P. M. inclusive of that day, the 8th of March, at these various gaging stations beginning at Lockport, and if you have will you state what the results of your computations are and what the flow is at the Power House, as computed from these different stations?

A. I have taken, to be exact, from 5:30 P. M. of that day until 12:30 A. M. the next morning, being seven hours; taking the measured discharge at the Lockport Discharge Station and adding to it the reservoir water that was drawn off at the same time below Lockport, that is for the condition represented at the end of each hour, and for this total time would give an average discharge throughout this period at the power station based upon the measurement made at the Lockport discharge section, which was some 3,000 feet above the old Bear Trap Dam, of 10,749 cubic feet per second.

Q. That is the average for that period?

A. That is the average for that period.

Q. From 5:30 P. M. to 1:00 A. M.?

A. Taking the measured discharge at Lemont and the storage of reservoir water that was drawn off below Lemont for the same period and in the same manner, the discharge at the power house was as computed 11,156 cubic feet per second. Using the Willow Springs Discharge Section in the same way, and taking into consideration the storage or reservoir water drawn off of the canal below Willow Springs, the discharge was 10,899 cubic feet per second.

At the Robey Street discharge section, taking the measured discharge and the reservoir water drawn off, the discharge at the Power House would be 10,386 cubic feet per second.

Loomis Street, treated in the same manner, would be 9,614 cubic feet per second. Dearborn Street, 9,801 cubic feet per second.

The average of all six of these computations is 10,436 cubic feet per second.

Q. What was the mean of the discharge at the Power House as shown by the records at the Power House for that time?

A. 10,117 cubic feet per second.

Q. What per cent. of variation is that?

A. Well, the per cent. of variation from the mean of these six as compared with the record as shown at the Power House is 3.06 per cent.

Q. Taking the various gaging stations, what is the per cent.?

A. The maximum at any place, maximum variation from the mean, at Loomis Street, in the Chicago River, was 7.86 per cent. I would say in that connection if the gaging stations in the Chicago River, the discharge of which is more affected by the variation in level of Lake Michigan, if they were left out this percentage would be closer.

Q. You stated yesterday I believe, that there was some difficulty in obtaining an accurate value for the storage?

A. Yes, sir.

Q. At those stations?

A. That is true.

Q. Loomis and Dearborn Street?

A. Loomis and Dearborn Street.

Q. Do you consider this is a better way to determine the agreement between the records at the Power House and those at the various gaging stations during that test than to take the hours which you were asked about yesterday on cross-examination?

A. I think there is no doubt of it.

Q. For the reasons that you have heretofore stated?

A. Yes, sir.

Q. You were asked yesterday something about the dredging of the channel or the widening of the channel in the earth section, which was done somewhat recently. Now do you know under what contract that is being done and with whom?

A. It is being done under a contract made in 1912.

Q. August, wasn't it?

A. August, 1912, with the Great Lakes Dredging and Dock Company, and at the end of last season's work, which was along in December, as I remember it, the work was practically 80 per cent. finished.

Q. By the first or sixth of October of last year, it was probably about 4/5ths done?

A. Yes.

Q. You were asked about the velocity at the index point during the tests on March 8, 1914, at Dearborn Street?

A. Yes, sir.

Q. I believe you stated that the velocity at the index point was about 2.4 feet per second?

Mr. Hopkins: I understood him to say miles per hour.

The Witness: I did not mean it miles per hour; if I said it that way I misspoke.

Mr. Adcock: Q. Would the mean for the cross section be less?

A. Yes.

Q. You were flowing, the recorded discharge at that velocity was approximately 7,000 cubic feet per second, was it not?

A. Yes.

Q. According to the population of the Sanitary District and the rate provided by law, the flow should be approximately 7,000 cubic feet per second, should it not?

A. 7500 cubic feet per second in round numbers.

Mr. Hopkins: I object to that, "as provided by law." That is a matter of interpretation. Just state it in figures.

Mr. Adcock: Q. As provided by the act under which the Sanitary District is organized, and in which the legal rate of dilution is fixed at 20,000 cubic feet per second for each 100,000 of population.

A. 20,000 cubic feet per minute for each 100,000 population.

Q. Yes. Now at that time you were making a test, were you not?

A. Yes.

Q. Under the ordinary operations of the channel to provide the dilution water which you have mentioned, 7500 cubic feet per second, how much in cubic feet per second of water would be flowing through the river itself?

A. Through the main river at Dearborn Street, I suppose you mean?

Q. Yes?

A. The way we were operating ordinarily would be to have 2,000 cubic feet per second coming through the 39th Street pumping station; and about 1700 cubic feet per second coming down through the North Branch, and the balance through the main river.

Q. So that there would be about 4,000 cubic feet per second of water going through the main river?

A. In round numbers.

Q. And approximately 5500 cubic feet per second through the main river, the south branch and the west fork?

A. Yes, except below Ashland Avenue, Mr. Adcock, where the river from Ashland Avenue to Robey Street would get the entire flow, but the river is much wider there and no bridges.

Q. This velocity which was mentioned, which you observed

and referred to, 1.6 miles per hour at the index point, was taken at a bridge opening, was it not?

A. Yes, sir.

Q. At Dearborn Street. You stated on your direct examination that prior to the opening of the Drainage Channel and the improvements made by the Sanitary District, you saw boats frequently stuck in the river, did you not?

A. Many times.

Q. Have you ever seen any boats stuck in the river since the opening of the channel and the making of the improvements by the Sanitary District and since the tunnels were taken out?

A. My recollection is only twice, once at the Pennsylvania railroad bridge at Stewart Avenue across the South Branch just south of 18th Street; and this was due to the fact that a new bridge foundation was being built in order to remove the old center pier bridge, and it became necessary in the construction of this bridge to build cofferdams out into the river, and the railroad company so clogged the stream that a boat got jammed in the draw.

Q. That was during the period of construction?

A. It was during the period of reconstruction. The other one was at Washington Street, at which time the Washington Street bridge was being rebuilt.

Q. The plans for those two bridges, the plans for the construction of the bridges and the manner of construction and the obstructions that were to be placed in the river while the bridges were being constructed, were approved by the Secretary of War, were they not?

A. There was a permit from the Engineering Officer for certain details in connection with it, and there was a permit for the general improvement, but there were certain details about stopping, likewise, that the Engineering Officer of the United States Army at Chicago granted the permit for.

Q. Now, in these bridges or bridge openings, where bridges have been built or improved under the improved type since the opening of the drainage channel, have you ever seen any boats stuck or damaged there?

A. No, sir, I do not think there have been any.

Q. You stated in the direct examination that the plans of the Sanitary District ultimately anticipate a flow through the Chicago River of approximately 8,000 cubic feet per second?

A. That would be through the South Branch.

Q. Yes, through the South Branch, and the 2,000 at 39th Street Conduit?

A. About 6,000 through the main river.

Q. No.

A. About that; there would be 1700 coming down the North Branch.

Q. That is the way it is now?

A. It will be that way too, if we are flowing 10,000 cubic feet, there will be 1700 coming down the North Branch.

Q. Are these bridges so built that you may dredge the channel of the river deeper, so that the velocities at the bridge openings may be less as may be necessary to increase your flow according to population?

A. They are so built, the foundations are carried down so that you can safely dredge to 30 feet depth at the foundation and deeper in the center of the river; and most of them you can go deeper than that with safety, I believe.

Q. But at the present time, with 4,000 cubic feet, approximately 4,000 cubic feet, going through the main branch and approximately 5500 cubic feet going through the South Branch and the West Fork, is the velocity except at certain restricted places where bridges are being constructed more than a mile and a quarter an hour?

A. No, it is not that much.

Q. It is not that much?

A. No.

Q. What would you say the velocity was?

A. Through the main river, it would be in the neighborhood of not to exceed a foot a second. That is 3600 feet an hour, and a mile is 5280 feet. It would be about ¾ of a mile an hour. In the South Branch, it would be a little less than a mile an hour.

Q. Now, are you speaking of the mean current?

A. Mean.

Q. A question was asked you this morning with reference to the flow of water in the winter time, and the suggestion or inference was endeavored to be drawn from the question asked that you flowed the water according to the demands of the Power House. Is that so?

Mr. Hopkins: I object to the question as stating an assumption.

Mr. Adcock: I am speaking of the mean daily flow?

A. Of the mean daily flow, I would say not. We have varied the flow from hour to hour during the day, so as to neutralize to better advantage power which otherwise would have gone to waste.

Q. In other words, during the winter time there is a peak load that comes on about 4:30, isn't there?

A. 4:30, and lasts until about 7:30.

Q. You endeavor to build up the head?

A. Store the water to use during that peak load.

Q. But when you take into consideration the mean daily flow, that corresponds approximately as near as you can make it, with the requirements according to population?

A. Very nearly. There have been some exceptions to that.

Q. But as a general rule that is true?

A. As a general rule we aim to get as near that as possible.

Q. It is your understanding that in the winter time when the water is cold that perhaps somewhat less water would flow through a particular opening than would flow during the summer time when it is warmer.

Mr. Hopkins: I object to the leading form of the question.

A. That is my opinion.

Mr. Adcock: That is all.

Re-cross Examination by Mr. Hopkins.

Q. Is that opinion you have just expressed based upon any test made by yourself?

A. It is based more, Mr. Hopkins, upon my observation of the amount of head or slope between Lake Michigan and the Power House.

Q. Just what observations have you made?

A. They were more or less general. Without being accurate, I would know that there is a certain amount of power being generated and that the elevation of the lake was so much, and it seemed to require, took more fall going from the lake to the power house than it did in the warmer weather.

Q. But under those conditions wasn't there floating ice in the river?

A. Not necessarily.

Q. Did you ever make observations of that kind when there was no ice in the river?

A. The same thing happens then, but how much of it was to be accounted for by the ice, and how much was on account of the water not flowing so readily, I could not say.

Q. Do you know any way of determining what effect the temperature of water has on the fluidity of it?

A. That would be a hard problem. I have never seen that

laid down in any books, but as I stated before I know it does not flow so readily through sand filters as it does when the water is warm.

Q. There you have smaller openings. You haven't a big wide, free flowing canal.

A. That is true, but the effect is there just the same. I do not mean by that to the same extent, but I mean the general theory.

Q. You do think it is there, leaving out ice effects, that it is there appreciably in the canal?

A. When the water is cold, yes, and by cold I mean the water temperature is from 32 to 41 Fahrenheit.

Q. That is not known in limits of percentage?

A. Oh, no.

Q. Such as 1 per cent.?

A. It would be purely a guess, and I have told you all that I know about it. In cold weather the water seems to take and I am of the opinion that it does take more head or slope in the Power House than when the water is around 60 or 70 degrees temperature.

Q. Regardless of how much head it takes to get it, you can take 10,000 cubic feet of water at the Power House in the winter time or the summer, can you not?

A. When we get this improvement finished, I think we can. I doubt if in the winter time we could flow 10,000 cubic feet under all conditions.

Q. Can you under all conditions in the summer time now?

A. I think we come closer to it. I would not say that.

Q. What difference between the two, as it is now?

A. What difference between what, how do you mean?

Q. As to whether you can get 10,000 in the summer time and in the winter time?

A. I have never tried to flow 10,000 for any length of time in the summer time when there was not a big run-off from storms, except for a very short period.

Q. What is the weight of a cubic foot of water at 70 degrees?

A. The weight at 70 degrees according to a table published in the American Civil Engineers Pocketbook, Mansfield Merriman, Editor in Chief, is 62.3 pounds per cubic feet.

Q. What is the weight of a cubic foot of water at 33 degrees?

A. About 62.418.

Q. During these tests that were made, were the pumps at 39th Street and along the North Branch stopped?

A. Yes.
Q. They were not running?
A. No.
Q. For how long a period?
A. We stopped them, I think it was the night before the test started; that is my recollection. That is the fresh water pumps. Of course we had to keep our sewage pumps going.
Q. How much difference in the flow through this south branch and the north branch would be occasioned by the stoppage of the pumps?
A. The pumps at Wilmette pump a thousand cubic feet a second; the ones at Lawrence Avenue, pumping through the Lawrence Avenue conduit, 40,000 cubic feet a minute, which is about 700 cubic feet a second, and the fresh water pumps at 39th Street, about 1700 cubic feet a second, the way we were running them at that time.
Q. About 7200?
A. 1700 cubic feet a second, the way we were running them at that time.
Q. Instead of 2,000?
A. At that time, we had just been running part of the plant.
Q. And those along the north shore were running how much at that time, during the test?
A. They were not running any.
Q. Any pumps at Fullerton Avenue?
A. There is a pump there, yes.
Q. Was that run ordinarily?
A. They run that ordinarily, yes.
Q. It was not running then?
A. I gave orders that it should not be running.
Q. So that the decrease from pumping plants was about 3400 cubic feet a second?
A. In round numbers, I would say that was so, 3,000 to 3400 somewhere in there.
Q. Wasn't there a great deal of storage in the south branch and the north branch of the river that would affect conditions at Dearborn Street, have to be drawn off?
A. Any lowering that was produced at the forks or the junction of the north and south branch would draw down the storage. For that reason I shut down these pumps so as not to have an excessive amount of it. There would have been more storage to have been drawn off, if those pumps had been working.
Q. In those computations that you made from 5:30 to

12:30, if you leave out Lemont, you very nearly check with the Power House, do you not?

A. I have not tried it.

Q. Have you got the figures before you?

A. If you leave out Lemont, it would give an average of 10,300 cubic feet per second as I figure it.

Q. And in this case as in the others, Lemont is quite a little higher than the other five measurements and is higher than the determinations at the Power House, is that not true?

A. It is higher. I would not say it is quite a little higher; I would say some higher.

Q. You made a change in the amount of flow between 5:30 and 6:30, did you not?

A. We changed the method of the discharge through the end of the canal.

Q. And increased the amount of flow?

A. I presume it increased the flow, but that was not intentional. We were trying to get as near that steady flow as was possible, but as I stated before I am of the opinion that those wheels under-rate the amount of water that is going through them, particularly when they are working under a full load, heavy load, with a low head.

Q. The chart shows about 400 change, does it not?

A. That is taken from the record.

Q. I mean at the Power House and Controlling Works?

A. Yes, sir, taken from the record of these wheels acting as meters.

Q. If the wheels under registered, that change would be even greater, would it not?

A. If they gave too small a rating, then the change would be greater.

Q. So that you were getting a change along about the 5:30 and the 6:30 hours, too?

A. There might have been some change there, but it was not as great a change or anywhere near it as from 4,000 to 10,000 cubic feet, the change that we put on at twelve o'clock noon.

Q. Did you understand that in the last average we made in regard to Willow Springs we left out the one o'clock hour?

A. I know you were talking a great deal about it. I do not remember now whether that was left out in all of the computations or not. I think at first you had it in and then you said you were willing to leave it out.

Q. The average was made with it in and with it out, was it not?

A. That is my recollection. As I said, you were talking so much about it, I have forgotten.

Q. And the average including that computation at one o'clock is greater than when it was left out?

A. I do not know. The record will show.

Q. The record will show that? It is consistent with all of these computations, both from one o'clock to five and from 5:30 to 12:30 as made, even with the assumption that the water at the Power House from 12 to 5, was overestimated, is it not; it is consistent with the other results?

A. As I stated before, I think we come nearer getting the accurate measurement of the water at the Power House when most of it is going over the dams, or the larger percentage of it is, than we do when most all of it is being used through the turbines.

Q. You think then that the error at the Power House and Controlling Works is more likely to come after six o'clock than before?

A. Well, under the conditions such as existed at that day.

Q. At that day?

A. Yes.

Mr. Adcock: Q. These computations that you have made in response to questions from the Cross-Examiner, and in response to questions on re-direct do not show any material disprecancy at the Power House?

A. I think the results under the circumstances are remarkably good.

Mr. Hopkins: Q. You mean within 10 per cent. one way or the other?

A. I did not say that.

Q. What do you say as to that?

A. What I said in a former examination was—

Q. What do you say now as to that?

A. I have not said anything.

Q. What will you say as to that?

A. I do not know how close this is to the absolute truth. All I know is that we had as competent men as it was possible for me to get to make these measurements, using the most up-to-date instruments and methods and I have given you the results as shown by the experiments made and by the computations that were honestly and competently made.

Q. But you prefer to take one of those rather than five,

even when you state you think that the measurement at the Power House may be ten per cent. in error,—you use the others to check on that?

A. I did not say that, if you will pardon me.

Q. I so understood you?

A. No. What I said was that the amount of water going through the turbines might be 10 per cent. in error. If I did not say that, I meant to say that, in my opinion. That was sometime ago and I put that on as the outside limits.

Q. Have you had occasion to change that?

A. I do not know whether the error is that much or not. I imagine it might be under a heavy load and low head, particularly.

Mr. Hopkins: That is all.

Thursday, May 21, 1914, 2:00 o'clock P. M.

GARDNER S. WILLIAMS, a witness recalled in sur-rebuttal on behalf of the defendant, having been previously sworn, testified as follows:

Direct Examination by Mr. Adcock.

Q. Mr. Shenehon in his cross-examination as to ice effects on the St. Clair River stated that Lake Erie normally rises about 2½ inches during the month of February of each year. Have you examined any data to determine the correctness of that statement since the examination of Mr. Shenehon? If you have, will you state what examination you have made and what your results are?

A. Table 26 of the Report of the International Waterways Commission on the Regulation of Lake Erie, 1910, in column 5 shows a change in elevation of Lake Erie for each month from February, 1860, to December, 1907, inclusive. And I find upon averaging the changes for the month of February for the 48 years that the average change is a rise of 0.054 feet, which is equal to 0.67 inch. I find that out of the 48 years considered, Lake Erie lowered in 19 of them.

Q. That is for the month of February?

A. For the month of February. And if these be excluded, the average change for the remaining 29 would be a rise of 0.18 feet, equal to 2.18 inches; so the figures of 2½ inches appears to be in error under either consideration.

Mr. Hopkins: What period of time did he take, do you know?

Mr. Adcock: Q. He stated that as a general proposition, did he not?

A. Mr. Shenehon arrived at this figure from a somewhat hasty examination by the hydrograph of the Great Lakes; and I do not assume that he made any computation to establish that relation accurately.

Q. What do the changes in elevations of Lakes Erie, Michigan and Huron for February, 1901, indicate to you as to the accuracy of the conclusions regarding ice effect given by Mr. Sabin in the report of the Chief of Engineers for 1902 (printed record, page 2496).

A. For the month of February, 1901, the surface of Lake Erie fell 0.24 feet. Assuming that for average conditions it should have risen 0.054 feet, the total change from normal would be a lowering of 0.294 feet, which would reduce the discharge of the Niagara River, using the Complainant's value of the increment about 3200 cubic feet per second nearly.

Subtracting this from the reduced discharge for February of 85,900 cubic feet per second as given by Mr. Sabin leaves 82,700 cubic feet per second to produce a lowering in Lake Erie. The abstraction from Lake Erie of 82,700 cubic feet per second for 28 days would lower that lake 0.78 feet, therefore during the month of February, 1901, Lake Erie should have fallen 0.78 feet from its normal, whereas it did fall only 0.294 feet or the effect on Lake Erie was only about 38 per cent. of what Mr. Sabin's figure would indicate.

Considering the effect on Lakes Michigan-Huron of reducing the flow of the St. Clair River 85,900 cubic feet per second for 28 days, as testified to by Mr. Shenehon, this would raise Lakes Michigan-Huron 0.18 feet. Lakes Michigan-Huron did actually raise during this month 0.06 feet, which corresponds exactly with the average change of those lakes for the month of February for the 48 year period from 1860 to 1907, as shown by Table 25 of the Report of the International Waterways Commission, already cited.

In view of these facts, it is my conclusion that the estimated effect of ice in the St. Clair River for February, 1901, is about 150 per cent. too large.

Q. What estimated effect?

A. The reduction of discharge of 85,900 cubic feet per second.

Q. That is as given by Mr. Sabin?

A. As given by Mr. Sabin. Reducing the amount as given by Mr. Sabin 85,900 cubic feet per second to correspond to these indications gives about 33,000 cubic feet per second

which checks almost exactly with Mr. Russell's figure of 34,070 in the report of the Chief of Engineers for 1904 (printed record, page 2518), which latter value was deduced from a comparison of the discharge of the St. Clair and Detroit Rivers.

Q. You were asked on your cross-examination, when you previously testified in this case (printed record, page 979), as to the consideration given to ice effects. Will you state the result of your investigations as to ice effect upon the discharge of these different outlets of the lakes under consideration in this case?

A. Ice effects as referred to in this case should include cold water effects, and may be classified under three heads, which in the order of their importance are:

First: Effect of cold in reducing the fluidity of the water.

Second: Effect of ice cover in cutting off cross section and reducing velocity in upper part of the stream.

Third: Effect of ice jams in temporarily retarding the flow.

As to the first: The effect of low temperatures on the flow of water has long been studied. In the flow through filter sands, the discharge of water at temperatures between 32 and 45 degrees fahrenheit is only about 60 to 70 per cent. of that of water at 70 degrees. The influence of this factor was encountered by me in some tests of turbine wheels at Holyoke about 15 years ago when the efficiency of the wheels was reduced between two and three per cent. on account of the effect of cold upon the fluidity of the water. Its effect on the flow in pipes and over weirs has been studied, and experiments upon the Sanitary Canal show the discharge to be reduced about ten per cent. between summer and winter conditions, which latter include floating ice.

As to the second: The formation of ice on the surface of a stream cuts off the cross section to the extent of about 9/10 of the thickness of the ice, and in addition the flow in the upper portion of the stream is retarded so that the vertical curve of velocities takes the form shown on Turner's Exhibit 1 (record printed, page 1569) rather than those on Shenehon's Exhibit C, for Identification (Record, printed page 2479). The combined effect of the two influences of ice cover has been variously estimated at from two to ten per cent.

As to the third: Ice jams are of intermittent occurrence and limited duration. While during their existence they notably reduce the discharge, this is compensated for in a large measure by the corresponding increased flow when they give

way, due to the increased slope coming from the storing of the water in the upper lake and the lowering of the level of the lower one.

Q. Is there a marked increase of slope at that time?

A. Quite decided, depending upon the permanence of the ice jam; the longer it lasts, the more it backs the water up above it and lowers the water below it and when it gives way, you have a high inclination relatively and markedly increased flow for some time, until the conditions adjust themselves.

Q. The flow is very much accelerated on account of that condition, immediately following the breaking up of the jam?

A. Yes. It is always accelerated to an appreciable amount.

If a jam should be assumed to block the St. Clair River completely for ten days so that no water flowed, it would reduce the annual discharge less than 2¾ per cent., omitting the compensation due to increased flow after it gave way; and if this were considered the effect of the jam would be even less than indicated by the percentage given.

No such stoppage has ever occurred, and it is to be doubted—I will say has ever occurred so far as any records or the memory of man indicate—and it is to be doubted if one reducing the flow 50 per cent. has existed.

The duration of ice jams rarely exceeds a week, so that the influence of this factor is of far less consequence than either of the others.

As to the distribution of these effects, the first, temperature influence is present with practically equal force in all the outlets of the lakes including the Sanitary Canal.

Similarly, the second, ice cover is a factor on all the rivers and on the canal, though of slightly greater importance on the canal, the St. Clair and Detroit Rivers and the St. Lawrence than on the Niagara.

The third, ice jams occur in all the outlets and on the canal, though those at Niagara usually occur later in the season than the others.

It is therefore my conclusion that any effect of cold and ice on the lake outlets will similarly influence the flow in the canal and so far as changing the estimated lowerings due to the actual Chicago diversion, is of no consequence, and that any difference in proportionate effect on the Niagara and the other rivers is far too small to account for the long known discrepancies between the measured Niagara discharges and those of the other lakes, that have puzzled engineers for more than a quarter of a century, and are still unexplained.

Q. Certain comments have been made by witnesses for

the Complainant, intended I believe in the nature of criticisms of the accuracy of weir measurements at the Cornell Hydraulic Laboratory in connection with the current meter tests of Professor Schoder, as described in his testimony (record printed page 1548). What can you say as to the accuracy of the weir measurements there?

A. The two weirs at Cornell were originally constructed under my direction, during the time I was in charge of the laboratory. The lower one as then built was a duplicate of the weir used by Messrs. Fteley and Stearns in their Farm Pond Experiments, except that it was 6.65 feet high instead of 6.55 feet, and it was 16 feet long instead of 19 feet. The effect of this small change in height, as testified by Mr. Haskell (record, printed page 2689) with which I fully concur, would make practically no difference, or would make no difference that could be detected by the most careful measurements of discharge that it has yet been possible to make upon the volumes of water concerned; and the discharge per foot of length of this weir at Cornell would be the same as that of the weir in the Farm Pond Gate House, the discharge over which was measured volumetrically by Messrs. Fteley and Stearns.

The formula derived by those investigators for the flow over their weir agreed within less than .2 of 1 per cent. of the measured discharges over it, and it is therefore my belief that their formula is applicable to the discharge of the Cornell weir within .3 of 1 per cent. Mr. Haskell estimated within .2 of 1 per cent. (record, printed page 2689).

Comparisons of the flow over this weir and the weir at the head of the canal, which was 11.25 feet in height, were made by me during three years, and the discharges as computed from the weir formulae in a series of over 100 simultaneous measurements agreed within 1 per cent., and for heads near that used by Professor Schoder in his current meter tests agreed within less than 1/2 of 1 per cent.

Since that time, Professor Schoder has changed the elevation of these weirs each about a foot, and has made a volumetric calibration of a section of the lower weir 4.22 feet long, in which the measured discharges for the same heads, which were repeated several times, agreed within considerably less than .1 of 1 per cent., and from the results of these final tests the weir discharge used for comparison with the current meter tests was computed.

It is therefore my conclusion, and my best judgment, that the weir discharges used by Professor Schoder were cer-

tainly accurate within less than 1 per cent. Mr. Haskell testified to an accuracy under the conditions before stated within considerably less than 1 per cent. (Record, printed page 2700.)

Q. Mr. Schoder testified as to certain current meter tests made in the laboratory at Cornell University. Have you any opinion as to the applicability of those tests to the conditions on the Niagara River, International Bridge Section?

A. During my connection with the hydraulic laboratory at Cornell University which I was in charge of for a period of six years, I observed on many occasions conditions similar to those which existed during the tests made by Professor Schoder. And from my recollections of those conditions, which I may say involved not only an observation of the surface of the water but measurements of the discharge with floats and current meters, observation of floating matter in the water, such as water logged sawdust, leaves and other foreign substances that would float at various depths below the surface, and from my observation of the condition of the surface of the water passing underneath the International Bridge, and my observations of the conditions in flowing water set up by similar obstructions in streams and elsewhere, it is my opinion that the conditions of experiment number 8 (record, printed page 1548) by Mr. Schoder were reasonably correspondent to the conditions in the mid channel between the piers of the International Bridge. And that the conditions of experiment number 9, would be quite applicable to the conditions in the region near the piers of the International Bridge.

Considering further the statement of Professor Turner that during the tests in the canal the meter was vibrating sidewise and up and down (record, printed page 1586) and the evidence of the record of direction current meter observations at Niagara shown on Shenehon's Exhibits C and D, of May 16, I also consider the conditions quite similar and that the errors of registration indicated by Professor Schoder's tests are applicable to the conditions at the International Bridge.

Mr. Adcock: I show the witness three sheets entitled "Direction measurements of Vertical Curves International Bridge, Plotted from Shenehon's Cross-Examination Exhibit C," the three sheets being similarly entitled, and ask that they be marked Williams' Exhibit 36.

(Three blue prints shown to witness were marked Williams' Exhibit 36.)

Q. I will ask you to describe the exhibits and state from what data they were prepared, and what they show?

A. Exhibit 36 was plotted from Shenehon's Exhibit C of May 18th, I believe, and represents graphically the directions there indicated as they were taken by the current meter at stations in the fourth span of the International Bridge.

Q. Was that the middle of the river?

A. That span is the one which carries the largest proportion of the discharge of the Niagara River.

Q. And was the span referred to by Mr. Shenehon in his cross-examination as such?

A. It has been referred to as one of two spans which carry over 50 per cent. of the discharge; and on page 5328 of the report of the Chief of Engineers for 1900, the percentage of discharge passing this span is given as 28.2.

I should say that the data in Shenehon's Exhibit D, is also included in these plottings.

The vertical line headed "Station 4 2/12" on each plate represents a direction at right angles to the International Bridge, and at right angles to the section that was measured.

The 4 2/12 locates the position of the meter in the cross-section horizontally as being 2/12 of the span from the pier. Similarly, the heading of the middle vertical, "Station 4 6/12" locates the meter as at the mid point or on a middle vertical of span 4. And the heading of the third vertical "Station 4 10/12" locates it as being at 10/12 the span from the American side, or 2/12 of the span from the pier at the Canadian end of span 4.

The first groups of radiating lines on the respective verticals indicates the positions taken by the meter at the water surface, that is when just a little more than immersed.

It will be noted that on the vertical near the pier at the left, the meter rotates in its position through more than 90 degrees.

The second series of rotating lines represents the position of the meter at the 1/10 depth, which is indicated by the numerals 0.1 underneath this group.

Similarly, the next group represents the various positions of the meter with the directions in which it was pointing at the .2 depth; similarly as to the .3, .4, .5, .6, .7, .8, .9, and at the bottom.

It is to be noticed that the variations of direction are substantially the same in magnitude whether the meter be at the 2/12 or the mid station point. The variations in direction are somewhat less in the upper part of the section at the

10/12 point, but in the lower part the changes are quite as marked as they are at the other positions.

These plottings represent graphically the changes of direction as recorded by the meter and indicate the disturbances of the flow through this section.

As regards the lower portion of the 4 10/12 vertical, the large variations there are probably due to the fact that the meter was no longer between the bridge piers, but had drifted downstream a considerable distance beyond the foot of the pier.

Q. So that the vertical line that appears on each sheet of the exhibit is a line which is at right angles to the gaging section line. Is that correct?

A. Yes.

Q. Then if the tail of the meter were on a line at right angles to the gaging section line, the line drawn through the tail of the meter and the station would coincide with the vertical line which appears on those sheets. Is that correct?

A. Yes, that is correct.

Q. The lines at an angle from the vertical line represent the position of the meter with reference to the line normal to the cross section. Is that right?

A. The line perpendicular to the cross section.

Q. Or perpendicular to the cross section?

A. Yes, those radiating lines represent the successive positions of the meter that were observed, and indicate to my mind the turbulence of the water, as there seems to be no continuity, no steady direction of the current, but it seems to be changing continuously.

Q. In other words, if the water were not turbulent, the meter would stay in one position, even if the current were not exactly normal or perpendicular to the discharge section?

A. It should stay very nearly in a constant direction. Of course a small vibration is to be expected, but no such vibration as observed here.

Q. Where you have a variation in position of nearly 95 to 100 degrees?

A. In several cases.

Q. Haskell's Exhibit A, of February 25, 1904, has been referred to by Mr. Haskell and also by Mr. Shenehon in the cross-examination of each of them. Will you describe Haskell's Exhibit A of that date?

A. Haskell's Exhibit A comprises six columns of figures.

The first column represents the elevations of Lake Huron at Harbor Beach during the open seasons of each year from 1884 to 1908 inclusive, referred to a datum 335.5 feet above sea level.

Column III represents the elevation of Lake Huron at Harbor Beach referred to the same datum for the mean elevation in the groups of observations shown on Williams Exhibit 21, being the groups shown on Complainant's Exhibit 1, including the observations of 1901 and 1908.

Column V represents the same elevations as Column III, excluding the observations of 1901.

Column II shows the mean fall between Lakes Huron and St. Clair during the open season for the years whose Huron elevations appear in column I.

Columns IV and VI show the falls from Lake Huron to Lake St. Clair for the groups of observations whose Huron elevations appear in Columns III and V respectively.

Q. The witnesses referred to made certain comparisons of the conditions shown by those various groups, expressing a preference for columns III and IV in relation to the conditions of I and II. Will you state what those conclusions have to do with the investigation with reference to the increment of the St. Clair River?

A. The preferences expressed by Mr. Haskell and Mr. Shenehon for the data in columns III and IV, over that in columns V and VI to be used in deriving a discharge curve to apply to the conditions of columns I and II—

Q. When you say a discharge curve, you mean a discharge referred to the elevation?

A. Yes. A discharge referred to the elevation,—confirms the correctness of the contention in my direct testimony that the observations of 1901 on the St. Clair River should have been included without correction in deriving the increment on Complainant's Exhibit 1, and that the increment there shown for the St. Clair River should have been about 28,000 as shown on Table XV of Williams' Exhibit 34, instead of 23,820 as given on Complainant's Exhibit 1, and as testified by the Complainant's witnesses in their 1909 testimony.

Q. As I understand, it has been stated by various witnesses for the Complainant that the method of getting the discharge of the river is, first, to observe the velocity at various depths on a series of verticals for a number of cases, and to find a ratio between the mean velocity of these verticals and the velocity at some point called the index, so that by observing the index velocity the mean velocity can be com-

puted without occupying with the meter the several stations on the several verticals. Am I correct?

A. Yes, that is correct.

Q. And that the ratio of velocity at any particular point or for any particular vertical to the index velocity is based on the mean of several velocities observed at the point or throughout the vertical. That is also true, is it?

A. Yes, that is the manner of determining the ratio between the individual points or the mean velocity in the vertical and the index.

Q. Is the method described a reasonable process for obtaining an average discharge?

A. Yes, so far as getting an average discharge is concerned, it is practically correct or reasonably correct.

Q. Is it a reasonable process in getting an increment?

A. No, it is not.

Q. What reasons have you for reaching that conclusion?

A. The correctness of the process, or the alleged correctness of the process depends upon the assumption that a constant ratio exists between the velocity at the index point and that at any other point in the section at the same time. This is only approximately true since the form of the vertical velocity curve changes with the depth.

Referring to page 2479 of printed record entitled "Typical Vertical Curves," it is seen that in the case presented for a depth of about 35 feet, the retarding effect of the bottom becomes pretty well eliminated by the time mid-depth is reached. In deeper sections the portion of the curve at the top which is nearly vertical extends over a larger proportion of the depth while in shallow streams the drag of the bottom extends nearly the full distance to the surface.

It therefore follows that the ratio by which the index velocity should be multiplied to give the mean will be less in a shallow than in a deep stream, so that the process of taking an average value for this ratio derived from verticals taken at different stages results in the high discharges being reduced and the low ones increased; as the high discharges correspond to high stages and vice versa, the difference between high and low discharges is reduced and the increment correspondingly reduced.

With discharges of 220,000 and 200,000 cubic feet per second, an error of ¼ of 1 per cent. due to using a mean index ratio will make a reduction of over five per cent. in the difference and a similar percentage error in the increment.

These ratios also vary with wind and barometic changes.

Q. You have spoken of the difference between high and low discharges as being reduced, and then you say that from that you reach a conclusion that the increment is correspondingly reduced. I wondered if you could explain that so that we may understand it just a little bit better.

A. Assume that at a certain elevation the current meter gaging shows a discharge of 220,000 cubic feet per second; that the ratio of the index to the mean velocity that is used was .80, and that this was in error ¼ of 1 per cent. for this discharge, being small by that amount. Then the coefficient used should have been .802. And if .802 had been used, the discharge would have been ¼ of 1 per cent. greater or 550 cubic feet per second. The real discharge would then have been 220,550.

Assume at the lower discharge the current meter gaging gives 200,000 cubic feet per second, and in this case the coefficient should have been .798 instead of .802, when the true discharge would be ¼ of 1 per cent. less or 500 cubic feet per second less, which would make the true discharge 199,500. The difference then was 21,050 cubic feet per second, whereas the difference of the original discharges was 20,000. The corrected value then is a little over five per cent. greater than the reported value. Now this is an error that so far as the increment is concerned is always in one direction.

Q. That is making the increment too small?

A. It always makes the increment too small. It is not a compensating error in any sense of the word.

Q. Am I correct in this understanding that the determination of an increment is essentially the correct determination of the discharges between a higher and lower elevation?

A. That is necessary for the determination of an increment.

Q. Then given a number of discharge measurements, and assume that the discharge measurements are referred correctly to the elevation of the lake, you may take the discharge at the highest elevation and the discharge at the lowest elevation, take the difference; and then take the discharge at the next pair all the way down, and the mean of those would be the true increment?

A. If the discharge were correctly measured.

Q. If the discharges were referred correctly to the elevation?

A. And were correctly measured.

Q. And were correctly measured? So that if the discharges at the high elevation were in each instance, taking a

number of discharge measurements, too low, and the low elevations were too high, the result would be that the increment would be too low?

A. The difference would be too small.

Q. And the increment would be too small?

A. And the increment would be too small also.

Q. Mr. Witness, I show you a photograph of a document headed "Lake Levels Niagara River, Vertical Curves Span 6, Station 4/12 International Bridge Section F. C. Shenehon Asst. Eng." This document, as I understand it, is attached to a letter written by F. C. Shenehon to E. E. Haskell dated February 13, 1899, and was furnished the defendant on request by Colonel J. C. Sanford, now in charge of the United States Lake Survey. I will ask you to describe the document handed you and state what in your opinion it has to do with the conclusions which you have reached in connection with the subject matter of the last question, and with matters under examination in this case.

I further ask that the document be marked Williams' Exhibit 37.

(Photograph of document referred to was marked Williams' Exhibit 37, May 21, 1914.)

Mr. Hopkins: That includes the letter?

Mr. Adcock: I will put the letter in if you want it.

Mr. Hopkins: Is that document you are offering a part of the public records there?

Mr. Adcock: Yes.

Mr. Hopkins: In connection with this work, or simply a letter between Mr. Shenehon and Mr. Haskell?

Mr. Adcock: As I understand, the letter discussed various subjects in connection with the measurement made by Mr. Shenehon at the International Bridge Section of the Niagara River. I will say this: If the United States wishes to offer the letter also, they may do so without objection to us; but for the purposes of this examination, the exhibit mentioned is all we desire; and we believe it unnecessary to encumber the record with the letter itself.

Mr. Hopkins: I would like to reserve an objection. I simply do not want to be understood as admitting that any letters written between people who happen to be in the employ of the United States Government are by virtue of that fact admissible.

Mr. Adcock: I assume that this letter was written by Mr. Shenehon in connection with his duties as assistant engineer in the Lake Survey Office, and the principal assistant engineer

in immediate charge of the Lake Survey in the measurements of the Niagara River at the International Bridge.

Mr. Hopkins: I know nothing about that. Without anything here to show what it is, I simply reserve an objection to it.

Mr. Adcock: I believe the request was made to the United States Attorney in charge of this case. And I assume that at some time you have been advised of the contents, although you may not exactly remember what it was.

Mr. Hopkins: We have always consented to have you furnished with a copy of anything that related to these issues, so far as that is concerned, but did not intend thereby to admit it was competent or admissible in evidence.

Mr. Adcock: You admit that this is a copy of—

Mr. Hopkins: Subject to verification, we will not dispute the authenticity of that letter.

Mr. Adcock: As to the materiality and relevancy and perhaps the competency, outside of the question as to being an accurate copy, you reserve the objection.

Mr. Hopkins: Yes.

A. This is a photograph of a document on file in the records of the Lake Survey at Detroit and is in part, or purports to be in part the record of current meter observations for the vertical curve at Station 4/12 of span 6, of the International Bridge.

The observations as indicated by the first column were taken on February 4 and 6, 1899. The column headed B gives the vertical depth of the meter in feet from the surface; and these positions are 1 foot, 3 feet, 6 feet, 9 feet, 12 feet, 15 feet, 18 feet, 21 and 24 feet respectively.

The column headed C, gives the length of the run in minutes.

Column D, gives the velocity by the index meter at the 3/10 depth.

Column E, gives the velocity by the traveling meter at the various depths indicated in Column B.

Column F, gives the per cent. velocity on the vertical to the velocity at the discharge station. That is it is the reading of the traveling meter divided by the reading of the meter at the 3/10 depth point.

Column G, gives the weights of the several observations, which are weighted according to time.

Column H, gives the weighted mean of the ratios for each point between the traveling meter and the meter at the index point. The average value of the weighted means is 84.4 per

cent. If we take the average value of the maximum ratios for each point as indicated in column F, this would be 85.94 per cent. If you take the average value of the minimum ratios for each point, we would get 80.95 per cent. showing a range of 5 per cent. in the averages of these ratios between those representing the maximum condition and those representing the minimum.

If we take the mean of the first observations at each point, we get 84.3 per cent. which practically coincides with the weighted mean, and if we take the mean of the fourth observation at each point, we get 85.1 per cent., showing a variation in this instance of .8 of 1 per cent. in the average for the entire vertical depending upon whether we take the first observations that were taken or the fourth.

There is no information available on the sheet to tell the elevations of lake surface corresponding to these observations, so that the effect of using the mean ratios instead of the actually observed ones, upon the derivation of an increment cannot be worked out from the data on this sheet, yet it indicates quite clearly the range through which these ratios between individual points and the index may pass.

In the report of the Chief of Engineers for 1900, page 5374, Mr. Sabin gives the results of his observations on the St. Clair River divided according to stage, although the stages are not given except that one set includes a certain elevation and those above it and the other set includes those below that elevation. The mean ratio for the upper stage of the observations between the 1/10 and 8/10 depth points inclusive is 96.79 per cent., and that for the lower stage is 96.58 per cent. The variation from the mean is 1/10 of 1 per cent. The range of stage, as I said, is not given.

Q. Mr. Williams I show you a plotting, which apparently represents certain vertical curves entitled "Niagara River Section Oakfield Vertical 8." I will ask that it be marked Williams' Exhibit 38, and ask you to describe the exhibit and state your conclusions from that exhibit with reference to the subject matter now under discussion.

(Plotting described was marked Williams' Exhibit 38, May 21, 1914.)

A. This is a plotting from the records of discharge observations at Section Oakfield on the Niagara River, which records were furnished by the office of the U. S. Lake Survey.

Q. That was a part of the Split Section?

A. Part of the Split Section. The numbers at the top of the plate represent the percentage which the velocities at the

several points are of the index velocity which is that at the 4/10 depth. The numbers at the right hand show the proportionate depths from surface to bottom. The broken lines connect the consecutive observations or observations made of the vertical at practically the same time.

The general form of this discharge curve, the mean of this curve will be found to bear out my statement made a short time ago that in the shallower water the effect of the bottom extended more nearly to the surface.

The depth at this station was, as I remember it, a little over 20 feet.

It will be noticed that the variations of velocity at the individual points represented on the horizontal lines cover a range between 8 and 10 per cent. of the index velocity. This plate therefore gives a graphic idea of the irregularity of velocities at the same points or depths in a vertical curve; and also indicates by the irregularity of the observations at the bottom, which cover a range of something over 20 per cent. of the index velocity, the disturbances set up in flowing water in the vicinity of the bounding surface. My own observations of the flow of water in pipes and open channels indicate that similar disturbances occur along the side walls of the latter and around the circumference of closed pipes; and that such disturbances are to be expected in the vicinity of the piers at the International Bridge.

Any one of the curves shown on Williams' Exhibit 38, might be the one corresponding to the condition at the time of a particular gaging, and by using an average value for the index ratio, an error of anywhere from 2 to 4 per cent. may be introduced. As the same causes which produce low readings in one vertical will produce them in the others, there is little or no compensation by balancing errors, and the whole discharge is similarly in error. In the case of the ratios being low for a lowering of the stage, then our average value for the ratio gives a discharge for the low stage which is greater than that actually existing and vice versa; so that the increment resulting from the observations is decreased.

Similarly in the case of increased ratios by a rising of the stage the use of the average ratio reduces the discharge at the high elevations and again decreases the increment as I have already stated.

Q. I show you Mr. Williams two charts which were marked Shenehon's Exhibits A and B for Identification, cross-examination. These charts were shown Mr. Shenehon on the occasion of his cross-examination in this case. I ask

that they be marked Williams' Exhibit 39A and 39B, and ask you to describe the charts and state by whom they were prepared and from what data.

(Charts shown to witness were marked Williams' Exhibits 39A and 39B, May 21, 1914, respectively.)

A. These are two charts which are plotted from the information contained in Williams Exhibit 4, for Identification, cross-examination, being the gage elevations at Buffalo and Chippewa for the month of November, 1908, showing the hourly water levels. The upper curve represents to the scale indicated by the elevations at the left of the sheets the elevation of the Buffalo gage from hour to hour, the dates and hours being indicated by the letters and numbers at the bottom of the sheets.

The lower irregular line represents the elevations indicated by the gage at Chippewa for the same dates and hours.

The charts indicate the regularity or irregularity with which changes at Chippewa follow changes of the Buffalo gage, and show graphically the extent to which the fluctuations of the Buffalo gage disappear in traveling down the Niagara River.

Adjourned to Friday, May 22, 1914, 2:00 o'clock P. M.

Friday, May 22, 1914, 2:00 o'clock P. M.

GARDNER S. WILLIAMS resumed the stand for further direct examination by Mr. Adcock and testified as follows:

Q. When a meter is used in swift running water and suspended upon a cable, what effect does the current have on the position of the meter?

A. It drifts the meter down-stream.

Q. What effect would the drifting of the meter have upon the discharge measurements usually?

A. In ordinary cases, it would have very little effect. In fact, if the section were uniform in area and shape throughout the length of the drift and a proper allowance were made for the change in vertical position of the meter due to the fact that more cable would have to be paid out in order to have it at the same depth, there should be no effect of consequence introduced into the discharge measurements.

Q. At the International Bridge Section of the Niagara

River, what would be the effect of drift? Is it an important proposition there?

A. It is, quite, for the reason that the piers which carry the bridge terminate a short distance below the section, and if the drift should be such as to carry the meter below the lower end of the piers, the meter would then be in a considerably larger section than that which has been measured, and the velocities there would be appreciably less; so that if the meter were in that position and the velocity measured, and those velocities applied to the area of the section between the piers, which is the one which was measured with the high degree of accuracy testified to by the Complainant's witnesses, the result would be a considerable diminution in the discharge.

Q. How far could a meter drift at this section from the plane of the station before it was below the piers of spans 4 and 5 of the International Bridge, those spans being the spans through which I believe about 50 per cent.—

A. A little more than 50 per cent.

Q. —a little more than 50 per cent. of the water of the Niagara River flows at the Bridge, as testified to by Mr. Shenehon.

A. A drift of between seven and eleven feet depending upon the depth at which the drift took place would carry the meter beyond the lower end of the pier, according to the best information that I have been able to secure.

Q. You have heard the testimony of the witnesses and examined the reports of the Chief of Engineers to determine what precautions were taken by the observers to prevent drifts. Will you state what those precautions were?

A. Yes, I have heard the testimony and have examined the printed records so far as they are known to me bearing upon this point; and the observers attached by means of a snatch block and a weight a guy to the cable of the meter so that the snatch block rode at any point—so that the weight, rather, rode just above the water surface. This guy was carried to the up-stream edge of the bridge around the outside of the *I* bars, and by pulling up on this guy the position of the cable could be shifted within certain limits at the water surface.

Q. How was the amount of pull or the distance that the meter cable was moved established?

A. The distance through which the cable should be moved was established by a series of computations based upon certain assumptions as to the effect of current on the cable and on the meter.

In the paper of Mr. Clinton B. Stewart, who had charge of

the discharge measurements at Niagara made for the Board of Engineers on Deep Waterways, which paper has been referred to in evidence in this case previously, and which was presented to the Western Society of Engineers and was read December 20th, 1899, and which is a description of the work done at the Niagara River for the International Waterways Commission, being practically the substance, in fact most of it word for word, a reprint of the report of the Board of Engineers on Deep Waterways upon this subject, there appears a plate entitled "Figure 6," which is not published in the report of the Board, but which was made in connection with the studies of the position of the meter in this gaging. And it is this study which is referred to on page 5332 of the Report of the Chief of Engineers for the United States Army, 1900, being the report of Mr. F. C. Shenehon, on the discharge of the Niagara River.

"The analysis of meter positions was first made by Mr. C. B. Stewart in discussing the Deep Waterways observations on this river, and out of this germ has been developed our own tables for meter location, and the static method of sounding."

Mr. Adcock: I ask that the plate referred to in Mr. Stewart's paper read on the 20th of December 1899 before the Western Society of Engineers be marked Williams' Exhibit 40.

(Plate referred to by witness was marked Williams' Exhibit 40, May 22, 1914.)

Mr. Hopkins: Let me ask a question or two about that.

(Q) Mr. Williams, does that chart appear in the report of the Engineers on Deep Waterways.

A. The chart does not.

Q. Does the detailed information appear in that report, so that any engineer could take it and make that chart?

A. I think that the mathematical analysis by which this chart was arrived at is not in the report. I would say that portions of this chart appear—

Q. Where is Mr. Stewart now?

A. Mr. Stewart is at the University of Wisconsin; he is a Professor there.

Mr. Hopkins: I wish to reserve an objection to the competency of that chart. I do not object on the ground that it is not the exact chart as appeared in the report to the Western Society of Engineers, but I do reserve the objection that merely because it is there, it does not make it competent.

The Witness: I think it can be identified through Mr. Shenehon.

Mr. Adcock: Q. Who was Mr. Stewart?

A. Mr. Stewart was the engineer in charge of the discharge measurements in the field for the Board of Engineers on Deep Waterways.

Q. Was he a Government Officer?

A. He was employed by the Board of Engineers on Deep Waterways. I do not think that he had any other connection with the Government except his connection with the Board.

Q. The Board of Engineers on Deep Waterways was a Board appointed under an act of Congress, was it not?

A. It was, by President McKinley. This is the chart which he made while in the service, or it is a copy of the chart which he made while in the service of the Board of Engineers to apply to the analysis to determine the position of his meters when he was making the Niagara observations.

Q. The original chart which he made, was that made for the Board of Engineers on Deep Waterways?

A. It was, and I think is now in the possession of the Lake Survey.

Q. That is the original of this chart?

A. Yes, I think so.

Mr. Adcock: I understand no objection is made on the ground that it is not the best evidence; that it is a copy of the chart.

Mr. Hopkins: A copy rather than the original?

Mr. Adcock: Yes.

Mr. Hopkins: No, no objection on that ground.

Mr. Adcock: Q. Then your understanding is that it was simply preserved in this form in the transactions or reports of the Western Society of Engineers by a paper which he presented, the original of which was made for the Board of Engineers on Deep Waterways, while Mr. Stewart was in their employ?

A. That is my understanding.

And I will say further that my reason for producing it in this form here is simply that I had it in my possession. At the time I was last in the Lake Survey Office, I did not have in contemplation introducing this question into the evidence, and therefore could not foresee that a copy of it from that source would be needed. I saw however in Professor Shenehon's possession while he was on the stand what to all appearances without an exact comparison was a blue print from

the tracing from which this photographic reproduction was evidently made.

Mr. Hopkins: Q. What is the source of your information that it was made for that Board and in connection with his duties on that Board?

A. Because it was necessary that it should have been made or a similar chart should have been made in order to solve the problems which he had to solve. I was informed by the members of the Board at the time that such an investigation was being made, and in discussing the matter with Professor Shenehon this chart has been referred to between us.

Q. What I had in mind was perhaps this chart was made for this particular report of the Western Society of Engineers?

A. I feel quite sure it was not. Of course I have no personal knowledge.

Mr. Adcock: I want to say further that previously in this case both sides have used the transactions of the American Society of Civil Engineers and the reports of the Western Society of Civil Engineers which bore upon these hydraulic questions, without any objection as to their competency or the fact that the particular document was not accurately or carefully prepared from data in existence.

Q. Will you describe the exhibit, Williams' Exhibit 40?

A. This is an exhibit which represents graphically the computed position of the current meters or of a current meter in the Niagara River at various depths below the surface, the depths covered ranging from a point about a foot below the water surface to a point 1½ feet above the bottom of the river.

Q. That was in span what?

A. There is indicated here a depth of 52 feet, which would represent the deepest portion of the river, being in spans 4, 5 and 6.

This chart or plate indicates that in the deepest water the meter shaft or the point of suspension would be 34 feet downstream from the guard rail of the bridge with the guy wire attached carrying a weight of 121 pounds, which is however located and adjusted in a different manner from that used by Professor Shenehon as testified to a few days ago, and the effect of the weight as used by Mr. Shenehon would be appreciably greater than the effect of the weight as used by Mr. Stewart.

Q. "How was the amount of pull or the distance that the meter cable was moved established"?

A. (Quoting from Mr. Stewart's paper): The pressure of the current on the meter was determined by lowering the meter wheel one foot under water and measuring the vertical angle of the cable. Then the pressure on the meter equals that of the water multiplied by the tangent of the angle. The velocity was also observed and from a number of observations, a very good curve showing the relation of velocity and pressure on meter was observed. This is the curve shown in figure 6 that has been introduced.

The point that I make is that the position of the meter, the computations seem to determine the position of the meter as dependent upon the angle which the cable made with the vertical or with the horizontal—it would make no difference which—when running in water of a certain velocity, and that there does not appear to have been any direct measurements of the force required to hold the meter in position against the current.

Professor Shenehon, when he took charge of the work, as appears from a letter written to his Chief, Mr. E. E. Haskell, then Assistant Engineer of the United States Lake Survey, dated February 13, 1899, referred to in my examination yesterday, which letter is a part of the records of the U. S. Lake Survey and a copy of which I have—

Mr. Hopkins: Was this letter offered the other day?

Mr. Adcock: That was the letter referred to, yes.

Mr. Hopkins: Same objection to the letter and the reading from it.

(Witness continues answer as follows):

—recognized the fact that the drifting of the meter downstream to the extent of 30 feet might cause the lower velocities in the curve to show an error of ten per cent; and that there was some possibility of error being introduced by a doubt as to the position of the meter, on account of the great inclination of the cable. He therefore conceived the idea of using a heavier weight and a smaller cable, in anticipation that it would be possible to prevent the meter from drifting as far as it had formerly done. And he assumed that by reducing the $\frac{3}{8}$ cable to quarter inch he would be able to reduce the pressures on the cable $\frac{1}{3}$, and he obtained authority to make these changes, or at least these changes were made. He asks for the authority in the letter to which reference has been made, and introduced the smaller cable on Meter B, and a heavier weight on both Meters A and B, but retained the $\frac{3}{8}$ inch cable on Meter A.

He then made a new computation to determine the position of the meter under the new conditions, and as a result of that computation arrived at the conclusion to which he testified, if my memory serves me right, that the drift of the meter in 50 feet of water with the small cable and the heavy weight would be 12½ feet. And upon the result of the computation which gave him that figure, he prepared a new chart of meter positions similar to the one which has just been introduced in evidence, and a blue print of which he had with him when on the stand; but as it was the only copy he had with him, I was not able to obtain a copy of it.

I made a cursory examination of it and found that the curve which he had adopted was similar in its general characteristics to that shown on the plate introduced, but had the base of 12½ feet instead of 32 feet as in the case of Mr. Stewart's curve. It was from this curve, according to Mr. Shenehon's testimony, that the locations of the meter were established, and corrections for its position made.

Q. Have you made or caused to be made any experiments to determine the accuracy of these assumptions?

A. Yes, I have.

Q. What experiments have you made and what are the results?

A. Upon the conclusion of Mr. Shenehon's cross-examination, I was impressed with the fact that the conclusions elicited in the cross-examination were not strictly in accordance with the laws of physics as I understood them, and I immediately arranged to have a series of experiments made in the naval tank of the University of Michigan, where we have been accustomed to rate meters and determine the forces which act upon a meter when it is subjected to a current; and also the forces which act upon the support.

For this purpose, Mr. Murray Blanchard from this office, who has had charge of the current meter work for the District on the sanitary canal, and who was formerly in the employ of the Lake Survey and participated in the measurements of the St. Clair and Detroit Rivers—

Q. He had charge of it?

A. He had charge of the measurements on the St. Clair during the last year, 1902, and had charge of the measurements on the Detroit River. He took the meters to Ann Arbor last Sunday or Sunday night. He was preceded by Mr. Ayres, my Assistant, who was here with me at that time, who made the necessary preliminary arrangements to get the use of the

tank without delay, and with the assistance of Professor Greene, formerly of the faculty of the University of Michigan, now of my office staff, and Mr. R. K. Holland, my Principal Assistant Engineer, a series of experiments were run to determine the force that was required to hold the meter when moving through the water at velocities ranging from 4 to 7 feet. These experiments were made with the apparatus which was used at the University for determining the force required to move boats and other structures through the water; the work being done under the immediate supervision of Professor Herbert C. Sadler, who was a witness in this case, and who has charge of the work in naval engineering at the University.

The resistance caused by the A Haskell Meter and the B Haskell Meter was measured, the meters being suspended upon a rod, and the resistence due to the rod was also measured, so that it could be deducted from the resistence of the meter and its weight, the weight being a reproduction of the weight described in the report of the Chief of Engineers for 1900, and illustrated in various illustrations relating to the work.

Q. Being the meter that was used by Mr. Shenehon, or the weight used by him?

A. The A meter, being the one used by Mr. Shenehon at the index point and the B meter, being the one used to traverse the vertical in coefficient work, as testified to by Mr. Shenehon.

Q. And the weight is the one—

A. And the weight being within about two pounds of the weight specified in the report.

Q. And the one used on the Niagara River?

A. And the one used on the Niagara, International Bridge, by the Lake Survey.

Q. Same shape?

A. Same shape as near as it was possible to establish it from the illustrations in the book.

The force required to resist the action of the water on the cables, quarter inch and three eighths inch was also observed, the cables being attached to the dynamometer with a weight at the bottom, and they were dragged through the water at the various rates of speed necessary to cover the range of velocities it was desired to investigate.

Q. That is from four to seven feet per second?

A. Four to seven feet per second, which corresponds to

the range of velocities reported to have been encountered at the International Bridge in the deeper spans.

Experiments were also tried upon quarter inch and 3/8 inch rods, and upon 3/8, 3/4 and inch pipe, in order to ascertain the effect of the water upon the surfaces of different size; and also the inclination which a circular,—particularly the inclination which a circular rod of metal would take at various velocities. And as suggested by me during the examination of Mr. Shenehon, it was found that the 3/8 inch rod would stand more nearly straight than the quarter inch. In other words if a 3/8 inch cable and a quarter inch cable were hung from the rail of the International Bridge, into the water of the Niagara River, the quarter inch cable would drift further down-stream than would the 3/8.

Q. Just let me ask you a question: Do you know of any further precaution which you could take, or any other experiments which you could make to better determine the forces necessary to hold the meter?

A. There is no better or more accurate way of determining that force, except to go to the site where the observations were actually made and establish a dynamometer apparatus and measure the force there instead of measuring it in the laboratory.

The dynamometer is an expensive piece of apparatus, and it would involve a large expense to make such a test in the field.

Whatever inaccuracies there would be in this test, or inapplicabilities, they would be the same ones as apply to the rating of meters in still water and using that rating to determine their action in running water; as, if one program is legitimate and proper then the determination of the force required to hold the meter when being dragged through the water at a given speed must coincide with the force which would be required to hold the meter if the water were running past it at the same speed.

Q. Will you give the results of your experiment, Mr. Williams?

A. The results of these experiments show that in a current such as exists at the International Bridge in spans 4 and 5, a B meter on the end of a quarter inch cable would drift 25½ feet below the plane of the point of support, if it were not restrained by a counter weight, which is something more than twice the distance which Professor Shenehon arrived at as the result of his computations, and as testified to by him.

Q. According to these experiments, what would have been

the location of the A meter at the index in spans 4 and 5, International Bridge Section, under the conditions referred to by Mr. Shenehon when last on the stand?

A. The A meter at the index point in spans 3 and 4 would have been either just on a line with the lower end of the piers or below them. There is some uncertainty as to the exact position of the lower end of the pier at this depth. But from the best information that I have been able to obtain, I would say that the meters would be below it.

Q. And what would have been the result of that condition?

A. The meter would have been in water which was traveling at a lower velocity than that between the piers, for the reason that the section of the river in which the meter was located would be wider by the width of the piers than that between them. The result would be that the reading of this meter would be less than it should have been or would have been had its location been as assumed between the piers, and when this velocity is multiplied into the area between the piers, the result would be a discharge lower than the actual.

Q. How about the B meter on coefficient work in these spans?

A. The B meter when used on coefficient work had applied to it the guy with the weight, as testified to by Mr. Shenehon; and as we are not informed and Mr. Shenehon was not able to tell to what extent the cable was drawn upstream at the surface for the several positions, we cannot establish with certainty the position it occupied at all points in the vertical. But if the meter were drawn up to the full extent possible by the cable, it would have been below the piers at all points below 35 feet. And if it were drawn up as one would naturally suppose by the amounts indicated upon the curve which Mr. Shenehon had computed as establishing the position of the meter, it would then have been below the piers at all points below about 27 feet.

Q. This calculation as to the position of the meter is made with reference to the weights and everything that the meter had on it, as described by Mr. Shenehon?

A. It is.

Q. What was the width of spans 4 and 5?

A. That is the channel width? In the report of the Chief of Engineers for 1900, page 5328, the width of span 4, is given as 234.2, and of span 5 as 235.8 feet.

Q. The piers, what is their width?

A. The width of piers is given by Mr. Stewart in the paper

already referred to, and concerning which Professor Shenehon testified that he would have no reason to doubt the accuracy of the statement there, as 13 feet in width (pp. 3302-3).

Q. Are spans 3 and 4 similarly affected by drift?

A. Span 6, next to the pier between it and span 5 would be affected practically the same as spans 4 and 5.

In span 3 the effect would be materially less, and it is somewhat questionable as to whether the drift in that case would actually carry the meters below the line of the pier, although it is possible it might do so in the coefficient work at some points.

Q. By how great a percentage would the area of the sections in spans 4 and 5 be increased by the drift of the meter below the piers?

A. That is a question that it is somewhat difficult to answer positively as it does not appear that the information regarding these piers shown upon the cross sections of the river as published in the report of the Chief of Engineers for 1900, and in the report of the Board of Engineers on Deep Waterways is sufficiently precise to permit of a close estimate. The width of the piers as stated, which Mr. Stewart says are water width, is 13 feet. And he says: "The piers have a batter on the sides of about one in 24." This would mean that in 24 feet depth of water the piers would be wider by two feet than at the surface.

At a point about 12 feet below the surface, the piers widen as shown by the cross sections already referred to, and as indicated by the plans of the bridge which I have been able to obtain from the Bridge Engineer of the Grand Trunk Railway. And the lower portion below that depth is indicated on these cross sections as being—

Q. You are referring now to what?

A. I am referring to the report of the Board of Engineers on Deep Waterways and the report of the Chief of Engineers for 1900. These would indicate that the width of the piers below a depth of from 12 to 20 feet is in the neighborhood of 25 feet. The plan of the bridge, however, furnished by the Bridge Engineer of the Grand Trunk Railway, does not indicate any such width at that point but would indicate that the piers are possibly, at the outside, 20 feet wide down to the point where they rest on the caisson at the bottom of the river.

The three piers would have the effect of increasing the width of spans 4 and 5 somewhere between 40 and 50 linear feet.

Q. That is at the point where the meters would rest below the piers; would increase that, wouldn't it?

A. Yes, at the points where the meters would be below the piers, the width would be increased by somewhere between 40 and 50 feet, the effect of which would be to increase the cross section somewhere between eight and ten per cent.

Q. From these experiments that you have made and the deductions that you have just indicated, do you have any opinion as to whether or not an error would be introduced into the discharge measurements of the Niagara River at the International Bridge Section? If so will you state what error might result?

A. This would introduce a very decided error into the discharge measurements. In the first place, the velocities obtained in the lower half of the vertical on coefficient work would be too small, thereby reducing the mean velocity, reducing the apparent mean velocity, and correspondingly the discharge.

This error would be present if the meter at the index point had been within the piers, but with the meter at the index point lower down-stream, this error is multiplied by the percentage of error that is introduced on account of the position of the meter at the index point, so that it seems from such approximate calculations as we can make with the data in hand that there is a possible error here of somewhere between 3 and 6 per cent. in the discharge of the Niagara River at the International Bridge.

Q. That is from that source alone?

A. From that source alone.

Q. What did you have to do with the experiments on flow in the Sanitary Canal during February and March, to which Mr. Wisner referred?

A. In conjunction with Mr. Wisner, I planned the scope of the investigation, assisted in the selection of locations for observing, in conference with Mr. Wisner, Mr. Blanchard and Mr. Ramey; and furnished a part of the apparatus used and a party of five men who participated in the test, and I have had a general oversight of the computations and reductions of the data obtained.

Q. Will you describe just in general the plan of the experiments?

A. The experiments contemplated starting with a flow in the canal of about 4,000 cubic feet per second well established, and suddenly increasing the discharge at the lower end of the canal to about 10,000 cubic feet per second and observing the

change in the elevation at the several gages along the canal, and also the change of discharge by current meters located at selected points along the canal. It was intended to continue the discharge of 10,000 cubic feet per second at the lower end of the canal until a flow of that amount should be established throughout the canal.

Q. What was the equipment used, and who were the observers, and what can you say as to their qualifications?

A. For the experiments on March 8-9, Mr. Murray Blanchard, to whom reference has several times been made, was in charge of the current meter measurements.

I may add to what has previously been said that Mr. Blanchard was also in charge of the measurements of the St. Lawrence River at the Couteau Rapids, which were performed for the Canadian Light & Power Company, in which not only the flow of the main stream was measured but the flow of its several branches, some eight or ten in all in separate channels between the islands through the Rapids.

Q. He was in charge also of the test that was made on February 22, was he not?

A. He was also in charge of the measurements that were made on February 22. Mr. Blanchard is a graduate of the University of Michigan and entered the employ of the Lake Survey where he remained for several years on discharge measurements, when he went to New York and was engaged under Mr. Noble on the Pennsylvania Tunnel work. From there he went to the work on the St. Lawrence; then went on some construction work in the South and from there came to the District where he is employed.

Q. You consider him to be a careful and a competent man to do this kind of work?

A. I do. He is very careful and received careful training in Lake Survey methods, and was regarded by his superiors there as a thoroughly reliable assistant.

Q. Now who was at the other places?

A. At the Power House—

Q. This was on March 8th?

A. Yes. The general manipulation of the gates including the Bear Trap Dam was under the direction of Mr. E. L. Cooley, who has been for many years, in fact I think since the inception of the Drainage Canal work, connected with the Sanitary District.

Q. In the Engineering Department?

A. In the Engineering Department, and has made prob-

ably more studies of the hydraulics of the canal than any man living.

As my personal representative at the Power House, in this test was Mr. R. K. Holland, my Principal Assistant Engineer, and Mr. William Rennie, my Assistant Electrical Engineer. Mr. Rennie particularly had charge of the observations of electrical output and manipulation of gates on the turbines. Mr. Holland made general records of all the rest of the manipulations at the Power House and as reported from the Bear Trap Dam.

At the Lockport Discharge Section, Mr. R. H. Burke, of the Sanitary District staff, who has been working on current meter measurements under Mr. Blanchard since his connection with the District, was stationed with a Haskell Meter which was operated from a cable suspended across the canal.

At Lemont, Mr. George E. Haggas, of my office staff, with a Haskell Meter, was stationed there. This meter was operated from the Bridge at the same point and under the same conditions as in the experiments by Mr. Moore testified to on behalf of the Complainant. Mr. Haggas was Mr. Blanchard's Principal Assistant on the measurements of the discharge of the St. Lawrence River, to which I have referred, and has been for some time connected with my office where he has had more or less to do with hydraulic work.

At Willow Springs, a Harbor Price Meter was operated by Mr. Herbert Ripley and Mr. J. T. O'Connor, of the District staff, the meter being operated from the Bridge. Mr. Ripley is a graduate of the Civil Engineering Department, University of Michigan, and has been connected with the District for several years.

Mr. O'Connor is an employee of the District and has been assisting Mr. Blanchard and Mr. Ramey in hydraulic work on the Canal.

The next location was at Robey Street where Mr. H. P. Ramey had a Harbor Price Meter which was operated from the bow of the steamer Robert R, being suspended from a boom six feet clear of the bow. The Robert R draws between three and four feet forward when loaded, as she was on this occasion.

Mr. Ramey has been connected with the District for some six or seven years I think. He is a graduate of the University of Michigan and while a student participated in considerable hydraulic work under my supervision, and has done a considerable amount of current meter work for the Dis-

trict. He has also made gagings of the canal by means of floats.

At Loomis Street, Mr. J. R. James, from the staff of my office had a small Price Meter which was operated from a six foot boom from the bow of the gasoline launch Thos. A. Mr. James is a graduate of the Engineering Department of the University of Michigan, and for something over two years, I believe, was connected with the United States Lake Survey Office at Detroit, and since that time for a year or more has been connected with my office.

At Dearborn Street, Mr. L. E. Ayres, my office Engineer was located with a small Price Meter, which was operated from the Bridge. Mr. Ayres is a graduate of the University of Michigan in civil engineering and has been on hydraulic measurements under me intermittently for the past six years; has gaged several small streams both by current meters and by floats, and participated in hydraulic measurements with the Pitot Tube, and the measurement of water over weirs.

Q. He has also participated in the experiments there in the naval tank?

A. Has also participated in the experiments in the naval tank and in the computations involved in the preparation of material for this case.

On February 22, Mr. Blanchard was in charge of the meter party; at the Power House, Mr. E. L. Cooley was in charge and Mr. R. K. Holland of my staff was there to take personal notes and check the observations of the various operators and performers.

At Lemont Mr. R. H. Burke was located with a Haskell Meter which was operated from the Bridge.

At Summit, Mr. Ramey was located with a Price Meter which was operated from the Robert R; and at Dearborn Street Mr. Haggas was located with a Haskell meter which was operated from the Bridge.

Mr. Blanchard devoted during this test most of his personal attention to the work of the Haskell Meter at Dearborn Street.

Q. For how long a period were the experiments continued?

A. A discharge of approximately 10,000 cubic feet per second was maintained at the lower end of the canal for about 14¼ hours, when it was reduced to about 8,000 cubic feet per second and continued at that for two hours more, by which time the demands of service required that the flow be brought down to a minimum to store water for the day load. During

the first 2¾ hours, 5,000 cubic feet per second was discharged at the Bear Trap Dam and during the next two hours about 2300 cubic feet per second was discharged there.

Q. On what date was this?

A. This was on March 8th.

Q. What success did you have in establishing a flow of 10,000 cubic feet throughout the canal and the Chicago River during the period which you mentioned?

A. It was not possible to establish a flow of 10,000 cubic feet per second throughout either the canal or the Chicago River during the period of the observations.

Q. What flows were you able to establish in that time?

A. At Lockport, the station being located 13,000 feet (2.46 miles) above the Power House and about 3,000 feet (3/5 miles) above the Bear Trap Dam, where the water was being withdrawn during the first five hours of the test, a discharge of 10,000 cubic feet per second was established about seven hours after the increased flow was started.

At Lemont, 37,200 feet further up (being 9½ miles from the Power House) a flow of 10,000 cubic feet was established about three hours later, or 10 hours after the opening of the gates.

At Willow Springs, 39,500 feet above Lemont and 16.9 miles from the Power House, the highest flow attained was about 9300 cubic feet per second, which was reached four hours after 10,000 at Lemont, seven hours after 10,000 at Lockport, and fourteen hours after the opening of the gates at the Power House.

At Robey Street, 68,500 feet above Willow Springs and 29.9 miles from the Power House, the highest flow established was about 8400 cubic feet a second, which occurred about nine hours after the flow of 10,000 cubic feet at Lemont and 12 hours after that at Lockport; and about 19 hours after the opening of the gates at the Power House.

At Loomis Street, 5650 feet above Robey or 31 miles from the Power House, the highest discharge observed was about 7200 cubic feet, which occurred about 11 hours after the 10,000 at Lemont, 14 hours after the 10,000 at Lockport and nearly 21 hours after the opening of the gates at the Power House.

At Dearborn Street, 22,450 feet further up, 35.2 miles from the power house, the change began about four hours after the opening and the flow increased to 7300 cubic feet per second at midnight or about 11¾ hours after the same discharge was observed at the Lockport meter.

Q. How would you interpret the results of these experi-

ments as to the time it would take to establish a flow of 10,000 cubic feet per second in the canal starting with a base flow of 4,167 cubic feet per second by opening to a capacity of 10,000 cubic feet per second at the lower end?

A. These tests indicate that such a flow could not be established at Robey Street in less than 24 hours.

Q. You spoke of the approximate flow of 10,000 cubic feet per second at Lockport. How near 10,000 cubic feet do you consider that it was during the time that you mentioned?

A. I think it might be in error five per cent. either way, that is a total error of 10 per cent. in there; possibly a part of the time a little bit more.

Q. You had a check on that did you not at Lockport?

A. The meter records at Lockport and Lemont agree with the Power House records within about 500 cubic feet a second for the period from 10:00 P. M. of March 8, to 1:00 A. M.; the Lemont record being intermediate between the Lockport and Power House. If the Lemont record were right, it would indicate that the Power House might be in error 2½ per cent.

Q. Do these experiments, tests, have any bearing on the discharge measurements of the outlets of the Great Lakes as carried on by the Lake Survey? If they have, will you state what your conclusions are with reference to that matter?

A. Yes. These experiments reproduce on a large scale the condition which exists on the rivers flowing out of the Great Lakes when either the lake at the lower end, as in the case of the St. Clair and the Detroit, lowers or the lake at the upper end, as in the case of any of the rivers, rises. A wave is immediately set up which passes down the river, and which has been used to determine the time that the discharge at the gaging station would correspond to that due to the changed elevation of the lake. These investigations prove very conclusively that the full effect of a change of stage of the governing body of water upon the flow past a given section does not coincide with the time of the change of the gage height at that section.

Q. That is the travel of the crest as it has been called?

A. The travel of the crest. That the travel of the crest gets there very much sooner than the increase of discharge does; and that the change of discharge coincident with the surge or with the passage of the crest may be anywhere from 10 to 80 per cent. too small depending upon the location for distances from the governing change of three miles or more.

Q. What is the essential distinction between the methods used by the Lake Survey and the witnesses who have been produced by the Complainant in this case of relating discharge measurements, and the method used by you, and what bearing do the experiments of March 8-9 on the Drainage Canal have on each?

A. The theory of the Government Engineers has been that at the gaging station the discharge changes corresponding to a change of elevation of the governing lake are completed coincidently with the surge of the gage or the passage of the crest of the wave caused by the change in the lake elevation; and that the time interval between the change in the lake elevation and its corresponding discharge is measured by the time of travel of the wave set up by the change, over the intervening distance. The fallacy of this assumption is proven by the canal tests wherein, for example, a flow of 10,000 cubic feet per second at Lemont did not produce a flow of more than 9300 cubic feet at Willow Springs in six hours, though according to the testimony of Mr. Moore (record printed page 2880) the change of elevation accompanying a change of discharge at Lemont, was observed at Willow Springs within about 30 minutes.

This being a regular channel, 162 feet in width and over 22 feet in depth, approximately straight, and with smooth vertical sides.

The theory upon which I have proceeded has been that the only way to establish a connection between the discharge and the lake elevations, from the observations in evidence, was to take periods when there was little change in the lake elevation, and therefore the mean elevation could be taken as representative of the condition for the whole period, and to compare this mean elevation with the mean of the discharges taken during that time.

I have also considered the fact, shown by the canal experiments, that a very much longer time must elapse between the occurrence of the lake elevation and the discharge corresponding than has been allowed by the complainant.

Adjourned subject to notice.

GARDNER S. WILLIAMS resumed the stand and testified further as follows:

Cross-Examination by Mr. Hopkins.

Q. Mr. Williams, in speaking of ice effects, you spoke of it as also affecting the canal. If as a matter of fact the same amount of water, as for instance 10,000 cubic feet a second, is taken at the Power House, it does not make much difference does it, even though it may require more slope to get it over, you are getting the 10,000 cubic feet of water, are you not?

A. If I understand your question to mean if 10,000 cubic feet of water is taken in the winter and 10,000 cubic feet of water is taken in the summer, the same quantity of water would be taken from the lake at both times, my answer is yes.

Q. If you are taking a certain amount of water in the canal, then the ice effect in the canal does not make any difference as to your effect on the level of the lake?

A. If you are taking a certain amount of water through the canal, the question of whether ice is there or is not, or anything else, does not make any difference in the quantity of water which is taken.

Q. Does it make any difference in the effect upon the lakes?

A. If it is taken from the lakes, I do not see that it would.

Q. Then it does not offset any ice effect in the St. Clair or any other rivers, if they are taking that amount of water?

A. On the assumptions that you are making, it would not.

Q. And in this case questions have been asked as to the effect of a certain diversion at Chicago, or the named amount of water, so many cubic feet of water per second; have not all the questions been on that basis?

A. Of various diversions at Chicago, yes.

Mr. Adcock: It is the effect of the diversion at Chicago.

Mr. Hopkins: Of a certain amount of water per second.

Mr. Adcock: Of the ultimate effect. There is not any theory about it, it is the ultimate effect which you have taken. You seek to enjoin us from taking the amount which we are taking.

Mr. Hopkins: Q. Now you discussed Mr. Sabin's results in 1901 and on page 3318 of the record (printed record, 3506) you said that in the month of February, 1901, the surface of

Lake Erie fell .24 feet. What was the source of that information?

A. The report of the International Waterways Commission, if I remember correctly.

Q. Have you that report?

A. I have not at the present moment.

Q. Have you got it where you can produce it?

A. No, it is not here. I think there is probably one in the office somewhere. I will see if I can find it.

Q. Have you that report now?

A. I have.

Q. Page 139?

A. (Referring to same.)

Q. Do you know how they determined the elevation at the first of the month say and the last of the month?

A. I do not.

Q. What would you regard as a proper way of getting the elevation for a certain time, say the first of February, 1901, of Lake Michigan-Huron?

A. If I wanted to be very accurate about it, I would take the mean elevation of all the gages of which I had a record on that day.

Q. The same with Lake Erie?

A. The same with Lake Erie.

Q. Do you know that the figure as put down in that report to which you referred showing the elevation for say the first of February, is the mean of the average for January, 1901, and of February, 1901?

A. I do not.

Q. Can you verify that, see whether that is the case or not?

A. What is the question?

Q. (Question read.)

A. In the present instance, the sum of the mean elevations for January and February is 235, and the elevation given for the first of February is 118, which is approximately ½ of the means of the two.

Q. Can you satisfy yourself from the data before you as to whether or not that was the method used throughout?

A. From random comparisons, it would appear that that is the method or that that may be the method.

Mr. Adcock: I would like to submit that it would be impossible to determine that a particular method was used, simply by making a comparison and finding that you might

get a result in that way. It is a kind of hit or miss proposition.

The Witness: I will say that it seems a fair inference that that was the method. I do not want to say that it was.

Mr. Hopkins: Q. If that method was used, it would hardly have very much value as far as picking the elevation for a certain day is concerned, would it?

Mr. Adcock: I object to the question, on the ground I think it is an unfair question to ask the witness, without calling attention to some statement in the report of the International Waterways Commission, or some evidence, which would indicate the method which they did use in determining the elevation of the water surface of Lake Erie for those different days. It would seem to me that the method which the Government's counsel asks the witness to use in determining how the elevation was obtained is entirely improper, because it would seem to me to be a hit or miss proposition. Unless you knew what the elevations, mean elevations were for the days mentioned, and make comparison in that way, it would not be of any value.

Mr. Hopkins: If you admit that, that is all I ask in that last question.

A. Just what is the question?

Q. (Question read as follows: "If that method was used, it would hardly have very much value as far as picking the elevation for a certain day is concerned, would it?")

A. It would depend upon the location of the day. If the day were midway between the means, I would think that this method would probably be as accurate as taking the reading of a single gage at a single time on that day.

Q. How about taking the mean of all the gages on that day?

A. A mean of all the gages would be, I think, a more accurate method than taking the mean of the month each side.

Q. You mean between the average of two months would not show at all if there was a sharp rise half way between, would it?

A. It would show part of it.

Q. Possibly only a small part?

Mr. Adcock: I object to this question on the ground it does not take into consideration the purpose which the International Waterways Commission had in mind in determining the elevation for those times.

Mr. Hopkins: Regardless of what the International Waterways Commission had in mind, the witness has taken certain

figures in that report and used them for comparison for a particular time, to show a fall or rise between the first and the last of the month, when in showing that, it does not accurately show or attempt to show the elevation at the two days which he is trying to use the rise and fall for.

Mr. Adcock: I understand in various considerations here, which we have taken up with reference to the hydraulics of the different lakes that the daily mean would not be of any particular value as compared with the monthly mean or the yearly mean. It depends upon the purpose for which you wish to use the data.

Mr. Hopkins: Exactly, it depends upon the purpose, but when you compare one day with another one you do want those days, rather than the average when they are all ironed out.

Q. (Question read as follows: "Your mean between the average of two months would not show at all if there was a sharp rise half way between, would it? A. It would show a part of it. Q. Possibly only a small part?")

A. As to how much it would show would depend altogether upon the distribution of the changes of elevation throughout the periods considered. If you want to give a particular case, I will try and figure it out for you and try and tell you how much the means would show.

Q. Do you consider that taking your figures from tables computed in that way, that you can get a comparison of one day with another day, with any great degree of accuracy?

A. I would expect that there might be considerable error in the elevations for any single day; but I think that as showing the change of elevation over a period of 30 days, it would be very accurate.

Q. But the way you get your change of elevation over 30 days is comparing the first of the month and the last of the month, so that you really do take two particular days, do you not?

A. What it appears we are getting for the change of elevation over 30 days is comparing a period of two months at which the day considered is the middle day with a period of two months in which the day considered is the middle day; and I think that is a quite accurate way of getting at this elevation.

Q. Will you take from this same table Lake Erie from the Buffalo gage, using the same method?

A. It would give you a change of .39 as compared with a change of .24 if you used the Buffalo gage.

Q. How many inches does that .39 represent?

A. .39 represents about five inches, $4\frac{1}{2}$, $4\frac{3}{4}$.

Q. That would make about two inches difference, would it not?

A. About an inch and $\frac{3}{8}$.

Q. You might have a certain average for say the month of January in any one year, a certain average for the month of February, and they might be very close together and still on the first of February have an elevation quite a little higher or quite a little lower than that average, could you not?

A. I think it is not likely considering the whole lake. You might at a single gage.

Mr. Adcock: That is there might be oscillations?

A. On one gage you can get anything. For instance you have the comparison of Buffalo and Cleveland; the Buffalo gage is notoriously unreliable, on account of the effect of winds and other things which raise the water or lower it at Buffalo, whereas Cleveland being near the waist of the lake as it is is much more dependable.

Mr. Hopkins: Q. You took one gage though didn't you, the Cleveland gage?

A. I took the one which the International Waterways Commission used; adopted their figures as being the result of the study of experts on the subject, presenting the matter as they believe it to be, I assumed, correct.

Q. Did they use it for any such purposes as you did?

A. Well they put it here and they spoke of the change in lake elevation during the month. It is given here, storage in lake Erie for the month, right straight along. It is evidently based upon this first column. I think they used it for exactly the purpose I used it.

Q. Are they not average values?

A. That is given as the storage for the month. Now I think as indicating a change of elevation for the month, this method is certainly as accurate as taking a single daily reading would be.

Q. Of a single gage?

A. Of a single gage.

Q. But not if you took the mean of all the gages of the lake?

A. It would depend on how many you had. If you had four, I think you would get more accurate results, that is to say if you had Amherstberg, Buffalo, Cleveland, and a gage on the Canadian shore.

Q. We have at least three of those?

A. You have three. You need the fourth to balance the other three.

Q. There is one at Toledo?

A. Toledo does not help you. You can use that in place of Amherstberg, if you want. Of course Amherstberg, must have a correction to bring it down to the level of Lake Erie.

Q. How many do you have in Michigan-Huron?

A. Michigan-Huron you have one at Harbor Beach, one at Milwaukee ordinarily. Of course there are some others; one at Chicago that might be used, and there is one at Mackinac. I do not know how accurately that one is observed. Of course there is one below the locks at the Soo, but that is too far away from the lakes.

Mr. Adcock: Q. Is that under the jurisdiction of the lake survey?

A. I do not think it is under the jurisdiction of the Lake Survey regularly.

Q. It is kept by the Government is it not?

A. I do not know just what the standing of the gage at Mackinac is. I know there has been one there at certain times.

Mr. Hopkins: Q. Then you would not consider taking the gage readings on a particular day at one gage as a highly accurate method of getting the rise or the fall during the month?

A. No, I would not.

Q. You just stated you consider this averaging scheme as accurate as that?

A. I think it would be.

Q. Now referring to page 129, will you take Lakes Michigan-Huron and from the gage at Milwaukee instead of the one at Harbor Beach see what result you would get for the change in elevation for the month of February, 1901?

A. You would get a raise by the Milwaukee gage of .195.

Q. At Harbor Beach there is no engineer officer there in charge, is there?

A. Harbor Beach?

Q. Yes?

A. I do not know.

Q. In the winter season?

A. I do not know.

Q. You do not know whether it is accurately watched, or not, or whether it freezes up or anything of that kind?

A. Well, considering the testimony of Mr. Shenehon that when the records from Harbor Beach were available he would

prefer them to Milwaukee, I would hardly assume that such was the condition.

Q. Was that statement concerning the winter season?

A. That statement was concerning yearly averages. I presume that included the winter; if I remember it rightly. I will not be positive that I remember the exact context.

Q. Did it not have to do with the discharge of the St. Clair River, being the gage nearest the discharge?

A. I think not.

Q. And also with reference to the time of measurements of the St. Clair River, which were usually in the summer?

A. That was not my recollection; that is not my recollection at this time.

Q. For a period of 30 days, would you ordinarily expect the average elevation from one gage at one part of the lake to be very different from another part of the lake?

A. Why I would expect them to be about what the records show. There are considerable variations.

Q. Do you not have any independent opinion regardless of the records; in case anyone were out of order, poorly kept, you could not detect that from the results?

A. I have a very decided opinion as to the accuracy of the gage measurements on the Great Lakes; and that is that it is altogether insufficient to detemine the effects of such diversions as we are considering in this case, with precision.

Q. Inaccurate for any other purpose, you think?

A. I think they are inaccurate for determining the elevations of the lake within the degree of precision that is necessary to determine the effect of the diversion in this case.

Q. And all the more so, inaccurate for taking a particular day as against another particular day to discredit actual measurements?

A. I would consider that the gage readings are about as accurate as the current meter determinations.

Q. Whether it was working or not?

A. We are talking about averages. I know of a case under the eyes of a civilian officer of the Engineer Corps, if there is such a term and I suppose there is, where gage readings were reported daily and the observer did not go within 600 feet of the gage. The records introduced in his case show again and again the impossibility of their accuracy. I called attention to some of those in my former testimony.

In this comparison, we have taken the information that is available. If the Lake Survey or anybody else has anything that is any better, we will be glad to have them produce it

and we will revise our opinions in accordance therewith. But so far as the conclusions in my testimony are concerned, they were based upon what I believed to be the best information at hand.

Q. If you found the best information at hand did not accurately show the two days you were comparing, would you still insist upon using it to establish the real truth?

A. No, I do not think the real truth is established by these gage readings or by meter discharges.

Q. I understand you do not have that great opinion of meter readings, but I was asking merely as to your method of trying to discredit it by something that is really inaccurate.

A. Here are two things coming from the same source, the officers of the United States Government. They are both presented in official reports, and I compare them for what they are worth. I state the source of my information and what the evidence there set forth or the statements there set forth seem to show.

Now, I do not vouch for the correctness of that showing or the correctness of the statements behind it. I simply have taken, as I say, two reports presumably of equal reliability and have shown their inconsistencies. One or the other is wrong; I do not know but both are.

Q. Although made for entirely different purposes, and that this method of averaging to get the elevation at a particular day is something you have already testified is very inaccurate?

A. Oh, I don't know as I said it was very inaccurate.

Q. I understood you to say it was as inaccurate as the readings of one particular gage, which you said were very inaccurate.

A. No, I think not. I do not think I used the words "very inaccurate" in there, because I do not think it would be.

Q. Would you consider the International Bridge and under that as a good place for working with a magnetic instrument?

A. It would depend somewhat how far under it.

Q. Suppose at the water surface?

A. If you wanted to determine a true north, I would say not. But I do not see that it would affect materially the vibrations which a needle would have.

Q. Supposing at the .2 or .4 depths?

A. My observation of the magnetic needle in the presence of a fixed lodestone, or body of iron, has been that it assumes

a certain position which it tends to retain although it is not the true north, and except when a locomotive or a train of cars was passing over the bridge, I can see no cause for the presence of the bridge creating a vibration of the needle.

Q. If you got further away from the bridge, say below it, would it have any effect?

A. It might change the direction at which the needle would point, but I can't see that it would affect the vibrations of it. That is I can't see why a needle should vibrate through say 90 degrees because the bridge was there, whether it was at the .1 depth or .9 depth, or any other depth.

Q. Will you describe the instrument as used to determine the direction of the current?

A. It consists of a needle floating in a vessel, and by means of electrical contacts, the position of the needle is repeated to an instrument above. That is a hand on a repeater is caused to travel across the dial, and at the time of coincidence in direction of the two needles, the hand traveling across the dial stops. That is as I recall the action of the apparatus.

Q. Considering nothing but the fluidity of the water as between 60 degrees and 33 degrees, what effect do you think it would have flowing over the weirs at Cornell, say where the flow was about 500 cubic second feet?

A. As to what?

Q. The difference it would make?

A. In the discharge for a given head?

Q. Yes?

A. Possibly one per cent.

Q. For the Niagara River?

A. Probably about the same.

Q. Did you ever make any observations at Cornell in regard to that matter?

A. We had some made, yes.

Q. Over weirs?

A. Yes.

Q. With no change of condition except the temperature?

A. That was the only change.

Q. Will you describe the tests that were made under your direction in the tank at Ann Arbor, in regard to the resistance of cables with various weights on them, whatever that test was that was made?

A. The plant at Ann Arbor which was utilized consists of the naval tank which is about 300 feet long, 20 feet wide, 22 feet wide, I believe between walls, and about 10 deep as I recall.

On this there runs a car which has a platform about 20 feet square. This car is driven by electrical apparatus and carries a dynamometer. In these tests the meters were first suspended on a rod which was held vertically in the water and the pull of the meter and rod was taken up on the dynamometer; the car being caused to travel the length of the tank so as to get certain speeds over the middle 100 feet.

The meters were then removed, and the travel was made with the rods, so that the amount of resistance that was due to the rod could be separated from that due to the meter.

At a velocity of 7 feet a second, the A meter with a 3/4 inch pipe support offered a resistance of 17 pounds. At a velocity of 6.15 feet per second, the same meter offered a resistance of 13.22 pounds. At a velocity of 4.88 feet per second, the resistance was 8.15 pounds. For a velocity of 4.16 feet per second, the resistance was 6 pounds. For a velocity of 3.1 feet, the resistance was 2.9 pounds.

This was supported upon a 3/4 inch pipe. The resistance of the pipe alone, at a velocity of 7.18 feet the resistance was 5.55 pounds. At a velocity of 6.27 feet, the resistance was 4.4 pounds. At a velocity of 4.92 feet the resistance was 2.75 pounds. At a velocity of 3.97 feet, the resistance was 1.8 pounds. At a velocity of 3.15 feet, the resistance was 1.1.

For the B meter, which was mounted upon a one inch pipe, for a velocity of 7.1 feet, the resistance was 15.95 pounds. For a velocity of 6.65 feet, the resistance was 14.1 pounds. For a velocity of 5.48 feet, the resistance was 9.75 pounds. For a velocity of 5.04 feet, the resistance was 8.15 pounds. For a velocity of 4.5 feet, the resistance was 6.6 pounds. For a velocity of 3.95 feet, the resistance was 5.12 pounds. For a velocity of 3.18 feet, the resistance was 3.15 pounds. For a velocity of 2.16 feet the resistance was 1.39 pounds.

The resistance of the 1 inch pipe alone: For a velocity of 7.12 feet, it was 7.65 pounds. For a velocity of 6.2 feet, the resistance was 5.95 pounds. For a velocity of 4.97 feet, the resistance was 3.95 pounds. For a velocity of 4.05, the resistance was 2.9. For a velocity of 4.02, the resistance was 2.85. For a velocity of 3.12, the resistance was 2.3 pounds.

I may say that the observations with the meter included the meter with its lead, so that subtracting the pipe from the meter and pipe gives the resistance of the meter and the lead.

Adjourned to Thursday, June 18, 10:30 A. M.

Thursday, June 18, 1914, 10:30 A. M.

GARDNER S. WILLIAMS resumed the stand and testified further on cross-examination as follows:

The Witness: I think there was a question pending.

Mr. Hopkins: Q. Did you finish the answer to the question Mr. Williams?

A. I think not.

Q. Will you go ahead and complete it?

A. If I recall, I had finished the experiments on the A and B meter and the one inch and 3/4 pipe, so that it is possible to get the pressures on the meters and their weights.

Q. Were the meters attached to the cable?

A. During these cable tests?

Q. Yes?

A. No, not during the cable tests. The meters were attached to the pipe. The resistance of the pipe, meter and weight was taken. Then the meter and weight were removed, the resistance of the pipe alone was taken and subtracting the resistance of the pipe from the resistance of the—

Q. It was not attached then directly to the cable?

A. Let me finish: Then the resistance of the meter and weight was obtained by subtracting from the combined resistance of the meter, weight and pipe, the resistance of the pipe.

Then the cables with the weights attached were rated for different lengths by subtracting one length from another the weight and the excess length of cable was eliminated—the weight and the common length of cable was eliminated, and the effect of the remaining length was obtained.

Q. The A meter was attached to a 3/4 inch pipe, was it?

A. Yes.

Q. What was the method of that attachment?

A. The staff of the meter was attached rigidly to the pipe, so as to maintain the shaft of the meter in a vertical position.

Q. How was the pipe attached to the car?

A. The pipe was supported on a frame which was operated with a parallel motion, so that any vertical pressures would be taken up in the frame, and the dynamometer was attached to measure only the horizontal pressure.

Q. The pipe was vertical, and rigidly attached to the car?

A. No, the pipe was raised vertically and attached to this parallel motion which was free to move back and forth

parallel to the position of the car, and the amount was measured by the dynamometer, which measured the amount of pull. The dynamometer is a separate machine mounted on a car; the frame of the scaffold standing vertical.

Q. But the pipe was held rigidly vertical?

A. The pipe was held rigidly vertical, and so was the staff of the meter.

Q. How far was it from the point of attachment of the pipe to the surface of the water?

A. About somewhere around 4 feet. I haven't the note book here and I do not remember exactly. The meter was run between 2 and 3 feet below the water surface.

Q. Under those circumstances you got considerable vibration in the pipe, did you not?

A. No we did not. That was one of the things we looked after, having discovered the effect of the vibration previous to running the meters.

Q. How deep was the axis of the meter below the surface of the water?

A. I say it was somewhere around 2 feet. I will not be certain as unfortunately I have not the notes with me.

Q. Then there was a length of about 6 feet of pipe involved?

A. No, I do not see where you get 6 feet.

Q. I understood it was 4 feet from the place of the attachment to the surface of the water and about 2 feet below the surface of the water to the axis of the meter?

A. I misunderstood your question. The place of the attachment was close to the surface of the water. The dynamometer as built is intended primarily for measuring the resistance of models of boats and the point of attachment of the boats to the dynamometer is 2 or 3 inches above the surface of the water, but our point of rigid support for the apparatus to be measured was a foot above that level and further down the pipe extended to the meter a length of somewhere around 3 feet of pipe, between 3 and 4.

Q. The motion of the meter then was even, without wabbling through the water?

A. Yes, reasonably so, about the same as it would be in an ordinary stream, and the same as it is in rating meters in the tank.

Q. What freedom did the meter have to adjust itself to the direction of the current?

A. It was free to move about its trunnions in a vertical plane and about its ordinary axis in a horizontal plane, so

that it had the same freedom it has when in a stream aside from that it acquires from the twisting of the cable which I think it practically never does.

Q. Did you have any ball bearings?

A. It was the ordinary meter as it is furnished by the Ritchie-Haskell Meter Company.

Q. Do you know whether it did have ball bearings or not?

A. I think the vertical shaft—the B meter was the latest type of meter which they turn out. The A meter we had consisted of a body and supports, which is an older make. It is about the same thing that you had on the Niagara, I think, as it was one that I got in 1897, I think.

Q. You did not put any ball bearings in it?

A. We did not put any ball bearings in it. It was as it was built.

Q. How much later type was the new meter, the B meter you had?

A. That was purchased a few weeks ago, that is within the past three months.

Q. Now have you got the plan of the lead you used?

A. I haven't it with me. The lead was shaped as nearly as could be determined by scaling the photograph of the lead used on the Niagara River, and it appears on Plate number 6, next to page 5327 of the report for 1900, and by getting the weight to correspond with the statements as to weight, which is indicated in the same report.

Q. What was the length of the weight?

A. Unfortunately I haven't those dimensions here, but I saw the weight day before yesterday, or rather not day before yesterday but Sunday, and without measuring it, from recollection I should say it was in the neighborhood of a foot in length. I may say that it was cast by extending the weight which belonged with the meter originally; that is by putting on additional weights of the same form, which is a boat shaped body.

Q. What was the breadth as you recall it?

A. It was the same as that furnished with the meter, and my guess would be somewhere about seven inches. I can secure that information and furnish it to you accurately.

Q. Were the two leads used on the two meters the same?

A. Yes, the same leads.

Q. What kind of a tail was used in each case?

A. The tail was a flat plate of wood in both cases.

Q. How long was the tail?

A. Oh, it was somewhere around—let's see, I don't want

to be positive that that tail was used in both cases, that is the one I saw was used in both cases. The tail as I recall it would be about two feet long, possibly 2½; or I will say from 18 to 30 inches.

Mr. Adcock: The tail on what?

A. On the weight. The tail as we used it I think was a little longer than that indicated on plate number 6, just referred to.

Mr. Hopkins: Q. Referring to the photograph which you have just mentioned and from which you got the form of the weight, just what is the length as shown on that photograph from which you reproduced the weight?

A. I will say the position of the lead is such that it is difficult to tell from this photograph just what the length was. The form that was taken was that which was the form of the weight furnished with the meter as purchased in 1897, which was a boat shaped body.

I will say that from this photograph the depth of the weight can be fairly well established, and having that and the width corresponding to the weight that was originally sent with the meter, why the length has to be a certain thing. It cannot be very different.

The photograph to which reference has just been made appears upon page 2461 of the printed record, being in volume 4.

Q. You made these tests at two depths, didn't you, one of eight feet and the other of five feet, to get the pressure on the cable?

A. The length of cable used was eight feet, five feet and two feet.

Q. That was the length of cable used?

A. Yes.

Q. You were getting your differences then on three feet of cable?

A. Getting our differences from six feet; that is we get two differences of three feet.

Q. Did you get a difference from two to eight feet?

A. Yes.

Q. Singly, too, to check with the others?

A. Why yes. All you have to do is subtract your observation for two feet from your observation for eight.

Q. Based on that six foot cable, the difference between two feet and eight feet, what would be the pressure on a quarter inch cable for 10 foot length at velocities of 4, 5, 6 and 7 feet per second?

A. I will have to work those out for you.

Q. About how long will is take?

A. I do not know. It might take half an hour. I was going to give you the observations themselves.

Q. What is the measuring principle on this dynamometer?

A. The dynamometer consists of a vertical lever which is held in a vertical position by calibrated springs in the nature of a spring balance, and a pencil at the top attached to a bar at the top records graphically on a drum rotated by a clock mechanism the deviation of the top of the bar from the vertical; this of course measuring the extension of the spring and thereby the amount of pull that is exerted at the bottom of the lever.

Q. That is it is a spring balance?

A. It is a spring balance, practically.

Mr. Adcock: Q. Was it a good dynamometer?

A. Yes, the spring is the highest grade steel spring as used for indicators in that class of device.

Q. The one that is ordinarily used?

A. Yes, and it is frequently calibrated with known pulls.

Q. And it was used by competent persons?

A. The experiments were made under direct supervision of Professor Sadler, who has employed that apparatus for measuring the resistance of ships and other bodies when drawn through the water, in order to calculate the horse power required and so on for driving ships of different models. It is similar in construction to that used by the United States Government in their dynamometer experiments at Washington in their naval tank; similar to that used by Professor Durand at Cornell, although I think a little more direct, and hence a little less liable to errors from complications.

Mr. Hopkins: Q. You gave the weight of your leads, did you not?

A. Yes, that is stated—I don't know as I did either.

Mr. Adcock: You stated that it was the same weight—

A. They were within two pounds.

Mr. Hopkins: Q. Just what is the weight in pounds?

A. I do not have the memorandum of that here, unfortunately, but my recollection is it was 139 pounds. We started to get the 136 pounds and we came within about two pounds. We took it out of this report (indicating).

Mr. Adcock: Q. When you say "this report," you mean what?

A. Took it out of the report of the Chief of Engineers for 1900. On page 5341, report of the Chief of Engineers for 1900, the statement is made: "The range was much reduced

in the winter and spring of 1899, by the use of the 136 pound lead on the B meter instead of the standard 36 pound one." And elsewhere, the statement is made that a similar weight was used on the other meter. And it was this weight that we were endeavoring to approximate.

Mr. Hopkins: Q. Mr. Williams, will you produce the notes and the details of those tests for the examination of the Government Engineers in this case?

A. Certainly.

Q. Taking the winter, how much retardation of flow in the Chicago Drainage Canal would be due to floating ice?

A. Well, it is hard to say. The reduction of flow in the canal, comparing the winter and summer conditions, is somewhere around a thousand cubic feet a second, when they are attempting to flow around 7,000.

The winter conditions are such that it is not possible to draw the amount of water through the Power House that is required to take care of their lighting loads, and on many days they have to cut out lights. The capacity of the wheels there is considerably less than 10,000 cubic feet a second, so that the winter conditions are such that they certainly cannot draw 10,000 cubic feet a second through the canal. How much of it is due to floating ice—

Q. You mean through the canal or the power house?

A. I say through the wheels at the power house. The trouble of course is partly in the wheels and partly in the canal. It is hard to say how much is in one place and how much in the other.

Q. Do you think with the same opening at the power house then there is 14 to 15 per cent. difference between the summer flow and the winter flow?

A. No, that includes some change in lake elevations. That figure I just gave is based upon taking the actual record, four months in warm weather and four months in cold weather the amount of water that is discharged.

Q. Do you know whether there was an effort made to flow the same amount in those two four month periods?

A. There was an effort made to flow through the wheels a greater amount in the winter than there was in the summer, and they were unable to get it.

I have during the past month been engaged on an investigation of the conditions of the electrical development, and we discovered very early in the investigation that in the winter they

were not able to get the quantity of water through there that they do get in the summer.

Q. Just what natural conditions do you attribute that to?

A. That is attributed to several things.

Of course in the first place there is the changing viscosity of the water due to the lowering of the temperature.

In the second place there is the effect of floating ice, which not only has an effect by rubbing along the banks, but it also has an effect in rubbing on itself. It is somewhat similar to the condition that you get when you try to transport sand in water. If you transport sand in water it requires a materially larger head to deliver a given quantity of water and sand. The presence of the sand in the water increases the resistance to the flow.

I believe that the presence of ice in the upper layers of the stream increases the resistance of flow there in a somewhat similar manner. And I may say that the coarser sands, as I recall the experiments, cause greater disturbance than the finer ones.

In addition to that, speaking of the winter condition, the lake is always lower in the winter than it is during—the general level of the lake is lower during the winter than during the summer and consequently there is not the head available to draw water through the canal, and as a result the flow at the Power House is deficient in the winter time, or is reduced in the winter time.

Q. That is on the assumption of putting everything through the power plant and not using the waste gates?

A. That is based upon observations in which the bulk of the water was used through the turbine. It is not however based solely upon that observation, because I have made experiments on a comparatively large scale, in which the effect of the viscosity of the water came out very clearly.

In this case, we had in two sets of tests water at about 70 degrees temperature, and in the other water between 33 and 40, with no floating ice. The water was passed through turbine wheels and over a weir, and the result indicated as I testified in my direct testimony, the effect of the change of temperature there of the water in the experiments ranges between 2.7 and 3.1 per cent.

Q. Where was that test made?

A. Made at Holyoke, at the testing flume.

Q. Is that the one through sand or something of that kind?

A. No sand.

Q. Would the viscosity of the water in the Drainage Canal

due to change of temperature from 70 degrees to say 33 degrees be any different or greater than it would be in the canal at Cornell or in the Niagara River?

A. I think the effect would be somewhat greater on the Sanitary Canal, on account of the greater percentage of foreign matter present in the water. If you increase the viscosity of the water, the presence of foreign matter would have a greater effect than it would in the less viscous fluid; and as the Niagara River is considerably clearer, freer from foreign matter than the Drainage Canal, I would expect the effect of viscosity due to change of temperature would be greater in the canal than in the river.

Q. Would that be as much as 100 or 150 per cent.?

A. I could conceive it might make 100 per cent. difference in the effect due to viscosity, or due to change of viscosity I mean.

Q. Is that your opinion as well as your conception?

A. I think it is quite possible it could. In fact I would not be surprised if that were found to be the case.

Q. I am speaking only of the viscosity of the water?

A. That is what I understood you to mean, the effect of the change of viscosity between hot and cold weather I would expect might be 100 per cent. greater in the canal than it would be in the rivers.

Q. Because of the nature of the water?

A. Because of the nature of the water.

Q. What per cent. would you give to the floating ice?

A. Well, that is a very hard thing to determine. I do not know of any experiments that really give us a basis upon which to make an accurate determination.

Q. Do you think taking four months in the winter the conditions as they are in the Chicago Drainage Canal that the floating ice for all that time would make a difference of five per cent.?

A. You mean in the capacity of discharge?

Q. Yes?

A. Well, it is hard to say. The effect of course of the floating ice only reaches through a part of the canal, on account probably of the chemical action taking place in the water. The ice disappears before it goes a great ways down the river or down the canal. That makes it rather difficult to base conclusions on any information that I have. And I do not know of any definite experiments to show what the effect on discharge is of the presence of floating ice, except that we know very well that it does reduce the discharge.

Q. As a matter of fact, does not floating ice go just as fast or faster than the water itself?

A. If it goes faster, it must receive the energy from somewhere, and the entire energy of flow is due to the difference of elevation in the—

Q. Isn't the energy in the fall of the ice?

A. In the fall of the stream.

Q. Isn't it a matter of fact that a float travels a little faster than the water in which it is traveling?

A. That is a matter that has been discussed upon theoretical grounds, and Mr. James B. Francis went into an analysis of it, and as I remember his decimal is out in the third place. That is if any correction was to be made it was—

Q. That does not indicate any retardation, does it?

Mr. Adcock: Wait a minute; he had not finished his answer.

A. It was so small that Mr. Francis decided that the float went at the same velocity as the water, and that appears to be borne out well by comparisons in measurements of discharge of floats with weirs where the two have checked within ½ of 1 per cent., so that I cannot conceive that there is any likelihood that the ice travels faster than the water surrounding it.

In fact, I am quite well aware that in many cases it does not travel so fast. I never have seen ice traveling through the water where it showed any indication of moving faster than the water in its vicinity, unless somebody was pushing it with a pike pole.

Q. Under what circumstances did you see it traveling slower?

A. When it jams on the sides, or is retarded by rubbing against some other cake of ice that is moving at a less velocity. Where you have a large cake of ice floating down, it necessarily assumes a velocity representing the mean of the current in which it is traveling. A small cake coming along moving in a swifter current will impinge upon it and be retarded by it. Such occurrences are very frequent when there is no jamming against the sides.

Q. How much of the time in the course of the winter is there floating ice in the canal?

A. I am not able to say.

Q. Do you know how much of the time Lake Michigan is frozen over at this end?

A. I think I can furnish you with that information.

The United States Deep Waterways Commission reports in

a table on page 196 the average dates of opening and closing of navigation at Chicago, Illinois, are: For closing, January 7; for opening, February 27, and that the information is based upon ice.

Q. When was that report?

A. The report is dated in 1896, and states further that the average dates of closing from the winter of 1876-77, to the winter of 1895-96, inclusive, at Chicago—

Mr. Adcock: Is that on account of ice?

A. That is on account of ice, was January 10, and the average date of opening was February 24, giving a period of days when the harbor is closed of 45.

Mr. Hopkins: Q. Do you know how much of that time, or does the report show how much of that time it is actually blockaded by ice?

A. It does not.

Q. Also whether or not the ice is in the lake or in the river?

A. It does not say anything about whether it is in the river or not.

I will tell you in just a moment, possibly, something with relation to this. (Referring to report mentioned.)

The statement is made on page 194—the larger proportion of the tables is actual ice record; some of the remainder are first and last vessels, and others official opening and closing. The record for Chicago is marked "ice." The records for some other places are, some of them marked first and last vessel; some of them "official." The conclusion is that this refers to the actual ice conditions.

Q. That is, that is the average of the beginning of some ice, and the average when the ice is out?

A. That is the average time that the port is closed on account of ice.

Q. But does not show whether ice is in there all the time?

A. It is not clear whether it extends beyond that, at certain times.

Q. It does not show where the ice is. I believe you have already stated.

A. Well, it was where it closed the port, evidently.

Q. Might it not be to some extent because of the difficulty of getting in and out of the port in the lake?

A. I don't quite get that question.

Q. (Question read.)

Mr. Adcock: That is some ice or what caused the difficulty?

Mr. Hopkins: Yes, ice. It does not mean that the river itself was frozen all that time?

A. I do not understand so. In fact at that time, or during a considerable portion of that time—yes, all of it, the river was discharging sewage in the lake. I think under those conditions there was very little ice in the river. And that also had a tendency to keep the lake open to a greater extent.

Q. With a constant current flowing now and carrying sewage, which is supposed to cause the water to be a little warmer than water without sewage, there is hardly so much ice in the river as there was then, is there?

A. There is certainly more ice in the river now than then because there could have been no ice in the river that did not form in the river except at the times when the Bridgeport pumping station was delivering more water than came from the sewers of Chicago. Now, there is ice in the river coming from the lake. The fact that there is a large body of water being drawn into the river tends to draw into it and clog up its mouth with the floating ice in the vicintity, or within the reach of the current.

Q. Now will you state what effect you think it has on the total volume then, that floating ice, percentage?

A. I have said that I have no data on which I can base that statement.

Q. Give us some outside limits, 10 per cent., 5 per cent., 2 per cent.?

A. I gave in my direct testimony a statement of the effects of the various causes of retardation of flow accompanying the presence of ice. My range I believe was from 3 to 10 per cent. I am not prepared to divide that into just how much is in one thing and how much is in the other. I think those limits are conservative.

Q. You think it might run as high as 10 per cent.?

A. I think the effect of the cold water, including the ice, might run as high as 10 per cent.

Q. Now it is true that at the Power House and Controlling Works, you can make an opening to take care of the same amount in winter that you do ordinarily in summer by increasing the openings to take care of that, say up to 10,000 cubic feet a second?

A. I doubt if you can make an opening at the Power House and Controlling Works that would produce a flow of 10,000 cubic feet through the canal in the winter. That is through the entire length including the river.

Mr. Adcock: Q. That is in its present condition?

A. That is in its present condition.

Mr. Hopkins: Q. If you were given permission, if the Sanitary District were given permission to take 10,000 cubic feet a second, they could not do it through the winter without an enlargement of the canal?

A. I think they would have to enlarge portions of the river in order to get that quantity of water through, at the present time.

Q. You said something about a fixed coefficient in the measurement of the Niagara River as tending to decrease the increment. You think a variable coefficient would have gotten better results?

A. I think a coefficient that coincided with the facts would have gotten better results than one which was simply the average of a large number of observations under different conditions.

Q. Suppose that the coefficient corresponded with the facts at the time the discharge measurements were made and the increment derived from that checked with the increment obtained by a fixed coefficient?

A. I should want to know how they were derived. I should want to know the number of observations upon which they were based, what degree of accuracy could be claimed or established for the observations?

Q. Did you know that in the coefficient work at the Open Section, Niagara River, that it was the fact that the coefficients were determined according to stage?

A. I do not think that that has been brought out in the testimony in this case so far.

Q. Referring to report of the Chief of Engineers for 1900, Appendix III, page 5347, are you familiar with the table of mean velocity coefficients at the Open Section as they appear on that page?

A. Somewhat.

Q. Did you ever yourself make any tests as between what we have called a fixed coefficient and a variable coefficient according to the stage, as to which will give you better results?

A. I have made tests which showed that it was not the same.

Q. What tests have you made?

A. Current meter tests.

Q. Where, under what circumstances?

A. In rivers, in the canal at Cornell, by comparing the discharges at different depths in the work of the Lake Survey.

Q. What was your range of depth?

A. We got ranges of depth from about 20 to 50 feet.

Q. You found you could not apply a coefficient determined at a 20 foot depth to a coefficient determined at 50 foot depth?

A. The two were not the same, so far as the records go.

Q. Did you ever get coefficient work out by taking into consideration all of those depths as the fixed coefficient?

A. Well, the whole point is that for the deeper depths the coefficient is greater than it is for the shallower ones all the way through, when your index point is near the top of your stream. If you go down to half depth, then I am not so sure what the results show.

Q. Take the condition at the Niagara River where the range of stage is not so great as from 20 to 50 feet, but is 4 feet, and competent engineers should make tests and determinations as to whether there would be any effect or difference between variable coefficients and fixed coefficients, and should come to the conclusion that there was no appreciable difference, much less than 1 per cent., would that have any effect on your opinion in that regard?

A. I should want to know who the competent engineers were and what investigations they made. I have also pointed out in my testimony that the difference would have to be considerably less than 1 per cent. Did I understand you to say 1 per cent.?

Q. Yes, that is what I said. I mean by less than 1 per cent., 1 per cent. on the increment.

A. I do not think any observations we have are within such a limit as to permit us to talk of increments within 1 per cent., either for comparison or any other purpose?

Q. Have you got your Exihibit 40?

A. Which exhibit is that, Mr. Hopkins?

Q. That is Stewart's cable inclinations?

A. There is a tracing of it that I made. (Indicating same.)

Q. In giving your conclusions as to how far the meter must have been down stream, were you basing that upon this exhibit as to the point at which the cable was held upstream by some other force?

A. Not at all. No, I understand Mr. Shenehon's device to be different from the one used by Mr. Stewart.

Q. What did you understand his method to be?

A. I understood it to be as shown here. I understand the

position of the weight above the water surface was maintained practically constant.

Q. So that the drift downstream would be from the water surface rather than from the bridge?

A. It would be from the position of the weight.

Q. That is close to the water surface?

A. Yes. In our computations, I think we assumed that that was about six inches above the water surface. I do not know whether we were correct in that assumption.

Q. Then did you understand that the sleeve weights which were used by Mr. Stewart were not used by Mr. Shenehon?

A. That was my understanding. Mr. Shenehon said so distinctly in his testimony.

Q. Do you think that would make any difference?

A. As to whether you use sleeve weights or put one big weight at the bottom, I think it would make a difference, yes.

Q. Did you take that into consideration?

A. We estimated the position of Mr. Shenehon's meter with the conditions as we understood them from Mr. Shenehon's testimony, which were, that the A meter was supported on a ⅜ cable, which was not drawn upstream, but was allowed to take the position which it naturally took as it swung from the bridge. That the B meter was attached to a quarter inch cable, and was held in the supposed plane of the meter support by drawing upstream on a device which we understood to be similar to the one which is shown upon this chart which is now before me, which is marked: "Lake level Niagara River, Analysis of Position of Meter 2B, with 120 pound lead, at Station 4 6/12 International Bridge Section, and comparison with meter A number 12, using sleeve weights. Scale ½ inch equals 5 feet. Francis C. Shenehon, United States Assistant Engineer, Number 33 Austin street, Buffalo, February 13, 1899."

Q. In getting your result, did you use the same method as that used by Mr. Shenehon as shown on the chart that you just referred to, taking into consideration the greater pressure according to your tests at the naval tank, or did you use the curve as shown on your Exhibit 40?

A. We used the information obtained from the tests in this naval tank, paid no attention to Exhibit 40.

Q. Suppose on the B meter, the block had been drawn up stream eight feet above the section, what is your conclusion as to how fr down stream the meter would be at 50 feet depth with a surface velocity of 6 feet per second?

A. Answering your question as asked, where the depth

was greater than 40 feet, the pressure on the meter was reduced to a 6 foot velocity, and where it was greater than 50 feet, the portion below 40, was assumed to be at 5 feet a second, so that this is giving you the advantage of that velocity at 5 feet a second between 40 and 50 feet depth over what you started out to assume. In these computations we assumed a velocity of 6½ feet as covering that position of the meter down to 40 feet, but when we got down to 40 feet we assumed the velocity of the current throughout the whole was 6 feet, and when we got down below 40, if the cable was below 40, we used 5 feet, taking into consideration the change of velocity in the vertical, as you go down.

Q. Is that your opinion as to what is the velocity down there?

A. That corresponds fairly with the velocity curves that appear for that section as I recall them.

Q. How far down stream would the meter be at that depth?

A. If you had drawn it up eight feet?

Mr. Adcock: At the water surface?

Mr. Hopkins: Substantially at the water surface?

A. Now do you mean eight feet above the vertical, or eight feet above the position at which it would naturally be in the water?

Q. No, eight feet above the bridge chord, eight feet up stream from the bridge chord?

A. If it were drawn up eight feet above the bridge chord, assuming that the meter were 50 feet below the surface of the water and it were drawn up eight feet above the plane of the bridge chord, the meter would then be five feet down stream from the plane of the bridge chord.

Q. You make the down stream drift under these circumstances about 13 feet?

A. Yes. It would be really a little more than five feet, because I am figuring from the water surface. Of course there would be a little further drift due to the length of cable between the weight and the water.

Q. On the plot to which you have just referred showing curves by Mr. Shenehon, doesn't he get a result of 12.5 feet?

A. His testimony was that he corrected for a drift of 12.5 feet.

Q. Then as far as the B meter is concerned, there was no great error in Mr. Shenehon's work?

A. Yes, because with the device as shown, keeping the

weight near the water, he could not have pulled it up eight feet from the plane of the bridge chord.

Q. You mean—

A. I will say that it is my opinion that he could not.

Q. You mean on account of the 80 pound weight that was used?

A. Yes.

Q. Well by adding sleeve weights, could it not be held at the water surface eight feet above the section?

A. By adding them where?

Q. To the 80 pound weight?

A. If you have added enough probably it could.

Q. Did you notice on this chart that you read that by adding to the 80 pound weight 2 or 3 sleeve weights, the meter can be held vertically in the bridge chord?

A. Yes, but it was the testimony of Mr. Shenehon that the weight used was 80 pounds. What he could have done and what he testified that he did do are necessarily two different things. I am basing my judgment on what he testified he did do. We asked him quite particularly about that point as we did not wish to be led into error.

Q. In estimating the error which in your opinion came from the location of the meter due to the increased cross-section, did you simply give the volume of discharge in direct proportion to the increased size of the cross-section? In other words if there were a 10 per cent. greater cross-section, there would be a 10 per cent. greater discharge?

A. The theory upon which we proceeded was that if a mean velocity was established for a cross-section of 100 per cent., and that velocity should have been applied to a cross-section of 110 per cent., the discharge would necessarily be increased 10 per cent.

Q. What is the condition of the water just below the bridge piers?

A. Considerably disturbed.

Q. As far as flowing down stream, though, is concerned, it is practically dead, is it not?

A. I think not. Of course there is an eddy there around the heel of the pier, very decided one, and the water closes in around that eddy pretty promptly. The experiments on the flow of water under conditions of that kind show that the velocity checks very promptly after passing the lower end of such an obstruction.

Q. Do you know what the shape of that pier is below the—

A. Yes, I think so.

Q. What is it?

A. I know approximately; the lower end, it is of rectangular section, lower half of the pier, plan, I mean.

Q. Do you know that it rests on a caisson?

A. I understand that it does.

Q. Do you know how far below the pier the caisson is?

A. We endeavored to find that out, and nobody seemed to be able to establish that fact for us, so that I was compelled to base my conclusions upon such information as I could get from outside sources.

Q. You never have made any soundings there, anything of that kind?

A. No, we had the Government soundings, which did not appear to be particularly definite in regard to the condition next to the piers. I mean we had the plotting from the Government soundings. We did not have their soundings.

Q. Do you know whether or not there is any stone below the piers of the caisson which would tend to protect it, make it more stable?

A. I understand that there is.

Q. With all that, then, would there not be an area just below those piers of dead water, or water in which the volume is much reduced in flow?

A. You mean velocity?

Q. Velocity?

A. The velocity immediately behind and below the piers would be considerably less than it is out in the middle of the section. At the same time, as I have said, as soon as that water passes those piers it begins to be retarded and checks very materially.

I can point out another illustration of that. The explanation that has been given as to the St. Lawrence River gaging has been that the reason there is such a difference in the results is on account of a change in velocity in the section, which must have occurred within a very few feet, undoubtedly less than we are considering here; and that seems to be the only explanation that has been given by which anybody is able to explain the difference between the later and the former gagings.

Now if such a condition could occur at the Three Point Section on the St. Lawrence to the extent that it is alleged to have occurred there, or appears to have occurred there, accepting that as the explanation for the difference in discharge shown by the different gagings, it would mean that there must be a

very much greater effect where the change is as abrupt as it is at the International Bridge.

Q. Do you accept that explanation of the St. Lawrence River yourself, or are you simply relying upon what other people state?

A. I know nothing about it.

Q. What is your opinion in regard to it?

A. I should want considerably more information than I have before I express an opinion.

Q. Then arguing from that to the International Bridge, you are not expressing your own opinion as to the actual fact at the International Bridge, but that is based upon the assumptions of other people which you do not accept of?

A. In speaking of the International Bridge, I am basing my opinion on my own observations of the effects of such disturbances upon flowing water, and just as I stated that the velocity is checked very appreciably where it passes by the edge of a square contraction of a submerged orifice.

I simply conceive of the St. Lawrence as a corroboration of that condition, if we are to accept as correct the judgment of the gentlemen in the Lake Survey who have given more study and brought more experience to the consideration of the question.

Q. You say "if we accept it." Do you accept it? In other words do you regard it as a corroboration?

A. Oh, I would take it simply for what it is worth.

Q. What is it worth?

A. A number of experts, who are supposed to be the most expert in the measuring of rivers, those who have given years of study to it, who have been brought up in it and have done practically all the good work that ever was done give that as an explanation.

Those of us who have studied water under other conditions where we have been able to weigh the volumes that were passing, where we have been able to measure it over weirs, measure with different devices, floats, pitot tubes, current meters and so on, would probably want more evidence on the subject—would certainly want more evidence on the subject than has been presented in this case.

But the fact remains that there is a discrepancy between two measurements alleged to have been made, two sets of measurements alleged to have been made at the same place by equally competent observers, and in going through the various causes for the difference, it has been clearly stated

that one thing and another thing failed to explain it, and the only explanation that has been offered is this one of a change of velocity through the section and that in one case the meter had drifted into a different position from that which it occupied in another.

Mr. Adcock: Q. That was Mr. Richmond who made that statement.

A. That was Mr. Richmond's explanation, and it was repeated by Mr. Shenehon.

Mr. Hopkins: Q. When you say "we should like more information," you mean you personally?

A. I mean myself personally. I used the editorial "we" in this case.

Q. Then do you not consider that these engineers of whom you have just spoken are entitled to some consideration for their work in the Niagara River?

A. I think they are. I think they have done very well with a difficult problem. I have said that many times.

Q. That question of the difficulty there and the change of the size of the section, or the place of the meter during the measurement, does not occur at the Open Section, does it?

A. No, I would not expect a variation of position of the meter at the Open Section would have any marked effect.

Q. Do you think it had any effect in what we call the Split Section?

A. I should not think so. Still I might say this in regard to the Open Section, that if it had an effect in the St. Lawrence, I would think it might have an effect in the Open Section.

Q. But you do not attempt to say one way or the other whether it had any effect at the St. Lawrence?

A. I do not—well, I will say I think it might have had some effect.

Q. So that you are not giving your own personal opinion, but simply arguing the case?

A. I am simply comparing such information as I have.

Mr. Adcock: Q. And giving your reasons?

A. Giving my reasons.

Q. As an expert?

A. For the notions and views that I hold, the opinions that I have. I think all the testimony we give in these scientific matters is based upon something outside of the specific matter which is included in the question. We base our judgments upon what we have done; what we know other people

have done; what we have thought about what we have done; what other people have thought about what we have done and what other people have thought about what they have done and what we have thought about what other people have done. We put this all together in a sort of melting pot.

Mr. Hopkins: Q. Now Mr. Williams, if the B meter was not in fact below the piers and the caisson and you determine your coefficient at your index point, does it make any difference whether the index point is below the bridge piers or not?

A. It would not, if you did not correct the indication of the B meter to correspond with that of the A meter at the index point, which is my understanding of what was done.

Q. But if that correction was not made, then it would not make any difference?

A. No, on the assumption that the A meter was between the piers.

Q. The B meter was between the piers?

A. The B meter was at the piers, if the velocities were not corrected to the velocity at the index point as indicated by the A meter, then of course your coefficient would be entirely correct within the degree of precision we are considering the observations in general. There would be no special error introduced due to the fact that the index point was not between the piers.

Q. Referring to your answer in regard to the pressure on 1/4 inch and 3/8 inch cable at velocities 5, 6 and 7, does it not show that the resistance on the 1/4 inch cable is 2/3 of that of the 3/8 inch cable. Take the 5-foot velocity.

A. Starting at the 7-foot and running back, the observed resistance of the 3/8 cable at a 7-foot velocity is 19.2. Subtracting 1/3 from it gives 12.8 pounds for a 1/4 inch cable, and the observation was 13.3.

Q. What percentage of difference?

A. About four per cent.

Q. Then the others?

A. At 6 foot velocity the observed resistance of the 3/8 cable is 15 pounds. Subtracting 1/3 gives 10 pounds as the resistance on the 1/4 inch cable, and the observed resistance is 10.3 pounds.

Q. About 3 per cent.?

A. That is about 3 per cent. For the 5-foot velocity, the resistance of the 3/8 cable is 11.2 pounds. Subtracting 1/3 gives 7.47 or 7-1/2, which latter figure coincides with the experimental result for the 1/4 inch cable.

Q. Now taking into consideration the possible errors of observation, do you think that it is poor physics to make an estimate of 2/3?

A. Let me see what you are referring to there.

Q. I understood you to say in your direct examination that estimating a 1/4 inch cable with that weight would give 2/3 resistance of the 3/8 inch cable did not conform to your idea of physics?

A. Let me see if I said just that.

Q. Do I quote you correctly?

A. I am a little in doubt as to just what I did say. I do not think I made the statement that you attribute to me.

Q. The statement was this, (at page 3359 of the typewritten record, printed record, 3526). "Upon the conclusion of Mr. Shenehon's cross-examination, I was impressed with the fact that the conclusions elicited in the cross-examination were not strictly in accordance with the laws of physics as I understood them, and I immediately arranged to have a series of experiments made in the naval tank of the University of Michigan, and so on?"

A. There was nothing said about 3/8 and 1/4 inch cable.

Q. Just what were you referring to there, Mr. Williams?

A. I was referring to the computed drift of the meter in that and in part to the assumption that has been suggested that the resistance of a 1/4 inch cable would be 2/3 that of a 3/8 inch.

Q. On page 3362, you say in your opinion the 1/4 inch cable would drift further down than the 3/8 cable. That would not be so if you put the same weight, say of 140 pounds, on each of them, would it?

A. Where do I say that?

Q. Page 3362, in the last complete paragraph, last sentence in it?

A. That says nothing about a weight on the cable. That statement is entirely correct as made here.

Mr. Hopkins: Read my question.

(Question read.)

A. No, it would not. You may strike out my previous answer; I did not understand the question.

Q. And the question of a cable drifting down-stream without weights on it was not involved in these experiments in the Niagara River, was it?

A. It is to a certain extent. It involves the resistance of the cable itself; in arriving at a theoretical discussion of this thing,

without basing it on experiments, you have to consider the weight of the cable.

Q. But with that size cable and the size weights that were used, the weight of the cable was not a very important factor; that is the difference in the weight of the cable between the 1/4 inch and the 3/8 inch?

A. It is quite an important factor as shown by the difference in amounts of drift that we get with the cables as compared with those which hitherto have been assumed in the placing of the meters at the bridge.

Q. But you get a greater amount of drift on the 3/8 cable with the weight on it, than you do on the 1/4 inch with the weight do you not?

A. Yes, I think so.

Q. And your tests check Mr. Shenehon's rather closely as to the amount of drift from the surface of the water?

A. Not according to his testimony. He testified that his drift was 12-1/2 feet and we made it 26.

Q. 26 feet from where?

A. Wait a minute, let us get that testimony straight on that, because as I understood the testimony—

Q. When the cable is held at the surface of the water, and taking a depth of 50 feet, how far down stream below that point at the surface where the cable is held does the meter drift?

A. About 13 feet.

Q. When you gave a drift of 26 feet, what do you mean by that, exactly?

A. I mean the drift of the meter when it was not restrained.

Q. That is from the top of the bridge?

A. Yes.

Q. How high above the water is that?

A. If you figure from the chord, it would be—let us assume it from the support of the meter; it is a distance of about 29 feet, leaving out the effect of that drift.

Q. You consider, do you, that a test in deeper water under the actual conditions, everything else being equal, would be better than the test as made in the naval tank?

A. I would consider that a test with a dynamometer under the actual conditions of flowing water would be more reliable than the test of dragging the meter through still water, being the same proposition of course that we have in rating the meter.

Q. Also would not the greater depth in the one case give you a little better results because of the fact that any error in observation would be accentuated to take a small range and apply it to a bigger one?

A. You mean now as to the resistance of the meter or the resistance of the cable?

Q. Using six feet of cable rather than ten feet or twenty?

A. I would prefer to use ten or twenty if I could measure the pull on it with the same degree of accuracy that I could measure the 6-foot cable.

Q. You did not know as a matter of fact did you that Mr. Shenehon used a dynamometer at the International Bridge of the Niagara River to determine this question?

A. I did not. There is nothing in his testimony to indicate it.

Mr. Hopkins: That is all.

Mr. Adcock: I offer in evidence letter from B. A. Eckhart, President of the Sanitary District of Chicago to Hon. Daniel S. Lamont, Secretary of War, dated June 16, 1896, with reference to the improvement of the Chicago River.

Also a letter from Major W. L. Marshall, Corps Engineer, to Brig. Gen. William P. Craighill, Chief of Engineers United States Army, dated Chicago, June 24, 1896.

A letter or permit addressed to B. A. Eckhart, President Sanitary District of Chicago, signed by Joseph B. Doe, Acting Secretary of War, dated July 3, 1896.

Also a letter addressed to Hon. Russell A. Alger, Secretary of War, signed by Thomas Kelly, President of the Sanitary District of Chicago, dated October 28, 1897.

Also a paper entitled "First Indorsement" to the above mentioned letter; United States Engineer Office, Chicago, Ill., October 29, 1897. Signed W. L. Marshall, Major Corps Engineers.

Permit dated November 16, 1897, to the Sanitary District of Chicago, signed R. A. Alger, Secretary of War.

A letter dated November 12, 1898, addressed to the Honorable Russell A. Alger, Secretary of War, signed by William Boldenweck, President.

Also the notation at the bottom of the letter as follows: "Through Maj. W. L. Marshall, Corps of Engineers, United States Army, 1637 Indiana avenue, Chicago, Ill."

Also a letter entitled "First Indorsement, U. S. Engineer's Office, Chicago, Illinois, November 15, 1898," and signed W. L. Marshall, Major Corps of Engineers.

Also a permit dated November 30, 1898; to the Sanitary District of Chicago, signed R. A. Alger, Secretary of War.

Letter dated December 16, 1898, addressed to the Hon. Russell A. Alger, Secretary of War, signed William Boldenweck, President Sanitary District of Chicago.

First indorsement to that letter entitled "First Indorsement United States Engineer's Office, Chicago, Illinois, December 21, 1898, signed W. L. Marshall, Maj. Corps Engineers."

Permit dated January 13, 1899, to the Sanitary District of Chicago, signed R. A. Alger, Secretary of War.

Letter dated April 26, 1899, from William Boldenweck, President Sanitary District of Chicago, addressed to Hon. Russell A. Alger, Secretary of War. Also paper entitled "First Indorsement United States Engineer Office, Chicago, Ill., May 1, 1899," signed W. L. Marshall, Maj. Corps of Engineers.

Permit dated May 12, 1899, to the Sanitary District of Chicago, signed by G. D. Meiklejohn, Acting Secretary of War.

Letter from William Boldenweck, President Sanitary District of Chicago to the Hon. Russell A. Alger, Secretary of War, dated February 27, 1899.

Paper entitled "First Indorsement U. S. Engineer Office, Chicago, Ill., March 1, 1899," signed W. L. Marshall, Maj. Corps of Engineers.

A permit dated March 10, 1899, to the Sanitary District of Chicago signed by R. A. Alger, Secretary of War.

A letter dated April 24, 1899, to Brig. Gen. John M. Wilson, Chief of Engineers, U. S. A., signed by W. L. Marshall, Maj. Corps of Engineers, U. S. A.

It is understood that any objection as to materiality and relevancy may be raised at the hearing.

Mr. Hopkins: Q. I also reserve objection to the competency especially as to those letters written by the Sanitary District of Chicago or any of its officers or officials, on the ground that they are self serving; I object also to letters of various engineering officers of the United States Army as being incompetent. There is no objection on the ground that they are not true copies of letters that were in fact written.

Mr. Adcock: No objection on account of their not being the best evidence.

Mr. Hopkins: No, no objection as between the copy and the original. I do object to their competency otherwise as

well as on the ground of materiality, as stated by Mr. Adcock.

Mr. Adcock: These letters to which I have just referred are as follows:

"THE SANITARY DISTRICT OF CHICAGO.
Chicago, June 16, 1896.

To the Honorable Daniel S. Lamont,
Secretary of War,
Washington, D. C.

Dear Sir:

The work of the Sanitary District of Chicago has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey street, Chicago, to Lockport in Will County, twenty-eight miles distant.

Our connection with Lake Michigan must be through the Chicago River with the West Fork of the South Branch of which we make a junction at Robey street. We send herewith a map showing in a general way our plans for improving the Chicago River by widening and deepening at the points indicated thereon by red hatchings and by figures which refer to explanations given in the legend on the map. It is desired to so correct and regularize the cross section of the river as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of 1-1/4 miles per hour. The cross section necessary to accomplish this can be obtained throughout the greater part of the distance between Monroe street and Robey street by dredging the river to a depth of 20 feet at mid-stream with 12 feet at dock lines, and a uniform slope away from the docks of 1 foot in 5 so that the full depth would be reached 40 feet from the dock lines; but there are places so narrow that this cross section can only be obtained by widening the river; and again the depth to be obtained in the vicinity of Van Buren street is limited by the height of the crown of the tunnel. To obviate this difficulty it is proposed to secure the requisite cross section by constructing a by-pass to the west of the bridges at Adams, Jackson and Van Buren streets as indicated. We ask your permission to proceed with the work upon the lines indicated and so far as is consistent with propriety the co-operation of the United States Engineering Department.

Awaiting your favorable reply and holding ourselves ready

to respond to any call from you for fuller information as to our plans, I am,

Yours respectfully,

B. A. ECKHART,
President."

"Subject: Application of Trustees Sanitary District, Chicago.

"UNITED STATES ENGINEER OFFICE.
1537 Indiana avenue, P. O. Drawer 132.
Chicago, Ill., June 24, 1896.

Brig. Gen. Wm. P. Craighill,
Chief of Engineers, U. S. A.,
Washington, D. C.

General:

I have the honor to report upon the application of Mr. B. A. Eckhart, President Board of Trustees, Sanitary District of Chicago, for the authority of the Secretary of War to make certain changes in the capacity of the channel of the Chicago River for drainage purposes.

As far as the work itself is concerned there can be no objection to it, as in every case the navigable channel of Chicago River will be improved, and at this stage I am unable to do otherwise than to recommend the granting of the authority sought.

The question that must come up later for the action of the War Department, to-wit: Whether the improved channel of Chicago River will be sufficient to carry 300,000 cubic feet of water per minute without lessening or destroying the navigability of Chicago River, or whether the City of Chicago will be allowed by the United States and Great Britian to take any water at all from the Great Lakes, with the inevitable result of lowering their levels is not now under investigation, and is one that will not probably be settled or decided by executive officers. It is or may rather be considered an international question.

For the present I have to respectfully recommend that the necessary authority be granted as requested for the general, under the conditions:

(1) That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each by-pass and each new dock or wharf, proposed to be built, in order that the Secretary of War, under the law, may act intelligently in each case.

(2) That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submitted for consideration.

(3) That it will not cover obstructions to navigation by reason of this work while in progress, or when completed.

(4) That the United States shall not be put to expense by reason of this work.

(5) That this authority will expire by limitation in two years from date, unless extended.

Very respectfully,
Your obedient servant,
W. L. MARSHALL,
Maj. Corps of Engineers.

Subject: Improvement of Chicago River.

WAR DEPARTMENT.
Washington.

July 3, 1896.

Sir:

I have the honor to acknowledge receipt of your letter of the 16th ultimo, requesting permission to make certain changes in the capacity of the channel of the Chicago River, for drainage purposes, at points indicated on the map accompanying the application, and in reply beg to say that upon investigation it is found that the permission requested can be granted upon the following conditions:

1. That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each by-pass, and each new dock or wharf, proposed to be built, in order that the Secretary of War may act intelligently in each case.

2. That the authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.

3. That it will not cover obstructions to navigation, by reason of this work while in progress, or when completed.

4. That the United States shall not be put to expense by reason of this work.

5. That this authority will expire by limitation in two years from date unless extended.

Very respectfully,
JOSEPH B. DOE,
Acting Secretary of War.

B. A. Eckhart, Esq.,
President The Sanitary District of Chicago,
Rialto Building,
Chicago, Ill.

THE SANITARY DISTR'CT OF CHICAGO.
Chicago, October 28, 1897.

To the Hon. Russell A. Alger,
Secretary of War,
Washington, D. C.

Sir:

I have the honor of transmitting to you through Maj. W. L. Marshall, Corps U. S. Engineers, plats showing the proposed widening of the Chicago River between Quincy and Harrison streets, to conform to the plans of this District for securing an adequate flow of water through the said stream. Our general plans have been heretofore submitted to the War Department and in the communication under date of July 3rd, 1896, signed by the then acting Secretary of War, Joseph B. Doe, have received a qualified approval subject to the general requirement that plans for each separate division of the work shall be submitted for specific approval. We respectfully ask your approval of the plans now transmitted.

Very respectfully,

THOMAS KELLY,
President.

1st Indorsement,

U. S. Engineer Office,
Chicago, Ills., October 29, 1897.

Respectfully forwarded to the Chief of Engineers U. S. A. The works indicated are by-passes and docks, indicated on the general plans conditionally approved by the Acting Secretary of War, July 3rd, 1896. (E. D. File No. 15715/5).

As these works make possible a material improvement in the capacity of Chicago River for navigation in the vicinity of Adams and Van Buren streets, I respectfully recommend that the necessary authority to do the work be granted by the Secretary of War, subject to all the conditions attached to the original authority dated July 3, 1896.

W. L. MARSHALL,
Maj. Corps Engrs.

Form No. 5.

Whereas, by Section 3 of the Act of Congress, approved July 13, 1892, entitled "An Act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors and for other purposes," it is provided that, without the premission of the Secretary of War, it shall not be lawful to build any wharf, pier, dolphin, boom, dam, weir, breakwater, bulkhead, jetty or structure of any kind outside established harbor lines or where no harbor lines are or may be established in any port, homestead, haven, harbor, navigable river, or other waters of the United States, in such manner as shall obstruct or impair navigation, commerce, or anchorage of said waters; or to excavate or fill, or in any maner to alter or modify the course, location, condition, or capacity of any port, roadstead, haven, harbor of refuge, or inclosure within the limits of any breakwater of the channel of any navigable water of the United States, unless approved and authorized by the Secretary of War;

And whereas, the Sanitary District of Chicago has submitted to the Secretary of War for his approval the attached plans for the widening of the Chicago River between Quincy and Harrison streets of said city, by the construction of bypasses and docks;

Now, Therefore, This is to certify that the Secretary of War hereby approves and authorizes the work shown on said plans upon the following conditions:

1. That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each bypass, and each new dock or wharf, proposed to be built, in order that the Secretary of War may act intelligently in each case.

2. That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.

3. That it will not cover obstructions to navigation, by reason of this work while in progress, or when completed.

4. That the United States shall not be put to expense by reason of this work.

5. That this authority shall expire by limitation in two years from date unless extended.

Witness my hand this 16th day of November, 1897, R. A. Alger, Secretary of War.

(War Office Seal.)

THE SANITARY DISTRICT OF CHICAGO.
Chicago, November 12, 1898.

Hon. Russell A. Alger,
Secretary of War,
(Washington, D. C.

Dear Sir:

We respectfully ask permission to construct a cofferdam around the east side of center pier of Adams street bridge in Chicago River, said cofferdam to extend 3 feet outside of protection of bridge and to be constructed of piles and timber to be filled with clay. We would also request permission to deposit clay outside of the cofferdam running north and south from center pier and extending into the bank. All material of cofferdam and all clay deposited to be removed at the expiration of four months, or sooner if in your judgment the demands of navigation require it.

Very respectfully submitted,
WILLIAM BOLDENWECK,
President.

Through Major W. L. Marshall,
Corps of Engineers U. S. A.,
1637 Indiana avenue,
Chicago, Ill.

1st Indorsement.

U. S. Engineers Office,
Chicago, Ill., November 15, 1898.

Respectfully forwarded to the Chief of Engineers, U. S. A.

This work is necessary to enable the trustees of the Sanitary District to avail themselves of the authority heretofore granted by the Secretary of War to construct its by-pass at Adams street, and in my opinion may be done without unreasonable obstruction to navigation. I therefore respectfully recommend that the authority asked for be granted by the Secretary of War under the following conditions, viz.:

1. That a practicable channel for the passage of commercial vessels at this point be maintained by the authorities of the Sanitary District during construction.

2. That all debris and material attendant upon this construction be removed from the channel prior to May 1st, 1899, at which date this authority to expire by limitation.

W. L. MARSHALL,
Maj. Corps of Engrs.

Form No. 5.

Whereas, by Section 3 of an Act of Congress approved July 13, 1892, entitled "An Act making appropriations for the construction, repair and preservation of certain public works on rivers and harbors, and for other purposes," it is provided that, without the permission of the Secretary of War, it shall not be lawful to build any wharf, pier, dolphin, boom, dam, weir, breakwater, bulkhead, jetty or structure of any kind outside of established harbor lines, or where no harbor lines are or may be established, in any port, roadstead, haven, harbor, navigable river, or other waters of the United States, in such maner as shall obstruct or impair navigation, commerce or anchorage of said waters; or to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of any port, roadstead, haven, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless approved and authorized by the Secretary of War;

And whereas, the Board of Trustees of the Sanitary District of Chicago, Illinois, has applied to the Secretary of War for permission to construct a temporary cofferdam around the east side of the center pier of Adams street bridge in Chicago River, at Chicago, Illinois, as shown on the attached blue print, and to deposit clay outside of the cofferdam running north and south from center pier and extending into the bank;

Now, Therefore, This is to certify that the Secretary of War hereby gives to said Board of Trustees permission to construct a temporary cofferdam around the east side of the center pier of Adams street bridge in Chicago River, at said place, as shown on said blueprint; and to deposit clay outside the cofferdam running north and south from center pier and extending into the bank, upon the following conditions:

1. That a practical channel for the passage of commercial vessels at this point shall be maintained by said Board of Trustees during construction.

2. That all debris and material attendant upon this construction shall be removed from the channel prior to May 1, 1899, at which date this authority shall expire by limitation.

3. That the work herein permitted to be done shall be sub-

ject to the supervision and approval of the Engineer Officer of the United States Army in charge of the locality.

Witness my hand this 30th day of November, 1898.

R. A. ALGER,
Secretary of War.

(War Office Seal.)

THE SANITARY DISTRICT OF CHICAGO.
Chicago, December 16, 1898.

Hon. Russell A. Alger,
Secretary of War,
Washington, D. C.

Dear Sir:

In carrying out the plans of this District for work in the Chicago River we have arranged to remove the bridges now existing at the Taylor street crossing and at the crossing of the Chicago Terminal Transfer Railway, just south of Taylor street, and to replace them with bridges having no center pier, of the bascule type. By carrying out this plan navigation is greatly benefited at the same time that the flow of water which we require is provided for. I transmit herewith plats in triplicate showing what we wish to do at the railroad crossing, which, in brief is to remove the existing swing bridge downstream far enough to admit of building the new bridge. The time during which the old bridge would have to be operated on the site to which we propose removing it will be about one year. We propose to leave one channel, on the east side open for navigation with a clearance of not less than forty-eight (48) feet at right angles to the line of navigation. Will you grant us a permit covering the conditions outlined so that we may proceed to do the work?

Respectfully submitted,
WILLIAM BOLDENWECK,
President.

1st Indorsement.

U. S. Engineers Office.
Chicago, Ill., December 21, 1898.

Respectfully forwarded to the Chief of Engineers, U. S. A.

The existing bridge is one of the worst obstructions in the Chicago River, which will be removed on the completion of the proposed bridge. The latter is designed to meet the views of the officer in charge of this District with reference

to obstructive bridges across Chicago River as expressed in the annual report of the Chief of Engineers for 1896, inasmuch as the design proposes a clear central channel 120 ft. wide measured perpendicularly to the axis of the river. It is the largest plan of the type yet proposed (about 270 ft.).

I respectfully recommend that the authority be granted to construct the temporary and new bridges under the following conditions, viz.:

1. The new bridge shall have a clear channel span of 120 feet, measured perpendicularly to the axis of the channel.

2. A channel of 17 feet in depth and 48 feet clear width, measured perpendicular to its axis, shall be maintained by the Sanitary District of Chicago during construction of the new bridge, along the eastern bank of the river.

3. The existing and temporary structures with their center pier, protection pier, guide piles, abutments, so far as they project beyond the dock lines and foundations, shall be removed to a depth of twenty (20) feet below Chicago city datum, immediately after the construction of the proposed bridge.

4. The channel of Chicago River throughout the length of the present protection pier, shall be dredged by the Sanitary District for the full width of 120 feet, to a depth of 17 feet below Chicago city datum immediately after the removal of the existing and temporary bridges.

5. This authority to lapse two years after its date, if not sooner availed of.

W. L. MARSHALL,
Maj. Corps Engrs.

Whereas, by section 3 of an act of Congress, approved July 13, 1892, entitled, "An Act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes," it is declared that it shall not be lawful to construct by authority of the legislative act of a state, any bridge, not already authorized by law, over a navigable water of the United States wholly within the limits of such state, without the approval by the Secretary of War of the location and plans of such bridge;

And whereas, the Sanitary District of Chicago, having authority under an act of the legislature of the State of Illinois, to replace the bridge at the crossing of the Chicago Terminal Transfer Railway, over the South Branch of the Chicago River, just south of Taylor street, Chicago, Illinois, with a

bridge of bascule type, without pier in the river; and also to move the existing swing bridge down stream to a new site, to be operated until the completion of the new bridge, or about one year; and has submitted a map showing the plans and locations of such proposed permanent and temporary bridges, as indicated, respectively, in red and green thereon;

Now, Therefore, This is to certify that the locations and plans of said bridges, as shown on said map, which is hereto attached, are hereby approved by the Secretary of War, subject to the following conditions:

1. That the new bridge shall have a clear channel span of One Hundred and twenty feet, measured perpendicular to the axis of the channel.

2. That a channel of 17 feet in depth and 48 feet clear width, measured perpendicular to its axis, shall be maintained by the Sanitary District of Chicago during construction of the new bridge, along the eastern bank of the river.

3. That the existing and temporary structures with their center pier, foundation pier, guide piles, abutments, as far as they project beyond the dock lines, and foundations shall he removed to a depth of 20 feet below Chicago city datum immediately after the construction of the proposed bridge.

4. That the channel of Chicago River throughout the length of the present protection pier, shall be dredged by the Sanitary District for the full width of one hundred and twenty feet to a depth of 17 feet below Chicago city datum immediately after the removal of the existing and temporary bridges.

5. That the authority herein given shall lapse two years after the date hereof, if not sooner availed of.

6. That the work herein permitted to be done shall be subject to the supervision and approval of the Engineer Officer of the United States Army in charge of the locality.

Witness my hand this 13th day of January, 1899.

R. A. Alger,
Secretary of War.

(War Office Seal.)

THE SANITARY DISTRICT OF CHICAGO.
Chicago, April 26, 1899.

Hon. Russell A. Alger,
Secretary of War,
Washington, D. C.

Dear Sir:

We respectfully ask permission to construct a cofferdam along the west side of the Chicago River, as shown on the accompanying drawings. The cofferdam is to be constructed of piles and timber, and filled with clay. All material of the cofferdam to be removed at the completion of the improvements, or sooner, if, in your opinion, the demands of navigation require it.

Very respectfully submitted,
WILLIAM BOLDENWECK,
President.

1st Indorsement.

U. S. Engineer Office.
Chicago, Ill., May 1, 1899.

Respectfully forwarded to the Chief of Engineers, U. S. A.

This cofferdam is necessary to enable the trustees of the Sanitary District to construct their by-pass on the west side of Chicago River between Adams and Van Buren streets, heretofore authorized by the Secretary of War.

I respectfully recommend that the authority asked be granted on conditions that:

1st. A practicable passageway for vessels of the largest class navigating Chicago River shall at all times during the continuance of this cofferdam be kept open and of dimensions shown on the map, and of the depth now available.

2nd. That immediately upon completion of the by-pass the cofferdam, and all debris attending its construction and use, shall be removed from the channel to a depth of 17 feet below Chicago city datum.

3rd. That this authority shall lapse and become void by limitation two years from this date, if not availed of before the expiration of that time.

W. L. MARSHALL,
Maj. Corps Engrs.

Whereas, by Section 10 of an Act of Congress, approved March 3, 1899, entitled "An Act making appropriation for the construction, repair and preservation of certain public works on rivers and harbors, and for other purpose," it is pro-

vided that it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill, or in any manner, alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same;

And whereas, the Sanitary District of Chicago has applied to the Secretary of War for permission to construct a temporary cofferdam along the west side of Chicago River, at Chicago, Illinois, as shown on the attached blueprint; which work has been recommended by the Chief of Engineers, subject to the conditions hereinafter set forth;

Now, Therefore, This is to certify that the Secretary of War hereby gives unto said Sanitary District of Chicago permission to construct a temporary cofferdam along the west side of the Chicago River, at said place, as shown on said blueprint, subject to the following conditions:

1. That a practicable passageway for vessels of the largest class navigating Chicago River shall be at all times during the continuance of this cofferdam, kept open, and of dimensions shown on said blueprint, and of the depth now available.

2. That immediately upon completion of the by-pass the cofferdam and all debris attending its construction and use shall be removed from the channel to a depth of 17 feet below Chicago city datum.

3. That this authority shall lapse and become void by limitation two years from its date, if not availed of before the expiration of that time.

4. That the work herein permitted to be done shall be subject to the supervision and approval of the Engineer Officer of the United States Army in charge of the locality.

Witness my hand this 12th day of May, 1899.

G. D. MEIKLEJOHN,
Acting Secretary of War.

(War Office Seal.)

THE SANITARY DISTRICT OF CHICAGO.
Chicago, Feb. 27, 1899.

Hon. Russell A. Alger,
Secretary of War,
U. S. A.,
Washington, D. C.

Sir:

On December 12th I wrote you in relation to the proposed substitution of bridges of the bascule type for the center pier swing bridges now in use at Taylor street, and by the railroad company crossing the Chicago River just south of Taylor street, asking at that time for a permit of the work necessary to be done at the Railroad Bridge, which permit you kindly granted under date of January 13, 1899. I now ask that you issue a corresponding permit for the work to be done at Taylor street in accordance with the plans submitted herewith, showing the location of the abutments, protection pier, and the width and alignment of channel which will result from this construction.

Very respectfully,
WILLIAM BOLDENWECK,
President.

1st Indorsement.

U. S. Engineer Office.
Chicago, Ill., March 1, 1899.

Respectfully forwarded to the Chief of Engineers U. S. A.

The proposed bridge will much improve navigable conditions at Taylor street by the substitution of a central channel draw span 120 feet clear width, for two 45 feet draw spans, but the new bridge cannot be constructed before the existing structure is entirely removed, without interrupting navigation, on account of the local conditions here, that are shown on the maps submitted.

I recommend that authority be granted for the construction of the new bridge as proposed, provided that the following conditions be accepted by the Officials of the Sanitary District of Chicago.

1st. The existing bridge at Taylor street, including its center and protection piers and foundations shall be entirely removed, to a depth of 22 feet below Chicago city datum, before any work of construction whatever is done under the new designs, and the channel put in navigable condition and so maintained during construction.

2nd. That upon the completion of the new bridge the officials of the Sanitary District of Chicago shall at once cause the new channel for its full width and for 150 feet on each side of the structure to be dredged to the full depth established in the Chicago River by authority of law.

3rd. That this authority will lapse and become void if not availed of within two years from its date.

W. L. MARSHALL,
Major Corps of Engrs.

Whereas, by Section 9 of an Act of Congress, approved March 3, 1899, entitled "An Act making appropriations for the construction, repair and preservation of certain public works on rivers and harbors, and for other purposes," it is provided that bridges, dams, dikes, or causeways may be built under authority of the legislature of a state, across rivers and other waterways, the navigable portions of which lie wholly within the limits of a single state, provided the location and plans thereof are submitted to and approved by the Chief of Engineers and by the Secretary of War before construction is commenced;

And whereas, the Sanitary District of Chicago, having authority under an Act of the legislature of the State of Illinois to replace the bridge across the South Branch of the Chicago River, at Taylor street, Chicago, Illinois, with a bridge of the bascule type, without pier in the river, has submitted a map of the location and plans of the same, which have been approved by the Chief of Engineers;

Now, Therefore, this is to certify that the map of location and plans of said bridge, which are hereto attached, are hereby approved by the Secretary of War, subject to the following conditions:

1. That the existing bridge at Taylor street, including its center and protection piers and foundations shall be entirely removed, to a depth of 22 feet below Chicago city datum, before any work of construction whatever is done under the new designs, and the channel put in navigable condition and so maintained during construction.

2. That upon the completion of the new bridge the officials of the Sanitary District of Chicago shall at once cause the new channel for its full width and for 150 feet on each side of the structure, to be dredged to the full depth established in the Chicago River by authority of law.

3. That this authority shall lapse and become void if not availed of within two years from its date.

4. That the Engineer Officer of the United States Army, in charge of the District within which the bridge is to be built, may supervise its construction, in order that said plans shall be complied with.

Witness my hand this 10th day of March, 1899.

R. A. ALGER,
Secretary of War.

(War Office Seal.)

UNITED STATES ENGINEER OFFICE,
#1637 Indiana Ave., Chicago, Ill.
April 24, 1899.

Brig. Gen. John M. Wilson,
Chief of Engineers, U. S. A.,
Washington, D. C.

General:

I have the honor to report as follows on the application of the trustees of the Sanitary District of Chicago for authority to open their drainage canal. It is a strange fact that this city has expended, or will expend, over $30,000,000 with the intention of diverting an apparently unlimited amount of water from the Great Lakes to the Mississippi drainage area for sanitary purposes without finding out whether such diversion would be allowed by the great interests of the United States and the Colonies of Great Britain along the chain of Great Lakes in the navigation of the rivers and harbors of the Great Lakes. Now, they ask the authority of an executive officer of the United States to open a channel that will to some unknown extent, lower the levels of all the Great Lakes below Lake Superior and of their outlets, introduce a current also unknown and not to be ascertained otherwise than by actual experiment, in Chicago River, the most important navigable river of its length on the Globe, but which is already obstructed by bridges, masses of masonry and bends, and of difficult navigation at best.

The possible effects of this diversion are not known further than that to some unknown degree they will be injurious. Whether the amount of this injury will be so small as to be accepted by the interests affected, in view of the manifest advantages to and apparent necessities of their neighbors, cannot be determined by other than the interests themselves.

It is clear to me that I am not competent to make a recommendation as to what should ultimately and definitely be done.

The matter of what effect the opening of this channel would have on the levels of the Great Lakes has been heretofore submitted to a Board of Engineers. The Board reported that the Great Lakes would be lowered, but that there was not sufficient data to determine the exact effects of the proposed discharge, and recommend extended investigations, which it is believed are being carried on now by the Deep Waterways Commission or Board. They have not reported. In my opinion the abstraction of from 300,000 to 600,000 cubic feet per minute will permanently lower Michigan, Huron and Erie from three to eight inches; not more than eight nor less than three, corresponding to an extreme reduction of from 160 to 466 tons in carrying capacity of the large vessels of the lakes, and that it will take from three to four years for this full effect to be obtained. But the state law is unlimited in its requirements. 20,000 cubic feet per minute must be taken from Lake Michigan for each 100,000 population of the District; already nearly 400,000 cubic feet must be taken, and at the same ratio of increase for a few decades, in a very short time there must be taken 1,000,000 c. ft. per minute under this indefinite law. The amount should be limited and the injurious effect stopped somewhere.

The mean current to be introduced in Chicago River upon the opening of the canal is estimated by the Engineers of the Drainage Board at 1¼ miles per hour, or 110 feet per minute. This is simply an assumption that with such velocity in an unobstructed river, the amount of 300,000 cubic feet per minute can be discharged through Chicago River,—but I have seen this river so jammed with vessels, drawing all the water that is in it,—that by leaping from deck to deck I could cross the river. What the velocity would be in such conditions, with Lake Michigan on one side and a great fall on the other side of such vessels, no one knows. But it is a simple mathematical problem to determine the effect on steel-plate vessels of from 2,000 to 4,000 tons mass drifting upon or striking stone piers with a velocity of near 2 feet a second. They will go to the bottom.

Individually I have to say that I am in entire sympathy with the people in their effort to purify their water supply. I have lost my only son from typhoid fever, produced, I believe from drinking water polluted by defective drainage at Chicago, which this channel will correct. In every proper way I have aided the officers of the Drainage District. I would like further to aid them, but I believe this question

to be entirely out of my sphere, and too great and important for me even to venture an opinion or make a recommendation about. Yet I may venture to suggest that the entire subject be referred to Congress for final solution, and that a conditional permit or authority be granted to the authorities of the Chicago Sanitary District by the War Department, awaiting action by Congress, to open their channel, and under the following conditions:

1st. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

2nd. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River. With 300,000 cubic feet per minute discharge, it will take one year to lower the level of Lakes Michigan and Huron 1/10 of a foot, and several years to reach the maximum permanent effect of this discharge, which will not probably much exceed three inches, so that the main injury to navigation, if any that can be expected before action by Congress, will be in Chicago River, and that can be at once abated.

All the changes made by the Sanitary District of Chicago, taken by themselves, have been such as to increase the navigable capacity of Chicago River. Taken in connection with the current to be introduced I am not able to say that the river will be as navigable as it was before these changes were made. The changes materially lessen the probable injury to navigation of this current, at the points where the changes have been or will be made.

I believe their channel will be entirely under control and that if the discharge be injurious it can be at once and at any time shut off, and it is evident that the War Department should preserve the right to control the current and discharge through the Controlling Works of this channel.

Very respectfully,
Your obedient servant,
W. L. MARSHALL,
Maj. Corps of Engineers, U. S. A."

Recess at 2 o'clock P. M.

Thursday, June 18, 2:30 P. M.

ISHAM RANDOLPH, a witness called in surrebuttal on behalf of the Sanitary District was first duly sworn by the Commissioner and testified as follows:

Direct Examination by Mr. Adcock.

Q. What is your full name?
A. Isham Randolph.
Q. Where do you reside?
A. In the City of Chicago.
Q. What is your business?
A. I am a civil engineer.
Q. Will you state your education and experience as civil engineer?
A. My education was in the school of experience. I began as an axeman in 1868, on the B. & O. Railroad, and since that time I have filled every intermediate position up to Chief Engineer.
Q. You were Chief Engineer of the Sanitary District from about 1893, weren't you?
A. From the 7th of June, 1893, to the 31st of July, 1907.
Q. And since that time until about sometime in December, 1913, you were Consulting Engineer for the Sanitary District?
A. I was Consulting Engineer up to the 1st of January, 1913.
Q. You were a member, weren't you, of a Board of Engineers that had to do with the determination of certain matters with reference to the building of the Panama Canal?
A. Yes, I was a member of the International Board of Engineers that decided the type of the canal. And I may further say in regard to that before you leave it that that Board was divided, eight to five; eight in favor of a sea level canal and five in favor of a lock canal. And I was one of the minority.
Q. What experience have you had as a civil engineer outside of your experience in connection with the Sanitary District of Chicago?
A. I was building railroads for 25 years. I have been Consulting Engineer for the City of Baltimore on track elevation; Consulting Engineer for the City of Toronto on track elevation; Consulting engineer for the City of Toronto on water supply.

I have had a great many minor experiences but those are the principal ones. I was Consulting Engineer for the Queen Victoria and Niagara Falls Power Commission to report to the Government of Ontario on the power possibilities at Niagara.

Q. What experience have you had and what studies have you made with reference to the commerce upon the Great Lakes and the vessels that are used to carry freight of various kinds?

A. Do you want me to go in detail into that?

Q. Just your general experience.

A. My attention was first called to that in Buffalo in 1906, when I was sent there by the Sanitary District to represent them in a hearing before the International Waterways Commission. At that hearing, Mr. Livingstone, President of the Lake Carriers Association, made a statement to the effect that the capacity of the lake carriers was 100 tons per inch. He stated how many there were in the service, and that they earned 50 cents a ton; and that a loss of six inches would cut them down 600 tons to the trip, and he figured up a loss of $2,500,000 per annum; and I did not know any better at that time. I swallowed it. But when I got back here and began to think of it, I did not believe there was any such boat on the lakes as that. I got the Blue Book of American shipping and scheduled all the boats on the lakes and figured up their capacity, and there was nothing in sight that ran over 80 tons and a fraction per inch.

That information I kept read for use, and in January, 1907, Mr. Taft gave a hearing in Washington on this subject, on this lake level subject and it was attended by representatives of the Lake Carriers, and all interests.

I went on in advance of the hearing and through Congressman Mann got a copy of the advance report of the International Waterways Commission. I found that they had embodied in that report Mr. Livingstone's statement without even quotation marks.

When I was called upon to address them, I addressed the Secretary as far as I had my address printed, and then paused. He asked me if I had seen the report of the International Waterways Commission. I told him I had; and I thanked him for asking me the question because it gave me an opportunity to call his attention to the statements made in that report. I then gave the statistics which I had.

The Vice-President of the Lake Carriers Association got up and demanded that I withdraw that statement. I asked

him why I should do that. He said: Because you are a civil engineer and don't know how to figure lake tonnage. I asked him how he figured it and he could not tell me. I wrote out the formula and handed it to General Ernst, who was sitting beside Mr. Taft. He looked it over and said: That is correct, and handed it back to me.

Then Mr. Harvey D. Goulder came around and asked me if I would not withdraw that statement. I asked him why. He said because my sources of information were not correct. I produced the Blue Book and asked if that was correct. He said that was authentic and sat down. The International Waterways Commission withdrew its reference to that matter.

Q. On that subject?

A. Yes.

Mr. Hopkins: I move that the entire answer be stricken out as entirely irrelevant, incompetent and immaterial; has nothing to do with the issues in this case; is hearsay. Any determination that he made in that regard is one thing, but discussions and conversations with various people I submit are incompetent and immaterial.

Mr. Adcock: I understand that the answer is simply with reference to his familiarity with the commerce upon the lakes and the capacity of the vessels.

Q. Do you know whether any Congressional Committee visited and inspected the works of the Sanitary District prior to the opening of the channel?

A. Yes, sir, they did.

Q. What committee was that?

A. That was a committee on Rivers and Harbors. I cannot carry all those dates in my mind, but I have them all here. I can refer to that, if I may.

Q. Yes, you may refer to data to refresh your recollection.

Mr. Hopkins: I move that that answer be stricken out as immaterial.

The Witness: You wish to know the date when they made their trip?

Mr. Adcock: Yes.

A. February 23rd, 1898.

Q. What did they do? How many were present?

A. I can't remember the number that were present, but there was more than a quorum of the Rivers and Harbors Committee. I know that. And Mr. Burton, the Chairman of

the Committee, who is now a Senator, was one of the members.

Q. What did they do while they were here?

Mr. Hopkins: Let it be understood this line of questioning is objected to.

Mr. Adcock: On the ground of relevancy and materiality.

Mr. Hopkins: Yes. And it is incompetent what those people did.

A. They were taken by train to various points along the canal where they could see it, winding up at Lockport.

Q. The channel at that time was practically completed, the main channel?

A. It was then about 95 per cent. completed.

Q. The water had not yet been turned in?

A. No.

Q. Did anyone representing the Sanitary District accompany the Committee?

A. The trustees and myself, and I think the clerk of the Board. I don't remember whether the attorney was along or not; I do not think he was.

Q. Did the Secretary of War at any time visit and inspect the works of the District?

A. Yes, sir, he did.

Q. When was that?

A. That was on the 5th of May, 1898.

Q. That was Secretary of War Russell A. Alger?

A. Russell A. Alger.

Q. Was he accompanied by General John M. Wilson?

A. Yes, sir, he was Chief of Engineers at the time.

Q. He was Chief of Engineers. Who else accompanied the Secretary of War and the Chief of Engineers on this inspection trip, and what did they do?

A. Well, John R. Tanner was of the party, and a majority of the Board of Trustees, and I was with them. They went down by train, stopping at points where they could see the channel to advantage, and getting off and looking at it and ending up at Lockport, where they examined the Bear Trap Dam, then in process of construction. We have pictures of the party at the various points along their journey.

Q. Have you got those pictures with you?

A. No, not with me; I have them in my album.

Q. Did the International Waterways Commission visit the works of the District and make an inspection of them?

A. Yes, sir, they did.

Q. If so when, and what did they do?

A. Do you care about the other visit of General Alger?

Q. Did General Alger inspect the works at another time?

A. He was here on the 24th of June, 1899, and made an examination of the harbor and the river, in company with the Sanitary Trustees and myself.

Q. Was the purpose of the work explained to General Alger and General Wilson?

A. Yes, sir.

Mr. Hopkins: Objected to as hearsay.

Mr. Adcock: Q. Then the International Waterways Commission was here October 16, 1906, were they?

A. Yes, sir.

Q. Was that the full Commission?

A. Yes, sir, full Commission.

Q. Including the Canadian members?

A. Yes, sir.

Q. Did they make an examination?

A. Yes, sir, they did; they went through it.

Q. They went down the channel?

A. They went down the channel in a boat. They examined the harbor and the river and the channel. And their hearing was the next day, on the 17th.

Q. Now as Chief Engineer of the Sanitary District, you had to do with the determination of the volume of flow of water through the channel, did you?

A. Yes, sir.

Q. Did you have anything to do with the so-called project of 1900, for the improvement of the Chicago River, and with the preparation of the plans for that project?

A. It was my project, and the plans were prepared under my direction.

Q. Were those plans submitted to the Secretary of War and Chief of Engineers, and approved by him?

A. Yes, sir.

Q. What did you take into consideration in determining the plans for that improvement?

A. I took into consideration that we wanted to pass through the main river, through the South Branch of the Chicago River as far as the Stock Yards Branch 480,000 cubic feet a minute.

Q. That would be about 8,000 cubic feet per second?

A. 8,000 cubic feet per second. We wanted to take in through the 39th street conduit 2,000 cubic feet per second, 120,000 a minute, making a total of 10,000 cubic feet from the junction of the Stock Yards Branch with the main river.

Q. Did you take into consideration what the mean current would be through the Chicago River and the South Branch and West Fork?

A. I figured it on the basis of a shade under a mile and a quarter an hour, except in bridge openings where it was slightly contracted.

Q. That was the current which the Secretary of War considered proper for navigation purposes was it, at that time?

A. Yes, sir.

Q. Now there were some modifications of the May 8th, 1899, permit, whereby the flow of water was limited. After about 1902, did you as Chief Engineer attempt to keep the flow within the limits of the permit as stated by the Secretary of War?

A. Up to June, 1902, I conformed fairly well to those figures. After that we exceeded them, and paid very little attention to that from that time on.

Q. That is in 1902, improvements were made in the Chicago River so as to create a greater cross-section for the flow of water?

A. In that year we excavated 600,000 cubic yards of earth from the river and we built 4,700 feet of new dock. The narrowest place in the river was beyond 22nd street. It was only 115 feet wide, and we enlarged that to 200 feet; 26 foot, mid-channel depth.

Q. In other words those improvements were such that a current would not be created of more than a mile and a quarter an hour with a flow exceeding the limitations which had been indicated by the Secretary of War?

A. That was true, wherever our channel was completed. There were some few narrow spots where the current still exceeded that.

Q. There were not very many of those places?

A. And not very serious.

Q. Rather immaterial, were they?

A. Yes, sir.

(Answer of the witness read as follows: "That was true where our channel was completed. There were some few narrow spots where the current still exceeded that.")

Q. That is at that time?

A. Yes, sir.

Q. Did you ever, prior to the improvements that were made by the Sanitary District, see boats stuck in the river?

A. Yes, sir, a number of times.

Q. Since that time, since the improvements have been made

by the Sanitary District and the City of Chicago, and since the removal of the tunnels—

A. Since the lowering of the tunnels.

Q. Since the lowering of the tunnels, do you know of or have you seen any boats stuck?

A. Once only. Two boats attempted to pass each other in a narrow draw and got stuck.

Q. That was an old swing bridge opening, was it?

A. Yes, sir.

Q. Do you consider that the conditions of navigation in the Chicago River are better now and with the flow of the Sanitary District through the Chicago River and its branches, than it was before the improvements were made and before the channel was opened?

A. I do, absolutely better.

Q. You have been familiar, have you not, with the Chicago River and navigation on that river for a number of years?

A. For 20 odd years.

Q. You have been on the river frequently?

A. Yes, sir.

Q. Taking the project of 1903 of the United States Government for the improvement of the St. Mary's, St. Clair and Detroit Rivers, do you consider that there would have been very much extra expense entailed by excavating deeper, say 6 inches? That is 6 inches deeper than the excavations that were made?

A. The expense would be very inconsiderable.

Q. What do you consider to be the proper amount of water that there should be under the keel of boats?

A. Well, my ideas on that subject I get from a study of what others have said and written.

Q. Yes?

A. My own experience is that on river steamers in the Mississippi and the Illinois, I can always tell as soon as we strike shallow water, no matter where I am on the boat, by the way the engines labor; feel it at once.

Q. Will you refer to some of the discussions of engineers with reference to that subject?

A. Yes, sir.

Q. Give the data?

A. In the report of the Board of Engineers on Deep Waterways from the Great Lakes to the Atlantic, 1901, page 219, I read:

"The speed attained by a ship in open sea will be reduced to

a marked degree on entering shoal water, even of unlimited width."

You will find that on page 219. On page 220, of the same: "Retardation in shoal water. * * * Observations made recently on the freight steamship Angeline, in the deep water of Lake Huron and the shoal water of Lake St. Clair, indicate that the retardation is about 18 per cent. (note, the Angeline is 414 feet long and 51 feet beam; was built in 1899). The depth under the keel was about 2 feet 10 inches, no allowance being made for settlement of the ship in the water which always occurs when the water is shoal."

The Senator (410 feet by 45 feet) is also cited with a loss of 16 per cent. in Lake St. Clair. This Commission provides for two feet of depth below the keel of vessels for which they designed a channel.

Mr. Hopkins: I want to object to this line of testimony, on the ground that it is immaterial. It is incompetent to put in the opinions of other people in this way. There is no objection, however, to the fact that the witness was reading from a copy and not the original report of the people or of the Board, whichever he is purporting to read.

Mr. Adcock: I understand that it has been the agreement and the practice in the course of taking this testimony to refer to reports of engineer officers and even to reports of various engineers which are authenticated, without making it necessary to produce the persons who gave the opinions in the report.

Mr. Hopkins: I understand that has been the practice, but I do not understand it has been the practice at all that merely because of the fact that some statement is made by some official of the Government or of an association, that it thereby becomes competent.

Mr. Adcock: It is used for what it is worth. The source of the statement is being shown and the witness discussing—

Mr. Hopkins: No objection in those cases that the original is not produced.

Mr. Adcock: There is no objection made on the ground it is hearsay, either; never has been.

The Witness: Shall I proceed?

Mr. Adcock: Yes, go ahead.

The Witness: Kent's Engineers' Pocket Book, 1900 Edition, treats of this subject on page 1007.

"The Medusa, a third class cruiser, length 265 feet, beam 41, draft 16' 6", displacement 2,880. Indicated horse power

for ten knots per hour, 700; for 14 knots per hour, 2,100; for 18 knots per hour, 6,400; for 20 knots per hour, 10,000.

Atlantic passenger steamer 525 feet long 63 feet beam, mean draft on trial 21.3, displacement 11,550 tons: Indicated horse power 10 knots per hour, 2,000; for 14 knots per hour, 4,600; for 18 knots per hour, 10,000; for 20 knots per hour, 14,500.

The Medusa's figures for 20 knots are from the trial in Stokes Bay and show the retarding effect of shallow water. The figures for the other ships for 20 knots are estimated for deep water."

Here we have an example of two vessels, one having a displacement of about 4 times that of the other. The larger requiring in deep water only 40 per cent. more power to give it 20 knots speed than was required to give the smaller vessel the same speed in shallow water.

It is a matter of common observation that the bow of a boat in rapid motion rises above the waist line and the stern settles below it. This settling of the stern is called the "squat." This squat is discussed in House of Representatives document number 1,160, 62nd Congress, third session, issued December 12, 1912. The observations were made by direction of Colonel W. M. Black on the Hudson River. On page 35, this table is printed: Speed eight miles per hour; channel depths 12 to 13 feet; squat 1.4. In depths 13 to 14 feet, squat 1.2; in depths 15 to 16 feet, squat .9 of a foot.

Speed 10 miles per hour, the squat in from 12 to 13 feet of water is 2-1/4 feet; in 13 to 14 feet 1.9 feet; in 15 to 16 feet, 1.4 feet.

In the observed case of the paddle wheel steamer Hendrick Hudson, 400 feet long, 45 feet beam, normal draft 9-1/2 to 10 feet, 22-1/2 miles in 135 feet of water, with squat 0.99 foot. In the same depth, 11-1/2 miles per hour, squat 0.15 foot. In water 14.4 deep, speed 9.14 miles per hour, squat 1 foot. In water practically the same depth, the greatest speed she could make was 9.48 miles.

On pages 34 and 35, Colonel Black says: "It is believed that the minimum clearance allowable for safe navigation in the Hudson River is 2 feet. In Germany, the clearance adopted as safe is 1 meter (39 inches)."

On page 100, and following, formulae, tables, etc., relating to the squat and clearance problems are given.

Captain Marshall states in the report of the Chief of Engineers for 1893, Appendix LL, pages 2798-9, in discussing the clearance over tunnels under the Chicago River: "There

should be at least 2 feet between the bottoms of vessels and the crowns of the tunnels to guard against chance obstructions of small extent lodging temporarily over the ridged crowns."

Q. Is it your opinion that the amount of water that should be under the keel of a boat is a matter of feet rather than inches?

A. Yes.

Q. Now assume that you had two or three feet of water under the keel, and say that the depth was decreased so that you would have six inches left, the effect upon navigation would be, perhaps, in the increased consumption of coal, or loss of speed.

A. Loss of speed and an increased consumption of coal. This one experiment shows here that in shallow water they could not get over a certain speed, no matter what power they applied.

Q. Would that increased consumption of coal, say on a trip from Lake Superior to Cleveland, considering the shallow places in the St. Clair River and Detroit River, amount to anything considerable?

A. I believe it would be negligible. I do not believe it could be computed. It must be borne in mind that through those channels the heavy loads are going with the current, and they come light upstream.

Q. Have you made any investigation to determine the amount of horse power that may be produced in the Des Plaines and Illinois Rivers with a diversion of 10,000, 12,000 and 14,000 cubic feet of water per second from Lake Michigan?

A. Yes, sir, I have.

Q. And this is outside of the power that is already developed by the Sanitary District at Lockport?

A. As Chairman of the Internal Improvement Commission of the state, I planned the waterway and water power development from Lockport to Utica, and I had to figure up those things then.

Q. There is available through the Sanitary District plant with 10,000 cubic feet about 30,000 horse power, is there not, at Lockport?

A. Yes, sir.

Q. How much with 14,000 cubic feet?

A. At Lockport it is 43,000 electrical energy.

Q. You are familiar with the market value per horse power of electrical energy in this vicinity?

A. Yes, sir.

Q. Will you give us the amount of horse power that may be developed in addition to that that is developed by the Sanitary District plant, in the Des Plaines and Illinois Rivers, and the market value of such horse power per year?

A. In the Des Plaines and Illinois Rivers below Lockport, with 10,000 cubic feet flowing, 80,000 net electrical horse power, 80 per cent. efficiency, can be produced. With 12,000 cubic feet per second, 96,000 horse power can be produced. With 14,000 cubic feet per second, 112,000 horse power can be produced.

Q. And including Lockport?

A. Including Lockport, 10,000 cubic feet would produce 110,900 net electrical horse power, 80 per cent. efficiency. 12,000 would produce 132,000 net electrical horse power, 80 per cent., and 14,000 would produce 155,000 net electrical horse power, 80 per cent.

Q. What is the market value of that horse power, of that electrical energy, here at Lockport at the place it is produced?

A. That is easily worth $25 per horse power.

Q. That would make a total of how much?

A. For the 10,000 cubic feet per second, $2,750,000; for the 12,000 cubic feet, $3,300,000; for the 14,000 cubic feet, $3,875,000.

Q. What horse power may be developed with the same volumes of water at Niagara Falls, under the practice there?

A. I have taken the maximum case at Niagara Falls which is the Shellcock Power Company. They have a 200 foot head. The other powers range from 135 to 156 feet head, but the Shellcock is the maximum.

Q. 10,000 cubic feet of the Shellcock power is 181,000 horse power. That sells there at $9.50, and it is worth $1,719,500. 12,000 cubic feet per second at the same point would develop 218,000 horse power, at 80 per cent. efficiency in every case, which is worth $2,071,000. 14,000 cubic feet per second would develop 254,400 horse power, and that is worth $2,416,800.

The raw water is selling in the Illinois Valley for nearly twice as much as the developed power is selling for on the busbar at Niagara.

Q. What is the bottom capacity of all the boats and vessels on the Great Lakes?

A. I get at it from two sources: The Blue Book of American Shipping, and the Statistical Report of Lake Commerce, put out by Lieutenant Colonel Mason M. Patrick.

Q. You are taking 1913?

A. 1913, yes, sir. I have it figured out for the 273 vessels over 396 feet long. I have not figured it for the lower class. That amounts to 2,746,576 tons.

Q. How much freight was actually carried in the year 1913?

A. 872 vessels of all sorts carried 79,718,970 tons.

Q. What were the earnings?

A. The freight paid on that was $44,380,864.81.

Q. What could they have earned in addition to what they did earn, had there been sufficient freight to have kept them busy?

A. They could have earned $7,462,085 more.

Q. That is about 25 per cent. more?

A. It is 24 per cent. as near as may be; that is figuring the 273 vessels only without considering the mosquito fleet, the smaller fleet.

Mr. Adcock: That is all.

Cross-examination reserved.

Adjourned subject to notice.

United States of America,
Northern District of Illinois, } ss.
Eastern Division.

IN THE DISTRICT COURT OF THE UNITED STATES

United States of America,
Complainant,
vs.
The Sanitary District of Chicago,
Defendant.
} Equity No. 114.
C. C. No. 29,019.

STIPULATION.

It is hereby stipulated that the following matter, pages 3601 to 3765, inclusive, being extracts from public hearings, briefs, letters, telegrams, and resolutions in connection with the application of the Sanitary District of Chicago of February 5, 1912, to divert 10,000 cu. ft. of water per second from Lake Michigan, may be considered in evidence with like effect as if witnesses were called and originals were produced and identified in this case, subject, however, to all objections as to materiality and competency.

J. H. WILKERSON
United States Attorney.
EDMUND D. ADCOCK
Attorney for Sanitary District of Chicago.

CHICAGO, August 12, 1914.

EXTRACTS FROM PROCEEDINGS BEFORE THE SECRETARY OF WAR IN CONNECTION WITH THE APPLICATION OF THE SANITARY DISTRICT OF CHICAGO, DATED FEBRUARY 5, 1912, FOR PERMISSION TO DIVERT 10,000 CUBIC FEET OF WATER THROUGH THE CHICAGO RIVER AND THE CALUMET RIVER.

Proceedings February 28, 1912, before Secretary of War, Henry L. Stimson.

Appearances for Sanitary District:

John C. Williams, Esq., Attorney; George M. Wisner, Chief Engineer; Thomas A. Smyth, President; and Thomas M. Sullivan and Thomas J. Healy, Trustees for the Sanitary District.

Stephen A. Foster, representing certain interests in Calumet district; E. C. Lindley, former attorney for the Sanitary District; Lawrence McGann, Commissioner of Public Works of Chicago; Dr. A. B. Young, Health Commissioner, Chicago; Lyman E. Cooley, civil engineer representing Finance Committee of Chicago; W. D. Weis, Hammond, Indiana; A. C. Barlow, Chicago; and Professor Barto, University of Illinois.

Also Representatives Madden, Mann, Wilson, McDermott, Sabath, Gallagher, Evans, Foss, Copley, Rodenberg, Foster, of Illinois; Senator Kern and Senator Shiveley and Representative Crumpacker, of Indiana.

Opposing application of Sanitary District:

Messrs. John Kennedy, W. J. Stewart, and David Seath, representing the Department of Marine and Fisheries of the Canadian government.

William Livingston, president of the Lake Carriers Association; Harvey D. Goulder, attorney for the Lake Carriers Association; and Arthur C. Sullivan, of the Chicago Board of Commerce; representing the navigation interests.

Senator William Alden Smith and Representatives James C. McLoughlin and Franciz H. Dodds, of Michigan.

J. T. Blackstock, representing Canadian power interests; George H. Eichelberger, representing Cleveland Chamber of Commerce; Fred C. Siguer, representing Association of Lake Lines; J. H. Davidson and H. A. Cooper, Representatives from Wisconsin; Mr. Bruce of Milwaukee; H. B. Ford and Edward T. Cahill of Chicago.

John C. Williams, Esq., in his opening statement, read the application for the permit, copy of which is as follows:

"The Sanitary District of Chicago.

Chicago, February 5th, 1912.

Sir:—

On behalf of the Board of Trustees of The Sanitary District of Chicago, I have the honor to apply for enlargement of the terms of an instrument executed by The Secretary of War May 8, 1899, as modified by instruments similarly executed on December 5, 1901, and June 30, 1910, respectively, in the following particulars and in view of the facts hereinafter set forth, to wit:

The flow of water from Lake Michigan through the canal of The Sanitary District of Chicago is now limited by the said instruments to 4167 cubic feet per second.

The population of the Sanitary District, the sewage of which is to be disposed of through the channels constructed and to be constructed by the said District, exceeds 2,500,000 persons and is rapidly increasing. The only method at present available for disposing of the sewage of this population is by diluting the same with water withdrawn from Lake Michigan and flowing through the Chicago Drainage Canal. The least amount of water necessary to render sewage innocuous by the dilution method has been estimated by well recognized sanitary experts as 1,000 feet per second for every 300,000 inhabitants; so that the amount permitted to be withdrawn by the instruments to which reference has been made is much below the amount at present needed by the District.

The Sanitary District has been for some time engaged in investigating methods and devising plans for the treatment of the sewage with a view to requiring less water for its safe dilution in the future. The methods of other states and countries for such treatment of sewage, are not as yet entirely satisfactory to all concerned, and any changes of methods for large cities must necessarily require several years.

Until these experiments are concluded and proper works installed, the use of additional water from Lake Michigan is essential to the health of the large population of the City of Chicago and of the Sanitary District and of those who live adjacent to the Des Plaines and Illinois rivers into which such waters are discharged.

Subject therefore to such restrictions as to you may seem proper for the protection of the public interest, and to such a method of supervision as you may suggest to promote the general welfare, and pending the completion of the investigations now being conducted to render the use of increasing quantities of water in the future necessary; I have the honor to apply for permission for The Sanitary District of Chicago to withdraw from Lake Michigan through the Chicago river and Calumet river—not to exceed ten thousand cubic feet of water per second; such permission to be revocable at any time by The Secretary of War, and subject to such action as the Congress of the United States may see fit to take in the premises.

Respectfully submitted,

GEORGE M. WISNER,
Chief Engineer.

Hon. Henry L. Stimson,
Secretary of War,
Washington, D. C."

Statement of Hon. William Alden Smith of Michigan.

"Mr. Secretary, I represent the unanimous opinion of the Congressional delegation from Michigan in opposition to this application * * *."

Statement of Mr. E. C. Lindley.

"In order that those who oppose this application may know the exact situation, I will in about ten minutes time, attempt to state it. It was in 1889 when the state of Illinois and city of Chicago determined that there must be relief in the way of the disposal of the sewage of that city. The state passed a law pursuant to its police power to provide for such, authorizing the construction of the main channel of the Sanitary District diverting the Chicago river so that it would empty into the Des Plaines river, drawing the water from Lake Michigan so as to take the sewage of the city away from the water supply of the city.

That tunnel was begun in 1889, was completed in 1900, and was opened, as I recall it, in January, 1900, after permits by the government to divert the Chicago river.

The Sanitary District has spent in the completion of its main channel and its subsidiary channels, in the neighborhood of seventy millions of dollars to provide for the disposal of the sewage of the city of Chicago so that sewage would not pollute its water supply and would not pollute the waters of Lake Michigan. In that expenditure, Mr. Secretary, it spent in the neighborhood of eleven millon dollars in widening the Chicago river, in replacing center pier bridges with bridges without anything to obstruct the vessels in the use of the river. So that it should be borne in mind that what the city of Chicago is attempting to do is not detrimental to the commerce of the lakes, but so far as the river is concerned is an improvement of that river in the interests of commerce, while at the same time protecting the lives of the people of the city of Chicago. I have never heard of the objection which Senator Smith makes this morning until this morning. Although I have been in many discussions, and with all due deference to the distinguished Senator, I hardly believe that the withdrawal of the small amount of water suggested is going to change materially the temperature of Western Michigan. We have heard heretofore that the withdrawal of this water would lower the level of the lakes and for that reason commerce might be affected, but as I

understand it even the opponents concede that if the level of the lakes was to be reduced the maximum amount they could have theoretically, that the reduction would not eventally exceed five inches.

Secretary Stimson: Do you know how it compares, the total flowage that is asked for, with the flowage through the St. Clair river, for instance?

Mr. Lindley: I did know, but I can't say off hand. I don't know what the flowage is through the St. Clair river.

Mr. Williams: About two hundred and twenty thousand cubic feet per second.

Mr. Lindley: About two hundred and twenty thousand cubic feet per second, I am told.

Secretary Stimson: Through the St. Clair?

Mr. Lindley: Through the St. Clair, so that the amount which we are asking would be about five per cent.

Now, Mr. Secretary, it is not proposed that this ten thousand cubic feet per second should be taken through the Chicago river. Eventually when the measurement of ten thousand requested is used only six thousand of it will go through the main channel or through the Chicago river. Two thousand cubic feet per second is to be taken through a tunnel or conduit which has been constructed at 39th street connecting with the main channel where it connects with the Chicago river. Two thousand cubic feet per second is to go through the Calumet channel now being constructed, the construction and completion of which is necessary as Judge Foster suggested, to give relief to the large portion of the city lying south of 87th street comprising a number of boundary towns, including the towns on the Indiana side of the line.

In other words, here is a project upon which seventy millions of money has been expended on condition that this amount of water which was recommended by the International Waterways Commission was to be appropriated for this purpose; so that the state of Illinois and the city of Chicago and the state of Indiana, if you please, are here only asking that you now approve a permit to take that amount of water which the International Waterways Commission had in mind to be appropriated to this purpose, and if I am not misinformed, when that report was crystalized into a treaty each of these two governments, the Canadian and the United States governments, were given permission to take a certain amount of water to be taken without going to that Commission was determined by including so much water for power purposes at Niagara and so much water for sanitary purposes, and it

must be remembered, gentlemen, that that Commission laid emphasis upon the proposition that the use of water such as is being made by Chicago and the district is the highest use of water.

I do not need to argue before you, Mr. Secretary, that from time immemorial domestic and sanitary purposes have had preference over manufacturing or commercial purposes, and that this is, as Judge Harlan said in the Supreme Court decision, the highest use to which the water can be put. Without the people there can be no commerce and without the people we will not need the peaches heard of; Chicago wants the peaches and wants the commerce, but along with it she wants to conserve the lives of her people and we do not believe that the small amount of water which we are asking for is going to be detrimental to either of the two interests.

If I were to take sides voluntarily for a mere commercial standpoint, I believe I could make a better argument that the commerce of the United States would be better subserved by the diversion of some water here sufficient to develop the so-called deep waterways, but we are not here arguing for that purpose today. We are here simply pursuant to the direction of the state of Illinois that we shall complete this work upon which we have spent so much money. In other words, and I will conclude my opening, Mr. Secretary, because I want to leave the time for the attorney to close, under the law by which these works have been begun, the district is enjoined to take from that channel sufficient water to dilute the sewage so as not to injure the health of the people below and so the water of the Illinois river and the Mississippi river will not be so polluted as to injure the lives of the people of the cities down that river. The law provides that the district must pass through the channel twenty thousand cubic feet per minute for every one hundred thousand people within its confines. The last census, as I recollect, gave the city of Chicago two million one hundred thousand people. Compliance with the Sanitary District therefore requires that there should be flowing through something like over four hundred thousand cubic feet per minute. The permit which you or your predecessor heretofore issued, does not permit that amount of diversion and it does seem to me that the Sanitary District has a right to be put in a position whereby it can comply both with the state law and the federal law.

Secretary Stimson: Of course, Mr. Lindley, you appreciate that my jurisdiction is concerned only with navigation.

Mr. Lindley: It is concerned only with navigation I appreciate.

Secretary Stimson: I have no right to balance off the rights of navigation against any other right. I have only the right to say whether or not the rights of navigation are impaired or affected or whether they are likely to be affected by the application in question.

Mr. Lindley: Yes, sir, I understand.

Secretary Stimson: And of course the state law that you cite is addressed to an entirely different purpose.

Mr. Lindley: Yes, sir.

Secretary Stimson: A sanitary purpose which is not within my jurisdiction and which does not affect me.

Mr. Lindley: Not in one sense, Mr. Secretary. I argued before Mr. Taft here that in view of the decision that the sanitary purposes were the highest purposes, that unless the opposition could show that there would be substantial interference, that it was as a matter of right the right of these people to take that water and that question is in the courts and is yet undetermined, but aside from that what I do impress upon you is that the government has been aware all the time that this amount of water was required by the law under which these works were constructed and the works have gone on with the knowledge of the federal government and therefore the federal government should put those who have placed their works in that condition in a position to comply with that law unless there is something more than imaginary objections in the way of a substantial interference with the commerce of the states.

Secretary Stimson: I appreciate the force of that argument, of course, but my suggestion was only in the way of narrowing down the argument as to whether or not there was such substantial things because however pressing the other I will assume the sanitary needs of Chicago are great and pressing but what I want are the facts which guide and justify my jurisdiction.

Mr. Lindley: * * * I can only say, Mr. Secretary, that three years ago when I went into this question, when with the Board, that the evidence showed the actual diversion which has taken place has not lowered the level of the Great Lakes. That the level of the Great Lakes at that time was higher than when the canal was opened, but I do not believe that would be the fact today; that the level fluctuates from a foot and a half to three feet in a great many years and as I say, even the opponents of this do not contend that eventually the max-

imum reduction in the level would exceed five inches for all the water that might be diverted if this application is granted, and therefore that the additional reduction occasioned by the request would not exceed two or two and a half inches."

Statement of Hon. James H. Davidson of Wisconsin.

"Mr. Secretary, every city on the east coast of Wisconsin is represented here today, Kenosha, Racine, Milwaukee, Sheboygan, Manitowoc, Two Rivers, Sturgeon Bay, Green Bay and Marinette. They are vitally interested in this question. It is a condition and not a theory that confronts us. The present level of Lake Michigan is as low as it has ever been. In fact but once has it been as low as it is now. It has gone in circles of from seven to ten years up and down.

The drainage canal was opened in 1900. It was the argument of those favoring that proposition that the lakes continued to rise after it was opened and quoted that as a demonstration that the diversion through the drainage canal did not affect the lake level. The fact that in those years 1889 and 1900 and 1905 to 1906 were the years of the up-turn of the cycle. During that up-turn, however, after this canal was opened, Lake Huron and Lake Michigan never attained the previous high level that they had attained at every one of the up-turns of the cycle theretofore since 1860. In other words the pool was not created. It can be charged to nothing else in my judgment than the diversion at Chicago. The result has been that instead of representing the high water part of the up-turn it only represented a point lower than the average from 1860 to the present.

Secretary Stimson: Do you know how much lower, sir?

Mr. Davidson: Something about half a foot as I recall. I am not positive about that.

A Bystander: About a foot and a half lower than high water.

Mr. Stimson: I mean the average.

Mr. Davidson: It commenced to recede and from that time it has been continuously going down and more rapidly than ever before. Why? Because the pool has not been created on the up-turn that had theretofore been created. Hence we maintain that the present existing low level of the lake is almost if not entirely caused by the diversion at Chicago. They have permission to extract something like four thousand cubic feet—four thousand one hundred and sixty cubic feet—

Mr. Secretary: Four thousand one hundred and sixty-seven.

Mr. Davidson: The information in the report sent in to Congress shows that they have extracted about seven thousand cubic feet, we believe and charge the fact to be upon information, that they have been and now are extracting, diverting through the drainage canal an amount almost double the amount permitted under the authority of the Secretary of War heretofore granted. The fact is that all of the harbors on the west shore of Lake Michigan are exceedingly low. This fact must be borne in mind. The policy of the general government has been in connection with the harbors of the lake. The general policy has been to improve the harbors to the shore line. The municipality deals with the question inside the shore line.

I have been a member of the committee on Rivers and Harbors for fourteen years and during that entire time that policy has been maintained. The result has been that every municipality in my state has spent large sums of money by bonding itself and otherwise to dredge out the inner channel to a depth suitable to the navigation of the lakes and commerce of the lakes. The government has been to a large expense in getting the channel outside the shore lines to the depth that has been dredged by different ports. This diversion if continued and the lowering of these levels if continued, necessarily means an extraordinarily heavy burden upon these municipalities in order to restore the commercial facilities that have been provided and restore them to their original condition of usefulness. Take the situation at Green Bay for instance, which city is represented here because of the very great interest it has in the question. The channel flowing from Fox River into Green Bay comes out through the bay for a long ways and the bay is shallow. It has been a tremendous expenditure to the government to maintain that channel out through the shallow portions of Green Bay. Consequently the reduction of the level permanently means that that expense must be very largely increased in order to maintain the commercial facilities there.

We insist that while Chicago is entitled to a reasonable amount of water, and I would not be narrow about it, I want them to have what is necessary for sanitary purposes—it must be under that system of sanitation which the world recognizes as the most successful and the most useful and that is not the dilution system.

They have constructed a great canal and at a tremendous cost, as the gentleman has stated. They did it upon their own responsibility and they could not have expected when they constructed that canal that it could be a permanent method of the disposal of sewage as the city would grow because it is evidence on the face of it that they could not keep up with the growth of the population by diverting the water from Lake Michigan to supply the necessary amount for that purpose. I maintain that we on the lakes have had no participation in the court's decision to which I refer by which under the law the drainage district is obliged to take an amount sufficient to dilute the sewage to a sanitary condition. We are not parties to that transaction. The commercial cities of Wisconsin have not been parties to it in any sense or at any time.

Secretary Stimson: I do not think that that was cited as binding on the government at all.

Mr. Davidson: I should hope not.

* * * * *

Mr. Davidson: Now in the first place we object to any further diversion than is now permitted. We believe there ought to be government regulation of the diversion and that the diversion should be held strictly to the amount permitted by the Secretary of War. We do not believe the necessities of sanitation, eliminating the power contracts and the use of water for power purposes which the drainage canal commission now enjoy, should be used to emphasize their demand for a greater flow of water. We believe that the flow now is more than is necessary for sanitation and hence we believe that this permit should be denied. The commercial interests of the state of Wisconsin are greatly affected by it and are opposed to the granting of this permit. * * *

Mr. Secretary, I have been asked if the cities in Wisconsin have contributed of their own funds for the creation of these channels on the lake. I will say all of them have. Kenosha, Racine, Milwaukee, Sheboygan, Manitowoc, Two Rivers, Green Bay, Marietta and Kewaunee, without exception. They have dug the channels inside the shore line and have spent millions of dollars by bonding themselves and have created terminal facilities to the shore line and into the mouth of the little river that usually runs into the lake at each of these ports.

Statement of Harvey D. Goulder, Cleveland, Ohio.

"* * * I have had occasion to argue the duty of the United States government to either wholly take charge or in common with the community, state or municipality take part in deepening the harbors because of the depth of the channels through the Great Lakes. We are doing what they are doing to improve the railroad. Of course you can see that the trunk line cannot expand beyond the capacity of its terminals. What has been spent by localities other than Chicago on its terminals? That is what I want. A very large share of authority is vested in this department and the head of this department with reference to the conservation and regulation of these waters for navigation purposes and the expenditure of many millions of dollars is intrusted to this department for that purpose. Now the question that is presented here to me as a lawyer, as a legal proposition and as a proposition in philosophy is this. Whether the department that is intrusted with the regulation and control of these waters for navigation purposes under the authority in our constitution to regulate commerce through the commerce clause and nothing else, whether when it becomes perfectly manifest and is conceded as I think it must be in all integrity, that that interest will be harmed and injured by taking water away from those navigation purposes, whether this department shall say 'We will permit that diversion, we will permit that impairment because in some question of sanitation or right or power or something else in the opinion of the Secretary of War the public or some portion or some faction of the public may be better served in another direction.'

Mr. Secretary: You need not argue that proposition. I shall call upon the other side to argue that.

Mr. Goulder: I ask whether that determination as a matter of reason should not be rather with Congress than with any department and I think the solution of this thing is to let Congress determine it.

Secretary Stimson: What I shall confine my examination to is the question as to whether or not navigation is impaired or would be impaired by any additional diversion of the water.

Mr. Goulder: As to the reduction of the level I think it is a mere waste of time for the Secretary of War to listen to any advocates or opponents of this measure. We have the best authority in the world on that subject right in this de-

partment. We have simply to call upon the office of the Engineering corps to get that kind of information which is absolute both in its integrity and in its authority. I make then only this further point. We do not like to be in a position as we have been—Mr. Livingston has been and I have been and we have all been in the position—that we are unwilling to give water for health purposes and all that sort of thing. Everybody recognizes that. We do not go into the technical question whether a city is a riparian proprietor or anything of that sort. We say this. We say that all reports, which I will submit to you in a brief, all the reports made to this commission before they made the expenditure showed that it was unnecessary to resort to this measure, that it could be taken care of by filtration and the cost would not be so very much different. If I understand they want this for the accommodation of Chicago south of 87th street. As I say it was originally reported that it was unnecessary to resort to this measure and that it could be taken care of by filtration without very much greater expense. There are other reports on file here. They were before Secretary Taft when he was Secretary of War.

* * * Further than that we had our hearing here in 1907 and the then President of the Sanitary Board stated as among the possibilities that this Calumet river being entirely within the boundaries of Illinois, it was not necessary to have a permit from the Secretary of War, to which Mr. Taft responded pleasantly, 'Then shall we treat this merely as a visit of courtesy, this hearing?'

Secretary Taft refused that permit. We were before him then under very much the same circumstances that we are here now.

Then an arrangement was made that they should go forward claiming that it was not necessary to have the permission of the United States and undertake to do that work. Thereupon an injunction was brought by the United States government and they claimed on the part of the drainage canal that there would be no substantial loss or interference with navigation. The case has been pending ever since 1907, I think it is.

* * * Some of the gentlemen who have come here have fallen into the very bad habit of thinking the shipping interest is the interest of the ship owner. It is nothing of the kind except in a very small degree. The shipping interest is the broad public interest and the whole country is interested and

every part of the country is interested in cheap navigation, cheap freight, a freight that probably every year repays all the money that the government has ever spent on the channels of the Great Lakes and we go in on that, not that the mere owner of the ship is the man to be regarded, it is the public. Therefore I say that when they say 'We have spent a whole lot of money' and there is nothing against that except the mere temporary interest for gain of the ship owner, we say that over against that can be matched every dollar the government has spent on these other channels and every dollar that the ports on the lakes have spent for terminals. That is the interest of the other side.

* * * Now what superior right has Chicago to the use of these waters for domestic purposes. Other places have just as good right to the water as Chicago.

Some day we may have a canal cut through from the Ohio River to Lake Erie and then it will be a question there as to the amount of water to be taken from the lakes. There are various communities that need this water or will need it in the future. They have the same right as Chicago to take water for these purposes.

In closing let me say this, that the use of water for taking care of the sanitary condition of the city of Chicago by dilution is something that we have outgrown. In every city, in every place along the lakes in Cleveland, in Buffalo, in every place except Chicago, we find that we are talking about filtration. We will talk about filtration in Cleveland for example. In the case of filtration we do not take the water away from the lake permanently, we take the water and run it with the filter into the lake. We want to have filtration and we shall have it, and it is going to be soon, and so in the case of Chicago. Chicago can do that. * * *"

Statement of Mr. Bruce, Representing the Greater Milwaukee Association of Milwaukee, Wisconsin.

"While we stand here and discuss and show you that Chicago has no right to get water for sanitary purposes because there are other means for sanitation disposal and while we believe that the state of Illinois has no right to get the water for power purposes because there are other means for securing power, we want to confine ourselves strictly to the question of navigation.

By way of navigation facts I want to say that our engi-

neers in Milwaukee have figured out that if this additional grant for water is given, it will reduce the level of Lake Michigan by fully eight inches, but if it were only six inches in the way of concrete facts, Milwaukee maintains three navigable rivers. We estimate that a dredging of six inches which will be necessary will be done at a cost of about one hundred and fifty thousand dollars. This is simply a concrete fact which might be added to the sum of information and which of course will multiply itself so far as applies to other localities.

Secretary Stimson: It would not need dredging, would it, a lowering of six inches?

Mr. Bruce: Here is the point I want to make on that score. Here we are at a low water point, the lowest we have had at at least thirty years. Now when the lowest point is reached if there should be additional lowering of six or eight inches it will mean the exposure of our dock tiling which is exposed to rotting and decay, and it will mean additional dredging. We aim to maintain a certain depth. If then the average level is reduced six inches our river dredging will have to be increased six inches in order to maintain the average depth. We hold that under the ordinances of 1787 the waters of the Great Lakes are dedicated to navigation and we protest against any diversion of water that will in the slightest degree affect the natural levels of the lakes and thereby affect our rivers and harbors.

Statement of George H. Eichelberger.

Representing Cleveland Chamber of Commerce.

"Mr. Secretary, I doubt whether anybody else here will desire to speak in behalf of the other cities in the Cleveland district, that is, Toledo, Lorain, Ashtabula, and Fairport Harbor, but the sentiment with regard to them along the south shore of Lake Erie is the same as with regard to Cleveland, and there is no difference between that and the situation at Milwaukee.

I want to call attention to two paragraphs which perhaps were overlooked, in the report of 1907, Second Division, page 14, Note N, at the bottom of the page:

> (n) The diversion of 10,000 cubic feet per second will lower the levels of Lake Michigan Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, be-

sides the important connecting channels, the Detroit and St. Clair rivers, by amounts varying from 4¼ to 6¼ inches for the different waters, and the diversion of 14,000 cubic feet will lower them from 6 to 8¼ inches. The diversion of 20,000 cubic feet will lower Lake Michigan-Huron about 13 inches and Lake Erie about 11 inches.

Secretary Stimson: Is that true of Cleveland?

Mr. Eichelberger: That is true of Cleveland. There is no question but what there will be necessity and great hardship worked there, in fact, in the outer basin, behind this three or four million dollar breakwater, they have built will be this necessity for dredging. Lake Erie is not like the other lakes. At almost every harbor in Lake Erie today this would mean an obstruction to navigation. The situation at Toledo is about the same as at Cleveland.

Looking a little beyond this request at this time, I happen to be one of those persons who argued the matter before Secretary Taft three years ago, and Mr. Littleton made the argument. They were then asking for 14,000 cubic feet of water, and the report of the President of the Sanitary District I have before me. He says that it takes about 6,000 cubic feet a second to reverse the current in the Chicago river.

Secretary Stimson: How much does that say?

Mr. Eichelberger: 6,000 cubic feet.

Since that time they have continued to spend further money, so when these gentlemen get the 10,000 cubic feet, they will come back here and want an additional amount, with the continued growth of population.

I understood you to say, Mr. Secretary, that you did not care to go into the matter of sewage; but the reason that it becomes important is that the public health is to some extent paramount.

Secretary Stimson: It may be paramount to Congress, but not here.

Mr. Eichelberger: Yes. However, the proposition that the commerce of the lakes will be hurt by this additional diversion of water is not chimerical, it is working out in practice. At that time they claimed that the lakes were fed by a subterranean or supernatural source, and that the amount taken out had no relation to the depth of water stage. But it has been proved that that is not correct. War Department engineers can verify that very easily to you.

Statement of Mr. Arthur Sullivan, of Chicago.

Mr. Secretary, * * * I would like to add a word as a vessel owner and a man operating steamers in the City of Chicago. The local situation there is something extremely critical. Under the present flow of 4,000 cubic feet,—we presume it is 4,000 cubic feet a second—navigation in the river is carried on at great hazard. The center pier structures and the swift current make it extremely dangerous and we have suffered loss of property and loss of life in consequence of these hazardous conditions. So far as any increase of the current goes, I should say it would mean disaster, and I am sure that so far as our ships are concerned we would not be able to operate them in the Chicago river.

I do not want to appear as antagonistic to the Sanitary District, only in respect of the increasing of the flow so that it will make it impossible for us to navigate our boats. * * *

The current in the river in the Chicago River at present is extremely detrimental to the safe handling of boats, and any increase in the velocity of the current would mean disaster. It would simply close Chicago as a port against any of the so-called modern ships, and to a large number of the vessels of an extremely smaller size.

Statement of Fred E. Signer.

Mr. Secretary, I represent the Association of Lake Lines. It is an association made up of package carriers. As package carriers we are more interested in the harbor conditions at the different ports than some of the other interests that have spoken before me (and) are interested in the Great Lakes as a whole. That is, you take the rail facilities and the crowded conditions at each one of the ports. That situation is creating more and more a demand for direct delivery by the boats to the industries along the lakes at the different ports, at which we operate to and from.

I judged that the navigation feature is the one which would be considered paramount here, and I had hoped to get two or three of our captains whose testimony I thought you would appreciate, coming from men who actually handle the boats and could tell you definitely and distinctly the hardships and the troubles they are having at the present time in navigating the Chicago River, and if an increased flow was allowed it would increase their trouble and possibly eventually drive us

out from making any direct deliveries in the Chicago Harbor. If the increased flow makes a reduction in the level, it will reduce the level in the harbors of the other ports we enter, and a corresponding situation will prevail, and from a commercial standpoint, the line of boats running between the Chicago River and the Milwaukee Harbor and to the other harbors which we operate to, it seems to me would match up considerably in excess of any of the commercial conditions that appear to be involved in this demand for an increased flow in the Chicago River.

Statement of Mr. H. B. Ford of Chicago.

Mr. Secretary, I am agent of the Union Steamboat Line. I am here to represent the Lake Lines Association at Chicago, in which are representatives, at Chicago, of what are known as the package freight lines, running from Lake Erie to Lake Michigan, and vice versa, and also to represent other marine interests.

The Lake Line Agents' Association is one of the associations I represent, and that association has from 25 to 30 steamers, carrying from 1,800 to 4,500 tons of package freight, and these from 25 to 30 steamers visit Chicago at least twice a month, and some of the fast ones that go straight through, three times a month. In other words, they are there every 10 or 11 days.

The Sanitary District of Chicago handles the current in the south branch and the main river as they see fit, without any notice to the marine interests or anyone else as to what the speed is going to be, and it interferes seriously with the free navigation of the South Branch. Our captains complain bitterly to the agents, particularly at night, of the speed of the current. Some of them have made the remark that if (it) had not been for the tug necessary to take them around the bends they could have come to their landing without using any steam.

When the Sanitary District opened the canal, they agreed with the Board of Trade to send every morning about 10 o'clock a notice to the Board of Trade as to what the current was to be for the next 24 hours. They did that for about 60 days, that information was posted on a blackboard. But after about 60 days it ceased, and has not been renewed. We have tried several times to find out why, but we have been answered indefinitely. We have made up our minds—and

when I say "we marine men," it was better for the marine men not to know what they were going to do.

Some of our captains find it impossible at certain times to leave our docks when they are bound south, or less than one-third loaded, when they cannot get a tug to help them, on account of the rapidity of the current. It is not safe to navigate a boat over 200 feet long in the south branch, which is only 200 feet wide in its widest part, and filled with pier structures between Lake street and Van Buren street. A boat bound in or bound out, drawing in the neighborhod of 17 foot, six inches, frequently goes across the river. If she is bound south she is going with the current and asks for the bridge and does not get it for some reason, and she has to back and when she backs it has a tendency to throw her stern to the port on the left hand and her bow to the starboard on the right hand. The current then catches her and until she strikes a bridge protection and gets across the river, she is going back. Then her stern is on this bridge protection, and it is very hard to get her to move along. We sometimes cannot do it even with three tugs, and the aid of a steam windlass, and then there is only one thing more for us to do, and that is that we apply to the Sanitary District, stating the facts, and asking them to shut off the current. That is the only way the boat can be relieved.

Secretary Stimson: Have you had to do that?

Mr. Ford: Yes, we did it three times last year, so I am told. None of our boats, but three others. When the boat is across the river that way she makes a dam, with just a little water going around her stern and her bow, and she may remain in that position for five or six hours—because it takes that long after they shut the dam at Lockport for the water to set back—and the water will be anywhere from eight to ten inches higher on one side of her than the other. Sometimes they will say, "All right, we will shut it off," when we apply to them, but more times they say, "Oh, no, we can't shut off the water now." We ask them when they can shut it off, and they probably name a time five or six hours later. And then we ask them why they cannot shut it off before then and they say, "It will interfere with our power contract we have, and our contract with the trolley company and the water works down there."

There is a report by one of the best engineers in the west that knows all about sanitation, sewage, and so forth, and my recollection is that his statement is that only 1,000 cubic feet of water is needed for Chicago to handle her sewage, that

what that will not dilute will be taken care of in some other manner. A thousand cubic feet will not interfere with navigation, with or without the current.

I have never seen a copy of that report. I have tried to get it in order to let you know the gentleman and his standing. Perhaps you can get a report, I cannot. That was Mr. George M. Wisner, the present Chief Engineer of the Sanitary District.

February 28, 1912.

MEMORANDUM FOR LAKE CARRIERS' ASSOCIATION,

To the Honorable Henry L. Stimson, Secretary of War:

1. The authority of the War Department in connection with public navigable waters is to preserve their integrity and guard against unreasonable obstruction in their free public use. The proponents furnish no basis of authority in the department for trading off, as it were, such public use in the interest of some other use of the waters, which seems the proposition involved in the application.

2. Therefore, while no one will question the necessary use for domestic purposes, nevertheless, this use is one which the department under authority to conserve navigable waters would not be expected to deal with.

3. Further, it is not denied that a reason for, or office of, the Sanitary Canal is to furnish power; and while it is said that this is merely an application of the flow, it nevertheless appears that besides the general injury to the commerce of and dependent on the Great Lakes System, this has also interfered specifically, and does from time to time, materially and seriously interfere with the navigation of Chicago River.

4. It is apparent also that other communities could similarly use the water, and to an extent which might most profoundly affect the navigable capacity of the Great Lakes and their connecting waters, to serious detriment of the interests of the general public of this country and Canada.

5. A circumstance of importance, not to be overlooked in any view of the case, is that application is specifically made to care for territory south of 87th street, in the face of two reports of experts, the one beginning at page 29, and the other at page 39, in the report of the Chicago Drainage Canal of 1907, second edition, to the effect that when the Drainage

Canal was originally proposed, an alternative method at about the same cost, would care for that section as well as for all except the central district of Chicago, the second report referred to strongly confirming the first mentioned.

6. Filtration plants are used in many of the principal cities of the world. We understand there is one in Washington. High authority exists for the proposition that it is not necessary to deplete the lake for such purpose, since under the alternative method, the water taken from the lake can be returned, less a small percentage of wastage, is practically unpolluted condition.

7. The point was suggested that inquiry should be narrowed to the sole question of the effect of taking out the additional flow. We submit that the question is broader; that it is artificial, narrow argument that having authority to remove one quantity, the question of injury to navigation be confined exclusively to the effect of removing the additional quantity without regard to the previous flow; but that is the old question of running the gauntlet, and that every additional subtraction must be treated in logic and in morals, with reference to the cumulated total flow.

8. There remains one other point introductory to the principal point of the effect on lake levels and navigation requirements. It has been suggested that because there are variations, through cycles of time, and from local, barometrical forces; and because these have to be met, therefore, a permanent reduction of the leval of half a foot, or a foot, or even more, may not be complained of. This we think sophistical and without merit. The same conditions and effects may be expected with the levels definitely and permanently reduced, with the permanently reduced base of level with which to reckon.

Heeding the admonition of the Honorable Secretary, that the question of interest here is the effect of reducing lake levels:

Precise figures may not be obtained, but the following has been computed by the President on full inquiry, and we submit as substantially correct.

It is found in active practice that the diminished carrying capacity of the largest bulk freighters upon the Great Lakes has been as much as 113 tons per inch of reduced loading depth per single one-way trip. This graduated to the smallest vessels in the bulk freight trade would, upon a very conservative basis, average 75 tons per inch per one-way trip,

150 tons per inch per round trip, if loaded both ways, as they frequently are; or, for six inches of diminished draft, approximately 450 tons each way, 900 tons per round trip. In normal seasons the vessels engaged in the bulk freight traffic make from twenty to twenty-five round trips; say twenty round trips, invariably loaded one way, frequently each way, and at 900 tons each would mean a loss of 18,000 tons per vessel for a season, and so for 400 vessels an approximate loss of 7,200,000 tons; and so with freight rates averaging forty cents per ton net, the loss to the vessels would therefore aggregate approximately $2,880,000 in a single season, which, capitalized at five per cent., amounts to $57,600,000; or, at a diminished draft of eight inches, cumputed in the same manner, the results would show approximately 600 tons one way, 1,200 tons per round trip, amounting, for 400 boats, averaging 20 trips each, and loaded both ways, with same freight rate, to $3,840,000, which, capitalized at five per cent., amounts to $76,800,000.

As a matter of fact, the average ore cargo during the season of 1911, as computed for the Annual Report, was 7,178 tons as against 8,325 tons in 1908, a loss of 1,147 tons per trip one way.

* * * * *

It was hoped to append statement showing the expenditures by the various ports on the shores of the Great Lakes, on both sides of the border, in the improvement of their respective harbors. There has been but partial success in securing this character of information in the limited time from the various municipalities, so that a list is not attempted. We cannot forbear stating, however, that an Engineer Officer of Cleveland gives the amount since 1870 expended at Cleveland as $6,143,591.92, including interest charges, and at Buffalo we are informed that such expenditures have been $4,880,149.02; figures indicative of the importance in which Lake Commerce is viewed by municipalities upon the shores of the Great Lakes. Also, we have taken from the Annual Report of the Chief of Engineers for the fiscal year ending June 30th, 1911, and for convenience group these itemized by ports, aggregating $105,461,130.60, a statement of which is appended. We assume that there will necessarily be before the Honorable Secretary the report of the Special Commission of U. S. Engineers,—of which General Bixby was Chairman, submitted to Congress February 9th, 1911; but we call attention to the language also of the Board of Engineers, in

their report in this connection, in which they emphasize the point, saying, "And, further, until the interests of the United States shall be satisfactorily safeguarded, as indicated by the Special Board, namely, that the State of Illinois, or its agency, shall assume entire responsibility in perpetuity for all damages by changes in lake levels incident to the work," the work be not undertaken, etc.

We have shown the increase in size of ships, and the effect of reduction. It remains in conclusion to say that it is essentially incorrect to consider all this as a question between the vessel owner as such and the Sanitary District. The vessel owner made a higher rate on his investment, with less effort when ships were smaller. He has built his ships, not only on the lakes, but throughout the world, larger and larger, because of the demands of commerce. The capacity of the ship and the facility and dispatch with which she is handled in port, controls the rate of freight, and the demands of trade and commerce regulate the whole. Therefore, it is the obvious advantage and necessity in every center of commerce, to meet the demands for cheapest and best transportation. It is for this reason that vessels have increased in size, and in recognition of the general demand, some of the strictures in our great system of waterways have been removed, and channels have been enlarged, the port facilities have been increased, breakwaters built by the Government, harbors dredged at local expense, and many millions of dollars invested in terminal facilities, not for any mere accommodation of the ship, but to meet the general demands of trade, which it is well understood, has for one of its prime, and doubtless its most important factor, cheap and efficient transportation. Anything which interferes with or abridges this, or retards its development, takes on the proportions of a public misfortune.

We cannot close more appropriately than by referring to the paper read by Sir William Henry White, at the meeting of the Society of Naval Architects and Marine Engineers, in New York, November 16th, 1911, in which this most eminent authority discussed the increase in size and capacity of ships, the necessity for corresponding increase in channels and in the ease and facility for moving the ships in port, and of handling their cargoes within some permissible time related to the expense of upkeep and operation of the ships. We may briefly quote:

"For each class the average size of ship has been increased, and the fact is apparent in every statistical 'Return' of the

movements of shipping. In 1860 the average gross tonnage of ships (exceeding 100 tons) on the Register of British shipping was 340 tons; in 1870, 580 tons; in 1880, 1,250 tons; in 1890, 1,570 tons; in 1902, 2,200 tons." (These are registered tons, not carrying capacity.) "Since the Suez Canal was opened, the average size of vessels passing through it has grown steadily; the same may be said of the vessels passing through the Sault Sainte Marie Canal."

Again he says: "Up to the present time the response made to the appeals from ship owners for increased accommodations for ships by authority of the great seaports of the world, has been neither niggardly nor unsatisfactory. At the present moment extensive and costly works are in progress which will provide accommodations for the largest ships now building, and leave some margin for further development. * * * Immense sums are being expended on improvements and extensions of docks and harbors, as well as on the approaches thereto, both by governments and by proprietary bodies." He mentions as one of the latest the project for making the dock and channel accommodations of the port of London suitable for the existing trade and for providing a proper margin to meet future developments at an estimated cost of over $72,000,000. And again on this subject: "The advantages to be obtained by the whole community, and not the profit of a particular section, ought and will determine what is done eventually."

So as to the benefit of Lake transportation to the country at large, official statistics are not lacking to show saving in a single season, over any other method of conveyance equal, if not exceeding, the entire expenditures of the Government from the beginning in Lake Improvements.

March 29, 1912.

Rspectfully submitted,

(Sgd.) HARVEY D. GOULDER,
Counsel.

(Sgd.) WILLIAM LIVINGSTONE,
President.

AMOUNT OF EXPENDITURE BY U. S. GOVERNMENT ON IMPROVEMENT AND MAINTENANCE OF HARBORS AND CHANNELS OF GREAT LAKES TO JUNE 30, 1911, AS SHOWN BY REPORT OF CHIEF OF ENGINEERS, U. S. A., FOR FISCAL YEAR ENDING JUNE 30, 1911.

Project	Improvement	Maintenance	Total
Grand Marais, Minn	$ 110,936.68	$ 5,390.49	$ 116,327.17
Agate Bay, Minn	234,057.53	21,419.34	255,476.87
Duluth-Superior	5,917,194.15	556,030.00	6,473,224.15
Port Wing, Wis	41,301.95	11,025.30	52,327.25
Ashland, Wis	198,017.28	293,207.76	491,225.04
Ontonagon, Mich	284,801.24	113,718.53	398,519.77
Keweenaw Waterway	1,057,127.72	281,303.67	1,338,431.39
Marquette, Mich	677,358.82	24,855.79	702,214.61
Marquette Harbor of Refuge	55,056.34	2,701.82	57,758.16
Grand Marais Harbor of Refuge	355,885.29	130,326.49	486,211.78
Manistique, Mich	79,132.62	.....	79,132.62
Gladstone, Mich	7,280.59	252.17	7,532.76
Menominee, Mich	387,010.61	24,831.10	411,841.71
Oconto, Wis	93,462.65	.....	93,462.65
Green Bay, Wis	508,284.90	49,667.84	557,952.74
Depere, Wis	7,418.22	.....	7,418.22
Sturgeon Bay and L. M. Canal and Harbor of Refuge	590,336.71	19,125.69	609,462.40
Algoma, Wis	293,832.95	24,384.20	318,217.15
Kewaunee, Wis	149,999.99	49,753.32	199,753.31
Two Rivers, Wis	301,172.75	29,162.87	330,335.62
Manitowoc, Wis	688,915.18	209,832.37	898,747.55
Sheboygan, Wis	603,989.75	29,176.12	633,165.87
Port Washington, Wis	226,133.09	7,435.40	233,568.49
Milwaukee, Wis	1,844,889.86	507,701.79	2,352,591.65
Racine, Wis	549,337.91	36,583.02	585,920.93
Kenosha, Wis	506,238.40	24,842.26	531,080.66
Waukegan, Ill	529,283.80	121,656.13	650,939.93
Fox River, Wis	3,847,542.55	.....	3,847,542.55
Chicago Harbor, Ill	2,431,921.04	131,513.43	2,563,434.47
Chicago River, Ill	1,349,770.02	113,365.18	1,463,135.20
Calumet Harbor, Ill	1,431,278.15	57,750.29	1,489,028.44
Calumet River, Ill	1,072,501.56	45,230.48	1,117,732.04
Indiana Harbor, Ind	1,405.59	.....	1,405.59
Michigan City, Ind	1,401,043.63	320,824.22	1,721,867.85
St. Joseph, Mich	806,206.61	79,836.66	886,043.27
St. Joseph River, Mich	4,555.49	1,707.84	6,263.33
South Haven, Mich	190,269.93	183,421.40	373,691.33
Saugatuck Harbor and Kalamazoo River	323,796.47	168,142.58	491,939.05
Holland, Mich	491,627.79	253,977.21	745,605.00
Grand Haven, Mich	542,976.82	420,573.06	963,549.88
Grand River, Mich	385,201.08	56,883.63	442,084.71
Muskegon, Mich	556,195.86	244,797.26	800,993.12
White Lake Harbor	207,862.44	153,439.72	361,302.16
Pentwater Harbor	179,899.10	148,642.47	328,541.57
Ludington	1,173,437.61	147,451.12	1,320,888.73
Manistee	330,160.80	143,571.52	473,732.32
Portage Lake (Manistee Co.)	254,129.21	130,807.59	384,936.80
Arcadia Harbor	.....	15,042.46	15,042.46
Frankfort	331,727.18	138,433.21	470,160.39
Charlevoix	80,206.04	129,993.98	210,199.02

Project	Improvement	Maintenance	Total
Petoskey	$ 118,239.40	$ 7,532.05	$ 125,771.45
Ship Channel between Chicago, Duluth and Buffalo	3,340,000.00	.....	3,340,000.00
St. Marys Falls	9,141,572.08	.....	9,141,572.08
Hay Lake and Middle Neebish	8,312,673.61	.....	8,312,673.61
Mackinac Harbor	5,457.87	.....	5,457.87
Cheboygan	190,310.69	.....	190,310.69
Rogers City, Mich	36.38	.....	36.38
Alpena	35,798.69	15,290.65	51,089.34
Saginaw River	971,978.28	.....	971,978.28
Sebewaing River	79,146.45	8,419.22	87,565.67
Harbor Beach	975,000.00	952,002.32	1,927,002.32
Black River (Monroe, Mich.)	85,848.58	12,008.31	97,856.89
Rouge River	80,355.28	26,270.18	106,625.46
Monroe Harbor	261,344.51	.....	261,344.51
Black River (Port Huron)	56,934.09	.....	56,934.09
St. Clair Flats Canal	.....	9,451.34	9,451.34
Clinton River, Mich	54,829.79	.....	54,829.79
Detroit River	9,687,829.99	.....	9,687,829.99
Toledo Harbor	2,457,667.79	186,827.56	2,644,495.35
Port Clinton, Ohio	105,209.29	1,933.70	107,142.99
Sandusky	1,121,819.73	40,004.76	1,161,824.49
Huron	461,111.32	70,219.66	531,330.98
Vermilion	164,779.57	.....	164,779.57
Lorain	943,162.82	36,066.61	979,229.43
Cleveland	6,105,284.06	532,346.78	6,637,630.84
Fairport	824,460.85	127,819.59	952,280.44
Ashtabula	1,361,330.19	29,676.87	1,391,007.06
Conneaut	909,031.43	50,399.32	959,430.75
Erie	1,446,160.42	.....	1,446,160.42
Dunkirk	987,846.56	.....	987,846.56
Buffalo	5,728,663.38	.....	5,728,663.38
Black Rock	2,303,717.30	.....	2,303,717.30
Tonawanda Harbor and Niagara River	661,671.45	.....	661,671.45
Niagara River	60,135.30	.....	60,135.30
Olcott	177,986.87	.....	177,986.87
Charlotte	765,124.14	.....	765,124.14
Puttneyville	*70,607.96	12,657.19	83,265.15
Great Sodus Bay	408,329.80	142,100.89	550,430.69
Little Sodus Bay	301,398.21	168,872.55	470,270.76
Oswego	2,383,438.40	.....	2,383,438.40
Cape Vincent	129,473.84	389.80	129,863.64
Ogdensburg	272,602.83	130,512.32	403,115.15
Total	$ 97,240,540.15	$ 8,220,590.45	$ 105,461,130.60

BRIEF ON BEHALF OF THE CLEVELAND CHAMBER OF COMMERCE.

Mr. Secretary:—

The Cleveland Chamber of Commerce comes to you representing the commercial interests and reflecting the sentiments not only of the people of Cleveland, but, indirectly, it represents far more than that, because the interest taken by the Cleveland Chamber of Commerce is, from the relation of Cleveland to the commerce of the Great Lakes, extended to include all of the lake cities and the vast shipping interests of the Great Lakes; because whatever subtraction of water would affect Cleveland, would be proportionately disastrous to all the Lake Erie ports from Toledo to Buffalo, as well as to those points along the south shore of Lake Erie which are rich in possibilities as shipping centers, but whose resources are as yet undeveloped.

And it is to inquire into the reasonableness of the request of the Sanitary District of Chicago, taking into consideration all of the interests involved, that we come before you.

We believe it needless to urge upon your consideration the report of the Chicago Drainage Canal by the International Waterways Commission dated Toronto, Ontario, January 4th, 1907, wherein a careful and exhaustive consideration is given to the subject in many of its phases, the conclusions of which are characterized by a fairness that should be obvious to all.

The people of the northwest territory find the outlet of the Great Lakes diverted by their natural watershed through the St. Lawrence River to the sea. Settlements from which sprang cities grew up along the shores of these great bodies of water and their development gave rise to great maritime interests. The Government of the United States assumed control over these waters, and has from time to time appropriated large sums towards improving their ports and the natural channels whereby commerce could be facilitated. Our present generation come into the great legacy of the benefits conferred by these waters, and it should be our aim to pass them on to the next generation without diminution of bulk or usefulness; or rather, we should strive to continue their development and enlarge their field of usefulness in all respects consistent with the general welfare. And it is in this view of the case that the request of the Sanitary District should be considered.

* * * * * * *

We must recognize that the diversion of water for sewage purposes through the Chicago River is an accomplished fact;

that engineers generally have insisted that it was the only means by which the central district of Chicago so drained could dispose of its sewage, and that vast sums of money have been spent in accomplishing this end. The readiness with which the plea of money already expended was urged at the hearing as a reason why more water should be permitted shows how the same plea will be made as the years go by with constantly increasing effect. Money expended now in providing for an additional flow through the Chicago River will, in a measure, be money lost if any other means of sewage disposal is attempted in the near future. The fact, therefore, that another method of sewage disposal is possible, and at but a comparatively slightly greater expense, and the fact that the demands for the Chicago River must constantly increase with the growth of population, are strong reasons why there should be no enlargement of the project while alternative means are available; certainly not until it could be conclusively shown that alternative means are inadequate, and the effect upon lake levels is exactly proven. If the effect will be as the reports now in your hands indicate, then there should be no permit granted of the kind now asked.

The contention that the withdrawal of this great volume of water from the lake would not deplete them, basing this conclusion upon the variation of lake levels due to wind and rainfall does not seem to demand serious consideration. However enormous the lakes may appear they must be considered as reservoirs and the quantity of water held in them to be subject to natural laws.

That the subtraction of water has resulted in the lowering of lake levels is rather conclusively indicated by the facts furnished by General Bixby showing lake levels for the year 1911. He states that during the past four years Lake Superior has dropped about 0.8 feet, thereby losing in storage capacity more than four months' total discharge; Lakes Michigan, Huron and Erie in the past two years have each dropped about 0.8 feet; and Lake Ontario in two years has dropped about 1.5 feet. On all the lakes the present water surface is at least 0.5 feet below the average for the past 51 years. The Lake Survey records for 1911 indicate that all the lakes are continuing their rapid drop in level.

We think that the inference is perfectly fair, that this lowering of lake levels is due, in part at least, to the depletion of the waters of Lake Michigan by the drainage canal, and

has verified the predictions of the engineering corps previously referred to.

We beg, therefore, to enter our protest against the War Department permitting any additional flow of water through the drainage canal by granting the permit requested, and would beg to be allowed to go further and ask that the War Department take steps to determine whether the Sanitary District is at present exceeding the quantity previously authorized, and if it is found that this be true, that the excessive quantity be prohibited.

In view of the foregoing it hardly seems necessary to deal with the several questions which were presented at the hearing before the Department on February 27th-28th, 1912. But, following the lines of argument, we wish to call your attention,

First, As to the right of the War Department to grant the permit asked for without Congressional action. We think a distinction should be drawn between an essential executive act and a question of broad, far reaching policy.

Second, Should your Department under the present treaty relations between the United States and Great Britain allow such action if it can be shown that from such permission material and irreparable damage will be done to the interests of the British Dominion of Canada;

Third, Does it not follow that the Honorable Secretary of War, as was suggested at the hearing, in the performance of his official duty confine his attention to the one question of whether this depletion would not injuriously affect commerce through its effect on the navigability of the Great Lakes;

Fourth, Is not the subject one of such broad, general significance as to involve the future policy of the Government with regard to the uses and diversions which may be made of the waters of the Great Lakes, and, therefore, is not the Drainage Board going too far to ask an administrative arm of the Government to determine the questions involved without Congressional authorization?

Respectfully submitted,

(Sgd.) GEORGE H. EICHELBERGER.
(Sgd.) HARVEY D. GOULDER.

Extracts from proceedings before the Secretary of War in regard to the application of the Sanitary District for permission to divert not to exceed 10,000 *cubic feet of water per second through the Chicago and Calumet Rivers. A hearing was given on March* 27, 1912, *to representatives of the Canadian Government and Canadian interests.*

Appearances:

Mr. Daniel Mullin, K. C.,
Counsel.
Mr. A. St. Laurent,
Assistant Deputy Minister, Department of Public Works, Canada.
Mr. W. J. Stewart,
Chief Hydrographer.
Mr. V. W. Forneret,
Supt. Engineer, St. Lawrence Ship Channel.
Mr. John Kennedy,
Consulting Engineer.
Representing the Government of the Dominion of Canada.
Mr. James White,
Secretary, and
Mr. A. V. White,
Engineer, representing the Canadian Commission of Conservation.
Mr. David Seath,
Secretary, representing the Montreal Harbor Commission.
Mr. F. S. Spence,
Acting Chairman, and
Mr. E. L. Cousins,
Chief Engineer, representing the Toronto Harbor Commission.
Mr. R. W. Reford,
President, and
Mr. L. Henderson,
Chairman of Harbor and Navigation Committee, representing the Montreal Board of Trade.
Mr. Andrew Allan,
President, and
Mr. Thomas Robb,
Secretary, representing the Shipping Federation of Canada.

Mr. F. E. Meredith, K. C.,
Counsel representing the Shipping Federation of Canada, and representing the Canadian Pacific Atlantic Steamship Lines, and the Canadian Northern Atlantic Shipping Line.
Mr. J. V. O'Donahoe,
Assistant General Manager, representing the Richelieu and Ontario Navigation Company.
Mr. Francis King,
Counsel representing the Dominion Marine Association.
Mr. G. T. Blackstock, K. C.,
Counsel, and
Mr. D. H. MacDougall,
Secretary, representing the Toronto Power Company.

BRIEF SUBMITTED ON BEHALF OF THE GOVERNMENT OF CANADA IN OPPOSITION TO THE ABOVE APPLICATION.

The proposed diversion so far as it affects navigation not only upon boundary waters but also upon the waters of Lake Michigan and the St. Lawrence river, from the point where it ceases to be a boundary water, as well as the canal system, presents serious objections from the Canadian standpoint to the granting of the permit asked for.

First, dealing with the legal aspect of the case, it must be borne in mind that, by the terms of the second clause of Article I of the International Boundary Waters Treaty, it is "agreed that so long as this Treaty shall remain in force, the same right of navigation shall extend to the waters of Lake Michigan and to all canals connecting boundary waters, and now existing or which may hereafter be constructed on either side of the line," as is given by the first clause of that Article with respect to boundary waters, that is to say, "that the navigation of all navigable boundary waters shall forever continue free and open for the purposes of commerce to the inhabitants and to the ships, vessels and boats of both countries equally, subject, however, to any laws and regulations of either country, within its own territory, not inconsistent with such privilege of free navigation and applying equally and without discrimination to the inhabitants, ships, vessels, and boats of both countries."

It will thus, be seen that the second clause of Article I secures to Canada free and unobstructed navigation of the

waters of Lake Michigan from which the proposed diversion is to be made. In other words, it secures to Canada, in express terms, the right to navigate those waters in any manner which the natural flow will permit. It is submitted, therefore, that any interference with the natural flow which decreases the navigable capacity of Lake Michigan or renders its navigation difficult in any way, is an infringement of the letter and spirit of the treaty.

The right to navigate necessarily implies that vessels of both countries plying on Lake Michigan shall be entitled to make all harbours including Chicago, without being subjected to perils not ordinarily incident to the navigation of Lake Michigan. It has been shown, by reason of the diversion of 4,167 c.f.s. now existing, the current in the Chicago river is of such velocity as to render it extremely detrimental to the safe handling of vessels, and any increase in the volume of the diversion would be fraught with disaster to vessels using the port of Chicago. The testimony of those representing these interests is to the effect that the diversion already existing renders the navigation of vessels, bound to and from the port of Chicago, extremely hazardous having, it is said already caused loss of life and property by reason of the swift current arising from such diversion. A large number of vessels are engaged in the carrying trade between Chicago and Canadian ports, chiefly laden with grain outward from Chicago, and these vessels while plying to and from this latter port are exposed to perils by the extreme current caused by the diversion of the waters of Lake Michigan through the Chicago river, a danger which will become greatly augmented if the increased flow asked for is permitted.

The diversions for power purposes at Niagara Falls on either side of the line are not analogous as they do not affect navigation, the water taken being returned again and the levels in the navigable portions are not lowered. But, the diversion at Chicago from which there is no return, on the other hand, means an absolute and permanent lowering of the levels of the Great Lakes system from Sault Ste. Marie to the head of the tide at Lake St. Peter on the St. Lawrence river. It is of the highest importance that the Great Lakes system on the boundary between the United States and Canada and finding its outlet by the St. Lawrence to the sea, so vital to the prosperity of the great interior sections of both countries, should be maintained in its integrity.

It is significant, that while the framers of the International

Boundary Waters Treaty, basing their work on that of the International Waterways Commission, accepted the latter's suggestion as to the diversion on the Canadian side at Niagara Falls, and increased the amount to be diverted on the United States side to 20,000 c.f.s., they evidently ignored the Chicago Drainage canal regarding which the Waterways Commission had suggested that the diversion should be limited to 10,000 c.f.s. The fair inference is that neither country agreed to the recommendation of the Waterways Commission that the diversion from Lake Michigan to the Chicago Drainage canal should not exceed 10,000 c.f.s. At all events in the absence of any mention of the Chicago Drainage canal in the Treaty, it is contended that Canada never agreed to the proposed diversion of 10,000 c.f.s. The spirit of the treaty indicates that the levels of boundary waters on one side are not to be disturbed by works or diversions on the other without proper approval.

It will be observed that by the second clause of Article II of the Treaty, it is declared "that neither of the high contracting parties intends by the foregoing provision [clause 1 of Article II, reserving exclusive jurisdiction and control over the use and diversion of all waters on its own side of the line which, in their natural channels, would flow across the boundary or into boundary waters] to surrender any right which it may have to object to any interference with, or diversions of, waters on the other side of the boundary the effect of which would be productive of material injury to the navigation interests on its own side of the boundary." This second paragraph of Article II expressly opens the door to Canada to object to any diversion of waters of Lake Michigan to the Chicago Drainage canal so far as such diversion would be productive of material injury to the navigation interests on the Canadian side of the boundary.

Article III dealing with "boundary waters" provides that in addition to the uses, obstructions and diversions heretofore permitted "no further or other uses or obstructions or diversions whether temporary or permanent of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side . . . . shall be made except by *authority of the United States or Dominion of Canada*, within their respective jurisdictions *and with the approval" of the International Joint Commission.* The final clause, after stating that the foregoing does not limit the right of either country to carry on dredging for the deepen-

ing of the channels within their own territory, provided the level or flow of water on the other side is not *materially* affected, closes as follows: "nor are such provisions intended to interfere with the *ordinary* use of such [boundary] waters for domestic and sanitary purposes."

Bearing in mind the scope and object of the treaty, embracing, as it does, the conservation of boundary waters and the maintenance of lake levels, any diversion from their natural channels of waters on either side of the boundary which materially affects the levels of boundary waters, is a violation of the spirit, if not the letter, of the treaty.

In this connection a very grave question arises as to whether the Chicago Drainage canal is not a matter which might properly be referred to the International Joint Commission under the treaty, but, without insisting on that course at the present time, Canada expressly reserves the right to raise the question at a subsequent stage if it should be deemed expedient to adopt that attitude.

Another consideration which, it is submitted, ought not to be lost sight of is, that the diversion of 10,000 c.f.s. proposed for the Chicago Drainage canal is not an "ordinary use" for sanitary purposes, but an extraordinary use, unprecedented in its magnitude and unparallel in its method of abstracting and not returning the water after using it for sanitary purposes, whereas the Treaty contemplates "only *ordinary use* for domestic and *sanitary* purposes."

Then again, as the United States Government Engineers consider 1,000 c.f.s.—10 per cent. of the Sanitary District's application—sufficient for navigation, the question arises: is the balance of 9,000 c.f.s. necessary for the "ordinary use" of sanitation purposes. It is submitted that the diversion of such an immense quantity of water for sanitary purposes is not an "ordinary use" when it is remembered that it is a solitary and isolated instance of such user. If Chicago is to demand large bodies of water for diluting sewage, its demands on Lake Michigan will depend on its continued growth, and other cities and towns—following the precedent of Chicago—will be just as much entitled to adopt similar dilution methods for treating sewage by the abstraction of large quantities of water, if they find such a course practicable, with disastrous results to the Great Lakes waterways system.

Referring to the diversion of water through the Chicago Drainage canal, the report of a special Board of Engineers, which is signed by General W. H. Bixby, Chief of Engineers, United States Army, dated January 23, 1911, at pp. 8-9 says:

"For purposes of navigation a diversion from Lake Michigan of less than 1,000 second-feet of water is all that will be necessary. For purposes of sanitation the works of the Sanitary District of Chicago were designed to allow the diversion of 10,000 second-feet and now contemplate a total of 14,000 second-feet, the additional 4,000 second-feet to be obtained by the diversion of water through the Calumet River and a connecting canal following the Sag route. The War Department, while awaiting the definite action of Congress, has so far permitted the diversion of 4,167 second-feet, and the Sanitary District is understood to be using about 7,000 second-feet. As the water which is at present being diverted from the lake appears to have already seriously affected the navigation of its harbors and connecting waterways, prompt Congressional action is recommended to limit the diversion.

"While it appears to have been assumed that the Sanitary District may be allowed to divert 10,000 second-feet so long as actually necessary for sanitary purposes, the diversion of the waters of the Great Lakes from their natural outlet for power development alone is inadmissible under the recent treaty between the United States and Great Britain. The future diversion of water from Lake Michigan for any purpose is fraught with difficulties. Not only has Canada an interest in the maintenance of lake levels which the United States must recognize, but every foot of water flowing through the Chicago Drainage canal lessens the flow at Niagara Falls and at the power sites along the St. Lawrence river, where, due to the fall available, the same amount of water will create about four times the power that can be generated from it on the Des Plaines and Illinois rivers. The treaty enables riparian owners of Canada, as well as of the United States, who consider themselves injured by such diversion, to bring suit in United States courts to protect their interests. The claim that more than 1,000 cubic feet per second is required for purposes of navigation cannot be maintained. The treaty, however, recognizes as proper the use of water for sanitary purposes, and it is the opinion of the Board that only such water should be diverted from Lake Michigan as is indispensable for sanitation, and then only with a provision for proper compensating works in the outlets of the lakes to prevent a lowering of their levels. Water thus diverted may be used incidentally for power purposes, but care must be exercised in authorzing the diversion of water for sanitary purposes to restrict it to the amount necessary for those purposes alone."

Extract from Appendix E, attached to the Chicago Harbour Commission Report (1909), where General W. H. Bixby, at page 313, says:

"There is another feature, while I am on the harbourage of Chicago—the Chicago river affects the entire Great Lakes system. The interests of all other harbours on the Great Lakes are entitled to a great deal of consideration in anything that is done in the Chicago river."

And, again, on the same page:

"The War Department holds every engineer in charge of districts responsible for protecting and safeguarding navigation needs of the general public. That includes the commerce on the Great Lakes that wants to come to Chicago, just as much as the commerce of Chicago itself that does not get outside Lake Michigan."

The report of the International Waterways Commission, dated January 4, 1907, at page 180, says

"The depth in the Welland canal and in the six canals employed to overcome rapids in the St. Lawrence river is now 14 feet, of which every inch is needed. At the head of the Cornwall canal in the St. Lawrence river the abstraction of 14,000 cubic feet of water per second at Chicago will lower the surface about 6¾ inches at mean level and much more at low water. To restore the depth in these canals involves the reconstruction of all the end locks and deepening the approaches thereto, and is estimated to cost $2,500,000.

"The total cost of restoring the depth in the harbours of the Great Lakes and the channels between the lakes is therefore roughly $10,000,000, and of restoring it in the Welland and St. Lawrence canals is $2,500,000 additional, or $12,500,000 in all.

"The shores of the Great Lakes are very far from being fully developed, and it is highly probable that many harbours not now in existence remain to be created, or, if in existence, remain to be improved. The lowering of the lakes' surfaces increases the difficulty and cost of such improvements. This consideration is of importance, although no money value can now be given it.

"The expenditure of the sums mentioned above will restore the depths now existing, but it will not prevent very serious annoyance to the navigation interests during the execution of the work. The time required will be several years, and in the meantime the vast commerce of the Great Lakes will be hampered, not only by deficient depth, but also by the

occupation of the channels, already crowded with commerce, by the excavating machines.

"It is evident from the foregoing that large bodies of water cannot be diverted by the Chicago Drainage canal without very serious detriment to the navigation interests of the Great Lakes and of the St. Lawrence valley. The greater the amount of water diverted the greater the injury. Chicago being one of the principal lake ports, there will be very few communities which will feel this detriment more than she will.

"In the presence of these interests the effect upon Niagara falls may be simply mentioned with a reference to our former reports upon that subject. The volume of Niagara falls will be reduced by the full amount diverted at Chicago."

Again, the same report, at page 181, states:

"The Chicago Drainage canal having been constructed with a capacity, as it turns out, of 14,000 cubic feet per second, full power development will call for the whole of that amount, and, in fact, power works are now under construction at Lockport to utilize it. Inasmuch as the sanitary requirements by the standard, fixed in the state law, are only 6,667 cubic feet per second for the present population of 2,000,000, it is evident that power development, incidental though it be, does lead to demands for waters not required for sanitary purposes."

The same report, again, at page 184, says:

"The diversion of 10,000 cubic feet per second will lower the levels of Lake Michigan-Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence river, besides the important connecting channels, the Detroit and St. Clair rivers, by amounts varying from 4¼ to 6¼ inches for the different waters, and the diversion of 14,000 cubic feet will lower them from 6 to 8¼ inches. The diversion of 20,000 cubic feet will lower Lake Michigan-Huron about 13 inches and Lake Erie about 11 inches.

"The lake traffic which passed through the Detroit river in 1905, was about 58,000,000 tons, valued at about $615,000,000. It is increasing annually, with marvellous rapidity. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit river in 1906, exceeded 65,000,000, valued at $690,000,000. The lowering of the water surface has a very injurious effect upon this traffic, and upon that of the Welland and St. Lawrence canals."

And, at page 211, it states:

"The extension to the Calumet region of the method of sew-

age disposal already applied to the Chicago river is not necessary to preserve the health of Chicago, there being other and better methods available for the Calumet region. The final cost of these methods is somewhat greater than that of the one proposed, but the works can be developed as the population increases, and only a part of their cost need be incurred at present, while their greater efficiency justifies the increase of final cost."

By Article XXVI of the Treaty of Washington, May 8, 1871, it was provided that "The navigation of the river St. Lawrence, ascending and descending from the 45th parallel of north latitude, where it ceases to form the boundary between the two countries, from, to, and into the sea, shall forever remain free and open for the purposes of commerce to the citizens of the United States, subject to any laws and regulations of Great Britain or of the Dominion of Canada not inconsistent with such privilege of free navigation." It is, therefore, apparent that the Government of the United States, equally with that of Canada, has a direct interest in protecting the navigation of the river St. Lawrence, as it appears that the free navigation of that river is open in perpetuity to citizens of the United States where it passes wholly through Canadian territory.

The State of Illinois, in response to the Treaty of Washington, (May 8, 1871), by Act of the General Assembly, approved April 4, 1872, granted "The use of the Illinois and Michigan canal, and all other canals that may be constructed by this State" to the citizens of the Dominion of Canada, on equal terms with citizens of the United States.

By treaties now in force, the Great Lakes waterways from Lake Superior to the sea, including all boundary waters as well as Lake Michigan in the United States, all connecting canals and the St. Lawrence river including that portion which flows wholly through Canadian territory, are open to the free navigation of both countries. The United States and Canada are equally concerned in maintaining unimpaired this great water highway for the benefit of the commerce of both countries.

In view of objections arising from the impossibility of preserving navigation unimpaired on the boundary waters, treaty rights covering such waters and the navigation of Lake Michigan and the St. Lawrence to the sea, international relations and comity as well as the impossibility of providing adequate compensation for injury to Canadian interests, both

public and private, it is urged that the permit asked for, should not be granted.

That the proposed diversion will be productive of material injury to the navigation interests on the Canadian side of the boundary, there is abundant evidence, a statement of which has been prepared by technical officers from the Canadian Government Departments of Public Works, Naval Service, and Marine and Fisheries, also the Montreal Harbour Commission, as follows:

In the following memorandum it is proposed to show that a diversion of 10,000 c.f.s. at Chicago through the Drainage canal will lower the water of all the lakes below Sault Ste. Marie, as well as of the St. Lawrence river as far east as Lake St. Peter.

That it will entail heavy losses upon Canada for the restoration of the lost depths in harbours and channels in the Great Lakes and St. Lawrence river.

That Canada must expend large sums on her canal system to render it as useful as it was designed to be.

That it will cause heavy loss to the inland marine interests and to shipping below Montreal, by reducing the draft and carrying capacities of the vessels.

That much of this loss must be borne by the consumer.

That many outlying shoals will be more dangerous to navigation under the new conditions than at present.

That injury will be done to many owners of private wharves by reason of the depth of water at, and approaching them, being reduced.

That injury will be done to many wharves and breakwaters that have been constructed of concrete on wooden cribs, by reason of the wood becoming exposed to the air for long periods, allowing rot to set in and imperilling the superstructure.

That granting 10,000 c.f.s. for power means a huge waste of energy as the same amount of water would generate much more power by the other route.

That the diversion of any quantity of water from Lake Michigan will lower the levels of all the lakes below Superior, hardly requires proof in these days, but the case may be stated briefly:

As the promoters and backers of the scheme assert, it is impossible to show on the lake shore, or on a gauge, the effect of a diversion. One cannot see, at the same time, the water level under natural conditions and under diversion but the

loss can be demonstrated as surely as any mathematical problem.

The following table will show the mean level of the lakes for 52 years and the lowest monthly mean.

Lakes	Mean of 52 Years	Lowest Monthly Mean
Huron-Michigan	581.35	578.98
Erie	572.59	570.70
Ontario	246.18	243.41
St. Lawrence R. (Rapide Plat)	224.8 (mean of 28 yrs.)	221.44
" (Head of Cornwall Canal)	201.07 " "	198.05

It is found by measurement and computation (see Report of International Waterways Commission on the Regulation of Lake Erie, p. 53), that the discharge of Lake Huron at Port Huron is 16,300 c.f.s. more when the lake surface has an elevation 580, than when it has one of 579; or, one foot of rise (near low water) means a difference in discharge of 16,300 c.f.s. Therefore, an increased discharge of 10,000 at or near low water means a lowering of 10,000/16,300 ft. or 7.4 inches.

If Lake Huron suffers a decrease in discharge of 10,000 c.f.s. at Port Huron, Lake Erie suffers a decrease in supply of the same amount which may be treated as an increase in discharge causing a loss of level. The same remark applies to Lake Ontario and the St. Lawrence river as far as tide water.

In Lake Erie the change in discharge for one foot change of level near low water, is 19,600 c.f.s. Therefore, an increase in discharge of 10,000 c.f.s. means a lowering of 10,000/19,600 ft. or 6.1 inches.

In Lake Ontario the change in discharge for one foot change of level near low water is 26,800 so that an increase in discharge of 10,000 c.f.s. means a lowering of 10,000/26,800 ft. or 4.5 inches.

At Rapide Plat, in the St. Lawrence river, the increment is 17,500 and the lowering is 6.8 inches.

At the head of the Cornwall canal the increment is 24,350 and the lowering 5 inches.

Loss of level on Lakes Huron, Erie, Ontario and the St. Lawrence river under the actual diversion and under assumed diversions of 10,000 and 14,000 c.f.s. through the Chicago Drainage canal:

Lake.	Actual Diversion	Loss of Level Assumed Diversion of 10,000 c.f.s.	14,000 c.f.s.
	Inches	Inches	Inches
Michigan-Huron	3.07	7.4	10.3
Erie	2.6	6.1	8.6
Ontario	1.9	4.5	6.3
Rapide Plat	2.8	6.8	9.6
Cornwall Canal	2.1	5.0	6.9
Coteau	2.2	5.4	7.6
Montreal	4.3	10.25	14.4
Lanoraie	2.2	5.4	7.6
Sorel	2.5	6.0	8.4

It is represented in the pleadings of the applicants that the fluctuations of the lake levels, some of which are undulations of surface recurring every few minutes, some of which are larger fluctuations occasioned by storms and barometric changes, others of which are semi-annual, the level being highest in summer and lowest in winter, and, still others extending over long periods or cycles of say seven to ten years, are so great and so irregular that a lowering of the lake levels of even six or eight inches cannot be distinguished and is not, therefore, detrimental in practice to navigation interests, because vessels must always load so as to be prepared for the lowest levels of water which are likely to occur during the time of any trip. This is denied on behalf of Canada because whatever might be the natural level of the lakes, at any particular season or moment, that level would always be reduced by artificial lowering. If, for example, it would at a high water season or high water movement, under natural conditions, be 24 inches above the average level it would, by the artificial lowering of 7 inches, be reduced to only 17 inches above the average; and, if at a time of low water when under natural conditions the level would have been 24 inches below average, it would, by the artificial lowering, be reduced to 31 inches below the average; and, as the practice of the larger vessels is to load to the greatest safe draft in time of high water as well as in time of low, the reduction of level would be detrimental in time of high water as well as in time of low, and the detrimental effect of artificial lowering of the water would therefore be felt at all times and under all conditions.

For example since 1900 there have been only 17 months in which the level of the lake has been as high as the average of 52 years (viz. 581.35). In every case had this diversion been in existence the level would have been below. In addition to this in five months in that time the lake would have been lower than the lowest mean 579.0.

As the water at the foot of the Sault Ste. Marie canal is

only from a foot to a foot and a quarter above that of Lake Huron it follows that any fall of lake level will cause a similar drop at the canal, the lower sill of which is a barrier that all vessels trading to Lake Superior must pass. When Lake Huron is at its extreme low level of 579.0 the Poe lock sill will have over it only 17.43 feet, and the Canadian 17.76 feet. Reduce this by 7.4 inches when each inch in draft means 25 to 110 tons of freight according to size of vessel, and it will be seen what a heavy toll will be exacted from the lake carriers.

In the St. Lawrence river any interference with the depth is very serious. All freight vessels passing east, take advantage of the smaller rapids, such as those opposite Cardinal, Rapide Plat, and Farrans Point, to shorten the passage by escaping the tedious process of locking down. In Rapide Plat these vessels experience no difficulty at mean water, but, when a less depth rules, they either take the canal or lighten their cargoes. Take six inches off the depth, the rapids must be avoided during all low water seasons.

When the dredging operations were undertaken a few years ago certain depths were decided upon and the vessels trading to the various ports always load to the last inch allowed. A reduction of this depth makes it impossible to load so deeply and the harbous and channels must be dredged to allow trading under the old favourable circumstances.

An approximate estimate, by officers of the Canadian Department of Public Works, of the amount that will be required to place the harbours in Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Detroit river, St. Lawrence river, not including entrances to canals near Montreal harbour, in the same condition as without diversion places the cost at not less than $11,367,000.

All canals have been designed for a certain draft at low water, Sault Ste. Marie 18 feet and the others 14 feet. If this diversion be permitted five to eight inches will be taken from these depths and much of their usefulness will be gone.

At Sault Ste. Marie, to repair the damage done by this diversion will mean the reconstruction of nearly the whole lock, because the lower sill and bottom must be lowered over seven inches. In addition the lower approach for a long distance must be deepened the same amount.

The same remarks apply to the upper and lower locks, the guard locks, the upper and lower approaches and the upper reaches of the Welland, Galops, Morrisburg, Farrans Point, Cornwall, Soulanges, and Lachine canals, the lower lock and

entrance to the Trent and Rideau canals, and the deepening of the Murray canal and approaches in which there is no lock. The engineers of these canals estimate the cost of this work at not less than $6,640,000.

Montreal, Canada's national harbour, with its 160 miles of improved channel and approaches, will suffer from this loss of water. The river will be affected from Montreal to tide water. Many millions of dollars have been spent in deepening and improving the channel. As autumn approaches the minimum depth of thirty feet is only available and vessels are compelled to observe great care in loading. Any reduction in this is serious to the vessel owner, the shipper and consumer. The lakes, to a large extent, feed the river and any diversion causing a diminution of supply from them must be opposed.

To restore depths in Montreal harbour and the ship channel it is estimated will cost not less than $930,000.

From these figures from Canadian harbours, Canadian canals, Montreal harbour and the ship channel, it will be seen that $18,937,000 at least will be required to restore conditions, as regards depths upset by this proposed diversion through the Chicago Drainage canal. This amount would be really a contribution from Canada to that work and should be considered in striking estimates for comparing that project with other means of sewage disposal.

From this it will be seen what an effect this diversion will have upon the most important inland waterway in the world. The damage is not only to the lakes, but to the immense works that have been constructed that we may derive the very fullest advantage from them, viz. the connecting rivers, canals, and harbours. Whilst the United States Government is interested in expenditures necessary to restore depths in its Soo canals, improved rivers, St. Clair Flats canals, and numerous harbours, Canada is vitally concerned in the same way in her harbours, her unequalled canal system and her national port of Montreal.

To allow anything to impair such vast improvements would be a retrograde movement in two ways, namely, sacrificing work already completed and allowing a loss of valuable water for dilution of sewage that might, and should have been, attended to by other more modern and sanitary methods. Other cities less wealthy and less important are compelled to look after their sewage without injuring neighbouring communities and why not Chicago? Had the divide not been there

they would have ere this completed the sewage disposal plant that must be undertaken very soon.

This loss in carrying capacity will be felt not only in nearly all the autumn months when we experience the annual low water, but also in all except the very high water years, it will mean earlier, longer and more frequent periods of low water, such as pertain now, as well as a lower low water than nature intended. In the autumn, grain from the western provinces is rushed to the head of Lake Superior and it takes the whole fleet all its time to prevent the elevators being filled before the close of navigation. If the carrying capacity of every boat is reduced from 150 to 100 tons each trip, congestion is sure to come and this is a condition the Canadian Government is trying to prevent.

That these seemingly small changes are important and divert traffic may be seen from the fact that in 1905, when the water in Lake Huron reached a minimum of 580.66 during the season of navigation and had a mean level for the year of 580.95, there passed east through the American canals at the Soo 32,632,268 net tons and through the Canadian canal only 4,146,740 net tons. Practically all the large carriers with grain, iron ore, flour and wheat passed through the United States canals.

In 1910 when the water in Lake Huron reached a minimum of 579.51 during the season of navigation and had a mean level of only 580.15 the Canadian canal with its three inches more water carried the bulk of the heavy freight east and passed nearly all the large carriers, the figures being Canadian canal 31,531,036 tons, and United States canals 15,602,673 tons.

That is to say, that, with plenty water, (19.89 feet to 20.78 feet in the Poe lock), the Canadian lock passed only 11.3 per cent of the freight, but, with low water (18.08 to 18.73 feet in the same lock) the extra three inches in the Canadian lock increased these figures to 67 per cent.

Under the present rapid development of our country, the question of improving our waterways and harbours and providing adequate transportation facilities, is a most vital one. Our main transportation problems are along an east-and-west line, with the distances very great. Cheap rates of transportation are a necessity for interchange of products at fair prices between the East and the West, and nothing helps more to provide this result than the improvement of our natural water transportation routes and supplying adequate depths in our channels and harbours.

Acting upon the assumption that all channels connecting the lakes were to have a depth of 20 feet at extreme low water and that our canals were to have 14 feet over their sills the vessel owners and the naval architects on both sides of the line set themselves to the problem of evolving the most economical freight carrier under these conditions, and they can, with truth, say they have given us the cheapest transportation system in the world. This was all done on the assurance of the governments that such would be the case, provided only that nature did not upset calculations by allowing the water to recede beyond anything ever observed.

If now the Government allows this Sanitary District to step in and take six to seven inches off the depth intended, these vessels are no longer what they were designed for, that is to say they carry a far less load than is economical and at the same expense, because each inch in draft means from 25 to 110 tons freight. If this new condition is to remain constant a new style of vessel must be designed and the old relegated to the scrap heap, as virtually happened the carrier of five years ago. Or if the depths are to be restored they will labour under a disadvantage for many years probably the balance of their lifetime. Knowing the extent of the lake commerce one can easily see the huge loss to the vessel owner and eventually to the consumer of the freight.

In the grain carrying trade of Canada there are 70 vessels, 61 of which are what is called Welland Canal size, and 9 larger.

Every inch of draft means a difference of 22 tons in carrying capacity in the canal sized vessel and the others average 53 tons, so that every trip means a loss of 1,342 tons per inch for the Canal fleet and 477 tons for the larger vessels.

During the season the Canal vessels will make twelve trips or total loss per inch draft of 16,104 tons, or for 7½ inches less water 120,780 tons at $2 per ton, $241,560. During the season the other nine vessels trading to Georgian bay and Lake Erie will make 28 trips, or a total loss of 13,356 tons per inch, or 100,170 tons for 7½ inches at 40 cents per ton, this represents a loss of $40,068, or a total loss per annum of $281,628 to the lake freighters in freight charges alone.

This loss will not be borne by the vessel owners so that freight rates will be raised and the consumer be compelled to pay. In addition to these losses, much Canadian freight, coal and grain is hauled in United States vessels and of this we have no record, but the quantity is not small.

The Canadian grain carrying fleet can in one trip transport 8,000,000 bushels of wheat.

Every inch means 60,000 bushels, 7½ inches, 450,000 per trip. For 23 trips to Georgian bay or Lake Erie 10,350,000 bushels or more than the capacity of the full fleet for one trip.

This is a matter which concerns not only the shipping interests, but, in deed, the welfare of the whole Dominion. Our trade is developing so rapidly that we cannot cope with the demands for necessary and immediate improvements in our rivers and harbours. At the present moment, when this country is compelled to make enormous expenditures to meet the exigencies of increasing trade by giving transportation facilities, why should existing conditions be rendered more difficult for the Dominion, to benefit a city that could have solved its problems of water supply and sewage disposal by some other methods, than by diverting a large volume of water, which is bound to affect detrimentally the most important internal system of navigation in the world.

To grant the requested diversion is a retrograde step in the development of our transportation system on the Great Lakes, when it is necessary that all energies should be directed towards the advancement and furtherance of the movement for improvement in transportation facilities.

The damage accomplished by the lowering of the lakes all St. Lawrence levels cannot be computed and shown simply by the loss of carrying capacity in tonnage for vessels. There is more to consider; the loss to the public at large in delaying cheaper rates; the loss to the country in rendering all harbour and channel improvements more costly and retarding their completion.

Mr. Hering in his report dated 15th October, 1907, page 35, to the President of the Sanitary District says that if the lowering of the lakes amounts to 6 to 8½ inches on a diversion of 14,000 c.f.s. the prohibition of that amount would certainly be in the interest of Chicago no less than of the entire lake region. We have shown that near the low water stages the lowering is from 4½ to 7½ inches for a 10,000 c.f.s. diversion, and surely if such a strong advocate of the Drainage canal would stop diversion for a lowering of 6 to 8½ inches, less enthusiastic persons are justified in asking for that treatment when the lowering is 4½ to 7½ inches.

Mr. Hering in the same report, same page, suggests a remedy in the shape of converting Lake Superior into a storage reservoir. The question of Lake Superior storage was taken

up by the International Waterways Commission in connection with its report on the Regulation of Lake Erie (see pp. 76-81) and the conclusion reached was that "the use of Lake Superior as a storage reservoir cannot be successful if navigation is to be maintained unimpaired on Lake Superior and the St. Mary river."

A dam and controlling works at the outlet of Lake Erie have been suggested to regulate the level of Lake Erie and incidentally raise the low-water level. A careful study of this proposal by the International Waterways Commission has shown that it is not feasible.

All compensation schemes are fraught with great difficulties both physical and international. No dams or weirs can be constructed in the boundary waters without the sanction of both countries.

Many shoals and reefs that are just dangerous will become very much so by having less water upon them and extending further into navigable channels. As it is not usual to remove these, extra buoys must be placed.

As government harbours, wharves and piers are affected injuriously, so private parties, not very well able to afford dredging will be compelled to shoulder their losses. True they can by treaty enter action in the United States courts and claim damages, but no private citizen can or will ever avail himself of this right unless his loss be very great.

With the fall of the water to a new datum mark below that on which all harbour works have been constructed, many crib foundations that carry concrete superstructures will have their upper timber exposed for long periods and rot will set in to the injury of the concrete. This is a damage that cannot be easily estimated and none has been allowed.

The diversion of 10,000 c.fs. is used to create 56,000 horse power at Lockport and Joliet, but the same quantity of water used for power by the St. Lawrence route would give nearly 300,000 h. p.

As the final diversion for the dilution method of sewage disposal rested upon the question of comparison of cost to the people of Chicago of it and other feasible methods, it would appear that outside communities and interests were neglected. Had the citizens of Chicago been told that they must restore conditions in Canada at a cost of $18,937,000, and in other lake harbours at fully the same cost, they would have learned that the dilution method would prove by long odds the most expensive.

This diversion is a matter of great importance to Canada on account of her peculiar make up. A vast area of wheat producing territory separated from the manufacturing section by a long extent of non-productive wilderness. West of the Great Lakes district is her vast undeveloped grain producing area, only a small fraction of which has yet been touched. For many years the bulk of its produce must be exported and for such freight the bulk freighter is at once the cheapest, most convenient and best. Canada is now completing her third transcontinental railway but all the world knows land transport cannot cope with such a system as nature has offered in the Great Lakes and the St. Lawrence. Canada contemplates vast expenditures in the near future in her Welland, St. Lawrence and Ottawa river canals to enable her to take better advantage of her great inheritance and it would be both criminal and suicidal to throw away what nature has thus provided.

This question of diversion is a dangerous one to play with; it will not down with this application. Chicago will not be satisfied now and there is little reason why the next request for diversion should not come from some community to divert directly from Boundary waters with as great injury to navigation as this will be. If one community be granted such great privileges, it will be most difficult to refuse others.

Whereas the application of the Sanitary District state "that it has for some time been engaged in investigating methods and devising plans for the treatment of the sewage with a view to requiring less water for its safe dilution in the future. The methods of other states and countries for such treatment of sewage are not as yet entirely satisfactory to all concerned and any changes of methods for large cities must necessarily require several years." And Mr. Williams, counsel for the Sanitary District, in his argument at the hearing on the 28th of February last, discussed the case from this standpoint.

In answer to this branch of the case the following statement is prepared by Mr. John Kennedy, Montreal, assisted by Mr. R. S. Lea, and Prof T. A. Starkey, M. D., and submitted:

In the present application what is asked is "Permission for the Sanitary District of Chicago to withdraw from Lake Michigan through the Chicago river and Calumet river—not to exceed 10,000 cu. ft. of water per second." It would be physically impossible to withdraw the desired water from Lake Michigan without first stopping and otherwise disposing

of the natural flow of these rivers and reversing their flow to such extent as to draw inward from Lake Michigan the 10,000 cu. ft. per second asked for, and the effect of so doing would therefore be the abstraction from the water supply of Lake Michigan all the natural flow of the rivers in addition to the 10,000 cu. ft. of lake water which it is desired to draw inland. The estimated average natural flow of the Calumet river into the lake is about 800 ft. per second, and that of the Chicago river is about 300 cu. ft. per second, which, added to the 10,000 ft. of fresh water it is desired to withdraw from the lake, makes a quantity of 11,000 cu. ft. per second of the water supply of Lake Michigan, which would be directly and indirectly abstracted from it, and turned into the Chicago Drainage canal and thence into the Mississippi. The effect of the abstraction of this quantity upon the level of Lake Michigan, of Lake Huron and of Georgian bay to which it is joined would be to permanently lower their surface about seven inches.

It is, therefore, to be clearly understood that the granting of the request of the applicants as it stands would allow both the drawing of 10,000 second feet of water directly from the lake and diverting from its ordinary supply the flow from the Calumet and Chicago rivers making in all about 11,000 ft. per second, will most seriously damage navigation.

The application states that the flow from Lake Michigan as permitted by the Secretary of War is limited to 4,167 cu. ft. per second. In the report on the Sewage Disposal of the Sanitary District by Mr. George M. Wisner, October 12th, 1911, it is stated that the average flow during June, July and August, 1911, was 7,065 cu. ft. per second. The application further states that the present population whose sewage is to be disposed of exceeds 2,500,000 persons and is rapidly increasing and that the only method at present available for disposing of the sewage of this population is by diluting the same with water withdrawn from Lake Michigan and flowing through the Chicago Drainage canal. It is further added that at least 1,000 cu. ft. per second is required to dilute the sewage of 300,000 people in this way and hence it is alleged that the quantity at present permitted to be withdrawn is insufficient.

The statement that dilution is the only method at present available must be understood to mean that Chicago has not so far adopted any other method, and not that no other method could have been adopted or has been made available. The

fact is that Chicago has taken no measures whatever so far to purify its sewage, although methods of sewage purification have been studied and brought into successful use in a great many cities in Europe and also in America during the last thirty or forty years.

For example, the city of London (dealing with sewage of 6,000,000 people) before discharging its sewage into the river Thames, removes the sludge or suspended matter by chemical precipitation, the sludge being then carried to sea in tank steamers.

In Manchester, England, the sewage of a population of about 600,000 people is first treated and then turned into the Manchester Ship canal, not only without causing any nuisance, but actually improving the canal water as supplied by its feeder, the Irwell river. These works have been in operation since the year 1900, or about the time of the opening of the Chicago Drainage canal. The method of purification employed there is by septic tanks and contact beds and is referred to in the report of Mr. Wisner (p. 26) as one of the methods considered for the purification of certain portions of some of the outlying districts of Chicago.

In Birmingham, England, the sewage of a population of practically 1,000,000 people is purified by tank treatment and sprinkling filters and is then discharged into a stream whose ordinary flow is only about 45 cu. ft. per second, or considerably less than the volume of the purified sewage. Dozens of other cities in England similarly discharge their treated sewage into comparatively small streams.

In the Emscher district, in Germany, with a population of about 2,000,000, the sewage is being purified and turned into a stream whose natural flow is from 200 to 300 cu. ft. per second.

In America, the city of Columbus, Ohio, with a population of about 175,000 people, purifies its sewage by tank treatment and sprinkling filters. The effluent is then discharged into the Scioto river, whose average flow varies from 30 to 50 cu. ft. per second. This dilution for the present population is much greater than that at Birmingham, but still amounts to less than ½ cu. ft. per second per thousand of population.

The city of Baltimore, Maryland, with a population of over 700,000, has installed a plant consisting of tanks and sprinkling filters for the purification of its sewage. It is proposed to further treat the effluent from this plant, already inoffensive and nonputrescent, by filtration through sand or

by chloride of lime, for the purpose of removing or destroying the germs, so as to protect the oyster beds down the river.

Toronto, with a population of 450,000, not only purifies its sewage by sedimentation, but, in addition, filters its whole water supply.

It is to be noted that in all these cases of proper sewage purification the quantity of water for diluting the final effluents is quite insignificant.

Elaborate series of experiments and investigations have been made during the last twenty or thirty years or longer. Notable among these are the experiments of the Massachusetts State Board of Health, which have been carried on continuously at the Experimental Station at Lawrence since 1887; the Manchester experiments (1896 to 1899), experiments at London, Birmingham, Leeds, and several other places in England; experiments carried out by Dr. Calmette at Lille, France, and by Dr. Dunbar, in Germany, and upon the results of these experiments a great many plants have been built and are successfully operating in practice, so that the subject of purification of sewage is far beyond the experimental stage.

These references prove that methods for dealing with sewage are available, and have been available for the last fifteen or twenty years, which are not only superior in every way to the dilution method, but are undoubtedly better for the preservation of health, which is the point urged in the application.

Mr. Hering in his report to the International Waterways Commission (December 15, 1905, p. 228) comes to the following conclusions as regards the comparison between purification and dilution methods:

"3. The extension of the dilution method to the outlying territory is not the only way of preserving the lives and health of the people of Chicago.

"4. For the Calumet area, as well as other districts, there are several methods for the disposal of sewage as effective as the present method of dilution in preventing the pollution of the lake waters."

Mr. Hering, in a subsequent report on the Sewerage of the Calumet District, addressed to the President of the Sanitary District (October 15, 1907, pp. 32-3), in discussing the question of choice as between the purification and dilution methods, expresses an opinion that the choice is largely governed by the question of the annual cost as represented by a balance between expenses and receipts, and that the dilution method for a population up to about 1,000,000 is the cheapest

only because it admits of disposing of water-powers created by the water used for dilution (4,000 cu. ft. per second) which he estimates at 22,500 horse-power.

It should be here noted that the basing of choice of methods as between dilution and purification on the returns yielded by the development of water-power, is wholly unjustifiable; because it is based on the taking of water from Lake Michigan to the damage of fast navigation and other interests throughout the whole extent of the Great Lakes, their connecting rivers, and the St. Lawrence, and a great lessening of the power which may be developed on the Niagara and on the St. Lawrence rivers.

Mr. Wisner, Chief Engineer of the Sanitary District, in his report of October 12, 1911, which report is indorsed by Mr. Elicott, Electrical Engineer, and by Messrs. C. D. Hill, W. A. Evans and Martin C. Schwab, members of a commission appointed by the Trustees of the Sanitary District, has arrived at practically the same conclusion as to the efficiency of the purification by tanks and sprinkling filters. He says in substance, as regards the Calumet District that even for the dilution method, tank treatment for the elimination of solid matter will be necessary and that at a later date it will be necessary to instal sprinkling filters or other treatment in connection with the settling tanks, and goes on to indicate sites suitable for the installation of the purification plants.

A similar method of treatment is recommended for the 39th street pumping station, the North branch and other districts, that is, the installation of sedimentation tanks followed later by sprinkling filters.

All the cases cited, many more which could be cited, and the above quoted opinions of the engineers of the Sanitary District go to prove that it is not necessary to withdraw water from Lake Michigan and to dispose of the sewage of either the City of Chicago or the outlying districts by the dilution method, but that methods of purification of sewage are not only feasible but are adopted with satisfactory results to the lives and health of other communities and can also be adopted with the same results for Chicago and its outlying districts; and that not only would this have the effect of ridding Lake Michigan of much pollution but it would rid the Illinois and Mississippi rivers of the large quantities of sewage, diluted though it be, which the present method of dilution pours into them. It is to be noted also that the experience of other cities, notably the experience of Manchester with the Man-

chester Ship canal, shows conclusively that the natural discharge of the Chicago river plus say 1,000 second feet drawn from Lake Michigan for navigation purposes, would be amply sufficient to carry away through the Drainage canal the purified effluents of Chicago and the whole Sanitary District.

Although not stated in the application, it is obvious that the desired 10,000 second feet of water is intended to be used to assist in conserving life and health by making it possible to discharge the untreated sewage of two and a half millions of the people of the Sanitary District into the Illinois river instead of into Lake Michigan and thus endeavor to prevent the lake water being made unfit for domestic use, but the fact is that the lake water in the vicinity of Chicago is tainted and unwholesome whether the sewage be kept out or not. Chicago is at the stagnant end of what is practically a stagnant lake, fed only by small streams, nearly of all of which discharge into the sewage of a large and rapidly increasing population and the drainage wastes of large and growing industrial establishments. The lake is further polluted by the sewage discharged by trading and passenger steamers which everywhere traverse its waters and throng its ports and which are especially numerous at Chicago. The effect of drawing so great a quantity of water as 10,000 second feet from the lake at Chicago is therefore to draw toward the waterworks intakes the worst water of the lake and to that extent not to conserve but to injure the health of its people.

Milwaukee, on the side of the lake and, therefore, in a better situation than Chicago for obtaining wholesome water from it, has found it necessary to adopt measures both for treating its sewage and filtering its water supply.

Lake Ontario is not a stagnant lake but has the Niagara flowing through it and a less dense surrounding population than has Lake Michigan, yet is so impure that the city of Toronto has deemed it wise for the preservation of health to instal a large and modern filtration plant for its water supply and a sewage purification plant in addition.

Montreal, which takes its water supply from the river St. Lawrence—the outlet of Lake Ontario—and is situated at the foot of a series of great rapids which tend to purify the water, is also installing a great filtration plant to purify its supply. A neighboring waterworks system which serves nearly all the suburban towns, is doing the same.

Cleveland, on Lake Erie which has the Detroit river flow-

ing through it, is understood to have also determined upon the installation of a waterworks filtration plant.

Chicago, because of its peculiar position and its vastly greater land and floating population is in far greater need of a waterworks filtration plant in order to obtain pure water and thus really conserve the life and health of its people. With such plant installed and any modern system of sewage purification adopted, there would be no need for drawing such large quantities from the lake as to be detrimental to the navigation interests and to the whole chain of the Great Lakes and their outlet rivers.

The application states that the Sanitary District has been engaged for some time in investigating methods and devising plans for the treatment of the sewage with a view to requiring less water for its safe dilution in future, and goes on to say that, until these experiments are concluded and proper works installed, the use of additional water from Lake Michigan is essential to the health of the large population of the City of Chicago and the Sanitary District. Mr. Williams, in pleading, says, that these experiments have already been carried on for two and a half years at a cost of $100,000, which is equal to an average cost of $40,000 per annum. Mr. Hering, in his report of 1907, states that the desired 10,000 cu. ft. per second discharged through the Drainage canal will produce at Lockport, 20,000 horse-power, and at Joliet, 27,300 horse-power, which, at an estimated value of $25 per horse-power, will produce an annual revenue of $1,407,500. Obviously, it will be very profitable to continue the experimental station indefinitely, because the annual returns from the sale of power will overbalance the annual cost of continuing investigations at the experimental station by $1,367,500; and, under such conditions, it cannot be expected that Chicago will be in any great haste to cease investigations and adopt one or more of the well known methods of sewage purification and, thereby, deprive itself of the plea of necessity for drawing the water from Lake Michigan, which yields such enormous profits in the selling of power.

The effect of drawing the quantity of water already drawn from Lake Michigan, and passing it through the Chicago river and Drainage canal, was shown at the hearing of the 28th of February, 1912, before the Secretary of War, to be decidedly detrimental to the use of the Chicago river as a navigation channel and harbour basin, by reason of the strength of the current which is created, and the passing of

10,000 second feet, for which permission is now asked, would be greatly more so. The increase in the quantity of water passed through the river wil increase the velocity of the current in direct ratio, but increase of velocity increases its dynamic force, that is, its damaging power in the handling of vessels, as *the square of the velocity*. The quantity of water which may be drawn from the lake under the existing permission of the Secretary of War, is 4,167 second-feet, but the actual quantity, according to Mr. Wisner's report (diagram p. 6) is about 7,000 second-feet, the actual effect is to increase its damaging forces 2.8 times and the effect of passing 10,000 second-feet would increase its force 5.75 times. Similar effects are, and would be, produced in the Drainage canal. The 4,167 second-feet which may be drawn from the lake under the existing permission, plus 300 second-feet the intercepted average natural discharge of the Chicago river, and, say, 1,100 second-feet pumped by the Chicago waterworks for city use makes a total discharge through the Drainage canal of 5,567 second-feet. This, in the rock section of the canal having a cross section of waterway of 161′ x 22′ makes a current of about a mile an hour which is quite safe for navigation but, if the draft through the Chicago river be increased to 10,000 second-feet plus the 300 second-feet from the Chicago river and 1,100 second-feet of waterworks pumpage the current would be raised to about 2.15 miles an hour and its strength increased over 4½ times, which would be dangerous.

It is urged, therefore, in view of the foregoing facts and considerations, that the application for permission for the Sanitary District of Chicago to withdraw from Lake Michigan through the Chicago and Calumet rivers—not to exceed 10,000 cubic feet of water per second—be not granted.

Respectfully submitted,

Daniel Mullin, K. C., Counsel.

John Kennedy, Consulting Engineer.

A. St. Laurent, Assistant Deputy Minister Public Works of Canada.

Wm. J. Stewart, Chief Hydrographer.

V. W. Fortescue, Superintending Engineer, St. Lawrence Ship Channel.

Representing the Government of Canada.

Mr. James White, Secretary, Commission of Conservation, Canada, read the following memorial:

Sir,—I have the honour to present herewith the views of the Executive Committee of the Commission of Conservation,

Canada, in regard to the application of the Board of Trustees of the Sanitary District of Chicago now before you.

The subject has been considered by the following members of the Executive Committee:

Hon. W. C. Edwards.
Sir Edmund B. Osler.
Hon. H. S. Béland.
Dr. J. W. Robertson.
Dr. C. C. Jones.
Mr. J. F. Mackay.

The views therein expressed are the unanimous opinions of the Committee.

The proceeding is understood to relate to the application of the Board of Trustees of the Sanitary District of Chicago, for a permit to increase the diversion of water through the Chicago Sanitary canal from 4,167 cubic feet per second to 10,000 cubic feet per second.

(1) In support of the application it is urged that the increased quantity of water is necessary to prevent the sewage of the Chicago Sanitary District affecting the water of the Desplaines and Illinois rivers to such an extent as to be a menace to the health of the inhabitants of the territory traversed by these streams. The charter of the Sanitary District provides that a dilution of 333⅓ cubic feet per second shall be provided for every 100,000 inhabitants of the District, which is double the dilution that the British Rivers Pollution Commission consider necessary.

During the trial of the suit of the State of Missouri against the State of Illinois and the Sanitary District of Chicago much expert evidence was adduced to cast doubt upon the efficiency of dilution by running streams. Be this as it may, it is unquestionable that the City of Chicago cannot reasonably expect that, with the wonderful growth of her population, she shall be allowed to make additional diversions to conform to the requirements of the Drainage Act, regardless of all the important interests affected thereby.

It is urged, therefore, that no additional diversion be permitted, but that the City of Chicago be compelled to purify its sewage to such an extent that, with the increase of population, the effluent will still comply with the best standards of sewage dilution. If based on the standard established by the charter of the Sanitary District, the present permitted flow of 4,167 cubic feet per second would meet the requirements of the law for a population of 1,389,000. It is obvious that,

with a bacterial reduction of one-half, this flow would suffice for a population of 2,778,000 or about 600,000 more than the present population (2,185,283) and would, therefore, suffice till about 1918. A bacterial reduction of two-thirds would suffice for 4,157,000 people—the estimated population in 1941.

(2) To proposals that Chicago treat her sewage, it has been objected that there "is no system of sewage purification now in practical use which can be relied upon to turn sewage into drinking water." To this, it is a sufficient reply to say that, it is not proposed "to turn sewage into drinking water." All that is urged is that the effluent be partially treated and sterilized sufficiently to prevent the bacterial content of the Illinois and Desplaines rivers rising above the best sanitary standards. To the objection that this does not comply with the strict wording of the Sanitary District charter, it is a sufficient answer that it complies with the spirit of it; that, lacking a permit from the Secretary of War, it would not be possible to secure the increased flow proportional to the increase of population; that the result aimed at in inserting this clause in the charter had been attained and that the clause must be interpreted in the light of reason.

(3) Respecting manufacturing wastes, the Committee on Engineering, on May 11, 1910, reported that manufacturers in the southern portion of the city and adjacent territory are allowed, unchecked, to discharge through the Calumet river into Lake Michigan, industrial wastes that endanger the water supply of Chicago. Nowhere, however, is there any intimation that Chicago has taken, or intends to take, any legal action to prevent the discharge of these wastes, some of which are stated by the Committee to be *"highly favorable to the growth of bacteria."*

(4) Up to December 31, 1908, the Trustees of the Sanitary District had expended $60,147,883 and, to date, have expended 62 million dollars. Had they adopted a channel of a more moderate size, they would have effected a very considerable economy, and, had the money thus saved, been expended on sewage sterilization works, the City of Chicago would not now be applying for a permit for the diversion of an additional amount of water.

(5) It has been urged that the question at issue is: which has the more just claim upon the waters of the Great Lakes, the Sanitary District of Chicago or the other users of the waters? So far as Chicago's water-supply is concerned, if contaminated, it is polluted by the residents of the city and

vicinity, and it is incumbent upon these residents to prevent this contamination and to purify their water-supply by some system of filtration.

The great city of London, with a population of seven and one-third millions, filters its water-supply and treats its sewage, but Chicago urges that it is impossible for her to do either. Her extravagance is put forward as an excuse for a diversion that injuriously affects the water-line on four thousand miles of shore—an action that injuriously affects a multitude of interests in two nations, and that injuriously affects the riparian rights in a vast territory.

(6) If imposing upon Chicago filtration of her water-supply and sterilization of her sewage results in checking or reducing the present extravagant use of water and, if it results in preventing the present unchecked discharge of wastes from stock yards, glucose factories, etc., refusing her application for an increased diversion of water will prove a blessing in disguise.

(7) Though a permit has only been granted for a diversion of 4,167 cubic feet per second, the Special Board of U. S. Engineers, of which Gen. W. H. Bixby was Chairman, in its report to Congress on January 23, 1911, stated that:

"The War Department, while awaiting the definite action of Congress, has, so far, permitted the diversion of 4,167 second-feet and the Sanitary District is understood to be using 7,000 second-feet."

Evidently therefore, the Sanitary District is, without any permit or authority whatsoever, diverting 3,000 second-feet in excess of the authorized amount.

(8) In terms of comparison, the Sanitary District is, at present, diverting from the St. Lawrence system an amount equal to the extreme low-water flow of the Ottawa river at the city of Ottawa, where it carries the drainage of 34,600 square miles of territory. It is proposed to divert, in a few years, one and one-half times this flow and the Sanitary Canal has been constructed to carry an amount equal to *double* the low-water flow of this, the greatest tributary of the mighty St. Lawrence.

(9) Respecting the contention that the diversion will be required for purposes of navigation, the United States Special Board of Engineers has stated that "for purposes of navigation a diversion from Lake Michigan of less than 1,000 second-feet of water is all that will be necessary"; and, again, that "the claim that more than 1,000 cubic feet per

second is required for purposes of navigation can not be maintained."

(10) Many estimates of the fall in levels of the Great Lakes caused by the diversion at Chicago, have been made. The accompanying profiles show the levels of the Great Lakes from 1860 to 1911.

The loss of level due to the abstraction of 7,000 second-feet is coloured blue and the periods during the season of navigation 1860-1911, when the water was below the mean level for the forty-year period, 1860-99, have been coloured in red. This indicates diagrammatically what is disclosed by a study of the gauge readings, viz., that since 1890, less water has been flowing down the St. Lawrence to the sea than during the thirty years preceding that date. While part of this deficiency is due to the clearing of the forests, draining of swamps and other operations incident to the development of the country, it is undeniable that a part of it is due to the Chicago Drainage canal. The net result is: that, while navigation is handicapped by the unavoidable loss of margin due to what may be called "development operations," the situation is further aggravated by the decrease due to the Chicago diversion.

The International Waterways Commission estimated that the amounts by which the *mean level* of the Great Lakes, as derived by observations from 1860-1907, would be lowered by the diversion of 10,000 cubic feet per second are as follows:

WATER LEVEL LOWERED BY DIVERSION AT CHICAGO

	7,000 cu. ft. per sec. Inches	10,000 cu. ft. per sec. Inches	14,000 cu. ft. per sec. Inches
Lake Huron-Michigan	4¼	6¼	8½
Lake Erie	3⅜	5½	7⅝
Lake Ontario	3	4¼	6
River St. Lawrence and Rapids Plat	3⅜	4⅝	6⅝

It is to be noted, however, that these reductions are calculated for *mean water* and *would be increased at low water* thus aggravating the injury to the interests of navigation. Thus, during 1911, the stage of Lakes Huron and Michigan was between 579 and 580, at which stage, the levels were lowered 5½ inches by the diversion of 7,000 cubic feet per second at Chicago. A diversion of 10,000 second-feet would have lowered them 7½ inches and 14,000 second-feet would have lowered them 10½ inches. As the average annual range of these lakes is 1.21 feet, it is apparent that even the present diversion is affecting their levels to the extent of 35 per cent.

of the annual range. It is contended that such diversion is in contravention of Article III of the Boundary Waters treaty of 1909, which forbids the construction of works that "materially" affect the levels of International Boundary waters.

(11) Respecting the contention that the changes in level caused by the Drainage Canal diversion do not concern shippers, and that, at most, the effects would be trifling, the U. S. Board of Engineers in reporting on this subject said:

"If one watched carefully the course pursued by shippers one would see that, as a rule, each vessel carries all that it can take and get out of its port, or into that it intends to reach. Vessel owners and managers are very shrewd, watchful men; they know what they can safely carry, allowing for storms and short detentions arising from passing causes; they average pretty well the practical depths, and *carry all the channel will stand.* * * * Should it be certain that these average depths were reduced three inches, or six inches, they must load accordingly and, not only the large boats, but also the small ones using the small harbours that the large ones cannot go into—all must lose the three or six inches as it may be; and, not for one or more trips, but for all trips and for all time; a diminution of capacity is not a single tax but a continuous one."

The Board estimate that a loss of draught of three inches will decrease the cargo-capacity of a vessel of 20 feet draught by 3 per cent., and of a vessel of 12 feet draught by 4 per cent. With a loss of draught of six inches, the capacity would be reduced by 6 per cent. and 8 per cent. respectively.

The Government of Canada has, at enormous cost, completed a waterway for vessels of 14 feet draught, at low water, from Fort William to Montreal, and, for vessels of 30 feet draught, from Montreal to the sea. Every inch abstracted from the available depth represents a loss of cargo capacity and a loss of income which is aggravated during low-water years like 1911.

In view of the foregoing, it cannot be seriously contended that the effects of the diversion are of little importance.

(12) The engineers of the Sanitary District have never concealed their intention to develop the full amount of water-power possible and to utilize the full capacity of the Sanitary canal, viz., 14,000 second-feet. Mr. L. E. Cooley, late Chief Engineer of the Sanitary District, has declared that it was his "hope and intention" to excavate a channel with a capacity of 16,667 cubic feet per second.

Mr. Cooley has also stated that: "It is estimated that the

flow of water that will eventually come from Lake Michigan through the Chicago Drainage canal, together with the natural flow of the river, will produce 173,000 horse-power, and, with the revenue therefrom, the State of Illinois proposes, eventually, to recoup itself for its expenditures and contribution to the deep waterway."

Every cubic foot of water abstracted at Chicago reduces the water-power that could be generated at Niagara Falls and in the rapids of the St. Lawrence, thus injuring the provinces of Ontario and Quebec and the state of New York, and owners of power on these rivers. In addition, the development of power on the Desplaines and Illinois rivers represents a great economic waste. Water used at Lockport, Ill., under a 34-feet head, has only one-fifth to one-seventh the efficiency obtainable at Niagara, to say nothing of the other power sites on the St. Lawrence. The electrical art is practically in its infancy and, with its development, the value to the community of great water powers will be enormously increased. No alienation of this valuable asset should be permitted.

The use of waters belonging essentially to International Boundary waters, entirely diverted from their natural channels, for the purposes of water-power development, is a use that cannot justly be sanctioned.

(13) It has been proposed that the Chicago Sanitary District erect compensation works. While the treaty of 1909 provides for works of this character, nevertheless, it is not the intent of the treaty to permit water diversions on the plea that compensation works may, or will, be built. Such works should only be a possible remedy to be applied in extreme and absolutely unavoidable cases. Clearly, neither the United States, nor Canada, could ever conserve the integrity of the levels of the Great Lakes by allowing to be instituted, so to speak, a policy of "diversion and compensation." Finally, no compensation works could compensate Canada for the injury done to her interests in the river St. Lawrence by the abstraction of water at Chicago.

(14) It is further contended that this diversion is in contravention of international law. Thus, Oppenheim, in his "International Law," I, 175, says:

"Just like independence, territorial supremacy does not give a boundless liberty of action. Thus, by customary International law a State is, in spite of its territorial supremacy, not allowed to alter the natural conditions of its own territory to the disadvantage of the natural conditions of the ter-

ritory of a neighbouring State—for instance, to stop or to divert the flow of a river which runs from its own into neighbouring territory."

(15) The Ashburton treaty, 1842, provides that certain channels in the Detroit, St. Clair, and St. Lawrence rivers "shall be equally free and open to the ships, vessels and boats of both parties." It is contended that any action, such as the Chicago diversion, is in contravention of the treaty inasmuch as it tends to destroy the navigable capacity of these channels.

For the above reasons, the Executive of the Commission of Conservation expresses the opinion that the application is without even the semblance of necessity, and desires to place on record its unqualified opposition to the proposition which is before you.

I have the honour to be
Sir

H. S. BELAND
For Chairman

MEMORANDUM OF ARGUMENT AGAINST THE APPLICATION OF THE CHICAGO SANITARY DISTRICT FOR PERMISSION TO DIVERT 10,000 CUBIC FEET OF WATER PER SECOND FROM LAKE MICHIGAN.

Submitted on behalf of the Dominion Marine Association (of Canada) representing all the vessels engaged in Canadian trade between the head of the Great Lakes and the St. Lawrence river.

(1) It is respectfully submitted that the question at issue upon the present application, namely, whether the proposed diversion will prejudice or impair navigation, can only be answered in the affirmative.

(2) The self evident fact that the diversion of water from Lake Michigan at Chicago must affect the levels of the other lakes and of the St. Lawrence river is established by ample authority already cited in evidence, and is practically conceded by the applicants. The figures submitted at the present hearing on behalf of the Canadian Government (computed with reference to periods of depression) show that, if anything, the loss has heretofore been underestimated. They indicate a lowering of the water at various points as follows:

	For a withdrawal at Chicago of 10,000 cubic feet per second
Lake Michigan	7.4 inches
Lower sill of lock at Sault Ste. Marie	7.0 "
Lake Huron	7.4 "
Lake Erie	6.1 "
Lake Ontario	4.5 "
Rapide Plat in St. Lawrence River	6.8 "
Cornwall Canal, Lock 21	5.0 "
Coteau	5.4 "
Montreal	10.2 "

(3) The applicants then resort to the suggestion that a loss of even 6 inches need not be considered seriously, inasmuch as navigators have to contend, in any event, with such a variety of heavier fluctuations in level due to conditions beyond present control. Such a suggestion might prevail if the depths of channels, canals and harbours in the waters named exceeded the load draught of the vessels passing through them by a sufficient margin; but the contrary is true, and the fact is, that, at almost innumerable points, the tonnage afloat is restricted in carrying capacity by the question of depth of water available. Vessels are built to utilize every inch of water available over the natural barriers to navigation, and, in periods of low water, as at present, the loss in carrying capacity is enormous. For each inch of this loss actually suffered by each vessel, within the limits of a correct table of losses such as the above, it is submitted that the diversion of water at Chicago must share the responsibility.

(4) The locks at Sault Ste. Marie, the natural barriers between Lake Huron and Lake Erie now artificially lowered to certain depths, the Welland and St. Lawrence canals, and the various harbours to be entered, are the principal factors in determining a vessel's load draught. In the season of 1911 the depth available in the Canadian lock at Sault Ste. Marie represented the maximum draught available in the upper waters and that was only 17 ft. and some inches for up-bound boats, and 18 ft. and some inches for boats down-bound which could be flooded out of the lock. The Welland canal, ordinarily safe at something over 14 feet, was the subject of special regulations in 1911, draught being cut down materially; while down-bound vessels in the Upper St. Lawrence ordinarily drawing 14 feet in the Rapide Plat at Morrisburg, went down the river at about 12 feet 6 or 8 inches, and suffered great delays as well, if weather conditions were adverse. Navigation in harbours and bays of limited depth all along the route was cut down in the same way. At each of these points, the proper proportion of the lost depth of

water must be attributed to the withdrawal at Chicago of part of the previous water supply of the lakes.

(5) In the year 1910, 20,899 vessels, carrying a total tonnage of 62,363,218 tons, passed through the canals at Sault Ste. Marie, or nearly five times as much as though the Suez canal which is open to the commerce of the world. Of the above vessels 12,927 carrying 25,927,661 tons, passed through on the American side, and 7,972 carrying 36,435,557 tons, pass through the deeper Canadian lock. Considering that the permitted draught of water in the Canadian lock was only seventeen feet and some inches for up-bound boats and eighteen feet and some inches for down-bound boats, and that those of the larger class could not carry within two or three thousand tons of their full capacity, the enormous effect of the loss of a few inches draught upon the earning power of the vessel and upon the trade of both countries is readily seen.

(6) The locks in the Welland and St. Lawrence canals limit the draught of vessels trading to Lake Ontario and St. Lawrence river ports, even in times of high water, and a great number of vessels passing through these canals are adapted for 18 feet navigation. With reference to such cases, there can be no question of the adverse effect of the Chicago Drainage canal upon navigation.

(7) Three statements marked "A," "B" and "C" respectively, and appended hereto, indicate with some fair degree of accuracy the loss in the carrying capacity of Canadian vessels which the allowance of the present application would entail. In statement "A" the actual figures for 1911, for a representative fleet, that of the St. Lawrence & Chicago Steam Navigation Company, Ltd., of Toronto, are set out. Statement "B" extends the computation, on the same conservative basis, to the whole Canadian fleet of bulk and package freight carriers, and Statement "C" suggests results with reference to the grain trade.

(8) Owners of the vessels last described, pay an extremely heavy insurance rate of eight per cent. per annum upon the insurable value of the hulls to cover marine risks as far east as Montreal. In order to decrease the risk of disaster from overloading and other causes, they have recently formed an association known as the Canadian Lake Protective Association, which is empowered to supervise and control navigation methods and punish offences against established rules. During 1911, this Association has been in touch with officials of the Dominion canals, including the canal at Sault Ste. Marie, and has sent out by telegraph from time to time, due

notice of the varying drafts of water permitted. It was instrumental in having penalties imposed by the Canal Superintendent at Sault Ste. Marie where vessels overloaded even an inch or two beyond the permitted draft, and similar close supervision was found necessary in the Welland and St. Lawrence canals. In the face of such facts, it is impossible to give serious consideration to the suggestion made by the applicants, that the loss of a few inches depth in the channels is of no consequence.

(9) On the Upper St. Lawrence river an extremely important passenger carrying fleet—that of the Richelieu & Ontario Navigation Company— a member of the Dominion Marine Association, is very seriously handicapped. Its steamers, which run the various rapids on the St. Lawrence, are the result of an enormous expenditure of time, labour and money in experimenting and in designing and building craft best adapted for their special purposes. They draw every inch of water available and, when the water is too low, are forced out of the rapids and into the canals. Every inch of water taken from the levels and diverted at Chicago means substantial loss to the business of this Company.

(10) All the above remarks apply with proportionately greater force to the much greater tonnage of the United States afloat on the Great Lakes and apply also in proportionate degree to the ocean tonnage trading up the St. Lawrence to Montreal through channels which share the loss of water occasioned by the withdrawal from the lakes at Chicago.

(11) It is submitted that merely local requirements for purposes of sanitation at Chicago or, at any other individual port, must be subordinate to requirements of navigation of such enormous importance over such wide areas, and especially so where, as in this case, *other methods of sanitation than the dilution method are available.*

(12) If the requirements of sanitation are to become an element in the present discussion, or, if any serious consideration whatever is to be given to the suggestion made by the applicants that the damage may be cured by compensating or remedial works in the lower reaches of the lakes and in the St. Lawrence river, then, it is submitted, a reference to the present International Joint Commission or direct consultation with the Government of the Dominion of Canada will be proper before any decision affecting the rights of the citizens of both countries is arrived at. This is particularly true with respect to the proposal for remedial works, as the Gov-

ernment of Canada must necessarily be a party to any such method of solving the problem.

(13) The recommendation of the International Waterways Commission in 1907, was not final in its character and was negative in its effect. It did not advocate the allowance of 10,000 cubic feet per second but rather the absolute prohibition of any greater amount. (Par. 43 of the Report.)

(14) For the above and other reasons it is respectfully submitted that the application of the Chicago Sanitary District should be refused.

Dated at Kingston, Ontario, the 25th of March, 1912.

FRANCIS KING,
Counsel for the Dominion Marine Association.

STATEMENT "A."

Approximate Loss in Carrying Capacity of St. Lawrence & Chicago Steam Nav. Co.'s Steamers on one inch draft at Minimum Load Line.

Name of Steamship	Length of Steamship	Loss per in.
E. B. Osler	510 feet	68 tons
W. D. Mathews	376 "	40 "
G. R. Crowe	332 "	32 "
Iroquois	260 "	24 "
Algonquin	250 "	21 "
		185 tons per inch of draft

Cargoes carried in 1911—28 each.

Average freight rate per ton—40 cents.

185x28x40=$2,156 per season loss for each inch taken from present depths or, for 6 inches, the loss would be $12,936.

A. A. WRIGHT

Toronto, March 14th, 1912

STATEMENT "B."

Canadian Bulk and Package Freight Fleet on Great Lakes:

Name of Steamship	Loss per Inch	
Emperor	75 tons	
Stadacona	70 "	
Midland Prince	65 "	
Midland King	40 "	Loss in weight carrying capacity per inch of draft at ordinary load draft.
E. B. Osler	70 "	
W. D. Matthews	40 "	
Collingwood	45 "	
G. R. Crowe	35 "	
Agawa	37 "	
	477 tons	
Add 61 vessels of canal size at say 22 tons	1,342	Tons less in weight carrying capacity per inch per trip or cargo.
Total	1,819	

The St. Lawrence and Chicago fleet lost 185 tons per inch per trip, and, at a low freight rate, $2,156 per inch per season. A total loss of ten times as many tons on the whole Canadian fleet (1819 tons) would amount, at a similar low freight rate, to $21.560 per inch per season, or to $129,360 for six inches.

If, in the next decade, the fleet increases at the same rate as in the past decade, this would be over a million dollars loss per annum.

N. B.—On the long haul to Montreal rates might run to $1.50 or $2.00 per ton instead of 40 cents taken above, but, of course, there would be fewer trips, say, 12.

STATEMENT "C."

The Canadian grain-carrying fleet can float, at one time, if fully loaded, to, say, 18 feet draft, at least 8,000,000 bushels of wheat.

1,800 tons loss per inch of draft, even at only 2,000 lbs. per ton, is equivalent to 60,000 bushels, and, at 6 inches loss, this would be 360,000 bushels, or a full cargo for the largest vessel afloat on the lakes. At only 23 trips per season to the Bay or Buffalo this would be 8,280,000, or more than the full capacity of the whole fleet.

COPY OF RESOLUTION OF THE KINGSTON BOARD OF TRADE

KINGSTON, ONTARIO, March 23, 1912

RESOLVED—That the Kingston Board of Trade vehemently protests against the diversion of the waters of Lake Michigan by the Chicago Sanitary District, and against the lowering of the levels in the Great Lakes and St. Lawrence river which admittedly results from such diversion;

That, while Kingston is a lake port occupying an important position at the foot of Lake Ontario and at the head of the St. Lawrence river, and affords trans-shipment facilities for a great part of the grain trade from the West, nevertheless, this protest is not made for entirely selfish reasons, but rather, because the diversion of water to provide this simple but wasteful method of disposing of the sewage of a single city, entails enormous loss and damage to navigation interests as far down the chain of lakes and river as tidewater, works great injury to the trade and commerce of the country, and threatens, if permitted, to form a precedent for further depletion and damage in order to satisfy the merely local and selfish demands of innumerable other municipalities;

That, for the benefit of both nations, the tremendous investments made in vessel property, and in canals, channels and harbours on the lakes and the St. Lawrence, and the invaluable trade facilities developed in this great waterway should be safeguarded and preserved, and that no local interest should be permitted in any way to prevail;

And, that the Government of the Dominion of Canada be urged to take every step possible to prevent the allowance of the present application of the Chicago Sanitary District.

Signed on behalf of the Kingston Board of Trade, at Kingston, Ontario, March 23rd, 1912.

EDW. RYAN, President
J. H. MACNEE, Secretary

STATEMENT OF F. S. SPENCE, ACTING CHAIRMAN OF THE TORONTO HARBOUR COMMISSION

MR. SPENCE: Mr. Secretary, in view of the comprehensive way in which the situation has been explained to you, I will not trespass more than two or three minutes and that, merely by offering under the circumstances, an illustration to emphasize the force of what has already been presented by these other gentlemen.

The Harbour Commissioners of Toronto, who have asked me to appear here at this time, compose a public body, having no interests to present but the public interests. Toronto has a population of something like 425,000, and is one of the largest cities of Canada, and is, with others, vitally interested in this question.

At the port of Toronto we have a landlocked harbour, of something over three square miles, being continuously increased in its area by works. Into this there have been made

two very wide channels, at an expenditure of more than $2,000,000. The construction of docks and facilities in the harbour has involved more than $4,000,000 expenditure.

The Commission I represent has property interests there, that are exercised for the public advantage, of more than $5,000,000. Into that harbour, there came last year, 3,192 vessels, with an aggregate tonnage of something over 1,600,000 and carrying approximately, one-half a million passengers, a great many of them from the United States, as was stated by the gentlemen who spoke a few moments ago.

Our situation, Mr. Secretary, is this: A part of that harbour does not provide enough water at low stages for the vessels that come in there. The vessels that come in under present conditions, generally have a draught of 14 feet, and a part of the harbour at our docks does not provide water at low stages to the depth of 14 feet, although we have dredged down to the rock. You can readily understand that, under circumstances of that kind, any lowering of the water would be a serious obstacle to the navigation at that port.

You will understand, then, how we watch with great interest the natural low-water stages which we are obliged to contend with, and how we would view with positive alarm any further permanent reduction of that level, particularly in view of our experience with the lessening of the flow in the St. Lawrence route, to any extent, which would also mean a lessening of the reservoir capacity of the Upper lakes, and, consequently, tend to further lessen what the actual flow would amount to. To cope with that, we would have to go to the enormous expense of removing the rock, or else extend our docks out into deep water; or, if neither of these things was done, it would mean a serious loss to the carrying interests in having to lighten their cargoes in order to get into the docks.

I offer this as an illustration of the situation, as presented by gentlemen who have already addressed you.

Toronto is about the only commodious harbour on the north shore. It is a harbour which vessels in stress of weather must find refuge in. That feature is one of great importance. We have come here arguing in favour of what we think our rights are. While we present the case as strongly as we can, we are not unmindful of the fact that our national interests are very vital to us, and would be considered by you, even beyond treaty terms. I think I can say that Canadians highly appreciate the attitude of the Government shown here, from

time to time, on that line, and it is a sentiment, I think, we all highly appreciate.

The other gentlemen here, I think, wish to offer some illustrations on the same line that I have followed, as to how their respective localities would be affected by this proposed diversion.

MR. DAVID SEATH, Secretary of the Montreal Harbour Commission, presented the following letter from the Harbour Commissioners of Montreal:

HARBOUR COMMISSIONERS OF MONTREAL

SECRETARY'S OFFICE

MONTREAL, 25th March, 1912

HON. HENRY L. STIMSON,
Secretary of War,
Washington, D. C.

SIR,—The Harbour Commissioners of Montreal, a body politic and corporate, constituted by Act of Parliament of the Dominion of Canada to administer the Harbour of Montreal, respectfully submit:

That the Harbour of Montreal is the point of interchange of traffic between the ocean and inland navigation, and, in the improvement of which there has been expended $20,000,000, and a further amount of $8,000,000 has been voted by Parliament for the carrying out of further improvements.

That, among the improvements carried out are extensive grain elevators for the transfer of water-borne grain with a storage capacity of over 4,500,000 bushels, and the largest conveyor system in the world for the delivery of grain to vessels.

The Commissioners also have a fleet of floating grain elevators of a capacity sufficient to transfer 25,000,000 bushels of grain from lake vessels to ocean vessels in the navigation season.

That the Commissioners have also provided the most modern facilities for the expeditious handling of freight of every description.

A dry-dock and ship-repairing plant to cost several millions of dollars are in course of construction.

That the withdrawal of the quantity of water from lake Michigan now taken by the Sanitary District of Chicago is lowering the level of the lakes, and the withdrawal of a larger

quantity of 10,000 cubic feet per second now applied for by the Sanitary District, will still more lower the level of all the Great Lakes and outlet rivers, as well as the level of the waters in the canals, and will seriously reduce the carrying capacity of the vessels navigating these canals and thereby be detrimental to the navigation interests of the Great Lakes and the traffic of the Harbour of Montreal.

The Harbour Commissioners of Montreal therefore respectfully urge that the application of the Sanitary District of Chicago now before you be not granted.

We have the honour to be, Sir

Your obedient servants

G. W. STEPHENS, President
DAVID SEATH, Secretary

STATEMENT OF MR. R. W. REFORD

President, Montreal Board of Trade

MR. REFORD: Mr. Secretary, I represent the Montreal Board of Trade, and desire to read a short memorial that we have drawn up on the subject under consideration:

To the Honourable HENRY L. STIMSON,
Secretary of War for the United States:

THE MEMORIAL OF COUNCIL OF THE MONTREAL BOARD OF TRADE HUMBLY SHEWETH:

That the Montreal Board of Trade objects to the application of the Chicago Sanitary District for a further diversion of water from Lake Michigan, up to 10,000 feet per second, for the following reasons:

That Montreal is the meeting place of inland and ocean navigation and that any lessening of the water supply of the navigation routes centreing in Montreal would be an interference with her rights and against her interests;

That any diversion of water out of the drainage basin of the Great Lakes and the St. Lawrence river and into any other drainage basin is contrary to the spirit of the treaties between Great Britain and the United States;

That the Canadian Government has spent large sums in deepening its inland harbours, canals and river channels and that the municipalities on the Great Lakes have expended considerable sums in the same direction, and that all such ex-

penditure will be rendered largely nugatory by any further lowering of the lake levels, and the interests of Canadians and of the said municipalities should not be ignored:

That such deepening of the harbours, canals and inland channels has, by enabling vessels of greater draught to use them, greatly lowered the inland water freight rates in which so many are interested and that any reduction of these depths will, by lessening the draught of the vessels, involve an increase in the freight rates;

That the needs of navigation demand that the levels of the Great Lakes and the St. Lawrence river be maintained at the highest possible point, all of the harbour works, channels and shipping being adapted to present conditions, and that the proposed diversion of water will alter these conditions materially to the detriment of all water transportation interests on the Great Lakes and the St. Lawrence river to below Montreal, and will occasion irreparable and permanent damage to trade;

That the demands of water transportation are increasing, and that anything which would prevent the expansion of water-carried trade should, in the interests of both Canada and the United States, be prevented;

That it has been demonstrated that the present diversion of water by the Chicago Sanitary District has lowered the levels of the Great Lakes below Lake Superior and also the levels of the St. Lawrence river, and it is certain that the diversion of more water will proportionately further lower the levels, and that such reduction of the depth of the channels means a large fixed loss in the earning power of vessels, for the decreased draught forced upon them by such reduced depths of water involves a serious lessening of their cargo carrying capacity;

That the principle upon which the application for further diversion of water is made is unsound and that, if conceded, future demands from other municipalities may be such that, to grant them, would destroy navigation in the commercial sense;

That the use of such great quantities of water by the city and district of Chicago for sanitary purposes is unnecessary owing to the advance of sanitary science, and, that the perpetuation or extension of present methods is a retrograde movement and not in the interests of public health;

That, while the Chicago Sanitary District states that its application is for a temporary use of the water for sanitary

purposes, it is known that such water is to be used also for the generation of electrical power, and that, once permanent plants are installed for such generation, the interests vested therein cannot be expected to urge any scheme which will tend to lessen their supply of water power:

That, against the benefit which Chicago will derive from the granting of this application must be set the combined losses which all the other towns and cities bordering on the shores of this waterway will suffer, and further, the power to be developed by the water proposed to be diverted will be a small fraction of the power that may be developed by the same water if allowed to remain in its own proper drainage basin;

That the flow of water through the Chicago Drainage canal should be strictly limited to the quantity of water now allowed, and that the drawing of water in excess of the present allowed quantity be prohibited by the proper authority, and measures be taken to gauge the water now diverted in order to regulate and govern the same.

The whole respectfully submitted,

R. W. REFORD
President

Signed on behalf of the Council of the Montreal Board of Trade.

L. HENDERSON
Chairman of Harbour and Navigation Committee

MONTREAL, 25th March, 1912

STATEMENT OF MR. F. E. MEREDITH, K. C.

MR. MEREDITH: Mr. Secretary, I will be very brief in what I have to say, but will file a short brief, with your permission.

SECRETARY STIMSON: Whom do you represent?

MR. MEREDITH: I am representing the Shipping Federation of Canada and its members.

As I have not mentioned its members in the brief which I expect to file, perhaps I should do so. I represent the Allan line, the White Star—Dominion line, the Thompson line, the Cunard line, the Donaldson line, the Manchester line, the South African line, the New Zealand Shipping Company, the Head line, the Canadian line, the Hamburg-American line; and then, there are two large coasting companies, the Dominion Coal Company, and the Nova Scotia Steel Company; in addition to that, the Atlantic Steamship service of the Cana-

dian Pacific Railway, and the Atlantic Steamship Service of the Canadian Northern Railway.

All these steamship lines, I have been requested to state, are entirely opposed to the granting of this application, so far as they can oppose it.

I may state, in order to give you an idea of the tonnage, that these lines represent a tonnage of about 590,000 tons, represented by the ships, and the value, I should suppose, would be about $30,000,000.

SECRETARY STIMSON: Are these lines all interested in the navigation of the lower St. Lawrence?

MR. MEREDITH: Up to Montreal, yes; and, there, they meet the inland carriers, represented by Mr. King.

SECRETARY STIMSON: Where do they claim that the diversion of water will affect them adversely?

MR. MEREDITH: You mean the ocean carrier?

SECRETARY STIMSON: Yes.

MR. MEREDITH: In looking at the Government brief—at all events we know the calculations which the engineers of the Government of Canada have made—we find, taking the harbour of Montreal, that the depth will be lessened by 10¼ inches. That is on page 13 of the Government brief.

SECRETARY STIMSON: I wanted to get an idea of where the shoe pinched, so to speak.

MR. MEREDITH: Yes. I may say at once, that although we were satisfied, naturally, with the Government figures—we had no reason to doubt their correctness—yet they disturbed us considerably, to think that there was going to be such a change in the levels, due to the diversion of 10,000 cubic feet per second, and we employed two independent engineers, and their estimates as to the lessening of water in the Montreal Harbour are even slightly greater than is the Government estimate, mentioned on page 13 of Mr. Mullin's brief.

Further down from Montreal, at Lanoraie, which is a few miles down, the taking out of 10,000 cubic feet would mean a lessening in depth of 5.4 inches; and at Sorel, 6.0 inches.

I do not think it is necessary for me to state that the object of all Trans-Atlantic boats is to get up to top of the navigation head as far as they can get. That has been the history of navigation in the world, and the Government of Canada has expended millions of dollars to enable these Trans-Atlantic boats to get to Montreal. We have a minimum draught there, or are supposed to have, of 27½ feet at low water. We load our ships to avail ourselves of every inch in that chan-

nel, and, during the low water, we have not an inch to spare. What is going to happen will be this: that if these figures are correct—and we have every reason to believe the figures are correctly quoted by the Government, and verified by our own engineers—we will really lose at the very least, during the low-water months, which in Canada are about four months—August, September, October and November—by the abstraction of this water—this 10,000 cubic feet—10 inches of our draught. Ten inches of our draught, roughly speaking, would mean, working it out as carefully as we can on our present fleet—of course the fleet is increasing each year and the loss would be greater each year—about $332,685. That would be the actual loss; that is working it out, as I have shown, in the brief that I will file.

GENERAL BIXBY: For how many inches of draught?

MR. MEREDITH: Ten inches of draught; during the low-water period, that is, which we calculate will be four months. That, we say, is taking the least loss we will suffer with the present fleet. The boats, as we all know, are getting larger. We have only to look at New York harbour and the other harbours of the world to see that that is true, and the larger the boats the cheaper the freight and the cheaper the merchandise to the consumer. If these figures are correct, the remedy, even if the Government of Canada were prepared to remedy and put back this ten inches by dredging, would not meet the trouble, because, even if they were prepared to do that, according to the figures which the engineers have given, which are referred to in the brief filed this morning by the Government, it would cost over $18,000,000 to put not only the St. Lawrence, but the St. Lawrence waterways and the Canadian waters in their former condition.

And I may say this: A great many ships that are used to carry freight to Montreal across the Atlantic are especially designed for the St. Lawrence. They get from the Government the exact depth they can rely on, and they build their ships to meet these special conditions.

Now, these special conditions, if this application is granted, are going to be entirely changed after people have invested large sums of money to build ships to suit that particular channel, and these ships will be running at a loss and will practically be on the scrap-heap.

That remedy is the only remedy, as I have said, and it will cost the Government $18,000,000, and it will take years to

bring about that remedy, and it will be an expense that will have to be borne by the tax-payers.

The ship owners also feel this: that, if once an application of this kind is granted, which will allow our water being taken from this international route, there is no reason why, if it is once granted, other municipalities should not make similar applications and obtain grants.

I thank you very much: I have stated some other propositions in my brief, which I will file with you, and I will not speak further, because I know my time has elapsed.

STATEMENT OF MR. ANDREW ALLAN, PRESIDENT OF THE SHIPPING FEDERATION OF CANADA

MR. ALLAN: Mr. Secretary, Mr. Meredith has practically stated the case for the Ocean Steamship lines of Canada; but I might enlarge, in a few words, on the position we take.

If it proves to be a fact that, the taking away of the water from Lake Michigan for the Chicago Drainage canal has the result of lowering the water in the St. Lawrence from Montreal to the sea, then the port of Montreal and the St. Lawrence route are very gravely affected.

We have been in the ocean steamship business for a great many years, and we have tried to assist in building up the port of Montreal; but, if this is going to have the effect it is claimed it will have, then the port of Montreal is going to suffer, very, very materially, and, as stated by Mr. Meredith, the desire is to bring the large ships to the port of Montreal. In 1906 we built two turbine steamers, the *Victorian* and the *Virginian*, and I have, here, the record of six voyages they made last autumn, beginning with the 15th of September, and ending with the 23rd of November. The depth of water was very low last year; we got down as low as 28 feet. Mr. Meredith made one error, I think, when he stated 27 feet. As a matter of fact, we got down to 28 feet.

To load these ships fully—and we should be able to load them fully, from Montreal—we have to leave a margin between the actual depth and the draught of the ship. To do that we sent these ships out at draughts ranging from 25 feet 5½ inches, to 26 feet, and they went out on the six voyages with vacant space to the extent of 8,340 tons and 25 feet 6 inches draught, the ship drawing 26 feet 6 inches. They would have carried 15,599 tons—practically, 15,600 tons—but

they short-shipped 8,340 tons, because there was not sufficient water to allow them to go to Quebec with safety.

If there is going to be further water taken away from the St. Lawrence, then I am afraid it will have the effect of putting the port of Montreal in a very bad position, and it almost looks to me as if the port of Montreal would have to be satisfied with comparatively small steamers, nothing more than 10,000 tons, perhaps.

It may not be interesting to you gentlemen, but to a certain extent I think we ought to explain ourselves. There are bigger steamers under construction at the present time, that it is hoped will be able to come to Montreal. I do not think that we could ever hope to bring them to Montreal if the result of taking of this water from lake Michigan is going to bring about the state of affairs that it is claimed will be the result.

SECRETARY STIMSON: This shortage that you speak of was on those two vessels alone?

MR. ALLAN: Yes; I have not given the figures of what was the result with the other lines, and I have not those figures, but I am sure a great many of them suffered, probably to the same extent we did last year. And, therefore, sir, if I might suggest, from a Canadian point of view, we are very desirous that nothing shall be done to take the water away from the St. Lawrence.

Mr. ALLAN submitted the following communication from the Shipping Federation of Canada:

MONTREAL, March 25, 1912

To Honourable HENRY L. STIMSON

Secretary of War of the United States

Washington, D. C.

IN THE MATTER OF THE PRESENT APPLICATION OF THE BOARD OF TRUSTEES OF THE SANITARY DISTRICT OF CHICAGO FOR THE ENLARGEMENT OF THE TERMS OF AN INSTRUMENT, EXECUTED BY THE SECRETARY OF WAR, MARCH 8, 1899, AS MODIFIED BY SUBSEQUENT INSTRUMENTS, DEALING WITH THE FLOW OF WATER FROM LAKE MICHIGAN

Memorandum submitted by the Shipping Federation of Canada, a body incorporated by the legislature of the Dominion of Canada, one of whose main objects is to safeguard the

interests of navigation, more especially of the St. Lawrence route, and whose President and members are the representatives of all the Atlantic, South African and Australian steamship lines trading to and from the St. Lawrence, and, also, of the coasting lines trading to and from the St. Lawrence, and, also, of the coasting lines of steamers trading between Nova Scotia and the St. Lawrence river.

The Canadian Pacific Atlantic steamship lines, trading to and from Montreal;

The Canadian Northern Atlantic steamship lines, trading to and from Montreal.

The above application having been carefully considered by the above Federation, its members and the above steamship lines, it was unanimously decided to oppose the granting of the above application, since, were it granted, navigation of the St. Lawrence route would be most seriously affected, more especially in view of the resulting lowering of the levels on the Great Lakes, the canals and the St. Lawrence river proper. The Federation and the steamship lines above mentioned, rely on what would result, if the application were granted on the levels, on the information obtained and furnished by the Government of Canada in their brief submitted to you and dated March 25, 1912, which shows that a diversion of 10,000 c. f. s. would result in a lowering of the water at Montreal by ten and a quarter inches (page 13) and they have obtained a report from two independent engineers on the result to the level of water at Montreal in the event of the present application being granted, which agrees on essential points with the conclusions arrived at by the engineers of the Government of Canada.

The number of vessels now employed in the St. Lawrence Atlantic trade to Montreal is seventy-five. These vessels make an average of five voyages per season and, for three voyages during the low-water months of August, September, October and November, the average load of these vessels would be reduced by at least 10 inches, which would work out as follows:

The average load of each vessel would be reduced at 53 tons per inch, or 530 tons on 10 inches—multiplied by three voyages per season equals 1,590 tons average loss of freightage per ship. 1,590 tons multiplied by 75 ships amounts to 119,225 tons, which, at the average freight rate of $2.29 per ton, works out at $273,093 loss of freight per season.

In addition to the trans-Atlantic lines, there are some twelve large steamers regularly trading from Montreal to

South African and Australian ports, making one trip per season. At least one-half of these vessels would be affected during the low-water months to the extent of ten inches in draught, which, on the average freight of $5 per ton, would work out as follows:

Six ships, average loss on 10 inches reduced draught at 53 tons per inch equals 530 tons per ship, or 3,180 tons loss on 6 ships, which, at $5 per ton, works out at $15,940.

In addition to the above, the carrying capacity of the deep draught colliers in the employ of the Dominion Coal Co. would be materially reduced, and, as shown in the attached letter, dated March 25th, that company, alone, estimate their loss at $43,642 per season.

Summarizing the above the result shows this:

Loss of freight charges on 75 Trans-Atlantic Liners	$ 273,093
Loss of freight charges on South African and Australian	15,940
Loss of freight charges on Coal Carriers	43,642
Total loss on season	$ 332,675

It is to be borne in mind that the loss, if the levels are decreased, will not only be suffered by the ship owners but also by the consumers. The smaller the ship the higher the freight, and it is unnecessary to refer to the fact that the universal practice at present, is to increase the size of the carrying vessel.

It is a fact that a very large number of steamers at present using the St. Lawrence route have been especially designed and built for that trade, relying on the minimum depth of the present channel which is availed of by ship owners to the last inch; that the lines of steamers furnishing this memorandum have a tonnage of 592,584 tons, and a tonnage value of about $30,000,000.

The whole most respectfully submitted

ANDREW A. ALLAN
President, Shipping Federation of Canada

THOMAS ROSS
Secretary, Shipping Federation of Canada

F. E. MEREDITH
Attorney for Canadian Pacific SS. Lines, and for Canadian Northern SS. Line

STATEMENT OF MR. GEORGE T. BLACKSTOCK, K. C.

Mr. BLACKSTOCK: Mr. Secretary, just a word or two, relating to the Niagara river, and the Power companies there. The intakes of those companies were designed in reference to the levels, as they then existed, at the time of the initiation of these works, and any alterations in those levels very seriously impairs the power of the companies to get their water, and, therefore, to generate the amount of power which their concessions at Niagara entitle them to generate.

Then, there is in addition to that, a very serious difficulty by reason of the accretion of ice which collects along the margin of the river. As you are aware, sir, one of the most serious difficulties every winter at Niagara, is in respect of the collection of ice at various points along the river; and you are aware, sir, that only four years ago a veritable cataclysm took place there, by which the power companies were almost entirely suspended, one of them completly suspended, and the others very seriously interfered with in their operations.

So that any diminution in the volume of water in that river is fraught with the gravest consequences to interests in that locality.

Mr. Secretary, perhaps you would allow me to offer one general observation. This is a very momentous occasion in respect of the interests that are involved here. Around the borders of these international waters are collecting very great populations, who, as time goes on, must from time to time, have increasing temptations to interfere with those problems. Now, the common sentiment of two countries, on either side, has suggested the idea of the protection of these waters, and a great precedent, one way or the other, must, on this occasion, be established: Either it must be said that the common sentiment and interests of the two countries are to be qualified by the particular interest of some one detached community, or else, that the general sentiment is to be maintained in its integrity. Now, I venture to make this observation. The proposed interference by the application now under consideration, is, as has been very well said by Mr. Mullin, extraordinary in its character. It is unheard of. Instead of maintaining the common pool between the two countries, one particular community proposes to very seriously diminish that pool. Does it not fill any ordinary mind with consternation to hear it suggested that some one community, itself the creation of the interests that it is now menacing, itself the creature of trade and commerce, should propose to skim off Lake Erie, by this

proceeding, no less than six inches of that surface. It appals me, and I venture to suggest that the onus of showing that the rights of navigation are not seriously interfered with, rests with those who are proposing the exercise of these extraordinary powers.

It is quite true, I apprehend, that you would not give any adhesion, or pay any attention to some purely chimerical suggestion of danger; but, on the other hand, is it to be said, can it be said, that that apprehension is slight and ill-founded which brings to your bar every interest from Chicago to the sea, all claiming to be seriously menaced by reason of this undertaking?

That very fact seems to me to constitute a complete answer to the application as made, and to show the very grave consequences which would ensue if it were acceded to.

RICHELIEU & ONTARIO NAVIGATION COMPANY, OFFICE OF THE GENERAL MANAGER

MONTREAL, March 24th, 1912

Hon. H. L. STIMSON
Secretary of War
Washington, D. C.

Chicago Drainage Canal

DEAR SIR:—With reference to the proposal to withdraw an additional amount of water from Lake Michigan, we respectfully beg to submit that we have been operating steamers in the passenger and freight business on the river St. Lawrence since 1867, and anything which has a tendency to lower the natural level of the waters is a matter of the gravest concern. We give you below, a description of the business and the possible effect of lowering the water levels.

Passenger

We carry passengers from the head of Lake Ontario all the way down the St. Lawrence river, running the St. Lawrence rapids, and have several millions of dollars invested in vessel property and the business is rapidly growing. Last year we transported 60,000 passengers over the Rapids Division, where the boats have to be especially constructed of a very light draught in order to get through. In this respect we have virtually built, within the past seven years, three special boats of exceptionally light draught on account of low water,

at an approximate cost of close on $1,000,000. There is never any too much, in fact, sufficient water in this part of the river and, on several occasions, owing to low water caused by natural conditions, we have been forced to withdraw the service. Last season, which was a season of low water over the entire chain of lakes, we suffered severely and were obliged to cease running the rapids a month earlier than usual.

Inasmuch as our business is a through business, run on a close schedule, making, connections with railroads, steamer lines and steamships, anything which interferes with the continuity of the service or puts one division of the line out of commission very seriously affects the earnings, and we are unalterably opposed to granting permission to withdraw water from any of the Lakes which it is known will have the effect of lowering the water further down the chain.

We contend that the importance of this traffic down the Lakes and River cannot be overestimated and that it must be protected.

Freight

An immense amount of money has been spent by the Governments of the United States and Canada, improving channels, dredging and canalizing in order to develop water-borne traffic through the chain of Lakes and the River, and the freight vessels have had the same trouble to contend with, so far as low-water conditions are concerned, as the passenger boats. Last year, vessels carrying cargoes to and from Montreal, were only able to load a percentage of their capacity which very seriously affected their operations, besides increasing the liability to accident and the cost of insurance.

We feel that any application on behalf of a particular district or locality cannot justly be considered separately, but must be judged in its relation to the whole chain of Lakes and River and their protection and general development for the benefit of all concerned.

There is every reason to believe that, in the future, low-water conditions are more liable to occur than in the past and no permission should be granted to take any water which will have the tendency to lower the depth at any other point between that and the sea.

Yours respectfully,

C. J. Smith
General Manager

REPLY OF SANITARY DISTRICT OF CHICAGO

IN THE MATTER OF THE APPLICATION OF THE SANITARY DISTRICT OF CHICAGO FOR A PERMIT TO DIVERT NOT TO EXCEED TEN THOUSAND CUBIC FEET OF WATER PER SECOND FOR SANITARY PURPOSES FROM LAKE MICHIGAN.

To the Honourable HENRY L. STIMSON

Secretary of War

SIR:—In presenting this statement of the reasons which prompted the Board of Trustees of The Sanitary District of Chicago to make the application which is now pending, and of the reasons why the suggestions made by those who have opposed the application should not have sufficient weight to defeat the application, it is my purpose to confine myself as closely as possible to the suggestion conveyed in the course of the hearings before you, that the sole purpose of the inquiry was to decide whether or not the interests of navigation would be substantially affected adversely by the granting of the permit. I am aware that the law which gives to the Secretary of War the right to issue the permit in question was passed solely in the interests of interstate commerce, and has its life and force only by virtue of the commerce clause of the Federal Constitution. It is assumed however, that in the protection of navigation interests it will not be necessary, in order to render more profitable the navigation of the Great Lakes, to imperil the health of a substantial part of the nation.

It has apparently been assumed in this hearing that the burden of proof is upon the Sanitary District, and that it is incumbent upon it to show that the granting of the permit in question would not substantially interfere with interstate commerce, and that the use of the water of Lake Michigan as contemplated is not inconsistent with an existing law of Congress. I respectfully submit that in the absence of a positive law of Congress prohibiting the work in question the State of Illinois, in the exercise of its police power, has a right to prescribe the use to which the waters of Lake Michigan shall be put, and that such an act is valid and effective until it affirmatively appears that it conflicts with the powers of the Federal Government with reference to the control of interstate commerce.

The Supreme Court of the United States, in the case of New Orleans Gaslight Co. *vs.* Drainage Commission, 197 U. S., 453, speaking through Mr. Justice Day, uses the following language in describing the governmental character of the exercise of the powers sought to be exercised by the Sanitary District:

"The drainage of a city in the interest of public health and welfare is one of the most important purposes for which the police power can be exercised."

The law under which the Sanitary District was organized has been declared constitutional by the Supreme Court of the State of Illinois in People *vs.* Nelson, 133 Ill. Rep., and in Trustees *vs.* Wilson, 133 Ill. Rep. It is therefore beyond the stage of discussion that the act is a valid act and a proper exercise of the power of the State, and it seems elementary that that valid law, and the valid exercise of the powers conferred by it, should not be rendered of no effect or interfered with, unless it shall affirmatively appear that it conflicts with some law of Congress enacted under the commerce clause of the Federal Constitution.

It must be borne in mind that there has been no legislation on the part of Congress directly bearing upon the Sanitary District canal. The policy of the United States Government, however, has been well established since 1822. In that year an act was passed providing for the construction of a channel connecting the southern bend of Lake Michigan with the Illinois river. Another law to the same effect was passed in 1827, and the State of Illinois, by the act of 1829, accepted the provisions of the Federal acts and by subsequent acts authorized and in fact constructed the Illinois and Michigan canal.

This canal had the effect of re-establishing a prehistoric natural waterway. Geologists are in accord in saying that at one time one of the outlets of Lakes Superior, Huron and Michigan was through the valley of the Desplaines and Illinois rivers, and the Supreme Court of the United States, in the case of Missouri *vs.* Illinois, 200 U. S., 496-526, declared the physical conditions which divided the watershed of Lake Michigan from the Mississippi river watershed "* * * are of the smallest. And if under any circumstances they could affect the case it is enough to say that Illinois brought Chicago into the Mississippi watershed in pursuance not only of its own statutes but also of the acts of Congress of March 30, 1822, and March 2, 1827, the validity of which is not disputed."

The Illinois and Michigan canal, constructed pursuant to the provisions of the acts above mentioned, had a dual function. In the first place, it was a navigable waterway of the United States and has been so declared by the Supreme Court of the United States, and incidentally to the purpose for which it was designed it disposed of a considerable portion of the sewage of the city of Chicago by a partial and, at times, complete reversal of the flow of the Chicago river.

The Illinois and Michigan canal was completed in 1848. In 1871 the policy of withdrawing water from Lake Michigan for navigation and sanitary purposes in Chicago was further recognized by an enlargement and deepening of the Illinois and Michigan canal at an expense of approximately $2,000,000. By 1887 the population of Chicago had increased to about 800,000 inhabitants. It then became a serious problem to prevent a large proportion of the sewage of the city from being emptied into the basin from which is water supply was received, and there was appointed by the mayor of the city of Chicago a Commission of Sanitary Engineers to study the best method of disposing of the sewage, and at the same time protect the water supply of the city. As a result of the investigations made by this Commission the Sanitary District act was presented to the General Assembly of the State of Illinois in 1889, and became effective on July 1 of that year.

In the determination of the question as to the proper method of disposing of the sewage of the city there were brought into consultation the most eminent engineers and experts in the disposal of sewage then available. Every then known method of sewage disposal was investigated and discussed, and the dilution method adopted and the percentage of dilution determined as stated in the Sanitary District organic act. Investigations since that time have demonstrated the wisdom of the degree of dilution provided for, namely, 20,000 cubic feet of water per minute for each 100,000 of population, and this percentage is now accepted as the standard minimum rate of dilution which it is safe to apply to domestic sewage (the statements in one of the briefs of those representing the Canadian interests to the contrary notwithstanding.)

The necessity of this degree of dilution is further demonstrated by the analysis of the waters in the Desplaines and Illinois rivers, made during the year 1911 and shown in the report of George M. Wisner, chief engineer of the Sanitary District, dated October 12, 1911, and on file in the office of the chief of engineers.

I also have the honour to submit as an appendix to this

brief marked "A" a letter from Professor Edward Bartow, Ph. D., director of the State Water Survey of the University of Illinois, a copy of which has already been filed in your office.

After the passage of the Sanitary District Act work was begun in the construction of the Sanitary District canal for a distance of 32 miles from Robey street in the city of Chicago, to Lockport, Ill., at which point the canal joins the upper basin of the Desplaines river in the city of Joliet. The canal was designed for a capacity of 10,000 cubic feet of water per second, but was actually constructed of a capacity of 14,000 cubic feet per second. The canal was substantially completed in 1898, and the Governor of the State was notified, in order that he might appoint a board of engineers, as provided for in the Sanitary District act, for the purpose of making a report as to whether or not the canal had been constructed in accordance with the authority granted by the General Assembly. Before this board reported and before any water was actually turned into the canal the act of Congress of March 3, 1899, was passed, Section 10 of which gives to the Secretary of War jurisdiction over the navigable waters of the United States. The Chicago river was and is a navigable waterway of the United States over which the Federal Government has assumed control. The question of the amount of water that might safely be taken through the Chicago river in diverting its course without injuring the interests of navigation became a matter of moment and investigation, and in view of the jurisdiction conferred upon the Secretary of War by the act of March 3, 1899, an application was made for a permit to reverse the flow of the Chicago river and flow through the same a sufficient quantity of water to dilute the sewage emptying into it.

A permit was granted on May 8, 1899, by the Hon. R. A. Alger, then Secretary of War. This permit is shown as an appendix on page 36 of the report upon the Chicago Drainage canal by the International Waterways Commission, 2nd ed., 1907.

It is pertinent to note in this connection, in view of an argument presented by one of the eminent gentlemen representing the Canadian interests, that that permit makes no mention of the withdrawal of water from Lake Michigan. The limit placed at that time was a flow of 300,000 cubic feet per minute through the Chicago river. The question of lake levels was not discussed nor mentioned, and the only reason for the limitations contained in that permit are stated to be, the pro-

tection of the Chicago river and its maintenance in such manner as to protect navigation and property interests in and along the river.

Subsequently the permit then granted has been modified, always with one purpose in view, namely, the maintenance of navigation in the Chicago river, and the prevention of a current which might be injurious to such navigation. It will at once be seen that up to the time the water was turned into the Sanitary District canal, and, in fact until plans were submitted for the reversal of the flow of the Calumet river in the year 1907 the question of the effect upon lake levels was never considered or discussed and the navigation interests have never even pretended that they had any right to interfere with the carrying out of the beneficent objects of the Sanitary canal, except to require such reasonable regulations as might be necessary to protect navigation in the Chicago river.

The present canal is a growth and development of the policy of both the State and the Nation as expressed in the acts of Congress and of the General Assembly of the State of Illinois from 1822 to the present time, and it is strange that after a policy has been declared and carried out for a period of ninety years, there should be, at this late date, so strenuous an effort to prevent the protection of the lives of the people of that large community because of some supposed and imaginary injury to navigation upon the Great Lakes.

It has always been assumed by those entrusted with the care of our waterways and the protection of our navigation that the works of the Sanitary District should be maintained and carried on. This is abundantly shown by the reports presented to you upon the oral argument. A compilation of quotations from some of these reports which are deemed pertinent, together with references to the reports themselves, will be attached hereto as appendix "B."

We therefore respectfully submit that the rights of the Sanitary District to withdraw water from Lake Michigan for sanitary and domestic purposes is not now in question, and the right is reserved at all times to maintain the supremacy of those rights.

The right to control the flow through the Chicago and Calument rivers we concede is vested in the Secretary of War. In view, however, of the frequent discussions and the insidious efforts made to continually restrict the use of the waters of Lake Michigan so that they may not be used for the highest purpose for which they are fitted, the Board of Trustees of the

Sanitary District has been prompted to apply for this permit. While we are entitled to the use of the waters of Lake Michigan as a matter of right, we also believe that we are entitled to this permit from the Secretary of War, in order that there may be evidenced that "spirit of harmony and conciliation which ought always to characterize the conduct of governments standing in the relation which that of the nation and those of the States bear to each other," as expressed by Chief Justice Marshall in the case of *Gibbons vs. Ogden*, 9 Wheaton, 1; and also to make manifest that which was referred to by Mr. Justice Johnson in the same case as that "frank and candid co-operation for the general good which should always take place where there is a seeming blending of the power of the two governments, and an apparent conflict."

II

I propose now as briefly as I may, and in view of the suggestions made by those who oppose the granting of the application, to discuss the imperative necessity existing to have a permit issued as asked for.

The amount of water asked for is necessary for the protection of the lives of the people of the Sanitary District.

In the oral statement which I had the honour to submit to you I did not think it necessary to engage in a discussion as to the requirements to properly dispose of the sewage of the population now residing in the Sanitary District. In view of the discussions that have since taken place and some of the documents submitted to you, however, it seems now, not inappropriate to very briefly set forth the basis upon which the application is made in this regard.

Experts in the disposal of sewage have been studying the question of the proper degree of dilution necessary, to render sewage innocuous for many years. In 1886 the Chicago Sewage Commission, as heretofore stated, was appointed by the mayor of the city of Chicago with this purpose in view. The most eminent engineers of the world were consulted and their advice taken, and it was then found that the degree of dilution, such as is provided for in the law creating the Sanitary District, was as small a percentage as was safe. The reports of sewage experts the world over are now unanimous in declaring that the degree of dilution provided for in the Sanitary District Act, passed by the General Assembly of the State of Illinois, was proper and necessary, namely, 20,000

cubic feet of water per minute for each 100,000 of population. With a population now exceeding two and one-half millions the Sanitary District actually needs for dilution purposes alone and for the protection of the lives of its people over 8,000 cubic feet of water per second.

The rapid increase in population renders it certain that within a very short time, and certainly by the time the Calumet-Sag channel now in course of construction is completed, the full amount now asked for, namely, 10,000 cubic feet per second, will be required to prevent the sewage of the Sanitary District becoming a nuisance and dangerous to the health and comfort of a large number of people, as well as destructive of one of the great industries of Illinois, namely, the fish industry, which is hereinafter referred to.

Only one answer has been suggested to our claim that necessity exists for the additional water. Those who have opposed the application have stated with confidence that Chicago should adopt some other method of treating its sewage and protecting the lives of its people. This is easily said, but I venture to suggest that no engineer of reputation, would be willing to jeopardize that reputation by unqualifiedly recommending any system of sewage disposal for a city like Chicago.

No one has even had the temerity to suggest that there was any known method at present available which could so efficiently and *economically* be employed in the disposal of the sewage of Chicago. The only conclusion to be drawn is that those who have opposed the application of the Sanitary District care nothing about the economies involved, if those economies are to be practised in behalf only of the public. The only money which they deem important to conserve and save, is money belonging to private interests, and they seem to assume the position that it is the duty of those intrusted with the administration of governmental functions to be heedless of the expense to the public, so long as private interests are protected.

The claim has been made that many cities abroad and at home have successfully treated their sewage by methods other than by dilution. Among those cities are the cities of London, Manchester, Birmingham in England, the Essen District in Germany, and Worcester, Mass., Columbus, Ohio, and Baltimore, Md., in the United States. None of these cities, with the possible exception of Worcester, Mass., is subject to the severe climatic conditions that confront Chicago in the win-

ter time. It has been found by experiment that the best methods of artificial sewage disposal, are much less efficient during extreme cold weather than in the summer months. It has been stated that these plants are only about 50 per cent. as efficient in the colder months as they are during the warmer ones. The dilution method as now employed works automatically, while any artificial method of disposal is dependent upon the human element.

At Worcester, Mass., some 15,000,000 gallons of sewage are treated daily. This sewage, after treatment, is discharged into the Blackstone river, a comparatively small stream—in the dry-weather months, having a drainage area of only 60 square miles. Two-thirds of this sewage is treated by removing the settling solids by chemical precipitation, and the remainder is treated by intermittent sand filters. The resulting effluent is in a highly putrescible state and could not with safety be discharged into any stream that supplied the drinking water of a community. The stream is so polluted that even fish could not exist any time during the year. To treat the sewage of Chicago by intermittent sand filters would require an area of over 7,000 acres, or 11 square miles, and the expense of obtaining the necessary land and preparing beds similar to those used at Worcester would be so enormous as to make it prohibitive.

There seems to be an impression that the city of Hamburg, Germany, with a population of nearly a million, has installed a complete sewage disposal plant. This matter has been investigated, and practically the only thing that is done toward the treatment of the sewage of this community is to catch the heavier solids and remove some of the larger floating matter by means of screens. The only purifying effect this has, is to render the river Elbe more sightly to the eye than it otherwise would be. The resulting effluent from these works is practically unimproved from a chemical or bacteriological standpoint.

The city of London, on the river Thames, where the rise and fall of the tide exceeds 20 feet twice, was compelled to remove the unsightly solids from its sewage. This is accomplished by means of chemical precipitating tanks, and the resulting effluent is allowed to discharge into the Thames some ten or twelve miles below London bridge. The solids taken from the sewage are carried to sea in tank steamers. The resulting effluent by this sewage treatment is practically improved 25 per cent. but would be absolutely unfit to be discharged into a source of water supply.

Manchester treats the sewage of about 600,000 people and the effluent is discharged into the Manchester ship canal. This water is not used for drinking purposes, and such an effluent, according to the analyses made, would be dangerous to discharge directly into Lake Michigan in the vicinity of the intakes of Chicago's supply of water.

Birmingham treats the sewage of a population of approximately a million people, and the effluent is allowed to discharge into a small stream. It is true that the effluent is less polluted than the stream itself, but in the stream exist no fish. Neither the stream nor the effluent could safely be discharged into a body of water that was to furnish a community with its water supply.

In the Essen district in Germany no attempt has been made to produce an effluent from the sewage disposal plants that would be safe for domestic use. The only result that is desired is that the river into which this sewage is discharged shall not be unsightly, which has been accomplished.

In the United States, at the city of Columbus, a purification plant was installed so as to avoid a nuisance in the Scioto river, which runs through this city. This river in the summer time is practically dry and the sewage amounts to more in volume than does the discharge of the river. This plant is actually operated only during the lower stages of the river, and during the high stages the sewage is discharged untreated into the river. It is well known that this plant when operated in the winter time is much less efficient than in the summer months. The water of this river is not used for any domestic supply.

The city of Baltimore has installed a large sewage disposal plant consisting of settling tanks and sprinkling filters for the purification of its sewage. It was installed primarily to protect the oyster beds some 18 or 20 miles below the city. The effluent will be discharged into a tidal water, which will never be used for domestic purposes. As this plant has never been operated and is just being completed, it is impossible to say whether the effluent will be inoffensive and non-purtescent, as was stated by Mr. John Kennedy, consulting engineer for the Dominion of Canada.

When the systems as installed in the principal cities in the world are studied it is found that nowhere does a situation exist similar to that of Chicago, where, if any other than the present method was employed, the sewage effluent coming from a disposal station would be discharged into the

source of its water supply. Chicago is so situated that it is possible by a combination of partial purification and dilution methods to dispose of its sewage without offence to any one and with perfect safety to its water supply. It is a comparatively simple and inexpensive matter to partially purify sewage, but to so thoroughly purify it as to render it safe to discharge it into the source of a water supply is so expensive as to make it a financial impossibility for the people of Chicago.

It is unfair to compare any American city's sewage disposal scheme with those of foreign cities. The average water supply of foreign cities is about 35 gallons per capita, whereas that of American cities runs as high as 235 gallons per capita, thus making it exceedingly burdensome to treat the sewage of the ordinary American city artificially.

The Sanitary District has expended in the last three years about $100,000 in carrying on an elaborate system of experiments on practical methods of sewage disposal for conditions such as exist in the city of Chicago. As a result of these experiments the Sanitary District has adopted plans by means of which the present dilution method can be augmented and supplemented by the use of partial purification methods, so that it will be entirely possible and practicable with some additional expense to take care of the sewage of Chicago after its population exceeds three millions of people by the installation of partial purification works, the effluent of which will be diluted with water coming from Lake Michigan, which will render it innocuous and harmless to the people residing along the Illinois river, through which the effluent flows, and to fish life. But in order to accomplish this it will take a number of years to make the installations. The Sanitary District has already by official action, instructed its chief engineer to prepare plans for the installation of settling tanks to be used in connection with all new works.

Chicago, through the Sanitary District, is taking active steps to force large manufacturing concerns, such as the slaughter-house industries, to remove their trade-wastes from their sewage before discharging it into the Chicago river or the drainage canal. This action will probably cost the industries affected in the neighborhood of a million dollars. Other industries will be affected to a lesser extent, but they are to be forced to purify their trade wastes, so that as the city grows it will require less water per capita for the proper dilution of the sewage coming from this large manufacturing centre.

Generally it is the plan of the Sanitary District to install by the year 1920, at which time it is estimated that the population of Chicago will be three million people, many partial purification works to supplement the general scheme as it now exists. It is absolutely necessary that Chicago so dilute its sewage that when it reaches the Illinois river it will have so purified itself and have an oxygen content that is sufficient to sustain fish life.

As has been stated, the Illinois river is the second largest fish-producing river in the United States, the production exceeding, at the present time, 46 million pounds of fish annually, which are shipped to the dense centres of population and afford the people a cheap food. This industry in the last few years has more than trebled. However, if Chicago is unable to properly dilute its sewage, this river will become so contaminated and polluted that this vast industry will be destroyed.

In case Chicago should be prohibited from discharging properly diluted sewage into the Illinois river it would be forced to discharge it, as before 1900, into Lake Michigan, thus creating conditions worse than those which existed prior to the building of the drainage canal, when the typhoid death rate was a disgrace to the community.

The fact that the present channel and the expenditure of 70 millions of dollars would be wasted by the installation of a new plan of sewage disposal at Chicago is not the greatest element of loss to the public. The change of the entire sewerage system in the city of Chicago, which would then be necessary, would involve an expenditure of probably 100 millions of dollars; and in addition to that, the expense of installing and maintaining such sewage disposal works as might at some future time be discovered or evolved must be taken into consideration, and that expense would probably be so enormous that it would impose a burden almost unbearable by the people of Chicago, who have already borne with patience the expense of the monumental works so successfully operated at this time. Such a change could not possibly be made within the next eight or ten years, as it would involve not only the construction of disposal works but also the reconstruction of sewerage systems, the building of large intercepting sewers, and incidental to this, the tearing up of the streets and the repavement of them.

The granting of the request which we now make does not in any wise foreclose the United States Government or the Secretary of War from any action in the future if it shall be

demonstrated that the water asked for is unnecessary in the treatment of sewage. If that time shall come it will not only be proper, but, if the interests of navigation are found to have been injured, it will be appropriate for the Secretary of War to revoke the permit and compel a change in the methods.

We deal, however, not with future conditions which are uncertain and indefinite, but with actual conditions which now exist; and so long as they do exist the necessity is imperative that Lake Michigan, the great storage basin provided by nature for the comfort and convenience of man, shall be used to promote the health and comfort of those who may avail themselves thereof.

The efficacy of the present method is amply demonstrated by the records of the health department of the city of Chicago before and after the opening of the Sanitary Canal.

The death rate from typhoid fever which, prior to 1900, ranged from 25 to 170 per hundred thousand population, decreased, in 1910, to about 12 per hundred thousand.

The enormous saving of human life effected by this means, therefore, is such that any restrictive measures which would interfere with the operations of the works of the Sanitary District should be applied most hesitatingly and for the most convincing reasons. And it is no answer to this suggestion to say that other methods may be found; for, so far as I am aware, there has been no suggestion in this hearing, or at any other time or place, of a method at present available as a substitute for the city of Chicago.

III.

Let us now consider the objections urged by those who fear the effect of a further withdrawal of water upon navigation:

The objection to the granting of the permit made by those who are interested in lake navigation is based upon fears for which there is no basis, and upon speculative theories that up to this time have not been demonstrated to be of practical force. It was suggested by one of the eminent gentlemen representing the Canadian interests that the unanimity with which the protest of the navigation interests was presented, and the cohesion of forces which feared that disastrous results might flow from the use of the lake waters for sanitary purposes should be considered by you as evidence of the substantial nature of the objections which should control in the determination of the question. It may be unfortunate, but it is

nevertheless true, that whenever any project or improvement is proposed for the public benefit a large number of persons with no knowledge as to substantial damages to accrue, and actuated only by the fear of an attack on their most vulnerable point namely, their pocketbook, become extremely active, insistent and persistent in defending themselves against even a possible invasion of their so-called vested rights. On the other hand, public interests are often neglected. The body politic is inclined to be lethargic, and only is aroused after the damage has been done and the calamity has befallen the community. The lives, health and comfort of nearly three millions of people are to a large extent dependent upon the action to be taken in this proceeding. The interests of this large population are sought to be represented by a few public servants whose duties require them to conserve the public interest. While it seems impossible to arouse the interest of all this population—who will be more seriously affected than if their source of income were to be interfered with, it seems easy to arouse every interest to a surprising activity, when only dollars are involved. In fact, however, so far as anything appearing in the hearing before you up to this time, no one has been able definitely to state in what manner or to what extent the interests of navigation would suffer or the investments of the transportation companies would be impaired.

It is true that general statements have been made showing the loss of profit to a transportation company by being deprived of sufficient water to load its vessels to their full capacity.

Natural fluctuations of the lake levels, however, are of sufficient magnitude to account for every inconvenience and every loss to which transportation companies have been and may be subjected. An attempt has been made to show that the mean level of the lakes for the past ten years has been below their mean level for the past 50 years. A comparison of the lake levels on such a basis is manifestly unfair. Up to 1886 the mean level of the lakes was much higher than it has since been. At that time the United States Government began improving the connecting channels, and every improvement that has been made has increased the capacity of those channels and the flow through the same, and in that manner reduced the lake levels. The Government improvements in the Detroit and St. Clair rivers alone during the past fifteen years have lowered the level of the water in Lake Michigan

at least one foot. We state this not in the way of criticism, for we believe that the gain to navigation by the increase in capacity of the connecting channels is largely in excess of any loss to navigation that might be suffered by reason of a general lowering of the level of the lake. We merely call attention to the fact in order to show that it is not fair to compare the levels of the lakes during the last ten years with the levels for any period antedating such Government work. An inspection of the charts prepared by the Lake Survey Corps of the United States Army shows that the level of the lakes has varied substantially in cycles of various durations. In the ten-year period previous to the opening of the Sanitary District channel in 1900 the lowest recorded level of the lake was in 1895. Since 1900 the lowest recorded level was in 1911, and that low level was several inches higher than the low level of 1895. It would not have been unreasonable to expect that at some time within ten years after 1900 the level of the lake would fall to a point as far below the average as in 1895, but even taking into consideration the diversion at Chicago which has already occurred, such has not been the case.

Undoubtedly the concerted opposition to the application of the Sanitary District would not have arisen had it not been for the unusual low-water conditions that prevailed on the Great Lakes during the past year. These conditions were not local to the Great Lakes, but were also prevalent throughout the country. Through the lack of information by the people and interests affected, this low level of the water surface of the Great Lakes has been wrongly attributed to the diversion of water by the Sanitary District. The condition during the past year has undoubtedly been caused by the lack of rainfall.

By consulting plate 22 of the International Waterways Commission Report, on the regulation of Lake Erie (1910) it will be found what has been the loss of level due to the flow of water through the drainage canal. The average stage of lakes Huron and Michigan in 1911 was over six-tenths of a foot (7¼ inches) lower than in 1910.

The chart prepared by the United States Lake Survey referred to by me, shows that from May, 1911, when Lake Superior was at its lowest stage for the year, it had risen so that on January 1 of this year it was practically one foot and three-tenths higher than in May, 1911. During the same period Lake Michigan has only risen about two-tenths of a foot. This can only be accounted for by the fact that the

United States Government, in the construction of the new Soo locks, has lessened the capacity of St. Mary river above the rapids by means of coffer-dams, &c. The effect of this has been to store the waters in Lake Superior, which naturally would have flowed into Lake Huron, and it is estimated that if this flow had not been interfered with, lakes Michigan and Huron would probably have been in the neighbourhood of three inches higher at the present time than they are.

The effect of diverting a certain amount of water from Lake Michigan, by way of the Chicago Drainage canal, upon the Great Lakes is a subject that has received the attention of all those who have made a study of the levels of the Great Lakes. To indicate the different results obtained, attention may be called to the estimates given in the report upon the Chicago Drainage canal by the International Waterways Commission (1907), page 7, wherein the effect of the withdrawal of 10,000 cubic feet from Lake Michigan at Chicago upon the St. Lawrence river at Rapide Plat is stated as four-tenths of a foot. This is approximately 4¾ inches.

The brief submitted by the Dominion of Canada, to which is affixed the signatures of the engineers who prepared the data therein contained, gives the effect at the same point, of the same diversion, as 6.8 inches. This is a difference of nearly 50 per cent. and is a fair indication of the lack of accuracy with which compilations can be made as to the effect of a diversion from a given body of water. Generally no two engineers figuring upon this effect arrive at the same result. This is to be expected by reason of the unknown quantities entering into the computation, and also because in making the computation the data obtained by the Lake Survey cannot all be used, and the results must vary according to the data that may be utilized.

Counsel for the Dominion of Canada and those representing the vessel interests claim a granting of the permit will result in great damage to the harbour of Montreal. It is claimed that the water surface will be lowered 10¼ inches. How these figures were arrived at, it is difficult to tell, as they seem to be at considerable variance with the report of the International Waterways Commission. The improvement of the St. Lawrence river between Montreal and Quebec was completed in 1906—six years after the opening of the drainage canal. In the report of the Department of Marine and Fisheries for 1910 it is stated: "At the present time a splendid channel of 30 feet at extreme low water exists from Montreal to Cap

à la Roche and to Quebec, by taking advantage of the tide." Whatever effect there is upon the St. Lawrence river by the withdrawal of water through the Chicago Drainage canal would have been felt before 1906, and the only additional lowering would be that caused by a greater diversion of water at Chicago since 1906, which is inappreciable.

On chart No. 2483 of the Canadian government charts of the harbour at Montreal, which are on file in the hydrographic office in the Navy Department, there are shown soundings of the harbour at Montreal, showing depths varying from 30.6 feet to over 41 feet. On this chart is the following: "The river (referring to the St. Lawrence) has a very great annual fluctuation and is usually at its highest about the second week in May and at its lowest from about the middle of September to the end of November. Its average height above the datum (low water of 1897) is, in May, 8 feet; June, 6 feet; July, 4¼ feet; August, 3¼ feet; September, 2¼ feet; October, 1¼ feet; November, 2¼ feet." So that with a channel dredged to 30 feet below the low water of 1897 there is ample water for vessels of 30 feet draught, and with a river having such great fluctuations due to natural causes it would be difficult, if not impossible, for navigators to notice any effect of the diversion at Chicago upon the St. Lawrence since 1906.

According to the Forty-third Annual Report of the Department of Marine and Fisheries of Canada of 1910 the total expenditures on the improvements of the St. Lawrence river since 1851 by all public appropriations has been $11,400,000. This is practically the amount that has been expended by the Sanitary District alone in the improvement of harbour facilities in the Chicago river.

Navigation interests represented by a government that has expended in their behalf less than one-sixth of the money expended by the Sanitary District for health and sanitation should not expect their protests to be seriously considered.

Objection is made by some of the gentlemen who presented arguments in opposition that it was unfair to argue that transportation companies must accommodate themselves to the natural conditions regarding fluctuations in lake levels, and that the argument presented by me in that respect is fallacious. Let us consider whether or no there is any fallacy in the arguments relating to navigation.

The only vessels now sailing the Great Lakes which could be affected by any variation in lake levels of from three to five inches are owned and operated by the ore-carrying com-

panies, particularly the Pittsburg Steamship Company, which is a subsidiary company of the United States Steel Corporation.

Mr. Livingstone, in his arguments, bases his calculations of the loss of carrying capacity upon boats 600 feet in length, and asserted that they averaged 113 tons per inch of draught, and 22 trips per season. This would result in a loss of tonnage of 2,486 tons per inch of draught. The lake survey chart submitted to you shows that the average level of lakes Huron, Michigan and Erie during the navigable season of 1910 was approximately six inches lower than the level of the same lakes during the same period in the year 1909.

On page 4833 of the printed record of the hearings had before the committee on investigation of the United States Steel Corporation (No. 54, March 11, 1912) is given a statement showing the operations of the Pittsburg Steamship Company for the year 1910. It appears from the testimony taken at that hearing, and on that day, that 30 per cent. of all the ore carried on the Great Lakes was transported by this company. The capital stock of the company, as appears from the statement referred to, is $7,880,000. The net profits of the company for the year 1910, after making deductions for interest charges and liberal deductions for depreciation, extinguishment funds, bond sinking funds, extraordinary replacements, &c., were $2,520,482.92. This is a profit of 32 per cent. upon the capital stock. It is our understanding that the year 1910 was not a year of unusual activity, but, on the contrary, was characterized by periods of business depression which were in some quarters regarded as unusual. We have not at hand the statement of the company for the year 1909, when they had available an average of six inches more water during the navigation season; but can it be reasonably contended, and can it be expected that any weight can attach to the argument that if a beneficent Providence had provided the same amount of water in 1910 as was provided in 1909, increasing the depth of water in the Great Lakes six inches, that the profits of the Pittsburg Steamship Company would have increased in the manner and to the extent indicated by the argument of Mr. Livingstone? If this were true, each boat would have had an increased tonnage of 14,916 tons. It appears from the testimony of the secretary of the Pittsburg Steamship Company, in the litigation now pending between the United States Government and the Sanitary District, that that company operates 73 boats having a draught of 19 feet

or more. This would mean a total difference in tonnage of 1,880,868 tons, and in the testimony of Mr. Freer before the investigation committee referred to above, it appears that the average freight rate charge was 65 cents a ton; so that the total increased receipts of this company alone, following such a line of reasoning, would have been $707,764.20 greater in 1910 had the level of the waters of the Great Lakes remained in substantially the same condition as during the year 1909. This would increase the profits of this company by approximately 9 per cent. It may be suggested in passing that if the public has received any benefit in the reduction of the price of steel by reason of these enormous profits, that benefit is not apparent to the casual examiner. The price of steel rails, as we are informed, has remained constant since the organization of this corporation.

We make these observations to show the character of the arguments presented against us, and the claims of those who make them, upon the protecting arm of the National Government, when brought into conflict with the higher function of government, in the preservation of human life and the promotion of the general welfare.

These suggestions are also submitted for the purpose of calling attention to the fallacy of the whole case presented by those who oppose our application on the ground of the loss of profits to the navigation interests. The fallacy lies in this, that the profits of the transportation companies depend, not upon depth of water, but upon the amount of freight carried. It is not and cannot be truthfully contended that any freight has not been carried by reason of lack of water which otherwise would have been. The commerce of the Great Lakes consists of a certain tonnage each year, and that tonnage is accommodated and cared for. The profits earned depend upon the volume of business and the rates charged. It is a well-known fact that it is more economical to use the deep-draught vessels, even when not loaded to their fullest capacity, than boats of the older type, and this is evidenced by the hundreds of boats lying idle in the ports of lakes Erie, Huron, and Michigan because they have been superseded by boats of modern type.

The present diversion from Lake Michigan at Chicago through the Chicago river is limited to 4,167 cubic feet of water per second. This limitation was placed upon the Sanitary District not because of any effect on lake levels or lake commerce, but in order to protect the Chicago river from an

excessive current. It is true that at certain times there has flowed through the Sanitary District channel and over its dam at Lockport a volume of water largely exceeding this amount, but regard has always been had to the maintenance of a safe current in the Chicago river. General Bixby, in his report quoted to you, asserts that the average amount now used by the Sanitary District is 7,000 cubic feet of water per second. This is more than the usual flow. But assuming that that statement is true, has any one appeared who has made the slightest claim that up to this date navigation has been injured by the operation of the Sanitary District canal? The contrary seems to be abundantly established. Every man conversant with navigation on the Great Lakes knows that during the past ten years the vessels that have been built have been built with larger capacity and deeper draught than ever before, and the tonnage now handled on the Great Lakes is greater than ever in the history of navigation in the United States. Why, then, this great fear that an additional grant of authority to use that which is necessary to preserve human life will bankrupt the transportation companies of the country?

According to the computations made by the International Waterways Commission, the effect upon the levels of Lakes Huron and Michigan of the diversion of 3,000 cubic feet of water per second in addition to that now taken would be 1.25 inches, and in the St. Lawrence river 1.40 inches. It must be borne in mind that even conceding 7,000 cubic feet of water per second has been withdrawn from Lake Michigan by the Sanitary District, such concession is not an admission that the permit heretofore issued by this Department has been violated, for, as already pointed out, none of the permits in any way limited the amount of water to be diverted from Lake Michigan. They were directed solely to the amount of water that should be taken through the Chicago river, the purpose being to maintain navigation on that river and prevent an excessive current. As already stated, 2,000 cubic feet is capable of being withdrawn through the Thirty-ninth street conduit entering the river practically at the beginning of the canal. This amount, added to the 4,167 cubic feet authorized to flow through the Chicago river, makes a total of 6,167 cubic feet per second, and in addition to this there is a considerable flow through the canal of water

withdrawn from the lake through the cribs and pumping stations used in the maintenance of the city's water supply.

As I attempted to show in the oral hearings, Chicago is itself interested in the maintenance of navigation and commerce, and will do everything in its power to protect them. No community in the United States and no port on the Great Lakes is more desirous of encouraging the activities incident to lake commerce. We merely feel we should be entitled, at least until it has been demonstrated that our works are injurious to the interests of navigation, to have the health and lives of our people protected.

The subject of the effect upon lake commerce of the diversion of water through the Sanitary Canal has been discussed many times and by many eminent engineers in the employ of the Government. It should be borne in mind that this work was not undertaken without thorough knowledge on the part of every well-informed engineer and official of the United States, and it seems strange that, after the successful operation of more than twelve years with no bad effects yet noticeable from such operation, the benefit of the tremendous expenditure made by the people of Chicago should be denied because of fears as to future effects not borne out by past experience.

The effect of the diversion of 10,000 cubic feet of water per second has been calculated with a great deal of care by the engineers in the Lake Survey. If all the theories can be relied upon, the observations are accurate, and calculations fairly made, it is probable that such a diversion would be theoretically determined as affecting the level of Lake Michigan to the extent of about five inches.

I do not wish to question the accuracy of the figures or the fairness of the calculations, but in view of the actual conditions existing in the lakes during the past ten years, I am constrained to say that I believe that there are unknown quantities and unknown conditions affecting lake levels which have not yet been determined or appreciated. The fact is indisputable that with a constant diversion through the Sanitary channel since January 17, 1900, the average level of Lakes Michigan and Huron was higher during the ten years immediately following than it was the ten years immediately preceding the opening of the channel. Of course it is immediately stated in answer to this, that this rise in lake levels was due to natural conditions, rainfall, &c. But it is equally true that the abnormally low

condition of the lakes during the past year and at the present time is also due to the same natural conditions,—rainfall, &c. In all the arguments presented to you the basis of the complaints of those who oppose our application seems to be a diversion of 10,000 cubic feet. It was asserted that we are already withdrawing from Lake Michigan from 4,000 to 7,000 cubic feet of water per second, yet not a single complaint is made, not a suggestion offered, that up to this time navigation has been injuriously affected. Why then the fear that the additional water asked for would bring such a calamity to the interests of commerce and navigation?

Chicago River Navigation.

Objection is made by some of those who appeared before you that the granting of the permit in question will injuriously affect navigation in the Chicago river. As has already been pointed out the limitations placed upon the Sanitary District do not refer to the amount of water to be taken from the lake, but have reference entirely to the conditions of that river and were imposed for the purpose of protecting navigation and preventing a current above that in which navigation may be properly conducted. The granting of the permit in question will increase the flow through the Chicago river eventually by 2,000 cubic feet of water per second. That is to say, of the 10,000 cubic feet of water to be withdrawn from Lake Michigan, 6,000 feet will eventually flow through the Chicago river, 2,000 through the Thirty-ninth street conduit, and 2,000 through the Calumet-Sag channel now in course of construction. In order to protect the interests of navigation, and in order to prevent a current injurious to commerce, the Sanitary District has acquired property adjoining the river, paying therefor nearly $5,500,000; has expended in dredging the river to a depth of 26 feet approximately $2,500,000; has removed centre-pier bridges and constructed in lieu thereof bridges of the bascule type with wider openings at the aggregate cost of over $3,000,000.

The project undertaken by the Sanitary District involves the widening of the river to a uniform width of 200 feet and dredging to a depth of 26 feet. This project is now practically completed except at those points where the work is delayed pending a decision by you of controverted questions of law and fact in relation to the removal of certain

bridges. The grand total of the sums of money expended by the Sanitary District up to this time in the improvement of that river and in the protection of navigation interests amounts to $11,437,820.69. This is an ample guarantee that the Sanitary District is safeguarding the commercial interests of the port of Chicago, and is doing all in its power to see to it that navigation will not be interfered with nor the interest of her Canadian friends injuriously affected. As pointed out in another part of this brief, the amount expended on this project alone exceeds the total amount expended by all public bodies of the Government of the Dominion of Canada in the improvement of the St. Lawrence river since 1851.

The improvements herein referred to provide for a flow of 6,000 cubic feet of water through the Chicago river, with a current not to exceed one mile per hour, and it is generally conceded by the navigation interests that a current of a mile and a quarter, as now permitted, is safe and not such as to create any hardship upon those seeking to use this waterway. At the time the first permit was issued by the Secretary of War, in 1889, the Chicago river was obstructed by centre-pier bridges, was narrow and shallow, and in some places its width did not exceed 90 feet and its depth did not exceed 16 feet. Navigation was interfered with, not only by the bridges and the narrowness of the channel and the shallowness thereof, but by tunnels constructed by the street railway companies and the City of Chicago, which have been removed in order to fully carry out the project of the Sanitary District for the improvement of the river and providing for the flowage necessary to purify the sewage. These considerations have to do, of course, only with navigation and commerce. We cannot, however, forbear again reverting to the fact that a still greater public benefit has come from changing the river from a putrid, ill-smelling nuisance into a clear, running stream which is no longer an eyesore or a menace to the inhabitants of the city.

Illinois Valley.

Protests have been filed against the granting of this permit largely conditional in their nature, by the Association of Drainage and Levee Districts of the State of Illinois. The protestants who are responsible for the resolution sent by that association and by the city councils and chambers

of commerce of certain cities and towns in the Illinois valley are fully acquainted with the beneficient results flowing from the use of the Sanitary District channel for the purpose for which it was constructed. As in other cases, these protests are based on the financial injury which will result from the supposed additional flooding of their land and the increased cost in the constructing of levees and the maintenance of levee districts. Of course, it is apparent that this has nothing to do with the question of navigation to which you confined the arguments at the hearing.. Mention is made, however, of the subject-matter because the protests are conditional and are predicated upon the present existence in the river of four dams, two maintained by the State of Illinois, through the Illinois and Michigan Canal Commissioners at Henry, and Copperas creek, and two maintained by the United States Government at Kampsville and La Grange respectively. The representatives of these associations were present in Chicago prior to the hearing on the 27th ult., and expressed themselves as perfectly satisfied with the progress being made toward the removal of these dams, and they concede that if the dams are removed their protests should be withdrawn. The State of Illinois, through its Canal Commission, has already taken action which will permit the Sanitary District, at is own expense, to remove the State dams. A bill has been introduced in Congress to remove the Government dams at Kampsville and La Grange, which so far has aroused no opposition. The only excuse for the presence of these dams was to maintain a sufficient depth of water in the Illinois river to provide for navigation by boats having a draught of seven feet. All agree that with the water now being sent to the Illinois river through the Sanitary District canal this depth can be maintained without the presence of the dams. We apprehend that there will be no difficulty in removing these dams before the full amount of water asked for is abstracted from Lake Michigan, and the removal of the dams will afford a channel of sufficient capacity to accommodate the flow of all the water asked for with less damage to the adjacent property owners than is caused by the present flow. I think I may say without fear of contradiction that had the progress which has been made toward the removal of these dams been made some months ago no protest would have come from this source, but, on the contrary, the application would have been endorsed and the co-operation of

the protestants would have been assured to us in the pending matter.

Rights of the Dominion of Canada under the Treaty of January 11, 1909.

A large part of the argument submitted by the Dominion of Canada consists of an attempt to ingeniously argue that by reason of the treaty between the United States and the Dominion of Canada, signed on January 11, 1909, the Dominion Government has a right to have a voice in the question as to the amount of water that shall be diverted from Lake Michigan for sanitary and domestic purposes.

With the proposition that the United States Government should at all times, as a matter of comity, listen to all protests and arguments that may be submitted by a neighboring friendly government against any exercise of its governmental functions, and that the same policy should be pursued by the officers entrusted with the administration of the laws of Congress, I have no quarrel. No complaint can be made, and none is here suggested, that the Dominion authorities and the Canadian interests were permitted to state their views freely in connection with the subject-matter pending before your. This opportunity, however, was a matter of comity and courtesy, and not a matter of right; and the opportunities thus afforded are not based upon any provisions of the treaty in question.

Counsel for the Dominion Government admits that Lake Michigan is not included within the definition of boundary waters as contained in the treaty. This lake is entirely within the territorial limits of the United States, and it would have been inappropriate to have included it within the term "boundary waters." This was recognized in the treaty itself, and the only rights given to Canada on Lake Michigan are those conferred by the second paragraph of Article I, in which it is provided:

"It is further agreed that so long as this treaty shall remain in force this same right of navigation shall extend to the water of Lake Michigan and to all canals connecting boundary waters, as now existing, or which may hereafter be constructed on either side of the line."

It seems to us the counsel occupied a dual position in claiming that the right of Canada to navigation was based upon the clause above quoted, thus admitting that, so far as

navigation was concerned, Lake Michigan was not a boundary water as defined in the treaty, and at the same time urging that Canada had a right to have a voice in the manner in which the waters of Lake Michigan should be used for sanitary and domestic purposes, on the theory that it is a boundary water as defined in the treaty.

There can be no question but that Lake Michigan was intentionally omitted from the provisions of the treaty; and this was proper. There was no reason why the United States should abandon its dominion over, and control of, a body of water lying entirely within its own boundaries. An examination of the record of the negotiations leading up to the adoption of the treaty will disclose that the subject-matter was discussed and that it was the intention of the parties to exclude this body of water from its provisions.

The right of those interested in navigation in Canada to protest against any diversion of water from Lake Michigan is not based upon this or any other treaty, but stands upon the same footing as any individual who is permitted to express his views to one charged with the performance of an official duty.

So far as the government of Canada itself is concerned, it is *expressly precluded* from entering any protest in this proceeding. Even assuming, for the sake of argument, that the government of Canada, as such, is entitled to have any voice as to the use to which the waters of Lake Michigan shall be put, that Government has bound itself by the terms of the treaty itself to refrain from protesting against the use of waters for domestic and sanitary purposes if the only purpose of such protest is to protect navigation. If the right of the citizens of Canada to navigate Lake Michigan should be exercised by those citizens to the detriment of sanitation, and such use should interfere with the use of the waters of Lake Michigan for domestic and sanitary purposes, then the Government of Canada would be guilty of violating the terms of the treaty.

Article VIII of the treaty expressly provides as follows:

"The following order of precedence shall be observed among the various uses enumerated hereinafter for these waters, and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of precedence:

"1. Uses for domestic and sanitary purposes.

"2. Uses for navigation, including the service of canals, for the purposes of navigation.

"3. Uses for power and for irrigation purposes.

"The foregoing provisions shall not apply to or disturb any existing uses of boundary waters on either side of the boundary."

It has been a matter of some surprise, in view of this definite and positive provision in the treaty as to the order of precedence to be observed in the uses to which the waters of the Great Lakes shall be put, that the Government of Canada should appear protesting against the use of the waters of Lake Michigan for sanitary and domestic purposes, on the ground that navigation will be interfered with. Some attempt is made to escape from the plain and natural interpretation of the words above quoted by calling attention to the last clause of Article III of the treaty.

The last paragraph of Article III is intended to guarantee to each Government the right to carry on its own works on its own side of the boundary line; and the last clause provides as follows:

"Nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes."

Because of the use of the word "ordinary" in this clause, counsel would insert it into Article VIII above quoted, making the first and paramount use to which the waters of the Great Lakes may be devoted "ordinary uses for domestic and sanitary purposes."

Manifestly, this was not the intention of the framers of the treaty. This is evidenced, first, by the fact that the word "ordinary" was not used; second, because it is expressly provided that the provisions shall not disturb any existing use of boundary waters on either side of the boundary; and if, under any construction, Lake Michigan could be construed as a boundary water because of its connection with Lake Huron, the Canadian Government had full notice of the fact that the waters of Lake Michigan were at the time of the signing of the treaty, being used for the purpose of diluting the sewage of the City of Chicago; and they consented that no provision of the treaty should interefere with that use. If the water of Lake Michigan is to be used to dilute the sewage of Chicago, a sufficient quantity thereof must be appropriated for that purpose, and the Canadian Government was fully aware of the plan for the treatment

of sewage which had been adopted and carried out by that city.

Counsel for the Dominion, as well as the representatives of the navigation interests, were careful to reserve the right to protest hereafter under the terms of the treaty, and called attention to the last paragraph of Article II, as follows:

"It is understood, however, that neither of the high contracting parties intends, by the foregoing provision, to surrender any right which it may have to object to any interference with or diversion of waters on the other side of the boundary, the effect of which would be productive of material injury to the navigation interests on its own side of the boundary."

This clause was not inserted for the purpose of giving either Government any right not already enjoyed by it. The right of one nation to protest against acts of another, which may be detrimental to the integrity of the nation or the interests of its inhabitants, is founded not upon treaties, but upon the general principles of international law; and this clause merely means that those general rights were not to be construed as having been taken away by the treaty, and it was not intended that the treaty should give them additional rights.

It may be here observed that a protest from the Dominion of Canada gainst the lowering of lake levels comes with rather poor grace. It is a matter of record in your department that during the improvement of the Detroit river in the construction of the Livingstone channel the United States Government sought to maintain the level of the lakes by the construction of remedial works on the Canadian side. A protest was entered on behalf of the Canadian Government, and those remedial works have not been constructed as was planned by the United States engineers.

The rights of the Dominion of Canada and the obligations of the United States arising under this treaty, in so far as the control of the waters of Lake Michigan is concerned, would be decided adversely to the Dominion Government, according to the principles of law that are clearly set forth in the opinion of Hon. Judson Harmon, Attorney General in 1895, rendered to the Secretary of State construing the treaty of Guadalupe-Hidalgo (Opinions of Attorney General, volume XXI, page 27).

On page 30 of the brief submitted by the Dominion of Canada this statement appears:

"Chicago is at the stagnant end of what is practically a stagnant lake, fed only by small streams, nearly all of which discharge into it the sewage of a large and rapidly increasing population, and the drainage wastes of large and growing industrial establishments."

This statement is surprising in its inaccuracy. The engineers in your department will inform you that, if Lake Michigan were a stagnant lake, Chicago would be at the headwaters of the watershed. It is well known that the waters of Lake Michigan are more potable than those of any of the Great Lakes, except Lake Superior, and, except in the vicinity of large cities which may be permitted to discharge their sewage into it, is a source of an abundant and exceptionally good supply of drinking water.

Compensating Works.

In view of the great importance to the people of Chicago that the request now made be granted, we have made some study of the question of the cost of such compensating works as might be necessary to nullify any effect of a diversion through the Sanitary District canal if such effect should be deemed injurious to navigation. This subject is one which requires great study and elaborate computations. It has been a subject which has been given consideration by many of the most eminent engineers of the country; and, bearing upon the general proposition of the practicability and efficacy of such works, I have the honor to attach hereto as an appendix, marked "C," a letter from Alfred Noble, of New York City, who is recognized as one of the most eminent engineers of the country.

I suggest, also, that Mr. Noble by his letter endorses in large degree the report of the Chief Engineer of the Sanitary District, to which reference has been made.

Conclusion.

We respectfully submit that it is abundantly shown:

1st. That there is an imperative need of the waters of Lake Michigan for sanitation purposes, as specified in our application.

2d. That the Sanitary District canal is the outgrowth and development of a scheme recognized by the United States

Government, the Dominion of Canada, and the State of Illinois since 1822.

3d. That we are entitled, as a matter of right, to the use of so much of the waters of Lake Michigan as may be necessary for sanitary and domestic purposes.

4th. That no substantial injuries have been shown to have been suffered by navigation interests in the past, and that the fears of future damage are too indefinite to weigh against the pressing needs of sanitation.

5th. That navigation in the Chicago river will be abundantly protected by such restrictions as may properly be imposed by the War Department.

6th. That the conditional protests of the associations and cities in the Illinois valley were based upon conditions that are already being eliminated.

7th. That the Dominion of Canada has no right under the treaty of January 11, 1909, to any voice in the disposition of the waters of Lake Michigan for sanitary purposes.

8th. That, even if it shall be possible in the future to care for the sewage of the Sanitary District without the use of the additional water asked for, the permit should be issued until such conditions arise, when the permit may be appropriately revoked or altered.

We agree with one of the eminent gentlemen who spoke on behalf of the Canadian Water Power Company, when he said that the question to be decided in this matter is a momentous one and of supreme importance.

It is a question as to whether or not fears shall be allowed to prevail over facts, and whether or not possible profits to navigation interests shall be considered of greater importance than the lives of the people of a community comprising one-thirtieth of the population of the nation.

We feel confident that the decision will be in the interests of humanity, and that the public interest will be protected and the general welfare promoted.

Respectfully submitted,

JOHN C. WILLIAMS,
Attorney for Sanitary District of Chicago.

Approved:

GEORGE M. WISNER,
Chief Engineer.

21559—12.

REPLY ON BEHALF OF CANADA.

IN THE MATTER OF THE APPLICATION OF THE SANITARY DISTRICT OF CHICAGO FOR A PERMIT TO DIVERT NOT TO EXCEED TEN THOUSAND CUBIC FEET OF WATER PER SECOND FOR SANITARY PURPOSES FROM LAKE MICHIGAN.

To the Honourable Henry L. Stimson,
Secretary of War.

Sir:—Replying to the brief, or suggestions, in behalf of the Sanitary District of Chicago filed by John C. Williams, Esquire, Attorney for the Sanitary District, it is respectfully submitted:—

That, while professing to confine himself as closely as possible to the suggestions conveyed in the course of the hearings before you, that the sole purpose of the enquiry was to decide whether, or not, the interests of navigation would be substantially affected adversely by the granting of the permit, the learned Counsel departs widely from this ground and dwells at great length upon the needs of Chicago with regard to sanitation. Indeed he seems to treat the question of injury to navigation very lightly, as if it were of but slight importance, instead of being, as it is, the sole question which you are called upon to determine on this application. It is not, as the learned Counsel for the Sanitary District suggests, that the protection of navigation interests would be rendered MORE profitable, but it is because navigation interests will not only be rendered enormously LESS profitable, but, that great expenditures amounting to over $18,000,000, at least, on the Canadian side of the line, will become necessary to restore the lost depths in Canadian harbours,—including the great national port of Montreal, the ship channel and the Canadian canals—that it is urged in behalf of the Canadian government, that the proposed diversion will be productive of material injury to navigation interests on the Canadian side of the boundary. It goes without saying that navigation interests on the United States side of the boundary will suffer injury in like manner, but, admittedly, to far greater extent in respect to the effect on shipping. It is abundantly clear that the navigation interests of both countries are not only seriously threatened by the proposed diversion but have already sustained material injury by the reduction of the levels of the great international waterways

system. This is manifest from the expert evidence of competent witnesses on both sides of the line including the United States Corps of Army Engineers, and the technical officers of the Canadian Government, as well as many eminent private engineers whose statements are before you.

By the Federal constitution, navigation is confided to Congress, hence it is submitted, the Legislature of the State of Illinois could not legally authorize the diversion of the waters of Lake Michigan, the effects of such diversion being manifestly productive of material injury to navigation.

In the absence of legislation on the part of Congress authorizing the diversion of the waters of Lake Michigan it is submitted, that, unless the Sanitary District obtains a permit from the Secretary of War authorizing such diversion, under Section 10 of the Act of Congress of March 3, 1899, by which the Secretary of War is given jurisdiction over the navigable waters of the United States, it is contended, that the claim set up in the brief of the attorney for the Sanitary District that they are entitled to use the waters of Lake Michigan as a matter of right, is not well founded.

The jurisdiction of the Secretary of War extends over all navigable waters of the United States and any injury to navigation within the territory of the United States is cognizable by him, so that, if the lowering of the levels of the waters of Lake Michigan and boundary waters within United States territory be productive of material injury to navigation, it is a matter that comes within the jurisdiction of the Secretary of War. That the lowering of the levels of the lakes, connecting channels, and canals, entailing heavy permanent losses to navigation interests, will occur as a direct result of the proposed diversion, is established beyond question in the brief filed on behalf of the Canadian Government and in the other statements filed on the part of Canadian interests, as well as by the International Waterways Commission report, and the report of the United States Corps of Engineers which is signed by General W. H. Bixby, Chief of Engineers, United States Army, dated January 23, 1911, wherein it is stated "As the water which is at present being diverted from the lake appears to have already seriously affected the navigation of its harbours and connecting waterways, prompt congressional action is recommended to limit the diversion."

It is not the desire, nor is it the intention of Counsel for the Canadian Government to reiterate the arguments put forward in the brief filed by him on the 27th of March, nor

to repeat anything that was urged, orally, on that occasion in opposing the granting of the permit asked for. This reply will be confined as nearly as possible, to dealing with new matter and answering statements made by the Counsel for the Sanitary District in his brief filed since the last hearing. At the same time reliance is placed upon the accuracy of the statements of fact and inferences drawn therefrom, as well as the general conclusions reached, as set forth in the Canadian Government's brief. The statements herein put forward are to be treated as supplementary to the brief already filed on the part of the Canadian Government.

Counsel for the Sanitary District, in several places in his argument, endeavoured, in substance, to show that the jurisdiction of the Federal Government is limited to the effects which the withdrawal of water from Lake Michigan through the Chicago river will have upon navigation in that river. He contends that, therefore, all that is asked in the application now pending, as well as in former applications, is permission to draw water through the Chicago and Calumet rivers, and that the Sanitary District has a perfect right to draw without permit any quantity of water from Lake Michigan which it may please, through channels other than the Chicago river.

We strongly protest against the assumption of any such right by the Sanitary District because the withdrawal from Lake Michigan of water through any channel and the diversion of the natural flow of the Chicago and Calumet rivers to the Mississippi instead of to Lake Michigan, have precisely the same effect of lowering the level of Lake Michigan and, consequently, to lower Lake Huron and all other bounary waters between Sault Ste. Marie and the tidewaters of the St. Lawrence; and, thereby, to affect adversely the navigation interests of both the United States and Canada throughout the whole extent of these waters. To that extent, such withdrawal is a violation of the Treaty of 1909.

The permit of May 8, 1899, recites that, whereas, the Sanitary District had been granted permission by the Secretary of War to enlarge the Chicago river so as to secure a flowage capacity of 300,000 cubic feet per minute, "it being intended to connect the said artificial channel (from Chicago to Lockport) with the west fork of the south branch of Chicago river at Robey street," the Secretary of War "hereby gives permission to open the channel constructed and cause the waters of Chicago river to flow into the same."

The permit of April 9, 1901, reduces the permitted "discharge from the river into the drainage canal."

The permit of December 5, 1901, increases the discharge permitted during certain hours of the day.

The permit of January 17, 1903, gives "permission to increase the flow through the Chicago river" until March 31, 1903.

The water pumped at Wilmette flows down the north branch of the Chicago river to its confluence with the south branch and thence along the channel of the latter to the head of the Drainage Canal at Robey street. The water pumped at the 39th street pumping station flows by the south branch of the Chicago river to the head of the Drainage canal at Robey street.

It is submitted that the permit of May 8, 1899, is the basal authorization for all diversions; that it authorizes the opening of the Drainage canal at Robey street; that it distinctly applies the name "Chicago river" to the channel from Lake Michigan to the head of the Drainage canal at Robey street; and further, authorizes the discharge into said canal of a specified amount of water. Later permits are simply modifications of the amount of water authorized to be discharged into the canal.

Counsel argues that the discharge from the Wilmette and 39th street pumping stations, the water pumped for domestic water supply and, inferentially, any other flowage not discharged into the Chicago river below the confluence of the north and south branches, do not come within the purview of the above mentioned permits. It is submitted, that this argument is absolutely untenable. It is further submitted that the discharge of the Sanitary canal at Lockport cannot legally exceed the amount authorized by the Secretary of War.

The fact that the permits heretofore granted specifically guard the interests of navigation in the Chicago river, does not preclude navigation interests elsewhere which are adversely affected by the diversion through the Chicago Drainage canal from protesting against the granting of the permit now asked for. It was only when it was found that the diversion already permitted was reducing the levels of the Great Lakes and connecting channels and canals, thereby causing material injury to navigation, that navigation interests on both sides of the border acting with a common impulse but without any preconcerted arrangement, joined

forces in vigorous protest against the granting of the present application.

As far as Canada is concerned in the question of joining in the concerted opposition to the proposal, it may be stated that this is the first occasion on which she has been invited to express her views. All previous permits were granted without reference to Canada. It is not in accordance with the facts to state that this concerted action is due to the unusual low-water conditions of the past season. On the contrary, it is due to the request of Chicago for more water. Against the unanimous action on the part of navigation interests, supported by the Dominion Government and butteressed by unquestionable data from unimpeachable sources, in protesting against any further diversion of the waters of Lake Michigan because of the injury to navigation, we have the bald statement of counsel for the Sanitary District that "the objection to the granting of the permit made by those who are interested in lake navigation is based upon fears for which there is no basis, and upon speculative theories that up to this time have not been demonstrated to be of practical force."

Referring to the statement of the learned Counsel for the Sanitary District that Counsel for Canada admits that Lake Michigan is not included within the definition of boundary waters as contained in the treaty, attention must be called to the various other references which were made during the hearing by Counsel for Canada, in which that admission was very much qualified, and a reservation of Canada's rights to have the question referred to the International Joint Commission was made by Counsel for Canada, not only in his oral statement, but in his brief filed with you.

Dealing with the rights of the Dominion of Canada under the Treaty of January 11, 1909, Counsel for the Sanitary District observes that "so far as the Government of Canada is concerned, it is expressly precluded from entering any protest in this proceeding."

Whether or not Lake Michigan may be considered a boundary water within the definition of the treaty, it cannot be questioned that the right of navigation of Lake Michigan is conceded to Canada while that treaty remains in force. If, therefore, the right of navigation of Lake Michigan on the part of Canada is obstructed in any way, as for instance by the diversion of waters from Lake Michigan through the Chicago river causing an increased current

and thereby rendering navigation of the Chicago river hazardous, Canada would be entitled to enter a protest. If Lake Michigan is a boundary water, or might so be considered under the spirit of the treaty, Canada would not be debarred from protesting against the proposed diversion, since, as it is submitted, that, by the true construction of Article VIII of the treaty defining the order of precedence, "uses for domestic and sanitary purposes" means "ordinary use." To hold that these words mean an extraordinary use such as the diversion at Chicago through the Drainage canal causing an irreparable loss to navigation, would defeat the object of the treaty which was the protection of boundary waters, while, in the first place, recognizing the right of either country to the ordinary use of boundary waters for domestic and sanitary purposes, and, secondly, "uses for navigation, including the service of canals, for the purposes of navigation." If by the first use for domestic and sanitary purposes it was contemplated that such a diversion could be made as would seriously impair navigation, it would be a violation of the spirit of the treaty.

Counsel for the Sanitary District goes so far as to state that "if the right of citizens of Canada to navigate Lake Michigan should be exercised by those citizens to the detriment of sanitation, and such use should interfere with the use of the waters of Lake Michigan for domestic and sanitary purposes, then the Government of Canada would be guilty of violating the terms of the treaty." It seems unnecessary to reply to such an extreme and unwarranted statement; but, as counsel has devoted considerable space to this point, it may be well to state that, while priority in the use of waters is set forth in the treaty, yet it was never intended that this priority was to work injustice to other legitimate users of the waters.

Counsel's argument is, in brief, that the treaty of 1909 permits the unlimited diversion of water so long as it is required for "domestic and sanitary purposes." The logical deduction, therefore, is that, if so required, the whole flow of Lakes Huron and Michigan could be diverted and the St. Clair river dried up—the *reductio ad absurdum*.

The principle affirmed in Article III is, that there shall be no uses, obstructions or diversions, whether temporary or permanent, of boundary waters on either side of the line except by the authority of either country within their respective jurisdictions. Exceptions are made in favour of

governmental works for the benefit of commerce and navigation, provided such do not materially affect the level or flow of the boundary waters on the other side. Here, again, the principle of maintaining the levels of boundary waters is apparent.

And finally we have the concluding clause quoted by the learned counsel "nor are such provisions intended to interfere with the ORDINARY USE of such waters for domestic purposes." What waters are here referred to? The answer is clear and simple: boundary waters. Yet Counsel for the Sanitary District endeavours to draw a distinction between the use of boundary waters for domestic and sanitary purposes as contained in the final clause of Article III, and the use of boundary waters in Article VIII, wherein the object is only to give the order of precedence in the several uses of boundary waters. It is respectfully submitted that Article III explains the meaning of the words in Article VIII, giving precedence to the "uses of boundary waters for domestic and sanitary purposes" and clearly shows that such uses are only "ordinary use."

To put the construction contended for by the learned counsel on Article VIII, and to hold that "uses for domestic and sanitary purposes," leaves such uses unrestricted, would be contrary to the letter and spirit of the treaty; whereas the use of boundary waters as provided for in the concluding clause of Article III, that is to say, "ordinary use" puts a reasonable construction on the language in Article VIII. Then again, the first mention of the use of boundary waters for domestic and sanitary purposes in the treaty is in Article III, and the words there employed, "ordinary use," show unmistakably what the framers of the treaty had in mind in giving precedence to the use of boundary waters for domestic and sanitary purposes in Article VIII. In other words, Article VIII does not enlarge the clearly expressed definition of the use of boundary waters for domestic and sanitary purposes in Article III, i. e., *ordinary use.* No significance can be attached to the omission of the word "ordinary" in Article VIII. The extent of the use had been already defined in Article III.

The foregoing is sufficient to demonstrate that the treaty contemplated only the "ordinary" use of water for these purposes and had reference to its abstraction by pumping for domestic and sanitary use and contemplates its use as a diluting agent when sewage is discharged into it. Additional weight is lent to this contention by the last paragraph

in Article III above quoted. However, a discussion of this branch of the case is not really pertinent to the question you have undertaken to determine.

The boundary waters treaty was conceived with the express purpose of conserving the integrity of the levels of the Great Lakes. It was not an object of the treaty to establish the priority of agency by which these levels might be disturbed, but rather than when once it has been decided by both countries that certain usages of water were for the common and general good, then the treaty provides for the priority of those uses. Any use of water, therefore, must, itself, first be approved and sanctioned by the two countries party to the treaty.

From the learned counsel's argument it would appear to one unfamiliar with the circumstances, that the Sanitary District was already, in the possession of rights under the treaty of 1909, to make the diversions in question. A wholesale diversion of water, such as is proposed by the Sanitary District, is a question which must be decided by the proper tribunal before any ground for considering priority of use would be created.

The learned counsel, on the theory that Lake Michigan is not a boundary water as defined in the treaty of 1909, contends that Canada has not a "right to have a voice" in the manner in which the waters of Lake Michigan should be used for domestic and sanitary purposes. Canada, however, declares that she has treaty rights in respect to diversions from Lake Michigan because such diversions directly affect boundary waters. Diversions from the lower end of Lake Michigan mean the taking away of waters which in their natural channels, would flow into boundary waters, and this taking away of such waters materially affects lake levels and results in serious injury to navigation and other interests on the Canadian side of the boundary. Indeed, this is also the ground taken by the special Board of Engineers under the chairmanship of Brig.-Gen. W. H. Bixby. In its report of January 23, 1911, to the U. S. Secretary of War, this Board states:

"The future diversion of water from Lake Michigan for any purpose is fraught with difficulties. *Not only has Canada an interest in the maintenance of lake levels which the United States must recognize*, but every foot of water flowing through the Chicago Drainage canal lessens the flow at Niagara Falls and at the power sites along the St. Lawrence river."

The learned counsel states that:

"the Canadian government had full notice of the fact that the waters of Lake Michigan were, at the time of the signing of the treaty, being used for the purpose of diluting the sewage of the City of Chicago; and they consented that no provision of the treaty should interfere with that use."

This allegation might have some force if the present application had reference to the limited use referred to. But it can be of no avail on an application for a largely increased amount, and, on such an application, in view of the restricted scope of the discussion as defined by you, Mr. Secretary, it is unnecessary to enter into any argument regarding the limited amount that might ultimately be found necessary.

Appendix "B" of the brief of Counsel for the Sanitary District quotes sections 19 and 43 of the report of the International Waterways Commission, and the argument has been advanced that this report constitutes a joint recommendation on the part of the Governments of Canada and the United States that a withdrawal of 10,000 cubic feet of water per second through the canal should be permitted.

Counsel for Canada contends that, inasmuch as it is a purely advisory body, no recommendations by the International Waterways Commission can bind either Government and that no such recommendation has been adopted by either.

II.

In the section of the brief submitted by Counsel for the Sanitary District which deals with the disposal of the sewage of Chicago the essential features of the argument are:—

(1) That there is no known method of sewage treatment which, if applied to Chicago, would make the effluent fit for being discharged into Lake Michigan near the intakes of the water works.

(2) That, therefore, the dilution method adopted for the treatment of the sewage of Chicago is the only feasible one at present known.

(3) That the 10,000 cubic feet of water per second now applied for by the Sanitary District is the least quantity by which the sewage of Chicago and its suburbs can be properly diluted and made fit for being discharged through the Drainage canal into the Illinois river.

With respect to the first contention, we reply that we have nowhere asserted or requested that the sewage of Chicago should be purified to such extent as to be fit for being dis-

charged into the lake and thus mixed with the supply for the waterworks.

We have simply asserted and maintained not by opinions, but by examples, cited, that the purification of sewage to such extent as to be non-putrescent and non-offensive, and thus made fit for being discharged into the Drainage canal and into the Illinois river, is entirely feasible.

The reports of the sanitary engineers upon the treatment of Chicago sewage, which we have quoted, bear us out in this contention.

The learned counsel himself, in his brief, admits that Chicago is so situated that it is possible by a combination of partial purification and dilution methods to dispose of its sewage without offense to any one and with perfect safety to its water supply. It is a comparatively simple and inexpensive matter to partially purify sewage.

The dilution method, or, more accurately, the power producing method, chosen by Chicago—and the one to which it so strenuously adheres—is not the combination of partial purification and dilution, which counsel and the experts of the Sanitary District admit to be quite feasible. It consists in taking the raw sewage of a prospective population of three millions, including the largest part of the industrial wastes, and demanding water enough to convert it into an innocuous stream of vast volume which is to be used for the generation of power estimated by Mr. Hering at 47,300 horse power, and then discharged into the Illinois river. It is the abstraction of this enormous quantity of water in utter disregard of navigation and other interests, to which we object, and for the reasons set forth in our former brief.

Counsel cites the case of Worcester, Mass., as one in which the treated effluent is unfit for domestic use and remarks that, if the intermittent filtration there used were adopted at Chicago, the cost of obtaining the necessary land and preparing filter beds would be so enormous as to make it prohibitive. The deductions thus drawn from the Worcester example are entirely irrelevant, because the conditions at Worcester and at Chicago are quite different, and the method which is suitable to one is not suited to the other.

The eminent engineers, Mr. Hering and Mr. Wisner in their reports show that the sprinkling system is that which is suitable for Chicago, and that it can be installed and operated at a moderate cost.

Mr. Wisner even goes so far as to indicate suitable sites by saying that "the sites available are to the north of the junction of the North Shore channel with the north branch of the Chicago river, near Lawrence avenue, on the flat tract of land which exists there. On the west side, sites seem to be available to the east of the old Ogden dam, and both north and south of the main channel. Pumping would have to be resorted to in any case. On the south side available sites in the Calumet region are many."

As regards the case of Manchester, England, quoted by counsel, he reiterates the remark that the effluent must be dangerous to discharge into Lake Michigan near the intake of the Chicago water supply. This is altogether beside the mark; the case really furnishes convincing proof that the very concentrated sewage of a large city is successfully treated to such extent as to be discharged into a much used navigation canal, not only with no bad results, but actually to improve the quality of water. This is exactly what is needed in the case of the sewage of Chicago which is to be carried off by its drainage canal.

It is recognized in the reports of the experts referred to, and in counsel's arguments, that the dilution method of disposing of the sewage of Chicago is inefficient, inasmuch as it permits the deposition of enormous quantities of putrescent sludge in the Chicago river, along the drainage canal, and in the Desplaines and Illinois rivers; and that screening and sedimentation must be adopted to remedy this serious defect. Also, that the industrial wastes must be specially treated.

Thus, the permit of January 17, 1903, expressly states that the extra water is granted "*in order to carry off the accumulations of sewage deposit which line the shore along the said city.*"

This admits the principle that some treatment of the sewage is needed to supplement the defects of dilution and it logically follows that further treatment, as carried out in other cities, would make the effluent fit for discharging, by way of the canal, with little or no dilution.

Counsel objects to purification of Chicago sewage on the ground that a purification plant is less efficient in winter than in summer, and quotes Columbus, Ohio, as a case in point. He says "that the climatic conditions in and around Chicago would be decidedly inimical to the efficient operation of any purification plant"; but all that he adduces in proof is that purification processes are less active in extreme cold weather

than in summer, and quotes the Columbus plant as his example. The learned counsel is quite wrong upon this point. Mr. Wisner, chief engineer of the Sanitary District, in his report on the "Disposal of Chicago Sewage," makes statement in direct contradiction to the contentions of counsel: He says: "From experiments carried on at the Thirty-ninth street testing station it is evident that, with sewage largely domestic and well prepared by settling, a yield of 2½ to 3 million gallons per acre per day may be expected with a bed of stone 1¼ to 2 inches in size, and 6 to 7 feet deep, and that the effluent will be stable for the greater portion of the year.

"Covering the filters will make a marked difference under any condition, causing the filter to deliver an effluent higher in nitrates during the winter months, and also nonputrescible. It is doubtful, however, whether it is necessary in the immediate future to cover filters, as satisfactory results can probably be obtained with open filters under weather conditions in Chicago. Even if the effluent is not as stable in the colder weather, the higher content of oxygen in the cold lake water will more than take care of the difference in the stability of the effluent."

Counsel draws attention to the terms used in our brief describing the purification plant at Baltimore, which implies that that plant is in actual operation. We are glad to correct the implication, and to explain that the language does not assert, and was not meant to imply that the works are actually in operation, but simply that the effluent from the sprinkling filters necessarily well purified, will be further treated in order to completely sterilize it.

It may, however, be added that the example loses neither force nor fitness by the correction, for it still shows that Baltimore has deemed it feasible and wise to both purify and sterilize its sewage, for the preservation of the life and health of its inhabitants and to keep wholesome its Chesapeake Bay oysters, and it, therefore, cannot be considered either impracticable or unreasonable to require that Chicago, for the preservation of the life and health of its citizens, shall install partial purification plants at the sacrifice of some of its power production works.

III.

In view of the fact that counsel for the Sanitary District has thought fit to give a brief historical sketch of the conditions at Chicago, prior to the initiation of the Drainage

Canal scheme, a few additions to the sketch may be pertinent:

In 1882, the United States granted a right of way through the public lands and, in 1827, made a grant of land to the State of Illinois to aid "in opening a canal to connect the waters of the Illinois river with those of Lake Michigan." Work was commenced in 1836 and, in 1848, the canal was opened from the Chicago river at Bridgeport to the Illinois river at La Salle. The summit level was eight feet above Lake Michigan (low water of 1847, Chicago datum), and, in time of drought—about 45 days in the year—received water by pumping from the Chicago river at Bridgeport.

In the late "fifties" the City of Chicago entered into an agreement with the canal authorities whereby the latter agreed to pump water all the year round, thus improving the sanitary condition of the Chicago river.

Later, a further agreement was made whereby the City of Chicago cut down the summit level. This work was completed in 1871, and 150 cubic feet per second was diverted from the Chicago river to the Desplaines river. The difference between the summit level of the canal and Lake Michigan, however, was so small that certain winds lowering the lake level, or a very heavy rainfall, would set the current in the Chicago river east into the lake.

The original land surveys show that in times of high water, the Desplaines river overflowed the low water parting and discharged into the south branch of the Chicago river. The Internal Improvement Commission of Illinois, Isham Randolph, Chairman, state in their report, 1909, that "The inference is plain, that the south branch of the Chicago river with its two forks, was the proper outlet for the flood waters of the Desplaines river and was maintained thereby. * * * What occasioned the diversion down the present course of the Desplaines river is a matter of speculation—it may have been due to silt deposits initiated by a beaver dam. * * * The present course bears every evidence of being very recent. * * * In 1849, the divide was overflowed at the spring breakup (much as in 1675, when Marquette was driven from his cabin) with ice gorges and great destruction of shipping and bridges in the Chicago river."

Even in 1877, after the new dam in the Ogden-Wentworth canal was constructed, at times of high floods, 75 per cent. of the Desplaines river waters came through Chicago as they did before the dams were built. As a result, the old pumping works at Bridgeport were rebuilt.

In brief, from the opening of the canal in 1848, to 1871, an insignificant amount of water was *pumped* from the Chicago river to the Desplaines river; from 1871, till the Bridgeport pumping station was completed, the canal diverted only 150 cubic feet per second, and, thereafter, till the present drainage canal was opened in 1900, 1,000 cubic feet per second.

Counsel for Chicago argues that the "present canal is a growth and development of the policy of both the State and Nation," and that "it is strange that after a policy has been declared and carried out for a period of ninety years, there should be, at this late date, so strenuous an effort to prevent the protection of the lives of the people of that large community because of some supposed and imaginary injury to navigation upon the Great Lakes."

To argue that the operation of a small pumping plant for 45 days in the year raising an insignificant amount of water for navigation purposes for locks 110 feet long, 18 feet wide and 6 feet deep, justifies the diversion of 10,000 cubic feet of water per second is a somewhat unusual expansion of terminology.

Counsel for the Sanitary District is imbued with the idea that the people tributary to that district are the public, and, that Canada and the opponents of the scheme are fighting for private interests. The waterways serve the public, afford them cheap rates both directly and by competing with railways; they afford the millions along their shores good drinking water, and, like Chicago, a means of diluting their sewage, not however, by throwing the water away, but by leaving it in the drainage basin.

There should be a distinction between the public of a municipality and the whole country. If, by dredging, or placing obstructions in the outlets of the lakes, the levels have been changed, the work was undertaken by the Government representing the whole people, for the benefit of navigation and the country generally. The Government is the one authority that may do as it pleases; the people of Chicago are only a portion of the whole and may do only what the whole permits.

All works carried out by the Federal Government have been for the benefit of the general public rather than for any locality or private interest, by making it possible to build larger and more economical freight carriers, always with a view of attaining cheaper transportation of food and other

supplies necessary for the comfort and welfare of both nations.

Counsel says, "We deal, however, not with future conditions which are uncertain and indefinite, but with actual conditions which exist now; and so long as they do exist, the necessity is imperative that Lake Michigan, the great storage basin provided by nature for the comfort and convenience of man, shall be used to promote the health and comfort of those who may avail themselves thereof."

If all lake cities could, and did, use the lakes as Chicago does, the unparalleled system of inland waterways would be utterly ruined.

The learned counsel for the Sanitary District renews his argument "that transportation companies must accommodate themselves to the natural conditions regarding fluctuations in lake levels," and contends that this argument in that respect is not fallacious. But no one makes any objection to the argument as stated in the above quotation. The objection applies to the fallacious contention that, navigation interests can afford to ignore any artificial aggravation of the troubles arising from natural conditions, and it is sheer folly to submit to the serious consideration of any tribunal a suggestion that, because, in the course of business, one loses any valuable commodity in a considerable variety of ways, he will not be prejudiced by any additional loss.

Since the culmination of a "high" cycle in the "eighties," the level of the Great Lakes has fallen below the average level that obtained prior to that period, and a critical examination of the gauge readings demonstrates that we have entered upon an era of distinctly lower levels. It is not possible to allocate to deficient precipitation, development operations and causes other than the Sanitary Canal, the proportion due to each. But, in the case of the Sanitary Canal, no such difficulty exists. The amount abstracted, instead of being inappreciable on account of the extent and variety of other losses, comes, in fact, as a very serious aggravation of the trouble.

The accompanying profile shows, diagrammatically, the actual effect upon the gauge heights of Lakes Michigan, Huron, Erie and Ontario, assuming that the full effect of the diversion of 7,000 cubic feet per second has been experienced during the years 1909, 1910 and 1911. The *bottom* of the solid black indicates actual gauge readings during these years, while the top indicates what the gauge readings would have

been but for the 7,000 c.f.s, diversion. If 10,000 cubic feet per second had been diverted, the gauge heights would have been reduced to the bottom of the red band.

It is necessary, however, to point out the complete inaccuracy of the statement submitted by counsel as the foundation for his examination of the calculations of the losses suffered by transportation companies. He states that "The only vessels now sailing the Great Lakes which could be affected by any variation in lake levels of from 3 to 5 inches are owned and operated by the ore-carrying companies, particularly the Pittsburg Steamship Co., which is a subsidiary company of the United States Steel Corporation."

This statement is simply not true, and doubt is thrown upon the accuracy of the information in the possession of the Sanitary District with reference to lake navigation.

The truth is that every vessel mentioned in connection with the statements submitted on behalf of the Dominion Marine Association and the Shipping Federation of Canada, is, at least in periods of low water, seriously affected by "variations in lake levels of from 3 to 5 inches." If they are loaded at the head of the lakes for Georgian Bay ports or Goderich, Point Edward, Port Colborne or Buffalo, they feel even such a slight variation at once, for the permitted draught of water at the Canadian canal at Sault Ste. Marie, at the opening of navigation, in the coming season is to be only 17 feet 5 inches for upbound vessels and 17 feet 10 inches for those downbound. If they are loaded for Kingston or Montreal, they feel the loss of even an inch of water at the Welland canal, or if not, then at the Rapide Plat in the St. Lawrence river or at some one of the various St. Lawrence canals. The same statement applies, not in theory, but infact, to every vessel that finds occasion to enter a harbour of limited depth anywhere on the lakes or river. Ocean tonnage, again, feels the loss in the same way, and reference must be had to the statements submitted on behalf of the two Canadian Associations mentioned as well as what was said by counsel for those bodies at the hearing in Washington on the 27th March last. These statements, it is submitted, are not at all met by any such methods as those adopted in the brief submitted for the Sanitary District.

The brief in question proceeds to state "that the profits of transportation companies depend, not upon the depth of water but upon the amount of freight carried," and "that it is not and cannot be truthfully contended that any freight

has not been carried by reason of lack of water which would otherwise have been." In answer, it is submitted that the remarks above quoted are so far removed from being statements of fact that they scarcely require contradiction. To take only one concrete case, the Canadian steamer "E. B. Osler" which could carry, three or four years ago, something over 10,000 tons of coal per trip, could, and did, in 1911, carry only something over 8,000, thus losing *not in imagination or theory, but in fact,* about 2,000 tons per trip with corresponding loss in earnings. It is an uncontroverted fact that vessels were forced to go down the Welland canal last year under restrictions as to draught, and were even turned back by canal officials to unload cargo at Port Colborne when drawing an inch or two too much. It is also an uncontroverted fact that boats ran the St. Lawrence at 12 feet and some inches draught which should have carried, and desired to carry, 14 feet, and that they were required on occasions, to go back and take out cargo at Prescott before being permitted to proceed. It is an uncontradicted fact that loss and inconvenience were suffered by ocean tonnage in the river below Montreal, and, in the face of these facts, the statements and arguments in the brief for the Sanitary District are futile and worse than useless.

It is also useless to contend that, in periods of high water, the loss due to the action of the Sanitary District may not be felt, for that is not the question immediately at issue, and it is utterly absurd to contend that no one has yet made the slightest claim up to this date, that navigation has been impaired by the operation of the Sanitary District canal; for we are dealing with existing conditions and every complaint that has been made, has applied to every inch of loss already suffered, and, it may be added, that all engineers agree, that, in periods of low water, the loss in level for a given withdrawal of water is very much greater than at times when the water is high.

In the brief submitted by counsel for the Sanitary District, attention is drawn to a supposed discrepancy in the figures used to show the loss of depth at the Rapide Plat by the International Waterways Commission, and those submitted by the representatives of Canada. The figures submitted for the Dominion of Canada were computed for periods of *low water* whereas those quoted from the report of the International Waterways Commission were calculated for *mean water,* a fact apparently ignored, or overlooked, in counsel's brief where comment is made on the difference between these

figures and other expert estimates. The figures submittd for the effect of the diversion at Montreal have been obtained from the best information now in possession of the Government Departments. This information has been acquired by direct flow measurements made since the publication of the report of the International Waterways Commission mentioned.

Counsel quotes "from chart No. 2483 of the Canadian Government charts of the Harbour of Montreal." This chart has not been published by the Canadian Government, and the figures cited by counsel do not correctly show the depths which govern the navigable draught in Montreal harbour. The latest chart of this harbour shows 30 feet in the channel approaching the piers and 29 feet alongside the wharves. It was dredged to what was considered a safe depth for a certain draught. If it be reduced by six or twelve inches, there can be no question that the efficiency of the harbour is greatly impaired.

Counsel states that:

"According to the Forty-third Annual Report of the Department of Marine and Fisheries of Canada of 1910 the total expenditure on the improvement of the St. Lawrence river, since 1851, by all public appropriations, has been $11,400,000. This is practically the amount that has been expended by the Sanitary District alone in the improvement of the harbour facilities in the Chicago river.

"Navigation interests represented by a government that has expended in their behalf less than one-sixth of the money expended by the Sanitary District for health and sanitation should not expect their protests to be seriously considered."

Counsel is under a misapprehension in this regard, as the amount referred to applies only to the improvement of the St. Lawrence Ship channel below Montreal prior to 1910, whereas the expenditure incurred by the Canadian Government, up to the end of the fiscal year 1910-11, on the St. Lawrence above Montreal in canal works, dredging of channels, harbours, &c., amounts to $52,000,000. To this amount must be added $20,000,000 expended on Montreal Harbour works, and $13,436,000 on the River St. Lawrence Ship channel below Montreal.

This makes a total expenditure of $85,436,000 incurred by the Canadian Government for the improvement of navigation on the St. Lawrence river between Lake Ontario and Quebec.

In addition to the above amount, $36,881,000 have been

expended on the Welland canal, $5,631,000 on the Sault Ste. Marie canal, and $21,000,000 on dredging and harbour works on the Great Lakes, making a grand total of $149,000,000 expended on works that are adversely affected by the diversion at Chicago.

As the improved St. Lawrence river and canals are entirely free to shipping interests on both sides of the boundary, most of this expenditure has been of benefit to both countries. Splendid results have been obtained by these improvements to the comfort and welfare of the citizens of both countries, but, on a system of navigation like the St. Lawrence, every inch of water in depth counts, and must be saved. Is this system which is utilized by both nations now to be impaired by the tapping of its source of supply, and by allowing part of this supply to be diverted to another valley to further the schemes of a city which should use some other means of disposing of its sewage?

Compensating works: Counsel submits a letter from Mr. Alfred Noble, of New York, on the subject of compensating works, but this contains no positive statement that they can be so constructed as to be effective. Such works should only be a possible remedy to be applied in extreme and absolutely unavoidable cases. Their enormous cost, *which must be borne by the Sanitary District*, the international difficulties involved, the numerous important interests that would be adversely affected, and other similar conditions, demonstrate the practical impossibility of ever constructing such works for conserving the levels of the Great Lakes. In addition, as stated in the report on Regulation of Lake Erie by the International Waterways Commission, works that would regulate the levels, at or near, some fixed stage would be so detrimental to the lakes and rivers below as to be inadmissible.

Replying to counsel's statement that:

"It may be here observed that a protest from the Dominion of Canada against the lowering of lake levels comes with rather poor grace. It is a matter of record, in your Department that during the improvement of the Detroit river in the construction of the Livingstone channel, the United States Government sought to maintain the level of the lakes by the construction of remedial works on the Canadian side. A protest was entered on behalf of the Canadian Government, and these remedial works have not been constructed as was planned by the United States engineers."

This statement ignores the fact that the Government of

Canada, in an Order in Council dated 11th January, 1911, recommended that, in view of the very strong protests, made by municipalities on the Canadian shore, further investigations should be made regarding the matter. It was further suggested that probably the whole subject would be better dealt with by the International Joint Commission.

Reference is made to the fact that "from May, 1911, when Lake Superior was at its lowest stage for the year, it had risen so that on January 1st of this year it was practically one foot and three-tenths higher than in May, 1911, During the same period Lake Michigan has only risen about two tenths of a foot." It is argued by the learned counsel that this is due to the obstructions in connection with the construction of the new Soo locks, and that, but for this interference with the flow, Lakes Michigan and Huron would have been in the neighborhood of three inches higher at the present time than they are. In reply, it may be stated that this obstruction was placed in the St. Mary river about two years ago, but its effect on the lower lakes could be only temporary. By the present time, the natural outflow from Lake Superior has been re-established and levels in Lakes Huron-Michigan restored.

Counsel for Chicago states that nearly 11½ million dollars have been expended in improving the Chicago river and urges that "this is an ample guarantee that the Sanitary District is safeguarding the commercial interests of the port of Chicago, and is doing all in its power to see to it that navigation will not be interfered with nor the interests of her Canadian friends injuriously affected."

The learned counsel centres attention only upon the port of Chicago. While it has been improved, it is wholly outside the mark to argue that "the grand total of the sums of money" expended by the Sanitary District at the port of Chicago is a proof that Chicago's "Canadian friends" are not being "injuriously affected." The statements already made before the Secretary of War, on behalf of the Government of Canada, and the Dominion Marine Association, and other Canadian interests, show that the diversions by the Sanitary District of Chicago do cause, throughout the whole extent of the St. Lawrence system, serious injuries to navigation, and other Canadian commercial enterprizes.

Conclusions.

We respectfully submit that it has been abundantly shown:

(1) That there is no imperative necessity for such a large diversion of water from Lake Michigan for sanitary purposes, as is requested in the application.

(2) That the historical facts presented in this brief show conclusively that the Sanitary canal cannot be considered as the outgrowth and development of a scheme which has received recognition by the United States Government, or that of the Dominion of Canada.

(3) That the claim that the Sanitary District is entitled, as a matter of right, to the use of so much of the waters of Lake Michigan as may be necessary for sanitary and domestic purposes, cannot be entertained in so far as it relates to the extraordinary and wasteful use proposed.

(4) It has been shown that very substantial injuries have been made, and are being suffered by navigation interests. Fears for future and more extensive damages, by reason of increased diversion, are exceedingly well founded, and justify the demand that some improved method of sewage disposal, which shall not require the abstraction of any considerable quantity of water from Lake Michigan nor the diversion of other outlets of waters which would naturally flow into it, be adopted.

(5) That the Dominion of Canada has the right to a voice in the disposition of the waters of Lake Michigan for sanitary purposes in so far as such diversion injuriously affects navigation, because her citizens are accorded, by treaty, the right of free navigation in that lake, and, in that no diversion can be made without injuriously affecting her harbours, channels and canals.

(6) It having been shown that the sewage of Chicago can be so treated and disposed of by other means than the present dilution methods, by which great quantities of water are withdrawn from Lake Michigan and discharged through the Drainage canal into the Illinois river, it is contended, on behalf of Canada, that the abstraction of water from Lake Michigan shall be limited to such quantity as shall not injuriously affect navigation interests on the Canadian side of the boundary, and that such limitations shall take effect at the end of such time, as, in your judgment, may be reasonably necessary for the Sanitary District to instal, and put into use, the works which may be required for disposing of

the sewage by other means than by the dilution method now in use.

(7) That, in view of the fact that the Sanitary District claims that permits hitherto issued deal only with the flow through the lower portion of the Chicago river, and that it has the right to take any amount of water, without permission, through the canal, provided it is supplied through other feeders, it is respectfully requested that all permits be only for such limited quantity of water as shall not injuriously affect navigation on the lakes and the St. Lawrence river, and be so worded as to state the total quantity which the Sanitary District of Chicago may be permitted to withdraw for domestic and sanitary purposes from the drainage basin of Lake Michigan.

We feel confident that the interests of humanity at Chicago, and the levels of the Great Lakes, and of the St. Lawrence river, can best be protected by the installation of a modern system of sewage disposal, rather than by using a method which has been shown to be injurious to the navigation and commerce of both nations, and, further, that the interests of the public generally will thus be protected and their welfare promoted.

Respectfully submitted,

DANIEL MULLIN, K. C.,
Counsel,

JOHN KENNEDY,
Consulting Engineer.

A. ST. LAURENT,
Assistant Deputy Minister Public Works, Canada,

WM. J. STEWART,
Chief Hydrographer,

V. W. FORNERET,
Superintending Engineer St. Lawrence Ship Channel,
Representing the Government of Canada.

Chicago, Ill., March 11, 1912.

Memorandum of opinion of Lieutenant Colonel George A. Zinn, then engineer in charge at Chicago, to the Secretary of War.

The Secretary of War is asked to grant a permit for the withdrawal of 10,000 cubic feet of water from Lake Michigan through the Main Sanitary Canal which terminates near Lockport, Illinois, and discharges into the Desplaines river at that place, from the Desplaines river thence into the Illinois river.

Has the Secretary of War jurisdiction in this matter and has he authority to issue such a permit? If it is determined

that the Secretary of War has jurisdiction and the necessary authority, the issuance of this permit will then depend upon the relative advantages and disadvantages, benefits and injuries which will follow the granting or withholding of it.

The jurisdiction of the Secretary of War over the navigable waters of the United States is derived from special and general legislation. The general legislation is found in the river and harbor act approved March 3, 1899, which defines the duties of the Secretary of War and determines the extent of his jurisdiction. It may be inferred that the jurisdiction of the Secretary of War is limited to the items named in that act. Under that act he may order the removal of bridges obstructing navigation, remove wrecks interfering with navigation, establish harbor lines when essential to the preservation and protection of harbors, authorize the creation of obstructions and the alteration of navigable channels in the navigable waters of the United States. Under the river and harbor act of August 18, 1894, it is the duty of the Secretary of War to prescribe rules and regulations for the use, administration and navigation of any or all canals and similar works of navigation that now are or may hereafter be owned and operated by the United States. He is also authorized to prescribe regulations covering the speed and movement of vessels and the opening of draw bridges. The acts of May 9, 1900, and March 3, 1905, further increase the jurisdiction of the Secretary of War over navigable waters. Section 10 of the Act of March 3, 1899, may perhaps be interpreted to confer upon the Secretary of War the necessary authority to grant the application of the Sanitary District, although if it be shown that the granting of the application will create an obstruction "not affirmatively authorized by Congress" the secretary has no authority in the case.

It would appear that the War Department entertained a doubt as to its authority from the language used in the two permits issued under date of July 11, 1900 (E. D. 35041/17 and 18), granting permission to the Sanitary District of Chicago to change, alter and improve the Chicago river. Condition 1 of both of these permits states:

That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action and that this permit shall be subject to such action as may be taken by Congress.

Let it be assumed that the Secretary of War has both au-

thority and jurisdiction, his action in this matter, as previously stated, will be determined by weighing the relative benefits and injuries, advantages and disadvantages attached to granting and withholding the permit.

Consider first the case of withholding the permit. The City of Chicago now empties all of its sewage and refuse matter flowing from streets, both solid and liquid, into the Chicago river. There are no catch basins at the river ends of the sewers and the street catch basins are inefficient so that large quantities of solid matter necessarily flow into the Chicago river in violation of Section 13 of the river and harbor act of March 3, 1899. It is reported that city officials have said that it would be cheaper to dredge the river than to build catch basins. That large quantities of solid matter do go into the river from city sewers and from overflow from streets is shown in the report of Mr. G. M. Wisner dated October 12, 1911, to the Board of Trustees of the Sanitary District of Chicago, in which Mr. Wisner states that the Main Sanitary Canal has been filled to the extent of about 2,340,000 cubic yards which fill must be removed to restore the main channel to its proper capacity. Some shoaling is known to have taken place in the Chicago river after the river was dredged by the United States and the Sanitary District.

The present allowance (permit of December 5, 1901), of 250,000 cubic feet per minute (4,167 cu. ft. per second) is not sufficient to properly dilute and carry off the sewage of the present population of the Sanitary District of Chicago, which includes the City of Chicago and some outlying territory. With the constantly increasing population of the Chicago region, it is evident that there will be a constantly repeated demand for more water for dilution. Many large cities at home and abroad have found themselves obliged to abandon the dilution method. It is not only possible for the Sanitary District to dispose of its sewage without an increase in its present allowance, but also imperative for it to adopt another system; if not now then in the near future. Other systems are available which will not require an increase in the present allowance.

Again, the adoption of some other system will not result in or require the abandonment of the existing channels and works of the Sanitary District.

Under present conditions, the Sanitary District cannot make use of the 10,000 cubic feet per second without creating a current in the Chicago river which will be injurious to navi-

gation. The 10,000 cubic feet required can only be used without injury to navigation after the Sag canal and other works contemplated for the removal of sewage in the Calumet region, recently placed under construction, have been completed, which event is not expected to take place within several years. The Sanitary District officials admit that they are now withdrawing about 7,000 cubic feet per second from Lake Michigan; the excess above 4,167 ft. per second being in violation of the terms of their permit. The current now existing in the river is injurious to navigation, as shown by collisions between vessels and bridges and the difficulty of stemming the current. The withdrawal of water from Lake Michigan has undoubtedly resulted in a permanent lowering of the water surfaces of all the Great Lakes.

At present the War Department has no practical means for determining the amount of water drawn from Lake Michigan. Effective supervision over the operations of the Sanitary District will be difficult and expensive.

The practical effect therefore of withholding an increased allowance will be to force the Sanitary District of Chicago and the City of Chicago to adopt another system of sewage disposal, or a combination of the present system with another system.

Consider now the effect of granting the application of the Sanitary District.

As justified, the increased allowance cannot be used immediately without injury to navigation in the Chicago river, and the temptation to use it will be very great, as the Sanitary District has up to now succeeded in escaping punishment for its offenses against the United States and navigation interests.

When the Sag canal is completed and the 10,000 cubic feet per second may be withdrawn without producing injurious currents in the Calumet and Chicago rivers, the other effect, previously referred to, of lowering the lake surfaces of the Great Lakes will be greatly increased, resulting in lessor depths in all lake channels and harbors, greatly diminished carrying capacity in vessels, etc.,—an injury which, measured in dollars and cents, will equal in a very few years the total cost of a new sewage system for the City of Chicago.

Has the Secretary of War authority to permit such injury even should he so desire?

There seems to be no question of the right of the United States to divert water flowing in navigable streams from one

place in the stream to another place in the same stream for the benefit of navigation. See case of *South Carolina* v. *Georgia et al.* (3 Otto, 4). The right of an individual, a state, or the United States to divert water from navigable streams or bodies to non-navigable streams has not been adjudicated to my knowledge.

It may be asserted that the diversion of water in the present case is from one navigable body of water (Lake Michigan) to another (Illinois river). The diversion, while beneficial, is not necessary for the improvement of navigation on the Illinois river or Lake Michigan. The right of the State of Illinois to use water from Lake Michigan for purposes of navigation in its Illinois and Michigan canal, connecting Lake Michigan and the Illinois river, has not been questioned, but the quantity used is practically nothing. Whether the diversion of water for navigation purposes in the Illinois and Michigan waterway in sufficiently large quantities to injure navigation on the Great Lakes would be legal or proper remains to be determined.

The granting of the permit applied for by the Sanitary District would result in an immediate and vast injury to navigation on the Great Lakes and would be of only temporary benefit to the Sanitary District of Chicago. Moreover, it appears to be a question that can properly be determined only by the Congress of the United States.

It is reported that 650,000,000 gallons of water per day are pumped from Lake Michigan by the various water works of the City of Chicago into its water supply system. A very small quantity of this amount of water returns directly to the lake the rest being discharged from streams and sewers into the Chicago river. This quantity is equal to 1,005 cubic feet per second and it is presumed that this withdrawal of water is included in the quantity allowed to be withdrawn by the Sanitary District of Chicago.

Attention is invited to Article III, *Treaty between the United States and Great Britain,*—boundary waters between the United States and Canada, Proclaimed May 13, 1910, which reads as follows:

It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter provided for by special agreement between the parties hereto, no further or other uses or obstructions or diversions, whether temporary or permanent, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line, shall be made except by authority of

the United States or the Dominion of Canada within their respective jurisdictions and with the approval, as hereinafter provided, of a joint commission, to be known as the International Joint Commission.

The foregoing provisions are not intended to limit or interfere with the existing rights of the Government of the United States on the one side and the Government of the Dominion of Canada on the other, to undertake and carry on governmental works in boundary waters for the deepening of channels, the construction of breakwaters, the improvement of harbors, and other governmental works for the benefit of commerce and navigation, provided that such works are wholly on its own side of the line and do not materially affect the level or flow of the boundary waters on the other, nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes.

(Sgd.) GEO. A. ZINN,
Lieut. Col., Corps of Engineers.

EXTRACTS FROM PROTESTS OF VARIOUS CITIES, ASSOCIATIONS, PROPERTY OWNERS AND INDIVIDUALS ON THE SHORES OF THE GREAT LAKES AND ALONG THE ILLINOIS RIVER.

Protest of Duluth Commercial Club, February 24, 1912.

"The Chief of Engineers. In reference to the desired increase for more water from the Great Lakes to pass through the Drainage canal at Chicago, we desire to enter our protest against any increase of the amount now allowed. We are of the opinion that for the conveyance of sewage both for the present and for the future, the water is now sufficient if the channels in the low lands and wide parts of the river are constructed in proportion to the canal. There is owned at this port several freighters of the largest class of freighting ships in the world. They combine and carry in one cargo more than one and one-half million tons from Lake Superior to the lower lakes. The depth of the connecting rivers are affected by the level of Lakes Huron and Michigan. These we think are now lowered by the present amount of water passing through the Drainage canal and think there is some evidence to support this in the last two years. The lowering of these rivers seriously affects the carrying capacity of these large steamers and we earnestly protest against granting any increase.

DULUTH COMMERCIAL CLUB."

Telegram From Mayor of Duluth to Secretary of War, Feb. 27, 1912.

"The common council of the City of Duluth has this day adopted a resolution in opposition to the granting of permission to the City of Chicago to withdraw from Lake Michigan 10,000 cubic feet of water per second on the grounds that such a diversion of water would be a menace to navigation on the Great Lakes.

N. B. CULLUM,
Mayor."

Resolution of The Greater Milwaukee Association to the Secretary of War, Feb. 27, 1912.

"Resolved by the Greater Milwaukee Association by its Board of Directors and Advisory Board in meeting assembled on February 27, 1912, that the request of the Chicago Drainage Canal authorities made to the Secretary of War of the United States of America for a further diversion of lake waters should be refused because such proposed diversion would be inimicable to the best interests of the public; and it is furthermore

Resolved that the Secretary of this Association shall forthwith dispatch to the Secretary of War of the United States of America a telegram as follows:

'The Greater Milwaukee Association by its Board of Directors and Advisory Board in meeting assembled on February 27, 1912, does hereby request the Secretary of War of the United States of America to refuse consent to the Chicago Drainage Canal authorities for a further diversion of lake waters for the reason that such a proposed diversion will seriously affect the lake levels by lowering the several harbor entrances and river levels in the ports of Lake Michigan. The Greater Milwaukee Association believes that the waters of the Great Lakes should be utilized for purposes of navigation and for sanitation only so far as conditions will permit. That the proposed increased diversion of these waters for the purposes of the Chicago Drainage Canal authorities would be inimicable to the best interests of the public.' "

Telegram From Herman Bleyer, Secretary Harbor Commission, to Secretary of War, February 27, 1912.

"Milwaukee Harbor Commission is now engaged in the task of devising means of improving present harbor conditions and formulating plans for the city harbor needs in years to come, [and] regards with solicitude the apparent increasing natural tendency toward lower water levels in the Great Lakes which if continued must result in added expense for river and harbor maintenance and great depreciation in carrying capacity of lake tonnage. In view of this disturbing aspect the Commission is unalterably opposed to anything which will in any manner lend its influence toward lower water levels on the lake. The Commission therefore respectfully but firmly protests in behalf of the shipping interests of Milwaukee against the further diversion of waters of the Great Lakes for any purpose whatsoever and earnestly appeals to the federal authorities to refuse all applications for water privileges now under consideration or which may be made in the future."

Resolutions of Merchants and Manufacturers Association of Milwaukee, March 5, 1912.

"Whereas the diversion of the waters of Lake Michigan in recent years for navigation, sanitation and power purposes, together with a reduced precipitation has tended toward the lowering of the lake level to a point where the efficiency of the several harbor entrances and river beds is seriously threatened, thus indicating that any further and permanent diversion of such water will tend to aggravate an already serious situation, be it

Resolved, that we, the Board of Directors of the Merchants and Manufacturers Association, believe that the primary and guaranteed purpose of the Great Lakes is dedicated to the use of navigation and therefore the duty of the government to maintain and protect the water levels in the interest of such navigation; that the use of the lake waters in large volumes for power purposes to the detriment of navigation is untenable, unwarranted and unjust and therefore should not be permitted; and be it further

Resolved, that we herewith enter our solemn protest against the demands of the City of Chicago and State of Illinois for any diversion of the waters of Lake Michigan which may by any possibility affect the level of the lake as existed under natural conditions."

Telegram From Francis E. McGovern, Governor of Wisconsin, to Secretary of War, Feb. 26, 1912.

"In the interest of the Wisconsin Lake ports I respectfully but earnestly protest against any increased diversion of water from Lake Michigan by Chicago Drainage Canal.

FRANCIS E. MCGOVERN,
Governor."

Telegram From Mayor of Two Rivers, Wisconsin, to Chief of Engineers, February 26, 1912.

"Being impossible to have a representative at hearing on February 28th, the City of Two Rivers, Wisconsin, hereby enters vigorous protest against granting of application of Sanitary District of Chicago to divert increased flow of water from Lake Michigan through Drainage canal, knowing it would be detrimental to the shipping interests of the Great Lakes and damaging to the improvements made by the government and municipalities as well as corporations and private individuals, by lowering this state of water.

CONRAD BAETZ,
Mayor."

Telegram From Mayor of Manitowoc, Wisconsin, to Secretary of War, Feb. 26, 1912.

"Mayor and city council of Manitowoc, Wisconsin, resolve to address the Secretary of War, following:

'The city protests against granting the pending application of the Sanitary District of Chicago for permission further to divert water from Lake Michigan through the Drainage canal in quantity proposed or any quantity. We believe permanent diversion will cause great and irreparable injury to this city.

'Every inch of the present depth in Manitowoc river is of great value to this city and to thousands of shippers and consumers both east and west of this port. If this proposed diversion will lower lake levels, which we deem unquestionable, it will work gross injustice to this and other upper lake ports that have been solving low water problems under work on river channels done at great expense to taxpayers. It will make sheer waste of large part of millions spent by federal government on harbors. Water works are city property and supply is from wells sunk in shore on Lake Michigan, largely

if not entirely supplied by percolation from lake, the surface levels of which rise and recede with surface of Lake Michigan. Present low lake level has so impaired supply that further material recession of lake level will utterly destroy water supply, necessitate entire rebuilding of pumping plant and result in great financial burden to city and county.'

HENRY STOLZE, JR.,
Mayor."

Telegram From Kewaunee, Wisconsin, to Congressman T. F. Konop, February 26, 1912.

"Council adopted resolution protest against further diversion water through Chicago Drainage Canal. Requested to appear behalf city. Letter follows.

W. WIESNER."

Resolution of Protest of Mayor and Common Council of City of Marinette, Wisconsin, February 24, 1912.

"Whereas, the Sanitary District of Chicago has made application to be allowed to divert ten thousand cubic feet of water per second from Lake Michigan through the Drainage canal, and

Whereas, such a flow of water would tend to perceptibly lower the level of Lake Michigan, thus making our harbor inadequate for deep draft vessels,

Now, Therefore, Be It Resolved, by the Mayor and Common Council of the City of Marinette

That we do earnestly protest against allowing any further diversion of water through the Chicago Drainage Canal and we do hereby petition the Honorable, the Secretary of War, and ask that he refuse to allow any further diversion of water from Lake Michigan through said canal.

Passed, adopted and approved this 24th day of February, 1912.

JOSEPH FISHER,
Mayor of Marinette.

Attest,

JOHN MOORE,
City Clerk."

Telegram From Marinette Chamber of Commerce to Senator Isaac Stephenson, of Wisconsin, February 26, 1912.

"* * * The Marinette Chamber of Commerce hereby most earnestly protest against the maintenance of any artificial outlet and hereby urge the Board of Engineers of the War Department to deny the application of the Chicago Drainage Canal Board for the diversion of an additional flow of Lake Michigan water through the Chicago Drainage Canal.

MARINETTE CHAMBER OF COMMERCE,
HORACE C. BAKER,
Secretary."

Resolution of Protest of Mayor and Common Council of Sheboygan, Wisconsin, February 23, 1912.

"* * * Whereas the government and cities have spent millions of dollars in giving the cities along the Great Lakes sufficient water to permit the use of the present lake freighters, and the past few years have demonstrated that the lake level was getting to a point where it is difficult to keep the harbor dredged to the required depth, therefore be it

Resolved by the Mayor and Common Council of the City of Sheboygan that we do protest strenuously against the granting of the application of the Sanitary District of Chicago, believing that the same is wholly unnecessary for the direct purposes mentioned, and even assuming it is for the purpose mentioned and none other, nevertheless we do protest for the reason above stated. * * *"

Resolution of Protest by Mayor and Common Council of City of De Pere, Wisconsin, February 24, 1912.

"Whereas the level of water in Lake Michigan has lowered to an alarming extent during the past two years, which is claimed by eminent authority to be caused by the amount of water now permitted to be taken by the Chicago Drainage Canal, and

Whereas, the lowering of the level of the water in Lake Michigan endangers the safe navigation of large freight carrying boats on Lake Michigan and Green Bay and the smaller boats on Fox river below, and

Whereas should the level of the water continue to lower it will practically destroy all of the water shipping facilities and

work gross injustice to our shippers as well as to the general public, and

Whereas this community and that adjacent thereto depend to a large extent upon the lake shipping facilities for the carriage of coal, merchandise and other commodities,

Now, Therefore, Be It Resolved by the Mayor and Common Council of the City of De Pere, Wisconsin, that for and in behalf of the people of this city, we do hereby object to and protest against granting permission for taking of any larger volume of water for said drainage canal than at present permitted until such time as it shall be established beyond doubt that the taking of water for such canal does not tend to lower the level of the water in Lake Michigan. * * *"

Protest of Mayor and City Council of Green Bay, Wisconsin, Feb. 23, 1912.

"Whereas the Sanitary District at Chicago has made application to be allowed to divert ten thousand cubic feet of water per second from Lake Michigan through the drainage canal, and

Whereas, such a flow of water would tend to perceptibly lower the level of Lake Michigan, thus making our harbor inadequate for draft vessels;

Now, Therefore, be it Resolved by the Mayor and Common Council of the City of Green Bay,

That we do earnestly protest against allowing any further diversion of water through the Chicago Drainage Canal and we do hereby petition the Honorable, the Secretary of War and ask that he refuse to allow any further diversion of water from Lake Michigan through said canal.

JOHN S. FARRELL."

"The above resolution was adopted by the unanimous vote of the Common Council at a meeting held February 23, 1912."

Signed by City Clerk.

Telegram From Secretary Michigan State Senate to Secretary of War, February 28, 1912.

"Dear Sir: At the session of the Michigan State Senate today the following resolution was adopted and I was directed to transmit the same to you forthwith:

Whereas application has been made to the Secretary of War for the diversion of ten thousand cubic feet of water per second into the Chicago canal, and

Whereas this will practically double the flow of water from Lake Michigan into the canal and not only endanger our harbor but be a great menace to our fruit industry which, though it has reached such proportions, is as yet only in its infancy, and

Whereas a hearing on said application has been fixed by the Secretary of War to be heard before him in his office in the War Department at Washington on Wednesday, February 28,

Therefore Be It Resolved this, the Senate of the State of Michigan, that on behalf of the popele of this state, we desire to enter a vigorous protest against the granting of such application for the Sanitary District of Chicago."

Telegram From Clerk of the House of Representatives, State of Michigan, to Secretary of War, February 28, 1912.

"The Michigan House of Representatives has this day unnimously adopted a resolution vigorously protesting against the granting by your Department of the application for diversion of ten thousand cubic feet of water per second from Lake Michigan on the ground that such action will practically double the flow of water. Every port in Michigan will be injured; every fruit farm in Western Michigan jeopardized, and the future development of the state hindered and perhaps permanently stopped. I am directed to wire this protest to you."

Letter of J. C. McLoughlin, Member of Congress, to Secretary of War, February 28, 1912.

"On behalf of the people of Western Michigan I wish hereby to object to the application of the Sanitary District of Chicago for authority to divert ten thousand cubic inches (feet) per second of water from Lake Michigan. The Congressional District I represent is in Western Michigan, has a coast line on the lake of about one hundred and fifty miles, and has eight harbors which were constructed and are maintained by the federal government. The said Sanitary District has authority to divert about four thousand cubic per second from Lake Michigan but for several years, as I am informed, diverted and is now diverting about seven thousand cubic feet, the result and effect of which diversion is that the level of the water in said lake has been so lowered as to make navigation of said harbors difficult and dangerous and their maintenance very expensive.

There are local reasons and conditions which influence the people of Michigan to resist the application made by the Sanitary District. The City of Muskegon takes its entire supply of water for domestic use and for fire protection from Lake Michigan. A pumping station has been built in the shore of lake. Intake pipes, cribs and wells have been laid and constructed. The low situation of water prevailing during recent years on account of diversion of water by said Sanitary District has made the maintenance and operation of said water plant very difficult and expensive. Said plant was constructed before water was diverted from Lake Michigan by said Sanitary District or by any other authority for such purpose as it is now diverted and used. If the level of Lake Michigan be further reduced by the diversion of the quantity of water demanded by the Sanitary District it will be necessary for the City of Muskegon to change and rebuild its entire water plant, which would involve an outlay of many thousands of dollars. * * *"

Telegram Mayor and Secretary of Chamber of Commerce, Charlevoix, Michigan, to Secretary of War, February 26, 1912.

"On behalf Charlevoix County's entire population protest against further concessions Chicago Drainage Canal. Water level already seriously affected and immense fruit interests jeopardized through chemical changes due to diversion of natural water flow."

Telegram From Mayor and City Council of Escanaba, Michigan, to Secretary of War, February 27, 1912.

"The City of Escanaba protests against the proposed enlarging of Chicago Drainage Canal. Such work would be incalcuable loss to all shipping interests of Lake Michigan. The commercialized damage to this city would be inestimable; the interests of the present and future generations demand the prevention of the proposed canal enlargement."

Telegram From the City of Petoskey, Michigan, to George A. Loud, February 26, 1912.

"Petoskey will expect you to fight attempt to take water from Lake Michigan for Chicago Drainage Canal. Amount already used has lowered level and hurt this city. Do your best."

Protest From the Mayor of Muskegon, Michigan, to the Secretary of War, March 13, 1912.

"In behalf of the City of Muskegon I wish to protest against the granting of the application of the Sanitary District of Chicago for authority to divert the waters of Lake Michigan to any greater extent than heretofore granted by the War Department. Muskegon is a growing city on the east side of Lake Michigan and about 110 miles northeast from the City of Chicago. It is situated on Muskegon Lake, which empties into Lake Michigan.

The lowering of the water level in Lake Michigan will injuriously affect the welfare of the city of Muskegon in many ways, but I will dwell shortly upon

The effect on the water system of said city,

The effect on the sewer system of said city,

The effect on the navigation interests of said city.

Muskegon has a water system situated on Lake Michigan from which it obtains its water supply. It has already expended nearly a half a million dollars thereon, and is now enlarging and improving this system to the extent of $300,000.00 more. The contracts are now made for new wells and new intake pipe and the work of construction has begun. The present intake pipe is out about 3900 feet from the shore line, but the new intake contracted for is to be placed about 7000 feet out. This change has been partly caused by the change of the level of Lake Michigan. The lowering of the lake level diminished the head of water and thereby decreased the flow of water into the wells from which we pump our supply. The cost of pumping the water has been increased due to the additional lift, and if the lake level should be diminished as contemplated by the Chicago Drainage Board it would become impossible to lift the water with our style of pumps. Any further lowering of the lake level will damage our water plant to such an extent that the engineers estimate the loss at upwards of $200,000.00.

Besides our water plant, there is the water plant of the city of North Muskegon situated on Bear Lake, which empties into Muskegon Lake. This would also be damaged.

On Muskegon Lake the Central Paper Mill Company has its own plant. This water plant, in the case of any further lowering of the lake level, would in all probability have to be rebuilt.

The sewer system of the city of Muskegon is all based upon outlets of the Muskegon Lake. These outlets are carried far enough into the lake so that the sewage is taken up by the current and distributed. The engineer informs me that if the lake level is diminished very much more a great many of these outlets will have to be taken up and relaid.

One of the most serious handicaps that would result from the further lowering of the lake level is this, that many boats could not reach the docks which they are at present using. Two docks in Muskegon Lake at which boats were accustomed to land have been abandoned in the last few years on account of the low water, and should the water level become still lower, many more of our old docks would have to be abandoned, or the owners would be put to an enormous expense of dredging alongside of these docks, and also in various spots where the lake is just sufficiently deep to allow some of our larger boats to pass at the present time.

Except in the cases above referred to, the entire depth of Muskegon Lake is now utilized, and any lowering of its surface involves the excavation of an artificial channel. It might mean eventually that open navigation on Muskegon Lake would be replaced by canal navigation.

* * * * * * *

Very truly yours,

HARRY A. RIETDYK,
Mayor."

Protest from the Toledo Commerce Club to the Secretary of War, April 24, 1912.

"Inasmuch as there is before your department for consideration the request of the City of Chicago for a greater allowance of water through the Chicago drainage canal for the purpose of by that method satisfying the sanitary demands of the city, and inasmuch as we believe that the favorable consideration of this request would be fraught with detrimental results to the harbor of the City of Toledo, as well as the majority of

the harbors on Lakes Michigan, Huron and Erie, we take occasion to present the resolutions adopted by the Board of Trustees of the Toledo Commerce Club, as follows:

"Whereas the question of the level of the water in the Great Lakes and their connecting waters is of vital importance to the transportation facilities afforded by the harbor of Toledo, for the reason that any slight fluctuation of the water at the western end of Lake Erie and the lower end of Detroit river immediately affects the level of the water in the Maumee river which constitutes Toledo's harbor; and

Whereas the record of the water levels on the different lakes and channels shows that a slight fluctuation of the levels in Lake Michigan or Lake Superior results in a corresponding fluctuation of the levels of the lower lakes and connecting waters; and

Whereas our information is that the demand of the City of Chicago would tend to lower the level of Lake Michigan from six to eight inches, depending upon the amount of water abstracted by the growing demands of the city;

Be it resolved therefore, that this board does hereby seriously protest against the favorable consideration by the War Department on the request of the City of Chicago.

* * * * *

(Signed) J. D. Biggers,
Secretary."

Protest of the Cleveland Chamber of Commerce.

"Whereas the City of Cleveland is deeply interested in the development of navigation and commerce upon the Great Lakes; and

Whereas it has expended large sums in developing the harbor facilities of Cleveland and has asked and secured large governmental appropriations for harbor developments at Cleveland; and

Whereas any lowering of the lake level is likely to create necessity for additional expenditures to maintain the proper depth of water in harbors; and

Whereas it appears extremely probable that the subtraction of water from Lake Michigan through the Chicago Drainage Canal has been the cause, or a contributing cause the prevailing low depth of water during the season of navigation in 1911, and that any additional subtraction of water from Lake

Michigan would result in further lowering the level of the lower lakes:

Therefore be it resolved that the Cleveland Chamber of Commerce, representing the shipping and commercial interests of Cleveland, hereby protests against permission being granted to the Sanitary District of Chicago by the Secretary of War to increase the flow of water through the Chicago Drainage Canal beyond the amount of 4167 cubic feet per second, the quantity heretofore authorized.

Protest of Board of Control of Sandusky, Ohio, to Hon. Carl C. Anderson, February 24, 1912.

"The City of Sandusky through its Board of Control protest most emphatically against granting the application of the Sanitary District of Chicago for permission to divert 10,000 feet of water per second from the waters of Lake Michigan. The hearing will be given on the 28th at Washington, D. C.

May me ask you to see that this protest is properly registered."

(Signed by Clerk of Board of Control.)

Protest of Sandusky Business Men's Association, February 24, 1912.

"The Business Men's Association respectfully ask that you register our emphatic protest against the proposal to divert 10,000 feet of water per second from the waters of Lake Michigan upon the application of the Sanitary District of Chicago.

* * * * *

(Signed by the Secretary.)

Protest of the Buffalo Chamber of Commerce to the Secretary of War, April 1, 1912.

* * * * *

"The Buffalo Chamber of Commerce, representing the commercial interests of the City of Buffalo, realizing the injury to its commerce that the granting of the application would inflict in addition to the recognition of the right of a community to use the public waters for the purposes containing the commercial element to the detriment of other communities located on the lakes, seriously interfering with the use of the Great

Lakes as an avenue to transportation, does most earnestly register its protest against the granting of the application.

Government records show that up to June 30, 1911, federal authorities had spent at Buffalo and Black Rock in waterway improvements and in the maintenance of same, $7,932,380.68, and during the same period the citizens of Buffalo expended in the improvement of its harbor, $4,880,149.02, or a total of $12,812,529.70, which in itself is evidence of the importance of the Great Lakes to the commerce of Buffalo, and the necessity of avoiding any interference with the use of them as a factor in the developing of Buffalo commercially. The level of Lake Erie was one foot five inches lower in 1911 than in 1908, attributed not only to natural causes, but to the diversion of water from Lake Michigan under the present permit. This condition in the past few years has resulted in the lowering of the loading capacity of vessels, which has been reflected in the rates charged, causing loss not only to the shipping interests but to commercial interests as well, and as the tendency is to build larger and larger boats in order to reduce the transportation cost to a minimum, any action that will interefere with the operation of the large boats should be viewed as a public calamity.

The City of Buffalo stands ready to do its share toward providing harbor facilities that will permit its use by the largest vessels, but deem it an injustice that they be asked to increase this expense with no resultant compensation. We deeply feel that the granting of this application will work irreparable damage to the commerce of the City of Buffalo as well as other communities adjacent to Buffalo who use Lake Erie as a means to promote said commerce, and as other methods than that of dilution of sewage are now in vogue, and if all cities located on the Great Lakes should adopt the dilution method, it would nullify the use of the lakes for other purposes to the detriment of the people at large. Therefore, inasmuch as there are alternative methods that can be used for sanitation purposes, and the granting of the application would work a hardship on the citizens of Buffalo, we ask that a careful recognition of our views be given when the application should be finally considered.

Very respectfully submitted,

HARBOR AND RIVER COMMITTEE,
BUFFALO CHAMBER OF COMMERCE."

Resolution of Protest Adopted by Buffalo Lodge No. 1, Shipmasters' Association.

"Whereas the navigation of the Chicago river is at present extremely hazardous, dangerous and expensive for boats using the waterway, and

Whereas that undesirable state of affairs for boats is caused primarily through the necessity of supplying the Chicago Drainage Canal with the water it uses, and

Whereas the Chicago river "S" Branch is used to deliver the supply, thus creating a swift current which is constantly running, and

Whereas this supply is being drawn from Lake Michigan, thus increasing the flow from the lakes over its natural drainage which tends to lower lake levels, and

Whereas it is proposed to still further increase the drainage from the lake by building a canal to the Mississippi, or some point adjacent, and to supply the water necessary for said canal from the lakes through Chicago river and thus increase the hazard of navigation of Chicago river, and also lower lake levels, be it

Resolved that Buffalo Lodge No. 1, Shipmasters' Association, emphatically protest and oppose the said project of drawing more water from the lakes, or increasing the already dangerous current of Chicago river, and that this action be communicated to all sister lodges of this association and request their approval of the same, and that sister lodges send copy of this resolution to senators and congressmen of their respective districts and state.

W. E. Clark,
Chairman Harbor Committee."

Resolution of Ogdensburg Lodge No. 10, Shipmasters' Association.

"Whereas the navigation of the Chicago river is at present extremely hazardous and dangerous for boats using that water, and

Whereas that undesirable state of affairs for boats is caused primarily through the necessity of supplying the Chicago Drainage Canal with the water it uses, and

Whereas the Chicago river, south branch, is used to deliver the supply, thus creating a swift current which is constanly running, and

Whereas this supply is being drawn from Lake Michigan thus increasing the flow from the lakes over its natural drainage and tends to lower lake levels, and

Whereas it is proposed to still further increase the drainage from the lakes by building a canal to the Mississipppi or some point adjacent and to supply the water necessary for said canal from the lakes through the Chicago river and thus increase the dangers of navigation of the Chicago river and also lower lake levels, therefore be it

Resolved that Ogdensburg Lodge No. 10, Shipmasters' Association emphatically protest and oppose the said project of drawing more water from the lake or of increasing the already dangerous current of the Chicago river.

Respectfully submitted,

M. A. LEONARD,
Secretary."

Protest of Lockport Board of Trade to Secretary of War, February 26, 1912.

Board of Directors of Lockport Board of Trade in special meeting assembled, this afternoon have directed me to advise you of our opposition to the proposed diversion of two thousand cubic feet of water per second for sanitary purposes at Chicago.

Such diversion could not fail to affect lake commerce as it would lower the level and furthermore the utilization of water forces for sanitation purposes is certainly the wrong practice, especially as such water forces are the source of municipal water supply.

We therefore wish to be recorded in opposition to the proposed diversion and beg to remain,

Yours very truly,

WILLIAM A. DICKENSON,
Secretary.

Protest of Mayor of North Tonowanda, New York, to the Secretary of War, February 24, 1912.

"* * * Our people are opposed to this application for the reason that it would have a tendency, however slight, to lower the waters of the Great Lakes to the great damage of navigation thereon and the government has expended millions

of dollars to improve navigation on the Great Lakes in order to take care of the greatest commerce on earth and anything which could in the slightest degree affect the level of the lakes will be an injury to our people and to the large majority of the people of the United States. * * *"

Telegram from Mayor of Tonowanda, New York, to the Secretary of War, February 27, 1912.

"* * * * We wish to advise you that our city and this section is opposed to any further diversion of lake waters for so-called sanitary purposes and we think Chicago has already done more than her share of damage to our lake channels on which the government has spent so much money. * * *"

Telegram from Fred E. Signer of Association of Lake Lines, February 19, 1912.

"* * * On behalf of the Association of Lake Lines using the Chicago river in package trade earnest protest is made against granting such application. The present current makes navigation difficult and any increase would seriously impair movement of vessels if not make impossible handling of goods to and from industries located on river. * * *"

Protest from Canadian Niagara Power Co. to Chief of Engineers, February 26, 1912.

"* * * The undersigned corporation, Canadian-Niagara Power Co., as the owner of certain water power rights on the Niagara river in the province of Ontario through grants from the Canadian government, claims and is enjoying the right to use the waters of that river at Niagara Falls for power purposes. This company respectfully objects to and protests against any diversion of the water of Niagara river or of the lake attributary thereto which shall impair or imperil the dominant rights of this company, the lower riparian owner, and it objects to and protests against any diversion of such upper water for power purposes."

Protest of Niagara Falls Power Company to Chief of Engineers, February 26, 1912.

"* * * This company respectfully objects to and protests against any diversion of the waters of the Niagara river or of the lakes attributary thereto which shall impair or imperil the dominant rights of this company, the lower riparian owner, and it objects to and protests against any diversion of such upper waters for power purposes.

Protest of Shenango Furnace Company, Pittsburg, Pennsylvania, to Secretary of War, February 26, 1912.

"* * * We hereby protest against any action on the part of the government which will further tend to reduce the level of any of the lakes.

During the year 1911 the critical points in the lake routes were six inches lower than the average level for the last fifty-one years.

There is invested in lake shipping some two hundred million dollars. Our company alone have invested in five ships amounting to over two million dollars. Carrying capacity of these vessels during the year 1911 was reduced over ten per cent., due to the lowering of lake levels by natural causes which must have been aggravated by the new outlet at Chicago."

Protest of City Council of Winchester, Illinois, to Secretary of War, March 18, 1912.

"* * * Whereas the Sanitary District of Chicago has petitioned the Secretary of War to increase the flow of water from Lake Michigan down the path of the Illinois river, and believing such action would cause an overflow of the Illinois river, doing immense damage to land tributary to this city, causing a great financial loss to this city and county be it therefore

Resolved that we protest against such action by the War Department until the same can be done without damage to the land owners of the Illinois river valley. * * *"

PROTEST OF ASSOCIATION OF DRAINAGE AND LEVEE DISTRICTS OF ILLINOIS

DIRECTORS

Jesse Lowe, Beardstown, Ill.
Edward Boyle, 218 LaSalle St., Chicago, Ill.
Eugène Brown, Peoria, Ill.
C. W. Brown, Jacksonville, Ill.
W. F. Roegge, Meredosia, Ill.
C. J. Lumpkin, Carlinville, Ill.
H. B. Atkinson, New Canton, Ill.
H. V. Teel, Rushville, Ill.
H. J. Marsh, Naples, Ill.

COMMITTEE ON LEGISLATION

C. W. Brown, Jacksonville, Ill.
Thos. Worthington, Jacksonville, Ill.
Jacob A. Harmon, Peoria, Ill.
C. J. Lumpkin, Carlinville, Ill.
F. A. Whitesides, Carrollton, Ill.
W. K. Curran, Pekin, Ill.

COMMITTEE ON RESOLUTIONS

T. E. Bottenberg, Rushville, Ill.
Lyman E. Cooley, Chicago, Ill.
V. P. Turner, Pekin, Ill.

COMMITTEE ON MEMBERSHIP

Henry L. Wood, Sheffield, Ill.
W. J. Graham, Aledo, Ill.
A. H. Bell, Bloomington, Ill.

H. J. PUTERBAUGH, President, Mackinaw, Ill.
LOUIS LOWENSTEIN, First Vice-President, Whitehall, Ill.
H. B. ATKINSON, Second Vice-President, New Canton, Ill.
GUY L. SHAW, Secretary, Beardstown, Ill.

SECRETARY'S OFFICE
BEARDSTOWN, ILLINOIS,

RESOLUTIONS PASSED BY THE ASSOCIATION OF DRAINAGE AND LEVEE DISTRICTS OF ILLINOIS

In Session at Springfield, Illinois, March 8th, 1912

Objecting to Increased Flow in Illinois River from [of] Water from Lake Michigan

1. WHEREAS, The turning into the valley of the Illinois river of waters from Lake Michigan by the Sanitary District of Chicago has caused great damage to the valley by overflowing valuable farming and timber lands and rendering them unproductive and unsanitary, and

2. WHEREAS, This great damage has been caused by the flow of less than 4,200 cubic feet per second, and

3. WHEREAS, The Sanitary District of Chicago is now asking the Secretary of War for a permit to increase the flow from Lake Michigan, down the path of the Illinois River, to 10,000 cubic feet per second, and

4. WHEREAS, Such flow will increase the damage done to the Illinois valley lands, and

5. WHEREAS, No provision has been made to prevent the damage that has been created by the flow from Lake Michigan, as exists now, to say nothing of the proposed increase, by either the Sanitary District of Chicago or the State of Illinois or the Federal Government, by the preparing of the channel of the Illinois River through the alluvial valley to care for same without damage, and

6. WHEREAS, 400,000 acres of the lands of the valley and numerous cities and villages are affected and damaged by the present flow and will be proportionately more damaged by the increased flow, and

7. WHEREAS, Great increase in cost to reclaim these lands and maintain the reclamation of the lands already reclaimed entailing cost to the thousands of land owners that can only be reimbursed by long expensive litigation, and

8. WHEREAS, The proper regulation of rivers of the United States is vested in the FEDERAL AUTHORITIES OF THE UNITED STATES, and any artificial changes of the natural conditions can only be made by authority of the Federal authorities and we cannot believe that it is any part of the policy of the United States either by sin or omission to damage the great

riparian interests in the lower valley or to prevent or handicap the development by reclamation of lands or their maintenance. On the contrary we look to the Federal authorities to remedy the present situation and to prevent further destruction of property. And recognizing the great authority of the United States in this matter,

9. THEREFORE, We respectfully represent that any higher water level in the river, which would be occasioned by this increased flow, would not only greatly damage and in many cases ruin the land owner, who has at great expense put such lands in cultivation, but also would render practically worthless hundreds of thousands of dollars of registered bonds, issued against said lands to pay for the reclamation of the same, many of which bonds are held in small amounts by investors of moderate means; therefore, be it

10. RESOLVED, By the Association of Drainage and Levee Districts of Illinois, in extraordinary session assembled, this 8th day of March, 1912, at Springfield, Illinois: That we protest against the granting of the permit for a greater flow through the valley of the Illinois river, and pray that no farther increase be allowed until the dams are removed and the channel so improved that the increased flow may be accommodated without damage to the lands of the valley and navigation be maintained. Be it further

RESOLVED, That this Association co-operate with all other interests affected by the improvement of the channel of the Illinois; and that a copy of these resolutions be transmitted to the secretary of war, to the chief of engineers of the United States army, the Governor of the state of Illinois, and all other interests affected.

Protest from Citizens of Chillicothe, Illinois.

"To the Honorable Henry L. Stimson,
Secretary of War,
Washington, D. C.

We, the undersigned owners of land adjacent to the Illinois river and citizens of the Illinois Valley in and near the City of Chillicothe, in the County of Peoria and State of Illinois, do hereby earnestly protest against and object to the granting of the petition of the Sanitary District of Chicago, in which they ask to be allowed to increase the water discharged by means of the Sanitary District canal from 3,200 ft. per second to 10,000 ft. per second.

We would respectfully show that the amount of water now discharged by said Sanitary District canal into the Illinois river has raised that river so as to cause its water to remain over the bottom lands much longer each year than formerly. It has caused vast areas of timber to die and has seriously impaired, if not entirely destroyed, the usefulness of many farms and large areas of land.

We would further show that it has entailed large expense upon those who have attempted to protect their lands by levees, in that it has imposed upon districts already formed, the necessity of increasing the size and height of their levees and the additional cost of pumping the water from such district against the increased amount of water in the river.

We would further respectfully protest against the granting of the prayer of said petition for the reason that said Sanitary District has not complied with the provisions of the statute with reference to compensation for lands damaged by reason of such overflow and resist the payment of such damage in such manner as to make it more expensive for the small land owner to recover his rights than he can afford.

All of which is respectfully submitted.

WM. M. MEAD,
President Business Men's Asso. Chillicothe, Peoria Co., Illinois.
C. B. ZINSER,
Treasurer, Business Men's Asso.
D. KELLY,
Chairman Partridge Drainage Dist., Chillicothe, Ill.
B. F. ZINSER,
Pres. First National Bank, Chillicothe, Ill.
ELLIS KIBBS,
Com. of Crow Creek Drainage Dist.
TRUETT MATTHEWS & Co.,
Bankers."

Protest of H. and E. F. Hunter, Chillicothe, Illinois, to the Secretary of War, March 12, 1912.

"As large owners of Illinois river bottom lands, we wish to enter our protest against permitting the Chicago Sanitary District to increase the flow of water through the Sanitary Canal from Lake Michigan. These Illinois river lands which

are among the most fertile in the world have already been seriously injured by the increased flow of water, damages for which can only be had after long and expensive litigation with the Sanitary District. This litigation is so expensive that it puts it practically beyond the range of the ordinary small land owner to get redress. We can see no reason why the residents of this valley should be subjected to all this loss for the sake of disposing of sewage which could be well taken care of in a better and more scientific way."

Resolution of Protest, City of Beardstown, Illinois.

"The following resolutions were adopted by the City Council, of the City of Beardstown, Illinois, at a regular meeting of the Council held Tuesday, March 5th, 1912, with instructions for the City Clerk to mail a copy of the said resolutions signed by the Mayor and City Clerk under the seal of the City of Beardstown to the Executive officers of the United States, Committee of Congress, Members of the National Congress and Senate from the State of Illinois and the Sanitary District of Chicago, to the Lakes-to-the-Gulf Deep Waterway Association, the Governor of the State of Illinois, the Rivers and Lakes Commission, the Mayor of Chicago, the Trustees of the Sanitary District of Chicago and the State Canal Commission, and others who may be particularly interested.

Whereas, The Sanitary District of Chicago, is now importuning the Secretary of War, to issue a permit, permitting an increase from 4,166 cubic feet per second to 10,000 cubic feet per second in the flow of waters from Lake Michigan down the Illinois river, and

Whereas, The present flow has caused an enormous amount of hardship and damage to the City of Beardstown and its inhabitants and to surrounding lands to say nothing of what an increase flow will mean, now

Therefore, be it resolved by the City of Beardstown through the Mayor and City Council that they hereby protest against such permit being issued, until the Illinois river is so improved by dredging and removal of locks and dams as to fit it to take care of the present flow, and that now asked for.

H. C. KEIL,
Mayor."

(Seal)
Attest:
R. B. MASLIN,
City Clerk.

Resolution of Protest by Beardstown Chamber of Commerce.

"Whereas, The turning into the valley of the Illinois river of waters from Lake Michigan by the Sanitary District of Chicago has caused great damage to the valley by overflowing valuable farming and timber lands and rendering them unproductive and unsanitary, and

Whereas, This great damage has been caused by the flow of less than 4,000 cubic feet per second, and

Whereas, The Sanitary District of Chicago is now asking the Secretary of War for a permit to increase the flow from Lake Michigan, down the path of the Illinois river, to 10,000 cubic feet per second, and

Whereas, Such flow will increase the damage done to the Illinois valley lands, and

Whereas, No provision has been made to prevent the damage that has been created by the flow from Lake Michigan, as exists now, to say nothing of the proposed increase, by either the Sanitary District of Chicago or the State of Illinois or the Federal Government, by the preparing of the channel of the Illinois river through the alluvial valley to care for same without damage, and

Whereas, 400,000 acres of the lands of the valley are affected and damaged by the present flow and will be proportionately more damaged by the increased flow, and

Whereas, Great increase in cost to reclaim these lands and maintain the reclamation of the lands already reclaimed entailing cost to the thousands of land owners that can only be reimbursed by long and expensive litigation, and

Whereas, The proper regulation of rivers of the United States is vested in the federal authorities of the United States, and any artificial changes of the natural conditions can only be made by authority of the federal authorities and we cannot believe that it is any part of the policy of the United States either by sin or omission to damage the great riparian interests in the lower valley or to prevent or handicap the development by reclamation of lands or their maintenance. On the contrary, we look to the federal authorities to remedy the present situation and to prevent further destruction of property. And recognizing the great authority of the United States in this matter, Therefore be it

Resolved, That the Chamber of Commerce of the City of Beardstown, Cass County, Illinois, do hereby protest against the granting of any permit to increase the flow of waters of Lake Michigan down or through the valley of the Illinois

River until after such time as the lower reach of the Illinois river is properly prepared to receive the same without damage to the lands of the valley and the agricultural and commercial interests; and be it further

Resolved, That the President and Secretary of this Chamber of Commerce are hereby directed to send copies of these resolutions to the Executive officers of the United States, Committees of Congress, Members of the National Congress and Senate from the State of Illinois, and the Sanitary District of Chicago, to the Lakes-to-the-Gulf Deep Waterway Association, the Governer of the State of Illinois and others who may be particularly interested.

Dated at Beardstown, Illinois, March 5th, 1912.

H. G. RUSSELL,
President.

(Seal)
The Beardstown Chamber of Commerce
Illinois (Seal) Beardstown

H. LERKEWICH,
Secretary.

Letter of Protest of Charles Schaaf to Secretary of War, February 23, 1912.

"I notice in the paper that on Feb. 28th you will give a hearing to the Sanitary District of Chicago for permission to divert an additional 10,000 cubic feet of water into the drainage canal. I wish to complain and say that the Sanitary District company has overflowed my land so that I am unable to make more than a living and if they are permitted to turn in more water my place will be a total loss. Before this water was turned in I could raise four or five thousand bushels of corn every year, now I do well to average one thousand a year—ten years ago my place was worth fifteen thousand dollars and now I would be *only to glad to sell for five thousand.* They ought to buy this bottom land before they are allowed to turn in the water. You may say sue them. Why we have been trying to sue them for 10 years but what can us poor farmers do with a company that is worth 50 to 60 millions, (*nothing*!) So I ask you in the name of God to not let them turn in more water, thanking you for any favors, believe me to be. * * *

CHARLES SCHAAF."

Protest of City Council of Rushville, Illinois, Dated March 5, 1912.

"Whereas, The turning into the valley of the Illinois river of waters from Lake Michigan by the Sanitary District of Chicago has caused great damage to the valley by overflowing valuable farming and timber lands and rendering them unproductive and unsanitary, and

Whereas, This great damage has been caused by the flow of less than 4,000 cubic feet per second, and,

Whereas, The Sanitary District of Chicago is now asking the Secretary of War for a permit to increase the flow from Lake Michigan down the path of the Illinois river, to 10,000 cubic feet per second, and,

Whereas, Such flow will increase the damage done to the Illinois valley lands, and

Whereas, No provision has been made to prevent the damage that has been created by the flow from Lake Michigan as exists now, to say nothing of the proposed increase, by either the Sanitary District of Chicago or the State of Illinois or the Federal Government, by the preparing of the channel of the Illinois river through the alluvial valley to care for same without damage, and,

Whereas, 400,000 acres of the lands of the valley are affected and damaged by the present flow and will be proportionately more damaged by the increased flow, and,

Whereas, Great increase in cost to reclaim these lands and maintain the reclamation of the lands already reclaimed entailing cost to the thousands of land owners that can only be reimbursed by long and expensive litigation, and,

Whereas, The proper regulation of rivers of the United States is vested in the *federal authorities of the United States* and any artificial changes of the natural conditions can only be made by authority of the federal authorities and we cannot believe that it is any part of the policy of the United States either by sin or omission to damage the great riparian interests in the lower valley or to prevent or handicap the development by reclamation of lands or their maintenance. On the contrary we look to the federal authorities to remedy the present situation and to prevent further destruction of property. And recognising the great authority of the United States in this matter, Therefore,

Be it, Resolved, That the City Council of the City of Rushville in Schuyler County, Illinois, do hereby protest against the granting of any permit to increase the flow of waters of

Lake Michigan down or through the valley of the Illinois river until after such time as the lower reach of the Illinois river is properly prepared to receive the same without damage to the lands of the valley and the agricultural and commercial interests."

Letter of Smith-Hippen Co., Pekin, Illinois, to Chief of Engineers, February 27, 1912.

W. H. Bixby,
Chief of Engineers, U. S. Army,
Washington, D. C.

Dear Sir:—

Your message of the 21st and letter of the 22nd refering to the hearing before the Secretary of War on the 28th, received. Referred same to a meeting of land owners and commissioners of the various drainage districts in this vicinity such as we could gather together and at their request wired you if it would not be possible to secure a postponement of the hearing or reserve the decision until a statement of the conditions could be prepared with a protest against increasing the present flow from Lake Michigan. Not hearing from you we suppose it was impossible for you to get this concession.

We know that if the lands owners and drainage commissioners are given a chance to make a protest, that they can demonstrate that the increased flow of water in the Illinois river without a corresponding depth of channel to provide for it will inculcate great loss on all of the drainage districts now organized or in the process of organization.

As a firm we now have invested in elevators along the Illinois river about $75,000.00. These houses were located and built on the basis of high water before the turning in of the extra water from Lake Michigan. This past year we were compelled to change our system of unloading at our Pekin elevator at a cost of over $1,100.00 because the increased floods each year overflowed our conveyors and rendered impractical this means of unloading boats which had been operated for years without any trouble with floods.

We find now that when the river is at flood state that the water is up over our foundations at practically every elevator and any increase in the volume of the water put it into all of our bins with a chance of great possible loss to both the buildings and their contents.

A further increase of water would mean that every river

house that we own would either have to be rebuilt or entirely remodeled and all approaches raised so as to get above any possible action of the water.

As most of the grain reaching our river houses is hauled over bottom roads, these would also have to raised a corresponding amount or our business would be hampered and handicapped by the longer period in which the flood water would submerge the roads.

The great difficulty with the flow of water from the drainage canal is that it is regulated entirely to suit the needs of the Sanitary District without regard to the loss or inconvenience to the river valley.

We find that the time of our greatest floods is the time at which the greatest amount of water is passed over the bear trap. Quoting from the Chicago Evening Post of April 30, 1909—"Flow in the drainage canal nearly doubled to meet emergency of record-breaking rainfall." And again from the same issue—"In the sanitary canal the flow first was increased from a normal of 350,000 cubic feet of water a minute to 480,000 cubic feet, and when that augmented flow failed to keep the river current flowing away from Lake Michigan, instructions were phoned to Lockport to lower the dam still farther to permit 600,000 cubic feet to pass over it each minute."

There are no records accessible to us by which we can prove these figures but we do know that our floods are augmented each year very considerably by the excessive amount of water let in through the drainage canal and a further increase of this amount would work us very serious damage.

We would welcome the time when ten thousand second feet of water could be passed down this river if the channel were prepared to receive it, but with conditions as they are at present we think it would be of great loss to all of the valley interests to increase the flow.

Yours very truly,

SMITH-HIPPEN COMPANY,

by A. J. AYDELOTT."

Protest of Citizens and Property Owners of Greene County, Illinois, to the Secretary of War, March, 1912.

"We, the undersigned citizens residing in Greene County, Illinois (which borders on the Illinois river), do hereby most earnestly protest against the granting of permission to the Sanitary District of Chicago to turn into the Illinois river valley any greater amount of water than the present flow of 4,200 cubic feet per second, until such time as by reason of the removal of the dams and other obstructions now in said river, a sufficient channel will be prepared to accommodate such increased flow without the great damage to agricultural and other interests that would necessarily result from such increased flow with the river in its present condition.

In support of this protest we respectfully call your attention to the fact that this increased volume of water is not needed for the purposes of navigation: that there are in our county thousands, and in the valley of the Illinois tens of thousands, of acres, of rich farming lands now in cultivation and highly productive, which by reason of their low elevation will be practically ruined in case the water level in the river is materially increased, and especially is this true by reason of the fact that the dams across the river have already raised the level at low water to a point which approaches the natural level of those lands. We most respectfully insist that the increased water level in the river, which would be occasioned by this additional flow, would not only greatly damage, and in many cases financially ruin, the land owners, who have, by years of unremitting toil and privation and the expenditure of vast sums of money, converted these lands from their natural condition of swamps into fertile and productive fields, but would also render practically worthless millions of dollars of drainage bonds which have been issued against these lands to pay off the cost of building levees, excavating ditches and installing pumping plants, etc., many of which bonds are held in small amounts by investors of moderate means, some of whom have the savings of a lifetime invested in them.

We therefore most earnestly request you to withhold your official permission to the turning into this fertile valley of this great increase of water, which, under present conditions, would be bound to cause such great and irreparable loss and damage to so many of our citizens.

All of which is respectfully submitted."

United States of America,
Northern District of Illinois, } ss.
Eastern Division.

IN THE DISTRICT COURT OF THE UNITED STATES.

United States of America,
Complainant,
vs.
The Sanitary District of Chicago,
Defendant.

Equity No. 114.
C. C. No. 29,019.

STIPULATION.

It is hereby stipulated that the matter on pages 3601 to 3845, inclusive, being extracts from public hearings, briefs, letters, telegrams, and resolutions in connection with the application of the Sanitary District of Chicago of February 5, 1912, to divert 10,000 cu. ft. of water per second from Lake Michigan, may be considered in evidence with like effect as if witnesses were called and originals were produced and identified in this case, subject to all objections as to materiality, relevancy and competency, but neither complainant nor defendant waives by this stipulation any objections as to competency, relevancy and materiality of any similar or like matters offered by the other party relative to said hearing.

CHAS. F. CLYNE,
United States Attorney.
EDMUND D. ADCOCK
Attorney for Sanitary District of Chicago.

Chicago, October 1st, 1914.

EXTRACTS FROM APPROVALS OF VARIOUS ASSOCIATIONS AND INDIVIDUALS, AND BRIEFS ON BEHALF OF THE STATE OF ILLINOIS AND THE CITY OF CHICAGO.

Letter of Approval by Major Thos. H. Rees, U. S. Engr., to Chief of Engrs. U. S. Army, Jan. 17, 1910.

"1. In connection with 1st indorsement of this date on letter from Chief Engineer, Sanitary District of Chicago of

January 10, 1910, I have the honor to submit the following report and recommendations:

2. The only questions in connection with this application that seem to require consideration by the War Department are the following:

(a) The reversal of the flow of water in the Calumet River.

(b) The change of hydraulic grade in the Calumet River.

(c) The velocity of current that may be generated in Calumet River.

(d) The diversion of water from Lake Michigan.

3. Although not stated in the application, I am informed by the Chief Engineer of the Sanitary District that it is proposed to provide for a flow in Sag Channel—of 2,000 cubic feet per second. The natural flow in the Calumet River varies between wide ranges and is largely affected by the stage of Lake Michigan. The drainage basin has an area of 825 square miles and the mean annual rainfall of this region is 33 inches. Assuming a run-off of 40 per cent. the average discharge of the river would be 800 cubic feet per second. During dry periods the discharge is practically nothing and a temporary rise in lake level sometimes causes a current up-stream. During freshets the discharge is greatly increased and may at times greatly exceed the 2,000 cubic feet per second proposed to be diverted into the Sag-Channel. At such times the surplus would discharge into Lake Michigan without any reversal of flow in the lower Calumet River. A large part of the sediment and sewage from the Grand Calumet and Little Calumet rivers would be carried into the Sag-Channel, thus diminishing the deposits of such material in the lower Calumet River and in Calumet Harbor. The reversal of flow in Calumet River would not be detrimental to navigation interests provided the reversed current has a moderate velocity.

4. A reversal of the flow in the Calumet River will necessarily cause a downward slope of the water surface from the Lake toward the Sag-Channel, thus lowering the hydraulic grade and slightly diminishing the depth of water in the channel. In the existing channel a flow of 2,000 cubic feet per second will cause a slope of about 1:1,000,000 and at "the Forks," which is the head of projected improvements, the hydraulic grade would be lowered only about 0.4 of an inch. This is negligible and the lowering of the hydraulic grade would not be prejudicial to navigation.

5. A flow of 2,000 cubic feet per second would generate in the existing channel a mean velocity not exceeding 0.45 feet

per second (0.3 miles per hour). Through bridge openings 120 feet wide the mean velocity would be about 0.83 feet per second (0.55 miles per hour). These velocities would not be detrimental to navigation interests.

6. It seems to have been condeded both by the War Department and by the International Waterways Commission that, subject to possible future action by the Courts or the Congress of the United States and to possible treaty stipulations with the Dominion of Canada, the Sanitary District of Chicago may divert from Lake Michigan through its Sanitary and Ship Canal, 10,000 cubic feet of water per second and no more, provided the currents thereby generated in navigable channels of the United States shall not be unduly harmful to navigation interests by reason of excessive velocities. The several outlets through which the Sanitary District proposes to effect this diversion are: The North Shore Channel from Lake Michigan at Wilmette, Ill., to the North Branch of Chicago River at Lawrence avenue (authorized and under construction); the Chicago River together with the South Branch and West Fork to Robey street (authorized and nearly completed); the 39th Street Conduit and pumping station (in operation); the Calumet River by means of the proposed Sag-Channel from the Little Calumet River at Blue Island to the main drainage canal at Sag. If the total diversion through all of these outlets be limited to 10,000 cubic feet per second and if the currents be restricted to harmless velocities, I can see no reason, so far as the interests of navigation are concerned, for denying this application of the Sanitary District of Chicago.

7. It is therefore recommended that this application of the Sanitary District of Chicago be granted subject to the following conditions:

1. That the total diversion of water from Lake Michigan by the said Sanitary District through all of its channels and outlets shall not exceed the rate of 10,000 cubic feet of water per second.

2. That the current generated in any navigable channel of the United States used in part for such diversion of water from Lake Michigan shall not have a mean velocity exceeding one and one-quarter (1¼) miles per hour.

3. That detailed plans showing the proposed location and method for the connection of the Sag-Channel with the Calumet or Little Calumet River and showing also any changes or alterations proposed to be made in said rivers shall be sub-

mitted by the Sanitary District for prior approval by the War Department, and this part of the work shall be subject to supervision by the U. S. Engineer Officer whose address is Chicago, Ill.

4. That this permission shall not be construed as authorizing the invasion of any legal rights of corporations or individuals, municipal or private, or as exempting the grantee from responsibility for damages that may result from the works herein authorized.

THOS. H. REES,
Major, Corps of Engineers."

Letter of Approval by Major Thos. H. Rees, U. S. Engr., to Chief of Engr., U. S. Army, Feb. 21, 1910.

"1. Replying to your letter of February 16, 1910 (E. D. 28918/265), in regard to the application of the Sanitary District of Chicago for permission to divert water from Lake Michigan through a proposed Calumet-Sag Channel, I have the honor to refer to the report of Colonel W. H. Bixby, Corps of Engineers, of December 4, 1906, from which I quote, 'so far as it provides for keeping a part of the Calumet Basin sewage from flowing into Lake Michigan and for diverting the same into the Sanitary District Canal and Illinois River the project deserves all reasonable and allowable commendation and encouragement. * * * The reasons given oblige me at present to recommend against any present favorable consideration of the present request unless the 10,000 cubic feet per second flowage possibly allowable through the Chicago River be reduced by the amount allowed to the Calumet. Otherwise I see no special objection to the permit as requested so far as concerns the interests of navigation.'

2. The recommendations of the Chief of Engineers of February 23, 1907, quoted by the Secretary of War in his memorandum of March 14, 1907, refer to the conclusions of the International Waterways Commission as set forth in report of January 4, 1907, printed as War Department Document No. 293. This report concludes with the following words:

'We therefore recommend that the Government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal.'

3. On May 4, 1906, the Secretary of War transmitted to the President for submission to Congress a report of May 3, 1906,

by the International Waterways Commission upon the preservation of Niagara Falls printed as Senate Document No. 434, 59th Congress, 1st Session in which 'The Comission therefore recommend that * * * a diversion for sanitary purposes not to exceed 10,000 cubic feet per second be authorized for the Chicago Drainage Canal. * * *'

4. I cannot find any definite concurrence by the Chief of Engineers or the Secretary of War in the conclusions and recommendations of the International Waterways Commission above quoted but the 'conclusions' were referred to by the Chief of Engineers to support his recommendations and the 'recommendations' were transmitted by the Secretary of War for submission to Congress without adverse comment. Therefore I stated in my letter of January 17, 1910, that it seems to have been conceded by the War Department that the Sanitary District may divert from Lake Michigan through its Sanitary and Ship Canal 10,000 cubic feet of water per second.

5. The former application of the Sanitary District which was denied in March, 1907, asked for approval of plans which contemplated an ultimate total diversion of 14,000 cubic feet of water per second from Lake Michigan. The application of January 10, 1910, contemplates a total diversion of 10,000 cubic feet per second.

THOS. H. REES,
Major, Corps of Engineers."

Letter of Approval by P. T. Cook to Secretary of War, Feb. 29, 1912.

"Subject, Increasing Second-Feet to Chicago Drainage Canal.—Sir: I am a student of the Great Lakes since 1875, when I began to hunt and fish on St. Claire Flats. My Indian and half-breed punters instilled the notion that there was a regular cycle of high and low water of about eleven years from crest to crest, with a difference of two to three feet. My personal experience was the purchase of a low lying farm on Huron Point, Lake St. Claire, and its sale several years later. When I bought, the farmer had been drowned out for a couple of years. When I sold, the entire farm could be plowed to the shore of the lake.

I think I have read of this cycle in the writings of Schoolcraft and Cass. I have heard it from the boatmen at Mackinac, and my guides on Superior. My own opinion is that the

cycle is irregular and dependent on the rainfall of the Great Lakes basin. A comparison of the rainfall from the records of the Weather Bureau with the gauge readings of the upper lakes should verify or disprove the tradition.

Twenty-five years ago, Capt. Lockwood, then in charge of rivers and harbors at this point, estimated the northward current on the east side of Lake Michigan at one-quarter to one-half mile per hour.

At the slowest rate, the 7,000 second feet now allowed the Drainage Canal would deduct 0.1416 feet from a width of twenty-five miles, and reduce the level of the lake 0.04423 feet or one-half inch.

Assuming locks 150 feet wide, 900 feet long with 22 feet over sill and assuming that lockages are made continuously at the average rate of those at Sault Ste. Marie for 1909, 35 Min., and allowing 30 per cent. displacement, 2,315 second-feet would supply the water, leaving 4,685 feet for power.

As the present supply gives a speed of two and one-half miles per hour in the rock-cutting sections of the canal, it is evident that the call for more water comes only from the neighborhood of the turning basins and from the waterwheels at Lockport.

If it should be found necessary to give some water for the basins, I respectfully suggest that the amount be limited to 2,500 feet, and the proviso be inserted in the grant that this extra amount shall, at all times, be available for ship canal use, and that no vested rights shall accrue by reason of its use for other purposes, no matter how long such use may become.

As to the effect on the climate of Michigan, the fears of my neighbors are groundless.

One illustration is enough. The Hon. William Livingstone is quoted, this morning, as saying: 'Lake Superior has fallen .8 foot in the last four years, Lakes Michigan and Huron .8 foot in two years, Lake Erie a .8 foot in two years and Lake Ontario 1.5 feet.'

The fact that Superior, Michigan and Huron show the same drop is conclusive proof that the canal is no factor in the lake level.

P. T. Cook."

Letter of Approval by Illinois Rivers and Lakes Commission, March 11, 1912.

"In connection with the request of the Sanitary District of Chicago for permission to extract a volume of ten thousand cubic feet of water per second from Lake Michigan, the Rivers and Lakes Commission of the State of Illinois begs to submit for your consideration the following statement of facts:

First: This volume of water is required in order to comply with the laws of Illinois.—Sanitary District Act of Illinois General Assembly, 1889.

Second: The connection between the Great Lakes and the Mississippi Valley was provided for by Congressional Act in 1832, as held by the Supreme Court of the United States in the case of Missouri *vs.* Sanitary District of Chicago.

Third: That the Sanitary and Ship Canal, as constructed, is of a size necessary under present conditions to carry out the waterway policy of the United States formed in 1832.

Fourth: The full project of the State of Illinois contemplates the sanitation of Chicago and of the Illinois River valley; the construction of a navigable waterway giving to this region facilities similar to those provided by the United States Government in the Ohio River and in the St. Mary's and other interlake channels, the same to be paid for so far as possible out of the water power created as incident to the work.

Fifth: We call your attention that this is a project distinctly in accordance with present-day views as to the use of public property for the general welfare and shows a marked advance over the methods heretofore used in creating public improvements.

Sixth: Opposition to this plan comes from and is urged in behalf of special interests, which derive almost exclusive benefits from the Government appropriations for the Great Lakes, whether spent in deepening channels, building locks or improving harbors.

Seventh: For entire confirmation of these facts, we refer you to the arguments of Mr. Isham Randolph, Mr. Gardner S. Williams and Mr. Robert R. McCormick.

ROBERT R. MCCORMICK,
Chairman."

Letter of Approval by Senator S. M. Cullom, March 20, 1910.

"I have just received the enclosed resolution adopted by Board of Trustees of the Sanitary District of Chicago, in reference to the increase in the flow of waters made necessary by the proposition to reverse the flow of the Calumet. It seems to me that there is merit in the proposition that a permit should be granted along the lines asked for by the Drainage Board.

I send the resolution to you, to again call your attention to the matter, in the hope that you may see your way clear to grant the permit requested.

Sincerely yours,

S. M. CULLOM."

Resolution of Approval by Chicago Association of Commerce.

"We respectfully invite your attention to the attached certified copy of a resolution adopted today by the Executive Committee of this Association with respect to the application of the Board of Trustees of the Sanitary District of Chicago to take additional water from Lake Michigan.

THE CHICAGO ASSOCIATION OF COMMERCE,
By E. U. KIMBARK,
President."

Resolution Adopted by the Executive Committee of the Chicago Association of Commerce in Regular Meeting Assembled on Friday, March 22, 1912.

"Whereas, the Board of Trustees of the Sanitary District of Chicago has petitioned the United States Government for an increased flow from Lake Michigan of from 4,167 cubic feet per second to 10,000 cubic feet per second, of which 2,000 cubic feet is to come through the Calumet River into the Drainage Canal, 2,000 feet through the tunnel leading from the Lake at 39th street and connecting with the Drainage Canal, and 1,000 cubic feet forced through the opening from the Lake to the North Branch of the Chicago River; therefore be it

Resolved, That the Executive Committee of the Chicago Association of Commerce approves the granting of said increase, provided it shall not become operative until after the

improvements in the channel are completed, namely, a width of 200 feet and a depth of 26 feet, with the exception of the modifications as to width heretofore made by this committee; and with the further provision that the flow of water is to be restricted by the United States Government in the event of undue interference with the navigation interests of Chicago.

I, H. F. Miller, business manager of the Chicago Association of Commerce, do hereby certify that the above is a true copy of a resolution adopted by the Executive Committee of the Chicago Association of Commerce at a regular meeting held on Friday, March 22, 1912.

H. F. MILLER,
Business Manager."

(SEAL)

Letter of Gov. Chas. S. Deneen of Illinois, March 25, 1912.

"I have requested Mr. Isham Randolph, to whom I have handed this letter, to represent the interests of our state at the hearing which he is to appear before you regarding the question of the diversion of water from Lake Michigan for the use of the Sanitary District of Chicago.

Mr. Randolph was a member of the Illinois Internal Improvement Commission and represented our state at certain conferences with the Board of Army Engineers, appointed by the Sixty-first Congress, in its investigation of the improvement of the lower Illinois River and is at present a member of the Illinois River and Lakes Commission.

C. S. DENEEN,
Governor."

Argument on Behalf of The State of Illinois Supporting the Prayer of The Sanitary District of Chicago for a Permit to Take 10,000 *Cubic Feet of Water Per Second from Lake Michigan, April* 3, 1912.

"To the Honorable Secretary of War:

As a preface to the appeal which I am about to make to your reason and your sense of justice, I shall in the briefest way recite a few historic facts.

Lake Michigan in order of magnitude stands third in the roster of the Great Lakes, with an area of 22,326 square miles. This body of water belongs wholly to the United States and is allotted to the several states which bound it as

follows: Indiana, 230 square miles; Illinois, 1,674 square miles; Wisconsin, 7,500 square miles; and Michigan, 12,922 square miles. (See Statistical Abstract of the United States for 1907, page 19.) In these waters, the treaty of Washington, 1871, gave the citizens of Great Britain equal rights of navigation with the citizens of the United States subject to the laws of the State bordering thereon. This treaty terminated by its own limitation in 1881 and thereafter the citizens of Great Britain had no treaty rights in these waters but were by courtesy accorded all the privileges they enjoyed under the treaty. And thus it has been until the promulgation on May 13, 1910, of the now existing treaty.

The history of Chicago is not ancient for only one hundred years have elapsed since the Fort Dearborn massacre. Modern as it is, however, it is crowded with incident. Chicago was incorporated in 1837 with a population of about four thousand. When the great fire of 1871 swept the city, the population was about three hundred and twenty-five thousand. Today, nearly forty-one years after the fire, the population has reached two million two hundred and fifty thousand. The source of water supply for this great city is and has been since its inception, Lake Michigan. For a long term of years that great reservoir was also the receiver of the sewage of the city and it was only when the waters became so foul as to produce disease that an effort was made to safeguard the water supply. The steps which led up to this effort and the details of its successful issue cannot be recounted here. The Chicago Sanitary and Ship Canal was dug and the flow of the Chicago River was caused to turn backward and through that once foul channel, the waters of Lake Michigan are flowing towards the Gulf of Mexico.

The legislation by the State of Illinois which authorized this great work had wide notoriety. The Sanitary District law which went into effect July 1, 1889, was widely advertised; its constitutionality was attacked but it was sustained by the courts. All of this was known to the Congress of the United States and to the executive departments of the Government and from no one of these did there come a protest to a prosecution of the work which was commenced Sept. 3, 1892. That work was prosecuted diligently for eight long years with the full knowledge of every department of the United States Government. The work was visited by Congressional delegations; by Secretaries of War; by Chiefs of Engineers, by officers of the United States Engineer Corps;

and no voice was raised in opposition. Literature describing the work was scattered broadcast. I myself sent out thousands upon thousands of concise reports describing the work. We sought publicity. On the seventeenth day of January, 1900, the dam at the south end of the channel was lowered and the waters of Lake Michigan began to flow southward. At that time, the Sanitary District had expended in creating the work over thirty-three million dollars. The water has been flowing through that channel for twelve long years without let or hindrance from any governmental source with the result that the typhoid death rate of the city of Chicago which in 1891 was 173.8 per 100,000 was in 1910, 13.26 per 100,000. Now you are asked to exercise your great power in restraint of this life giving flow; you are asked to rob humanity to enrich greed.

I am a part of the history of the Sanitary District; for fourteen years and two months, I was its chief engineer, the executive head of its construction, and I am and have been for nearly five years its consulting engineer and I know whereof I am speaking.

The opposition to the withdrawal of water for the uses of the Sanitary District come in great part from the shipping interests on the Great Lakes; the forefront of these is the Lake Carriers Association and of their opposition, I will now speak historically. This opposition first had an opportunity for official manifestation after the appointment of the International Waterways Commission in 1904 (?). I was first confronted by this opposition in June, 1906, when we were notified that a hearing would be given in Buffalo to all parties who wished to be heard in relation to the levels of the Great Lakes. This hearing took place on the 26th day of June, 1906, in the Federal building in Buffalo, and I was sent on to represent the Sanitary District of Chicago and defend its rights as best I could.

The meeting was a very depressing one to me, for I found myself friendless and in the enemy's country. The commission was unfriendly—when I say this I mean unfriendly officially, for in spite of our official differences I had personal friends on that commission, and I believe the official strike did not militate against personal kindness of feeling. The Canadian shipping interests were largely represented and were very hostile. Boston was upon its own dunghill and its opposition was bitter to the verge of brutality. The Lake Marine was there by its officers strongly arrayed against us.

The president of the Lake Carrier's Association, Mr. Livingstone, made an address which disconcerted me greatly. He said that the lowering of the lakes one inch meant to the modern lake carrier a loss of 100 tons carrying capacity and that the certain lowering of the lakes six inches meant a loss of 600 tons per trip, that the average number of trips per season was 23 and the average net earning 50 cents per ton. Then he gave the number of vessels that would be affected and showed an aggregate annual loss of $2,500,000. I came home much disheartened; but as I ruminated on the matter it occurred to me that there was no boat on the lakes that carried 100 tons per inch of draft. I got the Blue Book of American Commerce; scheduled all of the lake boats and computed their carrying capacity and was comforted.

Shortly thereafter the then Secretary of War, Mr. Taft, issued a notice that all who were interested in the question of lake levels would be accorded a hearing before him. Of course the Sanitary District took a hand in this. Its attorney and its chief engineer prepared arguments. I had all the data collected—to refute Mr. Livingtone's statements—in manuscript, but not knowing whether I would have a chance to use it I did not have it printed with the rest of my argument. The hearing was set for January 14, 1907. I went down a couple of days ahead of time to see if I could gather any new facts, that would help me. Through the help of our Congressman, James R. Mann, I secured an advance copy of the report of the International Waterways Commission, and therein—sure enough—was the Livingstone address without quotation marks and therefore adopted by the commission as its own. When my turn to address the secretary arrived I delivered my address as far as it was printed, and paused. The secretary addressed me thus: 'Mr. Randolph, have you seen the report of the International Waterways Commission?' I replied, 'Yes, Mr. Secretary, and I thank you for asking me that question, for it gives me an opportunity to call your attention to grievous misstatements in that report.' Then I read as follows:

'A Review of Some Questions Raised in the Report of the International Waterways Commission.'

On page 3, paragraph 24 of the report of the International Commission, I note a certain misleading statement into which the commission has doubtless been betrayed by the Lake Marine Interest, as I heard the assertion upon which it is based made to the commission in Buffalo on June 26th last by Mr.

Livingstone, president of the Lake Carriers Association. It is this:

'In the modern vessel each inch of increased draft adds about 100 tons to the carrying capacity.'

With this text they go on to state that:

'To lower the water surface six inches is to reduce the capacity of the vessel about 600 tons.'

Then they reason further:

'If the freight rate on ore be taken at 55 cents per ton, exclusive of the cost of loading and unloading, and the number of trips during the season at 22, there appears a loss of over $7,000 for the season for each vessel. The number of vessels navigating the Great Lakes which draw 19 feet or more is 417 and their tonnage is 1,514,414 tons, which is about three-quarters of the total tonnage of the lakes. It is a conservative estimate that the loss to navigation interests resulting from a reduction of six inches in the depth of water is $2,500,000 per annum, which capitalized at 4 per cent. amounts to a loss of $62,500,000.'

This is a terrific showing—but is it true. Here is the crux of the discussion.

I have made such a study as the sources of information available to me have admitted of and I find this:

The American Lake Marine comprises the following numbers of vessels of the several gross tonnages named:

265 vessels between 1 and 2 thousand tons.
158 vessels between 2 and 3 thousand tons.
77 vessels between 3 and 4 thousand tons.
99 vessels between 4 and 5 thousand tons.
31 vessels between 5 and 6 thousand tons.
23 vessels between 6 and 7 thousand tons.

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652 vessels total.

At the time I heard President Livingstone make this statement, I accepted it as authoritative, but later upon reflection, I grew skeptical and so I began to investigate and give my results:

I found that in the American Lake Marine there were at the time he made this assertion 153 vessels, between 300 and 400 feet long. Maximum length in this class 396 ft. x 45 ft. That there were 111 vessels between 400 and 500 feet maximum length in this class of 488 ft. x 52 ft. beam. That there were 42 vessels between 500 and 600 ft. long and the maximum length of this class was 588 ft. x 58 ft. beam.

Of the maximum in each class there were:
1—396x45.
2—488x52.
6—580x58.

For the sake of argument, let us figure all of each class as of the maximum of that class—a manifestly improper thing to do—and see what results we get.

396x45 gives us 41.2 tons per inch of depth.
488x52 gives us 59.4 tons per inch of depth.
580 x58 gives us 78.8 tons per inch of depth.

153 vessels multiplied by 41.2 equals	7,303.6 tons.
111 vessels multiplied by 59.4 equals	6,593.4 tons.
42 vessels multiplied by 78.8 equals	3,309.6 tons.
	17,206.6 tons total

for 1 inch in depth. 17,206.6 multiplied by six, gives us 103,239.6 tons for that depth. Multiply 102,239.6 by 22 trips and we get 2,271,271.2 tons as the year's loss of tonnage. This at 55 cents amounts to $1,249,199.16. Capitalize this sum at 4 per cent. and we get $31,229,979.00, instead of $62,500,000.00. Now let us try the inaccurate but approximately reasonable method of taking for these vessels an average between their maximums and minimum dimensions and see where we come out.

153 vessels 348x48 equal to 39.1 tons per inch,
or 5,982.3 tons.
111 vessels 444x48 equal to 47.3 tons each per inch,
or 5,250.3 tons.
42 vessels 540x56 equal to 70.8 tons each per inch,
or 2,973.6 tons.
14,206.2 total tons for one inch in depth.
14,206.2 multiplied by six (inches) equals 85,237.2 tons.
85,237.2 multiplied by 22 (trips) equals 1,875,218.4 tons, which, at 55 cents, amounts to $1,031,307.12, which sum capitalized at 4 per cent. amounts to $25,784,253.00 a considerable saving over $62,500,000.

It is proper before leaving this subject, to state that at least one vessel 600 feet long and 58 feet wide has been launched by the Chicago Ship Building Company and the same company is now building one 605 feet long x 60 feet. The tonnage per inch of depth of the first is 81.5 and of the second 85 tons. There is not a vessel in sight on the lakes having a carrying capacity of 100 tons per inch.

But why discuss any such proposition at all in view of the

report of a Board of Government Engineers that remedial works at the east end of Lake Erie will restore navigable depths at a cost of only $796,923.00; and when further it is demonstrable that a proper control of the waters of Lake Superior by works now installed, will remedy the whole evil? It may be urged that the existing works are inadequate, but it cannot be denied that they can be made adequate by a very inconsiderable additional expenditure.

As to the propriety of Canadian and U. S. Governmental advice to a city in any State of this Union as to the manner in which it shall dispose of its sewage and conduct its municipal engineering, I must leave the people of the several states to express their opinions.

ISHAM RANDOLPH.

Washington, D. C., Jan. 12, 1907.'

When I finished reading, the vice president of the Lake Carriers Association demanded that I withdraw the statement. I asked why I should. He replied, 'Because you are a civil engineer and don't know how to figure tonnage.' I asked how they figured it, and not one of them could tell me. I wrote out the formula, and giving it to General Ernst, who sat beside Mr. Taft, asked him if it was right. He examined it and said it was right. Then Harry D. Goulder, attorney for the Lake Carriers, came over and asked me to withdraw the report. I asked 'Why.' He said: 'Your sources of information are incorrect.' I showed him the book from which I got it. He said: 'That is authentic,' and sat down.

I have my copy of that report of the International Waterways Committee but it is a rare document. It was recalled and expurgated before re-issue.

Now the Chicago Sanitary and Ship Canal was built in conformity with the Illinois Sanitary District law passed in 1889, which requires that there shall be a dilution of 20,000 cubic feet per minute for every hundred thousand of the population draining into the channel. The work was predicated upon a population of three million and the flow required would therefore be 600,000 cubic feet per minute or 10,000 cubic feet per second.

What the view of prominent members of the United States Engineer Corps were in regard to this requirement is clearly shown by the following quotation from a report on a fourteen foot waterway from Chicago to St. Louis:

'The board does not condemn the present plan of taking 10,000 cubic feet per second, believing as it does that some

such amount will be needed to protect the lives and health of the people of a great city and of a populous valley, but it invites attention to the the fact that if a much larger amount be taken it will be necessary to construct remedial works elsewhere and that these are, or should be of an international character. It is led to make this remark by the attitude of the Illinois legislature and other principal advocates of this enterprise which is that a fourteen foot waterway is only a beginning and that a much deeper channel ultimately should be constructed, which means that a larger volume must be taken from Lake Michigan. It is the opinion of the board that the sanitary reasons for the abstraction of water so far exceed and overshadow the commercial reasons that the amount should be strictly limited by the sanitary necessities of the case. It is possible to fix a limit to the future growth of Chicago. In a future not a remote larger amounts of water may be needed for sanitary purposes, and channels deeper than fourteen feet will then become practicable in the open alluvial portion of the Illinois river.'

The signers of this report were: O. H. Ernst, Colonel Corps of Engineers; W. H. Bixby, Lieut. Col. Corps of Engineers (now General and Chief of Engineers); and Thomas L. Casey, Major Corps of Engineers.

From the report of the International Waterways Commission, dated December, 1906, I quote as follows:

'Any discussion of the preservation of Niagara Falls would have been incomplete without some reference to the Chicago Drainage canal, which was designed to divert from the southern end of Lake Michigan 10,000 cubic feet of water naturally tributary to the falls. A discussion of the effect of such diversion upon water levels, and consequently upon the navigation interests of the Great Lakes and of the St. Lawrence valley, could find no proper place in the Niagara Falls report. In recommending the allowance of 10,000 cubic feet per second to the Chicago Drainage canal the commission ignored those important questions. It is believed, in so doing, that it was accepting a general tacit agreement that some such amount was required to protect the health of Chicago, and that that city should have it without further question, whatever the effect upon navigation might be. It is believed also that the amount was all that Chicago asked or desired. It turns out that in this latter respect it was mistaken. Plans are on foot at Chicago which calls for a much larger amount at present and for amounts in the future to which no limit is assigned.

The commission has collected a large amount of information upon the subject and has held public hearings at Buffalo and Chicago, but its investigations are not entirely completed. It will at an early date submit a full report upon the subject.

(Signed) O. K. Ebner, *Chairman;*
George Clinton, *Member;*
E. E. Haskell, *Member.*'

There is so much that is pertinent and illuminating in the reports of the International Waterways Commission that I am tempted to quote therefrom in extenso but will resist that temptation and quote only a few passages. From their report transmitted Jan. 4, 1907, page 6, paragraph 19, I quote:

'In the expenditure of $40,000,000 for the drainage canal the people of Chicago, with its population of 2,000,000, incurred a burden equivalent to that due to an expenditure of $1,600,000,000 by the United States, with its population of 80,000,000—that is, enough to build eight or more Panama canals. It was a very serious effort and has commanded the admiration and sympathy of all observers. The diversion of 10,000 cubic feet per second from Lake Michigan affects other interests adversely, but these interests have withheld their opposition, seeming to believe that some such amount was necessary, and apparently willing to contribute their share to protect the lives and health of the people of a great city. The plans calling for that amount have been under public discussion for some years. Although withholding formal approval, the Federal authorities have taken no steps to prevent their execution. Congress has called for a plan and estimates for an improvement of the waterways connecting with it, the scope of which is fixed by that amount. There appears to be a tacit general agreement that Chicago needs or will need about 10,000 cubic feet of water per second for sanitary purposes and that the city should have it without further question.'

From the same report, page 15, (r) and (s) of the summary:

'(r) The diversion of 10,000 cubic feet of water per second at Chicago will render practicable a waterway to the Mississippi River fourteen feet deep. Any greater depth must be obtained by the abstraction of more water from Lake Michigan and at the expense of the navigation interests of the Great Lakes and of the St. Lawrence valley.

(s) The effect upon Niagara Falls of diverting water at Chicago is of secondary importance when considering the

health of a great city and the navigation interests of the Great Lakes and of the St. Lawrence valley, but it is proper to note that the volume of the falls will be diminished by the full amount diverted at Chicago.'

And paragraph 43 on page 16:

'A careful consideration of all the circumstances lead us to the conclusion that the diversion of 10,000 cubic feet per second through the Chicago river will, with proper treatment of the sewerage from areas now sparsely occupied, provide for all the population which will ever be tributary to that river, and that the amount named will therefore suffice for the sanitary purposes of the city for all time. Incidentally it will provide for the largest navigable waterway from Lake Michigan to the Mississippi river which has been considered by Congress.

We therefore recommend that the Government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage canal.

All of which is respectfully submitted.

(Signed) O. H. Ernst,
Brigadier-General, U. S. Army, retired; Chairman American Section.

George Clinton,
E. E. Haskell,
Members American Section.
Geo. C. Gibbons,
Chairman Canadian Section.
W. F. King,
Louis Coste,
Members Canadian Section.

Attest:

W. Edward Wilson,
Secretary American Section.
Thomas Cote,
Secretary Canadian Section.'

From Report, dated December 1, 1907, Appendix C, page 17, letter addressed to Secretary of War:

'The situation is fairly stated by the company, and the request seems to us reasonable. It is consistent with the recommendations contained in our report of March 19, 1906, which reads as follows, viz.:

"If the falls are to be preserved it must be by mutual agreement between the two countries. As a step in that di-

rection we recommend that legislation be enacted which shall contain the following provisions, viz.:

(a) The Secretary of War to be authorized to grant permits for the diversion of 28,500 cubic feet per second, and no more, from the waters naturally tributary to Niagara Falls distributed as follows:

	Cu. ft.
Niagara Falls Hydraulic Power & Manufacturing Co...	9,500
Niagara Falls Power Company.....	8,600
Erie Canal or its tenant (in addition to lock service)...	400
Chicago Drainage canal	10,000

(Signed) O. H. ERNST,
Brigadier- General, U. S. Army, retired, Chairman;
GEORGE CLINTON, *Member;*
E. E. HASKELL, *Member.*'"

It is proper to state here that the preceding part of this brief was prepared prior to my leaving Chicago on March 25th, to attend the hearing which you accorded to the Dominion of Canada and its shipping interests two days later. At that time I had no knowledge of what transpired before you on Feb. 28, last. As I journed to Washington, I had an opportunity to read a stenographic report of that hearing which informed me of certain erroneous and surprising statements made then, which in the interest of truth and in behalf of the State of Illinois, I must take notice of.

The hearing which you held on the 27th instant was also fruitful of assertions which I must refute if I can and I believe I can.

Carrying Capacity of Vessels.

First, I will deal with the claims made for capacities for lake steamers, which are palpably in error. I had hoped that the outcome of the hearing on Jan. 14, 1907, a certain phase of which I have hereinbefore recited, had put that question beyond the point of argument, but my hope is disappointed. The carrying capacity of any maritime craft is gauged by the amount of water which she displaces. Each cubic foot of fresh water weighs 61¼ lbs. I will make my illustration fit the lake carriers, with which this whole discussion arose.

The class of boat doing business on the Great Lakes is adopted for its utility and not its 'symmetry of mould'; it approaches very closely to the lines of a monster watering through; its horizontal section, save for the taper at stem and

stern—to make it ship-shape—is a parallelogram. To get at the area of this horizontal section, we multiply the length by the breadth and then take nine-tenths of the result as the approximately true area. Having the area and desiring to know the displacement each inch of depth, we multiply the area by 62½, divide by 12 (to get the weight per inch) and then divide the result by 2,000 lbs. The quotient will be the number of tons that the vessel will carry per inch of depth. An approximately accurate formula is:

Length a x breadth b divided by 42.7.

Revised Statute, Section 4150, of Navigation Laws, lays down clearly the rules for determining length, depth and width for computing tonnage. There is no vessel afloat on the Great Lakes that carries in excess of 82.2 tons per inch. I read on page 380 of the stenographic report of the hearing before you this statement from Mr. William Livingstone, president of the Lake Carriers Association: 'We figure our modern boat, that our 600 footers, that we average 113 tons per inch.' I trust that this is a stenographic error, for I heard Mr. Livingstone testify, under oath, on May 24, 1909, that the capacity of such boats was 80 tons per inch. This question is of importance because of the effort to show enormous losses to the shipping interests by reason of lowering the lakes. I considered it so important that I have figured out the tonnage capacity per inch of every American vessel of 400 feet length, or over, on the Great Lakes; and as an appendix hereto I submit a schedule giving all of these boats, with their tonnage, length and width as defined by statute and with the names of their owners. With this schedule I submit drawings of the lake carrier J. K. Sheadle, built in 1906, that you may see how to apply the statutory rules for determining dimensions. The data for the schedule submitted is offered by the Blue Book of American Commerce for 1910, a compilation for which Mr. Eugene T. Chamberlain, Chief of the Bureau of Navigation, Department of Commerce and Labor, is responsible.

The Hydrographs of the Great Lakes.

Mr. Secretary you are looking for the truth in regard to this controversy. You must found your ruling upon the bed rock of truth, or else that ruling will be like the house founded upon the sand; when the rain of criticism descends and the winds of opposition blow and the floods of indignation come

the decision will fall 'and great will be the fall of it.' Is not your confidence in the integrity of the U. S. Engineer Corps sufficient for you to accept their exhibit of recorded facts? Are they not men who will not lie? I am willing to rest the case of the State of Illinois on their facts—not on their opinions—I tie to their facts and many times I dissent from their opinions.

I submit herewith a hydrograph prepared by the 'United States Lake Survey' showing 'Monthly mean water levels of the Great Lakes from Official Records of 1860 to Date.'

To examine that exhibit, start in with Lake Superior, the level of which is about 22 feet above Lake Huron, into which it empties and it is, therefore, above and beyond the influence of the draft made upon the lakes by the Sanitary District of Chicago.

Note that its low water period came in 1892-3 and that it afterwards rose and kept well above the low water mark until April, 1911, when it fell 4½ tenths below the lowest previous water, but recovered and rose 1.65 feet. Now drop down to Lake Michigan and note its lowest water December, 1895, four years before the Chicago Sanitary Canal was opened. Note how it rose after that period and never has gotten as low since, although it showed a drop responsive to the reduced out-flow of Lake Superior, in 1911. Now note Lake Huron conditions, which are practically synchronous with those of Lake Michigan.

Now drop down about 8 feet to the surface of Lake Erie and note its lowest stage in November, 1895, a stage which it fell below by half a tenth of a foot, in February, 1902, but ever since then it has been well above that low water mark. Now drop down about 327 feet to the level of Lake Ontario and note its low water in November, 1895, and then see that ever since the opening of the Sanitary District the lowest stage reached by that lake has been nine-tenths of a foot above the low water of 1895, and that the lowest stage reached in 1911 was one foot and one-tenth above the low stage of 1895.

Mr. Secretary, weigh well this showing made by the loyal men of your own department, and then believe contrary showings from sources less well authenticated if you can. This brings me up to a discussion of arguments advanced by your honored Chief of Engineers, General William H. Bixby. My association with him, usually in opposition, extends over a number of years. We have been frank with each other and as he once expressed it to me 'we have played the game with

our hands on top of the table.' On Jan. 8th last I received a letter from him enclosing a copy of a letter which he had given to 'a few members of Congress.' The closing sentence of this letter reads, 'Moreover none of these copies was distributed until after I had shown you personally the blue prints and told you about them, as I considered that you especially were entitled to early notice of their interests.'

I will address myself now to the closing sentence of his enclosure to me. 'The end of 1912 will probably see these four lakes lower than in 1895-1896 (the lowest yet known since 1860) and more than 1.5 feet lower than their average of the past 51 years.'

Now I want to call your attention to what I consider a serious omission on the General's part when he promulgated his conclusions. He did not permit himself to consider the causes of lowering in the 13 years preceding 1900.

If you will consult Document No. 159, Fifty-sixth Congress, Second Session (a report prepared by Lieut. Col. J. W. Raymond, Mr. George Y. Wisner and Mr. Alfred Noble on Deep Waterways between the Great Lakes and the Atlantic) you will find this statement on pages 297-298: 'The low water level of Lakes Michigan and Huron has been lowered about 1 foot during the past 13 years by natural and artificial deepening of the St. Clair and Detroit Rivers.' That, mark you, was before one drop of Lake Michigan water had trickled into the Chicago Drainage canal. There is one foot of the 1.5 for which General Bixby contends, accounted for without making Chicago accessory to the recession. I shall take up this particular phase of the discussion again under the head of interlake channels.

Opposition to Granting the Permit Sought in the Sanitary District.

In taking up a discussion of the objections to the granting of the permit sought, I feel that I have to deal with honest conviction on the part of many of the objectors that the fears which they express are founded upon what they believe to be facts. In the front rank of this honorable class stands the Dominion of Canada, so ably represented by Hon. David Mullin, K. C. There is other opposition which is factious and still other which is purely selfish and which endeavors to mislead you by specious and fallacious allegations. It is not incumbent upon me to differentiate between these classes of ob-

jectors and to distinguish them by name. I think, however, that before I finish this discussion you will know who I think they are. although I name no names.

Dominion of Canada, Represented by Hon. David Mullin, K. C.

In conversation between this gentleman and Mr. J. C. Williams, counsel for the Sanitary District of Chicago, to which I was a party, Mr. Mullin said that he had been called suddenly in this case and had had scant time for preparing his discussion of it. This acounts largely for his use of so-called facts which he had no chance to verify, and I am sure he would not like to be held responsible for their accuracy. On page 4 (typewritten brief) he asserts that there has been no acquiescence by Canada in the granting to Chicago of 10,000 cubic feet per second. I have hereinbefore quoted at some length, from the reports of the International Waterways Commission. These reports are public documents submitted contemporaneously to both the United States and Canada. They were in the nature of information and advice to each Government, concurred in by the joint advisers. There is in this case something stronger than the old doctrine of consent given by silence. These great powers were informed and advised and no dissent came from either. If in their wisdom they thought the Sanitary District ought to be restrained, it was their duty to take action and save that District the cost of outlays they were prepared to make. Their joint servants received no instructions to protest against the taking of this water by the Sanitary District, and, assured by their silence, that District has gone on spending millions of money, raised by taxation, in perfecting its system along the lines of the original project. He takes up the question of water power and through misinformation states that the Sanitary District development at Lockport is 56,000 H. P., so I will go at some length into that question.

I do not think he quite appreciates the absurd conclusion he ascribes to the International Waterways Commission when he quotes from their reports of January 4, 1907 (see page 24), to the effect that 800 c. f. s. to be taken from the Calumet river and 300 c. f. s. taken from the Chicago river will be added to the 10,000 c. f. s. sought to be taken from Lake Michigan, thus making the total outflow '11,000' c. f. s. This water is measured at he discharge end of the canal and every cubic foot coming from any other source than the lake reduces the

direct abstraction from the lake. Hence, under his theory, using the terms he gives, only 8,900 c. f. s. would come from the lake reservoir direct.

In the matter of carrying capacity of lake vessels he falls into the same trap that so embarrassed the International Waterways Commission in 1907. Some president of a marine association must have told him that these vessels carry 110 tons to the inch of draft. Either this or the figures are based on the starved ton that coal dealers sometimes send to their retail customers.

On page 17 he takes up the traffic at Sault Ste. Marie and shows again that somebody has given him wrong information. I have with me a "Statistical Report of Commerce Passing Through Canals at Sault Ste. Marie, Michigan and Ontario, During Season of 1910, Prepared under Direction of Col. C. McD. Townsend, Corps of Engineers U. S. Army."

Let us contrast Mr. Mullin's statement with Col. Townsend's report. First, Mr. Mullin, "The Canadian Canal 31,531,036 tons and the American Canal carried 15,602,873 tons." Col. Townsend reports American Canal 25,927,661 tons, Canadian 36,435,557 tons. American per cent. 42, Canadian, 58. American Canal open 224 days. Canadian Canal open 248 days. This difference in time opening for traffic is not explained, but the deduction is that the Canadian Canal carried 10,507,896 tons more freight than the American Canal and was in commission for 24 days longer than the American Canal, or reduced to percentages 16 per cent. more freight or 10¼ per cent. more time. It seems certain that the longer navigation period through the Canadian lock had more to do with its larger usefulness than did its four inches greater depth over the miter sill.

On page 27 he has something to say about the water supply and sewage disposal of Toronto. Here his misinformation is second-hand. Toronto does filter its water supply. It is discharging raw sewage into its harbor; it proposes, unless its authorities have changed their plans since receiving the report of its water supply commission—of which I am a member—to discharge its raw sewage after removing a small percentage of coarser solids by screening, directly into Lake Ontario, without treatment. Constant reference is made to the reports of the International Waterways Commission.

Mr. Secretary, I urge you to get that full set of reports and read them carefully. Of course, Mr. Secretary, I do not presume to argue the propositions of law put up to you by the

learned King's Counsel. My knowledge of law is only that absorbed by thirty odd years of contaminating association with learned lawyers.

Among those who came to support Mr. Mullin's contention was Mr. R. W. Reford, president Montreal Board of Trade. On page 184 I read this statement made by him: 'The principle upon which application for further diversion of water is made is unsound and if conceded further demands from other municipalities may be such that to grant them would destroy navigation in a commercial sense.' The Maker of the Universe has so constructed the region around the Great Lakes that there is but one locality along the shore line of these 'unsalted seas' where water can be made to flow by gravity from one water shed into another water shed, and Chicago occupies that strategic position; hence there can be no ground for Mr. Reford's fears 'that other municipalities will make' menacing demands. Next came Mr. Allen, president Shipping Federation of Canada, owners of two ships, the 'Victorian' and the 'Virginia.' He says 'we send these ships out at drafts ranging from 27 feet 5½ inches to 26 feet and they went out in six trips with a vacancy of 8,340 tons and 27 feet 6 inch draft, the ships drawing 26 feet 6 inches.' This language needs interpretation for my understanding in view of what he says in the previous page (190) 'we get down to 29 feet, not 27 feet, as stated by Mr. Meredith.' Now if they had 29 feet of water, why did they load to only 26 feet 6 inches when they claim to load to the last inch of draft? Mr. Francis King, representing the Richelieu and Ontario Navigation Company (page 158) sets up a plea for certain excursion boats which 'shoot the chutes' at various rapids, much to the enjoyment of sensation-loving excursionists. I do not know whether Mr. King lays most stress on the thrills which run down the back-bones of the excursionists, or the earnings of the boat owners; but Mr. Secretary, I ask you if you will weigh those thrills against the pangs of fever-stricken Chicagoans, or the losses in those two boats against the loss of investment made by the people who, to save their lives, have put $65,000,000 into the Chicago Drainage canal. I want to set down to Mr. King's credit that where he gives the tonnage of boats that he lists, he has not followed Lake Carrier precedents.

Now as to the claims of lessened harbor depths at Toronto. Look at your hydrographs of Lake Ontario and decide on the credibility of the witnesses. It cannot help you there but I

believe the U. S. Engineers. And what I advise about Toronto, I advise about Milwaukee, Toledo, Cleveland and all of the lake cities and towns which have protested against issuing this permit, because of the lessened depth in their harbors. Now there is in Mr. Mullin's brief, on page 13, a table giving what it is now the actual lowering, what they think it will be with an abstraction of 10,000 cubic feet per second and what they thought it would be for 14,000 cubic feet per second. They say they know what it is under conditions of flow as they have existed and as they do exist.

Now every officers of the Corps of U. S. Engineers who has been stationed in Chicago for ten years past knows that the flow through the Chicago river has greatly exceeded the volume named in the permit of the Secretary of War. Prior to the opening of the power plant at Lockport the whole flow passed through the controlling works and by their measurements, constantly noted and recorded, we kept a reliable record of the flow. That information is among the records of the Sanitary District. Since the opening of the power plant, in the fall of 1907, the question of discharge has been more complicated and the records less reliable. Two years ago, in trying to arrive at the natural low water flow of the Illinois river, I had to determine the flow in the Sanitary canal, which I did by meter measurements taken at Romeo. I found the flow to be slightly in excess of 7,000 cubic feet per second. These gentlemen have assumed a state of facts which do not exist and they find an actual lowering of four and three-tenths inches at Montreal. Note the three-tenths inch—very accurate work that. In view of their lack of dependable knowledge, what reliance can you place upon their determinations for 4,166 cubic feet per second or 10,000 cubic feet per second, or 14,000 cubic feet per second? How great is your faith?

The Water Power.

It has been directly charged that the motive back of this request for a larger flow of water is that the increased flow may develop water power.

This has become a hoary charge which I have had to meet before Congressional committees and otherwise.

I was employed by the Sanitary District of Chicago on June 7, 1893, to build its drainage canal—that and nothing more.

At first the construction problems absorbed my thought and my activities. As by organization and training the work

itself ceased to demand my exclusive thought, I came to realize that some day there would be a man-made river rushing down the declivity from Lockport to Joliet and that a great potentiality would be running to waste which ought to be conserved for the benefit of the people, whose taxes had paid for the great work. I outlined a plan for this conservation and submitted it to the Board of Trustees, with the result that I was set down upon and told that I was employed to build a drainage canal, not to look after water power. I was sat down upon, but my upholstering is not of the kind that makes sitting a luxury for the sitter and I persisted in my purpose of having that water utilized and the power works at Lockport are today a monument to that persistency.

Now the cost of building that channel from Robey street, Chicago, to the controlling works was $33,000,000. The cost of giving the Chicago River dimensions adequate for the flow of 480,000 cubic feet per minute (8,000 cubic feet per second) has been $11,000,000. The pumping plant and the 39th st. conduit for the delivery of 120,000 cubic feet per minute (2,000 cubic feet per second) to make up the total of 600,000 cubic feet per minute required to dilute the sewage of 3,000,000 people has cost approximately $2,000,000, or a total of $46,000,000, without the slightest provision for water power. Now the dependable fall at the Lockport power site is 34 feet. A flow of 10,000 cubic feet per second falling 34 feet will yield 30,900 horse power on an efficiency of 80 per cent. Now to get this water to the controlling works cost $46,000,000, or $1,488.67 per horse power. The interest on this cost, at 5 per cent., is $74.43 per annum. The net earnings per horse power will not exceed $25 per annum. Do business men make those kinds of investment? To utilize this power, three more miles of channel had to be built and the power plant erected, which was done at a cost of approximating $4,500,000.

I was before the Rivers and Harbors Committee of Congress in regard to the Calumet-Sag channel, which the district desired to build to reverse the flow of the Calumet River, just as the Chicago River had been reversed. I was asking for 4,000 cubic feet per second, my estimates on the cost of such a channel were nearly $12,500,000. I was asked by a member of the committee if my real purpose in seeking to get this water was not to create water power with it? My answer was in the form of a demonstration of the value of the power set over against the cost. Horse power to be obtaine 12,360 net, cost $12,500,000; cost per horse power

$1,011.32. The answer conclusively removed the mercenary motive from my plea.

Now this all pertains to the Sanitary District, a creation of and therefore subordinate to the State of Illinois, which I represent in this controversy. The water—which is so necessary to the health and life of Chicago, is flowing past the wheels at Lockport and dropping in the next 62 miles 100 feet. One hundred feet of fall 10,000 cubic feet of water per second; after deducting 12 feet for necessary slope there remains 88 feet of head, 10,000 feet of water with a net potentiality of 80,000 horse power. The Sanitary and Ship Canal of Chicago was not created for gain, but for health and life, and incidentally commercial navigation. As a natural consequence of this great construction a great potentiality is running to waste down the Illinois River. Does not true conversation demand that it be used for the service of man?

Mr. Mullin, in his able presentation of the cause of the Dominion stated that this water would produce four times more power if flowing through the interlake channels and the St. Lawrence, than it would at Lockport. He had knowledge of the creation at Lockport only and not of the potentialities that lied down stream from it.

With all the vast possibilities of power between the head of the Niagara River and Lake St. Peter now available and unavailed of, I would ask Mr. Mullin if his opposition to the use of about 4½ per cent. of these potentialities by Illinois does not savor of selfishness, does not even suggest the dog in the manger, a position which I am sure he would not unwillingly occupy, either for himself or his people.

On page 75, chapter 16 of the report of the preservation of Niagara Falls which the President transmitted to Congress Aug. 21, 1911, the following statement is found:

A volume of 210,000 with a descent between the dead line and the upper gorge of 220 feet has a potential of over 5,000,000 horse power.

Now the drop from Lake Erie to Lake Ontario is, roundly stated, 327 feet, so that there is 107 feet not accounted for in this statement, I assume that 92 feet of the 107 feet may be useful head and on that assumption I find, using an efficiency of 80 per cent., upwards of 1,700,000 horse power running to waste or a total potentiality for 210,000 cubic feet per second of water dropping from Lake Erie into Lake Ontario of over 6,700,000 horse power. Of the other millions of horse power going to waste in the drop from Lake Ontario to Lake St. Peter, no mention is made.

Conditions at Montreal.

We have had a luminous illustration flashed upon us by our Canadian friends of the embarrassment which may result from discussing grave questions without having a basis of authenticated facts to sustain our position.

My knowledge of conditions in the Montreal harbor is meagre, gleaned from the Encyclopedia Britanica, Reports Nos. 100 and 110 of the U. S. Hydrographic Office and from maps studied in the Congressional library. As the results of these studies I have formed conclusions, not rock ribbed, but tentative. First, the ascertaining of the velocity of streams is a determination involving cross section, slope, roughness of channel and some judgment must be exercised in selecting the coefficients used in the computations. But with the velocity once known and the average width of the stream the depth due to any given volume of flow is easily ascertained with approximate reliability. Knowing the velocity in feet per second and the width of the stream, multiply the one by the other and divide the volume of flow per second by the result of the multiplication. The result thus found will be the depth due to that volume of water flowing with the known velocity.

The Encyclopedia tells us that the St. Lawrence Channel below Montreal permits ocean vessels drawing 30 feet at low water to reach the city docks. That after the river freezes over there is a local rise of 10 feet.

A map entitled 'Montreal Harbor from Latest Canadian Charts,' scale 1/12.000 published at Admirality, 8th of July, 1908.

Data on this Map.

River dredged to 30 feet below the low water of 1897. The width dredged is 450 feet with greater width at all curves. The river has a very great fluctuation and is usually at its highest in the second week of May and at it lowest from about the middle of September to the end of November. Its average height above datum of soundings is: In May, 8 feet; June, 6 feet; July, 5½ feet; August, 3½ feet; September, 2½ feet; October, 1½ feet; November, 2½ feet. The rise in level from Longue Point to Lachine Canal is 1.74 feet.

I scaled on this map the width opposite La Salle avenue, which seemed to be about an average width and found it 4,650 feet from city shore line to sand shoals opposite.

U. S. Hydrographic Report 100, gives datum as extreme low water of 1897 which was 13 feet and 7 inches on the old lock sill of the Lachine Canal at Montreal and it is 1½ feet below ordinary low water.

This is seemingly reliable data, but without knowing velocities no deduction could be made. This information was furnished by another Admirality map on which velocities are shown at certain points. These velocities are in knots per hour (Kn):

Just below Victoria Bridge 8 Kn.

Opposite DeLarimer av. 6½ Kn.

Opposite Montreal st. railway 5½ Kn.

Now a nautical mile or knot is 2,029 yards or 6,087 feet, hence 5½ Kn equal 334,785 feet per hour, or 9.3 feet per second.

By the approximate rule that I have given, used with the data available, I get 4,650 feet by 9.3 seconds gives 43,245 cubic feet; 10,000 cubic feet per second divided by 43,245 gives a depth of 23/100 of a foot. Conditions at Montreal are very much complicated by the inflow from the Ottawa River a few miles above the city.

The Bixby Report on Illinois Waterway.

Mr. Mullin, K. C., representing the Dominion of Canada, quoted with approbation a statement which appears in the report of a board of engineers, of which General Bixby was chairman, in which they state that 1,000 cubic feet per second was sufficient for all of the needs of navigation. This report wronged the interests and the rights of the State of Illinois so greatly that I asked for a hearing on it before Mr. William H. Taft, President of the United States. This request was granted and on April 13, 1911, General Bixby joined me and we argued the questions at issue before the President. As a result of that discussion the President wrote Governor Deneen the following letter:

The White House,
Washington, April 17, 1911.

Hon. Charles S. Deneen, Governor of Illinois:

Sir—I have your communication of April 15, 1911, under advisement. The project for a navigable waterway from Lake Michigan to the mouth of the Illinois River, and thence via the Mississippi to the Gulf of Mexico, is one of national importance and commands my sympathy.

In view of the work already accomplished by the Sanitary

District of Chicago, an agency of your State, which has constructed the most difficult and costly stretch of this waterway and made it an asset of the nation; and in view of the fact that the people of Illinois have authorized the expenditure of $20,000,000.00 to carry this waterway sixty-two (62) miles further to Utica, I feel that it is fitting that this work should be supplemented by the Government and that the expenditures recommended by the Special Board of Engineers on the waterway from Utica to the mouth of the Illinois River be made upon lines which, while providing a waterway for the nation, should otherwise benefit the State to the fullest extent.

On behalf of your State, there has been no legislative commission with whom the Board of Engineers could negotiate and the board has reported a project for the lower river which, I learn from your letter, is not satisfactory to the State.

In view of this fact, I shall recommend to Congress that the term of service of said board be continued and that it be empowered to re-open the question of the treatment of the lower Illinois River, and to negotiate with a commission hereafter to be created by your General Assembly, and to agree with such commission upon a plan for the improvement of the lower Illinois River and upon the extent to which the United States may properly co-operate with the State of Illinois in securing the construction of a navigable waterway from Lockport to the mouth of the Illinois River in conjunction with the development of water power by the State between Lockport and Utica.

Very truly yours,

WM. H. TAFT.

In conformity with the statement in that letter, the President did, on December 21, 1911, transmit to Congress a message containing this language:

The project for navigable waterway from Lake Michigan to the mouth of the Illinois River, and thence via the Mississippi to the Gulf of Mexico, is one of national importance. In view of the work already accomplished by the Sanitary District of Chicago, an agency of the State of Illinois, which has constructed the most difficult and costly stretch of this waterway and made it an asset of the nation, and in view of the fact that the people of Illinois have authorized the expenditure of $20,000,000.00 to carry this waterway 62 miles farther to Utica, I feel that it is fitting that this work should be supplemented by the government, and that the expenditures

recommended by the special board of engineers on the waterway from Utica to the mouth of the Illinois River be made upon lines which while providing a waterway for the nation should otherwise benefit that State to the fullest extent. I recommend that the term of service of said special board of engineers be continued and that it be empowered to reopen the question of the treatment of the lower Illinois River, and to negotiate with a properly constituted commission representing the State of Illinois, and to agree upon a plan for the improvement of the lower Illinois River and upon the extent to which the United States may properly co-operate with the State of Illinois in securing the construction of a navigable waterway from Lockport to the mouth of the Illinois River in conjunction with the development of water power by that State between Lockport and Utica.

This brings us up to the importance of—

The Lakes to the Gulf Deep Waterway.

The need of this waterway has been felt for generations and its inception goes back to the early days of the Nineteenth Century, when it was so strongly advocated by Albert Gallatin. Chicago has built the most costly link in this waterway and the whole Mississippi Valley is interested in its completion. Its need is great now and that need will be vastly accentuated after the opening of the Panama Canal.

The President evidenced his interest in this project when he sent the following letter to the chairman of the Rivers and Harbors Committee of Congress:

The White House,
Washington, D. C., Dec. 23, 1911.

Hon. S. M. Sparkham, Chairman, Rivers and Harbors Committee:

Sir—In view of the great importance to the whole country of the creation of a waterway from the Great Lakes to the Gulf of Mexico, I call your attention briefly to a consideration not taken up in the section of my message which related to that waterway. The State of Illinois has, by an overwhelming vote of the people, authorized the expenditure of $20,000,000.00 for building of that link in this waterway between the present terminus of the Chicago Sanitary canal—near Lockport—and Utica on the Illinois River, a distance of sixty-two miles. The opponents of the project have questioned the suf-

ficiency of the amount—authorized by the people of the State—to pay for the work planned by the Internal Improvement Commission of the State. These estimates, however, have been checked by the board of engineers, whose appointment was authorized by the Sixty-first Congress, Second Session, and were by them considered sufficient to cover the cost involved. See H. R. Document No. 1374, pages eight and ten. On page eleven, this statement is found.

'Should the State of Illinois be unable to complete the locks suggested by the board, or the bridges required by navigation, the United States might then properly undertake to complete these parts of the project, but as the authorized appropriation of $20,000,000.00 by the State is considered sufficient for all work above Utica, no estimates are submitted for these parts.'

I concur in the belief of the board as expressed above and feel that the Congress should endorse the project; and further in view of the character and ability of the men who have reported upon the project, I think that the United States runs small risks in guaranteeing any sum that this link in the project may cost in excess of the $20,000,000.00 that the State will provide. This work should progress in time with the improvement of the upper Mississippi, the Missouri and the Ohio rivers. Its importance warrants congressional action in its support.

(Signed) WILLIAM H. TAFT,
President.'

Now there can be no higher use of a natural resource than the saving of human life. Quotations made hereinbefore show how the water that is being abstracted from Lake Michigan is fulfilling the highest mission of saving life, and when you consider that it will at the same time serve to make a commercial waterway, you see how justly we can demand it, both in the name of humanity and of navigation. Canada has an outlet to the sea from the Great Lakes by a 14 foot channel. Should America have less to her southern sea? And be it remembered that this waterway will, when built, be a free channel, free to Canada, free to the world. Canada will need to reach southern ports by the short water route, just as will the citizens of the United States, who dwell in our lake ports.

Mr. James White, secretary Commission of Conservation, opposes the taking of this water for both economic and scenic reasons. Let us first consider the economic side of it. The

volume of water involved in this present controversy is 4 76/100 per cent. of the flow through the St. Clair River with the Lake Huron elevation 581.28 and 4 54/100 per cent. of the flow of the Niagara River. What will this abstraction accomplish? It conserves the life and health of the second greatest city in America. The typhoid death rate of that city in 1910 was 13 26/100 per 100,000; in 1891 it was 173 8/10. It makes a 14 foot navigation from the Great Lakes to the Gulf possible; it will afford 110,000 net electrical horse power. It makes the Illinois River, next to the Columbia River, the greatest producer of food fishes in America. Is not this true conservation? Can it be shown that 10,000 cubic feet of water used anywhere else in the world will do mankind as much good? When we contemplate the aesthetic side of it, our gaze concentrates at Niagara. The beauty and grandeur of that wonderful work of the Great Creator can be preserved by simple engineering construction. I laid a plan for this before the Minister of Public Work of the Dominion of Canada Feb. 13, 1911.

Dr. Pugsley referred this project to Messrs. St. Laurent and Coste with whom I conferred. Their expressed views to me were approving. When I presented my letter of introduction from Mr. Taft to Mr. Fielding, Minister of Finance, his first inquiry was, is there any money in it for Canada? He then said, 'We have to look at these things from the dollars and cents standpoint.'

I told him that the beauty of the Falls could be maintained and at the same time a larger use of water be granted for generation of power.

Confirming this assertion—although it has no reference to the project which I brought forward—I call attention to the fact that on August 21, 1911, the President transmitted to the Senate and House of Representatives a message giving 'Information relative to scientific investigations made by certain officers of the War Department for the preservation of Niagara Falls.'

In Chapter XVI, page 75 et seq., their conclusions are summed up. I quote therefrom:

Provided there be no large increase in up-lake diversions, the possibilities of continued and extended use of power at the Falls are conditioned upon the construction of regulating works in the Niagara River to avoid the wasteful outflow of water of Lake Erie. The injury to the scenic grandeur of the Falls, and the interference with the navigable waters of the

Niagara River and Lake Erie, due to up-lake diversions would be largely obviated by impounding in the lakes a portion of the winter out-flow during the months of December to April, inclusive, enough water may be saved to hold the lakes in a proper and economical level to the betterment of navigation, and yield a surplusage to practically offset diversions at the Falls. This is a practical engineering proposition but as the power companies are beneficiaries they should pay a fair share of the cost.

Here, all that—we as State and Sanitary District officials—have contended for through long years of controversy is admitted as being right in theory and capable of practical development.

Mr. White (I think it was he, I have not his brief to refer to) brought up the question of extravagant use of water by the District for purposes or dilution. If ever there was a long contested question this has been one. Let him scan the 8,000 printed pages of testimony in the case of the State of Missouri vs. The Sanitary District of Chicago and see if he can discover a scientific authority on either side of that great controversy who would admit that 20,000 cubic feet of water per minute was too much to use in diluting the sewage of 100,000 people. It is the habit of both sides of this controversy to appeal to the printed reports of the International Waterways Commission—and it is a good habit too—Mr. White has it. Now that commission employed sanitary experts to advise them; the best men they could find. These gentlemen stated as their second conclusion—

The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive are that a dilution of 3½ cubic feet per second for each 1,000 persons connected with the sewers as provided in the enactment of the Illinois Legislature of 1889, is as low a figure as it is now possible to state.

Page 51 of report dated Toronto, Ontario, January 4, 1907.

What was, after patient inventigation, determined upon was found to stand the test of 18 years of progressive science.

Objections from the State of Michigan.

Objections from a sovereign state must receive consideration and respect, but it is very hard to treat seriously the plea upon which the objections from Michigan are based. They are in the same super-sensitive category with the charge

raised some years ago that the cold water sent down the Mississippi River by the Chicago Canal was destroying the strawberry crop in Mississippi and Louisiana. In my study of these lake level problems in preparation for these ever recurring controversies, I ascertained as nearly as may be that the state of facts is very nearly as follows:

The discharge through the St. Mary's River is ordinarily 75,000 cubic feet per second. At the time I made my computations the reported flow through the St. Clair River was 206,400 cubic feet per second: 131,400 cubic feet of which must come from Lakes Huron and Michigan. Figured on the ratios of rainfall and area I find that Lake Michigan contributes 48.26 per cent (63.414 c.f.s.) and Lake Huron 51.74 per cent. (67,986 c.f.s.).

Now if Chicago takes 10,000 c.f.s. it leaves the outflow from Lake Michigan through the Straights of Mackinac 53,414 c.f.s. and the changed flow cannot, in my judgment, have an appreciable, or any effect upon the climate of Michigan. However, Congress has imposed upon a Commission of Engineers the duty of determining and reporting to it the climatic changes brought about in Michigan by the work of the Sanitary District. If you mean to wait for the determination of this question until those engineers report, we pray you to spur their action; for they are under your jurisdiction.

Objections from the Illinois Valley.

Sundry objections to granting the plea of the Sanitary District of Chicago until such time as the channel of the Illinois River has been made adequate to carry the flow artificially delivered to it, have been filed by associations and individuals living and owning property in the Illinois Valley. We have no quarrel with these petitioners, in fact there is a basis of reason in their effort to protect themselves through you. They are suffering a burden which they ought not to bear.

The Sanitary District of Chicago is required by its organic act to remove from the Illinois River the dams at Henry and at Copperas Creek. They have never done it and they have never done it because they have bene enjoined from doing it by a court of competent jurisdiction on the petition of the canal commissioners of the State of Illinois. You need not be burdened by the details of this family row. The dams ought to be removed—they are not needed for navigation—as is reported by a board of engineers of the U. S. Engineer

Corps, and they are a positive harm to the low lands along the river by holding the water at high and harmful elevations. These elevations are not great, but they are harmful.

Now, Mr. Secretary, do you feel called upon to punish one side or aid the other to this controversy? With these dams removed there would be peace in our camp and if you can see your way to their removal, we would regard you as a great pacificator.

Arbitrary Demand for Changed Methods of Sanitation.

The demand made upon the Sanitary District that it change its method of treating sewage after it had expended $66,000,000 is analogous to requiring a public service corporation which has, at great cost, put in a steam plant of type best known and approved at the time of its installation—triple expansion compound condensing engines, etc.—to discard the whole equipment while its usefulness and efficiency is unimpaired, and substitute therefor steam turbines.

The project of the District is designed to meet the requirements of a given population by dilution methods. When that limit of population is reached, remedial works will have been provided to care for the excess known to have accrued. There is a limit fixed to the amount of water that may be used by two governing considerations—

First—The volume which may safely be taken from Lake Michigan.

Second—The volume which may be discharged into the Illinois Valley without damaging the property adjacent to the stream.

Owner's Risk.

I do not know whether my belief based upon a natural perception of justice or whether it comes to me as the result of an aforesaid legal contamination, but I believe that when an investor with full knowledge of a certain risk that he runs, by reason of what he knows will come about as the result of certain plans of others which he has every reason to believe will be carried out, that he has no recourse at law; no action against the person or persons, corporation or municipality, which, by carrying out plans which were well known to be matured before he made his investment, cause him to lose profits which he hoped to secure.

It seems to me that the vessel owners are just in the condition of this investor. Prior to 1900 there were but 40 boats on the Great Lakes with keel length over 400 feet and all of these, except four, were less than 450 feet. The first of these to be built was the S. S. Curry, 432x45, built in 1893, when lake navigation was limited by the depth over the miter sill of the Weitzel Lock, which was 17 feet with the upper pool at 601.9, lower pool 584.4; in 1895 the Victory, 452x48, was built. Since 1900, 210 of the larger class boats have been built.

Inter-Lake Channels.

Lakes Superior and Huron are connected by the St. Mary's River Canal, the Sault Ste. Marie locks and the St. Mary's River. In 1881, when the Weitzel Lock was opened for traffic, I find the statement that with the water at elevation 601.9 in the upper pool and 584.4 in the lower pool, there were 17 feet of water over the miter sill, hence its elevation must have been 567.4. In 1881 the high level of Lake Huron 582.3. In 1887 the Poe Lock was connected; with lower miter sill at elevation 562.1 and a calculated depth of water over it of 22 feet; when this depth obtained the level of the lower pool must have been 584.1. This lock was completed in 1896, four years before the opening of the Chicago Drainage Canal. Prior to this lock being put into service the Government had been improving the lower St. Mary's River to a depth of 20 feet, greatly diminishing the slope in the St. Mary's River and thereby reducing the depth of water over the lower miter sills of the two American and the one Canadian lock. The statistical report of Lake Commerce through the St. Mary's Falls Canal for the year 1910 states that safe draft of water through the locks was only 18.4, which indicates an elevation of 580.5 for the lower pool, three feet and nine-tenths lower than the elevation of 1881.

A glance at the hydrograph for 1910 shows the extreme high water of 1910 to be just 580.5 and the mean for the months of open navigation of 580.25. To all intents for the uses of navigation the slope in the lower St. Mary's River is, therefore, wiped out. The next connecting channel is the St. Clair River, which begins in Huron and ends in Lake St. Clair.

Since the year 1900, the work of deepening and widening the interlake channels has gone steadily on. What has been accomplished in that direction is briefly but luminously set forth in Bulletin No. 20, Survey of the Northern and North-

western Lakes, published by U. S. Lake Survey Office, Detroit, Michigan, 1911, under authority of the War Department.

The present improvement dates from the project of 1867 for the construction of a straight ship channel 300 feet wide, protected by dikes, extending from deep water in the mouth of the South Pass to deep water in Lake St. Clair. This canal was formally opened July 25, 1871, although the channel had been used by vessels in the season of 1870. The original plan provided for 13 feet depth, which was modified in 1872 to 16 feet, and in 1886 to 18 and 20 feet. The river and harbor act of June 13, 1902, provided for two separate channels for up and down-bound traffic, by the excavation of a new channel 20 feet deep and 300 feet wide along the west side of the old canal. This west channel was opened to navigation September 3, 1906.

The existing canal consists of two channels above mentioned, extending from the mouth of the South Channel into Lake St. Clair a distance of 17,460 feet. For a distance of 7,221 feet at the upper end, the two channels are separated by a sand dike 100 feet wide, revetted by sheet piling, and the old or east channel is enclosed on its east side by a similar dike 50 feet wide. The old east channel is 292 feet wide between the dikes and the west channel is 300 feet wide. Below the dikes the two channels are combined with a uniform width of 750 feet. The depth of the channel is 20 feet.

Lower Detroit River. At Ballard's Reef there are occasional fluctuations in depths of from 3 to 5 feet, produced by high easterly or westerly winds which respectively raise or lower the water level at the west end of Lake Erie and similarly affect the level of the lower river. Display stations to show the depth existing at Ballard's Reef are maintained at Sandwich coal dock, at Smith's coal dock near Rogue River, and at Elliott Point about opposite the foot of Bois Blanc Island. During the season of 1910, the lowest mean depth in the river for any month was 19.7 feet, this being at Ballard's Reef.

Approved projects provide for the deepening of the present channel to 21 feet for a width of 600 feet from the head of Ballard's Reef to Bar Point, and for the same depth for 800 feet width from Bar Point to deep water in Lake Erie; also for a second channel (Livingstone Channel) of 22 feet depth and 300 feet width from Ballard's Reef to Bar Point, passing to the west of the Bois Blanc Island, and for the same

depth for 800 feet width from Bar Point to deep water in Lake Erie. The latter project will not be completed before 1912.

The conditions of the improved ship channels of the lower river, as existing at the beginning of the season of 1911, are described below.

Ballard's Reef. The channel is 600 feet wide, nad its center line is marked by the Grosse Isle South Channel Range. The present improved depth is 19.5 feet, with work in progress to secure 21 feet depth south of the junction with Livingstone Channel and 22 feet depth north of this junction. On account of these improvements, navigation will be restricted to 300 feet width during the season of 1911, and such portion of the channel will be marked by gas buoys with additional spar buoys when necessary.

Lime Kiln Crossing. The channel is 600 feet wide and 21 feet deep. A line 150 feet from the west side of the channel is marked at the north end by two lighted targets, one on Texas Dock and the other on the Canadian shore; and at the south end by two lighted targets placed on stakes driven in the water near the east short of Bois Blanc Island. A line 150 feet from the east side of the channel is marked at the north end by two lighted targets on the Canadian shore south of Texas Dock.

Amherstburg Reach. The channel is 600 feet wide, and 21 feet deep, except for an area about 100 feet square in its west half at the head of Bois Blanc Island where the least depth is 20 feet; the center line is marked by two light towers on Elliott Point. Just south of the intersection of Amherstburg Reach and Hackett Range, and east of the channel, is an anchorage basin 2,000 feet long and 300 feet wide, with 19.5 feet depth, marked on its easterly limit by four red spar buoys.

Hackett Range. The channel is 600 feet wide and 21 feet deep, except of an area of about 500 feet long and 100 feet wide in its east half abreast of Elliott Point, where the least depth is 20.5 feet; the center line is marked by two light towers at Amherstburg.

Bar Point Shoal. The improved channel through this shoal is 600 feet wide and 21 feet deep to the Detroit River lighthouse. For an additional 400 feet width to the westward there is 21 feet depth to deep water in Lake Erie in a straight channel passing to the west of the lighthouse. There is also a channel of 800 feet width and 22 feet depth to deep water in Lake Erie passing to the east of the lighthouse.

The Treaty.

Article V of the Treaty plainly recognized the recommendations of the International Waterways Commission in making the amount of water which may be taken on the Canadian side for power purposes as thirty-six thousand cubic feet per second.

For power purposes within the state of New York, it permits the use of water up to twenty thousand cubic feet per second. The allotment to the Sanitary District was evidently regarded as res adjudicata.

Article VIII clearly defines the uses for which water may be taken and gives their order of precedence.

(1) Use for domestic purposes.

(2) Uses for navigation, including the service of canals for the purposes of navigation.

(3) Uses for power and irrigation purposes.

And further safeguards the Sanitary District of Chicago by the sentence, 'The foregoing provisions shall not apply to or disturb any existing uses of boundary waters on either side of the boundary.'

In other words, the limitations of the Treaty were not intended to be retroactive. The Sanitary District, proceeding under a definitely and widely known plan, had been in actual operation for ten years and five months nearly, before the ratifications of the Treaty were exchanged.

I am firm in this view, because it is unthinkable that men worthy of citizenship should neglect the conservation of the lives of the people of their land and only give a care to the commercial interests of a few.

The State of Illinois is before your judgment seat because 40 per cent. of her people are charged with reducing the level of the Great Lakes. The quotations that I have made from official documents of this government show that under the direction of the United States Engineer Corps, by order of congress, work has been done in these interlake channels which has caused a reduction of lake levels vastly greater than has resulted, or can ever result, from the work of the Sanitary District of Chicago. The bulletin for the northern and northwestern lakes for 1905 showed a flow of 206,400 c.f.s. through the St. Clair River with Huron at elevation 581.40; the bulletin for 1911 showed a flow of 210,000 c.f.s. with Huron at elevation 581.28, that is, with a lake level reduced 12/100 of a foot the flow increased 3,600 c.f.s. These conditions are no

secret. During General Alexander McKenzie's term, as chief of engineers, I asked why he should object so to what we were doing when so much greater damage was being done to lake levels under his direction. His reply was, 'What I am doing is by order of congress.' On Dec. 9, 1909, I had this matter up with General Marshall, then chief of engineers. He said that he believed we would lose our lake level case; but he said, further, that he 'did not see why the government should make such a stir about what the district is doing when its own work is doing so much more to lower the lake levels.' He cited the lowering of the St. Mary's River and consequent diminished depth over miter sills on the Sault Ste. Marie locks resulting from improving the channel. But he said the remedy by control is simple and easy. Right here I will say that it has been a source of infinite satisfaction to me to deal with the members of the United States Engineer Corps who have ascertained and preserved the facts essential to an intelligent discussion of these matters. They have been frank and courteous with me, concealing no fact within their knowledge which has a bearing upon these discussions. They regard these facts from a viewpoint different from my own and my effort now is to have you see the merits and equities as I view them.

Mr. Secretary, none of the protestants who have filed objections or appeared personally before you, has proved, or can prove, that they have been damaged. They have presented what they fear they may suffer, not what they have suffered.

Now, I would not leave a doubt in your mind as to what Illinois wants.

The question has been raised—For how long a time is this water wanted?

As long as water runs down hill or floats a boat, Illinois wants this water. She wants it for the health and life of her people; she wants it for her own water-borne commerce and for that of her sister states; she wants it for the power that it will yield; she wants it for the fish that it will produce to feed all the people; she wants it now, henceforth and forever.

Now, Mr. Secretary, can you attach more importance to the desire of a few score people to secure large interest on their investments than to the claims that two and one-quarter million people have upon the use of their investment of $66,000,000—not for gain, but for health and life?

I have confidence that the call of humanity will prevail with you over the clamor of the captains of marine industry for more gain. We have spent our millions to preserve human life. They are piling up millions as an outcome of the expenditure of the people's money, in making deep channels between the 'unsalted seas.'

THE STATE OF ILLINOIS,
By ISHAM RANDOLPH,
Commissioned by Governor Charles S. Deneen to appear for the State."

EXHIBITS WITH BRIEF

OF THE

STATE OF ILLINOIS

IN BEHALF OF

The Sanitary District of Chicago.

APRIL 3, 1912.

OWNER OR MANAGER	NAME	Tons per inch of draft	Keel and beam	Built
A				
Acme Steamship Co., Duluth, Minn.	Ward Ames	70.9	440x56x21	1906
American Transit Co., Syracuse, N. Y.	John Dunn, Jr.	66.4	504x58x30	1907
B				
Becker, W. H., Cleveland, Ohio	Edwin N. Ohl	53.1	430x54x26	1907
Becker, W. H.	W. G. Pollock	51.3	430x52x26	1906
Becker, W. H.	Joshua W. Rhodes	51.3	430x52x26	1906
Becker, W. H.	Alexis W. Thompson	54.9	504x58x30	1906
Becker, W. H., manager Interstate Steamship Co.	James Laughlin	61.5	530x56x31	1906
Becker, W. H., manager Columbia Steamship Co.	Francis Widlar	44.7	416x50x26	1904
Bolanda, Cornelius, Buffalo, N. Y.	Adam E. Cornelius	51.3	430x52x26	1906
Bolanda, Cornelius, manager, Pennsylvania Steamship Co.	Jacob F. Kopp	60.7	480x54x30	1907
Bolanda, Cornelius, manager, American Steamship Co.	Clifford P. Mott	58.3	444x56x26	1906
Bolanda, Cornelius	Theodore H. Wiskwire	58.2	444x56x26	1906
Boland, J. J., manager, York Steamship Co., Buffalo, N. Y.	John J. Boland	60.7	480x54x30	1907
Bradley, M. A., manager, Alva Steamship Co., Cleveland, Ohio	M. A. Bradley	54.0	480x52x30	1906
Brown, J. J. H., Buffalo, N. Y.	G. A. Tomlinson	63.7	504x54x—	1906
Brown Steamship Co., Buffalo, N. Y.	J. J. H. Brown	53.6	442x54x26	1906
C				
Cambria Steamship Co., M. A. Hanna & Co., managers, Cleveland, Ohio	Daniel J. Morrell	73.6	560x58x33	1906
Cambria Steamship Co., M. A. Hanna & Co., managers, Cleveland, Ohio	Edward Y. Townsend	73.6	560x58x33	1906
Carter, E. D., Erie, Pa.	J. H. Bartow	63.7	504x54x30	1907
Carter, E. D., Erie, Pa.	E. D. Carter	63.7	504x54x30	1906
Chicago Navigation Co., Chicago, Ill.	J. S. Dunham	51.3	430x52x26	1906
Chicago Navigation Co., Chicago, Ill.	W. E. Fitzgerald	51.3	430x52x26	1906
Cleveland Cliffs Iron Co., Cleveland, Ohio	Wm. G. Mather	72.0	512x60x31	1906
Cleveland Cliffs Iron Co., managers, Grand Island Steamship Co.	Isbpeming	60.5	530x56x31	1906
Cleveland Cliffs Iron Co., managers, Grand Island Steamship Co.	Michigan	60.5	530x56x31	1906
Cleveland Cliffs Iron Co., managers, Grand Island Steamship Co.	J. H. Sheadle	60.5	530x56x31	1906
Cleveland Cliffs Iron Co., managers, Pr. Isle Transportation Co.	Angeline	60.4	414x51x26	1906
Cleveland Cliffs Iron Co., managers, Pr. Isle Transportation Co.	Peter White	63.7	504x54x30	1906
Cleveland Cliffs Iron Co., managers, Pr. Isle Transportation Co.	Presque Isle	47.6	406x50x26	1906
Cowle T., Co., Cleveland, Ohio	John B. Cowle (msk)		416x50x26	1903
Cronton Steamship Co., S. P. Cramer, manager, Bay City, Mich.	Caldera	60.7	504x54x30	1906
Cummings, Michael J., Oswego, N. Y.	Western Star	46.7	416x50x26	1906

Exhibits with brief—Continued.

OWNER OR MANAGER	NAME	Tons per inch of draft	Keel and bends	Built
D				
D. & C. Navigation Co., Detroit, Mich., (see also A. B. Wolvin)	City of Cleveland	48.9	425x52x28	1907
Detroit Steamship Co., J. H. Walsh, manager, Detroit, Mich	C. W. Ketcher	41.3	420x52x28	1907
Dearborn Transit Co., Dearborn, Mich	R. L. Walker	41.3	420x52x28	1906
E				
Elphicke & Co., Chicago, Ill., managers of Federal Steamship Co	W. L. Brown	39.3	430x52x28	1901
Elphicke & Co., Chicago, Ill., managers of Federal Steamship Co	Mary C. Elphicke	39.3	430x52x28	1901
Elphicke & Co., Chicago, Ill., managers of Cornell Steamship Co	John Mitchell	41.3	430x52x28	1906
Empire Steamship Co., Bennett & Co., managers, Buffalo, N. Y	Wm. H. Truesdale	38.5	432x52x28	1900
F				
Franklin Steamship Co., D. Sullivan, manager, Chicago, Ill	E. J. Earling	38.9	530x54x31	1906
Fremont Steamship Co., H. K. Oakes, manager, Detroit, Mich	B. F. Berry	38.4	480x52x30	1906
Frontier Steamship Co., W. M. Mills, manager, Tonawanda, N. Y	James Corrigan	39.3	530x54x31	1906
Frontier Steamship Co., W. M. Mills, manager, Tonawanda, N. Y	Daniel B. Meacham	39.3	530x54x31	1906
Frontier Steamship Co., W. M. Mills, manager, Tonawanda, N. Y	Josiah G. Munro	39.3	530x54x31	1907
G				
Gartland Steamship Co., D. Sullivan, manager, Chicago, Ill	William H. Wolf	43.7	504x54x30	1906
Gilchrist Transportation Co., Cleveland, Ohio	Geo. Garretson	48.7	530x54x31	1906
Gilchrist Transportation Co., Cleveland, Ohio	F. W. Gilchrist	48.7	416x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	Jos. C. Gilchrist	48.7	416x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	Frank J. Hecker	44.3	484x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	R. I. Ireland	48.7	416x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	H. P. McIntosh	48.7	530x54x31	1906
Gilchrist Transportation Co., Cleveland, Ohio	Geo. H. Russell	44.3	484x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	R. E. Scheck	48.7	416x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	John Sherwin	46.0	514x54x31	1906
Gilchrist Transportation Co., Cleveland, Ohio	Perry G. Walker	48.7	416x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	J. L. Weeks	48.7	416x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	David M. Whitney	47.3	464x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	Jas. B. Wood	46.0	514x54x31	1906
Gilchrist Transportation Co., Cleveland, Ohio	Lewis Woodruff	48.7	416x52x28	1906
Gilchrist Transportation Co., Cleveland, Ohio	H. S. Hill	48.7	416x52x28	1906

H				
Hawgood, W. A., Cleveland, Ohio	Brassford	48.4	414x80x30	1903
Hawgood, Arthur H., Cleveland, Ohio	S. S. Curry	46.5	422x42x30	1903
Hawgood, W. A. & A. H., Cleveland, Ohio	H. D. Goulder	47.6	532x54x31	1903
Hawgood, W. A. & A. H., Cleveland, Ohio	Edwin F. Holmes	49.0	470x50x30	1904
Hawgood, W. A. & A. H., Cleveland, Ohio	J. M. Jenks	48.4	414x50x30	1902
Hawgood, W. A. & A. H., Cleveland, Ohio	Sheldon Parks	49.7	532x54x31	1906
Hawgood, W. A. & A. H., Cleveland, Ohio	Henry B. Smith	47.6	532x54x31	1906
Hawgood, W. A. & A. H., Cleveland, Ohio	Abraham Stearn	47.6	532x54x31	1906
Hawgood, W. A. & A. H., Cleveland, Ohio	W. R. Woodford	49.7	532x54x31	1906
Hawgood, W. A. & A. H., Cleveland, Ohio	Umbria	49.0	490x50x30	1904
Hawgood, W. A. & A. H., managers, Atlas Steamship Co., Cleveland, Ohio	Wm. A. Hawgood	49.7	532x54x31	1907
Hawgood, W. A. & A. H., managers, Holmes Steamship Co., Cleveland, Ohio	Salt Lake City	49.7	532x54x31	1907
Hawgood, W. A. & A. H., managers, Milwaukee Steamship Co., Cleveland, Ohio	J. Q. Riddle	49.7	532x54x31	1906
Hawgood, W. A. & A. H., managers, Minerva Steamship Co., Cleveland, Ohio	Henry A. Hawgood	49.7	532x54x31	1906
Hawgood, W. A. & A. H., managers, Neptune Steamship Co., Cleveland, Ohio	Arthur H. Hawgood	72.0	648x54x31	1907
Hawgood, W. A. & A. H., managers, Wisconsin Steamship Co., Cleveland, Ohio	Wisconsin	49.0	490x50x30	1905
Hawgood Transit Co., Cleveland, Ohio	H. B. Hawgood	48.4	414x50x30	1903
Hutchinson, C. L. & Co., Cleveland, Ohio	Joseph G. Butler	47.6	532x54x31	1905
Hutchinson, C. L. & Co., Cleveland, Ohio	John A. McGean	53.5	422x52x30	1906
Hutchinson, C. L. & Co., Cleveland, Ohio	Marcus Mullen	48.7	416x50x30	1904
Hutchinson, C. L. & Co., Cleveland, Ohio	William A. Paine	58.4	490x52x30	1905
Hutchinson, C. L. & Co., Cleveland, Ohio	John Stanton	63.7	504x54x30	1905
Hutchinson, C. L. & Co., managers, Pioneer Steamship Co., Cleveland, Ohio	A. A. Augustus	52.7	504x54x—	1903
Hutchinson, C. L. & Co., managers, Pioneer Steamship Co., Cleveland, Ohio	D. R. Hannah	49.7	532x54x31	1906
Hutchinson, C. L. & Co., managers, Superior Steamship Co., Cleveland, Ohio	J. J. Sullivan	49.7	532x54x31	1907
I				
Interstate Steamship Co., J. M. St. Clair, Duluth, Minn.	B. F. Jones	49.5	530x54x31	1906
Jenkins Steamship Co., Cleveland, Ohio	Chas. O. Jenkins	49.7	504x54x30	1907
Jenkins Steamship Co., Cleveland, Ohio	F. B. Squire	48.0	410x50x28	1903
Jenkins, C. O., Cleveland, Ohio	Sir Thomas Shaughnessy	58.4	490x52x30	1906
Jenkins, C. O., manager, Ohio Steamship Co., Cleveland, Ohio	Jas. P. Walsh	58.4	490x52x30	1905
K				
Kinney Steamship Co., Cleveland, Ohio	J. S. Ashley	49.7	504x54x—	1906
Kinsman Transit Co., H. Steinbrenner, manager, Cleveland, Ohio	Mathew Andrews	49.7	532x54x31	1907
Kinsman Transit Co., H. Steinbrenner, manager, Cleveland, Ohio	Phillip Minch	58.4	490x52x30	1906
Kinsman Transit Co., H. Steinbrenner, manager, Cleveland, Ohio	Henry Steinbrenner	49.7	416x50x28	1901

Exhibits with brief—Continued.

OWNER OR MANAGER	NAME	Tons per inch of draft	Keel and beam	Built
L				
LaBelle Steamship Co., J. S. Ashley, secretary, Cleveland, Ohio	LaBelle	43.7	304x44x—	1898
Lake Transit Co., The, H. L. Shaw, manager, Bay City, Mich	City of Bangor	46.9	444x44x26	1894
Lake Transit Co., The, H. L. Shaw, manager, Bay City, Mich	Penobscot	45.8	442x44x26	1895
M				
Mahoning Steamship Co., J. S. Ashley & Co., managers, Cleveland, Ohio	Leonard C. Hanna	43.7	304x44x30	1896
Mahoning Steamship Co., J. S. Ashley & Co., managers, Cleveland, Ohio	Powell Stackhouse	43.7	304x44x30	1896
Manabe Steamship Co., J. Sellwood, manager, Duluth, Minn	Joe S. Morrow	51.1	420x48x—	1898
Manmee Steamship Co., W. White, manager, Cleveland, Ohio	Denmark	57.7	442x48x—	1898
McMillan, P. H., manager, Wolverine Steamship Co., Detroit, Mich	Senator	44.0	410x46x26	1896
McMillan, M. B., Detroit, Mich	Admiral	51.3	420x52x26	1896
Millinokett Steamship Co., H. L. Shaw, manager, Bay City, Mich	Millinokett	51.3	420x52x26	1896
Mohl, Edward, Erie, Pa	Wainwright	51.3	420x52x26	1896
Mitchell, John, Cleveland, Ohio	Hugh Kennedy	49.7	428x52x31	1898
Mitchell, John, Cleveland, Ohio	Lottie Caddy	47.6	428x52x31	1898
Mitchell, John, Cleveland, Ohio	Joseph Sellwood	47.6	428x52x31	1898
Mitchell, John, Cleveland, Ohio	Stephen M. Clement	38.4	400x52x30	1898
Mitchell, John, Cleveland, Ohio	John J. Albright	46.7	416x52x30	1899
Mitchell, John, Cleveland, Ohio	E. A. S. Clarke	46.7	416x52x30	1899
Mitchell, John, Cleveland, Ohio	James Gayely	46.7	416x52x30	1899
Mitchell, John, Cleveland, Ohio	Frank H. Goodyear	46.7	416x52x30	1899
Mitchell, John, Cleveland, Ohio	Wm. H. Gratwick	46.7	416x52x30	1899
Mitchell, John, Cleveland, Ohio	Wm. E. Reiss	46.7	416x52x30	1900
Mitchell, John, Cleveland, Ohio	Walter Scranton	46.7	416x52x30	1901
Mitchell, John, Cleveland, Ohio	Moses Taylor	46.7	416x52x30	1901
Mitchell, John, Cleveland, Ohio	Pendennis White	46.7	416x52x30	1900
Mitchell, John, Cleveland, Ohio	M. A. Hanna	46.0	416x54x30	1900
Mitchell, John, Cleveland, Ohio	Hendrick B. Holden	47.8	416x54x30	1900
N				
National Steamship Co., Detroit, Mich	W. K. Bixby	38.4	400x52x30	1902
Niagara Transit Co., W. M. Mills, manager, N. Tonawanda, N. Y	Wm. A. Rogers	47.6	428x52x31	1900

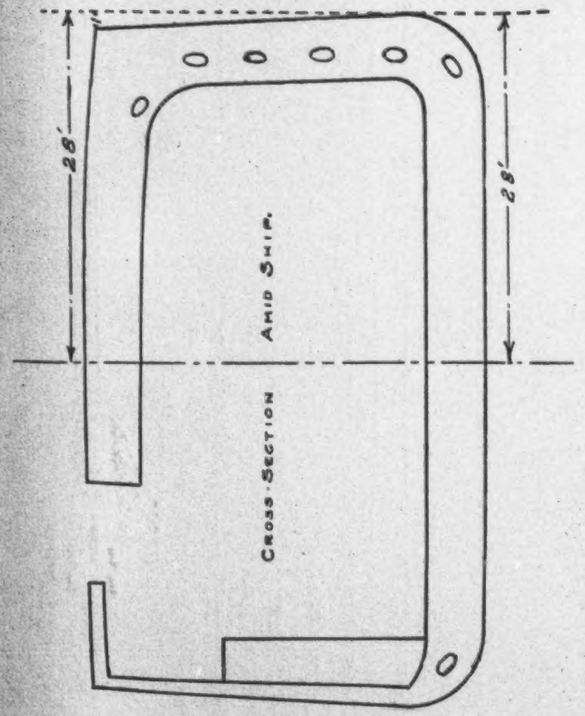
Exhibits with brief—Continued.

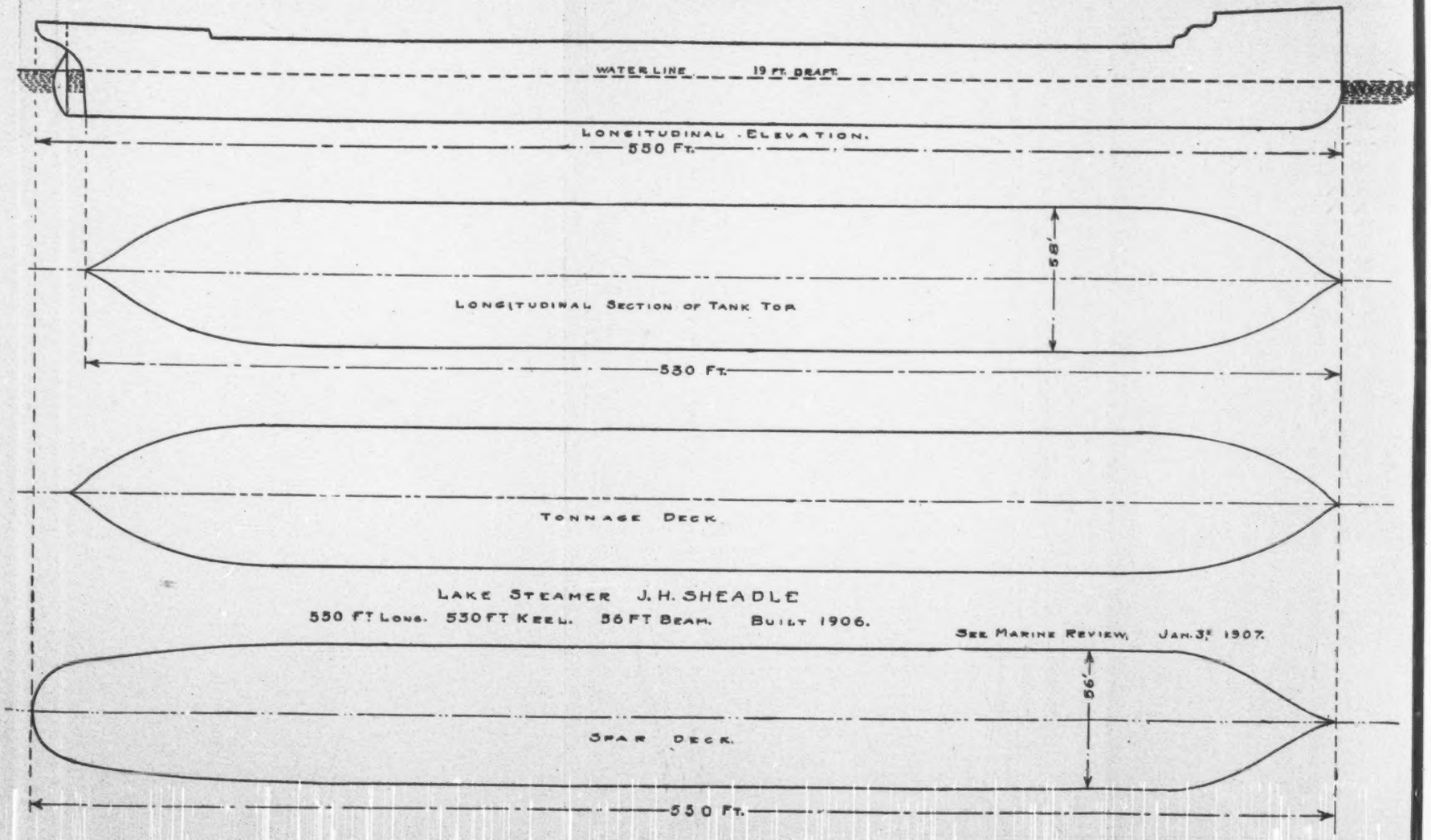
OWNER OR MANAGER	NAME	Tons per inch of draft	Keel and beam	Built
Pittsburg Steamship Co., Cleveland, Ohio	John A. Roebling	80.0	498x60x32	1906
Pittsburg Steamship Co., Cleveland, Ohio	Matoaka	80.3	480x50x30	1900
Pittsburg Steamship Co., Cleveland, Ohio	Mesaba Lee	80.3	480x50x30	1900
Pittsburg Steamship Co., Cleveland, Ohio	Superior City	80.3	480x50x30	1900
Pittsburg Steamship Co., Cleveland, Ohio	Simon J. Murphy	80.0	498x60x32	1900
Pittsburg Steamship Co., Cleveland, Ohio	Howard L. Shaw	80.0	498x60x32	1900
Pittsburg Steamship Co., Cleveland, Ohio	Sir Wm. Fairbairn	48.0	498x60x32	1900
Pittsburg Steamship Co., Cleveland, Ohio	Robert Fulton	44.6	414x48x30	1901
Pittsburg Steamship Co., Cleveland, Ohio	Alex. McDougall	48.4	414x50x27	1869
Pittsburg Steamship Co., Cleveland, Ohio	Sir H. Bessemer	46.2	413x48x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	Clarence A. Black	46.2	413x50x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	Corsica	46.2	413x48x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	Sir Wm. Siemens	46.2	413x48x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	Geo. Stephenson	47.0	402x48x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	John B. Trevor	36.0	400x39x24	1895
Pittsburg Steamship Co., Cleveland, Ohio	Crescent City	46.6	400x48x30	1897
Pittsburg Steamship Co., Cleveland, Ohio	Empire City	46.6	400x48x30	1897
Pittsburg Steamship Co., Cleveland, Ohio	Maricopa	46.6	400x48x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	James Watt	46.6	400x48x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	Bryn Mawr	47.0	400x50x27	1900
Pittsburg Steamship Co., Cleveland, Ohio	Jos. B. Eads	40.2	400x42x28	1894
Pittsburg Steamship Co., Cleveland, Ohio	Wm. R. Linn	46.6	400x48x30	1896
Pittsburg Steamship Co., Cleveland, Ohio	Queen City	46.0	400x48x30	1894
Postal Steamship Co., Detroit, Mich	Jno. J. Barium	62.7	504x54x30	1909
Postal Steamship Co., Detroit, Mich	Thomas Barium	58.4	480x52x30	1907
R				
Reiss Coal Co., Sheboygan, Wis	Price McKinney	52.1	420x54x26	1906
Richardson, W. C. & Co., Cleveland, Ohio	John P. Reiss	75.6	554x54x—	1909
Richardson, W. C., Manager Hannah Transit Co., Cleveland, Ohio	David Z. Norton	58.4	480x52x30	1906
Robey Transportation Co., L. C. Waldo, Manager, Detroit, Mich	Howard M. Hanna, Jr.	60.7	480x54x30	1906
	L. C. Waldo	50.8	413x48x28	1896
S				
Schiller Transit Co., Cleveland, Ohio	G. J. Grammer	46.5	434x48x26	1906
Smith, L. C. Transit Co., Syracuse, N. Y	Harry Coulby	72.0	540x56x31	1906
Smith, L. C. Transit Co., Syracuse, N. Y	Thompson Smith	53.6	430x52x26	1906
Shenango Steamship Co., W. B. Devoe, Manager, Cleveland, Ohio	Shenango	79.5	552x56x32	1909
Shenango Steamship Co., W. B. Devoe, Manager, Cleveland, Ohio	Wm. P. Snyder	60.5	530x56x31	1909

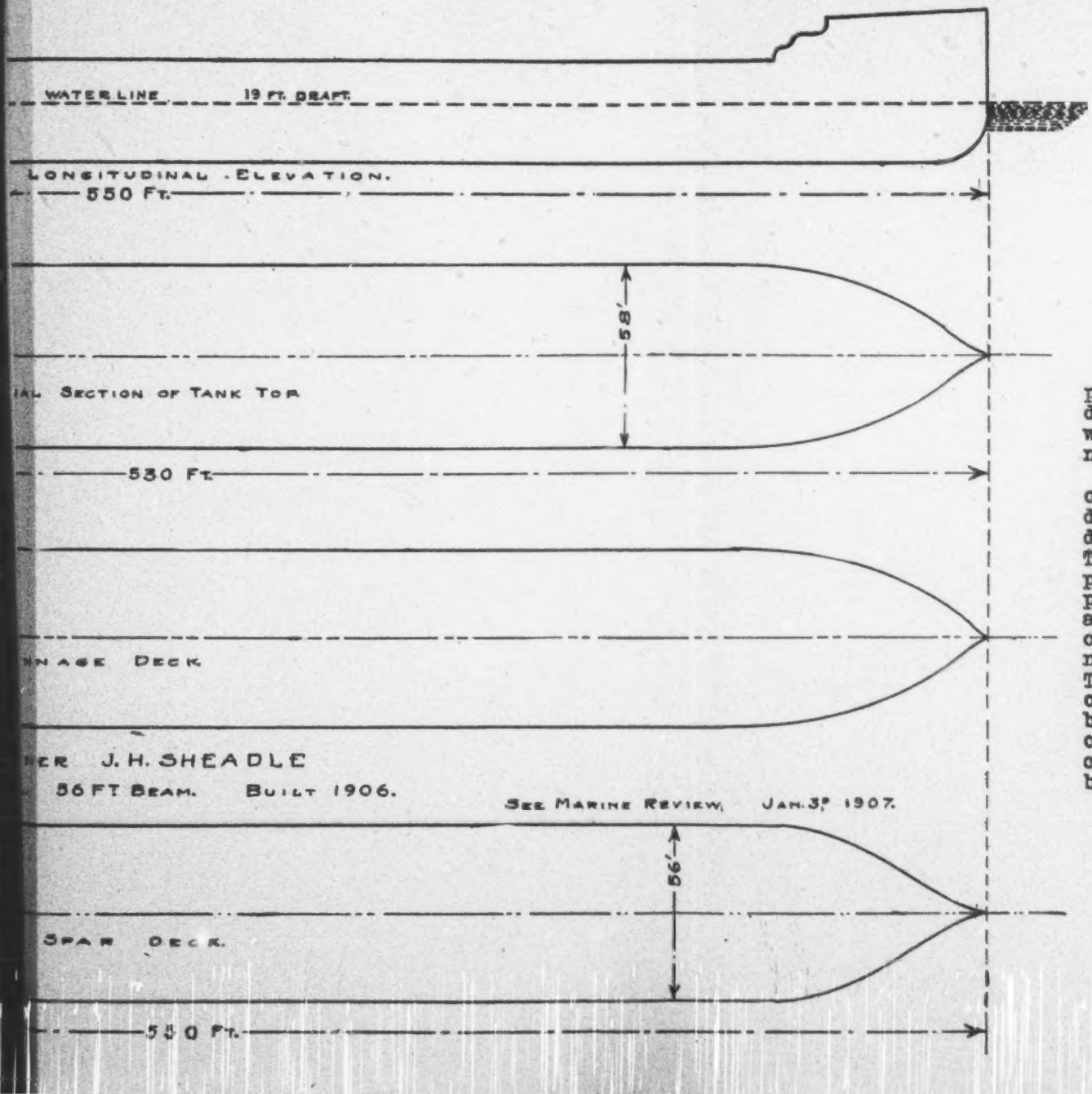
Shenango Steamship Co., W. B. Davock, Manager, Cleveland, Ohio	Wilson	75.2	554x60x22	1906
Steelecrest Steamship Co., Michigan City, Ind	Steelecrest	69.8	478x58x—	1909
Starke, Christopher H., Milwaukee, Wis	Christopher	46.0	410x45x26	1901
Sullivan, Estate of L. S., Toledo, Ohio	Eugene Zimmerman	58.4	480x57x30	1906
T				
Tomlinson, G. A., Duluth, Minn	Bell Bros	58.4	480x52x30	1906
Tomlinson, G. A., Duluth, Minn	Frank C. Bell	60.6	530x54x31	1906
Tomlinson, G. A., Duluth, Minn	Hoover & Mason	63.7	504x54x30	1906
Tomlinson, G. A., Duluth, Minn	Sahara	57.7	474x52x29	1907
Tomlinson, G. A., Duluth, Minn	Saxona	46.7	418x50x26	1903
Tomlinson, G. A., Duluth, Minn	Shiola	46.7	418x50x26	1903
Tomlinson, G. A., Duluth, Minn	Scoops	63.7	504x54x30	1906
Tomlinson, G. A., Duluth, Minn	Sonoma	46.7	418x50x26	1903
Tomlinson, G. A., Duluth, Minn	Sylvania	63.7	504x54x30	1906
Tomlinson, G. A., Manager Inter Ocean Steamship Co., Duluth, Minn	J. E. Davidson	63.7	504x54x30	1905
Tomlinson, G. A., Manager Inter Ocean Steamship Co., Duluth, Minn	Sierra	52.6	426x52x29	1906
Tomlinson, G. A., Manager Mutual Steamship Co., Duluth, Minn	Harry A. Berwind	72.2	532x58x31	1905
Tomlinson, G. A., Manager Mutual Steamship Co., Duluth, Minn	Fred G. Hartwell	60.4	504x56x30	1905
Tomlinson, G. A., Manager Mutual Steamship Co., Duluth, Minn	Wm. Livingstone	72.2	532x58x31	1905
Tonawanda Transit Co., Tonawanda, N. Y	Charles A. Weston	72.0	540x56x31	1906
Triton Steamship Co., J. R. Davock & Co., Managers, Cleveland, Ohio	Rufus P. Ramsey	51.3	490x53x36	1906
U				
U. S. Transportation Co., Cleveland, Ohio	Charles Hubbard	52.6	426x52x26	1907
U. S. Transportation Co., Cleveland, Ohio	Herbert W. Smith	49.4	414x50x26	1903
U. S. Transportation Co., Cleveland, Ohio	Lyman C. Smith	67.6	536x56x31	1903
U. S. Transportation Co., Cleveland, Ohio	L. C. Smith	46.4	414x50x26	1902
U. S. Transportation Co. (See, also, Wilkinson Transportation Co.)				
V				
Virginia Steamship Co., J. S. Ashley, Secretary, Cleveland, Ohio	Isaac M. Scott	63.7	504x54x—	1909
Vulcan Steamship Co., Cleveland, Ohio	Wm. B. Davock	51.3	490x53x26	1906
W				
Wilson Transit Co., Cleveland, Ohio	Andrew Carnegie	48.3	403x48x26	1907
Wilson Transit Co., Cleveland, Ohio	Chas. S. Hebard	63.7	504x54x30	1906
Wilson Transit Co., Cleveland, Ohio	J. E. Upson	63.7	504x54x30	1908
Wilson Transit Co., Cleveland, Ohio	Capt. Thos. Wilson	49.7	416x50x26	1900
Wilson Transit Co., Cleveland, Ohio	Henry W. Oliver	53.0	444x50x26	1901
Weston Transit Co., N. Tonawanda, N. Y	La Grande S. De Graffe	52.2	505x60x33	1906
Weston Transit Co., N. Tonawanda, N. Y	Wm. B. Kerr	52.2	505x60x33	1905
Weston Transit Co., N. Tonawanda, N. Y	Wm. M. Mills	52.2	505x60x33	1905
Wilkinson Transportation Co., U. S. Transportation Co., Managers, Cleveland, Ohio	J. P. Dureton	52.6	425x52x26	1905
Wilkinson Transportation Co., U. S. Transportation Co., Managers, Cleveland, Ohio	A. E. Nettleton	67.6	536x56x31	1909
Wolvin, A. B., Duluth, Minn., Manager Acme Steamship Co	James C. Wallace	60.7	532x58x31	1903

Exhibits with brief—Concluded.

OWNER OR MANAGER.	NAME.	Tons per inch of draft.	Keel and Beam	Built.
Wolvin, A. B., Duluth, Minn., Manager Acme Steamship Co.	Augustus B. Wolvin	70.33	440x46x22	1904
Wolvin, A. B., Duluth, Minn., Manager Peavey Steamship Co.	F. T. Heffelfinger	58.33	420x50x30	1901
Wolvin, A. B., Duluth, Minn., Manager Peavey Steamship Co.	Frank H. Peavey	58.33	420x50x30	1901
Wolvin, A. B., Duluth, Minn., Manager Peavey Steamship Co.	Geo. W. Peavey	58.33	420x50x30	1901
Wolvin, A. B., Duluth, Minn., Manager Peavey Steamship Co.	Frederick E. Weis	58.33	420x50x30	1901
Wolvin, A. B., Duluth, Minn., Manager Providence Steamship Co.	D. G. Kerr	64.16	440x52x32	1906
Wolvin, A. B., Duluth, Minn., Manager Providence Steamship Co.	Jas. H. Reed	64.16	440x52x32	1906
Wolvin, A. B., Duluth, Minn., Manager Standard Steamship Co.	H. P. Bope	70.33	440x46x22	1907


28'
28'
Amid Ship.
Cross-Section


WATER LINE 19 FT. DRAFT.
LONGITUDINAL ELEVATION.
550 FT.
58'
LONGITUDINAL SECTION OF TANK TOP
550 FT.
TONNAGE DECK
LAKE STEAMER J. H. SHEADLE
550 FT Lons. 530 FT KEEL. 56 FT BEAM. BUILT 1906.
SEE MARINE REVIEW, JAN. 3rd 1907.
56'
SPAR DECK.
550 FT.

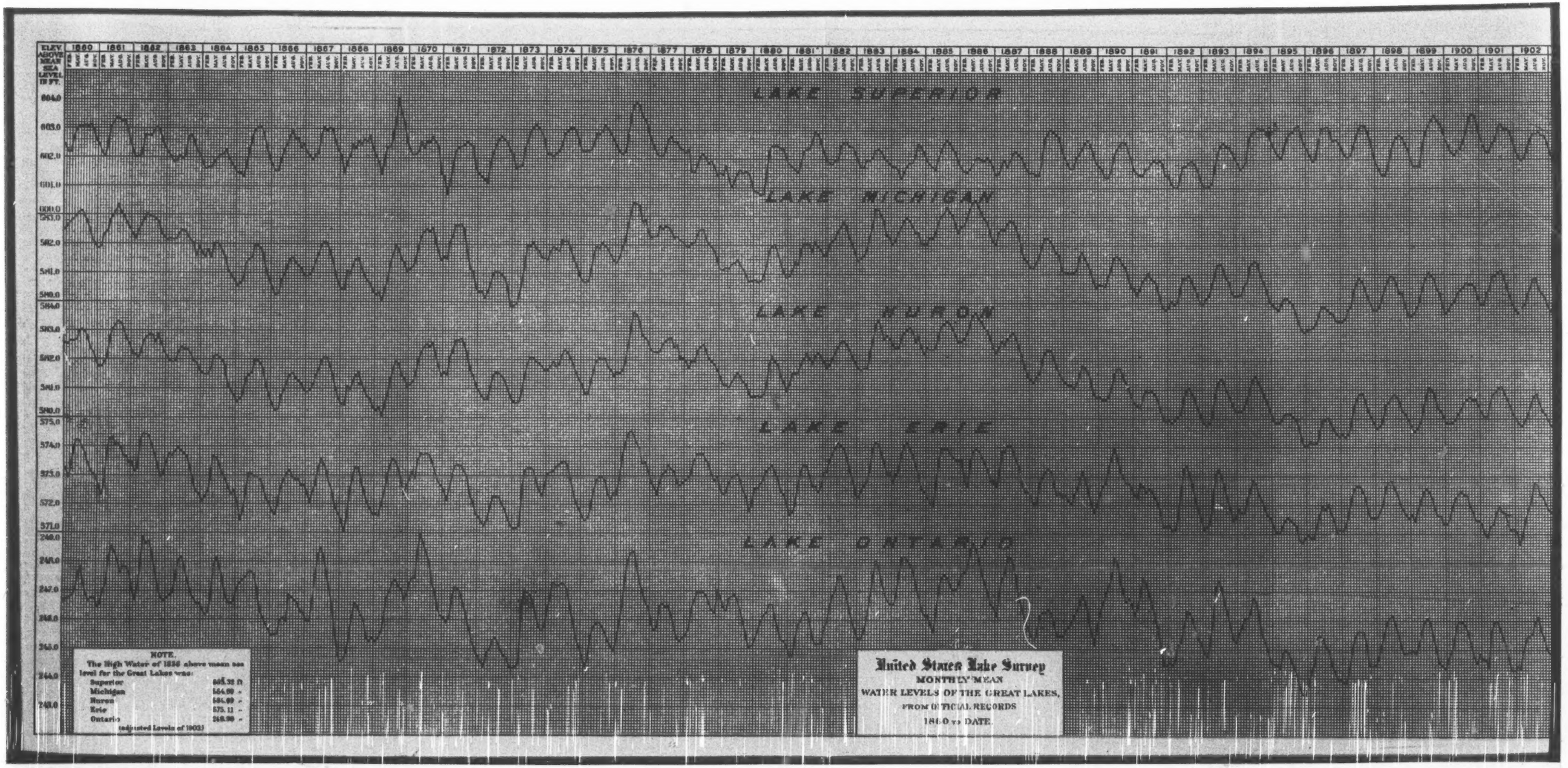

WATER LINE 19 FT. DRAFT.
LONGITUDINAL - ELEVATION.
550 Ft.
58'
IAL SECTION OF TANK TOP
530 Ft.
NAGE DECK
ER J. H. SHEADLE
56 FT BEAM. BUILT 1906.
SEE MARINE REVIEW, JAN. 3rd 1907.
56'
SPAR DECK.
550 Ft.

STATUTORY LENGTH, BREADTH, DEPTH & HEIGHT OF VESSELS.

Revised Statutes, Section 4150.

"The registry of every vessel shall express her length and breadth, together with her depth and height, under the third or spar deck, which shall be ascertained in the following manner:

The tonnage deck, in vessels having three or more decks to the hull shall be the second deck from below; in all other cases the upper deck of the hull is to be the tonnage deck. The length from the fore part of the outer planking on the side of the stern to the after part of the main stern-post of screw steamers and to the after part of the rudder-post of all other vessels measured on the top of the tonnage deck shall be accounted the vessel's length The breadth of the broadest part on the outside of the vessel shall be accounted the vessel's breadth of beam. A measure from the underside of the tonnage-deck plank, amidships, to the ceiling of the hold (Average thickness) shall be accounted the depth of hold."


ELEV. ABOVE MEAN SEA LEVEL IN FT.
1860 1861 1862 1863 1864 1865 1866 1867 1868 1869 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902
604.0
603.0
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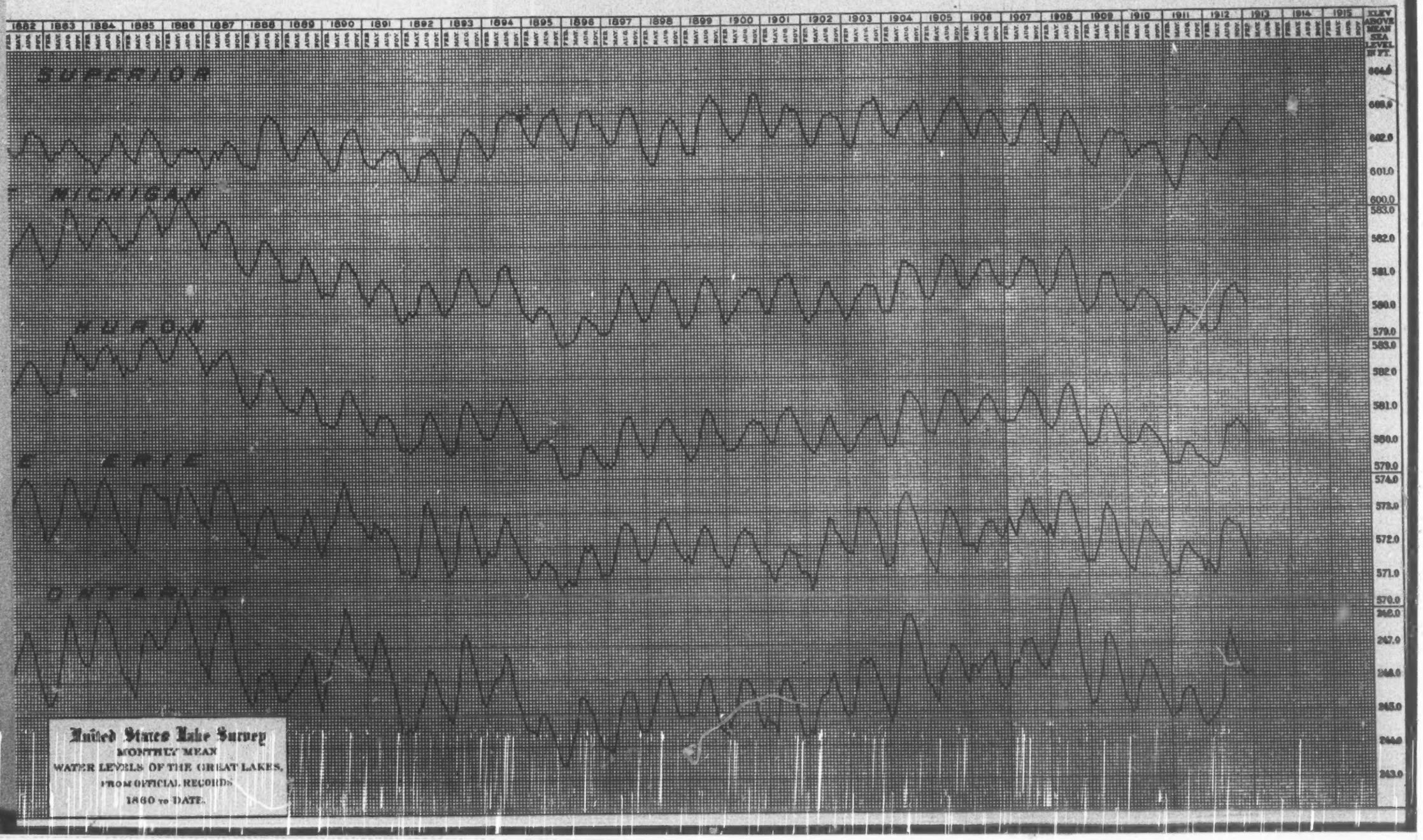
247.0
246.0
245.0
244.0
243.0
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ERIE
LAKE ONTARIO
NOTE.
The High Water of 1838 above mean sea level for the Great Lakes was:
Superior 605.32 ft
Michigan 584.69 "
Huron 584.69 "
Erie 575.11 "
Ontario 248.90 "
(adjusted Levels of 1903)
United States Lake Survey
MONTHLY MEAN
WATER LEVELS OF THE GREAT LAKES,
FROM OFFICIAL RECORDS
1860 TO DATE.


1860 1861 1862 1863 1864 1865 1866 1867 1868 1869 1870 1871 1872 1873 1874 1875 1876 1877 1878 1879 1880 1881 1882 1883 1884 1885 1886 1887 1888 1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915
ELEV ABOVE MEAN SEA LEVEL IN FT.
SUPERIOR
MICHIGAN
HURON
ERIE
ONTARIO
604.0
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243.0
United States Lake Survey
MONTHLY MEAN
WATER LEVELS OF THE GREAT LAKES,
FROM OFFICIAL RECORDS
1860 to DATE.

Letter of Approval by C. W. Wright to President Taft, March 26, 1912.

"I write to call your attention to an international opportunity in conservation of water supply.

It might well be presented to the Canadian Commission appearing before Secretary of War, Mr. Stimson, this week, and other interests there represented at the same time. I mean the holding back the waters of Lakes Michigan and Superior during the winter months which will keep the waters of all the lakes at the proper level during the open season for shipping; also permitting Chicago the required amount of water for the sanitary canal. Hoping this will be of interest to you and other conservationsists, I am

CLERIAN M. WRIGHT,
2109 W. Polk St., Chicago, Ill."

Letter of Approval by State Water Survey of the University of Illinois, March 28, 1912.

"Owing to the limited time I did not have an opportunity to speak in behalf of the request of the Sanitary District at the hearing on February 28th. I, therefore, request the privilege of making a brief statement.

The Illinois State Water Survey has been analyzing the waters of the Illinois river for a number of years. Our investigations show that the dilution at the present time is none too great, and should the flow be decreased we are certain that a nuisance would result during parts of the year. We, also, have been in close touch with the work being done by the Sanitary District and feel that they are acting in good faith, in their experiments to determine the proper method of disposing of the sewage of the increasing population of Chicago.

It is the business of the State Water Survey to make investigations which will enable the people of the State to have a pure water supply, and it is our belief that the sewage of Chicago must be diverted from the Lake, and that the curtailment of the amount allowed would work a hardship on the citizens of Chicago.

Our observations throughout the State have brought to our attention the fact that the last two years have included the periods of the lowest water in the Mississippi river as

well as in the Great Lakes. The effect of withdrawing 10,000 cu. ft. per second of water through the drainage canal will have an inappreciable effect in lowering the level of Lake Michigan as compared with the lowering that is being produced by enlargements in the channel of the Detroit river carried out by army engineers. Statements were made that Lake Superior, which cannot be affected in the least by the drainage canal, is lower than it has been for years. Likewise the Mississippi river, even below the outlet of the Illinois river where it is augmented by the drainage canal, has, during the past year, reached the lowest stage in many years.

We sincerely hope that after careful consideration you will see fit to grant the petition of the Sanitary District, which desires to take only one-twentieth of the flow from the Great Lakes. It is our belief that any lowering of the Lake Michigan level which this withdrawal might cause can be counteracted by the construction at the outlet of Lake Huron, of wing dams instead of dredging the channel as is now the practice.

EDWARD BARTOW,
Director State Water Survey."

Letter of Approval by Federation of South End Civic Bodies, March 28, 1913.

"The portion of Chicago most concerned in the matter before you, relating to the diversion of additional water from Lake Michigan, is the southern portion of the city known as the Calumet region, lying south of 87th street. Although, Mr. Secretary, you have indicated that the discussion should relate mainly to the alleged interference with navigation that might result from the permit, I am sure that the question of human life and sanitation will not be completely ignored on the same idea that a messenger in an automobile, charged with the delivery of a message at the quickest possible time, would feel justified in swerving from his most direct course to avoid running down a troop of children.

In order that the people of the Calumet region shall benefit from the Chicago Sanitary Canal, the additional diversion requested is necessary, under the state law, to properly dilute the sewage which will be emptied into the main drainage canal by the Calumet-Sag Canal, a supplementary channel now under construction.

This district comprises a population of upwards of 200,000 people larger than that of any other city in the state save

Chicago itself. A most unfortunate condition now obtains in this section owing to a delay of many years in building the Calumet-Sag Canal. Over a million dollars was recently spent in building the 95th street sewer system, which drains a large part of the District through a ten-foot sewer which has its outfall near the mouth of the Calumet river. About two miles distant, and receiving this sewage when southerly winds or other conditions cause the flow in that direction, is the intake of a large water tunnel just completed at an expense of some $6,000,000, which conveys this effluent back to the homes of the people in the guise of drinking water. Thus our people are compelled to pay $7,000,000 for the privilege of drinking their own filth, this endless chain being forced upon us by the injunction suit of the United States against the Sanital District of Chicago, which prevented the construction of the canal which our district had had every reason to expect for many years, and in expectation of which our various drainage and water plants were planned.

We, therefore, earnestly request the granting of the permit, Mr. Secretary, for the reason that the health and very lives of our people are at stake, which is a matter of far greater importance than any real or fancied injury to navigation. We urge the full permit. If this for any reason seems inadvisable, we must earnestly request a temporary permit for a period long enough to attend to the sewage disposal in some other way, so that in the mean time we may not continue to suffer this unexpected and intolerable nuisance.

The difference in the lake levels will not be the full result of 10,000 cubic feet diversion, but only about half that amount. The present permit allows about half the requested diversion, so that where a difference of six inches has been mentioned the real difference will be only three inches. We submit that this is too small a margin to be seriously considered in a navigation proposition. No navigation worthy of the name can afford to do business upon such a difference.

We submit that the city of Chicago is entitled to keep its house in order in the manner that seems best to its own people and that it is presumptuous for any foreign interest to attempt to dictate the sanitary policy of this city. If there may be an injury to navigation upon a difference in lake levels of three inches, the compensation for that damage is threefold: controlling works, deepening the channels or using less draft. The measure of the damage is the cost of the least expensive of these methods. But we contend that no

material damage can follow the additional diversion requested.

On the other hand this diversion makes possible a great and inestimable addition to the navigation of the Great Lakes and connecting waters. Instead of injuring navigation, it adds a navigable belt around Chicago and the additional project provides what Captain Marshall in the U. S. Engineer's report 1890 states as follows:

'The terminal facilities as far as possible access to Lake Michigan is concerned of the Calumet river and connected chain of lakes for a large system of commodious docks and wharves and harbors (needing only deepening by dredging) in public waters of the United States, point irresistably to the Calumet region as the proper terminus of the proposed waterway from Lake Michigan to the Mississippi river.'

To all these additional facilities Canada will have access equally with the United States. This connection with the Gulf of Mexico leading directly to the Panama Canal will give interior America and Canada the full benefits of this great artery of trade opening in addition to the teeming population of the Mississippi valley the inestimable value to transportation and commerce of free access to the ports of the world.

In conclusion we urge that as against the alleged damage to navigation of a difference of three inches in water levels is offset the sanitation of our people and the construction of channels that without the sanitation feature would not be built, costing as they do upwards of seventy millions of dollars, but which when completed will give the objectors the benefits of the lakes to the gulf waterway and the Panama Canal, the two greatest waterway projects in the world, both of which built and paid for by the United States of America.

HENRY W. LEE, C. E.,
Consulting Engineer, Federation of South End Civic Bodies, Chicago, Illinois."

Resolution of Approval by the Federation of South End Civic Bodies, March 29, 1912

"Herewith I submit brief on behalf of the Federation of South End Civic Bodies of Chicago, Ill., in connection with the hearing before you relative to the permit requested by the

Sanitary District of Chicago to divert 10,000 cubic feet per second of water from Lake Michigan.

HENRY W. LEE, C. E.,
Consulting Engineer, Federation of South End Civic Bodies, Chicago, Ill."

"Whereas in the year of 1903 the General Assembly of Illinois passed an act enlarging the corporate limits of The Sanitary District of Chicago and providing for the drainage of a part of the added territory by said Sanitary District by means of a canal through the Sag Valley, and

Whereas the territory so annexed has been taxed for such purpose from that time until the present, and

Whereas thereafter the Internal Waterways Commission, composed of representatives of the governments of the United States and the Dominion of Canada, reported to the President of the United States recommending the terms of a treaty to be entered into between the two governments which proposed treaty contained a provision that The Sanitary District of Chicago be allowed to extract from Lake Michigan, for sanitary purposes, as much water as should be necessary, not to exceed ten thousand cubic feet per second, and

Whereas thereafter The Sanitary District of Chicago applied to the Secretary of War for a permit to reverse the flow of the Calumet river according to plans which provided for the diversion from Lake Michigan of fourteen thousand cubic feet of water per second, which application was on March 14, 1907, denied by the Secretary of War, and

Whereas The Sanitary District of Chicago, for the purpose of meeting the objections urged by the War Department, has since made further investigation of the problem of disposing of the sewage of the Calumet District, including the southern part of the City of Chicago, which investigation involved the expenditure of large sums of money, and as a result of such investigation the engineers engaged therein deem it absolutely necessary to reverse the flow of said Calumet River to prevent the pollution of Lake Michigan, but find it possible to effect said reversal of flow by diverting from Lake Michigan not more than ten thousand cubic feet per second, and

Whereas application was presented to the Secretary of War for a permit to carry on said work according to the opinions expressed by the War Department from time to time, which application was approved by Major Thos. H. Rees of the Corps of Engineers assigned to the District of Chicago, and

Whereas it is of vital importance to the health of the people of Chicago that this work be carried on without further delay, and

Whereas it has heretofore been held by the Judge Advocate General of the War Department that the Secretary of War has jurisdiction of the subject matter involved in the application for permit made by The Sanitary District of Chicago and the right to issue such permit, and the plans of The Sanitary District of Chicago have been approved by all the engineers having knowledge thereof and interested in the proper solution of the problems of sewage disposal in the City of Chicago and environs,

Now, Therefore, Be it resolved that the Secretary of War be, and he is hereby respectfully urged to grant said permit applied for by The Sanitary District of Chicago, and

Be It Further Resolved that the governor of Illinois, the Mayor of Chicago, the President of the Board of Commissioners of Cook County, Illinois, the Mayor of Blue Island, the United States Senators and each member of the House of Representatives of the United States Congress from Illinois are hereby respectfully requested to use their good offices for the securing of such permit."

Letter of Alfred Noble, Engineer, of New York City, April 2, 1912, to the Attorney of The Sanitary District and Presented to the Secretary of War March 30, 1912.

"You have requested me to express opinions on the following points:

1. Is it practicable to compensate for an increased diversion through the Drainage canal from 4,000 cubic feet of water per second to 10,000 cubic feet per second, by obstructions in the natural outlets of the Great Lakes so that the natural levels of the lakes may be maintained?

2. Assuming that the population of the Sanitary District will be 3,000,000 in 1920, and that the sewage from this population would be sufficiently diluted for sanitary purposes by a supply of 10,000 cubic feet per second, is it practicable to provide the works for the partial purification, as designed and estimated for by the Chief Engineer of the Sanitary District, in time to provide for the subsequent increase of population?

3. If the existing permit to divert water from Lake Michigan were revoked, would it be practicable to provide for the sewage satisfactorily?

In reply to your first question, I have to say that exact compensation, etc., effective at all points along the line of naviga-

tion, is probably impracticable, but I am decidedly of the opinion that substantial compensation, involving no material loss to any interests, navigation or other, is entirely feasible. The obstructions might be, for the most part, simple dikes or embankments, not expensive in character, supplemented in places by movable obstructions of no great extent. Such obstructions in the Niagara river would raise the levels of Lakes Erie, St. Clair, Huron and Michigan, and the St. Mary river below the falls, not precisely in the same proportion as the lowering resulting from the diversion, but closely enough for all practical purposes. It seems clear that the best results would be given by obstructions which would raise Lake Erie slightly above its natural level, with perhaps not quite full compensation in Huron and Michigan. Since the effect on any of these lakes of withdrawing the additional amount of water would be only about 4 inches, it seems probable that compensation could be effected to within an inch, by the obstruction suggested. Similar works at the principal rapids in the St. Lawrence river would maintain the natural levels of that river at all points above Montreal, and of Lake Ontario.

In reply to your second question, I am of the opinion that the constructions proposed can be provided as rapidly as required.

In case of the revocal of the existing permit, as contemplated by your third question, it would be necessary to discharge the sewage directly into the river and lake, which course experience has shown to be dangerous. The works necessary for the purification of the sewage to such a degree that the effluent discharged into the river and lake would be harmless would require several years to construct.

ALFRED NOBLE,
Consulting Engineer."

Letter of Approval by Federation of South End Civic Bodies, April 5, 1912.

"Kindly accept the enclosed as supplementary to my brief filed with you on behalf of the Sanitary District of Chicago. If necessary, it might be filed on behalf of the opposition, because of 'flooded Canadian lands,' the facts showing that the relative level of Lakes Ontario and Superior have changed in eight years since 1900 with higher relative level at Lake Ontario instead of lower, as alleged.

I have believed that you will welcome the facts and these are so simple and so conclusive, that it would be a breach of duty to neglect to send them.

HENRY W. LEE, C. E.,
Consulting Engineer, Federation of South End Civic Bodies, Chicago, Ill."

"The enclosed tables are from the report of the International Commission for 1910. The difference of levels between Superior and the other lakes below it are shown in parallel columns.

The average for eight years preceding and eight years following 1900, when Chicago drainage canal was opened shows variations of +.043, —.069 and +.107 for Michigan, Erie, and Ontario, respectively below Superior. This is not based upon estimate or guess or approximation, but upon actual facts, reports for sixteen years from the highest official sources, averaged for an equal period before and after the diversion at Chicago.

The results show that both Michigan and Ontario are relatively higher as regards Superior than before the diversion, although Erie is —.069, average for the second eight year period.

This proves that the mean average fluctuation is about an inch and that it is variable plus and minus, and that the difference is too small to be seriously considered in connection with navigation, other variations constantly off-setting and far overwhelming this negligible item.

The allegation of three or six inches or other change in levels is disproved by the facts and the records, the only true criterion."

MEAN WATER LEVELS.

	Sup. & Marquette	Milwaukee		Harbor	Cleveland	Below	Oswego	Below
	Sup.	Mich.	below Sup.	Bend Huron	Erie	Sup.	Ont.	Sup.
1892	601.51	580.38	21.13	580.38	572.14	29.37	245.38	356.13
1893	1.86	0.66	21.20	0.57	2.09	29.77	5.98	355.88
1894	2.56	0.78	21.68	0.76	2.09	30.47	5.78	356.78
1895	2.62	579.74	22.88	579.83	1.17	31.45	4.29	358.33
1896	2.59	9.47	23.12	9.53	1.40	31.19	4.62	357.97
1897	2.60	580.13	22.47	580.13	1.96	30.64	4.80	357.80
1898	2.17	0.30	21.86	0.28	2.14	30.03	5.37	356.80
1899	2.69	0.32	22.37	0.29	1.91	30.78	5.20	357.49
1900	2.77	0.28	22.49	0.30	1.94	30.83	5.25	357.52
1901	2.75	0.54	22.21	0.57	1.30	31.36	5.06	357.69
1902	2.52	0.22	22.30	0.22	1.84	30.68	5.27	357.25
1903	2.73	0.31	22.41	0.36	2.38	30.35	5.87	356.86
1904	2.71	0.74	21.97	0.84	2.46	30.25	6.64	356.07
1905	2.74	0.88	21.86	0.95	2.17	30.57	6.21	356.53
1906	2.63	0.99	21.64	0.96	2.26	30.37	6.05	356.58
1907	2.51	1.02	21.49	1.05	2.73	29.78	6.66	355.85
					Erie Below Sup.		Ont. Below Sup.	
					30.455		357.148	
Mich. below Sup.								
1892-99			22.089					
1900-07			22.046		30.524		357.041	
			+ .043		— .069		.107	

Letter of Approval by David R. Forgan, Pres. Nat. City Bank of Chicago, to Pres. Taft, May 1, 1912.

"I have been asked to call your personal attention to a matter of importance to the City of Chicago in which the Association of Commerce is deeply interested.

The Sanitary District has made application to the Secretary of War to be allowed an increased flow from Lake Michigan from 4,167 cubic feet per second to 10,000 cubic feet per second. The Secretary of War has had a hearing in which the Sanitary District, navigation interests, and the Dominion of Canada have all been represented. The briefs in the case have been referred by the Secretary of War to Genral Bixby for analysis and report.

Now, to put the matter plainly, the members of the Association of Commerce who are in charge of this matter are afraid that the inclination of General Bixby, and also of the Secretary of War, will be simply to view the whole matter from the standpoint of navigation, and not give due weight to the consideration of the vital question for Chicago of its sanitation, and they wish me to request of you that, if pos-

sible, you give the matter some personal, or cabinet consideration when the proper time comes.

This I respectfully ask you to do in the interests of fairness in a rather complicated matter.

DAVID R. FORGAN,
President."

Letter of Approval by John V. Farwell to Pres. Taft, May 8, 1912.

"The Association of Commerce of Chicago whose public spirited work in this city and elsewhere I am sure you are familiar with, through Mr. Wheeler and others who are well known to you, has been deeply interested in the question of increased flow of water from Lake Michigan into the Sanitary District Canal.

Application, as I understand it, is now before the Secretary of War, to allow the District to increase the flow from 4,167 cubic feet per second to 10,000 cubic feet per second.

The Dominion of Canada and some shipping interests have been against this increase, whereas, nearly all Chicago interests are in favor of it.

Believing it to be a case to be viewed not only from the standpoint of navigation but from that much more important one, the health of millions of people living in Chicago and along the line of the Canal, the Association of Commerce were in hopes that you might be able to give the matter some personal attention, or have it brought before the Cabinet for thorough consideration before final decision is reached.

From what I can make out the Sanitary District was not very well represented by the best obtainable legal counsel in making arguments before the Secretary of War.

JOHN V. FARWELL,
President."

Letter of Approval by Secretary of the Treasury Franklin McVeagh to Secretary Stimson, May 27, 1912.

"Ever since the Cabinet meeting when Secretary Fisher urged upon your attention the deep interest of Chicago in the question of water for its drainage system, I have felt that I did not sufficiently accent my approval of the urgent representations which the Secretary of the Interior then made.

And at this rather late day I want to make it perfectly clear to you that I am profoundly impressed by the vital interest which Chicago has in your decision. It may well be that the present drainage system cannot be permanent; but a claim to that effect is recent. We started in with the full expectation that we had a permanent method of drainage, wholesome and unobjectionable from every point of view. It is only later that questions have been raised which seem to point to the necessity of another system of sewage disposal. But, Mr. Secretary, that is a tremendous engineering job and an exceeding financial job. And there are great complications which make obstacles of a most serious nature to any change of system. And, therefore, it must take time to do this—if it is ascertained that it must be done eventually. It is not easy for Chicago to raise sixty millions of dollars or a hundred millions, as this may require. We have spent sixty millions on that drainage canal. Of course, we can throw that away. But it is a serious thing to throw sixty millions away. And it is another very serious thing to raise sixty or a hundred millions, because the Constitution of Illinois restricts, in the most rigid manner, the bonded indebtedness of municipalities. Altogether this is not purely an engineering question you have to decide now; but it is an economic question. And it is a question of what is fair and just to a city of great size and importance, which is the second city in the country. We are a long way from you and you are a long way from us when you are in New York or in Washington. And we have, therefore, to make our appeal under certain disadvantages to an Eastern man. It is much easier for almost any Eastern man to understand an eastern city than to understand a western city. Moreover, Chicago doesn't have the popular appeal in the East that it has in the West. But to me the appeal of the real interests of Chicago is always most impressive. Chicago never plays the baby act; and it doesn't ask for sympathy. It is a manly municipality, and self-reliant. But it has the great interests of not only itself but of the Middle West in its keeping. And dealing with it is dealing with a very great body of public interests.

Now, if we must change our drainage system give us a chance to do it without, in the meantime, suffering. Of course, if the United States Government had said in the beginning that this drainage system was a temporary expedient we would never have entered upon it; and if now it is but a temporary expedient, then I think we should be patient with it

and give it time to change itself, meanwhile treating it generously so that the city can live throughout the interval healthily and safely.

I am appealing, of course, for my home. And I don't want to deny that. But it seems to me I am appealing rather for a great metropolis that happens to be dependent upon your decision.

FRANKLIN MACVEIGH."

Statement of Lawrence McCann, of Chicago, to Secretary of War Stimson, February 28, 1912.

"Mr. Secretary, I would simply ask that since the city of Chicago is referred to as a corporation, for its people I want to beg of the Secretary and the citizens representing other sections of the country, to understand that in the evolution of a great city and in the development of navigation certain things have arisen which may appear to conflict. But the citizens of Chicago would not perimt for one moment that they should appear to tolerate an evasion of any improvement or of any economy that may be developed; and neither the citizens of Chicago nor the corporation of Chicago through its properly accredited officers will yield in their zeal and in their determination to maintain the highest efficiency for navigation consistent with the preservation of conditions of health and safety in the city of Chicago.

I simply beg of you, Mr. Secretary, to keep in mind that the city of Chicago is made up of honorable people, and that many of the questions submitted today are not creditable, and insinuating that there may be an ulterior purpose and motive. There are none but the purest motives, the motives that inspire men and citizens to maintain pure homes, preserve life, promote health and happiness, and in the consideration of this question I want to beg in the name of the Mayor of Chicago, whom I am here to represent, and the people of the city of Chicago, as distinguished from the Sanitary District, that the question be given the simple and fair consideration which I know the Secretary will give it, and I beg for the Commission of the city of Chicago, that it be permitted to file a brief on this question, for the corporation of Chicago, treating the question of navigation, the question of good faith with the Government in carrying out of every regulation that has been laid down by the Government. As you will remember, Mr. Secretary, I have communicated with you, some months past,

in regard to this matter. These will be carried out in absolute good faith through your representatives and through yourself, and the city will take pleasure in co-operating and carrying out the law. But the city also asks that we be given every consideration in the protection of the health of the citizens of Chicago, until such time as a system may be adopted for sewage treatment as will be acceptable and a fair system, and especially considering that the people of Chicago have spent this great sum of money during a period when it was regarded as the most advanced method of treating sewage, when there were no protests and when it was believed that every step, every effort, and every expenditure was being made with the knowledge, the consent and the approval of the Federal authorities.

I simply ask permission in the name of Chicago to file a brief."

Statement on Behalf of the City of Chicago by Lyman E. Cooley, Consulting Engineer, Mar. 30, 1912.

"On the application of the Sanitary District of Chicago, for a permit to increase the flow into its main channel or outlet by way of the Chicago River and other feeders, and in the hearings relating thereto, the City of Chicago has been represented by the Commissioner of Public Works, Hon. Lawrence E. McGann, acting for the mayor, and by Aldermen Charles E. Reading, L. D. Sitts, W. F. Ryan, and John S. Derpa, acting for the city council, and by their consulting engineer, Lyman E. Cooley.

The City of Chicago, has been and is co-operating with the Sanitary District and supporting its contentions, and it has the most vital concern in the issues before you. The consideration of the subject matter has taken a very wide range and raised many questions, all of which could not be anticipated, and the city feels that it should submit a brief in its own behalf which would go fully into the mreits of the questions involved. But it seems that time cannot be allowed for this purpose. The representatives of the city therefore feel constrained to limit themselves to a statement which shall recite concisely the history of the matter, the position of the city, and re-enforce the position of the Sanitary District of Chicago, and the undersigned has been authorized and directed to prepare and submit such statement.

1. The Sanitary project was matured by the City of Chi-

cago in the years 1885-9 at a cost of about $100,000, under the advice of engineering and legal experts and with the co-operation of the State Board of Health of Illinois and a joint committee of the General Assembly. The city promoted the Sanitary District Act in force July 1 1889, and continued its oversight until the Sanitary District was adopted by the people and actually organized early in 1890. The purpose was to provide a main channel or outlet with necessary adjuncts by which the City, together with other municipalities within the corporate limits of the District, could dispose their sewage under certain conditions as laid down in the organic law. Since its organization the confines of the Sanitary District have been enlarged and the City of Chicago through annexation has absorbed in large part the urban population and now contains 94.5 per cent. of the population of the Sanitary District.

The City of Chicago is endowed with full municipal functions as a part of the political system of the state and could have undertaken the complete solution of the sanitary problem had it possessed the proper territorial limits and the necessary financial resources. The Sanitary District was therefore created for a limited and specific purpose. The city therefore views with the gravest concern any proposition or action which tends to limit or disbar any function or power of the Sanitary District because the burden will thus be shifted in greater or less degree, or wholly, back upon the city, with extraordinary complication and cost beyond the power of the city to meet.

The entire policy of the city and its environs for the past twenty-five years in respect to the sewage system, the park system, the harbor and waterway development and all collateral work, has shaped itself in conformity with the sanitary and ship canal project, and any attempt to change policies and conditions at this time will result in the utmost confusion and cannot be seriously entertained or admitted by our people.

2. The Sanitary and Ship Canal of Chicago was actually constructed across the Chicago Divide between the waters of the Chicago River at Robey street and the Desplaines River at Lockport, with a flowing capacity of 840,000 cubic feet of water per minute, or 14,000 cubic feet per second in round numbers at low water of 1847 in Lake Michigan. A small portion of this channel in the clay between Robey street and Summit was constructed with a preliminary capacity of more than 500,000 cubic feet of water per minute, and under the

law is subject to progressive development with the growth of population and also to complete development within one year after the General Government shall co-operate in the production of a through waterway. The cost of such development is relatively a small item. The channel was actually opened January 17, 1900, in compliance with Section 27 of the organic law and no change affecting the capacity thereof has since been made.

The City of Chicago does not admit any doubt as to the full right and power of the State of Illinois to authorize the particular solution and the method of applying it as outlined in the organic law, and attention is called to the decision of the U. S. Supreme Court in 1906, in the case of State of Missouri v. The State of Illinois and the Sanitary District of Chicago, where the whole subject matter was entered into and affirmatively decided. It is not now competent to raise questions as to the manner of the solution nor in regard to the right to take water to the extent of the capacity of the main channel or outlet, or 14,000 cubic feet of water per second at low water of Lake Michigan.

Under the authority of the state, the Sanitary District proceeded diligently and completed its channel as above stated, and had actually notified the Governor of that fact, before the end of the year 1898, and several months prior to the Act of Congress of March 3, 1899, Section 10 of which has been assumed to give jurisdiction in the premises. The permit issued by the Secretary of War and the Chief of Engineers, U. S. Army, May 8, 1899, does not bear out any such presumption, but is conditioned solely by the capacity of the Chicago River. In no event could the act cited have a retroactive effect.

The right of the United States to conserve the highways of commerce and the easements which it has developed is not questioned, and we assume that the right to take water cannot be exercised in a wilful and frivolous manner and so as to create unnecessary hardship to other interests, and therefore we admit a certain degree of supervision as to the manner in which the water shall be taken. The law of the State of Illinois also states that public waters shall not be entered upon and utilized in such manner as to unduly interfere with their uses for navigation.

In addition to the foregoing Chicago claims a right to 1,000 cubic feet per second by way of the Illinois and Michigan Canal and that such right is both proscriptive and by authority of law.

In view of the circumstances already stated the city is unable to develop properly and fully its contentions respecting the foregoing and it expressly reserves its rights in case they are not admitted.

3. The expenditures by the Sanitary District of Chicago from its organization down to January 1, 1912, have been $68,524,491.16

The expenditures by the City of Chicago for its intercepting sewer system along the lake front of the city have been 6,706,804.37

The total is $75,231,295.53

The same ratio of expenditure extended over the United States would represent about $3,000,000,000, or several times the amount expended by the United States upon its river and harbor system.

The further amounts that must be expended in developing and completing the program will bring the total well above $100,000,000. In addition the park boards have expended large sums and will expend still larger sums in parkways along the city front, which serve to protect the water supply of the city and to transfer the filth producing industries to the back lots. It is further recognized that the large sums required for harbor and waterway development must conform to the adopted program.

4. The waterway policy of the State of Illinois has been established from the beginning. The Sanitary District Act was intended by its promoters as primarily a health provision and an important consideration in its passage was that the same waters that performed the service for Chicago would perform a like service for all the urban population contiguous to the Desplaines and Illinois Rivers. A secondary motive was the contribution which would thus be made to the waterway policy of the state; and the state took good care that these provisions of law should be fully set forth. And from the standpoint of the state the Sanitary District Act is a waterway act in which Chicago is allowed certain rights of sewage disposal, in consideration of its investment. The state further defines its position by contemporaneous act and joint resolution and has since adopted a constitutional amendment by which the General Assembly is authorized to expend $20,000,000 between the end of the drainage canal and the head of the lower Illinois River at Utica for waterway

development and incidental water power. The state policy in this respect is based on the full capacity of the drainage canal or 14,000 cubic feet plus the capacity of the Illinois and Michigan Canal, or 1,000 feet, a total of 15,000 feet. The state recognized that a large volume of water will enable the production of a deep waterway not less than 14, feet, as stated in the joint resolutions of 1889 and 1897, and it is further recognized in the report of 1907, that the larger volume for which the Sanitary Canal was actually constructed will enable a still greater depth through the lower Illinois River.

5. The Association of Drainage and Levee Districts of the State of Illinois represents the lands subject to reclamation in the lower Illinois Valley, some 400,000 acres, and it recognizes the necessity for a deep and capacious channel, with a large and permanent water supply therein for the stability and maintenance of the lower Illinois River as well as for the sanitary welfare of the valley; and they are promoting the removal of the dams in this portion of the river and the development of such channel by dredging in conjunction with the water supply from Lake Michigan for the threefold object of drainage, sanitation and deep navigation.

The Lakes-to-the-Gulf Deep Waterway Association represents all interests in the several states bordering the route between Lake Michigan and the Gulf of Mexico, and this association has adopted a policy as set forth in its last two conventions, 1910 and 1911, for a waterway with a preliminary depth of 14 feet with all structures and rock cuts adapted to an ultimate depth of 24 feet, and the large water supply provided for by the State of Illinois is necessary to the carrying out of such a policy.

6. The water power development by the Sanitary District and by the State of Illinois comes strictly under the rules laid down by the U. S. Supreme Court in the Montello case. The Supreme Court of Illinois held in the case of the suit to test the validity of the Sanitary District Act, in June, 1900, that it would be unreasonable to deny the right to develop water power which was created by other than necessary work, and called attention to the fact that the burden of taxation might thus be mitigated. Under the project of the Deep Waterway Association eighty per cent. of the fall between Lake Michigan and the Mississippi River at Cairo, may be converted into water power and this amounts to about half of what the same water would produce if utilized for the same

purpose in the direction of the St. Lawrence, and not one-fourth as has been stated.*

There can be no objection to the development of such power under public ownership as proposed, and as the incident of other and necessary uses of the water for sanitary and deep waterway purposes. It is a circumstance not to be overlooked that the waters diverted are to be put to all of the three uses recognized in their order in the recent treaty respecting the boundary waters between the United States and Canada, to wit: domestic and sanitary, waterway, and water power. These uses are not alternative but cumulative, and they combine in a justification superior to any separate and distinctive reason.

7. The population of the Sanitary District, by the Federal Census of 1910 was 2,311,810. The contiguous population within ten miles of the water route between the Sanitary District and the Mississippi River was 445,828. The total population in the District and in the valley immediately concerned in the sanitary problem and also in the deep waterway was 2,757,638. Of this population 2,468,450 were urban or in communities of 2,500 people and upwards. The aggregate represents 49 per cent. of the total population of the state and 71 per cent. of the urban population.

The aggregate population in cities of 25,000 and upwards about the Great Lakes above Niagara in 1910 was 2,325,543, or less than the urban population of the Sanitary District and adjacent to the water route in the State of Illinois. The statistics for the minor cities are not yet available and these would increase the aggregate for the lakes. And again, we should add the urban population on the Canadian side, for which the data are not in hand. The total, however, would not greatly exceed the figures given for Illinois. There are other populations in the United States and Canada below Niagara which claim to be affected by the diversion of waters and again there are other populations in the United States below the mouth of the Illinois which are benefited thereby.

It may be said, therefore, that a population nearly if not substantially equal to that outside of Chicago and bordering the Great Lakes above Niagara have an indentical interest in the maintenance of all conditions which favor navigation.

*NOTE: This statement is based on complete development and full utilization by means of dams. Reserving the scenic attractions of Niagara River under the Treaty of 1909 and employing the usual methods of development, the statement in Topic 51 is also true.

It may be said further that such population have a deep and immediate concern in the development of a deep waterway through the State of Illinois and onward to the Gulf of Mexico, and that that deep interest should in truth extend to all the population about the Great Lakes and differ only perhaps in degree. In addition to the above this half of the total has a paramount interest in its life and health, which should be generously recognized by the other half even though minor damage and inconvenience be inflicted. If it is shown later that no actual harm or inconvenience is necessary, then most certainly there can be no valid ground for objection, in view of the tremendous potentialities involved in the diverted water.

8. The effect on lake levels and the damage caused thereby is likely to be overestimated. Causes affecting lake levels are many and show up in continual oscillation, sometimes through a considerable range, and in changes of general level with the seasons in the years, and through a cycle of years. There are no fixed rules to govern the variable effects due to difference in rainfall, vegetal cover, run-off and evaporation, and the individual and collective effects are so incapable of precise definition that it is impossible to deduce a remainder which could be assigned to an unknown cause. The fact of a diversion and the amount thereof would be discoverable only in the new outlet itself, and the valuation of the effects thereof would be purely a deduction from physical data and not a subject of direct observation. Whatever the effect may be, by such amount is lowered the general horizon of oscillation and change. Owing to the variations vessels cannot utilize the depth with the same degree of certainty as though a fixed and invariable plan prevailed, and it may be questioned whether a proper rule of damage can be based on the theory of a change in such plan. In other words, is it not attempted to apply the precision of the rifle to a shotgun problem?

It is to be noted that the natural depths at characteristic localities in the intermediate channels of the lakes were originally from ten to twelve feet and that these depths were increased at various times until a general depth of sixteen feet prevailed, and that between the years 1891 and 1895-6 these channels were deepened by four to five feet and greatly enlarged, and that coincident with the completion of these deeper channels we have the characteristic low water period. It is to be noted further that following the high water of 1886

there has been almost a continuous deficiency in rainfall, amounting to six feet more or less at various lake stations, and this coupled with accentuation of evaporation has produced profound results. It is to be noted also that the Board of Engineers on Deep Waterways, in its report of 1900, recognizes a permanent lowering of Lakes Michigan and Huron by nearly one foot, through a change in the outlet at Port Huron. It may be said further that the report of the International Waterways Commission for 1910 calls attention to the fact that the level of Lake Superior was unwittingly controlled for a number of years by the works of the International Bridge and of the water power companies at Sault Ste. Marie, with consequent influences on the levels of the lakes below, and this fact, though the effects were comparable with those assigned to the Chicago Drainage Canal, seems to have attracted no attention. These several and superior effects seem to have aroused no excitement among vessel interests, nor have they led to any propositions for remedying the same. It is therefore not quite understandable why such supreme importance is attached to the minor effects produced by the diversion at Chicago. The report of the First International Waterways Commission, 1896 (American section, known as "United States Deep Waterways Commission"), gives all obtainable information respecting lake levels prior to 1860, and it appears that the highest water known occurred in 1838, and that the lowest water known occurred nineteen years previously, in 1819-20, and that such low water was from eight inches to one foot lower than the low water of 1895-6. It appears, therefore, that the extreme fluctuation of the lake surface took place within a period of nineteen years, and before inhabitation had changed conditions in the watershed, and before lake channels had been disturbed. The range of fluctuation in Lake Michigan was between six and seven feet.

Had the Chicago diversion begun in 1895-6, contemporaneously with the opening of the deeper intermediate channels and the Poe Lock at the Soo, and when the lake fleet had not developed to these greater depths, it could not have been said that navigation interests were damaged by reason of the fact that the unutilized depths had been diminished by a number of inches. On the contrary, it is known that great loss in vessel property took place as soon as the larger depths were utilized by the greater carriers, and that such damages were without redress because what had been done was in the interest of the common welfare. The new lock at the

Soo authorized some time since and now under construction is to have a depth of 24½ feet, the same as that of the Drainage Canal, or several feet in excess of existing channels, and the policy of producing channels which shall equal such lock depth is already established. In view of this project actually in sight and in process of consummation, is it to be said that vessel interests will be damaged by a diminution in depth not yet utilized and for which no vessel exists? In the progressive deepening of lake channels and that of the harbors which must follow is not the effect of diversion substantially met, and, if not, does it involve more than a nominal increase in cost to meet the deficiency due to such cause?

9. A minor damage or inconvenience may be without redress under the doctrine of "comity among utilities," but that is no sufficient reason for denying the appropriation of public waters to beneficial use when and where the benefits are manifold and contribute in an extraordinary degree to the public welfare. The report of the International Waterways Commission, on the Chicago Drainage Canal, 1907, estimates the damage to be occasioned by the diversion of 10,000 cubic feet per second and the consequent lowering of the lakes by six inches at $1,500,000 per annum, in round numbers. On the other hand, the value from the bettered sanitary condition at Chicago and in the Illinois Valley cannot be estimated in figures; the value of the water highway that is to be produced with the aid of this diverted water is comparable with that of the Great Lakes; the reclamation of the overflow lands of the Illinois Valley is facilitated, and this represents a very large sum; water powers are created under public ownership, and this represents another large contribution to wealth; and again fisheries develop through the greater volume and the enrichment of the waters.

In the ten years between 1896 and 1906, the fisheries of the Illinois River increased from a catch of about 8,000,000 pounds to 22,000,000 pounds and the stream was second to the Columbia, where in fact the fish are the product of the sea. The value of these fish on the shore of the waters was over $770,000, or $11 per acre for all the water space in the Illinois Valley, and this value was doubled by the time the fish reached the consumer or exceeded $1,500,000, and will grow exceedingly with the fuller development of the Chicago program. In other words, the value of the annual fish crop which has come to pass through the carrying out of this en-

terprise exceeds all the damage which it is claimed has been occasioned to the shipping interests on the Great Lakes.

10. A remedy that may be applied so as to conserve the actual uses of water now made and avoid all damage is a complete answer to any objection to the taking of any volume of water that can be applied to other beneficial uses. No one will contend that waters cannot be appropriated if other and prior appropriations and dedications are not unduly interfered with.

The International Waterways Commission has examined a number of remedies, one of which is that of deepening channels and harbors by one foot at a cost of $12,500,000, which would allow the taking of 20,000 cubic feet of water per second, or a third more than the capacity provided for in the channels at Chicago. It is submitted that this cost would be still less if the deepening is part of the program for deeper channels and harbors now initiated by the construction of the new lock at the Soo.

The International Waterways Commission, in its report for 1910, suggests a remedy which it regards as better and sufficient by means of compensation work. It is now engaged in working out the problem connected therewith, and is to report thereon before closing its labor.

It is unnecessary to multiply instances or advance suggestions. Congress has authorized examinations and reports respecting the better control of lake levels and has also authorized examinations and reports based on the theory of utilizing waters diverted from Lake Michigan.

The State of Illinois directly and through its agencies has made a very large expenditure and is prepared to make other very large expenditures, the effect of which will be to produce a great waterway, which will pass to the control of the General Government, under all state laws thus far made and proposed, and the United States will thus be relieved of cost many times exceeding the cost of any remedies that may be required on account of diverted waters. It is felt, therefore, that the United States should raise no question of liability as against the State of Illinois and its agencies on matters beyond their jurisdiction.

11. The international question and the bearing thereon of the treaty of 1909 respecting boundary waters between the United States and Canada will not be entered into at this time. Attention, however, is called to an opinion furnished to the State Department by the Attorney General, Judson Harmon (see Opinions of Attorney Generals, 1895-7), in re-

gard to a boundary water of the United States and Mexico, the Rio Grande del Norte, the navigation of which is expressly guarded by specific terms in the treaty of Guadloupe Hidalgo, between the United States and Mexico. In this case the waters of the stream were consumed in the development of the State of Colorado and the Territory of New Mexico, and in the opinion the rules of international law applicable in such cases are fully set forth.

It appears that the right of the people of a State to develop their resources and opportunities is fundamental, and that the United States cannot qualify by treaty sovereign rights not possessed by it.

12. In conclusion it may be recapitulated:

(a) Under proper and sufficient authority, physically expressed in adequate channels actually constructed and in existence, the right is established to take 15,000 cubic feet of water per second from the Chicago River by way of the main drainage channel or outlet and by way of the Illinois and Michigan Canal.

(b) The Secretary of War and Chief of Engineers, U. S. A., may not impair this right, but shall regulate the manner of taking so that no undue injury shall occur to the navigable channels through which such waters shall pass, as heretofore contrued in permits.

(c) Independent of the questions referred to above under (a) and (b) the right to take the water should not be questioned in view of the enormous expenditures already made, the policies established and the expenditures predicated thereon, and in view of great and manifold benefits as contrasted to minor damage and inconvenience.

(d) Such minor damage as may occur is not irreparable and may be remedied at comparatively small cost, and the taking of waters for beneficial uses under such circumstances is not a subject for objection.

(e) The remedy, if any, is not within the jurisdiction of the State of Illinois and should be applied by the United States in view of the tremendous contribution of the State of Illinois and its agencies to a waterway of national and international importance.

(f) All the points herein referred to can be set forth and established in a brief in full which the time available has not permitted.

On behalf of and for the City of Chicago.

(Signed) LYMAN E. COOLEY,
Consulting Engineer."

United States of America,
vs.
Sanitary District of Chicago.

Proceedings in the above entitled cause before the Commissioner, on December 16, 1914.

Mr. Wilkerson: On behalf of the Complainant I desire to submit to the Commissioner and offer in evidence further documentary proof pursuant to the terms of the stipulation of the parties herein signed on November 16, 1914, as follows:

"UNITED STATES OF AMERICA

War Department.

Washington, October 28, 1914.

I hereby certify that the papers hereto attached are true copies of papers on file in this office, described as follows:

'Draft for a permit * * * respectfully submitted to the Secretary of War by the Sanitary District of Chicago for a formal permit to open the channel, the Sanitary District of Chicago by B. A. Eckart, one of the Trustees. (E. D. 28918/7.)

The Sanitary District of Chicago, letter of Alexander J. Jones, President, to Secretary of War, July 15, 1901. (E. D. 35242/67.)

The Sanitary District of Chicago, letter of Board of Trustees, to the Secretary of War, October 16, 1901. (E. D. 35242/69.)

The Sanitary District of Chicago, letter of William H. Baker, Vice President, to Major J. H. Willard, October 16, 1901. (E. D. 35242/70.)

The Sanitary District of Chicago, letter of Board of Trustees to the Secretary of War, October 24, 1901. (E. D. 35242/72.)

The Sanitary District of Chicago, letter of Thomas A. Smyth, et al., to the Secretary of War, December 29, 1902. (E. D. 35242/78.)

The Sanitary District of Chicago, letter of Robert R. McCormick, President, to Colonel W. H. Bixby, November 28, 1906. (E. D. 28918/57.)

The Sanitary District of Chicago, letter of Isham Randolph, Chief Engineer, to W. H. Bixby, December 3, 1906. (E. D. 28918/67.)

'G. Form of War Department permit desired by Sanitary District of Chicago * * *'. (E. D. 28918/65.)

The Calumet-Sag Channel. The Project. (E. D. 28918/60.)

Argument for reversing the flow of the Calumet River. (E. D. 28918/63.)

The Sanitary District of Chicago, letter of G. M. Wisner, Chief Engineer, to the Secretary of War, September 2nd, 1907. (E. D. 64900.)

'September, 1907. Sanitary District of Chicago. Plan of location of proposed North Shore Drainage Channel between Lake Michigan and North Branch of Chicago River' * * *. (E. D. 64900/1.)

(Signed) DAN C. KINGMAN.

I hereby certify that Dan C. Kingman, Chief of Engineers, U. S. Army, who signed the foregoing certificate, is the Chief of Engineers, U. S. Army, and that to his certification as such full faith and credit are and ought to be given.

In testimony whereof I, Lindley M. Garrison, Secretary of War, have hereunto caused the seal of the War Department to be affixed and my name to be subscribed by the Acting Assistant and Chief Clerk of the said Department, at the City of Washington, this 29th day of October, 1914.

(Signed) LINDLEY M. GARRISON,
Secretary of War.

By JOS. RANDOLPH,
(Seal) *Acting Assistant and Chief Clerk.*"

Whereas, the Sanitary District of Chicago, a municipal corporation duly organized by an Act of the General Assembly of the State of Illinois, approved May 29, 1889, in force July 1, 1889, and Acts amendatory thereof has proceeded under said Acts and the amendments thereto to construct a channel of a capacity capable of flowing 300,000 cubic feet per minute at a velocity of one and one-quarter miles per hours, and,

Whereas, the said channel connects with the West Fork of the South Branch of the Chicago River at Robey Street in the City of Chicago; and,

Whereas, under the powers conferred by the aforesaid Acts the said District prepared plans for deepening the West Fork of the Chicago River and the South Branch thereof throughout the entire length from Adams Street in the City of Chicago to Robey Street, so as to secure a depth of twenty feet, and,

Whereas, the said plans provided for widening the said river at sundry contracted points to secure the requisite volume of flow without undue acceleration of current and in those

places where widening was not possible the plans provided for the construction of by-passes or covered waterways, and in two instances for the removal of center pier bridges and the substitution of bridges of the bascule type without central supports; and,

Whereas, the general plans for this improvement were duly submitted to the Secretary of War in 1896 and by him approved in a certain communication dated July 3, 1896, said approval being subject to limitations therein set forth among which was the requirement that plans in detail for the several parts of the work should be submitted to the War Department for approval before any work should be done thereunder; and,

Whereas, in compliance with this requirement of the said approval of July 3, 1896, the Sanitary District has submitted to this Department plans for certain by-passes, cofferdams and bridge structures which have, from time to time, received the approval of the Secretary of War, as set forth in permits issued by him under the following dates: November 16, 1897; November 30, 1898; January 13, 1899, and March 10, 1899; and,

Whereas, the said District has proceeded under these several approvals and permits to perform the work shown upon the plans; and,

Whereas, the entire main channel of the said District and the work in the Chicago and Des Plaines Rivers is now rapidly approaching completion according to said plans; and

Whereas, it is necessary under the Act of Congress of September 19, 1897, that authority shall issue from the War Department under which the said Sanitary District may cause the waters of the Chicago River to flow to the west into the main channel of the said District; and,

Whereas, the widening and deepening, already accomplished, and as further projected by the Sanitary District is a betterment to navigation in the Chicago River; and,

Whereas, it has been shown by them that they have constructed such movable dams and sluice gates as will at all times secure absolute and complete control of the volume and velocity of flow through the main channel of said District and consequently through the Chicago River;

Now Therefore, by virtue of the authority vested in me by the laws of the United States I hereby authorize said Sanitary District of Chicago to open the channel constructed by it so soon as it shall have completed all of the work outlined by it in the Chicago River.

Said document has the following endorsement:

"Respectfully submitted to the Secretary of War by the Sanitary District of Chicago for a formal permit to open the channel.

The Sanitary District of Chicago, by B. A. Eckart, one of the Trustees."

Letter Head of
The Sanitary District of Chicago

Chief Clerk
Jul
17
1901
War Dep't.
Rec'd
Jul 17 1901
Office Secretary of War.

Chicago, July 15, 1901.

"To the Honorable Elihu B. Root,
Secretary of War,
Washington, D. C.

Sir:

I have the honor to request on behalf of the Sanitary District of Chicago that your order of April 9, 1901, restricting the flow of water through the Chicago River to 200,000 cubic feet of water per minute, may be so amended as to permit the Controlling Works at Lockport, the outlet of the main drainage channel, to be so regulated as to permit at that point a flow of 300,000 cubic feet of water per minute, between the hours of 4:00 P. M. and 12:00 o'clock midnight.

The Board of Trustees of the Sanitary District have rigidly observed the restrictions of your order of April 9th, 1901, but the result has been that the water in the Main Drainage Channel has become greatly polluted and very offensive both to sight and smell and is working such hardship upon the valley communities as to evoke frequent protest from various cities and municipalities along the Des Plaines and Illinois Valleys.

By such a modification of your restricting order as is herein petitioned, it would be possible for the Sanitary District to secure much better drainage of the City of Chicago and the purification of the waters of the Chicago River without any hardship or inconvenience whatever to the interests of navigation; as the opening of the controlling works to a flow of 300,000 cubic feet of water per minute would produce no appreciable effect upon the current of the Chicago River until three hours thereafter and would not produce the full effect until about eight hours after the opening of the gates. Therefore, by again diminishing the flow at midnight to the requirements of your order, or to 200,000 cubic feet of water per minute, the normal condition in the Chicago River would be restored before six A. M. on the following day and thus no hard-

ship or inconvenience occasioned to the navigation interests of the Chicago River.

I have the honor to be, very respectfully yours,

(Signed) ALEXANDER J. JONES,
President."

The above document has the following endorsement:

The Secretary.

60 of 1900 Office Chief of Engineers.

—

37 1901 35242

War Department Jul 18 35242

67 1901

War Department.

Chicago, Illinois, July 15, 1901.

Sanitary District of Chicago,
Alexander J. Jones, President.

Request that the restriction of April 9, 1901, regulating the flow of water through the Chicago River to 200,000 cubic feet per minute, may be amended to permit a flow of 300,000 cubic feet per minute between the hours 4 P. M. and twelve o'clock midnight.

Noted—Map Files.

Recd. Back. Office Chief of Engineers, July 26, 1901.
File 55, 65, 66, 68, accp.
Recd. Back. Office Chief of Engineers, July 25, 1901.
File 55, 65, 66, and ps accomp.

(Second endorsement.)

Office Chief of Engineers
U. S. Army.

July 22, 1901.

Respectfully returned to the Secretary of War.

By an instrument dated April 9, 1901, the Secretary of War directed the Sanitary District of Chicago to regulate the discharge from the Chicago River into the Drainage Canal so that the maximum flow through the Chicago River and its South Branch shall not exceed 200,000 feet per minute.

The Sanitary District now asks that this order be so amended as to permit an increase of the flow into the canal to 300,000 cubic feet per minute between 4 P. M. and 12 midnight, daily.

It is the opinion of Major Willard, expressed in the accompanying letter of the 16th inst., that the request should be

granted subject to revocation by the Secretary of War in case the increase be found dangerous to navigation.

I concur in this opinion and recommend that the order of April 9, 1901, be modified accordingly.

G. L. GILLESPIE,
Brig. Gen. Chief of Engineers,
U. S. Army.

35242

67
Inclos. 55, 65, 66, accompan'g

(Chief Clerk July 22, 1901. War. Dep't.)

Rec'd
Back Jul 22, 1901 Record Div. War Dep't.

Chief Clerk.

(Third Endorsement.)
War Department.
July 23, 1901.

Approved as recommended by the Chief of Engineers.

E. ROOT,
Secretary of War.

Rec'd Jul 25, 1901 Record Div.
back War Dep't.

Chief of Engineers.

Rec'd Office Chief of Engineers. Jul 25, 1901.
Rec'd Record Div.
Back Jul 25, 1901. War Dep't."

Letter Head of
The Sanitary District of Chicago.

Chief Clerk
Oct 19 1901
War Department.

Chicago, October 16, 1901.

Received
Oct 19 1901
Office
Secretary of War.

Hon. Elihu Root,
Secretary of War of the United States,
Washington, D. C.

Dear Sir:

The undersigned respectfully petition you as Secretary of War to give us permission for an increased flow in the Chicago River, over the 200,000 cubic feet a minute, now in force by your order of July 23, 1901. We, the petitioners, inasmuch as a number of very material improvements have been made in the Chicago River, such as removing center pier bridges,

widening the river at many points, and also deepening the same, thereby allowing a much greater flow without any perceptible increase in velocity of the current, believe that we are full justified in petitioning you to grant to the Board of Trustees of the Sanitary District of Chicago permission to increase the flow from 200,000 to 250,000 cubic feet per minute, during that period of the day allowing a flow of 200,000 cubic feet per minute.

Below we enumerate the following improvements:

The old Randolph Street center pier bridge is now removed, and all obstructions which hindered navigation will be out of the way in but a few weeks, and a bascule type, with a 140-foot opening, will be erected, similar to that on Taylor Street.

The old Harrison Street center pier bridge is removed, and a new bascule type bridge with 140-foot opening, with by-passes on each side, is being erected instead.

At Taylor Street the new bascule bridge is in operation, which has a clear opening of 120 feet.

The new bascule bridge of the Chicago Terminal Transfer Railway Company is about ready to be operated, and the old center pier bridge will immediately be removed.

Just north of 12th Street the river has been widened, by the cutting away of the 12-foot corner, which projected into the river at this place.

From 12th Street to Stewart Avenue, the river has been deepened below the hydraulic grade line to a depth of 26 feet. Also a strip from 400 feet above 18th Street to Stewart Avenue was made 200 feet wide.

At Canal Street, the old jack-knife bridge with projecting piers has been removed, and a new bridge of the bascule type—the same as at State, Randolph and Harrison Streets—is in process of erection. The river from Canal Street to 22nd Street has been widened in the east side about 30 feet.

The deepening of the river to 26 feet, from 22nd Street to about 500 feet west of Main Street, is almost completed. Along this stretch the river has been widened for a distance of about 300 feet at Collision Bend.

From 150 feet east of Halsted Street to 150 feet west of Halsted Street, the river was deepened to 28 feet.

From 900 feet east of Main Street to 300 feet west of Main Street, the river has been widened to 200 feet.

The old center pier bridge and pier at Main Street have been removed and a new bridge of the same type as at Taylor Street is being erected.

The old center pier bridge and center pier at Ashland Avenue have been removed, and a new bridge of the Page Bascule Type, with a clear opening of approximately 140 feet, with a 40-foot by-pass on each side of the river, is in process of erection.

The removal of the State Street center pier bridge has been contracted for, and a bridge of bascule type with 140-foot clear opening, and by-passes on each side, is to be erected immediately.

In view of the foregoing improvements that are being carried out now, and many others which will follow as quickly as said work can be performed, we feel justified in asking you to permit the Sanitary District of Chicago to increase the flow as hereinbefore suggested.

The Sanitary District of Chicago has ample funds to pay for all of these improvements as fast as they are carried out and many others that are being matured, as the Legislature during last spring empowered the District to issue $5,000,000 additional bonds, besides, the tax levy will be somewhat larger than in the past.

While we believe that the improvements that have been made on the Chicago River, and the additional improvements that will be completed in the very near future, warrant us fully to ask for your permission for a full flow of 300,000 cubic feet per minute, but inasmuch as we desire to give the greatest consideration to the navigation interests on the Chicago River, we will ask only for 250,000 cubic feet per minute until the close of navigation.

Trusting that you will immediately grant us said permission, we are,

Respectfully,

(Signed) WILLIAM H. BAKER.
JOSEPH C. BRADEN.
ZINA R. CARTER.
FRANK X. CLOIDT.
WILLIAM LEGNER.
THOMAS A. SMYTH.
THOMAS J. WEBB.
FRANK WENTER,

Board of Trustees of the Sanitary District of Chicago.

(Following endorsements on back of said document):
Office of Secretary

Office, Chief of Engineers.

2560 of 1900

40 Oct 21 35242 1901.

1901 69

War Department.

War Department.

Chicago, Ill.
October 16, 1901.

Board of Trustees of the
Sanitary District of Chicago:

Requests permission, for reason stated within, to increase the flow in the Chicago River from 200,000 cu. ft. per minute to 250,000 c. f. p. m. during that period of the day allowing a flow of 200,000 c. f. p. m.

Incloses letter signed by William H. Baker, Sec'y, to Maj. J. H. Willard, dated October 16, 1901.

1 Inc.

Incls. 74 noted in Map Files, Dec. 24, 1901.
Rec'd Office Chief of Engrs Jan 20 1903,
back with 78.
File 55, 67, 68, 70, 73. Permit & pleadings.
Inc. 70 & 1 Addt. Accompg.
Rec'd Oct 19 1901, Rec. Div. War Dep't
Chief of Engineers.

2 Indorsement.
Office Chief of Engineers
U. S. Army.

Oct. 23, 1901.

Respectfully referred to Lieut. Col. O. H. Ernst, Corps of Engineers for report. To be returned. By command of Brig. Gen. Gillespie.

(Signed) A. McKenzie,
Colonel, Corps of Engineers.

35242

69 U. S. Engineer Office
Incls. 70 accomp'g. Northwest Division Chgo 18 Rec'd
Oct. 26, 149

1901.

Third Indorsement.
Office of Division Engineer,
Northwest Division
Chicago, Ill. Nov. 5, 1901.

Respectfully returned to the Chief of Engineers with report of this date.

(Signed) O. H. ERNST.
Lt. Col. Corps of Engineers,
Div. Engr. N. W. Div.

35242-69
Inclos. 70 accompg.
1 inclo.

Fourth Indorsement.
Office Chief of Engineers
U. S. Army.
November 9, 1901.

Respectfully returned to the Secretary of War.

By direction of the Secretary of War, the Sanitary District of Chicago is required to regulate the discharge of water into the Chicago Drainage Canal so that the maximum flow through the Chicago River shall not exceed 200,000 cubic feet per minute from midnight to 4 P. M. nor 300,000 cubic feet per minute from 4 P. M. to midnight.

Application is now made by the Board of Trustees for permission to increase the flow between midnight and 4 P. M. daily, to 250,000 cubic feet per minute.

In the accompanying report of the 5th instant, the local engineer officer Lieut. Col. O. H. Ernst, Corps of Engineers, recommends that, in lieu of the present authorized rates of flow as stated above, authority be granted the applicant to regulate the discharge so that the maximum flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day the Board to be responsible for all damages resulting thereby to navigation interests.

I concur in this recommendation; it being understood that this permission will be subject to modification should the change authorized prove dangerous to navigation.

Previous papers herewith.

(Signed) G. L. GILLESPIE.
Brig. Gen. Chief of Engineers.

35242

69
Inclos 55, 67, 68, 70, 73, accomp'g.
Rec'd Nov 11, 1901. Rec. Div. War Dept.
Back Assistant Secretary.
(Asst. Secy's Office War
(Stamp) Dept. Nov. 15, 1901)

(Fifth Indorsement)
War Department.
November 25, 1901.

Approved as recommended by the Chief of Engineers, with the express understanding that this permission will be subject to such modification as the public interest may require, it being further understood that the Board is to be responsible for all damages inflicted upon navigation interests.

Let formal instrument of authority be prepared.

(Signed) WM. ___ SINGER,
Assistant Secretary of War.

Rec'd Nov. 26, 1901. Record Div. War Dept.
Back Judge Advocate Gen'l.

(Seventh Indorsement)

6353 B

War Department
Judge-Advocate-General's Office.
Washington, D. C., Nov. 4, 1901.

Respectfully returned to the Secretary of War with instrument prepared in duplicate.

(Signed) GEORGE B. DAVIS,
Judge-Advocate-General.
(Stamped) Chief Clerk Dec 5, 1901,
War Dept.

Rec'd Dec 5, 1901. Record Div. War Dep't.
back. Correspondence.
Rec'd Dec 7, 1901. Record Div. War Dep't.
back Chief of Engineers.

Letterhead of the Sanitary District
of Chicago.
Chicago, October 16, 1901.

Maj. J. H. Willard,
United States Government Engineer,
1637 Indiana Avenue, City.

Dear Sir:

I have been directed by the Board of Trustees of the Sanitary District of Chicago to forward to you the inclosed letter, addressed to the Secretary of War, which is in regard to increasing the flow of water in the Chicago River.

The Trustees would feel very grateful to you for your cooperation and assistance in bringing about the desired permission from the Secretary of War, and they desire that I

suggest that you take such action in the matter as you may deem consistent.

Yours very respectfully,
(Signed) WM. H. BAKER,
Vice-President.

Indorsed on the back as follows:

Office of the Secretary. Office Chief of Engineers.
Oct 19 2560 1901 Oct 21 35242

41 70 1901.
War Department War Department
U. S. Engineer Office
Chgo Northwest Division 149
18/1 Rec'd Oct. 26. 1901.
Chicago, Ill.,
Oct. 16, 1901.

Board of Trustees,
Sanitary Dist. of Chicago,
Wm. H. Baker, Sec'y.
to
Major J. H. Willard.
Rec'd. Office Chief of Engineers
Back Dec 7, 1901.
with inc. 69
Rec'd Office Chief of Engineers
Back Nov 7, 1901.
With inc. 69.

Letterhead of the Sanitary District
of Chicago.

Chicago, Oct. 24, 1901.

Hon. Elihu Root,
Secretary of War of the United States,
Washington, D. C.

Dear Sir:

The undersigned respectfully petition you as Secretary of War to give us permission for an increased flow in the Chicago River, over the 200,000 cubic feet a minute now in force by your order of July 23, 1901. We, the petitioners, inasmuch as a number of very material improvements have been made in the Chicago River, such as removing center pier bridges, widening the river at many points, and also deepening the same, thereby allowing a much greater flow without any perceptible increase in velocity of the current, believe that we are fully justified in petitioning you to grant

to the Board of Trustees of the Sanitary District of Chicago permission to increase the flow from 200,000 to 250,000 cubic feet per minute, during that period of the day allowing a flow of 200,000 cubic feet per minute.

Below we enumerate the following improvements.

The old Randolph street center pier bridge is now removed, and all obstructions which hindered navigation will be out of the way in but a few weeks, and a bascule type with 140 foot opening, will be erected, similar to that on Taylor street.

The old Harrison street center pier bridge is removed, and a new bascule type bridge, with 140 foot opening, with by-passes on each side, is being erected instead.

At Taylor street the new bascule bridge is in operation, which has a clear opening of 120 feet.

The new bascule bridge of the Chicago Terminal Transfer Railway Company is about ready to be operated, and the old center pier bridge will immediately be removed. (Tested October 25. Opened in 1m 55s.)

Just north of 12th street the river has been widened by the cutting away of the 12 foot corner, which projected into the river at this place.

From 12th street to Stewart avenue, the river has been deepened below the hydraulic grade line to a depth of 26 feet. Also a strip from 400 feet above 18th street to Stewart avenue was made 200 feet wide.

At Canal street the old jack-knife bridge with projecting piers has been removed, and a new bridge of the bascule type—the same as at State, Randolph and Harrison streets—is in process of erection.

The river from Canal street to 22nd street has been widened in the east side about 30 feet.

The deepening of the river to 26 feet, from 22nd street to about 500 feet west of Main street, is almost completed. Along this stretch the river has been widened for a distance of about 300 feet at Collision Bend.

From 150 feet east of Halsted street to 150 feet west of Halsted street, the river was deepened to 28 feet.

From 900 feet east of Main street to 300 feet west of Main street, the river has been widened to 200 feet.

The old center pier bridge and pier at Main street have been removed, and a new bridge of the same type as at Taylor street is being erected.

The old center pier bridge and center pier at Ashland ave-

nue have been removed, and a new bridge of the Page bascule type, with a clear opening of approximately 140 feet, with a 40 foot by-pass on each side of the river, is in process of erection.

The removal of the State street center pier bridge has been contracted for, and a bridge of bascule type with 140 foot clear opening, and by-passes on each side, is to be erected immediately.

In view of the foregoing improvements that are being carried out now, and many others, which will follow as quickly as said work can be performed, we feel justified in asking you to permit the Sanitary District of Chicago to increase the flow as hereinbefore suggested.

The Sanitary District of Chicago has ample funds to pay for all of these improvements as fast as they are carried out, and many others that are being matured, as the legislature during last spring empowered the District to issue $5,000,000 additional bonds, besides, the tax levy will be somewhat larger than in the past.

While we believe that the improvements that have been made on the Chicago River, and the additional improvements that will be completed in the very near future, warrant us fully to ask for your permission for a full flow of 300,000 cubic feet per minute, but inasmuch as we desire to give the greatest consideration to the navigation interests on the Chicago River, we will ask only for 250,000 cubic feet per minute until the close of navigation.

Trusting that you will immediately grant us said permission, we are,

Respectfully,
(Signed) WM. H. BAKER,
JOS. C. BRADEN,
ZINA R. CARTER,
FRANK X. CLOIDT,
WM. LEGNER,
THOMAS A. SMYTH,

FRANK WENTER,
Board of Trustees of the Sanitary District of Chicago.

Indorsed on the back of said document is the following:

Office Chief of Engineers
35242

72
Oct 28 1901
War Department.

U. S. Engineer Office
Chicago, Ill.
Received.

Oct 25 1901

Chicago, Ill., Oct. 24, 1901.

Board of Trustees of the
Sanitary District of Chicago.

They petition for permission to increase the flow in Chicago River from 200,000 to 250,000 cu. ft. per minute, inasmuch as a number of material improvements have been made in the river such as the moving center pier bridges, widening the river and deepening it. They enumerate the improvements made in the river and those now in progress.

They believe these improvements warrant them in asking for permission for 300,000 ft. per min. but they ask for only 250,000 until the close of navigation."

Letterhead of
The Sanitary District of Chicago.

To the Honorable Elihu B. Root,
Secretary of War,
Washington, D. C.

Dear Sir:

This being the closed season of navigation and no vessel interest being jeopardized by an increased current in the Chicago River, we feel it to be in line with the duty we owe to the citizens of Chicago and the obligation which rests upon us to use every endeavor to comply with the State law which brought the Sanitary District into existence, to request you to grant us permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute. We ask this in the interest of the health of the people of Chicago. The work of this District for construction, right of way, administration and interest has already cost our citizens $41,000,000.00; and other millions are being expended in the work of deepening and widening the Chicago River and substituting bascule bridges for the obstructive center pier structures which are so harmful to navigation. Our wish is, by introducing the largest possible volume of water from the lake during the closed season of navigation, to draw into the channel the

largest amount of contamination that can be reached by the current thus introduced. As you know, for long years the discharge of our sewers has been into the lake and the resulting foul sediment defiles the shore line for miles of frontage. When storms, such as we have recently been subjected to, churn up this slimy deposit it often drifts out to our water intakes making our water supply unpalatable and unhealthful. The more of this turbid water that we can draw into our channel, the better for the health of our people and the sooner shall we be able to carry off the accumulations of sewage deposit which line our shores. We are working with a steadfast purpose of making the Chicago River what it ought to be as a navigable stream and we feel a justifiable pride in what we have already accomplished in that direction.

We are now in the courts condemning lands for widening and deepening the river which will cost this District enormous sums of money, which we will gladly pay to hasten the results we have set out to attain.

We recognize your responsibility as the guardian of the interest of navigation but we believe that you will readily admit that even such vast interest ought and must make concessions to conserve the health of 2,000,000 of people and we shall hope for your favorable action upon our petition.

Very respectfully,

(Signed) THOMAS A. SMYTH,
JOS. C. BRADEN,
ZINA R. CARTER,
THOMAS J. WEBB,
FRANK X. CLOIDT,
FRANK WENTER,
WM. H. BAKER,
WM. LEGNER,
ALEXANDER J. JONES."

The above document has the following indorsements:

Office Chief of Engineers
Jan 2 35242 1903 35242

78
War Department
Office of the Secretary
Jan 5 3188 1903
War Department.
United States Engineer Office
Chi R Chicago, Ill. 26 3/2
Dec 30 1902 889
Rec'd _____

Chicago, Ill.,
Dec. 29, 1902.

Sanitary District of Chicago:

Requests permission of Secretary of War to increase the flow through the Chicago River from 250,000 to 350,000 cubic feet per minute.

Incls. 80 noted in Map Files, Jan. 27, 1903.
35242

69474 herewith
Jan 21, 1903 copy of inclo 80 to Lieut. Col. Ernst, by indorsement.
Rec'd back Office Chief of Engrs Jan 20 1903
Inclo 69, 74 & 2 additional Incls.

(First Indorsement.)
U. S. Engineer Office,
Chicago, Ill., Dec. 30, 1902.

Respectfully forwarded to the Chief of Engineers, with the recommendation that the petition be granted for the season closed to navigation; that is, that the flow of 350,000 cubic feet per minute be authorized until March 31st next, after which it shall be reduced to 250,000 cubic feet per minute, as now authorized.

(Signed) O. H. Ernst,
Lieut. Col., Corps of Engineers, Division Engineer, N. W. Div.

2nd Indorsement
Office Chief of Engineers,
U. S. Army.

January 5, 1903.

Respectfully forwarded to the Secretary of War concur-

ring in the recommendation of Lieutenant Colonel Ernst in 1st indorsement hereon.

By instrument dated December 5, 1901, the Secretary of War granted the Sanitary District of Chicago permission to regulate the discharge of water into the drainage canal so that the maximum flow through the Chicago River should not exceed 250,000 cubic feet per minute throughout the 24 hours of the day.

(Signed) G. L. GILLESPIE,
Brig. Gen. Chief of Engineers, U. S. Army.
(Stamp of Chief Clerk)
Rec'd Back Jan 5 1903. Record Div.
War Dept.
Judge Advocate General.

35242

78 Inclos. 69 and 74, accomp'g.
Rec'd Jan. 6, 1903—J. A. G. O.

6353 4th Indorsement C. B.
War Department.
Judge Advocate General's Office.
Washington, D. C., Jan. 16, 1903.

Respectfully returned to the Secretary of War with instrument prepared in duplicate.

(Signed) GEORGE B. DAVIS,
Judge-Advocate General.

Stamp as follows: Chief Clerk, Jan. 16, 1903, War Dept.
Rec'd Jan 16, 1903. Record Div.
Back War Dept.
Rec'd Jan 16, 1903. Record Div.
Back War Dept.
Rec'd Office Chief of Engineers Jan. 20, 1903.

Letter Head of The Sanitary District of Chicago.
Chicago, Dec. 3, 1906.

W. H. Bixby,
Col. Corps of Engineers, U. S. A.,
Federal Building, City.

Sir:

Although I personally delivered the maps and plans hereinafter enumerated, to you this afternoon, yet as a matter of record I think best to put it in the form of a letter:

A form of permit prepared by the attorney of the Sanitary

District of Chicago and submitted for the signature of the Secretary of War.

A description of the project of the Sanitary District for a channel to be known as the Calumet-Sag Channel designed to reverse the flow of the Calumet River.

A brief argument setting forth the causes which make this work necessary.

A map showing the water shed of the Calumet region in Indiana and Illinois.

A map showing the location of the proposed Calumet-Sag Channel.

A map showing the proposed guard lock and controlling works at entrance to the artificial channel of the Calumet-Sag Channel.

A profile on the center line of the proposed Calumet-Sag Channel.

Thanking you for your kindness in undertaking to forward this matter to the Secretary of War, I am,

Yours very truly,

(Signed) ISHAM RANDOLPH,
Chief Engineer.

The above document is indorsed as follows:

Office of Chief of Engineers.
Dec. 6 28918 1906

67

War Department.
United States Engineer Office.
Cal. R. Chicago, Ill. 295.
Rec'd Dec. 3, 1906. H. 5353

Chicago, Ill.,
December 3, 1906.

Sanitary District of Chicago.
Isham Randolph, C. E.

Submits form of permit desired from the War Department to authorize the construction of proposed Calumet-Sag Channel as described in project, argument and maps submitted herewith.

7 inclosures in triplicate.

Letter Head of Sanitary District of Chicago.
Chicago, Nov. 28, 1906.

Col. W. H. Bixby,
Corps of Engineers, U. S. A.
Federal Building, City.

Dear Sir:

By order of the Board of Trustees of the Sanitary District of Chicago, I have the honor to transmit herewith copy of the permit desired from the Secretary of War.

Yours very truly,
(Signed) ROBERT R. MCCORMICK,
President.

Indorsed on back as follows:
Office of Chief of Engineers.
Dec. 6. 28918 1906.

57
Office of the Secretary.
War Department. 12721/36
Nov. 20.
War Department 1907.
Cal. R. 5353. United States Engineer Office.
Chicago, Ill. 295/0/0.
Rec'd Dec. 3, 1906.

Chicago, Ill.,
Nov. 28, 1906.

Sanitary District of Chicago,
Robert R. McCormick, Pres.

Forwards form of permit desired from War Dept. for proposed Calumet "Sag Channel."

Note: See letter of Dec. 3 from Isham Randolph C. E. in lieu of the above.

"Whereas, Heretofore, to wit, on the 8th day of May, A. D. 1899, the Secretary of War issued to the Sanitary District of Chicago a permit in words and figures as follows, to wit:

"'Whereas, by Section 10 of An Act of Congress, approved March 3, 1899, entitled "An Act Making Appropriations for the Construction, Repair and Preservation of Certain Public Works on Rivers and Harbors, and for other purposes," it is provided that it shall not be lawful to alter or modify the course, location, condition or capacity of the channel of any navigable water of the United States unless the work has been

recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same; and

"'Whereas, The Sanitary District of Chicago, a municipal corporation organized under the laws of the State of Illinois, has constructed an artificial channel from Robey Street, Chicago, to Lockport, and has been heretofore granted permission by the Secretary of War to make certain improvements in the Chicago River for the purpose of correcting and regulating the cross section of the river so as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of 1 1/4 miles an hour, it being intended to connect the said artificial channel with the West Fork of the South Branch of the Chicago River at Robey Street, in the said City of Chicago; and

"'Whereas, the said Sanitary District of Chicago has now applied to the Secretary of War for permission to divert the waters of the said Chicago River and cause them to flow into the said artificial channel at Robey Street as aforesaid; and

"'Whereas, the said Sanitary District of Chicago represents that such movable dams and sluice gates as are necessary to, at all times, secure absolute and complete control of the volume and velocity of flow through the Chicago River have been constructed:

"'Now, Therefore, The Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the waters of Chicago River to flow into the same subject to the following conditions:

"'1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

"'2. That if, at any time, it become apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such an extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

"'3. That the Sanitary District of Chicago must assume

all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River.

"'Witness my hand this 8th day of May, 1899.

"'R. A. ALGER,
"'*Secretary of War.*

"'JOHN M. NELSON,
"'*Brig. Gen'l, Chf. of Engrs.*
"'*U. S. A.*'"

And Whereas, The said Sanitary District of Chicago, in accordance with said permit, issued as aforesaid, did open its said channel in the said permit mentioned and caused the waters of the Chicago River to flow therein and therethrough to and into the Des Plaines River and has ever since maintained said flow of water from the said Chicago River and through its said Main Channel as aforesaid for the purposes of sanitation and commerce; and

Whereas, in furtherance of the objects and purposes of said Sanitary District of Chicago, said District now proposes to construct a channel, collateral to its Main Channel in said permit aforesaid mentioned, in order to provide a proper outlet for the drainage and sewage of that portion of said District adjacent to the Calumet River, which said proposed channel is to connect with the Little Calumet River at a point near the City of Blue Island and extend thence southwesterly along the depression generally known as "The Sag" for a distance of about sixteen miles, connecting with the Main Channel of the said Sanitary District at a point on said channel known as "Sag Bridge," or more particularly, with original Section 5, of the Main Drainage Channel. The route of said proposed channel, and its connection with said Main Channel of said Sanitary District and said Little Calumet River, being more fully and completely shown by the maps and plats hereto attached and marked Exhibits "A," "B," and "C," respectively; and

Whereas, The said Sanitary District of Chicago, pursuant to the authority vested in it by the State of Illinois, has duly ordained that said proposed collateral channel be constructed of the following dimensions, to wit: Of a width of ninety feet through the rock portions of said channel, with vertical sides, and of a width of seventy feet through the earth channel, with side slopes of five on three. The minimum depth of

said artificial channel, below flow line, to be twenty-two feet; and that, upon its completion, it be a navigable channel or canal subject to the uses of navigation to the same extent as the Illinois and Michigan Canal; and that it be so connected with the Little Calumet River as to cause the waters of said Little Calumet River to flow therein, thus reversing the said flow, at ordinary stages, from Lake Michigan, and from thence into the Main Channel of the said Sanitary District, and through said Main Channel in the same manner as the waters of the Chicago River now flow there through; and

Whereas, It further appears by the plans submitted by said Sanitary District of Chicago, and accompanying this permit, that the proper provision has been made for controlling the waters flowing from the said Little Calumet River into said collateral channel of said Sanitary District, and for the protection of the people living in the valleys of the Des Plaines and Illinois Rivers from danger to their lives or property by reason of flood waters in said Little Calumet River; and

Whereas, It further appears that the said Sanitary District of Chicago has laid out its right of way for the construction of said collateral channel and is ready to procure the same by condemnation or purchase; and

Whereas, It further appears that said right of way will cost several hundred thousands of dollars, and that the proposed channel will cost, approximately, twelve millions of dollars; and

Whereas, It further appears that the said Sanitary District of Chicago desires, before incurring the expense of procuring said right-of way and the construction of said collateral channel, to have the consent and permission of the Federal Government to the diversion of the waters of the Little Calumet River into its said collateral channel as aforesaid that it may be assured that its construction of said collateral channel will not have been in vain; and

Whereas, It further appears that the construction and maintenance of said channel, as contemplated, will be for the benefit of the health of the people of said District and in the interest of commerce and navigation of both the Little Calumet and Illinois Rivers;

Now, Therefore, The Chief of Engineers consenting thereto, this is to certify that the Secretary of War hereby gives permission to said Sanitary District of Chicago to construct

its said collateral channel, as herein proposed, and as shown by the plans transmitted herewith; and to connect the same with said Little Calumet River and to cause the waters of said Little Calumet River to flow therein and from thence into the Main Channel of said Sanitary District of Chicago and from thence into the Des Plaines and Illinois Rivers.

Witness My hand this _____ day of December, A. D. 1906.

_____

Secretary of War.

The above document has the following indorsement:

Office of Chief of Engineers.
Dec. 6. 28918 1906.

65

War Department.
United States Engineer Office.
Cal. R. Chicago, Ill. 295/0/1.
Rec'd Dec. 3, 1906. (G) 5353.

Form of War Department permit desired by Sanitary District of Chicago for proposed construction of Calumet-Sag Channel as described in Maps "A," "B," and "C," accompanying.

"The Calumet-Sag Channel.
The Project.

It is purposed to excavate a channel southwestward from the confluence of 'Stoney Creek' with the 'Little Calumet.' The point of beginning is in the S. W. ¼ of Sec. 32-37-14.

The line of the channel to be excavated passes through the Town of Blue Island crossing Western avenue between Canal street and Devonshire street. It passes the uplift known as 'Lane's Island,' on the south side, and enters the Sag Valley proper on Sec. 22-37-12. Thereafter following the general location of the abandoned channel formerly used as a feeder to the Illinois and Michigan Canal and commonly known as the 'Sag Feeder.' It crosses the channel of the Illinois and Michigan Canal in Section 14-37-11, near the station on the Chicago & Alton R. R. now called 'Lambert' but formerly known as 'Sag Bridge.' It enters the main channel of the

Sanitary and Ship Canal at or about Station 975 in Contract Section 5, Civil Section 14-37-11. The dimensions of this channel will be, in the rock sections and in the sections underlaid with rock, which must be walled, ninety (90) feet wide with vertical sides, with such additional width as may be necessary to admit of cutting the sides with channeling machines. The channel in earth will have a bottom width of seventy (70) feet and side slopes of five (5) feet horizontal to three (3) feet vertical. The minimum depth of water below the hydraulic grade line is to twenty-two (22) feet. The flow of water through the channel must be under absolute control and the volume of water passing through it must not exceed four thousand (4,000) cubic feet per second. In normal seasons with mean lake stages the cross section and slope of the channel will—within a moderate variation—control the volume of flow, but to meet flood conditions absolute mechanical means must be provided to control the flow volume. The means of control which form integral parts of the project are: A guard lock at the Little Calumet end of the artificial channel which can be closed upon the manifestation of flood probabilities and then operated for navigation purposes only: A movable dam which may be of the Bear Trap type or of the Stoney Gate type, whichever a fuller study of the conditions to be met shall point to as the most desirable form of construction. Under normal conditions this movable dam will be closed barring out all flow from the Calumet River. When so closed the normal flow into the artificial waterway will be through the guard lock. When it becomes necessary to close the guard lock then water will be admitted by way of the movable dam in such volume—up to the prescribed flow of 4,000 cubic feet per second—as the conditions to be met seem to warrant. There will be a moderate deepening of the Calumet River from the Guard Lock eastward as far Riverdale where the Illinois Central R. R. crosses the said river. The channel hereinbefore described is to be spanned by movable bridges. The railroads to be crossed are the Chicago, Rock Island & Pacific R. R. main line and one transfer line; the Chicago Junction R. R., the Chicago & Grand Trunk Ry., the Wabash R. R., the Chicago & Joliet Electric R. R. and the Chicago & Alton Railway.

(Signed) ISHAM RANDOLPH,
Chief Engineer Sanitary District of Chicago."

The above document has the following indorsement:

"Office of Chief of Engineer.
Dec. 6. 28918 1906.

60

War Department.
United States Engineer Office.
Cal. R. 295/0/2.
Rec'd Dec. 3, 1906. 5353.
E.

Sanitary District of Chicago,
Isham Randolph, Chf. Engr.

Project for excavating a channel, together with necessary controlling works, from confluence of Stoney Creek and Little Calumet River to Sanitary District Drainage Canal at "Sag Bridge."

Dimensions of channel, 90' wide, 22' deep requiring flow of about 4,000 cu. ft. per second, and to be spanned by movable bridges."

Argument for Reversing the Flow of the Calumet River.

The map which accompanies this report gives the outlines or boundaries of the Calumet watershed. This watershed has a total area of 825 square miles; of this area 485 square miles belong to the State of Indiana and the remaining 340 square miles belong to the State of Illinois. The occupation of this territory for urban and industrial uses began first in Illinois but Indiana is forging to the front also. The advantages of level plains easily accessible to the cheapest of all forms of transportation, water borne carriers, and offering facilities for easy and cheap railroad construction has tempted capitalists to create great manufacturing plants, such as steel mills, car building shops, ship yards and their allied enterprises, and these have found a quick response to their invitation to the railroads centering in Chicago to come in and possess so much of the land as was needed for great freight yards where the raw materials needed by the manufacturers could be assembled for convenient delivery to the furnace, the forge and the workshop; from whence the finished product would be sent forth by these same railroads to purchasers in all parts of the land. In addition to manufacturing interests are the great grain handling conveniences which have found relief from the congested and contracted conditions along the Chicago River and have been planted along the Calumet River. All of these manifold industries give employment to multi-

tudes of men, and men must live within reasonable distances of their work and the normal man must have his mate, and thus mated they must "increase and multiply and replenish the earth," and they are doing it, and the Calumet region is growing populous. Marshes once the exclusive home of wild forms of life are now being reclaimed and streets are being raised above the flow line and houses front upon them, and the debris of manufactories and the ashes from the hearths of homes are serving to lift the general plane of the inhabited places above the level of the swamp. But people make sewage and this sewage must find a vent. That vent is now into the Calumet River and the Calumet River empties into Lake Michigan and Lake Michigan furnishes the drinking water for Chicago. The wealthy may drink "hydrox," "Waukesha" and mineral waters, but the poor, who are the overwhelming majority of the population, must drink the waters of Lake Michigan and humanity, duty, interest, every known argument demands that this water supply be purified. Investigation has shown that for Chicago the solution is to be found and found only in turning away the streams which flow into the lake and giving them a westward flow into which all the city's sewers must be turned.

It is argued that this sewage can be disposed of upon sewage farms. A sewage farm to be successful must be underlaid by a porous soil. Chicago is environed by a clay subsoil overlaid in almost all cases by a black loam of uncertain depth, hence the land disposal of sewage is not a solution of its problem available to Chicago. The verdict went forth 20 years ago condemning land disposal and a re-opening of the case can only result in an affirmation of the old verdict. The Chicago River has been reversed and is doing for the territory which it serves all that its projectors designed it to do. The necessity of caring for the sewage of the entire city brought about the annexation to the Sanitary District of nearly all of the low ground of the Calumet watershed within the State of Illinois; an area of 94.48 square miles and it matters not what the population of that territory may be today, when we know that only by vigorous prosecution of the projected reversal of the Calumet River can the work be carried to completion in time to meet the necessities of the population which—if there be no arrested development—will throng this region before the waters can be made to flow westward.

The above document has the following indorsement:

Office of Chief of Engineers.
Dec. 6. 28918. 1906.

63
War Department.
United States Engineer Office.
Cal. R. Chicago, Ill. 295/0/3.
Rec'd Dec. 3, 1906. 5353.
F.

Sanitary District of Chicago.

Argument for reversing the flow of Calumet River with map "D" accompanying.

Letterhead of the Sanitary District of Chicago.

September 2nd, 1907.

To the Honorable, the Secretary of War,
Washington, D. C.

Sir:

The Board of Trustees of the Sanitary District of Chicago has laid out and established a proposed right of way, which it expects to acquire, extending from the North Branch of the Chicago River, at Lawrence avenue, Chicago, to the western boundary of Lake Michigan, in the Village of Wilmette, Illinois, through which right of way it intends to construct and maintain a channel, as an adjunct to its Main Channel (including the Chicago River), extending from Lake Michigan to Lockport, Illinois.

The entrance of the proposed channel into Lake Michigan is shown upon the accompanying plat. In order to protect the mouth of the proposed channel against filling in with sand by the storms of Lake Michigan, it is proposed to construct a pile crib, filled with rock, extending out into Lake Michigan from the shore line a distance of, approximately, one thousand feet; and thence in a northwesterly direction a distance of, approximately, eleven hundred feet. It is further proposed to deposit within the limits of said proposed crib the spoil arising in the construction of the channel from the shore of Lake Michigan to the Chicago & Northwestern Railroad Company's tracks, in the City of Evanston, a distance of some two miles.

The accompanying plat of the plan outlined above is herewith submitted and the Board of Trustees will be grateful to

you if you will examine the same and approve, in order that work may be begun at as early a date as possible.

Yours very truly,
(Signed) G. M. WISNER,
Chief Engineer.

The above document is indorsed as follows:

Office of the Secretary.
Sep. 11. 14130. 1907.
War Department.
U. S. Engr. Office, Chicago Rivers and Harbors.
Rec'd Chicago, Ill., Sep. 4, 1907.
Office No. Chi. H N 1400.

Chicago, Ill.,
September 2, 1907.

Sanitary District of Chicago,
By G. M. Wisner, Chief Engineer.

Requests approval of proposed drainage channel to connect Lake Michigan at Wilmette, Ill., with North Branch of Chicago River; and permission to construct pile cribs in Lake Michigan at mouth of same and to deposit filling within the limits of such cribs.

Three inclosures—blueprints.

Inclo. 1 in Map Files. 8961 Flat.

Ford by Col. Bixby.

September 14, 1907, Indst. to Col. Bixby with inclos. 2 & 3, and copy of inclo. 5 accomp'g.

9:30 rec'd back Office Chief of Engineers August 16, 1901.

Inco. 5, 7, 9 and one addl.

Incls. 1, 2, 4 & W. D. P. C.

1st Indorsement.
Office District Engineer.
Chicago Rivers & Harbors.
Chicago, Ill., September 4, 1907.

1. Respectfully forwarded to the Chief of Engineers, U. S. Army, with recommendations that the applicant be notified that no objection will be made by the War Department to the constructions described in this request and its enclosed blueprint, provided that:

(a) The pier constructions, the filling behind the same, and the excavation of the proposed channel, to be under the supervision of the Chicago U. S. Engineer Office, so far as to see that the terms of the permit are not exceeded.

(b) The total diversion of water from Lake Michigan through Chicago River in the Illinois River to be no greater than already authorized by past War Department permits.

(c) The work to be commenced before December 31, 1908, and completed within five years thereafter.

2. Reasons for these recommendations are given in the report of this same date, herewith enclosed.

(Signed) W. H. BIXBY,
Lieut. Col. Corps of Engineers.

2 inclosures, 1 (b. p.) in triplicate.

2nd Indorsement.
War Department.
Office of the Chief of Engineers.
Washington,
September 10, 1907.

1. Respectfully forwarded to the Secretary of War.

2. The Sanitary District of Chicago proposes to connect Lake Michigan with the upper end of the North Branch of the Chicago River, for the purpose of diverting a limited quantity of water from the lake into the upper river so as to flush the sewage of the northern part of Chicago; and to construct a pile crib filled with rock, and other material, along the shore of Lake Michigan, about 15 miles north of the mouth of the Chicago River, for a length of about 1100 feet, and for a distance outward into the lake about 1,000 feet, reaching to about 10 feet depth of water.

3. This project has been under consideration by Lieut. Col. Bixby, to whose statement, in first indorsement hereon and in letter of the 4th instant herewith, attention is respectfully invited. Colonel Bixby recommends that the Sanitary District be advised that the War Department will make no objection to the project, as set forth in the applicant's letter, and indicated on the accompanying drawing, provided the following conditions are complied with:

(a) That the pier constructions, the filling behind the same, and the excavation of the proposed channel, shall be done under the supervision of the district engineer officer at Chicago, so far as to see that the work authorized is not exceeded;

(b) That the total diversion of water from Lake Michigan through the Chicago River into the Illinois River shall be no greater than already authorized by past War Department permits.

(c) That the work shall be commenced before December 31, 1908, and be completed within five years thereafter.

4. In this recommendation I concur.

(Signed) A. MacKenzie,
Brig. Gen. Chief of Engineers, U. S. Army.

64900
Inclos. 1, 2 & 4 accomp'g.
Stamp: Chief Clerk War Department, Sept. 11, 1907.
Cor. 2:20, Sept. 11.
Received Sept. 11, 1907. M. & R. Div. War Dept.
Rec'd Office Chief of Engrs. Sept. 13, 1907.

4th Indorsement. WHB-WJ.
War Department.
Office of the Chief of Engineers.
Washington.
August 11, 1911.

1. Respectfully returned to the Secretary of War.
2. Previous action is shown by 2d indorsement hereon and Department letter dated September 11, 1907, copy herewith, to Mr. Wisner.
3. Attention is invited to the accompanying letter dated July 21, 1911, from Mr. Wisner, in which he described certain deviations in the structures, as built, from the plans on which the prior action of the department was based and requests that permit be granted for the construction as built.
4. Inviting attention to 1st indorsement on said letter by the district officer, Lieut. Col. Geo. A. Zinn, Corps of Engineers, I recommend that Mr. Wisner be informed, with return of one of the maps, that the department will interpose no objection to the maintenance of the structures as built and shown on map now presented provided they do not prove obstructive to navigation or otherwise detrimental to the public interests.

(Signed) W. H. Bixby,
Chief of Engineers, U. S. Army.

Stamp: Assistant Acting Clerk, Aug. 12, 1911, War Department.
64900
Inclos. 5, 7-9 accompanying.
Aug. 12, 1911, correspondence Division. 11:45.
Rec'd Office Chief of Engrs., Aug. 16, 1911.

Here follows plan of location of proposed North Shore Channel with the following indorsement:

Office Chief of Engineers.
Sept. 6, 1907. 64900.
8961 flat. War Department.
Office of the Secretary.
Sept. 11. 14130. 1907.
War Department.
U. S. Engr. Office, Chicago Rivers & Harbors.
Rec'd Chicago, Ill., Sept. 4, 1907.
Office No. Chi. H N 1400/1.

September, 1907.

Sanitary District of Chicago.

Plan of location of proposed north shore drainage channel between Lake Michigan and North Branch of Chicago River, and crib work in connection therewith.

"War Department. WHB/FJL.
Office of the Chief of Engineers,
Washington.

December 18, 1911.

Memorandum for the Secretary of War:

In 1908, the United States, entered a friendly suit against the Sanitary District of Chicago, the primary object of which was to determine the rights of the district to divert from Lake Michigan by opening a new route from the lake via the Sag crossing from Calumet Lake to the Sanitary District Canal, an amount of water in excess of what was then b diverted (so as to secure a total of 14,000 cu. ft. per second), without first obtaining a permit from the Secretary of War in pursuance of Section 10 of the river and harbor act of March 3, 1899. At the time the action was brought the district was diverting, under permission from the War Department, 250,000 cu. ft. per minute (4,166 cu. ft. per second), all of which was diverted through the Chicago River into the drainage canal, the connection with the canal being made at Robey street in the City of Chicago. No increase in this amount has since been authorized by the Department; but by letter of June 30, 1910, the Secretary of War granted the district permission to divide the amount of water already authorized to be diverted (4,166 cu. ft. per second), in such manner as to reach the drainage canal by way of the Calumet River and a connecting channel, as well as by way of the Chicago River.

The bill of complaint in the aforesaid suit was filed in the Circuit Court of the United States for the Northern District of Illinois in March, 1908, and the answer of the defendant

was filed in June of that year. Engineer Department records show nothing further in regard to the progress of the action. It is, however, understood by informal verbal statements of various parties, that the taking of evidence on the part of the Government has been completed, and that the case is now pending. It is, therefore, assumed that the case is ready for a hearing; but so far as the record shows, no hearing has so far been had, nor has a date been set therefor. It is also informally understood that the Sanitary District of Chicago contemplates securing direct Congressional authorization for the project of reversing the flow of the Calumet River and of using the waters of Lake Michigan to the extent of probably 10,000 cu. ft. per second, and that a bill to accomplish this purpose, prepared by the Sanitary District, has been submitted by it informally to the President and been under consideration by the Attorney General.

There always has been and are now many serious objections to the diversion, from not only the point of view of navigation but also of conservation of resources and of sanitation.

The annual levels of the water surface of all the Great Lakes are at present considerably below their average of the past 51 years, and are still dropping rapidly. The present Sanitary District diversion is aiding the rapidity and extent of this undesirable drop of levels, every foot of which will add greatly to the cost of water transportation on the Great Lakes and also lessen the total quantity of freight possible through the Sault, and the St. Mary's, St. Clair, and Detroit Rivers and into lake harbors.

Owing to the few and low water falls and rapids of the Illinois River route and the many and high falls of the St. Lawrence River route, the water diverted from the lakes via Chicago and the Illinois River can be utilized for power only to 1/4 to 1/3 the extent possible by its original route via the Detroit and St. Lawrence Rivers, and will cause a potential loss of power (and corresponding loss of utility or profits) to Canada and New York State, equal to three to four times what Illinois can get from the diversion by its own route. This may mean several million dollars annual loss to Canada as well as to the United States, and is consequently a great waste of natural resources.

The question of injury to public health due to dumpage of filth into rivers is now attracting marked attention throughout the United States, and many states have passed stringent

laws on this subject, sometimes of total prohibition, and Massachusetts at least has found it practicable to stop such dumpages. A national association for prevention of pollution of streams has been incorporated and more active protests and more stringent laws may be expected in future in all states affected by such dumpages. Properly handled, the present authorized diversions at Chicago are sufficient to cover all actual sanitary necessity.

Under all the above circumstances, it seems extremely desirable that, if this injunction can be made permanent, the United States should push the case to final settlement.

(Signed) W. H. BIXBY,
Chief of Engineers, U. S. Army.

28918
1 inclosure (blueprint pamphlet of lake levels).
Inclo. 320 accomp'g."

The above document is indorsed as follows:

December 18, 1911.

Chief of Engineers:

Memorandum for Secretary of War in regard to injunction suit pending before Federal Court in Chicago to determine extent of diversion of water from Lake Michigan for sewerage of Chicago; temporary injunction should be made perpetual and action pushed to that end."

"War Department.
United States Engineer Office,
508 Federal Building.
Misc. 495/33. HBF-r.

Chicago, Ill., Nov. 24, 1913.

From: The District Engineer Officer.

To: The Chief of Engineers, U. S. Army, Washington, D. C.

Subject: Report on Illinois and Michigan Canal.

1. Pursuant to 2nd indorsement dated Sept. 5, 1913, on E. D. 47860/24, the following report and recommendation is submitted. The report required is chiefly as 'to whether the matter is of sufficient importance to justify the U. S. in endeavoring to compel Illinois to spend moneys for maintenance of this canal.'

2. The Illinois and Michigan Canal is a link of the waterway from Lake Michigan to the Mississippi River and extends from the Chicago River to the Illinois River at La Salle, 95.82 miles. It is available for boats of about four feet draft. It is crossed by 75 bridges, 6 of which are swing bridges, the

remainder being fixed spans of heights of from 12 to 25 feet. The present condition of the canal is described in Colonel Zinn's report of March 16, 1912.

3. The importance of this route from the U. S. point of view will be considered by referring briefly to (1) U. S. grants for canal; (2) U. S. appropriations for connecting channels, and (3) surveys, all of which depend on (4) U. S. estimate of commercial importance of the route.

4. Under its authority and responsibility to promote interstate commerce the U. S. Congress in 1822, granted under certain conditions 'the route of the canal and 90-foot strips on either side thereof.' This grant has been held by U. S. Supreme Court (Werling vs. Ingersoll, 1901, U. S. Reports, Vol. 181) to have been mutually abandoned, so far as land section in question was concerned, by the United States and State of Illinois. It has since been contended that this ruling was founded on an error as to fact, it having been discovered that the map had been filed as required by the law of 1822. Further land grants were made in 1827, 1842 and 1854. Canal was completed in 1848. History of the canal up to 1885 is found in Report of Chief of Engineers for 1887, page 2128 et seq. The total receipts by Illinois for canal lands is stated as $5,886,039.88. This amount, added to the tolls, rents, etc., collected by Illinois, as authorized by the United States, is the expenditure by the United States for this canal.

5. The United States' expenditures for connecting channels should also be considered, especially those for Illinois River amounting to about $2,000,000, and those for the Illinois and Mississippi Canal amounting to about $7,000,000. The canal was completed in 1907. It is plainly seen in the reports that this Illinois and Mississippi Canal was projected and built as a link of a waterway from Lake Michigan to the upper Mississippi River territories, the other link formed by the Illinois and Michigan Canal having been provided by Congress in the indirect manner noted, the assumption being that this canal would be maintained by Illinois in suitable condition for commerce; and because this Illinois and Michigan Canal was not properly maintained or improved after 1907, when the Illinois and Mississippi Canal was completed, the possible benefits from the latter have been practically nullified. The present project now being executed for the upper Mississippi River at a cost of $20,000,000 depends for a great share of its beneficial results on a suitable connection to Lake Michigan.

6. In addition to these money expenditures for actual construction, the interest of the United States in a waterway from Lake Michigan to the Illinois River is manifested by numerous surveys ordered by U. S. Congress. At the present time there is a special board considering the waterway from Lockport south. $1,000,000 is available for beginning U. S. share of the improvement when co-operation is assured.

7. The commercial importance of this route depends on its value (1) as a local transportation line; (2) as part of route via Hennepin Canal to upper Mississippi River, and (3) as part of a route via Illinois River to the lower Mississippi River. As to the general commercial advantages, Capt. W. L. Marshall, Corps of Engineers, reported in 1890 as follows:

'This route has invited attention as a practicable locus for a waterway between the Great Lakes and Mississippi River for many years, and its advantages have been so often reported to Congress that anything herein said would be mere repetition. It is sufficient to say that the minimum channel herein estimated upon will open a channel of commerce with a maximum annual capacity of 30,000,000 tons between the Great Lakes, with its terminus at their greatest port, and a system of navigable rivers penetrating one-half of the states and territories of the Union, with a total navigable length equal to more than half the circumference of the globe.' (Report, C. of E. 1890, p. 2452.)

It is understood that the law limits discussion of commercial importance of this route to references to records. It is not considered pertinent or necessary to discuss the fundamental question of the value of inland waterways in general.

8. While the above evidence may be considered sufficient to establish the fact that the United States has considered this route important as a portion of a waterway from the lakes to the Mississippi River, the question whether this fact leads to the procedure suggested of 'endeavoring to compel Illinois to spend moneys for maintenance of this canal,' is more complex. To determine this question it would seem necessary to arrive at some conclusion as to what is the proper project for this section of waterway, and if probable result of procedure suggested is in accord therewith. In this view brief reference will be made to the assets of the route, plans and recommendation that have been made by the Engineer Department, and the attitude of Illinois to this canal.

9. The assets of this route are the old right of way and the water powers.

10. As to the right of way, Major Riche reported on Jan. 24, 1904, on the 33 miles from Joliet to Chicago as follows:

'This right of way contains some 1,040 acres, which at $1,000 per acre would be worth $1,040,000. This valuation is based upon the cost of the right of way of the Sanitary Canal through the same territory, and is not believed to be excessive, especially in view of the ease and economy with which the line could be rendered available for railway purposes.'

On this same basis the total value will exceed 2½ million dollars. The status of this asset and others pertaining to the canal and depending on U. S. grants would seem to be an essential factor to be considered in connection with any plan of future co-operation between Illinois and the United States.

11. As to the value of water power, a special board reports:

'By modification in the project submitted by the former board that will be in harmony with its report, this board is of the opinion that 100,000 horsepower can be developed by the diversion of 10,000 cubic feet per second.

Under such circumstances it seems proper that the Federal Government should assume, in its dealings with the Sanitary District of Chicago and the State of Illinois, the principal beneficiaries, that the net horsepower developed by 10,000 cubic feet per second diverted from Lake Michigan should produce a revenue of $2,500,000 per year.

The board considers that the property owners along the canal and Illinois River are equitably entitled to the water power due to the natural flow alone of the Des Plaines and Illinois Rivers, and that any power which results from an added flow diverted from Lake Michigan belongs to the people of the United States and Canada.' (H. Doc. No. 50, 61st Cong., 1st sess., pp. 28 and 29.)

The actual amount of diversion allowed from Lake Michigan, and hence the actual value of this asset, depends on the case now pending in U. S. Court between the United States and the Sanitary District, and on future action of U. S. Congress.

12. Concerning this waterway numerous surveys and reports have been submitted to Congress. A list of these documents to 1905 is found on page 8 of report of latest survey, made in 1905 (H. Doc. No. 263, 59th Cong., 1st sess.) The plans prepared by the Engineer Department for enlarging the

old canal and for waterway from Illinois River to Lake Michigan of 7, 8 and 14 feet depth will be briefly noted.

13. In 1882 a plan was submitted for enlarging the Illinois and Michigan Canal to the dimensions adopted for the Illinois and Mississippi Canal. This estimate was $2,298,919.15, of which $1,028,412 was for channel work from Joliet to Chicago River, leaving $1,270,503.15 as the estimate made then for enlarging canal not now replaced by the drainage canal. This estimate is based on 20 cents per cubic yard for earth excavation and $1.75 for rock, and provides for locks at a cost of about $28,000 each. (Annual Report, C. E., 1883, pp. 1776-7.)

14. In 1890 surveys and estimate were made for this waterway from Illinois River to Lake Michigan. The estimate for 8 feet depth was, in round numbers, $14,000,000 from Joliet to Lake via Sag route, and about $17,000,000 via Chicago River. Estimates for total waterway were:

Via Chicago River	$26,883,153
Via Sag route	23,885,400

(Annual Report, C. E. 1890, pp. 2433-4.)

15. In 1900 a special board prepared plans for waterways of 7 and 8 feet depth. The proposed route in both of these plans is as follows:

'From Utica to Marseilles in the bed of the river; thence around the Marseilles Rapids by canal; thence in the bed of the river to near *the mouth of the Kankakee; thence through the Illinois and Michigan Canal* (18.3 miles) *to the Joliet basin;* thence by canal to the Sanitary Canal at Lockport, and thence via the Sanitary Canal and Chicago River to Lake Michigan.' The project involves 12 locks and 2 dams. (Annual Report C. E., 1901, p. 3048 et seq.)

The estimate for the 7 feet depth is:

From Utica to near Kankakee River	$2,055,187
Enlarging 18.3 miles of Illinois and Michigan Canal below Joliet	1,215,904
Total, Utica to Joliet	$3,271,091

For 8 feet depth about 10 per cent. should be added.

The 4 locks to be provided in the enlarged Illinois and Michigan Canal are each 40 by 260 feet.

The stretch from Joliet to Sanitary Canal has been provided by Illinois, which reduces the original estimate from over seven million dollars to amount above.

16. In 1905 a special board prepared plans for a 14-foot

waterway. This report suggests that its plan can be altered to provide for development of water powers. (H. Doc. No. 263, 59th Cong., 1st sess.)

In 1909 a special board by direct act of Congress reported on value of water powers and if same can help defray expenses of improvement. This board finds value as $2,500,000 per year as above noted. No plan for development of power by the United States is submitted. Its development by Illinois is favored on conditions, stated briefly: that earnings shall be applied to sanitary canal and power works till same are reimbursed, then United States shall receive percentage of earnings; also that the Sanitary Canal shall receive percentage of earnings; also that the Sanitary Canal shall be made U. S. waterway. (H. Doc. No. 50, 61st Cong., 1st sess.)

17. The special board now in existence is to pass upon plans to be submitted by Illinois. The report of this board states:

'In accordance with this agreement' (U. S. Law 1822 and 1827) 'the State constructed the Illinois and Michigan Canal from Bridgeport to La Salle, and improved the upper portion of the Illinois River by the construction of locks and dams at Henry and Copperas Creek.

'For many years this waterway was a valuable transportation route, but in recent years the State has neglected it and failed to maintain it abreast of the needs of commerce. The work now proposed by the State in connection with the canal of the Chicago Sanitary District contemplates a waterway from Lake Michigan to Utica' (near La Salle), 'which although departing from the line of the old canal, substitutes a waterway more than sufficient for any probable navigation. This will in effect fulfill the original agreement between the State and General Government for this section and incidentally develop a water power which the State considers a profitable business investment.'

The report further states that with the transfer to the United States of the locks and the control of the new waterway thus created, so far as needed by navigation, and the locks and dams at Henry and Copperas Creek on the Illinois River, the obligations of the State of Illinois to the United States with reference to the maintenance of the Illinois and Michigan Canal may be considered as adequately fulfilled, and any equities of the United States in the rights of way and other properties of this canal should be transferred by the

United States to the State of Illinois. (H. Doc. No. 1374, 61st Cong., 3d sess., p. 9.)

18. It is to be noted that the above referred to surveys were ordered directly by Congress and that the question of advisability or worthiness of the project is assumed or evaded. On this question the Chief of Engineers comments on report of 1909 above, as follows:

'An estimate will also be made of the cost of an 8-foot channel from Lake Michigan to the Mississippi River at St. Louis, which later, in connection with the present 8-foot project for that portion of the Mississippi River between St. Louis and Cairo, will provide for a least depth of 8 feet from Lake Michigan to the mouth of the Ohio River. It is expected that these additional estimates will be ready for submission to Congress before its next session. The Chief of Engineers is not prepared to state definitely for consideration by Congress that the construction of either of these channels is desirable until after accurate estimates are made.'

The existing special board states: 'Considered as a business investment, a waterway of even moderate depth from Chicago to the Gulf is still more or less experimental.' (H. Doc. No. 1347, 61st Cong., 3d sess., p. 6.)

19. From the above quotations it is seen that there is no approved project for a waterway from Lake Michigan to the Illinois River; that is (1) the advisability has not been specifically adjudged by the Engineer Department, and (2) physical plans have not been approved. Any interest the Engineer Department has in the construction of this waterway must be based on its supposed advisability which rests on the same basis as does the advisability of the Illinois and Mississippi Canal, and of the Illinois River, all three of which taken together should be improved or abandoned. The latest Act of Congress authorizing the present special board assumes such advisability and provides for approval of plans. Until such plans are approved it does not seem consistent that the Engineer Department should urge any specific costly work. The Engineer Department has specifically investigated and recommended abandonment of the major portion of the old canal, and could not in justice urge enlargement except of the 18.3 miles on Joliet end of canal, without full technical investigation leading to reversal of the previous recommendations of various boards and officers.

20. As to the question whether the canal, considered as an investment, and omitting its general benefits, has been a

burden to the state, the dissenting opinion in the Burke case in 1904 is specific on this question of fact as quoted by Major Riche, Jan. 24, 1907:

'The fact should not be lost sight of that the canal thus far has not been a burden to the state, and the evidence in this record does not show it ever will be burdensome to the state. The original cost of the canal, which was approximately $5,000,000, was paid for from the sale of lands donated to the state by the General Government for canal purposes, with the express understanding *that the canal should be forever maintained by the state.* From the time of its construction to the time of the filing of this bill the canal had earned more than $6,500,000, and there now remains in the state treasury, after paying all its expenses and after refunding to the state all monies appropriated for its use, the sum of $338,695.76.' (Burke v. Snively et al., Supreme Court of Illinois, 1904,—Illinois Reports, Vol. 208,—Phillips. Full copy enclosed with my report of the 10th inst., 33,-152/14.)

21. It seems worthy of note that the Illinois and Michigan Canal during the years of its successful operation was of benefit to the people of the State of Illinois chiefly, and aside from the returns (tolls, etc.), it is noted by the report of one board that the easily estimated direct saving in freight was over $2,000,000 for five years (Annual Report, C. E. 1887, p. 2128 et seq.). The primary intention of Congress in regard to waterways is to accommodate interstate traffic. Now, that the second canal has been provided, any further benefits that might accrue, if the Illinois and Michigan Canal is maintained in suitable condition, would be distributed to the people of more than one state, under which condition the expenditures previously made for the canal by the United States will be justifiable. It appears that of late years the annual income has not been sufficient for maintenance and the necessary betterments. It is pertinent to inquire what the state has done or failed to do to cause this falling off of commerce. Discriminating railroad rates have been allowed. The canal was not kept abreast of the needs of commerce even when its income was sufficient. A railroad treated in a similar manner would have failed.

22. The history of the proposed transfer of all or part of this canal is briefly as follows: In 1882, the legislature of Illinois passed an act ceding the canal to the United States under certain conditions. A board of engineer officers appointed to consider the proposition reported:

'The Board then presents the following reasons why the United States should not accept the cession of the Illinois and Michigan Canal under the conditions of the existing act: (1) The canal should not be enlarged upon the whole of the present line; on the contrary, it would be judicious to abandon the greater portion of it. (2) The act does not provide for the cession to the United States of that portion of the Illinois River improvement now owned by the State of Illinois, and which forms an essential part of the through line.

'3rd. The act is not sufficiently definite as to the obligations which the United States would assume in accepting the transfer of the canal.

'Although the Board is of opinion that the United States should not accept the canal under the existing conditions, it is further of opinion that the water-route of which the canal forms a part should be controlled by the General Government, and that acceptance should promptly follow a proposition to transfer it under conditions so modified as to remove the objections stated.' (Annual Report C. E., 1887, p. 2160.)

23. In 1907 a bill was introduced in U. S. Congress, H. R. 24271, 59th Cong., 2d sess., whereby the United States was to cede in *toto* all rights to right of way from Joliet to Chicago River to the State of Illinois, who was to transfer same to the Sanitary District of Chicago. This bill was reported on unfavorably by the district engineer officer because the transfer gave away valuable rights as to right of way and water power, which the United States should hold until a waterway was built to the Mississippi River.

24. The object, authority, and responsibility of the United States is to secure a suitable waterway from Lake Michigan to the Mississippi River. By direct appropriations such a waterway has been or is being provided for portions of the route. For the section of the route from the Illinois River to Lake Michigan, U. S. Congress attempted to reserve the right of way in 1822. By default of Illinois this attempt became void. In 1827 Congress provided for this section by the indirect means of land grant to Illinois. When the canal's traffic was profitable the State of Illinois used it as a money-making machine; she failed to properly improve it, and it has practically fallen into decay and consequent disuse. Such a history of the canal under state control is natural and to be expected, when we consider that commerce, and especially interstate commerce, is not a state's prime care, but that numerous other needs absorb a state's

funds and governmental concern. The state's interest in this canal has heretofore been measured by the money returns she received and a little short thereof. The proposed transfers of all liabilities to the United States, the state keeping the assets, denote this same interest. The present status of this Burke case displays this same attitude. Illinois by her constitution, as interpreted by her Supreme Court, estops herself from properly maintaining this waterway, but she keeps the assets that are perhaps worth over two million dollars, instead of ceding them back to the United States. On the other hand, Illinois has built the drainage canal. Although built primarily for local interests, which properly bore the burden of its cost, its value for navigation is great, the estimate of 1890 for an 8-foot channel from Lake Michigan to Joliet being over 14 million dollars.

25. This very natural attitude of the states is presumed to be the main reason why the United States was given the authority and responsibility concerning waterways for interstate commerce. It would seem that failure to assume this responsibility and authority has resulted in the confusion and lack of progress in this case. The simplest and only direct and apparently satisfactory policy by which this waterway can be handled is believed to be the general plan usually pursued: (1) for the United States to decide if it is advisable; (2) then prepare plans that destroy no assets and include water powers; (3) appropriate necessary money for the work; (4) condemn dam sites, etc., and complete the work; (5) and then determine the ownership of the assets. It seems clear from the above history that if a suitable waterway is ever built from Lake Michigan to the Mississippi River, the cost borne by the United States will be the total cost, lessened only by all or part of the value of the assets that pertain to the route. Inasmuch as the main assets—that is, the old right of way and the water power due to the flow permitted by the United States from Lake Michigan—are believed to belong to the United States, it is not seen what the United States can hope to gain by co-operation. Whether or not these assets are turned over to Illinois in return for total or partial construction of a waterway or are realized in some other manner is of more interest to Illinois than it is to the United States. However, as the latest act of Congress on this subject provides for continuation of co-operation, the attitude of the department must be to assist this

attempt and if possible force it to a climax of execution or failure.

26. Effect of proposed procedure is foreshadowed in prior decision in this Burke case, from which is quoted the following extract from decision of Supreme Court of Illinois—Illinois and Michigan Canal:

'The question whether the *cession of* Congress, and the acceptance thereof by the state, constitute a contract on the part of the state to forever keep and maintain the canal in such condition that the general government may use it as a public highway does not arise for determination. If such a contract arose out of the grant of the land and the acceptance thereof, the complaint that the provision of the state constitution here under consideration, if construed to deny to the legislature power to appropriate any sums whatever from the public treasury for the purpose of repairing or maintaining the canal in usable condition as a public highway would impair the obligation of that contract, cannot be urged by the appellees, who appear in the suit only in their capacity as officers, which positions they hold under and by authority of the constitution of the State of Illinois and the statutes made in pursuance thereof. The rights of these appellees are not affected by any alleged impairment of the alleged or supposed contract between the Federal Government and the State of Illinois. The only person who may complain that a law impairs the obligation of a contract is one who has an interest in the enforcement of the obligation of the contract said to be impaired. (Templeton v. Horne, 82 Ill., 491; 15 Am. & Eng. Ency. of Law, 2d Ed., 1059.) If it shall be found that the grant of the lands and the acceptance thereof constitute a contract, and a question of the enforcement of the contract shall arise, the United States and the State of Illinois, in the exercise of the sovereign power which they respectively possess, it may be confidently asserted, will adjust their respective rights and obligations amicably, honorably and justly. No obligation will be impaired or repudiated. The appellees are but servants of the state, charged temporarily with the performance of duties in and about certain public affairs of the state which the state has intrusted to them to be performed, and in that capacity they appear in this proceeding. They do not represent the United States and have no power to submit for decision the question whether contract obligations accrued by reason of the cession and acceptance of the lands, much less to insist that, notwithstanding the changed conditions which have, it seems, ren-

dered the canal wholly unnecessary, if not entirely useless, as a highway to the United States, the alleged contract can only be discharged by the specific performance thereof.'

Burke v. Snively.

Richard E. Burke v. Clarence E. Snively et al., opinion filed February 17, 1904; rehearing denied April 7, 1904.

27. It is therefore assumed that the effect of the United States appearing in this case will be to establish (1st) the contention that there is a contract between Illinois and the United States, and (2d) the nature of this contract, whether it is (a) a narrow contract requiring specific fulfillment by enlarging this canal, or (b) a broad contract to provide a suitable waterway from Lake Michigan to the Illinois River. If the ruling be that the contract is a narrow one (a), it is believed that any attempt to enforce it will be, in fact, futile. The required dimensions of the canal are nowhere specified and it would seem that these dimensions must hereafter be determined, as they have been heretofore by Illinois. If the ruling be that a broad contract exists, the obligation resting on Illinois will not be lessened, but may be met by (1) specific fulfillment—enlarging old canal—or (2) otherwise providing a waterway, and such a ruling by her Supreme Court should have the effect of causing Illinois to decide promptly how this acknowledged obligation would be met. Illinois' self-inflicted paralysis in this case is perhaps more technical than it is intentional. She has the undoubted right to maintain this canal or not, according to her judgment on costs and benefits, but in case she refuses to maintain it, its forfeiture should be considered. It seems plain to me that Illinois has already forfeited this canal, but as its possession by the United States will be of no value except appropriation be made for a waterway along all or part of it, it seems advisable to help Illinois into condition so she can decide this question one way or the other, and decide it by a body capable of carrying out her decision either (1) by appropriation for maintenance of old canal or otherwise providing a waterway, or (2) by forfeiture. The general effect of the proceeding suggested will simply be to determine that the legislature of Illinois may decide whether this canal shall be maintained. The pending test case is concerning an appropriation of $50,000 made by the Illinois legislature for this canal. The enlarging of the whole canal is not the issue. The issue is the legislature's right to enlarge the canal and the obligation to do so or forfeit it, or adopt another

plan. The enlargement of part of this old canal is part of another feasible plan. The establishment of this right and obligation is important to the United States as a factor in present negotiations for co-operation, or if co-operation fails, as a factor to be considered in connection with advisability and possibly reduced total cost of execution of this work by the United States.

28. In order to consider further the effect of procedure suggested, it is assumed that the first result will be to establish the contention that there is a contract and that the nature of the contract will be left mainly to the decision of Illinois. The question will then arise as to how she can carry out her obligations. As the physical plan of the work would seem to require the approval of the United States it would seem that approval could properly be given (a) to a project for enlarging the old canal; (b) to a project for a deep waterway now under consideration by the special board and the State of Illinois; or (c) what might be called a composite plan, which is a modification of the plan prepared in 1900 'for 7 or 8 feet depth by old canal from Joliet for 18.3 miles to below the mouth of Kankakee River; thence in river bed.' The modification suggested being that the section of waterway in river bed be adapted to the Illinois plan for developing power; that is, that the two dams below Morris be located to properly develop the power. This plan would provide for navigation and could further be modified by the earnings of the two dams being applied to the construction of the two dams above Morris and changing the navigation route from old canal to the river. This plan would seem to offer the best chances of immediate results and embraces no feature disapproved by the department. This plan is proposed because at the present time the Sanitary District is apparently attempting to build a power dam just below the state dam at Joliet. Such a dam would be of no benefit to navigation, as would a dam below Morris.

29. It appears to me pertinent to submit to the department my impression as to why this question has been submitted to the United States. I think that it is primarily a local controversy between the Illinois and Michigan Canal Commissioners and the Sanitary District and others. Apparently the difficulty of deciding who shall spend the 20 million dollars authorized by the people of Illinois is the reason which delays action of the legislature, and I do not

think it is the business of the United States to take sides in this controversy, but only to use its every effort to force some kind of a decision. The compromise, or modification of plan of 1900, suggested, may be satisfactory to all parties. The cost of this plan would be about $10,000,000. Over $1,000,000 would be spent in enlarging the 18.3 miles of old Illinois and Michigan Canal. If this plan is approved by the department and could be presented to the governor of Illinois in verbal conference with the Secretary of War, or in some other manner, he might decide to submit it to the legislature of Illinois as a means of securing immediate results and incidentally saving $10,000,000. A decision in pending suit, favorable to the U. S. contention would permit Illinois to choose this plan. At the present time she is prohibited from such choice. If this plan is chosen the $50,000 now appropriated by Illinois could be used without loss, on section of canal (near Joliet) included in plan.

30. As there is an inherent element of futility in any attempt to coerce a state and the results may be only indefinite delay, such attempt is, in my opinion, justified only when it is part of a definite plan which includes action to prevent such delay or to be followed in case of such delay. It is therefore assumed that so far as the engineer department is concerned it has determined on such a definite plan, including proper time limit for attempt and alternate action. My recommendations are based on this assumption.

In this case the time allowable would seem to be the time that under existing laws is necessary for the state legislature to be assembled and to consider this question. The alternate action might be submission of the whole question to Congress with definite conclusion as to (1) advisability and (2) physical plans; and definite recommendations either to (a) abandon this waterway and its allied connections, or (b) appropriate $10,000,000, more or less, for construction of waterway and utilization of assets, providing for immediate necessary condemnation and subsequent settlement of legal questions. Such a definite attitude of the Engineer department is justified because of the present deplorable condition. Many millions of dollars, spent on recommendations of the engineer department, are practically wasted unless this waterway is built.

31. It is recommended that, in the case now pending, the United States appear and assert that there is a contract between Illinois and the United States, and further assert

that the specific performance by maintaining the old canal is the only mode of fulfillment ever adopted by Illinois and cannot be abandoned until some other mode is fully provided for unless the whole contract is abandoned and final settlement made with the United States. It is further recommended that Illinois be informed of the opinion of the War Department as to the other plans that are considered sufficient to fulfill the obligation of Illinois. Such opinion as to deep waterway plan is printed in report of existing special board above quoted. A modified plan, based on plan of 1900, is above referred to; if this plan is approved by the department, Illinois should be so informed.

(Signed) H. B. Ferguson,
Major Corps of Engineers.

7 inclosures."

Mr. Shenehon: The government also offers in evidence hydrograph of United States Lake Survey similar to U. S. Exhibit Number 5, but extending the monthly mean elevations of the lake surfaces up to and including November, 1914.

The monthly mean elevations of the water surfaces of Lake Superior at Marquette, Lake Michigan at Milwaukee, Lake Huron at Harbor Beach, Lake Erie at Cleveland, Lake Erie at Buffalo, Lake Ontario at Oswego, for the year 1913, and a portion of the year 1914. Also monthly mean elevations of the St. Lawrence River at Ogdensburg for September and October, 1913. This is an official document of the United States Lake Survey.

Extract from the official report of Mr. W. S. Richmond, U. S. Junior Engineer of the Lake Survey, dated May 19, 1911, beginning line 8, page 51, as follows:

"As a basis of comparison of these measurements with those of former years, and of study of their internal consistency, the discharge formula derived by Assistant Engineer Thomas Russell, in 1904, corrected for more recent levels to the St. Clair Flats gage, has been used. It is

Q=197,065÷35,145 (Fort Gratiot—580.52)—20928 (St. Cl. Flts.—578.18).

All discharge measurements were corrected by the quantity, 20928 (St. Cl. Flats—575.18). From each result was subtracted the quantity, 197,065÷35,145 (Ft. Gratiot—580.52) and the resulting residuals reduced to percentages of the latter quantity.

Also extract from same report, beginning on the 6th line from the bottom of page 53, as follows:

"Plate 8 shows the measurements of 1908, 1909 and 1910, corrected by the quantity, 20,928 (St. Clair Flats—575.18), plotted with respect to Lake Huron elevation at the shore position of Ft. Gratiot gage. Each plotted point represents the mean of five measurements grouped in order of lake stage. In four or five instances, a mean of 3, 4, and 6 measurements was used instead of 5."

Plate 8 referred to in this extract is Defendant's Exhibit 23 (Vol. VII, p. 138).

Extract from Appendix 3 of the Annual Report of Lieutenant Colonel G. J. Lydecker, Corps of Engineers U. S. Army, for the fiscal year ending June 30, 1900, page 5320, as follows:

"In my last annual report (page 3854, Report Chief of Engineers for 1899) I stated that we had found indications of a marked deepening since 1867, in the channel of the St. Clair River just below its head, and it was thought that this might have caused a material change in the outflow from Lake Huron during recent years; but further careful investigation shows clearly that there has been no such change in the regimen of the river. It also shows the great danger of jumping to conclusions in matters of this kind, and suggests the propriety of avoiding an expression of opinion on any important point until all the facts in the case are positively ascertained."

Also extract from the report of Assistant Engineer E. E. Haskell, same volume, page 5323, as follows:

"In my last year's report I called attention to what seemed at that time a clear case of enlargement, by scour, of the head of the St. Clair River. A preliminary survey of this reach was made by Mr. Sabin in December, 1898. The results of this survey, when compared with the chart of the survey of 1867, showed what seemed to be a cutting out of the river bed to a depth of about 18 feet greater, for an area covering a portion of the gorged reach. Upon the strength of this evidence I made the statement that appears in my last Annual Report. Early last fall Mr. Sabin called my attention to the fact that the survey of 1859 of this reach, as charted, agreed much closer with present conditions than did the survey of 1867. It immediately occurred to me that it would be well to secure the original field notes of the surveys of 1859 and 1867, and replat them on the same scale as

the detailed survey made last fall, and then compare the three surveys. Accordingly, the old notes were obtained and the surveys of 1859 and 1867, platted anew on the scale of 1:5,000, putting on all soundings taken. Tracings of these new plats were sent to Mr. Sabin and he was requested to make a very careful comparison of these with the results of his recent work. He has accomplished this, and discusses the matter very carefully in his report. His conclusions are that the changes that have taken place are small, that between 1859 and 1867, the most restricted cross section may have enlarged about 9,000 square feet, and that the line of deepest water may have moved a little westward; that between 1867 and the present time the changes, if any, are unimportant. What seemed at the outset, therefore, as a reasonable explanation for the low stage of water in Lakes Huron and Michigan, culminating in 1895, is set at naught, and we must return to the question of rainfall and evaporation for new data for a satisfactory solution."

Extract from the Report of Assistant Engineer L. C. Sabin, beginning page 5393 (1900), omitting tables 20, 21, 22, and all plates, as follows:

"FALL FROM LAKE HURON TO LAKE ERIE.

"In considering the total fall in the channel connecting Lakes Huron and Erie we are fortunate in having a series of water levels for the two lakes extending over a period of forty-five years without interruption. We have also a series at the St. Clair Flats Canal, 1873 to date, excepting the years 1879 to 1882; a series on the Detroit River at the lighthouse depot from 1867 to 1881; and a short series on Detroit River from 1861 to 1866, published in the report of Chief of Engineers for 1868. A series on the Detroit River made by the officials of the Detroit water works from 1853 to 1898, with the exception of 1860 to 1865, when only high and low stages were recorded, is also at our disposal through the courtesy of Mr. C. W. Hubbell, civil engineer to the Board of Water Commissioners of the City of Detroit.

"(Table No. 20.)

"In presenting a summary of these water levels in table number 20, only the months that are entirely free from ice have been considered, and the result for each year is the mean of the levels for the six months, June to November, inclusive. In order to obtain a continuous record of the fall in St. Clair River alone, the level of Lake St. Clair for the several years when no record was kept at the St. Clair Flats

has been deduced from the Detroit River readings by adding 0.44 foot, which is the mean fall from the Flats to lighthouse depot for six years when records were kept at both places. The results for Lakes Huron, St. Clair and Erie are shown on Pl. XVI. (It may be well to again call attention to the fact that the fall from the flats to Detroit is in reality 0.378 foot greater than shown by this table, the precise level line of 1899, having shown that discrepancy in the levels carried to New Baltimore from Port Huron at the head of St. Clair River, and from Gibralter, at the foot of Detroit River; but as this discrepancy occurs between Windmill Point and New Baltimore, it affects only the fall in Lake St. Clair.)

"The table shows clearly that since 1888 the fall in St. Clair River has been less than in former years, and the mean results for several groups of years are shown in the following table:

Number of years	Period	Mean elevation Lake Huron	Mean elevation Lake St. Clair	Mean fall.
17	1855-1872	581.81	576.36	5.45
16	1873-1888	581.92	576.33	5.59
11	1889-1899	580.23	575.17	5.06

"This change in fall in the St. Clair River has been attributed to a supposed change in regimen through the gorge at the head of the river, and since this opinion has been given some publicity it may be well to consider the question in some detail. In December, 1898, a cursory survey of the narrowest section of the river was made in accordance with your orders, and in 1899 the conditions at the head of the river were carefully developed. The results of this survey are shown on Plate I. The individual soundings are not shown on this plate, but the area was thoroughly covered, and the conditions are better represented by the submarine contours ten feet apart. The successive cross-sections of the river will also assist in bringing out the form of the channel. The 60-foot submarine contour extends from a point opposite the lighthouse to a little below section 'Arthur,' some 3,200 feet. Within the northern half of this area there is a very narrow 70-foot area about 1,400 feet long. To the westward of this area there is a shoal with a minimum depth of about 22 feet. Between this and the American shore there is a narrow channel having 36 feet of water, the 30-foot curve running up above the lighthouse about 400 feet. Between sections 'Culvert' and 'Fish' the shoal runs out, and the two channels merge in one. These characteristics are clearly brought out by the contours and cross-sections.

"Two surveys had previously been made of this locality,

one in 1859 and one in 1867. The soundings shown on the map of the 1859 survey are apparently accurately located, and in general they agree very closely indeed with the results of our recent survey. The only changes apparent since 1859 are as follows: The 70-foot area appears to have been extended about 700 feet downstream, with a width of only 50 feet. It may also have shifted to the westward a little, and the deep channel near the west shore may have diminished in width. If these changes are real the area of cross-section at the immediate head of the river remains about the same, all lines having been shifted a little to the westward. In the vicinity of section 'Arthur' but few soundings are given on the 1859 map, but it appears that the 50-foot and the 60-foot contours may have been extended downstream about 600 feet each, the 60-foot contour having terminated in 1859 about 400 feet above section 'Arthur.' The width of this section has apparently been reduced about 50 feet since 1859 by the building of docks. Below section 'Stauber' the sounding plotted are so infrequent that no definite conclusions can be drawn, though it appears that the deep-water areas have moved to the west, toward the concave bank, and a possible deepening of five feet may have taken place over small areas.

"The survey of 1867 is by no means as satisfactory, although a large number of soundings are available. The method followed seems to have been to sound on lines between shore stations without locating any of the soundings. This renders the actual location quite indeterminate. To distribute the soundings along the lines equidistant does not make the lines consistent with one another, and is indeed a very improbable distribution, considering the existing currents. A reasonable distribtuion can be made which will agree almost perfectly with present conditions, and any distribution which can be made establishes the fact that the 60-foot curve has not been extended since that time. In the central channel east of the lighthouse two 66-foot soundings were obtained in 1867 which agree with the present depth; to the westward appears the shoal, and the deep channel with 36 feet of water nearer the shore. There are four soundings of 60 feet at about section 'Fish,' one above section 'Arthur,' and one just below this section, which is the present limit of the 60-foot curve. No 70-foot soundings were obtained in 1867, but since the 70-foot area existed in 1859. as at present, and since only one line of soundings crossed this area in

1867, at a point where it exceeds 50 feet in width, it is not strange that it was missed.

"Although the data furnished by the previous surveys are imperfect we may conclude that between 1859 and 1867, the area of cross-section of the river at the most restricted point may have increased in area about 9,000 square feet for a length of about 60 feet, the 50-foot and 60-foot contours having been extended downstream about this distance. It also appears that since 1859, the deepest channel may have moved a little to the westward or toward the concave bank. There is no evidence of any important changes in area above section 'Arthur' since 1867, and it is quite certain that the limits of the 60-foot depth have not been extended downstream since that time. Below this section the depths may have increased a few feet over narrow areas.

"As to the effect of the extension of the 60-foot curve between 1859 and 1867, if the restricted cross-section acts as a submerged weir, its effect would be quite important, but if it is considered simply as a portion of the stream the effect on the slope would be very small. The mean fall in the St. Clair River from 1861 to 1867 was about three-tenths of a foot less than the fall from 1855 to 1859, but the level of Lake Huron had also fallen, and when the Huron level was restored in 1876 and 1886, the high slope was again found.

"Since the mean annual fluctuation of the water surface of Lake Erie is greater than that of Lake Michigan-Huron, the conclusion has been drawn that in high stages the slope in the connecting channel is low and that in low stages the slope is high. While, as will be shown, this is partially true as regards the seasonal changes in stage, and can easily be explained, it is an entirely erroneous conclusion as applied to years of high and low water. On the contrary, when we consider a term of years, it is found that the relation of stage to slope is well marked, though subject to occasional variations, as in the case of the fall at the head of the river.

"The relation of the fall in the St. Clair River to the level of Lake Huron is brought out on Plate XIV, fig. 1, in which the elevation of Lake St. Clair is plotted with reference to the stage of Lake Huron, the 6-month mean values for June to November being used. (Table No. 20.)

"Since the question under consideration is whether a permanent change in the slope of the river occurred about 1888, due to changes in regimen at the rapids, we will consider

the relation of slope to stage for the two periods before and after the supposed change. We have therefore computed by the method of least squares the relation of the level of Lake St. Clair to that of Lake Huron for thirty-three years, 1855 to 1888, excepting 1860, when no levels are available. The equation expressing this relation is found to be

"Lake St. Clair=574.32+0.707 (Huron stage—579)——
(eq. 1)

expressed as relation of fall to Huron stage this becomes

"Fall in St. Clair River=4.68+0.293 (Huron stage—579)
(eq. 2)

"That is, a rise in Lake Huron of 1 foot occasions an increase in fall of about 0.29 foot. While this relation is by no means fulfilled at all times it represents, as nearly as the data will allow, the normal condition existing from 1855 to 1888. Treating the eleven years, 1889 to 1899, since this change in regimen is said to have taken place, in the same manner, we find the equation—

"Lake St. Clair=574.20+.788 (Huron—579) or —— (eq. 3)

"Fall in St. Clair River=4.80+.312 (Huron—579)—(eq. 4)

"The difference between the equations (2 and 4) is in the wrong direction to indicate an enlargement of section, but this is of no consequence, for it is too small to indicate any change in area; it is due simply to the fact that Lake Huron is not the only factor controlling this fall, and it is only by taking a long series of years that we may arrive at the normal relationship.

"Having established as far as possible by this method that there has been no change in hydraulic conditions in recent years, we may now determine the equation which most nearly expresses the relation of fall to stage for 44 years' observations, and this is found to be:

"Fall=4.67+.30 (Huron—579).

"On Plate XIV, fig. 1, the straight line represents the relation of the elevation of Lake St. Clair to Lake Huron as deduced from this equation. In Table No. 21, the elevation of Lake St. Clair is computed by this equation for each year, and the results are given in column f, the computed fall is given in column g, and the error of the computed value for each year appears in column 8. It is seen that the computed values are in error as much as 0.30 foot in three years, but for thirty-three years the error is less than 0.20 foot.

(Table 21.)

"The effect of Lake Erie on the elevation of Lake St. Clair has not thus far been considered, as in the preceding equa-

tions the fall in the St. Clair River is made to depend upon the elevation of Lake Huron alone, while Lakes Huron and Erie generally rise and fall somewhat in unison on account of the similar climatic conditions and the partial control of Erie by Huron; yet they do not always act together. From 1865 to 1866 Huron fell 0.3 foot, while Erie rose 0.15 foot, and from 1866 to 1867 the reverse occurred. At such times Lake Erie must have an independent effect on the level of Lake St. Clair, and from the results of 44 years' observations we may obtain the equation expressing the elevation of Lake St. Clair in terms of the elevation of Huron and Erie as follows:

"C=576.05+.407 (H—581.46)+.452 (E—573.09) — — (6) where C is the elevation of Lake St. Clair above mean tide and H and E are the elevations of Lake Huron and Erie, respectively. By a simple transformation we find the fall in St. Clair River

"f=4.67+.593 (H—579.0)—.452 (E—571.50)— — — (7)

"In Table No. 21, column k, the difference between the observed fall and that computed by equation (7) is given for each year, and it is seen that these residuals are in general very small. The greatest error of the computed fall is 0.28 foot in 1883. There are ten years in which the error exceeds 0.1 foot and but five years when it exceeds 0.2 foot. This equation then expresses very closely the relation which has existed between the level of Lake St. Clair and that of Lakes Huron and Erie for forty-four years, and indicates that the level of Lake St. Clair is so nearly controlled by the lakes above and below it that its local supply can have little effect on the variations in its annual mean level, though it may affect its monthly mean, as will appear later.

"On Plate XVI, the computed and observed elevations of Lake St. Clair are shown by the two curves, and the correspondence is thus brought out graphically. The full line represents observed elevations and the dash line shows the computed values. Had a pronounced change in regimen taken place at the head of the river between 1886 and 1888, such as an important scour at the rapids, the same equation would not express this relationship before and after the change, because the fall in the St. Clair River would have been less for a given discharge after the scour; yet it is seen that the computed and actual elevations of Lake St. Clair are in very close agreement from 1868 to 1882, and from 1885 to 1899.

"Neither is the present low fall in the river unprecedented, for in 1866 it was lower than in the past three years, and dur-

ing the five years, 1864 to 1868, the mean fall in the St. Clair River was but 0.1 foot greater than in the past five years, although the stage was about a foot higher. During 1847 and 1848 the level of Huron was as low as at present. According to the published record the mean fall from Huron to Erie for the four months of May and October, 1847 and 1848 (the only months for which we have the Erie record in these two years), is less than seven feet, and the result at the waterworks in Detroit for the only one of these months when we have a record is consistent with the record for Erie.

"We have thus shown, first, that the surveys furnish no evidence of a change in the regimen of the St. Clair River since 1867, though they indicate that a small permanent change may have taken place between 1859 and 1867; second, that the water levels indicate that no permanent change of importance has taken place in the conditions governing the slope in the St. Clair River; and third, that the present relative elevations of the lakes is not unprecedented, and hence that there is no reason to suppose that, as far as natural conditions are concerned, the level of Lake Huron will not return to its normal stage.

"The fact still remains, however, that the mean level of Lake Huron for the past ten years is about 1.70 feet below the mean for the preceding thirty-four years, while Lake Erie is but one foot below that mean. As to the reason for this condition, it is possible that the improvement of the channel of the Detroit River may have had a slight effect, certainly not exceeding 0.2 foot. Considering the lower lake system as a whole, there is little question that the deficiency in precipitation in the recent years is sufficient to account for the present levels, and without going into this question of precipitation and evaporation, it may be said that it is quite possible the deficiency of the former and excess of the latter for Lake Michigan-Huron as compared to Lake Erie might be sufficient to account for the lower level of Lake Huron. But since the climatic conditions on the two lakes are usually similar, to attribute this difference in level to a change in this respect will not carry much weight unless established by an analysis of the existing data.

"There is a possible explanation of the question, however, which does not involve any changes in channel depth or differences in climatic conditions between the two lakes. It makes the present low water of Lake Huron depend upon natural causes which may be removed, and if at this time the

precipitation return to the normal the lakes will return to their usual stage.

"The effect of changes in slope at the head of St. Clair River upon the discharge from Lake Huron has been mentioned above, and it has been shown that a decrease in fall of 0.01 foot in 4.4 miles between G. T. R. and dry dock may occasion a decrease in discharge of approximately 1,200 cubic-foot seconds, this value having been determined by two measurements of discharge in December, 1898, when the water was backed up by ice, one of these measurements having shown a discharge of 47,600 cubic-foot seconds below the normal when the fall was 0.39 foot below that corresponding to the stage.

"During the past winter the water levels taken at Sand Beach and mouth of Black River gave the following results:

Month	Sand Beach	Black River	Fall	Normal fall without ice effect.	Difference.
January	579.38	578.52	0.86	1.20	0.34
February	579.38	578.70	0.59	1.20	.61
March	579.42	578.76	0.66	1.20	.54

"Assuming a decrease in discharge of 1,200 cubic-foot seconds for each 0.01 foot decrease in the fall at the head of the river, we derive the effect of ice on the discharge as given in the table below, and since a change in discharge of 10,000 cubic-foot seconds is equivalent to a depth of about 0.02 foot a month over Lake Michigan-Huron, we have the resulting storage as shown, which for the three months amounts to 0.36 foot:

Month.	Fall diminished by ice.	Corresponding decrease in discharge.	Storage depth.
	Feet.	Cubic-foot seconds	Feet.
January 1900	0.34	40,800	0.082
February 1900	0.61	73,200	.146
March 1900	0.56	64,800	.130
Total, three months			.36

"That is, if we accept this reasoning, the level of Lake Michigan-Huron is, in the spring of 1900, 0.36 foot higher than it would have been if we had had no ice in the St. Clair River during the past winter.

"During the fourteen years from 1875 to 1888 there was a mean of twelve days each winter when the temperature, as recorded by the weather bureau at Port Huron, went below 14 degrees F. in December and January, while from 1889 to 1899 the mean number of days in these months when the tem-

perature went below 14 degrees was six. During the past winter there were eight days in December and January when the temperature went below 14 degrees. The formation of ice depends upon the occurrence of very low temperature lasting for several days, so that it may be estimated by the number of very cold days better than by the mean temperature. Judged by this standard then, it is reasonable to suppose that the ice effect has been much less during the past ten years than it had been during the preceding fourteen years.

"Let us consider how the formation of ice in the lower St. Clair River would affect the water levels in any given year. The discharge being greatly diminished, Lake St. Clair would tend to drain off into Lake Erie during the winter, and it would be lowered to such a point that the flow through the Detroit River would approximately equal the discharge through the St. Clair. The elevation of this point would depend upon the relative effects of ice upon the two rivers, but the effect on the St. Clair is usually much greater than on the Detroit. The total fall in the St. Clair would thus be increased, while that in the Detroit would be diminished. The difference between the diminshed supply to Lake Erie and the diminished outflow following the lower level would be shown by the greater total fall between Huron and Erie during the months of ice effect than would naturally exist without ice.

"In 1873 water-gage readings were started at St. Clair Flats Canal, and have been continued since that time, except that from 1879 to 1883 readings were omitted during part of each year. We have therefore taken out in one group the means of the months for Lakes Huron, St. Clair and Erie from 1873 to 1887, omitting 1879 to 1883, inclusive, and in another group from 1888 to 1899, inclusive. The resulting mean monthly falls are given in table No. 22, and those are shown graphically on Plate XVII.

(Table No. 22.)

"Comparing the results of the first ten years with the curves of the past twelve years, the greater effect of ice during the former period seems to be clearly shown. In the first place it is noticed that the mean annual range of Lake Huron has been increased from 0.9 foot, as in former years, to 1.03 feet, the winter months now showing a relatively lower stage. The St. Clair curve is very instructive. It shows that in the earlier period the water surface of Lake St. Clair fell rapidly

in January and February, when it was drained off into Lake Erie, while in later years the subsidence of level is but half as great. But these points are most strikingly shown by the mean annual curves of fall in the St. Clair River. The range in the mean annual curve of fall for recent years is but 3 inches, whereas the range in the mean curve in the earlier period was 8 inches. A reference to Plate XVII will show the disturbance in this slope between December and April, and the very much smaller disturbance in the past twelve years. The range in the fall of the Detroit River has not been changed, though in recent years the curve is smoother. The maximum fall is shown in December as before, but the minimum, which occurred in February, is eliminated, and only one minimum that of May, is shown in the mean curve of recent years.

"A word may be added here as to the cause of the condition already mentioned, that in the channel connecting Lakes Huron and Erie, the fall is greater in those months when the water level is receding. This is occasioned by the facts, first, that Lake Erie has a greater mean annual range in level than has Michigan-Huron, due in part at least to the effect of the supply to the former from the latter; and second, that the seasons are earlier on Erie than on Michigan-Huron. Comparing the mean annual curves of Huron and Erie it is seen that Erie reaches its maximum in June, and begins to fall while Huron is still rising. The Huron curve from July to October is almost identical with the Erie curve from June to September, that is, there is practically the same subsidence in the two lakes during the three months succeeding the maximum, but since Erie is about a month in advance, the fall in the connecting channel is increasing with a falling stage. As Erie reaches its maximum a month earlier than Huron, so is its subsidence checked a month earlier, and we have from November to April a generally decreasing fall in the connecting channel. Between March and April Huron rises slowly, but Erie, on account of its earlier season has a sharp rise in this month, causing the occurrence of the lowest fall of the year either in April or May. Thus we have a cycle of changes resulting in a low slope in the first half of the year and a high slope in the latter half due to seasonal changes, but, as has been shown, the slope in the high-water years is greater than in low-water years.

To return to the question of the effect of the ice on the relative levels of Huron and Erie, it has been shown that the wa-

ter levels give evidence of much greater disturbance of the natural slope during the winter months of the years from 1873 to 1878 and from 1884 to 1887 than during the winters of the past twelve years, and that, judged by the number of cold days in each winter, the recent years have been much less favorable for the formation of ice. The probable effect of the diminished slope at the head of the river caused by ice during the past winter has been shown to be more than four inches. While this effect may be overestimated in the foregoing table, there is no doubt that in the consideration of the effect of ice we are dealing with conditions which are very potent and that the lack of ice effect due to recent mild winters furnishes a plausible explanation of the present low water of Lake Huron as compared with Lake Erie. The conclusion seems to be clearly indicated that nature has provided a system of regulating works in the St. Clair River which she has neglected to use to their full capacity during recent years."

Extract from the Report of Assistant Engineer F. C. Shenehon on page 5332, as follows:

"The wetted perimiter of the bridge section as developed by the soundings is so broken and irregular, and the water is so perturbed and deflected by the bridge piers and by a caisson that escaped during construction and lies across a portion of span 6, that the validity of results derived from such a section may be questioned.

"A discussion of this point, however, points to an error to be expected from this source but little in excess of that of an open-river section. Let it be assumed that the eddies and boilings close to the piers make correct estimates of the flow impossible in areas extending for certain distances from them, and that the caisson lying across a portion of span 6 adds another uncertain area.

"The resulting indetermination as affecting the total volume of flow may be closely estimated as follows:

"Taking the doubtful regions as those portions of the cross-sectional area extending ten feet in spans 1, 2, 8, and 9 and 20 feet from the piers in the remaining spans; adding 300 square feet for the caisson, they are as follows:

	Square feet.		Square feet.
Span 1	90	Span 7	404
2	110	8	340
3	500	9	200
4	660		
5	900	Total	4260
6	940		

"This is about 10 per cent. of the total cross-section. With a velocity taken as half that of the mean velocity of the river the discharge in question is 5 per cent. of the total volume.

"It is not probable that the errors in estimating the flow in these 19 doubtful places will all have the same sign. In some the quantity will be taken too great and in some too small, so that the summation will balance error against error and eliminate a part of them. It will, therefore, be entirely safe to assign 10 per cent. as a maximum error in the sum of the partial discharges.

"With this liberal allowance the indetermination in the volume of flow of the full river, from this cause, is seen to be 10 per cent. of 5 per cent., which is but one-half of 1 per cent.

"In view of the small cost of gauging from a bridge as compared with open-river work the bridge section warrants the large excess of coefficient work necessary to place its results in comparison with those of a simpler section with unbroken flow.

"Regarding the final results, the checking of the volume of the discharge is more reliable because the two sections present conditions so different as to require independent methods of treatment for the determination of coefficients."

Extract from page 5343, as follows:

"The third element that enters into the substation coefficient is the direction coefficient.

"The direction of the current flow was not, as a rule, at right angles to the bridge, but at midspan the trend was 2 or 3 degrees to the eastward, and nearer the piers was deflected from them, so that for each opening the threads tended to converge in a vena contracta.

"The surface indication of the direction was taken as the direction at all depths, and the angle taken by a 20-foot line flush with the water surface, to which was attached a weighted float, while the upstream end was attached to the weight of the B meter lowered from the south side of the bridge just below the water, was accepted as a basis for direction coefficient.

"This was observed for all substations, and additional observations were put in around the piers.

"The influence of the direction element on the measured discharge is minute, almost negligible.

OPEN SECTION.

TABLE 5. INDEX VELOCITIES AS PERCENTAGES OF MEAN INDEX VELOCITY.

	Group No.							
	1.	2.	3.	4.	5.	6.	Total.	Weighted Means.
Number of observations in group elevation of.....	10	10	10	10	10	7	57	....
Lake gauge	572.0	571.4	571.2	571.1	570.9	570.5	....	571.2
Mean index velocity	4.84	4.58	4.51	4.45	4.38	4.21	....	4.51
Station:								
1	42.6	33.9	28.4	23.5	25.6	29.2	....	30.6
2	81.3	79.0	78.6	77.6	77.3	77.2	....	78.5
3	95.9	96.8	97.7	99.7	98.8	97.6	....	97.8
4	104.5	105.1	105.4	106.0	106.7	106.2	....	105.6
5	126.6	127.8	129.3	127.9	128.1	126.6	....	127.8
6	129.2	130.5	133.1	133.0	134.4	136.1	....	132.5
7	124.1	125.1	126.1	126.4	125.6	125.7	....	125.5
8	121.3	122.9	124.6	124.9	124.5	123.3	....	123.6
9	118.2	121.1	120.5	121.4	121.6	122.1	....	120.7
10	108.9	110.5	110.3	110.4	110.7	112.4	....	110.4
11	107.7	110.6	110.7	111.9	110.8	110.2	....	110.3
12	106.7	107.6	108.9	108.6	108.3	109.5	....	107.8
13	92.6	93.5	91.9	92.7	91.2	91.9	....	92.3
14	100.0	99.8	99.3	99.9	101.0	98.8	....	99.9
15	92.4	90.9	91.3	90.4	91.8	90.7	....	91.3
16	84.1	84.3	84.6	84.2	83.7	83.1	....	84.0
17	64.1	64.9	61.4	62.1	61.0	59.9	....	61.8

Page 5347, the following table:

OPEN SECTION—MEAN VELOCITY COEFFICIENTS.

568.0		0.937	0.927	0.932	0.933	0.933	0.939	0.927	0.907	0.908	0.921	0.935	0.917	0.914	0.925	0.893
567.5	Volume	.9325	.9235	.9295	.9294	.9295	.9355	.9235	.908	.890	.9165	.932	.9145	.910	.918	.855
567.0	taken	.928	.920	.926	.926	.926	.932	.920	.890	.885	.912	.929	.912	.906	.911	.848
566.5	from	.9235	.9165	.9225	.9225	.9225	.9285	.9165	.895	.891	.9075	.928	.9065	.902	.904	.840
566.0	table.	.919	.913	.918	.919	.919	.925	.913	.891	.887	.903	.923	.907	.898	.897	.833
565.5		.9145	.9065	.9145	.9155	.9155	.9215	.9065	.887	.883	.8985	.920	.9045	.894	.890	.826
565.0		.910	.903	.911	.912	.912	.918	.903	.883	.879	.894	.917	.902	.890	.883	.819

Extract page 5353, as follows:

"In investigating the form of the vertical curves, those of stations 1 and 17 were set aside as in too shallow water for developing the curve, and the remaining 15 were divided into three sets of five each of as near the same depths as possible.

"By dividing the discharge observations with all the high gages in one group and all the low-gage measurements in the other, and taking for each group the mean of the eight-tenths depth ratios, a percentage was derived for each mean stage, high and low. A similar treatment of the velocity ratios at the subsurface depth, 565, gave likewise two ratios.

"Taken in connection with the index, through which both curves must pass at ratio 1.00, the high-gage curve was defined by three points and the low by three points. The difference in the areas of the two curves divided by the depth indicated the extent of the variation of the coefficient.

"This matter will be taken up again later in a discussion of vertical curves in the light of the added high-water observations of 1900, and it may be stated now that the eight-tenths depth ratio showed little change for change of gage, the mean change in 15 curves for a gage movement of 1 foot being but a tenth of one per cent. At 565 the change amounted to an increase of 1.2 per cent. as the mean of the 15 station curves.

"The following summary shows the distribution of the ratio change:

Series number.	Number of observations.	Mean depth.	Stations in series.	Increment in ratio for feet rise in section gauge. Per cent.	Add to coefficient on this account for feet rise in gauge. Per cent.
1.....	95	34	4, 5, 6, 7, 8	2.14	0.4
2.....	91	28	3, 9, 10, 11, 12	1.36	.3
3.....	83	17	2, 13, 14, 15, 16	.06	.0
Total.....	269	..	15	...	..
Mean.....	....	26.3	....	1.2	.2

"A second increment to the coefficient for rise of gage is due to the excess of the top feet percentage over the mean.

"Had the index been located at a percentage of depth instead of at an invariable elevation, the error of constant coefficient for the mean velocity percentage of each series would have been as follows:

"Indicated Error of Assumption of Constant Velocity.

"Coefficient When Index Is Taken at Percentage Depth.—

For 1-foot rise of gage: Series 1, constant coefficient would be 0.3 per cent. too small; Series 2, constant coefficient would be 0.3 per cent. too small; Series 3, constant coefficient would be 0.0 per cent. too small.

"Mean of 15 curves gives coefficient 0.2 per cent. too small, which is almost a negligible quantity. And so far as these observations go they tend to prove the proposition of fixed velocity relations at tenths of depth.

"An indication is given that a strong downstream wind speeds the upper strata more than those near the mid-depth, causing a slight reverse flexure to the vertical curve as it nears the surface. Two to three per cent. marks the extent of this departure from the curve of calm weather."

Extract from Appendix EEE, of Annual Report of the Chief of Engineers U. S. A. for the fiscal year ending June 30, 1901, report of Principal Assistant Engineer E. E. Haskell, page 3771, as follows:

"Our winter's work in the measurement of the discharge of this river will be of exceptional value. It has thus far been a matter of conjecture as to what effect the freezing over of the river had on the volume of outflow from Lake Huron. Assistant Sabin, in his annual report, called attention to this matter, and pointed out that, while dependent upon the weather, it might be large enough to materially affect the relative stage of water in the lower lakes. We are now prepared, or will be on completion of the reduction of our observations, to throw much light upon this matter. To anticipate our results: The temperature conditions of the early winter were such that by January 20, Lake St. Clair and the St. Clair River, from its mouth to a point above Stag Island, had frozen over. The foot of Lake Huron had also frozen over and what is familiarly known as the 'Ice Bridge' had formed at Fort Gratiot. This left open water from a point just below Fort Gratiot to a point some little distance above Stag Island. The fall between our Grand Trunk gage —near the head of the river—and the one at the mouth of Black River fell off about two-thirds. The open river above mentioned enabled us to continue discharge measurements as usual. Observations were made at Section Dry Dock until such time as floating ice enough had broken off from and run under the ice bridge to block the river from near Stag Island to a point above this section. A new section, called Craig, was immediately selected above the mouth of Black River where observations were made until the ice broke up near the

last of March. Almost immediately after the closing of the river in January, as above outlined, the discharge fell off approximately 50 per cent., and did not resume normal conditions of flow until the river became clear of ice about the middle of May. During the general breaking up of the ice, immense masses of it were forced into the river by northerly winds and so choked the flow that for a time but very little water could have found its way through. For some days Lake St. Clair was but a few inches above the level of Lake Erie. This condition of restricted flow has made itself manifest in the relative elevations of Lakes Huron and Erie, and we find that for the month just closed Lake Huron was 0.55 foot higher, while Lake Erie was 0.75 foot lower than during June, 1900. Here then is the explanation for the present low stage of water in Lake Erie, which will be thoroughly substantiated when the results from the complete reduction of our observations are ready for presentation."

Extract from the Report of Assistant Engineer Francis C. Shenehon, page 3773, as follows:

"These objections prevailed and a new section just above Point Three Points was tested. This showed a maximum velocity of about 5.5 feet per second, with a midstream depth of 60 feet and a width of 1,686 feet between terminal crib locations.

"The stream approaches this section from a long, straight course. It is free from 'boilers' and eddies."

Extract from report of Principal Assistant Engineer E. E. Haskell, for 1902, being included in the Report of the Chief of Engineers, U. S. Army, for 1902 (pages 2777-8), as follows:

"January shows a loss of discharge of 13,500 cubic feet per second; February a loss of 21,650 cubic feet per second, and March a loss of 13,080 cubic feet per second. The April indication of the Oswego gage shows too great a discharge by 3,195 cubic feet per second. The mean loss of flow for these four months spread over the whole year is about 4,280 cubic feet per second. For the month of February—the month of intense cold, when the upper river is frozen over, the loss of outflow is seen to be about 10 per cent. The loss is shown to be mainly accounted for by the increased slope in the river above the Galops Rapids, Table 22a. For February the slope from Ontario to Galops is shown to be 2.78 feet as against a normal summer slope for this stage of Ontario of 2.07 feet.

"The lessened depth on the Galops weir is due to the loss

of head caused by the river being frozen over and by the iced shallows of the approach. It is extremely gratifying to find that the efficiency of the Galops weir is so little impaired by ice that one per cent. will measure its decreased flowing power, even in February.

"This analysis is extremely satisfactory and the winter flow of the St. Lawrence may be stated with great positiveness. The storage value of the ice period is stated by Mr. Shenehon to be equivalent to about 7 inches on the surface of Lake Ontario."

Extract from the report of Assistant Engineer F. C. Shenehon, for 1902, included in the report of the Chief of Engineers, U. S. Army, for 1902, as follows:

TABLE No. 22a.—SLOPE OF ST. LAWRENCE RIVER FROM OSWEGO TO GALOPS RAPIDS, AND DISCHARGE EFFECT OF ABNORMAL SLOPE IN SPRING AND WINTER MONTHS.

Month.	Water surface Oswego.	Water surface Galops.	Slope.	Normal slope.	Excess slope.	Corresponding loss of discharge.
January	245.43	242.91	2.52	2.07	+0.45	+11,592
February	245.52	242.74	2.78	2.07	.71	18,290
March	245.83	243.23	2.60	2.09	.51	13,138
April	246.39	244.13	2.26	2.12	.14	3,606
May	246.67	244.52	2.15	2.14	+ .01	+ 258
June	246.82	244.70	2.12	2.15	— .03	— 673
July	246.77	244.63	2.14	2.14	.00	000
August	246.43	244.20	2.14	2.13	+ .01	+ 258
September	246.02	243.92	2.10	2.11	.01	— 258
October	245.69	243.57	2.12	2.10	+ .02	+ 516
November	245.44	243.34	2.10	2.09	.01	258
December	245.43	243.28	2.15	2.09	+ .06	+ 1,545
Sums					+1.88	+48,530
Means					+ .157	+ 4,044

"This loss of head in the river above the Galops Rapids, giving less water on the crest of the weir and therefore a lessened discharging power, accounts for about 4,000 cubic feet per second throughout the whole year. Part of this loss of head occurs above Ogdensburg, where a portion of the winter the water is running through a tube, of which the ice forms the upper part, instead of in an open channel, with consequent increased frictional resistance and loss of cross-sectional area, and the remainder in the ice-choked shallows above the Galops.

"Returning to Table 22, in which the discharge is measured, not by the one weir at the Galops, but by the three that have been calibrated, the following losses are shown:

Month.	Loss by Table 22a.	Loss by Table 22.	Subtract.	Loss by Table 22 corrected.
January	11,592	15,800	2,300	13,500
February	18,290	23,950	2,300	21,650
March	13,138	15,380	2,300	13,080
April	3,606	5,495	2,300	3,195
December	1,545	2,437	2,300	137
Sums	48,171	63,062	11,500	51,562
Yearly means	4,014	5,205	.....	4,297

"A comparison of the losses in the first and last columns shows a loss of efficiency of the Galops weir of about 3,300 cubic feet per second for February and about 1,900 for January. The 2,300 subtracted from the values in Table 22, is the August and December indication of the amount by which this method of investigation gives a cumulative error of result.

"Taking the area of Lake Ontario as 7,240 square miles, a discharge of 6,400 cubic feet per second continuing throughout the year represents the volume of water in the top foot of its depth. It follows that the storage value of the ice retardation of flow, 4,000 cubic feet per second throughout the year, is 4,000 divided by 6,400, or 0.625 feet. An open winter, therefore, with other conditions of inflow and rainfall and evaporation remaining normal, would result in a lowering of the surface of the lake about six-tenths of a foot."

Table No. 19—Three Points Section, St. Lawrence River, same report, page 2803, as follows:

TABLE No. 19.—THREE POINTS SECTION, ST. LAWRENCE RIVER.—Station Elements.

Elements.	STATIONS. 1.	2.	3.	4.	5.	6.	7.	8.	9.
Section Gauge 226.03.									
1. Depth at station.....	4.7	7.2	21.2	23.8	28.4	36.4	42.4	47.6	56.1
2. Width	86	100	100	100	100	100	100	100	100
3. Area.....square feet..	422	801	1,948	2,263	2,703	3,479	4,215	4,880	5,530
4. Approximate index velocity	1.71	3.19	4.33	4.46	4.79	4.93	5.19	5.11	5.26
5. Coefficients:									
Vertical	.888	.908	.885	.856	.877	.895	.907	.948	.941
Transverse	1	1	1	1	1	1	1	1	1
Direction	.956	.951	.970	.988	.993	.996	.996	1	.999
Combined	.849	.863	.858	84.6	.871	.891	.903	.948	.940
6. Direction angle.....	17° S.	18° S.	14° S.	9° S.	7° S.	5° S.	5° S.	1° S.	2° N.
7. Percentage discharge...	.3	1.1	3.7	4	5.3	6.9	8.9	10.8	12.4
8. Weight used.....	0	1	4	4	6	7	9	10	12

TABLE No. 19.—THREE POINTS SECTION, ST. LAWRENCE RIVER.—Station Elements.

Elements.	STATIONS. 10.	11.	12.	13.	14.	15.	16.	17.	Weighted means (total)
Section Gauge 226.03.									
1. Depth at station.....	55.1	52.7	45.3	36.2	26.7	18.3	9.1	5.3	....
2. Width	100	100	100	100	100	100	100	100	1,686
3. Area .....square feet...	5,476	5,242	4,494	3,567	2,656	1,788	986	551	51,091
4. Approximate index velocity	5.20	4.81	4.52	4.22	4.02	4.14	4.07	3.83	4.79
5. Coefficients:									
Vertical	.920	.922	.905	.899	.920	.927	.910	.927	.898
Transverse	1	1	1	1	1	1	1	1	1
Direction	.998	.996	.990	.996	.995	.990	.990	.985	.994
Combined	.918	.918	.896	.895	.916	.918	.918	.914	.908
6. Direction angle.....	4° N.	5° N.	8° N.	5° N.	6° N.	8° N.	8° N.	10° N.	0°. 3 N.
7. Percentage discharge....	11.8	10	8.2	6.1	4.5	3.1	1.8	1	....
8. Weight used	12	10	8	6	5	3	2	1	0

Extract from the report of Assistant Engineer Louis C. Sabin, forming part of the report of the Chief of Engineers, U. S. Army, 1902 (pages 2822-2825), as follows:

"Winter Discharge.—In my annual report of 1900 (Report Chief of Engineers, p. 5398) attention was called to the probable effect of ice upon the discharge of St. Clair River, and the very important effect of this condition upon the levels of Lakes Michigan, Huron, and Erie. In order to test the magnitude of this effect, instructions were received to continue the measurement of discharge through the winter of 1900-1901. It so happened that this winter was a favorable one for the work, as the blocking was more nearly complete and longer continued than during the preceding or following winter.

"The ice that forms on the border of Lake Huron in the early winter finds its way into the river and is finally stopped when the weather becomes cold enough to freeze over some of the more sluggish reaches of the lower river. The ice continues to come in from the lake, the blocking becoming more complete until nearly the entire river is covered. As in some places broken pieces find their way below the surface, partial dams are frequently made. Meantime an ice bridge has formed across the head of the river, which wastes away slowly from the downstream side and is renewed from above.

"It was late in December, 1900, before the effect of ice on the discharge was apparent. During January, 1901, the running ice interfered greatly with the observations, sometimes precluding the possibility of working on the river, but from January 2, to February 2, eleven discharges were measured at section 'Drydock.' Early in February the ice reached and passed this section and eventually covered the river as far up as the mouth of Black River. In anticipation of this, Section 'Craig' had been selected, and gaging stations marked by ranges, and this section was used during February and March, when 38 discharge determinations were made. About March 23, a break occurred, the river cleared to Stag Island, and later to Algonac. It blocked again early in April, and did not finally become entirely clear until May 8. From March 25 to April 26, the conditions varied greatly from day to day, and sixteen measurements were made.

"Plate II shows the changes in the fall from 'G. T. R.' to 'M. B. R.' and from 'M. B. R.' to 'D. D.' during the period December 27, 1900, to May 31, 1901, with notes concerning the ice conditions as nearly as can be stated. On January 16,

the effect of the ice is very marked, the blocking progressing rapidly for several days. About February 2, the ice has extended up the river to section 'Drydock,' and the fall between 'M. B. R.' and 'D. D.' increases to the middle of March, when the ice has reached the mouth of Black River. A temporary break partially cleared this upper reach, and from March 14 to 23, the fall from 'M. B. R.' to 'D. D.' diminished. On March 24 a general break occurred, which restored both the falls to their normal value. Still another blockade in the lower river is shown by the sudden decrease in the fall, beginning April 17, and from this time the blockade was more or less effective until the final clearing of the river on May 8th.

"During February and March, 1901, when section 'Drydock' was blocked with ice, the discharge was measured at section 'Craig.' On this section the meter stations were 100 feet apart, the first one being 50 feet from the dock at west end of section. As the water will show at the east end of the section, it was covered by ice near the east bank, the portion of the section so covered varying from day to day, but never extending west of station 12. The discharge through the partial area represented by station 12, varied from 2,000 to 3,000 cubic foot-seconds. The discharge beyond the twelfth partial area varied from nothing to 1,500 cubic foot-seconds. The velocities were measured by the usual method up to the edge of the ice on the east side, and the discharge beyond was determined by occasional observations through the ice. The discharge beyond station 12 was so small that a considerable percentage of error in its determination would have a trifling effect on the total discharge.

"On this section the observations were so made as to give a vertical curve for each station at every complete observation for discharge. When two meters were used, one was kept at the four-tenths depth point while the other meter occupied successively the odd-numbered tenths of depth, as the one-tenth, the three-tenths, the five-tenths, etc. The following day when the station was visited the one meter remained as before at the four-tenths depth point while the other meter occupied successively the even-numbered tenths of depth.

"The greater number of the discharge measurements on this section, however, were taken with three meters—one remaining at four-tenths depth, while another occupied the surface—the one, two, three, four and five-tenths depth points, successively, and the third meter occupied the bottom, the

nine, eight, seven, six, five and four-tenths depth points, successively. The length of run for each position of the meters was in general 50 seconds, but when the three meters were at four, five and six-tenths depth, respectively, a run of 200 seconds was made. The ratio of the velocity observed at any given point in the vertical to the velocity observed simultaneously at the four-tenths depth point was obtained for each observation, and when combined these gave the coefficient by which it was necessary to multiply the four-tenths depth velocity to give mean velocity for the station. This program gave a complete vertical curve for each observation of discharge, and was equivalent to a direct measurement of the mean velocity. This method was adopted because it was known that enough discharges would not be measured on this section to warrant the refinement of obtaining the vertical curves with the multiple meter set, and the practical agreement of the measurements made at the two sections under similar conditions of slope indicate that the results so obtained are at least as accurate as the effective value of the fall can be obtained.

"Law of Winter Discharge.—In Table No. 5, is given a summary of the discharge measurements taken at section 'Drydock' during the ice period. The elevations of water surface were read from the records of the self-registering gages. The record for 'G. T. R.' was taken twelve minutes early, and of 'M. B. R.' eight minutes early it being considered that this time was required for a given elevation of water surface at the gages to have its effect at the section. In each case the observed elevation is the mean of the elevations corresponding to each observation for current velocity. The quantities in column 9, give the discharge as observed, to the nearest hundred cubic-foot seconds, without any corrections.

"Platting the observed discharges in column 9, with reference to the fall from 'G. T. R.' to 'D. D.' ($=f_2$, col. 7) indicated that the discharge varied approximately as the square root of this fall; but it also appeared that the discharges measured at a high stage were greater than those measured at a low stage. It is evident that the stage is not the controlling factor in the fall under the existing conditions. There are not enough discharges to differentiate the effects of fall and stage with any great accuracy, and the effect of the stage being a comparatively small factor that value of this effect was adopted which when applied to the observed discharge would give values for the discharge at mean stage most nearly

proportional to the square root of the fall. After several trials the following empirical equation was derived for the discharge in cubic feet per second.

"$Q = 205{,}000 \sqrt{f_2} + 12{,}000$ ('G. T. R.' + 579.2) Eq. 2 where f_2 is the fall from 'G. T. R.' to 'D. D.'

"The greatest variation of 'G. T. R.' from the stage 579.2 was 1.1 feet, giving a maximum value to the correction for stage of 13,000 cubic-foot seconds.

"In column 15 of the table this effect of the stage has been applied so that the quantities in this column represent, according to this assumption, the discharge that would have been observed, with the fall that obtained, had the water stage at 'G. T. R.' been 589.2 at the time of the observation. These corrected values of discharge have been platted, and are shown on Plate 3, where the curve $205{,}000 \sqrt{f_2}$ is also drawn.

"In column 16, the discharges, computed by equation 2, for the observed conditions of stage and fall, are given. These values compared with the observed discharges, column 9, give the residuals in column 17. It is seen that eight of these residuals are greater than 6,000 cubic second feet. It is not thought, however, that the observed discharges are in error as much as these residuals indicate, but that the greatest portion of the error is in the determination of the fall between gages. In other words, it is thought that the discharge can be more accurately measured than the actual effective fall. In column 18, equation 2 is used to derive the fall corresponding to the observed values of the discharge, and the residuals are shown in column 19. It is seen that there is but one residual as great as 0.06 foot, or three-quarters of an inch, and all but eight are less than 0.04 foot, or one-half inch. Considering, for example, discharge number 124, the discharge computed from the observed fall differs by 10,200 cubic foot-seconds from the observed discharge; the fall, however, computed from the observed discharge by the same formula differs by only 0.033 foot from the actual fall.

"When the river is covered with ice above the gage at Section 'Drydock' the fall from 'G. T. R.' to 'D. D.' increases with no increase in flow, but rather with a diminished discharge, as the blocking of the river is so much more effective. At such times, therefore, the fall in a reach of the river not obstructed by ice must be used for reference. All of the determinations for discharge taken at section 'Craig' were made under these conditions, and as the range in fall from 'G. T. R.' to 'M. B. R.' during the time these discharges were

taken was too small to develop the law connecting discharge and slope, the discharge at 'Drydock' and 'Craig' have been considered together for this purpose.

"A summary of the 'Craig' discharges is given in Table No. 6. When the discharges measured at both sections were platted with reference to the fall from 'G. T. R.' to 'M. B. R.' the value of discharge appeared to vary more nearly as f_1 0.4 than as f_1 0.5. It was also seen that for a given fall the discharge at high stage was greater than at low, although there was no connection between stage and slope. In this case it was found that if each discharge was corrected to mean stage by applying the factor 10,000 cubic foot seconds per foot change in stage, the results would then more closely follow the fall between the two gages. As before, the greatest correction for stage is 11,000 cubic foot seconds, corresponding to 1.1 feet variation in stage. There is no theoretical reason for this particular value of the stage factor, neither is there any theory advanced for the use of the exponent 0.4 applied to the fall. The equation below agrees more closely with the observed results than any other found, and the use of the exponent 0.5 results in bunching the residuals, although it has been used successfully when the discharges measured at section 'Drydock' are referred to the total fall from 'G. T. R.' to 'D. D.'

"There is one point, however, to which attention should be called in this connection: The area of cross-section of the river at the point where the 'G. T. R.' gage is established is approximately 40,000 square feet, and the cross-sectional area at the location of the 'M. B. R.' gage is approximately 60,000 square feet. (See Table No. 1 and Pl. 1, Report Chief of Engineers, 1900, p. 5363.) The flow is therefore not uniform, and the difference in velocity heads for the two sections is available for overcoming the friction between them. We should then expect the discharge to vary approximately as the square root of the observed fall plus this difference in velocity heads, and this is found to be the case in a general way; but since an equation of this form would not be convenient to use in determining the discharge from an observed fall, it has not been used.

"The equation adopted to connect the discharge and fall is as follows:

$Q = 250{,}000\ f_1\ 0.4 + 10{,}000\ ('G.\ T.\ R.' - 579.2)$ Eq. 3 where Q is discharge in cubic foot seconds, and f_1 is the fall in feet from 'G. T. R.' to 'M. B. R.'

"The quantities in column 10 of Tables 5 and 6 represent, according to the assumption that the discharge is increased 10,000 cubic foot seconds for 1 foot rise in stage, what the discharge would have been with the observed fall had 'G. T. R.' been at elevation 579.2. These quantities are platted on the diagram Plate IV, where the curve 250,000 f_1 0.4 is also shown. The quantities in columns 11 are the discharges computed from the equation 3, and these, compared with the observed discharges in columns 9, give the residuals in columns 12.

"Out of 60 measurements on the two sections, 14 have residuals greater than 6,000 cubic foot seconds, but, as in the case of the 'Drydock,' discharges referred to the fall from 'G. T. R.' to 'D. D.,' comparatively small errors in the determination of the fall will account for what appear to be large errors in discharge. The fall computed from the observed discharge for each measurement is shown in columns 13, and the indicated errors in the fall are given in columns 14. Thirteen measurements out of the 60 have residuals greater than 0.02 foot, and the largest error indicate in the fall is less than five-eighths of an inch.

"In a case where the slope is governed by the stage, and the discharge is referred to the latter, suppose one foot rise in stage to be equivalent to 20,000 cubic foot seconds; then an error of 0.05 foot in gage reading is equivalent to 1,000 cubic foot seconds discharge; but suppose a foot rise to stage results in increasing the fall between two gages from 1.0 to 1.1 feet, then if the discharge is considered a linear function of the fall, an error of 0.05 foot in the reading of one gage, resulting in the same error in fall, would be equivalent to 10,000 cubic foot seconds error in discharge. The accuracy demanded in the determination of the water level when the discharge is made a function of the slope is thus apparent, and one should not consider that the water levels are absolute, while all errors are attributed to the determination of the discharge. To illustrate that the falls are really approximate, the ranges in the value of the fall during the time occupied by the discharge measurement are given in Table No. 6 for 5 of the discharges.

"Effect of Ice on Lake Huron Stage.—We may now determine the effect of the ice upon the elevation of Lake Huron during the winters for which we have observations of the local slope. For this determination the discharges that would have taken place had the river remained clear cannot be de-

termined by equation 1, involving the elevation of Lake St. Clair, for during the ice period the diminished supply to Lake St. Clair lowers its level very much and the discharge indicated by equation 1 would be too great. In order to get a quantity with which to compare the actual discharge, the equation derived in 1900, involving only the elevation of Lake Huron, has been used.

"The discharges corresponding to the mean elevations of Lake Huron are shown in column 3 of Table No. 7. The discharges, computed from the known fall at the head of the river are given in column 4; the differences in second feet for each month are shown in column 5, and the effects in feet of depth on Lake Michigan-Huron and Lake Erie are shown in the final columns. It is seen that the effect on Lake Michigan-Huron is 0.31 foot in 1900, 0.52 foot in 1901, and 0.27 foot during the past winter. These quantities will not be affected more than about 0.03 foot by the fact that the quantities in column 3 are derived from the actual lake level instead of from the somewhat lower level that would have obtained for each month after the first had there been no obstruction. The cumulative effect on Lake Erie, however, would be considerably reduced by taking into account the fact that when the lake is lowered by the diminished supply from St. Clair River the discharge of the Niagara River is decreased, partially compensating the loss from above."

Also Table No. 6, Discharge of St. Clair River and Table No. 7, Effect of Ice in St. Clair River, pages 2836-37.

TABLE NO. 6—DISCHARGE OF ST. CLAIR RIVER.

(Measurements at Section Craig during winter of 1900-1901 when river was partially blocked with ice.)

1.	2.	3.	4.	6.	8.	9.	10.	11.	12.	13.	14.
		Observed data.					Results from equation No. 3				
No. of measurement.	Date. 1901.	Water levels above mean tide at New York. G.T.R. Feet.	M.B.R. Feet.	Fall from G.T.R. to M.B.R. Feet.	Meters used at 0.4 depth.	Observed discharge (cubic feet per second).	Q—10,000 (G.T.R.—579.2 (cubic feet per second).	Discharge computed by equation 3 (cubic feet per second).	Residual discharge (computed observed cubic feet per second).	Fall f' computed for observed discharge by equation 3. Feet.	Residual fall (computed observed). Feet.
79	Feb. 4	579.579	579.482	0.098	10B	100,000	96,200	102,500	+ 2,500	0.092	—0.006
80	5	.558	.463	.095	10B	103,800	100,400	100,900	— 2,900	.102	+ .007
81	6	.305	.190	.115	10B	100,500	99,500	106,300	+ 5,800	.100	— .015
82	7	.193	.077	.116	10B	100,800	100,900	105,500	+ 4,700	.103	— .013
83	8	.152	.037	.115	10B	102,100	102,600	104,800	+ 2,700	.108	— .007
84	12	580.002	.916	A.087	10B	111,800	103,800	102,100	— 9,700	.111	+ .024
85	16	579.252	.143	.110	10B	104,300	103,800	103,900	— 400	.111	+ .001
86	19	.505	.398	.108	10B	112,200	109,200	105,700	— 6,500	.126	+ .018
87	20	.700	.612	B.090	10B	115,600	110,600	100,400	—15,200	.130	+ .040
88	21	.348	.240	.108	10B	108,500	107,000	104,100	— 4,400	.120	+ .012
89	23	.163	.058	.105	10B	105,400	105,800	101,100	— 4,300	.116	+ .011
90	25	.145	.037	.108	10B	108,100	108,700	102,100	— 6,000	.124	+ .016
91	26	.255	.142	.113	10B	108,900	108,300	105,100	— 3,800	.124	+ .011
92	27	.292	.178	.113	11B	111,600	110,700	105,400	— 6,200	.130	+ .017
93	28	.066	578.960	.106	11B	105,100	106,400	100,600	— 4,500	.118	+ .012
94	Mar. 1	578.855	.723	.132	11B	106,300	109,700	107,800	+ 1,500	.128	— .004
95	2	579.400	579.300	C.100	11B	111,300	109,300	101,500	— 9,800	.126	+ .028
96	4	.168	.006	D.160	11B	113,900	114,200	119,800	+ 5,900	.141	— .019
97	5	.398	.258	.140	11B	114,700	112,700	115,800	+ 1,100	.137	— .008
98	6	.242	.087	.156	11B	115,600	115,200	119,300	+ 3,700	.144	— .012
99	7	.016	578.869	.147	11B	108,500	110,300	114,300	+ 5,800	.129	— .018
100	8	.100	.938	.162	11B	113,100	114,100	119,700	+ 6,600	.140	— .022
101	9	.419	579.289	E.130	11B	116,100	113,900	112,700	— 3,400	.140	+ .010
102	11	578.695	578.560	.135	11B	107,100	112,100	107,200	+ 100	.134	— .001
103	12	579.482	579.347	.135	11B	119,800	117,000	115,000	— 4,800	.150	+ .015
104	13	.237	.108	.138	11B	115,900	115,500	113,600	— 2,300	.146	+ .008
105	14	.067	578.899	.168	11B	115,800	117,100	121,200	+ 5,400	.150	— .018
106	15	.748	579.610	.138	11B	126,900	121,400	118,700	— 8,200	.165	+ .027
107	16	.292	.161	.131	11B	119,300	118,400	111,800	— 7,500	.154	+ .023
108	18	.381	.205	.176	11B	123,900	122,000	126,600	+ 2,700	.167	— .009
109	19	.192	.034	.158	11B	117,500	117,600	119,400	+ 1,900	.152	— .006
110	22	.340	.177	.172	11B	122,400	120,900	125,100	+ 2,700	.163	— .009
111	23	.301	.108	.192	11B	128,400	127,400	130,200	+ 1,800	.186	— .006

Note.—The range in value of observed fall f'—G.T.R.—M.B.R., is as follows:

A. No. 84, 0.03 to 0.14.
B. No. 87, 0.02 to .12.
C. No. 95, .00 to .13.
D. No. 96, .11 to .23.
E. No. 101, .06 to .16.

TABLE NO. 7.—EFFECT OF ICE IN ST. CLAIR RIVER DURING WINTERS OF 1900, 1901 AND 1902.

1.	2.	3.	4.	5.	6. Difference, or effect or ice.	7.
Date.	Elevation of Lake Huron at Sand Beach. Feet.	Discharge of St. Clair River by equation 4 of 1900 cubic feet per second.	Discharge derived from fall at head of river by equations Nos. 2 & 3 cu. ft. per second.	Cubic feet per second.	Depth Lake Michigan-Huron. Feet.	Depth Lake Erie. Feet.
1900.						
January	579.38	183,100	147,300	35,800	0.07	—0.34
February	579.38	183,100	139,200	43,900	.09	— .41
March	579.42	183,900	126,300	57,600	.12	— .54
April	579.53	186,000	173,200	12,800	.03	— .12
Total for winter					.31	
1900.						
December	580.02	195,300	191,100	4,200	.01	— .04
1901.						
January	579.77	190,600	160,300	30,300	.06	— .28
February	579.64	188,100	102,200	85,900	.18	— .81
March	579.62	187,700	133,900	53,800	.11	— .51
April	580.10	196,800	130,500	66,300	.14	— .62
May	580.31	200,800	189,000	11,800	.02	— .11
Total for winter					.52	
1901.						
December	579.60	187,300	174,300	13,000	.03	— .12
1902.						
January	579.51	185,600	124,700	60,900	.13	— .57
February	579.31	181,800	129,100	52,700	.11	— .50
Total for winter					.27	

Extract from the Report of Junior Engineer Murray Blanchard (1903), included in the Report of the Chief of Engineers U. S. Army for 1903 as follows (pages 2813-14):

"Discharge of Detroit River.—The discharge section at Fort Wayne was sounded at the beginning of the season with a 70-pound 'fish' weight suspended on a No. 9 galvanized wire. The heavy weight made the deflection of the sounding wire from the vertical considerably less than in the 1901 soundings. It appears that too large a deflection correction was applied to the soundings in 1901, so that a recomputation of the area for that year has been made by applying the corrections given in Table No. 1, found on page 5330, Appendix III, Report of the Chief of Engineers, United States Army, for 1900. This table, computed by Asst. Engineer F. C.

Shenehon, has been tested on soundings made in the swift current of the Niagara River with various deflections. The close agreement of the two seasons' determinations of the partial areas on Section Fort Wayne indicates that no scour has taken place, and the discrepancy in the total areas has been attributed to errors of observation. The mean of the two determinations of the area has been used in computing all of the discharges summarized in this report, which accounts for the disagreement with the volumes of discharge summarized in the last report. The two area measurements and the mean value used are given in Table No. 1.

"The meters were rated about once a month, and a rate comparison, whenever the meters were used, was made by running them side by side on the section at the same depth. The rating equations of the meters and their application are given in Table No. 2. A comparison of all the ratings made in 1901 and 1902 is shown in Tables Nos. 3 and 4.

"Stations Nos. 4, 9, 15 and 20, were selected for vertical curve observations, and about 20 curves were measured at each station. A comparison with the 1901 multiple meter curves is shown on Plates Nos. 1 to 4. The co-efficients at the 0.3, 0.5 and 0.7 depths are those used in the discharge computations. The mean of the discharges at these depths is used as one discharge, and the means of the three co-efficients for each station agree closely for the two years, except for the shallow station No. 20, where the curve is abnormal and varies. The discrepancy on this station in the two years, although amounting to 2 per cent., would not affect the partial discharge more than 60 cubic feet per second, or 0.0003 of the average total discharge. Therefore the multiple meter co-efficients have been used for both seasons.

"In the two seasons 117 discharges have been measured with a range of 1.6 feet in the Windmill Point or Lake St. Clair stage, of 2.5 feet in the Amherstburg or Lake Erie stage, and of 50,000 cubic feet per second in the discharge. Some of the observations were made when the river was rough and the wind strong, because such conditions are generally found with extreme stages and accompany a very high or low discharge. In such cases, however, there is generally a large fluctuation in the stage of Lake Erie and an uncertainty as to the effective stage of that lake.

"In Table No. 6, the results of the discharge measurements for 1901 and 1902, are given, with the corresponding gage

readings at Windmill Point, Fort Wayne Section, and Amherstburg.

"Very respectfully, your obedient servant,

MURRAY BLANCHARD,
Junior Engineer.

MAJ. W. L. FISK,
Corps of Engineers, U. S. Army."

TABLE 1.—AREA MEASUREMENTS, 1901 AND 1902.

Station.	—Area for Stage 574.4— 1901.	1902.	Mean used.
1.....	822	773	798
2.....	3,060	3,024	3,057
3.....	3,760	3,761	3,760
4.....	4,021	4,019	4,020
5.....	4,421	4,435	4,428
6.....	4,571	4,591	4,581
7.....	4,582	4,623	4,602
8.....	4,648	4,640	4,644
9.....	4,474	4,490	4,482
10.....	4,285	4,294	4,290
11.....	4,154	4,182	4,168
12.....	3,910	3,936	3,923
13.....	3,862	3,912	3,887
14.....	4,022	4,068	4,045
15.....	4,117	4,161	4,139
16.....	4,107	4,131	4,119
17.....	4,138	4,190	4,164
18.....	3,959	3,961	3,960
19.....	3,624	3,555	3,590
20.....	1,742	1,717	1,729
21.....	383	385	384
Total....	76,692	76,848	76,770

Extract from the Report of the United States Deep Waterways Commission 1896, being House Document No. 192, 54th Congress 2nd Session; page 28:

"From 1815 to 1830 there appears to have been lower water in all the lakes than the period now passing, except Lake Champlain, which has had the lowest and the highest water of 70 years within the last 30."

Extract from the Report of J. E. Mahoney, included in the report of the U. S. Deep Waterways Commission, page 179, as follows:

"Characteristic High and Low Waters.

"The following table gives the characteristic high and low waters, so far as they can be assigned, from the earliest records down to the present time. These may be accepted provisionally as an indication of the nature of the conclusions from the record.

CHARACTERISTIC HIGH AND LOW WATERS—1815 TO 1895.

Year.	Lake Michigan (below high water of 1838).	Detroit River (below high water of 1838).	Lake Erie (below high water of 1838).	Lake Ontario (above zero of Oswego gauge).
HIGH WATERS.				
1814 and 1815	Unusually high.	Unusually high.		July, 1815.....2.89
1838	July 0.00	Summer 0.00	June 0.00	July 4.75
		August 0.49		September 3.77
1852		July 1.07		June 4.25
1858	November 0.69	June 0.15	June 19.....—0.25	June 4.75
1859	July 0.65	July 0.65	April 0.27	July 4.78
1862	June 1.67		June 0.69	May 4.76
1870	September 2.12	July 1.29	July 1.35	May 4.83
1876	July 1.20	July 0.57	June 0.59	July 4.25
1886	June 1.16		June 1.20	May 4.52
LOW WATERS.				
			1810 and 6.00.	March, 1816.....0.06
			1811, general.	
1819	February 6.67	March 6.67	June 5.33	March .....—0.69
	June 4.67	June 5.82	August 5.75	June 1.73
1820	About same as 1819.	About same as 1819.	August 5.04	March .....—1.19
1825			General level. 4.00	March .....—1.77
1841	December 4.43	October 6.15	October 4.47	December 0.66
1846	December 5.08		March 4.47	March .....a 0.00
1847	February 5.50		March .....(3.88)	January 1.00
1848	March 6.....5.65		March .....(4.22)	November .....a 0.00
1857	January 3.55	January 3.32	January 3.37	January 0.24
1866	February 4.46		February 3.49	January 1.34
1868	December 4.34	February 3.96	February 4.07	January 0.39
1869	March 4.63	January 3.67	February 3.53	January 1.10
1873	January 4.82	January 3.66	January 3.95	January 0.19
1881	January 3.76	January 3.51	January 3.50	February 0.61
1891	December 4.99		November 3.90	December 0.29
1892	January 4.87		February 4.01	February 0.36
1895	December 5.75		November 4.41	November .....—0.71

a—From the original record of Mr. J. W. Judson, C. E., March, 1847 and 1848, for Lake Erie are approximate.

REMARKS:—High Waters: 1790, Lake Erie = 5.50 feet above 1819. The high water of 1838, referred to as a plane of reference, is the plane adopted by the Lake Survey. Low Waters: 1822, Lake Erie, 5 feet below high water of 1838; 1826, Lake Ontario in March = —1.77 feet.

"The Record.

"The record is appended, and is compiled separately for each lake and river, and exhibits all the information obtainable except in regard to the St. Lawrence and Lake Champlain. The list is as follows: Lake Superior, 2 sheets; Lake Michigan-Huron, 4 sheets; Detroit River, 1 sheet; Lake Erie, 5 sheets; Lake Ontario, 5 sheets.

"No diagram has been drawn to exhibit the graphical record, as it has been thought wise to defer this until the final digest has been made. The authority for the information is set forth in connection with the several collections of data.

Very respectfully submitted,

J. E. MALONEY."

Extract from the discussion of Defendant's witness Mr. Lyman E. Cooley in the Journal of the Western Society of Engineers for February, 1912, as follows (pages 138-9):

"In 1819 the lakes were the lowest ever known in the history of the Great Lakes—a foot lower than they have ever gone since—at a time when man had made no impression upon the watersheds of the Great Lakes and no improvement of them. In 1838 the lakes went higher than they were ever known to have gone before or since. In fact, the French records at Detroit indicate that the water has not been higher in 200 years. The entire range was about 6½ feet between those dates. We have had, apparently, changes in the base levels, such as occurred about 1889 in the levels of Lakes Michigan and Huron, by which these lakes were lowered from 6 in. to 1 ft. The cause assigned is probably correct, the changes occurring in the outlet at Port Huron, although there is room for difference of opinion in regard to that, in view of what occurred in 1819 and again in 1838."

The discussion of Mr. George M. Wisner in Journal of the Western Society of Engineers for February, 1912 (p. 126), as follows:

"We need this water, and our right to take it should not be questioned; but it is questioned, and the result will be that, if denied the desired 4,000 cu. ft. of water, the City of Chicago must within the next ten years spend at least $20,000,000 more to take care of its sewage in a less effective manner than it would if this additional flow were available, which, according to the Government's own witnesses, would lower the level of the lake possibly 2½ inches."

Discussion of Mr. Robert R. McCormick in the Journal of

the Western Society of Engineers, February, 1912 (page 144), as follows:

"The Author.—Our meeting has been successful to this extent, that we have stimulated discussion. From my own point of view, I wish there had been elements here who would have given more spice to it. Perhaps a sense of courtesy towards this meeting prevented me from putting a little acrimony into it myself. Not that I have any feelings of that kind, but what we need is noise, noise to go outside of the four walls of this building, noise which will reach into other states. I do not magnify the facts at all when I say that if all the conditions which Mr. Cooley and I both look forward to had taken place and we went to Congress with a bill, I do not believe it would receive five votes outside of the Illinois delegation. I make that as a statement of opinion—it cannot be made a statement of fact—which has come to me through meeting as many as I have of the residents of other cities on the lake and meeting their firm conviction that the present height or the present lowness of the lake is due to the Chicago Drainage Canal, and that Chicago is finding a cheap way of benefiting itself at the expense of the country. That impression, I wish to say further, has been deliberately fostered."

Extract from the paper by Mr. Clinton B. Stewart, on the Discharge Measurement of the Niagara River at Buffalo, New York, in the Journal of the Western Society of Engineers, read December, 1899. This paper is referred to in Record Volume 6, pages 3521-2. (Page 2 as follows):

"The piers have a battir on the sides of about 1:24, so that the water width of the intermediate spans may be taken as constant. They have a length of about 35 ft. with a cut water on the up-stream end, the down-stream end being rectangular in form. Eddies are produced, by the piers, to some extent, but they do not extend more than about five ft. from the pier, and in most cases the current remains practically linear and with about the same amount of fluctuations as near the middle of the span. It is thought that little error has been introduced from this source."

And again, pages 14 and 15:

"Observations for the mean direction of flow of the river. In order to determine the mean direction of flow of the river, three discharge measurements were selected in which the direction of the current for each of the meter stations had been observed, and when the direction part of the meter had worked very satisfactorily. This gave 3 sets of 21 readings each, and

at distances apart of about 80 ft. The maximum range in direction of the current in any one of the sets was about 10°. The mean of the three sets gave an azimuth of 187°.0 from the magnetic south as the mean direction of flow of the river. The variation of the mean direction at any point from the mean direction of the whole river would not exceed 2° or 3°.

"Observations for the direction of the normal to the bridge or to the line of the discharge section. In these observations the meter was placed on the ground and lined parallel with the cross ties. About 20 observations were made at each end of the bridge. The mean of 40 observations gave the azimuth of the normal to the discharge section as 185° 1'.

"From this it will be seen that the mean direction of flow of the river is 2 degrees to the right from the normal to the discharge section, and that the mean direction of flow and the discharge section are practically at right angles.

"In the case of the individual discharge measurements, no corrections were necessary to the measured velocities on account of the direction of the current. In the case of the transverse curves, the velocities at stations near the piers have been corrected by multiplying them by the cosine of the angle from the mean direction of flow of the river."

Extract from Report on Waterway from Lockport, Illinois, to the mouth of the Illinois River, being House Document No. 1374, 61st Congress 3rd Session (page 9) as follows:

"While it appears to have been assumed that the Sanitary District may be allowed to divert 10,000 second-feet so long as actually necessary for sanitary purposes, the diversion of the waters of the Great Lakes from their natural outlet for power development alone is inadmissible, under the recent treaty between the United States and Great Britain. The future diversion of water from Lake Michigan for any purpose is fraught with difficulties. Not only has Canada an interest in the maintenance of lake levels which the United States must recognize, but every foot of water flowing through the Chicago Drainage Canal lessens the flow at Niagara Falls and at the power sites along the St. Lawrence River, where, due to the fall available, the same amount of water will create about four times the power that can be generated from it on the Des Plaines and Illinois Rivers. The treaty enables riparian owners of Canada, as well as of the United States, who consider themselves injured by such diversion, to bring suit in United States Courts to protect their interests. The claim that more than 1,000 cubic feet per second is required for purposes

of navigation cannot be maintained. The treaty, however, recognizes as proper the use of water for sanitary purposes, and it is the opinion of the Board that only such water should be diverted from Lake Michigan as is indispensable for sanitation, and then only with a provision for proper compensating works in the outlets of the lakes to prevent a lowering of their levels. Water thus diverted may be used incidentally for power purposes, but care must be exercised in authorizing the diversion of water for sanitary purposes, to restrict it to the amount necessary for those purposes alone."

Plot showing analysis of position of meter 2B with 120 pound lead, appended to letter of Mr. Francis C. Shenehon, U. S. Assistant Engineer to Principal Assistant Engineer E. E. Haskell, February 13, 1899, and referred to in the testimony of Defendant's witness Mr. Gardner S. Williams.

Profile of the St. Lawrence River and canals compiled from official records. Signed by Thomas Monro M. Inst. C. E. Commissioner.

Blueprint entitled "Drift of Current Meter B in Niagara River." Gardner S. Williams, consulting engineer, Ann Arbor, Michigan, May 27, 1914, showing an analysis of meter position.

Manuscript copy of Report Board of Engineers to investigate effect of the diversion of water at Chicago, 1895, as follows:

"UNITED STATES OF AMERICA

War Department.

Washington, Dec. 1, 1914.

"I hereby certify that the attached papers being a copy of a report dated Aug. 16, 1895, by a Board of Officers constituted by S. O. No. 14, Corps of Engineers, 1895, are true copies of the original on file in the office of the Chief of Engineers, U. S. Army.

(Signed) DAN C. KINGMAN,
Chief of Engineers, U. S. Army.

"I hereby certify that Dan C. Kingman who signed the foregoing certificate is the Chief of Engineers, U. S. Army, and that to his certification as such full faith and credit are and ought to be given.

"In testimony whereof, I, Lindley M. Garrison, Secretary of War, have hereunto caused the seal of the War Department to be affixed and my name to be subscribed by the Assistant

and Chief Clerk of the said Department, at the City of Washington, this first day of December, 1914.

(Signed) LINDLEY M. GARRISON,
Secretary of War.
By JOHN C. SCOFIELD,
Assistant and Chief Clerk.

(Seal War Department.)

"Chicago, Illinois, August 16, 1895.

Brig. Gen. William P. Craighill,
Chief of Engineers, U. S. A.,
Washington, D. C.

General:

"The Board of Engineers appointed by virtue of S. O. No. 14, C. S. Corps of Engineers to consider and report upon 'the probable effect of the operation of the Chicago Drainage Canal upon the lake and harbor levels and upon the navigation of the Great Lakes and their connecting waterways' submits the following report.

"The Board met in Chicago, August 12, 1895, and on the 13th and 14th accompanied the officers of the Drainage Canal over the line under construction. Every facility and courtesy possible has been extended by the trustees and engineers of the canal for a full investigation of the subject matter. A brief description of the canal is extracted from the printed report furnished the Board by these gentlemen.

"The Main Drainage channel of the Sanitary District of Chicago is now under contract from its confluence with the South Branch of the Chicago River, at Robey Street, in the city of Chicago, to its southern terminus, in Will County, Illinois. At the southern end of the channel the controlling works will be located. Beyond these works, the construction contemplated by the District will be the work necessary for conducting the flow from the channel in conjunction with the waters of the Des Plaines River down the declivity to and through the City of Joliet, and making such changes in the Illinois and Michigan Canal as the new conditions developed will make necessary.

"The first work put under contract extended southwesterly from the Willow Springs road, and these sections were numbered consecutively Nos. 1 to 14. Average length of sections, 1 mile. Easterly from Willow Springs road, the sections are lettered from A to O, omitting J. The lettered sections are, except for a short distance near Summit, entirely in glacial drift, defined in the specifications thus: 'Glacial drift shall comprise the top soil, earth, muck, sand, gravel, clay, hard

pan, boulders, fragmentary rock displaced from its original bed, and any other material that overlies the bed rock.'

"The sections from 1 to 14 were put under contract in July, 1892; from A to F were put under contract late in 1892, and early in 1893; and G to M, inclusive, were contracted for in December, 1893. Sections N and O were put under contract May 2nd, and section 15, August 27th, 1894.

"Earth was first broken on 'Shovel Day', September 3rd, 1892, on the Rock Cut below Lemont.

"The Des Plaines valley is traversed by the river from which it takes its name—a stream of wide fluctuations with no constant and reliable fountain supply. During some seasons its whole discharge would pass through a six-inch pipe, and at others its volume reaches 800,000 cubic feet per minute. Then it rolls majestically along, flooding the whole valley. Such being the situation, control of this stream was a condition precedent to the successful prosecution of the work upon the main Channel. This control has been secured by the outlay of nearly $1,000,000 in constructing what is known as the River Diversion Channel.

"About 13 miles of new river channel had to be excavated with the location of the Main Drainage Channel, and about nineteen miles of levee built to divorce the waters of the Des Plaines watershed from the channel which is to receive the waters of Lake Michigan and pass them on to the Mississippi River, via the lower Des Plaines and the Illinois Rivers. The width of the River Diversion Channel on the bottom is 200 feet, side slopes 1½ to 1, grade generally 12-100 per 1,000 feet.

"At the head of this River Diversion it was necessary to provide a safety valve in the form of a spillway, to allow surplus water to flow towards Chicago, because arrangements have not as yet been perfected for carrying the entire flood waters of the Des Plaines through Joliet.

"This spillway is a concrete dam capped with cut stone, and its wings faced with stone masonry; it is 397 feet long and its crest is 16.25 feet above Chicago datum (this datum is referred to the low water of Lake Michigan of 1847, and is 579.61 above sea level at Sandy Hook). No water flows over this spillway until the volume passing the water gage above it reaches 300,000 cubic feet per minute.

"The cross-section of the earth sections from A to E inclusive is 202 feet on the bottom, side slopes two to one. This section extends for about 500 feet into the west end of F and then reduces to 110 feet on the bottom, preserving the

same side slopes. The explanation for this change of cross-section is as follows: Throughout the rock sections, and those sections in which there is a preponderance of hard material, or where rock may appear, the section adopted is designed according to law for a flow of 600,000 cubic feet of water per minute, which means provision for a population of 3,000,000 people. The narrow channel provides for a flow of 300,000 cubic feet per minute, or for about the present population of Chicago. The enlargement of the narrow channel can be made by the easier method of excavation, such as dredging; whenever the needs of the city require it. The grade throughout the lettered sections is one foot in 40,000 (.025 per 1,000 feet) and the bottom of the channel at Robey Street is 24.448 feet below datum. The numbered sections from No. 1 to No. 6 inclusive are underlaid with solid rock. The width of the bottom in rock, is 160 feet, and walls of masonry laid in cement will be built upon the rock surface to a height of five feet above datum. Section 7 to 14, inclusive, are in solid rock; width at bottom 160 feet, sides vertical, prism taken out in three stopes with offset of six inches on each side for each cut, making top width of 162 feet; grade in rock 1 foot in 20,000 (.05 per 1,000).

"Section No. 15 is also in rock and its cross sections is enlarged at its south end so as to form a 'windage basin' in which large vessels may be turned around. The controlling works are located on this section. These works will consist of gates or movable dams by which the flow of water from the Main Channel into the tail race, which is to deliver the outflow into the Des Plaines River, can be controlled.

"This river below Lockport follows the trough of the valley down a steep declivity to the canal basin in Joliet. The fluctuations in Lake Michigan, by varying slope of water surface, will be felt at the controlling works, and provisions must be made to meet these fluctuations within a range of five feet above datum and eight feet below, or an extreme oscillation of 13 feet. The fall from datum at the controlling works to the level of the upper basin will be about 42 feet, in a distance of about 4 1/3 miles. As the plans for controlling works have not been finally adopted by the Board of Trustees they cannot now be discussed.

"The total amount of excavation involved in the construction of the Main Channel is 26,077,765 cubic yards of glacial drifts and 12,071,668 cubic yards of solid road, or an aggregate of 38,149,433 cubic yards, to which must be added the

material excavated from the River Diversion; glacial drift, 1,564,403 cubic yards; solid rock, 258,926 cubic yards; total River Diversion, 1,823,329; grand total Main Channel and River Diversion, 39,972,762 cubic yards. All of this work is now under contract and in addition thereto 384,958 cubic yards of retaining wall."

In response to the request of the Senior Member of the Board the Board of Trustees of the Sanitary District of Chicago has furnished a report on Lake Level effects on account of the main channel of the Sanitary District of Chicago containing briefs by Trustee L. E. Cooley, C. E., and by Thos. T. Johnston, Assistant Chief Engineer, accompanied by numerous blue prints.

These papers present a full discussion of the subject as viewed by the canal officials, and will be found in the Appendix marked A.

What Is the Outflow of the Lower Lakes?

In November, 1891, the Chief of Engineers U. S. A., at the request of the Secretary of the American Society of Civil Engineers (who had been asked by the Chief Engineer of the Montreal Harbor Commission of Canada, to suggest the subject), ordered a set of observations made to determine the amount of water flowing down the Niagara River. The time was especially propitious as the water was then very low.

The results of these measurements were somewhat unexpected, and they were repeated in May, 1892. The second set corroborated the first, and the whole formed the subject of a report to the Chief of Engineers, which appeared in his annual report of 1893, page 4364, and following. But, as the subject was important, the "Engineering News" anticipated the appearance of the official report by publishing in its issue of March 8, 1893, this report, with the permission of the Chief of Engineers. This publication was the first ever made in which as a result of careful measurements a relation between the level of the lakes, and their outflow, or discharge, had been established and given to the public. Prior determination of this discharge had not attempted to detect this relation, and nothing more than a general determination of a season's work had been published.

In all plans for the Chicago Drainage Canal the early measurements had been taken, and those studying the subject chose such isolated figures as suited them best.

The report of 1892, being so late in appearance, long after

the Drainage Canal was put under construction, escaped the notice of many who are interested in navigation, for two reasons. Some were too busy to see anything, unless specially brought to their notice. Others thought the whole matter already fully canvassed, and settled. It is true there is nothing showing that the consent of Congress had been asked, for this enterprise. Certain that the subject had not been treated as an Interstate affair; to say nothing of its being an International affair. The United States has always been slow to move; with its many sleeping rights it has for many years been loath to exercise them. Not till 1888 did it begin to exercise positive legislation over its navigable waters in order to preserve them for all its citizens. Each River and Harbor bill since then is found to have sections strengthening the hands of those who wish to keep the waterways open, and in good order for all classes of navigators. Not till 1890 had any prohibitive clauses been enacted into laws forbidding, for example, the destruction of channels by improper dumpings. Saw mills went their own unchecked way every year clogging up the streams. Railroads bridged all smaller streams, in the states, without interference from the United States. Many other features can be quoted. But it is sufficient to say that all that is now changed. The adopted policy is to defend, as well as improve all water courses, now navigable, or probably navigable in the reasonably close future. Waterways are under the charge of the United States, and there is no likelihood of their being abandoned for some time to come.

With this an established fact it is impossible to think that U. S. supervision shall not be extended to the Chicago Drainage Canal in due time. Under whatever law built, and for whatever purpose constructed, just so soon as it is shown that that canal affects, or becomes a part of the system of navigable waterways of the United States some supervision or control of it must follow. When boats use it for harbor purposes; when its waters add to the Illinois River, or take from the lakes, they alter natural conditions and the matter rises for consideration under national authority.

The water levels of the Great Lakes are very delicate. Storms, barometric changes, rainfall, even tidal changes are felt. Records show at Buffalo no less than 13 feet as a total possible change, between the lowest and the highest gage readings. Each lake is a basin. The water is constantly pouring in from not only one, but several inlets. The over-

flow, however, is now always out of the one outlet provided for that purpose; the second one formerly at Chicago, has been plugged up.

As in our basins when the water rises enough to take two, three, or more of the small holes to carry it off, it is always to be noted that those holes are always carrying that surplus off. They do not wait until the water has time to pass from one end to the other. In the same channel the head alone governs the rate of outflow, and that head is measured by the gage reading at the outlet. The supply of water in the lake: The net supply, allowing for evaporation, is the sole cause of the outflow. That supply depends solely upon rainfall, but the lake when it receives more than it has been reciving must discharge more. When it has less there is less to run out. If the outlet be dug down, or new ones made the water runs off faster than it ran off before.

The outflow is instantly affected by a changed inflow; Provided there is enough such to increase or reduce the head. If we have a rainfall of one inch over the lake area (and such are not uncommon events), there is a head of one inch to run off. But if there are two outlets to run out of, instead of one this inch must run off sooner than through the one.

If the new outlet should reduce the levels of Lake Michigan and Huron about 6 inches this effect will be produced in full in about two years; it is not then a question of many years as some suppose.

We may feel very sure, therefore, that in this question two points are certain.

1st. The drainage canal is not solely a State affair; but a national one.

2nd. The tapping the lakes must affect their levels. But it is said, first, that the changes in levels does not concern shippers, and then that at most the affects will be trifling.

If one watched carefully the course pursued by shippers one would see that as a rule each vessel carries all that it can take, and get out of its port, or into that it intends to reach. Vessel owners, and managers are very shrewd, watchful men. They know what they can safely carry allowing for storms, and short detentions arising from passing causes. They average pretty well the practicable depths, and carry all the channels will stand. They are as conversant as are theorists about the effects of storms, but they keep good watch on ruling depths. Now should it be certain that these average depths were reduced three inches, or six inches, they must load ac-

cordingly. And not only the large boats, but also the small ones using the small harbors that the large ones cannot go into. All must lose the three, or six inches, as it may be; and not for one, or more trips, but for all trips, and for all time; a diminution of capacity is not a single tax, but a continuous one. A vessel that when light draws six feet, and loaded twelve feet, must lose three inches out of 72, say four per cent. in capacity each loading; a vessel drawing 12 feet light and 20 feet loaded, would lose somewhat over three per cent. in capacity at each end every loading.

Should the loss of levels be six inches instead of three, then these figures become doubled. Will the loss be six inches or will it be three? This is an important question and we have only the Niagara River discharge observations from which to answer it. These cover a range of about 1 foot and eight-tenths. There were scattering observations outside these limits, but the mass of results was secured between gage readings, mean lake level, the highest, and —1. '85. The "smooth curve" as published enables us to note the fall of 0' .53 on the gage per 10,000 cubic feet per second for the first foot of fall and 0' .44 for the whole.

These observations, especially at the lower readings are erratic and indicate a need for more measurements, especially at these levels. This lower portion of the gage should be studied and additional observations made, and the Board is a unit in suggesting the importance of a series of gagings of the St. Clair River at the present time for this purpose, and to furnish additional knowledge of the relation between gage readings, and discharge. The subject is of such general bearing upon the navigation of the lakes, that it demands careful treatment, and full data. The Niagara data do not show how much Lakes Huron and Michigan would be lowered, even if 0'53 were the net loss to Lake Erie. The opinion expressed by Mr. Johnson that the effect on the two upper lakes would be some 15 per cent. greater than upon Erie would seem to point to a probable loss of say 0'61. This possible loss of seven inches certainly is important enough to justify careful measurements of the discharge through the St. Clair. It is true that the law as it stands, and the intention of the Trustees contemplates the abstraction of only 300,000 cubic feet under present conditions, but after the canal is opened measurements would not be so instructive, and we must assume that ultimately the entire 600,000 cubic

feet per minute will be drawn from Lake Michigan as required by the State Law.

The abstraction of 10,000 cubic feet of water per second from Lake Michigan will lower the levels of all the Lakes of the system except Lake Superior and reduce the navigable capacities of all harbors and shallows throughout the system to an extent that may be determined, if at all, by actual measurements only. Under the laws of the United States these changes in capacity cannot be made without Federal authority, and to enable the executive officers of the United States to act advisedly in the matter it is necessary in the opinion of the Board not only that these measurements be taken but that the money cost of restoring the navigable depths in channels and harbors be carefully estimated.

In this connection the Board submits without expression of opinion an estimate prepared by Mr. Charles H. Keep, Secretary of the Lake Carriers Association, of the commercial losses in carrying capacity of the Lake fleet, should a reduction be made in Lake levels of one, three or six inches.

(Appendix Marked B.)

The Board notices that the same peculiarity exhibited by the Niagara discharge curve, is pointed out by Mr. Johnston as existing in the Morris, Ill., and South Branch Chicago River curves. (See page 25 Appendix A1.)

The Board also notes Mr. Johnston's conclusions on page 23, Appendix A-1, that "applying the reasoning to the St. Clair and Detroit Rivers, then the value of Q'—Q may be taken from the diagrams illustrating the tables before described, the only uncertainty being as to the value of "d." Suppose "d" to be unity, and the mean depth 20 feet. Then Q'—Q will equal something greater than 20,000 cubic feet per second," which practically corresponds with the deductions made from the Niagara River observations.

So many uncertainties arise in the application of hydraulic formulae that the only way to ascertain the approximate discharge of these streams is to measure them for periods long enough to eliminate accidental fluctuations and to cover all stages.

While the navigable capacity of all harbors and channels on the Great Lakes below St. Marys Falls will be injuriously affected by a diminution in depth, the navigability of the inner harbor of Chicago will be diminished also by the introduction of a current therein, which in the present condition of the river even with the minimum flow of 5,000 cubic feet per

second or 300,000 cubic feet per minute is entirely inadmissible. The estimates of the effect of the Drainage Canal upon this harbor should also consider this element.

The Board of Trustees have not yet determined upon a plan of treatment of this navigable channel, and their plans may be such as may improve, impair or destroy its utility as a navigable river.

All of which is respectfully submitted.

O. M. Poe,
Col. Corps of Engineers,
Br. Brig. Genl. U. S. Army.
E. H. Ruffner,
Major of Engineers, U. S. A.
W. L. Marshall,
Major Corps of Engineers."

Statistical Report of Lake Commerce passing through Canals at Sault Ste. Marie Michigan and Ontario during season of 1913. This is not to be published in the record, but is placed in the hands of the Commissioner for such reference as either party to this suit may wish to make.

Extract from the letter of Colonel Charles E. L. B. Davis, Corps of Engineers U. S. Army to the Chief of Engineers dated January 12, 1906, and printed in House Document Number 266, 59th Congress, 2nd Session, as follows, pages 5-6:

"Survey of Ship Channel Connecting Waters of the Great Lakes Between Chicago, Duluth and Buffalo.

United States Engineer Office,
"Detroit, Mich., January 12, 1906.

"General: 1. In accordance with instructions contained in Department letter of May 2, 1905, I have the honor to submit the following report and estimates of cost of a—

"Ship channel connecting waters of the Great Lakes between Chicago, Duluth, and Buffalo, with a view to obtaining depths of twenty-two and twenty-five feet, respectively, and sufficient width.

"2. The present project for a ship channel through the connecting waters of the Great Lakes was adopted by the River and Harbor Act of July 13, 1892, the object being to provide a navigable depth of 20 feet by excavating channels to a minimum width of 300 feet through the shoal places in the specified waters, at an estimated cost of $3,340,000, the scope of improvement being limited to shoals not specifically provided for by the then existing appropriations—that is,

the appropriations made specifically for improving the channels in St. Marys River, St. Clair Flats Canal, and Detroit River.

"3. Under approval of the War Department, dated October 20, 1892, operations were commenced in the spring of 1893, and by 1897 channels of the prescribed depth of 20 feet and widths of 300 feet or more had been excavated through all of the shoal areas originally specified in the project. Since 1898 the work has consisted in increasing the width and depth of channels at angles, some exposed places in the open lake, and other critical points, and in removing many isolated shoals of comparatively small area that have been found to interfere with the safe navigation of the channel by the larger class of vessels now in use.

Planes of Reference.

"4. At the time of the adoption of this project certain planes of reference were adopted for the various portions of the connecting waters referred to mean tide level at New York expressed in feet above that level. For the ten years between 1892 and 1902 the prevailing water levels of Lakes Huron, St. Clair and Erie had been almost continually below the assumed elevations, and in consequence the actual draft available was considerably below the 20 feet called for by the project.

"5. For this reason Maj. W. H. Bixby, Corps of Engineers, then in charge of this District, in his project of October 13, 1902, for the improvement of Middle and West Neebish Channels, recommended certain changes in these reference planes which received the approval of the Secretary of War October 31, 1902, and which have been used in the estimates.

"6. These reference planes are as follows: 601.5 for Lake Superior, 580.2 at the head of Little Rapids, 579.3 through Hay Lake, 578.9 in Little Mud Lake, 578.8 at Sailors Encampment, in Mud Lake, and Lake Huron. Such levels correspondent to 573.8 in Lake St. Clair (head of canal) and 570.8 in Lake Erie, these being the monthly means of November, 1895, when the three lakes taken together were at their lowest since 1860, when the records of Lake Michigan and Huron were commenced."

Extract from the Report of Principal Assistant Engineer Francis C. Shenehon on the hydraulic investigations made in connection with a study for the Preservation of Niagara Falls included in Senate Document No. 105, 62nd Congress, 1st Session. (Chapter 3, including Plates 1 and 3.)

"Chapter 3. The Hydraulic Conditions.

"Lake Erie is a natural basin filled with water; the Niagara River is a notch or cut in its brim permitting definite quantities of water to spill out; and the water flows out here because it is the lowest place on the brim, and because it leads to lower levels, and seaward.

"The notch or sluiceway at the head of the river is in limestone hard enough to resist rapid wear under the influence of the running water. Because the dead water of the lake forms a settling basin, the water at the head of the river carries little sediment, and this accounts for the slight abrasive effect of the flow, and for the stability of this low rock barrier, wier, or dam whose integrity is essential for the retention of Lake Erie at its proper surface level. In discussing the hydraulics of the Niagara River, this low rock barrier, reaching from the head of the river to the International Bridge, will be spoken of as the initial weir.

"The river is flowing almost due north as it breaks out of Lake Erie. (See Pl. 1.) At the head it has the usual trumpet entrance, but narrows down in 1¼ miles to little more than 1,500 feet in width, with a natural depth of about seventeen feet and a velocity as great as 8 miles an hour. As it approaches the International Bridge 1¼ miles farther down, it grows a little wider, deeper, and slower. At the foot of Squaw Island it widens to 2,300 feet, and the first sharp descent of about five feet from the level of the lake is passed. Two miles farther down the river is split into two channels by Grand Island—the Canadian Channel about 10 miles long and the American or Tonawanda Channel about 13 miles long. From Squaw Island to the foot of Grand Island, and as far down as Welland River, the current is moderate and the river is navigable; in fact, the Welland River is a side entrance to the Welland Canal.

"The 'dead line,' marking the beginning of the dangerously swift water approaching the rapids, runs from Chippawa at the mouth of the Welland River across to the entrance of the Hydraulic Canal at Port Day. Along this line velocities run as high at 3½ miles an hour at ordinary stages, and in high water are greater. The uppermost cascades of the rapids approaching the Horseshoe Fall are about a mile below the 'dead line,' and the shallow water marking the brim of the upper river basin is little below Chippawa. From the uppermost cascades to the crest of the Horseshoe Fall is five-eighths of a mile.

"The cataract drops into a deep basin or pool where the current is moderate, with water as deep as 189 feet, and this Upper Gorge pool is navigable from near the cataract to Suspension Bridge, a distance of about 2 miles. At Suspension Bridge is the brim over which the water spills out of the Upper Gorge pool and makes the descent of the Whirlpool Rapids to the Whirlpool. The Whirlpool is another deep basin, the water having a rapid rotary motion. The water is spilled out of the Whirlpool basin over the brim at the head of the Lower Rapids; and at the foot of these rapids, from Lewiston and Queenston down, is the broad, still, deep, navigable river stretching in a straight reach of 7 1/16 miles to Lake Ontario.

"The profile of the river from Chippawa to Lewiston is shown on Plate 2.

"It is evident that the Niagara River is a series of basins or pools, linked by swift water or rapids, which form the sluiceways or spillways from these basins. There are four distinct basins (see Pl. 3) and as these have a most important bearing on the measurement of the river flow, and make the determination of diversion effects possible, the identity of each must be emphasized.

"Lake Erie is the initial or parent pool; from Squaw Island to the rapids above the Cataract is the second, or Grass Island-Chippawa pool; the Upper Gorge is the third pool; and the Whirlpool, the fourth. The peculiarity of these basins is that the height of the water surface near their outlets indicates with considerable precision the amount of water flowing through the river. Because of this fact it is possible, by painting certain graduations on gage boards fixed vertically at the proper elevation and placed in proximity to the crest of each weir, to make the water surface itself disclose the volume of river flow. If such a board were set in Lake Erie at the lighthouse on the north end of the breakwater, and the graduations were in units of a thousand cubic feet per second, each graduation would be a little over half an inch long. The graduations of the board set up in the second pool at Grass Island, or at Chippawa above the Upper Rapids, would have graduations a little more than half as large; at Suspension Bridge, in the third pool, the graduation would be about 1¼ inches long, and in the Whirlpool 1¾ inches.

"An increase in the river flow of 22,400 cubic feet per second at ordinary lake stages, which results from a rise in the water surface of Lake Erie of 1 foot, produces at Chippawa

and Grass Island a rise of 0.56 foot, of 2.29 feet at Suspension Bridge, and 2.47 feet in the Whirlpool.

"These pools are shown in Plate 3. Assumed stages of the several pools are indicated by the scales shown on the left-hand side of each gage board, and the corresponding river flow is shown by the scale on the right-side.

"That the water-surface elevations existing in these several pools should maintain certain definite relations to one another is not accidental, but depends on well-known hydraulic laws. Among hydraulic engineers it is a well known fact that a dam or weir with the water flowing over the crest forms an instrument by which the volume of flow may be measured. After a particular weir has been calibrated the elevation of the water surface, as shown by a water gage in the pool above the crest of the weir, gives the measure of the flow.

"In the case of the Niagara River the weirs are natural formations, and the term 'weir' is not technically precise. Nevertheless, they serve the same purpose as artificial weirs in forming pools by rock rims, or by constrictions. They enable calibrations to be made, so that the water-surface elevation of any pool indicates the corresponding volume of flow.

"The initial weir at the head of the river has a width of 1,690 feet, the width of the second weir at the head of the Cataract Rapids is 3,740 feet, the third at Suspension Bridge at the head of the Whirlpool Rapids 390 feet, and fourth at the head of the Lower Rapids, which is the outlet of the Whirlpool, is 390 feet. Comparing the length of the weir crest at the head of the Upper Rapids with that in the outlet of the Whirlpool, it is not difficult to understand the relative fluctuations of the river. The great length of the weir at the head of the Upper Rapids, 3,740 feet, permits the passage of an increased volume of flow by a small rise; while the short length, 390 feet, of the Whirlpool outlet weir chokes the flow and compels a very considerable rise before the area of outflow is sufficient to pass the additional water. This large movement in the Whirlpool makes the fourth weir an extremely sensitive measuring instrument, and for a similar reason at Suspension Bridge the vertical water movement is large also, and the senstitiveness of the third weir as a measuring instrument is likewise great. The weir at the head of the river has an intermediate length and the rise corresponding to an increment of flow is seen to be intermediate, one foot as against 0.56 foot for the second weir and 2.47 feet for the fourth weir.

The initial weir at the head of the river has a peculiarity not shared by the other three weirs, namely, that it is affected by backwater from the pool below, which reaches from the head of the Upper Rapids to Austin Street, Black Rock, at the foot of Squaw Island. The fall from Lake Erie to Austin Street has already been stated as in the neighborhood of five feet. The very extensive and careful measurements made by the Lake Survey in 1898 to 1900, pointed to the fact that the outflow from Lake Erie was increased about eight-tenths of 1 per cent. by lowering the water surface of the river at Austin Street, one-tenth of a foot, and subsequent investigations at the time of the July-August, 1908, shut down of the Niagara Falls Power Co., as well as certain slope observations, closely corroborate the earlier conclusions.

"While the lower river weirs are entirely free from backwater effect in the pools below them, the initial weir at the head of the river has this greater complexity, and it is because of this fact that the surface level of Lake Erie is affected by the diversion of water in the second pool lying above the first cascades of the Upper Rapids.

"Looking at the other three weirs of the river series from the lower level upward, it is very plain that no known elevation of Lake Ontario, or of the Niagara River at Lewiston, can have any effect whatever in the outflow from the Whirlpool. From Lewiston up to the Whirlpool is a distance of 3½ miles, with a rise of 47 feet. In this reach of turbulent rapids and swift water and some cascades, the possibility of backwater due to Lake Ontario's height is unquestionably absent. The height of the water surface in the Whirlpool is therefore dependent on the volume of river flow alone. In the winter season, however, ice in the rapids is not unlikely to create somewhat different conditions of outflow, and for this reason the ice period is not here considered. It is probable that small changes do occur from time to time in the river Reach between the Whirlpool and Lewiston, as well as in the Whirlpool Rapids reach from the Whirlpool to Suspension Bridge. The bottom, however, throughout these reaches is of rock which the current cannot easily move. As regards scour, the condition of the water entering the Whirlpool Rapids is very similar to that of water entering the river from Lake Erie. While the water is violently agitated at the foot of the Cataract, it afterwards passes slowly through the deep settling basin of the upper gorge, where particules detached by the impact of the cataract are precipitated.

"Whatever may be the permanence of the channels of these rapids for a long term of years, the fixity of conditions since water gages were established in the Whirlpool and at Suspension Bridge in 1906, is attested by the water-gage records themselves.

"From the Whirlpool through the Whirlpool Rapids to Suspension Bridge is a river reach of a mile with a rise of 48 feet, and this, like the Lower Rapids is a turbulent series of sluices and rips. That any backwater effect may proceed from normal conditions in the Whirlpool to affect the height of the water at Suspension Bridge and in the Upper Gorge pool is impossible.

"That the height of the water at the foot of the Cataract does not have any backwater effect on the river at the head of the Upper Rapids is manifest.

"The upper river pool terminated by the first uppermost cascades of the Upper Rapids, and of the American Channel, includes the intakes of the Ontario Co. on the Canadian side and of the two large canals on the American side. A nice question in backwater effect may seem to be presented by the locations of the intakes of the Electrical Development Co. and of the Canadian Niagara Falls Power Co. Between the intake of the Ontario Co., and the intake of the Electrical Development Co., is a descent of 23 feet, including four cascades; and from the intake of the Electrical Development Co. to the intake of the Canadian Niagara Falls Power Co. is a descent of 15 feet more, including one cascade. It is very certain that any diversion of water, or any small raising of the water at the last named intake, can have no possible effect on the elevation of the water above the first cascade or in the upper river pool. It is certain also, on the face of it, that any diversion made by the Electrical Development Co., or any small raising of the water at its intake will not effect the upper river above the first cascade. The very presence of the cascades themselves is evidence of water flowing sheer, presenting rather the effect of a free fall than of water passing over a drowned weir."

Also extract from Chapter, "The Outflow of Lake Erie," beginning on page 25 and ending on page 27, as follows:

In the whole length of the Niagara River (except for diversions) practical continuity of flow is in force. That is, the contributions of water entering by creeks or rivers between Buffalo and Youngstown are so trivial, compared to the great volume of river flow that under ordinary summer con-

ditions they may be neglected. Any evaporation from the river surface is also negligible.

It follows that the volume of flow under quiescent or normal conditions is the same for each cross-section of the river. If the volume of flow were measured simultaneously at Buffalo, Suspension Bridge and Lewiston, the results would be the same. The water entering the river at Buffalo passes out of the river at Fort Niagara neither appreciably increased nor diminished.

For this reason it does not make any great difference at what section the volume of flow is measured, except that it is desirable to make the measurements at such a point as will serve to give the most accurate results. A straight reach of river with a smooth bottom, together with a velocity of four or five miles an hour, a depth of 30 feet or more, and a fairly smooth, eddyless surface, presents excellent conditions, and better if the water is running faster below it.

A vertical plane perpendicular to the direction of the current cuts the stream in what is called the hydraulic section. Soundings taken at intervals from bank to bank along the line in which the plane intersects the surface, as every ten feet, develop the bottom profile. The area between the bottom and the water surface is the cross-sectional area. For purposes of current measurement, the river is conceived to be made up of a series of sub-streams flowing side by side, each perhaps 100 feet wide. The vertical line at the middle of each substream is the station, and at some fixed percentage of the depth below the surface on the station, as the four-tenths depth, is the controlling current-measuring point called the index.

The current is running slowly next to the banks and fastest out toward the middle of the river, and the plotted curve showing the velocities (for index depth) at various distances across the section is called the transverse curve of velocities. At different depths the current velocity is different, being swiftest near the surface and perhaps half as swift at the bottom. The plotted curve showing the velocity at a station for each tenth of depth is called the vertical curve of velocities.

Because, at varying distances from the bottom and from the banks, the velocity of water flowing straight and smooth is governed by the laws of fluid friction, no abrupt changes occur, except perhaps very close to the bottom or to the banks. The transition from the high velocity near the surface to the lower velocity a foot above the bottom is gradual,

so that the vertical curve of velocities is generally a smooth curve, and the curves at different stations show great similarity. That the forms of vertical curves in smooth stream flow adhere to type is well recognized, and the vertical curves of the Niagara River are closely approximated by those of the St. Clair and the St. Lawrence Rivers.

The transverse curve of velocities is likewise easy, and reproduces in general outline the bottom profile. The deepest water on the section is also likely to be the swiftest, and as the water grows shallower the velocities grow less. The orderly way in which water flows, with remarkable adherence to a fixed plan, makes the accurate measurement of the volume of flow easily possible.

The preliminary work in measuring the volume of flow consists in accurate soundings and a determination of the cross-sectional area of each substream; then the determination of the velocities at different points in each substream, as percentages of the velocity at the index. The index, which is midway of each substream and at three-tenths or four-tenths depth, is a sampling point for velocities to the extent that the velocity measured there is finally the key to the mean velocity in the whole substream. Before, however, a co-efficient is determined which will reduce the observed velocity at the index to the mean substream velocity, much preliminary work must be done in measuring simultaneously the velocity at the index and at other points in the substream. The possibility of a reduction co-efficient is due to the adherence of the different parts of the substream to fixed relative velocities. Some evidence of this law of stream flow is cited in the report of 1900, already referred to, page 5343. In interpreting this statement of fixed velocity relationships, conditions of river equilibrium are understood, and the measurements at the points must be of long enough duration to eliminate the flame-like spurting and lagging of the current threads characteristic of river flow. In arriving at the co-efficient of reduction, it is necessary also to measure the directions of the current, or its deviation from the normal to the section. The operations having in view the determination of the reduction co-efficients are called co-efficient work.

After the cross-sectional areas and the co-efficients are determined, a single velocity measurement at each of the station indexes constitutes a river traverse or discharge measurement. For each substream the volume of flow is the product of the index velocity multiplied by the reduction co-efficient,

and by the cross-sectional area, at the time of the measurement. The total river volume of flow is the sum of the volumes in all of the substreams.

While a discharge measurement is being made a water gage on the hydraulic section records the water surface elevation, as a basis for determining the cross-sectional areas at the time of the measurements. This is called the section gage. In the measurement of the discharge of the Niagara River at the International Bridge, a second water gage just above the head of the river records the level of Lake Erie. A third gage at Austin Street, Black Rock, records the level there, thus determining the backwater effect of the river below. The velocity measurements in the Niagara River work were made with current meters of the propeller-wheel type, and these were calibrated on still-water bases and subsequently in flowing water. The process of calibration is called rating. For detailed description of meter rating on a still-water base, and for much detail which cannot be repeated here, reference is again invited to the Report of 1900.

The measurements of the volume of flow of the Niagara River were made first at the International Bridge, where the downstream lower bridge chord defined the hydraulic section and the bridge itself served as an observing platform. The river flows in nine streams through the openings of the nine spans. The spans are numbered from east to west, span 9 being next to the Canadian bank. Spans 4, 5 and 6, have clear openings at the water line of about 235 feet, with depths reaching 50.7 feet, and together carry 73.1 per cent of the river flow. The remaining spans vary from 138.4 feet to 187 feet. For purposes of measurement each of the three long openings was conceived to be divided into three substreams, and each of the shorter openings into two substreams, making in all 21 substreams. The index at the stations was taken at three-tenths depth. The International Bridge Section, with the river broken up into nine streams, with the bottom and slopes around the piers somewhat ragged, and the piers themselves creating eddies, proved more complex than a section in the unbroken open river. This complexity made co-efficient work more laborious. The error likely to enter from the added complexity is discussed on page 5332 of the Report of 1900, and appears to be in the neighborhood of a half of 1 per cent.

Chapter VIII.

The Shutdowns of the Niagara Falls Power Co.

On May 13, 1908, the Lake Survey Office was notified by Mr. Philip P. Barton, General Manager of the Niagara Falls Power Co., that, to permit an examination of the east abutment of the upper steel arch bridge, where it was thought to have suffered from the wash of the tunnel discharge, this company would shut down its plant shortly after midnight of June 13.

As the shutdown was to cover a period of some hours, the opportunity to observe the rise of water surface following a return to the river channels of about 8,000 cubic feet per second of flow appeared of great importance. As the rise in the river, provided quiescent weather conditions prevailed, would conversely measure the lowering due to this diversion, elaborate preparations were made to test the rise at critical points, and also to measure the change in diversion causing this rise.

Box gages were set at the heads of each of the two large canals on the American side, to test at intervals the records of the self-registering gages maintained by the power companies. Another gage was set, as in 1907, on the hydraulic section in the Niagara Falls Power Co's canal. A box gage was set also at Prospect Point close to the crest of the American Fall, in the position occupied by the self-registering gage in 1907. To observe precedent conditions, readings at 10-minute intervals were taken on the gage at Prospect Point, beginning on the morning of the 13th, and, to secure a record of conditions during the shutdown and afterwards, were continued day and night up to the morning of the 15th.

To make sure of a record at Buffalo and at the foot of Austin Street, staff-gage readings were taken during the critical period to reinforce the self-registers. The gages at Niagara Falls were insured against stoppages by a constant patrol.

Current-meter measurements of the volume of flow in both large canals were made before the shutdown, as the gates closed, and after they were opened again.

Had the weather conditions remained good, even so brief a period as this would have given some valuable information, for, in addition to the shutdown of the Niagara Falls Power Co., the Niagara Falls Hydraulic Power & Manufacturing Co., had arranged to restrict its flow so as to permit the greatest possible change. Unfortunately, the results were of small value. The shutdown in the power canal began about mid-

night and was completed by 1:20 in the morning. The hydraulic canal, on the other hand, had not completed its partial shutdown before six o'clock Sunday morning. Meanwhile, a stiff southwest storm on Lake Erie arose about midnight and caused the water at Buffalo to rise a foot and a half by three o'clock in the morning. This rise in the lake, causing increased flow in the river and, therefore, greater heights at all points, is entangled with that coming from the shutdown, and the two cannot be separated. The rise on the crest of the American Fall between midnight and three o'clock was 0.1 foot. Up to two o'clock it was 0.06 foot, or three-fourths inch, and this, if attributable solely to shutdown, would be fairly corroborative of anticipated results.

The examinations of the June shutdown having shown the need of repairs on the abutment of the bridge and in the tunnel of the power company, a second shutdown of this company, aggregating practically ten days, was made in July and August. Considerable preparations were again made to make the most of this partial return of the river to a state of nature, and the observations were extended to incorporate very precise information of the influence, not alone on the river-surface levels, but also on Lake Erie's outflow. Early notification was sent to this office by the power company, and the hydraulic company offered its co-operation to the extent of a preliminary increase of flow, and a cessation, on Sunday, July 19, only, of the larger part of the flow of its canal.

The power company shut down at 1:30 on the morning of the 19th, and remained closed until 12:30 on the morning of the 28th, when power house No. 1, resumed, power house No. 2 remaining shut down.

On August 1, at 11:30 at night, the shutdown was again complete and remained so up to 7:30 in the evening of August 2, when both power houses resumed.

The shutdown was, therefore, practically complete on the nine days, July 19 to 27, and nearly complete on August 2, or ten days in all.

The mean condition of the river for these ten days of lessened diversion is compared with the river condition on six days preceding the shutdown, July 13 to 18, and on four days after resumption, August 3 to 6, making ten days in all of the condition of normal diversion.

During the ten days of diversion the mean water consumption of the two American companies was 7,850 cubic feet per second, and during the shutdown it was 1,640 cubic feet, a

change in consumption of 6,210 cubic feet. (See table 39.) The small diversions of these companies prevailing at this time were due to the existing business depression.

The average consumption of the Ontario Co. from July 13 to August 6, as derived from its curves of total load, using a co-efficient of 0.0866 to convert kilowatts to cubic feet per second, was less than 1,500 cubic feet, and was slightly less during the shutdown, owing to the lighter load of the three Sundays included, than in the six days before and four days following. During the shutdown a box gage was established just above the forebay of the Ontario Co. Taken in connection with the Chippewa gage, this gage was an index of the comparative flow over the water wall and through the conduit of this company, in the two periods.

Prior to the shutdown and after resumption the flow in the canals of the American companies was frequently measured with current meters, and during the shutdown of the power company the flow in the hydraulic company's canal was measured daily.

During the 5-day period, July 28 to August 1, while power house No. 2 was still shut down the flow in both canals was measured daily. The flow in the power company's canal was nearly equal to that existing when both power houses were in operation. For this reason the results of this period have small value and do not appear in this report.

During the 25-day period, from July 13 to August 6, self-registering gages were maintained in Lake Erie at Buffalo, and in the river at Black Rock, Schlosser's dock, Grass Island, Wing Dam, and Suspension Bridge; and on the Canadian side at Black Creek, Chippewa, Crest of the Horeshoe Fall, and in the Whirlpool.

During the shutdown, in order to insure observations in case of stoppages of the self-registering gage instruments, readings at 10-minute intervals day and night were made on staff gages in Lake Erie and at Austin Street, Black Rock and the patrol of the self-registers by inspectors was bi-daily or more frequent. No pains were spared to make the record complete and accurate. Additional staff gages were read at Prospect Point, on the crest of the American Fall, and in the canals of the two American Companies, and, as has been before stated, in the approach to the Ontario Company's intake.

During this 25-day period, to corroborate the values of the change in Lake Erie outflow shown by the Suspension Bridge

and Whirlpool gages, 50 measurements of the flow of the river were made at the International Bridge, Buffalo.

The many activities of this period kept a considerable party of civil engineers and assistants busy. In addition, a part of the staff-gage reading at Buffalo and at the Ontario Company's intake was done by an inspector employed by the American section of the International Waterways Commission.

The results of the shutdown are discussed in Chapters IX to XI, entitled "Effect on Lake Erie," "Effect on the Niagara River above the Upper Rapids" and "Effect on Rapids and Falls."

No photographs were made in this period because it was well known in advance that the small change in diversion would have no visible effect on the American Fall, and because increased water consumption by the Canadian Companies to supply the power company's customers with electric current during the shutdown would mask any small effect on the main rapids and Horseshoe Fall.

For this latter reason no gage readings were taken at Terrapin Point, and, except as confirmatory of results elsewhere, little weight has been given to the gage readings on the Canadian end of the Horseshoe Fall.

So far as effects on Lake Erie and the river above the rapids or on the American Fall are concerned, the diversions of the Electrical Development Co. or of the Canadian Niagara Falls Power Co., have no bearing. These two companies combined supplied, according to the total load curves furnished by them, an average of 7,110 kilowatts more during the 10-day period of the shutdown than during the 10-day period of comparison before and after the shutdown; and the production of this excess current meant an additional water consumption not exceeding 1,000 cubic feet per second. The Ontario Co., on the other hand, according to its total load curve, consumed less water by 100 cubic feet during the shutdown than in the period of comparison. This, as has been explained elsewhere, is because the shutdown period contains three Sundays when manufacturing plants were not running, while the period of comparison is all working days.

In discussing the change of flow in the Niagara in these two periods, the small difference in consumption indicated for the Ontario Co. is not considered, because changes in the water wasted over the water wall may exceed this amount and be of different sign.

The detailed results of the shutdown of July-August, 1908, are given in Table 39, and this needs some explanation.

TABLE 30.—THE EFFECTS OF THE SHUTDOWN OF JULY AND AUGUST, 1908.

DURING DIVERSION.

Date 1908.	Mean water diversion (cubic feet per second). Niagara Falls Power Co.	Niagara Falls Hydraulic Power & Manufacturing Co.	Sum.	Elevation of Lake Erie by Buffalo gage. Feet.	River gages (residuals in hundredths of a foot). Austin Street.	Schloesser's Dock.	Grass Island.	Chippawa.	Wing Dam.	Prospect Point.	Residuals of discharge as shown by weirs. Suspension Bridge.	Whirlpool.
July 13	6,300	1,700	8,000	573.26	+ 7	—4	+13	+ 9	+15	...	+ 100	+ 100
July 14	6,500	1,600	8,100	573.28	+11	—7	....	+ 8	+13	...	— 100	+ 700
July 15	6,500	1,500	8,000	573.25	+14	—7	....	+ 8	+12	...	— 100	— 200
July 16	6,300	1,250	7,550	573.13	+12	—7	....	+ 6	....	+5	— 600	+ 300
July 17	6,800	1,200	8,000	573.68	+ 5	—5	+13	+ 5	+12	+5	+1,100	+1,100
July 18	6,700	1,500	8,200	573.51	+11	—2	+14	+13	+14	+5	+ 700	+1,100
Aug. 3	6,000	1,200	7,200	573.12	+11	0	+19	+15	+14	+4	— 200	.....
Aug. 4	5,550	1,400	6,950	573.23	+17	+1	+19	+15	+14	+4	+ 100	+1,000
Aug. 5	6,500	1,500	8,000	573.32	+23	+3	+19	+15	....	+4	+ 700	+1,300
Aug. 6	7,000	1,500	8,500	573.40	+11	—2	+13	+10	....	+3	— 400	+ 100
Means (10 days)			7,850	573.318	+12.2	—3.0	+15.7	+10.4	+13.4	+4.3	+ 30	+ 610

TABLE 39.—THE EFFECTS OF THE SHUTDOWN OF JULY AND AUGUST, 1908—Continued.
DURING SHUTDOWN.

Date. 1908.	Mean water diversion (cubic feet per second). Niagara Falls Power Co.	Niagara Falls Hydraulic Power & Manufacturing Co.	Sum.	Elevation of Lake Erie by Buffalo gage. Feet.	River gages (residuals in hundredths of a foot). Austin Street.	Schlosser's Dock.	Grass Island.	Chippawa.	Wing Dam.	Prospect Point.	Residuals of discharge as shown by weirs. Suspension Bridge.	Whirlpool.
July 19	....	750	750	573.30	+14	0	+36	+19	+21	+7	—1,800	.....
July 20	....	1,350	1,350	573.12	+13	+2	+39	+22	+20	+8	— 300	.....
July 21	....	1,800	1,800	573.15	+12	+6	+40	+23	+20	+8	0	+1,100
July 22	....	1,800	1,800	573.25	+14	+3	....	....	+16	+5	— 800	0
July 23	....	1,800	1,800	573.05	+15	+4	+38	....	+16	+5	—1,200	+ 100
July 24	....	1,750	1,750	752.88	+15	+4	+38	....	+16	+5	—1,000	+ 400
July 25	....	1,750	1,750	573.03	+15	+6	+40	+25	+16	+4	— 800	+ 500
July 26	....	1,700	1,700	573.01	+19	+7	+42	+25	+15	+4	— 700	+ 700
July 27	....	1,600	1,600	573.16	+16	+3	+38	+21	+12	+4	—1,100	— 200
Aug. 2	1,000	1,100	2,100	573.10	+17	+3	+35	+20	+19	+5	—1,500	.....
Means (10 days)			1,640	573.105	15.0	+3.8	+38.4	+22.1	+17.1	+5.5	— 920	+ 370

	Decrease in diversion.	Rise at river gauges during shutdown. Austin. Street. Feet.	Schlosser's Dock. Feet.	Grass Island. Feet.	Chippawa. Feet.	Wing Dam. Feet.	Prospect Point. Feet.	Decrease in total river discharge during shutdown. Suspension Bridge. Cubic Feet.	Whirlpool. Cubic Feet.
Summation	6,210	2.8	6.8	22.7	11.7	8.7	1.2	950	240
Mean.....cubic feet								900	

River gauges: A (+) residual indicates that the river is higher than its normal height for the corresponding lake stage; A (—) residual indicates that the river is lower than its normal height for the corresponding lake stage.

Residuals of discharge are in cubic feet per second. A (+) residual indicates that the flow in the river is greater than normal for the corresponding height of Lake Erie. A (—) residual indicates that the reverse is true.

Diversions refer to those on American side only. That of the Ontario Power Co. was practically constant for this period.

It will be noticed that Lake Erie at Buffalo was at elevation 573.32 during the ten days of diversion and 573.10 during the shutdown, making the lake 0.22 foot low for the latter period. This difference in level, however, does not produce any error in the results because it is eliminated by reducing to a common lake-level plane. For each day the elevation of the water surface for that day's level of Lake Erie at Buffalo is computed for each gage by its equation of equivalent river heights. If the Chippewa gage on July 14 shows 0.08 foot higher than its computed height, a plus residual (+8) is set down. If on July 20 the river at Chippewa is shown by the gage to be 0.22 foot higher than its computed height, a plus residual (+22) is set down. The excess of the residual during this one day of shutdown over that of this day of diversion (22—8) shows that for exactly the same lake stage the river for the shutdown day is 0.14 foot high, and that is the evidence of these two days as to the effect of the shutdown. The mean residual during the diversion days subtracted algebraically from the mean residual during the shutdown shows, if plus, the rise, and if minus, the lowering due to the shutdown.

The equations of equivalent river height by which these residuals are derived are very exact, but if any small constant error should exist in them it is eliminated by the subtraction.

As, however, any error in the ratio of change at the river gages for a unit change of Lake Erie at Buffalo is not eliminated by subtraction, some discussion is needed to indicate how large it may be.

A gage was maintained at Grass Island in 1903, and the equation resulting from the observation was—

$$\text{Grass Island (1903)} = 560.826 + 0.543\ h \qquad (3)$$

in which h is the water-surface elevation of Lake Erie at Buffalo above 570. The ratio of river change to lake change is 0.543.

In 1907 a gage at the same place showed—

$$\text{Grass Island (1907)} = 560.528 + 0.555\ h \qquad (4)$$

For Lake Erie at stage 573 this gives the water surface at Grass Island as follows:

1903	562.45
1907	562.193

This shows a lowering between 1903 and 1907 of 0.262, or a little over three inches. This lowering is mainly due to the removal of the temporary diverting dam of the Ontario Co., the use of water by that company, and some increased diversions on the American side. The ratios, however, in the two

equations, 1903, 0.543, and 1907, 0.555, differ by but 0.012 foot, or one-eighth inch, for a change of a foot at Buffalo.

A combination of the 1903 and 1907 observations gives a ratio 0.556, or roundly 0.56, which has been used in the reductions and in this report.

As the Chippawa gage is just across the river in the same pool, its equations are of interest in relation to the ratio of change.

The 1906 gage at Chippawa gives—

$$\text{Chippawa (1906)} = 561.240 + 0.549\ h \qquad (5)$$

No separate equation is derived for the 1907 observations, but for the observations of 1906 and 1907 combined the following equation results:

$$\text{Chippawa (1906-7)} = 561.228 + 0.557\ h \qquad (6)$$

For Lake Erie at 573 these equations give:

Chippawa (1906) 562.887
Chippawa (1906-7) 562.899

The ratio, 0.56, identical with that at Grass Island, has been used in the reductions and in this report.

The four derived ratios summarized are:

Grass Island (1903) 0.543
Grass Island (1907) ..... .555
Chippawa (1906) ..... .549
Chippawa (1906-7) ..... .557

There seems little doubt about the propriety of the ratio 0.56, representing as it does the later conditions. However, if 0.50 were the proper ratio instead of 0.56, the error entering into the results in this pool during the shutdown would not exceed (0.22×0.06), or 0.013 foot.

The 1906 observations gave for the Willow Island gage at the head of the American Channel a ratio of 0.422, and the 1907 observations for Wing Dam a little further downstream give 0.412.

In the Whirlpool the following variations of ratio are shown:

1906 ..... 2.478
1907 ..... 2.482
1906-7 ..... 2.458

and the ratio used in reductions is 2.47.

For Suspension Bridge the range of ratios is greater:

1906 ..... 2.285
1907 ..... 2.375
1906-7 ..... 2.286

and 2.29 was accepted as a proper ratio.

At Austin Street, Black Rock, the observations show ratios as follows:

1903	0.830
1907	.802
1899, 1900, 1903, 1907	.821

and 0.82 is accepted as correct.

The ratios at Prospect Point, Terrapin Point and at the Canadian end of the Horseshoe Fall are likely to have errors as great as five per cent. or more of their values, because the ratios depend on the records of a few months only.

TABLE 40. COMPARISON OF DAILY MEAN WATER-SURFACE ELEVATIONS OBSERVED AND COMPUTED

Date 1908	Buffalo	Austin Street			Schlossers Dock			Chippawa		
		Observed	Computed	River high	Observed	Computed	River high	Observed	Computed	River high
	Feet	Feet	Feet		Feet	Feet		Feet	Feet	
July 13	573.26	567.98	567.91	+ 7	564.16	564.20	— 4	563.12	563.03	+ 9
July 14	573.23	568.03	567.92	+11	564.15	564.22	— 7	563.12	563.04	+ 8
July 15	573.25	568.04	567.90	+14	564.16	564.23	— 7	563.14	563.06	+ 8
July 16	573.13	567.92	567.80	+12	564.09	564.16	— 7	563.05	562.99	+ 6
July 17	573.68	568.20	568.25	+ 5	564.36	564.41	— 5	563.28	563.23	+ 5
July 18	573.51	568.22	568.11	+11	564.35	564.37	— 2	563.32	563.19	+13
July 19	573.30	568.08	567.94	+14	564.27	564.27	+ 0	563.28	563.09	+19
July 20	573.12	567.92	567.79	+13	564.16	564.14	+ 2	563.19	562.97	+22
July 21	573.15	567.94	567.82	+12	564.17	564.11	+ 6	563.18	562.95	+23
July 22	573.25	568.04	567.90	+14	564.25	564.22	+ 3	.....	563.05	.....
July 23	573.05	567.89	567.74	+15	564.15	564.11	+ 4	.....	562.94	.....
July 24	572.88	567.75	567.60	+15	564.04	564.00	+ 4	.....	562.84	.....
July 25	573.03	567.87	567.72	+15	564.11	564.05	+ 6	563.14	562.89	+25
July 26	573.01	567.89	567.70	+19	564.14	564.07	+ 7	563.16	562.91	+25
July 27	573.16	567.98	567.82	+16	564.19	564.16	+ 3	563.20	562.99	+21
July 28	573.16	567.97	567.82	+15	564.17	564.15	+ 2	563.15	562.98	+17
July 29	573.11	567.95	567.78	+17	564.13	564.14	— 1	563.11	562.97	+14
July 30	573.16	567.97	567.82	+15	564.14	564.15	— 1	563.12	562.98	+14
July 31	573.17	567.98	567.83	+15	564.13	564.17	— 4	563.12	563.00	+12
Aug. 1	572.94	567.76	567.64	+12	563.99	564.01	— 2	562.98	562.85	+13
Aug. 2	573.10	567.95	567.78	+17	564.17	564.14	+ 3	563.18	562.98	+20
Aug. 3	573.12	567.90	567.79	+11	564.10	564.10	+ 0	563.08	562.93	+15
Aug. 4	573.23	568.02	567.85	+17	564.18	564.17	+ 1	563.15	563.00	+15
Aug. 5	573.32	568.19	567.96	+23	564.22	564.29	+ 3	563.26	563.11	+15
Aug. 6	573.40	568.13	568.02	+11	564.23	564.25	+ 2	563.18	563.08	+10

Date 1903	Buffalo Feet	Grass Island Observed Feet	Grass Island Computed Feet	River high	Wing Dam Observed Feet	Wing Dam Computed Feet	River high	Prospect Point Observed Feet	Prospect Point Computed Feet	River high
July 13	573.36	562.46	562.33	+13	558.47	558.32	+15	.....	512.85	.....
July 14	573.28	.....	562.34	.....	558.46	558.33	+13	.....	512.89	.....
July 15	573.25	.....	562.35	.....	558.46	558.34	+13	.....	512.89	.....
July 16	573.13	.....	562.29	.....	.....	558.29	....	512.93	512.88	+ 5
July 17	573.68	562.65	562.52	+13	558.59	558.47	+12	512.98	512.95	+ 3
July 18	573.51	562.62	562.48	+14	558.58	558.44	+14	512.97	512.92	+ 5
July 19[1]	573.30	562.75	562.39	+36	558.58	558.37	+21	512.97	512.90	+ 7
July 20[1]	573.12	562.65	562.26	+39	558.48	558.28	+20	512.95	512.87	+ 8
July 21[1]	573.15	562.64	562.24	+40	558.46	558.26	+20	512.94	512.86	+ 8
July 22[1]	573.35	.....	562.24	....	558.50	558.34	+16	512.94	512.89	+ 5
July 23[1]	573.05	562.62	562.24	+38	558.42	558.26	+16	512.91	512.86	+ 5
July 24[1]	572.88	562.52	562.14	+38	558.34	558.18	+16	512.89	512.84	+ 5
July 25[1]	573.02	562.59	562.19	+40	558.38	558.22	+16	512.88	512.85	+ 4
July 26[1]	573.01	562.62	562.20	+42	558.38	558.23	+15	512.90	512.86	+ 4
July 27[1]	573.16	562.66	562.28	+38	558.41	558.29	+12	512.91	512.87	+ 4
July 28[1]	573.16	562.49	562.28	+21	558.37	558.29	+08	512.90	512.87	+ 3
July 29[1]	573.11	562.40	562.26	+20	558.37	558.28	+09	512.90	512.87	+ 3
July 30[1]	573.16	562.45	562.28	+17	558.39	558.29	+10	512.91	512.87	+ 4
July 31[1]	573.17	562.44	562.30	+14	558.40	558.30	+10	512.91	512.88	+ 3
Aug. 1[1]	573.24	562.33	562.14	+18	558.81	558.19	+12	512.88	512.84	+ 4
Aug. 2[1]	573.10	562.62	562.27	+35	558.47	558.28	+19	512.92	512.87	+ 5
Aug. 3	573.12	562.43	562.23	+19	558.39	558.25	+14	512.90	512.86	+ 4
Aug. 4	573.22	562.48	562.29	+19	558.44	558.30	+14	512.92	512.88	+ 4
Aug. 5	573.32	562.59	562.40	+19	.....	558.36	....	512.94	512.90	+ 4
Aug. 6	573.40	562.50	562.37	+13	.....	558.36	....	512.92	512.89	+ 3

[1]Shutdown. [2]Partial Shutdown.

The residuals of Tables 39 and 40, therefore, in the conversion processes necessary to make the results comparable, have not been subjected to distortion.

The mean decrease in the diversion in the two 10-day periods compared was 6,210 cubic feet per second. The first effect of this was to add that much water to the flow over the Rapids, and this required a rise in the Chippawa-Grass Island pool of 0.117 foot as shown at Chippawa; this backed up the river so as to cause a rise at Austin street, Black Rock, of 0.028; and this in turn lessened the outflow from Lake Erie, as indicated by the gages at Suspension Bridge and in the Whirlpool by 600 cubic feet per second. The final outcome was that the change in flow over the Rapids was 6,210 less 600, or roundly 5,600, and the bulk of this went over the main rapids. At the same time, the Electrical Development Co. and the Canadian Niagara Falls Co. assuming part of the burden laid down by the Niagara Falls Power Co. which had shut down, took from the main rapids perhaps 1,000 cubic feet, giving a probable excess flow over these rapids and the Horseshoe Fall of only 4,500 cubic feet per second.

In order, therefore, to derive the final effect of a diversion of 10,000 cubic feet in the American Canals, the difference in the residuals shown in the summary must be multiplied by 10,000/5600,, or by 1.79. The effects of 10,000 cubic feet so diverted are given in the discussion in specific chapters.

The agreement of the residuals from day to day is sufficient warrant that heavy rainfalls or wind storms did not interfere with the essential fairness of the test; but to make the evidence complete, the following abstracts furnished by the weather observer at Buffalo, Mr. D. Cuthbertson, are included in this report:

TABLE 41.—WEATHER CONDITIONS, 1908.

	Wind		Precipitation (inches).	Barometer.
	Direction from which blows.	Velocity (miles per hour).		
During Diversion.				
July 13, partly cloudy	SW.	9.0	0.41	29.13
July 14, partly cloudy	SW.	11.0	.00	29.09
July 15, partly cloudy	NW.	16.0	.00	29.20
July 16, clear	SW.	8.0	.00	29.32
July 17, cloudy	S. & SW.	20.0	1.02	28.94
July 18, cloudy	W. & SW.	16.0	.92	28.86
Aug. 3, partly cloudy	SW.	10.0	.00	29.18
Aug. 4, partly cloudy	SW.	17.0	Trace	29.06
Aug. 5, cloudy	SW.	18.0	.10	28.94
Aug. 6, partly cloudy	SW.	17.0	.01	29.02
Total			2.55	
Mean	SW.	14.2	....	29.07
During Shutdown.				
July 19, cloudy	NE.	7.0	0.03	29.13
July 20, partly cloudy	N.	7.0	0.00	29.32
July 21, cloudy	N.	5.0	.77	29.20
July 22, clear	SW.	9.0	Trace	29.28
July 23, clear	NE.	8.0	.00	29.36
July 24, cloudy	E.	14.0	.04	29.40
July 25, partly cloudy	E.	9.0	.07	29.39
July 26, clear	E.	9.0	.00	29.36
July 27, clear	NE.	8.0	.00	29.28
Aug. 2, clear	N.	9.0	.01	29.13
Total	....	....	.94	.....
Mean	N. & E.	8.5	....	29.30
Differences		5.7	1.61	—0.23

The fact that Lake Erie, with its 240 miles of length, was but 0.22 foot higher during the 10-day period of diversion than during the shutdown indicates the small effect of the southwest wind, with its higher velocity, as opposed to the north and east winds of the shutdown period.

The precipitation, except as it might cause a slight rise in Chippawa Creek, is of little moment. The high precipitation of July 17 and 18, during diversion, was probably still running off on the 19th and 20th, and therefore affected both periods, and its influence is largely eliminated by subtraction.

Note.—In Appendix 3, the following tabulations of data are given:

Table 42—Volume of river flow by three weirs.

Table 43—Variation at different gages.

Table 44—Flow in power canal for shutdown periods.

Table 45—Flow in hydraulic canal for shutdown periods.

Table 46—Water-surface elevations at various gages during shutdown period."

Extract from the same document (page 50) as follows:

"At the time of the shutdown of the Niagara Falls Power Co. in July-August, 1908, the change in the flow over the Rapids was the amount due to the return to the river of the diversion of 6,210 cubic feet per second, less 600 cubic second-feet decrease in Lake Erie outflow, or 5,610 in all. As at that time the normal river flow was upwards of 224,000 cubic second feet, the change in the river flow was only 2½ per cent. While this is not a large quantity to predict results upon, it is a full third of existing local diversions. (See Table 39, Chapter VIII.)

"The lowering at Chippawa due to this diversion was proved by the shutdown to be at the rate of 0.21 foot for a diversion of 10,000 feet, or 0.04 foot (½ inch) less than computed from the observed equivalent river heights. At Grass Island it was 0.40, or 0.15 foot more than shown by equivalent river heights, but an excess was expected here as a localized effect."

Extract from the same document as follows (page 59):

"To verify the cross-sectional area derived by the methods described above, Section No. 1 was sounded with a 95-pound projectile-shaped cast-iron weight. The area resulting from these soundings showed for identical gage heights about ⅓ of 1 per cent. larger than by the more precise method of level and rod."

Extract from same document Chapter 15, current meter tests (pages 72 to 74, inclusive), as follows:

"Chapter XV. Current-Meter Tests.

"The hydraulic work of the Lake Survey on the outflow of the Great Lakes depends fundamentally for its accuracy on the proposition that the Haskell Current Meter rated on a still-water base gives the true velocity of flowing water. The work of the Lake Survey up to the time of the experiments here briefly described contains no demonstration on this vital points.

"On the face of it, an efficient rating on a still-water base, in which a mass of water is at rest and the instrument is passed through it, should show the same wheel revolutions as a current rating, in which the meter is at rest and the water flows through it. It would seem to be merely a matter of relative motion between instrument and water. However, it is claimed that the impact on the wheel vanes of the particles of flowing water, owing to the intricate nature of their movements, does not have the same effect in wheel revolutions

as the impact between the vanes and the inert particles of still water.

"In submitting formulas for discharge of the Niagara and St. Lawrence Rivers, it seemed proper to apply a correction for instrumental error, if such error existed, and these experiments were made to determine this point.

"The Haskell Current Meters, one of type A, called L. S. 4A, and one of type B, L. S. 1B, were carefully rated on a still-water base. The methods used were similar to those used in rating meters for the discharge work in the Niagara and St. Lawrence Rivers, and described in the Reports of the Chief of Engineers, United States Army, for 1900 and 1901, except that the meter was suspended from the deck of a light catamaran, whose hulls were of 8-inch diameter cedar poles, with a clear width of 12 feet between hulls.

"Each meter was rated three times, and the rating equation is derived from all observations corresponding to the river velocities of the current rating.

"In the still-water rating, a 200-foot base was used, marked by beads soldered on a galvanized-iron wire. This wire was stretched taut over the still water, and acted in addition as a guide for the catamaran.

"The current rating of the meters was done in the Detroit River just above the Lake Survey depot at Fort Wayne, and about 200 feet out from the dock line.

"A section of the steel pontoon sweep was suspended in the current, held by a head anchor. A second section was suspended tandem from the first by two galvanized-iron wires, one on each side, having beads soldered on them 200 feet apart. The starboard wire formed the current rating base. The length between beads of the wires was measured, before and after the tests, by a steel tape.

"The sweep catamarans have decks that overhang at the sides the cylindrical steel hulls. These overhangs were extended so as to drop the meters into the water 12 feet outside the starboard hulls, in order to place the instruments where the current lines would be entirely clear of hull influences.

"The 4A meter, was placed abreast the zero bead on the upper catamaran; the 1B meter was about five feet downstream from the 200-foot bead on the lower catamaran. The axes of the meter wheels were set 1 foot below the water surface.

"The two catamarans hanging fair with the current

aligned the meters so that the current threads passing the first passed close to the second also. The catamarans showed little movement, either sidewise or streamwise.

"As doubt exists as to whether a float travels at the same speed as the water in which it is immersed, and as a float must penerate the surface skin and be in some measure affected by the wind, it seemed best to avoid floats, and to make visible a ball of the water itself, so that its transit between the two terminal beads could be timed. It was found that about four ounces of a strong fluid, bluing, or a strong solution of aniline red, injected into the river at a depth of about a foot, would color a ball of water perhaps a foot in diameter at the start, which held together so that about 70 seconds later it would complete the transit of the 200-foot base, with a size not often more than double, and still a fairly compact mass of color.

"The colored water was injected about five feet upstream and a little to one side of the upper meter, 4A, using a small bicycle pump, pointed downwards and moving at the speed of the water as closely as it could be followed. When the center of the ball of color passed the initial bead of the base wire, the registration of both meters was started by pressing the stems of two stop watches. When its center reached the 200-foot bead, its transit was signaled and both registers were thrown out of circuit by stopping the stop watches. The total number of wheel revolutions for each observation, the transit time of the fluid, and its path were noted.

TABLE 66.—TESTS OF ACCURACY OF HASKELL CURRENT METERS L. S. 4A AND L. S. 1B IN DETROIT RIVER.

Number of observation. a	Date. b	Time of day. c	Velocity (feet per second). By meter 4A. d	By meter 1B. e	Mean by meters. f	By fluid transit. g	Residuals. f-g
	1906.	P. M.					
1	June 1	1.00	2.89	2.97	2.93	2.99	−6
2	do	1.06	2.89	2.84	2.86	2.96	−10
3	do	1.10	2.83	2.72	2.78	2.74	+4
4	do	1.12	2.87	2.74	2.80	2.88	−8
5	do	1.15	2.81	2.86	2.84	2.92	−8
6	do	1.17	2.81	2.86	2.84	2.88	−4
7	do	1.20	2.75	2.68	2.72	2.83	−11
8	do	1.22	2.83	2.84	2.84	2.86	−2
9	do	1.27	2.81	2.76	2.78	2.87	−9
10	do	1.30	2.82	2.72	2.77	2.81	−4
11	do	1.35	2.81	2.90	2.86	2.88	−2
12	do	1.37	2.58	2.72	2.65	2.78	−13
13	do	1.40	2.62	2.70	2.66	2.66	0
14	do	1.43	2.84	2.96	2.90	2.79	+11
15	do	1.53	2.86	3.02	2.94	2.97	−3
16	do	1.55	2.86	2.91	2.88	2.92	−4
17	do	1.57	2.86	2.87	2.86	2.84	+2
18	do	1.59	2.86	2.82	2.84	2.87	−3
19	do	2.00	2.72	2.85	2.78	2.72	−6
20	do	2.02	2.79	2.70	2.74	2.80	−6
21	do	3.32	2.72	2.76	2.74	2.72	+2
22	do	3.35	2.81	2.85	2.83	2.70	+13
23	do	3.37	2.88	2.86	2.87	2.84	+3
24	do	3.38	2.89	2.80	2.89	2.92	−3
25	do	3.41	2.86	2.92	2.89	2.96	−7
26	do	3.43	2.82	2.80	2.81	2.84	−3
27	do	3.45	2.76	2.80	2.82	2.88	−6
28	do	3.47	2.87	2.84	2.86	2.85	+1
29	do	3.50	2.83	2.85	2.84	2.92	−8
30	do	3.52	2.83	2.96	2.90	2.94	−4
31	do	3.55	2.74	2.85	2.80	2.80	0
32	do	4.01	2.82	2.90	2.86	2.87	−1
33	do	4.03	2.82	2.85	2.84	2.82	+2
34	do	4.05	2.86	2.87	2.86	2.80	+6
35	do	4.07	2.86	2.87	2.86	2.80	+6
36	do	4.09	2.80	2.91	2.86	2.70	+16
37	do	4.11	2.74	2.90	2.82	2.70	+12
38	do	4.13	2.65	2.68	2.66	2.68	−2
39	do	4.15	2.71	2.72	2.72	2.78	−6
40	do	4.17	2.65	2.67	2.66	2.80	−14
41	do	4.19	2.65	2.65	2.65	2.53	+12
42	do	4.22	2.68	2.72	2.70	2.70	0
43	do	4.25	2.74	2.71	2.72	2.80	−8
44	do	4.27	2.70	2.74	2.72	2.67	+5
		A. M.					
45	June 2	10.45	2.90	2.96	2.93	2.82	+11
46	do	10.48	3.04	2.99	3.02	2.92	+10
47	do	10.50	2.99	3.04	3.02	3.04	−2
48	do	10.52	2.88	3.01	2.92	2.85	+7
49	do	10.55	2.92	2.98	2.95	2.93	+2
50	do	11.00	2.88	2.90	2.89	2.88	+1
51	do	11.06	3.01	2.92	2.96	3.01	−5
52	do	11.07	2.98	3.01	2.97	2.92	+5

53	do	11.10	2.98	2.98	2.98	2.85	+13
54	do	11.14	2.95	2.96	2.96	2.90	+ 6
55	do	11.15	2.90	2.98	2.94	2.96	− 2
56	do	11.20	2.97	2.98	2.98	2.96	+ 2
57	do	11.22	2.88	3.08	2.96	3.11	−15
58	do	11.25	2.93	3.01	2.97	2.92	+ 5
		P. M.					
59	do	12.57	3.00	2.99	3.00	3.01	− 1
60	do	12.59	3.01	3.07	3.04	3.03	+ 1
61	do	1.00	2.97	2.97	2.97	2.89	+ 8
62	do	1.39	2.88	2.91	2.90	2.85	+ 5
63	do	1.41	2.88	2.94	2.91	2.93	− 2
64	do	1.44	2.85	2.92	2.88	2.92	− 4
65	do	1.45	2.95	2.96	2.96	2.85	+11
66	do	1.47	2.87	2.92	2.90	2.90	0
67	do	1.48	2.85	2.86	2.86	2.85	+ 1
68	do	1.50	2.95	2.94	2.94	2.99	− 5
69	do	1.52	2.91	2.91	2.91	2.86	+ 5
70	do	1.55	2.88	2.94	2.91	2.91	0
71	do	1.57	2.88	2.89	2.88	2.92	− 4
72	do	1.59	2.89	2.87	2.88	2.96	− 8
73	do	2.00	2.89	2.94	2.92	2.91	+ 1
74	do	2.02	2.84	2.89	2.86	2.82	+ 4
75	do	2.05	2.75	2.89	2.82	2.80	+ 2
76	do	2.07	2.93	2.84	2.88	3.05	−17
Means			2.843	2.878	2.859	2.862	5.5

Still water base and current base 200 feet long. Current flows S. W.
June 1—Weather fair. Wind 4 to 6 miles per hour from W.
June 2—Weather fair. Wind 10 to 12 miles per hour from N. N. W.

"The 76 observations of Table 66 show the result in detail. The velocity of the current as shown by the color fluid is taken as the true velocity and is given in column g. The velocity of the current as shown by the meters is given in columns d and e and the mean velocities shown by the two meters in column f. The mean velocity shown by the fluid and by the mean of the two meters for the 76 observations is practically identical—2.862 and 2.859 feet per second.

"On June 1, 44 observations showed a mean velocity of 2.818 feet per second by the fluid and 2.806 by the meters, the meters giving a lower velocity by nearly ½ of 1 per cent. On June 2, 32 observations showed a mean velocity of 2.922 by fluid and by the meters 2.933, the meters giving a higher velocity by about ½ of 1 per cent. These small divergencies are the expected errors of observations characteristic of hydraulic work. Individual observations show larger divergencies, coming from fluctuating velocities.

"The tests demonstrate conclusively the correctness of the indications of the Haskell meters.

"The 4A meter rated in these experiments was the meter most largely used in the measurements of the Niagara and St. Lawrence Rivers, and the 1B meter was used in the lat-

ter river. Both of these meters were used in the measurements of the flow in the Niagara Falls Power Co.'s canal (see Chapter XII) and with velocities close to those of the tests of 1906.

"The correction for instrumental error is taken as zero."

Letter from Major Charles S. Bromwell, U. S. Engineer's Office, Chicago, to Thomas A. Smyth, President Sanitary District, dated February 24, 1913, as follows:

"Engineer Office, United States Army.
509 Federal Building.
Chicago, Illinois, Feb. 24, 1913.

Mr. Thomas A. Smyth,
President, Sanitary District of Chicago,
American Trust Building,
Chicago, Ill.

Dear Sir:

"I am directed by the War Department to notify you that measurements made by the Engineer Department during January indicate that since the Secretary of War's decision of January 8, 1913, you have been diverting from Lake Michigan more water than the 4,167 second feet authorized by the existing War Department permits.

"Your attention is invited to Section 10 of the Act of March 3, 1899, which is being violated by such diversion, also to the provisions of Sections 12 and 17 of the same act, a marked copy of which is inclosed.

"Kindly advise this office what steps, if any, you propose to take to keep future diversions within the limits of the existing War Department permits and how soon such reduction of diversion may be expected.

"I have also to inform you that a continuation of the excess diversion may require action by the United States District Attorney.

Very respectfully,

C. H. B.
Major, Corps of Engineers.

8
1 inclosure
CHLR
140/233."

Letter from Thomas A. Smyth, President Sanitary District to Major Charles S. Bromwell, dated February 27, 1913, as follows:

"Letterhead of
The Sanitary District of Chicago
American Trust Building.

February 27, 1913.

Major Charles S. Bromwell,
Corps of Engineers, U. S. A.
Federal Building, Chicago, Ill.

Dear Sir:

"I am in receipt of your favor of the 24th instant, concerning the diversion of water from Lake Michigan through the Channel of the Sanitary District.

"As a number of the members of the Board will be out of town during the next two weeks, I have called a meeting of the Board for the 13th prox., at which time your letter will be placed before them for consideration and prompt reply.

Yours very truly,
(Signed) THOMAS A. SMYTH,
President.

A true copy."

Letter from Major Charles S. Bromwell to Thomas A. Smyth, dated March 15, 1913, as follows:

"Engineer Office, United States Army,
509 Federal Building.
Chicago, Illinois, March 15, 1913.

Mr. Thomas A. Smyth,
President, Sanitary District of Chicago,
American Trust Building,
Chicago, Illinois.

Dear Sir:

"I am directed by the War Department to notify you that measurements made by the Engineer Department during February, 1913, indicate that since the Secretary of War's decision of January 8, 1913, you have been diverting from Lake Michigan more water than the 4,167 second feet authorized by the existing War Department permits.

"Your attention is invited to Section 10 of the Act of March 3, 1899, which is being violated by such diversion, also to the provisions of Sections 12 and 17, of the same Act, a marked copy of which is enclosed.

"Please advise this office what steps, if any, you propose to take to keep future diversions within the limits of the existing War Department permits and how soon such reduction of diversion may be expected.

"I have also to inform you that a continuation of the ex-

cess diversion may require action by the United States district attorney.

Very respectfully,

CHARLES S. BROMWELL,
Major, Corps of Engineers.

GWS
1 inclosure.
CHLR
140/236."

Letter from Edmund D. Adcock, Attorney for Sanitary District of Chicago, to Major Charles S. Bromwell, dated March 22, 1913:

"Je Mai Nt Iendrai
Lunion Fait Force

Mar 26 1913

Hotel Netherland
New York.

U. S. Engineer Office
Chicago, Ill.
March 22, 1913.

H. P. Whitaker, President.
George W. Swett, Manager.
Major Charles S. Bromwell,
Corps of Engineers, U. S. A.,
Federal Bldg., Chicago, Ill.

Dear Sir:

"I have before me your letters of February 24th and March 15th, 1913, respectively, addressed to Thomas A. Smith, President of the Board of Trustees of the Sanitary District of Chicago. Also a copy of the letter of President Smith to you dated February 27, 1913.

"The Board of Trustees took up for consideration your various communications and the subject matter therein referred to at a meeting of the Board held on March 11, 1913, and I was directed by resolution of the Board to reply to your letter of the 24th. However, on the morning of the 12th I was compelled to leave Chicago for New York where I have been since and am now engaged in the taking of testimony in the case of the United States of America versus The Sanitary District of Chicago. Hence, the delay in answering your letter.

"The suit above referred to was filed by the United States some time in the year 1908 in the District (then Circuit) Court of the United States for the Northern District of Illinois to enjoin the Sanitary District from constructing a channel known as the Sag Channel from the Calumet River to a

point on the main channel of the Sanitary District at Sag, and also to enjoin the District from reversing the flow of the Calumet River through the proposed new channel, and from taking the waters from Lake Michigan for the purpose of diluting the sewage of the Calumet District immediately south of the City of Chicago—in so far as such withdrawal might increase the amount of water that the Sanitary District had been theretofore authorized to take by the Secretary of War, etc., etc. This new channel is an adjunct to the main channel and is designed to serve the population of the Sanitary District in that portion of the district known as the Calumet region. One of the legal questions involved is, that the State of Illinois has the right to provide for the health of its citizens in the manner that it has; that the United States has not interfered and could not interfere with the right of the sovereign state to reasonably provide for the preservation of the lives and health of its citizens.

"The amount of water proposed to be diverted through the Sag Channel was approximately 4,000 cubic feet per second; that was at that time the capacity of the proposed channel. On June 30, 1910, while said suit was pending the Sanitary District was granted a permit by the Secretary of War to complete and construct the new channel and to reverse the flow of the Calumet River, and to take water from Lake Michigan through this new channel, provided, however, that the water that might be taken through the new channel and that taken through the main channel should not in the aggregate exceed the amount authorized by the Secretary of War. Upon the issuance of this permit of June 30, 1910, the Sanitary District entered upon the construction of the Sag Channel, and has up to the present time expended and contracted to expend upwards of several million dollars in its construction.

"You are no doubt aware that the International Waterways Commission by its report of 1907 recommended that no question be raised as to the right of the Sanitary District to flow through its channels for sanitary purposes at least 10,000 cubic feet of water per second, etc., etc. You are likewise probably aware that the Sanitary District under its Organic Act of 1889, commenced the construction of its channels through which it was to flow the waters of Lake Michigan for the purpose of diluting the sewage of the inhabitants of the Sanitary District; that on January 17, 1900, after approximately ten years devoted to construction work, and after the expenditure of many millions of dollars the main

channel of the Sanitary District was completed and the waters of Lake Michigan from that time on has flowed through the main channel into the Des Plaines River in quantities at most times sufficient to dilute the sewage in accordance with the specific provision of the Organic Act.

"Until the decision of the Honorable Secretary of War of January 8, 1913, it was the general belief that the Secretary of War would without question formally consent under present existing conditions to the taking of water up to at least 10,000 cubic feet per second from Lake Michigan through the channels of the Sanitary District.

"The Act under which the Sanitary District is organized and under which it is now operating makes it mandatory upon the Trustees of the Sanitary District to cause not less than 20,000 cubic feet of water per minute for each 100,000 of the population of the District to flow from Lake Michigan through its channels. The population of the District is such that to comply with its organic law, it is necessary that the Board of Trustees cause more than 4,167 cubic feet of water per second to flow through the channels of the Sanitary District. That condition has existed for a number of years past and the Sanitary District has been flowing through its channels sufficient water to dilute the sewage pursuant to its Organic Act (20,000 cubic feet per minute for each 100,000 of population). The Sanitary District cannot either under the law of its creation or if it intends to preserve the health of the inhabitants of the District reduce that flow.

"I have at some length pointed out to you the facts with most of which no doubt you are familiar so that the situation in which the Sanitary District is now placed may be fully considered by you.

"The Board of Trustees of the Sanitary District appreciate their responsibility in the matter. It is their desire that the rights of the Sanitary District be finally determined. With this in view, and inasmuch as the suit now pending relating to the Sag Channel involves issues which are somewhat similar to the questions now involved in the interrogatories propounded in your two letters, I respectfully suggest that the bill of complaint in the case of the United States vs. Sanitary District now pending be amended or a supplemental bill filed so that all the issues above referred to may be settled and promptly adjudicated. A great deal of testimony has been already taken, all of which will apply to the issues that would be raised by the proposed amended proceedings. A great deal of time, work and trouble would be saved

by pursuing the method I suggest and the Sanitary District will co-operate to speedily make up and try the issues upon the issues which may be presented by the amended or supplemental bill proposed, and will also stipulate that all testimony thus far taken, be treated as having been taken in the amended proceeding.

"I respectfully request that before any definite conclusion is reached by the Government with reference to these suggestions that a conference be arranged between the representatives of the Sanitary District and the Government at such time and place as may be convenient to the Government representatives.

Very respectfully,

EDMUND D. ADCOCK,

Attorney for the Sanitary District of Chicago."

Mr. Wilkerson: Referring to the notice served by counsel for defendant as to exhibits to be submitted on behalf of defendants, pursuant to stipulation of November 16, 1914, the United States reserves the right to specify such further documents or parts of documents as may be pertinent to any matters covered by subdivisions 3 and 4, of the paper entitled, "Memorandum of Documents to be referred to and exhibits to be submitted on behalf of defendants as further evidence in this case," served on counsel for the United States on December 6, 1914. This reservation is made because the time within which defendant is to specify particular documents has been extended by agreement until December 21, 1914, at which time the complainant is to present oral evidence concerning certain documents, in accordance with said stipulation of November 16, 1914.

Mr. Adcock: I offer in evidence on behalf of the defendant the following:

Extract from report of Mr. L. C. Sabin, July 1, 1900, Appendix III, Chief of Engineers, Report, Vol. 2, part 8, at p. 5401:

"The effect of withdrawing from Lake Michigan-Huron a certain amount of water through an independent outlet may now be determined within the limits of accuracy of our discharge equation. It has been said that the true discharge equation is probably of a higher degree than the first. A given change in stage at high levels would doubtless result in a greater change in discharge than at low levels. Consequently the continuous withdrawal of a fixed amount per second would effect a greater subsidence of lake level in low stages than in high stages. Considering the increment of discharge per foot rise in stage to be constant and equal to 19,030 cubic foot-seconds, the ultimate effect of withdrawing, say, 10,000 cubic foot-seconds, through an independent outlet will be to lower Lake Michigan-Huron 10,000÷19,030 or 0.525 foot, about 6¼ inches. If in very low water the increment of discharge becomes as low as 18,000 cubic foot-seconds the effect at low stage would be about 0.55 foot; and if at high stages the increment becomes as high as 22,000 cubic foot-seconds, the effect on the high stage would be 0.45 foot. When the lakes are below the mean stage of ultimate effect of the withdrawal of 10,000 cubic foot-seconds is probably not less than a half a foot.

"The area of Lake Michigan-Huron is, approximately, 45,314 square miles. A discharge of 10,000 cubic foot-seconds is equivalent to 0.0205 foot depth over the entire lake surface. The rate of fall, then, due to withdrawal of this amount of water alone would be 0.0205 foot per month, and to lower the lake 0.525 foot would require 25.6 months; but as soon as the lakes begin to fall on account of this additional discharge the discharge through the natural outlet will be diminished on account of the lower stage, and the rate of fall will thereby be diminished. The mathematical express of this law, giving the net change after months, is rather complicated and need not be given here. The results derived from it are given in the following table."

"Resolution Passed by the Forty-Fourth General Assembly, Special Session, 1906.

"Whereas, the Congress of the United States is now considering the report of the International Waterways Commission; and

"Whereas, said report contains a recommendation that the amount of water to be diverted from the Great Lakes through the Chicago Drainage Canal be limited to ten thousand (10,000) cubic feet per second; and

"Whereas, said limitation would in the future render futile the expenditure of fifty million ($50,000,000) dollars already expended by the Sanitary District of Chicago, and render impossible the completion of said project, and endanger the health of the people of Illinois and of the City of Chicago; and

"Whereas, the amount of water to be diverted for domestic and sanitary purposes should, under no circumstances, be limited by a treaty with a foreign power, or by any legislation to be enacted by Congress, thus placing the Sanitary District of Chicago—organized to preserve the health of the people—upon the same plane as commercial enterprises organized for private gain; now

"Therefore, be it resolved, by the Senate of the Forty-fourth General Assembly of the State of Illinois, convened in extraordinary session, the House of Representatives concurring therein, that in any treaty to be hereafter entered into, no statement whatever binding the trustees of the Sanitary District of Chicago shall be made, and the local conditions of such canal and the volume of water to be accommodated therein should be left wholly and solely to the regulation of the Federal Government, as the conditions of the canal's drainage may require; and

"Be It Further Resolved, that in any legislation to be hereafter enacted by Congress a provision should be included permitting the Sanitary District of Chicago to use such water as may be necessary in the discretion of the Secretary of War, and such legislation, if any, should be specifically provided that that portion of the report of the said International Waterways Commission referring to the Sanitary District of Chicago and the amount of water to be diverted through its channels should be entirely ignored; and

"Be It Further Resolved, that the two Senators and the members of Congress representing this state be and they are

hereby respectfully requested to do all in their power to incorporate the provision above referred to in any legislation to be passed by Congress, and prevent the incorporation of any statement in any treaty to be entered into with a foreign power placing any restriction upon the amount of water to be withdrawn through the Drainage Canal of the Sanitary District of Chicago; and

"Be It Further Resolved, that a copy of this resolution be forwarded immediately to the Secretary of State, to each Senator and Representative in Congress from this state, and to the President of the United States."

Mr. Adcock: I desire to offer in evidence all papers and documents offered for identification, or other documents, copies of which appear in the record, and not formally offered; and I desire that the documents which have been marked for identification, and bearing an identification number, may be considered as offered.

Mr. Wilkerson: If there happens to be any document which is offered, which is not copied in the record, it is understood you will give it to the Commissioner, so it will be printed. In other words, we want everything in the case in the printed record.

Mr. Adcock: I am not offering anything that does not now appear in the printed record. I simply make this offer in order to clear up any possible technicality as to whether the documents which were referred to by the witnesses and printed in the record, or identified by the witnesses, were not formally offered in evidence.

Mr. Wilkerson: There is not now in the record anything that is not printed, and that we have not used in our discussions of the case.

Mr. Adcock: No; everything is in the printed record now.

Saturday, December 19, 1914.
12:00 M.

Present:
Mr. Wilkerson, on behalf of the United States.
Mr. Adcock, on behalf of the Sanitary District.

The evidence of ISAAC DE YOUNG taken, so far as time is concerned, by stipulation today, instead of on last Wednesday.

ISAAC DE YOUNG, a witness called in rebuttal on behalf of the Government, was first duly sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. Please state your full name to the Commissioner?
A. Isaac DeYoung.
Q. Where do you live?
A. Sault Ste. Marie, Michigan.
Q. What is your occupation?
A. Civil engineer.
Q. In what service are you engaged?
A. U. S. War Department.
Q. Are you connected with the Lake Survey?
A. No.
Q. You are connected with what branch of the War Department; who is your immediate superior?
A. Engineer Department. My immediate superior is Mr. L. C. Sabin.
Q. How long have you been in the Government service?
A. Since 1901.
Q. What was your preparation before you went into the Government service, briefly?
A. Graduated from the Chicago Manual Training School and the University of Michigan.
Q. And you went directly after your graduation into the Government service?
A. No, sir, I was employed with the Big Four Railway about three or four months.
Q. And by any other companies?
A. Then from there, I was employed by the Michigan-Lake Superior Power Company, Sault Ste. Marie, Michigan.
Q. For how long?
A. 1898 to 1901.

Mr. Wilkerson: I will say that this evidence is directed to and is in connection with the Statistical Report of Lake Commerce for the season 1913, which is specified and offered in evidence.

Q. Referring specifically, Mr. DeYoung, to the canals at Sault Ste. Marie, have you had occasion recently to make any survey that has had to do with the Poe Lock?
A. Yes, sir.

Q. When was that survey made?
A. During November.
Q. 1914?
A. 1914.
Q. State generally what the nature of the survey was?
A. We had a diver cleaning off the sill preparatory to closing the locks, and while we had a diver down, we had him hold the sounding pole on the lower platform entering the lock; and we took several soundings on the sides and in the center of the lock; and the rod held was read by engineers' level.
Q. As to the elevation of the platform above the floor of the lock what did you find?
A. We found that on the sides the platform was not worn down from the passage of boats, but in the center it was worn slightly.
Q. How much?
A. Oh, I should judge about a half an inch.
Q. And as to the places which were not worn, as to their elevation above the floor, what did you find?
A. That was found to be the same elevation as the floor of the lock.
Q. And in the middle, it was worn down about half an inch?
A. About half an inch.
Q. Just where is that platform with reference to the floor of the lock?
A. The platform is partly outside of the masonry, the lower end of the masonry of the lock. It is separated by the two surface gates, lower surface gates.
Q. Is the platform below the lower guard gate?
A. It is.
Q. It is the only platform there is in that particular vicinity?
A. Yes, sir.

Cross-Examination by Mr. Adcock.

Q. What is your title there, Mr. DeYoung?
A. U. S. Assistant Engineer.
Q. What are your duties?
A. My duties have been designing lock gates and immediate charge of construction of the east approach to the locks, —dredging.

Q. Entirely engineering matters?
A. Entirely engineering.
Q. You were not connected with the War Department, at the time the Poe Lock was built?
A. No, sir.
Q. Do you have anything to do with the operation of the lock, directly?
A. Operating, and care only in connection with repairs.
Q. The operation of the lock and the passing of boats through the lock and so forth, that is done by somebody else besides you, isn't it?
A. Yes, sir.
Q. Did you make these soundings personally?
A. No, sir; under my immediate supervision.
Q. Were you present when the—
A. No, sir.
Q. Who did make the soundings?
A. Inspector Owen Frederick.
Q. Did you make any examination of the notes, field notes, that were made by the engineers who made this survey?
A. I examined them after they were made.
Q. You were not present at all when that was done?
A. No, sir.
Q. Do you know the elevation of the top of this platform that you speak of, as compared with the elevation of the top of the lower miter sill of the Poe Lock?
A. I don't think I do. I think, however, it is the same elevation.
Q. That is only an opinion that you have?
A. Yes.
Q. You don't know anything about it?
A. No, sir.
Q. Did you ever examine the plans under which the Poe Lock was built, particularly referring to this platform?
A. I have examined them, not particularly. I may say here that the plans are not very complete that we have in the office, in connection with the Poe Lock.
Q. So you never made any examination of those plans to determine the elevation of the top of this platform as compared with the elevation of the top of the lower miter sill of the Poe Lock as shown by those plans,—construction plans?
A. I have examined the plans in that connection but I don't remember exactly what I saw. The plans are very—they show—

Mr. Adcock: I move to strike out what they show. Don't say what they show. I want to get what you know.

A. What is the question again?

Q. (Last question read to the witness.)

A. I have examined those plans, but I don't remember now the relative elevations.

Q. Did you receive any instructions from anyone with reference to making a survey of the lock there; that is before the survey was made?

A. No, sir, only to make the survey.

Q. From whom did you receive that instruction?

A. Mr. L. C. Sabin.

Q. What did he say about it, did he write you a letter?

A. No, sir.

Q. Just told you that?

A. His method of giving instructions is by scrap notes.

Q. Did he say why he wished you to make the survey?

A. No, sir.

Q. What time in November did you make the survey?

A. I don't remember.

Q. What day?

A. I don't remember the date.

Q. Was it before or after the 16th of November?

A. I think it was after the 16th.

Q. Do you know how long?

A. Perhaps I might refresh my recollection.

Q. You know Thanksgiving day was about the 24th?

A. Yes.

Q. Was it after Thanksgiving?

A. It was before Thanksgiving, I am pretty sure.

Q. It was before, two or three days before? It was between the 16th and Thanksgiving day?

A. As far as I remember, yes, sir.

Q. You were first assistant to Mr. Sabin from 1900, were you?

A. No, sir.

Q. You never knew of a survey of this kind being made before, did you?

A. Yes, I do. There was a survey made of the east approach to the lock, taking 10 by 10 soundings, and the soundings extended up into the lock. These were rough, from water surface levels.

Q. Only?

A. Yes.

Q. So you would not obtain very accurate results in that way?
A. They could be taken within one-tenth of a foot.
Q. Did you make those soundings?
A. No, sir.
Q. Did you ever examine the notes of those soundings?
A. No, sir.
Q. When were they made?
A. I think they were made in 1904.

Re-direct Examination by Mr. Wilkerson.

Q. Is the miter sill the same elevation as the floor of the lock?
A. I think it is.
Q. Mr. DeYoung, I understood you to say you were in immediate charge of the survey?
A. Yes, sir.
Q. The work was done by engineers who worked under your direction?
A. Yes, sir.
Q. You took their reports?
A. Yes, sir.
Q. And from the reports made to you in this regular course of business, you make your statement that the platform is not elevated above the floor?
A. Yes.
Q. That is right, is it?
A. Yes, sir.

Re-cross Examination by Mr. Adcock.

Q. You were not present when the soundings were made or the survey was made?
A. No, sir.

Further Re-direct Examination by Mr. Wilkerson.

Q. When you say you were not present, you mean you were not actually on the ground?
A. I was not right there at the level.
Q. Where were you?

A. I was in the office.
Q. These men reporting to you right along?
A. I examined the notes.
Mr. Adcock: After the survey was made.
A. You probably understand how it is done.
Mr. Wilkerson: Describe how it is done so that we will get it into the record.
A. The level being set up, you read the bench mark of which we know the elevation, and then we read on the rod which shows the elevation of the bottom of the rod. If I had been right there at the level I would not have known any more about the accuracy of it than I would have if I had been right there in the office, not taking the notes.
Mr. Adcock: Q. How many men were there engaged in making this survey to determine the elevations,
A. There was the diver, the instrument man and the rod reader.
Mr. Wilkerson: We reserve the right at any future time to have the plans to which Mr. Ripley referred incorporated into the record.
Mr. Adcock: Q. How long ago did you make an examination of the notes of the survey of 1904?
A. I had the plans out some time during the last month.
Q. The last month?
A. Yes.
Mr. Wilkerson: Q. This platform has not been rebuilt since you have been there, has it?
A. No, sir.
Mr. Wilkerson: That is all.
Mr. Adcock: That is all.

TABLE SUBMITTED BY DEFENDANT SHOWING EXPENDITURES ANNUALLY FROM 1890—1912 INCLUSIVE, ETC.

EXPENDITURES BY THE SANITARY DISTRICT OF CHICAGO.
Cost of Works for Sanitation up to Dec. 31, 1912.

1890	$ 67,963.38	
1891	144,870.38	
1892	980,481.45	
1893	3,631,674.03	
1894	5,909,921.93	
1895	6,764,139.03	
1896	5,048,378.02	
1897	3,195,592.00	
1898	1,876,625.30	
1899	3,967,258.40	
1900	2,618,141.25	
1901	1,225,682.07	
1902	2,007,410.62	
1903	2,011,672.37	
1904	1,635,314.50	
1905	2,770,052.56	
1906	1,568,251.23	
1907	1,931,703.70	
1908	1,268,502.27	
1909	2,044,755.68	
1910	2,396,700.65	
1911	830,554.28	
1912	544,418.86	
		$54,441,676.00
Estimated cost in 1913 and 1914, to complete works 10,000 C. F. P. S.		2,249,243.61
Main channel extension and Water Power Act		5,463,702.64
Calumet-Sag Channel		555,061.39
Miscellaneous		22,337.19
Administration other than Sanitation, 1890-1913		796,102.11
Maintenance and operation		1,660,024.61
City of Chicago Contract, Oct. 27, 1910		1,688,053.62
Expended by City of Chicago Intercepting sewers, pumping stations, etc., 1880-1907		7,404,162.74
Fixed Charges		10,521,484.26
Grand total		$84,802,748.17

VOL. 7

United States of America,
Northern District of Illinois,
Eastern Division. } ss.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,019 and Equity No. 114.

INDEX OF EXHIBITS OFFERED IN EVIDENCE BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

Mr. James H. Wilkerson,
United States Attorney, and
Mr. Albert L. Hopkins,
Assistant United States Attorney,
For Complainant.

Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
For Respondent.

1914
The Gunthorp-Warren Printing Company
Chicago

VOL. VII.

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3123	745	Shenehon's Ex. K	Shenehon's Ex. K, April 15, 1914	948	Three Curve Series
3123	747	Shenehon's Ex. L	Shenehon's Ex. L, April 15, 1914	948	Three Curve Series
3123	749	Shenehon's Ex. M	Shenehon's Ex. M, April 15, 1914	948	Three Curve Series
3123	751	Shenehon's Ex. N	Shenehon's Ex. N, April 15, 1914	948	Three Curve Series
3123	745	Comps. Ex. F	Shenehon's Ex. K	948	Three Curve Series
3123	747	Comps. Ex. G	Shenehon's Ex. L	948	Three Curve Series
	749	Comps. Ex. H	Shenehon's Ex. M	948	Three Curve Series
	751	Comps. Ex. I	Shenehon's Ex. N	948	Three Curve Series
	745	Three Curve Series, 1-4	Shenehon's Ex. K, L, M, N	948	
3123	53	U. S. Ex. 3	U. S. Ex. 3	10	
	725	Shenehon's B and C	Shenehon's Ex. B and C	2660	
3124	745	Shenehon's Ex. K, L, M, N	Shenehon's Ex. K, L, M, N	948	
	753	Shenehon's Ex. O, P, Q	Shenehon's Ex. O, P, Q, April 15, 1914	949	One Curve Series
	753	Comps. Ex. J. K, L	Shenehon's Ex. O, P, Q	949	One Curve Series
	753	One Curve Series	Shenehon's Ex. O, P, Q	949	One Curve Series
3125	753	Shenehon's Ex. O, P, Q	Shenehon's Ex. O, P, Q	949	One Curve Series
	759	Shenehon's Ex. R	Shenehon's Ex. R, April 15, 1914	933	Red and blue
	759	Comps. Ex. A	Shenehon's Ex. R	933	Red and blue
3126	759	"The red and the blue"	Shenehon's Ex. R	933	Red and blue
	759	Shenehon's Ex. R	Shenehon's Ex. R	933	Red and blue
3127	761	Shenehon's Ex. S	Shenehon's Ex. S April 15, 1914	1216	

Page of printed record	Page or folio of exhibits	Description used in text o. testimony	Description used in folio of exhibits	Page introduced	Remarks
3127	761	Stearns' Ex. O	Shenehon's Ex. S	1216	
3127	763	Shenehon's Ex. T	Shenehon's Ex. T, April 16, 1914	1207	Table of Consistencies
	763	U. S. Ex. M	Shenehon's Ex. T	1207	Table of Consistencies
	761	Shenehon's Ex. S	Shenehon's Ex. S	1216	
3128	53	U. S. Ex. No. 3	U. S. Ex. No. 3	10	
	763	Shenehon's Ex. T	Shenehon's Ex. T	1207	Table of Consistencies
	765	Shenehon's Ex. U1,	Shenehon's Ex. U1,	882	Three Point Computations
	767	U2, U3, U4, U5	U2, U3, U4, U5, April 16, 1914		
	765-69	Hayford's Ex. 1, 2, 3, 4, 5	Shenehon's Ex. U1 to U5	882	Three Point Computations
3129	765-69	Shenehon's Ex. U1,	Shenehon's Ex. U1	882	Three Point Computations
	49	U5	to U5		
	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	St. Clair Discharge Curve
3130	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	St. Clair Discharge Curve
3137	49-55	Ex. 1, 2, 3, 4	U. S. Ex. 1, 2, 3, 4	7-10	Discharge Curves
	759	Shenehon's Ex. R	Shenehon's Ex. R	933	Red and blue
3140	759	Shenehon's Ex. R	Shenehon's Ex. R	933	Red and blue
3141	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	St. Clair Curve
	725-27	Shenehon's Ex. B-D	Shenehon's Ex. B and D		
3142	733	Shenehon's Ex. E, F, G, H	Shenehon's Ex. E, F, G, H		
	725-27	Ex. B and D	Shenehon's Ex. B and D		
3147	53	Govts. Ex. No. 3	U. S. Ex. No. 3	10	
	763	Shenehon's Ex. T	Shenehon's Ex. T	1207	
3153	745	Shenehon's Ex. K, L, M, N	Shenehon's Ex. K, L, M, N	948	Three Curve Series
3155	589	Groat's paper	Freeman's Ex. 4	1183	Discharge by Sus. Bridge and Whirlpool Gages
3156	733	Shenehon's Ex. E, F, G, H	Shenehon's Ex. E, F, G, H	2806, 3086	
3157	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	St. Clair Curve
3157	759	Shenehon's Ex. R	Shenehon's Ex. R	933	Red and blue
3174	721	Moore's Ex. 5	Moore's Ex. 5	2884	Printed in Record, page 2889
3184	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curve Curve
3184	49-55	"Ex. 1, 2, 3, 4"	U. S. Ex. 1, 2, 3, 4	7-10	

Page of printed record	Page of folio of exhibits	Description used in text of testimony	Description used in folio of exhibits	Page introduced	Remarks
3190	739	Shenehon's Ex. H	Shenehon's Ex. H	2809	Fluctuations Niagara
3191	733	Shenehon's Ex. E, F, G	Shenehon's Ex. E, F, G	2806-3086	Discharge Curves Niagara
3192	733	Shenehon's Ex. E	Shenehon's Ex. E	3086	
3199	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curve
3200	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curve
3215	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3216	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3217	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3221	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3240	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3240	725-29	Shenehon's Ex. B and D	Shenehon's Ex. B and D		
3254	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curves Niagara Curves
3274	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3275	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3325	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	
3326	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	
3327	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	
3329	759	"The red and blue"	Shenehon's Ex. R	933	
3335	49	Ex. No. 1	U. S. Ex. No. 1	7	
3350	771	Shenehon's Ex. V	Shenehon's Ex. V, May 18, 1914	3350	Lake Erie and Chippawa
3351	771	Shenehon's Ex. V	Shenehon's Ex. V	3350	
3354		"This Chart"	Shenehon's Ex. V	3350	
3359	731	Shenehon's Ex. D1	Shenehon's Ex. D1, May 18, 1914	3339	Open Section—Williams' Selections
	729	Shenehon's Ex. D	Shenehon's Ex. D	3087	Open Section—Niagara
3366	771	Shenehon's Ex. V	Shenehon's Ex. V	3350	Erie and Chippawa
3366	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3367	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3368	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3370	53	U. S. Ex. No. 3	U. S. Ex. No. 3	10	

Page of printed record	Page of folio of exhibits	Desciption used in text of testimony	Description used in folio of exhibits	Page introduced	Remarks
3463	792	Wisner's Chart 34-A	Wisner's Ex. 14F, June 16, 1914	3463	
3464	792	Wisner's Ex. 14G	Wisner's Ex. 14F	3463	Chart 34A—Canal Tests
3467	792	"Chart 14C"	Wisner's Ex. 14F	3463	Chart 34A—Canal Tests
3469	792	"Chart 14C"	Wisner's Ex. 14F	3463	Chart 34A—Canal Tests

EXHIBITS ATTACHED TO BILL OF COMPLAINT OF THE UNITED STATES NO. 115, EXHIBITS A TO G INCLUSIVE.

EXHIBIT "A."

"WHEREAS, by Section 10 of an act of Congress approved March 3, 1899, entitled 'An Act making appropriations for the construction, repair and preservation of certain public works, on rivers and harbors, and for other purposes,' it is provided that it shall not be lawful to alter or modify the course, location, condition or capacity of the channel of any navigable water of the United States unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same:

AND WHEREAS, The Sanitary District of Chicago, a municipal corporation, organized under the laws of the State of Illinois, has constructed an artificial channel from Robey street, Chicago, to Lockport, and has been heretofore granted permission by the Secretary of War to make certain improvements in the Chicago river for the purpose of correcting and regulating the cross section of the river so as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles an hour, it being intended to connect the said artificial channel with the west fork of the south branch of Chicago river at Robey street in the said City of Chicago.

AND WHEREAS, The said Sanitary District of Chicago has now applied to the Secretary of War for permission to divert the waters of the said Chicago river and cause them to flow into the said artificial channel at Robey street as aforesaid;

AND WHEREAS, The said Sanitary District of Chicago represents that such movable dams and sluice gates as are necessary to, at all times, secure absolute and complete control of the volume and velocity of flow through the Chicago river have been constructed;

NOW THEREFORE, The Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said Sanitary District of Chicago

to open the channel constructed and cause the water of Chicago river to flow into the same, subject to the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it become apparent that the current created by such drainage works in the south and main branches of Chicago river, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago river and its South Branch.

3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago river.

Witness my hand this 8th day of May, 1899.

R. A. ALGER,
Secretary of War."

(WAR SEAL OFFICE)
JOHN M. WILSON,
Brig. Genl. Chf. of Engrs. U. S. A.

EXHIBIT "B".

"WHEREAS, under date of May 8th, 1899, the Secretary of War granted permission unto The Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of Chicago river to flow into the same, upon the following condition, *inter alia:*

'2—That if, at any time, it becomes apparent that the current created by such drainage works in the south and Main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its south Branch.'

AND WHEREAS, It is alleged by various commercial and

navigation interests that the present discharge from the river into the Drainage Canal sometimes exceeds three hundred thousand (300,000) cubic feet per minute, causing a velocity of nearly three (3) miles per hour, which greatly endangers navigation, in the present condition of the river.

Now, THEREFORE, This is to certify that the Secretary of War, upon the recommendation of the Chief of Engineers, hereby directs said Sanitary District to regulate the discharge from the river into the Drainage Canal so that the maximum flow through the Chicago river and its south branch shall not exceed two hundred thousand (200,000) cubic feet per minute.

WITNESS my hand this ninth day of April, 1901.

ELIHU ROOT,
Secretary of War."

EXHIBIT "C".

"WAR DEPARTMENT,
WASHINGTON,

File No. 2560 of 1900.

July 23, 1901.

SIR:

Referring to War Department order of April 9th last, restricting the flow of water through the Chicago River under War Department permit of May 8, 1899 to 200,000 cubic feet per minute, and replying to your letter of the 15th instant, in which you request, for reasons stated, that the said order be amended to permit a flow of 300,000 cubic feet per minute between the hours of 4 P. M. and twelve o'clock midnight, I beg to inform you that I have this day approved the modification last referred to, which approval will be subject to revocation by the Department in case the increase shall prove to be dangerous to navigation.

Very respectively,

ELIHU ROOT,
Secretary of War.

Mr. Alexander J. Jones,
President, Sanitary District of Chicago,
Chicago, Illinois."

EXHIBIT "D".

"J. A. G. O.
(6353).

WHEREAS, Under date of May 8th, 1899, the Secretary of War granted permission unto the Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, upon the following condition, *inter alia;*

"2.—That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch";

AND WHEREAS, The Secretary of War subsequently directed said Sanitary District of Chicago, to regulate the discharge of water into the Chicago Drainage Canal so that the maximum flow through the Chicago River shall not exceed 200,000 cubic feet per minute from midnight to 4 p. m., nor 300,000 cubic feet per minute from 4 p. m. to midnight;

AND WHEREAS, Said Sanitary District of Chicago has applied to the Secretary of War for permission to increase the flow between midnight and 4 p. m. daily, to 250,000 cubic feet per minute; and the Chief of Engineers has recommended that the increase applied for be granted, but that the rate of flow from 4 p. m. to midnight be reduced to 250,000 cubic feet per minute, so that the flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day.

NOW, THEREFORE, This is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto the said Sanitary District of Chicago permission to regulate said discharge so that the maximum flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day, upon the following conditions:

1.—That this permission shall be in lieu of the present authorized rates of flow as stated above.

2.—That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

3.—That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

WITNESS my hand this 5th day of December, 1901.

W. CARY SANGER,
Assistant Secretary of War."

EXHIBIT "E".

"J. A. G. O.
(6353)

WHEREAS, under date of December 5, 1901, by an instrument supplementary to the original permission granted by the Secretary of War, May 8, 1899, to the Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of the Chicago River to flow into the same, the Secretary of War, pursuant to authority reserved in said permission of May 8, 1899, gave permission to the Sanitary District of Chicago to regulate said discharge so that the maximum flow per minute throughout the twenty-four hours of the day, upon the following conditions, *inter alia:*

"That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require":

AND WHEREAS, The said Sanitary District of Chicago has applied for permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute during the closed season of navigation, in order to carry off the accumulations of sewage deposit which line the shores along the city;

NOW, THEREFORE, This is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto said Sanitary District of Chicago permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute, until the 31st day of March, 1903, after which date it shall be reduced to 250,000 cubic feet per minute, as now authorized, upon the following conditions:

1.—That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

2.—That said Sanitary District of Chicago shall be respon-

sible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

WITNESS my hand this seventeenth day of January, 1903.

W. CARY SANGER,
Assistant Secretary of War."

EXHIBIT "F".

"THE SANITARY DISTRICT
OF CHICAGO.
Chicago, February 5th, 1912.

SIR:—

On behalf of the Board of Trustees of The Sanitary District of Chicago, I have the honor to apply for enlargement of the terms of an instrument executed by The Secretary of War May 8, 1899, as modified by instruments similarly executed on December 5, 1901, and June 30, 1910, respectively, in the following particulars and in view of the facts hereinafter set forth, to wit:

The flow of water from Lake Michigan through the canal of The Sanitary District of Chicago is now limited by the said instruments to 4167 cubic feet per second.

The population of the Sanitary District, the sewage of which is to be disposed of through the channels constructed and to be constructed by the said District, exceeds 2,500,000 persons, and is rapidly increasing. The only method at present available for disposing of the sewage of this population is by diluting the same with water withdrawn from Lake Michigan and flowing through the Chicago Drainage Canal. The least amount of water necessary to render sewage innocuous by the dilution method has been estimated by well recognized sanitary experts as 1,000 feet per second for every 300,000 inhabitants; so that the amount permitted to be withdrawn by the instruments to which reference has been made is much below the amount at present needed by the District.

The Sanitary District has been for some time engaged in investigating methods and devising plans for the treatment of the sewage with a view to requiring less water for its safe dilution in the future. The methods of other states and countries for such treatment of sewage, are not as yet entirely satisfactory to all concerned, and any changes of methods for large cities must necessarily require several years.

Until these experiments are concluded and proper works

installed, the use of additional water from Lake Michigan is essential to the health of the large population of the City of Chicago and of the Sanitary District and of those who live adjacent to the Des Plaines and Illinois rivers into which such waters are discharged.

Subject therefore to such restrictions as you may deem proper for the protection of the public interest, and to such a method of supervision as you may suggest to promote the general welfare, and pending the completion of the investigations now being conducted to render the use of increasing quantities of water in the future necessary; I have the honor to apply for permission for The Sanitary District of Chicago to withdraw from Lake Michigan through the Chicago river and Calumet river—not to exceed ten thousand cubic feet of water per second; such permission to be revocable at any time by The Secretary of War, and subject to such action as the Congress of the United States may see fit to take in the premises.

Respectfully submitted,

GEORGE M. WISNER,
Chief Engineer.

HON. HENRY L. STIMSON,
Secretary of War,
Washington, D. C."

EXHIBIT "G."

In the Matter of the Application of the Trustees of The Sanitary District of Chicago for Permission to Divert from Lake Michigan 10,000 *Cubic Feet of Water Per Second.*

WAR DEPARTMENT.

WASHINGTON, January 8, 1913.

The Sanitary District of Chicago applies to the War Department for permission to increase the amount of water it is authorized to withdraw from Lake Michigan from 4,167 cubic feet per second, the amount now authorized, to 10,000 cubic feet per second.

The Chicago Drainage Canal was opened in January, 1900. It reverses the flow of the Chicago River, which formerly emptied into Lake Michigan, and as a result a portion of the waters of that lake, instead of following their former course

through Lakes Huron, Erie and Ontario into the St. Lawrence, are now carried across the watershed into the Illinois River, and through that to the Mississippi and the Gulf of Mexico. The canal thus serves as a system of drainage for the City of Chicago, carrying the sewage of that city southward to the Mississippi, and thus protects the water supply of that city, which is taken from Lake Michigan.

Permission to divert water from Lake Michigan was first granted by my predecessor, Secretary Alger, on May 8, 1899. He permitted a flowage of 5,000 cubic feet per second, but his permit contained the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it becomes apparent that the current created by such drainage works in the south and main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its south branch.

Subsequently, during the administration of Secretary Root, the amount of the current permitted to be taken was modified or restricted until December 5, 1901, when it was fixed at the amount now permitted, and these permits contained the condition—

that the permission herein given shall be subject to such modifications as in the opinion of the Secretary of War the public interests may from time to time require.

On March 14, 1907, an application made for permission to divert an additional 4,000 cubic feet per second for the purpose of reversing the current of the Calumet River and flowing that river also through the canal to drain the southern portion of Chicago was denied by Secretary Taft in an opinion in which he referred once more to the desirability of submitting "this question of capital and national importance to the Congress of the United States."

It is clear that even under the conditions heretofore manifested on these applications, the proposition to divert the waters of Lake Michigan into another watershed has not been entertained without hesitation and careful restriction by my predecessors. The propriety of obtaining congressional sanction for the project has been pointed out from the beginning; and the form in which the permit has been granted, even for the moderate amount of diversion permitted, has been so phrased as to indicate that the permission was predicated upon the absence of any substantial injury to commerce.

The sanitary canal has never received the direct sanction of Congress. It was built solely under the authority of the State of Illinois, as given in its 1889 general act for creating sanitary districts. And although pursuant to the suggestion of my predecessors the question of the propriety of its diversion of water from Lake Michigan was presented urgently in the reports of the Chief of Engineers for the years 1899 and 1900 as transmitted to Congress, no action upon the question has ever been taken by that body. In the argument before me it was urged that the present canal represented the growth and development of a national policy expressed in two acts of Congress, 1822 and 1827, which authorized the construction of a canal "to connect the Illinois River with Lake Michigan," thus connecting the two watersheds. (Acts of Mar. 30, 1822, and Mar. 2, 1827.) But these statutes authorized a canal for the purpose of navigation and not sanitation. (*Missouri* v. *Illinois,* 200 U. S., 526.) The Illinois and Michigan Canal, actually constructed under their authority, derived its water for navigation purposes from the Calumet, Des Plaines, and Chicago Rivers, and not from the Lakes. And although in the latter part of its existence it was used to a very slight extent to help purify the waters of the Chicago River and thus sanitate the City of Chicago, such a purpose could not have been dreamed of at the time its construction was authorized by Congress, 90 years ago. I can not see that its authorization and construction offer the slightest congressional sanction for the great canal now under discussion, which was not even contemplated until much more than half a century later. Even at the time when the present canal was constructed and opened it is very evident that its ultimate possible effect upon the navigation of the Great Lakes was not clearly realized by those interested in that navigation. The evidence before me indicates that the withdrawal of water from Lake Michigan at Chicago would require about five years to produce its full effect upon the levels of the Great Lakes (see report of International Waterways Commission on Chicago Drainage Canal, p. 7) and that this effect would be still further obscured by periodic oscillations in the lake levels. These facts may easily explain any inaction on the part of the Nation and their representatives to this withdrawal of water and make it clear that any argument of implied acquiescence must be scrutinized with unusual care.

In this respect the situation is now very different. The present application was opposed by representatives of 23

cities and 6 States interested in harbors and commerce upon the Great Lakes, notably the Cities of Duluth, Milwaukee, Toledo, Cleveland and Buffalo. It was opposed by representatives of the navigation interests engaged on the Chicago River as well as on the Great Lakes; and by the official representatives of the Canadian Government as well as private Canadian interests engaged in the navigation of the Lakes and the St. Lawrence River, including representatives of the Cities of Kingston and Montreal.

A very careful consideration of the voluminous evidence and statements submitted, as well as a consideration of the reports of other commissions and boards of engineers who have investigated the subject, leaves no doubt in my mind that the withdrawal of 10,000 cubic feet per second would substantially interfere with the navigable capacity of the Great Lakes and their connecting rivers. The Chief of Engineers, whose statutory authority in passing upon this application is concurrent with and independent of my own, and whose opinion upon such a question of scientific conclusion must be given especially weight, so states in his recommendation. His conclusions are corroborated by the authority of other boards of investigation, notably the report of the International Waterways Commission of January 4, 1907.

Careful observations and calculations conducted under the offices of the United States Lake Survey and reported through the Chief of Engineers, covering observations for the last 46 years, indicate that a withdrawal of 10,000 cubic feet per second would reduce levels at various places as follows:

	Inches.
Lakes Huron and Michigan	6.9
Lake St. Clair	6.3
Lake Erie	5.4
Lake Ontario	4.5
St. Lawrence River and Rapide Plat	4.8 plus.

The foregoing effects would be produced at mean lake levels; the lowering effects would be much greater at low-water periods—the precise time when any additional shortage would be most keenly felt. This reduction would create substantial injury in all of the American harbors of the Great Lakes and in the St. Marys, St. Clair and Detroit Rivers. It would produce equal injury in Canadian harbors on the Great Lakes, and a still greater injury on the lower St. Lawrence, the

Canadian officials claiming a probable lowering effect of 12 inches at Montreal at low water.

The United States has improved about 106 harbors and rivers on the Great Lakes affected by this diversion and has spent on such improvement over ninety millions of dollars. The Canadian Government has improved over 50 harbors on Georgian Bay and Lakes Huron, St. Clair, Erie and Ontario. By treaty, American vessels are accorded equal rights of navigation with Canadian vessels in all these waters, including the St. Lawrence River. The reduction of the water in these harbors and channels would diminish to just that extent the amounts of these improvements, and would nullify to just that extent the effects of the moneys which have been appropriated for that purpose by the respective Governments. Connecting various portions of these waterways are the two canals at the Sault Ste. Marie, the Welland Canal, and a number of canals on the St. Lawrence River. The available depth of water over one or all sills of each of these canals would be affected, and in some cases reconstruction might even be made necessary.

The enormous lake traffic which uses these harbors and these rivers is increasing with great rapidity, both in gross volume and in the size and average draft of the vessels employed therein. The Chief of Engineers reports that to lower the water surface 6 inches would reduce the permissible load of one of the large modern vessels by from 300 to 550 tons, with a consequent loss of from $3,600 to $7,500 in freights for such vessel per season. The International Waterways Commission reported that it would be a conservative estimate which would make the loss to the navigation interests resulting from a reduction of 6 inches in the depth of water as $1,500,000 per annum, or a sum which, capitalized at 4 per cent., would amount to a loss of $37,500,000 (see third progress report of International Waterways Commission of Dec. 1, 1907, p. 24). The lowest careful estimate of injury to American vessels alone is reported by the Chief of Engineers at $1,000,000 per year.

The argument was made before me that, owing to the well-known fact that the levels of the lake vary, owing to winds and change of barometric pressure, by amounts even greater than the reduction which would be caused by this canal, therefore the proposed reduction is of no consequence. This argument is well disposed of in the report of the International

Waterways Commission of January 4, 1907, on page 8, as follows:

It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they cannot see it they will not know it and will not feel it. The argument is fallacious. It is true that they cannot see it immediately, but they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works.

In a word, every drop of water taken out of Chicago necessarily tends to nullify costly improvements made under direct authority of Congress throughout the Great Lakes, and a withdrawal of the amount now applied for would nullify such expenditures to the amount of many millions of dollars, as well as inflict an even greater loss upon the navigation interests using such waters.

On the other hand, the demand for the diversion of this water at Chicago is based solely upon the needs of that city for sanitation. There is involved in this case no issue of conflicting claims of navigation. The Chief of Engineers reports that so far as the interests of navigation alone are concerned, even if we should evenually construct a deep waterway from the Great Lakes to the Mississippi over the route of the sanitary canal, the maximum amount of water to be diverted from Lake Michigan need actually be not over 1,000 feet per second, or less than a quarter of the amount already being used for sanitary purposes in the canal. This estimate is confirmed by the report of the special board of engineers on the deep waterway from Lockport, Ill., to the mouth of the Illinois River, dated January 23, 1911. It is also confirmed by the practical experience of the great Manchester Ship Canal in England. From the standpoint of navigation alone in such a waterway too great a diversion of water would be a distinct injury rather than a benefit. It would increase the velocity of the current and increase the danger of overflow and damage to adjacent lands.

We have, therefore, presented in this case claims of entirely different characters and jurisdictions—the claim of sanitation on the one side and of navigation on the other; the vital interest of a single community on the one side and the broad interest of the commerce of the nation on the other. The discretion given to the Secretary of War under sections

9 and 10 of the act of 1899 is very broad, but I have very grave doubts as to whether it was intended to authorize him to grant a permit which would inflict a substantial injury upon commerce in order to benefit sanitation. The entire purpose and scope of that legislation was to make him the guardian of the commercial interests of the nation represented in their waterways. And while he sometimes under that statute must decide that the interests of one class of transportation are less important and must yield to the conflicting interests of another class, I have considerable doubt whether it was intended to give him authority to sacrifice substantial interests of navigation to entirely different claims over which he normally has no jurisdiction whatever.

But however that may be, and without resting my decision upon the question of my legal authority, I am quite clear as a matter of discretion that under the facts presented by this case no further diversion of water should be permitted at Chicago without the direct sanction of the Congress of the United States. I do not for one moment minimize the importance of preserving the health of the great City of Chicago; but when a method of doing this is proposed which will materially injure a most important class of the commerce of the nation and which will also seriously affect the interests of a foreign power, it should not be done without the deliberate consideration and authority of the representatives of the entire nation. The growth of Chicago is phenomenal and its representatives are quite unwilling to put any final limit to the demand which may be made upon the waters of Lake Michigan for its sanitation under the system now in use. I have before me the report of 1911 of the president of the sanitary district in which he says:

> I am of the opinion that the presumption that our water supply is to be limited to 10,000 cubic feet per second, or 600,000 cubic feet per minute, is gratuitous and mischievous and should not be voiced by the officials of this district. I believe that we should have the volume requisite to our needs as they appear and are justified.

It is therefore quite conceivable that compliance with their sanitary needs according to this method of sanitation may eventually materially change this great natural watercourse now existing through the Lakes. The weighing of the sanitation and possibly the health of one locality over against the commerce of the rest of the Nation and the consideration of our relations and obligations to Canada in respect to a great international waterway are not matters of mere technical or scientific deduction. They are broad questions of national

policy. They are quite different in character, for example, from the question of fixing the proper location of a pierhead line or the height or width of a drawbridge over a navigable stream—fair samples of the class of questions which come to the Secretary of War for decision under the above mentioned act of 1899. While the researches and opinions of experts in the respective fields are necessary and useful as an assistance toward reaching a fair and proper policy, the final determination of that policy should belong not to an administrative officer but rather to those bodies to whom we are accustomed to entrust the making of our laws and treaties.

In my view of the proper exercise of my discretion in this matter the foregoing considerations are sufficient for a decision of this case. Having reached the conclusion that the proposed diversion of the waters of Lake Michigan would substantially injure the interests of navigation on the Great Lakes which it is my legal duty to protect, it would clearly follow that the present application should be denied.

I have carefully examined, however, the evidence which both sides have introduced bearing upon the sanitary needs of the City of Chicago, and my conclusion is in no way shaken. I am not persuaded that the amount of water applied for is necessary to a proper sanitation of the City of Chicago. The evidence indicates that at bottom the issue comes down to the question of cost. Other adequate systems of sewage disposal are possible and are in use throughout the world. The problem that confronts Chicago is not different in kind but simply larger and more pressing than that which confronts all of the other cities on the Great Lakes, in which nearly 3,000,000 people of this country are living. The urban population of those cities, like that of Chicago, is rapidly increasing, and a method of disposition of their sewage which will not injure the potable character of the water of the Lakes must sooner or later be found for them all. The evidence before me satisfies me that it would be possible in one of several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition. A recent report of the engineer of the sanitary commission (Oct. 12, 1911) proposes eventually to use some such method, but proposes to postpone its installation for a number of years to come, relying upon the present more wasteful method in the meanwhile. It is manifest that so long as the city is permitted to increase the amount of water which it may take from

the Lakes, there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage. This is particularly true in view of the fact that by so doing it may still further diminish its expenses by utilizing the water diverted from the Lakes for water power at Lockport. But it must be remembered that for every unit of horsepower realized by this water at Lockport four units of similar horsepower would be produced at Niagara, where the natural conditions are so much more favorable. Without, therefore, going more into detail in a discussion of this question, I feel clear that no such case of necessity has been presented by the evidence before me as would justify the proposed injury to the many varied interests in the great waterways of our lakes and their appurtenant rivers.

It remains only to consider certain special arguments that have been pressed upon me. It has been urged that the levels of the lakes, even if lowered, could be restored by compensating works. To a certain extent that is true. But the very nature of this consideration offers another illustration of the importance of having the whole question passed upon by Congress. Such compensating works can only be constructed by the authority of Congress and at very considerable cost. It is not a matter which is in the hands of the Secretary of War. Permission to divert water which will at one and the same time nullify the effect of past appropriations and make necessary similar expenditures in the future, should be granted only with the express consent of the body in whose hands the making of such appropriations and the authorization of such works rest.

Furthermore, in most cases such compensating works could only be constructed with the joint consent of our neighbor Canada. The United States Government alone would be unable, even if it were willing to spend its own funds, to compensate for the damage done through the lowering of these levels, unless Canada were willing to join in constructing the portion of such works which would necessarily stand upon Canadian soil.

The question therefore becomes not merely national but international, and this leads me to the consideration of the arguments which were urged by both sides in reference to the treaty with Great Britain in respect to Canada of January 11, 1909. A careful consideration of that treaty fails to indicate to me that it is in any way controlling upon the

questions now before me. It gives to the citizens of both countries certain mutual rights of navigation in the waters of the Great Lakes and their connecting rivers; but beyond that the question of the right to this diversion at Chicago seems to me to have been carefully excluded. The applicants for the permit have urged upon me that article 8 of the treaty gives a preference to the uses of water of the lakes for domestic and sanitary purposes over the uses of such water for navigation. Article 8, however, applies only to future cases brought before the International Joint Commission; and furthermore I am clearly of the opinion that the domestic and sanitary purposes referred to in that article were intended to be the "ordinary" uses of such waters for domestic and sanitary purposes referred to in article 3. It would be quite contrary to our own national policy to give such a preference to an extraordinary sanitary use of such a character as to create a substantial injury to navigation. The matter has been before our own Supreme Court in the case *of the United States* v. *the Rio Grande Dam & Irrigation Co.* (174 U. S., 690). In that case the Supreme Court held that a company which proposed to take the water of the Rio Grande river for the purpose, among others, "of supplying water to cities and towns for domestic and municipal purposes" could be prevented from so doing when the result would be a substantial injury to the navigability of the Rio Grande river farther down. In its opinion the court said:

> The question always is one of fact, whether such appropriation substantially interferes with the navigable capacity within the limits where navigation is a recognized fact. In the course of the argument, this suggestion was made, and it seems to us not unworthy of note, as illustrating this thought. The Hudson river runs within the limits of the State of New York. It is a navigable stream and a part of the navigable waters of the United States, so far at least as from Albany southward. One of the streams which flows into it and contributes to the volume of its waters is the Croton river, a non-navigable stream. Its waters are taken by the State of New York for domestic uses in the City of New York. Unquestionably the State of New York has a right to appropriate its waters, and the United States may not question such appropriation, unless thereby the navigability of the Hudson be disturbed. On the other hand, if the State of New York should, even at a place above the limits of navigability, by appropriation for any domestic purposes, diminish the volume of waters, which, flowing into the Hudson, make it a navigable stream, to such an extent as to destroy its navigability, undoubtedly the jurisdiction of the National Government would arise and its power to restrain such appropriation be unquestioned; and within the purview of this section (act of Sept. 19, 1890, ch. 907) it would become the right of the Attorney General to institute proceedings to restrain such appropriation.

The treaty, however, contains provisions in its article 10 by which "any questions or matters of difference arising between the high contracting parties involving the rights, obli-

gations, or interests of the United States or of the Dominion of Canada, either in relation to each other or to their respective inhabitants, may be referred for decision" to an international joint commission established by the said treaty. The hearing before me brought forth the fact that the Government of Canada regards the proposal contained in this application as one which effects the material interests of that country. The establishment by formal treaty between the two countries of a tribunal with jurisdiction to decide just such questions seems to me to afford an additional reason against the assumption of jurisdiction to decide the question by an administrative officer of one of those countries.

In short, after a careful consideration of all the facts presented, I have reached the following conclusions:

First. That the diversion of 10,000 cubic feet per second from Lake Michigan, as applied for in this petition, would substantially interfere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.

Second. That that being so, it would not be appropriate for me, without express congressional sanction, to permit such a diversion, however clearly demanded by the local interests of the sanitation of Chicago.

Third. That on the facts here presented no such case of local permanent necessity is made evident.

Fourth. That the provisions of the Canadian treaty for a settlement by joint commission of "questions or matters of difference" between the United States and Canada offer a further reason why no administrative officer should authorize a further diversion of water, manifestly so injurious to Canada, against Canadian protest.

The prayer of the petition is therefore denied.

HENRY L. STIMSON,
Secretary of War.

EXHIBITS ATTACHED TO THE ANSWER OF THE SANITARY DISTRICT OF CHICAGO.

EXHIBITS A TO M INCLUSIVE.

(Exhibit A is a copy of Act of May 29, 1889, creating the Sanitary District and amendments thereto.)

Exhibits Attached to Answer.

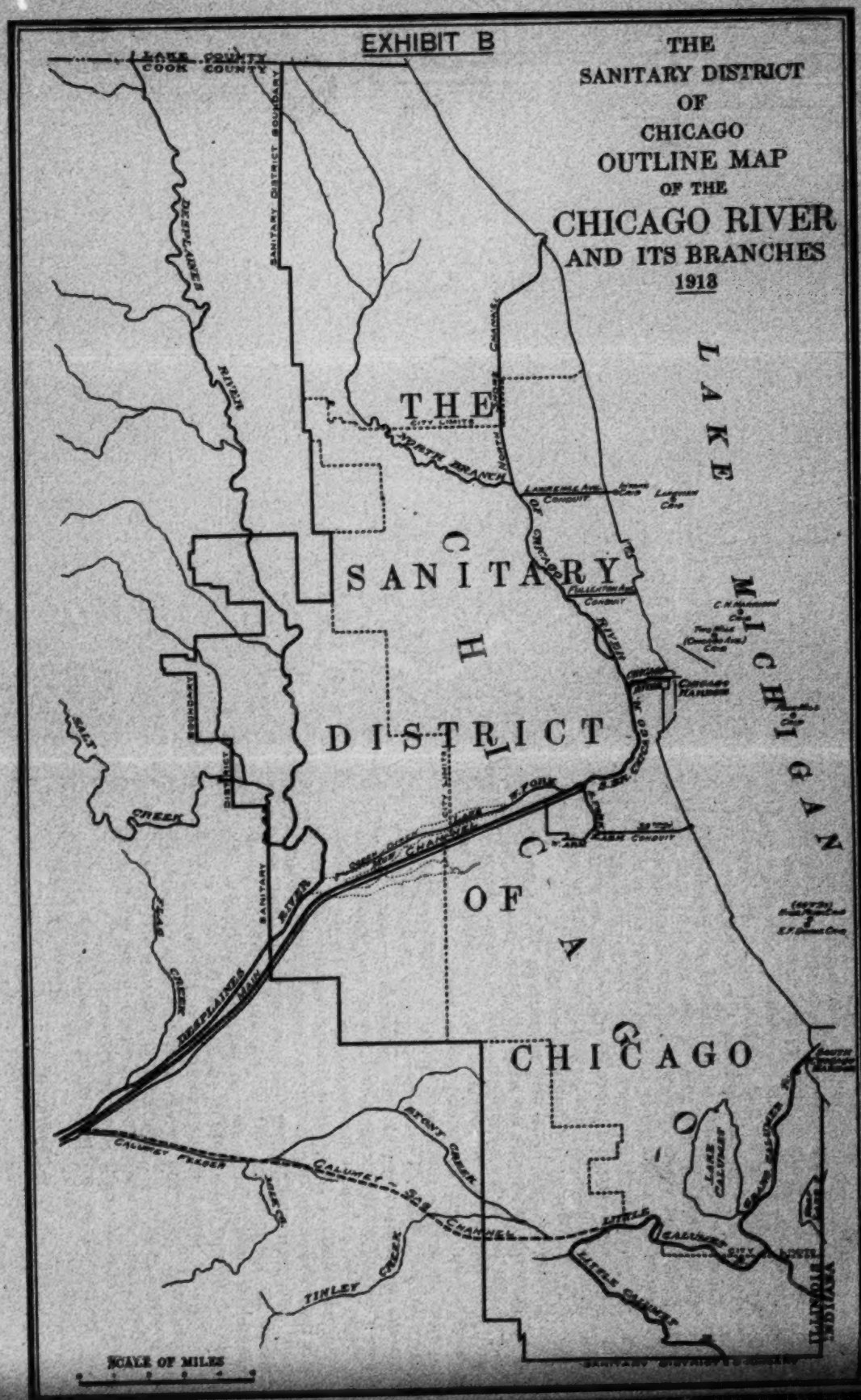


EXHIBIT "C"

War Department
Washington,

March 14, 1907.

In the matter of the application of the Sanitary District of Chicago to reverse the flow of the Calumet River.

This application is made under Section 10 of the act of March 3, 1899 (30 Stat. L., 1151), which provides as follows:

> "Sec. 10. That the creation of any obstruction, not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead haven, harbor, canal, lake, harbor of refuge. or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same."

The application of the Sanitary District is for leave to reverse the flow in the Calumet River in such a way as to make the water to flow out of the lake instead of to flow into it and to discharge the water from the Calumet River into the Drainage Canal. The Chief of Engineers was at first of opinion that such a change in the flow of the river, it was not within the power of the Chief of Engineers to recommend, or within the power of the Secretary of War to permit. This expression of opinion as to the construction of the statute was submitted to the Judge Advocate General, who holds that Section 10, as quoted above, applies to this case and that it is one in which work could be allowed under the recommendation of the Chief of Engineers and the permission of the Secretary of War. Upon the construction of the Judge Advocate General I requested the Chief of Engineers to make his recommendation, which he has done as follows:

February 23, 1907.

1. Respectfully returned to the Secretary of War.

2. The subject of the abstraction of water from Lake Michigan has been elaborately investigated by the Lake Survey Office at Detroit, and the results are published in the annual reports of the Chief of Engineers for the years 1900, 1902 and 1904. The international Waterways Commission has also given it careful consideration, and its conclusions are set forth in report of January 4, 1907, printed as War Department Document No. 293.

3. In my opinion, this abstraction will undoubtedly lower the levels of all the waters of the Great Lakes, except those of Lake Superior, and thus diminish the navigable capacity and depth of the various channels and harbors which have been deepened and improved under authority of Congress.

4. Leaving out Lake Superior, there are more than 100 works of river and harbor improvements on the Great Lakes and their connecting waters, for which appropriations aggregating more than $80,000,000 have been made. The application of this vast sum has resulted in securing and maintaining specified depths and widths of channel, which Congress has decided to be required for the accommodation of the traffic using those waters.

5. To diminish these depths, even to a slight extent, would not only prove a serious injury to the traffic, but would practically undo the work which has been accomplished by Congressional direction, and necessitate the expenditure of further large sums of money for restoration. Any project that tends, in a measure, to annul or reverse the orders of Congress, as expressed in the various river and harbor acts appropriating funds for improving the harbors and channels connecting with the Great Lakes, should meet the disfavor of the Department, unless it has been sanctioned by that body. In my judgment, such a project is the one under consideration, and for this reason I am unwilling to recommend favorable action thereon, assuming that the Department is empowered to take such action, as is held by the Judge Advocate General.

A. MACKENZIE,
Brig. Gen., Chief of Engineers, U. S. Army."

It is quite evident from the reading of the statute that Congress intended in this statute, as in many others, to give the

Chief of Engineers authority, independent of the Secretary of War, in reaching a conclusion as to the wisdom and propriety of granting a permit under the section, and that unless the Chief of Engineers shall recommend the granting of the permit, the Secretary of War is without power to give the requested authority. It follows, therefore, that the application must be denied whatever my view of the case.

The decision of the Chief of Engineers and its final character has made it unnecessary for me to consider the merits of the question, but I may say this much, that the application for a change in the Calumet River is to be made the basis for the withdrawal of a large amount of water from Lake Michigan and that all interested in the enormous lake traffic view the settlement of the question with grave apprehension. Added to this, is the international complication which is likely to arise in the threatened lowering of the lake level in the ports and harbors and canals of Canada. On the other hand, it is maintained with great emphasis and elaboration of detail that the change in the Calumet River, is essential to the healthful sanitation of Chicago, and that the threatened injury to navigation is so small as to be negligible.

Between two such great interests, the decision must be affected more or less by large public policy and expediency, and while I agree in the construction of the Judge Advocate General that the issue is left by statutes to the recommendation of the Chief of Engineers and the concurrent decision of the Secretary of War, it may be fortunate that circumstances now require submission of this question of capital and national importance to the Congress of the United States.

WM. H. TAFT,
Secretary of War.

(Reprinted from proceedings of Board of Trustees, March 27, 1907, pages 211-12.)

EXHIBIT "D."

"WAR DEPARTMENT
WASHINGTON, September 11, 1907.

SIR:

Referring to your letter of 2nd instant, in which you request approval of proposed drainage channel to connect Lake Michigan at Wilmette, Ill., with the North Branch of the Chicago River; also permission to construct a pile crib in Lake Michigan at mouth of same, and to deposit filling within the limits of such crib, I beg to inform you that the War Department will interpose no objection to the project as set forth in your letter and indicated on drawing submitted, provided the following conditions are complied with:

1. That the pier constructions, the filling behind the same, and the excavation of the proposed channel shall be done subject to the supervision and approval of the local officer of the Corps of Engineers, U. S. Army, at Chicago, so far as to see that the work authorized is not exceeded;

2. That the total diversion of water from Lake Michigan through the Chicago River into the Illinois River shall be no greater than already authorized by past War department permits;

3. That the work shall be commenced before December 31, 1908, and completed within five years thereafter.

Very respectfully,

ROBERT SHAW OLIVER,
Acting Secretary of War

G. M. Wisner, Esq.,
Chief Engineer, The
Sanitary District of Chicago
American Trust Building,
Chicago, Illinois."

EXHIBIT E.

Permit

WAR DEPARTMENT, WASHINGTON,
June 30, 1910.

SIR:

Referring to your application of the 27th instant on behalf of the Board of Trustees of The Sanitary District of Chicago to open a channel from the Calumet River to its existing Main Channel so as to substitute two routes instead of one between Lake Michigan and its canal, I have the honor to advise you to the following effect:

It appears from the records of the Department that by an instrument executed May 8, 1899, The Sanitary District of Chicago was given permission to connect its Drainage Canal with the South Branch of the Chicago River at Robey Street, in the City of Chicago, and to divert the waters of Lake Michigan through the Chicago River into said canal, subject to certain specified conditions designed to limit the amount of such diversion and in other ways to protect the public interest. The permission so granted was subsequently modified at various times, and by an instrument executed December 5, 1901, the amount of flow was fixed at not exceeding 250,000 cubic feet per minute, equivalent to 4,167 cubic feet per second, which is the present rate allowed. At the time the original permit was given a connection with the Calumet River was not mentioned but if it had been it is probable that a connection with that river as well as with the Chicago River would have been allowed.

So long as the water-flow remains unchanged there seems to be no special objections to its extension to both rivers instead of confining it to a single one, especially since if the new (Calumet) route be developed later to a navigable state the double route will be advantageous to navigation interests. Accordingly, in view of the favorable recommendation of the Chief of Engineers and of the consent thereto by the Attorney General, under the condition hereinafter prescribed, the Department hereby modifies the existing permission so as to allow the division of the already permitted water-flow in such manner as to reach the Sanitary District Canal by way of the Calumet River and a connecting channel, as well as by way of its present route through the Chicago River, subject to all pertinent conditions of the existing permissions and to other express conditions, as follows:

(a) That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of The Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

(b) That if at any time it become apparent that the current created by such drainage work in the Calumet, as well as Chicago rivers, be unreasonably obstructive to navigation, or injurious to property, the Secretary of War reserves the right to close the discharge through said channel or rivers, or to modify it to such an extent as may be demanded by navigation and property interests along said rivers.

(c) That The Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in the Calumet as well as Chicago river.

(d) That the amount of water withdrawn from Lake Michigan, through the Chicago and Calumet rivers together, shall not exceed the total amount of 250,000 cubic feet per minute (4,167 cubic feet per second) already authorized to be withdrawn through the Chicago River alone.

(e) That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

(f) That this permission shall in nowise affect or in any manner be used in the friendly suit now pending in the Circuit Court of the United States for the Northern District of Illinois brought by the United States of America against the Sanitary District of Chicago, to determine the right of the said Sanitary District to divert from Lake Michigan for sanitary purposes an amount of water in excess of that now being diverted, without having first obtained a permit from the Secretary of War.

(g) That the War Department shall have free access at all times to the waterflow records of The Sanitary District of Chicago and free access also to the regulating works and all other parts of its canals for the purpose of checking records or making water-flow measurements.

(h) That the plans for the proposed work shall be submitted to and approved by the Chief of Engineers and the Secretary of War.

(i) That the work shall be subject to the supervision and

approval of the Engineers Officer of the United States Army in charge of the locality.

Very respectfully,

ROBERT SHAW OLIVER,
Acting Secretary of War.

Mr. George M. Wisner,
Chief Engineer, Sanitary District of Chicago, Chicago, Ill.
(Reprinted from the proceedings of the Board of Trustees, November 2, 1911, pages 1323-25.)

EXHIBIT "F."

MEMORIAL TO CONGRESS ON THE SUBJECT OF THE ILLINOIS AND MICHIGAN CANAL.

(Laws Extra Session, 1826, p. 97.)

To the Honorable the Senate and House of Representatives of the United States of America in Congress assembled: The memorial of the General Assembly of the State of Illinois respectfully represents that the construction of a canal uniting the waters of Lake Michigan with the Illinois river, will form an important addition to the connecting links in the chain of internal navigation, which will effectually secure the indissoluble union of the confederate members of this great and powerful Republic. By the completion of this great and valuable work, the connection between the north and the south, the east and the west, would be strengthened by the ties of commercial intercourse and social neighborhood, and the union of the states might bid defiance to internal commotion, sectional jealousy and foreign invasion. All the states of the Union would then feel the most powerful motives to resist every attempt at dissolution. To effect so great and desirable an object, your memorialists believe to be of sufficient importance to engage the attention and awaken the munificient patronage of a government whose principle of action is the promotion of the general welfare. Your memorialists are sensibly alive to the spirit of improvement that manifests itself in almost every section of our extensive country, and would fain lend a helping hand in so great and good a cause; their situation, however, forbids their doing much, without the aid of the federal government; into whose treasury almost all the funds whether brought hither by emigrants or earned by the industry of their citizens, are

paid for the purchase of the public lands. While this state of things shall continue and the money thus paid into the treasury of the Union is taken out of our State, our people will not be able to engage in the glorious work of improving our common country. Ought the people of this State to stand by with folded arms and behold the great work of internal improvement progress in other states without making an effort to improve their own conditions, and at the same time advance the interest of our beloved country? A condition thus paralyzed, is at war, not only with our interests, but with the best feelings of our hearts. Did this State possess the public domain lying within its bounds, as in the case with the older members of this confederacy, your memorialists would not appear before your honorable body to solicit aid in this important work. If, as your memorialists believe, the construction of this canal would be highly beneficial to the Union at large; if the receipts into the treasury of the United States would be augmented by the increased sales of public lands; and if the interest of this State would be also advanced thereby; is it unreasonable to apply to a paternal government for assistance in the promotion of such beneficial ends? It is unnecessary for your memorialists to enlarge on the great advantages of this canal to the Union, in the facilities to be afforded in the event of a war with either the Indian tribes inhabiting our frontier, or the British nation. Your honorable body is aware that this State is situated on the borders of an Indian country, filled with numerous and powerful tribes of the sons of the forest. If our country should be again engaged in war, the saving of expense in the transportation of munitions of war, would alone defray the expense of the contemplated canal, and justify the United States in making a liberal appropriation for its construction. Your memorialists do not, however, ask your honorable body to appropriate money out of the treasury to aid them in this work; they only ask for a tract of land, through which the contemplated canal may pass, and which, for a series of years, will be wholly unproductive to the government unless the canal shall be commenced under auspices favorable to its completion; in which event all the land in the vicinity would immediately become available to the United States. Your memorialists sincerely believe that a liberal appropriation of land for this object, would, even in a pecuniary point of view be of immense importance to the treasury of the Union. The public lands in the vicinity would not only sell, but at a considerable advance upon the minimum price. Should this

opinion be correct (and does not experience justify it?) the United States would be gainers by the proposed donation to the State. Your memorialists further state that at their last session, they passed an act of incorporation, upon very liberal terms, authorizing a company to construct the projected canal; but the remoteness of the country from the residence of capitalists, has prevented them from engaging in the work. At their present session, your memorialists have repealed the charter; and their only hope of soon beginning the work depends upon the liberality of your honorable body. Your memorialists have caused the route to be explored and estimates to be made of the probable expense of the work; from which it appears that the cost of constructing the canal will not be less than $600,000 and may possibly amount to $700,000. To the end, therefore, that your memorialists may be enabled to commence and complete this great and useful work, we pray your honorable body to grant to this State the respective townships of land through which the contemplated canal may pass; the avails of which, to be appropriated exclusively, to the construction of said canal, upon such terms and conditions as to your honorable body may seem proper.

EXHIBIT "G."

"An Ordinance for Cleansing the Chicago River and Appropriating the Proceeds of Two Hundred and Fifty Bonds Therefor.

SECTION 1. Be it ordained by the Common Council of the City of Chicago (June 5, 1865), That the plan of the board of public works for cleansing the Chicago River and its branches by cutting down the summit of the Illinois and Michigan Canal below the level of Lake Michigan so as to draw from it at a low stage of water in the lake not less than twenty-four thousand (24,000) cubic feet of water per minute, is hereby approved, and said board are hereby authorized to execute said work.

SECTION 2. That the board of public works are hereby authorized and empowered for the purpose of prosecuting the work described in the previous section, to make any contract necessary to carry into effect such purpose with the trustees of the Illinois and Michigan Canal, in conformity with and subject to the general provisions of the city charter.

SECTION 3. That as a temporary expedient for cleansing the South Branch of the Chicago River, the said board are hereby authorized and empowered to contract with the said trustees for the pumping from the river

into the canal, by the hydraulic works at Bridgeport, and discharging through the canal of such amount of water as shall be found necessary and practicable for such purpose.

SECTION 4. That for the purpose of carrying out the improvement specified in the foregoing sections, the board of public works be and they are hereby authorized to issue 250 bonds of the denomination of $1,000 each, to be dated July 1, 1865, and payable in New York, twenty-five years after the date thereof, with coupons for interest, at the rate of seven per centum per annum, payable semi-annually in New York; the said bonds to be issued in conformity with the provisions of an act of the General Assembly of the State of Illinois, approved February 15, 1865, and entitled 'An act to amend an act entitled an act to reduce the charter of the City of Chicago, and the several acts amendatory thereof, into one act, and to revise the same,' approved February 13, 1863."

EXHIBIT H.

APPLICATION OF THE SANITARY DISTRICT FOR THE IMPROVEMENT OF THE CHICAGO RIVER.

CHICAGO, June 16, 1896.

To the Honorable Daniel S. Lamont,
Secretary of War,
Washington, D. C.

DEAR SIR:

The work of The Sanitary District of Chicago has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport in Will County, twenty-eight miles distant.

Our connection with Lake Michigan must be through the Chicago river with the West Fork of the South Branch of which we make a junction at Robey Street. We send herewith a map showing in a general way our plans for improving the Chicago River by widening and deepening at the points indicated thereon by red hatchings and by figures which refer to explanation, given in the legend on the map. It is desired to so correct and regularize the cross section of the

river as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles per hour. The cross section necessary to accomplish this can be obtained throughout the greater part of the distance between Monroe Street and Robey Street, by dredging the river to a depth of 20 ft. at mid stream, with 12 ft. at dock lines and a uniform slope away from docks of one foot in five, so that the full depth would be reached forty feet from the dock lines; but there are places so narrow that this cross section can only be obtained by widening the river; and again the depth to be obtained in the vicinity of Van Buren Street is limited by the height of the crown of the tunnel. To obviate this difficulty it is purposed to secure the requisite cross section by constructing a by-pass to the west of the bridges at Adams, Jackson and Van Buren Streets, as indicated. We ask your permission to proceed with the work upon the lines indicated and so far as is consistent with propriety the co-operation of the United States Engineering Department.

Awaiting your favorable reply, and holding ourselves ready to respond to any call from you for fuller information as to our plans, I am

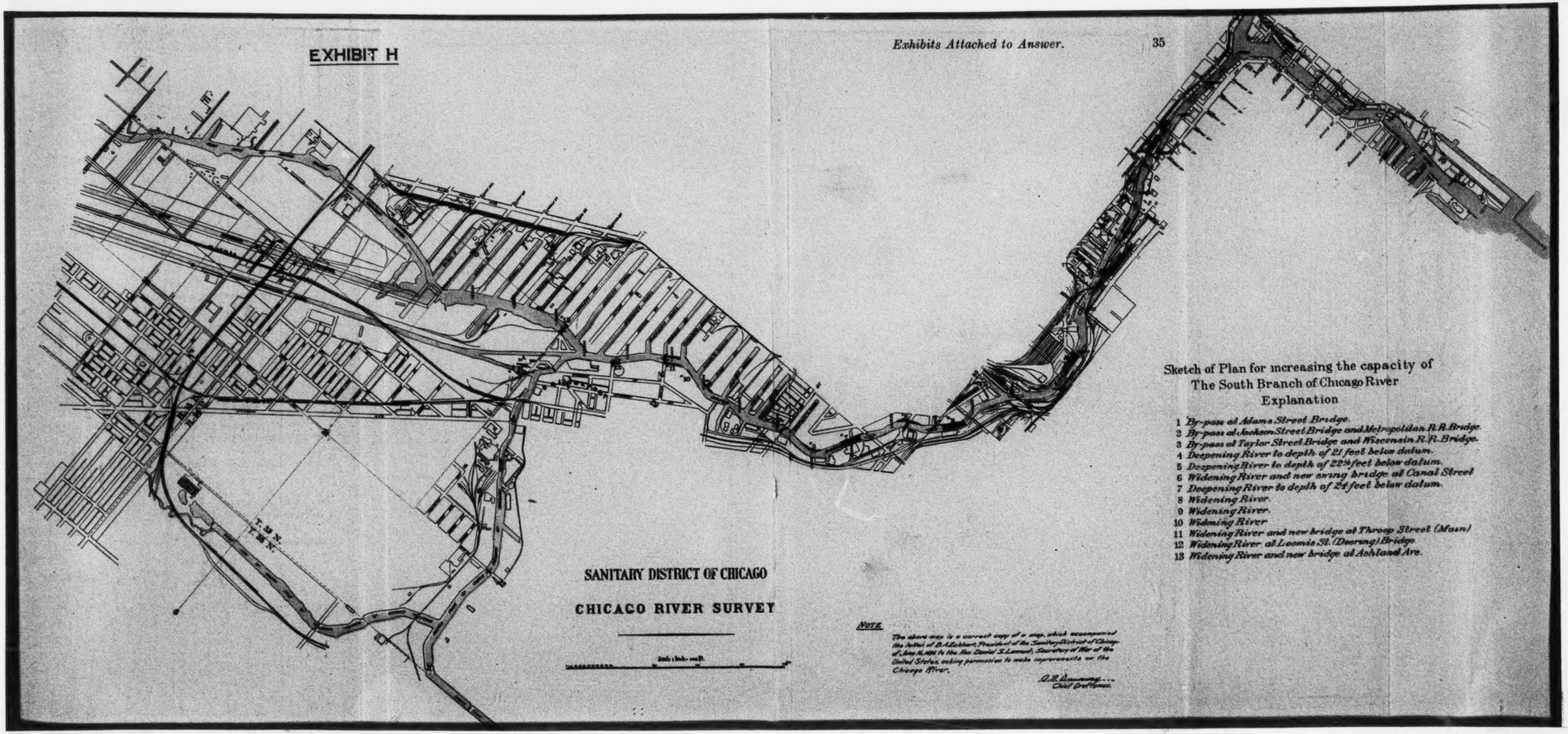
Yours respectfully,

(Signed) B. A. ECKHART,

President.

A copy of the above letter is found at Page 297 of the Clerk's Copy Letter Book "C," being letter book from September 20, 1895, to January 11, 1907.

EXHIBIT H



SANITARY DISTRICT OF CHICAGO

CHICAGO RIVER SURVEY

Scale 1 Inch = 200 Ft.

NOTE.

The above map is a correct copy of a map which accompanied the letter of B. A. Eckhart, President of the Sanitary District of Chicago of June 16, 1899 to the Hon. Daniel S. Lamont, Secretary of War of the United States, asking permission to make improvements on the Chicago River.

A. N. Rosenwald
Chief Draftsman

Sketch of Plan for increasing the capacity of
The South Branch of Chicago River
Explanation

1 By-pass at Adams Street Bridge.
2 By-pass at Jackson Street Bridge and Metropolitan R.R. Bridge.
3 By-pass at Taylor Street Bridge and Wisconsin R.R. Bridge.
4 Deepening River to depth of 21 feet below datum.
5 Deepening River to depth of 22½ feet below datum.
6 Widening River and new swing bridge at Canal Street
7 Deepening River to depth of 24 feet below datum.
8 Widening River.
9 Widening River.
10 Widening River
11 Widening River and new bridge at Throop Street (Main)
12 Widening River at Loomis St. (Deering) Bridge.
13 Widening River and new bridge at Ashland Ave.

EXHIBIT I.

PERMIT FOR THE IMPROVEMENT OF THE CHICAGO RIVER.

(Permit of July 3rd, 1896.)

Improvement of the Chicago river.

July 3, 1896.

SIR:

I have the honor to acknowledge the receipt of your letter of the 16th ultimo, requesting permission to make certain changes in the capacity of the channel of the Chicago River for drainage purposes at points indicated on the map accompanying the application, and in reply beg to say that upon investigation it is found that the permission requested can be granted upon the following conditions:

1. That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each by-pass and each new dock or wharf proposed to be built, in order that the Secretary of War may act intelligently in each case.
2. That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submitted for consideration.
3. That it will not cover obstructions to navigation by reason of this work while in progress or when completed.
4. That the United States shall not be put to expense by reason of this work.
5. That this authority will expire by limitation in two years from date unless extended.

Very respectfully,

(Signed) JOSEPH B. DOE,
Acting Secretary of War.

B. A. Eckhart, Esq.,
President the Sanitary District of Chicago, Rialto Building, Chicago, Ill.

EXHIBIT J.

THE SANITARY DISTRICT OF CHICAGO.

Security Building.

CHICAGO, April 26, 1900.

To the Honorable
The Secretary of War.

SIR:

The Sanitary District of Chicago, a municipal corporation organized and existing under the laws of the State of Illinois, respectfully represents that, by the laws of the State of Illinois and the charter of this petitioner, it is authorized to enter upon, widen, deepen and otherwise improve any navigable stream, river or other water-way. That in pursuance of the power conferred upon it by the statutes of the State of Illinois, and in the performance of the duties enjoined upon it by the act of the Legislature authorizing its creation, and under which it is acting, it has been determined to improve the Chicago River by widening and deepening the same and to the end that such action on the part of your petitioner may be conformable to law and the statutes of the United States in that behalf, it hereby makes application for permission to make the changes, alterations and improvements in said Chicago River from or near Lake Street in the City of Chicago to or near Ashland Avenue in the City of Chicago, said work to conform to the plan and specifications as follows:

(a) A map herewith exhibits the existing boundaries of that part of the South Branch of the Chicago River which it purposes and desires to improve.

(b) The work to be done contemplates widening the river to a width of two hundred (200) feet between dock lines, except in so far as bridge abutments may project into the stream outside of the new dock lines; said widening in all cases to be made with a view of improving the navigability of the stream.

(c) The work to be so done as to ultimately permit excavation of the river bed to a depth of thirty (30) feet below water surface throughout the central portion of the stream.

(d) The widening of the river is to be so disposed that the effect will be to produce a straighter channel than now exists and, furthermore, to result in a continuous dock line having straighter alignment and being better disposed for navigation than the docks which now exist.

(e) The work to be done is to be prosecuted progressively as to time. The rate of progress being limited by the rapidity with which right of way may be acquired and the resources for the execution of the work to be made available. The modification and alteration of said river as above indicated will greatly benefit navigation in said river. Your petitioner, therefore, respectfully requests that the plan of improvement as above outlined be approved by you.

Awaiting as early a reply as practicable under the circumstances, your petitioner has the honor to be,

Very respectfully yours,

THE SANITARY DISTRICT OF CHICAGO,

By WILLIAM BOLDENWECK,

President.

Attest:

JOSEPH F. HAAS,

Clerk.

EXHIBIT J-i.

CHICAGO, June 7, 1900.

To the Honorable,
the Secretary of War.

SIR:—

Under date of April 26, 1900, the Sanitary District of Chicago had the honor to address a communication to you containing an outline of the proposed improvement of a portion of the South Branch of the Chicago River. Accompanying the letter was a map showing the location of the South Branch of the Chicago River, the bridges spanning said river and, also, the width of the stream along the entire course of the South Branch of the river. Since that date the Sanitary District of Chicago passed an ordinance for the improvement of the South Branch of the Chicago River from the south line of Twelfth Street to the east line of Ashland Avenue, so as to make said South Branch, between the lines aforesaid, of a uniform width of two hundred (200) feet; the work to be done so as to ultimately permit excavation of the river bed to a depth of thirty (30) feet below water surface throughout the central portion of said stream, in accordance with the plans adopted by the Board of Trustees of the Sanitary District of Chicago, a copy of which plans is hereto annexed. The ordinance referred to being marked Exhibit "A," with this

letter; and the maps showing the plans of the proposed improvement being marked Exhibit "B." The maps are in two sections, known respectively as No. 2 and No. 3.

The Sanitary District of Chicago is a municipal corporation, organized and existing under the laws of the State of Illinois and by the laws of said State and the charter of said Sanitary District, it is authorized to enter upon, deepen, widen and otherwise improve any navigable stream, river, or other water-way; and that in pursuance of the power conferred upon it by the statutes of the State of Illinois and in performance of the duties enjoined upon it by the act of the legislature authorizing its creation, and under which it is acting, it determined upon said plans outlined in the enclosed ordinance and further illustrated by the maps hereto annexed; and the said Sanitary District, in compliance with the Statutes of the United States, hereby makes application to you for permission to make the changes, alterations and improvements in said South Branch of the Chicago River, from the south line of Twelfth Street to the east line of Ashland Avenue.

Awaiting as early a reply as practicable under the circumstances, your petitioner has the honor to be,

Very respectfully yours,

THE SANITARY DISTRICT OF CHICAGO,

By WILLIAM BOLDENWECK,

President.

Attest:

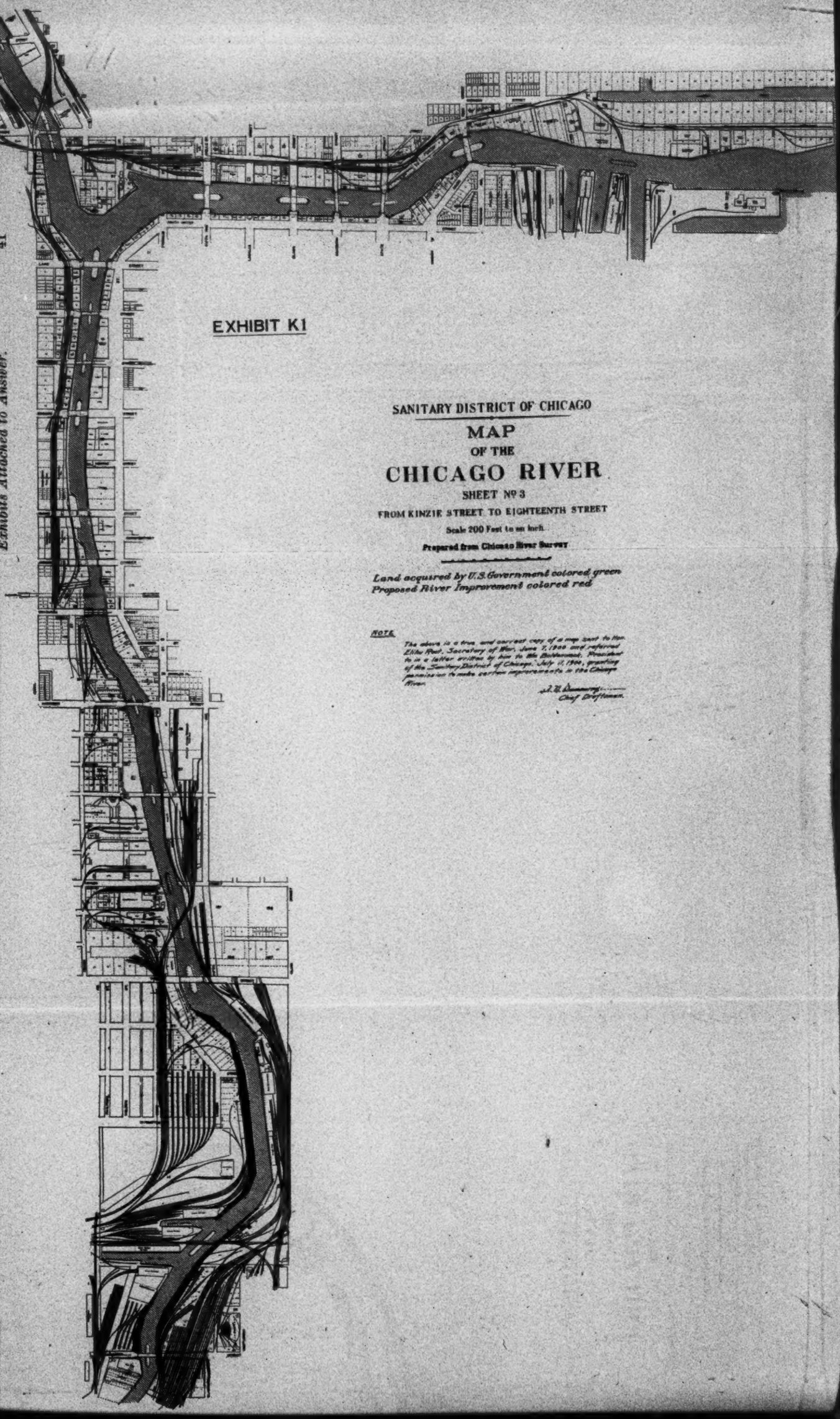
JOSEPH F. HAAS,

Clerk.

41

Exhibits Attached to Answer.

EXHIBIT K1



SANITARY DISTRICT OF CHICAGO

MAP
OF THE
CHICAGO RIVER

SHEET № 3

FROM KINZIE STREET TO EIGHTEENTH STREET

Scale 200 Feet to an Inch

Prepared from Chicago River Survey

Land acquired by U.S. Government colored green
Proposed River Improvement colored red

NOTE.

The above is a true and correct copy of a map sent to Hon. Elihu Root, Secretary of War, June 7, 1906 and referred to in a letter written by him to the Board of Trustees, President of the Sanitary District of Chicago, July 7, 1906, granting permission to make certain improvements in the Chicago River.

J. H. Dunnavan
Chief Draftsman.

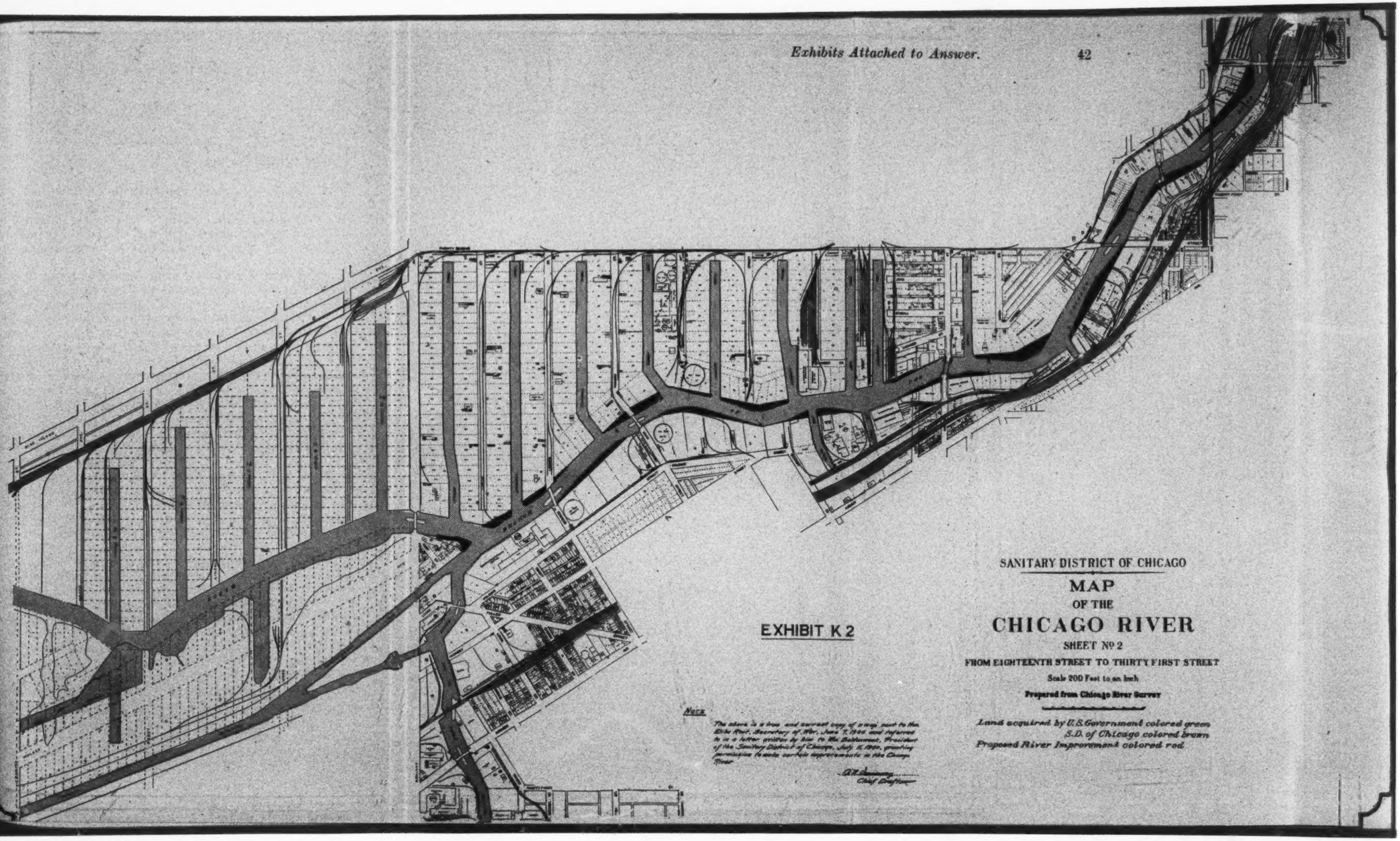


EXHIBIT K 2

SANITARY DISTRICT OF CHICAGO

MAP
OF THE
CHICAGO RIVER

SHEET Nº 2

FROM EIGHTEENTH STREET TO THIRTY FIRST STREET

Scale 200 Feet to an Inch

Prepared from Chicago River Survey

Land acquired by U.S. Government colored green
S.D. of Chicago colored brown
Proposed River Improvement colored red

NOTE

The above is a true and correct copy of a map sent to the Hon. Secretary of War, June 7, 1900 and referred to in a letter written by him to Mr. Bakewell, President of the Sanitary District of Chicago, July 11, 1900, granting permission to make certain improvements in the Chicago River.

Chief Engineer

EXHIBIT L.

War Department,

WASHINGTON, July 11, 1900.

SIR:

I have the honor to acknowledge the receipt of your letter of April 26th last, requesting, in behalf of the Sanitary District of Chicago, permission to change, alter and improve the Chicago River, from Lake Street to Ashland Avenue, in Chicago, as shown on maps which accompanied your said letter.

Replying thereto I beg to inform you that there is no objection on the part of the War Department to the prosecution of work of improvement of Chicago River, specified in the above mentioned letter and delineated on the maps which accompanied the same, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the general government in any way with the expense incident to the carrying out of the project, and does not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago River and cause them to flow into the artificial channel, such permission being subject to the following conditions, viz:

"1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action and that this permit shall be subject to such action as may be taken by Congress.

"2. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

"3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navi-

gation interests by reason of the introduction of a current in Chicago River.

Very respectfully,

ELIHU ROOT,
Secretary of War.

Mr. Wm. Boldenweck,
President the Sanitary District of Chicago,
Security Building, Chicago, Ill."

EXHIBIT L-1.

War Department,

WASHINGTON, July 11, 1900.

SIR:—

In response to your application of the 7th ultimo, for permission to make certain changes, alterations and improvements in the South Branch of the Chicago River, from the south line of Twelfth Street to the east line of Ashland Avenue, as shown on plans which accompanied said application, I beg to inform you that there is no objection on the part of the War Department to the prosecution of the work as specified, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the general government in any way with the expense incident to the carrying out of the project, and does not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted, under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago River and cause them to flow into the artificial channel such permission being subject to the following conditions, viz:

"1. That it be distinctly understood that it is the intention of the Secretary of War to submit the question connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

"2. That if, at any time, it become apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge

through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

"3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River.

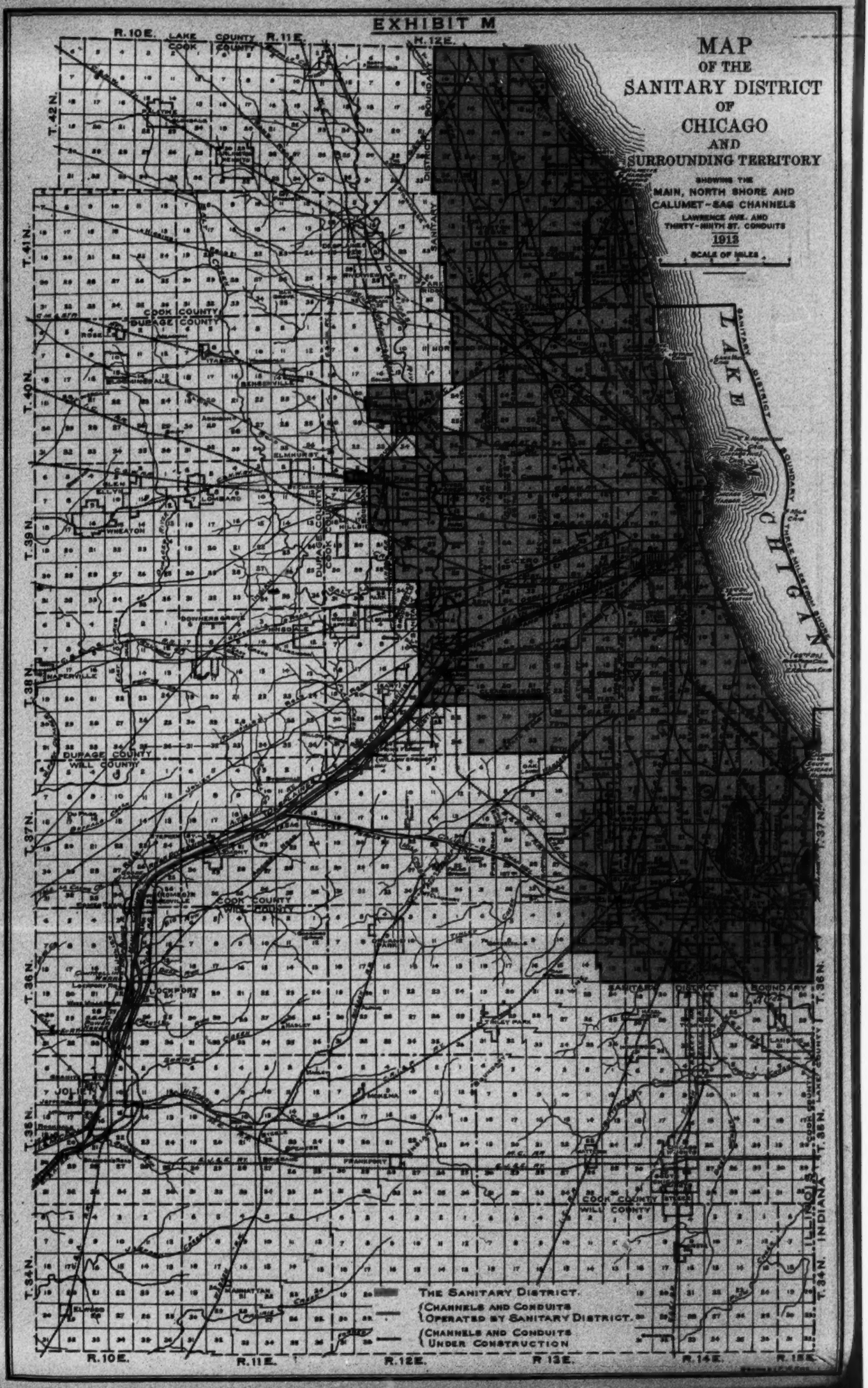
Very respectfully,

ELIHU ROOT,
Secretary of War.

Mr. Wm. Boldenweck,
President the Sanitary District of Chicago,
Security Building, Chicago, Ills."

Exhibits Attached to Answer.

EXHIBIT M



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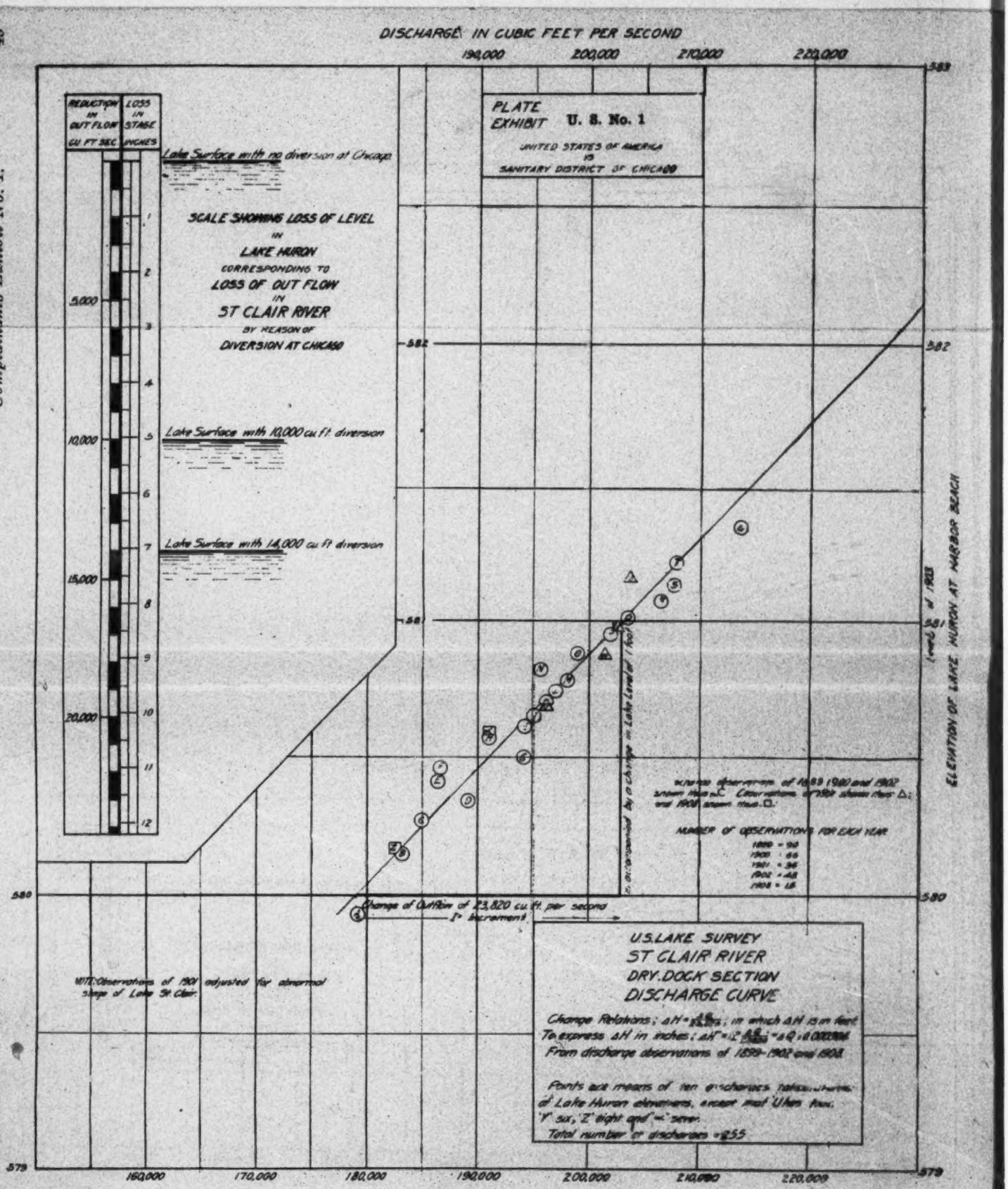

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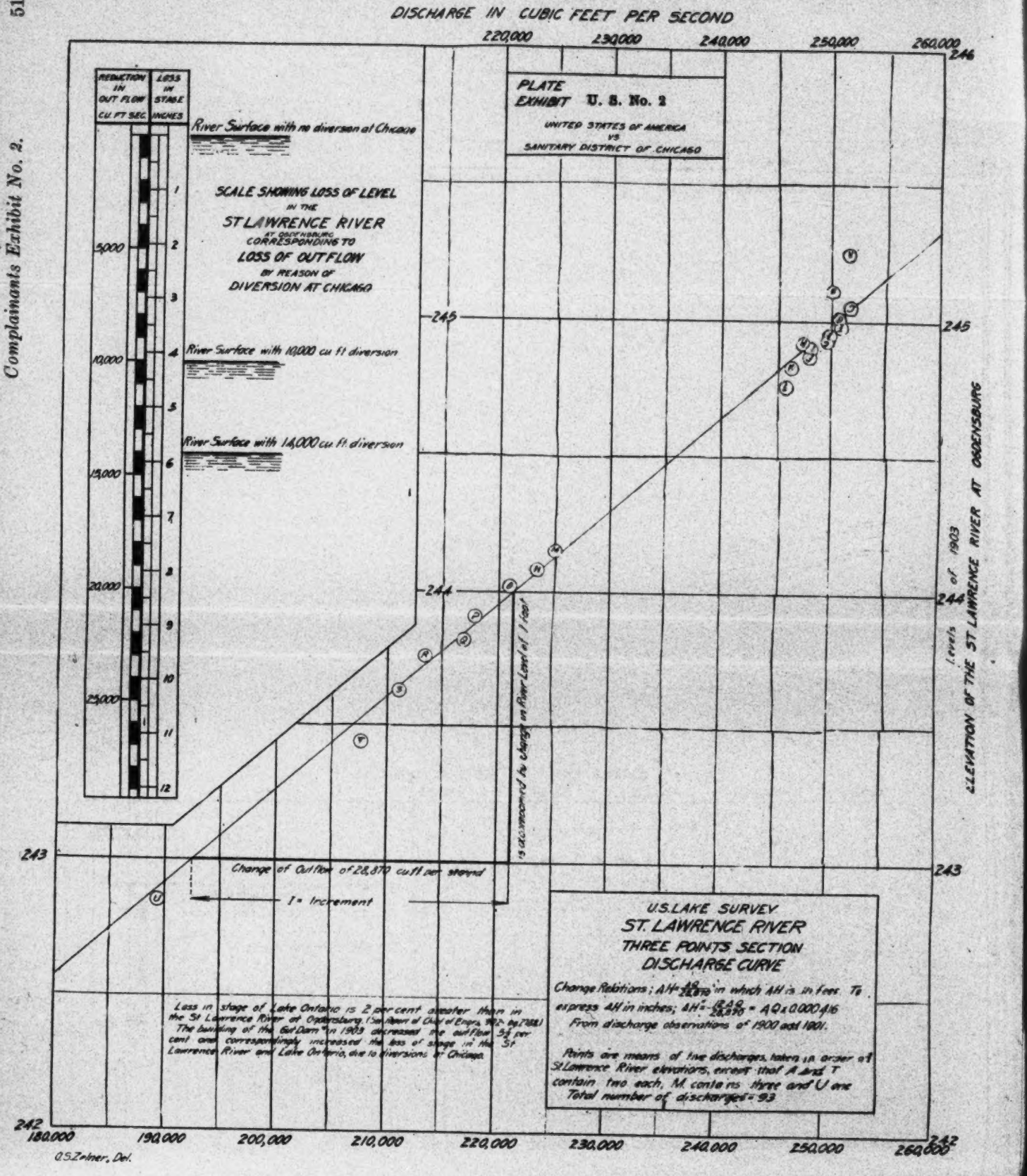

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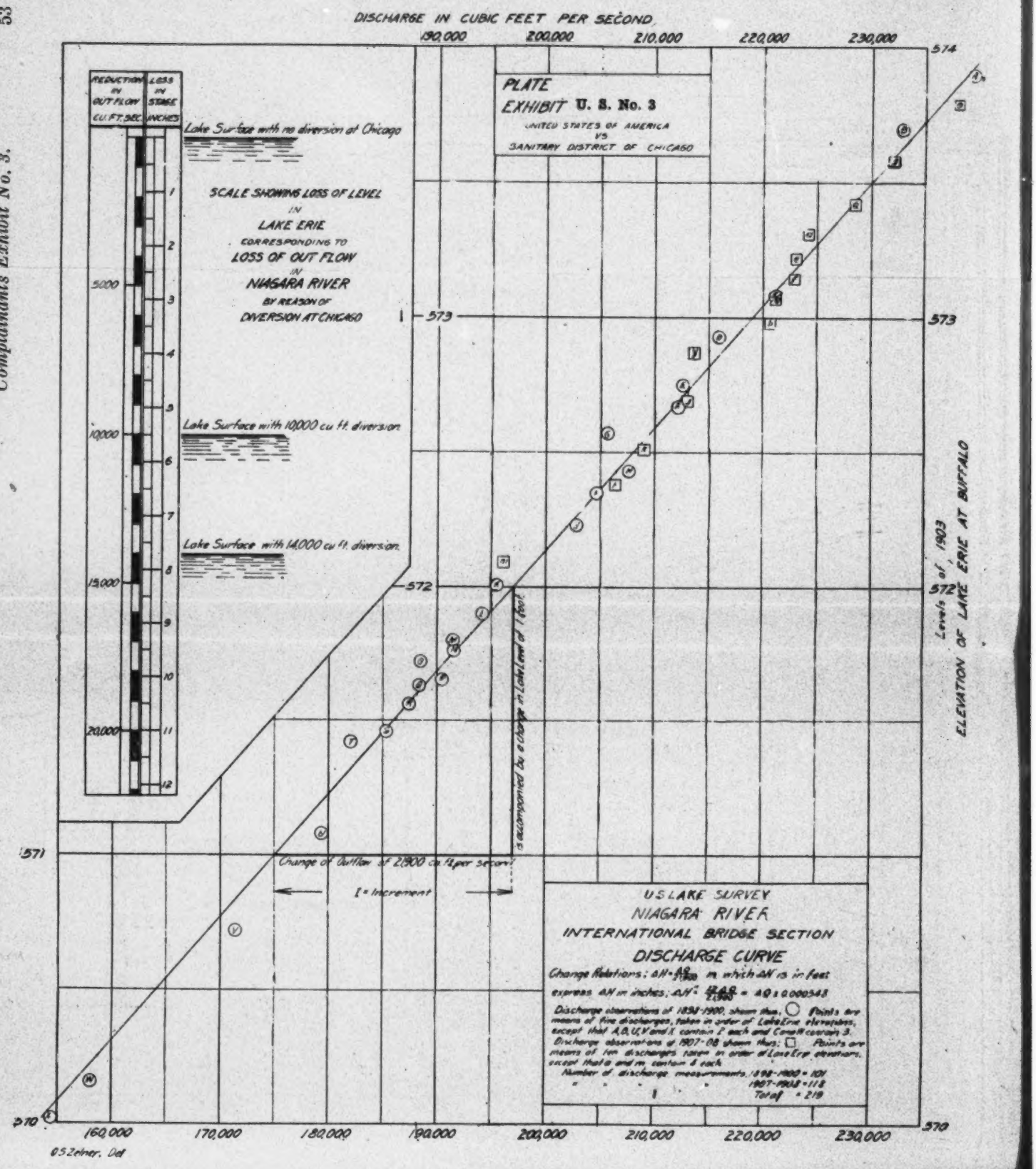

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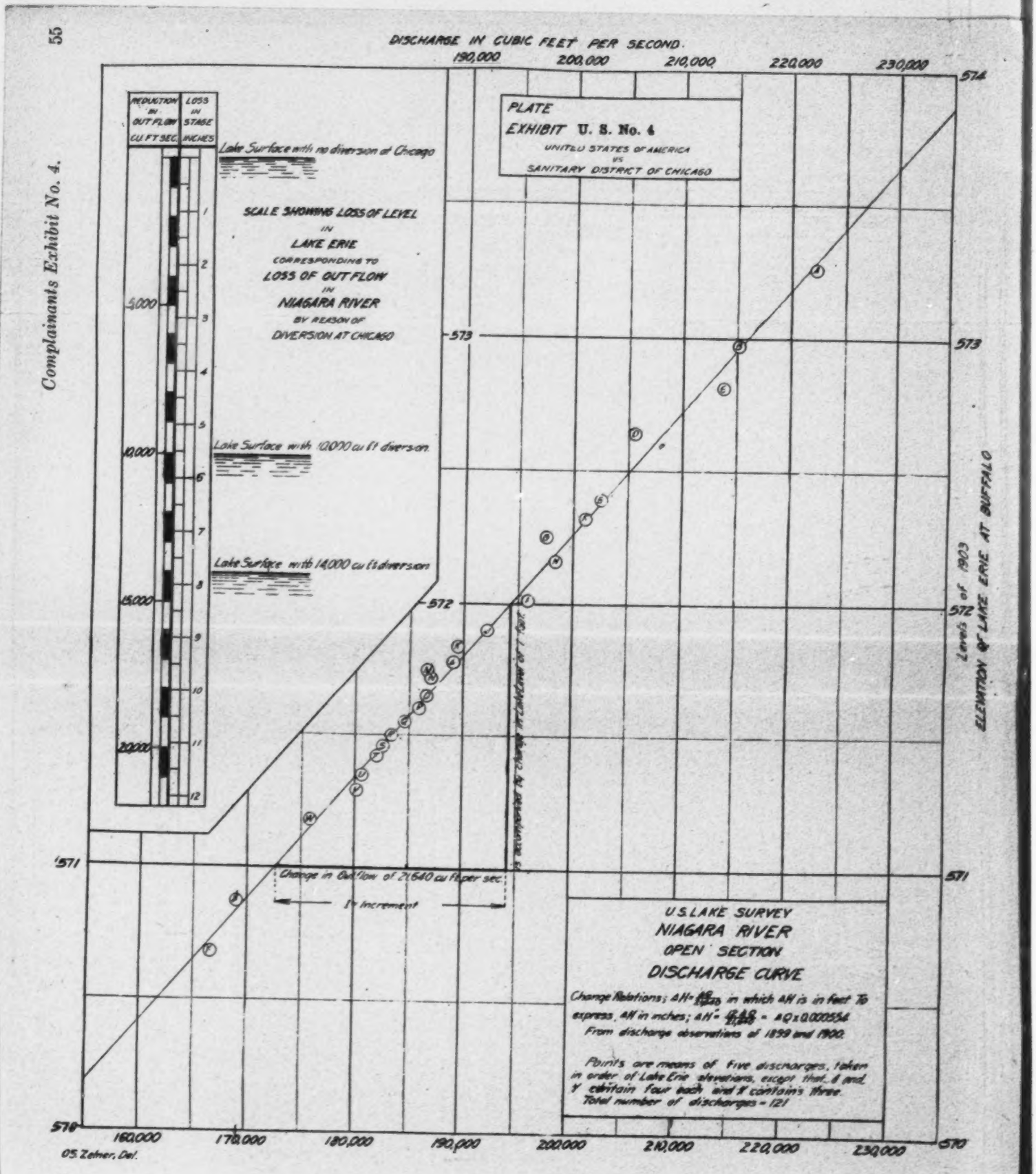
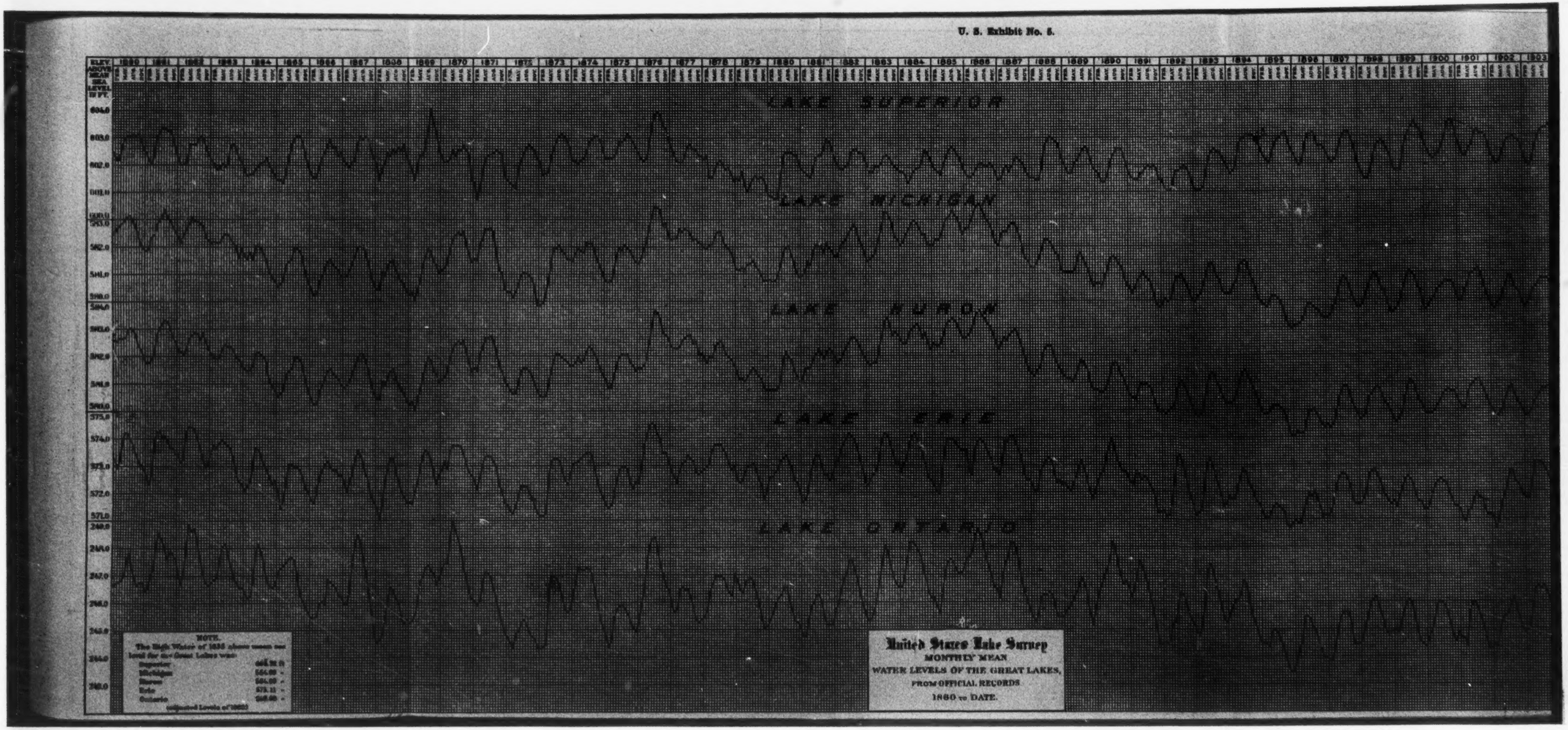
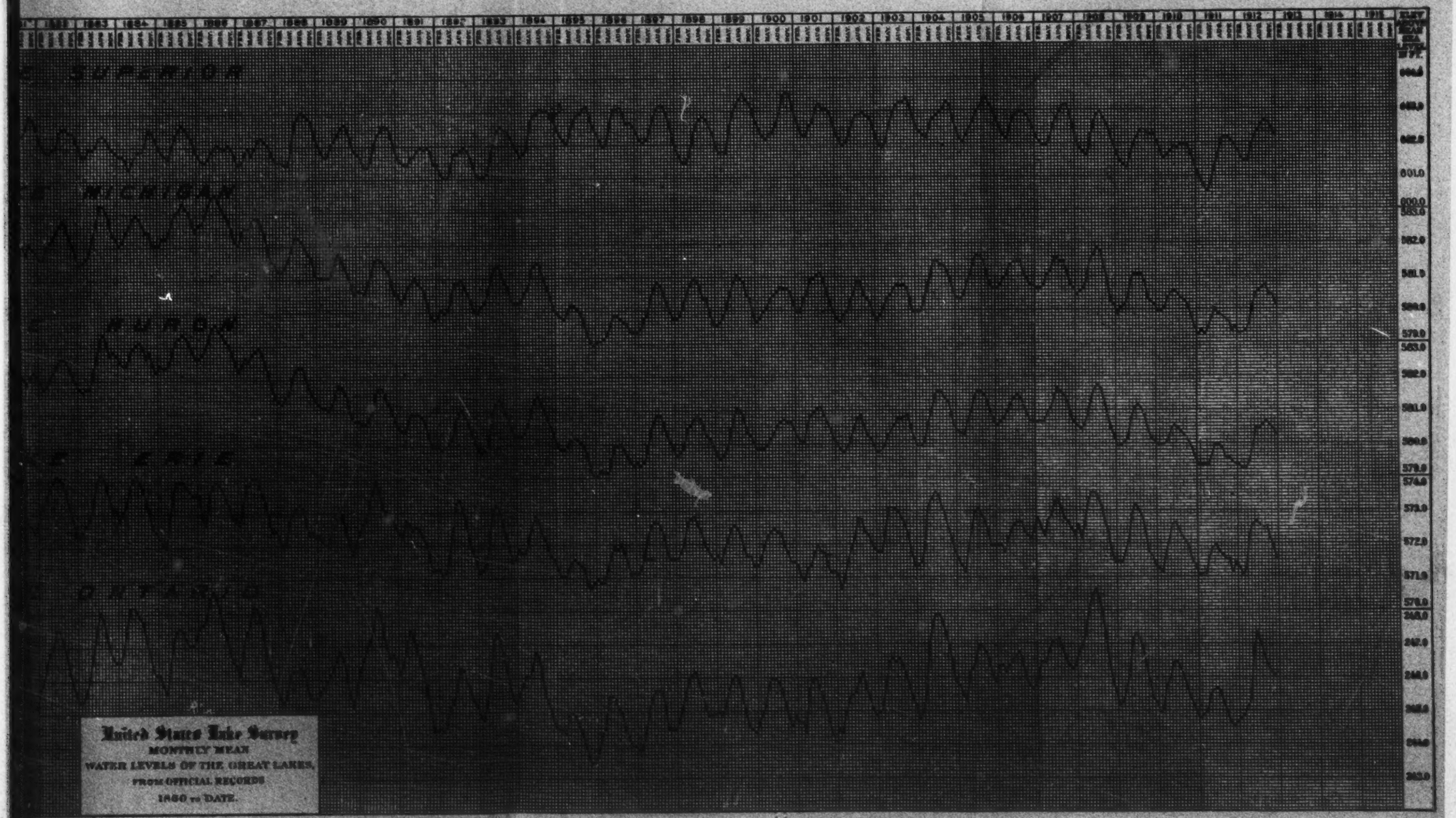
Complainants Exhibit No. 4.



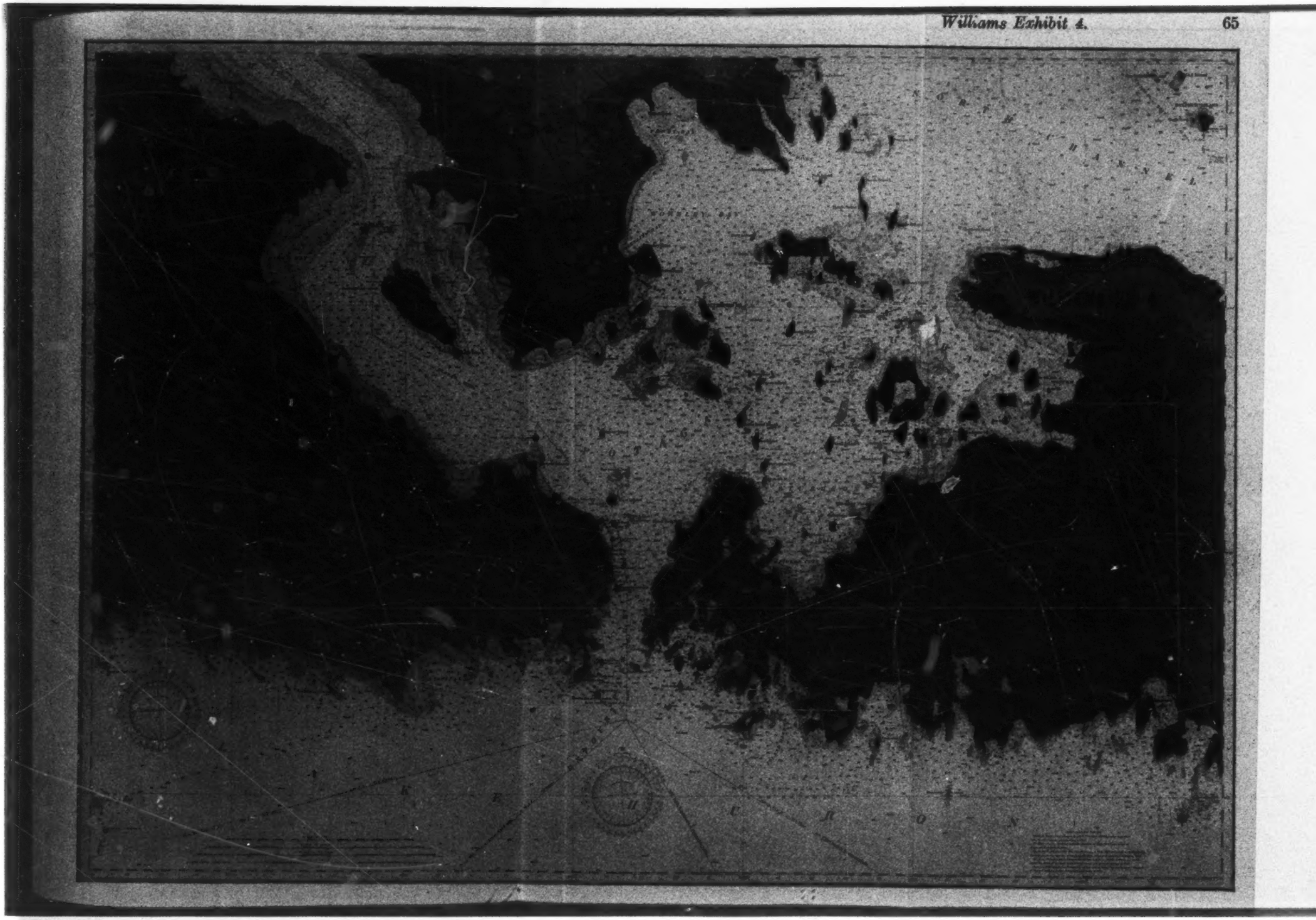
U. S. Exhibit No. 5.

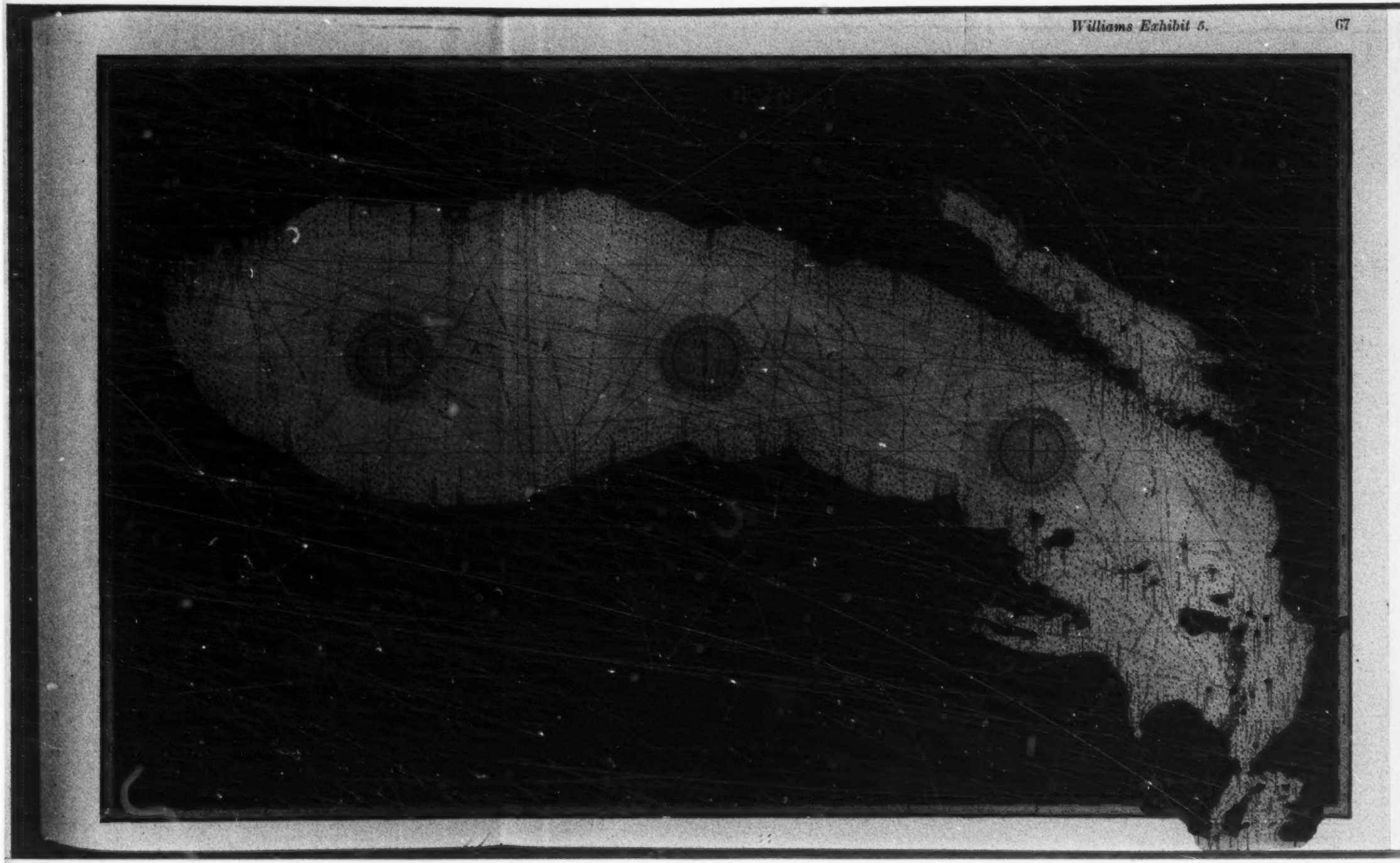




United States Lake Survey
MONTHLY MEAN
WATER LEVELS OF THE GREAT LAKES.
FROM OFFICIAL RECORDS
1860 TO DATE.

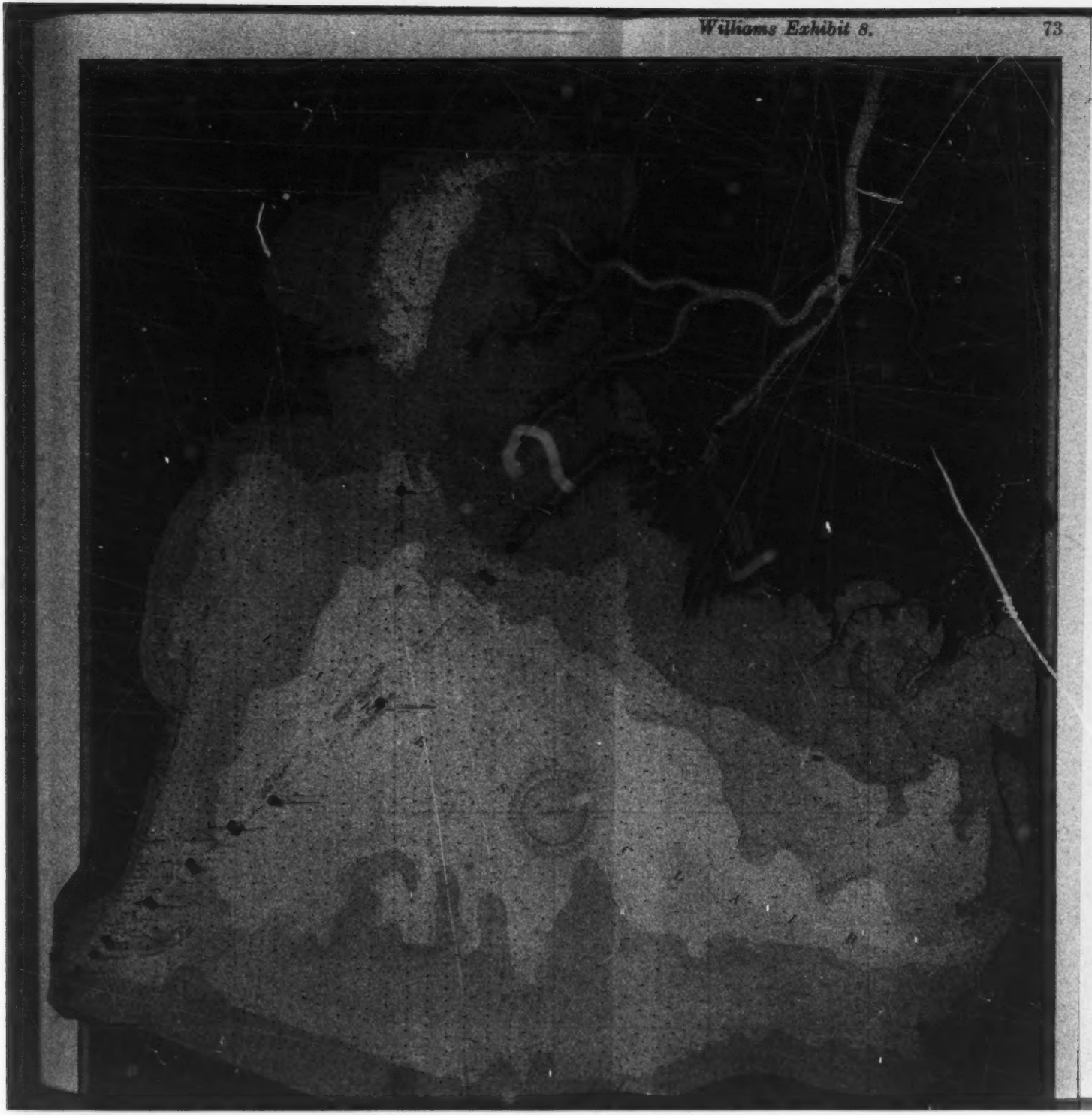
WHITEFISH BAY
HEAD O

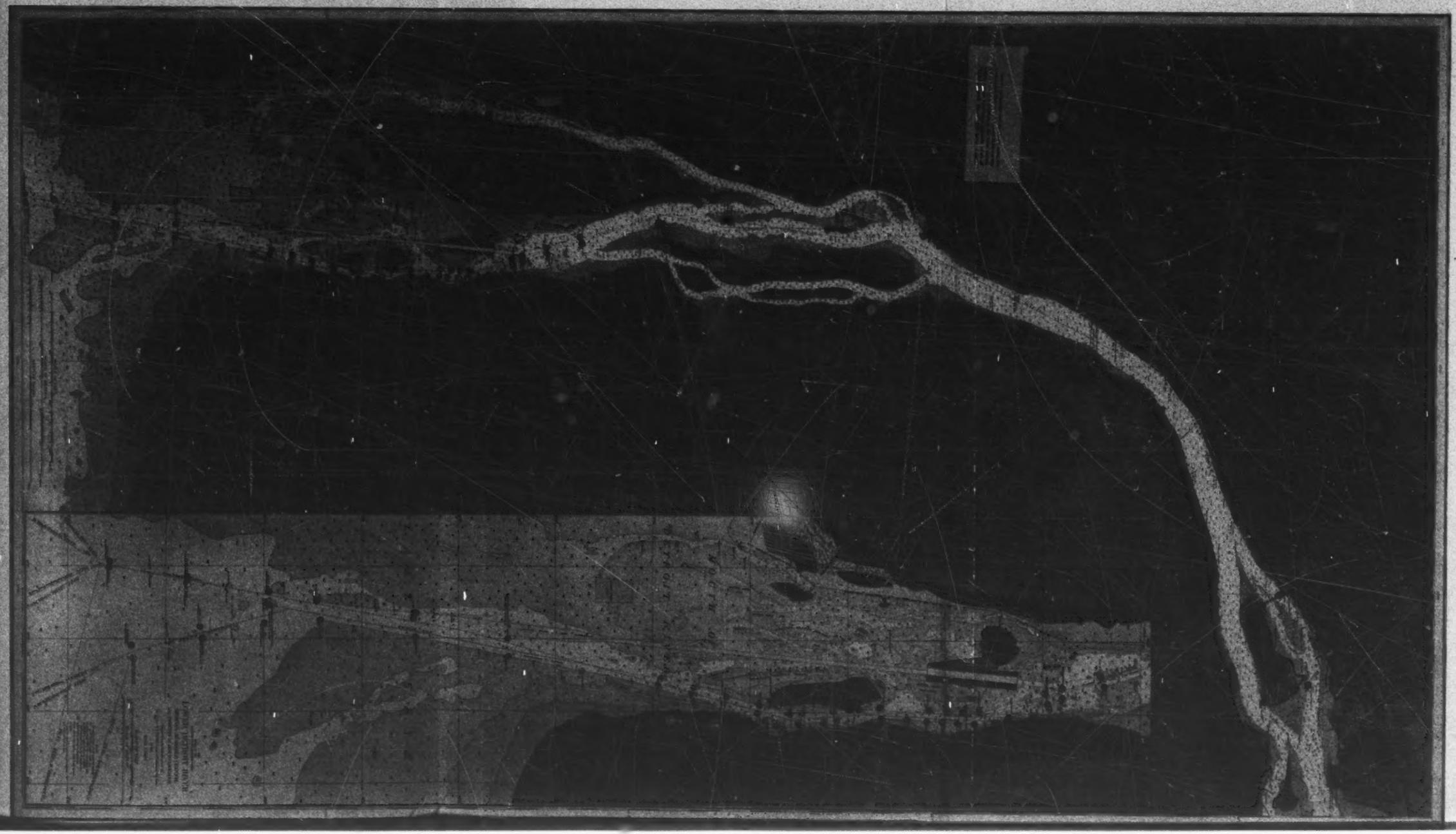

GREAT BRITAIN
IRELAND
EUROPE



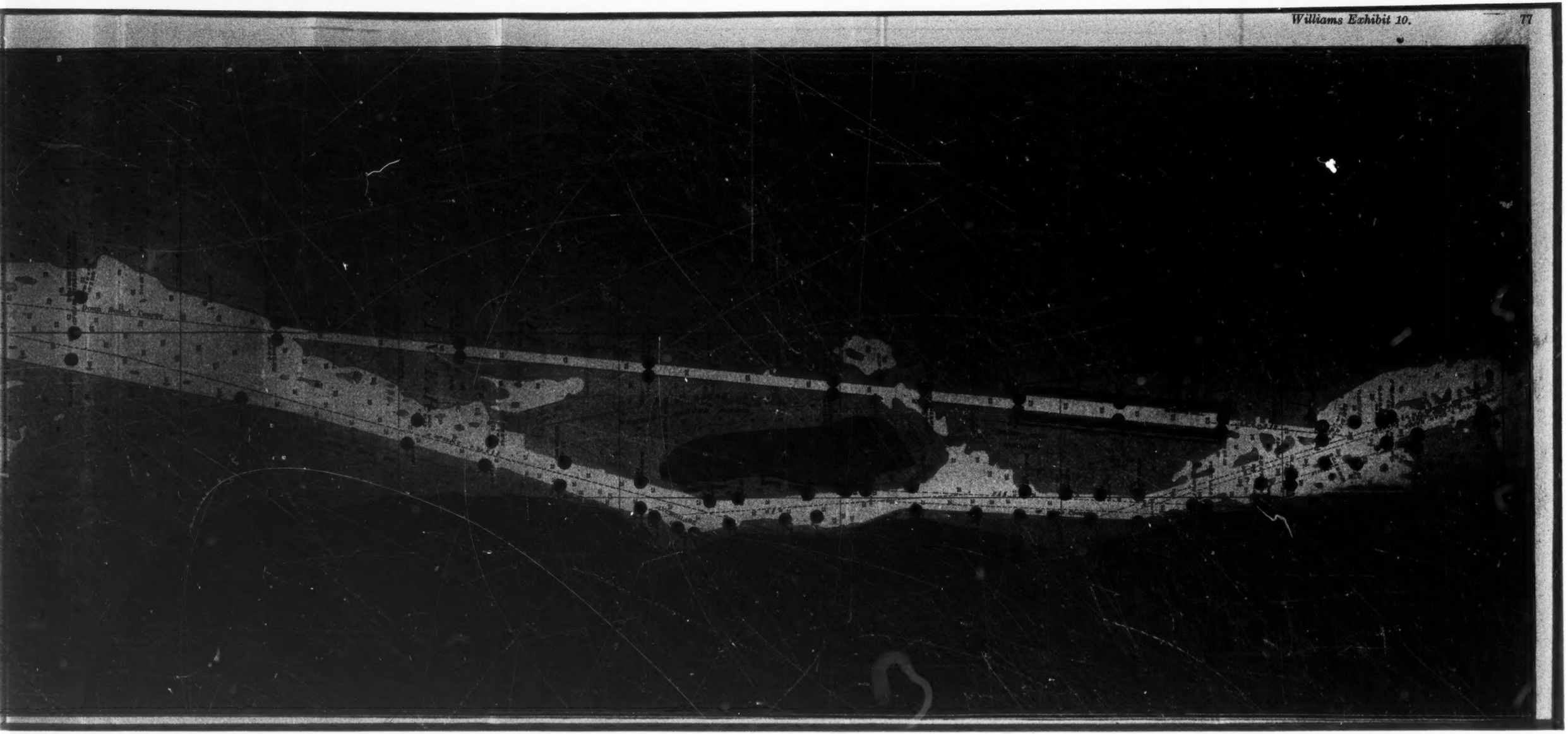
L A K E
H U R O N

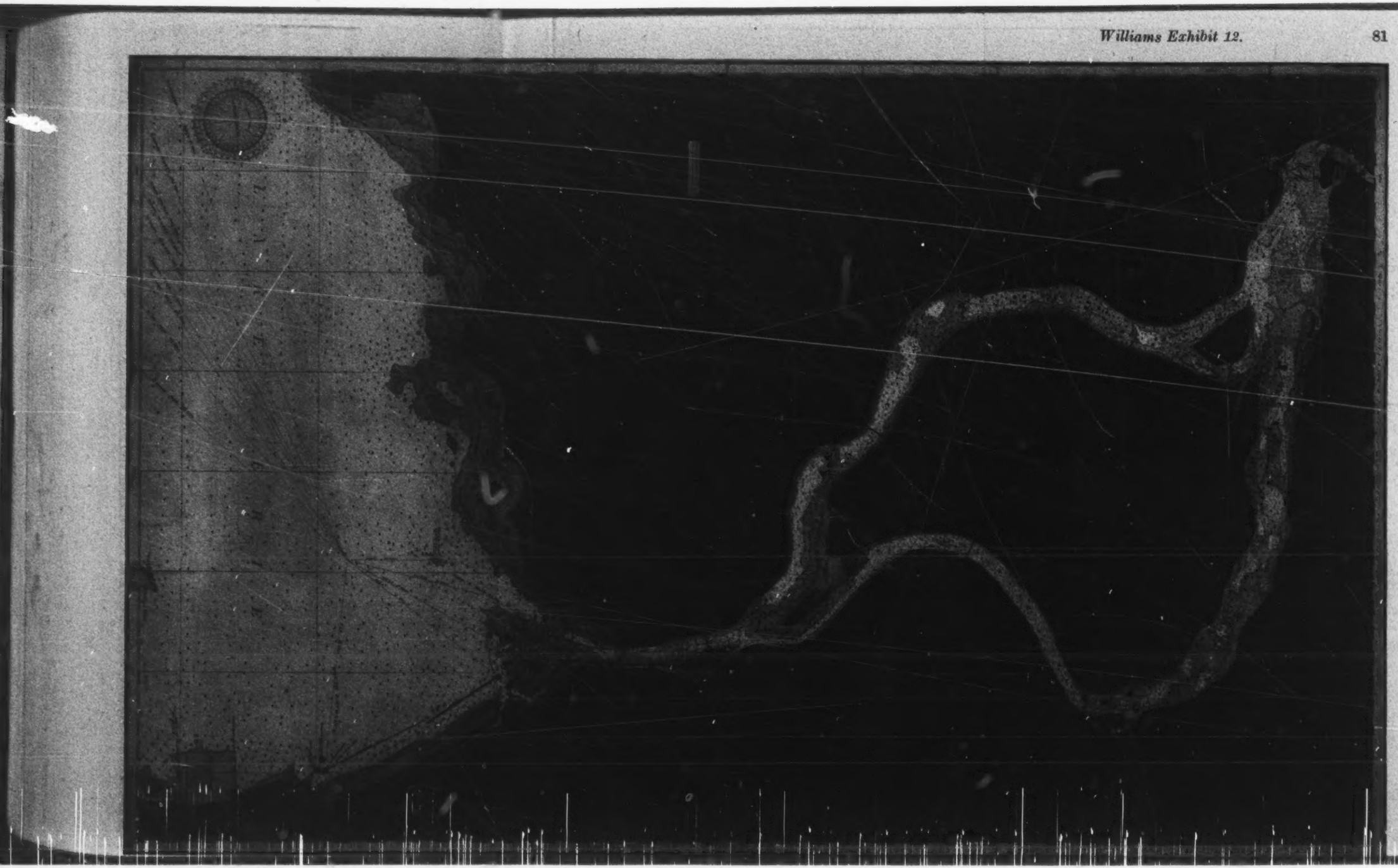
SAINT CLAIR RIVER

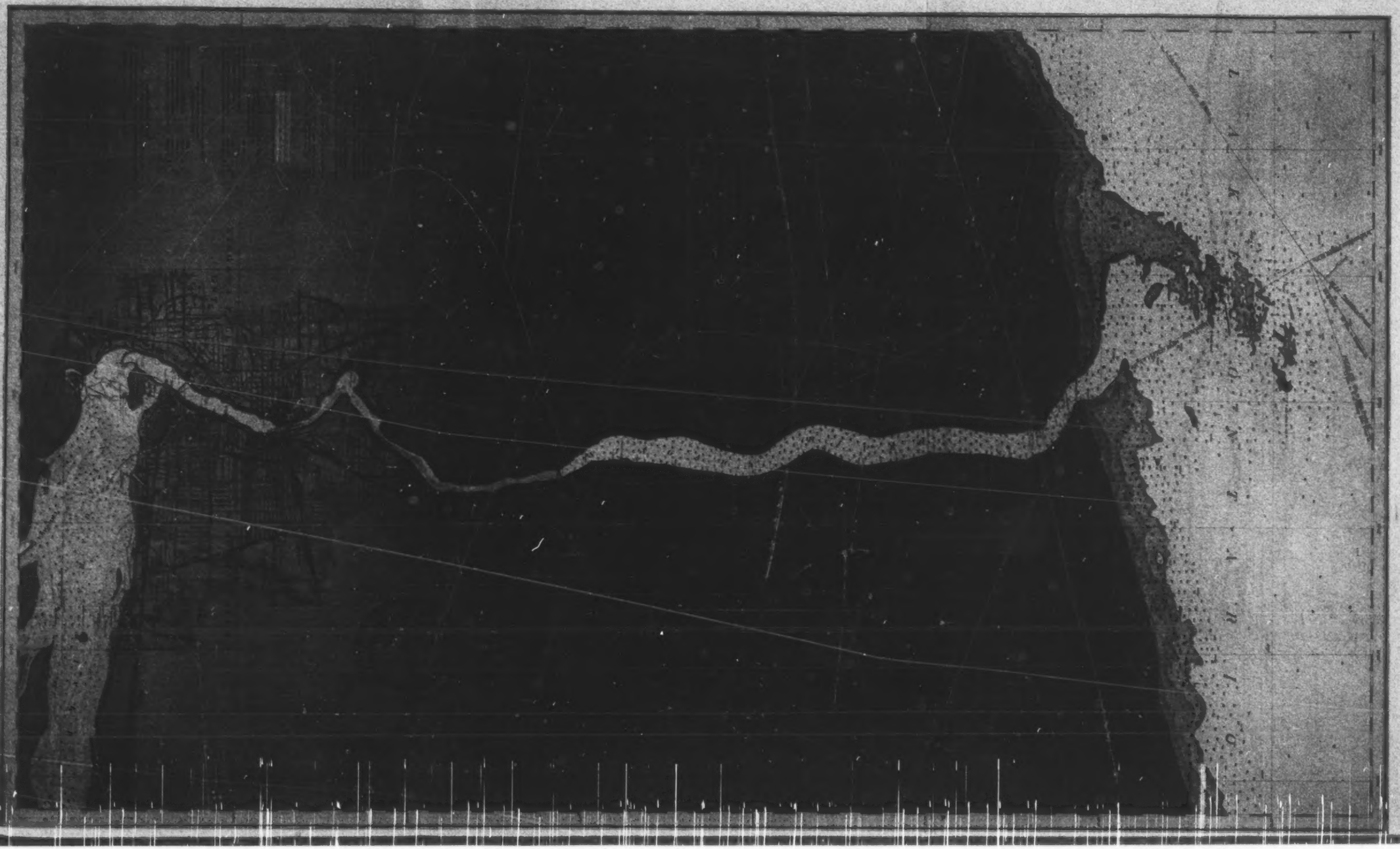


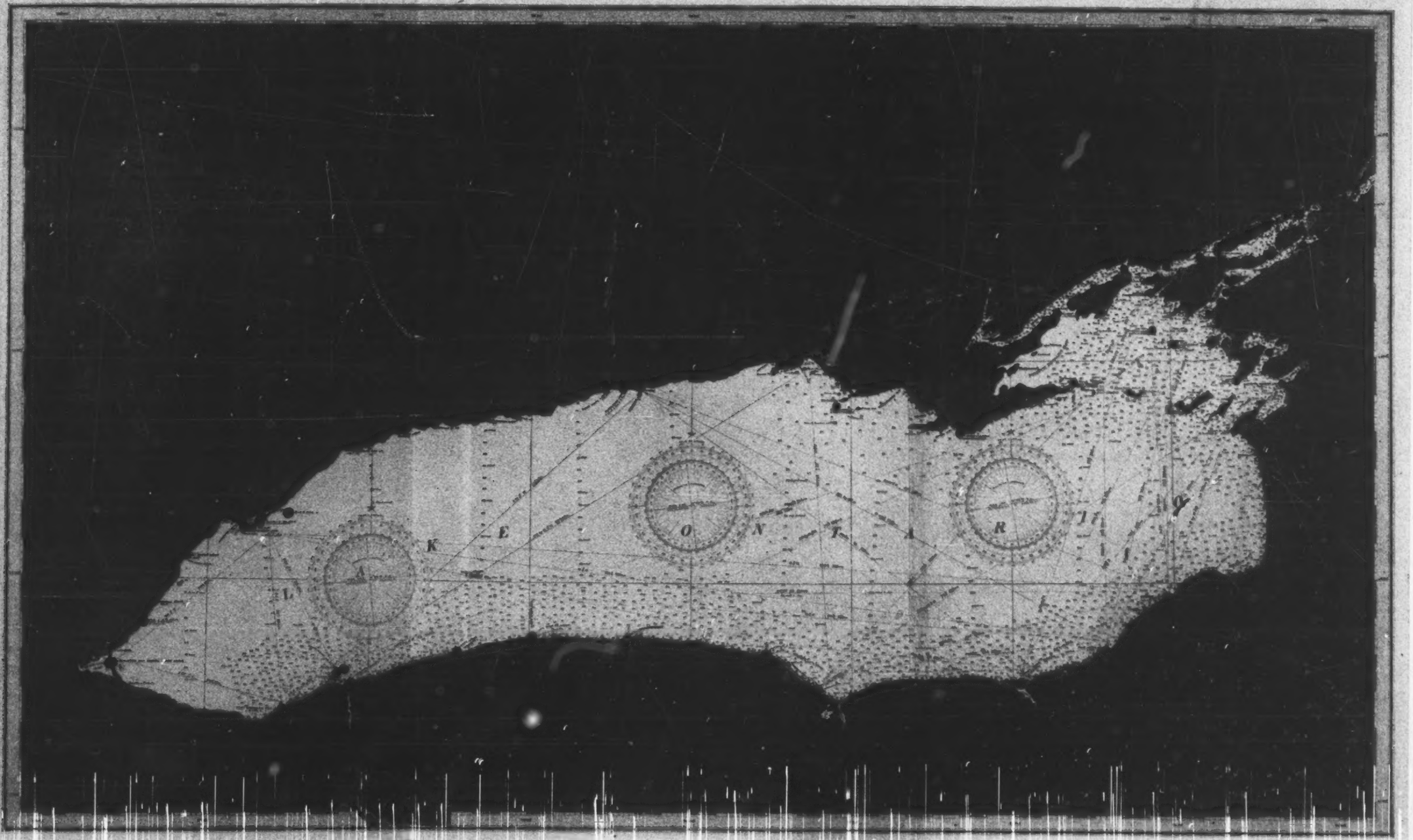


LOWER DETROIT RIVER
SHOWING LIVINGSTONE CHANNEL
AND POSITIONS OF AIDS TO NAVIGATION
Lieut.-Col. JOHN MAVITY, Corps of Engineers, U.S. Army, to 1912, and
Lieut.-Col. J.C. SANFORD, Corps of Engineers, U.S. Army
to 1913.
SCALE 1:32000.
NOTE.
Sailing lines
Range lines








K E
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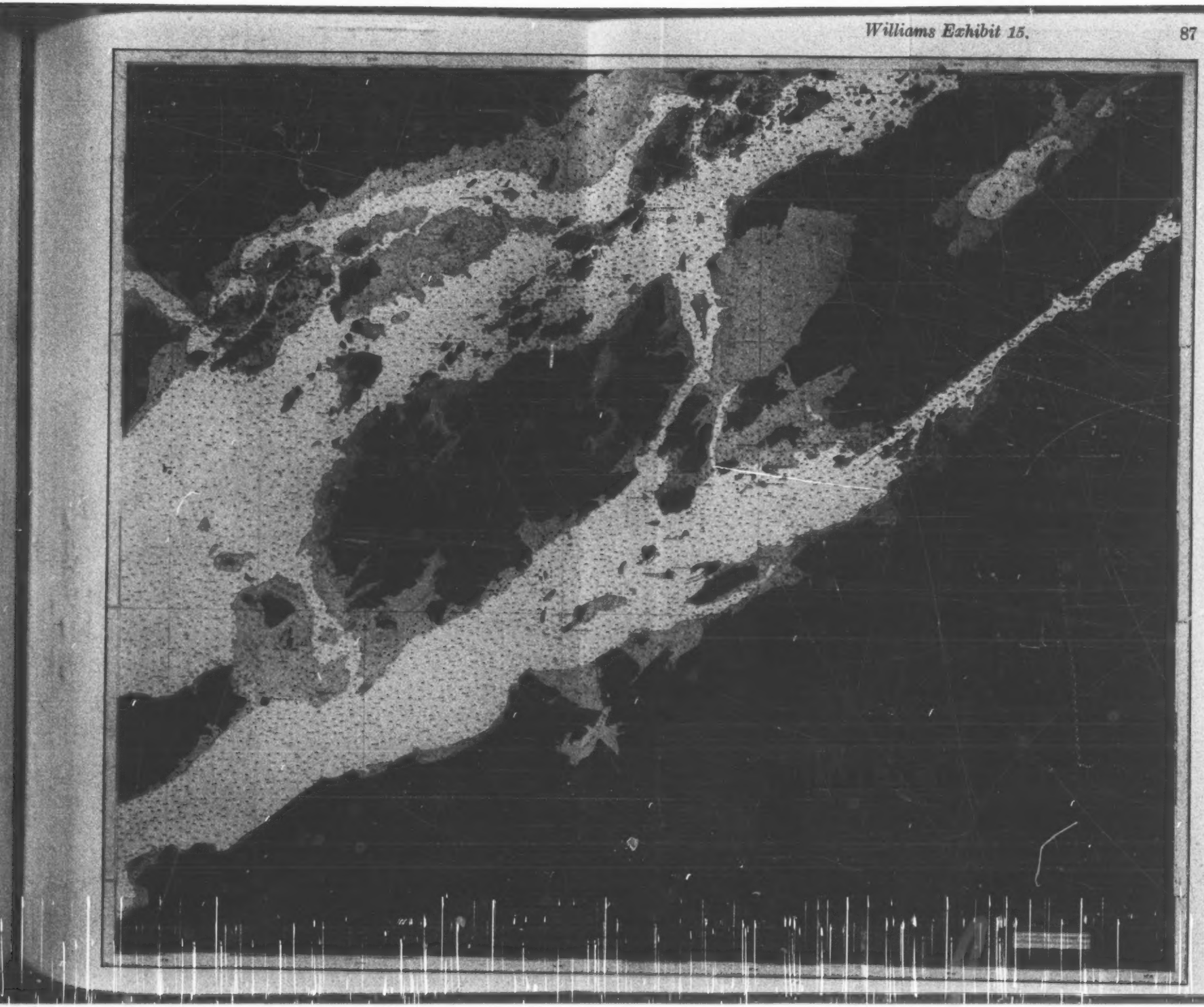
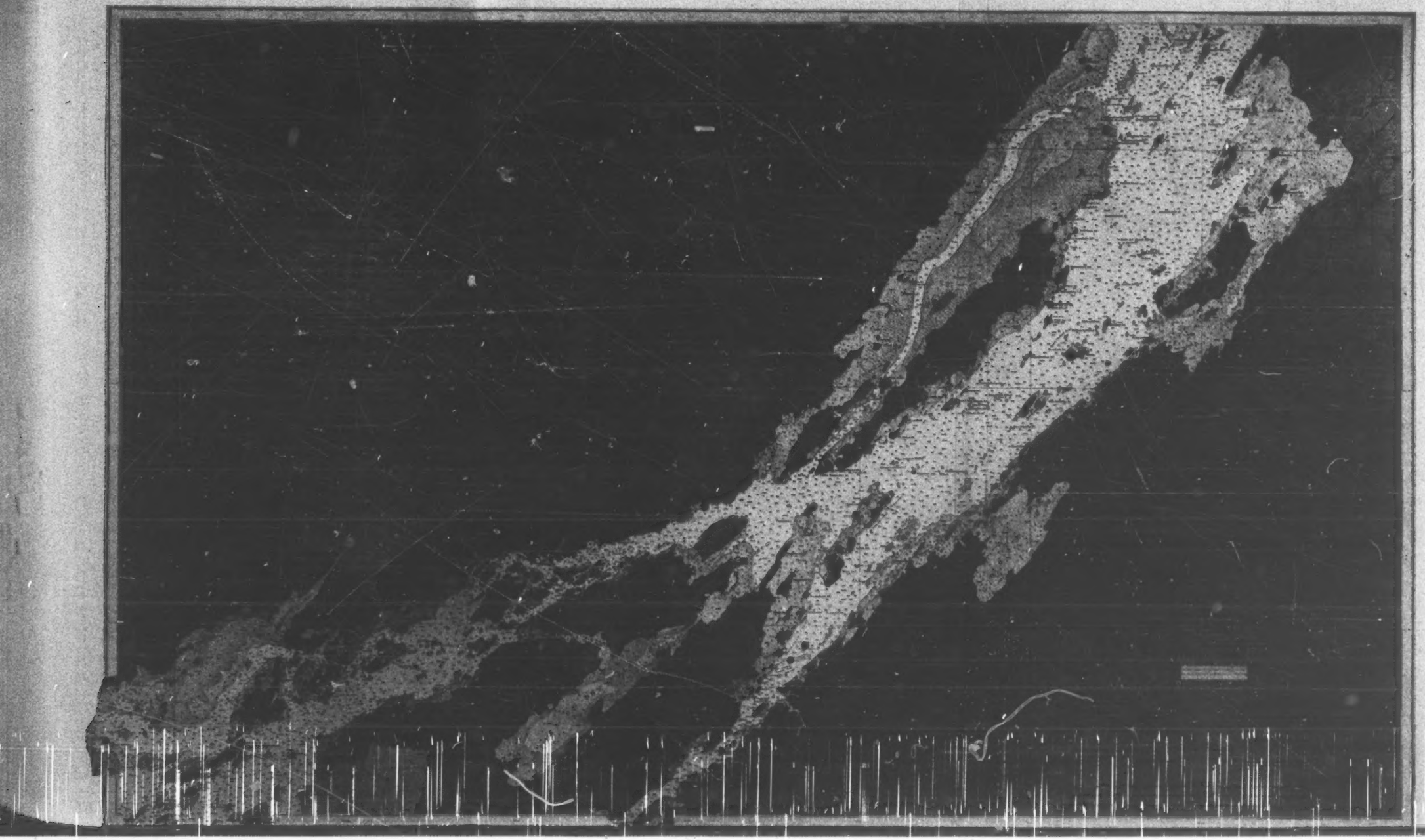
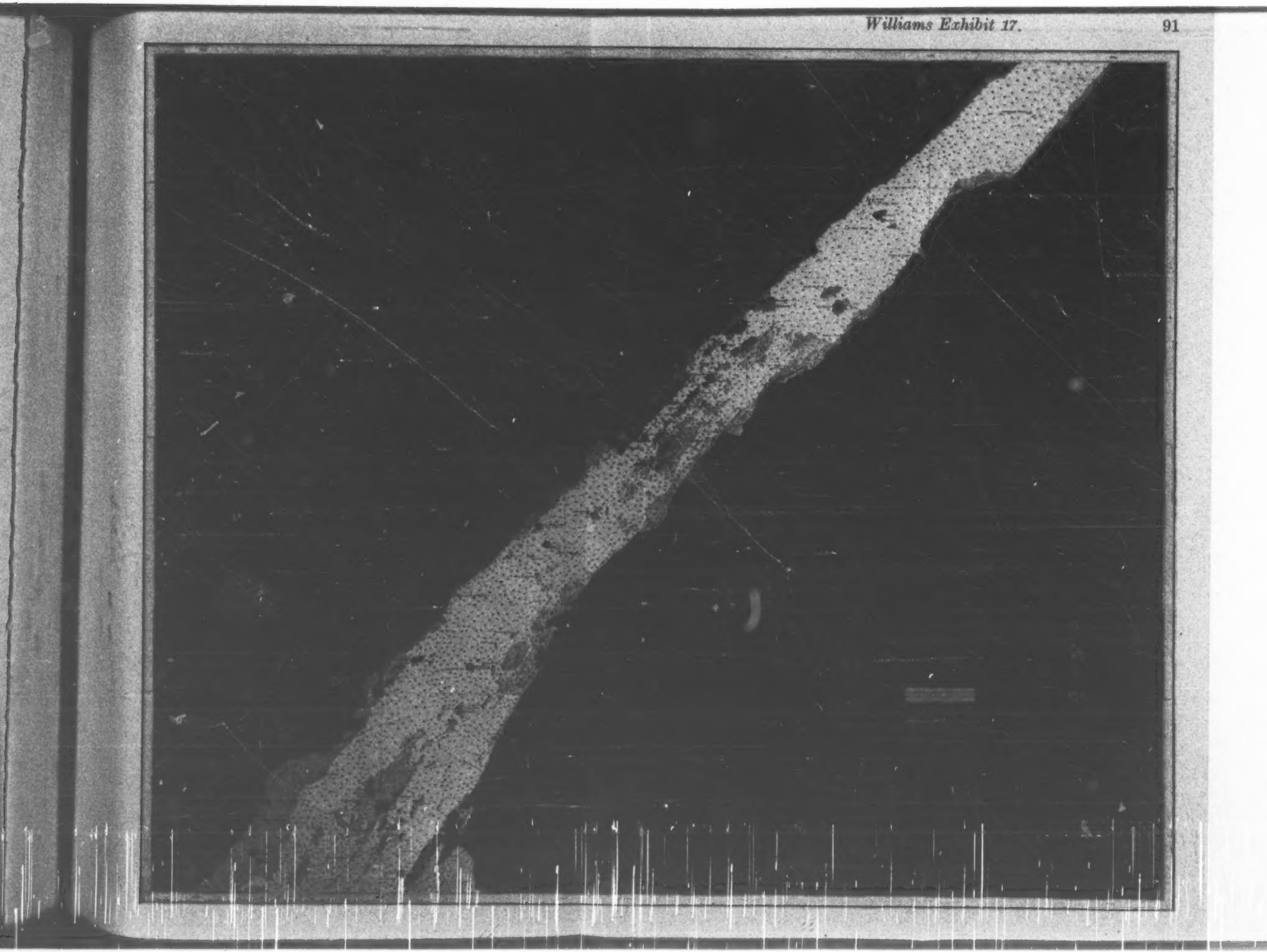
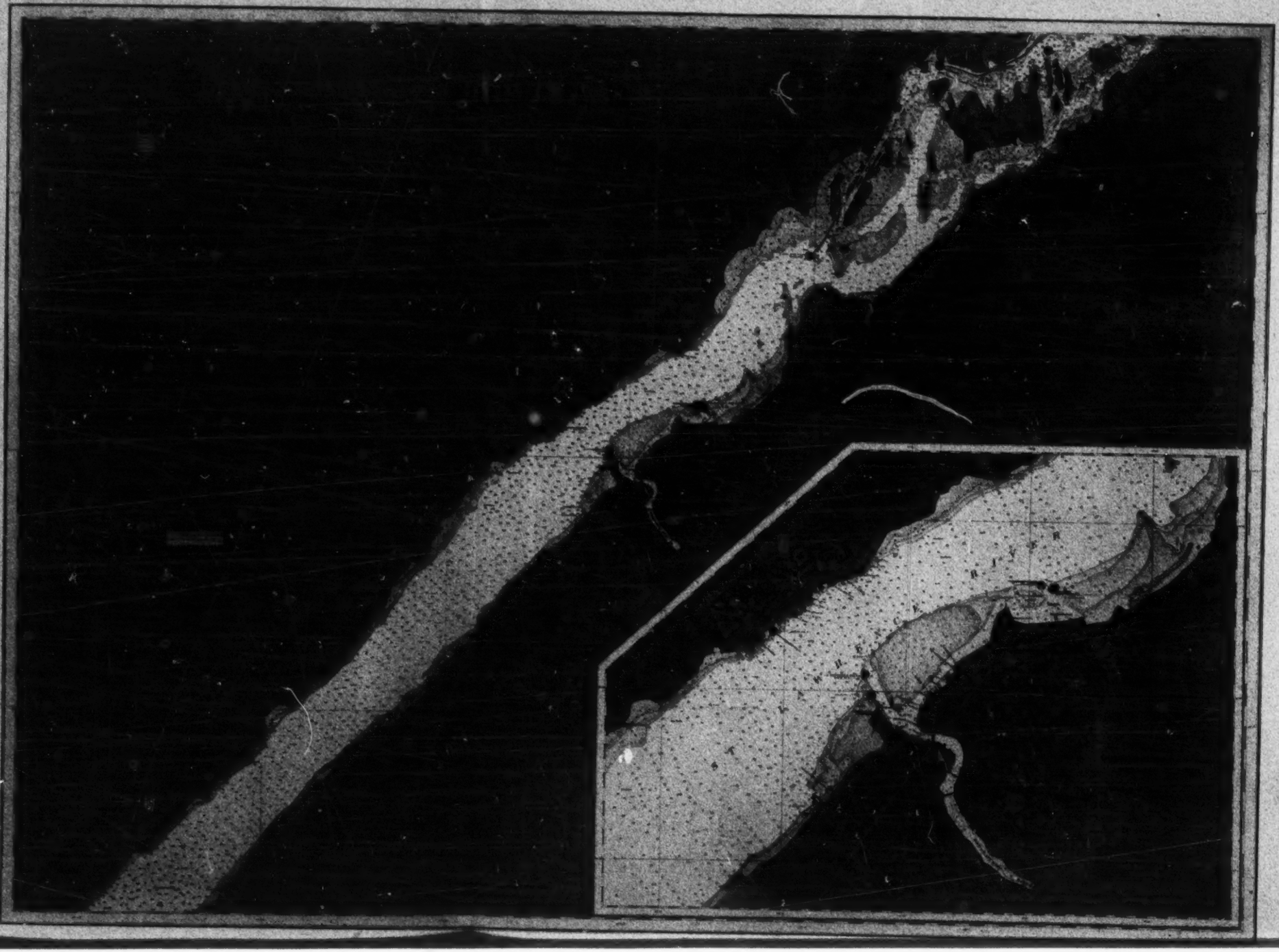
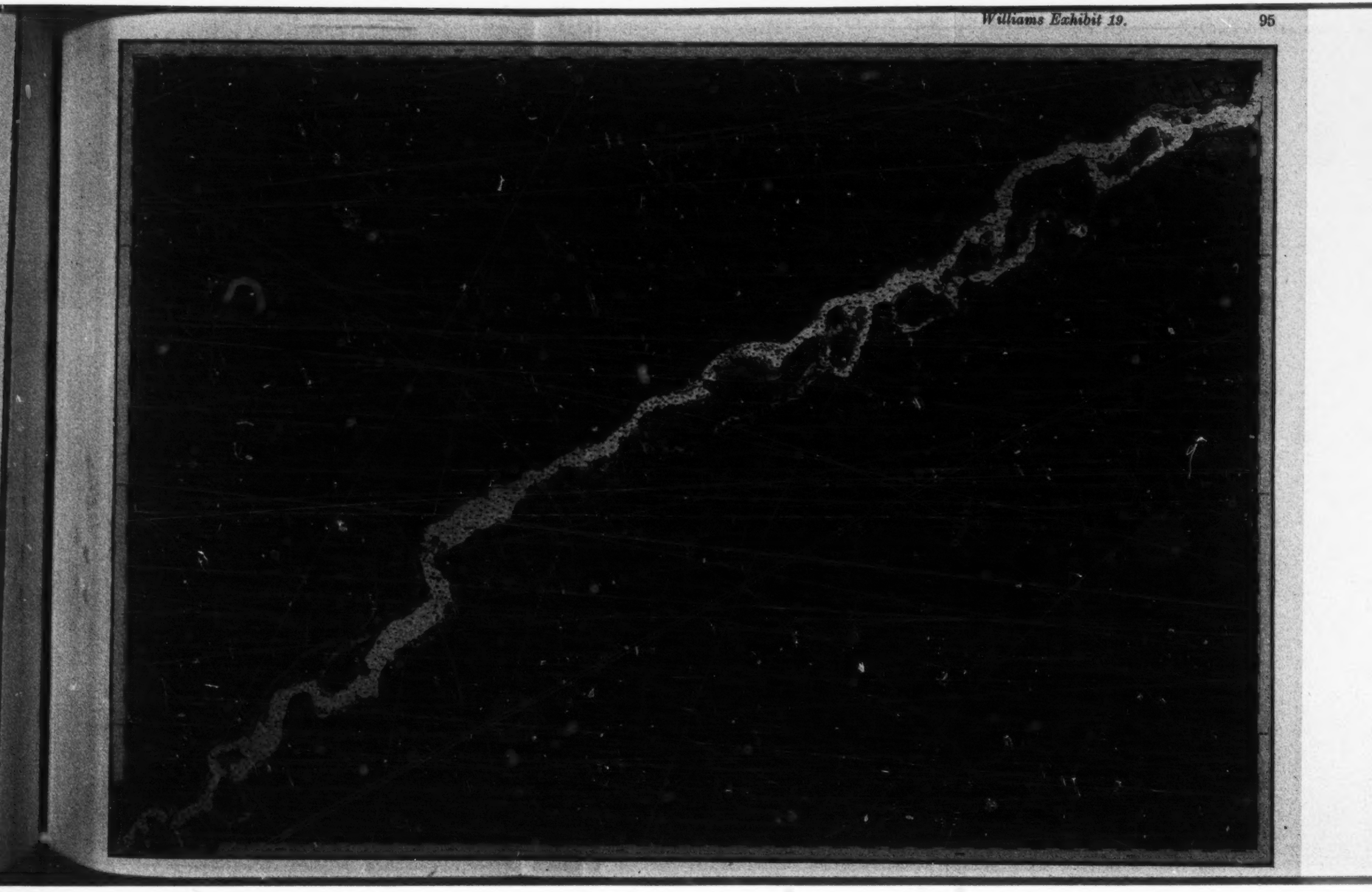
R

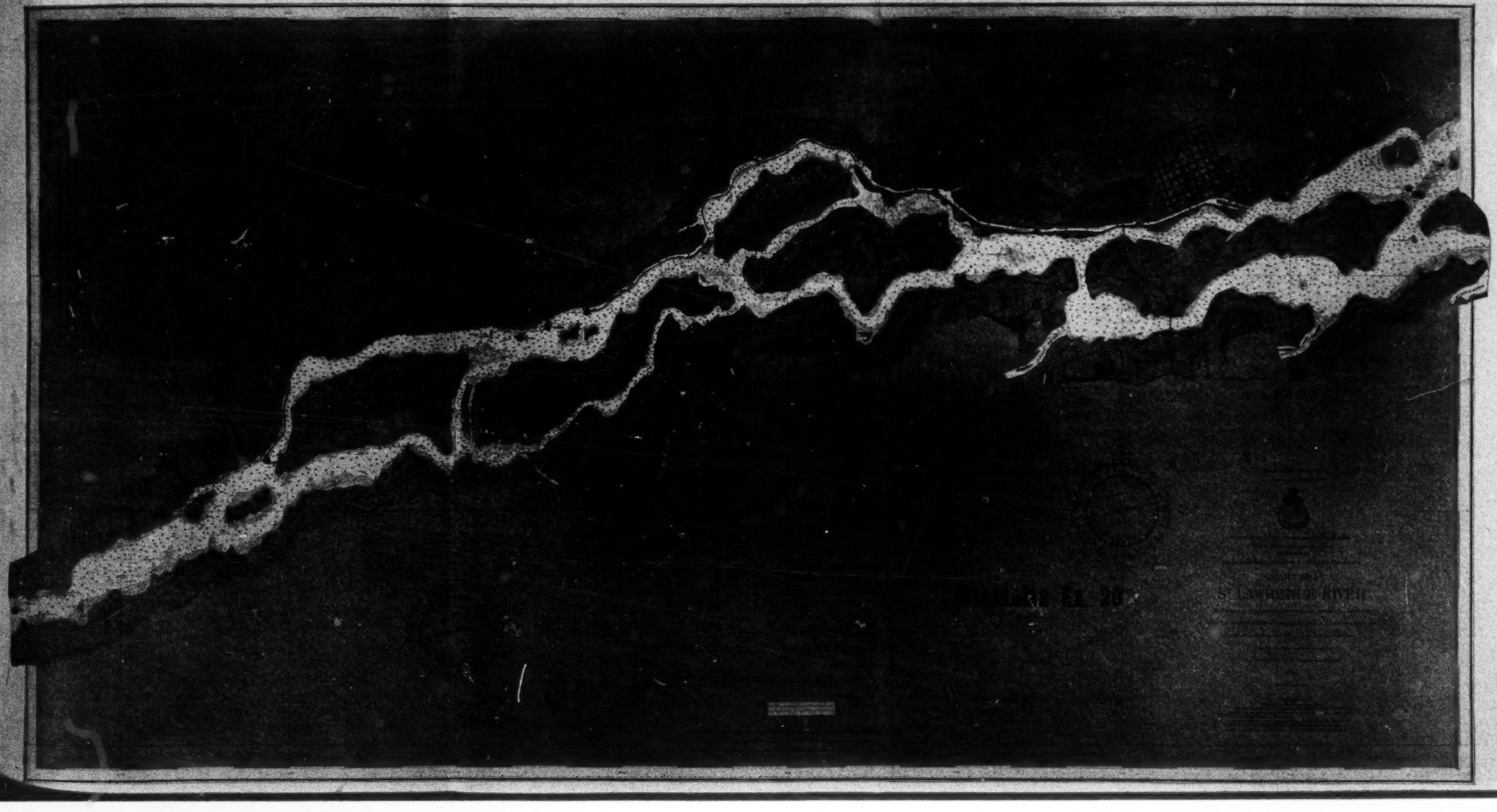











WILLIAMS EX. 20
ST. LAWRENCE RIVER

Williams Ex. 21

U. S. LAKE SURVEY
Discharge Measurements—Dry Dock Section
ST. CLAIR RIVER
1899-1900-1902

1-Table
Sheet 1
(7 Sheets)

No. of Meas.	Date	Water Surface		Fall	Rise+ Fall—	WIND		Discharge Cu. Ft. per Sec.
		Lake Huron	St. Clair Flats			Dir.	Vel.	
154	Dec. 22, 1900	579.65	574.66	4.99		S.W.	25	174,200
89	Nov. 17, 1899	9.71	4.66	5.05		S.E.	17	174,000
153	Dec. 21, 1900	9.90	4.66	5.24		S	18	175,900
2	May 1, 1899	9.93	4.91	5.02		S.E.	20	183,600
81	Nov. 22, 1899	9.97	4.66	5.31		S	18	180,300
87	Dec. 1, 1899	580.00	4.86	5.14		S.W.	20	177,900
156	Dec. 27, 1900	0.00	4.66	5.34		S.W.	16	179,700
65	Oct. 16, 1899	0.03	4.86	5.17		S	16	180,300
149	Dec. 17, 1900	0.03	4.71	5.32		S.E.	16	183,500
150	Dec. 18, 1900	0.04	4.71	5.33		S.E.	15	182,100
A Means	Group 1....	579.93	574.74	5.19				179,200
217	Sept. 6, 1902	580.05	575.26	4.79		S.W.	15	170,700
86	Nov. 29, 1899	0.10	4.66	5.44		S.W.	12	181,400
1	Apr. 29, 1899	0.11	4.91	5.20		S.	10	188,000
84	Nov. 27, 1899	0.16	4.66	5.50		S.W.	6	186,500
61	Oct. 10, 1899	0.16	4.86	5.30		S.E.	16	180,900
63	Oct. 13, 1899	0.17	4.86	5.31		S.	15	184,500
78	Nov. 15, 1899	0.17	4.66	5.51		S.W.	10	185,700
85	Nov. 28, 1899	0.18	4.66	5.52		S.W.	15	185,400
70	Oct. 23, 1899	0.20	4.76	5.44		S.E.	14	183,000
144	Dec. 8, 1900	0.21	4.81	5.40		S.W.	12	185,600
B Means	Group 2....	580.15	574.81	5.34				183,200
239	Sept. 25, 1902	580.21	575.36	4.85		E.	10	179,200
137	Nov. 30, 1900	0.22	4.81	5.41		S.W.	20	182,500
151	Dec. 19, 1900	0.24	4.71	5.53		S.W.	15	185,300
79	Nov. 16, 1899	0.25	4.66	5.59		E.	10	187,600
83	Nov. 24, 1899	0.26	4.66	5.60		E.	4	192,900
4	May 4, 1899	0.28	4.96	5.32		E.	9	189,700
229	Sept. 17, 1902	0.30	5.16	5.14		S.E.	7	179,000
98	July 2, 1900	0.30	5.16	5.14		S.	12	182,400
93	June 21, 1900	0.31	5.16	5.15		S.W.	12	188,200
100	July 5, 1900	0.31	5.16	5.15		S.W.	14	182,200
C Means	Group 3....	580.27	574.98	5.29				184,900
82	Nov. 23, 1899	580.32	574.66	5.66		N.E.	17	195,200
6	May 6, 1899	0.32	4.96	5.36		S.	7	194,200
227	Sept. 16, 1902	0.32	5.16	5.16		S.	6	186,500
230	Sept. 17, 1902	0.32	5.16	5.16		S.	10	181,700
5	May 5, 1899	0.33	4.96	5.37		W.	7	190,900
155	Dec. 26, 1900	0.33	4.66	5.67		N.W.	10	194,200
62	Oct. 11, 1899	0.34	4.86	5.48		S.	13	190,000
99	July 3, 1900	0.34	5.16	5.18		S.W.	20	182,500
219	Sept. 8, 1902	0.36	5.26	5.10		S.W.	12	184,000
92	June 20, 1900	0.39	5.16	5.23		N.E.	10	191,700
D Means	Group 4....	580.34	575.00	5.34				189,100

Williams Ex. 21

2-Table Sheet 1 (7 Sheets)

U. S. LAKE SURVEY

Discharge Measurements—Dry Dock Section

ST. CLAIR RIVER

1899-1900-1902

	No. of Meas.	Date	Water Surface		Fall	Rise+ Fall-	Wind		Discharge Cu. Ft. per Sec.
			Lake Huron	St. Clair Flats			Dir.	Vel.	
	88	Dec. 2, 1899	580.39	574.86	5.53		S.W.	16	190,300
	10	May 31, 1899	0.39	5.21	5.18		S.	18	186,300
	139	Dec. 3, 1900	0.39	4.81	5.58		S.W.	10	191,200
	226	Sept. 15, 1902	0.39	5.26	5.13		S.W.	15	177,900
	131	Nov. 8, 1900	0.40	4.91	5.49		N.W.	12	191,600
	212	Sept. 3, 1902	0.41	5.26	5.15		S.W.	17	176,600
	94	June 22, 1900	0.42	5.16	5.26		E.	12	190,300
	148	Dec. 15, 1900	0.42	4.71	5.71		S.E.	6	193,800
	240	Sept. 26, 1902	0.43	5.46	4.97		S.	6	182,600
	225	Sept. 15, 1902	0.43	5.26	5.17		S.W.	13	182,100
E	Means	Group 5.....	580.41	575.09	5.32				186,300
	235	Sept. 22, 1902	580.44	575.16	5.28		S.W.	4	184,100
	231	Sept. 18, 1902	0.45	5.16	5.29		S.	9	183,500
	218	Sept. 6, 1902	0.46	5.26	5.20		S.W.	12	184,000
	8	May 25, 1899	0.46	5.16	5.30		S.W.	14	194,000
	90	Dec. 6, 1899	0.46	4.56	5.90		N.W.	20	198,800
	130	Sept. 19, 1900	0.47	5.11	5.36		S.E.	10	187,300
	220	Sept. 8, 1902	0.47	5.26	5.21		S.W.	20	176,700
	228	Sept. 16, 1902	0.47	5.16	5.31		S.	12	179,800
	142	Dec. 6, 1900	0.48	4.81	5.67		S.W.	12	190,200
	234	Sept. 22, 1902	0.48	5.16	5.32		S.W.	4	187,800
F	Means	Group 6.....	580.46	575.08	5.38				186,600
	138	Dec. 1, 1900	580.48	574.81	5.67		N.W.	12	196,800
	140	Dec. 4, 1900	0.48	4.81	5.67		N.W.	12	196,000
	9	May 29, 1899	0.49	5.21	5.28		S.	16	194,400
	72	Oct. 27, 1899	0.50	4.76	5.74		N.E.	10	196,900
	67	Oct. 18, 1899	0.51	4.86	5.65		S.W.	13	194,400
	91	June 19, 1900	0.51	5.16	5.35		N.E.	12	194,400
	129	Sept. 19, 1900	0.51	5.11	5.40		S.E.	14	185,700
	3	May 3, 1899	0.52	4.96	5.56		N.E.	15	191,200
	89	Dec. 4, 1899	0.52	4.56	5.96		N.W.	20	200,900
	95	June 25, 1900	0.53	5.16	5.37		N.E.	10	191,400
G	Means	Group 7.....	580.50	574.94	5.56				194,300
	102	July 7, 1899	580.54	57[illegible].16	5.38		S.W.	11	190,700
	236	Sept. 23, 1902	0.54	5.21	5.33		N.	5	187,900
	152	Dec. 20, 1900	0.55	4.[illegible]	5.89		N.W.	10	194,800
	69	Oct. 20, 1899	0.57	4.[illegible]	5.81		N.E.	12	200,400
	116	Aug. 4, 1900	0.57	5.[illegible]	.21		S.W.	11	186,900
	238	Sept. 24, 1902	0.57	5.[illegible]	.36		E.	20	190,800
	224	Sept. 13, 1902	0.58	5.[illegible]	.32		W.	15	187,000
	18	June 12, 1899	0.58	5.26	.22		S.	20	194,400
	233	Sept. 20, 1902	0.59	5.21	5.38		S.E.	3	188,600
	222	Sept. 11, 1902	0.59	.21	5.38		S.W.	12	190,100
H	Means	Group 8.....	580.57	575.14	5.43				191,900

Williams Ex. 21

3-Table Sheet 3 (7 Sheets)

U. S. LAKE SURVEY

Discharge Measurements—Dry Dock Section

ST. CLAIR RIVER

1899–1900–1902

No. of Meas.	Date	Water Surface		Fall	Rise+ Fall—	Wind		Discharge Cu. Ft. per Sec.
		Lake Huron	St. Clair Flats			Dir.	Vel.	
221	Sept. 10, 1902	580.59	575.26	5.33		S.W.	15	184,800
133	Nov. 10, 1900	0.60	4.86	5.74		S.W.	7	198,400
136	Nov. 16, 1900	0.60	4.86	5.74		S.W.	10	197,200
13	June 5, 1899	0.60	5.27	5.33		S.W.	18	196,000
68	Oct. 19, 1899	0.61	4.86	5.75		N.	9	197,600
71	Oct. 27, 1899	0.61	4.76	5.85		N.E.	9	198,800
115	Aug. 4, 1900	0.61	5.36	5.25		S.W.	10	188,200
123	Sept. 10, 1900	0.62	5.26	5.36		S.W.	8	191,600
124	Sept. 10, 1900	0.62	5.26	5.36		S.W.	7	190,400
12	June 3, 1899	0.62	5.26	5.36		E.	8	199,000
I Means	Group 9.....	580.61	575.10	5.51				194,200
73	Oct. 28, 1899	580.62	574.76	5.86		N.W.	10	194,600
74	Oct. 28, 1899	0.63	4.76	5.87		N.	10	196,300
237	Sept. 23, 1902	0.63	5.21	5.42		N.	12	190,600
7	May 23, 1899	0.64	5.16	5.48		N.	10	201,600
15	June 7, 1899	0.64	5.36	5.28		S.	16	196,400
132	Nov. 9, 1900	0.64	4.91	5.73		N.W.	20	198,600
216	Sept. 5, 1902	0.64	5.26	5.38		N.E.	6	194,500
101	July 7, 1900	0.66	5.16	5.50		S.W.	16	191,100
19	June 13, 1899	0.68	5.36	5.32		S.	18	193,900
96	June 29, 1900	0.68	5.16	5.52		N.W.	18	192,900
J Means	Group 10....	580.65	575.11	5.54				195,000
117	Aug. 6, 1900	580.68	575.36	5.32		W.	12	192,900
207	Aug. 26, 1902	0.69	5.36	5.33		W.	7	192,600
145	Dec. 10, 1900	0.69	4.81	5.88		N.W.	16	201,800
113	Aug. 2, 1900	0.69	5.36	5.33		S.W.	10	189,200
66	Oct. 17, 1899	0.70	4.86	5.84		N.W.	7	198,700
141	Dec. 5, 1900	0.70	4.81	5.89		N.W.	16	201,100
146	Dec. 11, 1900	0.70	4.81	5.89		N.W.	20	204,500
206	Aug. 25, 1902	0.70	5.46	5.24		N.	6	194,000
223	Sept. 12, 1902	0.71	5.26	5.45		S.W.	4	195,000
56	Sept. 7, 1899	0.72	5.16	5.56		S.	12	192,500
K Means	Group 11....	580.70	575.12	5.58				196,200
198	Aug. 18, 1902	580.72	575.51	5.21		S.W.	9	193,200
215	Sept. 5, 1902	0.72	5.26	5.46		W.	7	195,400
103	July 23, 1900	0.73	5.31	5.42		S.W.	7	189,400
109	July 28, 1900	0.73	5.36	5.37		S.W.	9	193,300
128	Sept. 18, 1900	0.73	5.06	5.67		E.	9	197,000
97	June 30, 1900	0.74	5.16	5.58		N.W.	17	196,400
14	June 6, 1899	0.74	5.30	5.44		S.W.	12	203,300
143	Dec. 7, 1900	0.75	4.81	5.94		N.E.	8	202,400
232	Sept. 19, 1902	0.75	5.21	5.54		N.	12	194,800
77	Nov. 3, 1899	0.75	4.83	5.92		N.E.	17	204,900
L Means	Group 12....	580.74	575.18	5.56				197,000

Williams Ex. 21. U. S. LAKE SURVEY 4-Table

Discharge Measurements—Dry Dock Section Sheet 4

ST. CLAIR RIVER (7 Sheets)

1899-1900-1902

	No. of Meas.	Date	Water Surface		Fall	Rise+ Fall—	Wind		Discharge Cu. Ft. per Sec.
			Lake Huron	St. Clair Flats			Dir.	Vel.	
	11	June 2, 1899	580.76	575.26	5.50		N.	14	204,200
	110	July 28, 1900	0.76	5.36	5.40		S.W.	12	194,300
	202	Aug. 20, 1902	0.76	5.46	5.30		S.E.	6	196,000
	135	Nov. 15, 1900	0.77	4.86	5.91		N.W.	20	200,500
	105	July 24, 1900	0.77	5.26	5.51		N.E.	9	190,500
	134	Nov. 13, 1900	0.78	4.86	5.92		N.W.	16	203,400
	118	Aug. 8, 1900	0.79	5.26	5.53		N.W.	15	193,800
	211	Sept. 2, 1902	0.79	5.36	5.43		N.	9	197,400
	64	Oct. 14, 1899	0.80	4.86	5.94		N.W.	18	209,200
	104	July 24, 1900	0.81	5.28	5.53		N.W.	13	191,200
M	Means	Group 13....	580.78	575.18	5.60				198,000
	114	Aug. 22, 1900	580.81	575.36	5.45		S.W.	7	196,400
	119	Aug. 8, 1900	0.81	5.26	5.55		N.W.	17	192,900
	120	Aug. 27, 1900	0.81	5.26	5.55		S.W.	12	191,000
	200	Aug. 19, 1902	0.81	5.46	5.35		N.	12	196,000
	210	Aug. 28, 1902	0.81	5.36	5.45		N.E.	14	196,700
	208	Aug. 26, 1902	0.82	5.36	5.46		W.	14	194,800
	195	Aug. 14, 1902	0.82	5.61	5.21		N.E.	6	197,400
	54	Sept. 1, 1899	0.82	5.26	5.56		N.	7	201,900
	20	June 14, 1899	0.84	5.36	5.48		S.	17	194,200
	112	Aug. 1, 1900	0.85	5.36	5.49		N.E.	9	195,000
N	Means	Group 14....	580.82	575.36	5.46				195,660
	122	Sept. 4, 1900	580.85	575.26	5.59		N.E.	8	193,100
	199	Aug. 18, 1902	0.85	5.51	5.34		S.W.	11	192,200
	52	Aug. 30, 1899	0.87	5.36	5.51		S.E.	11	199,900
	60	Sept. 22, 1899	0.87	5.06	5.81		N.W.	8	204,900
	201	Aug. 19, 1902	0.87	5.46	5.41		N.E.	13	201,800
	209	Aug. 27, 1902	0.87	5.42	5.45		N.	9	198,000
	121	Sept. 4, 1900	0.88	5.26	5.62		E.	9	195,100
	126	Sept. 14, 1900	0.89	5.21	5.68		N.E.	11	196,900
	53	Aug. 31, 1899	0.91	5.36	5.55		E.	9	200,700
	16	June 8, 1899	0.91	5.36	5.55		N.W.	10	206,700
O	Means	Group 15....	580.88	575.33	5.55				198,900
	17	June 10, 1899	580.92	575.36	5.56		N.	8	205,900
	55	Sept. 6, 1899	0.94	5.16	5.78		N.	10	202,900
	196	Aug. 15, 1902	0.95	5.61	5.34		N.	6	201,200
	203	Aug. 21, 1902	0.95	5.46	5.49		N.E.	12	202,000
	106	July 25, 1900	0.96	5.31	5.65		N.	18	197,900
	50	Aug. 28, 1899	0.96	5.36	5.60		N.	13	206,900
	21	June 15, 1899	0.96	5.36	5.60		N.W.	13	202,300
	111	July 31, 1900	0.96	5.36	5.60		N.W.	12	199,300
	193	Aug. 12, 1902	0.96	5.66	5.30		N.E.	11	199,500
	49	Aug. 24, 1899	0.97	5.36	5.61		S.	10	200,300
P	Means	Group 16....	580.95	575.40	5.55				201,900

Williams Ex. 21

5-Table Sheet 5 (7 Sheets)

U. S. LAKE SURVEY
Discharge Measurements—Dry Dock Section
ST. CLAIR RIVER
1899-1900-1902

	No. of Meas.	Date	Water Surface		Fall	Rise+ Fall-	Wind		Discharge Cu. Ft. per Sec.
			Lake Huron	St. Clair Flats			Dir.	Vel.	
	31	Aug. 29, 1899	580.98	575.36	5.62		E.	10	204,100
	214	Sept. 4, 1902	580.99	5.26	5.73		N.W.	22	209,600
	75	Nov. 1, 1899	581.00	4.86	6.14		N.	19	207,200
	204	Aug. 21, 1902	1.00	5.46	5.54		N.E.	12	201,500
	197	Aug. 16, 1902	1.00	5.51	5.49		N.E.	13	200,400
	194	Aug. 13, 1902	1.01	5.66	5.35		S.E.	8	194,400
	107	July 26, 1900	1.02	5.31	5.71		N.E.	10	200,900
	23	June 17, 1899	1.02	5.36	5.66		N.	8	205,100
	57	Sept. 8, 1899	1.02	5.16	5.86		N.W.	5	206,400
	58	Sept. 9, 1899	1.02	5.16	5.86		N.W.	8	204,300
Q	Means	Group 17....	581.01	575.31	5.70				203,400
	59	Sept. 14, 1899	581.04	575.16	5.88		S.E.	8	205,900
	108	July 26, 1900	1.04	5.31	5.73		N.E.	16	199,100
	147	Dec. 13, 1900	1.06	4.76	6.30		N.W.	25	214,100
	76	Nov. 1, 1899	1.07	4.86	6.21		N.	19	212,500
	46	Aug. 16, 1899	1.08	5.36	5.72		N.	10	205,400
	35	July 26, 1899	1.08	5.56	5.52		S.	12	196,700
	205	Aug. 22, 1902	1.08	5.46	5.62		N.W.	16	207,500
	31	July 20, 1899	1.09	5.55	5.54		S.E.	14	203,900
	27	July 15, 1899	1.09	5.56	5.53		S.E.	10	205,300
	213	Sept. 4, 1902	1.09	5.26	5.83		N.W.	20	213,500
R	Means	Group 18....	581.07	575.28	5.79				206,400
	43	Aug. 12, 1899	581.11	575.51	5.60		S.W.	17	203,100
	44	Aug. 14, 1899	1.11	5.46	5.65		N.	15	210,500
	48	Aug. 23, 1899	1.11	5.36	5.75		N.W.	10	206,700
	45	Aug. 15, 1899	1.12	5.46	5.66		N.	15	210,900
	22	June 16, 1899	1.13	5.36	5.77		N.W.	12	210,800
	33	July 24, 1899	1.14	5.56	5.58		N.	9	206,000
	125	Sept. 12, 1900	1.14	5.28	5.86		N.W.	20	200,600
	26	July 12, 1899	1.15	5.51	5.64		N.	12	211,800
	34	July 25, 1899	1.15	5.56	5.59		N.W.	9	206,800
	42	Aug. 8, 1899	1.16	5.56	5.60		N.	10	208,300
S	Means	Group 19....	581.13	575.46	5.67				207,600
	38	July 29, 1899	581.18	575.56	5.62		S.	18	206,200
	24	July 29, 1899	1.18	5.46	5.72		S.W.	10	207,100
	37	July 28, 1899	1.19	5.56	5.63		S.W.	9	205,300
	29	July 18, 1899	1.19	5.56	5.63		N.W.	13	206,800
	30	Aug. 3, 1899	1.18	5.56	5.62		S.	6	206,300
	40	Aug. 5, 1899	1.21	5.56	5.65		W.	6	205,000
	41	Aug. 7, 1899	1.22	5.56	5.66		N.	10	209,900
	32	July 22, 1899	1.22	5.56	5.66		N.W.	12	210,900
	25	July 11, 1899	1.25	5.51	5.74		W.	10	210,600
	30	July 19, 1899	1.28	5.56	5.72		N.W.	10	207,200
T	Means	Group 20....	581.21	575.54	5.67				207,800
	127	Sept. 17, 1900	581.29	575.08	6.21		N.W.	25	209,000
	36	July 27, 1899	1.33	5.56	5.77		N.E.	10	209,300
	47	Aug. 27, 1899	1.33	5.36	5.97		N.W.	12	217,400
	28	July 17, 1899	1.39	5.56	5.83		N.W.	15	218,900
U	Means	Group 21....	581.34	575.39	5.95				213,600

Williams Ex. 21.

U. S. LAKE SURVEY

Discharge Measurements—Dry Dock Section

ST. CLAIR RIVER

1901

A-Table Sheet 6 (7 Sheets)

No. of Meas.	Date	Water Surface		Fall	Rise + Fall —	Wind		Discharge Cu. Ft. per Sec.
		Lake Huron	St. Clair Flats			Dir.	Vel.	
164	May 22, 1901	580.37	574.76	5.61		S.W.	20	193,300
165	May 22, 1901	0.41	4.76	5.65		S.W.	20	194,600
182	June 11, 1901	0.62	4.96	5.66		S.W.	12	200,500
166	May 23, 1901	0.73	4.76	5.97		S.W.	10	203,500
167	May 23, 1901	0.77	4.76	6.01		S.W.	14	202,500
159	May 17, 1901	0.78	4.56	6.22		S.W.	7	206,000
157	May 14, 1901	0.79	4.54	6.25		N.E.	12	211,200
180	June 22, 1901	0.81	5.06	5.75		S.W.	14	201,600
174	June 4, 1901	0.82	4.96	5.86		S.W.	10	204,600
158	May 15, 1901	0.82	4.54	6.28		N.	12	210,700
Means	Group 1-01	580.69	574.77	5.92				202,800
181	June 11, 1901	580.83	574.96	5.87		W.	6	208,100
180	June 10, 1901	0.85	4.96	5.89		S.W.	12	202,200
160	May 18, 1901	0.86	4.61	6.25		N.	20	213,500
183	June 13, 1901	0.86	4.96	5.90		N.E.	7	205,100
187	June 17, 1901	0.88	5.01	5.87		E.	7	202,300
162	May 20, 1901	0.89	4.84	6.05		N.E.	10	210,000
161	May 20, 1901	0.89	4.79	6.10		N.E.	12	212,400
192	June 28, 1901	0.90	5.16	5.74		S.W.	18	198,900
163	May 21, 1901	0.90	4.81	6.09		E.	12	213,000
184	June 14, 1901	0.92	4.96	5.96		N.E.	5	209,100
Means	Group 2-01	580.88	574.91	4.97				207,700
179	June 10, 1901	580.92	574.96	5.96		S.W.	10	207,900
185	June 14, 1901	0.92	4.96	5.96		N.E.	12	206,600
188	June 20, 1901	0.92	5.06	5.86		E.	5	201,800
186	June 15, 1901	0.93	5.04	5.89		N.E.	15	208,900
173	June 3, 1901	0.95	4.96	5.99		N.W.	5	211,000
191	June 27, 1901	0.95	5.16	5.79		S.W.	9	206,400
190	June 26, 1901	581.02	5.11	5.91		S.W.	12	205,800
172	May 29, 1901	1.04	4.86	6.18		N.	11	211,000
171	May 28, 1901	1.08	4.96	6.12		N.	25	231,800
170	May 28, 1901	1.11	4.86	6.25		N.	20	219,400
Means	Group 3-01	580.98	574.98	6.00				209,000
178	June 8, 1901	581.11	574.96	6.15		N.E.	10	218,500
175	June 7, 1901	1.13	4.96	6.17		W.	20	208,800
176	June 7, 1901	1.14	4.96	6.18		W.	20	211,300
165	May 24, 1901	1.17	4.76	6.41		N.W.	15	216,100
169	May 25, 1901	1.19	4.76	6.43		N.	28	220,700
177	June 8, 1901	1.24	4.96	6.28		N.W.	12	215,100
Means	Group 4-01	581.16	574.89	6.27				213,400

Group	Meas. Disc.	Comp. Disc.
1-01 (V)	202,800	196,200
2-01 (W)	207,700	201,300
3-01 (X)	209,000	202,500
4-01 (Y)	213,400	203,700

Discharge was decreased by ¼ of 1 per cent for each tenth foot Lake St. Clair was below normal, as expressed by equation St. Clair = 574.79 + 0.60 (Harbor Beach — 580).

Elevations of St. Clair have not been corrected for adjustment of December, 1903, which increased elevations 0.06 feet.

Williams Ex. 21.

U. S. LAKE SURVEY

Discharge Measurements—Dry Dock Section

ST. CLAIR RIVER

1908

Table

Sheet 7
(7 Sheets)

No. of Meas.	Date	Water Surface		Fall	Rise + Fall −	Wind		Discharge Cu. Ft. per Sec.
		Lake Huron	St. Clair Flats			Dir.	Vel.	
0813	Dec. 14, 1908	579.90	575.03	4.87		S.E.	8	167,950
0814	Dec. 14, 1908	579.94	4.99	4.95		S E.	8	173,270
0812	Nov. 23, 1908	580.03	5.09	4.94		S.E.	2-20	178,300
0815	Dec. 18, 1908	0.11	4.92	5.19		N.W.	25	181,520
0811	Nov. 21, 1908	0.23	5.10	5.13		S.E.	8	189,680
083	Nov. 7, 1908	0.48	5.37	5.11		W.	20	166,930
080	Nov. 11, 1908	0.48	5.28	5.20		N.W.	6	191,870
I Means	Group 1-08.	580.17	575.11	5.06				182,500
0810	Nov. 11, 1908	580.51	575.31	5.20		N.W.	18	195,090
088	Nov. 10, 1908	0.52	5.31	5.21		S.W.	4	190,160
086	Nov. 10, 1908	0.56	5.32	5.24		N.E.	2	191,160
08	Nov. 10, 1908	0.60	5.32	5.28		N.E.	2	192,570
084	Nov. 9, 1908	0.61	5.37	5.24		S.W.	30	191,380
081	Nov. 7, 1908	0.62	5.38	5.24		S.W.	20	190,420
085	Nov. 9, 1908	0.67	5.37	5.30		S.W.	20	197,460
072	Nov. 7, 1908	0.69	5.38	5.31		S.W.	25	187,760
X Means	Group 2-08.	580.59	575.34	5.25				191,000

TABLE B. U.S. LAKE SURVEY Sheet 1 (6 Sheets)
Williams Ex. 22 HYDRAULICS OF ST. CLAIR RIVER
MEAN SLOPE
FOR PERIOD NOVEMBER-DECEMBER 1908

SIDNEY MOORE, Asst. Engr.
APRIL, 1909.

GAGES	Miles from Ft. Gratiot Lighthouse	Differences of Distances	Mean Elevation Nov.-Dec. 1908	Differences of Elevation	Fall from Ft. Gratiot L.H.
Harbor Beach	53.		584.38		
		17.6		0.12	
Huronia Beach	1.36		584.26		
		1.36		0.07	
Ft. Gratiot L.H.	0.00		584.19		0.00
		0.26		0.63	
Sect. on Gorge	0.26		583.56		0.63
		0.08		0.24	
Section Gage (1908)	0.34		583.32		0.87
		0.46		-0.20	
G.T.R.	0.80		583.52		0.67
		1.57		0.41	
Mouth of Black River	2.37		583.11		1.08
		2.53		0.42	
Dry Dock (Dunford)	4.90		582.69		1.50
		2.10		0.45	
Roberts Landing	26.9		582.24		1.95
		13.8		0.10	
St. Clair Flats Canal	38.8		582.14		2.05

Williams Ex. 22

U. S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

Summary of Discharge Measurements
Section Gorge

Sheet 2
(6 Sheets)
Table 5
Sherman Moore, Jun. Engr.
April, 1906

No.	Date 1906	Water Surface Elevations				Fall		Change at Lake		Wind		Volume of Discharge					Weighted Mean Index Velocity
		Fort Gratiot	G.T.R.	Dry Dock	St. Clair Flats	Ft. G. G.T.R.	G.T.R. D.D.	Rise	Fall	Dir.	Vel. miles	46A	1B	14B	15B	Adopted	
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S
1	Nov. 18	580.58	579.62	578.75	573.07	0.96	0.87	0.10	0.01	W.N.W.	20		195,660			195,660	6.49
2	Nov. 27	580.35	579.73	578.87	573.10	0.62	0.85	0.05	0.25	S.W.	40		190,230	180,040		185,130	6.14
3	Nov. 27	580.53	579.68	578.96	573.11	0.85	0.88	0.09	0.22	S.W.	25		196,830	192,960		194,400	6.42
4	Nov. 26	579.90	579.29	578.53	573.12	0.61	0.80	0.14	0.13	S.W.	20	172,660	175,570			174,700	5.85
5	Nov. 26	580.06	579.45	578.66	573.13	0.61	0.79	0.20	0.17	S.	18		178,640	176,750		177,700	5.91
6	Dec. 1	580.49	579.84	579.01	573.11	0.65	0.83	0.06	0.02	S.W.	35		195,470	191,090		193,280	6.38
7	Dec. 2	580.75	580.04	579.13	573.11	0.71	0.91	0.09	0.05	W.S.W.	20	203,710		200,110		201,910	6.63
8	Dec. 3	580.67	579.95	579.11	573.12	0.72	0.87	0.07	0.13	W.S.W.	20	190,250		194,540		196,900	6.48
9	Dec. 4	580.37	579.70	578.84	573.07	0.67	0.86	0.20	0.24	S.W.	16		189,360		189,800	189,580	6.27
10	Dec. 9	580.38	579.68	578.72	574.98	0.70	0.96	0.24	0.35	W.	10		188,270		201,000	188,270	6.27
11	Dec. 9	580.11	579.40	578.63	574.94	0.65	0.83	0.13	0.14	N.W.	8		185,230		194,220	185,230	6.19
12	Dec. 10	579.96	579.23	578.48	574.96	0.65	0.82	0.09	0.19	S.E.	3		183,570	182,910		183,240	6.13
13	Dec. 10	580.00	579.34	578.58	574.97	0.66	0.81	0.14	0.20	S.E.	12		180,090	181,640		180,860	6.05
14	Dec. 11	579.93	579.31	578.46	574.89	0.62	0.83	0.26	0.26	W.	4	180,510		181,900		181,200	6.06
15	Dec. 12	580.03	579.30	578.57	574.96	0.64	0.82	0.41	0.32	S.W.	12	181,060			192,570	181,060	6.03
16	Dec. 12	580.11	579.46	578.67	574.97	0.65	0.81	0.01	0.40	S.W.	15	178,040			191,430	178,040	6.09
17	Dec. 15	580.11	579.44	578.60	574.94	0.67	0.84	0.19	0.19	S.W.	8			184,060	197,260	184,060	6.16
18	Dec. 16	580.08	579.41	578.39	574.92	0.67	0.83	0.12	0.08	N.W.	4	188,730	182,860			185,680	6.19
19	Dec. 16	580.10	579.42	578.37	574.92	0.68	0.85	0.04	0.12	N.W.	2	191,040	183,730			187,400	6.25
20	Dec. 17	580.06	579.33	578.46	574.98	0.73	0.85	0.16	0.20	N.E.	13	192,430			198,740	192,430	6.45
21	Dec. 18	579.77	579.13	578.20	575.06	0.64	0.79	0.33	0.33	S.S.W.	35		166,400	174,510		170,460	5.74
22	Dec. 19	579.77	579.17	578.42	575.10	0.60	0.75	0.47	0.17	S.W.	10		166,100	170,860		168,480	5.66

Williams Exhibit 22.

U. S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

Summary of Discharge Measurements
Section Dry Dock

Sheet 1
(6 Sheets)
Table 7
Sherman Moore, Jun. Engr.
April, 1909

Number	Date 1908	Water Surface Elevations				Fall		Change at Lake		Wind		VOLUME OF DISCHARGE (cubic feet per second)				
		Pipe Grates	G.T.R.	Dry Dock	St. Clair Flats	Ft. G. G.T.R.	G.T.R. D.D.	Rise	Fall	Dir.	Vel. Miles	44A	1B	14B	16B	Adopted
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R
8801	Nov. 1	580.46	579.51	579.60	578.36	0.88	0.91	0.01	0.11	S.W.	20		190,940	189,000		190,420
8802	Nov. 2	580.51	579.58	579.67	578.36	0.92	0.91	0.02	0.11	S.W.	22		189,270	186,240		187,760
8803	Nov. 7	580.39	579.60	579.64	578.37	0.94	0.92	0.08	0.10	W	20		187,860	184,000		186,930
8804	Nov. 8	580.43	579.70	579.76	578.37	0.89	0.86	0.13	0.26	S.W.	28	188,720			189,000	191,360
8805	Nov. 9	580.49	579.72	579.87	578.37	0.87	0.85	0.16	0.28	S.W.	30	195,040			190,870	197,600
8806	Nov. 10	580.38	579.76	579.84	578.33	0.89	0.88	0.04	0.32	N.E.	3	189,780		189,540		191,140
8807	Nov. 10	580.43	579.73	579.80	578.33	0.90	0.87	0.15	0.11	N.E.	7	192,460		189,540		192,570
8808	Nov. 10	580.34	579.68	579.76	578.31	0.89	0.87	0.04	0.79	S.W.	4	188,200	191,120			190,160
8809	Nov. 11	580.30	579.69	579.69	578.31	0.84	0.84	0.16	0.14	N.W.	6		189,812		189,000	191,570
8810	Nov. 11	580.33	579.67	579.84	578.31	0.86	0.83	0.06	0.15	N.W.	16		192,540		187,440	189,060
8811	Nov. 21	580.42	579.69	579.84	578.30	0.82	0.86	0.19	0.22	S.E.	6		188,610		189,780	188,880
8812	Nov. 20	579.85	579.24	579.41	578.08	0.61	0.82	0.10	0.30	S.E.	3-20		179,020	176,970		178,200
8813	Dec. 14	579.72	579.14	579.30	578.08	0.64	0.78	0.05	0.20	S.E.	6		177,660		179,280	177,990
8814	Dec. 14	579.78	579.17	579.30	578.09	0.60	0.78	0.02	0.14	S.E.	6		178,270		183,510	179,370
8815	Dec. 15	579.98	579.30	579.51	578.09	0.68	0.79	0.12	0.09	N.W.	28		179,780	180,280		181,530
	Mean....	580.13			578.34											187,980

Williams Exhibit 22.

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HYDRAULICS OF ST. CLAIR RIVER.
Discharge of St. Clair River.
Section "George."

(1) Sheet 1
Table 2 (a)
Sherman Moore, Jun. Engr.
March, 1920

Number	Date	Water Section Elevations				Fall		Change at Lake		Wind		Ratings				Volume of Discharge (cubic ft. per sec.)					Weighted Mean Index Velocity
		First Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. G. to G.T.R.	G.T.R. to D.D.	Rise	Fall	Dir.	Vel. Miles	1B	14B	15B	46A	1B	14B	15B	46A	Adopted	
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
1	1908																				
2	Nov. 15	580.11	579.69	579.71	579.07	0.99	0.91	0.10	0.01	W.N.W.	30	10				192,850				192,900	6.43
3	27	580.25	579.73	579.89	579.10	0.52	0.89	0.06	0.26	S.W.	40	10	12			188,570	176,710			188,900	6.14
4	28	579.90	579.32	579.48	578.18	0.58	0.84	0.14	0.13	S.W.	20	10	12			194,250	191,410			192,800	6.43
5	30	580.06	579.45	579.63	578.13	0.61	0.82	0.54	0.34	S.	12	10			11	175,240			171,170	173,200	6.86
6	Dec. 1	*580.53	579.84	579.97	578.11	*0.69	0.27	0.09	0.02	S.W.	25	10	12			176,970	174,990			176,000	5.91
7	2	580.75	580.04	579.09	578.11	0.71	0.98	0.10	0.05	W.S.W.	30		12				180,440			180,400	5.85
8	3	580.07	579.36	579.07	578.13	0.71	0.23	0.07	0.10	W.S.W.	30		12		11		198,760		201,980	200,400	6.62
9	4	580.37	579.76	579.80	578.07	0.61	0.91	0.07	0.10	W.S.W.	30		12		11		193,250		197,500	195,400	6.46
10	9	580.28	579.16	579.86	578.06	0.72	0.90	0.28	0.19	S.W.	16	11		12		187,690		198,170		187,700	5.27
11	9	580.11	579.46	579.59	578.04	0.65	0.87	0.13	0.13	W.	10	11		12		188,750		199,260		186,850	5.27
12	10	579.96	579.26	579.44	578.06	0.70	0.86	0.10	0.13	N.W.	8	11		12		183,670		193,520		188,700	5.19
13	11	580.09	579.34	579.49	578.07	0.75	0.85	0.14	0.10	S.E.	3	11	12			181,990	181,280			181,630	5.13
14	11	579.95	579.21	579.44	578.09	0.74	0.87	0.14	0.17	S.E.	12	11	12			178,540	179,980			179,300	5.06
15	12	580.03	579.30	579.52	578.06	0.73	0.88	0.20	0.06	W.	4				11		180,810		178,980	179,600	4.98
16	13	580.11	579.43	579.62	578.07	0.68	0.86	0.41	0.36	S.W.	13			12	11			190,680	179,980	179,800	5.08
17	15	580.11	579.44	579.66	578.04	0.67	0.88	0.01	0.40	S.W.	15			12	11			189,910	181,290	181,200	5.09
18	16	580.08	579.41	579.65	578.05	0.67	0.88	0.19	0.19	S.W.	8		12	12			182,500	186,620		183,500	5.16
19	16	580.10	579.42	579.53	578.02	0.68	0.89	0.13	0.09	N.W.	4	11			11	190,770			187,120	182,900	5.19
20	17	580.06	579.35	579.46	578.04	0.71	0.89	0.04	0.13	N.W.	2	11			11	182,190			189,530	185,900	5.25
21	18	579.97	579.16	579.36	578.03	0.81	0.80	0.13	0.20	N.E.	8-16			12	11			197,220	191,040	191,000	5.48
22	19	579.77	579.17	579.36	578.10	0.60	0.79	0.47	0.17	S.W.	10	11	12			164,780	172,840			168,800	5.74
												11	12			164,740	169,420			167,100	5.66
												16B	14B	15B	Price	16B	14B	15B	Price		
23	1908																				
24	Oct. 13	580.32	579.97	579.93	578.20	0.65	0.84	0.22	0.29	W.	15	H	G			186,260	188,800			186,000	6.23
25	14	580.18	579.82	579.90	578.25	0.70	0.83	0.06	0.15	W.	15	H		X		188,710		191,220		190,000	6.37
26	15	580.47	579.75	579.93	578.24	0.72	0.82	0.05	0.13	W.N.W.	18-30	H		X		184,570		189,610		187,100	6.19
27	16	580.49	579.71	579.86	578.23	0.78	0.85	0.03	0.05	W.N.W.	28	H		X		182,330		188,550		185,400	6.13
28	16	580.41	579.65	579.84	578.24	0.76	0.89	0.05	0.11	W.N.W.	20	H		X		191,740		193,750		192,700	6.34
29	26	579.76	579.20	579.41	578.21	0.56	0.79	0.19	0.19	S.W.	15	H		X		170,060		167,850		169,000	5.67
30	26	579.88	579.27	579.41	578.23	0.61	0.86	0.24	0.00	S.W.	15	H		X		171,000		166,800		169,900	5.72
31	27	580.25	579.80	579.73	578.21	0.45	0.87	0.13	0.14	W.	8	H	G			186,790	188,030			187,900	6.22
32	27	580.23	579.99	579.82	578.20	0.53	0.87	0.26	0.07	W.	20	H	G			191,040	193,960			192,500	6.33
33	27	580.25	579.95	579.82	578.21	0.60	0.83	0.04	0.26	W.	20	H	G			187,670	189,030			188,400	6.24
34	28	580.14	579.48	579.61	578.14	0.62	0.87	0.06	0.12	W.	10	H	G			190,230	189,270			189,800	6.34
35	Nov. 1	579.73	579.10	*579.30	*578.12	0.63	*0.90	0.09	0.06	S.E.	8	H	G			185,460	182,910			184,700	6.16
														X			178,630	177,190		177,900	6.01

*Elevations interpolated.

Williams Ex. 22.

Williams Ex. 22.

U. S. LAKE SURVEY.
HYDRAULICS OF ST. CLAIR RIVER.
Discharge of St. Clair River.
Section Gorge.

Sheet 5
(6 Sheets)
Table 2, p. 2
Sherman Moore, Jun. Eng.
March, 1910

Number	Date	Water Surface Elevations				Fall		Change at Lake		Wind		Ratings				Volume of Discharge (cu. ft. per sec.)					Weighted Mean Index Velocity
		Fort Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. G. to G.T.R.	G.T.R. to D.D.	Rise	Fall	Dir.	Vel. Miles	10B	14B	15B	Price	10B	14B	15B	Price	Adopted	
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
36	1909																				
37	Nov. 1	579.78	579.15	*578.26	*575.11	0.63	*0.89	0.16	0.12	S.E.	7		G	X			174,740	176,580		175,700	5.92
38	4	580.23	579.61	578.74	575.00	0.71	0.87	0.27	0.15	W.	6			X	F			194,280	199,700	194,900	6.47
39	5	580.02	579.34	578.51	575.00	0.68	0.83	0.04	0.09	W.	6	H			F	184,570			190,630	184,600	6.18
40	5	579.98	579.29	578.50	575.02	0.69	0.79	0.21	0.21	W.	6	H			F	183,380			186,860	183,400	6.16
41	8	580.00	579.36	578.48	575.00	0.73	0.88	0.41	0.04	S.W.	4	H				182,886				182,900	6.13
42	8	579.99	579.31	578.55	575.02	0.68	0.76	0.09	0.3	S.	4	H				177,850				177,800	5.96
43	6	580.01	579.33	578.48	575.02	0.69	0.82	0.23	0.09	N.E.	8	H		X		180,060		181,570		181,000	6.06
44	6	579.97	579.28	578.50	575.00	0.69	0.78	0.07	0.13	N.E.	8	H		X		180,410		181,210		180,800	6.07
45	6	580.00	579.29	578.48	575.00	0.71	0.83	0.11	0.12	N.E.	8	H		X		182,760		183,560		183,700	6.17
46	6	579.97	579.24	578.42	575.10	0.73	0.82	0.09	0.15	N.E.	8	H				180,630				180,600	6.06
47	10	579.88	579.85	*578.02	575.08	0.63	*0.93	0.07	0.07	S.E.	5			X	F			168,950	169,530	169,000	5.72
48	10	579.76	579.07	*578.03	575.08	0.69	*1.04	0.17	0.02	S.E.	5			X	F			174,480	173,460	174,500	5.89
49	13	*579.68	579.07	*578.21	575.06	*0.61	*0.86	0.10	0.25	S.E.	6	H		X		173,420		177,010		175,200	5.91
50	Dec. 2	579.66	579.07	578.25	575.11	0.61	0.82	0.06	0.07	N.E.	10	H	G			176,210	180,170			178,200	6.02
51	2	579.69	579.09	578.29	575.10	0.60	0.80	0.11	0.01	N.E.	10	H	G			174,180	179,550			174,300	5.96
52	2	579.78	579.13	578.33	575.11	0.65	0.80	0.09	0.08	N.E.	6	H	G			174,950	180,230			175,000	5.96
53	2	579.76	579.14	578.34	575.12	0.62	0.80	0.07	0.12	N.E.	6	H	G			176,040	182,180			176,000	6.03
54	2	579.89	579.17	*578.39	575.06	0.72	*0.88	0.13	0.10	NE.-SE	2-2		G	H			184,640	178,640		178,600	6.10
55	4	579.76	579.14	*578.27	575.06	0.62	*0.87	0.24	0.10	SE-SW.	2-2		G	H			181,620	173,340		175,200	6.00
56	4	579.71	579.11	*578.28	575.07	0.60	*0.83	0.22	0.06	S.E.	2		G	H			172,780	171,870		172,200	5.89
57	6	579.50	578.90	578.26	575.06	0.51	0.73	0.21	0.11	S.W.	3-0	H	G			158,120	164,040			161,100	5.45
58	6	579.84	579.25	578.43	575.07	0.59	0.82	0.48	0.20	S.W.	15		G				179,000			179,000	5.99
59	9	580.05	579.45	*578.70	575.15	0.60	*0.75	0.24	0.11	S.W.	15		G	H			178,830	171,090		174,900	5.83
60	10	580.16	579.53	*578.73	575.11	0.63	*0.80	0.05	0.12	S.W.	15	H	G			188,220	185,600			186,900	6.21
61	10	580.21	579.56	*578.72	575.09	0.65	*0.84	0.11	0.31	W.	15	H	G			189,780	187,970			188,900	6.27

*Elevations interpolated.

HYDRAULICS OF RIVERS. Appendix 2.
Discharge of St. Clair River (6 Sheets) Table 6.
Section Dry Dock Sherman Moore, Jun. Engr.
March, 1910

Number	Date	Water Surface Elevations				Fall		Change in Lake		Wind		Ratings					Volume of Discharge (Cubic feet per second)					
		Fort Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. G. to G.T.R.	G.T.R. to Dry Dock	Rise	Fall	Dir.	Vel. Miles	46A	1B	14B	15B		46A	1B	14B	15B		Adopted
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
	1908																					
09- 1	Nov. 7	*580.48	579.61	578.96	575.36	0.68	0.85	0.31	0.11	S.W.	20		10	12				190,940	189,900				
09- 2	7	*580.44	579.53	578.93	575.36	0.71	0.90	0.02	0.31	S.W.	25		10	12				188,270	186,280				190,400
09- 3	7	*580.33	579.46	578.80	575.37	0.67	0.86	0.06	0.10	W.	20		10	12				187,860	186,000				187,800
09- 4	9	*580.45	579.75	578.85	*575.37	0.70	0.90	0.12	0.26	S.W.	30	11			12		188,720			193,930			190,900
09- 5	9	*580.52	579.82	578.93	*575.37	0.70	0.89	0.16	0.08	S.W.	20	11			12		196,040			190,870			191,400
09- 6	10	*580.39	579.70	578.80	*575.32	0.69	0.90	0.04	0.13	N.E.	2	11		12			189,790		192,540				197,500
09- 7	10	*580.43	579.73	578.83	*575.32	0.70	0.91	0.15	0.11	N.E.	2	11		12			192,490		192,580				191,200
09- 8	10	*580.34	579.65	578.74	*575.31	0.69	0.91	0.04	0.19	S.W.	4	11	10				189,200	191,120					192,600
09- 9	11	*580.34	579.66	578.78	*575.25	0.68	0.88	0.15	0.14	N.W.	6		10		12			188,810					190,300
09-10	11	*580.34	579.67	578.80	*575.31	0.67	0.87	0.08	0.15	N.W.	15		10		12			192,540		193,930			191,900
09-11	21	*580.05	579.40	578.50	*575.10	0.65	0.90	0.19	0.23	S.E.	8		10		12			189,610		197,940			195,100
09-12	23	579.85	579.24	578.37	*575.09	0.61	0.87	0.10	0.28	S.E.	2-20		10	12				179,620	176,870	189,760			189,700
09-13	Dec. 14	579.72	579.14	578.32	575.03	0.58	0.82	0.05	0.20	S.E.	8		10		12			167,950		179,380			178,300
09-14	14	579.76	579.17	578.35	574.99	0.59	0.82	0.22	0.14	S.E.	8		11		12			173,270		183,520			168,000
09-15	18	579.63	579.30	578.47	*574.92	0.62	0.83	0.12	0.29	N.W.	25		11	12				179,750	183,280				173,300
																							181,500
												267	268	14B	15B	10B	267	268	14B	15B	10B	
09- 1	Nov. 15	580.24	579.56	578.65	575.05	0.66	0.91	0.24	0.20	S.W.	15	G				H	197,430				193,740	193,700
09- 2	15	580.26	579.66	578.78	575.03	0.70	0.90	0.07	0.35	W.	5	G				H	200,860				190,130	190,100
09- 3	16	579.92	579.32	578.40	575.17	0.66	0.83	0.26	0.26	N.E.	12-30		G	G				190,950	187,660				187,600
09- 4	16	579.66	579.02	578.22	575.13	0.54	0.80	0.30	0.50	E.-S.E.	12		G	G				172,480	170,550				171,000
09- 5	19	579.78	579.19	578.30	575.10	0.59	0.80	0.15	0.16	S.E.	18	G			H		185,420			176,520			176,600
09- 6	19	579.80	579.22	578.41	575.09	0.58	0.81	0.12	0.23	S.E.	20	G			H		187,750			183,760			183,800
09- 7	20	579.42	578.91	578.16	575.08	0.53	0.75	0.36	0.42	S.E.	25-35		G			H		181,170			163,200		163,200
09- 8	20	579.80	579.22	578.35	574.98	0.58	0.87	0.53	0.18	S.E.-S.W.	35-10		G			H		180,700			178,470		178,500
09- 9	22	580.23	579.57	578.70	575.21	0.66	0.87	0.34	0.47	N.W.	10-18	G		G			203,300		202,270				203,300
09-10	22	580.18	579.50	578.64	575.25	0.65	0.86	0.13	0.27	N.W.	18	G		G			197,270		197,280				197,300
09-11	24	579.95	579.30	578.33	575.26	0.65	0.92	0.09	0.29	N.E.	4		G		H			190,940		189,460			189,500
09-12	24	579.80	579.20	578.39	575.25	0.60	0.81	0.29	0.25	N.E.	4		G		H			185,220		184,180			184,200
09-13	26	579.84	579.27	578.50	575.21	0.57	0.77	0.16	0.14	N.E.	2				H	I				180,270	178,990		179,000
09-14	26	579.85	579.27	578.44	575.20	0.58	0.83	0.34	0.35	S.E.	2			I	H				182,830	179,660			181,900
09-15	27	579.45	578.90	578.12	575.16	0.55	0.78	0.35	0.31	S.E.	10-20			I		H			168,930		169,980		169,400
09-16	27	579.44	578.95	578.18	575.14	0.50	0.77	0.33	0.17	S.E.	18			I		H			167,840		169,200		168,500
09-17	27	579.63	579.06	578.26	575.14	0.57	0.80	0.20	0.36	S.E.-S.W.	18-8			G		I			170,310		169,010		169,700
09-18	28	580.05	579.40	578.55	575.09	0.65	0.85	0.33	0.44	N.W.	15	G	G				194,200	194,200					
09-19	29	579.97	579.35	578.50	575.13	0.62	0.85	0.25	0.12	N.	12-0	G	G				195,450	196,550					
09-20	29	579.83	579.24	578.44	575.15	0.59	0.80	0.24	0.29	N.W.	12	G	G				188,780	186,870					
09-21	30	579.79	579.17	578.36	575.12	0.62	0.81	0.22	0.25	N.E.	0	G				I	181,050				176,130		176,100
09-22	30	579.82	579.18	578.38	575.12	0.64	0.80	0.27	0.15	E.	0	G				I	183,360				178,720		178,700
09-23	30	579.90	579.27	578.44	575.11	0.63	0.83	0.31	0.28	E.	0	G				I	182,490				178,710		178,700
09-24	Dec. 7	580.18	579.53	578.63	575.14	0.65	0.91	0.76	0.84	S.W.	12-60	G			I		190,200			190,880			190,900

*Elevations Interpolated.

Williams Exhibit 22.

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U. S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

Daily Mean Water Surface Elevations—Adjusted Levels of 1903

May 1910	Harbor Beach	Fort Gratiot (Shore)	Section Gorge	G. T. R.	M. B. R.	Dry Dock Section	St. Clair	Marine City	Roberts Landing	Herson Island	Salt Block	St. Clair Flats Canal
A	B	C	D	E	F	G	H	I	K	L	M	N
1	580.29	580.11	579.68	579.51	.....	578.70	577.84	576.77	576.36	575.91	575.60	575.07
2	580.42	580.26	579.79	579.72	.....	578.88	577.71	576.80	576.45	575.99	575.87	575.62
3	580.41	580.53	.....	579.85	.....	579.00	577.94	577.01	576.57	576.11	575.94	575.74
4	580.43	580.35	.....	579.75	*579.25	578.98	577.81	577.03	576.61	576.16	576.05	575.84
5	580.40	580.28	.....	579.66	*579.26	578.96	577.76	576.99	576.60	576.19	576.04	575.80
6	580.40	580.21	*579.67	*579.63	*579.20	578.84	577.73	576.96	576.57	576.15	576.02	575.82
7	580.28	580.17	579.67	579.57	579.20	578.81	577.86	576.92	576.51	576.10	575.99	575.77
8	580.21	580.10	579.58	579.50	579.13	578.74	577.63	576.87	576.47	576.06	575.96	575.71
9	580.34	580.14	579.68	579.55	*579.11	578.76	577.64	576.88	576.47	576.04	575.98	575.70
10	580.42	580.22	579.69	579.58	579.22	578.81	577.66	576.89	576.47	576.03	575.98	575.67
11	580.42	580.28	579.75	579.64	579.23	578.82	577.69	576.91	576.38	575.96	575.75	575.80
12	580.50	580.35	579.78	579.68	579.28	578.86	577.68	576.83	576.40	575.94	575.78	575.66
13	580.43	580.38	579.81	579.71	579.30	578.88	*577.64	576.82	576.39	575.92	575.77	575.66
14	580.33	580.16	579.62	579.52	579.13	578.73	577.55	576.78	576.33	575.90	575.79	575.62
15	580.34	580.09	579.55	579.44	*579.08	578.65	577.50	576.73	576.33	575.86	575.81	575.64
16	580.29	579.97	579.47	579.40	*579.02	578.60	577.45	576.68	576.29	575.87	575.78	575.64
17	580.12	*579.66	579.33	579.22	.....	578.50	577.43	576.73	576.35	575.88	575.90	575.59
18	580.45	580.19	579.69	579.59	.....	578.80	577.65	576.89	576.47	576.02	575.93	575.64
19	580.35	580.12	579.60	579.51	*579.10	578.71	577.53	576.74	576.34	575.89	575.80	575.53
20	580.36	580.02	579.58	579.44	*578.90	578.63	577.46	576.71	576.31	575.86	575.79	575.66
21	580.36	580.16	579.68	579.54	*579.15	578.73	577.56	576.75	576.34	575.90	575.79	575.53
22	580.34	580.10	579.66	579.55	*579.10	578.70	577.53	576.77	576.35	575.92	575.82	575.59
23	580.44	580.14	579.68	579.53	*579.19	578.77	577.62	576.85	576.44	576.01	575.98	575.65
24	580.51	580.25	579.74	579.62	.....	578.84	577.66	576.88	576.45	575.99	575.90	575.64
25	580.49	580.23	579.79	579.66	.....	578.84	577.66	576.84	576.43	575.99	575.85	575.62
26	580.53	580.35	579.82	579.71	*579.36	578.88	577.68	576.88	576.43	575.97	575.85	575.60
27	580.51	*580.23	579.79	579.69	.....	578.86	*577.66	576.82	576.41	575.96	575.84	575.59
28	580.43	580.23	579.69	579.56	.....	578.78	577.60	576.81	576.39	575.94	575.84	575.59
29	580.36	580.09	579.62	579.53	.....	578.73	577.61	576.87	576.45	576.03	575.96	575.65
30	580.46	580.41	579.91	579.78	.....	578.96	577.75	576.92	576.50	576.04	575.90	575.59
31	580.48	580.50	580.01	579.90	*579.47	579.06	577.82	576.97	576.50	*576.02	*575.88	575.59
Mean	580.40	580.21	579.68	579.60	579.19	578.80	577.63	576.85	576.43	575.99	575.88	575.62

*Less than 30 hourly readings.

Williams Exhibit 23.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Daily Mean Water Surface Elevations—Adjusted Levels of 1903

Sheet 2
(37 Sheets)
2-Table 2

June 1910	Harbor Beach	Fort Gratiot (Shore)	Sectina Gorge	G. T. R.	M. B. R.	Dry Dock Section	St. Clair	Marine City	Roberts Landing	Herson Island	Salt Block	St. Clair Flats Canal
A	B	C	D	E	F	G	H	I	K	L	M	N
1	580.61	580.43	579.90	579.77	.....	578.95	577.74	576.92	576.47	*575.90	575.88	575.59
2	580.59	580.76	579.94	579.80	.....	579.06	*577.73	576.90	*576.45	575.96	575.85	575.59
3	580.58	580.70	579.98	579.82	.....	*579.18	577.77	576.94	.....	576.02	575.90	575.65
4	580.43	580.31	579.79	579.64	*579.30	*579.02	577.70	576.90	*576.51	576.02	575.94	575.66
5	580.48	580.25	579.78	579.62	.....	578.86	577.69	576.91	576.50	576.03	575.99	575.71
6	580.54	580.37	579.86	579.71	.....	579.03	*577.74	576.96	576.53	576.06	575.97	575.71
7	580.62	580.45	*579.90	579.76	*579.41	578.98	577.76	576.97	576.53	576.06	575.96	575.69
8	580.57	580.36	579.84	579.71	.....	578.92	*577.71	576.92	576.52	576.05	575.95	575.72
9	580.49	580.45	579.82	579.67	.....	578.89	*577.69	576.90	576.48	576.02	575.93	575.67
10	580.55	580.65	579.88	579.71	.....	578.91	*577.69	576.81	576.46	576.00	575.90	575.66
11	580.61	581.07	579.96	579.78	.....	578.97	*577.72	576.78	576.44	576.01	575.89	575.65
12	580.69	580.42	*579.88	579.71	.....	578.93	*577.73	576.84	576.50	576.07	575.98	575.70
13	580.55	580.35	*579.82	579.66	.....	578.89	577.71	576.81	576.49	576.05	*575.96	575.70
14	580.58	*580.33	579.81	579.67	.....	578.88	577.70	576.85	576.48	576.04	*575.95	575.69
15	580.57	*580.35	579.83	579.67	.....	578.92	*577.71	576.92	576.48	576.04	575.95	575.68
16	580.53	.....	579.81	579.68	.....	578.90	.....	576.91	576.47	576.03	575.94	575.67
17	580.48	580.32	579.78	579.64	*579.12	578.85	*577.64	576.88	576.46	576.01	575.93	575.66
18	580.55	580.41	579.80	579.72	579.32	578.94	577.70	576.91	576.47	576.02	579.92	575.66
19	580.51	580.32	579.81	579.68	*579.32	578.89	577.67	576.90	576.46	576.01	575.92	575.65
20	580.54	580.36	579.83	579.71	.....	578.91	577.70	576.90	576.47	576.03	575.92	575.65
21	580.54	580.34	579.83	579.70	*579.32	578.92	577.70	576.91	576.47	576.03	575.92	575.66
22	580.51	580.31	579.79	579.68	.....	578.86	577.67	576.89	576.47	576.01	575.92	575.66
23	570.55	580.30	579.85	579.73	.....	578.94	577.72	576.91	576.48	576.02	575.93	575.66
24	580.53	580.43	579.89	579.74	*579.36	578.94	577.73	576.90	576.46	576.03	575.91	575.66
25	580.48	580.31	579.83	579.69	579.27	578.90	577.70	576.89	576.47	576.03	575.94	575.67
26	580.48	580.29	579.79	579.67	*579.25	578.88	577.69	576.89	576.47	576.02	575.93	575.67
27	580.52	580.30	579.80	579.69	.....	578.89	577.71	576.91	576.48	576.02	575.93	575.66
28	580.54	580.40	579.87	579.75	*579.34	578.97	577.77	576.93	576.49	576.03	575.94	575.66
29	580.53	580.35	579.84	579.71	579.30	578.92	577.74	576.91	576.48	576.02	575.94	575.65
30	580.50	580.29	579.79	579.68	*579.22	578.88	577.71	576.89	576.47	576.02	575.94	575.66
Mean	580.54	580.42	579.84	579.71	579.28	578.92	577.71	576.90	576.48	576.03	575.93	575.66

*Less than 23 hourly readings.

Williams Ex. 23.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Daily Mean Water Surface Elevations
Adjusted Levels of 1903

Sheet 3
(37 Sheets)
3-Table 2

July 1910	Harbor Beach	Fort Gratiot (Shore)	Section Gorge	G. T. R.	M. B. R.	Dry Dock Section	St. Clair	Marine City	Roberts Landing	Herson Island	Salt Block	St. Clair Flats Canal
a	b	c	d	e	f	g	h	i	k	l	m	n
1	580.50	580.32	579.73	579.66	*579.27	578.91	577.74	576.90	576.48	576.01	575.93	575.65
2	580.45	580.27	579.70	579.64	*579.27	578.88	577.72	576.90	576.48	576.01	575.94	575.65
3	580.34	580.49	579.82	579.76		578.98	577.70	576.93	576.50	576.02	575.94	575.63
4	580.46	580.53	579.85	579.78		579.00	577.81	576.92	576.48	576.01	575.91	575.61
5	580.28	580.26	579.70	579.65	*579.20	*578.86	577.72	576.90	576.49	576.03	575.96	575.65
6	580.24	580.16	579.61	579.54	*579.16	578.80	577.65	576.88	576.48	576.02	575.97	*575.66
7	580.46	580.28	579.72	579.64		578.90	577.72	576.91	576.49	576.03	*575.96	*575.65
8	580.30	580.16	579.62	579.56	*579.19	*578.84	577.67	*576.88	576.49	*576.02	*575.93	575.65
9	580.36	580.16	579.64	579.55	579.18	*578.86	577.69		576.51		575.98	575.67
10	580.40	580.21	579.64	579.58	579.24	*578.82	577.67		576.52		575.98	575.68
11	580.45	580.29	579.73	579.66	579.29	*577.92	577.71	*576.96	576.50		575.96	575.64
12	580.37	580.12	579.61	579.54	579.15	578.80	577.66	576.91	576.49		*576.02	575.66
13	580.48	580.38	579.80	579.72	*579.30	578.96	577.76	576.96	576.51	*576.08		575.65
14	580.30	580.21	579.62	579.56		578.86	577.66	576.92	576.48	576.05		575.66
15	580.41	580.32	579.67	579.61	*579.26	578.87	577.66	*576.90	576.48	576.04	575.96	575.65
16	580.42	580.38	579.79	579.66	579.31	578.96	577.75		576.49	576.03	575.99	575.65
17	580.45	580.39	579.80	579.73	*579.33	579.01	577.78		576.48	576.04	575.93	575.61
18	580.47	580.70	579.86	579.78	*579.46	579.03	577.77	*576.95	576.49	576.03	575.93	575.62
19	580.49	580.30	*579.74	579.65	579.27	578.93	577.74	576.93	576.51	576.06	575.98	575.65
20	580.34	580.08		579.50	579.13	578.79	577.65	576.86	576.47	576.03	575.95	575.65
21	580.42	580.15		579.51	579.21	578.86	577.67	576.85	576.47	576.03	575.97	575.63
22	580.49	580.19		579.58	579.27	578.90	577.67	576.85	576.48	576.02	575.96	575.62
23	580.20	580.31	*579.64	579.30	579.24	578.86	577.69	*576.90	576.48	576.03	575.96	575.62
24	580.13	*580.00	*579.46	579.43	579.10	578.74	577.67		576.50	576.06	576.02	575.67
25	580.46		579.81	579.75	579.47	578.98	577.82		576.56	576.10	576.02	575.66
26	580.44		579.78	579.68		578.98	577.81		576.54	576.08	576.01	575.66
27	580.44	*580.72	579.76	579.66	*579.37	*578.94	577.78	*576.95	576.53	576.07	576.00	575.65
28	580.43	580.32	579.79	579.67	579.30	578.95	577.76	576.94	576.53	576.07	575.99	575.65
29	580.36	580.22	579.72	579.62	579.26	578.92	577.75	576.96	576.55	576.10	576.03	575.69
30	580.33	580.47	579.93	579.79	579.42	579.02	577.82	576.97	576.55	576.07	575.98	575.64
31	580.45	580.29	579.80	579.66	579.29	578.93	577.76	576.92	576.51	576.06	575.98	575.64
Mean	580.42	580.30	579.73	579.64	579.28	578.90	577.73	576.92	576.50	576.04	575.97	575.65

*Less than 28 hourly readings.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Daily Mean Water Surface Elevations
Adjusted Levels of 1903

August 1910	Harbor Beach	Port Gratiot	Section Gorge	G. T. R.	M. B. R.	Dry Dock Section	St. Clair	Marine City	Roberts Landing	Herson Island	Salt Block	St. Clair Flats Canal
a	b	c	d	e	f	g	h	i	k	l	m	n
1	580.37	†580.13	579.58	579.85		578.83	577.73	576.92	576.53	576.08	576.04	575.68
2	580.39	580.25	579.66	579.63	*579.19	578.90	577.74	576.91	576.50	576.05	575.98	575.62
3	580.26	580.10	579.53	579.50	579.17	578.79	577.65	576.86	576.47	576.02	575.96	575.62
4	580.11	*580.22	579.51	579.75	*579.39	578.99	577.82	576.97	576.56	576.07	575.99	*575.56
5	580.05		579.50	579.60		*579.01	577.83	577.01	576.59	576.03	576.01	*575.50
6	580.16	*580.49	579.94	579.78	579.41		577.81	576.94	576.52	576.08	575.98	575.55
7	580.20	580.28	579.70	579.66	579.36		577.71	576.87	576.46	575.99	575.93	575.56
8	580.30	580.15	579.60	579.55	579.20		577.65	576.84	576.44	575.96	575.92	575.54
9	580.25	580.01	579.49	579.48	579.14	*578.79	577.61	*576.80	576.46	576.00	575.99	*575.56
10	580.30	580.21	579.66	579.59	579.20	578.80	577.67		576.44	575.99	575.93	*575.53
11	580.34	580.22	579.66	579.58	579.20	578.79	577.66		576.42	575.95	575.89	575.51
12	580.23	580.07	579.52	*579.47	579.09	578.70	577.58	*576.78	576.38	575.93	575.89	575.51
13	580.31	580.06	579.49	*579.48	579.10	578.70	577.56	576.77	576.36	575.91	575.87	575.49
14	580.30	580.14	579.57	579.54	579.14	578.74	577.61	576.79	576.38	575.92	575.86	575.48
15	580.26	580.13	579.56	*579.49	579.13	578.73	577.58	*576.77	576.36	575.90	575.86	575.47
16	580.29	580.16	579.62	579.55	579.14	*578.73	577.60	*576.81	576.36	575.90	575.86	575.47
17	580.27	580.16	579.57	579.51	579.13	578.74	577.58		576.36	575.90	575.86	575.47
18	580.40	†580.24	579.78	*579.66	579.32	578.90	577.69	*576.86	576.40	575.93	575.87	
19	580.37	580.23	579.78	*579.67	579.25	578.88	577.70	576.85	576.42	575.95	575.89	
20	580.21	579.99	579.48	579.45	579.07	578.69	577.56	576.77	576.37	575.93	575.90	*575.49
21	580.19	579.87	579.36	579.36	578.98	578.58	577.50	576.74	576.34	575.90	575.88	575.49
22	*580.14	*579.84	579.34	*579.36	*579.01	578.57	577.48	*576.72	576.32	575.88	575.84	575.47
23	*580.19	579.96	579.44	*579.40	579.14	578.64	577.55	576.72	576.29	575.86	575.80	575.43
24	*580.28	579.85	579.36	579.34	579.02	579.60	577.50	576.73	576.32	575.83	*575.80	575.45
25	*580.28	579.89	579.42	579.40	579.17	578.68	577.58	576.87	576.45	575.98	*576.15	575.49
26	*580.45	580.40	579.98	579.78	579.56	578.98	577.75	576.88	576.42	575.91	*575.85	575.42
27	*580.40	580.14	579.61	579.56	579.18	578.79	577.63	576.79	576.36	575.89	575.84	575.44
28	*580.28	580.15	579.65	579.59	579.18	578.79	577.62	*576.79	576.35	575.86	575.82	575.42
29	*580.32	580.13	579.70	579.68	579.20	578.79	577.61	*576.80	576.34	575.86	575.81	575.43
30	*580.16	579.86	579.60	579.35	579.03	578.60	577.48		576.30	575.86	575.82	575.45
31	*580.34	580.24	579.79	579.60	579.21	578.89	577.67		576.36	575.87	575.90	575.40
Mean.....	580.33	‡580.15 ‡580.08	579.60	579.55	579.18	578.77	577.64	576.83	576.41	575.94	575.90	575.50

*Less than 23 hourly readings.
†Gage at Shore.
‡Gage on Piles.
To Reduce from Gage on Piles to Gage at Shore add +0.07 ft.

Williams Ex. 23

U. S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

Daily Mean Water Surface Elevations

Adjusted Levels of 1903

Sheet 5
(27 Sheets)
5-Table 2

Sept., 1910	Harbor Beach	Fort Gratiot (Pilot)	Sectica Gorge	G. T. R.	M. B. R.	Dry Dock Section	St. Clair	Marine City	Roberts Landing	Harsen Island	Salt Block	St. Clair Flats Canal
a	b	c	d	e	f	g	h	i	k	l	m	n
1	*580.37	580.34	579.82	579.70	*579.29	578.90	577.69	*576.82	576.36	575.90	575.81	575.40
2	580.34	580.30	579.85	579.48		578.71	577.55		576.32	575.89	575.82	575.45
3	580.19	580.08	*579.56	579.51	*579.34	*578.79	577.57		576.32	575.89	575.82	575.44
4	580.20	580.02	579.63	579.54	579.16		577.59		576.23	575.91	575.83	575.47
5	580.18	579.93	579.44	579.40	579.11		577.56			575.93		575.32
6	*580.17	579.91	579.44	579.40	579.16	*578.80	577.57	*576.83	*576.40	575.96	*575.93	575.80
7	*580.33	580.14	*579.84	579.80	579.19	578.81	577.94	576.81	576.37	575.92	575.94	575.46
8	580.34	580.06	*579.80	579.54	*579.10	578.72	577.59	*576.70	576.38	575.90	575.84	575.46
9	580.29	580.29	579.90	*579.35	579.09	577.76	*576.57	576.41	576.40	575.79	575.79	575.43
10	580.34	580.09		579.56	*579.13	578.76	577.60	576.78	576.35	575.90		575.45
11	580.27	580.01		579.47	579.12	578.70	577.53	576.75	*576.31	575.87		575.44
12	580.30	580.11	*579.41	579.59	579.35	578.80	577.61	*576.77	*576.37	575.87	*575.81	575.49
13	580.24	580.26	*579.93	579.74	579.46	578.90	577.68		576.34	575.87	575.77	575.38
14	580.21	580.10	579.80	579.55	*579.40	578.76	577.56		576.30	575.86	575.76	575.39
15	580.27	580.10	*579.62	579.54	*579.16	578.75	577.57	*576.78	576.30	575.84	575.76	575.38
16	580.28	579.99	*579.40	579.44	579.05	578.66	577.50	578.70	576.28	575.82		575.37
17	580.21	579.99		579.44	579.05	578.66	577.47	579.71	576.28	575.82		575.37
18	580.41	580.30	*579.84	579.66	579.34	578.85	577.62	576.77	576.33	575.83		575.36
19	580.13	579.66	*579.51	579.40	*578.92	578.61	577.45	576.64	576.24	575.78	*575.75	575.38
20	580.21	580.05	579.83	579.49	579.06	578.60	577.51	576.69	576.28	575.80	575.74	575.36
21	580.26	580.13	579.69	579.66	579.13	578.77	577.57	576.70	576.27	575.79	575.72	575.34
22	580.08	579.81	579.37	*579.33	578.88	578.53	577.39	576.61	576.19	575.74	575.70	575.33
23	580.08	579.91	579.36	*579.39	578.94	578.56	577.42	576.60	576.18	575.73	575.68	575.30
24	579.77	579.51	579.12	579.05	578.68	578.31	577.26	576.52	576.14	575.75	575.70	575.36
25	579.96	579.78	579.27	579.24	*578.96	578.43	577.33	576.53		575.70	575.67	575.38
26	580.10	579.90	*579.47	579.34	578.94	578.57	577.41	576.59	*576.18	575.72	575.68	575.36
27	579.96	579.73	*579.56	579.23	578.84	578.47	577.36	576.59	576.19	575.75	575.70	575.39
28	580.24	*580.02	579.84	579.46	579.09	578.68	577.50	576.64	576.20	575.73	575.68	575.33
29	580.08	*579.86	579.31	579.29	578.92	578.53	577.37	576.56	576.16	575.70	575.67	575.37
30	580.06	579.73	579.23	579.21	578.83	578.46	577.33	576.56	576.16	575.71	575.69	575.29
Mean	580.20	580.00	579.82	579.46	579.09	578.68	577.53	576.69	576.26	575.82	575.76	575.36

*Less than 24 hourly readings.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Daily Mean Water Surface Elevations
Adjusted Levels of 1903

Sheet 6
(37 Sheets)
6-Table 2

Oct. 1910	Harbor Beach	Fort Gratiot (Piles)	Section Gorge	G. T. R.	M. B. R.	Dry Dock Section	St. Clair	Marine City	Roberts Landing	Herson Island	Salt Block	St. Clair Flats Canal
a	b	c	d	e	f	g	h	i	k	l	m	n
1	580.40	*580.65	579.67	579.69	579.20	578.89	577.61	576.78	576.31	575.79	*576.71	*575.36
2	580.25	*579.88	*579.56	579.44	579.08	578.66	577.49	*576.65	576.20	575.72		*575.25
3	579.86	579.67	*578.97	579.06	578.66	578.22	577.21	*576.43	576.06	575.65	*575.56	*575.27
4	580.01	579.72	579.17	579.21	578.84	578.46	577.37	576.60	576.20	575.70	575.73	575.33
5	580.19	579.67	579.27	579.32	*578.89	578.54	577.37	576.56	576.15		575.68	575.29
6	580.39	580.34	579.81	579.78	*579.40	578.95	577.67	576.78	576.26	*575.71	575.65	575.29
7	580.25	579.98	579.48	579.46	579.05	578.67	577.43	*576.64	576.23			575.36
8	580.13	579.91	579.31	579.35	578.94	578.60	577.44		576.22	*575.62		575.38
9	580.40	*580.35	579.84	579.74	579.35	578.94	577.66		576.31	575.83	*575.68	575.34
10	580.13	579.89	579.47	579.38	578.98	*578.62	577.44	*576.62	*576.24	575.82	575.72	575.38
11	580.22	580.00	579.43	579.44	579.05	578.69	577.49	576.68		575.83	575.73	575.38
12	580.16	579.96	579.70	579.47	*579.11	578.70	577.46	576.61		575.74	*575.73	575.39
13	579.85	579.83	579.50	579.34		*578.34	577.20	576.45		575.68		575.31
14	580.04	579.87	579.38	579.32			577.37	576.56		575.72		575.23
15	580.02	579.79	579.40	579.23	*578.74	*578.36	577.32	576.53	*576.06	575.70		575.20
16	580.18	579.96	579.60	579.41	579.01	578.64	577.42		576.13	575.72	*575.61	575.27
17	579.92	579.75	579.20	579.19	578.83	578.47	577.28		576.09	575.67	575.58	575.26
18	579.90	579.72	579.15	579.19	578.80	578.44	577.26	*576.48	576.06	575.66	575.57	575.24
19	579.94	579.66	*579.14	579.13	578.77	578.40	577.24	576.45	576.06	575.64	575.57	575.24
20	580.10	579.86		579.46	579.04	578.64	577.41	576.54	576.09	575.65	575.54	575.26
21	579.73	579.46		579.00	578.63	578.27	577.19	576.43	576.03	575.67	575.57	575.28
22	579.97	579.66		*578.53	578.85	578.52	577.41	576.65	576.26	575.84	575.78	575.30
23	580.20	579.97			579.08	578.64	577.41	*576.89	576.13	575.67		575.18
24	579.97	579.65	*578.89	*579.13	578.75	*578.41	577.26	*576.47	*576.08	575.68	*575.61	575.23
25	580.04	579.58	579.40	579.22	578.94	578.57	577.36		576.06	575.62	575.53	575.15
26	580.03	579.81	579.36	579.23	578.87		577.29		576.08	575.61	575.53	*575.18
27	580.04	579.93	579.61	579.39	579.06	*578.53	577.44	*576.57	576.17	575.73	*575.64	575.19
28	580.18	580.10	579.65	579.50	579.09	578.73	577.48	576.60	576.16	575.70		575.14
29	580.09	*580.03	*579.69	579.40	579.01	578.65	577.40	576.52	576.07	*575.62		575.11
30	579.92	*579.34		578.96		578.33	577.27	576.52	576.14	*575.71		575.23
31	579.93	*579.70	*579.22	579.12	*578.76	578.41	577.21	576.36	575.97	575.53	*575.49	575.07
Mean.....	580.06	579.80	579.43	579.30	578.96	578.59	577.38	576.56	576.14	575.70	575.63	575.24

*Less than 23 hourly readings.

U. S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

Daily Mean Water Surface Elevations

Adjusted Levels of 1903.

Nov. 1910	Harbor Beach	Port Gratiot (Piles)	Section Gorge	G. T. R.	M. B. R.	Dry Dock Section	St. Clair	Marine City	Roberts Landing	Herson Island	Salt Block	St. Clair Flats Canal
A	B	C	D	E	F	G	H	I	K	L	M	N
1	579.63	579.14	*579.15	578.70		578.05	577.01	576.26	575.96	575.64	575.53	575.12
2	580.01	579.76	*579.23	579.27		578.48	577.95	576.40	575.98	575.55	575.48	575.02
3	*579.98	579.84	579.35	579.34	*575.85	578.50	577.24	576.36	575.93	575.48	575.43	575.02
4	579.98	579.72	579.30	579.25		578.44	577.21	576.35	575.92	575.49	575.44	575.06
5	*579.90	*579.72	579.10	579.16	*575.75	578.40	577.20	576.39	575.97	*575.41	575.50	575.08
6	*580.03	*579.74	579.22	579.23		578.55	577.33		576.04		575.53	575.05
7	*579.98		579.19	579.26		578.49	577.25		*575.98		575.49	575.03
8	579.90	579.78	579.30	579.24	*575.68	578.45	577.21	*576.36	*575.92		*575.44	575.00
9	579.79	*579.50	*579.00	579.09		578.20	577.14	576.33	575.91		575.42	575.03
10	579.91		*579.35	579.23		578.54	577.30	576.44	576.00		575.44	575.02
11	580.19	*580.11	579.41	579.52	*575.08	578.71	577.45	576.57	576.13	*575.72	575.51	575.05
12	580.13	580.14	*579.53	579.80		578.76	577.45	*576.55	576.07	575.62	575.45	574.98
13	580.08	580.05		579.47		578.54	577.36		576.02	575.59	575.44	575.00
14	579.87	579.74	*579.22	579.19	*575.70	578.40	577.17	*576.31	*575.92	575.50	575.37	574.99
15	579.90	579.84	579.35	579.26		578.47	*577.19	*576.26	575.95	*575.53	575.38	574.98
16	579.98	579.84	579.32	579.28		578.48			575.95		575.39	574.97
17	579.81	579.63	*579.18	579.08					575.89		575.36	574.97
18	579.76	579.63		579.07	*575.69	*578.33	*577.14	*576.36	575.87		575.38	*574.97
19	579.78	579.80		579.04		578.25	577.04	576.24	575.82		575.31	*574.95
20	579.86	579.28		578.79		578.04	576.86	576.12	*575.73		575.29	*574.92
21	579.86	579.34		578.76	*575.36	578.02	576.90	576.14	*575.78		575.31	574.91
22	579.68	579.30		578.90			576.93	576.12	575.72		575.23	574.84
23	579.44	579.06		578.61			576.78	576.05	575.60	*575.18	575.25	574.87
24	579.70	579.41		578.89			576.98	576.15	575.73	575.25	575.24	574.83
25	579.81	579.62	*579.23	579.07	*575.63	*578.25	577.05	576.25	575.77	575.28	575.23	574.83
26	579.82	579.60	*579.25	579.05		578.25	577.05	576.23	575.78	575.29	575.28	574.85
27	579.47	579.30	*579.24	578.70		577.96	576.91		575.65	*575.21	575.21	574.87
28	579.58	579.36	*579.26	578.86		578.09	576.91		575.73	*575.27	575.22	574.87
29	579.80	579.72	*579.34	579.20	*575.76	578.27	577.16	*576.36	575.92	575.41	575.23	*574.88
30	579.92	579.78		579.27		578.40	577.15	576.32	575.86	575.24	575.29	*574.86
Mean	579.80	579.62	579.27	579.12	575.72	578.27	577.13	576.31	575.90	575.48	575.37	574.96

*Lake Gauge 24 hourly readings.

Williams Exhibit 23.

U. S. LAKE SURVEY.

HYDRAULICS OF ST. CLAIR RIVER.

Daily Mean Water Surface Elevations.—Adjusted Levels of 1903.

Date 1906	Harbor Beach	Huronia Beach	Section Gage	G. T. R.	M. B. R.	Dry Dock Dunford	Roberts Landing	St. Clair Flats Canal
A	B	C	D	E	F	G	H	I
Nov. 1	580.71			579.87	579.47	579.06	576.53	575.48
2	580.65			579.80	579.37	578.97	576.51	575.48
3	580.70			579.85	*579.32	579.00	576.53	575.48
4	580.98			580.46		579.49	576.63	575.34
5	580.85			580.09	*579.55	579.22	576.59	575.45
6	580.71			579.91		579.06	576.54	575.43
7	580.70			579.84		578.99	576.46	575.37
8	580.58			579.69		578.86	576.39	*575.36
9	580.59			579.76	*579.35	578.90	576.32	s575.37
10	580.51			579.71	579.29	578.84	576.29	s575.32
11	580.80	*580.46		579.70	579.29	578.85	576.32	*575.31
12	*580.56	580.30		579.73	*579.35	578.90	576.41	575.27
13	580.49	580.52	*579.40	579.65	*579.22	578.81	576.30	575.23
14	580.38	580.30	*579.34	579.55	*579.13	578.72	576.28	575.23
15	580.25	579.97	579.13	579.30	578.96	578.54	576.36	575.25
16	580.52	580.48	579.48	579.67	579.27	578.84	576.36	*575.14
17	580.46	580.26	579.31	579.50	*579.12	578.68	576.18	s575.10
18	580.47	580.42	579.28	579.63	*579.32	578.77	576.19	s575.08
19	580.38	580.32	579.28	579.54	*579.36	578.68	576.14	s575.07
20	580.34	580.28	579.20	579.50	579.09	578.65	576.13	s575.11
21	580.24	580.19	579.21	579.41	*575.93	578.56	576.09	s575.10
22	580.13	580.04	579.09	579.28		578.45	576.05	s575.09
23	580.16	580.05	579.10	579.30	*578.91	578.45	576.04	s575.08
24	580.08	579.99	579.05	579.26		578.42	576.05	s575.07
25	579.99	*579.83	578.92	579.11		578.30	576.02	*575.06
26	580.14		579.01	579.18	*579.12	578.43	576.31	575.21
27	580.06		579.89	579.80	579.36	578.92	*576.37	575.12
28	580.46	580.04	579.32	579.50	*579.12	578.66	*576.24	575.12
29	580.37	580.20	579.32	579.52		578.66	576.16	*575.06
30	580.11			579.19		578.39	*576.17	s575.07
Mean	580.46	580.23	579.25	579.61	579.23	578.77	576.30	575.23
Dec. 1	580.01		*579.67	579.77		578.88		*575.13
2	580.88		579.79	580.01		579.13	*576.39	*575.10
3	580.34	*579.95	579.17	579.34	*578.85	*576.54	576.28	*575.16
4	580.34	580.43	579.33	579.52		578.71	576.23	575.06
5	580.37	580.41	579.31	579.52		578.66	576.14	575.01
6	579.99	579.91	578.99	579.09		578.32	576.05	s575.01
7	580.16	580.09	579.17	579.35	*579.13	578.57	*576.27	*575.08
8	580.35	*580.22	*579.29	579.44	579.04	578.65	576.27	575.04
9	580.32	580.35	579.28	579.47	579.04	578.63	576.13	574.97
10	580.10		579.01	579.18	578.78	578.30	576.05	*574.97
11	580.14	*580.13	579.12	579.26	578.85	578.46	576.09	*574.99
12	580.34	580.13	579.23	579.41	579.01	578.61	576.22	*575.00
13	580.32	580.12	*579.23	579.37	578.96	578.56	576.15	*576.00
14	580.17	579.98	*579.10	579.21	578.82	578.43	576.09	*575.00
15	580.33	580.18	*579.24	579.43	578.97	*578.54	576.07	*574.93
16	580.27	580.20	579.24	579.44	579.01	*578.56	576.06	*574.92
17	580.05	580.05	*579.06	579.26	578.83	578.43	576.00	*574.92
18	580.03			579.24	578.84	*578.54	576.10	s574.97
19	580.21		*579.14	579.27	*578.77	*578.56	576.22	*575.06
20	580.30		*579.39	579.37		578.86	*576.21	*574.90
Mean	580.27	580.15	579.25	579.40	578.92	578 59	576.16	575.02

*Less than 23 hourly readings.
sTri-daily Staff Gage readings.

Williams Ex. 23

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Daily Mean Water Surface Elevations.—Adjusted Levels of 1903.

Sheet 1 (37 Sheets)
Table I

Date 1909	Harbor Beach	Huronia Beach	Fort Gratiot (Crib)	Section Gorge	G. T. R.	M. B. R.	Dry Dock Detroit	Dry Dock Section	Roberts Landing	St. Clair Flats
A	B	C	D	E	F	G	H	I	K	L
Oct. 1	580.82				580.04		*579.23			578.20
2	580.86				579.92		579.09			578.34
3	580.86				579.94		579.00			578.34
4	580.82			*579.78	579.79	*579.33	578.97			*578.33
5	580.83			579.75	579.77	579.32	578.94			*578.32
6	580.83			579.72	579.74	579.30	578.93		*578.50	578.32
7	580.81			579.68	579.71	579.26	578.90		578.47	578.32
8	580.63		*580.37	579.64	579.68	579.20	578.85		578.43	578.40
9	580.41		*580.23	*579.62	579.64	579.15	578.82		578.43	578.40
10	580.31		580.09		579.60	579.04	578.72		578.40	578.40
11	580.27		579.96		579.43	*579.02	578.68		578.56	578.34
12	580.11		579.94	*579.01	579.16	578.84	578.54		578.73	578.30
13	580.45		580.03	579.48	579.40	579.09	578.73		578.53	578.32
14	580.56		580.31	579.68	579.67	579.25	578.98		578.43	578.34
15	580.54		580.26	579.60	579.69	579.26	578.96		578.36	578.33
16	580.59		580.39	579.77	579.77	579.33	578.94		578.41	578.33
17	580.52		580.03	579.72	579.71	579.28	578.87		578.30	578.19
18	580.43		580.01	*579.69	579.69	579.26	578.85		578.29	578.19
19	580.29				579.64	579.20	578.82		578.27	578.31
20	580.22				579.46	579.06	578.61		578.21	578.34
21	580.02			*579.20	579.20	*578.80	578.46		578.27	578.31
22	580.04			579.78	579.78	579.31	578.94		578.36	578.33
23	580.02			579.94	579.96	579.47	579.07		578.32	578.17
24	580.32				579.60	579.16	578.77		578.27	578.36
25	580.20			*579.21	579.36	578.86	578.51		578.20	578.33
26	580.23			579.37	579.36	578.94	578.57		578.28	578.29
27	580.50			*579.03	579.64	579.20	578.81		578.30	578.36
28	580.44				579.63	579.20	578.82	*578.70	578.28	578.38
29	580.24				579.43	*579.07	578.63	578.57	578.17	578.16
30	579.97				579.10		578.32	578.27	578.09	578.13
31	580.16				579.34	*578.86	578.48	*578.46	578.10	578.13
Mean	580.40		580.23	579.90	579.60	579.13	578.80	578.48	578.34	578.26
Nov. 1	580.02				579.06	*578.74	*578.32		578.06	*578.06
2	580.10				579.16	*578.91	578.46		578.19	*578.13
3	580.31				579.36	*579.01	578.69	*578.61	578.18	578.13
4	580.35	*580.36			579.44		578.74	578.71	578.19	578.09
5	580.17	*580.15			579.22	*578.90	578.68	*578.24	578.10	578.09
6	580.07	*580.00			579.28	578.87	578.47	578.40	578.06	578.06
7	579.86	579.89			578.96	578.60	578.23	578.17	578.08	578.06
8	580.39	*580.34			579.57	579.15	578.72	578.69	578.15	578.06
9	580.02				579.14	578.78	578.23		578.03	578.06
10	579.94				579.05	578.60	*578.23		578.01	578.06
11	579.96	*579.89			579.00	*579.67	*578.27	*578.26	578.03	*578.06
12	580.26	*580.06			579.43	579.04	578.61	*578.56	578.09	578.04
13	579.99	*579.89			579.09	578.72	*578.46		578.00	578.06
14	579.91				579.09	578.68	*578.22		578.00	578.06
15	580.33	*580.46			579.51	579.06	578.67	*578.72	578.13	578.06
16	580.06	579.79			579.09	578.74	578.34	*578.46	578.14	578.10
17	580.05	579.86			579.35	578.96	*578.01	*578.75	578.22	578.06
18	580.38	580.16			579.35	579.06		578.01	578.15	578.06
19	580.06	579.86			579.12	578.76		578.36	578.13	578.06
20	580.03	579.91			579.06	578.69		578.27	578.08	578.06
21	580.31	580.51			579.53	579.13		578.66	578.16	578.07
22	580.40	580.06			579.58	*579.13		578.69	578.23	578.06
23	580.23	580.50			579.44	*579.06		578.67	578.24	578.05
24	580.08	580.16			579.28			578.43	578.14	578.24
25	580.19	580.20			579.29			578.49	578.19	578.23
26	580.06	579.95			579.19	*579.77		578.40	578.14	578.21
27	579.90	579.44			578.98	578.59		578.19	578.08	578.15
28	580.26				579.49	579.04		578.61	578.13	578.15
29	580.15	*580.07			579.38	578.94		578.58	578.10	578.13
30	580.05	579.96			579.15	578.75		578.36	578.06	578.10
Mean	580.12	580.16			579.27	578.87	578.42	578.51	578.11	578.10
Dec. 1	580.02	580.02		*579.28	579.20	578.79		578.34	578.01	578.11
2	579.90	*579.86		*579.11	579.08	578.66		578.25	578.06	578.10
3	579.96	*579.97		*579.19	579.13	*578.68		*578.36	578.06	578.08
4	580.01	579.96		579.19	579.13				578.03	578.08
5	579.76	579.86		579.08	578.93				578.07	578.10
6	579.99	579.93		579.14	578.99	*578.57		*578.47	578.17	578.08
7	580.28	580.27		579.69	579.44	*579.06		578.89	578.32	578.12
8	580.33	579.96		*579.24	579.23			*578.80	578.40	578.16
9	580.41	580.26		*579.56	579.43	*579.08			578.57	578.17
10	580.40	580.32		*579.56	579.50	*579.16			578.57	578.11
11	580.12	*580.17		*579.44	579.26				578.13	578.12
12	579.76				578.94				*578.00	578.12
Mean	580.06	580.03		579.20	579.19	578.90		578.40	578.14	578.12

*Less than 23 hourly readings.

Williams Ex. 23

Sheet 10
(37 Sheets)
Table 6
W. S. Richmond, Jun. Engr.
April, 1911

U. S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

Time Interval required for Change of Lake Stage at Fort Gratiot to be Felt at Various Gages and Sections

GAGE OR SECTION	From Fort Gratiot Lighthouse Gage				Section from Channel Entrance Miles
	Miles	Time	Time to Nearest 10 Minutes	Minutes per Mile	
		h min.			
Section Gorge	0.45	1			
G. T. R.	0.80	2			
M. B. R.	2.45				
Dry Dock (Dunford)	4.65				
Dry Dock (Section)	5.10	16	20	3.14	
St. Clair	13.8	44	40	3.19	
Marine City	21.6	59	1:00	2.73	
Roberts Landing	25.6	1:09	1:10	2.69	
Section Sny	27.4	1:14	1:10		0.3
Section Bridge	30.8	1:32	1:30		0.8
Henson Island	32.4	1:37	1:40	2.99	
Salt Block (gage)	33.7	1:41	1:40	3.00	
Section M. C.	33.9	1:42	1:40		1.5
Section Salt Block	34.6	1:44	1:40		
Section Bassett	34.7	1:44	1:40		0.3
Section S. E. Bend	34.9	1:45	1:40		
St. Clair Flats	39.4	2 approx.	2 approx.	3.06?	

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Discharge of St. Clair River
Section Gorge

W. S. Richmond, Jun. Engr.
April, 1911.

Number	Date	Water Surface Elevations				Fall		Change at lake		Wind		Ratings				Volume of Discharge (cu. ft. per sec.)					Weighted mean Index Velocity
		Fort Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. G. to G.T.R.	G.T.R. to D.D.	Rise	Fall	Dir.	Vel. miles	1B	10B	14B	15B	1B	10B	14B	15B	Adopted	
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
61	1910 May 9	(Sluice) 580.33	579.66	578.89	575.69	.84	.76	.09	.00	N.W.	15		K	L				187,160	191,500		189,230	5.23
62	9	.36	.70	.91	575.67	.66	.79	.04	.02	N.W.	13		K	L				186,860	190,060		188,310	5.23
63	17	579.98	.13	.42	.56	.80	.76	.15	.05	S.E.	30	K				165,560					165,560	5.53
64	17	.65	579.98	.33	.66	.67	.68	.02	.27	S.-S.E.	60-20		K					165,430			Rejected	4.90
65	18	580.23	579.63	.64	.58	.60	.70	.26	.02	W	40			L	M							
66	18	.24	.66	.53	.57	.88	.84	.17	.01	W	45-55			L	M			188,470	187,540	188,020	5.22
67	18	.41	.72	.94	.57	.66	.79	.04	.03	W	40			L	M			185,570	187,710	186,640	5.16
68	18	.24	.44	.61	.33	.78		.00	.41	S.E.	6	K	K			120,050	178,040	190,040	191,800	180,920	5.30
69	18	.10	.32	.67	.33	.67	.86	.21	.02	S.E.	8	K	M			120,100	163,280			179,040	5.98
70	18	.16	.34	.71	.34	.62	.83	.11	.07	S.	10	K	M			165,730	179,560			186,340	6.19
71	18	.09	.46	.86	.36	.62	.77	.08	.07	S.	15	K		L		178,190		176,190		182,660	6.08
72	18	.62	.63	.84	.55	.60	.78	.00	.14	S.	18	K		L	M	175,850		173,560		177,190	5.88
73	20	579.93	.34	.61	.36	.86	.79	.11	.00	S.E.	5			L	M			173,220	181,080	174,720	5.83
74	20	580.07	.47	.67	.53	.80	.80	.06	.01	S.E.	6			L	M			177,940	181,760	179,640	5.98
75	20	.04	.44	.63	.36	.60	.79	.00	.04	S.E.	10		M		M		186,570		181,000	178,550	5.93
76	20	.00	.41	.64	.33	.60	.77	.06	.04	S.E.	8		M		M		178,270		178,240	180,940	6.02
77	20	.12	.53	.72	.54	.60	.81	.07	.00	S.W.	3		M	L			186,960	187,200		178,300	5.93
78	21	.19	.54	.75	.55	.65	.79	.02	.03	N.W.	12	K								187,220	6.21
79	21	.15	.53	.75	.55	.65	.78	.01	.06	N.W.	10	K				188,150				188,150	6.21
80	June 13	.34	.74	.92	.70	.60	.82	.10	.00	S.W.	6		M		M	187,630				187,630	6.19
81	13	.41	.77	.96	.70	.64	.81	.07	.04	S.W.	8		M		M		185,780		189,960	188,370	6.24
82	13	.31	.66	.86	.70	.66	.78	.02	.04	S.W.	10		M				189,560		191,440	190,510	6.28
83	13	.32	.68	.90	.71	.64	.78	.01	.01	S.W.	6	K	M			188,930	187,830			188,380	6.32
84	13	.37	.77	.95	.71	.60	.82	.07	.01	S.W.	13	K		L		187,230	188,310			187,800	6.20
85	14	.33	.68	.90	.71	.64	.86	.00	.00	S.	2	K		L		186,740		188,710		187,730	6.16
86	14	.22	.65	.86	.69	.67	.87	.00	.01	N.E.	2				M			190,510	189,310	189,910	6.27
87	14	.32	.69	.89	.69	.63	.79	.01	.01	N.E.	4	K			M			188,120	186,790	187,455	6.20
88	14	.33	.70	.91	.69	.63	.79	.00	.00	N.E.	6	K			M	190,300			189,280	189,800	6.27
89	14	.33	.67	.89	.68	.66	.78	.00	.00	N.E.	4	K	M			189,450			189,130	189,290	6.26
90	14	.23	.57	.80	.68	.66	.78	.00	.00	N.E.	4	K	M			185,370	184,080			184,720	6.11
91	17	.29	.61	.71	.67	.68	.90	.03	.04	S.W.	4	K	M			187,080	186,070			186,580	6.16
92	17	.35	.66	.92	.68	.65	.76	.05	.01	S.E.	2	M	M			185,540	186,180			185,860	6.15
93	18	.48	.83	.99	.67	.65	.84	.14	.02	N.W.	8	M	M	M		185,490	187,080			186,280	6.16
94	18	.43	.79	579.00	.67	.64	.79	.15	.23	N.W.	8	M	M	M			191,040	191,780		191,410	6.30
95	18	.42	.76	578.96	.67	.63	.84	.13	.17	N.W.	6	M	M	M			186,220	187,820		187,020	6.15
96	18	.44	.76	.98	.68	.64	.75	.04	.23	N.W.	15		M	M	M			190,960	189,650	190,300	6.26
97	18	.39	.69	.97	.67	.62	.83	.09	.20	N.W.	16	M			M	189,360		185,890	185,410	185,650	6.13
																			188,660	189,000	6.26

*Observations supplied.

HYDRAULICS OF ST. CLAIR RIVER
Discharge of St. Clair River
Section Gorge

(Sheet 12 of 13 sheets)
W. S. Richmond, Asst. Engr.
April, 1911

Number	Date	Water Surface Elevations				Fall		Change at lake		Wind		Ratings				Volume of Discharge (cu. ft. per second)					Weighted Mean index velocity
		Fort Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. G. to G.T.R.	G.T.R. to D. D.	Rise	Fall	Dir.	Vel. Miles	1B	10B	14B	15B	1B	10B	14B	15B	Adopted	
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
	1910	(Shore)																			
98	June 29	580.28	579.66	578.89	575.66	.62	.77	.13	.11	N.	4	M			M	178,530			181,150	179,840	5.93
99	30	.34	.70	.91	.66	.64	.79	.12	.13	N.E.	5	M			M	183,120			186,000	184,560	6.09
100	30	.36	.73	.94	.66	.63	.79	.14	.12	N.E.	4	M	M			184,760	188,710			186,740	6.16
101	30	.40	.76	.94	.66	.62	.84	.24	.12	N.W.	2	M	M			188,740	192,490			190,620	6.28
102	30	.33	.72	.92	.66	.61	.80	.08	.13	N.E.	10		M	M			188,980	186,260		186,620	6.22
103	29	.38	.75	.94	.67	.69	.81	.12	.01	N.W.	4			M	M			193,720	193,480	193,600	6.38
104	29	.43	.80	579.01	.66	.63	.79	.05	.02	N.W.	2			M	M			193,310	191,750	192,530	6.34
105	29	.41	.74	578.96	.66	.67	.78	.00	.00	N.W.	4			M				186,710		186,710	6.16
106	30	.37	.63	.85	.66	.65	.77	.03	.03	N.W.	2	O	M			186,990	186,890			186,940	6.15
107	30	.28	.65	.87	.67	.63	.78	.01	.01	S.	2	O	M			185,130	185,270			185,200	6.13
108	30	.28	.68	.88	.68	.60	.80	.00	.00	S.W.	2										
109	30	.28	.66	.88	.66	.62	.78	.01	.01	N.E.	4		M		M		184,770		184,770	184,770	6.14
110	30	.28	.65	.86	.66	.63	.79	.01	.01	N.E.	3		M		M		181,700				
111	July 1	.33	.69	.90	.64	.64	.79	.01	.01	N.E.	2			M	M			182,980	182,340	182,660	6.08
112	1	.25	.63	.85	.64	.62	.78	.06	.02	S.W.	4	O		M				184,030	184,780	184,408	6.09
113	1	.30	.70	.89	.65	.60	.81	.00	.10	S.W.	4	O		M		185,660		185,000		184,330	6.10
114	1	.33	.68	.90	.65	.65	.78	.07	.00	N.W.	4	O			M	184,570		182,940		183,550	6.06
115	1	.30	.64	.88	.64	.66	.78	.01	.03	N.E.	2	O			M	188,480			189,090	188,780	6.24
116	2	.29	.63	.90	.64	.66	.73	.01	.01	S.W.	2		M		M	185,960			186,810	186,380	6.02
117	2	.28	.60	.88	.66	.68	.72	.00	.03	S.W.	2		M	M			184,130		185,850	185,090	6.12
118	2	.24	.56	.81	.66	.68	.75	.02	.02	S.W.	2		M	M			185,630	183,930		184,780	6.12
119	2	.27	.62	.86	.64	.65	.74	.05	.01	S.W.	4	O		M		184,960	184,180	181,840		183,010	6.06
120	5	.33	.69	.89	.65	.64	.80	.23	.15	N.E.	9	O		M		190,060		187,480		188,780	6.26
121	5	.36	.68	.86	.65	.68	.82	.15	.06	N.E.	12			M	M			189,980	190,580	190,280	6.29
122	5	.25	.60	.80	.65	.65	.80	.08	.01	N.E.	12	O				189,230		189,010		189,120	6.25
123	Aug. 5	.22	.62	.84	.54	.60	.78	.05	.00	N.W.	2	O	M			194,790	185,050			184,910	6.12
124	6	.21	.56	.78	.54	.65	.80	.01	.03	N.E.	2			O	O			185,410	187,100	186,260	6.18
125	8	.19	.58	.80	.54	.61	.78	.10	.05	N.E.	2-10		O	O			186,620	183,610		185,080	6.14
126	8	.14	.52	.74	.55	.62	.78	.01	.03	N.E.	4	O	O			184,120	183,350			183,740	5.92
127	9	579.94	.38	.63	.54	.56	.75	.05	.01	S.	15	O			O	181,660			181,460	181,570	6.04
128	9	.96	.32	.56	.54	.64	.76	.02	.04	S.	15		O	O			177,470	174,720		176,100	5.88
129	9	.95	.39	.63	.54	.56	.76	.00	.04	S.	10		O	O			174,540	172,070		173,300	5.79
130	9	.98	.43	.71	.60	.53	.74	.04	.00	S.	10-30			O	O			167,790	168,470	168,130	5.61
131	9	.99	.45	.75	.60	.51	.73	.11	.00	S.	35			O	O			170,630	172,120	171,370	5.99
132	10	580.14	.57	.89	.51	.57	.86	.05	.01	N.	20-40	O			O	176,260			174,630	175,440	5.84
133	10	.18	.56	.82	.51	.62	.74	.04	.00	N.	5		O		O		186,830		185,800	187,310	6.23
134	10	.22	.63	.81	.51	.59	.82	.04	.00	N.	6		O		O		186,020		183,040	184,530	6.12
													O	O			188,100	184,680		186,390	6.18

*Elevations supplied.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Discharge of St. Clair River
Section Gorge

W. S. Richmond, Jun. Engr.
April, 1911

Number	Date	Water Surface Elevations				Fall		Change at Inlet		Wind		Ratings				Volume of Discharge (cu. ft. per sec.)					Weighted Mean Index Velocity
		Fort Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. Gr. to G.T.R.	G.T.R. to D. D.	Rise	Fall	Dir.	Vel. Miles	1 B	10 B	14 B	15 B	1 B	10 B	14 B	15 B	Adopted	
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
	1910	(Shore)																			
135	Aug. 10	580.24	579.50	578.82	575.52	65	.77	.01	.02	N.	6		O	O			186,970	183,310		185,390	6.15
136	10	.24	.61	.82	.53	63	.79	.02	.01	N.	5		O		O		186,990		185,530	186,260	6.19
137	10	.24	.61	.81	.54	63	.80	.02	.01	N.	4		O		O		186,270		185,150	185,710	6.16
138	11	.24	.58	.82	.51	66	.76	.01	.15	N.	6			O	O			184,010	183,960	183,980	6.10
139	11	.22	.59	.81	.50	63	.78	.11	.03	N-N.E.	10			O	O			185,180	184,560	184,870	6.13
140	11	.27	.64	.82	.50	63	.82	.13	.07	N.E.	10-20	O			O	187,030			186,610	186,820	6.19
141	11	.21	.58	.83	.51	63	.75	.02	.11	N-N.E.	18	O			O	183,720			182,330	183,020	6.07
142	11	.18	.54	.78	.53	64	.76	.03	.08	N.W.	10	O	O			184,990	184,030			184,510	6.13
143	12	.11	*.50	.72	.50	*.61	*.76	.00	.08	S.W.	4		Q	O			180,030	179,590		179,810	5.99
144	12	.04	*.43	.70	.50	*.61	*.72	.00	.05	S.W.	3		Q	O			176,700	175,810		176,260	5.87
145	12	.06	*.47	.71	.50	*.61	*.76	.04	.02	N.E.	8			O	O			178,320	176,480	177,400	5.74
146	12	.10	*.49	.74	.50	*.61	*.75	.09	.12	N.E.	6			O	O			180,260	181,750	181,000	6.02
147	12	.05	*.45	.69	.50	*.60	*.76	.06	.05	N.E.	5	O			O	181,350			179,340	180,340	6.01
148	12	.02	*.42	.67	.49	*.60	*.75	.11	.06	S.W.	6	O	Q			182,100	181,740			181,920	6.07
149	13	579.95	*.31	.56	.49	*.57	*.75	.02	.12	S.W.	3	O	Q			172,470	172,300			172,380	5.77
150	13	580.15	*.52	.76	.48	*.62	*.77	.23	.05	S.W.	5	O			O	184,610			183,280	183,940	6.12
151	13	.06	*.45	.71	.48	*.61	*.77	.05	.13	S.W.	5			O	O			179,520	179,300	179,420	5.98
152	13	.07	*.46	.71	.48	*.61	*.75	.15	.00	S.W.	6		Q	O			180,890	181,940		181,420	5.96
		(piles)																			
153	Sept. 12	579.92	.57	.61	.34	55	.78	.16	.15	N.E.	8	R		Q		180,840		179,760		180,130	6.01
154	19	.97	.42	.65	.35	55	.77	.10	.16	N.E.	8	R	S	Q		183,430	181,160			182,300	6.08
155	20	580.01	.44	.65	.35	57	.79	.22	.12	S.	6			Q	S			180,810	180,890	180,840	6.02
156	20	.17	.60	.76	.35	58	.83	.23	.07	S.	6		S		S		188,300		187,610	188,000	6.24
157	20	.06	.51	.73	.37	.54	.78	.10	.22	{S-S.W. N.	8 12	R				182,310				182,310	6.06
158	20	.04	.49	.71	.36	55	.78	.00	.03	N.	10	R	S			179,790	173,480			176,640	5.87
159	21	.14	.55	.75	.35	.59	.80	.15	.11	W.-S.W.	5	R			S	187,800			182,810	185,300	6.15
160	21	.22	.64	.83	.35	.66	.81	.05	.09	{W. N.E.	3 15	R	S			187,320	186,230			186,780	6.18
161	22	579.80	*.25	.45	.26	*.52	*.90	.15	.10	S.E.	3		S	Q			178,140	178,970		178,560	5.98
162	22	.91	*.37	.54	.28	*.54	*.83	.10	.02	S.	3			Q	S			183,370	181,230	182,300	6.11
163	23	.93	*.39	.60	.30	*.54	*.79	.11	.15	N.W.	3	R			S	182,460			180,670	181,580	6.17
164	23	.97	.44	.66	.30	.53	.79	.11	.14	S.E.	2	R	S			181,030	181,040			181,040	6.05
165	24	.41	.00	.30	.26	.41	.70	.13	.12	E.-S.E.	25			Q	S			166,520	166,010	166,320	5.50
166	24	.33	578.92	.20	.23	.41	.72	.14	.10	E.-S.E.	20			Q	S			165,010	164,180	164,600	5.56
167	24	.38	.94	.34	.26	.70	.44	.10	.05	E.-S.E.	20-10	R				168,990		167,500		168,240	5.60
168	24	.25	.87	.25	.37	.41	.62	.20	.15	S.E.	15	R		Q	S	162,710		161,010		161,860	5.49
169	25	580.01	579.43	.00	.28	.58	.83	.18	.28	N.E.	10		S		S		184,640		183,880	184,120	6.14
170	26	579.90	.34	.38	.27	.56	.76	.20	.26	N.E.	8		S		S		182,210		180,710	181,460	6.09
171	27	.69	.13	.36	.26	.60	.74	.18	.15	S.W.	12-18		S	S			171,280	169,230		170,250	5.79
172	27	.73	.10	.37	.30	.63	.73	.20	.20	{S.W. W.	20 16		S	S			173,160	172,600		172,880	5.85

Number	Date	Water Surface Elev.				Fall		Change at Lake		Wind		Ratings				Volume of Discharge (cu. ft. per sec.)					Weighted mean index velocity
		Fort Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. G. to G.T.R.	G.T.R. to D.D.	Rise	Fall	Dir.	Vel. miles	1B	10B	14B	15B	1B	10B	14B	15B	Adopted	
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T	U	V	W
	1910	(Piles)																			
173	Sept. 27	579.66	579.14	578.44	575.22	.51	.70	.19	.07	W.	10			S	S			168,860	169,000	168,930	5.50
174	27	.72	.20	.47	.29	.52	.73	.07	.16	S.W.	15			S	S			174,320	174,890	174,600	5.86
175	27	.75	.24	.50	.29	.51	.74	.11	.15	W.-S.W.	15			S	S			177,000	177,470	177,240	5.96
176	28	*580.16	.57	.78	.25	*.59	.79			N.W.	8			S	S			189,350	188,860	189,100	6.23
177	28	* .17	.58	.79	.25	*.59	.79			N.	8	R			S	187,350			185,430	186,390	6.15
178	28	* .04	.47	.67	.25	*.57	.80			N.E.	8	R				186,920		185,750		186,340	6.20
179	28	* .06	.49	.70	.25	*.57	.79			N.-N.E	10		S	S	S		184,080	183,800		183,940	6.12
180	28	* .11	.53	.73	.26	*.58	.80			N.N.E	8		S	S	S		187,800		187,600	187,700	6.24
181	Oct. 24	579.31	*578.87	* .17	.27	*.44	*.70	.13	.06	S.W.	30			T	S			158,070	159,120	158,600	5.86
182	24	.62	*579.13	* .39	.26	*.50	*.74	.14	.11	S.-S.W.	20		S	T			169,150	168,220		168,680	5.99
183	24	.57	.05	* .31	.22	.52	*.74	.14	.04	S.W.	8	S	S			166,660	166,070			166,360	5.91
184	25	.57	.10	* .47	.17	.61	*.79	.09	.04	W.-S.W.	8	S		T		184,620		184,970		184,800	6.18
185	26	.54	.26	* .48	.16	.58	*.78	.06	.12	W.	4	S			S	181,190			180,970	181,080	6.05
186	26	.66	.12	* .37	.16	.54	*.78	.08	.19	W.-S.W.	7		S		S		173,970		172,330	172,650	5.79
187	26	.74	.16	* .39	.16	.58	*.77	.12	.07	W.-S.W.	6			T	U			177,910	177,660	177,780	5.96
188	26	.79	.22	* .46	.15	.56	*.77	.11	.11	S.-S.W.	10		S	T			179,100	179,740		179,420	6.02
189	26	580.45	.79	.98	.11	.66	.84	.30	.00	N.W.	20-30		U	T			204,210	202,980		202,600	6.71
190	31	579.81	.30	.45	.06	.51	.75	.13	.24	S.-S.W.	6	S			U	183,320			183,250	183,280	6.15
191	31	.82	.31	.48	.06	.51	.73	.12	.10	S.-S.W.	6			T	U			181,640	180,540	181,090	6.08
192	Nov. 1	.31	578.85	.20	.09	.46	.66	.06	.17	S.-S.E.	12		U	T			164,760	166,950		165,860	5.63
193	1	.17	.72	.10	.07	.45	.62	.04	.07	S.-S.W.	20	S	U			156,760	156,010			156,380	5.33
194	1	.25	.76	.06	.09	.49	.70	.23	.05	S.-S.W.	18-35	S		T	U	163,060		164,860		163,960	5.57
195	1	.24	.83	.15	.11	.41	.68	.07	.30	S.-S.W.	35		U	T	U			164,130	161,230	162,680	5.52
196	1	.08	.98	.01	.09	.40	.67	.08	.03	S.-S.W.	25				U		153,490		153,270	153,380	5.22
197	2	.66	579.12	.27	.02	.54	.85	.08	.00	W.N.W.	15	S	U	T	U	180,310			179,600	179,960	6.06
198	2	580.00	.45	.60	.01	.55	.85	.01	.08	W.N.W.	12		U		U		188,110	190,000		189,060	6.34
199	2	579.78	.21	.40	.01	.54	.81	.20	.00	W.N.W.	10		U	T	U		178,960		181,090	180,030	6.05
200	2	580.03	.46	.63	.01	.57	.93	.36	.00	N.N.W.	2			T	U			192,650	192,030	192,340	6.44
201	2	.16	.58	.69	.02	.58	.89	.09	.12	N.N.W.	3			T	U			194,320	193,100	193,710	6.48
202	9	*579.52	.02	.26	.07	*.50	.76			S.-S.E.	8	U		T	U			169,000		168,440	5.70
203	9	* .54	.04	.23	.05	*.50	.79			S.	25			T	U	167,880		176,150	173,490	173,820	5.88
204	9	* .51	.01	.26	.01	*.50	.73			S.	6		U	U	U		169,840		169,160	169,500	5.73
205	9	* .61	.09	.22	.01	*.52	.87			S.	4		U	U			178,500	180,800		179,650	6.09
206	11	.97	.39	.56	.04	.58	.83	.17	.00	W.	20				U		184,790		186,220	185,510	6.22
207	11	580.17	.57	.72	.04	.60	.85	.20	.12	W.	25-35			T	U			190,940	189,340	190,140	6.36
208	11	579.99	.45	.66	.07	.54	.77	.14	.07	W.	35-20	U				185,800		184,340		185,070	6.19
209	11	580.14	.53	.70	.07	.62	.82	.33	.03	W.	20	U				190,090				190,090	6.35

*Elevations supplied.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER.
Discharge of St. Clair River,
Section Dry Dock.

Sheet 18
(37 Sheets)
Table 11
W. S. Richmond, Jun. Engr.
April, 1911

Number	Date	Water Surface Elevations				Fall		Change at Lake		Wind		Ratings					Volume of Discharge (cubic ft. per second)					
		Port Gratiot	G.T.R.	Dry Dock Section	St. Clair Flats	Ft. G. to G.T.R.	G.T.R. to Dry Dock	Rise	Fall	Dir.	Vel. Miles	1B	10B	14B	15B	713	1B	10B	14B	15B	713	Adopted
A	B	C	D	E	F	G	H	Z	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
	1910	(Shore)																				
290	June 22	580.29	579.67	578.86	575.65	0.62	0.79	0.19	0.22	N.E.	2			M		K			122,870		191,150	182,670
291		.27	.66	.85	.65	.61	.78	.22	.24	N.E.	4		M	M				168,630	187,830			185,330
292		.30	.67	.86	.65	.63	.79	.14	.21	S.W.	2		M		M			188,200		188,460		185,280
293		.41	.76	.94	.65	.65	.83	.10	.07	N.E.	4	M			M		188,320			190,190		189,260
294		.43	.80	579.00	.65	.63	.80	.21	.25	N.E.	2-6	M		M			190,660		189,830			190,240
295		.39	.75	578.97	.66	.64	.78	.16	.07	N.E.	4-6		M	M				191,180	187,350			189,200
296		.46	.79	.96	.66	.67	.81	.10	.06	N.W.	12		M		M			190,940		196,140		190,080
297		.51	.80	579.00	.67	.71	.80	.09	.08	N.W.	13	M			M		192,560			195,050		193,580
298		.45	.74	578.94	.66	.71	.80	.22	.16	N.W.	20	M		M			192,360		192,500			192,480
299		.37	.65	.95	.67	.72	.90	.13	.16	N.E.	4			M	M				194,790	188,450		186,620
300		.39	.74	.95	.66	.65	.79	.14	.06	N.W.	10		M		M			194,150		192,020		193,080
301		.27	.26	.87	.65	.61	.78	.06	.22	N.W.	6	M	M				183,970	187,830				185,900
302		.33	.70	.90	.66	.63	.80	.12	.07	N.W.	2	M		M			188,570		190,360			189,460
303		.39	.66	.93	.67	.63	.78	.04	.09	S.W.	6			M		K			184,300		185,330	184,980
304		.40	.75	.97	.68	.65	.78	.16	.31	N.W.	4-8		M		M			192,480		192,120		192,300
305	July 6	.18	.55	.83	.64	.63	.72	.21	.33	S.S.W.	8	O	M				181,030	184,830				182,930
306	6	.10	.49	.78	*.63	.61	.71	.30	.24	S.W.	12		M		M			183,530		181,560		182,540
307	9	.19	.57	.84	.64	.62	.73	.13	.09	S.W.	3	O		M			180,900		182,030			181,460
308	9	.26	.64	.90	.65	.62	.74	.04	.05	S.E.	15			M	M				182,280	185,980		185,980
309	21	.21	.51		.60	.70		.46	.78	S.W.-N.E.	2-20			M	M							Rejected
310	21	.16	.51	578.84	.62	.65	0.67	.41	.63	S.S.W.-S.E.	25-30		M	M				179,450	177,500			178,520
311	22	.23	.63	.90	.62	.60	.73	.22	.12	S.-S.W.	10-12		M		M			186,830		186,960		186,900
312	23	.21	.59	.87	.60	.62	.72	.05	.07	S.	2-5			M	M				183,460	183,200		183,380
313	23	.29	.64	.92	.63	.64	.72	.12	.10	S.-S.W.	5-45	O			M		184,390			182,580		183,980
314	Aug. 2	.31	.68	.95	.62	.63	.73	.12	.06	N.E.-N.N.E.	6-8		Q		Q			188,910		186,420		187,660
315	2	.29	.62	.86	.62	.67	.76	.06	.21	N.-N.N.E.	5-8		Q					182,450	183,780			183,120
316	3	.15	.52	.83	.61	.63	.69	.08	.23	E.-S.W.	2-2	Q		Q			178,230		181,000			181,000
317	3	.10	.49	.77	.62	.61	.72	.29	.21	S.-S.S.W.	4-7	Q					174,000	180,380				180,380
318	4	.36	.64	.91	*.66	.62	.73	.07	.00	W.-W.S.W.	18		Q		Q			184,430		183,340		183,890
319	4	*.44	.79	579.06	*.72	*.65	.71	.07	.00	WSW.-WNW.	18-30		Q		Q				188,510	188,220		188,360
320	4	*.55	.86	.07	*.64	*.67	.81			NNW.-NW.	20-25		Q		Q			192,670	191,790			192,230
321	5	*.33	.69	578.92	.60	*.64	.77			W.S.W.-W.	18-20		Q					183,460	183,190			183,320
322	5	*.50	.84	579.04	.64	*.66	.80			S.W.	20-35		Q		Q				188,190	188,700		188,440
		(Piles)																				
323	Sept. 7	.21	.63	578.84	.48	.58	.79	0.11	0.07	S.E.	0-2		Q		Q			186,520	186,950			186,740
324	7	.14	.56	.82	.46	.56	.77	.09	.12	S.-S.E.	2		Q		Q			187,100		178,030		187,100
325	8	579.84	.32	.58	.46	.52	.74	.08	.24	S.S.E.-S.	4-18		Q		Q				173,170	168,910		173,170
326	8	580.00	.45	.66	.46	.55	.79	.27	.21	S.	15		Q		Q			183,740		178,410		183,740
327	8	.24	.61	.79	.47	.63	.83	.30	.01	S.	15		Q		Q			186,040	187,480			186,760
328	9	.56	580.00	579.16	.40	.56	.84	.08	.22	N.N.W.	28-30		Q		Q				202,950	193,440		202,950
329	9	.23	579.75	578.96	.44	.53	.77	.36	.20	N.W.-N.E.	30-10		Q		Q			189,230	191,740			191,740
330	10	.10	.52	.78	.44	.57	.78	.13	.09	S.	4	Q			Q		182,780		185,720			184,260
331	11	.03	.50	.70	.43	.53	.80	.04	.11	S.	4	Q			Q		181,310	179,870				181,310
332	11	.17	.58	.81	.45	.59	.77	.09	.11	W.S.W.-W.	8-45							187,000	220,440			203,720
333	Oct. 11	.10	.58	.81	.45	.52	.77	.07	.07	W.S.W.	20-30							186,580		180,810		Rejected

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Williams Exhibit 23.

Williams Ex. 23

U. S. LAKE SURVEY.
HYDRAULICS OF ST. CLAIR RIVER
Summary of Discharge
Section Say.

Sheet 16
(37 Sheets)
Table 13
W. S. Richmond, Jun. Engr.
April, 1911

Number	Date 1910	Wind		Water Surface Elevations					Discharge of River	Channel Discharge						Mean Channel Discharge	Per cent of Flow
		Dir.	Vel.	Fort Gratiot	G.T.R.	Dry Dock	Roberts Landing	St. Clair Flats		Meter	Rating	Discharge	Meter	Rating	Discharge		
A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S
1	May 25	W.	10	(Shore) 580.31	579.66	578.86	576.42	575.61	186,800	10B	M	11,360	15B	L	11,340	11,350	6.1
2	" 25	N.W.	12	.32	.69	.87	.43	.61	187,200	10B	M	11,360	1B	K	11,320	11,340	6.0
3	" 25	N.W.	12	.40	.68	.86	.43	.59	190,800	1B	K	11,340	14B	K	11,380	11,360	6.0
4	" 25	N.W.	8	.40	.63	.82	.40	.68	189,700	15B	L	11,170	14B	K	10,840	11,000	5.8
5	" 26	N.W.	6	.35	.64	.83	.42	.66	187,500	15B	L	11,660	713	K	11,510	11,580	6.2
6	July 11	S.	6	.20	.67	.96	.51	.67	185,300	10B	M	10,580	15B	M	10,900	10,740	5.8
7	" 12	S.E.	15	.03	.42	.72	.52	.68	175,200	15B	M	10,390	10B	M	10,070	10,230	5.8
8	" 12	S.E.	15	.03	.47	.82	.54	.65	175,900	15B	M	10,660	14B	M	10,420	10,540	6.0
9	" 12	S.E.	15	579.97	.41	.73	.47	.64	173,900	14B	M	10,130	10B	M	10,140	10,140	5.8
10	" 12	S.E.	15	580.12	.52	.79	.48	.66	178,900	14B	M	10,360	10B	M	10,340	10,350	5.8
11	Sept. 1	N.E.	8	(piles) .19	.62	.86	.36	.41	189,400	15B	Q	10,770	14B	Q	10,850	10,810	5.7
12	" 1	N.E.	8	.28	.73	.91	.40	.43	192,400	14B	Q	11,150	15B	Q	10,770	10,960	5.7
13	" 1	N.E.	8	.29	.72	.92	.39	.42	192,800	14B	Q	10,910	15B	Q	10,780	10,840	5.6
14	" 1	N.E.	10	.22	.67	.87	.38	.40	190,700	14B	Q	11,080	10B	Q	10,960	11,020	5.8
15	Oct. 6	S.E.	8	579.86	.62	.86	.19	.36	178,600	10B	S	10,500	14B	S	10,330	10,420	5.8
16	" 8	S.E.	10	.60	.18	.44	.16	.37	172,100	14B	S	10,150	10B	S	10,160	10,160	5.9
17	" 8	S.E.	10	580.13	.46	.66	.20	.37	188,100	15B	S	10,620	10B	S	10,530	10,580	5.6
18	Nov. 20	W.	10	579.84	579.98	* .23	575.73	574.83	178,300	14B	U	10,970	10B	U	10,980	10,930	5.1
19	" 25	W.N.W.	20	.57	.99	* .23	.76	.83	179,400	14B	U	11,040	15B	U	11,079	11,060	6.2
20	" 25	N.W.	30	.65	579.03	.25	.78	.83	182,300	14B	U	11,030	15B	U	11,040	11,040	6.1

*Elevations supplied.

Williams Exhibit 23.

Williams Ex. 23

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Summary of Discharge
Section Bridge

Sheet 17
(37 Sheets)
Table 15
W. S. Richmond, Jun. Engr.
April, 1911

Number	Date 1910	Time of Day	Meter	Rating	Wind		WATER SURFACE ELEVATIONS						Discharge	Discharge of River	Percent of Flow
					Dir.	Vel.	Fort Gratiot	G. T. R.	Dry Dock	Roberts Landing	Herons Island	St. Clair Flats			
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q
							(shore)								
1	May 26	11:00-11:30	10B	M	N.W.	10	580.25	579.78	578.96	576.50	576.02	575.52	580	188,100	.31
2	May 26	12:40-13:00	10B	M	S.W.	15	.44	.82	.98	.48	.00	.51	623	191,600	.32
3	May 26	13:10-13:30	10B	M	N.W.	15	.46	.77	.91	.43	575.96	.42	618	191,700	.32
4	May 26	14:00-14:40	15B	L	N.W.	18	.43	.71	.89	.43	.95	.50	615	191,400	.32
5	May 26	16:40-17:30	15B	L	N.W.	18	.49	.76	.91	.44	.96	.50	667	191,500	.32
6	July 13	8:20- 9:00	71B	K	N.W.	12	.52	.84	579.01	.52	*576.06	.64	454	193,900	.23
7	July 13	9:20-10:50	10B	M	N.W.	13	.51	.79	.00	.51	* .06	.64	396	193,500	.21
8	July 13	10:40-12:30	14B	M	N.W.	12	.54	.66	578.88	.50	* .06	.65	426	187,900	.23
9	July 13	13:40-14:30	14B	M	N.W.	12	.43	.69	579.01	.53	* .07	.65	415	190,400	.22
							(piles)								
10	Sept. 2	8:00- 8:50	15B	Q	N.E.	4	.00	.44	578.69	.30	575.85	.44	306	181,900	.17
11	Sept. 2	9:20- 9:50	15B	Q	N.E.	4	.05	.52	.73	.33	.88	.44	394	183,800	.16
12	Sept. 2	10:50-11:10	14B	Q	N.E.	4	.09	.50	.70	.33	.89	.44	290	181,900	.16
13	Oct. 7	12:40-13:10	71B	K	N-N.W.	6	.02	.51	.73	.21	* .77	.35	343	184,500	.19
14	Oct. 7	13:00-13:30	71B	K	N-N.W.	6	.06	.53	.71	.25	* .78	.36	344	185,700	.19
15	Oct. 7	13:40-14:20	10B	S	N-N.W.	4	.07	.51	.72	.23	* .78	.36	356	186,000	.19
16	Oct. 7	14:30-15:50	14B	S	N-N.W.	3	.00	.48	.70	.22	* .77	.36	333	183,500	.18
17	Nov. 25	14:30-16:30	14B	U	N.W.	20	579.66	.10	.30	575.84	.32	576.36	409	182,000	.23
18	Nov. 25	15:30-16:10	71B	K	N.W.	20	.76	.19	.37	.84	.33	.84	422	186,000	.23

*Elevations Supplied.

U. S. LAKE SURVEY.
HYDRAULICS OF ST. CLAIR RIVER.
Summary of Discharge.
Section Bassett.

Sheet 18.
(37 Sheets)
Table 17
W. S. Richmond, Jun. Engr.
April, 1911.

Number	Date 1910	Wind		Water Surface Elevations						Discharge of River	Channel Discharge						Mean Channel Discharge	Percent of Flow
		Dir.	Vel.	Fort Gratiot	G.T.R.	Dry Dock	Roberts Landing	Hersco Island	St. Clair Flats		Meter	Rating	Discharge	Meter	Rating	Discharge		
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T
1	June 8	S.W.	2	(Shore) 580.38	579.69	578.02	576.53	576.04	575.60	187,700	1B	K	11,633	14B	K	11,311	11,470	6.1
2	8	S.W.	2	.33	.66	.90	.51	.04	.58	185,800	1B	K	11,842	713	K	11,724	11,780	6.3
3	9	N.E.	4	.24	.59	.82	.45	.02	.68	182,800	10B	M	11,304	14B	K	11,239	11,320	6.3
4	9	N.E.	6	.26	.65	.88	.50	.04	.67	183,700	10B	M	11,550	15B	L	11,627	11,590	6.3
5	9	N.E.	6	.31	.69	.90	.51	.02	.68	185,300	712	K	11,336	15B	L	11,330	11,330	6.1
6	July 14	S.	6	.19	.58	.84	.46	.04	.65	181,700	14B	M	11,386	10B	M	11,156	11,270	6.2
7	14	S.W.	6	.23	.57	.84	.47	.02	.65	182,100	14B	M	11,398	15B	M	11,780	11,590	6.4
8	14	S.	12	.19	.58	.87	.48	.03	.64	182,300	712	K	11,403	15B	M	11,646	11,530	6.3
9	Aug. 30	S.E.	15	(Piles) 579.73	.22	.50	.26	575.86	.46	171,500	14B	Q	10,150	15B	Q	10,005	10,080	5.9
10	30	S.E.	15	.65	.34	.57	.30	.87	.45	176,100	15B	Q	10,154	14B	Q	10,222	10,200	5.8
11	30	S.E.	12	.77	.26	.56	.28	.84	.44	173,500	15B	Q	9,574	14B	Q	9,837	9,710	5.6
12	30	S.E.	12	.84	.36	.61	.29	.84	.44	176,100	15B	Q	9,977	14B	Q	10,020	10,000	5.7
13	Oct. 14	S.W.	4	.91	.43	*.66	*.16	.74	.27	182,300	14B	S	11,192	15B	S	11,211	11,200	6.1
14	14	S.W.	1	.90	.36	*.59	*.16	.74	.28	181,700	10B	S	10,801	15B	S	10,779	10,790	5.9
15	14	S.W.	3	.88	.36	*.58	*.18	.76	.28	182,700	15B	S	11,230	10B	S	11,081	11,150	6.1
16	14	N.E.	3	580.01	.44	*.66	*.18	.75	.29	185,400	713	S	10,687	10B	S	10,603	10,640	5.7
17	Nov. 28	N.W.	10	579.22	578.74	577.97	575.65	*.25	574.99	166,400	15B	U	10,239	10B	U	10,373	10,350	6.3
18	28	N.W.	10	.25	.76	578.01	.68	*.30	.88	166,700	15B	U	10,949	14B	U	10,108	10,180	6.1
19	28	N.W.	10	.39	.86	.05	.70	.25	.89	171,500	15B	U	10,706	14B	U	10,741	10,720	6.3

*Elevations supplied.

Williams Ex. 23.

U. S. LAKE SURVEY.
HYDRAULICS OF ST. CLAIR RIVER.
Summary of Discharge.
Section South East Bend.

Sheet 19
(37 Sheets)
Table 19
W. S. Richmond, Jun. Engr.
April, 1911

Number	Date 1910	Wind		Water Surface Elevations						Discharge of River	Channel Discharge						Mean Channel Discharge	Percent of Flow
		Dir.	Vel.	Fort Gratiot	G.T.R.	Dry Dock	Roberts Landing	Herons Island	St. Clair Flats		Meter	Rating	Discharge	Meter	Rating	Discharge		
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T
1	June 2	S.E.	6	(Shore) 580.41	579.72	579.94	*576.41	575.93	575.58	191,100	14-B	K	55,530	1-B	K	56,050	55,790	29.3
2	" 3	E.	2	.42	.77	.99	*.44	.97	.59	191,600	15-B	L	56,500	10-B	M	56,600	56,550	29.6
3	" 3	N.E.	13															
3	" 3	N.E.	20	*.67	.98	*.95	*.50	576.65	.64	183,400	14-B	K	54,240	15-B	L	57,480	57,100	30.3
4	" 3	N.	13	*.44	.79	*.82	*.50	.08	.67	190,300	10-B	M	54,710	14-B	K	54,970	54,840	28.8
5	July 19	N.W.	8	.29	.64	.93	.50	.07	.55	185,200	15-B	M	55,260	10-B	M	54,280	54,870	29.6
		S.W.	16															
6	" 19	S.-W.	15-8	.39	.66	.96	.52	.07	.64	185,300	14-B	M	55,910	15-B	M	55,430	55,660	30.0
7	" 20	S.W.	15-20	.60	.44	.73	.46	.05	.65	174,700	10-B	M	52,240	14-B	M	53,640	52,440	30.0
8	" 20	S.-W.	13-15	.08	.47	.77	.47	.04	.64	176,800	10-B	M	52,420	15-B	M	53,210	52,820	29.9
9	Aug. 24	S.-S.W.	20	(Piles) 579.66	.22	.49	.27	572.86	.47	168,700	14-B	Q	52,100	15-B	Q	51,980	52,040	30.8
10	" 24	S.S.E.	15	.55	.31	.57	.32	.90	.47	175,700	14-B	Q	52,120	15-B	Q	51,850	51,980	29.6
11	" 26	E.N.E.	15	580.19	.61	.81	.35	.68	.42	180,300	14-B	Q	56,980	15-B	Q	56,740	56,860	30.1
		N.E.	20															
12	" 29	N.-E.	15.8	.16	.90	.82	.36	.90	.43	188,600	15-B	Q	56,870	14-B	Q	57,420	57,140	30.3
13	Oct. 13	N.E.	4	579.33	578.96	.27	*.16	.60	.33	167,200	14-B	S	50,120	15-B	S	49,510	49,820	29.8
		S.E.	15															
14	" 13	S.-E.	13-15	.62	579.13	.37	*.17	.71	.33	170,600	15-B	S	51,250	14-B	S	50,120	50,680	29.7
15	" 13	S.E.	10	.57	.09	.41	*.16	.71	.30	169,300	15-B	S	53,280	10-B	S	51,430	51,840	30.7
16	" 14	S.S.W.	2	.93	.35	*.56	*.16	.75	.27	182,900	14-B	S	54,300	10-B	S	53,700	54,000	29.5
17	Nov. 26	N.	8	.67	.14	.25	575.75	.23	574.86	182,400	14-B	U	55,940	10-B	U	55,660	55,800	30.6
18	" 26	N.W.	4	.60	.12	.33	.76	.25	.86	183,100	14-B	U	55,760	15-B	U	56,270	56,020	30.6
19	" 26	W.	2	.51	.01	.24	.76	.26	.85	178,800	15-B	U	56,050	10-B	U	56,140	56,100	31.9

*Elevations supplied.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Summary of Discharge
Section M. C.

Number	Date 1910	Wind		Water Surface Elevations						Discharge of River	Channel Discharge						Mean Channel Discharge	Percent of Flow
		Dir.	Vel.	Fort Gratiot	G.T.R.	Dry Dock	Roberts Landing	Salt Block	St. Clair Flats		Meter	Rating	Discharge	Meter	Rating	Discharge		
A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T
1	May 20	S'ly	10	(Shore)						185,100	15B	L	32,180	1B	K	32,250	32,220	17.4
2	" 21	W.	25	580.25	579.59	578.77	576.39	575.34	575.49	209,300	15B	L	33,840	1B	K	33,920	33,880	16.2
3	" 21	W.	25	.01	.46	*579.06	.51	.36	.58	208,600	15B	L	32,220	14B	K	31,930	32,080	15.4
4	" 21	W.	20	.89	.90	.05	.49	.38	.58	203,600	10B	M	33,970	14B	K	32,840	33,400	16.4
5	" 21	S.W.	12	.76	.93	.03	.53	.90	.59	208,400	10B	M	34,600	1B	K	34,860	34,730	16.7
				.80	.98	.09	.51	" .90	.59									
6	July 18	N.N.E.	8	580.61	579.72	579.05	576.52	575.96	575.66	197,000	10B	M	34,440	14B	M	35,120	34,780	17.7
7	" 18	N.N.W.	20	.91	.52	.07	.51	.96	.63	208,300	14B	M	37,080	10B	M	35,700	36,390	17.5
8	" 18	N.N.W.	25	.85	.61	.06	.49	.93	.62	206,300	10B	M	34,880	15B	M	35,720	35,300	17.1
9	" 18	N.N.W.	25	.94	.57	.06	.50	.92	.63	209,800	10B	M	35,590	15B	M	35,830	35,710	17.0
10	Aug. 31	N.E.	15	(Piles)						190,200	15B	Q	34,120	14B	Q	34,630	34,380	18.0
11	" 31	N.E.	12	580.39	579.74	578.90	576.34	575.77	575.42	185,700	14B	QQQ	33,120	15B	QQQ	33,480	33,300	18.0
12	" 31	N.E.	10	.17	.61	.82	.32	.78	.43	189,500	10B	QQQ	32,630	15B	QQQ	32,790	32,660	17.3
13	" 31	N.E.	10	.24	.67	.87	.37	.82	.40	188,900	10B	QQQ	32,690	14B	QQQ	33,410	33,050	17.5
14	Oct. 11	S.W.	2	580.06	579.49	578.75	*576.23	575.72	575.37	183,900	14B	S	33,200	15B	S	33,240	33,220	18.2
15	" 12	N.	25	.32	.80	579.01	" .12	.70	.26	191,200	15B	S	35,330	14B	S	35,600	35,470	18.6
16	" 12	N.	25	.05	.04	578.80	" .13	.73	.27	184,800	15B	S	34,430	10B	S	34,200	34,320	18.6
17	" 12	N.	25	.04	.62	.83	" .12	.72	.26	184,600	14B	S	33,960	10B	S	33,330	33,650	18.2
18	Nov. 19	W.	4	579.74	579.17	578.35	576.84	576.30	*574.96	179,800	14B	U	32,080	10B	U	31,510	31,790	17.7
19	" 19	N.W.	8	.61	.06	.31	.32	.30	" .96	175,500	14B	U	31,610	10B	U	31,040	31,330	17.9
20	" 19	N.W.	8	.60	.04	.28	.61	.30	" .95	175,400	14B	U	31,940	15B	U	31,780	31,860	18.2

*Elevations Supplied.

Williams Exhibit 23.

U. S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Summary of Discharge
Section Salt Block

W. S. Richmond, Jun. Engr.
April, 1911

Number	Date 1910	Wind		Water Surface Elevations						Discharge of River	CHANNEL DISCHARGE						Mean Channel Discharge	Percent of Flow
		Dir.	Vel.	Fort Gratiot	G.T.R.	Dry Dock	Roberts Landing	Salt Block	St. Clair Flats		Meter	Rating	Discharge	Meter	Rating	Discharge		
A	B	C	D	E	F	G	H	I	K	L	M	N	O	P	Q	R	S	T
1	June 4	S.-W.	4	(shore)						197,500	14B	K	77,420	1B	K	79,170	78,300	41.7
		N.-E.	8	680.36	679.60	678.92	678.61	678.04	678.08									
2	June 6	S.W.	4	.26	.71	.94	.55	.97	.70	186,700	1B	K	73,680	10B	M	77,380	77,970	41.7
3	June 6	S.-W.	4	.42	.77	.99	.54	.98	.70	189,300	10B	M	80,630	15B	L	80,270	80,300	42.4
4	June 6	N.-W.	8	.32	.72	.93	.54	.96	.70	187,800	10B	M	73,250	15B	K	79,050	76,700	41.8
5	June 7	S.-W.	10-16	.46	.80	679.01	.55	.94	.69	190,600	15B	L	78,540	14B	K	76,460	77,500	40.7
6	July 15	S.	1-5	680.22	679.80	678.87	678.47	678.06	678.04	183,000	10B	M	72,460	14B	M	73,630	72,540	39.6
7	July 15	W.	6	.25	.65	.92	.49	.96	.64	184,100	14B	M	73,600	10B	M	73,340	73,470	39.9
8	July 15	S.S.E.	6	.23	.64	.92	.51	.95	.65	185,000	14B	M	73,020	15B	M	74,510	73,760	39.9
9	July 16	S.-W.	4	.29	.55	.83	.45	.94	.65	183,300				10B	M	73,260	73,260	39.6
10	Aug. 26	N.-W.	10	(piles)	679.78	678.99	678.42	678.03	678.02	194,000	10B	Q	72,170	14B	Q	73,190	72,680	37.1
		S.-W.	8	680.28														
11	Aug. 26	S.-W.	8	.26	.68	.91	.49	.96	.62	191,500	14B	Q	70,370	10B	Q	70,260	70,320	36.7
12	Aug. 27	W.S.W.	1	.03	.46	.73	.23	.84	.43	183,100	713 Price	Q	70,060	15B	Q	70,440	70,700	38.6
13	Aug. 27	S.	3	.02	.45	.71	.25	.83	.43	182,800	10B	Q	69,160	15B	Q	70,360	69,760	38.2
14	Oct. 10	S.W.	3-5	679.94	679.39	*678.63	*678.22	678.00	678.36	181,600	15B	S	71,670	10B	S	71,200	71,440	39.4
15	Oct. 10	S.	3	.90	.39	.68	* .23	.71	.27	179,700	15B	S	69,370	14B	S	69,570	69,610	38.7
16	Oct. 10	S.	1	.81	.31	.59	* .19	.72	.27	178,400	15B	S	69,470	14B	S	68,850	68,160	38.7
17	Oct. 11	S.-S.W.	5-7	680.04	.47	.69	* .23	.76	.29	184,400	10B	S	71,040	15B	S	72,240	71,640	38.9
18	Oct. 11	S.-S.W.	6	.10	.52	.76	* .22	.74	.36	187,200	10B	S	73,330	713 Price	S	73,260	73,440	39.2
19	Nov. 21	S.W.	12-20	679.20	678.73	677.97	678.00	678.32	674.23	196,000	14B	U	66,130	15B	U	65,990	66,060	40.2
20	Nov. 22	W.	4	.27	.84	*678.37	.74	.23	.84	171,800	15B	U	71,960	10B	U	Reject	71,960	41.9
21	Nov. 23	W.	6	.51	.96	* .39	.72	.21	.82	169,900	14B	U	71,180	10B	U	Reject	71,180	41.9

*Elevations Supplied.

Sheet 22
(37 Sheets)

U.S. ENGR. SURVEY

Williams Ex. 23. HYDRAULICS OF ST. CLAIR RIVER TABLE 24

PERCENTAGE DISCHARGE IN CHANNELS OF DELTA.

W. S. RICHARDS, Asst. Engr.
APRIL 15, 1911.

Month	Bay	Sawmill	Mud	South	Middle	North	Total
June	6.0	0.2	0.1	29.5	16.9	47.7	100.1
July	5.8	0.3	0.2	28.9	17.3	39.8	99.3
Aug.	5.7	0.2	0.2	30.2	17.7	37.6	97.6
Oct.	5.8	0.3	0.2	29.9	18.4	38.8	99.3
Nov.	6.1	0.3	0.2	31.0	17.9	41.4	102.7
Mean	5.9	0.1	0.2	30.1	17.8	39.9	99.7

Williams Ex 23

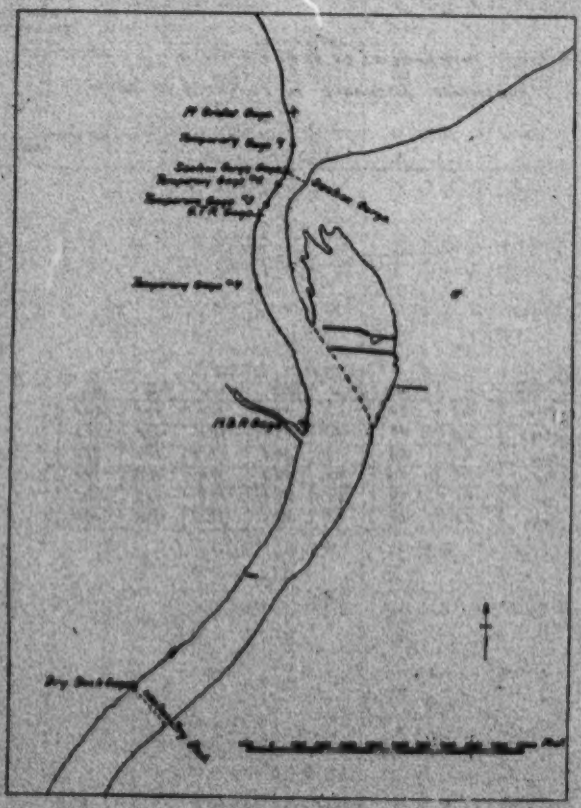
Sheet 23
(37 Sheets)
PLATE 8

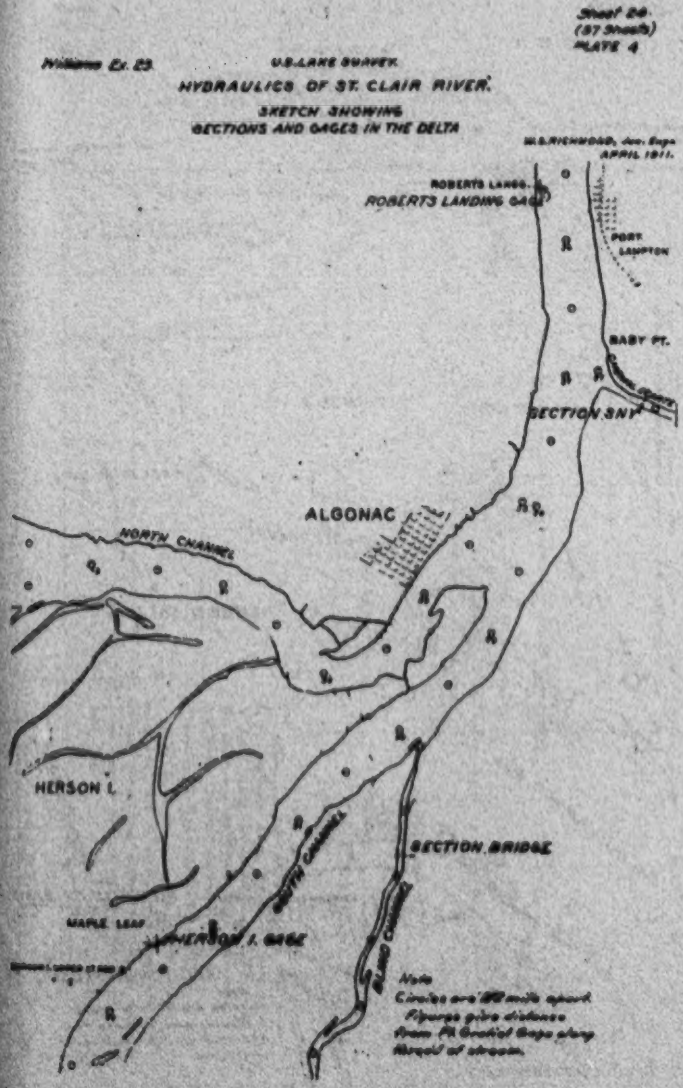
U.S. LAKE SURVEY

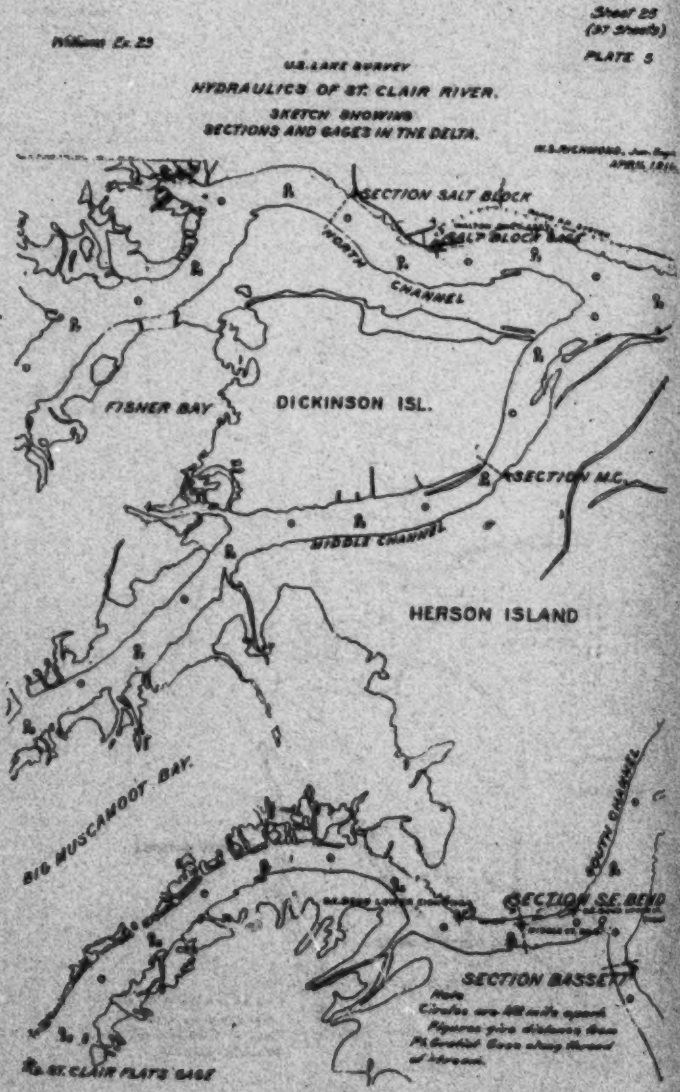
HYDRAULICS OF ST. CLAIR RIVER.

Sketch showing Sections and Gages at Head of River

APRIL, 1911.




Sheet 24
(37 Sheets)
PLATE 4
Williams Ex. 23.
U.S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER.
SKETCH SHOWING
SECTIONS AND GAGES IN THE DELTA
W.S. RICHWOOD, Asst. Engr.
APRIL 1911.
ROBERTS LANDG.
ROBERTS LANDING GAGE
PORT LAMBTON
BABY PT.
SECTION 3N1
ALGONAC
NORTH CHANNEL
HERSON I.
SECTION BRIDGE
SOUTH CHANNEL
MAPLE LEAF
HERSON I. GAGE
Note
Elevations are USE mean tide datum
Figures give distance
from Pt Grondal Gage along
thread of stream.


Sheet 23
(37 Sheets)
Williams Ex. 23
PLATE 5
U.S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER.
SKETCH SHOWING
SECTIONS AND GAGES IN THE DELTA.
APRIL, 1911.
SECTION SALT BLOCK
SALT BLOCK GAGE
NORTH CHANNEL
FISHER BAY
DICKINSON ISL.
SECTION M.C.
DIBBLE CHANNEL
HERSON ISLAND
BIG MUSCAMOOT BAY.
SOUTH CHANNEL
SECTION S.E. BEND
SECTION BASSETT
Note
Circles are 400 mile square
Figures give distances down
Mt. Crushed Stone along thread
of stream.
ST. CLAIR FLATS GAGE

Sheet 56
(29 Sheets)

Williams Ex. 23¹

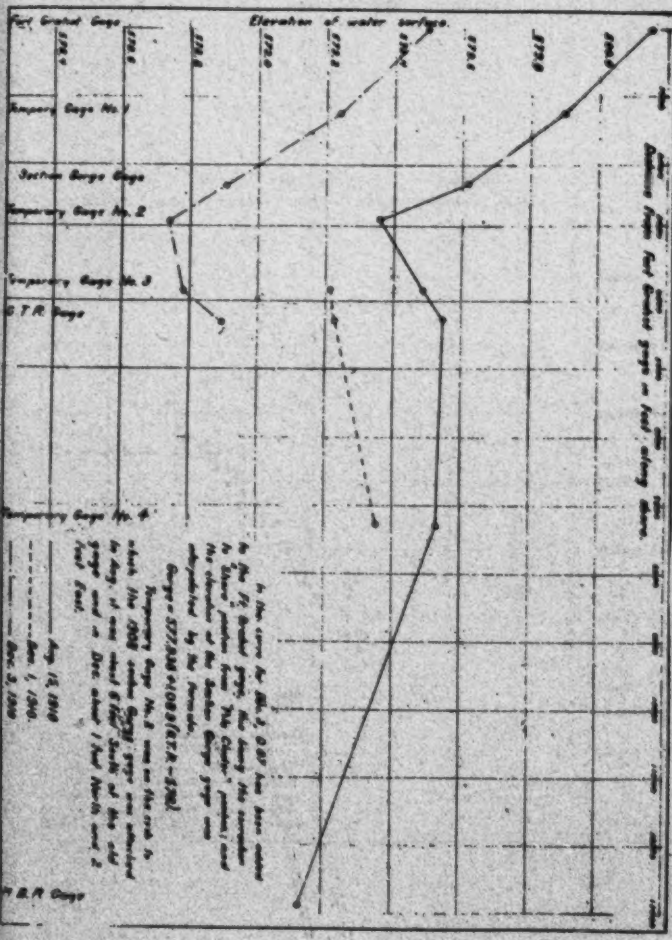
U.S. LAKE SURVEY

PLATE 7

HYDRAULICS OF ST. CLAIR RIVER

LOCAL SLOPES ALONG WEST BANK AT HEAD OF RIVER

W.S. RICHARDSON, Asst. Engr.
APRIL 1911.



Williams Ex 23

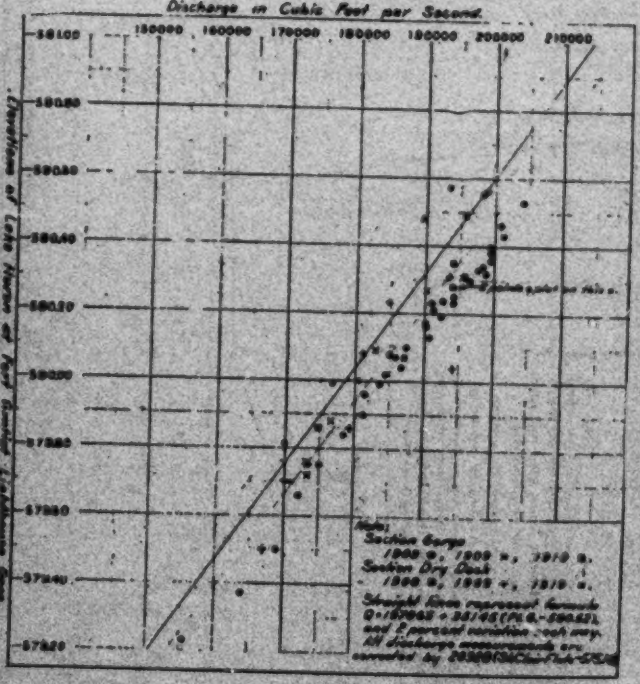
Sheet 27
(37 Sheets)
PLATE 18

U.S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER.

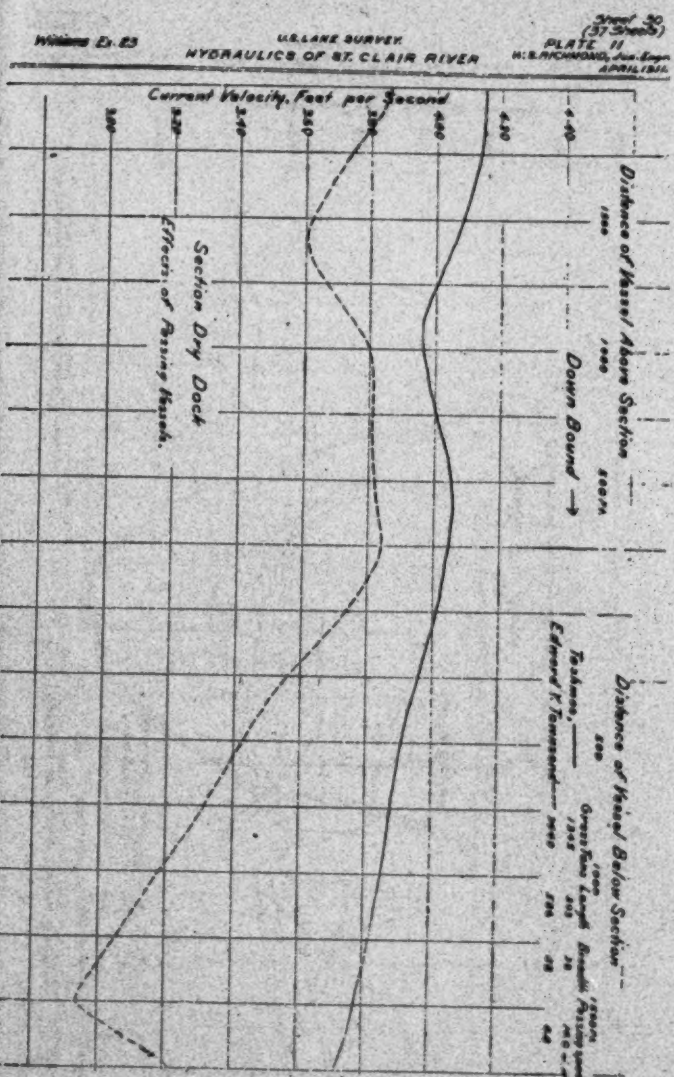
DISCHARGE OF ST. CLAIR RIVER
MEANS OF FIVE.

W.S. RICHMOND Jun. Engr.
APRIL, 1911



Williams Ex. 23.
U.S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Sheet 26
(37 Sheets)
PLATE 9
H.S.A. RICHMOND, Junr. Engr
APRIL 1911
Current Velocity, Feet per Second
Distance of Vessel Above Section
Down Bound
Distance of Vessel Below Section
Section Gorge
Effects of Passing Vessels.

Williams Ex. 23
U.S.LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Sheet 124
(37 Sheets)
PLATE 10
APRIL 1911
Current Velocity, Feet per Second
Distance at Head/ Above Section
Distance at Head/ Below Section
Section Gauge
Effects of Passing Vessels
← Up Bound
City of St. Ignace
J.S. Keefe
C.M. Starke
Ocklawaha


Williams Ex. 23
U.S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Sheet 30 (37 Sheets)
PLATE II
H. S. RICHARDSON, Asst. Engr.
APRIL 1911.
Current Velocity, Feet per Second
Distance of Vessel Above Section
Down Bound →
Distance of Vessel Below Section
Section Dry Dock
Effects of Passing Vessels.
Steamer, ——
Entered L. Tennessee
Gross Tons
Length
Breadth
Passing speed

Williams Ex. 23
U.S. LAKE SURVEY
HYDRAULICS OF ST. CLAIR RIVER
Sheet 2
(37 Sheets)
PLATE 18
U.S. RICHMOND, Asst. Engr.
APRIL 1911
Current Velocity, Feet per Second
Distance of Vessel Above Section
Distance of Vessel Below Section
Tacoma
Dramico
Minnie
Ramapo
Length
Beam
Draft
Section Dry Dock
Effects of Passing Vessels
Up Bound

Williams Ex. 23

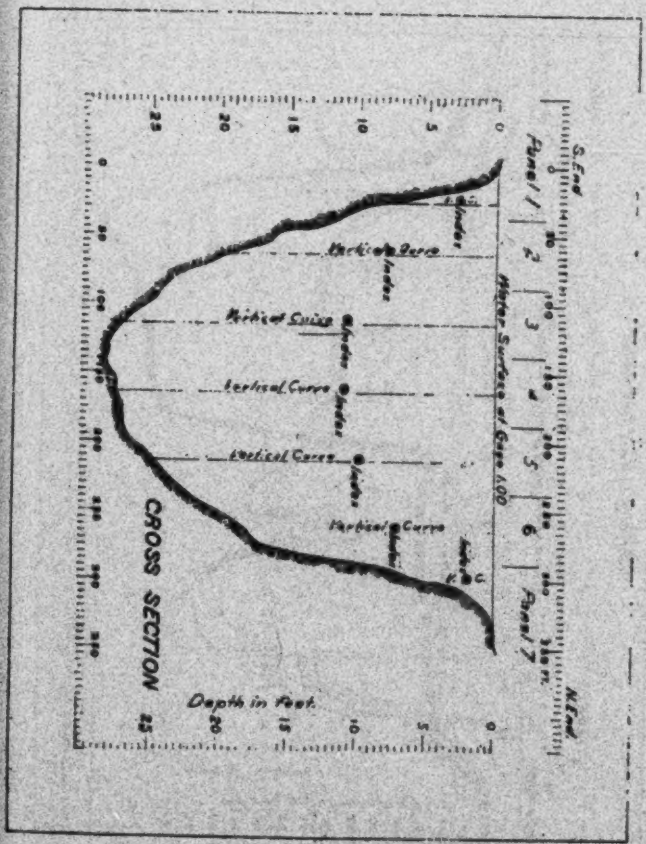
U.S. LAKE SURVEY

Sheet 32
(37 Sheets).
PLATE 13

HYDRAULICS OF ST. CLAIR RIVER

CHENAL ECARTE.
SECTION 8 N.Y.

W.S. RICHMOND, Jun. Engr.
APRIL 1911



Sheet 33
(97 Sheets)

Williams Ex 23.

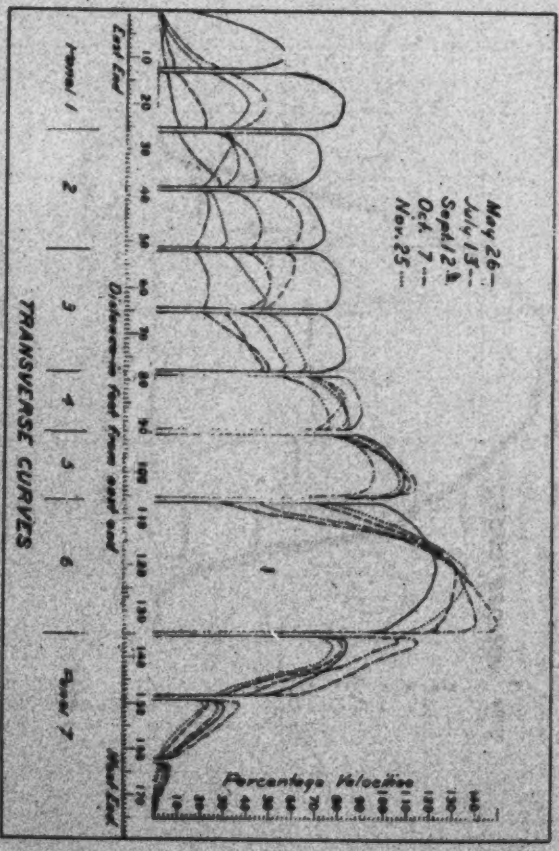
PLATE 18

U.S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

BLIND CHANNEL
SECTION BRIDGE

W. S. RICHMOND, Asst. Engr.
APRIL 1911.



Williams Ex. 28.

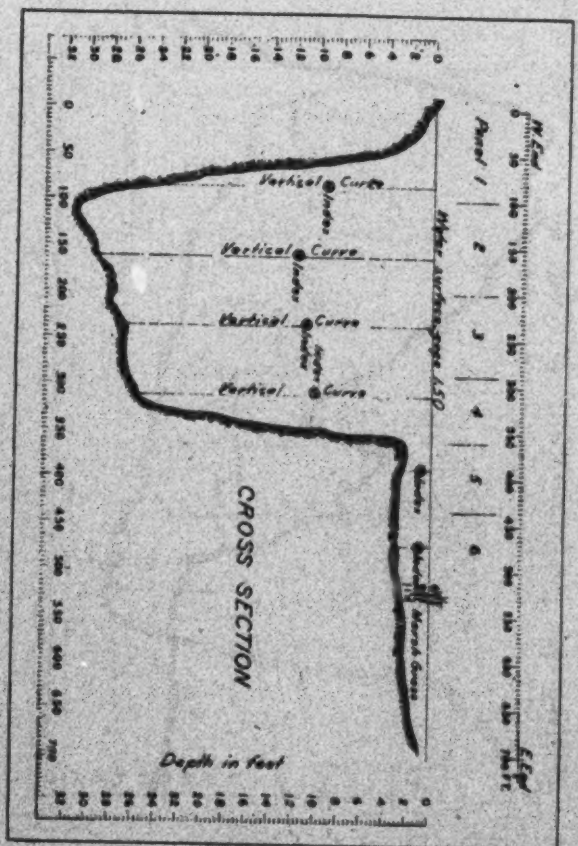
Sheet 34
(37 Sheets)
PLATE 19

U.S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

BASSETT CHANNEL.
SECTION BASSETT.

W.B. RICHMOND Asst. Engr.
APRIL 1911.



Williams Ex. 23.

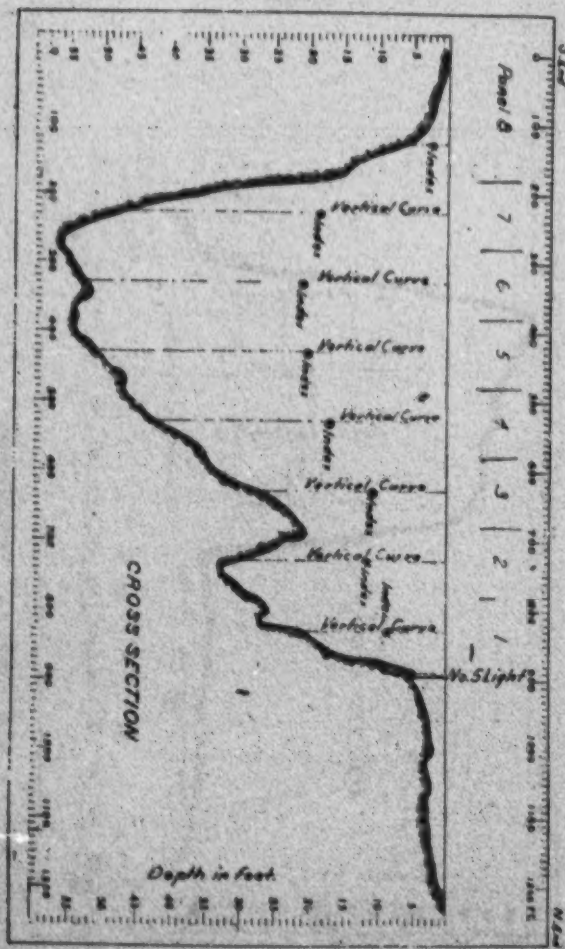
U.S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

SOUTH CHANNEL
SECTION S.E. BEND.

PLATE 22
Sheet 35
(37 Sheets)

H.S. RICHMOND Asst. Engr.
APRIL 1911.



Williams Ex. 23

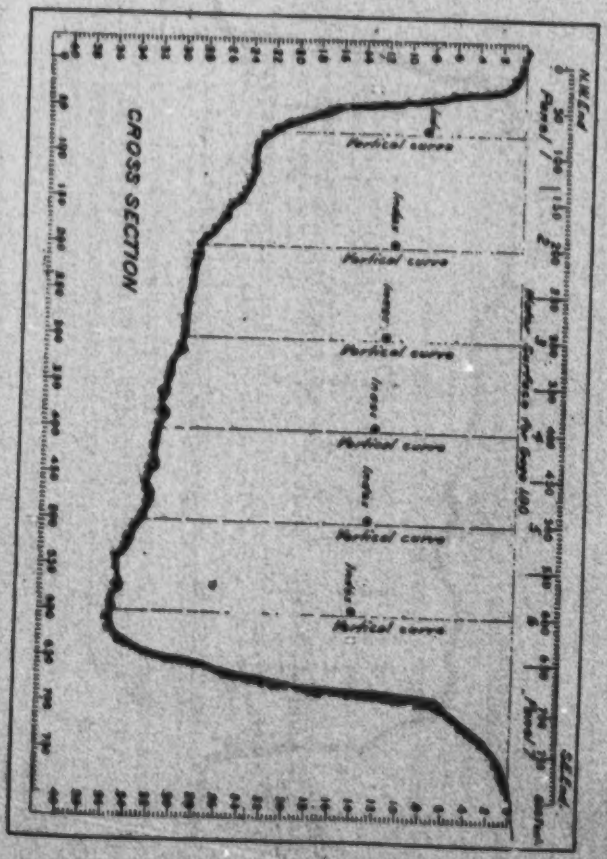
U.S. LAKE SURVEY.

HYDRAULICS OF ST. CLAIR RIVER

MIDDLE CHANNEL
SECTION MC.

PLATE E 5
Sheet 36.
(37 Sheets.)

W.S. RICHARDSON Jun. Engr.
APRIL, 1911.



Sheet 37
(37 Sheets)
PLATE 28

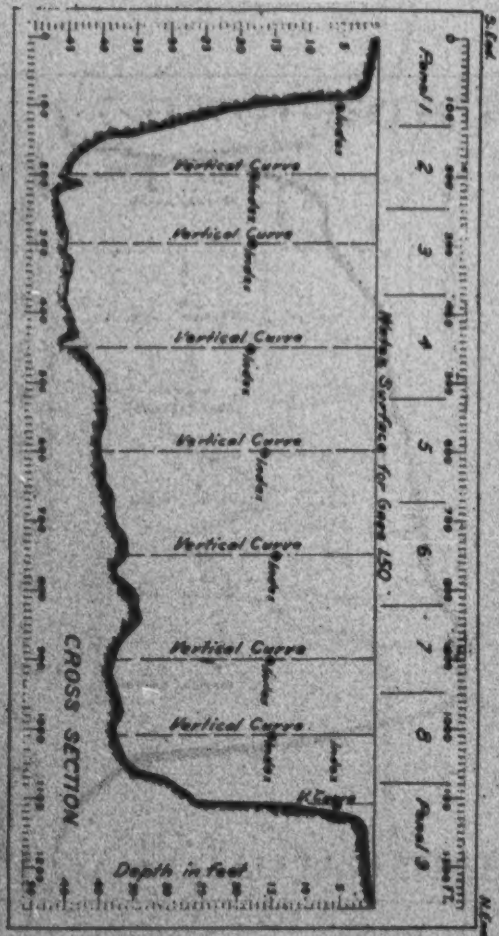
Williams Ex. 23

U.S. LAKE SURVEY

HYDRAULICS OF ST. CLAIR RIVER

NORTH CHANNEL
SECTION SALT BLOCK

W.D. RICHMOND, Asst. Engr.
APRIL 1911.



Williams Ex. 24.

Table No. 1
SUMMARY OF DISCHARGES.
International Bridge Section.
NIAGARA RIVER.

Sheet 1
(5 Sheets)

Levels of 1903.
F. B. M. Buffalo Light House, 580,101.
F. B. M. International Bridge, No. 2,562,258.

F. C. Shenehon,
U. S. Asst. Engineer
1906

Measurement No.	Date	Elevation of Water Surface Above Mean Tide, New York: Lake Erie Level	Elevation of Water Surface Above Mean Tide, New York: Section Gage at Bridge	Fall Lake Erie to Bridge	Change at Lake During Measurement, Feet: Rise	Change at Lake During Measurement, Feet: Fall	Wind: Direction from which it Blows	Wind: Approx. Velocity Miles per Hour	Discharge Cubic feet per Second	Rating No. Used: Meter I.S.B.	Rating No. Used: Meter I.S.A.	Weighted Mean Index Velocity	Percentage Residuals
	1903												
1	Sept. 10	571.44	566.97	4.48	0.03	0.23	N.E.	8	180,600	1		5.14	−2.2
2	12	572.03	567.39	4.67	0.06	0.23	S.W.	6	195,800	1		5.84	−0.6
3	13	571.96	567.23	4.63	0.00	0.21	S.W.	8	195,000	1		5.81	−0.3
4	15	572.01	567.26	4.63	0.07	0.11	S.W.	9	195,500	1		5.81	−0.6
5	15	572.16	567.42	4.74	0.44	0.02	S.W.	9	198,900	1		5.91	−0.4
6	17	571.74	567.19	4.55	0.06	0.13	S.W.	6	188,500	1		5.68	−1.2
7	17	571.75	567.16	4.59	0.13	0.06	S.W.	7	190,400	1		5.72	−0.4
8	20	571.96	567.23	4.71	0.13	0.20	N.W.	5	195,000	1		5.84	−0.3
9	20	571.79	567.20	4.59	0.15	0.06	N.E.	5	191,200	1		5.73	−0.3
10	23	571.70	567.13	4.57	0.03	0.12	S.W.	10	189,100	1		5.67	−0.6
11	23	571.77	567.13	4.64	0.23	0.07	S.W.	12	191,100	1		5.74	−0.2
12	24	571.76	567.06	4.70	0.06	0.10	N.E.	6	193,800	1		5.84	+1.1
13	24	572.24	567.34	4.90	0.10	0.12	N.E.	4	206,800	1		6.15	+3.5
14	27	572.35	567.38	4.97	0.10	0.01	N.W.	4	208,900	1		6.14	+1.4
15	27	572.33	567.43	4.90	0.02	0.13	N.W.	6	208,200	1		6.15	+1.5
16	29	571.85	567.22	4.63	0.03	0.15	S.W.	7	188,900	1		5.65	−2.2
17	29	571.73	567.15	4.58	0.04	0.15	S.W.	7	187,400	1		5.62	−1.7
18	Oct. 1	571.42	566.87	4.55	0.11	0.09	S.E.	3	181,900	1		5.53	−1.1
19	1	571.43	566.80	4.59	0.22	0.04	S.E.	2	184,800	1		5.61	−0.2
20	4	571.66	567.04	4.59	0.11	0.20	S.E.	3	186,700	1		5.66	−0.2
21	4	571.76	567.08	4.68	0.16	0.01	S.	2	190,100	1		5.72	−0.6
22	6	571.41	566.88	4.53	0.00	0.00	N.E.	6	182,200	1		5.54	−0.9
23	6	571.08	566.94	4.72	0.28	0.04	N.E.	6	188,000	1		5.71	−0.5
24	8	571.72	567.02	4.67	0.13	0.08	N.	5	186,900	1		5.68	−0.8
25	8	571.72	567.06	4.67	0.10	0.10	N.	6	186,900	1		5.67	−0.9
26	11	572.04	567.34	4.70	0.00	0.74	S.W.	18	212,500	1		6.18	+1.0
27	11	571.90	567.61	4.38	0.08	0.32	S.W.	16	196,900	1		5.80	+0.3
28	12	571.57	566.93	4.62	0.12	0.07	E.	5	188,500	1		5.71	+0.7
29	13	571.64	566.90	4.68	0.14	0.11	E.	8	190,400	1		5.76	+0.9
30	15	571.80	567.28	4.64	0.21	0.03	N.W.	8	188,900	1		5.64	−1.7
31	15	572.03	567.32	4.71	0.14	0.04	N.W.	6	193,500	1		5.76	−1.8
32	17	571.14	566.67	4.47	0.02	0.03	S.E.	8	183,200	1		5.51	+2.9
33	17	571.02	566.56	4.44	0.08	0.16	E.	5	175,600	1		5.41	0.0
34	17	570.79	566.36	4.43	0.04	0.10	S.E.	10	172,300	1		5.40	+1.7
35	17	570.64	566.29	4.35	0.01	0.23	S.E.	10	169,200	1		5.27	+0.8
36	19	571.41	566.96	4.45	0.42	0.05	S.W.	10	180,300	1		5.45	−2.0
37	21	571.61	567.02	4.59	0.02	0.21	S.W.	12	184,900	1		5.58	−1.7
38	21	571.61	567.03	4.58	0.02	0.23	S.	12	186,700	1		5.73	+0.6
39	22	.....	566.87	.....	.....	.....	S.W.	30	234,500	1		6.27	.....
40	23	.....	567.07	.....	.....	.....	W.	12	194,900	1		5.96	.....
41	25	571.66	567.05	4.61	0.07	0.06	S.W.	10	189,000	1		5.68	0.0
42	25	571.68	567.06	4.62	0.06	0.03	S.W.	10	192,200	1		5.80	+1.4
43	27	572.22	567.74	4.48	0.46	0.30	N.W.	12	201,000	1		5.88	−1.3
44	27	572.01	567.61	4.30	0.06	0.13	N.W.	12	209,600	1		5.87	−0.1
45	Nov. 1	572.29	567.39	4.90	0.00	0.37	S.S.W.	14	207,100	1		6.15	+2.2
46	1	571.97	567.27	4.70	0.16	0.15	S.W.	14	195,800	1		5.95	0.0
47	1	571.86	567.36	4.50	0.11	0.02	W.	10	194,900	1		5.80	+0.8
48	2	571.82	567.25	4.57	0.07	0.22	W.	12	193,000	1		5.76	+0.1
49	4	571.60	566.93	4.67	0.07	0.06	S.	10	188,000	1		5.71	0.0
50	4	571.53	566.89	4.64	0.01	0.23	S.	10	188,900	1		5.67	+0.3
51	4	571.47	566.78	4.69	0.12	0.07	S.	8	187,600	1		5.72	+1.4
52	4	571.44	566.77	4.67	0.05	0.06	S.	7	185,700	1		5.67	+0.6
53	9	570.11	565.96	4.15	0.60	0.46	N.E.	8	155,600	1		4.92	−0.9
54	9	570.14	565.71	4.43	0.45	0.27	N.E.	12	157,200	1		5.02	−0.2
55	9	.....	565.51	.....	.....	.....	N.E.	10	163,200	1		5.18	.....
56	10	570.00	565.58	4.42	0.18	0.00	N.E.	10	154,100	1		4.95	−0.4
57	10	570.03	565.60	4.43	0.07	0.34	E.N.E.	12	154,500	1		4.98	−0.6
58	10	570.34	565.65	4.69	0.67	0.08	E.N.E.	10	161,600	1		5.18	+1.2
59	15	.....	566.00	.....	.....	.....	S.W.	20	238,100	1		6.61	.....
60	15	.....	566.21	.....	.....	.....	S.W.	20	238,000	1		6.34	.....
61	21	571.87	566.97	4.90	0.10	0.12	S.E.	3	197,100	1		5.96	+1.8
62	21	571.66	566.91	4.74	0.00	0.10	S.E.	4	190,000	1		5.78	+0.6
63	22	571.79	566.85	4.94	0.05	0.08	S.E.	10	191,700	1		5.83	−0.1
64	23	571.66	566.90	4.76	0.02	0.27	S.E.	10	198,800	1		5.87	+3.4

See Table No. 3.

Williams Ex. 24

Table No. 1

SUMMARY OF DISCHARGES
International Bridge Section
NIAGARA RIVER

Sheet 1 (5 Sheets)

Levels of 1903
P. B. M. Buffalo Light House, 600.101
P. B. M. Int'n'l Bridge No. 2, 582.258

F. C. Shenehon
U. S. Asst. Engineer

Reference No. of Measurement	Date	Elevation of Water Surface Above Mean Tide, New York: Lake Erie Level	Elevation of Water Surface Above Mean Tide, New York: Section Gage at Bridge	Fall Lake Erie to Bridge	Change at Lake During Measurement Feet: Rise	Change at Lake During Measurement Feet: Fall	Wind: Direction from Which it Blows	Wind: Approx. Velocity Miles per Hour	Discharge Cubic Feet per Second	Rating No. Used: Meter L.S. 2B	Rating No. Used: Meter L.S. 4A	Weighted Mean Index Velocity	Percentage
	1902												
69	Nov. 22	572.79	567.81	4.98	0.07	0.06	N. W.	8	214,900	1		6.27	-4.5
70	23	572.82	567.72	5.10	0.25	0.24	W.	7	208,500	1		6.12	+2.1
71	24	571.44	566.69	4.75	0.14	0.02	S.E.	10	182,900	1		5.60	-2.8
72	26	571.43	566.69	4.74	0.06	0.12	S.E.	10	183,500	1		5.62	-4.4
73	26	571.74	566.85	4.89	0.09	0.03	N.E.	8	192,400	1		5.85	+2.6
74	28	571.54	566.77	4.77	0.04	0.04	N.W.	5	187,500	1		5.72	+4.8
75	28	571.81	566.83	4.98	0.38	0.04	N.W.	4	192,000	1		5.86	+0.3
76	29	571.46	566.74	4.72	0.05	0.08	S.E.	3	188,500	1		5.70	+2.0
77	29	571.56	566.77	4.79	0.20	0.10	S.E.	3	186,500	1		5.68	-4.1
78	29	571.63	566.80	4.83	0.26	0.06	E.	5	188,100	1		5.72	+4.3
79	Dec. 1	572.01	567.96	5.05	0.07	0.18	W.	18	221,200	1		6.43	+1.1
80	1	572.97	567.95	5.02	0.17	0.15	N.W.	20	217,600	1		6.32	-4.1
81	1	572.82	567.82	4.90	0.24	0.15	N.W.	20	218,200	1		6.33	+0.4
82	1	572.80	567.81	4.89	0.13	0.23	W.	20	215,000	1		6.26	+1.6
83	6	572.50	567.37	5.13	0.07	0.14	S.W.	20	215,600	1		6.41	+4.0
84	7	573.09	568.43	5.25	0.04	0.26	W.	20	234,500	1		6.66	+4.1
85	7	573.10	568.26	4.92	0.17	0.27	W.	15	222,600	1		6.39	+4.1
86	8	573.05	568.01	5.04	0.14	0.05	W.	20	219,400	1		6.35	+4.1
87	8	573.00	567.97	5.03	0.04	0.04	W.	20	218,800	1		6.35	+2.0
88	10	573.80	568.74	5.15	0.15	0.04	W.	25	238,000	1		6.69	+3.1
89	10	573.93	568.72	5.19	0.09	0.15	W.	30	240,900	1		6.76	+0.6
90	10	573.70	568.62	5.08	0.15	0.11	W.	30	231,300	1		6.54	-1.3
	1899												
91	Feb. 7	571.44	566.98	4.86	0.00	0.04	N.E.	10	178,600	1		5.84	-4.2
92	8	571.58	566.95	4.83	0.04	0.00	N.W.	16	180,500	1		5.85	-4.7
93	14	571.24	567.23	4.12	0.00	0.13	W.	18	161,500	1	See Table No. 2.	5.22	-11.5
94	15	571.39	567.31	3.98	0.03	0.00	S.W.	20	168,900	1		5.40	-4.9
95	15	571.23	567.20	4.03	0.00	0.04	S.W.	18	168,700	1		5.36	-7.3
96	15	571.23	567.17	4.15	0.01	0.00	S.W.	24	172,900	1		5.70	-4.4
97	15	571.23	567.03	4.20	0.00	0.00	W.	24	177,100	1		5.83	-0.9
98	16	571.24	567.15	4.09	0.02	0.00	S.	6	169,400	1		5.56	-4.9
99	16	571.24	567.19	4.05	0.01	0.01	S.W.	6	168,900	1		5.55	-4.7
100	17	571.23	566.99	4.04	0.01	0.02	W.	6	179,700	1		5.89	-1.3
101	17	571.20	566.98	4.02	0.01	0.01	W.	6	177,300	1		5.83	-2.2
102	17	571.23	566.97	4.04	0.04	0.02	W.	6	181,000	1		5.96	-0.5
103	24	571.23	566.90	4.39	0.03	0.02	W.	8	182,000	1		5.74	-0.7
107	24	571.40	566.90	4.50	0.01	0.02	W.	8	180,100	1		5.76	-1.9
108	25	571.23	566.70	4.53	0.00	0.11	N.W.	8	176,400	1		5.61	-2.3
109	25	571.27	566.71	4.56	0.06	0.24	E.	10	175,600	1		5.74	-1.3
110	25	571.17	566.56	4.61	0.00	0.10	S.E.	12	176,200	1		5.62	-1.6
111	25	571.26	566.54	4.71	0.06	0.05	S.E.	12	180,700	1		5.83	+0.3
112	Mar. 1	571.03	566.65	4.73	0.23	0.00	W.	8	186,100	1		5.90	-0.7
113	6	571.26	566.80	4.55	0.00	0.31	N.E.	8	174,900		5	5.52	-1.3
114	7	571.45	566.60	4.85	0.15	0.00	N.E.	16	181,000		5	5.80	-1.0
115	20	572.80	567.55	4.85	0.00	0.26	N.W.	13	194,000	2		6.08	-1.4
117	23	572.26	566.93	4.96	0.02	0.36	S.W.	12	219,400	2		6.86	-1.3
118	23	572.17	566.80	4.97	0.07	0.01	S.W.	10	217,600	2		6.83	-1.3
119	24	572.22	566.91	4.31	0.17	0.00	W.	26	185,200	2		5.90	-1.9
120	24	572.30	567.76	4.54	0.08	0.14	W.	28	192,800	2		6.12	-1.0
121	24	572.26	567.63	4.73	0.00	0.09	W.	22	196,600	2		6.10	-1.1
122	May 19	572.72	567.69	5.08	0.12	0.00	W.	15	213,300		5	6.51	+0.1
123	19	572.66	567.66	4.99	0.11	0.11	W.	15	210,800		5	6.43	+0.1
124	19	572.73	567.67	5.06	0.00	0.05	W.	15	212,800		5	6.48	0.0

Note:—
Nos. 116, 117, 118. Span 1 blocked with ice.
No. 114. Span 9 blocked with ice.
Nos. 91, 92, 100, 101, 102. Spans 1 and 9 blocked with ice.
Nos. 86 to 90, inclusive. Spans 1 and 9, and east half of Span 2 blocked.
No. 86. Discharge for Sta. 3½ is interpolated.
No. 120. Discharge for Span 2 is interpolated.
No. 119. Discharge for Spans 1 and 2, and Sta. 3½ interpolated.

Williams Ex. 24. Table No. 1 Sheet 3
(5 Sheets)

SUMMARY OF DISCHARGES.
International Bridge Section.
NIAGARA RIVER.

Levels of 1903.
P. B. M. Buffalo Light House, 590.101.
P. B. M. International Bridge No. 2, 562.258.

F. C. Shenehon,
U. S. Asst. Engr.
1906

Measurement No.	Date	Elevation of Water Surface Above Mean Tide, New York		Fall Lake Erie to Bridge	Change at Lake During Measurement, Feet		Wind		Discharge Cubic Feet per Second	Rating and Meter		Weighted Mean Index Velocity	Percentage Residuals
		Lake Erie Level	Section Gage at Bridge		Rise	Fall	Direction from which it Blows	Approx. Velocity Miles per Hour		Meter Used	Rating		
	1906												
a	July 16	572.37	567.55	4.82	0.13	0.04	S.E.	4	205,100	D. W. 12A.	Velocity=0.06+1.006 revolutions. No. 2.	6.06	+0.3
b	16	572.39	567.55	4.84	0.12	0.07	N.E.	6	206,100			6.08	+0.6
c	18	572.67	567.71	4.96	0.05	0.04	S.W.	14	214,000			6.23	+1.4
d	19	572.40	567.66	4.74	0.13	0.14	S.W.	16	201,600			5.93	−1.7
e	20	572.42	567.62	4.80	0.16	0.06	S.W.	12	208,200			6.07	+0.3
f	21	572.81	568.00	4.81	0.11	0.19	S.W.	16	214,800			6.22	+0.3
g	22	572.26	567.55	4.71	0.10	0.16	E.	10	203,700			6.01	+0.8
h	22	572.46	567.72	4.74	0.08	0.30	W.	10	208,800			6.13	+1.2
i	22	572.23	567.64	4.60	0.06	0.05	W.	8	202,400			5.95	−0.6
j	25	572.52	567.79	4.73	0.35	0.22	S.W.	10	207,000			6.07	−0.1
k	27	572.57	567.79	4.78	0.05	0.30	S.W.	4	203,100			5.91	−3.2
l	28	572.64	567.81	4.83	0.06	0.17	S.W.	10	200,700			5.86	−4.6
m	28	572.21	567.70	4.51	0.14	0.30	S.W.	16	197,500			5.80	−1.7
n	29	572.70	567.94	4.76	0.07	0.64	S.W.	26	208,900			6.07	−1.4
o	29	572.71	567.94	4.77	0.23	0.18	N.W.	25	207,300			6.02	−2.2
p	29	572.01	568.11	4.90	0.41	0.07	W.	25	214,400			6.18	−2.0
q	29	572.86	568.09	4.77	0.05	0.41	S.W.	25	213,400			6.16	−0.9

Williams Exhibit 24

TABLE No. 2
SUMMARY OF DISCHARGES
Open Section
NIAGARA RIVER

Sheet 1 (5 Sheets)

Levels of 1903
P. B. M. Buffalo Lighthouse 580.101
P. B. M. Guard Lock..... 576.454

F. C. Shenehon, U. S. Asst. Engr.

Reference No. of Measurement	Date		Elevation of Water Surface Above Mean Tide, New York		Fall Lake Erie to Section	Change at Lake During Measurement, Feet		Wind		Discharge Cubic Feet Per Second	Meter and Rating		Weighted Mean Index Velocity	Percentage Error
			Lake Erie Level	Section Gage		Rise	Fall	Direction from which it Blows	Approx. Velocity Miles per Hour		Meter L.S. 4A	Meter L.S. 3B		
	1903													
1	Aug.	30	571.80	566.93	4.87	0.02	0.00			191,000		4	5.13	+1.2
2		31	572.14	567.16	4.98	0.00	0.07			200,200		4	5.33	+1.2
3		31	571.93	567.07	4.86	0.21	0.03			186,800		4	5.25	+1.2
4		31	571.85	567.02	4.83	0.00	0.15			182,000		4	5.19	+1.2
5	Sept.	1	571.87	566.96	4.91	0.21	0.23			188,100		4	5.32	+1.2
6		1	572.22	567.19	5.03	0.12	0.08			203,600		4	5.45	+1.2
7		2	571.77	566.94	4.83	0.23	0.08			189,900		4	5.11	+1.2
8		4	571.89	566.88	5.01	0.06	0.14			190,600		4	5.17	+1.2
9		7	571.70	566.75	4.95	0.26	0.22			184,700		4	4.99	+1.2
10		7	571.73	566.84	4.91	0.24	0.25			184,200		4	4.99	+1.2
11		8	572.02	566.94	5.14	0.33	0.13	S.W.	18	196,600		4	5.25	+0.2
12		14	571.73	566.67	4.96	0.33	0.06	S.W.	20	188,200		4	5.07	+0.2
13		15	571.63	566.74	4.89	0.11	0.06	N.W.	4	186,600		4	5.06	+0.2
14		15	571.70	566.62	4.97	0.13	0.11	S.W.	8	189,460		4	5.11	+0.2
15		15	571.78	566.52	4.92	0.05	0.04	S.W.	4	185,700		4	5.02	+0.2
16		16	571.70	566.57	4.93	0.41	0.01	S.W.	4	185,800		4	5.02	+0.2
17		16	571.65	566.79	4.86	0.60	0.30	S.W.	12	183,500		4	4.96	+0.2
18		16	571.40	566.60	4.80	0.10	0.16	S.W.	8	180,800		4	4.89	+0.2
19		16	571.76	566.88	4.88	0.02	0.08	S.W.	16	185,000		4	5.02	+0.2
20		16	571.87	566.88	4.99	0.28	0.08	S.W.	16	190,200		4	5.13	+0.2
21		18	571.93	566.96	4.96	0.44	0.07	S.W.	20	191,600		4	5.16	+0.2
22		19	571.80	566.67	4.93	0.12	0.12	N.E.	10	183,200		4	5.01	+0.2
23		19	571.53	566.76	4.77	0.08	0.02	N.E.	12	176,000		4	4.84	+0.2
24		19	571.43	566.57	4.86	0.07	0.10	N.E.	12	178,100		4	4.89	+0.2
25		20	571.73	566.76	4.96	0.02	0.21	N.	15	186,000		4	5.07	+0.2
26		20	571.77	566.80	4.97	0.18	0.07	N.	10	185,800		4	5.13	+0.2
27		20	571.69	566.86	4.97	0.11	0.03	N.W.	5	189,400		4	5.04	+0.2
28		21	*571.95	566.95	4.99			N.W.	15	187,300		4	5.07	+0.2
29		21	572.24	567.21	5.12	0.40	0.02	W.N.W.	15	201,000		4	5.36	+0.2
30		22	571.55	566.86	4.70	0.10	0.14	N.W.	28	181,800		4	4.98	+0.2
31		22	572.08	566.98	5.10	0.42	0.00	N.W.	28	198,600		4	5.21	+0.2
32		25	571.50	566.58	4.92	0.52	0.28	S.E.	8	186,500		4	5.08	+1.2
33		25	571.53	566.61	4.92	0.10	0.43	S.E.	8	181,000		4	4.96	+1.2
34	Oct.	4	571.66	566.73	4.93	0.02	0.17	N.	8	186,200	5		4.94	+0.2
35		5	571.39	566.59	4.80	0.11	0.03	N.	4	181,900	5		4.88	+0.2
36		6	571.43	566.51	4.91	0.12	0.10	N.E.	8	181,600	5		4.87	+0.2
37		6	571.44	566.53	4.92	0.10	0.03	N.E.	10	181,400	5		4.86	+0.2
38		7	571.57	566.56	5.01	0.00	0.05	S.E.	4	183,400	5		4.96	+0.2
39		7	571.38	566.47	4.91	0.01	0.42	N.E.	5-13	178,700	5		4.75	+1.2
40		9	571.78	566.76	5.02	0.31	0.14	S.W.	15-8	192,500	5		5.11	+1.2
41		11	571.35	566.51	4.84	0.17	0.22			181,900	5		4.87	+0.2
42		11	571.60	566.59	5.01	0.24	0.00	S.W.	0-8	186,800	5		4.98	+0.2
43		13	571.39	566.43	4.96	0.28	0.20	S.W.	8	180,000	5		4.85	+0.2
44		13	571.33	566.51	4.82	0.06	0.16	S.W.	4	180,200	5		4.83	+0.2
45		15	571.48	566.53	4.95	0.00	0.04	S.W.	6	182,500	5		4.88	+0.2
46		19	571.55	566.57	4.98	0.10	0.22	N.	3-7	182,200	5		4.90	+0.2
47		20	571.20	566.31	4.89	0.05	0.16			177,700	5		4.81	+0.2
48		20	571.43	566.43	4.99	0.32	0.12	N.N.E.	3-10	182,100	5		4.93	+0.2
49		21	571.26	566.25	4.99	0.07	0.07	E.	7	179,600	5		4.86	+0.2
50		21	571.27	566.25	4.99	0.00	0.13	N.E.	5	179,400	5		4.85	+0.2
51		27	571.41	566.51	4.90	0.14	0.28	E.	4	185,000	5		4.96	+0.2
52		27	571.36	566.40	4.96	0.07	0.15	N.E.-E.	10-13	182,500	5		4.93	+0.2
53		28	571.49	566.52	4.97	0.25	0.20	S.W.-S.E.	8-3	185,700	5		4.98	+0.2
54		29	572.02	566.51	5.51	0.69	0.09	S.W.	20-14	199,800	5		5.38	+0.2
55		30	571.63	566.62	5.00	0.22	0.11	N.E.-W	3	180,400	5		5.07	+0.2
56		31	571.57	566.62	4.94	0.04	0.24	N.N.E.	4	185,400	5		4.96	+0.2
57		31	571.53	566.70	4.98	0.22	0.14	E.N.E.	4	180,600	5		4.89	+0.2
58		31	571.12	566.45	4.67	0.06	0.16	N.E.	4	170,400	5		4.63	+0.2
59	Nov.	1	571.01	566.63	4.38	0.38	0.20	N.-N.E.	20-15	163,800	5		4.42	+0.2
60		2	570.78	566.69	4.10	0.15	0.27	N.E.	10	159,400	5		4.33	+0.2
61		2	570.82	566.64	4.18	0.62	0.31	N.E.	8	163,800	5		4.43	+0.2
62		3	571.10	566.12	5.04	0.24	0.37	SE.-NE	10	195,800	5		5.31	+0.2
63		3	570.67	566.93	4.74	0.04	0.59	E.N.E.	7	166,200	5		4.57	+0.2
64		4	572.39	567.33	5.06	0.97	0.25	S.W.	15-13	214,400	5		5.38	+1.2
65		4	572.29	567.31	5.03	0.11	0.39	W.	20	222,000	5		5.38	0.0

*Gage height interpolated from Section Gage.

See Table No. 4.

Williams Ex. 24 — Sheet 5 (5 Sheets)

TABLE No. 2

SUMMARY OF DISCHARGES

Open Section

NIAGARA RIVER

Levels of 1903
P. B. M. Buffalo Lighthouse 580.101
P. B. M. Guard Lock..... 576.454

F. C. Shenehon,
U. S. Asst. Engr.
1906

Discharge No.	Date	Elevation of Water Surface Above Mean Tide, New York: Lake Erie Level	Elevation of Water Surface Above Mean Tide, New York: Section Gage	Fall Lake Erie to Section	Change At Lake During Measurement Feet: Rise	Change At Lake During Measurement Feet: Fall	Wind: Direction from which it Blows	Wind: Approx. Velocity Miles per Hour	Discharge Cubic Feet Per Second	Meter and Rating: Meter L.S. 4A	Meter and Rating: Meter L.S. 2B	Weighted Mean Index Velocity	Percentage Residuals
	1899												
60	Nov. 6	571.84	566.65	4.99	0.00	0.07	N.W.	2	153,400	5		4.94	−0.5
61	7	571.86	566.89	4.97	0.15	0.15	N.W.-W.	1-5	154,200	5		4.92	−0.2
62	11	571.46	566.43	5.03	0.05	0.26	E.N.E.	10	151,700	5		4.98	−0.7
63	11	571.17	566.30	4.87	0.84	0.23			174,400	5		4.73	−1.3
70	22	570.73	566.89	4.84	0.15	0.34	N.E.	8	167,500	5		4.82	0.0
71	23	570.84	566.75	4.79	0.14	0.10	N.E.-E.	8-10	164,300	5		4.80	+0.4
72	24	571.32	566.28	5.03	0.31	0.13	N.E.	1	155,700	5		4.94	+1.7
73	24	571.43	566.38	5.00	0.14	0.05	NE NW	4	153,500	5		4.91	+1.5
74	25	571.43	566.43	5.01	0.08	0.19	N.E.-N	4	153,200	5		4.91	+0.2
75	26	571.30	566.33	4.97	0.15	0.05	N.W.	6	151,900	5		4.92	+1.5
76	27	571.84	566.45	5.11	0.28	0.02	S.W.	2	156,400	5		5.08	+2.0
77	27	571.72	566.89	5.19	0.15	0.04	S.W.-W.	5	191,800	5		5.13	+2.0
78	28	571.97	566.76	5.21	0.22	0.05	S.W.	12	194,500	5		5.15	+0.6
79	28	571.58	566.76	5.12	0.11	0.20	S.W.	15	193,300	5		5.13	+1.0
80	29	571.78	566.61	5.14	0.26	0.02	W.	2	190,300	5		5.08	+0.5
81	29	571.68	566.64	5.04	0.13	0.23	S.W.	10	185,700	5		5.02	+0.9
82	Dec. 2	572.63	567.27	5.36	0.14	0.29	S.W.	30	207,400	5		5.26	−0.1
83	2	572.41	567.07	5.34	1.66	0.06	S.W.	20-30	206,600	5		5.40	+1.9
84	4	571.46	566.36	5.09	0.28	0.06	W-N.W.	3-5	182,100	5		4.96	−0.1
85	4	571.78	566.56	5.17	0.06	0.06	N.W.	0-1	189,000	5		5.06	+0.4
86	5	571.89	566.66	4.90	0.84	0.70	W.N.W.	c	195,200	5		4.81	+3.2
87	6	572.17	567.22	4.95	0.16	0.30	W.N.W.	30	192,800	5		5.01	+1.9
88	6	571.71	566.77	4.94	0.14	0.61	N.W.	10	184,400	5		4.89	+1.8
89	9	570.88	565.96	4.92	0.41	0.26	E.	7	168,500	5		4.88	+1.2
90	9	570.98	565.92	5.00	0.21	0.06	E.	3	169,600	5		4.89	+1.0
	1900												
91	June 26	572.73	567.41	5.32	0.88	0.13	S.W.	10-20	215,900	5	See Table No. 4.	5.40	+2.9
92	26	573.04	567.71	5.33	0.06	0.55	S.W.	34	216,300	5		5.57	+0.9
93	26	572.41	567.31	5.10	1.06	0.05	S.W.	15-40	228,900	5		5.33	+1.8
94	26	572.94	567.91	5.03	0.06	0.96	N.W.	45	214,100	5		5.41	−0.1
95	30	572.80	567.50	5.30	0.61	0.48	NW-W.	12-20	215,300	5		5.53	+0.9
96	30	572.96	567.73	5.22	0.31	0.20	W.-N.W.	30-35	214,100	5		5.46	+0.3
97	July 5	573.33	567.20	5.13	0.06	0.19	S.W.	4-5	201,600	14		5.36	+0.4
98	5	572.41	567.25	5.16	0.18	0.13	S.W.	5-13	202,900	14		5.43	+0.6
99	6	573.76	567.46	5.30	0.13	0.15	S.W.	10-20	208,900	14		5.40	+0.8
100	6	573.66	567.47	5.19	0.04	0.12	S.W.	20	206,600	14		5.43	+0.8
101	9	573.15	567.78	5.37	0.20	0.32	N.W.	5	221,400	14		5.71	+1.1
102	9	573.09	567.43	5.66	0.10	0.35	W.N.W.	5	205,900	14		5.37	+1.4
103	10	573.25	567.19	5.06	0.03	0.35	NW-SW	5-10	200,700	14		5.34	+0.4
104	10	572.77	567.41	5.36	0.42	0.15	S.W.	15	214,300	14		5.64	+1.8
105	11	572.71	567.61	5.10	0.19	0.09	S.	15-25	205,000	14		5.37	+2.1
106	11	572.26	567.24	5.02	0.32	0.28	S.W.	25-30	195,800	14		5.20	+1.8
107	12	573.21	567.72	5.49	0.16	0.60	NW-W.	5-25	216,900	14		5.66	+1.6
108	12	573.04	567.41	5.63	0.06	0.79	W.S.W.	20	213,100	14		5.53	+1.6
109	13	572.26	567.20	5.06	0.06	0.07	W-N.W.	3-5	199,300	14		5.27	+1.4
110	14	572.82	567.25	5.17	0.10	0.04	S.W.	5	203,900	14		5.38	+0.9
111	14	572.26	567.21	5.05	0.03	0.20	W.S.W.	15	194,400	14		5.17	+0.6
112	15	572.33	567.26	5.07	0.24	0.04	S.W.	15	200,700	14		5.23	+0.2
113	16	572.15	567.13	5.02	0.10	0.15	S.W.	15	196,500	14		5.24	+0.3
114	17	572.88	567.38	5.50	0.09	0.05	W.	24-40	215,200	14		5.44	+1.6
115	17	572.36	567.36	5.00	0.10	0.30	S.W.	40	201,600	14		5.23	0.0
116	18	572.26	567.20	5.06	0.27	0.20	NW-SW	10-5	201,300	14		5.23	0.0
117	19	573.11	567.00	5.02	0.39	0.24	S.E.	3	201,100	14		5.36	+2.5
118	20	572.39	567.32	5.07	0.26	0.04	S.W.	10	201,600	14		5.32	0.4
119	21	572.25	567.21	5.04	0.37	0.29	N.W.	10	199,600	14		5.09	0.7
120	22	572.38	567.10	5.28	0.12	0.21	S.W.	0-2	199,600	14		5.29	0.2
121	24	572.22	567.17	5.05	0.28	0.13	S.-S.W.	4-6	200,300	14		5.31	+0.8

Williams Ex. 25

TABLE No. 2
SUMMARY OF DISCHARGES
Three Points Section
ST. LAWRENCE RIVER

Sheet 1 (2 Sheets)
F. C. Shenehon
Assistant Engineer
May, 1921

Reference No. of Measurement	Date	Elevation of Water-Surface Above Mean Tide, N. Y.		Fall Ogdensburg to Section	Change at Ogdensburg during Measurement		Wind		Discharge Cubic Feet per Second	Meter Used			Approximate Weighted-Mean Index Velocity	Percentage Variation
		Ogdensburg at Gage 12	Section Gage		Rise	Fall	Direction from which it Blows	Approx. Velocity in Miles per hour		4 A	2 B	3 B		
1	Sept. 26	244.14	226.50	17.64	0.12	0.02	O.	0	232,800	1			4.78	+1.0
2	27	244.08	226.40	17.68	.06	.06	O.	0	223,000	1			4.80	+0.3
3	27	244.10	226.37	17.73	.05	.03	W.	5	233,300	1			4.81	+0.3
4	28	243.99	226.32	17.67	.00	.07	N.	7	219,700	1			4.85	+0.8
5	28	244.02	226.33	17.69	.01	.02	N.	5	221,100	1			4.78	+0.5
6	Oct. 1	243.94	226.15	17.79	.06	.07	E.	5	219,300	1			4.72	+0.5
7	3	244.04	226.32	17.72	.02	.10	W.	5	219,400	1			4.78	+1.3
8	4	244.13	226.41	17.72	.05	.09	S.W.	10	233,800	1			4.67	+2.3
9	5		226.42				S.W.	11	223,000	1			4.56	
10	9	243.90	226.20	17.91	.20	.03	N.E.	6	217,700	1			4.62	+1.3
11	10	243.80	226.20	17.81	.17	.00	N.	5	216,200	1			4.79	-0.4
12	11	243.94	226.06	17.88	.25	.00	N. W.	2 5	219,400	1			4.78	+0.1
13	12		226.16				S.W.	10	231,100	1			4.81	
14	17	243.84	226.06	17.78	.24	.20	W. S.W.	4-10 15-20	217,000	1			4.73	-0.5
15	18	244.05	226.37	17.68	.00	.30	W.	13	232,800	1			4.79	-0.6
16	19	243.83	226.68	17.15	.15	.22	N.	5	208,400	1			4.56	+1.2
17	22	243.83	226.66	17.17	.11	.08	S.	7	215,000	1			4.68	+0.5
18	23	243.77	226.70	17.07	.15	.06	S.	7	213,300	1			4.63	+0.5
19	24	243.90	226.96	17.93	.06	.06	S.W. N.W.	4	217,700	1			4.75	-0.3
20	25	243.86	226.46	17.40	.00	.00	N.E.	5	208,200	1			4.66	0.0
21	26	243.73	226.51	17.97	.15	.08	S.	6	213,700	1			4.66	+1.0
22	29	243.75	226.72	17.03	.17	.08	S.	1	210,500	1			4.62	+1.5
23	30	243.25	226.20	17.05	.50	.51	N.E.	15	180,200	1			4.34	-0.5
24	31	243.69	226.53	17.16	.33	.00	N.E. S.W.	5 1	209,000	1			4.64	+1.1
25	Nov. 1	243.90	226.00	17.37	.06	.13	S.	11	215,800	1			4.69	+1.0
26	2	244.07	226.63	17.44	.20	.16	S.W. W.	17 8	222,700	1			4.80	-0.3
27	2		226.66				N.W.	1	211,700	1			4.66	
28	8	243.65	226.64	17.01	.13	.06	N.E.	5	212,500	1			4.63	-0.7
29	10	244.04	226.34	17.70	.00	.17	S.W. W.	12 9	221,700	1			4.77	+0.3
30	12	243.81	226.23	17.58	.05	.14	S. S.W.	10 8	216,700	1			4.74	-0.5
31	14	243.89	226.61	17.28	.19	.31	N.W. S.W.	3 3	215,300	1			4.74	-0.7
32	25	244.13	226.47	17.66	.13	.20	W.	9	224,600	1			4.82	+0.1
33	27	243.40	226.16	17.24	.11	.07	N.W.	4	207,400	1			4.64	-1.0
34	28	243.49	226.48	17.01	.00	.07	N.E.	6	207,800	1			4.61	-0.6
35	30	243.51	226.23	17.28	.05	.03	N.E.	1	212,500	1			4.77	-1.4
36	Dec. 4	243.70	226.72	17.98	.00	.13	N.E.	9	215,400	1			4.74	-1.3
37	5	243.60	226.70	17.16	.13	.04	N.E.	7	215,200	1			4.74	0.0
38	6	244.02	226.10	17.84	.04	.10	N.W.	3	223,000	1			4.83	-0.5
39	7	244.19	226.40	17.79	.20	.10	S.W. N.	5 4	227,700	1			4.90	-0.4
	1921													
40	Apr. 20	244.28	227.24	17.85	.04	.04	E. S.W.	2	248,200	1			5.27	+0.1
41	20	244.23	227.24	17.27	.01	.04	S.W.	1	250,800	1			5.22	-0.2
42	20	244.20	227.24	17.42	.05	.08	E.	2	246,900	1			5.14	+0.4
43	30	244.01	227.2	17.26	.01	.08	E.	2	246,000	1			5.15	-0.0
44	May 2	244.47	227.37	17.80	.04	.18	N.W. N.W.	18 20	245,400	1			5.10	+0.6
45	2	244.23	227.43	17.46	.09	.09	N.W. N.W.	18 20	243,100	1			5.11	+1.3
46	3	244.38	227.24	17.66	.14	.02	E. W.	1	243,400	1			5.07	+0.9
47	6	244.26	227.43	17.46	.07	.03	W.	1	249,300	1			5.18	-0.2
48	9	244.23	227.46	17.45	.03	.01	N. S.W.	1	249,000	1			5.16	-0.1
49	7	244.24	227.50	17.26	.09	.01	S.	1	248,900			1	5.17	+0.1
50	7	244.27	227.51	17.26	.01	.03	S.	1	252,100			1	5.23	-0.9
51	7	243.96	227.54	17.42	.08	.03	S.	1	251,700			1	5.22	+0.1
52	8	244.20	227.41	17.29	.03	.04	S.	1	244,500	1			5.07	+0.1
53	8	244.20	227.42	17.42	.11	.00	S.	1	243,900	1			5.04	+1.5
54	8	244.22	227.40	17.44	.02	.04	S.	1	242,100	1			5.05	+0.8
55	8	244.20	227.39	17.41	.02	.02	S.	1	248,200	1			5.15	-1.4
56	8	244.18	227.37	17.81	.02	.04	E.	2-1	248,600	1			5.15	-1.3
57	9	244.26	227.41	17.44	.06	.02	E.	2-1	246,700	1			5.15	-0.3
58	10	244.05	227.39	17.37	.07	.03	E.	2-1	243,400	1			5.04	-0.3
59	10	244.17	227.33	17.46	.00	.02	E.	2-1	245,600	1			5.10	-0.5
60	10	244.24	227.41	17.48	.14	.02	N. S.E.	1 10	248,700	1			5.13	-0.3
61	14	245.00	227.76	17.21	.00	.03	S.W. S.	10 4	252,700	1			5.16	+0.6
62	14	245.01	227.64	17.32	.02	.04	S.W. S.	8 3	251,900	1			5.18	-0.4
63	14	245.00	227.67	17.28	.01	.04	S.W. S.	10 4	247,200	1			5.07	+1.0

Williams Ex. 25

TABLE No. 3.
SUMMARY OF DISCHARGES
Three Points Section
ST. LAWRENCE RIVER

Sheet 2
(2 Sheets)
F. C. Shenehon,
Assistant Engineer.
May, 1906

Measurement No.	Date	Elevation of Water Surface Above Mean Tide, N. Y.		Fall Ogdensburg Section 2	Change at Ogdensburg during Measurement		Wind		Discharge Cubic Feet per Second	Meter Used			Approximate Weighted-Mean Index Velocity	Percentage Residuals
		Ogdensburg at Gage 12	Section Gage		Rise	Fall	Direction from which it Blows	Approx. Velocity in Miles per hour		4 A	2 B	3 B		
64	May 15	244.97	237.61	17.36	0.06	0.01	S.	2-13	249,400		1		5.06	+0.2
65	15	245.00	237.66	17.34	.01	.00	S.	7-8	251,100		1		5.10	−0.1
66	15	244.99	237.68	17.31	.01	.01	S.	2-12	251,700	1			5.13	−0.5
67	16	244.93	237.54	17.39	.13	.00	S.	2	248,500	1			5.14	−0.1
68	16	244.97	237.40	17.57	.01	.06	S.	5	250,400	1			5.12	−0.3
69	16	244.93	237.60	17.33	.04	.03	S.W.	10	251,200	1			5.20	−1.0
70	June 18	244.88	237.43	17.45	.17	.01	N.	3	250,000	1			5.23	−1.1
71	18	244.94	237.56	17.38	.06	.01	E.	1	248,700	1			5.13	+0.2
72	18	244.93	237.56	17.37	.02	.17	S. E.	2-5 1	248,900	1			5.11	−0.1
73	19	244.84	237.50	17.34	.00	.05	S.	1	248,800	1			5.17	−1.1
74	19	244.95	237.56	17.37	.04	.05	W. S.	20 2	250,600	1			5.19	−0.6
75	19	245.00	237.72	17.37	.16	.22	E.	8-10	249,700	1			5.15	+1.6
76	20	244.94	237.42	17.36	.02	.02	S.	1	246,000	1			5.09	+0.1
77	20	244.87	237.51	17.28	.37	.20	S.	1	248,900	1			5.14	−0.6
78	20	245.09	237.64	17.45	.19	.18	S.	1	246,100	1			5.04	+3.0
79	21	244.91	237.61	17.30	.14	.06	S.W.	10	250,500	1			5.16	−1.0
80	21	245.01	237.68	17.33	.04	.03	S.W.	12	249,900	1			5.13	−0.4
81	21	245.06	237.74	17.34	.09	.09	S.W.	10	252,800	1			5.20	−0.2
82	22	244.93	237.49	17.33	.06	.06	N.W.	1	246,800	1			5.10	−0.6
83	23	244.90	237.50	17.40	.04	.00	W.	1	251,100		1		5.19	−1.3
84	24	245.05	237.74	17.31	.00	.04	N.W.	1-3	251,400	1			5.15	+0.3
85	24	245.05	237.72	17.33	.00	.00	S.	2	251,500	1			5.17	−0.2
86	24	245.13	237.77	17.36	.09	.01	W.	2-5	252,700	1			5.19	+0.7
87	25	244.99	237.71	17.28	.13	.01	S.W.	2	252,400	1			5.20	−0.8
88	25	245.06	237.71	17.35	.06	.13	S.W.	3	253,100	1			5.21	−0.3
89	25	245.23	237.67	17.56	.18	.00	S.W.	5	252,600	1			5.30	−1.9
90	26	244.94	237.61	17.33	.03	.03	W.	2	250,700	1			5.19	+0.7
91	26	245.02	237.63	17.39	.08	.00	W.	1	250,200	1			5.18	+0.4
92	26	244.97	237.63	17.34	.03	.03	W.	2-5	249,300	1			5.13	+0.2
93	July 2	245.17	237.90	17.27	.13	.07	S.W.	18-15	249,200	1			5.12	−2.6
94	2	245.25	237.90	17.35	.04	.04	S.W.	18-15	250,900	1			5.14	−3.8
95	3	245.01	237.62	17.39	.05	.09	N.E.	2	250,700			1	5.10	−0.1
96	3	244.94	237.56	17.38	.02	.02	N.	2	248,700			1	5.08	+0.2

WILLIAMS EX. 26. Sheet 1

TABLE No. 1. LAKE SUPERIOR AT SUPERIOR, WIS., AND MARQUETTE, MICH.

Monthly means of water levels above mean tide at New York. Marquette readings depend on zero of gage-601.75 and B. M. 3-609.91 sea level elevations. U. S. Lake Survey level adjustment of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860 a	c602.44	c602.19	c602.19	602.69	602.92	603.09	603.05	603.10	603.08	603.12	602.95	c602.59	602.78
1861 a	c602.48	602.15	602.01	602.42	603.05	603.20	603.36	603.32	603.23	603.26	602.92	602.54	602.83
1862 a	602.19	602.00	602.03	602.09	602.77	602.76	602.73	602.90	603.02	602.95	602.62	602.35	602.53
1863 a	602.16	602.03	601.86	601.90	602.03	601.95	602.09	602.71	602.73	602.56	602.21	602.10	602.19
1864 a	601.81	601.60	601.67	601.69	601.85	602.00	602.09	602.10	602.25	601.99	601.80	601.65	601.87
1865 a	601.47	601.46	601.33	601.77	602.26	602.67	602.99	603.07	603.08	602.87	602.34	602.03	602.28
1866 a	601.74	601.53	601.53	601.98	602.23	602.42	602.71	602.94	602.67	602.69	602.36	602.47	602.27
1867 a	602.20	602.09	601.90	602.12	602.12	602.72	603.05	602.93	603.01	602.90	602.56	602.24	602.49
1868 a	602.08	601.49	601.85	602.04	602.44	602.35	602.57	602.49	602.62	602.50	602.75	602.32	602.30
1869 a	602.10	601.86	601.41	601.99	602.39	602.40	602.77	603.23	604.08	603.56	603.22	602.57	602.63
1870 a	602.32	602.11	602.12	602.22	602.55	602.38	602.55	602.55	602.72	602.56	602.38	601.45	602.32
1871 a	601.36	600.76	601.18	601.68	602.21	602.33	602.40	602.46	602.56	602.49	602.42	601.68	601.96
1872 b	601.47	601.36	601.24	601.14	601.79	602.17	602.44	602.61	602.77	602.67	602.52	602.22	602.03
1873 b	602.12	d601.67	d601.70	d601.71	602.31	602.61	602.90	603.08	603.14	603.04	602.90	602.60	602.48
1874 b	d602.15	602.13	602.09	602.19	602.26	602.46	602.84	602.93	603.03	603.09	602.91	602.60	602.56
1875 b	602.28	602.24	602.28	602.28	602.50	602.86	602.85	602.94	603.17	603.02	602.88	602.68	602.67
1876 b	602.48	602.27	602.18	602.21	602.75	603.43	603.82	603.93	603.82	603.49	603.33	603.05	603.06
1877 b	602.69	602.45	602.19	602.11	602.10	602.32	602.70	602.76	602.60	602.60	602.39	602.32	602.44
1878 b	602.20	602.32	601.55	601.52	601.79	602.07	602.14	602.02	601.85	601.92	601.72	601.40	601.87
1879 b	d601.50	601.46	601.76	601.37	601.01	601.24	601.48	601.60	601.49	601.58	601.50	d601.20	601.43
1880 b	d600.88	d600.84	d600.75	d600.78	d601.47	602.30	602.45	602.44	602.44	602.30	602.33	602.07	601.76
1881 b	601.81	601.71	601.62	601.53	601.83	602.27	602.33	602.38	602.61	602.95	602.88	602.60	602.21
1882 b	602.25	602.00	601.89	601.81	601.97	601.99	602.44	602.56	602.60	602.43	602.41	602.22	602.21
1883 b	601.99	601.70	601.70	601.95	601.98	602.06	602.31	602.33	602.29	602.09	601.94	601.83	602.01
1884 b	d601.76	d601.73	d601.61	601.32	601.54	601.74	601.88	601.89	602.16	602.52	602.42	602.21	601.90
1885 b	601.98	601.80	601.72	601.67	602.00	602.28	602.52	602.64	602.57	602.40	602.25	601.92	602.15
1886 b	601.72	601.59	601.53	601.62	601.87	602.01	602.08	601.99	601.97	602.07	601.92	601.78	601.85
1887 b	601.47	601.49	601.80	601.97	601.76	601.92	602.20	602.28	602.14	602.07	601.83	601.61	601.88
1888 b	601.50	601.51	601.44	601.44	601.91	602.09	602.38	603.02	602.97	602.88	602.74	602.39	602.28

1889 b	602.07	601.85	601.68	601.69	603.04	602.16	602.35	602.54	602.67	602.51	602.20	601.90	602.14
1890 b	601.76	601.63	601.39	601.36	601.57	602.02	602.32	602.47	602.60	602.57	602.36	602.00	602.00
1891 b	601.64	601.51	601.47	601.43	601.69	601.68	601.88	601.95	601.89	601.94	601.83	601.42	601.69
1892 b	601.42	601.14	601.01	601.02	601.35	601.73	601.76	601.88	601.93	601.83	601.66	601.38	601.51
1893 b	601.10	601.01	601.06	601.16	601.66	602.18	602.48	602.54	602.45	602.42	602.26	602.03	601.86
1894 b	601.85	601.67	601.76	601.91	602.69	602.91	602.97	603.10	603.02	603.04	602.99	602.80	602.56
1895 b	602.60	602.28	602.11	602.01	602.38	602.70	602.90	602.95	603.09	603.14	602.85	602.52	602.62
1896 b	602.32	602.12	601.92	602.01	602.66	603.04	603.10	603.12	602.95	602.63	602.70	602.55	602.59
1897 b	602.39	602.16	602.08	602.11	602.45	602.78	603.08	603.20	603.14	602.94	602.64	602.21	602.60
1898 b	601.83	601.65	601.46	601.46	601.70	602.18	602.59	602.72	602.82	602.76	602.56	602.33	602.17
1899 b	601.96	601.76	601.79	601.76	602.47	602.96	603.19	603.35	603.51	603.32	603.21	603.00	602.69
1900 b	602.63	602.45	602.23	602.13	602.30	602.36	602.58	602.94	603.46	603.54	603.51	603.13	602.77
1901 b	602.78	602.48	602.28	602.22	602.51	602.61	603.09	603.22	603.04	603.07	603.00	602.68	602.75
1902 b	602.32	602.11	601.97	602.02	602.34	602.64	602.88	602.89	602.93	602.81	e602.81	e602.58	602.53
1903 be	602.24	601.96	601.88	602.07	602.56	602.94	603.14	603.25	603.27	603.40	603.18	602.80	602.73
1904 be	602.50	602.34	602.23	602.17	602.47	602.77	602.86	602.95	603.08	603.26	603.14	602.74	602.71
1905 be	602.47	602.13	602.04	602.26	602.49	602.67	602.97	603.10	603.32	603.33	603.17	602.96	602.74
1906 be	602.72	602.43	602.22	602.15	602.48	602.78	602.90	602.93	602.95	602.84	602.66	602.45	602.63
1907 be	602.22	602.06	601.94	601.94	602.10	602.55	602.70	602.93	603.17	603.15	602.88	602.53	602.51
1908 be	602.10	601.87	601.72	601.63	602.03	602.57	602.85	602.92	602.77	602.59	602.23	601.99	602.27
1909 be	601.69	601.46	601.35	601.29	601.62	601.94	602.18	602.40	602.40	602.29	602.26	602.26	601.93
1910 be	602.01	601.74	601.51	601.62	601.75	601.90	601.88	601.97	601.96	601.92	601.68	601.41	601.78
1911 be	601.07	600.89	600.66	600.54	600.82	601.27	601.62	602.09	602.18	602.18	602.03	601.90	601.44
1912 be	601.76	601.53	601.43	601.45	601.90	602.20	602.35	602.53	602.65	602.60	602.44	602.20	602.09
1913 be	601.89	601.57	601.51	601.64	602.07	602.36	602.64	602.78	602.83	603.02	602.88	602.70	602.32

a Superior, Wis. b Marquette, Mich. c Interpolated by the same differences to the observed monthly means for that year as are found in the means of monthly means for the ten year series 1862-71. d Interpolated by applying the average difference of Marquette, Mich., and Sault Ste. Marie, Mich., water levels for the year to the monthly mean at Sault Ste. Marie Mich. e From records of self-registering gage.

Note.—Superior, Wis., records are found in Report of Chief of Engineers 1876, and are reduced to sea level elevations and 0.45 ft. added to reduce to the new levels. This difference of 0.45 ft. is the same as used to correct the levels at Duluth, Minn. There is an uncertainty of 0.4 ft. in the elevation of the zero of the gage at Superior, Wis. The possible alternative would make the levels 0.4 ft. lower than given in the table. The Marquette, Mich., records are considered reliable.

TABLE No. 2. LAKE MICHIGAN AT MILWAUKEE, WIS.

Monthly means of water levels above mean tide at New York, depending on check point. (1876) on Chestnut St. Bridge (destroyed) as 586.55, and check point (1902) on same bridge as 584.47 Sea level elevations in ft. U. S. Lake Survey level adjustment of 1903.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	582.51	582.60	582.72	582.85	582.97	583.09	583.13	582.94	582.74	582.43	582.10	581.94	582.68
1861	581.83	581.92	582.31	582.41	582.83	582.99	583.12	583.36	583.05	582.93	582.70	582.53	582.66
1862	582.33	582.18	582.48	582.64	582.89	583.02	582.92	582.91	582.84	582.73	582.34	582.20	582.62
1863	582.13	582.18	582.17	582.17	582.38	582.47	582.42	582.20	582.11	582.02	581.58	581.92	582.15
1864	581.69	581.55	581.80	581.51	582.02	582.01	581.91	581.73	581.46	581.07	580.90	580.77	581.53
1865	580.56	580.65	580.82	581.31	581.47	581.51	581.94	581.96	581.84	581.60	581.04	580.73	581.29
1866	580.47	580.23	580.28	580.73	580.91	581.20	581.46	581.52	581.37	581.26	581.17	580.91	580.96
1867	580.89	580.94	581.12	581.41	581.63	581.94	582.00	582.02	581.75	581.42	580.96	580.61	581.40
1868	580.45	580.41	581.09	580.99	581.27	581.48	581.51	581.17	580.93	580.70	580.63	580.35	580.91
1869	580.25	580.32	580.06	580.43	580.76	581.20	581.67	581.93	581.82	581.46	581.34	581.06	581.03
1870	581.12	581.21	581.51	581.93	582.27	582.41	582.52	582.43	582.57	582.17	581.77	581.42	581.94
1871	581.57	581.49	582.09	582.29	582.64	582.68	582.71	582.48	581.81	581.12	581.07	580.48	581.87
1872	580.35	580.35	580.13	580.38	580.63	581.00	581.03	581.01	580.94	580.82	580.53	579.87	580.59
1873	579.87	579.91	580.22	580.79	581.35	581.96	581.94	582.04	581.85	581.79	581.56	581.52	581.24
1874	581.48	581.77	581.92	581.82	581.80	582.17	582.10	582.11	581.86	581.51	581.31	580.97	581.73
1875	580.77	580.70	580.76	581.12	581.66	581.92	581.89	582.06	581.99	581.84	581.63	581.44	581.48
1876	581.39	581.50	581.92	582.12	582.74	583.15	583.49	583.42	583.37	582.79	582.89	582.42	582.61
1877	582.28	582.29	582.29	582.67	582.56	582.63	582.60	582.48	582.27	582.28	582.16	582.10	582.38
1878	581.96	581.91	582.07	582.09	582.39	582.53	582.54	582.22	582.02	581.91	581.78	581.46	582.07
1879	581.15	581.16	581.20	581.19	581.32	581.39	581.48	581.29	581.17	580.95	580.73	580.76	581.15
1880	580.80	580.71	580.75	580.92	581.26	581.77	581.99	582.02	581.72	581.38	581.06	580.89	581.27
1881	580.90	581.11	581.40	581.31	581.82	582.05	582.02	582.02	581.79	582.12	581.95	581.85	581.70
1882	581.68	581.62	581.99	582.12	582.22	582.49	582.62	582.81	582.69	582.28	582.07	581.74	582.19
1883	581.48	581.52	581.61	581.82	582.30	582.66	583.26	583.23	583.04	582.82	582.37	582.29	582.37
1884	582.07	582.19	582.44	582.62	582.83	582.99	582.83	582.69	582.44	582.44	582.08	582.05	582.47
1885	582.06	582.29	582.25	582.44	582.80	583.01	583.10	583.31	583.17	583.03	582.73	582.44	582.72
1886	582.67	582.69	582.97	583.24	583.50	583.57	583.38	583.15	582.91	582.81	582.47	582.14	582.96
1887	582.06	582.43	582.50	582.54	582.74	582.87	582.81	582.67	582.33	581.88	581.55	581.43	582.32
1888	581.25	581.20	581.38	581.59	581.97	582.24	582.25	582.13	581.98	581.73	581.68	581.10	581.71
1889	581.08	581.05	581.03	581.04	581.12	581.58	581.76	581.52	581.35	581.10	580.75	580.57	581.16
1890	580.65	580.61	580.59	580.91	581.14	581.55	581.62	581.54	581.24	581.23	580.89	580.54	581.05
1891	580.53	580.26	580.47	580.78	580.86	581.03	580.96	580.79	580.56	580.20	579.80	579.74	580.49

1893	579.96	580.08	579.95	580.01	580.42	580.46	580.89	580.97	580.77	580.58	580.20	579.99	580.35
1893	579.96	580.12	580.23	580.69	580.99	581.32	581.34	581.17	580.85	580.71	580.32	580.25	580.67
1894	580.26	580.29	580.55	580.70	581.24	58 40	581.43	581.35	580.92	580.71	580.44	580.09	580.78
1895	579.91	579.80	579.77	579.97	580.13	580.18	580.07	579.95	579.68	579.31	579.09	578.98	579.74
1896	579.06	579.10	579.11	579.29	579.57	579.89	579.83	579.76	579.66	579.61	579.39	579.34	579.47
1897	579.33	579.41	579.72	579.89	580.38	580.65	580.84	580.78	580.53	580.24	579.98	579.76	580.13
1898	579.72	579.86	580.18	580.50	580.78	580.91	580.89	580.69	580.34	580.33	579.92	579.58	580.31
1899	579.53	579.61	579.81	580.08	580.52	580.83	581.04	580.96	580.82	580.49	580.31	579.81	580.32
1900	579.66	579.77	579.94	580.07	580.31	580.42	580.53	580.70	580.65	580.66	580.52	580.19	580.28
1901	579.95	579.92	580.34	580.49	580.92	580.97	581.06	581.11	580.92	580.56	580.23	579.95	580.53
1902	579.76	579.61	579.84	579.91	580.30	580.50	580.83	580.85	580.48	580.33	580.22	579.93	580.21
1903	579.72	579.90	580.09	580.36	580.45	580.63	580.81	580.71	580.79	a580.62	a580.26	a579.94	580.36
1904	a579.99	a579.98	a580.26	a580.72	a581.09	a581.47	a581.48	a581.38	a581.31	a581.18	a580.88	a580.54	580.86
1905	a580.39	a580.31	a580.45	a580.33	a581.09	a581.48	a581.62	a581.59	a581.49	a581.05	a580.78	a580.63	580.98
1906a	a580.61	a580.76	a580.91	a581.09	581.35	581.47	581.48	581.45	581.10	580.91	580.75	580.70	581.05
1907a	580.64	580.68	580.74	581.00	581.16	581.52	581.52	581.44	581.42	581.17	580.76	580.65	581.06
1908a	580.48	580.57	580.64	580.94	581.50	581.64	581.83	581.72	581.28	580.92	580.27	580.13	580.99
1909a	579.88	580.02	580.10	580.36	580.88	581.08	581.05	581.07	580.80	580.32	580.21	580.17	580.50
1910a	579.95	579.94	580.01	580.37	580.50	580.57	580.49	580.33	580.29	580.10	579.78	579.46	580.15
1911a	579.20	579.40	579.23	579.50	579.77	580.05	579.89	579.85	579.75	579.65	579.37	579.48	579.60
1912a	579.27	579.29	579.35	579.52	580.05	580.46	580.53	580.63	580.71	580.41	580.42	580.18	580.07
1913a	580.01	579.84	580.13	580.82	581.13	581.26	581.26	581.26	580.98	580.75	580.44	580.30	580.68
1914a	580.07	580.04											

a From records of self-registering gage on harbor pier.

Note.—These water levels also depend on B. M. on N. E. corner of Dr. Lapham's house at No. 321 Poplar St. as 596.385 ft. The Milwaukee staff gage readings as reduced from publication in previous reports are slightly inconsistent owing to various assumptions in regard to the stability of the gage and reference bench marks. The results of spirit leveling at infrequent intervals show a slight difference in the relative elevations of the reference B. M. on Dr. Lapham's house and the check point on the masonry pier of the Chestnut St. Bridge. In the above table these different results are ascribed to the natural discrepancies of the levels and reductions are made on the assumption that these marks have remained stable and at the relative elevations as originally determined. This assumption is supported by the results of the latest levels (1901). Levels in August, 1901, and November, 1902, indicate that the gage zero had raised 0.03 and 0.05 ft. respectively since the previous test in 1896, explained no doubt by extensive improvements being made in the vicinity. The corrections due to this change in zero have been uniformly distributed. Previous to 1896 the gage zero remained stable with reference to the check point.

The Milwaukee gage is situated at the foot of Poplar St. in the Milwaukee River, about two miles above the mouth and the readings do not indicate the stage of Lake Michigan during high stages of water or ice gorges in the river.

WILLIAMS EXHIBIT 26 Sheet 3.

TABLE No. 3. LAKE HURON AT HARBOR BEACH, MICH.

Monthly means of water levels above mean tide at New York depending on B. M. "Jenks" 610.86 and gage bolt "E" 583.21 sea level elevation in feet U. S. Lake Survey level adjustment of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1874	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1875	581.16	581.10	581.14	581.33	581.68	581.99	582.18	582.15	582.11	581.84	581.20	581.45	.....
1876	581.74	581.72	581.85	582.13	582.73	583.22	583.66	583.60	583.49	583.09	582.94	582.75	582.74
1877	582.46	582.45	582.38	582.46	582.63	582.59	582.77	582.67	582.40	582.26	582.21	582.16	582.45
1878	582.06	581.89	582.06	581.99	582.39	582.56	582.60	582.50	582.21	582.22	582.03	581.83	582.20
1879	581.53	581.29	581.25	581.28	581.41	581.55	581.59	581.46	581.38	581.14	581.02	581.00	581.32
1880	581.06	580.99	580.98	580.99	581.30	581.88	582.19	582.08	581.97	581.61	581.49	581.29	581.49
1881	581.16	581.55	581.56	581.58	581.90	582.07	582.22	582.05	581.89	582.14	582.27	582.10	581.87
1882	581.95	581.72	581.86	582.08	582.25	582.48	582.62	582.48	582.56	582.33	582.08	581.93	582.21
1883	581.73	581.68	581.72	581.73	582.30	582.72	583.20	583.40	583.08	582.75	582.86	582.75	582.49
1884	582.56	582.41	582.45	582.76	582.98	583.04	583.12	583.00	582.65	582.81	582.46	582.20	582.70
1885	582.47	582.38	582.38	582.49	582.89	583.18	583.24	583.39	583.29	583.06	582.87	582.67	582.86
1886	582.67	582.74	582.93	583.22	583.55	583.64	583.48	583.33	583.15	583.02	582.75	582.43	583.06
1887	582.26	582.45	582.66	582.57	582.77	582.89	582.97	582.76	582.41	582.19	581.74	581.45	582.43
1888	581.34	581.25	581.42	581.58	582.00	582.30	582.33	582.37	582.09	581.78	581.60	581.39	581.79
1889	581.25	281.17	581.15	581.08	581.22	581.58	581.61	581.75	581.58	581.21	580.87	580.71	581.28
1890	580.78	580.66	580.64	580.78	581.09	581.52	581.71	581.71	581.44	581.23	581.03	580.73	581.11
1891	580.53	580.42	580.30	580.72	580.96	580.91	580.94	580.84	580.65	580.28	579.97	579.91	580.64
1892	579.93	579.87	579.93	580.05	580.14	580.67	580.99	581.04	580.87	580.66	580.33	580.09	580.38
1893	579.84	579.79	579.87	580.25	580.88	581.21	581.35	581.21	580.91	580.73	580.47	580.28	580.57
1894	580.23	580.24	580.39	580.62	581.02	581.32	581.47	581.20	581.01	580.77	580.58	580.28	580.76
1895	579.96	579.84	579.85	579.95	580.12	580.19	580.16	580.07	579.94	579.65	579.26	579.02	579.83
1896	579.09	579.21	579.11	579.14	579.54	579.91	579.97	580.01	579.83	579.63	579.49	579.38	579.53
1897	579.45	579.36	579.47	579.84	580.41	580.65	580.83	580.84	580.58	580.23	580.07	579.81	580.13
1898	579.66	579.72	579.95	580.44	580.56	580.72	580.82	580.71	580.52	580.21	580.13	579.94	580.28
1899	579.68	579.54	579.69	579.86	580.40	580.79	581.06	580.99	580.79	580.38	580.24	580.05	580.29
1900	579.82	579.83	579.86	579.98	580.13	580.30	580.55	580.64	580.72	580.66	580.66	580.46	580.30

1901	580.22	580.08	580.07	a580.55	580.81	580.91	581.06	581.11	580.93	580.66	580.43	580.10	580.57
1902	580.00	579.81	579.73	579.91	580.16	580.48	580.76	580.83	580.51	580.27	580.17	579.93	580.21
1903	579.74	579.78	579.92	580.27	580.39	580.56	580.75	580.73	580.80	580.83	580.41	580.12	580.36
1904	579.91	579.91	580.08	580.63	580.96	581.42	581.55	581.53	581.36	591.26	580.95	580.50	580.84
1905	580.38	580.30	580.29	580.66	580.95	581.40	581.57	581.56	581.45	581.22	580.93	580.67	580.95
1906	580.53	580.69	580.76	580.94	581.20	581.33	581.45	581.36	581.12	580.87	580.68	580.65	580.95
1907	580.65	580.68	580.68	580.90	581.08	581.30	581.64	581.49	581.42	581.21	580.83	580.62	581.05
1908	580.52	580.43	580.58	580.85	581.26	581.60	581.76	581.67	581.27	580.86	580.46	580.23	580.96
1909	579.90	579.92	580.03	580.14	580.76	581.07	581.13	581.02	580.80	580.40	580.12	580.08	580.45
1910	579.99	579.98	579.99	580.10	580.40	580.54	580.42	580.33	580.20	580.08	579.83	579.52	580.12
1911	579.38	579.35	579.35	579.37	579.66	579.98	579.93	579.85	579.58	579.56	579.44	579.39	579.57
1912	579.35	579.23	579.22	579.44	579.89	580.45	580.41	580.54	580.67	580.54	580.43	580.28	580.04
1913	580.13	580.06	580.08	580.73	580.99	581.14	581.29	581.18	580.88	580.70	580.50	580.38	580.67

a From records of automatic gage after April, 1901.

Note—By Lake Survey levels run in March, 1901, it was found that water levels as being reported from this station were 0.07 ft. too high from the adopted elevations of the reference bench marks. This error was first dropped from the published mean of May, 1901.

The original gage established by Asst. Engr. Gilbert and used until 1884 was probably correct, this error being introduced by the frequent transfer to new gages subsequently set by the gage observers.

This table to Jan., 1892, is reduced from Chief of Engineers reports; from Jan., 1892, to date from records in this office. A correction of 0.07 ft. has been made to the reported monthly mean after Jan. 1, 1895.

There is a lack of data to show definitely when this error was first introduced, the above date being selected arbitrarily, suggested by a comparison with Milwaukee records.

TABLE No. 4. LAKE ST. CLAIR AT ST. CLAIR FLATS CANAL.

Monthly means of water level above mean tide at New York depending on gage zero 575.42 and P. B. M. Old Club 576.571 Sea level elevation in feet. U. S. Lake Survey level adjustment of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1872	.....	.....	.....	.....	.....	.....	575.53	575.67	575.53	575.51	575.02	574.98	.....
1873	574.48	574.71	575.05	575.93	575.95	576.22	576.36	576.35	576.12	575.87	575.68	575.89	575.72
1874	575.11	574.47	575.90	576.12	576.08	576.29	576.46	576.37	576.16	575.92	575.63	575.32	575.82
1875	575.16	575.10	575.26	575.27	575.84	576.01	576.24	576.17	576.02	575.85	575.67	575.57	575.68
1876	575.72	576.17	576.95	576.92	576.69	577.58	577.74	577.57	577.10	576.77	576.66	577.51	576.95
1877	577.04	575.58	574.30	575.26	575.51	576.34	576.59	576.50	576.25	.....	576.30	576.09	.....
1878	575.98	575.06	575.82	.....	.....	576.74	576.86	576.77	576.43	576.24	575.91	575.67	.....
1879	575.26	574.57	575.26	575.81	575.69	.....	.....	.....	.....	.....	.....	.....	.....
1880	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1881	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1882	.....	.....	.....	.....	577.05	.....	577.47	577.46	576.13	575.93	.....	.....	.....
1883	.....	.....	.....	.....	576.40	577.13	577.80	577.72	577.26	576.89	576.23	.....	.....
1884	574.99	575.44	576.81	577.05	577.22	577.39	577.44	577.15	576.79	576.57	576.45	576.42	.....
1885	576.88	576.08	576.92	576.94	576.79	577.16	577.06	577.18	577.03	576.71	576.20	576.38	576.62
1886	575.81	574.92	575.70	576.36	577.05	577.10	577.11	576.99	576.84	576.66	576.67	576.65	576.84
1887	576.30	576.41	576.41	576.61	576.83	576.92	576.92	576.74	576.46	576.13	576.34	576.61	576.46
1888	575.72	575.51	575.22	575.87	575.89	576.10	576.39	576.29	576.05	575.77	575.71	575.67	576.43
1889	575.77	574.83	574.74	575.04	575.42	575.97	576.11	575.96	575.76	575.37	575.64	575.53	575.83
1890	575.50	575.35	575.32	575.71	575.97	576.40	576.33	576.09	575.85	575.63	575.09	575.02	575.42
1891	575.08	575.13	574.92	575.20	575.24	575.35	575.42	575.31	575.18	574.86	575.60	575.45	575.77
1892	574.32	573.57	573.76	574.59	575.13	575.75	575.95	575.77	575.66	575.21	574.62	574.70	575.09
1893	573.76	573.86	574.70	575.13	575.54	575.88	575.92	575.74	575.48	575.22	574.82	574.60	574.93
1894	575.05	574.55	574.92	575.07	575.52	575.75	575.79	575.60	575.44	575.18	574.94	575.04	575.10
1895	575.34	575.35	574.75	574.25	574.55	574.69	574.75	574.71	574.50	574.19	574.94	574.86	575.22
1896	574.23	573.39	573.62	574.15	574.40	574.76	574.93	575.00	574.77	574.67	574.21	574.19	574.60
1897	574.48	574.83	574.78	574.82	575.24	575.34	575.49	575.46	575.20	574.84	574.67	574.70	574.99

1898	574.64	574.16	574.79	575.23	575.33	575.55	575.60	575.46	575.19	574.93	574.88	574.96	575.06	
1899	574.86	574.63	574.59	574.71	575.13	575.40	575.57	575.51	575.20	574.90	574.77	574.71	575.00	
1900	574.24	574.35	574.83	574.93	575.04	575.21	575.29	575.34	575.22	575.07	574.94	574.80	574.94	
1901	574.65	573.74	574.02	573.23	574.33	575.09	575.30	575.30	575.28	574.96	574.67	574.70	574.61	
1902	.....	.....	.....	574.52	574.76	575.13	575.76	575.62	575.34	575.24	574.95	575.06	.....	
1903	575.25	.....	.....	.....	575.42	575.55	575.68	575.60	575.39	575.45	574.95	575.35	.....	
1904	574.18	574.50	a575.64	575.91	575.86	576.19	576.25	576.14	575.98	575.74	575.34	575.45	575.60	
1905	574.52	574.20	574.81	575.11	575.45	575.88	576.07	576.01	575.84	575.60	575.32	b575.17	575.33	
1906	575.40	574.26	574.36	575.19	575.45	575.66	575.79	575.80	575.58	c575.45	575.33	57b.21	575.29	
1907	575.38	574.88	574.91	575.53	575.67	576.00	576.16	576.06	575.90	575.76	575.47	575.40	575.60	
1908	575.17	574.53	575.49	575.92	576.16	576.34	d576.40	d576.38	d575.98	575.64	575.23	574.98	575.68	
1909	574.69	573.89	573.98	575.24	576.00	576.05	576.12	576.02	575.73	575.31	575.08	575.75	575.32	
1910	574.59	574.05	575.16	575.24	575.59	575.62	575.60	575.45	575.32	575.20	574.89	574.44	575.10	
1911	573.33	573.36	574.12	574.74	574.84	575.08	575.08	574.95	574.80	574.83	574.60	574.70	574.54	
1912	574.70	574.90	575.14	575.28	575.37	575.51	575.45	575.44	575.55	575.31	575.23	575.02	575.24	
1913	575.46	574.49	574.98	576.34	576.29	576.29	576.29	576.16	575.78	575.50	575.40	575.20	575.68	
1914	574.64	574.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

a No readings 8-25, incl. b No readings after Dec. 20. c Auto. gage installed Oct. 4th.
d Staff gage means.

Note:—Staff gage zero 575.42 is mean value, by precise levels, from Algonac, 1903 and 1908. P. B. M. Old Club was established by the 1908 levels.

WILLIAMS EXHIBIT 20 Sheet 5.

TABLE No. 5. LAKE ERIE AT CLEVELAND, OHIO.

Monthly mean of water levels above mean tide at New York depending on B. M. 1, 581.41 sea level elevation in feet. Lake Survey level adjustment of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	573.26	572.90	573.30	574.00	574.21	574.18	573.92	573.76	573.42	573.12	573.03	572.87	573.50
1861	572.61	572.33	572.77	573.81	574.24	574.31	574.06	574.10	573.92	573.69	573.67	573.44	573.58
1862	573.43	573.14	573.28	574.18	574.42	574.42	574.39	574.01	573.70	573.32	572.98	573.01	573.69
1863	573.46	573.75	573.69	573.81	573.99	573.85	573.73	573.65	573.26	572.82	572.41	572.38	573.40
1864	572.09	572.24	572.45	572.95	573.65	573.60	573.34	573.07	572.85	572.54	572.37	572.44	572.90
1865	572.01	571.43	571.75	572.47	573.05	573.03	572.99	572.91	572.87	572.57	572.19	572.05	572.44
1866	571.78	571.62	572.01	572.59	572.81	573.07	573.18	572.93	572.87	572.86	572.62	572.63	572.58
1867	572.34	572.02	572.42	572.74	573.26	573.57	573.38	573.07	572.68	572.34	571.84	571.62	572.61
1868	571.42	571.04	571.63	572.46	572.91	573.30	573.27	572.75	572.48	572.03	571.87	571.66	572.23
1869	571.65	571.58	572.06	572.36	572.91	573.30	573.58	573.48	573.21	572.76	572.30	572.65	572.65
1870	572.89	573.12	572.89	573.54	573.75	573.72	572.76	573.71	573.46	573.08	572.78	572.66	573.28
1871	572.45	572.12	572.57	573.05	573.32	573.35	573.33	573.12	572.95	572.28	572.10	571.66	572.60
1872	571.58	571.34	571.25	571.45	571.89	572.26	572.25	572.22	571.99	571.82	571.49	571.26	571.73
1873	571.16	571.17	571.24	572.52	573.19	573.27	573.25	573.19	572.79	572.49	572.29	572.66	572.44
1874	573.05	573.10	573.13	573.30	573.39	573.46	573.49	573.33	572.87	572.43	572.01	571.80	572.95
1875	571.57	571.40	571.54	571.94	572.41	572.84	572.97	572.96	572.82	572.33	572.18	572.40	572.28
1876	572.36	572.92	573.57	574.09	574.41	574.52	574.41	574.11	573.94	573.41	573.49	573.15	573.70
1877	a572.75	572.59	572.36	572.79	573.04	573.12	573.36	573.22	573.14	572.74	572.66	572.74	572.88
1878	572.82	572.96	573.09	573.51	573.77	573.77	573.77	573.53	573.40	573.05	572.85	572.93	573.29
1879	572.51	572.37	572.40	572.76	572.91	573.00	573.03	572.81	572.48	572.25	571.78	572.04	572.53
1880	572.54	572.58	572.72	572.88	573.15	573.26	573.35	573.11	572.88	a572.44	a572.36	a572.02	572.77
1881	a571.61	a571.72	a572.04	572.74	573.14	573.38	573.33	573.01	572.66	572.61	572.43	572.64	572.61
1882	573.11	573.11	573.56	573.78	573.98	574.13	574.06	573.92	573.65	573.20	572.88	572.87	573.48
1883	572.28	572.49	572.68	572.80	573.20	573.96	574.16	574.10	573.79	573.47	573.09	573.12	573.27
1884	572.79	573.05	573.24	573.79	574.06	574.14	573.92	573.76	573.33	573.00	572.52	572.45	573.34
1885	572.27	572.06	571.92	572.74	573.47	573.98	573.94	573.95	573.80	573.70	573.58	573.53	573.24
1886	573.55	572.82	572.63	573.51	573.81	573.91	573.89	573.68	573.44	573.21	572.90	572.85	573.34

1887	572.62	573.04	573.85	573.87	574.05	574.06	573.84	573.52	573.20	572.70	572.43	572.45	573.31	
1888	572.27	572.00	572.10	572.73	572.98	573.11	573.26	573.16	572.72	572.35	572.41	572.29	572.61	
1889	572.31	572.15	571.99	572.34	572.52	572.95	573.15	572.84	572.45	572.03	571.76	572.02	572.38	
1890	572.38	572.67	572.79	573.28	573.62	573.90	573.61	573.17	572.96	572.79	572.76	572.58	573.05	
1891	572.31	572.29	572.75	572.62	572.44	572.58	572.48	572.21	572.03	571.65	571.31	571.28	572.15	
1892	571.31	571.10	571.14	571.70	572.50	573.26	573.38	573.03	572.71	572.15	571.82	571.55	572.14	
1893	571.17	571.25	571.47	572.20	573.04	573.23	572.95	572.61	572.23	571.88	571.46	571.56	572.09	
1894	571.84	571.72	571.75	572.15	572.54	572.85	572.73	572.36	572.19	571.87	571.63	571.56	572.10	
1895	571.23	571.00	571.01	571.26	571.48	571.57	571.46	571.38	571.28	570.80	570.70	570.86	571.17	
1896	570.96	570.88	570.83	571.28	571.66	571.93	571.81	572.02	571.70	571.46	571.09	571.12	571.39	
1897	571.09	571.29	571.66	572.21	572.54	572.64	572.63	572.47	572.19	571.70	571.57	571.54	571.96	
1898	571.59	571.79	572.05	572.63	572.78	572.81	572.59	572.39	572.01	571.81	571.69	571.62	572.14	
1899	571.67	571.46	571.83	572.13	572.44	572.56	572.46	572.21	571.85	571.61	571.62	571.34	571.93	
1900	571.36	571.57	571.92	572.23	572.39	572.47	572.34	572.31	571.99	571.75	571.49	571.45	571.94	
1901	571.35	571.00	570.88	571.29	571.31	571.72	571.91	571.78	571.71	571.33	571.16	571.19	571.39	
1902	571.08	570.63	570.94	571.49	571.86	572.12	572.74	572.72	572.38	572.29	572.02	571.83	571.84	
1903	571.72	571.70	572.28	573.06	573.09	573.06	572.98	572.76	572.59	572.25	571.77	b571.43	572.39	
1904 b	571.32	571.42	572.01	573.13	573.33	573.52	573.41	573.10	572.84	572.49	572.12	571.77	572.54	
1905 b	571.52	571.31	571.18	571.83	572.46	572.98	573.06	572.87	572.63	572.31	571.93	571.91	572.17	
1906 b	571.94	571.93	571.71	572.13	572.40	572.60	572.64	572.63	572.35	572.21	572.17	572.42	572.20	
1907 b	572.76	572.46	572.24	572.71	572.88	573.27	573.31	573.03	572.77	572.69	572.41	572.26	572.73	
1908 b	572.57	572.19	572.06	573.27	573.51	573.51	573.32	573.14	572.68	572.31	571.71	571.42	572.69	
1909 b	571.48	571.46	571.78	572.08	572.90	573.20	573.00	572.80	572.36	571.76	571.61	571.30	572.15	
1910 b	571.25	571.16	571.66	572.08	572.57	572.61	572.40	572.22	572.02	571.88	571.46	571.34	571.87	
1911 b	571.04	571.09	571.06	571.61	571.88	571.94	571.75	571.61	571.52	571.53	571.18	571.42	571.47	
1912 b	571.28	571.08	571.23	572.28	572.59	572.66	572.56	572.49	572.50	572.15	571.92	571.55	572.02	
1913 b	572.23	572.41	572.45	574.03	573.98	573.86	573.57	573.24	572.75	572.43	572.27	572.14	572.95	
1914 b	572.01	571.71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	

a Readings interpolated by applying average difference of readings for year to monthly means at Erie, Pa.
b From automatic gage records.

Note.—The Cleveland gage has been frequently inspected and the water levels are considered reliable.

TABLE No. 6. LAKE ONTARIO AT OSWEGO, N. Y.

Monthly means of water levels above mean tide at N. Y., depending on gage zero 244.12 and B. M. "A" 251.90, sea level elevations in feet. U. S. Lake Survey adjustment of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct.	Nov.	Dec.	Mean
1860	246.58	246.72	246.77	246.80	247.03	247.57	247.82	247.26	246.86	246.67	246.75	246.73	246.96
1861	246.44	246.56	247.01	247.23	248.16	248.54	248.32	248.07	247.60	247.81	247.82	247.61	247.60
1862	247.11	246.69	247.18	248.08	248.38	248.62	248.72	248.26	247.61	247.08	246.73	246.62	247.63
1863	246.77	246.83	246.91	247.63	248.03	248.18	247.77	247.31	246.93	246.74	246.56	246.57	247.19
1864	246.33	246.17	246.26	246.83	247.82	248.12	247.80	247.34	246.81	246.58	246.55	246.65	246.94
1865	247.08	247.23	247.38	247.46	247.62	247.66	247.51	246.90	246.29	246.07	245.82	245.66	246.89
1866	245.46	245.47	245.48	245.96	246.02	245.92	246.84	246.74	246.65	246.52	246.28	246.20	246.13
1867	245.96	245.92	246.62	247.52	248.21	249.48	248.11	247.48	246.98	246.33	246.59	244.83	246.84
1868	244.51	244.61	244.88	245.52	246.12	246.54	246.42	246.13	245.94	245.35	245.20	245.37	245.55
1869	245.22	245.34	245.56	246.09	246.75	246.97	247.29	247.35	247.17	247.08	246.68	246.85	246.53
1870	247.26	247.41	247.41	248.35	248.95	248.63	248.31	247.97	247.28	246.95	246.38	246.13	247.59
1871	246.06	245.89	246.00	246.67	247.12	247.06	246.91	246.46	246.12	245.62	245.21	244.90	246.18
1872	244.73	244.51	244.35	244.84	244.96	245.29	245.35	245.19	244.90	244.74	244.69	244.35	244.82
1873	244.26	244.37	244.50	246.40	246.96	246.91	246.87	246.58	246.15	245.73	245.62	245.79	245.84
1874	246.37	246.74	247.29	247.20	247.17	247.28	247.22	246.97	246.34	245.93	245.40	245.03	246.56
1875	244.72	244.36	244.65	245.41	245.70	245.87	245.93	245.75	245.55	245.27	245.10	244.90	245.27
1876	245.29	245.97	246.52	247.50	248.07	248.29	248.36	247.91	247.30	246.97	246.61	246.40	247.10
1877	245.91	245.63	245.78	246.46	246.54	246.42	246.45	246.20	245.77	245.37	245.25	245.38	245.93
1878	246.48	246.88	246.38	246.64	246.98	246.96	246.72	246.88	a246.59	246.33	246.21	247.00	246.50
1879	246.80	246.46	246.33	246.70	246.81	246.81	246.67	246.31	245.91	245.47	245.10	245.11	246.21
1880	245.30	245.63	245.95	246.15	246.33	246.53	246.52	246.09	245.74	245.36	245.30	245.10	245.88
1881	244.73	244.72	245.39	245.80	245.99	246.20	246.30	245.98	245.39	245.19	245.19	245.20	245.51
1882	245.73	245.91	246.52	246.81	247.02	247.55	247.53	247.19	246.81	246.30	245.87	245.62	246.57
1883	245.30	245.35	245.60	245.15	246.72	247.49	248.03	247.84	247.37	246.94	246.69	246.56	246.68
1884	246.51	246.91	247.58	248.16	248.19	248.09	247.99	247.64	247.22	246.80	246.30	246.15	247.30
1885	246.15	245.88	245.59	246.27	247.07	247.44	247.58	247.44	247.20	247.02	247.07	247.24	246.83
1886	247.60	247.67	247.81	248.45	248.65	248.41	248.04	247.59	247.24	246.83	246.51	246.44	247.60
1887	246.18	246.92	247.48	247.[illegible]	248.20	248.16	247.88	247.38	246.76	246.37	246.02	245.76	247.06
1888	245.45	245.20	245.54	246.17	246.31	246.28	246.14	246.24	245.65	245.46	245.41	245.41	245.82
1889	245.62	245.77	246.06	246.17	246.32	246.63	246.62	246.57	246.07	245.57	245.18	245.79	246.02

1890	246.26	246.60	246.97	247.17	247.52	248.16	247.99	247.33	246.97	246.64	246.71	246.51	247.07
1891	246.19	246.45	246.99	247.47	247.24	246.83	246.55	246.11	245.68	245.04	244.44	244.43	246.12
1892	244.51	244.48	244.61	245.20	245.25	245.81	246.33	246.25	246.04	245.60	245.32	245.20	245.38
1893	244.87	244.77	245.25	245.96	247.13	247.37	247.11	246.57	246.31	245.78	245.37	245.23	245.98
1894	245.56	245.75	246.06	246.10	246.27	246.80	246.60	246.03	245.51	245.26	244.95	244.57	245.79
1895	244.50	244.44	244.33	244.87	245.00	244.89	244.59	244.35	244.00	243.67	243.41	243.43	244.29
1896	243.80	244.27	244.49	245.41	245.43	245.34	245.08	244.94	244.46	244.23	243.97	243.99	244.62
1897	243.87	243.83	244.30	244.96	245.41	245.62	245.61	245.60	245.10	244.47	244.41	244.47	244.80
1898	244.64	245.06	245.48	245.92	246.07	246.18	245.85	245.51	245.09	244.84	244.88	244.90	245.37
1899	244.98	244.88	245.14	245.69	245.94	246.07	245.92	245.46	b244.95	b244.55	b244.42	b244.36	245.20
1900b	b244.63	b244.88	b245.19	245.80	245.99	245.91	245.82	245.54	b245.12	b244.72	b244.56	244.84	245.25
1901b	244.68	244.62	244.39	245.63	b245.91	b245.99	b245.74	b245.42	b245.10	b244.65	b244.28	b244.36	245.06
1902b	244.42	244.30	244.95	245.40	245.47	245.55	245.97	246.11	245.66	245.42	245.05	244.89	245.27
1903b	244.92	245.16	245.75	246.44	246.56	246.44	246.59	246.35	246.07	245.72	245.36	245.11	245.87
1904	244.72	245.00	245.63	247.00	247.61	247.87	247.89	247.64	247.25	246.87	246.36	245.81	246.64
1905	245.79	245.49	245.29	246.13	246.25	246.59	246.98	246.90	246.75	246.45	246.07	245.88	246.21
1906	246.13	246.10	245.91	246.25	246.36	246.41	246.58	246.27	245.81	245.52	245.59	245.71	246.05
1907	246.34	246.47	246.47	246.86	247.09	247.12	247.12	246.90	246.50	246.40	246.33	246.33	246.66
1908	246.73	246.99	247.39	248.02	248.46	248.62	248.34	247.95	247.14	246.44	245.92	245.51	247.29
1909	245.17	245.28	245.70	246.18	247.16	247.30	247.16	246.82	246.28	245.84	245.35	245.21	246.12
1910	244.94	245.03	245.75	245.97	246.42	246.46	246.29	246.05	245.70	245.38	245.15	244.89	245.67
1911	244.77	244.86	244.96	245.44	245.60	245.66	245.54	245.19	244.88	244.62	244.50	244.63	245.05
1912	244.76	244.87	245.10	245.32	246.82	247.34	247.01	246.66	246.36	246.17	246.08	246.11	246.05
1913	246.51	246.75	246.71	247.86	247.97	248.02	247.83	247.31	246.74	246.29	246.06	245.91	247.00
1914	245.60	245.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

a Interpolated. b From records of self-registering gage.

Note—Recent spirit leveling, executed with much care, determined the zero of Oswego staff gage 7.78 ft. below B. M. "A". The value previously used in all reports is 7.75 ft. The gage is cut in the vertical face of cut stone masonry, founded upon solid ledge rock, and is free from any possibility of settlement, hence readings are all reduced for the later value.

The records have been carefully kept and are reliable, but do not always indicate the stage of Lake Ontario, as the gage readings are influenced by high stages of water in Oswego River. These high stages usually occur in the spring months, and give gage readings from 0.2 to 0.3, or even more, above the level of Lake Ontario.

WILLIAMS EXHIBIT 27

Sheet 1 (2 Sheets)
Table 1

TABLE No. DETROIT RIVER AT AMHERSTBURG, ONT.

Monthly means of water levels above mean tide at New York, depending on Gage B. M. as 579.337 sea level elevation in feet. U. S. Lake Survey level adjustment of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1899	.....	.....	.....	.....	.....	572.81	572.76	572.39	572.15	571.98	571.85	571.44	.....
1900	571.63	571.77	572.19	572.45	572.64	572.73	572.57	572.56	572.20	572.03	571.55	571.60	572.16
1901	571.57	571.19	571.12	571.59	571.56	572.04	572.20	572.15	572.03	571.59	571.19	571.62	571.64
1902	571.21	570.86	571.13	571.63	572.09	572.34	572.99	573.00	572.64	572.49	572.20	571.98	572.05
1903	571.81	571.81	572.44	573.20	573.34	573.22	573.18	572.99	572.82	572.39	571.84	571.67	572.56
1904	571.56	571.61	572.20	573.28	573.60	573.74	573.68	573.38	573.08	572.73	572.24	572.05	572.76
1905	571.78	571.45	571.55	572.03	572.76	573.22	573.30	573.18	572.40	572.45	572.02	572.05	572.39
1906	572.10	572.14	572.00	572.43	572.68	572.92	573.02	572.97	572.70	572.38	572.32	572.48	572.51
1907	572.91	572.66	572.47	572.94	573.17	573.63	573.64	573.41	573.10	572.82	572.51	572.41	572.97
1908	572.72	572.29	572.90	573.40	573.73	573.77	573.62	573.47	572.99	572.58	571.83	571.58	572.91
1909	571.75	571.64	571.81	572.43	573.09	573.48	573.22	573.10	572.64	571.94	571.57	571.77	572.40
1910	571.58	571.50	571.76	572.31	572.76	572.90	572.80	572.52	572.30	572.01	571.52	571.52	572.12
1911	571.25	571.04	571.22	571.89	572.10	572.18	572.00	571.91	571.83	571.78	571.24	571.61	571.67
1912	571.61	571.47	571.71	572.42	572.79	572.89	572.81	572.75	572.74	572.33	571.90	571.69	572.28
Mean to 1905, incl.													

Note.—The water level at this station are all from records of self-registering gage. In the adjustment of levels made in 1903, the correction of levels of Lake Erie ports with those of the upper lakes was made by comparison of water levels with those at this station, making the elevation of gage B. M. 579.172. Subsequent precise levels from P. b. M. Trenton (1877) using the adjusted elevation gives the elevation of Gage B. M. 579.337. The later value is adopted, giving the water levels at Amherstburg on the same plane as other stations on Detroit River and above, but probably about 0.15 ft. too high as compared with Lake Erie gages. The slope of the river from Amherstburg to Lake Erie has not been definitely determined, but is assumed to be from 0.10 to 0.15 feet.

TABLE No. LAKE ST. CLAIR AT WINDMILL PT.

Monthly means of water levels above mean tide at New York, depending on P. B. M. 12 as 584.22, sea level elevation in feet, U. S. Lake Survey level adjustment of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1897	574.28	574.64	574.57	574.75	575.20	575.11	575.22	575.15	574.93	574.58	574.47	574.22	574.77
1898	574.20	.....	574.76	575.01	575.11	575.26	575.30	575.19	574.90	574.64	574.65	574.68	.....
1899	574.65	574.57	573.59	574.32	574.88	575.18	575.30	575.22	574.93	574.65	574.49	574.10	574.66
1900	574.03	574.24	574.67	574.64	574.79	574.99	575.01	575.06	574.89	574.74	574.52	574.41	574.67
1901	574.01	573.06	573.32	572.69	573.94	574.81	575.04	575.07	574.89	574.56	574.30	574.47	574.18
1902	573.31	572.96	573.96	574.22	.....	.....	575.50	575.41	575.08	574.92	574.62	574.64	.....
1903	574.69	574.40	574.75	575.31	575.27	575.38	575.44	575.36	575.29	575.04	574.54	574.94	575.03
1904	573.74	573.92	574.92	575.64	575.61	575.92	575.97	575.82	575.60	575.31	574.94	574.89	575.19
1905	575.78	573.50	573.57	574.73	575.11	575.66	575.80	575.74	575.52	575.18	574.84	574.73	574.87
1906	574.86	573.99	574.00	574.88	575.20	575.42	575.58	575.54	575.30	575.08	574.99	574.89	574.98
1907	574.94	574.65	574.60	575.24	575.44	575.78	575.90	575.76	575.51	575.40	575.05	574.96	575.27
1908	574.71	574.00	575.04	575.56	575.88	576.07	576.10	576.06	575.70	575.34	574.70	574.45	575.30
1909	574.32	573.49	573.62	574.85	575.69	575.85	575.83	575.70	575.35	574.82	574.69	575.27	574.96
1910	574.36	573.67	574.71	574.88	575.22	575.34	575.31	575.07	574.97	574.74	574.41	574.01	574.72
	See Note												See Note
1911	573.07	572.94	573.77	574.44	574.60	574.83	574.73	574.64	574.46	574.43	574.13	574.24	574.13
1912	574.46	574.45	574.84	574.98	575.09	575.22	575.16	575.10	575.18	574.90	574.73	574.43	574.85
1913	574.92	574.23	574.56	576.09	576.06	576.04	575.99	575.81	575.33	574.98	574.85	574.70	575.30
Means to 1905, incl.													

Note.—The water levels at this station are reduced from tri-daily staff-gage readings made under the direction of the U. S. Lake Survey Office, Detroit. The readings from Jan., 1911, to Mar., 1912, are in doubt, as the new float gage furnished the gage reader in former month was injured soon after it was received, and this was not discovered until the latter month. Readings for this period have been corrected +0.13 ft. determined by comparison with St. Clair Flats Canal, Fort Wayne, and Amherstburg.

WILLIAMS EXHIBIT 27

Sheet 2 (2 Sheets.)
Table 3

TABLE No. DETROIT RIVER AT FORT WAYNE

Monthly means of water levels above mean tide at New York, depending on B. M. Warehouse, as 584.317, U. S. Lake Survey adjusted levels of 1903.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1905	.....	.....	.....	.....	.....	.....	.....	.....	.....	574.30	574.01	573.92	.....
1906	574.03	573.53	573.29	574.08	574.38	574.62	574.78	574.74	574.54	574.34	574.15	574.16	574.22
1907	574.33	574.16	573.94	574.43	574.63	575.03	575.13	575.00	574.70	574.63	574.28	574.16	574.54
1908	574.06	573.52	574.40	574.86	575.21	575.37	575.38	575.30	574.89	574.56	573.94	573.68	574.60
1909	573.63	573.06	573.10	574.14	574.91	575.14	575.08	574.98	574.66	574.04	573.90	574.34	574.25
1910	573.72	573.23	573.96	574.18	574.53	574.65	574.60	574.39	574.26	574.05	573.65	573.41	574.05
1911	572.51	572.40	572.98	573.75	573.89	574.08	573.97	573.93	573.78	573.72	573.29	573.52	573.48
1912	573.75	573.62	574.07	574.29	574.43	574.56	574.42	574.38	574.43	574.10	573.86	573.58	574.12
1913	574.16	573.79	573.98	575.36	575.38	575.34	575.23	575.04	574.61	574.28	574.07	.....	.....
1914	.....	573.38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Williams Exhibit 27.

WILLIAMS EXHIBIT 28. Sheet 1
8 Sheets

ELEVATIONS OF WATER SURFACE OF LAKE ST. CLAIR

From record of self-registering gage at

ST. CLAIR FLATS, MICH.

In terms of U. S. Lake Survey adjusted levels of 1903.

	1909			1910			
Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April
1	575.55	575.08a	575.11	576.43	573.83	574.46a	575.08
2	575.54	575.13a	575.10	576.19	573.84	574.55	575.06
3	575.54	575.13	575.08	576.05	573.90	574.66	575.07
4	575.52a	575.09	575.06	575.90	573.91	574.75	575.08
5	575.52a	575.09	575.16	575.67	573.95	574.88	575.09
6	575.52	575.09	575.08	575.43	574.02	575.09	575.12
7	575.50	575.08	575.10	575.24	574.05	575.26	575.10
8	575.48	575.06	575.25	575.05	574.05	575.33	575.13
9	575.46	575.09	575.17	574.90	574.06	575.40	575.13
10	575.43	575.08	575.11	574.79	574.07	575.43	575.13
11	575.54	575.08	575.12	574.65	574.06	575.45	575.09
12	575.59	575.04	575.22	574.54	574.05	575.43	575.07
13	575.33	575.06	575.36	574.45	574.05	575.46	575.09
14	575.24	575.06	575.37	574.47	574.05	575.48	575.10
15	575.22	575.05	575.29	574.45	574.04	575.47	575.10
16	575.23	575.16	575.31	574.38	574.02	575.40	575.11
17	575.19	575.09	575.40	574.31a	574.03	575.40	575.19
18	575.19	575.02	575.39	574.28a	574.09	575.42	575.19
19	575.21	575.08	575.51	574.22	574.13	575.36	575.17
20	575.24	575.05	575.77	574.17	574.16	575.28	575.36
21	575.31	574.97	575.97	574.13	574.20	575.28	575.49
22	575.23	575.06	576.24	574.19	574.24	575.27	575.53
23	575.17	575.22	576.50	574.11	574.26	575.27	575.58
24	575.24	575.24	576.64	574.06	574.27	575.25	575.48
25	575.31	575.23	576.80	574.01	574.27	575.23	575.52
26	575.22	575.21	577.01	573.97	574.27a	575.19	575.64
27	575.18	575.15	577.04	573.92	574.2va	575.17	575.67
28	575.15	575.10	577.04	573.87	574.37	575.11	575.68
29	575.14	575.12	577.10	573.84	.....	575.10	575.65
30	575.15	575.12	577.03	573.81a	.....	575.08	575.56
31	575.11	.....	576.73	573.82a	.....	575.10	.....
Mean	575.33	575.10	575.78	574.62	574.09	575.19	575.28

Note.—Elevations previous to March, 1910, are referred to zero of reference gage as 576.20. Inspection of Dec. 13, 1909, corrects elevation of zero by—0.01—576.19. Readings in December, January and February should therefore be corrected by—0.01, to give correct elevations.

a=Mean of partial day only.

WILLIAMS EXHIBIT 28. Sheet 2.

U. S. LAKE SURVEY.

Daily Mean Elevations of Water Surface at

ST. CLAIR FLATS CANAL.

In Feet above Mean Tide at New York. Adjusted Levels, 1903.

Day	1900 April	1900 May	1900 June	1900 July	1900 August	1900 Sept.	REMARKS.
1	574.25	574.97	575.33	575.42	575.63	575.32	
2	574.25	575.03	575.33	575.45	575.63	575.32	
3	574.28	575.02	575.63	575.47	575.62	575.27	
4	574.32	575.03	575.33	575.47	575.63	575.27	
5	574.27	575.03	575.34	575.42	575.63	575.27	
6	574.27	575.03	575.35	575.42	575.63	575.22	
7	574.30	575.07	575.42	575.50	575.62	575.22	
8	574.50	575.07	575.42	575.53	575.63	575.22	
9	574.53	575.07	575.43	575.53	575.62	575.22	
10	574.29	575.07	575.43	575.53	575.57	575.22	
11	574.34	575.07	575.42	575.57	575.57	575.22	
12	574.72	575.07	575.43	575.57	575.57	575.22	
13	574.49	575.07	575.43	575.57	575.57	575.22	
14	574.67	575.07	575.43	575.62	575.52	575.22	
15	574.70	575.07	575.42	575.63	575.53	575.22	
16	574.92	575.07	575.42	575.63	575.53	575.22	
17	575.02	575.15	575.42	575.62	575.42	575.23	
18	575.02	575.17	575.43	575.62	575.43	575.23	
19	575.02	575.17	575.42	575.63	575.43	575.22	
20	575.02	575.14	575.43	575.60	575.42	575.17	
21	575.02	575.22	575.42	575.62	575.42	575.12	
22	575.02	575.22	575.42	575.62	575.42	575.13	
23	575.03	575.22	575.43	575.62	575.42	575.12	
24	575.02	575.22	575.43	575.62	575.42	575.12	
25	574.97	575.22	575.42	575.62	575.43	575.07	
26	574.97	575.22	575.42	575.62	575.42	575.12	
27	574.97	575.22	575.43	575.62	575.42	575.12	
28	574.97	575.27 Interpolated	575.43	575.62	575.43	575.12	
29	574.97	575.27 Interpolated	575.42	575.62	575.43	575.12	
30	574.97	575.27 Interpolated	575.43	575.63	575.43	575.12	
31	.....	575.27 Interpolated	.....	575.62	575.42	.....	
Mean	574.71	575.13	575.40	575.57	575.51	575.19	

Daily mean values during 1900, 1901 and 1902, are from tri-daily staff-gage readings.

1903 values are from self-registering gage records. All values are in terms of the 1903 determination of zero, 575.418.

WILLIAMS EXHIBIT 28.

Sheet 2—Cont'd

Day	1899 October	1899 November	1901 May	1901 June			REMARKS.
1	575.07	574.92	573.31	574.97	.....	.....	
2	575.04	574.92	573.32	575.03	.....	.....	
3	575.03	574.89	573.30	575.03	.....	.....	
4	575.03	574.82	573.29	575.02	.....	.....	
5	574.97	574.82	573.16	575.02	.....	.....	
6	574.92	574.82	573.30	575.02	.....	.....	
7	574.93	574.82	573.31	575.02	.....	.....	
8	574.92	574.82	573.36	575.02	.....	.....	
9	574.93	574.82	573.94	575.03	.....	.....	
10	574.92	574.83	574.13	575.02	.....	.....	
11	574.91	574.83	574.26	575.02	.....	.....	
12	574.92	574.82	574.44	575.02	.....	.....	
13	574.92	574.72	574.53	575.02	.....	.....	
14	574.92	574.72	574.60	575.02	.....	.....	
15	574.92	574.72	574.60	575.10	.....	.....	
16	574.92	574.72	574.64	575.13	.....	.....	
17	574.92	574.72	574.62	575.07	.....	.....	
18	574.92	574.72	574.66	575.12	.....	.....	
19	574.93	574.73	574.72	575.13	.....	.....	
20	574.83	574.73	574.87	575.13	.....	.....	
21	574.83	574.72	574.87	575.13	.....	.....	
22	574.83	574.72	574.83	575.12	.....	.....	
23	574.83	574.72	574.82	575.13	.....	.....	
24	574.82	574.73	574.82	575.12	.....	.....	
25	574.83	574.73	574.83	575.13	.....	.....	
26	574.83	574.72	574.83	575.17	.....	.....	
27	574.82	574.72	574.94	575.23	.....	.....	
28	574.83	574.72	574.92	575.23	.....	.....	
29	574.83	574.72	574.92	575.23	.....	.....	
30	574.83	574.72	574.92	575.23	.....	.....	
31	574.82	.....	574.92	.....	.....	.....	
Mean	574.90	574.77	574.33	575.08	.....	.....	

WILLIAMS EXHIBIT 28. Sheet 6.

U. S. LAKE SURVEY.

Daily Mean Elevations of Water Surface at

ST. CLAIR FLATS CANAL.

In Feet Above Mean Tide at New York, Adjusted Levels, 1903.

Day	1900 June	1900 July	1900 August	1900 Sept.	1900 Oct.	1900 Nov.	Remarks
1	575.07	575.22	575.42	575.32	575.13	575.19	
2	575.10	575.22	575.42	575.32	575.12	575.12	
3	575.10	575.22	575.42	575.32	575.12	575.07	
4	575.22	575.22	575.42	575.32	575.12	575.02	
5	575.29	575.22	575.42	575.32	575.12	575.02	
6	575.10	575.22	575.42	575.32	575.09	575.02	
7	575.17	575.22	575.27	575.32	575.02	574.97	
8	575.29	575.22	575.22	575.22	575.07	574.97	
9	575.22	575.22	575.32	575.27	575.12	574.97	
10	575.22	575.22	575.32	575.32	575.12	574.92	
11	575.22	575.22	575.32	575.27	575.12	574.92	Daily mean values during 1899, 1900 and 1902, are from tri-daily staff-gage readings. 1908 values are from self-registering gage records. All values are in terms of the 1906 determination of zero, 575.413.
12	575.22	575.22	575.34	575.32	575.12	574.92	
13	575.20	575.22	575.32	575.26	575.12	574.92	
14	575.29	575.22	575.32	575.27	575.12	574.92	
15	575.22	575.22	575.32	575.26	575.12	574.92	
16	575.22	575.22	575.32	575.21	574.99	574.92	
17	575.22	575.27	575.32	575.14	575.06	574.92	
18	575.22	575.22	575.32	575.12	575.07	574.92	
19	575.22	575.22	575.32	575.17	575.07	574.92	
20	575.26	575.22	575.32	575.22	575.07	574.92	
21	575.22	575.22	575.32	575.17	575.02	574.92	
22	575.22	575.27	575.32	575.12	574.92	574.87	
23	575.22	575.27	575.32	575.12	575.02	574.87	
24	575.22	575.34	575.22	575.12	575.02	574.87	
25	575.22	575.37	575.42	575.07	575.02	574.87	
26	575.22	575.37	575.37	575.02	575.02	574.87	
27	575.22	575.37	575.32	575.06	575.02	574.87	
28	575.22	575.42	575.22	575.12	575.02	574.87	
29	575.22	575.42	575.22	575.12	575.02	574.87	
30	575.22	575.42	575.22	575.12	575.02	574.87	
31	.....	575.42	575.32	.....	575.02	.....	
Mean	575.21	575.29	575.34	575.23	575.07	574.94	

Day	1900 Dec.	1902 Aug.	1902 Sept.	1902 Nov.	1902 Dec.		Remarks
1	574.87	575.82	575.42	575.42	575.12	.....	
2	574.87	575.82	575.42	575.42	575.10	.....	
3	574.87	575.82	575.32	575.42	575.16	.....	
4	574.87	575.82	575.29	575.24	575.06	.....	
5	574.87	575.74	575.22	575.46	575.01	.....	
6	574.87	575.79	575.22	575.42	575.01	.....	
7	574.87	575.73	575.29	575.27	575.06	.....	
8	574.87	575.72	575.32	575.26	575.04	.....	
9	574.87	575.72	575.32	575.27	574.97	.....	
10	574.87	575.72	575.32	575.22	574.97	.....	
11	574.87	575.72	575.27	575.21	574.99	.....	
12	574.87	575.72	575.29	575.27	575.09	.....	
13	574.84	575.72	575.32	575.23	575.09	.....	
14	574.82	575.67	575.32	575.23	575.09	.....	
15	574.77	575.67	575.32	575.26	575.09	.....	
16	574.77	575.57	575.22	575.14	574.99	.....	
17	574.77	575.62	575.22	575.10	574.92	.....	
18	574.77	575.57	575.22	575.09	574.97	.....	
19	574.77	575.56	575.27	575.07	575.06	.....	
20	574.73	575.52	575.27	575.11	574.99	.....	
21	574.73	575.53	575.22	575.10	574.96	.....	
22	574.73	575.52	575.22	575.09	574.96	.....	
23	574.72	575.52	575.27	575.09	574.91	.....	
24	574.72	575.52	575.27	575.07	574.96	.....	
25	574.74	575.52	575.42	575.09	574.90	.....	
26	574.73	575.42	575.32	575.21	574.99	.....	
27	574.73	575.46	575.32	575.12	574.94	.....	
28	574.73	575.42	575.32	575.12	574.94	.....	
29	574.73	575.42	575.32	575.09	574.97	.....	
30	574.73	575.42	575.32	575.07	574.91	.....	
31	574.73	575.42	.....	.....	574.89	.....	
Mean	574.80	575.62	575.34	575.23	574.98	.....	

WILLIAMS EXHIBIT 28. Sheet 4.

U. S. LAKE SURVEY.

Daily Mean Elevations of Water Surface at

ST. CLAIR FLATS CANAL.

In Feet Above Mean Tide at New York, Adjusted Levels, 1903.

Day	1899 April	1900 May	1900 June	1900 July	1900 August	1900 Sept.	Remarks
1	574.26	574.97	575.22	575.42	575.62	575.52	
2	574.32	575.02	575.22	575.46	575.62	575.32	
3	574.30	575.02	575.22	575.47	575.62	575.27	
4	574.32	575.02	575.22	575.47	575.62	575.27	
5	574.27	575.02	575.24	575.42	575.62	575.27	
6	574.27	575.02	575.26	575.42	575.62	575.22	
7	574.30	575.07	575.42	575.50	575.62	575.22	
8	574.50	575.07	575.42	575.52	575.62	575.22	
9	574.52	575.07	575.42	575.52	575.62	575.22	
10	574.30	575.07	575.42	575.52	575.57	575.22	
11	574.24	575.07	575.42	575.57	575.57	575.22	
12	574.72	575.07	575.42	575.57	575.57	575.22	
13	574.42	575.07	575.42	575.57	575.57	575.22	
14	574.67	575.07	575.42	575.62	575.52	575.22	
15	574.70	575.07	575.42	575.62	575.52	575.22	
16	574.92	575.07	575.42	575.62	575.52	575.22	
17	575.02	575.12	575.42	575.62	575.42	575.22	
18	575.02	575.17	575.42	575.62	575.42	575.22	
19	575.02	575.17	575.42	575.62	575.42	575.22	
20	575.02	575.14	575.42	575.60	575.42	575.17	
21	575.02	575.22	575.42	575.62	575.42	575.12	
22	575.02	575.22	575.42	575.62	575.42	575.12	
23	575.02	575.22	575.42	575.62	575.42	575.12	
24	575.02	575.22	575.42	575.62	575.42	575.12	
25	574.97	575.22	575.42	575.62	575.42	575.07	
26	574.97	575.22	575.42	575.62	575.42	575.12	
27	574.97	575.22	575.42	575.62	575.42	575.12	
28	574.97	575.27 Interpolated	575.42	575.62	575.42	575.12	
29	574.97	575.27 Interpolated	575.42	575.62	575.42	575.12	
30	574.97	575.27 Interpolated	575.42	575.62	575.42	575.12	
31	.....	575.27 Interpolated	.....	575.62	575.42	.....	
Mean	574.71	575.13	575.40	575.57	575.51	575.19	

Daily mean values during 1899, 1900 and 1903 are from tri-daily staff-gage readings.

1908 values are from self-registering gage records.

All values are in terms of the 1908 determination of zero, 575.418.

Day	1899 Oct.	1899 Nov.					Remarks
1	575.07	574.92	.....	.....	.....	.....	
2	575.04	574.92	.....	.....	.....	.....	
3	575.02	574.86	.....	.....	.....	.....	
4	575.02	574.83	.....	.....	.....	.....	
5	574.97	574.83	.....	.....	.....	.....	
6	574.92	574.83	.....	.....	.....	.....	
7	574.92	574.82	.....	.....	.....	.....	
8	574.92	574.83	.....	.....	.....	.....	
9	574.92	574.83	.....	.....	.....	.....	
10	574.92	574.83	.....	.....	.....	.....	
11	574.92	574.83	.....	.....	.....	.....	
12	574.92	574.83	.....	.....	.....	.....	
13	574.92	574.72	.....	.....	.....	.....	
14	574.92	574.72	.....	.....	.....	.....	
15	574.92	574.72	.....	.....	.....	.....	
16	574.92	574.72	.....	.....	.....	.....	
17	574.92	574.72	.....	.....	.....	.....	
18	574.92	574.72	.....	.....	.....	.....	
19	574.92	574.72	.....	.....	.....	.....	
20	574.92	574.72	.....	.....	.....	.....	
21	574.88	574.72	.....	.....	.....	.....	
22	574.83	574.72	.....	.....	.....	.....	
23	574.83	574.72	.....	.....	.....	.....	
24	574.83	574.72	.....	.....	.....	.....	
25	574.83	574.72	.....	.....	.....	.....	
26	574.83	574.72	.....	.....	.....	.....	
27	574.83	574.72	.....	.....	.....	.....	
28	574.83	574.72	.....	.....	.....	.....	
29	574.83	574.72	.....	.....	.....	.....	
30	574.81	574.72	.....	.....	.....	.....	
31	574.81	.....	.....	.....	.....	.....	
Mean	574.90	574.77	.....	.....	.....	.....	

WILLIAMS EXHIBIT 28 Sheet 1.
U. S. LAKE SURVEY.
Daily Mean Elevations of Water Surface at
HARBOR BEACH, MICH.
In Feet Above Mean Tide at New York, Adjusted Levels, 1903.

Day	1900 April	1900 May	1900 June	1900 July	1900 August	1900 Sept.	REMARKS.
1	579.8	580.21	580.61	580.85	581.04	580.81	
2	579.9	580.31	580.62	581.01	581.06	580.71	
3	579.8	580.18	580.58	581.01	581.11	581.18	
4	579.8	580.06	580.38	580.91	581.11	580.78	
5	579.7	580.28	580.48	581.06	581.14	580.74	
6	579.6	580.31	580.65	581.05	581.18	580.94	
7	579.7	580.28	580.75	580.81	581.04	580.38	
8	580.0	580.31	580.88	581.31	581.06	580.84	
9	579.9	580.41	580.71	581.21	580.91	580.94	
10	579.7	580.18	580.71	581.11	580.91	580.81	
11	579.5	580.41	580.65	581.06	580.84	580.78	
12	579.7	580.34	580.65	581.11	581.11	581.04	
13	579.9	580.51	580.78	581.11	581.21	581.11	
14	579.4	580.84	580.75	581.04	581.01	580.88	
15	579.8	580.38	580.81	581.04	581.04	580.81	
16	579.9	580.21	581.05	581.18	581.01	580.61	
17	579.8	580.28	580.65	581.18	580.96	580.78	
18	579.8	580.46	580.78	581.18	580.91	580.78	
19	579.9	580.06	580.88	581.01	580.91	581.01	
20	580.0	580.91	580.95	581.06	580.94	580.74	
21	579.9	580.51	580.91	581.11	580.94	580.81	
22	580.0	580.51	580.75	581.14	581.21	580.81	
23	580.1	580.48	580.91	580.91	580.86	580.84	
24	579.9	580.44	580.81	580.96	580.94	580.78	
25	580.1	580.41	580.96	581.04	581.04	580.71	
26	580.1	580.31	580.86	581.01	580.84	580.74	
27	579.9	580.48	580.88	581.21	580.64	580.64	
28	579.8	580.41	581.01	581.08	580.91	580.41	
29	580.1	580.44	580.91	581.11	580.81	580.81	
30	580.0	580.71	581.05	581.41	580.81	580.74	
31	.....	580.55	.....	581.11	580.84	.....	
Mean	579.85	580.39	580.79	581.04	580.90	580.70	

During 1900, the daily means are from the daily staff gage readings.
1901 are from self-registering gage records

Day	1900 October	1900 Nov.	1901 May	1901 June			REMARKS.
1	580.64	580.68	580.63	580.94	.....	.....	
2	580.31	580.26	580.73	580.92	.....	.....	
3	580.34	580.51	580.77	580.93	.....	.....	
4	580.51	580.41	580.70	580.80	.....	.....	
5	580.48	580.41	580.72	580.75	.....	.....	
6	580.44	580.21	580.99	580.90	.....	.....	
7	580.38	580.31	580.68	581.03	.....	.....	
8	580.31	580.31	580.75	581.11	.....	.....	
9	580.34	580.38	580.79	580.98	.....	.....	
10	580.14	580.34	580.74	580.83	.....	.....	
11	580.34	580.34	580.81	580.87	.....	.....	
12	580.31	580.34	580.75	580.98	.....	.....	
13	580.21	580.18	580.93	580.87	.....	.....	
14	580.61	580.18	580.85	580.93	.....	.....	
15	580.31	580.31	580.79	580.87	.....	.....	
16	580.11	580.14	580.75	580.84	.....	.....	
17	580.08	579.71	580.78	580.80	.....	.....	
18	580.34	580.21	580.53	580.93	.....	.....	
19	580.51	580.28	580.91	580.90	.....	.....	
20	580.48	580.11	580.81	580.92	.....	.....	
21	580.21	580.94	580.81	580.93	.....	.....	
22	579.88	580.24	580.61	580.85	.....	.....	
23	580.14	580.21	580.85	581.09	.....	.....	
24	580.31	580.31	580.97	580.89	.....	.....	
25	580.34	580.34	580.97	580.99	.....	.....	
26	580.56	580.21	580.98	580.94	.....	.....	
27	580.48	580.14	580.93	580.94	.....	.....	
28	580.77	580.11	580.95	580.94	.....	.....	
29	580.61	580.01	580.96	580.96	.....	.....	
30	580.51	580.18	580.86	581.07	.....	.....	
31	580.34	.....	580.97	.....	.....	.....	
Mean	580.38	580.24	580.81	580.91	.....	.....	

WILLIAMS EXHIBIT 28. Sheet 6.

U. S. LAKE SURVEY.

Daily Mean Elevations of Water Surface at

HARBOR BEACH, MICH.

In Feet Above Mean Tide at New York. Adjusted Levels, 1903.

Day	1900 June	1900 July	1900 August	1900 Sept.	1900 Oct.	1900 Nov.	REMARKS
1	580.11	580.34	580.68	580.66	580.64	580.28	
2	580.24	580.18	580.61	580.48	580.54	580.84	
3	580.44	580.28	580.64	580.94	580.61	580.54	
4	580.34	580.41	580.54	580.74	580.64	580.84	
5	580.21	580.38	580.61	580.61	580.68	580.71	
6	580.21	580.34	580.61	580.98	580.68	580.74	
7	580.31	580.41	580.61	580.74	580.84	580.61	
8	580.24	580.51	580.68	580.74	580.94	580.51	
9	580.38	580.58	580.61	580.71	580.78	580.61	
10	580.21	580.48	580.71	580.61	580.81	580.64	
11	580.41	580.54	580.71	580.64	580.88	580.58	
12	580.31	580.64	580.61	580.96	580.81	580.71	
13	580.28	580.58	580.68	580.91	580.74	580.91	
14	580.34	580.38	580.54	580.88	580.74	580.71	
15	580.31	580.48	580.58	580.41	580.71	580.91	
16	580.28	580.58	580.61	580.71	581.14	580.71	During 1900, the daily means are from tri-daily staff gage readings.
17	580.31	580.41	580.58	581.08	580.68	580.41	
18	580.34	580.71	580.54	580.78	580.98	580.68	
19	580.34	580.57	580.61	580.51	580.64	580.34	
20	580.38	580.64	580.68	580.51	580.56	580.41	
21	580.21	580.81	580.56	580.74	580.48	580.68	
22	580.24	580.61	580.68	580.74	580.48	580.78	
23	580.28	580.66	580.54	580.64	580.44	580.84	
24	580.36	580.64	580.61	580.64	580.71	580.71	
25	580.31	580.71	580.61	580.51	580.54	580.84	
26	580.21	580.74	580.71	580.74	580.38	580.88	
27	580.41	580.66	580.66	580.64	580.74	580.58	
28	580.24	580.61	580.74	580.71	580.48	580.54	
29	580.64	580.61	580.74	580.71	580.54	580.64	
30	580.51	580.61	580.64	580.81	580.48	580.58	
31	.....	580.78	580.71	.....	580.21	.....	
Mean	580.30	580.53	580.63	580.73	580.66	580.66	

Day	1900 Dec.	1902 Aug.	1902 Sept.	1902 Nov.	1902 Dec.		REMARKS
1	580.58	580.90	580.76	580.71	580.61	.....	
2	580.48	580.83	580.98	580.66	580.98	.....	
3	580.41	580.96	580.56	580.70	580.34	.....	
4	580.51	580.96	580.93	580.66	580.34	.....	
5	580.81	580.75	580.66	580.85	580.37	.....	
6	580.64	580.90	580.30	580.71	579.99	.....	
7	580.61	580.90	580.60	580.70	580.16	.....	
8	580.38	580.94	580.53	580.58	580.33	.....	
9	581.01	580.86	580.76	580.90	580.33	.....	
10	580.71	580.74	580.50	580.51	580.10	.....	
11	580.71	581.01	580.89	580.50	580.14	.....	
12	580.44	580.96	580.66	580.58	580.35	.....	
13	580.51	580.70	580.63	580.49	580.22	.....	
14	580.66	580.83	580.58	580.38	580.17	.....	
15	580.44	580.80	580.32	580.35	580.25	.....	1902 and 1908 values are from self-registering gage records.
16	580.38	580.83	580.41	580.52	580.27	.....	
17	580.14	580.85	580.29	580.45	580.05	.....	
18	580.34	580.70	580.44	580.47	580.03	.....	
19	580.41	580.79	580.58	580.38	580.21	.....	
20	580.58	580.79	580.43	580.34	580.30	.....	
21	580.14	580.90	580.40	580.24	580.39	.....	
22	580.06	580.94	580.45	580.13	580.23	.....	
23	580.04	580.88	580.49	580.16	580.02	.....	
24	580.24	580.83	580.44	580.05	580.01	.....	
25	580.41	580.78	580.14	579.99	580.14	.....	
26	580.24	580.79	580.27	580.14	580.23	.....	
27	580.24	580.82	580.29	580.68	580.23	.....	
28	580.48	580.73	580.45	580.46	580.23	.....	
29	580.41	580.70	580.80	580.37	580.02	.....	
30	580.54	580.65	580.45	580.11	579.76	.....	
31	580.84	580.86	.....	.....	580.40	.....	
Mean	580.46	580.83	580.52	580.46	580.21	.....	

WILLIAMS EXHIBIT 28. Sheet/

ELEVATIONS OF WATER SURFACE OF LAKE HURON.

From record of self-registering gage at

HARBOR BEACH, MICH.

In terms of U. S. Lake Survey adjusted levels of 1903.

	1909			1910			
Day	Oct.	Nov.	Dec.	Jan.	Feb.	March	April
1	580.82	580.02	580.03	579.84	579.95a	579.90	580.06
2	580.66	580.10	579.90	580.24	597.97	579.91	579.99
3	580.58	580.31	579.96	580.28	580.01	579.95	579.87
4	580.55	580.35	580.01	580.31	580.07	579.92	579.85
5	580.53	580.17	579.78	579.44	580.34	579.91	579.90
6	580.52	580.07	579.99	580.11	580.23	579.83	580.06
7	580.51	579.86	580.35	579.99	579.92	580.15	580.32
8	580.43	580.29	580.23	579.94	580.00	580.23	580.06
9	580.41	580.02	580.41	580.12	580.06	580.11	580.08
10	580.31	579.94	580.40	579.91	580.04	580.02	580.13
11	580.27	579.98	580.12	579.91	579.81	579.91	580.09
12	580.11	580.26	579.76	579.96	579.84	579.88	580.10
13	580.45	579.99	579.39	579.98	579.97	580.26	580.10
14	580.58	579.91	579.86	579.89	580.02a	580.51	580.06
15	580.54	580.33	580.29	579.89	579.88a	580.04	579.95
16	580.58	580.06	580.12	579.92	579.90	580.12	579.90
17	580.52	580.05	580.03	579.83	580.08	580.00	579.93
18	580.43	580.35	580.27	579.88	580.05	579.87	580.09
19	580.39	580.06	580.21	580.14	579.94	579.78	580.30
20	580.22	580.02	580.09	579.79a	579.86	580.07	580.43
21	580.02	580.31	580.03	580.02	580.00	579.94	580.19
22	580.54	580.40	580.30	580.45	580.02	580.03	580.11
23	580.53	580.22	580.23	580.14	580.04	579.88	579.93
24	580.33	580.06	580.11	580.09	580.05	579.78	580.28
25	580.20	580.10	580.10	580.02	579.96	580.13	580.37
26	580.23	580.05	580.11	579.70	579.61	579.99	580.24
27	580.50	579.90	580.12	579.88	579.90	579.76	580.31
28	580.44	580.26	580.12	580.16c	579.99	579.86	580.23
29	580.24	580.15	580.16	579.86c	.....	579.96	579.95
30	579.97	580.08	580.04	580.05c	.....	579.93	580.22
31	580.16	.....	579.98	580.00c	.....	580.06	.....
Mean	580.40	580.12	580.06	579.99	579.96	579.99	580.10

Note:—a=Mean of partial day only.

c=No record, intake of float pipe clogged. Readings given are single readings of reference gage.

WILLIAMS EXHIBIT 28. Sheet 3

U. S. LAKE SURVEY.

Daily Mean Elevations of Water Surface at

HARBOR BEACH, MICH.

In Feet above Mean Tide at New York, Adjusted Levels, 1903.

Day	1899 April	1899 May	1899 June	1899 July	1899 August	1899 Sept.	REMARKS.
1	579.8	580.21	580.61	580.85	581.04	580.81	
2	579.9	580.31	580.68	581.01	581.08	580.71	
3	579.8	580.18	580.58	581.01	581.11	581.18	
4	579.8	580.06	580.38	580.91	581.11	580.78	
5	579.7	580.28	580.48	581.06	581.14	580.74	
6	579.6	580.31	580.65	581.05	581.18	580.94	
7	579.7	580.28	580.78	580.81	581.04	580.38	
8	580.0	580.31	580.88	581.31	581.08	580.84	
9	579.9	580.41	580.71	581.31	580.81	580.94	
10	579.7	580.16	580.71	581.11	580.91	580.81	
11	579.5	580.41	580.65	581.08	580.84	580.78	
12	579.7	580.34	580.65	581.11	581.11	581.04	
13	579.9	580.51	580.78	581.11	581.31	581.11	
14	579.4	580.54	580.75	581.04	581.01	580.88	
15	579.8	580.38	580.81	581.04	581.04	580.81	During 1899, the daily means are from tri-daily staff gage readings.
16	579.9	580.51	581.05	581.18	581.01	580.61	
17	579.8	580.28	580.85	581.18	580.98	580.78	
18	579.8	580.48	580.78	581.16	580.91	580.76	
19	579.9	580.68	580.88	581.01	580.91	581.01	
20	580.0	580.61	580.95	581.08	580.94	580.74	
21	579.9	580.51	580.91	581.11	580.94	580.81	
22	580.0	580.51	580.75	581.14	581.21	580.81	
23	580.1	580.48	580.91	580.81	580.88	580.84	
24	579.9	580.44	580.81	580.98	580.94	580.78	
25	580.1	580.41	580.95	581.04	581.04	580.71	
26	580.1	580.31	580.88	581.01	580.84	580.74	
27	579.9	580.48	580.88	581.21	580.84	580.64	
28	579.8	580.41	581.01	581.08	580.91	580.41	
29	580.1	580.44	580.91	581.11	580.81	580.81	
30	580.0	580.71	581.05	581.41	580.81	580.74	
31	.....	580.58	.....	581.11	580.84	.....	
Mean	579.85	580.39	580.79	581.03	580.99	580.70	

Sheet 8—Cont'd

Day	1899 Oct.	1899 Nov.					REMARKS.
1	580.64	580.66					
2	580.31	580.36					
3	580.94	580.81					
4	580.51	580.41					
5	580.48	580.41					
6	580.44	580.31					
7	580.33	580.31					
8	580.31	580.31					
9	580.94	580.33					
10	580.14	580.34					
11	580.34	580.34					
12	580.31	580.34					
13	580.21	580.18					
14	580.61	580.18					
15	580.81	580.21					
16	580.11	580.14					
17	580.66	579.71					
18	580.34	580.21					
19	580.51	580.26					
20	580.46	580.11					
21	580.21	580.04					
22	579.66	580.24					
23	580.14	580.21					
24	580.31	580.21					
25	580.24	580.24					
26	580.56	580.21					
27	580.48	580.14					
28	580.71	580.11					
29	580.61	580.01					
30	580.51	580.01					
31	580.34						
Mean	580.33	580.24					

Sheet 1
(19 Sheets)

WILLIAMS EXHIBIT 29.

DAILY MEAN ELEVATIONS OF WATER SURFACE. AT AMHERSTBURG, ONT.

From tri-daily staff gage readings at Waterworks Dock. In terms of the U. S. Lake Survey, adjusted levels of 1903.

1898

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	573.09	572.97	572.65	572.40	572.07	571.52
2	573.00	572.90	572.60	572.55	571.67	571.58
3	572.96	572.87	572.65	572.34	571.94	572.00
4	572.94	572.86	572.36	572.35	572.13	572.90
5	573.22	572.77	572.45	572.20	572.00	570.73
6	573.16	572.80	572.26	572.53	570.87	571.77
7	572.99	572.77	571.79	572.46	571.97	571.45
8	572.87	572.76	572.34	572.33	571.41	571.62
9	573.27	572.85	572.40	572.32	572.69	571.52
10	572.87	572.72	572.63	572.59	572.77	570.80
11	573.22	572.81	572.56	572.09	572.03	571.63
12	573.22	572.73	572.55	572.16	572.13	572.00
13	573.10	572.82	572.52	572.42	572.07	571.90
14	572.95	572.93	572.44	572.05	571.89	571.72
15	572.90	572.68	572.49	571.79	571.68	572.61
16	573.08	572.69	572.41	572.42	572.20	572.74
17	573.06	572.65	572.42	573.09	572.18	572.47
18	572.88	573.11	572.02	572.57	572.04	572.25
19	572.77	572.86	572.10	571.89	571.74	572.76
20	572.76	572.78	572.36	572.42	572.17	572.15
21	573.12	572.74	572.59	572.15	572.12	572.02
22	572.87	572.70	572.65	571.18	571.64	572.34
23	572.90	572.70	571.91	571.72	571.65	571.34
24	572.95	572.67	572.29	572.20	571.52	571.70
25	572.70	572.46	572.28	572.35	572.03	572.22
26	573.04	572.76	572.13	571.82	571.76	572.09
27	572.91	572.85	572.39	571.92	571.98	570.93
28	572.60	572.87	572.50	572.33	572.23	572.17
29	572.88	572.54	572.43	572.22	572.06	572.11
30	572.77	572.67	572.30	571.72	571.46	571.97
31	573.07	572.62	.....	571.74	.....	572.17
Mean	572.97	572.77	572.38	572.19	571.94	571.91

Sheet 2.
(19 Sheets)

WILLIAMS EXHIBIT 29.

DAILY MEAN ELEVATIONS OF WATER SURFACE AT AMHERSTBURG, ONT.

From tri-daily staff gage readings at Waterworks Dock.
In terms of the U. S. Lake Survey adjusted levels of 1903.

1899

Day	Jan.	Feb.	Mar.	April	May
1	572.29	572.01	572.00	571.66	572.57
2	572.25	571.97	571.94	571.85	572.60
3	572.17	572.06	571.94	572.15	573.10
4	572.60	571.78	571.83	572.26	572.84
5	572.18	571.92	570.66	572.27	572.71
6	572.45	571.92	571.83	572.45	572.74
7	570.62	571.90	571.86	572.38	572.87
8	571.67	571.70	571.92	572.13	572.64
9	572.38	No record	571.83	572.11	572.73
10	572.46	571.79	572.22	572.42	572.75
11	572.62	571.83	571.92	572.57	572.49
12	572.40	571.75	571.33	572.33	572.65
13	572.33	571.73	571.87	572.51	572.21
14	571.77	571.78	572.47	572.18	572.31
15	572.06	571.75	571.46	572.38	572.72
16	572.13	571.74	572.05	572.33	572.72
17	572.04	571.68	572.51	572.55	572.93
18	572.09	571.73	572.07	572.65	572.36
19	572.14	571.76	571.27	572.48	572.55
20	572.20	571.88	571.47	572.67	572.73
21	571.93	571.87	573.09	572.77	572.76
22	572.13	571.72	572.25	572.57	572.85
23	572.30	571.80	571.04	572.77	572.81
24	572.01	571.80	571.88	572.65	572.88
25	571.91	571.97	572.68	572.60	572.84
26	571.54	571.83	572.30	572.57	572.86
27	571.74	571.19	572.39	572.69	572.76
28	571.89	571.61	572.12	572.59	572.96
29	571.88	.....	570.87	572.60	572.88
30	571.63	.....	572.30	572.63	572.83
31	571.98	.....	572.18	.....	572.94
Mean	572.06	571.80	571.91	572.43	572.74

Sheet 3
(19 Sheets).

WILLIAMS EXHIBIT 29.

DAILY MEAN ELEVATIONS OF WATER SURFACE AT AMHERSTBURG, ONT.

From records of self-registering gage.
In terms of the U. S. Lake Survey adjusted levels of 1903.

1899

Day	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	572.76	572.74	572.76	572.46	572.03	571.88	571.23
2	572.81	572.70	572.51	572.54	572.30	572.47	571.31
3	573.00	572.79	572.81	572.37	572.04	572.30	571.72
4	572.83	572.78	572.61	572.67	572.00	570.96	571.48
5	572.81	572.76	572.80	572.23	571.99	571.67	570.73
6	572.87	572.77	572.79	572.62	571.91	571.83	571.19
7	572.81	572.93	572.66	572.39	572.20	571.87	571.34
8	572.75	572.32	572.76	572.41	572.10	571.86	571.62
9	572.88	572.53	572.84	572.33	571.88	571.68	571.82
10	573.06	572.82	572.51	572.43	571.94	571.84	571.74
11	573.07	572.78	572.67	572.07	571.90	571.79	571.96
12	572.87	572.70	572.40	571.84	571.93	571.83	570.93
13	572.86	572.89	572.62	571.97	571.97	571.91	571.14
14	572.78	572.82	572.88	572.22	571.90	572.08	572.01
15	572.47	572.85	572.87	572.31	572.11	571.67	571.38
16	572.62	572.72	572.64	572.26	571.98	572.04	571.89
17	572.80	572.68	572.58	572.14	571.87	572.04	571.76
18	572.78	572.67	572.51	572.07	571.90	571.84	571.82
19	572.91	572.82	572.50	572.11	571.97	571.72	571.32
20	572.69	572.82	572.48	572.05	572.08	571.96	571.45
21	572.85	572.73	572.19	571.88	572.20	571.91	571.46
22	572.94	572.99	572.29	571.99	572.05	571.90	571.78
23	572.69	573.02	572.53	572.40	571.79	572.27	571.85
24	572.78	572.98	572.50	572.01	571.89	571.86	570.74
25	572.77	572.76	572.37	571.83	571.87	571.81	570.79
26	572.81	572.76	572.53	571.93	571.83	571.78	571.15
27	572.82	572.67	572.51	571.91	571.95	571.78	571.28
28	572.77	572.85	572.69	571.64	571.88	571.57	571.32
29	572.61	572.50	572.62	571.71	571.70	571.68	571.40
30	572.83	572.60	572.49	571.53	572.06	571.79	571.59
31	.....	572.83	572.42	.....	572.19	.....	.....
Mean	572.81	572.76	572.59	572.14	571.98	571.86	571.44

Note:—The self-registering gage is located opposite the foot of Bois Blanc Island. The approximate fall from the Waterworks Dock staff gage is .14 foot.

Sheet 4
(19 Sheets)

WILLIAMS EXHIBIT 29

DAILY MEAN ELEVATIONS OF WATER SURFACE AT AMHERSTBURG, ONT.

From records of self-registering gage.

In terms of the U. S. Lake Survey, adjusted levels of 1903.

1900

Day	June	July
1	572.78	572.60
2	572.33	572.86
3	572.68	572.50
4	572.75	572.54
5	572.74	572.61
6	572.75	572.49
7	572.71	572.60
8	572.64	571.85
9	572.83	572.31
10	572.86	572.67
11	572.70	572.33
12	572.87	572.48
13	572.78	572.47
14	572.72	572.59
15	572.87	572.59
16	572.90	572.53
17	572.70	572.44
18	572.90	572.64
19	572.74	572.73
20	572.74	572.56
21	572.71	572.47
22	573.07	572.72
23	572.94	572.63
24	572.78	572.68
25	572.75	572.67
26	572.72	572.79
27	572.59	572.75
28	572.55	572.75
29	572.31	572.62
30	572.48	572.64
31	.....	572.59
Mean	572.73	572.57

Note:—The self-registering gage is located opposite the foot of Bois Blanc Island. The approximate fall from the Waterworks Dock staff gage is .14 foot.

Sheet 5
(19 Sheets)

WILLIAMS EXHIBIT 29

ELEVATIONS OF WATER SURFACE OF DETROIT RIVER

From record of self-registering gage at

AMHERSTBURG, ONT.

In terms of U. S. Lake Survey adjusted levels of 1903:

1909

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	.....	.....	572.11	572.07	572.14
2	.....	.....	.....	572.33	571.59	572.37
3	.....	.....	.....	572.41	571.70	572.01
4	.....	.....	.....	572.50	571.58	572.04
5	.....	.....	.....	572.51	571.91	571.90
6	.....	.....	.....	572.37	572.22	571.07
7	.....	.....	.....	572.36	572.05	571.11
8	.....	.....	.....	572.40	571.95	571.09
9	.....	.....	.....	572.42	572.27	571.19
10	.....	.....	.....	572.38	572.04	571.67
11	.....	.....	.....	572.07	571.96	572.00
12	.....	.....	.....	570.93	571.95	572.78
13	.....	.....	.....	571.32	572.19	571.97
14	.....	.....	.....	571.42	571.99	570.75
15	.....	.....	.....	571.59	571.82	571.12
16	.....	.....	.....	571.21	572.08	571.71
17	.....	.....	.....	571.89	569.96	571.09
18	.....	.....	.....	571.95	571.54	571.18
19	.....	.....	.....	572.05	571.61	571.96a
20	.....	.....	.....	572.23	571.60	572.07a
21	.....	.....	.....	571.76	571.82	571.98
22	.....	.....	.....	571.52	571.82	571.88
23	.....	.....	.....	572.07	571.85	572.10
24	.....	.....	.....	571.91	572.37	572.25
25	.....	.....	.....	571.95	571.90	572.36
26	.....	.....	.....	571.68	572.03	572.32a
27	.....	.....	.....	571.38	572.03	c
28	.....	.....	.....	571.68	571.90	c
29	.....	.....	.....	571.97	572.20	c
30	.....	.....	.....	571.98	572.14	c
31	.....	.....	.....	571.87	.....	c
Mean	.....	.....	.....	571.94	571.87	571.77

Note:—a = Mean of partial day only.

b =

c = No record, gage out of order.

This gage is maintained and operated under direction of U. S. Engineer Office, Detroit District.

Sheet 6.
(19 Sheets)

WILLIAMS EXHIBIT 29.

ELEVATIONS OF WATER SURFACE OF DETROIT RIVER

from record of self-registering gage at

AMHERSTBURG, ONT.

In terms of U. S. Lake Survey adjusted levels of 1903.

1910

Day	Jan.	Feb.	Mar.	April	May	June
1	a	571.69	571.47	572.11	572.81	572.45
2	a	571.54	571.49	572.18	572.71	572.88
3	a	571.55	571.70	572.27	572.69	572.80
4	a	571.18	571.67	572.24	572.84	573.14
5	a	571.39	571.65	572.26	572.81	573.00
6	a	571.36	571.57	571.93	572.83	572.81
7	571.37b	571.41	571.20	571.77	572.96	572.76
8	571.64	571.45	571.54	572.17	572.94	572.86
9	571.50	571.42	571.71	572.12	572.72	573.00
10	571.64	571.38	571.81	572.16	572.77	573.14
11	571.64	571.61	571.88	572.29	572.84	572.94
12	571.65	571.54	571.73	572.25	572.67	572.84
13	572.15	571.28	571.22	572.25	572.70	572.96
14	572.07	571.52	571.28	572.24	572.75	572.91
15	571.72	571.64	571.63	572.24	572.91	572.91
16	571.56	571.45	571.71	572.48	572.89	572.94
17	571.67	571.66	571.85	572.24	572.89	572.88
18	571.14	571.52	571.96	572.46	572.29	572.85
19	571.32	571.47	571.77	571.97	572.84	572.96
20	571.53	571.53	571.75	572.03	572.86	572.96
21	571.48	571.52	571.83	572.33	572.84	572.92
22	570.92	571.64	571.78	572.65	572.88	572.89
23	571.46	571.37	571.98	572.41	572.76	572.85
24	571.59	571.54	571.85	572.40	572.89	573.14
25	571.72	571.58	571.80	572.37	572.80	573.03
26	571.73	571.61	572.11	572.66	572.67	572.93
27	571.29	571.60	572.25	572.57	572.77	572.82
28	571.69	571.69	572.03	572.95	572.91	572.78
29	571.58	.....	572.12	572.73	572.73	572.83
30	571.70	.....	572.16	572.46	572.15	572.86
31	571.61	.....	571.92	.....	572.41	.....
Mean	571.58	571.50	571.76	572.31	572.76	572.90

Note:—a = no record, gage out of order.
b = mean of partial day only.

This gage is maintained and operated under direction of U. S. Engineer Office, Detroit District.

Sheet 7.
(19 Sheets)

WILLIAMS EXHIBIT 29.

ELEVATIONS OF WATER SURFACE OF DETROIT RIVER

from record of self-registering gage at

AMHERSTBURG, ONT.

In terms of U. S. Lake Survey adjusted levels of 1903.

1910

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	572.80	572.73	572.43	571.55	571.93	571.30
2	572.83	572.67	572.54	572.26	571.35	571.43
3	572.82	572.73	572.24	572.23	572.07	571.70
4	573.09	572.21	572.51	572.11	571.95	571.89
5	573.08	572.18	572.39	572.19	571.62	572.22
6	572.89	572.54	572.15	571.93	571.10	572.01
7	572.85	572.73	572.40	572.43	571.68	571.10
8	572.89	572.58	572.38	572.31	571.44	571.11
9	572.77	572.53	572.20	571.97	571.86	571.61
10	572.67	572.68	572.43	572.25	571.06	572.01
11	572.81	572.55	572.40	571.99	571.68	571.59
12	572.79	572.68	572.26	572.37	571.95	571.61
13	572.72	572.57	572.29	572.62	571.16	571.40
14	572.92	572.57	572.35	572.10	571.60	570.60
15	572.83	572.55	572.28	572.10	571.31	571.07
16	572.90	572.62	572.35	572.08	571.29	571.73
17	572.96	572.60	572.22	572.33	571.52	571.89
18	572.92	572.52	572.11	572.20	571.31	571.90
19	572.82	572.55	572.57	572.19	571.74	571.10
20	572.76	572.57	572.13	572.21	571.90	571.14
21	572.65	572.60	572.28	572.33	571.43	571.42
22	572.57	572.43	572.58	571.13	571.71	571.75
23	572.74	572.46	572.26	571.94	571.66	571.81
24	572.60	572.52	572.31	571.93	571.68	571.58
25	572.59	572.04	572.12	571.94	571.46	571.68
26	572.74	572.31	572.43	572.00	571.71	571.29
27	572.70	572.38	571.82	571.17	571.44	571.26
28	572.72	572.50	572.18	571.24	571.44	571.53
29	572.68	572.79	572.28	571.69	570.70	571.54
30	572.64	572.46	572.09	571.68	570.95	571.42
31	572.67	572.36	.....	571.81	.....	571.56
Mean	572.80	572.52	572.30	572.01	571.52	571.52

Note:—This gage is maintained and operated under direction of U. S. Engineer Office, Detroit District.

Sheet 8
(19 Sheets)

WILLIAMS EXHIBIT 29

DAILY MEAN ELEVATIONS OF WATER SURFACE OF LAKE ERIE

from tri-daily staff-gage readings at

CLEVELAND, O.

In terms of the Lake Survey adjusted levels of 1903.

1898

Day	Oct.
1	571.96
2	571.91
3	571.94
4	572.02
5	572.05
6	572.10
7	572.03
8	571.97
9	571.87
10	571.95
11	571.59
12	571.94
13	571.94
14	571.64
15	571.84
16	571.76
17	572.08
18	572.00
19	571.61
20	571.75
21	571.75
22	571.44
23	571.49
24	571.55
25	571.63
26	571.81
27	571.71
28	571.75
29	571.71
30	571.54
31	571.94
Mean	571.81

WILLIAMS EXHIBIT 29 Sheet 9 (19 Sheets)

DAILY MEAN ELEVATIONS OF WATER SURFACE OF LAKE ERIE,

from tri-daily staff gage readings at

CLEVELAND, O.

In terms of Lake Survey adjusted levels of 1903.

	1899 June	1900 July
1	572.56	572.38
2	572.61	572.44
3	572.67	572.18
4	572.57	572.27
5	572.58	572.44
6	572.58	572.29
7	572.58	572.34
8	572.60	572.54
9	572.63	572.48
10	572.64	572.39
11	572.56	572.36
12	572.55	572.17
13	572.50	572.31
14	572.54	572.31
15	572.67	572.30
16	572.62	572.24
17	572.55	572.07
18	572.49	572.38
19	572.59	572.30
20	572.49	572.32
21	572.59	572.30
22	572.52	572.36
23	572.46	572.30
24	572.45	572.49
25	572.51	572.59
26	572.49	572.50
27	572.42	572.37
28	572.53	572.41
29	572.60	572.26
30	572.52	572.28
31	.....	572.28
Mean	572.56	572.34

Sheet 10.
(19 Sheets)

WILLIAMS EXHIBIT 29.

Memorandum of daily water levels at Cleveland Harbor, Ohio, each being a mean of readings taken at 7:00 A. M., 1:00 P. M. and 7:00 P. M. Elevations are referred to Mean Lake Level 1860-75, which is 572.77 ft. above Mean Tide at New York.

All the following readings are below this datum, unless marked +, when they are above.

Day	1898 July	1898 Aug.	1898 Sept.	1898 Oct.	1898 Nov.	1898 Dec.	1899 Jan.	1899 Feb.	1899 Mar.	1899 Apr.	1899 May	1899 June
1	.04	.18	.55	.81	1.39	1.56	1.03	1.16	1.20	.95	.52	.20
2	.05	.21	.57	.86	1.31	1.47	1.44	1.12	1.19	.81	.46	.15
3	.06	.41	.58	.83	1.20	1.13	1.31	1.08	1.01	.75	.08	.09
4	+ .02	.31	.91	.75	1.20	.62	1.24	1.27	.94	.72	.32	.20
5	+ .04	.35	.85	.72	1.38	.58	1.14	1.18	1.61	.72	.44	.19
6	.00	.30	.71	.67	1.12	1.20	.84	1.19	.76	.69	.45	.19
7	.05	.40	.62	.74	1.29	1.42	.95	1.23	.84	.61	.41	.19
8	.14	.31	.79	.80	1.45	1.32	1.21	1.36	1.13	.70	.47	.16
9	.27	.24	.62	.90	.74	1.18	.83	1.41	1.10	.74	.42	.14
10	.18	.27	.49	.82	.41	1.81	.89	1.30	.91	.67	.42	.13
11	+ .01	.26	.70	1.17	.73	1.53	.84	1.27	1.16	.73	.40	.20
12	.12	.33	.68	.83	.98	.98	1.06	1.28	1.21	.73	.47	.22
13	.17	.28	.77	.83	1.10	1.05	1.11	1.34	1.08	.64	.32	.27
14	.26	.31	.79	1.13	.97	1.74	1.19	1.34	.77	.75	.34	.22
15	.24	.53	.70	.93	1.27	1.46	1.04	1.35	1.35	.78	.31	.09
16	.24	.52	.75	1.01	1.00	1.47	.97	1.35	1.13	.68	.20	.15
17	.29	.17	.81	.69	1.00	1.52	.94	1.40	.96	.62	.09	.22
18	.30	.28	.93	.77	1.07	1.37	.81	1.41	.90	.60	.30	.28
19	.25	.31	.79	1.16	.93	1.10	.94	1.44	.86	.58	.32	.18
20	.30	.43	.78	1.04	.95	1.32	1.03	1.42	.89	.56	.29	.28
21	.22	.45	.74	1.02	1.02	1.28	1.22	1.36	.70	.48	.29	.18
22	.15	.45	.92	1.34	1.18	1.07	.98	1.39	1.02	.46	.25	.24
23	.22	.48	.89	1.28	1.17	1.53	.90	1.28	1.05	.40	.31	.31
24	.22	.45	.82	1.22	.95	1.00	.92	1.32	.84	.53	.31	.32
25	.41	.56	.89	1.14	1.14	1.04	1.07	1.20	.60	.48	.38	.25
26	.17	.37	.90	.96	.91	1.22	1.13	1.47	.88	.54	.36	.28
27	.24	.41	.85	1.06	.98	1.31	1.07	1.50	.62	.52	.51	.35
28	.39	.51	.83	1.02	1.15	1.12	1.21	1.48	.71	.60	.15	.24
29	.48	.60	.88	1.06	1.07	1.29	1.16	.....	.81	.48	.33	.17
30	.23	.51	.88	1.23	1.29	1.08	1.26	.....	.75	.20	.21	.24
31	.11	.59	.....	.83	.....	.76	1.12	.....	.81	.....	.21	.....

Sheet 11.
(19 Sheets)

WILLIAMS EXHIBIT 29.

Day	1899 July	1899 Aug.	1899 Sept.	1899 Oct.	1899 Nov.	1899 Dec.	1900 June	1900 July
1	.29	.44	.71	1.13	1.01	1.56	.34	.39
2	.41	.36	.76	1.12	.93	1.58	.24	.33
3	.30	.28	.80	1.14	.80	1.13	.34	.59
4	.28	.38	.57	1.24	1.38	1.20	.25	.50
5	.27	.29	1.15	1.10	1.09	1.96	.30	.33
6	.23	.39	.69	1.15	1.15	1.29	.29	.48
7	.26	.45	.86	1.15	1.20	1.70	.22	.43
8	.10	.48	.93	1.13	1.17	1.36	.23	.23
9	.35	.55	.77	1.30	1.31	1.21	.18	.29
10	.32	.53	.80	1.27	1.18	1.48	.33	.39
11	.36	.52	.81	1.24	.98	1.42	.23	.41
12	.33	.58	.94	1.18	1.09	1.30	.23	.60
13	.26	.46	.86	1.17	1.17	1.44	.33	.46
14	.34	.45	.86	1.19	1.49	1.07	.13	.46
15	.35	.38	.95	1.12	1.31	1.30	.23	.46
16	.26	.57	1.02	1.21	1.04	1.28	.26	.53
17	.26	.58	1.00	1.17	1.17	1.59	.28	.69
18	.35	.58	1.03	1.11	1.25	1.45	.21	.38
19	.26	.65	.74	1.05	1.20	1.31	.30	.47
20	.21	.67	.83	1.07	1.18	1.21	.31	.45
21	.31	.81	1.11	1.08	1.20	1.53	.36	.46
22	.21	.73	1.15	1.27	1.17	1.21	.24	.41
23	.21	.64	.91	1.26	.74	1.22	.24	.47
24	.24	.65	1.13	1.23	1.12	1.07	.30	.28
25	.38	.63	.85	1.22	1.12	1.32	.36	.17
26	.30	.76	.67	1.30	1.20	1.27	.41	.27
27	.26	.67	1.20	1.17	1.26	1.30	.45	.40
28	.25	.55	1.30	1.11	1.30	1.50	.38	.35
29	.44	.69	1.11	1.13	1.36	1.16	.38	.51
30	.40	.75	1.09	1.08	1.35	1.33	.49	.49
31	.35	.70	.....	.88	.....	1.98	.....	.48

WILLIAMS EXHIBIT 29 Sheet 12 (19 Sheets)

ELEVATIONS OF WATER SURFACE OF LAKE ERIE

From Record of Self-registering Gage at

CLEVELAND, OHIO

In Terms of U. S. Lake Survey Adjusted Levels of 1903

1909

Day	Oct.	Nov.	Dec.
1	571.86	571.58	571.74
2	572.08	571.37	571.84
3	572.06	571.50	571.76
4	572.08	571.61	571.70
5	572.08	571.57	571.57
6	572.03	571.68	571.32
7	572.00	571.57	571.24
8	572.01	571.72	571.05
9	572.03	571.80	571.11
10	571.92	571.58	571.34
11	571.78	571.54	571.53
12	571.24	571.62	571.75
13	571.44	571.74	571.52
14	571.47	571.57	570.90
15	571.72	571.60	571.28
16	571.67	571.60	571.36
17	571.70	571.24	571.15
18	571.83	571.57	571.13
19	571.75	571.22	571.33
20	571.76	571.19	571.24
21	571.54	571.48	571.30
22	571.60	571.76	571.40
23	572.07	571.89	571.41
24	571.88	571.94	571.40
25	571.50	571.68	571.66
26	571.44	571.69	571.50
27	571.64	571.66	571.28
28	571.72	571.73	571.27
29	571.64	571.88	571.50
30	571.55	571.72	571.15
31	571.52	.....	571.33
Mean	571.76	571.61	571.39

WILLIAMS EXHIBIT 29 Sheet 13 (19 sheets)

ELEVATIONS OF WATER SURFACE OF LAKE ERIE

From Record of Self-registering Gage at

CLEVELAND, OHIO

In Terms of U. S. Lake Survey Adjusted Levels of 1903

1910

Day	Jan.	Feb.	Mar.	Apr.	May	June
1	571.25	571.22	571.27	571.86	572.45	572.57
2	571.38	571.23	571.28	571.92	572.52	572.60
3	571.27	571.39	571.35	571.93	572.65	572.71
4	571.51	571.12	571.39	571.91	572.65	572.70
5	571.23	571.22	571.45	571.94	572.61	572.67
6	571.37	571.23	571.45	571.92	572.56	572.62
7	571.13	571.14	571.42	571.99	572.60	572.59
8	571.16	571.15	571.55	571.91	572.61	572.58
9	571.29	571.19	571.61	571.92	572.56	572.66
10	571.26	571.21	571.61	571.94	572.53	572.72
11	571.22	571.19	571.72	572.07	572.61	572.75
12	571.26	571.21	571.73	571.98	572.57	572.59
13	571.59	571.08	571.72	571.97	572.65	572.63
14	571.72	571.12	571.86	571.95	572.60	572.62
15	571.29	571.13	571.68	571.99	572.57	572.63
16	571.14	571.14	571.65	572.02	572.57	572.64
17	571.17	571.30	571.75	572.00	572.42	572.62
18	570.93	571.14	571.77	572.06	572.44	572.61
19	571.12	571.09	571.66	571.94	572.59	572.65
20	571.14	571.13	571.69	572.30	572.54	572.62
21	571.35	571.15	571.76	572.26	572.59	572.61
22	571.17	571.18	571.71	572.21	572.60	572.59
23	571.05	571.05	571.86	572.22	572.50	572.58
24	571.25	571.12	571.78	572.26	572.61	a572.82
25	571.25	571.11	571.78	572.32	572.57	a572.65
26	571.21	571.01	571.85	572.23	572.63	a572.53
27	571.13	571.08	571.90	572.35	572.58	a572.46
28	571.28	571.21	571.81	572.45	572.57	a572.48
29	571.23	.....	571.86	572.35	572.52	572.42
30	571.24	.....	571.85	572.32	572.67	572.44
31	571.21	.....	571.81	.....	572.63	.....
Mean	571.25	571.16	571.66	572.08	572.57	572.61

Note: a—Gage not in commission account of repairs; values from tri-daily staff gage readings of U. S. Engineer Office gage at Cleveland.

Note: b—Mean of partial day only, the remaining hours of the day being supplied from mean stage range.

Sheet 14.
(19 Sheets)

WILLIAMS EXHIBIT 29.

ELEVATIONS OF WATER SURFACE OF LAKE ERIE

From Record of Self-Registering Gage at

CLEVELAND, OHIO.

In Terms of U. S. Lake Survey Adjusted Levels of 1903.

1910

Day	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	572.38	572.37	572.19	571.79	571.39	571.79
2	572.40	572.40	572.14	571.86	571.54	571.57
3	572.40	572.37	572.05	571.74	571.78	571.42
4	572.56	572.35	572.20	571.64	571.76	571.58
5	572.41	572.27	572.08	571.78	571.60	571.86
6	572.36	572.28	572.03	572.28	571.62	571.83
7	572.36	572.28	572.10	572.13	571.41	571.07
8	572.37	572.23	572.12	572.03a	571.54	571.25
9	572.31	572.18	572.21	572.07	571.27	571.40
10	572.31a	572.26	572.10	571.97	571.41	571.50
11	572.33a	572.26	572.07	571.79	571.45	571.55
12	572.30	572.29	572.02	572.07	571.64	571.57
13	572.38	572.28b	572.13	572.00a	571.45	571.20
14	572.49	572.29b	572.11	571.88	571.48	571.00
15	572.51	572.24	571.98	571.90	571.54	571.37
16	572.58	572.25	572.01	571.89	571.44	571.39
17	572.64	572.21	571.96b	571.98	571.33	571.15
18	572.54	572.24	571.93	571.94b	571.31	571.10
19	572.43	572.29	572.06	571.93b	571.40	570.99
20	572.25a	572.23	571.93	572.05	571.42b	571.23
21	572.28a	572.17	571.99	572.09	571.33	571.41
22	572.29	572.08	572.05	571.56	571.43	571.17
23	572.33a	572.09	571.91	571.92	571.16	571.15
24	572.30a	572.06	571.90	571.64	571.16	571.16
25	572.41a	572.02	571.89	571.93	571.39b	571.19
26	572.43	572.12	571.90a	571.85	c	571.01
27	572.33	572.04	571.86a	571.74	c	570.99
28	572.42	572.11	571.89	571.85	571.58	571.20
29	572.37	572.26	571.90	571.94	571.49	571.26
30	572.47	572.08	571.79	571.33	571.50	571.27
31	572.40	572.11	.....	571.64	.....	571.07
Mean	572.40	572.22	572.02	571.88	571.46	571.34

Note:—a=Mean of partial day only, the remaining hours of the day being supplied from mean stage range.

b=Mean of partial day only, range not well defined, etc.

c=No record, repairs being made to gage.

Sheet 15.
(19 Sheets)

WILLIAMS EXHIBIT 29.

BUFFALO HARBOR, N. Y.

Record of Daily Mean Water Level, U. S. Engineer Self-Registering Gauge in U. S. Light House Slip, Inner End U. S. South Pier.
Zero of Gauge at Elevation 573.15 feet above mean tide of N. Y. Adjusted U. S. Lake Survey Levels of 1903.
Feet and tenths above or below zero.

	1898						1899	
Date	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
1	−0.3	−0.6	−0.9	−1.4	−1.0	−0.4	−1.7	−1.5
2	−0.3	−0.6	−0.8	−1.3	−0.6	−0.8	−1.0	−1.5
3	−0.3	−0.4	−0.8	−1.3	−1.2	−1.6	−1.2	−1.6
4	−0.3	−0.3	−0.5	−1.3	−1.3	−2.8	−1.0	−1.5
5	−0.8	−0.4	−0.6	−1.1	−0.8	−0.6	−0.7	−1.6
6	−0.6	−0.6	−0.5	−1.5	+1.0	−0.4	−1.4	−1.6
7	−0.5	−0.5	−0.1	−1.4	−0.6	00.0	+1.6	−1.6
8	−0.4	−0.4	−0.5	−1.2	−0.3	−0.5	+0.5	−1.2
9	−0.4	−0.7	−0.9	−1.3	−2.0	−0.7	.....	−1.3
10	−0.5	−0.7	−1.3	−1.4	−1.9	+0.4	.....	−1.6
11	−0.9	−0.7	−1.1	−0.4	−0.9	−0.3	−2.0	−1.6
12	−0.9	−0.5	−1.4	−1.0	−1.0	−2.0	−1.7	−1.6
13	−0.8	−0.7	−1.2	−1.4	−1.0	−1.6	−1.7	−1.6
14	−0.7	−0.7	−1.1	−0.9	−1.0	−0.4	−1.0	−1.6
15	−0.6	−0.5	−1.0	−0.9	−0.6	.....	−0.9	−1.7
16	−0.6	−0.3	−1.0	−1.4	−1.4	.....	−1.5	−1.7
17	−0.5	−0.1	−1.1	−2.0	−1.5	.....	−1.4	−1.7
18	−0.2	.....	−0.6	−1.5	−1.4	.....	−1.6	−1.7
19	.....	.....	−0.9	−1.0	−1.0	.....	−1.4	−1.7
20	.....	.....	−1.2	−1.5	−1.2	−1.0	−1.3	−1.7
21	−0.2	−0.6	−1.4	−1.2	−1.6	−1.7	−0.9	−1.8
22	−0.8	−0.6	−1.2	+0.2	−0.6	−1.9	−1.1	−1.5
23	−0.8	−0.5	−0.8	+0.2	−0.8	−0.7	−1.6	−1.6
24	.....	−0.5	−1.2	−1.0	−1.2	−0.6	−1.3	−1.6
25	.....	−0.4	−1.0	−1.2	−1.2	−1.8	−1.2	−1.8
26	.....	−0.8	−1.0	0.0	−1.7	−1.0	−0.2	−1.8
27	−0.7	−1.0	−1.2	−1.4	−1.5	0.0	−1.0	−0.8
28	−0.5	−1.0	−1.3	−2.3	−1.6	.....	−1.3	−1.3
29	−0.4	−0.6	−1.3	−1.2	−1.5	−1.0	−1.3	.....
30	−0.6	−0.9	−1.3	−0.9	−0.8	−1.4	−1.0	.....
31	−0.8	−0.8	.....	−1.2	.....	−1.8	−1.5	.....

Blank spaces—No record, gauge out of order.

WILLIAMS EXHIBIT 29.
BUFFALO HARBOR, N. Y.

Sheet 16.
(19 Sheets)

Record of Daily Mean Water Level, U. S. Engineer Self-Registering Gauge in U. S. Light House Slip, inner end U. S. South Pier. Zero of Gauge at elevation 573.15 feet above mean tide at N. Y. Adjusted U. S. Lake Survey Levels of 1903. Feet and tenths above or below zero.

Date	1899										1900											
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	-1.6	-0.7	-1.2	-0.6	-0.6	-0.9	-1.2	-1.6	-1.8	-1.0	-1.0	-0.9	.....	-1.0	-1.1	-0.9	-0.7	-0.9	-1.0	-1.6	-0.6	-1.2
2	-1.7	-1.1	-1.3	-0.7	-0.5	-0.7	-1.2	-0.9	-2.3	-0.8	0.0	.....	.....	-1.2	-1.0	-0.5	-1.0	-0.7	-1.0	-1.4	-1.3	-1.5
3	-1.7	-1.2	-1.6	-0.8	-0.6	-1.0	-1.0	-1.7	-1.2	-1.7	-1.5	.....	.....	-1.0	-0.6	-0.5	-0.5	-0.9	-0.7	-1.4	-1.3	-1.6
4	-1.8	-1.3	-1.4	-0.8	-0.6	-1.0	-1.4	-1.6	-0.6	-1.5	-1.9	-2.0	-2.1	-1.0	-0.6	.....	-0.8	-0.8	-1.0	-1.2	-1.2	-1.6
5	-0.9	-1.3	-1.3	-0.7	-0.5	-1.0	-1.0	-1.7	-1.3	-0.1	-1.5	-1.7	-2.4	-0.8	-0.7	.....	-0.8	-0.9	-1.0	-1.1	-1.0	-0.8
6	-1.4	-1.3	-1.1	-0.6	-0.5	-0.9	-1.4	-1.7	-1.4	-1.0	-2.0	-1.7	-1.2	-0.8	-0.9	-0.7	-0.5	-0.8	-0.6	-1.2	-1.5	-1.2
7	-1.4	-1.4	-1.1	-0.6	-0.6	-1.0	-1.2	-2.0	-1.5	-0.8	-1.5	-1.9	-1.5	-1.0	-1.1	-0.6	-0.5	-0.7	-1.5	-1.1	-1.6	-1.5
8	-1.2	-0.9	-1.1	-0.5	-0.4	-1.0	-1.3	-1.9	-1.6	-1.6	-2.0	-1.8	-1.9	-1.0	-0.8	-0.5	0.0	-0.6	-1.3	-1.3	-1.3	-1.0
9	-1.3	-1.0	-1.0	-0.6	-0.5	-1.1	-1.3	-1.7	-1.2	-2.0	-2.0	-0.4	-1.8	-1.0	-0.8	-0.6	-0.4	-0.7	-1.2	-1.4	-1.0	-0.4
10	-1.6	-1.2	-1.1	-0.8	-0.7	-0.9	-1.3	-1.6	-1.5	-1.7	-1.8	-1.9	-1.7	-1.0	-0.7	-0.8	-0.7	-0.6	-1.3	-1.4	-1.1	-1.2
11	-1.4	-1.3	-0.8	-0.8	-0.8	-1.0	-1.0	-1.6	-1.9	-1.8	-2.4	-1.9	-2.0	-1.5	-0.8	-0.6	-0.5	-0.5	-1.0	-1.4	-1.4	-1.1
12	-0.8	-1.2	-1.0	-0.8	-0.7	-0.7	-0.8	-1.6	-1.6	+0.2	-1.6	-1.9	-1.8	-0.8	-0.8	-1.0	-0.4	-1.2	+1.3	-1.4	-0.2	-1.0
13	-1.2	-1.2	-0.8	-0.7	-0.8	-1.0	-1.1	-1.6	-1.6	-0.8	-1.8	-1.0	-1.7	-0.8	-0.6	-0.8	-0.5	-0.6	-1.0	-1.6	-1.1	-0.4
14	-2.0	-1.0	-0.9	-0.7	-0.8	-1.5	-1.3	-1.5	-0.9	-2.2	-1.7	-1.3	-1.7	-0.6	-0.6	-0.8	-0.8	-1.0	-1.4	-1.4	-0.7	-1.8
15	-1.0	-1.0	-1.0	-0.7	-0.7	-1.5	-1.4	-1.8	-1.2	-1.2	-2.0	-1.3	-2.0	-1.2	-0.6	-0.8	-0.8	-0.9	-1.6	-1.3	-0.9	-1.8
16	-1.3	-1.0	-1.1	-0.6	-0.5	-1.2	-1.3	-1.7	-1.8	-1.8	-1.8	-1.4	-1.8	-1.3	-1.0	-0.9	-0.7	-0.7	-0.3	-1.4	-1.5	-1.8
17	-1.8	-1.2	-1.4	-0.6	-0.6	-1.1	-1.3	-1.4	-0.6	-1.4	-2.2	-1.6	-1.0	-1.4	-0.7	-0.8	-0.8	-0.9	-0.8	-1.2	-1.5	-1.8
18	-1.6	-1.2	-0.8	-0.6	-0.4	-1.0	-1.3	-1.4	-1.4	-1.7	-1.8	-1.6	-1.9	-1.1	-0.8	-1.0	-0.8	-0.9	-1.4	-1.1	-1.4	-1.3
19	-1.1	-1.2	-0.6	-0.8	-0.7	-1.0	-1.6	-1.7	-1.3	-1.0	-1.8	-1.6	-1.8	-0.8	-0.8	-1.0	-0.9	-1.1	-1.6	-1.8	-1.6	-1.4
20	-0.7	-1.2	-0.8	-0.8	-0.7	-1.0	-1.3	-0.8	-1.6	-1.0	-1.8	-1.8	-1.3	-1.2	-0.4	-0.9	-0.8	-0.8	-0.8	-1.6	-1.7	-1.6
21	-1.7	-1.2	-0.9	-0.7	-0.5	-0.7	-0.9	-0.9	-1.8	-1.1	-1.4	-2.1	-1.7	-1.0	-0.5	-0.8	-0.5	-1.0	-1.0	-1.5	+0.5	-1.8
22	-1.4	-1.2	-1.0	-0.8	-1.0	-0.8	-1.1	-0.6	-1.7	-1.6	-1.6	-1.7	-1.8	-1.1	-0.4	-1.0	-0.9	-1.0	-1.2	-1.4	-1.5	-1.8
23	-0.1	-1.3	-1.0	-0.6	-1.0	-1.1	-0.7	-0.5	-2.3	-1.8	-1.5	-1.3	-1.5	-1.1	-0.6	-1.2	-1.0	-1.0	-1.3	-1.4	-1.3	-1.6
24	-0.9	-1.2	-1.0	-0.8	-1.0	-1.1	-1.1	-0.5	-1.7	-0.6	-2.0	-1.2	-1.4	-1.1	-0.7	-0.8	-1.0	-0.8	-1.5	-1.4	-2.4	-0.6
25	-1.5	-1.1	-1.0	-0.7	-0.8	-1.1	-1.1	-0.6	-1.7	-0.6	-1.2	.....	-1.7	-1.1	-0.7	-0.8	-0.9	-0.8	-1.4	-1.7	-3.0	-0.9
26	-1.2	-1.2	-1.0	-0.7	-0.7	-1.3	-1.5	-0.5	-1.6	-0.6	-0.6	.....	-1.4	-1.0	-0.8	-0.8	-0.8	-0.9	-1.2	-1.3	-2.4	-1.1
27	-1.4	-1.2	-1.0	-0.6	-0.6	-1.2	-0.8	-0.7	-1.6	-1.0	-1.2	.....	-1.0	-0.9	-0.7	-0.6	-0.9	-0.7	-1.4	-1.5	-1.6	-1.5
28	-1.1	-1.2	-0.8	-1.1	-0.7	-1.4	-0.6	-1.0	-1.2	-0.8	-0.6	.....	-1.1	-0.9	-0.7	-0.5	-0.8	-0.8	-1.6	-1.6	-1.3	-1.5
29	+0.4	-1.1	-0.7	-1.0	-0.6	-1.2	-0.3	-1.3	-1.3	-1.2	-1.0	.....	-1.3	-1.0	-0.9	-0.5	-0.7	-1.0	-1.3	-1.6	-1.2	-0.4
30	-1.1	-1.3	-0.5	-0.6	-0.6	-1.2	-0.9	-1.6	-1.4	-1.2	-0.9	.....	-1.4	-1.0	-0.8	-0.5	-0.7	-1.0	-1.3	-1.6	-1.2	-1.4
31	-1.3	.....	-0.9	.....	-0.6	-1.1	.....	-2.0	.....	-0.5	-1.0	.....	-1.0	.....	-0.7	.....	-0.5	-1.0	.....	-1.8	.....	-1.4

Sheet 10—Cont'd.

Date	1901												1902				
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.		
1	−1.4	−1.3	−2.4	−2.0	−2.0	−1.5	−1.2	−1.2	−1.6	−1.8	−1.3	−1.9	−1.6	−2.0	−1.7		
2	−1.3	−2.0	−2.5	−2.4	−1.8	−1.5	−1.1	−1.3	−1.5	−1.4	−2.0	−1.8	−0.6	−1.6	−2.0		
3	−1.8	−2.6	−2.4	−2.2	−1.8	−1.4	−1.2	−1.4	−1.4	−1.3	−2.1	−2.3	−0.9	−0.6	−1.9		
4	−1.4	−2.0	−2.4	−1.8	−1.8	−1.7	−1.3	−1.4	−1.3	−1.5	−1.4	−1.9	−1.0	−1.5	−2.2		
5	−1.8	−1.8	−2.3	−2.1	−1.9	−1.6	−1.2	−1.8	−1.3	−1.0	−1.8	−2.1	−1.0	−1.8	−2.4		
6	−1.8	−1.8	−2.3	−2.3	−2.2	−1.5	−0.9	−1.8	−1.3	−1.8	−1.9	−2.1	−1.8	−2.2	−2.0		
7	−1.5	−2.0	−2.6	−1.8	−2.2	−1.2	−0.8	−1.4	−1.3	−1.8	−1.2	−1.7	−2.1	−1.9	−2.0		
8	−1.6	−2.4	−2.6	−1.8	−2.1	−1.0	−1.3	−1.1	−1.9	−1.7	−1.6	−2.2	−1.9	−2.0	−2.1		
9	−2.0	−2.4	−2.7	−1.8	−2.1	−1.8	−1.3	−1.8	−1.7	−1.6	−1.6	−2.2	−2.0		−1.9		
10	−1.8	−2.0	−2.3	−2.0	−2.1	−1.7	−1.2	−1.0	−1.4	−1.6	−2.1	−0.6	−1.7		−2.1		
11	−1.8	−2.1	−1.7	−2.0	−1.7	−1.6	−1.6	−1.5	−1.2	−1.8	−2.5	−2.0	−1.0		−2.0		
12	−0.6	−1.8	−2.1	−2.1	−1.7	−1.7	−1.7	−1.6	−1.0	−1.8	−1.1	−2.0	−1.6		−1.9		
13	−1.6	−2.0	−3.0	−2.2	−1.7	−1.7	−1.6	−1.6	−1.0	−1.0	−1.5	−2.0	−1.6		−1.7		
14	−1.6	−2.0	−2.3	−2.1	−2.0	−1.6	−1.5	−1.6	−1.5	−1.6	−1.0	−1.5	−1.6	−2.0	−2.2		
15	−1.6	−2.0	−2.3	−2.0	−2.0	−1.5	−1.4	−1.4	−0.7	−1.2	−1.3	−1.2	−2.0	−2.0	−2.3		
16	−0.4	−2.2	−2.3	−2.1	−2.0	−2.0	−1.3	−1.5	−0.4	−1.6	−1.5	−1.7	−2.3	−2.1	−2.2		
17	−1.0	−2.2	−2.2	−2.1	−1.9	−1.7	−1.2	−1.6	−1.0	−1.4	−2.0	−1.7	−1.7	−2.1	−1.4		
18	−1.3	−2.2	−2.4	−1.9	−1.9	−1.5	−1.1	−1.8	−1.4	−1.0	−2.0	−1.4	−1.6	−2.0	−2.0		
19	−1.6	−2.0	−3.6	−2.2	−2.2	−1.6	−1.4	−1.7	−1.6	−0.8	−2.1	−1.6	−1.8	−2.0	−2.2		
20	−1.0	−2.1	−2.6	−2.8	−2.2	−1.5	−1.1	−1.6	−1.4	−2.0	−2.0	−1.6	−2.0	−2.1	−2.1		
21	−1.4	−2.2	−1.9	−2.4	−2.2	−1.5	−1.2	−1.6	−1.4	−1.8	−2.0	−1.5	−2.4	−2.2	−2.1		
22	−2.0	−2.2	−1.9	−1.9	−2.0	−1.5	−1.3	−1.5	−1.4	−1.7	−2.0	−1.3	−2.0	−2.2	−2.1		
23	−1.9	−2.3	−2.3	−1.9	−2.0	−1.3	−1.3	−1.2	−1.4	−1.2	−2.8	−1.6	−1.5	−2.3	−2.1		
24	−1.7	−2.3	−2.3	−1.9	−2.2	−1.3	−1.2	−1.4	−1.8	−1.9	−2.5	−1.9	−1.9	−2.3	−2.3		
25	−1.5	−2.3	−2.4	−1.9	−2.3	−1.4	−1.8	−1.4	−2.7	−1.7	−1.6	−2.0	−1.9	−2.3	−2.4		
26	−1.5	−2.4	−2.0	−1.9	−2.2	−1.3	−0.7	−1.6	−1.7	−1.8	−1.8	−2.0	−2.0	−2.2	−2.5		
27	−1.6	−2.4	−1.8	−1.9	−2.0	−1.2	−1.5	−1.7	−1.7	−2.0	−2.0	−1.8	−1.0	−2.4	−2.2		
28	−1.4	−2.5	−1.8	−2.0	−2.3	−1.3	−1.2	−1.6	−1.6	−2.3	−1.9	−2.0	−1.8	−2.2	−2.2		
29	−1.6		−2.0	−2.0	−1.7	−1.0	−1.2	−1.4	−1.4	−2.0	−1.4	−1.7	−2.3		−1.8		
30	−2.2		−2.4	−2.0	−1.6	−1.2	−1.0	−1.3	−1.4	−1.9	−2.0	−1.5	−2.1		−1.2		
31	−1.5		−2.0		−1.6		−1.1	−1.5		−1.6		−0.7	−2.2		−1.5		

Blank spaces—No record; gauge out of order.
U. S. Engineer Office, Buffalo, New York. Map No. 6A. Drawer No. 64.

WILLIAMS EXHIBIT 29 Sheet 17 (19 Sheets)

ELEVATIONS OF WATER SURFACE OF LAKE ERIE

From record of self registering gage at

BUFFALO, N. Y.

In terms of U. S. Lake Survey adjusted levels of 1903.

1909.

Day	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	.....	.....	.....	572.47a	571.46	571.42
2	.....	.....	.....	572.11	572.14	571.34b
3	.....	.....	.....	571.93	571.90	571.49b
4	.....	.....	.....	571.83	571.82	571.55
5	.....	.....	.....	571.80	571.58	571.60
6	.....	.....	.....	571.92	571.25	573.11
7	.....	.....	.....	571.93	571.43	572.93
8	.....	.....	.....	571.89	571.50	573.60
9	.....	.....	.....	571.82	571.00	573.27
10	.....	.....	.....	571.96	571.51	572.43
11	.....	.....	.....	572.28	571.58	571.45
12	.....	.....	.....	573.90	571.52	570.74
13	.....	.....	.....	573.30	571.22	571.67
14	.....	.....	.....	572.88	571.53	573.60
15	.....	.....	.....	572.25	571.78	572.74
16	.....	.....	.....	572.78	571.41	572.17
17	.....	.....	.....	572.06	573.75	572.73
18	.....	.....	.....	571.73	571.87	572.90
19	.....	.....	.....	571.61	572.28	572.12
20	.....	.....	.....	571.40	572.01	572.11
21	.....	.....	.....	572.00	571.69	572.04
22	.....	.....	.....	572.40	571.43	572.05
23	.....	.....	.....	571.20	571.57	571.84
24	.....	.....	.....	571.48	570.87	571.56
25	.....	.....	.....	571.86	571.67	571.04
26	.....	.....	.....	572.10	571.55	571.43
27	.....	.....	.....	572.08	571.55	571.93
28	.....	.....	.....	571.79	571.60	571.79
29	.....	.....	.....	571.52	571.17	571.44
30	.....	.....	.....	571.53	571.43	571.74
31	.....	.....	.....	571.68	.....	571.59
Mean	.....	.....	.....	572.05	571.64	572.05

Note.—a=Partial day only.

b=Mean of partial day, the remaining hours of the day being supplied from mean stage range.

WILLIAMS EXHIBIT 29 (Sheet 18)
(19 Sheets)

ELEVATIONS OF WATER SURFACE OF LAKE ERIE

from record of self-registering gage at

BUFFALO, N. Y.

1910.

Day	Jan.	Feb.	Mar.	Apr.	May	June
1	571.44	571.20	571.12	571.71	572.21	572.94
2	571.36	571.10	571.26	571.69	572.29	572.58
3	572.12	571.04	571.28	571.59	572.37	572.57
4	570.92a	571.50	571.28	571.75	572.50	572.27
5	571.56	571.21	571.34	571.74	572.53	572.46
6	571.33	571.16	571.53	572.04	572.61	572.65
7	571.76	571.09	571.97	572.18	572.47	572.77
8	571.34	571.04	571.62	571.96	572.45	572.69
9	571.41	571.07	571.48	571.92	572.78	572.43
10	571.13	571.07	571.42	571.88	572.70	572.26
11	571.13	570.83	571.41	571.61	572.62	572.29
12	571.07	571.01	571.44	571.70	572.69	572.78
13	c	571.25	571.80	571.72	572.49	572.63
14	c	571.04	571.80	571.76	572.51	572.63
15	570.92	570.97	571.66	571.80	572.44	572.63
16	571.15	571.14	571.60	571.63	572.35	572.54
17	570.99	570.84	571.47	571.83	572.52	572.61
18	571.92	571.19	571.38	571.78	573.18	572.68
19	571.65	571.05	571.60	572.10	572.45	572.57
20	571.22	570.89	571.64	571.88	572.44	572.55
21	571.19	570.97	571.58	572.05	572.51	572.55
22	572.32	570.98	571.66	572.00	572.45	572.54
23	571.64	571.36	571.43	572.13	572.64	572.56
24	571.34	570.95	571.69	572.17	572.58	572.20
25	571.19	570.93	571.83	572.19	572.61	572.39
26	571.10	570.89	571.63	572.22	572.70	572.41
27	571.72	570.97	571.50	572.29	572.60	572.59
28	571.25	570.99	571.81	572.02	572.64	572.60
29	571.37	.....	571.66	572.15	572.60	572.55
30	571.18	.....	571.69	572.62	572.88	572.52
31	571.28	.....	571.96	.....	572.79	.....
Mean	571.38	571.06	571.57	571.97	572.57	572.55

Note.—a=Mean of partial day only.
b=
c=No record.

WILLIAMS EXHIBIT 29 Sheet 19 (19 Sheets)

ELEVATIONS OF WATER SURFACE OF LAKE ERIE

from record of self-registering gage at

BUFFALO, N. Y.

In terms of U. S. Lake Survey adjusted levels of 1903.

1910.

Day	July	Aug.	Sep.	Oct.	Nov.	Dec.
1	572.58	572.35	571.78	572.42	571.71	571.42
2	572.48	572.28	571.91	571.55	572.06b	571.49
3	572.52	572.22	572.50a	571.62	571.49b	571.46
4	572.02	572.69	c	571.94	571.48b	571.16
5	572.12	572.84	572.01	571.74	571.67	570.48
6	572.30	572.45	572.43	571.86	c	570.56
7	572.44	572.13	572.09	571.66	c	572.19
8	572.39	572.17	571.99	571.83	c	572.23
9	572.46	572.18	572.09	572.08	c	571.13a
10	572.47	572.32	571.80	571.92	c	c
11	572.42	c	571.85	572.31	c	c
12	572.42	572.01	571.92	571.53	572.06	c
13	572.62	572.08	571.72	571.50	572.14	572.18a
14	572.38	572.10b	571.68	551.93	571.59	573.53
15	572.39	572.04	571.82	571.99	571.87	571.86
16	572.18	571.98	571.71	571.97	571.88	571.22
17	571.95	572.01	571.80	571.65	571.80	571.59
18	572.03	572.16	571.83	571.76	571.90	571.24
19	572.23	572.06	571.44	571.78	571.48	572.29
20	572.29	572.01	571.57	571.47	571.22	571.73
21	572.39	571.97	571.72	571.36	571.69	571.27
22	572.47	572.11	571.27	573.11	571.47	571.18
23	572.28	572.04	571.66	572.04	571.53	571.27
24	572.42	572.10	571.52	572.05	571.79	571.67
25	572.64	572.45	571.96	571.85	571.68	571.09
26	572.46	572.30	571.52	571.69	571.42	571.56
27	572.49	572.03	572.09	572.63	570.60	571.40
28	572.35	571.81	571.82	572.47a	571.49	570.97
29	572.38	571.28	571.57	571.82	572.32	570.76
30	572.45	571.73	571.80	572.34	572.07	c
31	572.36	571.88	.....	571.80	.....	c
Mean	572.37	572.13	571.83	571.92	571.68	571.50

Note.—a=Mean of partial day only.
b=Mean of partial day only, using also mean of range.
c=No record, driving clock stopped.

WILLIAMS EXHIBIT 30 Sheet 1 (5 Sheets)

MONTHLY MEANS OF LAKE LEVELS

as derived from

U. S. Lake Survey Automatic-gage Records

Date	Lake Ontario at Tibbetts Pt.	Lake Erie at Buffalo	Lake Erie by Staff gage at Cleveland, Ohio	Lakes Mich.-Huron at Harbor Beach
1904				
July	247.78	573.41	.....	581.55
Aug.	247.56	573.12	.....	581.53
Sept.	247.17	572.84	.....	581.36
Oct.	246.84	572.61	.....	581.26
Nov.	246.33	572.31	.....	580.95
Dec.	245.75	572.13	.....	580.50
1905				
Jan.	245.60	571.74	.....	580.38
Feb.	245.28	571.23	.....	580.30
Mar	245.06	571.32	.....	580.29
Apr.	245.80	571.79	.....	580.66
May	246.13	572.38	.....	580.95
June	246.47	572.97	.....	581.40
July	246.89	573.28	.....	581.57
Aug.	246.68	573.06	.....	581.56
Sept	246.72	572.86	.....	581.45
Oct.	246.48	572.65	.....	581.22
Nov.	246.21	572.29	.....	580.93
Dec.	246.01	572.44	.....	580.67
1906			Shenehon	
Jan.	246.23	572.39	.....	580.53
Feb.	246.02	571.95	571.93	580.69
Mar.	245.76	571.72	571.71	580.76
Apr.	246.05	.....	572.10	580.94
May	.....	.....	572.39	581.20
June	.....	.....	572.58	581.33
July	246.40	.....	572.67	581.45
Aug.	246.14	.....	572.65	581.35
Sept.	245.78	.....	572.40	581.12
Oct.	245.66	.....	572.26	580.87
Nov.	245.55	.....	572.22	580.68
Dec.	.....	.....	.....	.....

F.G.R. Doc. 31, 1906

WILLIAMS EXHIBIT 30 Sheet 2 (5 Sheets)

DAILY MEAN ELEVATIONS OF WATER SURFACE OF LAKE ONTARIO

from self-registering gage records and tri-daily staff-gage readings

AT OSWEGO, N. Y.

in terms of the Lake Survey adjusted levels of 1903.

1900.

Day	Sept. a	Oct. a	Nov. a	Dec. b
1	245.31	244.90	244.43	244.78
2	245.27	244.84	244.60	244.82
3	245.33	244.83	244.56	244.72
4	245.33	244.83	244.51	244.72
5	245.33	244.83	244.67	244.92
6	245.34	244.82	244.62	245.02
7	245.24	244.78	244.43	244.92
8	245.20	244.95	244.59	244.92
9	245.22	244.89	244.98	245.02
10	245.13	244.89	244.73	244.89
11	245.05	244.89	244.46	245.02
12	245.39	244.85	244.54	244.82
13	245.14	244.79	244.48	245.15
14	245.15	244.80	244.51	244.92
15	245.05	244.78	244.54	244.92
16	245.10	244.90	244.39	244.92
17	245.16	244.76	244.28	244.82
18	245.11	244.81	244.34	244.72
19	244.96	244.69	244.38	244.75
20	244.90	244.60	b244.42	244.82
21	245.06	244.59	244.94	244.75
22	245.09	244.57	244.53	244.69
23	245.04	244.55	244.62	244.62
24	245.04	244.64	244.42	244.89
25	244.97	244.56	244.43	244.82
26	244.94	244.52	b244.50	244.92
27	245.01	244.63	b244.52	244.72
28	244.96	244.59	b244.65	244.82
29	244.91	244.55	244.46	244.89
30	244.95	244.46	244.68	244.62
31	.....	244.35	.....	244.65
Mean	245.12	244.72	244.54	244.84

Note.—(a), from self-registering gage records.
(b), from tri-daily staff-gage readings.

WILLIAMS EXHIBIT 30 Sheet 3 (5 Sheets)

DAILY MEAN ELEVATIONS OF WATER SURFACE OF LAKE ONTARIO

from self-registering gage records and tri-daily staff-gage readings

AT OSWEGO, N. Y.

in terms of the Lake Survey adjusted levels of 1903.

1901

Day	April	May	June	July
	b	a	a	a
1	245.12	246.10	245.92	245.92
2	245.09	246.08	245.91	245.94
3	245.12	246.14	245.99	245.94
4	245.39	246.09	245.97	245.90
5	245.32	246.06	245.93	245.85
6	245.32	246.02	245.95	245.88
7	245.32	246.00	246.01	245.92
8	245.52	245.96	246.10	245.94
9	245.55	245.95	246.11	245.90
10	245.52	245.93	246.04	245.85
11	245.55	245.95	246.01	245.88
12	245.52	245.89	246.03	245.79
13	245.55	245.93	246.02	245.77
14	245.55	245.90	246.00	245.74
15	245.52	245.88	246.00	245.74
16	245.55	245.86	245.96	245.74
17	245.50	245.85	245.95	245.75
18	245.50	245.86	245.95	245.75
19	245.55	245.83	245.95	245.72
20	245.62	245.82	245.96	245.66
21	245.72	245.77	245.98	245.69
22	245.80	245.78	245.96	245.71
23	245.95	245.83	246.03	245.69
24	246.02	245.87	246.04	245.68
25	246.02	245.85	246.01	245.53
26	246.05	245.81	246.00	245.44
27	246.00	245.82	246.00	245.40
28	246.00	245.84	246.01	245.44
29	246.02	245.81	246.02	245.56
30	246.12	245.85	246.01	245.65
31	.....	245.85	.....	245.68
Mean	245.63	245.91	245.99	245.74

Note.—(a), from self-registering gage records.
(b), from tri-daily staff-gage readings.

WILLIAMS EXHIBIT 30 Sheet 4 (5 Sheets)

DAILY MEAN ELEVATIONS OF WATER SURFACE OF ST. LAWRENCE RIVER

from self-registering gage records

AT OGDENSBURG.

In terms of the Lake Survey adjusted levels of 1903.

1901.

Day	April	May	June	July
1	244.01	244.89	244.87	244.99
2	243.91	244.95	244.85	245.14
3	243.71	244.84	245.15	244.94
4	243.98	244.97	245.12	244.82
5	244.18	244.91	244.97	244.70
6	244.09	244.86	245.03	244.96
7	244.19	244.93	245.13	245.11
8	244.39	244.86	245.22	244.81
9	244.30	244.82	245.16	244.95
10	244.22	244.77	245.10	244.96
11	244.30	244.88	245.03	244.72
12	244.36	245.03	244.95	244.75
13	244.35	245.19	244.91	244.85
14	244.35	245.00	245.01	244.92
15	244.39	244.97	244.49	244.92
16	244.38	244.91	244.78	244.88
17	244.36	244.83	244.83	244.87
18	244.53	244.84	244.85	244.79
19	244.45	244.52	244.92	244.68
20	243.73	244.00	244.89	244.77
21	243.87	244.72	244.98	244.80
22	244.39	244.75	244.91	244.77
23	244.54	245.00	245.05	244.77
24	244.67	244.14	245.07	244.64
25	244.67	244.42	245.01	244.51
26	244.68	244.80	244.99	244.46
27	244.86	244.82	245.06	244.53
28	244.93	244.65*	245.06	244.55
29	244.93	.....	245.11	244.58
30	244.85	.....	245.19	244.87
31	.....	244.89*	.....	244.88
Mean	244.35	244.82	244.99	244.81

Note.—May 29th and 31st records are for partial days only.

WILLIAMS EXHIBIT 30 Sheet 5 (5 Sheets)

DAILY MEAN ELEVATIONS OF WATER SURFACE OF ST. LAWRENCE RIVER.

from self-registering gage records

AT OGDENSBURG.

1900.

Day	Sept.	Oct.	Nov.	Dec.
1	.....	243.98	243.95	243.91
2	.....	243.97	244.12	243.84
3	.....	244.07	243.69	243.88
4	.....	244.06	243.87	243.63
5	.....	244.04	243.80	243.78
6	.....	243.77	243.81	243.99
7	.....	244.10	243.77	243.97
8	.....	244.02	243.60	244.31
9	.....	243.87	243.65	244.01
10	.....	243.87	243.95	243.91
11	.....	244.04	243.70	.....
12	.....	243.98	244.08	243.91
13	.....	243.87	243.49	244.38
14	.....	243.82	243.74	243.82
15	.....	243.98	243.94	243.80
16	.....	243.83	243.54	243.82
17	244.20	243.99	243.60	243.73
18	243.99	244.02	243.74	243.72
19	244.00	243.65	242.97	244.25
20	244.35	243.84	243.60	243.96
21	244.36	243.90	244.59	243.75
22	244.23	243.77	243.79	243.83
23	244.16	243.79	244.01	243.88
24	244.15	243.84	243.36	244.07
25	244.06	243.59	243.01	244.14
26	244.13	243.78	242.68	244.03
27	244.13	243.73	243.52	243.97
28	244.04	243.70	243.52	244.02
29	244.02	243.73	243.74	244.30
30	244.01	243.07	243.83	244.26
31	.....	243.70	.....	243.88
Mean	244.14	243.85	243.69	243.96

Note.—Gage was started on September 17th, 1900.
Elevations are in terms of Lake Survey adjusted levels of 1903.

WILLIAMS EXHIBIT 31

Sheet 1
(3 Sheets)

TABLE I—LAKE SUPERIOR DRAINAGE AREA
Mean monthly and annual rainfall, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1898	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.8	1.1	.....
1899	1.5	1.3	1.7	2.2	3.2	3.7	2.2	3.4	3.5	2.4	0.5	2.0	27.6
1900	1.3	1.1	0.8	1.1	0.8	2.1	3.4	4.7	6.0	2.7	1.6	1.1	26.7
1901	1.4	0.5	2.0	1.1	1.5	3.9	4.8	2.2	3.0	3.0	1.7	1.7	26.8
1902	1.0	1.2	0.8	1.5	2.5	2.9	2.8	2.6	2.9	2.8	2.7	2.2	26.8
1903	1.1	0.9	1.7	1.8	3.9	1.4	3.8	2.9	3.8	2.9	2.3	1.5	28.0
1904	1.3	0.7	1.7	0.9	2.7	2.9	2.7	3.1	4.0	3.9	0.8	2.1	26.8
1905	1.2	0.8	2.0	1.7	2.8	4.3	4.3	2.3	4.7	2.7	2.7	1.0	30.5
1906	2.08	0.92	1.57	1.23	3.36	4.85	1.70	3.55	3.00	2.87	3.17	1.82	30.12

TABLE II—LAKE MICHIGAN DRAINAGE AREA
Mean monthly and annual rainfall, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	2.50	0.96	0.81	1.41	3.29	1.84	1.80	3.28	2.51	0.91	2.92	4.18	26.41
1896	1.25	1.26	1.53	3.60	4.07	2.82	4.05	3.42	5.45	1.53	2.09	2.18	33.25
1897	4.02	1.37	3.03	2.97	2.42	3.40	2.78	1.94	1.49	1.85	2.85	2.21	30.33
1898	2.70	2.20	3.51	1.84	3.00	3.67	2.10	3.33	2.84	4.24	2.30	1.52	33.25
1899	1.61	1.41	2.81	1.55	3.80	3.19	3.81	1.55	2.94	2.68	1.14	2.25	28.74
1900	1.31	2.87	1.64	1.90	2.48	2.65	5.53	3.95	3.66	3.24	3.32	0.75	33.30
1901	1.67	1.38	3.04	1.09	2.40	2.91	4.29	2.36	2.50	3.36	1.36	2.23	28.59
1902	0.75	1.29	2.49	1.83	4.37	5.17	5.16	1.41	3.68	2.19	2.65	2.29	33.28
1903	1.62	2.03	2.18	3.15	2.86	2.44	4.35	4.97	3.77	2.02	1.63	1.99	33.01
1904	1.67	1.93	3.39	2.21	4.29	2.04	2.91	3.08	3.97	2.98	0.40	1.82	30.69
1905	1.61	1.52	2.29	2.23	4.96	4.96	4.34	3.50	3.06	2.86	2.18	1.50	35.03
1906	2.79	1.43	2.24	1.78	2.90	3.87	2.40	3.24	2.97	2.95	3.37	2.32	32.35

TABLE III—LAKE HURON DRAINAGE AREA

Mean monthly and annual rainfall, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	3.75	1.35	1.18	1.50	2.41	1.50	1.54	2.81	2.91	1.86	3.18	3.84	27.92
1896	2.37	1.94	1.37	2.08	2.65	2.39	2.28	3.84	4.71	2.00	3.16	1.80	30.59
1897	3.47	1.82	2.96	3.01	3.45	2.59	4.17	2.75	1.06	3.27	3.21	3.40	35.16
1898	2.95	2.55	2.88	1.31	2.69	3.41	1.28	3.16	2.67	4.20	2.08	2.74	31.90
1899	2.25	1.32	3.49	1.47	3.25	3.44	3.48	1.04	3.38	2.78	1.20	3.39	31.09
1900	1.81	3.62	1.68	1.29	2.36	3.09	4.24	2.97	3.52	2.45	3.87	1.56	32.46
1901	2.16	1.49	2.85	1.55	2.81	2.28	4.21	2.86	2.41	3.16	2.04	2.62	30.44
1902	1.46	1.33	2.81	1.89	3.20	4.16	4.56	2.32	3.57	3.22	2.81	2.23	33.68
1903	2.29	2.06	1.99	1.79	2.48	2.94	3.52	3.99	3.68	2.86	2.01	3.10	33.31
1904	1.99	2.21	2.82	2.44	3.75	2.67	2.75	3.12	3.88	2.62	0.99	2.19	31.43
1905	2.17	1.91	2.23	1.63	4.08	3.74	3.89	2.53	3.00	3.48	2.56	1.51	33.03
1906	2.86	1.59	2.10	1.58	2.45	4.07	2.70	2.79	2.38	4.16	2.92	2.50	32.10

WILLIAMS EXHIBIT 31
Sheet 2
(3 Sheets)

TABLE IV—LAKE HURON-MICHIGAN DRAINAGE AREA
Mean monthly and annual rainfall, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	3.15	1.16	1.00	1.50	2.83	1.66	1.66	3.03	2.72	1.41	3.05	4.00	27.17
1896	1.83	1.61	1.44	2.80	3.32	2.59	3.12	3.63	5.06	1.77	2.64	1.98	31.79
1897	3.73	1.60	2.99	2.99	2.95	2.98	3.50	2.36	1.26	2.59	3.03	2.83	32.81
1898	2.83	2.38	3.17	1.56	2.83	3.53	1.67	3.24	2.75	4.21	2.18	2.15	32.50
1899	2.25	1.36	3.16	1.51	3.51	3.32	3.63	1.28	3.17	2.73	1.17	2.84	29.93
1900	1.57	3.26	1.66	1.58	2.41	2.88	4.85	3.43	3.58	2.82	3.60	1.17	32.81
1901	1.92	1.44	2.94	1.33	2.61	2.58	4.24	2.62	2.45	3.25	1.71	2.43	29.52
1902	1.12	1.31	2.65	1.86	3.80	4.64	4.84	1.88	3.62	2.72	2.73	2.27	33.44
1903	1.97	2.36	2.08	2.44	2.66	2.70	3.91	4.45	3.72	2.46	1.83	2.57	33.15
1904	1.83	2.07	3.00	2.33	4.00	2.37	2.82	3.10	3.92	2.79	0.71	2.01	31.04
1905	1.91	1.72	2.26	1.91	4.51	4.32	4.10	2.99	3.02	3.18	2.38	1.66	33.96
1906	2.82	1.49	2.18	1.70	2.72	3.95	2.57	3.05	2.72	3.44	3.19	2.39	32.22

TABLE V—LAKE ST. CLAIR DRAINAGE AREA
Mean monthly and annual rainfall, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	3.08	0.95	1.41	1.57	2.84	1.29	1.98	2.57	2.87	1.36	4.03	4.26	28.21
1896	1.42	2.11	1.86	2.58	2.69	3.42	4.82	4.18	4.04	1.82	2.22	1.55	33.31
1897	2.53	1.56	3.24	2.47	3.89	2.72	3.61	2.71	0.83	1.56	4.98	2.48	32.58
1898	3.33	2.74	3.24	1.86	2.11	3.09	1.67	2.21	3.16	4.82	2.98	2.56	33.77
1899	1.95	1.72	3.93	0.65	3.39	1.97	2.13	0.59	2.75	3.39	1.73	2.71	26.91
1900	1.68	4.02	2.28	1.55	2.84	3.28	3.92	2.87	1.65	2.53	3.52	0.58	30.72
1901	1.90	1.94	2.08	1.82	2.78	1.91	3.76	2.22	2.14	1.71	1.63	3.36	27.23
1902	1.14	1.05	2.62	1.18	3.47	5.85	6.94	1.72	5.58	2.59	1.61	2.02	35.77
1903	1.88	2.71	1.68	3.41	2.64	3.83	4.64	4.13	2.58	2.23	1.81	2.22	33.76
1904	3.16	2.17	3.21	2.52	2.58	1.98	3.32	4.06	2.88	2.02	0.62	2.01	30.53
1905	1.97	1.90	1.35	1.96	3.80	4.04	3.97	3.40	2.53	2.78	2.77	1.71	32.18
1906	2.13	1.07	2.01	1.79	2.92	4.04	3.72	2.89	1.78	5.19	2.32	3.39	33.26

TABLE VI—LAKE ERIE DRAINAGE AREA

Mean monthly and annual rainfall, in inches

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	3.31	0.97	1.44	1.78	2.27	1.94	2.00	2.94	2.33	1.40	4.37	4.33	29.08
1896	1.78	2.61	2.60	2.92	2.37	3.76	6.44	3.18	4.65	1.36	2.21	1.78	35.75
1897	2.49	1.87	3.59	2.72	3.83	2.76	4.49	2.92	0.80	1.18	5.36	2.43	34.44
1898	3.88	2.53	4.09	2.03	3.17	3.05	2.80	3.45	3.09	4.52	3.21	2.70	38.52
1899	2.48	1.91	3.97	1.12	4.20	1.97	3.24	1.22	3.25	2.72	1.69	3.20	30.97
1900	2.11	4.03	2.53	1.86	2.28	2.91	4.93	2.99	2.01	2.60	4.16	1.05	33.46
1901	2.03	1.70	2.72	3.08	3.83	3.01	3.30	3.12	2.81	1.59	2.09	3.64	32.92
1902	1.41	1.13	2.54	2.08	3.49	6.47	6.25	1.61	4.85	2.43	1.97	2.87	37.10
1903	2.08	3.36	2.30	4.09	2.13	3.86	4.63	4.82	2.04	2.56	1.95	2.26	36.08
1904	4.15	2.95	4.50	3.23	3.66	2.21	4.21	3.27	2.76	1.95	0.46	2.32	35.67
1905	2.15	1.66	1.78	2.72	4.57	4.77	4.19	3.61	2.98	2.88	2.73	1.90	35.94
1906	1.71	1.03	2.78	2.01	2.60	3.22	4.09	3.95	2.69	4.36	2.57	3.47	34.48

WILLIAMS EXHIBIT 31.

Sheet 3
(3 Sheets)

TABLE VII.—LAKE ONTARIO DRAINAGE AREA.

Mean monthly and annual rainfall, in inches.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1895	3.27	1.59	1.50	1.77	2.52	2.13	2.51	3.43	2.52	1.63	3.71	4.00	30.58
1896	2.43	4.09	3.21	1.24	2.41	2.60	3.86	2.46	4.52	2.33	2.99	1.37	33.51
1897	2.52	1.81	3.22	2.66	3.41	2.95	5.25	2.36	1.56	1.29	4.41	3.39	34.83
1898	3.31	2.26	2.31	2.06	3.10	2.87	1.72	4.34	3.24	4.82	2.73	2.63	35.61
1899	2.22	1.61	3.48	1.46	3.26	2.01	2.87	1.34	3.66	2.89	1.74	3.91	30.45
1900	2.87	3.84	3.42	1.51	1.80	2.56	4.21	2.37	2.38	3.07	5.15	2.00	35.18
1901	2.33	1.76	2.98	4.16	4.45	3.01	3.87	3.96	3.03	1.54	2.62	4.10	37.81
1902	2.36	2.25	2.73	2.67	2.55	4.48	6.45	2.39	2.81	3.24	1.66	2.87	36.46
1903	2.79	2.63	3.31	2.54	1.01	5.11	4.00	4.76	1.52	3.93	1.72	2.61	35.93
1904	3.30	2.59	3.12	3.11	3.62	3.18	4.47	3.41	3.69	2.46	0.67	2.27	35.89
1905	2.19	1.84	1.70	1.85	2.87	4.99	4.45	3.77	2.59	3.56	2.20	2.87	35.58
1906	2.02	1.08	2.69	1.79	2.94	5.05	3.08	3.13	2.97	4.67	2.36	2.73	34.51

WILLIAMS EXHIBIT 32.

F F F 2.

ENGINEER OFFICE, U. S. ARMY,
Detroit, Mich., July 20, 1903.

GENERAL: I have the honor to submit with my annual report for the fiscal year ending June 30, 1903, a special report on the outflow, rainfall, and evaporation in the valley of the Northern and Northwestern Lakes.

Very respectfully, your obedient servant,

WM. H. BIXBY,
Major, Corps of Engineers.

Brig. Gen. G. L. GILLESPIE,
Chief of Engineers, U. S. A.

U. S. ENGINEER OFFICE, JONES BUILDING,
Detroit, Mich. June 25, 1903.

MAJOR: I have the honor to submit the following discussion of the outflow, rainfall, and evaporation in the valley of the Great Lakes:

DRAINAGE BASINS.

The outlines and areas of the drainage basins of the several lakes were first determined. Plate I is a map of these basins. This map was compiled from the best topographical maps available. It was also compared with a similar map prepared by the Deep Waterway Commission. The watershed or boundary of the basin was determined by a study of the sources of the streams. In the United States the land survey maps show these with considerable accuracy. It is likely that the township in which a stream has its rise is in almost all cases correctly given, and the location of the source is known within less than 6 miles. In a portion of Canada the maps have equal accuracy.

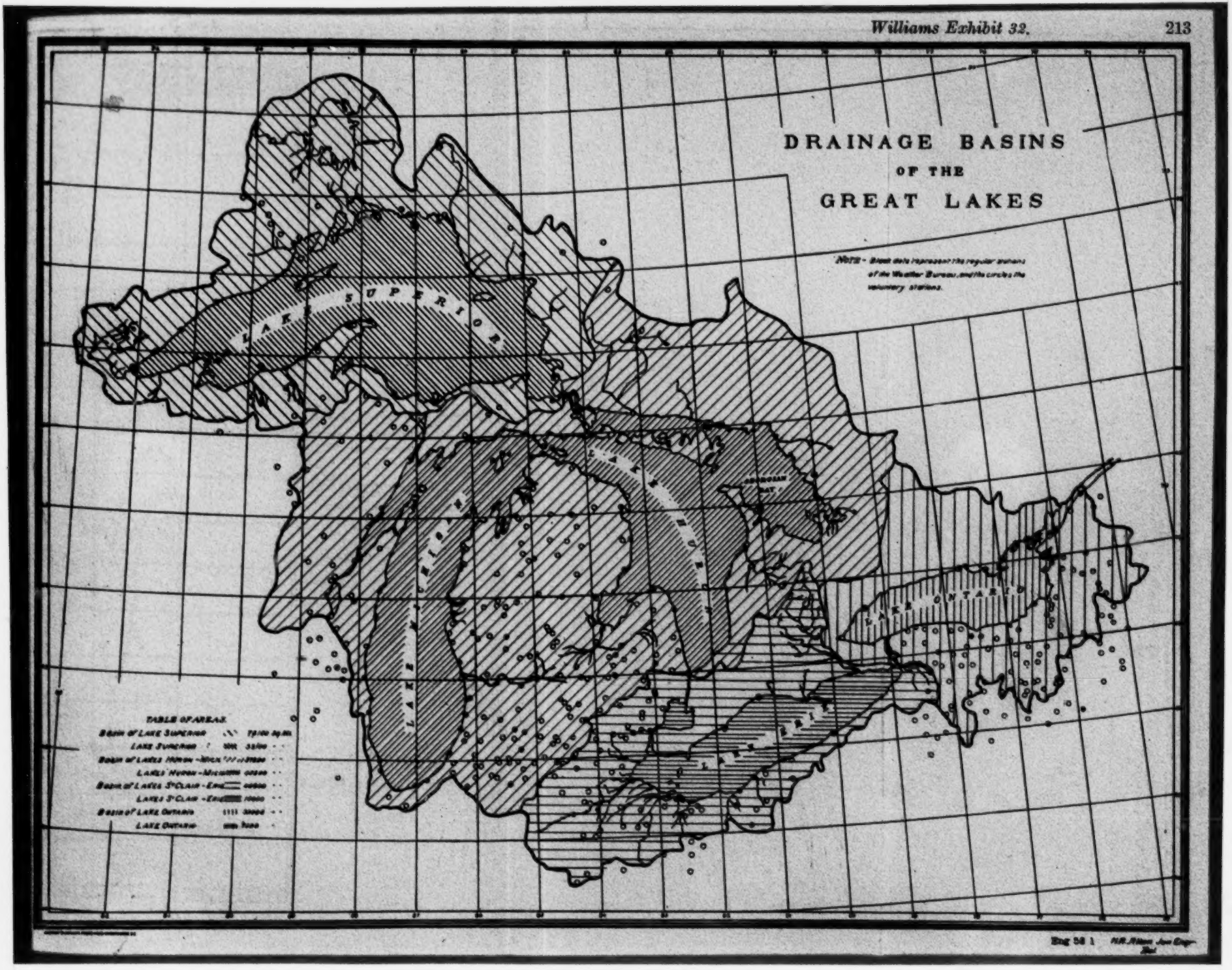
In order to make an approximate estimate of the error in the determination of the area of the drainage basin, it might reasonably be assumed that the best located part of the boun-

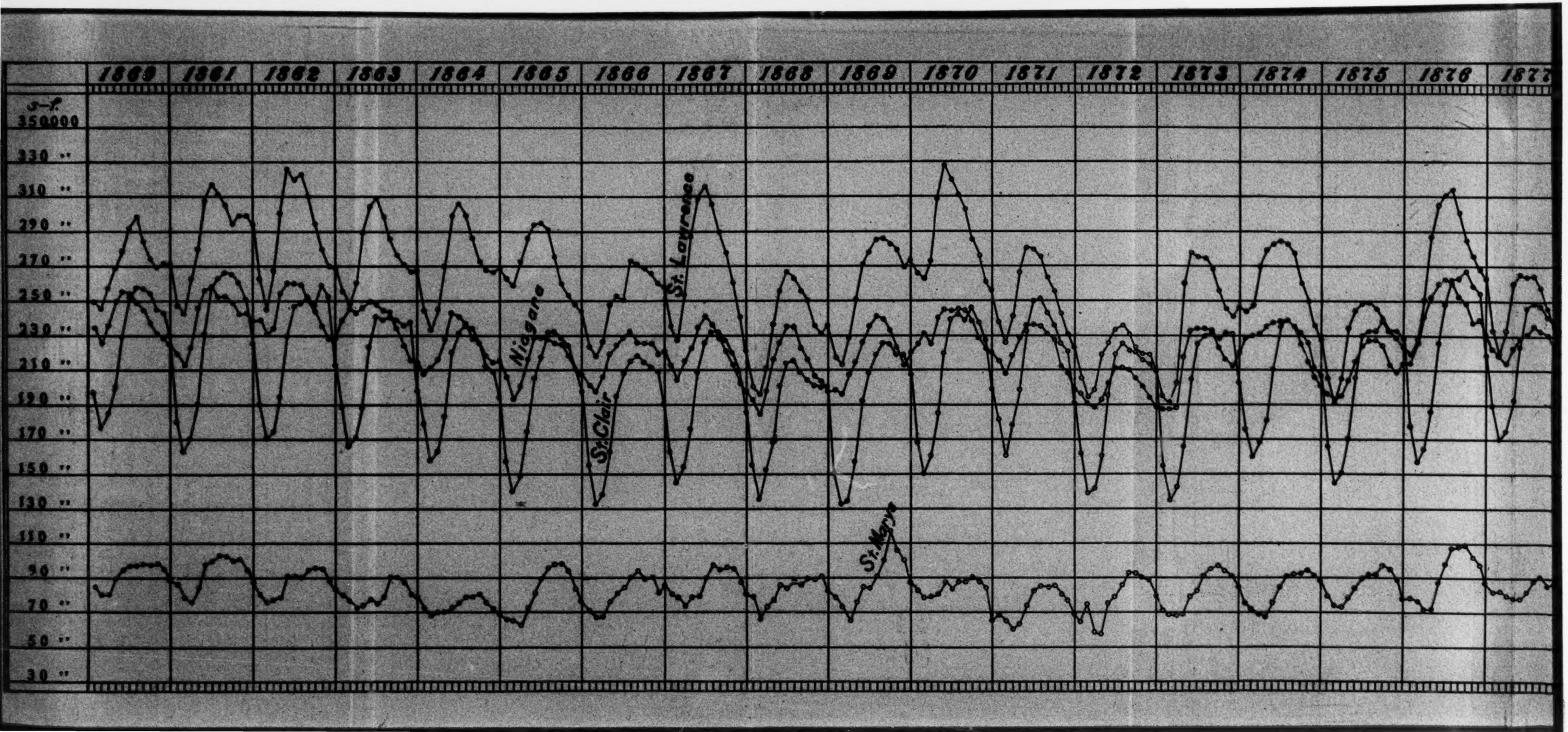
dary was never more than 6 miles in error, and this not oftener than once in a hundred miles. This error would sometimes be inside the basin and sometimes outside as a compensating error. Since there is about 2,500 miles of the developed boundary line known with this accuracy, there might be about 500 miles uncompensated, which would make a possible error of about 1,500 square miles. In the northwestern part there is about 900 miles of the boundary where the maps are less accurate, and it might be reasonably assumed that the location is never more than 20 miles in error, and this not oftener than once in a hundred miles. Then the uncompensated possible error in this part of the boundary would be about 3,000 square miles, and the total possible error with this assumption would be about 4,500 square miles, or about 1½ per cent. of the total area of the basins. It is therefore probable that the areas of the several basins are correctly determined within less than 2 per cent.

After the boundary line was drawn on the map the area included by it was determined as follows:

Quadrilaterals of one degree or less in extent, bounded by meridians and parallels, were selected so as to completely cover the basin; this gave a polygon, the sides of which were meridians and parallels. The total area of this polygon was determined accurately from geodetic tables of areas. Those small parts of the polygon which extended outside of the boundaries of the basin were measured on the map with a planimeter and subtracted, the remainder being the area of the basin. This work was done with care and checked, and it is believed that the areas of the lakes and basins as herewith given on Plate I are as accurate as extant maps will permit.

In determining the area of the lakes their connecting waters were included; the lines of division between the lakes were chosen at the points where the discharge measurements were made, viz, Sault Ste. Marie, Port Huron, Buffalo, and Ogdensburg. For this determination the lake survey maps were used and the same method followed as for the entire basin. It is seen from this map that the northeast watershed approximates a straight line for a distance of more than 800 miles—that is, a straight line could be drawn for that distance so that at no point would its distance from the watershed be more than 30 miles. It will also be noticed that at certain points the shores of Lakes Superior, Michigan, and Erie approach to within less than 10 miles of the boundaries of their basins.


DRAINAGE BASINS
OF THE
GREAT LAKES
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
GEORGIAN BAY
LAKE ERIE
LAKE ONTARIO
TABLE OF AREAS.


1860
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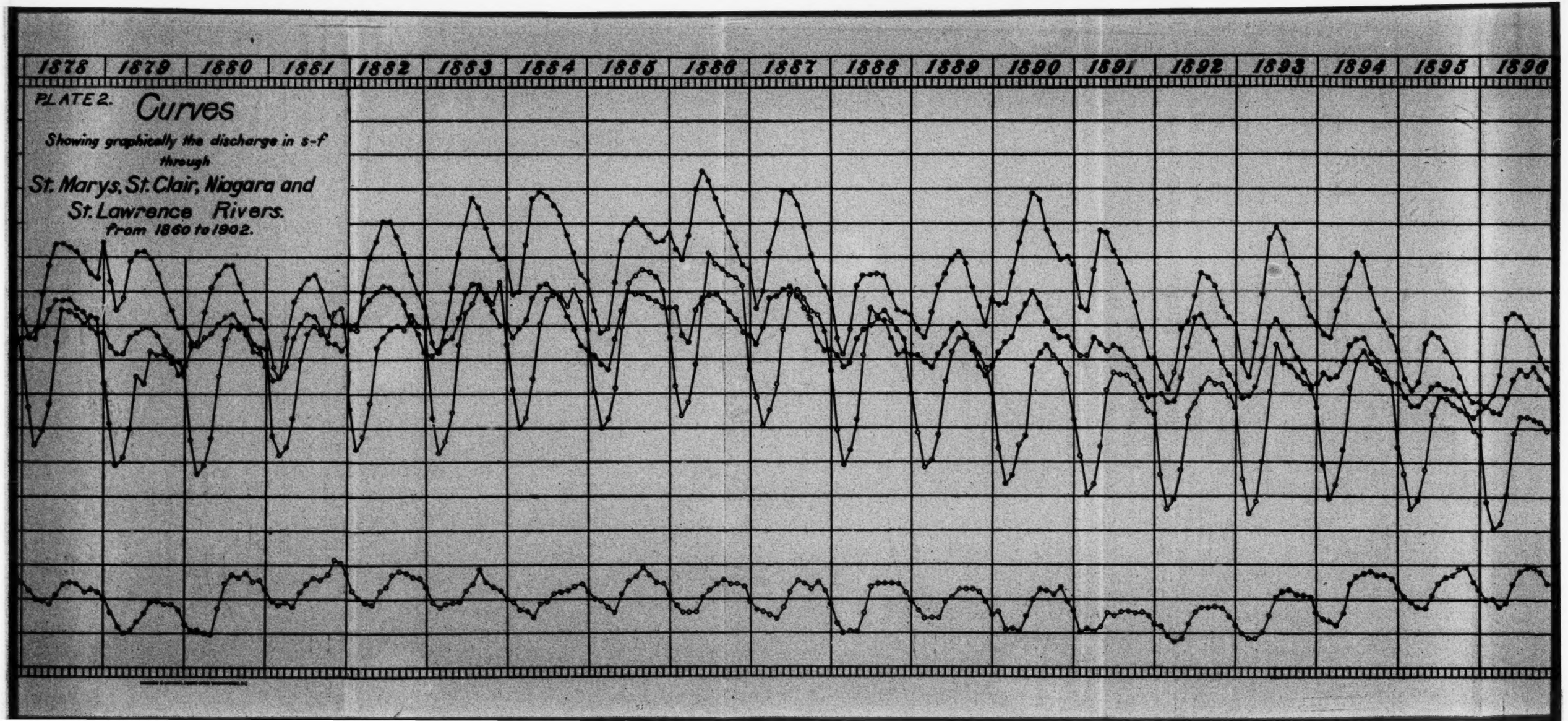
1876
1877
Niagara
St. Clair
St. Lawrence
St. Marys


1878
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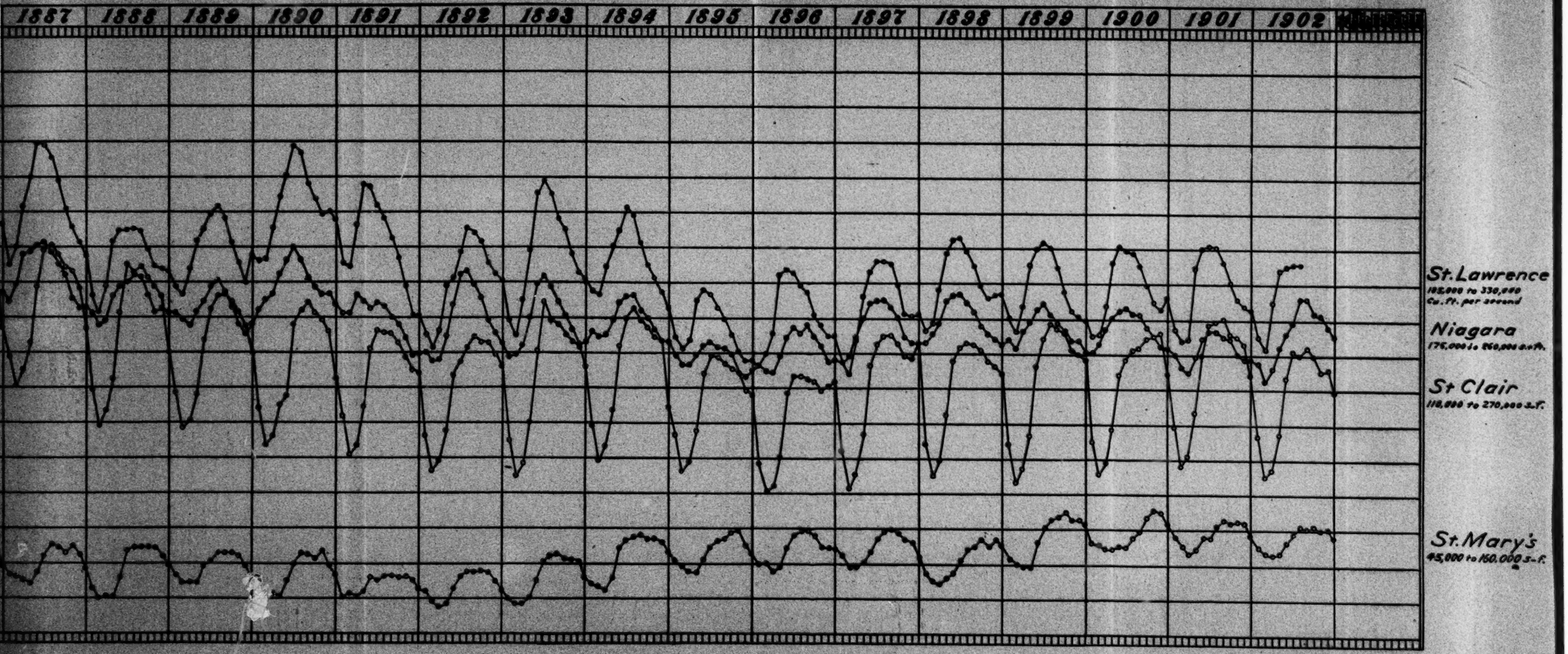
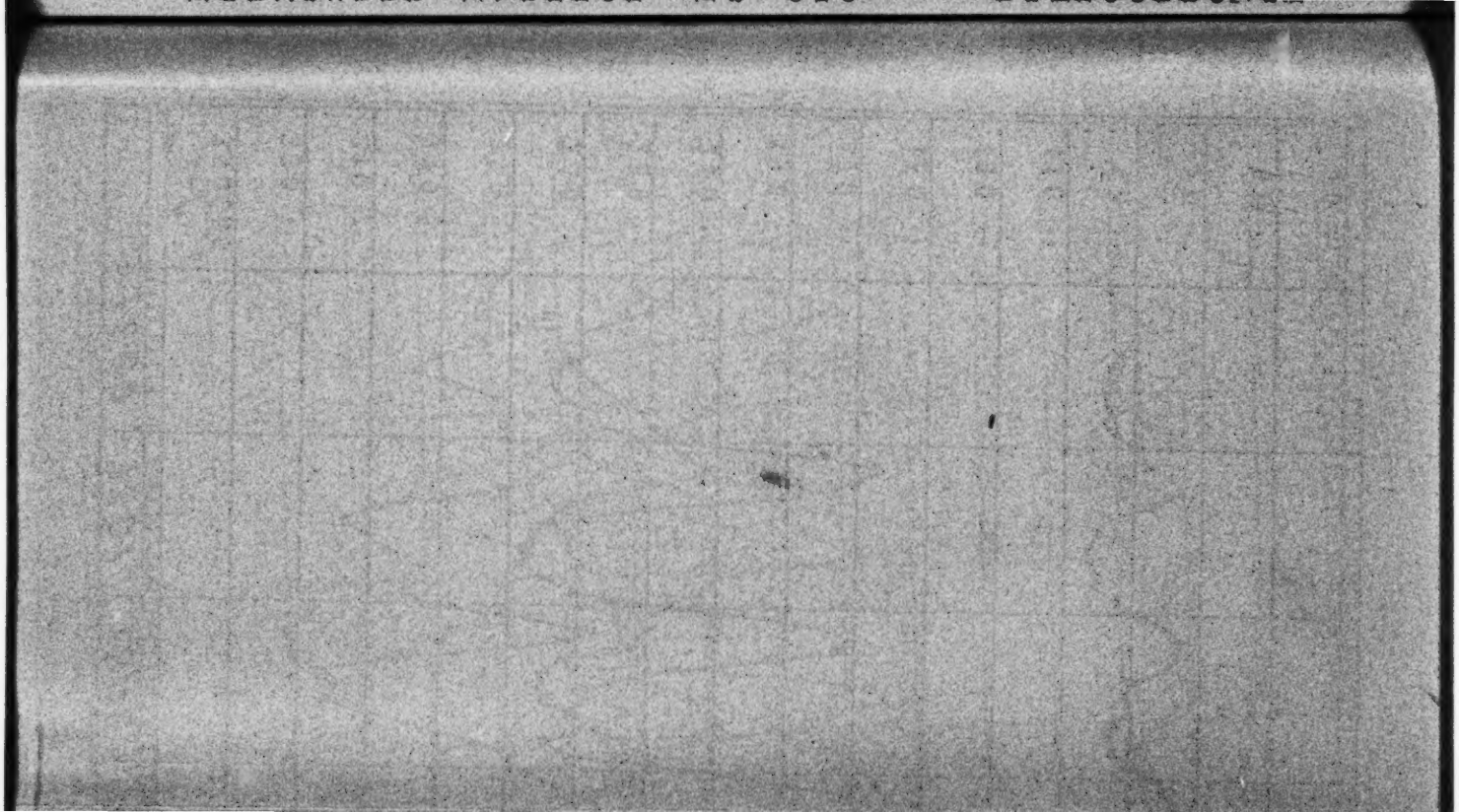
1893
1894
1895
1896
PLATE 2.
Curves
Showing graphically the discharge in s-f through
St. Marys, St. Clair, Niagara and St. Lawrence Rivers.
From 1860 to 1902.


1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
St. Lawrence
185,000 to 330,000
Cu. Ft. per second
Niagara
176,000 to 260,000 c.f.
St Clair
118,000 to 270,000 c.f.
St. Mary's
45,000 to 150,000 c.f.
H.R. Allen Jun. Engr
Del.

Eng 58 1



LAKE ELEVATIONS.

The changes in the elevation of the surfaces of the Great Lakes, and consequently of the rivers connecting them, are small, the mean annual change being less than 2 feet, while the extreme range in monthly means for the last forty-two years is less than 5½ feet. The records of the elevations of all the lakes, except St. Clair, since 1860 are continuous and reasonably trustworthy. They have been published from year to year in the Report of the Chief of Engineers, from which they have been collected and are herewith given in Tables I to V.

The elevations of Lake St. Clair, herewith given in Table III, are not all directly observed; before 1872 no observations were made at Lake St. Clair; all the elevations given in the tables before that date and a few after it have been computed from the observed elevations of Lakes Huron and Erie. The formula used for such computations is taken from page 5397 of the Report of the Chief of Engineers for 1900, and is as follows:

St. Clair Flats=574.06+.407(H—580)+.452(E—570) where H=elevation of Lake Huron and E=elevation of Lake Erie, as herewith given in Tables II and IV.

For Lake St. Clair the elevation for the summer months only have been used, as the elevations during the winter months are often seriously disturbed by the ice, as discussed on page 2822 of Report of Chief of Engineers for 1902.

OUTFLOW AND DISCHARGE FORMULAE.

The outflow from the lakes has been measured at different times by the United States lake survey; the measurements since 1896 have been made with modern and improved appliances; the results have been very accordant. The discharge formulas derived from this later work have been used in this discussion. It is found that within the small observed range of the surface elevation the discharge is so near a linear function of the surface elevation that one can be derived from the other with considerable accuracy; therefore, the discharge can be determined whenever the surface elevation is known. This has been done for the years 1860 to 1902, and the results are herewith given in Tables VI to IX, and also shown graphically in Plate II.

The discharge from Lake Superior was measured at Sault Ste. Marie from 1896 to 1899, and discharge formulae were deduced therefrom in 1900.

Between 1887 and 1892 the outlet of Lake Superior was somewhat contracted by the building of the International Bridge piers at Sault Ste. Marie, and also by the closing of some of the small streams on both sides of the river. These changes make the discharge formulae different for different periods, as follows:

Before 1888, discharge in s-f=46,047+19,429 x (elev.—600).

From 1888 to 1895, inclusive, discharge in s-f=39,798+17,656 x (elev.—600).

From 1896 to 1898, inclusive, discharge in s-f=43,466+17,656 x (elev.—600).

After 1898, discharge in s-f=49,235+17,656 x (elev.—600).

In these formulae "elevation" means the elevation of lake surface as herewith given in Table I.

The data and methods used in determining such formulae, not having as yet been printed or otherwise published, are herewith attached and marked "Appendix A."

The outflow from Lakes Michigan and Huron was measured at Port Huron from 1898 to 1900. The results are given on pages 2819 et seq. of the Report of the Chief Engineers for 1902. It was found that the discharge of St. Clair River was not exactly a linear function of the surface elevation of Lake Huron, but was modified by two causes—first, the surface elevation of Lake St. Clair, and, second, ice during the winter season.

The formula for the discharge of St. Clair River during the summer months includes the surface elevation of both Lakes Huron and St. Clair. It is given on page 2821 of the Report of the Chief of Engineers for 1902, as follows:

Discharge in s-f=190,700+37,500(H—580 ft.)—18,000(St. Clair—575 ft.), in which H=the surface elevation of Lake Huron as herewith given in Table II, and St. Clair=the surface elevation of Lake St. Clair as herewith given in Table III. This formula is used in computing the discharge of the St. Clair River for the summer months—June to November, inclusive. For the winter months—December to April, inclusive—this formula is not applicable because of the ice effects.

A formula for the discharge of St. Clair River when the elevation of Lake Huron is alone considered is given on page 5362 of the Report of the Chief of Engineers for 1900, as follows:

Discharge in s-f=194,900+19,060 x (H—580 ft.), H being the elevation of Lake Huron as given in Table II.

During the winters of 1900, 1901, and 1902 the ice effects were measured. The results are given on page 2837 of the Report of the Chief of Engineers for 1902, and show that the discharge from Lake Huron as computed from the preceding formula was diminished by ice, as follows:

	Second-feet.
December	8,600
January	41,750
February	60,833
March	55,700
April	39,550
May	11,000

Since these three years' observations are all that is known of ice effects it is assumed that they show the average effect of ice. Therefore the discharge for the winter months was first computed from the preceding formula and then each month reduced by the quantities in the above table. This determination of the winter discharge of St. Clair River has the least data and is the most involved and uncertain of any of the discharge determinations. The ice effects are certainly very erratic, and the assumption that the mean of the three observed years is the mean of the forty-three years considered may be somewhat in error.

The outflow from Lake Erie was measured at International Bridge, Niagara River, from 1898 to 1900. The results are given in the Report of the Chief of Engineers for 1900, pages 5326 et seq. The formula for the discharge of Niagara River derived from these results is as follows:

Discharge in s-f=158,500+22,462(C—570 ft.).

C is the elevation of Lake Erie as herewith given in Table IV.

This formula may require two small corrections: First, the discharge should be increased by the flow through the Welland and Erie canals. The flow through the Welland Canal is is estimated by the department of railways and canals of Canada as 1,100 s-f. The flow through the Erie Canal is estimated by the New York engineer for water supply as 1,200 s-f, making a total of 2,300 s-f. The second correction is due to a difference between the zeros of the gauges at Cleveland and Buffalo. This difference has been observed and determined for calm weather, when it amounts to about 8,500 s-f. For use in this connection the mean for both calm and windy

weather should be known; therefore, on account of the remaining uncertainties in these two corrections, neither of them has been applied. The two corrections are in opposite directions and tend to eliminate each other.

The outflow from Lake Ontario was measured from 1900 to 1902. The resulting formula for the discharge of St. Lawrence River is given on page 2793 of the Report of the Chief of Engineers for 1902, and is as follows:

Discharge in s-f=946833+25761 (0—240 ft.),

in which 0 is the elevation of Lake Ontario at Oswego, as herewith given in Table IX.

It was found that for Lake Ontario there was a small correction, due to ice effects, for the winter months. These corrections are given on page 2809 of the Report of Chief of Engineers for 1902, and are as follows:

Percentage of loss on account of ice:	Per cent.
January	6.2
February	9
March	5.3
April	1.2

These percentages have been computed and subtracted from the discharge, as given by the preceding formula.

In the preceding formula the elevation of lake surface above sea level is expressed in feet, and "s-f" means cubic feet per second.

Discharge measurements are still continued by the lake survey, so that it is probable that the preceding formula will in time be slightly modified, so as to be a little more exact, but no large change is expected or possible.

By means of the preceding formula the discharge tables herewith given (VI to IX) have been derived from the tables of surface elevation herewith given (I to V).

RAINFALL.

The rainfall (which includes snowfall) has been compiled from the records of the United States Weather Bureau and the Canadian meteorological service. The period chosen is the sixteen years from 1882 to 1898. The years before 1882 were not used, because the number of stations where rainfall records were kept were few in number; the four years since 1898 could now be added, and thus increase the value of the result. The stations at which observations were made are shown on Plate I herewith. The Weather Bureau stations

are indicated by special marks; the other stations are volunteer stations. At many of these observations were made for only a part of the time. It will be seen that the stations are quite unsymmetrically placed in the basin, most of them being in the southern part. This is the most serious defect in the rainfall data. Since the rainfall diminishes both to the north and to the west, it is evident that the direct mean of the rainfall as observed at these stations would be greater than the mean rainfall of the whole basin. To avoid this source of error as far as possible two methods of reduction were employed. The first was to prepare a map for each month on which the stations used during that month were plotted in their proper geographical positions; the inches of rainfall at each station were written in figures, then curves of equal rainfall were drawn among the plotted points as contours are drawn. These curves show the regions of equal rainfall; the irregular areas bounded by these curves were then measured with a planimeter and each one multiplied by its rainfall, and a mean of all taken, which was assumed to be the mean rainfall in the basin for that month. This method was applied from 1883 to 1893; it required a great amount of work, and was finally changed to the second method, which was shorter and perhaps equally accurate, as follows:

The Weather Bureau has determined the lines of equal rainfall from all available data and published the results in the form of a map (Plate VII of report for 1897); from this map the rate of change in rainfall due to the change in latitude and longitude was determined for each basin. The mean latitude and longitude of the basins was also found; then the rainfall at each station was corrected by its distance in latitude and longitude from the center of the basin.

The results for the several basins are herewith given in Tables X to XIII, and are as follows:

The mean annual rainfall in—	Inches.
Lake Superior basin	=26.27
Lakes Huron and Michigan basins	=32.12
St. Clair and Erie basins	=34.08
Ontario basin	=36.87

The rainfall records are kept in inches, while the unit of discharge is cubic feet per second, or s-f. In order to compare them with each other it is necessary to express both quantities in the same unit; for this purpose the following table is prepared, which shows the equivalent in s-f of the rainfall in the several basins:

Annual rainfall—	s-f.
Superior basin	=147,164
Huron and Michigan	=325,857
St. Clair and Erie	=102,308
Ontario	= 89,557

EVAPORATION.

It is assumed that if the mean annual discharge or outflow from a basin be subtracted from the mean annual rainfall into the basin the remainder will be the mean annual evaporation. For the basin of Lake Superior the mean annual rainfall from the preceding table is 147,164 s-f. The mean annual discharge for sixteen years (1882-1898) from Table VI herewith is 69,954 s-f; the difference is 77,210 s-f=13.78 inches. There is a small correction to apply to this quantity, due to the fact that Lake Superior was 1.31 inches higher at the end of the period considered than at the beginning; this makes a correction of —0.03 inch, and the evaporation for the Lake Superior basin is 13.75 inches.

For the Huron and Michigan basins the mean annual rainfall from the preceding table is 325,857 s-f. The inflow from St. Marys River from Table VI herewith is 69,954 s-f, making the total inflow 395,811 s-f. The discharge or outflow from Table VII herewith is 191,980 s-f. The difference between the inflow and outflow is, then, 203,831 s-f=20.29 inches.

There is a correction to apply to this quantity, due to the fact that Lakes Huron and Michigan were 22.8 inches lower at the end of the period considered (1882 to 1898) than at the beginning; this makes a correction of +0.47 inch, and the evaporation of the Huron and Michigan basin is 20.56 inches.

For the St. Clair and Erie basin the mean annual rainfall from the preceding table is 102,308 s-f. The inflow from St. Clair River from Table VII herewith is 191,980 s-f, making the total inflow 294,288 s-f. The discharge or outflow from Table VIII herewith is 216,468 s-f. The difference between the inflow and outflow is, then, 77,820 s-f=25.90 inches. There is a correction to apply to this quantity, due to the fact that Lake Erie was 12.30 inches lower at the end of the period than at the beginning; this makes a correction of +0.20 inch, and the evaporation of the St. Clair and Erie basin is 26.10 inches.

For the Ontario basin the mean annual rainfall from the preceding table is 89,557 s-f. The inflow from Niagara River is 216,468 s-f, making the total inflow 306,025 s-f.

The discharge or outflow through the St. Lawrence River from Table IX herewith is 248,518 s-f. The difference between the inflow and outflow is, then, 57,507 s-f=23.67 inches. There is a correction to apply to this quantity, due to the fact that Lake Ontario was 10.56 inches lower at the end of the period than at the beginning; this makes a correction of +0.15 inch, and the evaporation of the Ontario basin is 23.82 inches.

WEATHER BUREAU RECORDS.

Temperature, humidity, and wind, together with rainfall, are the four elements which very largely control evaporation. These have accordingly been compiled from the Weather Bureau records. On account of the unsymmetrical geographical distribution of the stations in the basins, a direct mean of the observations would not give a correct mean for the basin. For use and further reference in connection with this report and discussion, the Weather Bureau observations have therefore been reduced in the same manner as previously described for rainfall, and, as so reduced, are given in Tables X to XXV herewith.

GENERAL RESULT.

The results for each basin are herewith summarized, as follows:

Superior basin.

Area of drainage basin	square miles	76,100
Area of Lake Superior	do	32,100
Discharge St. Marys River (mean 1882-1898)	s-f	69,954
Discharge St. Marys River (mean 1860-1903)	do	77,345
Annual rainfall (mean 1882-1898)	inches	26.27
Annual evaporation (mean 1882-1898)	do	13.75
Temperature (mean 1882-1898)		35°.95 F.
Wind, velocity per hour (mean 1882-1898)	miles	9.7
Humidity, percentage of saturation (mean 1882-1898)	per cent.	76.5

Huron and Michigan basins.

Area of drainage basin	square miles	137,800
Area of Lakes Huron and Michigan	do	45,500
Discharge St. Clair River (mean 1882-1898)	s-f	191,980
Discharge St. Clair River (mean 1860-1902)	do	197,820
Annual rainfall (mean 1882-1898)	inches	32.21
Annual evaporation (mean 1882-1898)	do	20.56
Temperature (mean 1882-1898)		42°.08 F.
Wind, velocity per hour (mean 1882-1898)	miles	10.3
Humidity, percentage of saturation (mean 1882-1898)	per cent.	76.5

St. Clair and Erie basins.

Area of drainage basin	square miles	40,800
Area of Lakes St. Clair and Erie	do	10,600
Discharge Niagara River (mean 1882-1898)	s-f	207,468
Discharge Niagara River (mean 1860-1902)	do	219,843
Annual rainfall (mean 1882-1898)	inches	102.308
Annual evaporation (mean 1882-1898)	do	26.10
Temperature (mean 1882-1898)		48°.01 F.
Wind, velocity per hour (mean 1882-1898)	miles	10.4
Humidity, percentage of saturation (mean 1882-1898)	per cent.	73.6

Ontario Basin.

Area of drainage basin	square miles	33,000
Area of Lake Ontario	do	7,400
Discharge of St. Lawrence River (mean 1882-1898)	s-f	248,518
Discharge of St. Lawrence River (mean 1860-1902)	do	251,930
Annual rainfall (mean 1882-1898)	inches	36.87
Annual evaporation (mean 1882-1898)	do	23.82
Temperature (mean 1882-1898)		44°.10 F.
Wind, velocity per hour	miles	10.6
Humidity, percentage of saturation (mean 1882-1898)	per cent.	74.9

These results are apparently consistent with each other, at least within the limits of the accuracy of the data. Formerly there was a marked inconsistency between the derived discharges of the St. Clair and Niagara and St. Lawrence rivers, the St. Clair being nearly as large as the Niagara, and the St. Lawrence being very much larger than the Niagara. The investigations of ice effects, made by the United States lake survey, has reduced the derived discharge of both the St. Clair and the St. Lawrence rivers, so that now their relation to the derived discharge of the Niagara is entirely reasonable, and there is no longer cause for the theory that a part of the discharge from Lake Erie passes by underground percolation into Lake Ontario.

Very respectfully,

E. S. Wheeler,
Assistant Engineer.

Maj. William H. Bixby,
Corps of Engineers, U. S. Army.

APPENDIX A.

Memoranda prepared July 17, 1900, by Asst. Engineer E. S. Wheeler, for the discussion of the discharge observations made in St. Marys River at Sault Ste. Marie in 1896-1899, under the river and harbor office of Col. G. J. Lydecker, showing the data and methods used in determining formulae for Lake Superior outflow.

Four separate groups of observations were made and two different cross sections used during 1896-1899. In 1896 Mr. E. E. Haskell made 34 measurements at the Spry dock section and 11 measurements at the bridge section. The former were published in the Annual Report of the Chief of Engineers for 1897. In 1899 Mr. T. Russell made 65 measurements at the Spry dock section and 34 at the bridge section.

The measurements at Spry dock section include the entire outflow from Lake Superior; those at the bridge section include only the flow which passes under the bridge. A gauge at the south end of the bridge was read for all four groups. This gauge is in span 1, which is a part of the Chandler-Dunbar canal; its relation to the bowlder gauge was determined by several sets of simultaneous observations, as follows:

Gauge at bridge.	Gauge at bowlder.	Gauge at bridge.	Gauge at bowlder.	Gauge at bridge.	Gauge at bowlder.	Gauge at bridge.	Gauge at bowlder.
Feet.		Feet.		Feet.		Feet.	
601.70	+ .11		.20		.17		.17
.80	.11		.20		.16		.16
.91	.10		.19		.17		.17
.91	.11		.19		.17		.16
601.90	.11		.19		.17		.16
602.00	.11		.19		.16		.16
.00	.11		.19		.16		.16
.10	.11		.18		.16		.16
.17	.11	602.00	.21		.16		.17

The mean of this determination is 0.17 feet; and a comparison of these observations does not indicate any change due to stage. The difference between the gauge at the bowlder and at the bridge was therefore taken as 0.17 feet at all stages, and the bridge gauge readings were increased by this amount, so that in the following discussion all gauge readings have been reduced to and referred to the gauge at the west end of the southwest canal pier.

In order to make the four groups of measurements comparable with each other, the two Spry dock groups were diminished by the amount that was passing outside of the bridge at the time the observations were made. The outside flow was measured in 1896 and found to be 5,000 s-f at stage 601.17, with an increment of 950 s-f for each foot of rise in the gauge. In 1899 the outside flow was found to be 10,768 s-f

at stage 601.17, with the same increment of 950 s-f for each foot of rise in the gauge. The flow under the bridge resulting from such measurements and corrections is as given in the following tables:

[From current measurements made at Spry dock in 1896 by E. E. Haskell.]

Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.
Feet.	*S-f.*	*Feet.*	*S-f.*	*Feet.*	*S-f.*
600.95	a 54,720	601.20	63,020	601.42	68,140
601.02	55,800	.26	63,770	.44	68,330
.07	56,250	.26	63,954	.45	68,205
.07	56,660	.26	64,204	.46	68,045
.09	56,831	.27	63,045	.49	68,430
.10	60,106	.27	63,606	.49	68,946
.21	57,679	.28	63,275	.50	68,260
.25	59,869	.30	63,694	.50	67,096
.28	62,049	.41	64,517	.51	69,207
.28	62,269	.43	63,045	.52	64,467
.27	60,560	.43	63,449	.53	66,888
.27	61,650	.44	63,965	.55	69,450
.28	62,971	.46	63,139	.71	69,452
.28	63,121	.46	64,099	.72	a 64,615
.29	59,863	.46	63,440	.88	69,227
.30	62,971	.47	64,010	.88	71,097
.31	61,045	.47	63,570		
.32	61,255	.51	63,289	601.41	68,980
.32	61,702	.51	62,913	Increment, 17.139.	

a These figures are questionable.

[From current measurements made at Spry dock in 1896 by T. Russell.]

Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.
Feet.	*s-f.*	*Feet.*	*s-f.*	*Feet.*	*s-f.*
600.92	53,897	601.10	58,483	601.19	67,020
.97	53,738	.10	59,031	.19	66,736
.00	54,504	.11	58,519	.19	66,897
.00	55,656	.11	58,703	.19	66,967
.03	54,954	.11	60,809	.20	66,021
.03	54,060	.11	59,805	.20	65,809
.05	55,139	.13	57,897	.20	66,730
.07	55,688	.16	57,758	.21	67,009
.07	53,877	.13	55,046	.23	65,204
.09	55,408	.14	58,090	.23	65,809
601.00	55,440	.14	58,897	.25	65,011
.00	55,881	.14	58,698	.25	65,743
.04	55,730	.15	56,419	.29	69,964
.05	55,660	.15	57,980	.29	64,5297
.06	56,617	.15	56,468	.40	63,560
.08	54,497	.15	57,080	.41	66,729
.08	56,964	.15	66,129	.44	66,075
.08	55,480	.16	56,440	.55	69,7827
.08	55,603	.16	56,996	.57	64,5099
.08	56,287	.17	57,288		
.08	55,965	.17	64,397	601.12	56,986
.08	57,191	.19	59,647	Increment, 15,389.	
.10	54,493	.19	59,586		

[From current measurements made at bridge in 1896 by E. E. Haskell.]

Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.
Feet.	*s-f.*	*Feet.*	*s-f.*	*Feet.*	*s-f.*
601.38	69,540	601.90	69,897	600.98	66,276
.36	69,310	.93	70,510		
.49	70,080	.97	69,943	601.41	77,028
.73	77,028	602.05	69,260	Increment, 10,897.	
.85	79,109	.14	64,408		

[From current measurements made at the bridge in 1899 by T. Russell.]

Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.	Bowlder gauge.	Discharge.
Feet.	*c-f*	*Feet.*	*c-f*	*Feet.*	*c-f*
601.61	68,921	602.26	80,676	602.52	88,326
.69	71,466	.27	80,883	.53	84,210
.86	74,252	.39	80,898	.54	85,722
.95	76,047	.32	81,009	.56	85,213
.98	76,176	.33	82,706	.64	87,599
602.13	78,577	.34	81,950	.64	88,638
.13	77,469	.39	83,106	.65	88,072
.17	79,300	.44	84,914	.67	87,850
.21	79,088	.45	83,850	.67	86,736
.21	81,397	.47	83,297	602.98	97,196
.24	80,483	.49	84,395	602.31	82,194
.25	81,835	.52	85,184	Increment, 16,430.	

These groups have also been discussed and platted separately, the discharge in each case being represented graphically by a straight line.

In their discussions the groups were given different weights due to the number of observations, range in gauge readings, and accuracy of rating, and the discharge at the mean stage was found by giving to each group a weight equal to the product of its rating into the square root of the number of observations.

The relative weight was assigned as follows:

Spry dock:

1896..... 10
1899..... 8

Bridge:

1899..... 3
1896..... 1

The number of observations was as follows:

Spry dock:

1896..... 52
1899..... 62

Bridge:

1899..... 34
1896..... 11

The results of the four groups were then:

	Date.	Gauge.	Discharge.	Weight.
Spry dock	1896	601.41	68,980	10×√52
Do	1899	601.19	86,926	8×√62
Bridge	1899	602.31	82,194	3×√34
Do	1896	601.31	77,669	1×√11

Giving at stage 601.402 a discharge of 63,000 s-f.

The increase in discharge for 1 foot change in gauge was found by giving to each group a weight equal to the product of its rating and range in gauge reading, as follows:

Spry dock:		
1896	17,139	10×10
1899	15,963	8× 7
Bridge:		
1899	16,426	3×17
1896	18,227	1× 9

Giving 16,706 s-f. as the change in discharge for 1 foot change in gauge reading; and at gauge 600, a discharge of 39,578 s-f; and a discharge equation of—

(1) Discharge=39,578+16,706×(gauge —600),

applicable to the discharge under 8 spans of the bridge, not including spans 1 and 2, which are in the Chandler-Dunbar Water Power Canal.

The observations show that the discharge curve may be taken as a linear function of elevation without appreciable error, at least within the small range of elevation used. To obtain the total flow in the river there must be added the flow through the Canadian Water Power, the Chandler-Dunbar Water Power, the two ship canals, and the two small streams on the Canadian side.

The flow through the river before the building of the bridge will first be determined. From a report (with sketches) of Asst. Engineer E. E. Haskell, dated June 11, 1896,* it is found that the building of the bridge and approaches and other works (largely in shallow parts of the river), done between 1887 and 1892, diminished the cross-section of the river (at stage 601.53) 38 per cent. in width and 26.4 per cent. in area, diminished the discharge 14 per cent., and increased the mean velocity 17 per cent. (The sketch which accompanies Mr. Haskell's report shows that the width of the cross-section before 1888 was 4,200 feet and after the obstructions were made was only 2,600 feet.) From this data it is possible to determine the discharge equation before 1888. First, by the preceding equation the discharge is zero at stage 597.63, and therefore (assuming the discharge curve to be a straight line) 597.63 must be the elevation of the bottom of the river. This

*Not published.

therefore there is already one gauge reading, viz, 597.63, at which the discharge before 1888 is known. If now the increment for unit of gauge can be determined the discharge equation will be complete. Since the discharge after obstruction is 14 per cent. less than before, the increment after obstruction must be 14 per cent. less than the increment before. Since the increment after obstruction is 16,706 s-f, it follows that the increment before was 19,429 s-f. Since the discharge is zero at gauge 597.63, the discharge at gauge 600 is 46,047 s-f, and a new discharge equation may be written.

(2) Discharge=46,047+19,429×(gauge—600),
applicable to all gauge readings before 1888.

Between 1888 and 1895 the only outside flow was through two small streams on the Canadian side and through the United States canal. The amount of this flow is estimated as 1,674 s-f at stage 601.53, with an increment of 950 s-f for foot of rise. Adding the corrections to equation (1) there results the following:

(3) Discharge=39,798+17,656×(gauge—600),
applicable to all gauge readings from 1888 to 1895, both years inclusive.

The outside flow from 1896 to 1898 includes the two ship canals, the two water powers, and the two small streams; the total is estimated as 5,000 s-f at stage 601.17 with an increment of 950 s-f for each foot of rise. Adding these amounts to equation (1) there results the following,

(4) Discharge=43,466+17,656×(gauge—600),
applicable to all gauge readings from 1896 to 1898, inclusive.

In 1899 both water powers had been enlarged, and it is estimated that the total outside flow at stage 601.17 was 10,768 with an increment of 950 s-f. Adding these corrections to equation (1) there results,

(5) Discharge=49,235+17,656×(gauge—600),
applicable to gauge readings in 1899 and until further changes are made in the outside flow.

Collecting the equations, the relation between discharge and gauge at southwest canal pier is therefore assumed as follows:

Equation for discharge through eight spans of the bridge,

$$\text{Discharge}=39{,}578+16{,}706\times(\text{gauge}-600) \quad (1)$$

Equation for total discharge before 1888,

$$\text{Discharge}=46{,}047+19{,}429\times(\text{gauge}-600) \quad (2)$$

Equation for total discharge from 1888 to 1895, inclusive,

$$\text{Discharge}=39{,}798+17{,}656\times(\text{gauge}-600) \quad (3)$$

would be equally true before the obstructions were made, and

Equation for total discharge from 1896 to 1898, inclusive,

$$\text{Discharge}=43{,}466+17{,}656\times(\text{gauge}-600) \quad (4)$$

Equation for discharge in 1899 and until further changes are made,

$$\text{Discharge}=49{,}235+17{,}656\times(\text{gauge}-600) \quad (5)$$

TABLE I.—*Showing, in feet, the mean monthly elevation of Lake Superior above locks at St. Marys Falls Canal.*

Date.	January.	February.	March.	April.	May.	June.
1860	601.99	601.74	601.74	602.24	602.47	602.64
1861	602.08	601.70	601.56	601.97	602.00	602.75
1862	601.74	601.55	601.56	601.64	602.32	602.56
1863	601.71	601.58	601.41	601.45	601.56	601.56
1864	601.35	601.15	601.22	601.24	601.40	601.23
1865	601.02	601.01	600.88	601.33	601.81	602.12
1866	601.39	601.38	601.01	601.53	601.78	601.91
1867	601.75	601.64	601.45	601.67	601.67	602.27
1868	601.63	601.04	601.40	601.50	601.99	602.09
1869	601.05	601.41	600.96	601.54	601.94	601.95
1870	601.87	601.65	601.67	601.77	602.10	602.01
1871	601.165	601.002	600.786	600.859	601.446	601.664
1872	600.948	600.884	600.628	600.580	601.469	601.627
1873	601.285	601.109	601.186	601.152	601.709	601.825
1874	601.471	601.314	601.205	601.084	601.501	601.589
1875	601.606	601.448	601.407	601.467	601.961	602.252
1876	601.644	601.502	601.337	601.373	602.107	602.454
1877	601.835	601.660	601.746	601.621	601.935	601.998
1878	601.473	601.316	601.114	601.068	601.373	601.622
1879	600.925	600.435	600.182	600.311	600.695	600.866
1880	600.339	600.293	600.139	600.217	600.957	601.734
Mean	601.422	601.270	601.173	601.329	601.737	601.962

TABLE I.—*Showing, in feet, the mean monthly elevation of Lake Superior above locks at St. Marys Falls Canal*—Continued.

Date.	July.	August.	September.	October.	November.	December.
1860	602.60	602.62	602.65	602.67	602.59	602.54
1861	602.91	602.87	602.78	602.61	602.47	602.49
1862	602.52	602.45	602.37	602.30	602.17	601.90
1863	601.94	602.39	602.25	602.11	601.78	601.65
1864	601.94	601.85	601.80	601.84	601.65	601.50
1865	602.54	602.62	602.61	602.42	601.98	601.52
1866	602.39	602.49	602.52	602.34	602.04	602.02
1867	602.60	602.45	602.56	602.54	602.11	601.79
1868	602.12	602.04	602.17	602.14	602.30	601.87
1869	602.52	602.79	602.69	602.51	602.77	602.19
1870	602.10	602.10	602.27	602.11	601.98	601.00
1871	602.095	601.954	602.005	601.805	601.698	601.190
1872	602.041	602.267	602.420	602.291	602.157	601.962
1873	602.869	602.893	602.895	602.683	602.549	602.067
1874	602.307	602.304	602.265	602.477	602.307	602.180
1875	602.940	602.989	602.945	602.819	602.698	601.673
1876	602.145	602.191	602.225	602.080	602.019	602.120
1877	602.177	602.289	602.095	602.009	601.895	601.699
1878	601.741	601.699	601.415	601.288	601.441	601.289
1879	601.124	601.152	601.075	601.009	600.961	600.888
1880	601.956	601.886	601.901	601.787	601.701	601.517
Mean	602.196	602.262	602.249	602.101	602.012	601.874

Date.	January.	February.	March.	April.	May.	June.
1861	601.199	601.105	601.126	601.011	601.427	601.925
1862	601.489	601.371	601.154	601.103	601.514	601.958
1863	601.145	601.040	601.060	601.128	601.118	601.485
1864	601.131	600.940	600.864	600.664	601.055	601.120
1865	601.247	601.128	600.988	600.982	601.408	601.741
1866	601.004	600.889	600.846	600.988	601.301	601.467
1867	600.945	600.810	600.778	600.661	600.986	601.442
1868	600.945	600.804	600.645	600.695	601.288	602.085
1869	601.288	601.089	601.080	601.005	601.616	601.796
1870	601.804	600.720	600.728	600.687	601.120	601.704
1871	600.668	600.778	600.627	600.501	601.501	601.180
1872	600.515	600.467	600.577	600.430	600.940	601.930
1873	600.669	600.664	600.498	600.649	601.295	601.757
1874	601.095	600.951	600.841	601.288	602.204	602.441
1875	601.801	601.696	601.484	601.442	601.945	602.082
1876	601.468	601.407	601.288	601.280	601.995	602.207
1877	601.722	601.416	601.421	601.287	601.910	602.270
1878	601.189	600.988	600.808	601.089	601.531	601.888
1879	601.028	601.117	601.097	601.051	601.919	602.207
1880	601.977	601.770	601.939	602.084	601.516	601.774
1881	602.097	601.994	601.979	601.707	602.086	602.044
1882	601.74	601.57	601.49	601.56	602.90	602.17
Mean	601.275	601.099	601.028	601.049	601.849	601.933

Date.	July.	August.	September.	October.	November.	December.
1861	601.969	601.790	601.599	602.427	602.324	602.026
1862	601.948	602.097	601.920	601.908	601.940	602.073
1863	601.691	602.086	601.728	601.876	601.499	601.989
1864	601.979	601.417	601.434	601.549	601.677	601.413
1865	602.919	602.148	602.004	601.781	601.649	601.288
1866	602.089	601.773	601.684	601.682	601.886	601.166
1867	601.819	601.744	601.646	601.739	601.560	601.085
1868	602.248	602.227	602.150	602.140	601.941	601.618
1869	602.098	602.070	602.040	601.916	602.017	601.999
1870	602.028	601.974	601.940	602.119	601.926	601.818
1871	602.268	602.274	602.226	601.994	601.146	602.040
1872	601.440	602.451	602.559	601.402	601.128	602.041
1873	602.868	602.098	602.006	601.847	601.799	601.868
1874	602.247	602.201	602.089	602.001	601.438	602.121
1875	602.469	602.427	602.095	602.179	602.256	602.048
1876	602.098	602.140	602.111	601.966	602.015	602.051
1877	602.469	602.284	602.285	602.271	602.197	601.979
1878	601.974	602.098	602.086	602.096	601.997	602.010
1879	602.097	602.719	602.695	602.571	602.412	602.468
1880	602.041	602.248	602.199	602.094	602.079	602.099
1881	602.419	602.284	602.099	602.074	602.119	602.136
1882	602.40	602.26	602.42	602.39	602.36	602.07
Mean	602.093	602.109	602.097	602.087	601.913	601.995

TABLE II.—*Showing, in feet, the mean monthly elevation of Lakes Huron and Michigan at Sand Beach.*

Date.	January.	February.	March.	April.	May.	June.
1860	582.32	582.27	582.41	582.36	582.46	582.47
1861	581.49	581.58	581.66	581.66	581.69	581.69
1862	581.66	581.66	581.62	582.04	582.41	582.51
1863	581.95	581.70	581.65	581.73	582.04	582.01
1864	581.39	581.34	581.34	581.44	581.67	581.81
1865	580.81	580.30	580.47	580.98	581.13	581.31
1866	580.13	579.96	579.93	580.20	580.54	580.77
1867	580.84	580.50	580.77	581.09	581.26	581.47
1868	580.10	580.03	580.74	580.94	581.05	581.19
1869	579.90	579.97	579.71	580.05	580.41	580.61
1870	580.17	580.36	581.16	581.55	581.98	582.17
1871	581.23	581.14	581.74	581.94	582.29	582.57
1872	580.40	580.32	579.79	580.20	580.91	581.19
1873	579.09	579.08	580.13	580.54	581.04	581.31
1874	581.21	581.36	581.49	581.94	581.97	581.97
1875	580.65	580.59	580.65	580.99	581.17	581.31
1876	581.00	581.21	581.34	581.68	582.03	582.13
1877	581.96	581.94	581.97	581.95	582.13	582.31
1878	581.55	581.36	581.56	581.48	581.86	581.97
1879	581.08	580.78	580.74	580.77	580.99	581.19
1880	580.54	580.49	580.47	580.48	580.88	581.07
Mean	580.975	580.889	581.015	581.304	581.589	581.781

Date.	July.	August.	September.	October.	November.	December.
1860	582.78	582.69	582.69	582.11	581.99	581.99
1861	582.94	583.05	582.97	582.73	582.44	582.31
1862	582.51	582.54	582.34	582.09	582.20	582.11
1863	582.05	582.00	581.95	581.69	581.46	581.31
1864	581.89	581.79	581.49	580.97	580.70	580.51
1865	581.30	581.41	581.49	581.25	580.99	580.81
1866	581.11	581.17	581.09	580.91	580.68	580.49
1867	581.74	581.67	581.49	581.07	580.81	580.61
1868	581.16	580.99	580.86	580.65	580.39	580.19
1869	581.38	581.30	581.17	581.11	580.94	580.77
1870	582.17	582.01	582.29	581.99	581.68	581.48
1871	582.38	582.15	581.73	581.38	581.05	580.85
1872	581.10	581.07	580.97	580.85	580.68	580.48
1873	581.64	581.66	581.49	581.48	581.26	581.06
1874	581.89	581.79	581.69	581.38	580.79	580.61
1875	581.07	581.04	581.08	581.49	581.26	581.06
1876	582.13	582.09	582.09	582.06	582.03	581.93
1877	582.36	582.16	581.89	581.73	581.70	581.50
1878	582.09	581.99	581.79	581.71	581.48	581.28
1879	581.08	580.98	580.77	580.69	580.51	580.31
1880	581.07	581.07	581.06	581.10	580.99	580.79
Mean	581.914	581.866	581.709	581.449	581.244	581.064

Date.	January.	February.	March.	April.	May.	June.
1861	580.65	580.61	580.65	580.67	580.89	580.97
1862	581.44	581.42	581.38	581.57	581.74	581.84
1863	581.26	581.17	581.21	581.29	581.79	581.89
1864	582.05	581.99	581.94	582.25	582.47	582.57
1865	581.49	581.37	581.37	581.69	582.09	582.29
1866	582.13	582.08	582.03	582.71	583.04	583.24
1867	581.73	581.64	581.75	582.03	582.36	582.56
1868	580.89	580.74	580.91	581.09	581.49	581.69
1869	580.74	580.69	580.64	580.97	581.73	581.93
1870	581.07	581.13	581.37	581.97	582.18	582.38
1871	582.69	582.61	582.69	582.91	582.46	582.66
1872	579.49	579.46	579.49	579.89	580.69	580.89
1873	579.89	579.86	579.89	579.78	580.37	580.57
1874	579.73	579.73	579.69	580.11	580.51	580.71
1875	579.89	579.89	579.89	579.91	579.99	580.19
1876	579.89	579.77	579.69	579.79	579.99	580.19
1877	579.61	579.69	579.69	579.69	579.97	580.17
1878	579.89	579.89	579.89	580.09	580.13	580.33
1879	579.89	579.89	579.89	579.88	579.88	580.08
1880	579.84	579.79	579.69	579.64	579.69	579.89
1881	579.69	579.69	579.69	580.10	580.26	580.46
1882	579.81	579.81	579.85	579.95	579.99	580.19
Mean	580.367	580.327	579.360	580.474	580.736	580.936

TABLE II.—*Showing, in feet, the mean monthly elevation of Lakes Huron and Michigan at Sand Beach*—Continued.

Date.	July.	August.	September.	October.	November.	December.
[illegible]	581.71	581.54	581.36	581.46	581.76	581.89
[illegible]	582.11	582.17	582.05	581.98	581.87	581.49
[illegible]	582.69	582.69	582.67	582.54	582.25	582.24
[illegible]	582.61	582.49	582.14	582.00	581.69	581.69
[illegible]	582.73	582.55	582.70	582.59	582.39	582.13
[illegible]	582.97	582.88	582.64	582.51	582.24	581.99
[illegible]	582.46	582.25	581.99	581.86	581.59	581.34
581. 66	581.56	581.46	581.27	581.09	580.94
581. 30	581.24	581.07	580.70	580.38	580.23
581. 20	581.20	580.98	580.72	580.52	580.35
580. 43	580.39	580.14	579.77	579.43	579.43
580. 45	580.53	580.38	580.15	580.09	579.85
580. 84	580.70	580.41	580.20	579.97	579.77
580. 98	580.69	580.50	580.26	580.07	579.77
579. 73	579.68	579.50	579.21	579.03	578.58
579. 58	579.57	579.39	579.19	579.05	578.98
580. 39	580.40	580.14	579.79	579.67	579.37
580. 89	580.97	580.06	579.77	579.69	579.39
580. 64	580.55	580.25	579.94	579.80	579.41
580. 11	580.20	580.26	580.26	580.26	580.08
580. 69	580.66	580.39	580.17	579.98	579.69
580. 26	580.32	580.07	579.76	579.66	579.45
Mean	581.178	581.145	580.980	580.720	580.573	580.311

TABLE III.—*Showing, in feet, the mean monthly elevation of Lake St. Clair at St. Clair Flats Canal.*

Date.	June.	July.	August.	September.	October.	November.
[illegible]	577.08	577.00	576.89	576.99	576.87	576.99
[illegible]	577.89	577.13	577.80	577.05	576.89	576.75
[illegible]	577.13	577.14	576.94	576.73	576.67	576.99
[illegible]	576.79	576.66	576.60	576.37	576.06	575.96
[illegible]	576.69	576.26	576.19	575.96	575.80	575.69
[illegible]	575.94	576.10	576.07	576.00	575.77	576.07
[illegible]	576.09	576.00	575.90	575.81	575.70	575.69
[illegible]	576.89	576.94	576.77	576.69	575.69	575.75
[illegible]	576.06	576.06	575.69	576.45	575.15	576.06
[illegible]	575.97	576.09	576.20	576.15	575.96	575.94
[illegible]	576.69	576.69	576.66	576.67	576.66	576.64
[illegible]	576.57	576.67	576.25	576.15	575.69	575.67
[illegible]	575.66	575.61	575.53	575.43	575.39	574.99
[illegible]	575.70	575.84	575.59	575.60	575.75	575.69
[illegible]	575.17	575.24	575.25	575.06	575.09	575.11
[illegible]	575.69	575.15	575.05	575.60	575.73	575.69
[illegible]	577.46	577.49	577.45	576.98	576.65	576.64
[illegible]	576.69	576.47	576.25	575.13	576.05	575.18
[illegible]	576.69	576.74	576.65	576.81	576.13	575.79
[illegible]	575.89	575.91	575.70	575.52	575.57	575.11
[illegible]	576.19	576.29	576.15	576.97	576.73	576.07
Mean	576.59	576.45	576.35	576.15	575.91	575.70

Date.	June.	July.	August.	September.	October.	November.
[illegible]	576.26	576.40	576.29	576.01	575.81	575.89
[illegible]	577.30	577.26	577.25	577.16	576.89	576.11
[illegible]	577.01	577.08	577.09	577.14	576.77	576.69
[illegible]	577.27	577.28	577.08	576.97	576.45	576.76
[illegible]	577.04	576.96	577.05	576.91	576.89	576.86
[illegible]	576.96	576.99	576.87	576.73	576.58	576.32
[illegible]	576.89	576.80	576.69	576.54	576.61	576.69
[illegible]	576.96	576.97	576.17	576.09	575.86	575.89
[illegible]	576.86	576.99	576.85	576.84	576.86	576.97
[illegible]	576.26	576.21	576.07	575.73	576.13	575.49
[illegible]	576.89	576.80	576.69	576.54	576.74	576.80
[illegible]	576.78	576.89	576.85	576.84	576.69	576.70
[illegible]	576.89	576.97	576.87	576.36	576.10	576.69
[illegible]	574.57	574.69	574.69	574.47	574.07	574.79
[illegible]	574.64	574.61	574.57	574.66	574.55	574.79
[illegible]	576.89	576.77	576.84	576.69	574.73	574.65
[illegible]	575.49	575.49	575.34	575.07	574.61	574.73
[illegible]	575.89	575.49	575.32	575.08	574.79	574.69
[illegible]	575.09	575.17	575.09	575.10	574.94	574.99
[illegible]	574.97	575.26	575.16	575.16	574.84	574.36
[illegible]	576.01	575.64	575.50	575.15	575.11	574.89
Mean	576.89	576.01	575.92	575.70	575.40	575.17

TABLE IV.— *Showing, in feet, the mean monthly elevation of Lake Erie at Cleveland.*

Date.	January.	February.	March.	April.	May.	June.
1860	573.35	573.90	573.89	574.00	574.20	574.27
1861	572.70	572.42	572.08	573.90	574.23	574.09
1862	573.55	573.53	573.37	574.27	574.51	574.52
1863	573.55	573.34	573.78	573.90	574.08	574.00
1864	573.16	573.23	573.54	573.04	573.74	573.69
1865	572.10	571.89	571.94	572.50	573.14	573.12
1866	571.97	571.71	572.10	572.66	572.90	573.16
1867	572.49	572.01	572.51	572.98	573.38	573.46
1868	571.51	571.13	571.79	572.55	573.00	573.09
1869	571.74	571.67	572.15	572.45	573.00	573.19
1870	572.90	572.81	572.98	573.62	573.94	573.97
1871	573.04	572.81	573.09	573.14	573.41	573.42
1872	571.67	571.43	571.94	571.54	571.96	572.08
1873	571.26	571.26	571.20	572.61	573.28	573.42
1874	573.14	573.19	573.32	573.39	573.46	573.52
1875	571.90	571.49	571.65	572.03	573.00	573.19
1876	573.46	573.01	573.66	574.13	574.30	574.32
1877	573.04	572.98	573.45	573.59	573.13	573.15
1878	572.91	573.05	573.16	573.60	573.86	573.97
1879	573.90	573.96	573.49	573.85	573.00	573.09
1880	573.63	573.67	573.83	573.97	573.94	573.93
Mean	573.459	573.357	573.566	573.699	573.456	573.55

Date.	July.	August.	September.	October.	November.	December.
1860	574.01	573.95	573.81	573.21	573.13	573.08
1861	574.15	574.19	574.01	573.79	573.76	573.73
1862	574.45	574.10	573.79	573.41	573.07	573.01
1863	573.98	573.74	573.35	573.01	573.50	573.47
1864	573.43	573.16	573.04	573.03	573.46	573.39
1865	573.03	573.00	573.06	573.05	573.30	573.14
1866	573.37	573.03	573.05	573.05	573.71	573.71
1867	573.47	573.16	573.77	573.43	573.03	573.11
1868	573.08	573.04	573.57	573.13	573.06	573.10
1869	573.67	573.57	573.30	573.05	573.30	573.34
1870	573.95	573.80	573.55	573.17	573.07	573.05
1871	573.48	573.21	573.04	573.27	573.19	573.15
1872	573.04	573.21	573.06	573.01	573.54	573.56
1873	573.94	573.98	573.88	573.59	573.26	573.25
1874	573.56	573.48	573.06	573.62	573.10	573.09
1875	573.06	573.05	573.01	573.48	573.27	573.29
1876	574.50	574.20	574.03	573.50	573.56	573.51
1877	573.45	573.31	573.23	573.53	573.75	573.69
1878	573.96	573.69	573.49	573.14	573.24	573.23
1879	573.19	573.20	573.27	573.24	573.27	573.13
1880	573.44	573.20	573.07	573.03	573.45	573.11
Mean	573.657	573.377	573.136	573.774	573.351	573.31

Date.	January.	February.	March.	April.	May.	June.
1881	571.70	571.51	572.13	573.03	573.35	573.45
1882	573.20	573.10	573.45	573.67	574.07	574.08
1883	572.97	573.09	573.77	573.39	573.35	573.40
1884	573.56	573.14	573.39	573.35	574.13	574.09
1885	573.26	573.15	573.01	573.03	573.50	573.50
1886	573.64	573.61	573.72	573.63	573.30	573.29
1887	573.70	573.13	573.01	573.06	574.14	574.15
1888	573.26	573.09	573.19	573.03	573.07	573.05
1889	573.40	573.24	573.05	573.43	573.61	573.61
1890	573.47	573.70	573.56	573.37	573.71	573.69
1891	573.40	573.33	573.24	573.72	573.53	573.53
1892	571.49	571.10	571.33	571.79	573.59	573.61
1893	571.26	571.24	571.56	573.20	573.13	573.14
1894	571.23	571.51	571.54	573.24	573.60	573.61
1895	571.28	571.09	571.10	571.35	571.57	571.57
1896	571.05	570.97	570.98	571.37	571.75	571.75
1897	571.18	571.26	571.76	573.00	573.68	573.70
1898	571.68	571.58	572.14	573.73	573.87	573.90
1899	571.76	571.55	571.98	573.38	573.53	573.55
1900	571.43	571.68	573.01	573.38	573.46	573.47
1901	571.44	571.09	570.97	571.38	571.40	571.39
1902	571.17	570.79	571.04	571.56	571.95	571.93
Mean	573.01	571.98	572.14	573.56	573.90	573.91

TABLE IV.—*Showing, in feet, the mean monthly elevation of Lake Erie at Cleveland*—Continued.

Date.	July.	August.	September.	October.	November.	December.
[illegible]	573.42	573.10	573.75	573.70	572.84	573.73
[illegible]	574.15	574.01	573.74	573.29	572.97	573.46
[illegible]	574.26	574.19	573.90	573.56	573.19	573.21
[illegible]	574.01	573.85	573.42	573.09	572.61	572.54
[illegible]	574.09	574.04	573.89	573.72	573.57	573.69
[illegible]	573.96	573.76	573.53	573.30	573.01	573.09
[illegible]	573.90	573.61	573.26	572.79	572.69	572.54
[illegible]	573.25	573.25	573.01	573.44	573.20	572.96
[illegible]	573.24	573.09	572.64	572.12	571.96	572.11
[illegible]	573.70	573.28	573.07	573.00	572.76	573.09
[illegible]	573.57	573.39	573.13	572.74	571.30	571.37
[illegible]	573.47	573.13	572.80	572.54	571.91	571.64
[illegible]	573.04	572.70	572.28	571.97	571.57	571.65
[illegible]	573.09	572.45	572.20	571.96	571.73	571.65
[illegible]	571.35	571.47	571.37	570.89	570.79	570.95
[illegible]	571.90	572.11	571.79	571.65	571.13	571.31
[illegible]	573.73	573.56	573.28	573.79	571.96	571.69
[illegible]	573.66	573.46	573.10	571.90	571.79	571.61
[illegible]	573.57	573.19	571.94	571.70	571.71	571.49
[illegible]	573.43	573.40	573.05	571.84	571.59	571.54
[illegible]	573.00	571.97	571.90	571.43	571.35	571.29
[illegible]	573.03	573.51	573.47	573.36	573.11	571.91
Mean	573.11	573.05	573.05	573.29	572.10	572.05

TABLE V.—*Showing, in feet, the mean monthly elevation of Lake Ontario at Oswego.*

Date.	January.	February.	March.	April.	May.	June.
[illegible]	246.67	246.81	246.96	246.89	247.12	247.06
[illegible]	246.58	246.69	247.11	247.03	246.77	246.63
[illegible]	247.20	246.78	247.27	246.17	245.97	246.71
[illegible]	246.78	246.62	247.00	247.73	246.19	246.07
[illegible]	246.43	246.38	246.38	246.58	247.01	246.51
[illegible]	247.17	247.39	247.47	247.15	247.71	247.75
[illegible]	246.65	246.69	246.97	246.65	246.13	246.01
[illegible]	246.04	246.01	246.71	247.01	246.20	246.37
[illegible]	244.60	244.70	244.97	246.61	246.21	246.09
[illegible]	246.31	246.43	246.66	246.19	246.84	247.06
[illegible]	247.05	247.50	247.30	246.44	249.04	248.72
[illegible]	246.15	246.66	246.19	246.79	247.22	247.15
[illegible]	244.68	244.60	244.44	244.68	246.05	246.36
[illegible]	244.40	244.47	244.59	246.63	247.00	247.01
[illegible]	246.44	246.84	247.30	247.38	247.36	247.35
[illegible]	244.68	244.47	244.73	246.68	246.60	246.66
[illegible]	246.40	246.08	246.61	247.30	246.17	246.30
[illegible]	246.98	246.71	246.66	246.65	246.68	246.38
[illegible]	246.67	246.79	246.48	246.73	247.07	247.06
[illegible]	246.90	246.84	246.89	246.80	246.98	246.98
[illegible]	246.41	246.09	246.68	246.91	246.98	246.40
Mean	246.280	246.094	246.346	246.980	247.344	247.280

Date.	July.	August.	September.	October.	November.	December.
[illegible]	247.91	247.85	246.56	246.78	246.84	246.80
[illegible]	246.43	246.28	247.09	247.20	247.31	247.70
[illegible]	246.80	246.86	247.78	247.17	246.98	246.72
[illegible]	247.08	247.40	247.08	246.89	246.66	246.68
[illegible]	247.09	247.42	246.90	246.67	246.54	246.74
[illegible]	247.09	246.98	246.98	246.38	246.91	246.75
[illegible]	246.98	246.89	246.74	246.81	246.37	246.89
[illegible]	246.89	247.37	247.07	246.49	246.68	246.68
[illegible]	246.83	246.89	246.98	246.44	246.89	246.49
[illegible]	247.08	247.44	247.28	247.17	246.77	246.93
[illegible]	246.49	246.89	247.27	247.04	246.67	246.89
[illegible]	246.89	246.89	246.81	246.71	246.68	246.50
[illegible]	246.44	246.89	246.89	246.89	246.72	246.44
[illegible]	246.67	246.89	246.87	246.89	246.89	246.83
[illegible]	246.89	247.17	246.49	246.89	246.46	246.12
[illegible]	246.89	246.89	246.84	246.89	246.17	246.89
[illegible]	246.89	246.89	247.09	247.05	246.89	246.83
[illegible]	246.89	246.89	246.89	246.89	246.84	246.87
[illegible]	247.09	246.96	246.89	246.49	246.20	247.11
[illegible]	246.78	246.89	246.89	246.55	246.12	246.19
[illegible]	246.61	246.19	246.81	246.40	246.89	246.19
Mean	247.288	247.093	246.986	246.874	246.680	246.697

TABLE V.—*Showing, in feet, the mean monthly elevation of Lake Ontario at Oswego*—Continued.

Date.	January.	February.	March.	April.	May.	June.
1861	244.88	244.98	245.42	245.93	246.05	245.9
1862	245.68	245.69	245.98	246.08	247.11	247.0
1863	246.41	246.47	246.71	246.98	246.98	246.8
1864	246.93	246.97	247.06	246.98	247.15	247.0
1865	246.98	246.98	246.98	246.98	247.15	247.0
1866	247.08	247.19	247.36	246.98	246.79	246.7
1867	246.98	247.08	247.08	246.98	246.79	246.7
1868	246.98	246.98	246.98	246.98	246.79	246.7
1869	246.71	246.98	246.98	246.98	246.41	246.3
1870	246.24	246.98	247.08	246.98	247.08	246.9
1871	246.98	246.98	247.08	246.98	246.98	246.8
1872	246.98	246.98	246.98	246.98	246.98	246.8
1873	246.98	246.98	246.98	246.98	246.98	246.8
1874	246.98	246.98	246.98	246.98	246.98	246.8
1875	246.98	246.98	246.98	246.98	246.98	246.8
1876	246.98	246.98	246.98	246.98	246.98	246.8
1877	246.98	246.98	246.98	246.98	246.98	246.8
1878	246.98	246.98	246.98	246.98	246.98	246.8
1879	246.98	246.98	246.98	246.98	246.98	246.8
1880	246.98	246.98	246.98	246.98	246.98	246.8
1881	246.98	246.98	246.98	246.98	246.98	246.8
1882	246.98	246.98	246.98	246.98	246.98	246.8
1883	246.98	246.98	246.98	246.98	246.98	246.8
1884	246.98	246.98	246.98	246.98	246.98	246.8
1885	246.98	246.98	246.98	246.98	246.98	246.8
1886	246.98	246.98	246.98	246.98	246.98	246.8
1887	246.98	246.98	246.98	246.98	246.98	246.8
1888	246.98	246.98	246.98	246.98	246.98	246.8
1889	246.98	246.98	246.98	246.98	246.98	246.8
1890	246.98	246.98	246.98	246.98	246.98	246.8
1891	246.98	246.98	246.98	246.98	246.98	246.8
1892	246.98	246.98	246.98	246.98	246.98	246.8
1893	246.98	246.98	246.98	246.98	246.98	246.8
1894	246.98	246.98	246.98	246.98	246.98	246.8
1895	246.98	246.98	246.98	246.98	246.98	246.8
1896	246.98	246.98	246.98	246.98	246.98	246.8
1897	246.98	246.98	246.98	246.98	246.98	246.8
1898	246.98	246.98	246.98	246.98	246.98	246.8
1899	246.98	246.98	246.98	246.98	246.98	246.8
1900	246.98	246.98	246.98	246.98	246.98	246.8
Mean	246.980	246.988	246.998	246.978	246.980	246.9

Date.	July.	August.	September.	October.	November.	December.
1861	246.87	246.83	246.69	246.64	246.67	246.6
1862	247.01	247.03	246.98	246.98	246.98	246.9
1863	246.71	246.64	246.61	246.61	246.61	246.6
1864	246.93	246.93	246.71	246.98	246.98	246.9
1865	246.98	246.98	246.98	246.98	246.98	246.9
1866	246.98	246.98	246.98	247.11	247.08	247.0
1867	246.98	246.98	246.98	246.98	246.98	246.9
1868	246.98	246.98	246.98	246.98	246.98	246.9
1869	246.98	246.98	246.98	246.98	246.98	246.9
1870	246.98	246.98	246.98	246.98	246.98	246.9
1871	246.98	246.98	246.98	246.98	246.98	246.9
1872	246.98	246.98	246.98	246.98	246.98	246.9
1873	246.98	246.98	246.98	246.98	246.98	246.9
1874	246.98	246.98	246.98	246.98	246.98	246.9
1875	246.98	246.98	246.98	246.98	246.98	246.9
1876	246.98	246.98	246.98	246.98	246.98	246.9
1877	246.98	246.98	246.98	246.98	246.98	246.9
1878	246.98	246.98	246.98	246.98	246.98	246.9
1879	246.98	246.98	246.98	246.98	246.98	246.9
1880	246.98	246.98	246.98	246.98	246.98	246.9
1881	246.98	246.98	246.98	246.98	246.98	246.9
1882	246.98	246.98	246.98	246.98	246.98	246.9
1883	246.98	246.98	246.98	246.98	246.98	246.9
1884	246.98	246.98	246.98	246.98	246.98	246.9
1885	246.98	246.98	246.98	246.98	246.98	246.9
1886	246.98	246.98	246.98	246.98	246.98	246.9
1887	246.98	246.98	246.98	246.98	246.98	246.9
1888	246.98	246.98	246.98	246.98	246.98	246.9
1889	246.98	246.98	246.98	246.98	246.98	246.9
1890	246.98	246.98	246.98	246.98	246.98	246.9
1891	246.98	246.98	246.98	246.98	246.98	246.9
1892	246.98	246.98	246.98	246.98	246.98	246.9
1893	246.98	246.98	246.98	246.98	246.98	246.9
1894	246.98	246.98	246.98	246.98	246.98	246.9
1895	246.98	246.98	246.98	246.98	246.98	246.9
1896	246.98	246.98	246.98	246.98	246.98	246.9
1897	246.98	246.98	246.98	246.98	246.98	246.9
1898	246.98	246.98	246.98	246.98	246.98	246.9
1899	246.98	246.98	246.98	246.98	246.98	246.9
1900	246.98	246.98	246.98	246.98	246.98	246.9
Mean	246.980	246.980	246.980	246.980	246.980	246.9

TABLE VI.—*Showing, in c-f, the mean monthly discharge of St. Marys River*

Date.	January.	February.	March.	April.	May.	June.
1860	56,711	58,000	72,000	72,000	72,000	72,0
1861	58,000	58,000	72,000	72,000	72,000	72,0
1862	58,000	58,000	72,000	72,000	72,000	72,0
1863	58,000	58,000	72,000	72,000	72,000	72,0
1864	58,000	58,000	72,000	72,000	72,000	72,0
1865	58,000	58,000	72,000	72,000	72,000	72,0
1866	58,000	58,000	72,000	72,000	72,000	72,0
1867	58,000	58,000	72,000	72,000	72,000	72,0
1868	58,000	58,000	72,000	72,000	72,000	72,0
1869	58,000	58,000	72,000	72,000	72,000	72,0
1870	58,000	58,000	72,000	72,000	72,000	72,0
1871	58,000	58,000	72,000	72,000	72,000	72,0
1872	58,000	58,000	72,000	72,000	72,000	72,0
1873	58,000	58,000	72,000	72,000	72,000	72,0
1874	58,000	58,000	72,000	72,000	72,000	72,0
1875	58,000	58,000	72,000	72,000	72,000	72,0
1876	58,000	58,000	72,000	72,000	72,000	72,0
1877	58,000	58,000	72,000	72,000	72,000	72,0
1878	58,000	58,000	72,000	72,000	72,000	72,0
1879	58,000	58,000	72,000	72,000	72,000	72,0
1880	58,000	58,000	72,000	72,000	72,000	72,0
1881	58,000	58,000	72,000	72,000	72,000	72,0
1882	58,000	58,000	72,000	72,000	72,000	72,0
1883	58,000	58,000	72,000	72,000	72,000	72,0
1884	58,000	58,000	72,000	72,000	72,000	72,0
1885	58,000	58,000	72,000	72,000	72,000	72,0
1886	58,000	58,000	72,000	72,000	72,000	72,0
1887	58,000	58,000	72,000	72,000	72,000	72,0
1888	58,000	58,000	72,000	72,000	72,000	72,0
1889	58,000	58,000	72,000	72,000	72,000	72,0
1890	58,000	58,000	72,000	72,000	72,000	72,0
1891	58,000	58,000	72,000	72,000	72,000	72,0
1892	58,000	58,000	72,000	72,000	72,000	72,0
1893	58,000	58,000	72,000	72,000	72,000	72,0
1894	58,000	58,000	72,000	72,000	72,000	72,0
1895	58,000	58,000	72,000	72,000	72,000	72,0
1896	58,000	58,000	72,000	72,000	72,000	72,0
1897	58,000	58,000	72,000	72,000	72,000	72,0
1898	58,000	58,000	72,000	72,000	72,000	72,0
1899	58,000	58,000	72,000	72,000	72,000	72,0
1900	58,000	58,000	72,000	72,000	72,000	72,0
Mean	58,000	58,000	72,000	72,000	72,000	72,0

TABLE VI.—*Showing, in a-f, the mean monthly discharge of St. Marys River*—Continued.

Date.	July.	August.	September.	October.	November.	December.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	89,760	90,577	91,659	90,960	85,130	78,577

Date.	January.	February.	March.	April.	May.	June.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	67,180	62,790	62,890	68,972	71,980	78,714

Date.	July.	August.	September.	October.	November.	December.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mean	88,894	88,980	81,980	81,489	79,944	78,799

Mean discharge from 1860 to 1902 = 77,943 S.-F. Mean discharge from November, 1901, to October, 1902, inclusive, = 80,824 S.-F.

TABLE VII.—*Showing, in c-f, the mean monthly discharge of St. Clair River.*

Date.	January.	February.	March.	April.	May.	June.
1860	197,260	177,228	185,125	200,712	223,216	233,420
1861	181,240	168,038	170,840	193,808	221,169	228,264
1862	188,233	170,668	174,060	194,282	220,264	227,271
1863	186,411	168,469	170,649	188,188	214,783	241,648
1864	177,547	157,702	162,694	185,706	219,648	230,726
1865	187,159	169,736	168,159	173,646	205,947	217,264
1866	156,437	151,780	157,668	182,583	194,574	207,660
1867	169,449	148,319	159,676	175,564	205,997	225,057
1868	185,056	165,211	162,304	167,548	201,435	214,139
1869	151,944	135,486	139,673	156,875	191,715	208,459
1870	157,689	150,489	161,310	185,466	220,495	228,779
1871	161,921	141,323	177,866	197,564	229,075	249,941
1872	168,209	139,404	142,440	160,162	195,599	218,693
1873	164,982	135,211	141,676	165,643	203,722	224,645
1874	176,218	159,736	167,599	180,890	210,993	224,899
1875	168,539	145,312	151,936	170,979	208,303	230,216
1876	170,294	157,130	164,740	186,227	228,319	245,117
1877	190,317	171,043	174,843	196,517	224,307	246,138
1878	182,683	160,270	168,743	183,569	219,720	239,854
1879	173,891	146,904	152,804	170,086	201,054	195,979
1880	168,449	143,216	148,156	164,490	200,073	221,686
Mean	171,965	152,047	159,111	178,606	213,149	230,048

Date.	July.	August.	September.	October.	November.	December.
1860	258,672	257,168	254,195	245,166	242,295	230,280
1861	246,574	235,585	264,617	259,841	250,646	234,611
1862	240,080	251,510	247,400	258,986	252,099	213,206
1863	239,308	240,257	239,301	234,941	237,059	197,104
1864	234,905	232,516	225,938	212,471	208,794	188,542
1865	230,849	231,797	228,500	223,697	209,697	196,373
1866	214,305	218,257	214,316	211,078	210,309	191,288
1867	231,984	228,301	227,224	220,153	210,217	186,300
1868	218,268	209,284	204,209	200,267	200,190	199,858
1869	217,249	220,244	225,135	217,925	216,051	205,694
1870	241,781	239,468	245,738	236,786	227,190	196,699
1871	251,019	245,265	236,090	225,449	220,580	191,256
1872	224,570	220,979	219,939	215,519	213,125	208,911
1873	229,544	220,507	222,264	221,065	221,191	208,089
1874	257,847	254,966	252,070	236,191	211,226	207,497
1875	231,267	232,248	237,500	226,417	224,622	228,984
1876	261,035	262,589	256,889	257,788	254,105	217,749
1877	246,916	246,914	241,359	237,407	233,264	211,429
1878	237,736	235,371	230,284	224,719	223,552	195,649
1879	214,220	213,689	213,267	207,563	207,791	201,127
1880	220,316	223,995	222,080	218,980	217,888	216,675
Mean	236,495	235,976	233,787	229,071	225,300	205,841

Date.	January.	February.	March.	April.	May.	June.
1881	195,239	183,889	189,213	173,744	210,366	226,702
1882	180,993	167,130	164,921	185,874	217,064	228,175
1883	176,453	166,207	168,208	178,408	215,017	227,457
1884	187,980	170,251	176,176	186,285	220,273	244,778
1885	180,870	169,709	174,843	185,080	220,366	224,103
1886	184,220	170,871	165,988	177,036	241,340	272,408
1887	195,845	171,648	160,179	194,634	220,276	247,650
1888	180,670	168,171	166,148	178,888	212,289	240,313
1889	187,864	168,647	161,888	183,214	197,450	224,400
1890	191,888	172,888	161,888	183,888	194,888	216,888
1891	188,888	172,888	161,888	183,888	194,877	216,888
1892	187,888	172,888	161,888	183,888	194,840	216,888
1893	187,888	172,888	161,888	183,888	194,888	216,888
1894	187,888	172,888	161,888	183,888	194,888	216,888
1895	187,888	172,888	161,888	183,888	194,888	216,888
1896	187,888	172,888	161,888	183,888	194,888	216,888
1897	187,888	172,888	161,888	183,888	194,888	216,888
1898	187,888	172,888	161,888	183,888	194,888	216,888
1899	187,888	172,888	161,888	183,888	194,888	216,888
1900	187,888	172,888	161,888	183,888	194,888	216,888
Mean	189,296	169,999	164,797	184,288	206,888	224,888

Date.	July.	August.	September.	October.	November.	December.
1881	240,888	240,888	240,888	240,888	240,888	240,888
1882	240,888	240,888	240,888	240,888	240,888	240,888
1883	240,888	240,888	240,888	240,888	240,888	240,888
1884	240,888	240,888	240,888	240,888	240,888	240,888
1885	240,888	240,888	240,888	240,888	240,888	240,888
1886	240,888	240,888	240,888	240,888	240,888	240,888
1887	240,888	240,888	240,888	240,888	240,888	240,888
1888	240,888	240,888	240,888	240,888	240,888	240,888
1889	240,888	240,888	240,888	240,888	240,888	240,888
1890	240,888	240,888	240,888	240,888	240,888	240,888
1891	240,888	240,888	240,888	240,888	240,888	240,888
1892	240,888	240,888	240,888	240,888	240,888	240,888
1893	240,888	240,888	240,888	240,888	240,888	240,888
1894	240,888	240,888	240,888	240,888	240,888	240,888
1895	240,888	240,888	240,888	240,888	240,888	240,888
1896	240,888	240,888	240,888	240,888	240,888	240,888
1897	240,888	240,888	240,888	240,888	240,888	240,888
1898	240,888	240,888	240,888	240,888	240,888	240,888
1899	240,888	240,888	240,888	240,888	240,888	240,888
1900	240,888	240,888	240,888	240,888	240,888	240,888
Mean	240,888	240,888	240,888	240,888	240,888	240,888

TABLE VII.—*Showing, in s—f, the mean monthly discharge of St. Clair River*—Continued.

Date.	July.	August.	September.	October.	November.	December.
1891	229,625	224,720	224,342	227,245	240,220	212,225
1892	227,558	220,259	220,495	225,766	229,631	226,694
1893	242,209	232,288	245,565	242,876	254,975	218,511
1894	245,809	247,553	240,289	250,050	244,430	227,470
1895	227,995	221,054	221,570	227,705	251,248	222,805
1896	226,209	226,772	225,740	224,799	252,794	224,216
1897	250,560	245,987	237,230	236,874	225,260	220,073
1898	226,169	220,279	220,494	220,569	222,205	190,119
1899	231,576	221,260	219,269	212,540	204,740	190,488
1900	213,260	216,189	212,425	208,466	201,508	174,804
1901	201,371	199,031	194,270	186,809	179,804	179,205
1902	182,859	180,985	194,538	194,777	189,440	161,916
1903	207,800	205,944	199,067	196,436	186,575	161,916
1904	214,569	206,151	203,688	199,270	195,511	160,205
1905	195,958	194,289	181,440	177,851	166,956	165,926
1906	176,567	175,097	174,056	166,515	171,401	174,288
1907	190,737	189,808	194,510	187,883	186,479	186,199
1908	193,274	194,789	189,494	185,262	189,413	176,807
1909	205,600	204,805	203,305	199,430	189,800	189,681
1910	191,765	194,240	189,409	200,060	202,190	172,976
1911	209,585	212,215	202,070	196,936	198,178	178,679
1912	189,660	189,700	190,085	179,730	181,760	189,695
Mean	216,646	217,068	217,869	210,689	207,888	191,042

Mean discharge from 1890 to 1902 = 197,880 S-F. Mean discharge from November, 1902, to October, 1906, inclusive, = 191,960 S-F.

TABLE VIII.—*Showing, in s-f, the mean monthly discharge of Niagara River.*

Date.	January.	February.	March.	April.	May.	June.
1890	208,748	205,951	224,648	240,270	256,097	254,412
1891	219,147	212,958	228,741	246,108	253,760	257,288
1892	227,598	221,058	224,197	254,415	252,804	256,804
1893	230,240	244,734	243,478	245,109	252,148	247,000
1894	207,467	210,895	215,582	235,704	242,838	241,285
1895	205,970	198,648	199,280	216,009	230,051	229,551
1896	200,204	198,910	208,670	216,698	229,640	230,480
1897	212,088	208,649	214,280	225,097	232,748	240,711
1898	198,418	198,888	197,126	215,779	232,168	234,648
1899	197,584	198,019	208,728	215,629	232,098	234,040
1900	205,497	200,620	205,427	220,081	244,734	244,040
1901	215,552	208,141	210,242	220,081	244,095	233,788
1902	198,012	198,651	198,588	220,081	238,973	231,288
1903	196,577	198,805	198,274	217,159	238,773	233,979
1904	200,081	200,154	203,588	224,049	238,773	233,949
1905	195,797	191,986	198,113	204,089	214,695	220,214
1906	212,539	208,111	240,711	220,081	238,973	233,080
1907	208,209	213,696	212,288	220,081	238,973	233,949
1908	208,084	207,059	208,588	220,081	238,973	233,949
1909	220,901	212,797	214,280	220,081	238,973	233,949
1910	217,873	216,474	221,616	226,210	231,977	238,747
Mean	212,714	211,280	216,270	229,198	238,198	235,496

Date.	July.	August.	September.	October.	November.	December.
1890	240,273	244,279	227,242	220,096	226,231	224,960
1891	241,717	238,619	240,272	242,408	245,287	237,711
1892	229,120	230,584	240,272	238,068	237,488	236,120
1893	244,218	242,218	240,716	238,264	234,488	232,221
1894	240,445	238,218	240,272	237,873	238,787	215,889
1895	237,683	238,218	240,272	238,249	230,718	238,889
1896	241,263	238,218	240,272	234,788	215,273	229,887
1897	240,445	238,218	240,272	238,068	231,248	238,889
1898	240,273	238,218	240,272	238,119	228,280	197,218
1899	240,273	238,218	240,272	238,517	232,154	230,048
1900	240,273	238,218	240,272	238,068	237,488	230,279
1901	241,263	240,272	240,272	238,068	237,488	197,218
1902	238,120	238,218	240,272	238,068	237,488	196,284
1903	241,263	240,272	240,272	238,068	237,488	230,279
1904	238,514	238,218	240,272	238,068	237,488	230,279
1905	237,683	238,218	240,272	238,068	237,488	230,279
1906	238,120	238,218	240,272	238,068	237,488	230,279
1907	238,120	238,218	240,272	238,068	237,488	230,279
1908	238,120	238,218	240,272	238,068	237,488	230,279
1909	238,120	238,218	240,272	238,068	237,488	230,279
1910	238,120	238,218	240,272	238,068	237,488	230,279
1911	238,120	238,218	240,272	238,068	237,488	230,279
1912	238,120	238,218	240,272	238,068	237,488	230,279
Mean	239,401	238,869	239,956	239,614	235,241	218,899

TABLE VIII.—*Showing, in s-f, the mean monthly discharge of Niagara River*—Continued.

Date.	January.	February.	March.	April.	May.	June.
1903	196,026	199,156	206,844	222,097	221,052	220,4
1904	200,270	201,272	200,698	244,436	240,220	227,9
1905	211,720	214,448	220,720	228,415	230,746	219,0
1906	208,191	208,022	208,224	245,659	251,717	236,0
1907	211,510	213,720	220,640	228,087	230,465	240,0
1908	240,200	239,624	219,597	229,280	246,102	241,2
1909	213,147	220,810	246,288	247,480	251,488	241,9
1910	211,550	208,446	207,888	221,648	227,424	228,0
1911	212,420	209,515	206,221	213,055	217,086	208,1
1912	213,901	209,492	208,191	224,197	241,524	234,1
1913	218,400	211,920	208,288	219,573	218,189	214,0
1914	199,947	198,219	198,126	198,707	216,977	208,1
1915	196,828	196,460	198,541	209,940	220,908	208,0
1916	203,888	199,184	198,660	208,516	217,576	208,9
1917	196,150	196,941	198,225	199,894	199,786	196,7
1918	196,086	199,899	179,165	189,273	197,889	196,0
1919	196,035	199,489	197,809	210,169	211,576	196,1
1920	196,284	200,739	198,589	220,897	220,618	208,4
1921	205,020	196,216	201,697	208,288	215,289	215,0
1922	191,070	195,707	208,649	210,615	214,276	214,0
1923	200,845	196,264	199,288	199,456	199,158	196,4
1924	194,781	174,670	181,980	196,980	208,201	203,1
Mean	208,548	205,477	205,477	216,448	224,110	220,9

Date.	July.	August.	September.	October.	November.	December.
1903	220,220	220,128	220,970	219,147	215,104	210,0
1904	227,717	242,270	242,209	238,400	230,212	224,1
1905	220,084	220,616	240,208	230,446	224,020	220,0
1906	245,223	244,270	238,220	237,208	227,084	224,0
1907	240,080	240,240	240,277	242,621	240,[illegible]	228,2
1908	247,200	240,456	237,781	232,088	226,111	224,0
1909	242,770	239,240	234,488	231,160	216,104	218,0
1910	228,740	222,502	221,620	218,207	214,025	211,0
1911	207,277	206,254	205,508	208,110	210,020	208,0
1912	231,020	232,720	227,468	228,791	222,517	217,0
1913	216,287	210,140	208,110	197,204	197,701	196,0
1914	208,445	208,251	208,894	206,025	201,440	196,0
1915	224,754	218,147	210,613	208,720	196,746	196,0
1916	221,949	218,222	209,712	208,228	197,126	196,0
1917	196,216	197,539	199,203	199,466	196,240	196,0
1918	196,120	196,262	196,707	196,228	196,020	196,0
1919	220,287	216,020	209,713	196,707	196,791	196,0
1920	224,088	224,201	222,670	221,179	196,464	196,0
1921	211,748	207,487	202,070	196,668	196,010	196,0
1922	212,080	210,450	208,221	196,220	196,220	196,0
1923	196,464	196,264	196,988	196,228	196,227	196,0
1924	208,087	202,456	212,982	211,963	208,885	204,0
Mean	220,277	218,294	218,096	210,918	208,713	204,0

Mean discharge from 1903 to 1924 = 210,948 s-f. Mean discharge from November, 1903, to October, 1924, inclusive = 214,406 s-f.

TABLE IX.—*Showing, in s-f, the mean monthly discharge of St. Lawrence River.*

Date.	January.	February.	March.	April.	May.	June.
1860	249,965	245,806	267,019	288,910	278,101	266,012
1861	246,639	242,055	265,115	279,654	267,726	257,009
1862	253,782	245,109	267,081	281,486	265,759	259,081
1863	254,576	246,394	260,424	280,095	248,902	267,736
1864	243,945	239,213	244,577	269,674	268,425	258,181
1865	248,067	237,708	271,901	268,709	268,200	264,261
1866	252,988	240,208	268,549	267,551	262,653	249,907
1867	254,745	237,054	255,709	267,225	248,469	245,456
1868	248,267	246,545	260,911	268,209	254,659	265,478
1869	247,150	243,454	267,581	269,669	270,895	270,596
1870	249,416	251,960	272,629	268,261	267,569	259,319
1871	257,469	248,349	260,674	268,265	260,429	276,974
1872	245,962	246,987	267,668	269,086	264,776	252,277
1873	248,139	240,960	261,641	260,267	277,288	275,288
1874	244,429	244,508	260,940	272,630	261,705	264,086
1875	245,242	240,250	265,087	264,295	264,087	248,219
1876	249,297	245,288	260,980	268,728	265,150	250,615
1877	253,213	250,016	262,514	260,257	265,261	262,645
1878	246,405	251,660	267,749	264,688	276,813	270,205
1879	256,643	249,478	245,583	260,688	272,178	272,940
1880	249,520	249,580	266,771	251,606	266,563	264,706
Mean	248,284	246,906	248,044	267,271	261,290	264,894

Date.	July.	August.	September.	October.	November.	December.
1860	266,453	264,080	272,728	268,227	270,868	270,272
1861	261,260	264,262	262,786	266,196	266,456	262,042
1862	261,267	259,787	262,556	270,269	270,773	267,520
1863	267,164	265,214	275,265	270,681	265,264	264,251
1864	267,221	266,267	272,424	268,500	268,726	265,210
1865	260,467	274,726	269,696	268,271	264,661	262,849
1866	272,287	270,262	266,218	264,262	268,751	264,720
1867	265,482	266,264	276,212	260,089	261,026	261,427
1868	266,287	264,216	261,052	264,262	260,268	262,264
1869	264,720	264,245	261,726	270,260	266,068	272,464
1870	271,025	268,217	264,242	270,040	261,252	264,216
1871	274,720	262,216	264,269	261,772	261,226	262,220
1872	264,222	260,721	262,260	259,109	257,221	259,062
1873	274,722	267,024	262,264	264,612	261,269	264,160
1874	262,720	276,219	260,268	260,062	262,262	262,570
1875	262,221	262,260	260,272	268,722	257,267	262,220
1876	262,221	262,771	262,777	270,264	267,064	262,227
1877	262,672	262,720	262,642	267,262	262,247	262,264
1878	262,222	272,464	262,720	260,062	262,277	272,644
1879	262,267	260,211	262,262	267,267	267,640	262,262
1880	264,062	262,262	264,264	262,722	262,722	262,262
Mean	265,267	275,264	264,462	266,267	262,965	262,142

Date.	January.	February.	March.	April.	May.	June.
1881	262,264	260,164	262,262	262,712	264,221	262,227
1882	262,262	262,262	260,262	262,674	267,444	260,262
1883	262,262	264,262	262,264	266,112	271,212	269,274
1884	262,264	262,262	272,262	262,772	262,264	262,262
1885	262,262	262,262	262,262	262,262	262,262	262,262
1886	262,262	262,262	262,262	262,262	262,262	262,262
1887	262,262	262,262	262,262	262,262	262,262	262,262
1888	262,262	262,262	262,262	262,262	262,262	262,262
1889	262,262	262,262	262,262	262,262	262,262	262,262
1890	262,262	262,262	262,262	262,262	262,262	262,262
1891	262,262	262,262	262,262	262,262	262,262	262,262
1892	262,262	262,262	262,262	262,262	262,262	262,262
1893	262,262	262,262	262,262	262,262	262,262	262,262
1894	262,262	262,262	262,262	262,262	262,262	262,262
1895	262,262	262,262	262,262	262,262	262,262	262,262
1896	262,262	262,262	262,262	262,262	262,262	262,262
1897	262,262	262,262	262,262	262,262	262,262	262,262
1898	262,262	262,262	262,262	262,262	262,262	262,262
1899	262,262	262,262	262,262	262,262	262,262	262,262
1900	262,262	262,262	262,262	262,262	262,262	262,262
Mean	262,262	262,262	262,262	262,262	262,262	262,262

Date.	July.	August.	September.	October.	November.	December.
1881	262,262	262,262	262,262	262,262	262,262	262,262
1882	262,262	262,262	262,262	262,262	262,262	262,262
1883	262,262	262,262	262,262	262,262	262,262	262,262
1884	262,262	262,262	262,262	262,262	262,262	262,262
1885	262,262	262,262	262,262	262,262	262,262	262,262
1886	262,262	262,262	262,262	262,262	262,262	262,262
1887	262,262	262,262	262,262	262,262	262,262	262,262
1888	262,262	262,262	262,262	262,262	262,262	262,262
1889	262,262	262,262	262,262	262,262	262,262	262,262
1890	262,262	262,262	262,262	262,262	262,262	262,262
1891	262,262	262,262	262,262	262,262	262,262	262,262
1892	262,262	262,262	262,262	262,262	262,262	262,262
1893	262,262	262,262	262,262	262,262	262,262	262,262
1894	262,262	262,262	262,262	262,262	262,262	262,262
1895	262,262	262,262	262,262	262,262	262,262	262,262
1896	262,262	262,262	262,262	262,262	262,262	262,262
1897	262,262	262,262	262,262	262,262	262,262	262,262
1898	262,262	262,262	262,262	262,262	262,262	262,262
1899	262,262	262,262	262,262	262,262	262,262	262,262
1900	262,262	262,262	262,262	262,262	262,262	262,262
Mean	262,262	262,262	262,262	262,262	262,262	262,262

TABLE IX.—*Showing, in s-f, the mean monthly discharge of St. Lawrence River*—Continued.

Date.	July.	August.	September.	October.	November.	December.
1891	258,781	220,087	220,111	220,443	220,443	220,443
1892	207,724	202,238	273,434	226,268	202,470	241,[illegible]
1893	213,625	220,260	220,019	273,[illegible]	220,[illegible]	220,[illegible]
1894	220,260	224,073	222,[illegible]	272,170	220,[illegible]	220,[illegible]
1895	220,270	220,405	220,783	271,[illegible]	220,[illegible]	220,[illegible]
1896	224,120	222,726	220,511	270,049	224,[illegible]	220,[illegible]
1897	220,260	220,260	271,149	220,[illegible]	220,[illegible]	220,[illegible]
1898	220,226	227,720	247,709	220,[illegible]	220,[illegible]	220,[illegible]
1899	272,[illegible]	220,251	251,[illegible]	240,[illegible]	220,[illegible]	244,[illegible]
1900	220,[illegible]	220,272	270,[illegible]	220,[illegible]	220,[illegible]	241,[illegible]
1901	220,726	224,401	249,[illegible]	220,[illegible]	220,[illegible]	220,[illegible]
1902	220,511	227,720	220,[illegible]	241,[illegible]	224,[illegible]	220,[illegible]
1903	220,169	220,251	220,[illegible]	220,[illegible]	220,[illegible]	220,[illegible]
1904	227,094	220,626	220,[illegible]	220,[illegible]	224,[illegible]	224,[illegible]
1905	219,244	220,604	220,[illegible]	191,[illegible]	224,[illegible]	220,[illegible]
1906	227,[illegible]	224,[illegible]	211,[illegible]	218,[illegible]	220,[illegible]	220,[illegible]
1907	241,[illegible]	241,[illegible]	220,[illegible]	220,[illegible]	220,[illegible]	218,[illegible]
1908	247,[illegible]	220,[illegible]	220,[illegible]	220,[illegible]	220,[illegible]	220,[illegible]
1909	240,[illegible]	220,[illegible]	220,[illegible]	220,[illegible]	211,[illegible]	220,[illegible]
1910	220,[illegible]	220,717	220,[illegible]	220,[illegible]	214,[illegible]	220,[illegible]
1911	251,250	242,099	231,474	231,437	214,[illegible]	224,[illegible]
1912	241,[illegible]					
Mean	227,247	220,921	242,494	232,[illegible]	222,[illegible]	222,[illegible]

Mean discharge from 1860 to 1902—251,920 s-f. Mean discharge from November 1892 to October 1898 inclusive—248,513 s-f.

TABLE X.—*Showing, in inches, the mean monthly rainfall in the basin of Lake Superior.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											1.48	1.[illegible]
1893	1.49	0.59	0.68	1.95	3.49	4.38	3.86	1.77	3.33	2.73	2.97	1.[illegible]
1894	.86	1.75	1.14	2.57	3.32	1.83	2.74	4.38	3.35	4.38	1.48	2.[illegible]
1895	1.38	.61	1.38	1.48	1.98	3.68	3.04	3.16	3.04	1.80	2.65	1.[illegible]
1896	1.71	1.76	1.27	1.76	1.48	2.11	1.49	*3.08	3.68	2.84	2.04	1.[illegible]
1897	.99	1.34	.80	1.48	1.98	6.20	1.60	1.09	1.18	2.88	1.49	1.[illegible]
1898	1.96	1.13	1.68	3.01	2.67	3.70	1.83	3.74	3.61	2.79	2.68	.[illegible]
1899	1.37	1.87	1.48	3.36	3.32	3.70	4.38	3.74	3.61	1.69	1.30	2.[illegible]
1900	2.80	2.84	1.68	1.67	3.32	2.59	4.13	3.08	2.48	2.88	1.68	.[illegible]
1901	1.08	1.68	1.70	.87	1.48	3.13	3.13	2.79	2.65	2.65	1.96	2.[illegible]
1902	1.08	1.08	1.11	1.84	2.48	1.83	2.22	1.79	2.18	2.65	2.01	1.[illegible]
1903	1.68	1.08	1.11	1.84	2.48	3.68	3.13	3.74	3.68	2.68	2.03	2.[illegible]
1904	1.68	2.03	1.68	2.66	3.32	1.83	3.68	3.08	3.73	4.51	2.30	1.[illegible]
1905	1.70	.64	2.30	2.03	3.70	3.68	3.68	3.74	4.48	1.91	1.68	1.[illegible]
1906	2.27	1.03	.87	1.38	3.07	3.83	2.28	3.68	4.48	1.91	1.68	.[illegible]
1907	1.76	.96	1.83	2.38	4.69	1.76	4.69	3.68	1.69	2.68	4.38	1.[illegible]
1908	2.68	1.38	1.38	1.69	3.07	3.18	4.69	2.48	3.68	2.51	1.74	1.[illegible]
1909	1.13	1.77	1.68	.77	3.07	4.69	2.48	2.48	2.48	2.79		
Mean	1.60	1.36	1.38	1.90	2.84	2.72	3.06	2.70	2.73	2.68	1.97	1.[illegible]

TABLE XI.—*Showing, in inches, the mean monthly rainfall in the basin of Lakes Huron and Michigan.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											2.66	1.[illegible]
1893	2.31	2.69	1.19	1.66	4.29	5.86	4.11	1.94	2.68	3.19	2.69	1.[illegible]
1894	2.07	2.19	2.69	1.08	2.77	2.73	3.29	3.47	2.80	4.44	2.12	2.[illegible]
1895	2.03	1.74	1.80	2.48	2.69	2.61	2.67	4.69	3.04	2.69	2.03	2.[illegible]
1896	4.03	2.69	1.19	1.73	1.66	2.11	3.29	1.73	2.68	2.69	1.73	2.[illegible]
1897	2.03	2.69	2.84	2.48	1.66	2.11	1.66	2.69	2.11	2.69	2.44	2.[illegible]
1898	2.03	2.03	.[illegible]	1.08	2.69	4.48	2.73	1.66	2.19	1.66	2.44	2.[illegible]
1899	2.73	2.03	2.03	2.73	2.69	2.84	2.67	2.77	1.97	2.69	2.03	2.[illegible]
1900	2.44	2.03	1.73	2.03	.20	1.97	2.84	2.77	1.66	1.74	1.70	2.[illegible]
1901	2.77	1.66	1.73	1.66	4.17	2.84	2.03	2.18	2.81	2.19	2.84	2.[illegible]
1902	2.77	1.66	1.73	2.03	2.69	2.44	4.29	2.03	2.84	2.69	2.11	2.[illegible]
1903	2.73	2.69	2.19	2.69	2.69	2.73	2.73	2.77	2.73	2.69	2.28	2.[illegible]
1904	2.07	1.66	2.03	1.66	2.69	2.69	1.66	2.19	2.68	1.66	2.07	2.[illegible]
1905	2.73	1.66	1.73	2.73	2.69	2.69	2.84	2.19	2.68	1.66	2.73	2.[illegible]
1906	1.66	1.66	1.73	2.73	2.69	2.69	2.67	1.66	1.66	1.66	1.66	2.[illegible]
1907	2.70	1.66	2.03	2.03	2.69	2.77	1.66	2.68	2.48	2.66		
1908	2.73	2.66	2.73	1.73	2.66	2.77	1.66	2.68	2.48	2.66		
Mean	2.90	2.39	2.01	2.39	2.64	2.90	2.66	2.75	2.94	2.63	2.39	2.[illegible]

TABLE XII.—*Showing, in inches, the mean monthly rainfall in the basin of Lakes St. Clair and Erie.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											2.56	2.23
1893	1.66	3.94	1.45	2.03	6.66	4.96	5.13	2.02	3.87	3.21	3.01	2.31
1894	2.15	3.91	2.61	1.51	2.72	3.20	3.61	1.76	2.37	2.46	1.96	2.81
1895	2.70	1.36	.96	2.64	3.91	4.78	2.89	3.34	3.56	3.79	3.21	2.50
1896	3.39	1.99	2.52	2.61	2.64	2.47	1.91	2.97	4.45	1.49	3.77	3.19
1897	1.97	6.11	1.94	1.73	2.49	3.03	1.43	2.93	2.71	3.25	3.13	2.86
1898	2.54	1.76	2.66	2.25	2.95	2.29	2.90	2.55	3.22	2.57	3.48	1.76
1899	2.19	1.66	1.60	3.15	4.51	3.43	2.71	1.13	2.77	1.44	3.41	3.43
1900	4.11	3.10	2.89	3.31	5.30	2.88	1.98	2.44	3.49	4.20	2.96	1.43
1901	2.14	4.20	3.13	2.06	1.61	2.96	2.76	2.31	1.98	2.07	4.55	2.30
1902	2.26	2.76	2.43	2.55	7.97	5.99	3.43	2.88	3.43	1.10	3.08	1.66
1903	2.79	4.56	3.13	4.75	4.11	2.89	3.43	2.07	1.50	3.40	3.10	3.33
1904	1.92	2.75	1.61	3.05	5.53	2.02	1.03	.97	4.01	3.21	1.88	2.20
1905	3.15	.71	1.43	1.96	2.39	1.80	3.09	2.74	3.39	1.87	4.08	4.02
1906	1.79	2.60	2.60	2.98	2.57	3.79	4.52	3.54	4.50	1.79	2.51	1.95
1907	2.51	1.66	3.62	2.59	3.62	4.77	4.04	2.89	.79	1.51	5.29	2.09
1908	3.73	2.47	4.11	1.87	3.21	2.91	2.99	2.92	2.91	2.40	.....	.....
Mean	2.61	2.84	2.38	2.62	3.95	3.21	2.98	2.65	2.81	2.42	3.35	2.51

TABLE XIII.—*Showing, in inches, the mean monthly rainfall in the basin of Lake Ontario.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											1.96	2.37
1893	2.00	2.94	1.84	2.01	5.90	4.90	4.69	2.37	2.84	2.30	2.18	1.93
1894	3.67	3.08	2.11	1.13	2.64	3.46	3.46	2.89	2.22	3.43	2.28	3.05
1895	2.82	1.79	.89	2.98	2.74	4.05	3.16	3.68	3.13	4.09	2.30	2.95
1896	3.79	2.02	2.05	2.20	2.21	2.83	2.88	2.77	3.77	1.96	4.74	1.97
1897	2.75	4.30	1.82	1.89	1.94	2.77	1.73	2.77	1.74	3.30	2.03	2.73
1898	2.47	1.84	2.75	2.85	2.35	3.39	1.86	4.13	3.40	4.29	3.59	2.70
1899	3.91	2.81	1.62	3.16	3.39	6.19	5.17	2.03	3.10	3.47	5.80	3.41
1900	3.98	3.39	3.09	2.90	4.26	4.24	2.79	4.81	4.06	4.90	2.98	2.98
1901	3.06	3.66	3.25	1.96	1.19	2.73	4.39	4.24	1.62	3.96	2.86	4.08
1902	1.72	2.29	2.93	1.09	5.91	5.39	4.26	3.70	3.16	1.99	3.66	1.46
1903	2.09	3.56	2.13	3.53	5.01	3.30	3.32	4.05	3.94	3.31	2.03	3.22
1904	2.94	2.61	1.62	3.15	6.77	3.23	2.69	1.49	4.07	4.22	2.07	2.45
1905	2.64	1.77	1.67	1.99	2.65	2.57	2.60	2.69	2.29	1.41	3.64	3.94
1906	3.10	4.47	3.03	1.07	3.89	2.09	4.96	2.30	4.36	2.05	3.66	1.43
1907	2.27	1.66	3.07	2.46	3.35	3.96	3.13	2.86	3.03	.90	4.20	3.04
1908	3.71	3.09	3.19	2.51	3.58	3.00	3.30	3.37	3.30	3.08	.....	.....
Mean	2.91	2.70	2.42	2.39	3.71	3.58	3.30	3.05	3.16	2.98	3.09	2.74

TABLE XIV.—*Showing, in degrees F., the mean monthly temperature in the basin of Lake Superior.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											39.1	14
1893	0.5	7.2	32.6	44.6	42.5	66.4	69.6	66	50.7	39.1	29.9	13.3
1894	2.3	2.7	16.6	33.9	47	60.3	68.6	69.3	53.1	43.4	28.2	10.9
1895	0.0	1.2	11.9	34	45.8	55.6	66	64.5	53.4	38.9	29.1	17.1
1896	2.6	8.8	21.3	38.1	39.3	58	63.5	61.6	51.2	46.8	34.5	7.9
1897	−1.1	3.2	16.7	34.2	52	65.6	64.8	69	56	37.4	28.9	15.1
1898	−.4	6.6	10.9	31.9	40.6	55.7	60.7	57.9	50.7	37.7	27.7	19.7
1899	15.4	4.1	29.5	36.4	48.5	65.1	61.6	61.3	55	44.5	27.6	26.6
1900	9	11.6	16.7	37.4	41.3	55.1	65	57.6	51.8	46.6	32.3	16
1901	15.2	8.5	16.2	36	46.3	64.1	57.7	63.9	52.6	42.4	28.3	23.2
1902	6.6	12.9	20.9	38.9	42.6	55.9	64.9	62.9	52	44.4	28.6	11.6
1903	1.1	4	16.6	29	42	61.6	66.3	61.3	54.7	41.9	28.2	8.5
1904	5.7	10	26	37.9	46.6	61.3	64.3	63.6	56.6	44.3	33.1	21.9
1905	5.3	7.9	18	40.2	50	57	62.6	63.7	55.2	37.3	29.5	17.7
1906	10.5	12.9	18.7	37.8	48.6	60.3	66.7	61.9	53.7	39.6	32.6	17.9
1907	8.7	13.2	17.8	36.3	46.6	59.2	66.5	60.1	58.7	45.6	34.6	19.1
1908	15.3	14.6	30.7	37.3	50	55.9	63.7	60.7	54.6	40.4	.....	.....
Mean	6.2	8.2	18.4	35.7	46.3	57.2	62.2	63.1	53.9	41.1	30.6	15.7

TABLE XV.—*Showing, in degrees F., the mean monthly temperature in the basin of Lakes Huron and Michigan.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1860	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28.8	26.6
1861	19	16.9	26.4	36.2	46.2	58.4	68.8	66.2	54.1	44.4	28.4	26.6
1862	19	18.9	26.7	36.2	45.7	59	68.5	66	61.6	45.6	30	26.6
1863	11.9	8.9	17.5	37.6	46.3	58.7	66	66.1	56.9	43.9	28.7	26.6
1864	15	13.9	27.6	40	46.1	59.2	68.2	64.8	56.9	46.4	31.6	27.9
1865	12.1	13.6	26.9	39	46.1	60.6	70.3	66.4	58	46.5	32.6	24.7
1866	19.3	16.4	29.6	38.9	46.3	61.7	68.9	66.3	58.5	47.9	34.7	28.3
1867	20.4	12.6	30.1	41.5	49.7	60.6	69	64.8	57.6	49	34.1	28.6
1868	22.6	24.4	30	41.9	48.9	61.6	68.5	64.7	54.9	45.5	40.4	32.6
1869	23.1	21.6	34.9	41.6	49.4	61.6	67.3	64.3	58.6	44.9	34	31.6
1870	18.3	20.9	29.4	39.7	48.9	60.7	68.9	65.5	58.7	47.6	33.5	29.3
1871	9.6	15.3	30	36	46.6	60.9	67.3	64.3	57.9	47.9	33.3	29.3
1872	21.9	17.5	34.7	42.5	50.1	63.3	69.3	66.1	60.6	47.5	36.9	29.3
1873	14.9	13.9	30.6	42.3	52.9	64.9	68.1	65.6	58.9	46.4	33.3	29.3
1874	22.6	20.7	33.5	42.9	51.8	63.7	68.4	65.9	58.6	46.7	37.5	29.3
1875	19.1	20.7	27.4	40.1	48.6	59.6	68.7	66.3	62.7	51.9	38.6	32.6
1876	20.4	21.6	30.6	40.4	50	61.6	67.6	65.5	61.6	48.7	.....	.....
Mean	18.9	18.1	28.6	40.9	48.4	61.4	68	65.8	58.3	45.8	33.9	28.1

TABLE XVI.—*Showing, in degrees F., the mean monthly temperature in the basin of Lakes St. Clair and Erie.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1860	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	40.4	34.6
1861	21.6	23.6	33.5	44.9	54.1	66.6	70.3	67.3	59	50.7	42.3	34.6
1862	25.3	27	33.1	43.1	53.4	66.4	68.5	66.1	67.2	44.9	39	34.6
1863	23.3	21.4	31.4	43.1	53.6	65.5	67.3	65.6	61.6	48.6	44.1	34.6
1864	23.3	24.3	34.3	47.3	54.3	66.4	68.5	65.7	60.1	49.1	37.4	34.6
1865	20.3	20.4	33.1	46.6	53.6	67.8	69.3	66.3	60.2	48.1	36.6	34.6
1866	25.6	24.3	34.3	46.6	54.3	67	68.5	66.1	60.2	48.1	40.6	34.6
1867	23.6	23.3	33.5	45.4	53.4	66.9	67.1	65.7	60.1	48.3	40.6	34.6
1868	23.6	23.3	33.5	45.4	53.4	66.9	67.1	65.7	60.1	48.3	40.6	34.6
1869	23.4	23	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	40.6	34.6
1870	23.4	23.3	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	40.6	34.6
1871	23.4	23	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	40.6	34.6
1872	23.4	23.3	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	40.6	34.6
1873	23.4	23.3	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	40.6	34.6
1874	23.4	23.3	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	40.6	34.6
1875	23.4	23.3	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	40.6	34.6
1876	23.4	23.3	33.6	46.4	54.3	66.9	67.1	66.1	60.2	48.1	.....	.....
Mean	24.5	23.9	33.1	45.9	53.5	67.2	71.1	66.6	60.2	50.7	40	35.6

TABLE XVII.—*Showing, in degrees F., the mean monthly temperature in the basin of Lake Ontario.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1860	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	36.7	34.6
1861	21.9	22.9	32.3	43.7	53.4	66	68.6	66.3	54.3	46	36.5	34.7
1862	24.3	25.4	32.9	42	52.3	66	68.6	66.3	62	45.5	38.2	32
1863	19.3	21.7	31.1	42.6	52.3	65.9	68.3	66.7	56.8	45.6	37.6	32
1864	23.7	23.6	33.5	44.5	53.3	67.1	69	64.8	56.5	46.2	33.1	34.7
1865	23	22.6	32.1	43.6	52.3	68.1	72.1	68	58.1	44.5	36.2	32.1
1866	24.7	23.6	32.9	43	53.3	68	68.9	66.8	58.1	45.2	37.6	32
1867	23.2	23.6	32.1	43.1	52.3	67.9	68.8	66.6	61.9	48.1	38.1	32.6
1868	23.1	21.6	34.6	41.4	49.3	67.6	67.3	65.7	57.1	46	38.9	32.6
1869	23.1	21.6	34.1	42.7	51.3	68	68.4	66.3	58.6	46.6	38.9	32.6
1870	23.1	21.6	34.1	42.7	51.3	68	67.4	66.3	58.7	46.9	34.3	32.6
1871	23.1	21.6	34.1	42.7	51.3	68	67.4	66.3	58.7	46.9	34.3	32.6
1872	23.1	21.6	34.1	42.7	51.3	68	67.4	66.3	58.7	46.9	34.3	32.6
1873	23.1	21.6	34.1	42.7	51.3	68	67.4	66.3	58.7	46.9	34.3	32.6
1874	23.1	21.6	34.1	42.7	51.3	68	67.4	66.3	58.7	46.9	34.3	32.6
1875	23.1	21.6	34.1	42.7	51.3	68	67.4	66.3	58.7	46.9	34.3	32.6
1876	23.1	21.6	34.1	42.7	51.3	68	67.4	66.3	58.7	46.9	.....	.....
Mean	23.5	21.5	33.4	41.8	52.6	68.3	67.4	66.2	56.9	46.6	36.4	32.5

TABLE XVIII.—*Showing, in per cent, the mean monthly relative humidity in the basin of Lake Superior.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1897											76.4	78.9
1898	79.1	78.8	70.2	66.2	66	69.5	66	70.1	71.1	74.7	73.1	76.8
1899	76.9	76.6	73.7	70.3	65.5	70.7	72.1	74.6	72.9	66.7	75.3	80.3
1900	73	73.5	75	71.3	68.3	72.7	74	74.7	69.7	73.7	66	68.7
1901	68.7	68.7	76.2	76.9	64.7	71.7	70.4	76	74	72.3	73.7	76.7
1902	78.3	77.7	75.3	73	70	76.7	77.3	77	72.3	70.7	73	81
1903	78.7	83	80.7	77.2	70.7	75.7	76.2	76.5	77.5	79.3	68.2	82.6
1904	84.2	84	76.2	74.7	70.5	73	76	75.9	77.7	77.5	80	81.7
1905	82.3	80.5	77	68.6	71	76.2	74	76	77.2	78.2	76.6	78.3
1906	82	81.6	80.5	74.5	68.5	68.6	71.5	74	75.3	72.5	82.2	84
1907	81	84	79.5	75.5	72.3	75.5	70.8	77.6	79.5	77	82.5	83.5
1908	80.2	74.6	75	79.2	68.5	71.2	74	73	76.3	69.5	81	80
1909	80	84	84.5	73.8	70.3	68.8	67.2	74	72.8	68	84.2	85
1910	85	85.8	74.5	71.5	76.2	75	74.8	73.2	74	73	82.2	82.5
1911	86	82.8	76.8	79.5	74.5	70	71.5	72.2	77.5	79.2	87.6	85
1912	85	87.2	84.2	77.2	67.2	73.8	79	77	76.6	82.5	85	86.5
1913	86.8	86.2	83.8	80	73.2	76.8	75	76.8	75.5	80	.....	.....
Mean	81.9	80.8	77.8	73.7	69.9	72.1	73.2	75	75	76.5	80	81.7

TABLE XIX.—*Showing, in per cent, the mean monthly relative humidity in the basin of Lakes Huron and Michigan.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896											78.4	80.9
1897	79.3	77.8	71.4	67.7	71.4	76.6	73.1	73.4	73.3	74.9	75.1	78.4
1898	75.2	75.8	75.3	69	68.5	73.2	72.5	73.7	74.1	73.4	70	82.4
1899	73	73.5	77	73.5	74	73.6	73.6	76.4	76	80.6	81	82.6
1900	84.2	80.6	80.6	79.4	72.8	75.3	75.2	77	76.8	75	76.8	80.5
1901	81	82.5	78.3	80.2	68.5	74.2	70.8	72.5	75	73.2	75.5	84.7
1902	82.8	82.5	79.6	71.3	74.7	71.6	72.8	75.7	77.6	79.8	80.7	80.4
1903	84.3	81.8	78.6	79	73.2	81.1	74.8	72.3	76.7	79	82.7	81.8
1904	84.1	84.1	78.3	80.2	72.4	74.4	70.7	74.6	77.1	82.1	77.1	79
1905	84.4	82.7	80.1	74.1	69.6	72.9	70.8	74.7	74.8	74.3	79.6	77.8
1906	83.6	82.8	76.8	70	72.7	69.3	72.7	76.3	76.1	75.1	80.3	82.2
1907	83.6	81	80.8	79	71	74.3	72.6	71	74.2	78.9	78.9	82.4
1908	82.6	80	76.1	78.1	78	70.3	68.3	70.4	75.6	73.7	78.6	78.7
1909	81.1	80.1	79.4	76.4	69	68.7	68.4	71.4	71.3	68	77.6	81.3
1910	82.6	79.7	84.3	76.7	70.8	69.6	73	74.7	80.6	79.4	82.4	80.1
1911	82.2	81.1	81.2	76.7	71	72.4	74.7	74.6	75.8	77.4	78.7	82.6
1912	83.1	82.7	79.7	70.7	74.1	75.7	70	79	76.9	82.6	.....	.....
Mean	81.8	81.2	77.5	73.9	71.5	74	72.1	74.3	75.8	76.5	78.8	81.2

TABLE XX.—*Showing, in per cent, the mean monthly relative humidity in the basin of Lakes St. Clair and Erie.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1896											72.4	76.5
1897	73.2	77.9	70	66.8	66	70.6	70.5	67.3	71.9	72.6	66.5	72.5
1898	77.6	80.7	73.2	66.7	67.2	70.1	68.2	66.2	71	71.9	70	76.1
1899	76.1	76.5	73.2	72.6	73.2	72.5	74.6	73.8	73.2	73.5	66	79.3
1900	81.8	77.8	76.6	74.8	72.8	72.3	69.6	72.8	70.6	72.8	74	79.6
1901	78.1	80	76.5	69.8	66	72.6	68.1	66.8	72.2	69.8	71.5	77.7
1902	81	77.6	73.1	64.7	67.6	66.8	68.6	70.6	74.6	74.5	73.2	75.6
1903	80	80.5	74.3	68.3	65.5	70	71.6	67.1	74	70.8	69.6	77.1
1904	79.6	79.5	75.6	66.1	73.3	72.6	68.8	70.6	77.5	80.6	74.3	78.7
1905	82.5	77.1	77.6	72.6	68.6	71.6	67.6	70.1	71.6	69.6	72.6	72.6
1906	79.1	82.3	77	66.5	77.6	77.7	68.8	72.3	74.8	71.7	72.6	80.3
1907	86.7	86.3	80	74.8	71.6	71.5	69	69	69.6	73.2	72.6	79.6
1908	76.8	78	69.9	79	69.1	67.8	61.2	66	72.3	74.5	74.1	77.6
1909	68	80.3	74.7	69.3	68.1	65.6	68.7	67.1	66.3	65.1	76.3	81.1
1910	82.7	81	76.1	73.1	68.5	70.6	72.5	72.8	76.6	72.1	76	80.1
1911	82.5	80.6	77.5	72.6	71.6	67.6	71.1	71.1	65.5	69.1	77.8	79.6
1912	79.6	79.8	75.6	66.8	71.9	70.5	67.8	72.8	72.3	73.8	.....	.....
Mean	80.1	79.6	75.4	70.1	70.1	71.1	69.5	70.2	72.3	72.6	73.1	77.9

TABLE XXI.—*Showing, in per cent, the mean monthly relative humidity in the basin of Lake Ontario.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											74.8	80.2
1893	78.4	76.5	74.7	76.8	73	76.6	75	71.8	74.2	72.6	69.1	77.4
1894	78.2	78.9	77	73.8	72.8	70.7	73.5	70.4	74.6	73.5	76.5	78.6
1895	80.2	80.3	80.2	74.7	76	77.6	80	81	77.7	81.3	81.3	80
1896	82.7	80.7	81	73	74.2	73.3	74	73.7	76.3	79.3	79	84
1897	84.2	80.7	78	67	67.7	73.7	73	70.3	80.7	73.7	71.3	82.7
1898	82.7	79	80.2	68.7	71	70	66.2	66.7	79	77	78.3	79
1899	80	80	78.7	66.7	72.3	73.3	72.7	72.7	78	77	80.7	79
1900	81.3	81.3	79	66.7	72.3	72.3	67.7	72.3	76.3	79	77.7	83.3
1901	80.7	79	76.3	71.3	67.3	67.3	66.3	70.3	74	66.7	70.3	79.7
1902	79.7	81.3	79	68	76.3	77	70.3	72.3	71	73.3	77.3	80.7
1903	81.7	80	76.3	72.7	73	79	70.7	73.3	76.3	73.3	72.7	82.7
1904	78.3	78.3	73.7	67.3	71.3	70	70.7	66.7	74.3	73.7	74.3	79
1905	80	78.3	77.7	68.3	68	72	72.3	67.3	67.7	73.7	68.3	83.3
1906	80.7	81.7	76.7	74.3	65.7	66.7	71	70	72.7	73.7	74.3	78
1907	79	78.7	76	67.3	69.3	67.3	74.3	71.3	67.3	69	77.3	79.3
1908	78.3	78.7	71.3	68	72.3	74	67	74.3	76	78	.....	.....
Mean	80.2	80.2	78.5	70	71.2	72.3	72	72.4	73.7	74.6	75.7	79.9

TABLE XXII.—*Showing, in miles per hour, the mean monthly velocity of wind in the basin of Lake Superior.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											9.4	9.3
1893	11.3	9.9	11.1	10.3	10.4	9	7.5	7.2	7.7	8.3	8.9	10.7
1894	8.9	8.6	7.4	8.2	8.7	8.3	7.2	8.6	8.7	11.1	10	9.1
1895	7.6	7.9	8.5	8.4	8.4	7.9	8.6	8.1	8.3	8.7	9.4	8.3
1896	10.3	11.6	9.4	9.3	8.6	7	7.2	7.4	8.9	9.5	10.6	9
1897	9.3	9.3	8.6	10.3	8.3	8.1	7.1	7.6	8.6	10	8.9	9.6
1898	8.9	8.9	8.7	8.7	8.3	8.9	8.6	8.8	8.4	7.5	7.3	9.3
1899	7.8	8.3	8.7	9	8.3	7.9	7.1	7.9	8.1	7.9	8	7.8
1900	8.6	10.6	9.4	8.9	8.3	7.5	7.9	8.3	8.9	8.3	8.9	9.7
1901	7.9	8.2	8.8	8.5	8.9	8.6	7.6	8.9	8.2	8.8	8.2	10.1
1902	9	8.7	9	11.3	8.9	7.6	7.1	7.4	8.2	8.6	10.1	7.9
1903	8.9	9.3	10.2	11.3	8.9	8.9	7.7	8.4	8.9	8.3	9.4	9.6
1904	9	8.5	10.7	9.4	10.3	8.3	7.7	7.3	8.9	10	10.3	9.7
1905	8.5	10.3	10.1	10.1	9.9	8.7	8.4	9	11.1	11	8.5	10.4
1906	9.6	10.5	11.5	11	10.7	8.8	7.8	8.6	10.4	9.7	10.3	9.3
1907	10.7	9.6	10.2	11.3	9.7	9.4	7.9	8.6	9.7	9.6	10.3	9.3
1908	9.3	10.3	11.6	10	9.6	9	8.7	7.9	9.6	10.7	.....	.....
Mean	9	9.4	9.8	10	9.3	8.2	7.5	7.9	9.2	9.5	9.5	9.4

TABLE XXIII.—*Showing, in miles per hour, the mean monthly velocity of wind in the basin of Lakes Huron and Michigan.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1892											9.5	10.1
1893	11	11.5	10.6	11	11.1	8.5	8.6	8.1	8.4	10	12.5	10.6
1894	10.4	9.8	9.4	10.7	9.6	8.9	7.6	8.1	8.2	10.4	9.6	10.7
1895	8.4	8.6	9.6	10.3	8.6	8.6	7.5	7.8	8.1	8.9	10.3	11.3
1896	10.7	11.6	10.4	9.3	8.9	7.8	7.5	7.9	8.3	8.3	11.9	9.6
1897	10.4	11.1	10.3	11.1	9.2	8.9	7.8	8.2	8.3	8.3	9.6	11.4
1898	10.4	10.1	11.2	11.1	9.2	8.9	7.8	8.2	8.3	8.3	8.9	10.8
1899	10.6	10.4	9.7	10.1	10.3	7.8	7.9	7.7	8.3	8.7	8.9	10.1
1900	10.4	12.4	11.2	11	10.3	8.7	7.9	8	8.3	8.7	11.5	11.4
1901	9.6	10.6	10.6	10.6	10.3	8.9	8.3	8.8	8.4	11	11.2	10.4
1902	10	10.3	11.3	12.6	11.4	8.9	8.3	8.4	8.4	10.7	11.7	10.1
1903	10.6	10.6	10.6	12.4	11.1	9.1	8.3	8.4	11.3	11.6	11.9	10.6
1904	11.3	10.4	10.7	10.4	11.1	8.9	8.3	8.3	8.4	10.6	12.1	10.6
1905	10.7	10.6	10.7	10.6	10.7	8.6	8.7	8.3	11.6	10	11.2	11.3
1906	10.7	12.6	11.3	10.3	11.4	8.6	8.7	8.3	10.4	10.1	10.1	9.9
1907	11.3	11.1	11.7	10.3	10.4	8.9	8.3	8.3	8.4	11.3	12.6	11.3
1908	11.3	12.3	11.1	11.3	10.4	8.9	8.3	8.3	8.4	11.3	.....	.....
Mean	11.3	11.5	11.4	11.5	10.4	8.8	8.3	8.3	9.4	10.4	11.4	11.3

TABLE XXIV.—*Showing, in miles per hour, the mean monthly velocity of wind in the basin of Lakes St. Clair and Erie.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1860											10	11.5
1861	11.6	11.7	11.5	10	10.3	7.6	7.5	8.1	8.7	9.7	12.2	11.8
1864	11.4	10.2	9.8	9.8	8.5	7.4	8.1	7.9	9	10.4	11.6	12.6
1865	12.2	10.2	11.2	10.9	9.1	8.9	8.3	8.5	9	9.4	11.4	12.9
1866	11.2	12.6	10.8	10.3	8.3	7.7	7	7.7	9	9.1	12.7	10.4
1867	14.2	13	10.9	11.2	7.7	7.1	8	7	8.2	10.7	12.1	10.6
1868	10.7	10.4	12	9.6	9.2	8.6	7.5	8.5	8.6	10.7	11	12.3
1869	12	12.1	9.6	9.6	9.7	8.4	7.3	7.7	8.3	9.8	10.2	12
1870	12.6	11.6	11.7	10.3	8.6	8.3	8.2	7.3	8	8.8	10.8	11.8
1871	9.1	12.4	11.6	9.9	8.5	7.5	8.7	7.7	7.9	10.4	12.6	10.1
1872	11.8	10.3	10.4	12.2	10.7	8.2	7.9	8.7	10	11	12.2	11.1
1873	11.7	12.4	12.7	14.2	10.6	8.3	8.2	8.4	11	11.2	12.1	14.1
1874	12.1	13.2	12.9	9.6	10.2	8.5	9	7.8	9.6	10.3	14.1	13.2
1875	13.2	13.1	12.5	10.3	9.7	8.1	8.5	8.1	10	12.6	11	12.4
1876	10.3	13.8	12.4	11.9	11.3	8.7	9.6	9.3	10.3	10.5	14.5	11.9
1877	12.9	12.1	12.9	12.6	10.2	8.1	8.9	8.3	8.5	10.5	14	12.7
1880	13.4	13.5	11.5	11.5	9.4	8.3	8.7	8.7	10.4	13	.....	.....
Mean	12	12	11.6	10.9	9.5	8.3	8.3	8.2	9.2	10.5	12.1	12.1

TABLE XXV.—*Showing, in miles per hour, the mean monthly velocity of wind in the basin of Lake Ontario.*

Date.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1860	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	9.5	12.6
1861	12.1	15	12.4	9.1	11	7.5	8.1	8	7.7	12.4	13.4	12.2
1864	14.6	12.5	11.1	9.3	10.1	7.2	8.7	8.2	9.7	11.7	12.2	14.2
1865	16.2	12.7	13	11.1	8.9	9.3	8	8.2	8.5	9.1	11.2	14
1866	12.8	15..	12'	9.9	9.3	8.9	7.8	8.3	9.6	10.6	15.2	12.5
1867	16.5	15.2	12.8	11.9	7.5	7	8.2	7.8	9.1	11.3	12.6	11.9
1868	13.6	12.1	12.5	11	9.4	8.7	7.3	8.1	8.4	11.5	11.8	12.5
1869	12.9	12.9	9.2	8.9	8.5	8.1	8.1	8.3	9.1	9.7	10.9	14.1
1870	12.8	13.2	12	10.7	8.9	7.9	9.1	8.9	7.8	9.6	12.1	12
1871	10.8	12.7	12	10.6	9.2	7.2	8.1	7.4	7.9	9.7	13	13.2
1872	11.6	10.8	12.1	11.5	9.7	8.1	7.8	7.6	8.7	10.1	11.4	11.9
1873	12.1	13.2	12.4	11.9	9.3	7.6	8.7	7.4	9.4	10.5	12.7	12.7
1874	12.6	12.9	11.9	9.7	8.8	8.3	8.2	7.8	8.4	10	13.1	12.9
1875	13.7	14.5	11.6	8.8	8.7	6.5	7.9	7.5	8.6	12.2	10.9	11.6
1876	9.9	14.2	14.9	10.9	11.2	8.8	9	9	9.5	9.9	13.6	12.6
1877	14.7	13.5	14.1	13	10.8	9	8.5	8.7	8.9	10.2	14.4	13.1
1880	12.9	11.9	11.8	11.2	9.1	8.6	8.4	9.3	10.1	11.3	.....	.....
Mean	13.2	13.2	12.3	10.5	9.4	8.2	8.3	8.1	9	10.6	12.5	12.9

REPORT

ON

REGULATION OF LAKE ERIE.

INTERNATIONAL WATERWAYS COMMISSION.

OFFICE OF THE AMERICAN SECTION,

BUFFALO, N. Y., January 8, 1910.

1. The act of the Congress of the United States, approved June 13, 1902, which requested that the Government of Great Britain be invited to join in the formation of this Commission, defined one of the duties of the Commission as follows, viz.:

"The said Commissioners shall report upon the advisability of locating a dam at the outlet of Lake Erie, with a view to determining whether such dam will benefit navigation, and if such structure is deemed advisable, shall make recommendations to their respective Governments looking to an agreement or treaty which shall provide for the construction of the same, and they shall make an estimate of the probable cost thereof."

2. The Great Lakes, lying between the United States and Canada, with their connecting channels and their natural outlet to the sea, the St. Lawrence River, of which a description will be found in the appendix to this report, constitute the most important system of inland navigation in the world. The traffic which passed through the Detroit River, its busiest link, in 1907, amounted to 71,226,895 tons, valued at about $700,000,000. About 70 per cent. of this traffic is carried in large freight carriers which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the lakes. With the depth now available they are usually loaded to a draft of about 19 feet, but careful watch is kept upon the stage of the waterways and advantage is taken of any temporary increase of stage to load the vessels deeper. The number of deep-draft vessels, as well as their size, and the share of lake traffic which they carry is increasing each year, while the lake traffic itself is increasing with great rapidity. Vessels which would carry an additional load of 85 tons for each inch of additional draft have recently been

added to the fleet. Every inch added to the available depth of water would, therefore, be of material benefit to commerce.

3. The method heretofore employed for deepening the natural channels is that of excavation, but it has been suggested that a more economical and otherwise better method would be to raise the surface of the water by obstructing the flow of the outlets. For Lake Erie in particular a definite plan, with estimates of cost, was proposed by the Board of Engineers on Deep Waterways in their report dated June 30, 1900, published as House Document No. 149, Fifty-sixth Congress, first session. The official character of this report and the ability displayed in its preparation seems to have led to the provisions of law under which this Commision is now acting, and to make of it a proper starting point for this discussion. It was proposed by the Board to "regulate" the level of Lake Erie.

4. By the term "regulation of a lake's level" is meant the maintenance of its level at or near some fixed stage, which implies such control of the discharge as will make the latter nearly equal to the total supply—rainfall and inflow less evaporation—at all times. In some cases, this may be accomplished by a submerged weir in the outlet, of such length that a small increase or decrease of stage will increase or decrease the discharge over the weir by an amount equal to the change in the total supply. A work of this kind operates automatically, but manifestly it requires more or less range of stage and the topography must be such that a great length of weir can be found; it does not lend itself to the most complete regulation.

5. The works proposed by the Board were for the regulation of Lake Erie within a range so small that it might be considered almost complete regulation. They consisted of a submerged weir in connection with a set of sluice gates "so designed that with the sluice gates all closed the low-water flow of the regulated stage of the lake will be discharged over the fixed submerged weir, and with the sluice gates all open the additional volume of overflow necessary to maintain the lake at nearly the same level will pass through the sluices at times when the lake is receiving its maximum supply." They were to be placed near the angle in the Bird Island Pier, at the head of Niagara River, and were designed to hold the level of the lake at or near 574.5, old levels, or 574.7, 1903 levels, above mean tide at New York. This is higher than any monthly mean stage reached since authentic records have been kept, that is, since 1860. It was a maximum

not to be exceeded. It is not definitely stated what the minimum monthly stage would be under regulation, but it may be inferred from certain paragraphs in the Board's report that it was to be about 573.7, 1903 levels. (See paragraph 104 of the appendix.)

6. The Great Lakes constitute a series of enormous natural reservoirs, each of which serves to regulate the flow in the river constituting its outlet, and to maintain the lake below. They are inter-dependent. The study of one, to be complete, must include the study of all. The total area drained by them is about 287,688 square miles, an area considerably larger than the German Empire. Of this total, about one-third is occupied by the lakes themselves, that is, is devoted to reservoir purposes. The result is a uniformity of level and a uniformity of flow which is truly wonderful. In Table A are given the areas of the lake surfaces and of the drainage basins.

TABLE A.

LAKE	Area of Lake Surface in Square Miles	Drainage Area Including Lake Surface, in Square Miles	Ratio of Lake to Drainage Area
Superior	32,000	76,134	1: 2.37
Michigan	22,336	65,799	1: 2.95
Huron	22,978	72,008	1: 3.13
St. Clair	503	6,194	1: 12.31
Erie	9,968	34,573	1: 3.47
Ontario	7,243	32,980	1: 4.55
Total	95,068	287,688	1: 3.02

Authority: 1906 U. S. Lake Survey report.

The areas of the small lakes and streams are taken as a part of the land area.

In Table B are given the average and the extreme variations in the levels during the period from 1860 to 1907.

TABLE B.

	Superior	Huron	Erie	Ontario
	Feet	Feet	Feet	Feet
Extreme range, 1860-1907	3.52	4.64	3.89	5.34
Maximum range in 1 year	(1860) 2.67	(1876) 1.94	(1892) 2.28	(1867) 3.65
Minimum range in 1 year	(1891) 0.49	(1879) 0.59	(1895) 0.87	(1907) 0.70
Average annual range	1.18	1.21	1.56	1.60

In Table C are given the average and the extreme variations in the discharge of the outlets for the period 1860 to 1907:

TABLE C.

	St. Marys River	Detroit River	Niagara River	St. Lawrence River at its Head
	c. f. s.	c. f. s.	c. f. s.	c. f. s.
Average discharge for entire period	82,000	204,200	212,200	254,400
Greatest excess average for any one month	46,700 Sept., 1869. 57%	71,200 July, 1865. 35%	45,600 June, 1876. 21%	96,800 May, 1902. 38%
Greatest excess average for any one year	19,100 1874. 23%	30,200 1886. 15%	26,500 1876. 13%	49,000 1902. 19%
Greatest deficiency average for any one month	33,800 Feb., 1862. 41%	98,900 Feb., 1874. 48%	43,500 Mar., 1900. 20%	102,200 Feb., 1903. 40%
Greatest deficiency average for any one year	16,900 1879. 21%	30,600 1886. 15%	31,800 1895. 15%	62,800 1895. 25%

No work of man ever has approached or ever will approach this perfection of regulation. The question now is, can he add to that which exists in any important degree.

7. Evidently the answer to this question must be based upon careful analysis and close computation. The data for its solution are found in the records of the water levels, and in the measurements of discharge taken during the last 48 years, principally under the direction of the Chief of Engineers, U. S. Army. Actual values assigned to rainfall and evaporation are not well determined and cannot be used. It is the relative value of these elements which it is necessary to know, and that value is found in the discharge measurements.

8. Soon after the organization of the Commission, a committee of two of its engineer members was appointed to collect all of the available data, and to make an hydraulic analysis of the general regulation of all the lakes. It was well known at the outset that this would be a long and laborious task, but it proved to be more so than was expected, and it was only recently completed. The full report of the committee is hereto attached as an appendix. A brief synopsis of it is here given.

9. Beginning about 1860, and continuing to date, daily or tri-daily water-level observations have been taken at Mar-

quette on Lake Superior, Milwaukee on Lake Michigan, Cleveland on Lake Erie, and Oswego and Charlotte on Lake Ontario. Beginning at later dates, observations have been taken at Sault Ste. Marie, Harbor Beach on Lake Huron, St. Clair River, St. Clair Flats Canal, Windmill Point on Lake St. Clair, Amherstburg on Detroit River, Buffalo on Lake Erie, Ogdensburg on St. Lawrence River, and Lock 27 at the head of Galop Rapids, Lock 24 at the head of Rapide Plat and Lock 21 at the head of Long Sault Rapids, on St. Lawrence River. Self-registering automatic gages giving a continuous graphical record of the rise and fall of the water were not installed until 1899. The record for each of the above-mentioned gages, except the last two, from 1860 to 1907, inclusive, has been completed by interpolation. For Lock 24, on the St. Lawrence, the record has been completed from 1880, and for Lock 21, from 1870. There are a few isolated records of dates earlier than 1860, but they are not well authenticated and cannot be used here.

10. As was stated in our report of January 4, 1907, upon the Chicago Drainage Canal, "Variations in the level of the lake's surface, due to winds and to change of barometric pressure, are frequent and irregular and at times violent. Variations of more than 6 inches are very common, often occurring hourly for many hours in succession, while variations of 2 or 3 feet within an hour are not uncommon. Besides these irregular variations there is a regular annual variation due to difference in rainfall, evaporation, and run-off, the water level being highest in midsummer and lowest in midwinter. The levels are affected also by the greater or less severity of the winter and by the consequent greater or less decrease in the discharging capacity of the outlets by ice. In order to study the annual oscillations it is necessary to eliminate the irregular oscillations, and that is accomplished by using the average levels for a month." The monthly mean stage has been obtained by taking the average of the gage readings for a month, and is given for each of the above-mentioned gages in Tables 2-17. The monthly mean stages of Lakes Superior, Michigan-Huron, St. Clair, Erie, and Ontario, from 1860 to 1907, inclusive, are shown on Plate 1.

11. The volume of discharge of the outlet at any given stage is obtained from a formula deduced from actual measurements of discharge at such stages as happened to exist at the time of observation. Formulae of this kind were deduced for each of the outlets of the Great Lakes. During the winter of 1896 discharge measurements of the St. Marys River,

the outlet of Lake Superior, were made at Spry's Dock Section, located about a mile below the St. Marys Rapids. In 1902 discharge measurements of the same stream were made at the International Bridge which connect Sault Ste. Marie, Mich., with Sault Ste. Marie, Ontario. In 1905 similar measurements were made at "Section Brewery," located about 2,000 feet below Spry's Dock Section. All of these observation were made by the U. S. Lake Survey. Up to the year 1887, the discharging capacity of the St. Marys River remained nearly uniform. Since that date, numerous artificial works have been constructed at the Sault, which have modified its discharging capacity to an important degree. During the years 1887 and 1888, the International Bridge was built, which with its piers and approaches materially reduced the cross section. In 1892, the Edison Sault Electric Company placed power works in the bed of the stream. In 1895, a power canal on the Canadian side was opened to use. In 1905, a power canal on the Michigan side was opened to use, compensating works in connection therewith having been placed in the river in 1901 and 1902. The amount of water diverted by the power canals has increased from time to time since they were opened, and so has the quantity used by the American and Canadian locks. To conform to these changes it was necessary to deduce eleven different discharge formulae for the St. Marys River alone.

12. The discharge formula for St. Clair River, the outlet of Lake Michigan-Huron, was deduced from observations made by the U. S. Lake Survey in 1899, 1900, 1901, and 1902.

In 1900, the Chicago Drainage Canal began diverting water from Lake Michigan. The amount diverted between January, 1900, and June, 1904, inclusive, was computed from data furnished by the U. S. Engineer Office at Chicago. The flow through the canal since June, 1904, has been assumed to be 4,167 cubic feet per second, the quantity authorized in the permit of the Secretary of War. It is believed to have been greater, but the difference is not sufficient to vitiate the results sought for here. An application by the Commission to the Sanitary District of Chicago for a copy of their record met with a refusal to furnish it.

13. The discharge formula for the Detroit River was derived from measurements taken at Fort Wayne, Michigan, by the U. S. Lake Survey in 1901 and 1902.

14. For the Niagara River, the outlet of Lake Erie, discharge measurements were made at the International Bridge at Buffalo, and at a point about 1,800 feet down stream, called

the "Open Section." These observations were begun in 1897 for the Board of Engineers on Deep Waterways, and were continued in 1898, 1899, and 1900, by the U. S. Lake Survey.

15. The discharge formula for the St. Lawrence River, the outlet of Lake Ontario, was deduced from measurements made by the U. S. Lake Survey in 1901 and 1902 at "Three Points Section," situated about 15 miles below Ogdensburg, N. Y., and 9 miles below the head of the Galop Rapids.

16. With the discharge formulae and the gage records, the average discharge, in cubic feet per second, has been computed for each month from 1860 to 1907, inclusive, for each outlet. The results for St. Marys River are given in Table 19; those for Detroit River in Table 20; those for Niagara River in Table 21; and those for St. Lawrence River at its head in Table 22.

17. The total supply of water to a reservoir or lake depends upon the inflow or transmitted supply from another watershed, the precipation on the surface of the lake, the run-off from the lake's watershed, and evaporation from the lake's surface, or the outflow from and storage in the lake. Of these factors, for the Great Lakes, the transmitted supply, the discharge, and the storage are known separately, while the value of precipitation, run-off, and evaporation is known collectively. The local supply for any lake is the water-yield from its own watershed, and is equal to the total supply minus the transmitted supply or inflow from the watersheds situated above. The supply factors have been deduced for Lakes Superior, Michigan-Huron, Erie, and Ontario, for each month from 1860 to 1907, inclusive, and the results are given in Tables 24, 25, 26, and 27. They are shown graphically upon Plates 2 to 17 inclusive.

18. It is to be noted that minus values for the monthly mean local supply have frequently occurred, that is to say, the evaporation has frequently exceeded the precipation and run-off. For Lake Superior, minus values occurred at some time during 41 of the 48 years considered; this usually happened in December, but it sometimes occurred in each of the months from October to April inclusive. The greatest minus value occurred in December, 1870, when the evaporation exceeded the precipation and run-off by 106,600 cubic feet per second.

19. For Lake Michigan-Huron, minus values occurred in 33 out of the 48 years considered. This usually happened in September, October, or November, but it sometimes happened also in August and December. The greatest minus value oc-

curred in September, 1871, when the evaporation exceeded the precipitation and run-off by 125,700 cubic feet per second. In that year minus values occurred in each of the four months from August to November. In 1894, minus values occurred from August to December, inclusive.

20. For Lake Erie, minus values occurred with extraordinary frequency. They are found in every year, and in many years in all of the last six months. From June, 1884, to March, 1885, inclusive, that is, for 10 consecutive months, evaporation exceeded precipation and run-off continuously, the average excess for the entire period being 40,400 cubic feet per second. There is no month, except the month of May, in which a minus value has not been found in some year between 1860 and 1907. The excessive evaporation in Lake Erie may be attributed to the facts that the lake is shallow and its longer axis lies in the direction of the prevalent winds.

21. For Lake Ontario, minus values occurred less frequently than with the other lakes, but were found in 27 out of the 48 years. The greatest minus value occurred in January, 1877, when the evaporation exceeded the precipitation and run-off by 40,300 cubic feet per second.

22. To obtain the general law which governs these supply factors, Table 28 was prepared, which gives their average for the entire period from 1860 to 1907. The averages for Lakes Superior, Michigan-Huron, Erie, and Ontario, are shown graphically on Plate 18. From these, it appears that evaporation exceeds the local supply in Lake Superior during December and is nearly equal to it during January; that evaporation is nearly equal to the local supply in Lake Michigan-Huron during October and November; that it exceeds the local supply in Lake Erie during the last half of the year, July to December; and, as a general rule, does not exceed the local supply in Lake Ontario.

23. The maximum stage of one lake does not occur at the same time as that of another lake, and this is true also of the minimum stage. Nor does the maximum outflow occur at the time of the maximum total supply, nor the minimum outflow at the time of the minimum total supply. The lake may continue to fall while the supply of water is increasing and *vice versa*. These great forces require time to act. The following table shows the ratio, R, between the maximum discharge and the maximum total supply for each lake, the time interval, $T_{MAX.}$, which elapses between the maximum total supply to any lake and the maximum discharge from that

lake, and the time interval, $T_{MIN.}$, which elapses between the minimum total supply and the minimum discharge.

LAKE	R	$T_{MAX.}$	$T_{MIN.}$
Superior	0.524	98 days	91 days
Michigan-Huron	0.647	82 "	101 "
Erie	0.884	76 "	132 "
Ontario	0.955	56 "	20 "

From which it is to be inferred that the interval of time required for an increasing supply to show its effect upon the level of Lake Superior is about 98 days, and for a decreasing supply it is about 91 days; in Lake Erie, the corresponding intervals are 76 days and 132 days respectively; for the other lakes, the intervals are somewhat less.

24. With the data which have been given, it is now possible to show what the practical result will be of an attempt to regulate the level of any lake within any given limits. For illustration, the Commission has selected the regulation of Lake Erie, between the limits 573.7 and 574.7, 1903 levels, by means of a submerged weir and sluice gates, as proposed by the Board of Engineers on Deep Waterways. In this case, the sluice gates cannot be set daily or at frequent intervals, to meet conditions as they arise, because of the difficulty of ascertaining what the true level of the lake is and what its consequent discharge is at any particular time. The irregularity and occasional violence of its oscillations make it necessary to take the average of a considerable number of observations—usually those of a month—to find the true level. The gates can, therefore, be set not oftener than once a month, and then only approximately. It is necessary to fix upon some definite elevation for the stage of the lake at the beginning of each month and then to set the sluice gates to give a discharge which will bring the lake to the level desired at the end of the month. That is to say, it is necessary to estimate the total supply which the lake will receive during the month to come. For regulation between the levels 573.7 and 574.7, the stage values at the beginning of each month should be approximately as follows:

January 1	573.8	May 1	573.9
February 1	573.7	June 1	574.0
March 1	573.7	July 1 to November 1	574.0
April 1	573.8	December 1	573.9

In Table 33 are given the actual supply to Lake Erie, and the supply which would have been estimated if regulating works had been in operation for each month from January, 1890, to December, 1906, inclusive, and their difference. The table gives also the level which the lake would have reached with regulating works, and the difference between the stage reached and the stage desired. The actual supply and the stage are rarely identical with those expected, and in some cases the differences are important. For example, the actual supply in March, 1891, was 37,100 cubic feet per second less than would have been estimated, and in the following month, April, 1891, it was 47,800 cubic feet less than would have been estimated; the stage reached at the end of April, 1891, would have been 573.48, or 5 inches lower than the stage desired. In April, 1892, the supply was 40,200 cubic feet per second, and in the following month it was 29,400 cubic feet per second, more than would have been estimated, and the stage reached at the end of May would have been 574.54, or about 6½ inches higher than the stage desired. In July, 1892, the actual supply was 35,300 cubic feet per second less than would have been estimated. In June, 1893, the actual supply was 39,000 cubic feet per second less than would have been estimated, and in June, 1901, it was 32,300 more. Numerous other instances of important differences will be found in the table. They may occur in any part of the year. They show that it is not possible to foretell the stage under regulation, a month in advance, within 5 or 6 inches; that is to say, that a margin of about 6 inches must be allowed at the upper and lower limits proposed for regulation. If the attempt be made to regulate within a range of one foot, with this margin, there will be no range left for setting the sluice gates, which is absurd. In other words, the regulation of Lake Erie within a range of 1 foot, or between the limits 573.7 and 574.7, is impracticable.

25. It appears, however, from a study of Table 33, that it would have been possible during the period covered by the table, 1890 to 1906, to regulate the level of the lake between the limits 573.31 and 574.74, or within a range of about 18 inches. This period covers the extreme low-water year, 1895, but not an extreme high-water year, like that of 1876. Computations were made to ascertain the effect of regulation between the limits 572.0 and 574.5 in the two extreme years. The results are given in Table 35, and are shown graphically on Plate 21. It is found that the extreme range from high water of 1876 to low water of 1895, which was 3.78 feet, would

under regulation have been reduced to about 2.5 feet. The high levels of 1876 would not have been raised, but the low levels of November and December, 1895, would have been raised 1.38 and 1.37 feet, respectively, and the annual mean level of 1895 would have been raised about 1.07 feet. This would benefit Lake Erie, and is, therefore, worthy of examination.

26. It must not be forgotten that these numbers refer to monthly mean or annual mean stages. It sometimes happens that the stage varies as much as 7 or 8 feet in one day, and more than 2 feet in one hour. Storms raise the water level at Buffalo, several feet higher than normal, and lower it, at Amherstburg, by a like amount; the difference of level between the two ends of the lake in extreme cases having been as great as 15 feet. To control these irregular variations is impossible. It is possible only to regulate the monthly mean stage within the limits of about 2.5 feet. Whether or not it will be expedient to undertake the regulation of Lake Erie between these limits must depend upon the following considerations.

27. Effect Upon Lake Erie. An examination of Plate 21 shows that for a year of excessive supply, such as 1876, the regulation of Lake Erie would not improve navigation. In 1895, a year of deficient supply, the mean level during the eight-month season of navigation would have been raised from 571.31 under natural conditions, to 572.41 under regulated conditions, and navigation would have been improved by an increase of 1.1 feet in the stage. The extreme low stages for the navigation season would have been raised at least 1 foot without appreciable increase in the extreme high stage. This is equivalent to deepening every harbor and channel in Lake Erie by that amount.

28. Effect Upon Lake St. Clair. The increase in the stage of Lake Erie will decrease the mean slope in the Detroit River, and will cause Lake St. Clair to rise, until the slope be so far restored as to give to the discharge through the Detroit River a value equal to the natural discharge. The amount which Lake St. Clair will rise on account of an increase of 1 foot in the stage of Lake Erie, is computed to be 0.61 foot. (See paragraph 121 of the Appendix.)

29. Effect Upon Lake Michigan-Huron. As backwater from Lake Erie raises the level of Lake St. Clair, so backwater from Lake St. Clair raises the level of Lake Michigan-Huron. The effect of an increase of 0.61 foot in the stage

of Lake St. Clair is to raise the level of Lake Michigan-Huron 0.27 foot. (See paragraph 123 of the Appendix.)

30. Effect Upon Lake Ontario, and the St. Lawrence Canals. Any change in the outflow of Lake Erie will change the water levels of Lake Ontario. If the inflow to Ontario is increased the lake level will rise, and with decreased inflow the level will fall. For the extreme years, 1876 and 1895, the effect upon Lake Ontario of the regulation of Lake Erie is shown in Table 36, and on Plate 21. For the high water year, 1876, there would have been but little change; at no time during the year would the regulated stage of Lake Ontario differ from the actual stage more than 1½ inches. In 1895, the low water year, the oscillation would have been increased. The high water of May would have been about 1 inch higher, while the low water of September, October, and November would have been 4.08, 4.46, and 4.00 inches, respectively, lower under regulation than under the natural conditions. To lower the level of Lake Ontario is to lower the St. Lawrence River and to injuriously affect navigation in the St. Lawrence canals. A comparison of the gage records upon Lake Ontario and at these canals shows that a fall of 4.56 inches in the level of Lake Ontario will lower the level in the Galop canals about 4.56 inches, in the Morrisburg canals by about 6.65 inches, and in the Iroquois Canal, Lock 25, by about 7.66 inches. During periods of low-water it would be necessary to diminish the draft of vessels navigating the canals about 7.66 inches, by decreasing their loads.

31. Effect Upon Niagara River. The effect upon Niagara River would not be important. The stage would not fluctuate through any greater range than under natural conditions. During the winter months, more frequent low water would probably occur, in which case the power companies at Niagara Falls would probably have more difficulty in keeping the channels to their intakes free from ice. During the autumn months navigation might be slightly injured by the prolongation of the low-water season, due to the storage in Lake Erie of a part of the natural discharge.

32. Effect Upon the City and Harbor of Buffalo. Low-lying portions of the city of Buffalo and the adjacent territory are subject to overflow both from the lake and from tributary streams, especially Buffalo Creek. Floods from the lake are due to storms blowing from the southwest. During the severe storm of January 20, 1907, Lake Erie rose to 579.45, or 6.49 feet above the mean for that month, or 7.0 feet above the mean of the preceding and following months. Iron fur-

naces were extinguished, a pumping plant was seriously crippled, and much damage was inflicted upon the lands and property in Buffalo adjacent to the lake and to Buffalo Creek. Under regulation, the monthly mean level of the lake upon that occasion would have been about 2½ inches higher than it was and the height of the flood would have been increased by that amount. Floods from Buffalo Creek are now of common occurrence. With a few days of warm weather in the winter, the discharge of the creek becomes so great as to overflow its banks, and the water sometimes floods an area of 1,600 acres, having a population of 10,000. It is stated by the Department of Public Works of Buffalo that a rise of 2 feet in the stages of the lake causes a rise of about 1 foot in Buffalo Creek in the center of the flood district. Most of the floods in Buffalo Creek occur during January, February, and March, when Lake Erie is at its lowest stage. Some of the greatest floods have occurred during the extreme low-water periods, such as those in the winters of 1896, 1898, 1900, and 1902. With the winter level regulated at a height greater than it actually was upon those occasions, the flood height would have been increased, and greater damage would have occurred.

33. Ice Jams. During every winter ice jams form on Horseshoe Reef at the head of Niagara River. The ice in the lake is blown toward the outlet by a southwest wind, and is piled upon the shallow reef, where it forms an ice jam extending from near the bottom to several feet above the surface of the water. In some instances, the bergs have been 20 to 30 feet high. The proposed regulating works, being placed about a mile below Horseshoe Reef, would aggravate this difficulty. The neck of the outlet might become so effectively blocked with ice that the flow of the river would be materially decreased as was the flow of the St. Clair River in the winters of 1901 and 1902. If those conditions should exist, a severe southwesterly storm, such as has occurred on numerous occasions, would inundate the lower part of Buffalo. These ice jams seriously interfere with navigation. The average date of opening navigation in the spring, at Buffalo, is April 9, while at Cleveland, the average date is March 23. The difference of 17 days in the dates of opening the two Lake Erie ports is due to ice jams. It is probable that it would be materially increased by the construction of the regulating works. It is to be observed that the ice jams would make it difficult to maintain the works.

34. Effect Upon the Low-lying Shores of Lake Erie. There are low-lying portions of the shores of Lake Erie where the water is shut out by dykes and where pumping is now required. To raise the level of the lake would increase the amount of such pumping. It is possible, also, that there are points other than Buffalo, where great commercial interests are concentrated, and where local drainage is deficient, but for reasons which will appear presently it has not been considered necessary to make a detailed investigation of every locality.

35. The advantages then of regulating Lake Erie, between the limits 572.0 and 574.5, are that the low-water stages of Lake Erie will be raised about 1 foot; those of Lake St. Clair will be raised about 0.61 foot; and those of Lake Michigan-Huron, about 0.27 foot; without in any case increasing the high water stage.

36. The disadvantages are that the oscillations in Lake Ontario are increased about 5½ inches, and low water is made lower by about 4½ inches; that the depth in the St. Lawrence canals will be diminished by about 7.66 inches; that the city of Buffalo and its southerly suburbs will suffer by increased damage from floods, and from a postponement of the date of opening navigation in the spring.

37. In weighing these advantages and disadvantages, it is to be remembered that the persons who are to benefit by the former are not identical with those who are to suffer from the latter. Those navigating the St. Lawrence canals are not specially concerned with deepening the harbors of Lake Erie; nor are those occupying the low-lying portions of Buffalo sufficiently compensated for the injury to their property by the beneficial effects upon navigation. If the advantages and disadvantages could be equally distributed, we are inclined to think that the former would outweigh the latter, and that the expediency of the undertaking would be a question of cost. As the matter stands, it involves the question of damages to vested rights, which in this case is peculiarly intricate. It is our opinion that the advantages are not of such overwhelming character as to justify the two governments in entering upon that vexatious question, and we therefore recommend that the "regulation" of Lake Erie be not undertaken, meaning thereby the most complete practicable regulation such as can be secured by a dam and sluice gates located at or near Buffalo.

38. It does not follow that nothing can advantageously be done to improve or maintain the level of the lake. It is

possible to raise the level of any lake by simply reducing the size of the outlet. With a reduced cross section, the outlet requires a steeper slope, and the average level of the lake is raised, but the oscillations will go on as before, and the discharge will remain the same. To raise the level of Lake Erie will raise also, but to a less degree, the levels of Lake St. Clair and of Michigan-Huron, and will thus benefit those waters, while it will have no effect upon Lake Ontario or the St. Lawrence River. It would be physically practicable to raise the level many feet, but here again vested rights must be considered, and the amount which the level should be raised is in our judgment limited to that which will not interfere with those rights.

39. It is believed that somewhere in the Niagara River, between Lake Erie and the Falls, a submerged dam may be placed which will greatly benefit the navigation of the waters above without injury to those below and with only minor damages, if any, to the adjoining lands. Without any attempt to "regulate" Lake Erie, the level of the lake may be raised sufficiently to compensate for the damages heretofore inflicted by the Chicago Drainage Canal and other deteriorating influences. To distinguish works of this kind from those designed to "regulate" the lake, they may be called "compensating" works.

40. The upper Niagara River is a valuable safety-valve for the protection of Buffalo from the effects of storms upon Lake Erie, and should not be obstructed by a dam. It is possible that the extreme lower end of the reach, that is, the section just above the Falls, may not be available because of excessive overflow to be caused in the valley of the Welland River. To determine the best site it has been necessary to make additional surveys. These were begun in July, 1909, and are still in progress. After their completion it is our intention to submit a supplementary report upon the subject.

41. In connection with the hydraulic analysis of the general regulation of all the lakes, attention is invited to a discussion of the regulation of Lake Superior, of Lake Michigan-Huron, and of Lake Ontario, which will be found in the Appendix, paragraphs 125-132, 148-155. Without going into details it may be stated in general terms, that, as in the case of Lake Erie, only a very moderate degree of improvement in regulation over what nature provides is practicable in any of the lakes, and that, such as it is, this improvement is obtained at the expense and to the injury of the navigable chan-

nels below. If the level of any lake has been lowered, whether by diversion through the Chicago Drainage Canal or by enlargement of the outlet, the remedy seems to lie in "compensating" rather than in "regulating" works.

42. Attention is invited also to a discussion of the use of Lake Superior as a reservoir, which has been proposed by persons not familiar with the Great Lakes, to compensate for the diversion of water through the Chicago Drainage Canal (see Appendix, paragraphs 133-147). The result of the discussion is to show: 1, that Lake Superior, being naturally one of the greatest and best regulators of flow to be found in the world, maintains a flow in the St. Marys River, its outlet, which is remarkably uniform; 2, that uniformity of flow in that river is essential to the best interests of navigation of the river itself; 3, that during the winter months when navigation is suspended this uniformity of flow is still necessary to maintain the level of Lake Huron, and keep it in condition to maintain in its turn the St. Clair and Detroit Rivers in the spring when navigation opens. It is not in the power of man to improve this uniformity of flow to any important degree. He may disturb it, making it less uniform, by storing water in Lake Superior, but any water withheld at one season would create a deficiency in the lake below, which must be replaced by a equivalent increase of discharge from Lake Superior at another season. This would simply increase the oscillations in the level of the lakes below, that is, would injure them, without compensating in any degree for the diversion of water through the Chicago Drainage Canal.

O. H. ERNST,
Brig. Gen'l., U. S. Army, Retired,
Chairman, American Section.

GEORGE CLINTON,
Member, American Section.

E. E. HASKELL,
Member, American Section.

GEO. C. GIBBONS,
Chairman, Canadian Section.

W. J. STEWART,
Member, Canadian Section.

Attest:
W. EDWARD WILSON,
Secretary, American Section.

The SECRETARY OF WAR OF THE UNITED STATES.
The MINISTER OF PUBLIC WORKS OF CANADA.

APPENDIX.

INTERNATIONAL WATERWAYS COMMISSION.
OFFICE OF AMERICAN SECTION,
BUFFALO, N. Y., December 4, 1900.

THE INTERNATIONAL WATERWAYS COMMISSION:

Your committee, which was appointed to investigate the advisability of locating a dam at the outlet of Lake Erie (as proposed by the Board of Engineers on Deep Waterways) and the maintenance and regulation of suitable levels on the other lakes in the Great Lakes system, now has the honor to report upon these subjects. It is hoped that this investigation will be of assistance to the Commission in considering the subjects mentioned above.

THE GREAT LAKES.

1. The Great Lakes, comprising Lakes Superior, Michigan, Huron, Erie, and Ontario, situated between the United States and Canada, differ from the high seas in that the latter have diurnal tides while the former have periodic and seasonal stage cycles. Lake Superior, the largest of these lakes, has a length, from Duluth to Point Iroquois, of 383 miles and a breadth of approximately 160 miles. Its maximum recorded depth is 1012 feet. The outlet of this lake is the St. Marys River. The length of Lake Michigan is approximately 321 miles; its breadth, 118 miles, and its maximum measured depth 870 feet. Lake Huron is about 220 miles long and 101 miles wide, with a maximum measured depth of 750 feet. Lakes Michigan and Huron are connected by the Strait of Mackinac, and their outlet is the St. Clair River. Lake St. Clair is approximately 26 miles long and 24 miles wide; its maximum depth is less than 24 feet, except at the head of the Detroit River, the outlet of the lake. Lake Erie is about 240 miles in length, with a maximum width of 57 miles; its maximum depth, as recorded by the U. S. Lake Survey, is 210 feet. Niagara River is the outlet of this lake. Lake Ontario is about 190 miles long, 57 miles wide, and has a maximum recorded depth of 730 feet. The present natural outlet of this lake, as well as of the entire Great Lakes system, is the St. Lawrence River.

AREAS OF THE SEVERAL LAKES AND WATERSHEDS OF THE GREAT LAKES SYSTEM.

2. The areas of the surfaces of the Great Lakes and their watersheds, as detemined by the United States Lake Survey, are shown in Table 1.

TABLE 1.

LAKE.	Area of Lake Surface in Square Miles.	Drainage Area, Including Lake Surface in Square Miles.	Ratio of Lake to Land Area.
Superior	32,000	76,134	1: 1.37
Michigan	22,336	65,799	1: 1.95
Huron	22,978	72,008	1: 2.13
Michigan-Huron	45,314	137,807	1: 2.04
St. Clair	503	6,194	1: 11.31
Erie	9,968	34,573	1: 2.47
Ontario	7,243	32,980	1: 3.55

Authority: 1906 United States Lake Survey report. (Unpublished).

3. The land area for any watershed is considered as the difference between the total drainage area and the area of the lake surface. The areas of the small lakes and streams are taken as a part of the land area.

4. The ratio of lake to land area is least for Superior and greatest for St. Clair, and increases with each succeeding lake lower in the system, St. Clair excepted.

WATER-LEVEL RECORDS OF THE GREAT LAKES AND THEIR CONNECTING RIVERS.

5. Beginning about 1860 and continuing to date, daily or tri-daily water-level observations have been taken on the several lakes and connecting channels of the Great Lakes. These readings have been reduced to monthly mean stage by determining the average for the month. In 1899, the first self-registering automatic gages, giving a continuous graphical record of the rise and fall of the water, were installed. The water-level records tabulated in this report pertain directly to the stage of the waters of the Great Lakes system. In nearly every instance, they have been placed at the service of the Commission through the Chief of Engineers' reports, or have been obtained from the United States Lake Survey.

6. MARQUETTE. The elevation of the water surface of Lake Superior above mean tide at New York was observed at Superior, Wis., for the period from 1860 to 1871, inclusive, while from 1872 to 1907, inclusive, it was observed at Mar-

quette, Mich. The self-registering gage, located at Marquette, was placed in operation in November, 1902. During the forty-eight years of observations, there were months when no records were taken. For the years 1860 and 1861, missing values have been supplied by adding (algebraically) to the observed reading of the following or preceding month the monthly mean rise or fall of water surface from 1860 to 1871, inclusive. Missing values in the period from 1871 to 1888, inclusive, have been supplied by adding to Sault Ste. Marie, Mich., readings the monthly mean fall from Marquette to Sault Ste. Marie for that period. Missing values for the period from 1889 to 1901, inclusive, have been supplied from the Sault Ste. Marie readings by applying to these readings the monthly mean fall from Marquette to Sault Ste. Marie for that period. The stage of Lake Superior, from 1860 to 1907, inclusive, at Marquette, Mich., and Superior, Wis., is given in Table 2.

7. Sault Ste. Marie. The monthly mean stage of the St. Marys River, the outlet to Lake Superior, was observed at the southwest pier, Sault Ste. Marie, Mich., (above the locks) from November, 1870, to December, 1907, inclusive. Before November, 1899, the readings were taken with a staff gage, but since that time a self-registering gage has been in operation. To make the records complete from January, 1860, to October, 1870, inclusive, the mean monthly fall from 1871 to 1888, inclusive, from Marquette to Sault Ste. Marie, has been subtracted from the corresponding Marquette readings. These monthly mean stages at Sault Ste. Marie (above the locks) are given in Table 3.

8. Milwaukee. The water-level records giving the stage of water of Lake Michigan, from 1860 to 1907, inclusive, were taken at Milwaukee, Wis. The monthly mean elevations of water surface are given in Table 4.

9. Harbor Beach. From September, 1874, to December, 1907, inclusive, the stage of Lake Huron was observed at Harbor Beach, Mich., (formerly Sand Beach). From April, 1901, to December, 1907, inclusive, the stage was recorded by a self-registering gage. The water levels from January, 1860, to August, 1874, inclusive, were derived by the United States Lake Survey, (see page 4105, appendix EEE, annual report of the Chief of Engineers for 1904), as follows: January, 1860, to September, 1864, inclusive, from observations at Point aux Barques; and October, 1864, to August, 1874, inclusive, from observations at Port Austin. These water

levels for Lake Huron stage, from 1860 to 1907, inclusive, are given in Table 5.

10. G. T. R. Water-level observations have been taken near the head of the St. Clair River, at G. T. R. (Grand Trunk Railway) from March, 1899, to December, 1907, inclusive. The computed G. T. R. monthly mean gage readings from January, 1860, to February, 1899, inclusive, were derived from the relation deduced between the monthly mean stage at Harbor Beach and Grand Trunk Railway, from March, 1899, to December, 1904, inclusive. The equations are: for assumed open season, from April to December, (G. T. R.—578)=0.889 (Harbor Beach—578)—0.529, and for the winter season of January, February and March, (G. T. R.—578)=0.889 (Harbor Beach—578)—0.235. The actual observations showed that during the average open season the fall from Harbor Beach to G. T. R. remained practically constant for the same stage, but increased slightly with increasing stages of Lake Huron, while during the winter months the fall decreased materially but also increased slightly with increasing stages of the lake. The G. T. R. gage data are shown in Table 6.

11. St. Clair Flats Canal. In July, 1872, the first authentic records of the stage of Lake St. Clair were taken at the St. Clair Flats Canal. These readings were recorded continuously up to December, 1907, inclusive, with the exception of October, 1877; April and May, 1878; June, 1879, to August, 1881, inclusive; November, 1881, to April, 1882, inclusive; June, September, and October, 1882; December, 1882, to April, 1883, inclusive; January to March, 1902, inclusive; February to April, 1903, inclusive; January, 1906, to October, 1906, inclusive; and August, 1907, to December, 1907, inclusive. From January, 1860, to June, 1872, inclusive, no observations were taken. Values for the missing monthly mean water levels at St. Clair Flats Canal for January, 1861, to July, 1865, inclusive; January, 1866; April and May, 1878, and June, 1879, to August, 1881, inclusive, have been deduced from the monthly means of observations taken simultaneously at St. Clair Flats Canal, the Light-house Depot, Detroit, Mich. (see 1868, United States Lake Survey report in report of the Secretary of War, Fortieth Congress, third session, Vol. 2, 1868-69, p. 985), and Amherstburg, Ont., from which the derived relation between fall from Light-house Depot to Amherstburg, and fall from St. Clair Flats to Amherstburg has been determined. The equation expressing this relation is: (Fall St. Clair Flats to Amherstburg)=1.0357 (Fall Light-house Depot to

Amherstburg)+0.377. Those missing for January, 1868, to March, 1868, inclusive; January, 1869, to March, 1869, inclusive; December, 1869, to March, 1870, inclusive; January and February, 1871; and December, 1871, to March, 1872, inclusive, have been derived from the monthly means of observations taken simultaneously at St. Clair Flats Canal, Old Detroit Waterworks, located at the foot of Orleans Street, Detroit, Mich. (see Forty-ninth regular report of the Board of Water Commissioners to the Common Council of the city of Detroit, 1901), and Amherstburg, Ont., from which has been derived the relation between the fall from St. Clair Flats to Old Detroit Waterworks, and fall from St. Clair Flats to Amherstburg. The derived equation is: (Fall St. Clair Flats to Amherstburg)=0.9378 (Fall Old Detroit Waterworks to Amherstburg)+0.853. Those missing for August, 1865, to December, 1865, inclusive; February, 1866, to December, 1867, inclusive; April, 1868, to December, 1868, inclusive; April, 1869, to November, 1869, inclusive; April, 1870, to December, 1870, inclusive; March, 1871, to November, 1871, inclusive; April, 1872, to June, 1872, inclusive; and October, 1877, have been derived independently from Light-house Depot observations and from Old Detroit Waterworks' records taken at the foot of Orleans Street, Detroit, Mich., as previously explained. The mean of the two derived values has been used for St. Clair Flats. For all months of the year 1860, the St. Clair Flats values (as given on p. 4097, United States Lake Survey report of 1904) have been reduced by 0.67 foot, so as to obtain the original readings taken as the Old Detroit Waterworks, foot of Orleans Street, which were not available. From the original readings thus obtained, new values for stage at St. Clair Flats Canal have been derived by the fall method previously described. The value 0.67 foot represents the mean fall from St. Clair Flats Canal to Old Detroit Waterworks, as deduced on p. 4082 of the United States Lake Survey report for 1904. The derived values for November, 1881, to April, 1882, inclusive; June, September, and October, 1882; and December, 1882, to April, 1883, inclusive, have been obtained by first subtracting 0.48 foot (0.477) from the New Detroit Waterworks' readings and then applying the mean monthly fall from St. Clair Flats to New Detroit Waterworks, as deduced from observations taken at those points from January, 1889, to June, 1901, inclusive. The value referred to above (0.48 foot) represents the discrepancy in the elevation of the zero of the New Detroit Waterworks' gage, as determined about 1878 and during the period from 1893 to

1897. In the forty-ninth regular report of the Board of Water Commissioners of Detroit, it was assumed that the error occurred when the gage was moved and that it had remained at a constant elevation from January, 1878, until 1893. A comparison of these data with those taken simultaneously at St. Clair Flats Canal indicates that the change occurred after May, 1889. Those for January to March, 1902, inclusive; February to April, 1903, inclusive; January to October, 1906, inclusive; and August to December, 1907, inclusive, have been derived from the observations taken at Windmill Point, Lake St. Clair, by applying the mean monthly fall from St. Clair Flats Canal to Windmill Point, as determined from simultaneous observations taken at those points from January, 1897, to July, 1907, inclusive. The monthly mean levels of Lake St. Clair, at St. Clair Flats Canal, are given in Table 7.

12. Windmill Point. Water-level readings have been taken at Windmill Point, near the outlet of Lake St. Clair, by the United States Lake Survey, from 1897 to 1907, inclusive, with the exception of February, 1898, and May and June, 1902. The monthly mean stage values from January, 1860, to December, 1896, inclusive, and for the three missing months mentioned above, have been derived from the St. Clair Flats Canal readings by applying to those values the mean monthly fall from St. Clair Flats Canal to Windmill Point, as determined from simultaneous observations made at those points from January, 1897, to July, 1907, inclusive. The monthly mean values at Windmill Point are given in Table 8.

13. Amherstburg. For several years, commencing with July, 1899, water-surface readings have been taken at the foot of the Detroit River, by which a good relation has been obtained between the water levels at Cleveland, Ohio, and Amherstburg, Ont. The values from January, 1860, to June, 1899, inclusive, and July to December, 1907, inclusive, were derived by applying to the Cleveland, Ohio, readings the mean monthly fall from Amherstburg to Cleveland, as determined from stimultaneous observations at those places from July, 1899, to December, 1904, inclusive. The Amherstburg monthly mean water-surface readings are shown in Table 9.

14. Cleveland. Water-level readings of Lake Erie have been taken at Cleveland, Ohio, from 1860 to 1907, inclusive, with the exception of January, 1877, and October, 1880, to March, 1881, inclusive, which values have been supplied by applying to the monthly mean values for Erie, Pa., the corresponding yearly mean difference of stage between Erie and

Cleveland. The values from January, 1860, to December, 1903, inclusive, have been taken from the United States Lake Survey report for 1904, beginning with p. 4097. Those from January, 1904, to December, 1907, inclusive, have been taken from the United States Lake Survey annual reports. These monthly mean water levels of Lake Erie, at Cleveland, Ohio, are given in Table 10.

15. BUFFALO. All of the water-surface records taken at Buffalo, prior to March, 1887, were accidently destroyed, and values have been derived from Cleveland readings by applying to such readings the mean monthly fall from Cleveland to Buffalo, as derived from simultaneous observations taken at those places from June, 1899, to December, 1906, inclusive. Values for January and February, 1901, and December, 1902, have been supplied in the same way. From 1888 to 1898, inclusive, the monthly means have been derived from the U. S. Lake Survey tables by subtracting 0.1 foot from the records there given. This correction has been determined by a comparison with Cleveland of the mean of the three months, June, July, and August, for each year during this period. From March, 1899, to December, 1907, inclusive, the gage records have been taken with a self-registering automatic gage, located at the Buffalo Breakwater Light-house. The monthly mean elevations of Lake Erie, at Buffalo, N. Y., from 1860 to 1907, inclusive, are given in Table 11.

16. CHARLOTTE. Water-level readings of Lake Ontario have been taken at Charlotte, N. Y., from January, 1860, to October, 1907, inclusive. In 1906, the United States Lake Survey's automatic gage was destroyed and since that time has not been replaced. These monthly mean water-surface elevations of Lake Ontario at Charlotte, N. Y., are given in Table 12.

17. OSWEGO. Water-level observations have been taken at Oswego, N. Y., from 1860 to 1907, inclusive. These water levels give the true elevations of Lake Ontario for that period, with the possible exception of some spring months when the Oswego River is at flood stage. These water-surface elevations of Lake Ontario, at Oswego, N. Y., are given in Table 13.

18. OGDENSBURG. The water-level records of the St. Lawrence River, taken at Ogdensburg, N. Y., are very incomplete. The missing monthly means for Ogdensburg have been derived from Oswego readings by use of the following equation, which has been derived from monthly mean levels at those two places, as deduced from simultaneous observations: (Og-

densburg—240)=0.9426 (Oswego—240)—0.553. The St. Lawrence River water levels, at Ogdensburg, are shown in Table 14.

19. Lock 27. The Canadian Government has observed the stage of water on the sills of the several locks in the St. Lawrence canals for many years. The observations taken at Lock 27, which is located at the head of Galop Rapids in the St. Lawrence River, date from January, 1875, and are complete to December, 1907, inclusive, with the exception of June, 1878, February, 1880, and August and September, 1890, the values for which have been derived from Oswego values, using the following formula: (Lock 27—240)=0.9457(Oswego —240)—1.845. For the period from January, 1860, to December, 1874, inclusive, the water-level values have been derived from Oswego, N. Y., readings according to the above formula, which assumes a mean-fall relation between Oswego and Lock 27 during that period. Table 15 gives the monthly mean water-level records of the St. Lawrence River, at Lock 27, head of Galop Rapids, from 1860 to 1907, inclusive.

20. Lock 24. The water-level readings taken at Lock 24 have been observed from January, 1880, to December, 1907, inclusive, and are complete with the exception of February, 1880, April and May, 1882, and May, 1890. Lock 24 is located at the head of the Morrisburg Canal. This canal was built along a portion of the north shore of the St. Lawrence River, and provides a 14-foot navigable channel around the Rapide Plat. Table 16 gives the monthly water levels at Lock 24, head of Rapide Plat, St. Lawrence River, from January, 1880, to December, 1907, inclusive.

21. Lock 21. The stage observations taken at Lock 21, the upper entrance to the Cornwall Canal and at the head of the Long Sault Rapids in the St. Lawrence River, were begun January, 1870, and are complete to December, 1907, inclusive, with the exception of September, 1882. The monthly mean water-surface readings at Lock 21, Cornwall Canal, head of Long Sault Rapids, St. Lawrence River, are given in Table 17.

22. Plate 1 shows the monthly mean stage of Lakes Superior, Michigan-Huron, St. Clair, Erie, and Ontario from 1860 to 1907, inclusive.

NOMENCLATURE.

23. The following abbreviations and terms are used in this report.

S = Total supply to any lake, in cubic feet per second.

R = Run-off from watershed, in cubic feet per second.

D = Discharge of lake's outlet, in cubic feet per second.

E = Evaporation from lake surface, in cubic feet per second.

P = Precipitation on lake surface, in cubic feet per second.

I = Inflow or transmitted supply from lake above, in cubic feet per second.

L = Local supply, or supply from lake's own drainage area, in cubic feet per second.

s = Storage on lake surface, in cubic feet per second, (positive or negative).

A = Area of lake, in square feet.

h = Depth, in feet, on lake surface, measured from any datum.

t = Time, in seconds, for one-twelfth of a year.

i = Increment, or rate of change of discharge in cubic feet per second per foot change in stage.

u = Coefficient.

g = Acceleration due to gravity, = 32.2 feet per second per second.

b = Width of section, or length of crest of submerged weir in feet.

h_U = Head, in feet, on crest of submerged weir, measured from upstream side.

h_D = Head, in feet, on crest of submerged weir, measured from down-stream side.

F = Fall in stream, expressed in feet.

C = Coefficient.

V = Mean velocity, in feet per second.

k = Theoretical velocity head, in feet, = $V^2 \div 2g$.

h_s = Height of swell, in feet.

d = Mean depth, in feet.

$R_{MAX.}$ = Ratio between the maximum value of mean monthly discharge and the maximum value of mean monthly total supply of any lake.

$T_{MAX.}$ = Time interval in days between the date of the occurrence of the maximum value of mean monthly total supply to any lake and that of the maximum value of mean monthly discharge from that lake.

$T_{MIN.}$ = Time interval in days between the date of the occurrence of the minimum value of mean monthly total supply to any lake and that of the minimum value of mean monthly discharge from that lake.

GENERAL EQUATION FOR STREAM FLOW.

24. The discharge equations of all rivers in the Great Lakes system, with the exception of the St. Marys River, have been derived by use of a submerged-weir formula. Each river bed has been assumed to represent a submerged weir with a broad, flat crest, whose upstream and downstream faces are of considerable length. The location of the submerged weir has been assumed to be at or near the critical cross section, which is generally at the head of the river. The submerged-weir formula is generally recognized in one of the following two forms:

$$D = u\frac{2}{3}b\sqrt{2g}\,(h_U - h_D)^{\frac{3}{2}} + ubh_D\sqrt{2g}\,(h_U - h_D)^{\frac{1}{2}} \quad (1)$$

$$D = u\frac{2}{3}b\sqrt{2g}\,\left(h_U + \frac{h_D}{2}\right)(h_U - h_D)^{\frac{1}{2}} \quad (2)$$

where h_U represents the depth on the average elevation of the crest of the weir, measured from the upstream side,
h_D the depth on the average elevation of the crest of the weir, measured from the downstream side, and
b, the length of the weir crest in feet. The quantity, (h_U—h_D), represents the fall (F) in the stream, or the difference between the upstream and downstream heads. The quantity, $u2/3b\sqrt{2g}$, taken as a whole, represents a variable coefficient (C) which has been derived for each river and is applicable only to that river. This submerged-weir formula reduces to the form,

$$D = CF^{\frac{1}{2}}\left(h_U + \frac{h_D}{2}\right) \quad (3)$$

and was so used in deriving the discharge equations of the several rivers. For every measurement of river discharge, all factors are known with the exception of the coefficient, which has been derived. Knowing the way in which the coefficient for each river varies according to the upstream and downstream head, it is a comparatively simple matter to compute the discharges of the several outlets according to the proper formula. On the St. Clair, Detroit, and St. Lawrence Rivers, the coefficients vary as a function of the upstream and downstream head on the submerged weir. The curve used, showing the manner in which C varies, is the equilateral hyperbola, with its asymptotes parallel to the co-ordinate axes. It is:

$$C = \frac{y}{1 + \frac{x}{h_U}} \quad (4)$$

in which C is the coefficient depending on h_U or h_D, the upstream or downstream head, respectively.
x and y are constants, which represent the distance of the asymptotes from the y and x axes, respectively.
For convenience in deriving the unknown values, this hyperbolic equation has been transformed into a straight-line equation by dividing by y, which gives

$$C = \frac{1}{\frac{1}{y} + \frac{x}{yh_v}} \qquad (5)$$

and then taking the reciprocal of each member:

$$\frac{1}{C} = \frac{1}{y} + \frac{x}{y}\left(\frac{1}{h_v}\right) \qquad (6)$$

DISCHARGE OF ST. MARYS RIVER, OUTLET TO LAKE SUPERIOR.

25. The Marys River, from Point Iroquois, in Lake Superior, to the head of the United States Ship Canal, at Sault Ste. Marie, Mich., is a wide stream with comparatively little slope, there being about two-tenths of a foot fall in this distance. At the latter location, rapids (about one-half a mile in length) connect the upper and lower St. Marys River. The submerged weir of rock at the head of these rapids controls the discharge of water from Lake Superior, and any change in this submerged weir would cause a change in the volume of discharge for the same stage. Any auxiliary channel connecting with the pool immediately above the weir would increase the river discharge for the same stage by the volume thus diverted. During the epoch, 1860 to 1907, inclusive, the regimen of the St. Marys River, above the rapids, was changed on several occasions. In 1887 and 1888, the International Bridge across the St. Marys Rapids was constructed. Prior to that time, the river discharged at the bridge site through four channels, viz., the main rapids and three small streams situated between the islands lying adjacent to the north shore. The building of the bridge piers and approaches and the filling in of portions of the three small streams (called *a*, *b*, and *c*) on the north side of the main channel reduced the effective area at this critical discharge cross section so that the flow of the St. Marys River was materially decreased.

26. In 1889, the Canadian Water Power Company (now the Lake Superior Power Company) commenced work on a power plant and used for its canal the northerly of the three small streams (*c*) previously mentioned. The flow therein was practically stopped until the latter part of 1895, when this power plant was opened. During the year 1892, the Edison Sault Electric Light & Power Company (now the Chandler-Dunbar Water Power Company) built a dyke from the second pier on the American side of the International Bridge, parallel to the shore, for a distance of about 1,500

feet down the stream. The area inclosed by the American shore and this dyke is used as a forebay by the power company, practically shutting off from the main channel the flow through these two spans. By December, 1892, the flow of the river had been restricted by the building of the piers and approaches to the International Bridge, the shutting off of spans 1 and 2 from the main channel on the American side, and the closing of stream *c* on the Canadian side. Beginning in December, 1895, the Lake Superior Power Company started the operation of its plant on a large scale, using water at the rate of approximately 3800 cubic feet per second. This power plant has been in continuous operation since then, with the exception of February and March, 1896, and has gradually increased the quantity of water used until it now reaches about 6000 cubic feet per second. The use of water by the American and Canadian locks has also increased from time to time until it now amounts to an average flow of about 600 cubic feet per second. In 1901, the Michigan Lake Superior Power Company started work on the construction of a compensating works in the rapids of the St. Marys River, about 300 feet above the International Bridge. These works practically shut off the entire flow through spans 9 and 10, the first two spans on the Canadian side of the river. In January, 1905, the Michigan Lake Superior Power Company began to divert water through its canal, using about 8500 cubic feet per second at that time.

27. DISCHARGE MEASUREMENTS. During the winter of 1896, discharge measurements of the St. Marys River were taken by the United States Government at Spry's Dock Section, located about a mile below the St. Marys Rapids. The discharge equation deduced from these observations, modified for the various efflux conditions, has been the governing factor for the determination of the outflow of Lake Superior from January, 1860, to September, 1901, inclusive. The derived equation is:

$$D_{RIVER}=18826\ (\text{Southwest Pier Gage}-600)+37060. \quad (7)$$

See 1906 United States Lake Survey report (unpublished).

28. The Southwest Pier Gage is located at the southwest pier above the American locks at Sault Ste. Marie, Mich. At the time that these measurements were taken, the Chandler-Dunbar Water Power Company was using 1065 cubic feet of water per second through its works; streams *a* and *b* on the north side of the main channel were still open, and the Lake Superior Power Company's plant was closed.

29. In 1902, the United States Lake Survey measured the flow through the St. Marys Rapids at the International Bridge, which connects Sault Ste. Marie, Mich., with Sault Ste. Marie, Ont. The discharge equation derived from these observations gives the flow through the rapids after spans 9 and 10 (the first two spans on the Canadian side) were closed by the construction of the compensating works of the Michigan Lake Superior Power Company. It is:

$D_{RAPIDS} = 15540$ (Southwest Pier Gage—600) + 30510. (8)

30. During February and March, 1905, observations of the flow in the St. Marys River were taken at "Section Brewery," located about 2000 feet below the Spry's Dock Section. The discharge equation derived from these measurements is:

$D_{RIVER} = 18484$ (Southwest Pier Gage — 600) + 41829. (9)

This formula gives the total flow of the river, while that derived from the 1902 measurements gives only the flow through the St. Marys Rapids.

31. ST. MARYS RIVER DISCHARGE FORMULAE, AS USED FOR THE DIFFERENT EFFLUX CONDITIONS. The discharge formula governing the first period, 1860-1888, inclusive, was derived from the measurements made in 1896 and 1902 (the fifth and tenth periods of efflux) in conjunction with hydraulic data taken at the International Bridge Section in 1901 and 1902. The mean stage of the St. Marys River at the Southwest Pier (above the locks), Sault Ste. Marie, Mich., from 1871 to 1905, inclusive, was 601.86 feet above mean tide at New York. The 1896 discharge measurements give: $D_{RIVER} = 18826$ (Southwest Pier Gage — 600) + 37060. The discharge of the river at mean stage was 72076 cubic feet per second. Deducting from this value 1065 cubic feet per second (the amount of water used by the Chandler-Dunbar Water Power Company) and 1798 cubic feet per second (the discharge of two small streams on the north side of the rapids) gives the flow through the main channel of the St. Marys Rapids as 69200 cubic feet per second. From the vertical and transverse percentage velocity curves deduced from observations made at the Bridge Section, for spans 3-10, inclusive, in 1901, and for spans 3-8, inclusive, in 1902, the ratio of flow of the entire cross section to that for any partial section has been determined. These curves show the modification in the transverse velocity curve due to the construction, by the Michigan Lake Superior Power Company, of the compensating works located about 300 feet above the bridge. With these data, the transverse percentage velocity curve at the International Bridge Section, for the first period, has been constructed for the entire main channel,

which included the channels for spans 1 and 2 of the bridge, next the American shore. This curve has been integrated and its mean ordinate, or mean percentage velocity, computed. The product of this value and the mean velocity of the rapid's flow at mean river stage under the 1896 conditions, or during the fifth period of efflux, gives the mean velocity for the main channel under the original conditions, or for the first period of efflux. The product of the mean velocity and the area of the cross section before the bridge was built gives the discharge of the main channel for mean river stage. The equations giving the actual computations are:

$$D_1 = A_1 \left(\frac{D_5}{A_5} \times \text{mean percentage } V_1\right) = A_1 V_1 \qquad (10)$$

$$= 13690\left(\frac{69200}{10650} \times 0.925\right) = 13690 \times 6.01 = 82280$$

cubic feet per second, discharge of main channel for mean river stage under original conditions.

32. With the volume of flow known for mean river stage, the only remaining step is to derive the increment of discharge per foot change in stage. In deriving this increment, use has been made of Bernouilli's theorem applied to open channels with steady flow, expressed as follows:

$$\text{Friction head} = F + \frac{V^2_{\text{UPSTREAM}}}{2g} - \frac{V^2_{\text{DOWNSTREAM}}}{2g} \qquad (11)$$

33. It has been assumed that the friction heads before and after the rise were proportional to the squares of the respective velocities at the Bridge Section. The two cross sections used are: The upper one, located nearly opposite the Southwest Pier Gage, and the lower one, at the International Bridge. Under original conditions, the areas of the upper and lower cross sections were 46260 and 13690 square feet, respectively, and the width were 3400 and 2383 feet, respectively, at 601.86 feet, the mean river stage at Southwest Pier Gage. According to formula 10, the discharge of the river at this stage was 82280 cubic feet per second. The corresponding mean water surface at the Bridge Section was 600.56 feet. Substituting these values in the preceding formula gives: Friction head before rise=1.30+0.049—0.562=0.787 foot. Actual measurements taken under the conditions existing for the fifth and tenth periods show that a rise of 1 foot at Southwest Pier Gage for mean river stage caused a rise of 0.636 and 0.592 foot at the bridge, respectively. These are the values for rise before and after the

compensating works had been constructed. The mean of the above values (0.614 foot) has been used as the assumed rise under original conditions, since the relation appeared to be nearly constant for two radically different discharge periods. After a rise of 1 foot at the upstream section, the mean velocity became $\frac{D}{49660}$ feet per second, and the corresponding velocity head was $\frac{(\frac{D}{49660})^2}{2g}$. For the rise of 0.614 feet at the downstream section, the mean velocity became $\frac{D}{15150}$ feet per second, and the corresponding velocity head was $\frac{(\frac{D}{15150})^2}{2g}$. The potential head after rise was: $F=1.30+1.00-0.614=1.686$ feet. Substituting the new values in Bernouilli's formula gives: Friction head after rise $= 1.686+ \frac{(\frac{D}{49660})^2}{2g} - \frac{(\frac{D}{15150})^2}{2g}$. Under the previous assumption that the friction heads before and after the rise were proportional to the square velocities, we have:

$$0.787 : 1.686 + \frac{(\frac{D}{49660})^2}{2g} - \frac{(\frac{D}{15150})^2}{2g} :: 6.01^2 : (\frac{D}{15150})^2 \qquad (12)$$

whence D=103840 cubic feet per second. This value represents the discharge through the main channel at 1 foot above mean river stage, 601.86. The difference between this discharge value and 82280, the discharge for mean stage, is 21560 cubic feet per second, the increment of discharge for 1 foot rise above mean stage. This method was also used for the determination of the increment for one foot below mean stage, which gave 20720. The mean of 21560 and 20720, viz., 21140 cubic feet per second, has been used as the increment of discharge.

34. The discharge formula governing the flow through the main channel for the period is as follows:

$D_{1\ \text{MAIN CHANNEL}}=21140$ (Sou't west Pier Gage—601.86)+ 82280. (13)

35. The two small streams (*a* and *b*) situated on the north side of the main channel had a flow of 1800 cubic feet per second at mean river stage, with an estimated increment of discharge per foot rise of 950 cubic feet per second. The

third small stream (*c*) situated also on the north side of the main channel had an estimated flow of 1800 cubic feet per second at mean river stage, with an estimated increment of discharge per foot rise of 950 cubic feet per second. By combining the above results, the discharge formula of the St. Marys River for the original conditions, or first period, (January, 1860, to November, 1888, inclusive), before any alterations had occurred in the outlet to Lake Superior above the St. Marys Rapids, is:

$D_1 = 23040$ (Southwest Pier Gage — 601.86) + 85880. (14)

36. The construction of any engineering structure necessarily takes time; so, in the building of the piers and approaches for the International Bridge, some time elapsed before the completion of the substructure. It is assumed that original conditions prevailed to December 1, 1888, after which the piers and approaches for the International Bridge are considered as having been completed, and stream *c*, adjacent to the north shore, as having been closed. This date marks the beginning of the second period, which is assumed to continue to December, 1892, inclusive. The discharge formula governing the flow through the main channel for this efflux condition has been computed in the same way as that for the first period. It is:

$D_{2\ \text{MAIN CHANNEL}} = 19080$ (Southwest Pier Gage—601.86)+ 77200. (15)

37. Two small streams (*a* and *b*) situated on the north side of the main channel were still flowing, as in the first period. Combining the results of the flow through the main channel and streams *a* and *b* gives the total flow in the St. Marys River for the second period as:

$D_2 = 20030$ (Southwest Pier Gage—601.86)+79000. (16)

38. For the third period, January, 1893, to November, 1895, inclusive, the efflux condition was the same as that for February and March, 1896, when the discharge measurements were taken. It is assumed that the Chandler-Dunbar Water Power Company closed spans 1 and 2, on the American end of the International Bridge, at the beginning of this period. The volume of water used by them was estimated to be about 1065 cubic feet per second. Streams *a* and *b* were still flowing. The equation of discharge for St. Marys River for the third efflux condition is:

$D_3 = 18826$ (Southwest Pier Gage—600)+37060. (17)

39. In December, 1895, the beginning of the fourth period, the Lake Superior Power Company began using water on a large scale, estimated by the chief engineer of the Lake

Superior Power Company at 3800 cubic feet per second. The Chandler-Dunbar Water Power Company is assumed to have been still using 1065 cubic feet per second. Streams *a* and *b* were still flowing. The discharge equation for the fourth period, from December, 1895, to January, 1896, inclusive, is:

D_4=18826 (Southwest Pier Gage—600)+40860. (18)

40. The fifth epoch, February and March, 1896, marks the date of the first discharge measurements of the St. Marys River used in this report. The discharge formula for the river flow is:

D_5=18826 (Southwest Pier Gage—600)+37060. (19)

41. For the sixth period, April, 1896, to December, 1897, inclusive, the auxiliary flow is estimated at 3500 cubic feet per second through the works of the Lake Superior Power Company. Streams *a* and *b* were still open. The Chandler-Dunbar Water Power Company was using approximately 1065 cubic feet per second. The three latter are included in the river discharge formula as derived from observations made in February and March, 1896. The discharge equation of the St. Marys River for this period is:

D_6=18826 (Southwest Pier Gage—600)+40560. (20)

42. For the seventh period, January, 1898, to March, 1899, inclusive, 4000 cubic feet per second is estimated as the side flow through the works of the Lake Superior Power Company. Streams *a* and *b* were still flowing. The Chandler-Dunbar Water Power Company is estimated to have been still using about 1065 cubic feet per second. The discharge through the locks for this period and previous thereto has not been incorporated in the discharge equations, owing to the fact that it is considered to have been, comparatively, a small quantity. The discharge equation giving the flow of the St. Marys River for this period is:

D_7=18826 (Southwest Pier Gage—600)+41060. (21)

43. For the eighth period, April, 1899, to December, 1899, inclusive, the side flow through the works of the Lake Superior Power Company is estimated at 4000 cubic feet per second. Streams *a* and *b* were still flowing. The Chandler-Dunbar Water Power Company is assumed to have increased its flow at the beginning of the period from 1065 cubic feet per second to 1400 cubic feet per second. It is estimated that the American and Canadian locks were using at that time an average flow of 600 cubic feet per second. By combining the above data, the net side flow, other than that at the time of the 1896 discharge measurements,=4000+(1400—1065)+600=4935 cubic feet per second, (4940 used). The discharge

formula for the St. Marys River for this period is:

$D_9 = 18826$ (Southwest Pier Gage $- 600) + 42000$. (22)

44. For the ninth period, January, 1900, to September, 1901, inclusive, streams *a* and *b* are assumed to have been closed at the beginning of the epoch. The shutting of these two channels decreased the increment of discharge per foot rise by 950 cubic feet per second, or to 17880, but did not change the total discharge for the main channel at stage 600 on account of the discharge of streams *a* and *b* being approximately zero at this stage. The side flow through the works of the Lake Superior Power Company is estimated to have been 5000 cubic feet per second. The Chandler-Dunbar Water Power Company and the American and Canadian locks are assumed to have been using 1400 and 600 cubic feet per second, respectively. By combining the above data, the net side flow of the river, other than that at the time of the 1896 measurements, was: $5000 + (1400 - 1065) + 600 = 5935$ cubic feet per second, (5940 used). The discharge formula for the St. Marys River for this period is:

$D_9 = 17880$ (Southwest Pier Gage—600)$+43000$. (23)

45. For the tenth period, October, 1901, to December, 1904, inclusive, the discharge formula derived from the measurements taken at the International Bridge in 1902, after the compensating works had been constructed by the Michigan Lake Superior Power Company, is:

$D_{10\ \text{MAIN CHANNEL}} = 15540$ (Southwest Pier Gage—600)$+ 30510$. (24)

46. This equation represents the flow through the St. Marys Rapids and does not take into account the flow through the Chandler-Dunbar Water Power Company's forebay and plant. Previous to this period, the quantity of water used by the Chandler-Dunbar Water Power Company is considered directly in the discharge equation. The side flow through the works of the Lake Superior Power Company is estimated to have been 5000 cubic feet per second. The Chandler-Dunbar Water Power Company and the American and Canadian locks are estimated to have been using about 1400 cubic feet per second and 600 cubic feet per second respectively. The discharge formula of the St. Marys River, used for this efflux condition, is:

$D_{10} = 15540$ (Southwest Pier Gage—600)$+37510$. (25)

47. For the eleventh period, January, 1905, to December, 1907, inclusive, the discharge formula depends on discharge measurements made by the United States Lake Survey in February and March, 1905, at "Section Brewery," located

about 2000 feet below Spry's Dock Section, which was situated opposite the power house belonging to the Michigan Lake Superior Power Company. During this period, the side flow through the works of the Lake Superior Power Company, the Michigan Lake Superior Power Company, the Chandler-Dunbar Water Power Company, and the American and Canadian locks is estimated at 6000, 8500, 1400, and 600 cubic feet per second, respectively. The discharge formula giving the total flow of the river for this period, based on the 1905 measurements, is:

D_{11}=18484 (Southwest Pier Gage—600)+41830. (26)

48. It has been noted that the discharge formula for efflux periods 10 and 11 show a difference in the increment of discharge of 2944 cubic feet per second for substantially the same conditions, the only known change in the regimen being an assumed constant diversion of 8500 cubic feet per second through the canal of the Michigan Lake Superior Power Company. This difference in increment is probably due in part to greater leakage at high stage through the dam of the Chandler-Dunbar Water Power Company.

49. The following table gives a summary of the discharge equations for the St. Marys River for the several efflux periods:

TABLE 18.

SUMMARY OF ST. MARYS RIVER DISCHARGE EQUATIONS FOR THE DIFFERENT EFFLUX CONDITIONS.

No. of Period.	Length of Period.	Discharge Equation, St. Marys River.
1	Jan. 1860—Nov. 1888	D_1 = 23040 (Southwest Pier Gage — 601.86)+33330
2	Dec. 1888—Dec. 1892	D_2 = 20030 (Southwest Pier Gage — 601.86)+79000
3	Jan. 1893—Nov. 1895	D_3 = 18426 (Southwest Pier Gage — 600.00)+37000
4	Dec. 1895—Jan. 1896	D_4 = 18526 (Southwest Pier Gage — 600.00)+36800
5	Feb. 1896—Mar. 1896	D_5 = 18826 (Southwest Pier Gage — 600.00)+37080
6	Apr. 1896—Dec. 1897	D_6 = 18826 (Southwest Pier Gage — 600.00)+40500
7	Jan. 1898—Mar. 1899	D_7 = 18826 (Southwest Pier Gage — 600.00)+41000
8	Apr. 1899—Dec. 1899	D_8 = 18826 (Southwest Pier Gage — 600.00)+42000
9	Jan. 1900—Sep. 1901	D_9 = 17880 (Southwest Pier Gage — 600.00)+43000
10	Oct. 1901—Dec. 1904	D_{10} = 15540 (Southwest Pier Gage — 600.00)+37510
11	Jan. 1905—Dec. 1907	D_{11} = 18484 (Southwest Pier Gage — 600.00)+41830

Southwest Pier Gage gives the elevation of the water surface of St. Marys River at Southwest Pier, above the locks, Sault Ste. Marie, Mich., above mean tide at New York.

50. The monthly mean discharge values of the St. Marys River, from January, 1860, to December, 1907, inclusive, are given in Table 19.

51. Probable Effect Upon Mean Level of Lake Superior of Obstructions in St. Marys River at Head of Rapids. Any obstruction placed in a river at or near its critical or con-

trolling discharge section changes the volume of flow and affects the level of the lake above and also the levels of those below. The construction of the piers and approaches of the International Bridge changed the discharge of the river and raised the mean level of Lake Superior. The shutting off of spans 1 and 2 on the American side, from the main channel, by the Chandler-Dunbar Water Power Company, and the construction of the compensating works by the Michigan Lake Superior Power Company have also had their effect on the level of Lake Superior and the lower lakes. The ultimate effect of these obstructions placed in the main channel has been derived for mean river stage on the assumption that no diversions have been made by the Lake Superior Power Company or the Michigan Lake Superior Power Company. This maximum effect on lake levels has not entirely taken place, owing to these diversions by the said power companies. In treating this subject, use has been made of the incomplete-weir formula, river-discharge increments and river-gage relations. The discharge through the main channel of the St. Marys Rapids for the third to ninth periods, inclusive, for mean river stage at Southwest Pier Gage, (1871 to 1905, inclusive,) 601.86, has been previously computed as 69200 cubic feet per second. The corresponding measured mean water surface at the International Bridge Section during this period of flow was 600.61. In 1902, after the compensating works of the Michigan Lake Superior Power Company were built, practically closing spans 9 and 10, the mean water surface of this section was measured as 600.98 for the same discharge, 69200 cubic feet per second. This rise of 0.37 foot in the water surface represents the swell, h_s, at the International Bridge Section, due to the shutting off by the compensating works of the two spans on the Canadian side of the rapids. These actual measurements afford a means for determining an experimental value of u in the incomplete-weir formula.

$$D = ub\sqrt{2g}\left\{\frac{2}{3}\left[(h_s+k)^{\frac{3}{2}}-k^{\frac{3}{2}}\right]+d\,(h_s+k)^{\frac{1}{2}}\right\}. \qquad (27)$$

where D=69200 cubic feet per second, the discharge through the St. Marys Rapids, in third to ninth periods, inclusive, with mean water surface at International Bridge of 600.61, and in tenth period with mean water surface of 600.98, b_A= 1511 feet, width of channel after obstruction by compensating works,

2g=64.4 feet per second per second,

h_s=height of swell, in feet.

$k = \frac{V^2}{2g} = \frac{(D/A_B)^2}{2g} =$ 0.655 foot=theoretical velocity head previous to placing of obstruction, and where A_B is area of cross section of main channel before compensating works were built=10650 square feet.

$d = \frac{A_B}{b_B} = \frac{10650}{1794} =$ 5.937 feet=mean depth previous to construction of works, where b_B is width of channel in third to ninth periods, inclusive. Substituting these values in the above equation and solving gives a value for u of 0.899. The building of the piers and approaches of the International Bridge, according to computations, reduced the discharge through the main channel from 82280 to 77200 cubic feet per second, decreased the channel width from 2383 to 2232 feet, and changed the cross-sectional area from 13690 to 12490 square feet. Substituting these values in the incomplete-weir formula and using the experimental value of u (0.90) gives the swell, h_s, at the bridge site, due to the construction of the piers and approaches, as 0.183 foot. The corresponding rise at Southwest Pier was 0.298 foot. This latter value represents the estimated rise in mean lake level caused by the building of the International Bridge. About four years after the International Bridge was built, the Chandler-Dunbar Water Power Company shut off spans 1 and 2, on the American side, from the main channel. This obstruction reduced still more the mean discharge through the main channel. Using the incomplete-weir formula.

$$D = ub\sqrt{2g}\left\{\frac{2}{3}\left[(h_s+k)^{\frac{3}{2}}-k^{\frac{3}{2}}\right]+d(h_s+k)^{\frac{1}{2}}\right\}$$

for determining the effect of building the bridge piers and approaches and closing spans 1 and 2, where D = 82280 cubic feet per second, discharge at mean river level, 601.86, under original conditions,

u=0.90, experimental coefficient for present case,

b_A=1794 feet, width of channel after obstructions were built,

2g=64.4 feet per second per second,

$k = \frac{V^2}{2g} = \frac{(D/A_B)^2}{2g} =$ 0.562 feet, theoretical velocity head previous to placing of obstructions, where A_B is area of cross section of main channel before structures were placed =13690 square feet.

$d = \frac{A_B}{b_B}$ =5.745 feet=mean depth before structures were placed, whereb_B=2383 feet,
and solving for h_s gives 0.496 foot as the swell at the Bridge Section due to the construction of these works. The discharge formula for the flow through the main channel of the rapids, after the bridge piers and approaches were built and spans 1 and 2 were closed, according to 1896 measurements, is: $D_{RAPIDS\ 3-9}$=17880 (Southwest Pier Gage—600.00) +35995, while that after the compensating works were built, according to the 1902 measurements, is: $D_{RAPIDS\ 10}$=15540 (Southwest Pier Gage—600.00)+30510. The increment at Southwest Pier Gage, as determined in 1896 and 1902, is 17880 and 15540, respectively, while that at the Bridge Section for the 1896 conditions was unknown, and for 1902 was 22600. In order to determine the increment at the bridge, under the 1896 conditions, the assumption has been made that the increments of discharge per foot rise under the same efflux conditions are directly proportional for various points in a stream. This proportion is; Increment Southwest $Pier_{10}$: increment Southwest Pier $_{3-9}$ :: increment $Bridge_{10}$: increment $Bridge_{3-9}$ or, inserting values, 15540 : 17880 :: 22600 :X. Solving: X=26000. The difference between the discharge through the main channel in the rapids for the first period and the third-ninth period is 82280—69200=13080 cubic feet per second. This quantity represents the volume of water cut off by the construction of the bridge piers and approaches and closing of spans 1 and 2. Since 1 foot rise at the bridge, under original conditions, is equivalent to an increase in discharge of 26000, then the swell caused by these obstructions, involving a reduction in discharge of 13080 cubic feet per second, is =0.503 foot. The swell at the bridge, due to the building of the piers and approaches for the International Bridge, the shutting off of spans 1 and 2 by the Chandler-Dunbar Water Power Company, and the closing of spans 9 and 10 by the construction of the compensating works, computed by the incomplete-weir formula, is 0.817 foot. Subtracting 0.37 foot, the actual measured swell due to the building of the Compensating works, gives 0.447 foot as the swell at the Bridge Section due to the building of the piers and approaches of the International Bridge and the shutting off of spans 1 and 2.

52. Summarizing: The swell at the Bridge Section, due to the construction of the piers and approaches and shutting off of spans 1 and 2, is:

Incomplete weir, (direct)	0.496 foot
Increment	.503 foot
Incomplete weir, (indirect) 0.817 — 0.370	.447 foot
Mean swell	.482 foot

53. The above value represents the swell at the bridge due to these obstructions, but it does not represent the true effect on the St. Marys River at Southwest Pier. Since the increment of discharge at Southwest Pier is 17880, the swell at that point, due to decreasing the discharge through the rapids by 13080, is $\frac{13080}{17880}$ =0.732 foot. By water-surface relations between Southwest Pier and mean water surface at Bridge, it is found that for mean river stage (601.86) at Southwest Pier, the corresponding mean water surface at Bridge is 600.613. Adding 0.482 foot, the mean swell at the bridge due to the construction of the piers and approaches and shutting off the spans 1 and 2, gives 601.095 as the new mean water surface. The gage readings as Southwest Pier, corresponding to this mean water surface at the bridge, is 602.645. The difference between 602.645 and 601.86 is 0.785, the swell due to building these obstructions.

54. Summarizing: The swell at Southwest Pier, due to building the piers and approaches for the International Bridge and shutting off of spans 1 and 2, is:

Increment method	0.732 foot
Gage relations	.785 foot
Mean	.758 foot

55. During the period immediately following the building of the compensating works, the mean water surface at the Bridge Section was 600.54 for mean river stage. The rapid's discharge, corresponding to this gage height, was 59300 cubic feet per second. The difference between the mean rapid's discharge before and after the building of these works is computed to be 69200—59300=9900 cubic feet per second. The increment of discharge at the bridge, as determined by measurement, was 22600. From these data, the swell at the bridge is computed to be $\frac{9900}{22600}$ =0.439 foot. Actual measurements taken before and after the compensating works were built give the swell at the bridge as 0.37 foot.

56. Summarizing: The swell at the Bridge Section, due to the construction of the compensating works, is:

Increment (direct)	0.439 foot
Actual measurement	.370 foot
Incomplete weir (indirect, 0.817 — 0.482)	.335 foot
Mean	.381 foot

57. The swell at the Southwest Pier for this period, computed by the increment method, is =0.638 foot, while by gage relations it was 0.648 foot. The mean of these two values gives 0.643 foot as the rise in the mean river stage at the southwest pier, due to the compensating works.

58. SUMMARY. The mean stage of St. Marys River at the southwest pier, from 1871 to 1905, inclusive, is 601.86. The effect of the building of the piers and approaches to the International Bridge and the shutting off of spans 1 and 2 on the American shore by the Chandler-Dunbar Water Power Company was to raise the mean river level at the Southwest Pier 0.758 foot, or to an elevation of 602.618. The effect of the construction of the compensating works on the mean river level at Southwest Pier was to raise it 0.643 foot, or to a new mean river stage of 603.261. The mean water surface at the International Bridge, after the compensating works were built, corresponding to 603.261 at Southwest Pier, was 601.423 feet. Subtracting from this value the swell at the bridge, due to the compensating works namely, 0.381 foot, gives the mean water surface at the bridge, before the compensating works were built, as 601.042. Subtracting from this new value 0.482 foot, the swell at the Bridge Section due to the construction of the piers and approaches to the International Bridge, and the shutting off of spans 1 and 2 from the main channel, gives 600.56 as the original mean water surface at the Bridge Section. The effect of placing obstructions in the St. Marys River at or near the International Bridge site has been to raise the mean level of the river at the bridge and Southwest Pier, and also the mean level of Lake Superior. If no diversions from the upper river had occurred, the ultimate rise in the mean level of the St. Marys River and Lake Superior would have been approximately 1.40 feet; but, owing to diversions having taken place, this rise has been diminished.

ST. CLAIR RIVER DISCHARGE.

59. During the period from April, 1899, to September, 1902, inclusive, the United States Lake Survey measured the discharge of the St. Clair River, the outlet to Lake Huron,

in the vicinity of Port Huron, Mich. These measurements have been used in deriving a formula for the flow of this river in terms of G. T. R. and Dry Dock gage heights. The elevation of the crest of the submerged weir has been assumed at 543 feet above mean sea level. The St. Clair River discharge formula, as derived, is:

$$D = \left(\frac{C_{G.T.R.} + C_{D.D.}}{2}\right) F^{\frac{1}{2}} \left(h_U + \frac{h_D}{2}\right) \qquad (28)$$

in which the coefficients depending on the stage at G. T. R. and Dry Dock, derived from the discharge measurements, are:

$$C_{G.T.R.} = \frac{2700.316}{\frac{62.872}{h_U} - 1}, \text{ and } C_{D.D.} = \frac{2766.21}{\frac{61.982}{h_D} - 1}, \text{ respectively.}$$

60. This discharge equation of the St. Clair River, depending on the gage readings at G. T. R. and Dry Docks, has been transformed to one depending on G. T. R. and St. Clair Flats, on account of the long series of readings taken at the St. Clair Flats Canal. In order to substitute the St. Clair Flats Canal readings for Dry Dock readings in the discharge formula, the following equation was used: (Fall, G. T. R. to St. Clair Flats Canal)=7.4482 (Fall G. T. R. to Dry Dock)—1.9657. The St. Clair River discharge formula, as transformed, is:

$$D = \frac{C_{G.T.R.} + C_{ST.\ CLAIR\ FLATS\ CANAL}}{2} F^{\frac{1}{2}} \left(h_U + \frac{h_D}{2}\right). \qquad (29)$$

The coefficients derived in this transformed equation are:

$$C_{G.T.R.} = \frac{1308.339}{\frac{64.674}{h_U} - 1}, \text{ and } C_{ST.\ CLAIR\ FLATS\ CANAL} = \frac{1445.118}{\frac{59.123}{h_D} - 1}.$$

61. This last equation, expressed in terms of St. Clair Flats and G. T. R., has been used to compute the mean discharges of St. Clair River from 1860 to 1907, inclusive.

62. In 1900, the Chicago Drainage Canal began deverting water from Lake Michigan. The quantity used from 1900 to June, 1904, inclusive, has been computed from data furnished the Commission by the United States Engineer Office at Chicago. The flow through the canal for the last half of the year 1904, and 1905, 1906, and 1907, has been assumed to be the quantity authorized in the permit of the Secretary of War.

DETROIT RIVER DISCHARGE.

63. The Detroit River discharge equation has been derived from measurements taken at Fort Wayne, Mich., by the United States Lake Survey during the summers of 1901 and 1902. The elevation of the crest of the weir is assumed as 540 feet above mean sea level. A part of these observations were rejected owing to the fluctuation in the level of water at Amherstburg during the discharge measurement. The remaining discharges were used in determining the discharge equation. The discharge formula, as derived, is:

$$D_{\text{DETROIT}} = \frac{C_{\text{W.PT.}} + C_{\text{AM H.}}}{2} F^{\frac{1}{2}} \left(h_U + \frac{h_D}{2}\right). \qquad (30)$$

in which $C_{\text{W.PT.}}$ for the upstream head at Windmill Point $= \frac{11.745}{\frac{52.248}{h_U} - 1}$,

$C_{\text{AMH.}}$ for the downstream head at Amherstburg $= \frac{20.529}{\frac{60.083}{h_D} - 1}$,

F = fall, Windmill Point to Amherstburg,

h_U = upstream head on crest of submerged weir, determined by Windmill Point gage heights,

h_D = downstream head on crest of submerged weir, determined by Amherstburg gage heights.

64. Owing to the lack of sufficient observations, no winter discharge formula have been derived for the Detroit or St. Clair Rivers. It is, undoubtedly, true that for the same slope the discharge is less with an ice covering than without one, on account of the increased friction.

Ice gorges occur in the St. Clair and Detroit rivers nearly every winter, creating an abnormal slope in the river that is gorged. Under such conditions, the discharge value, computed from the river not gorged, has been used as the correct monthly mean inflow to Lake Erie.

65. The monthly mean discharge values of the Detroit River from January, 1860, to December, 1907, inclusive, are given in Table 20.

NIAGARA RIVER DISCHARGE.

66. The discharge of the Niagara River has been determined by measurements taken at the International Bridge, located at Buffalo, N. Y., and at a point about 1800 feet down stream at the "Open Section." These observations were begun in 1897 under the direction of E. E. Haskell, Engineer for

the United States Deep Waterways Commission. At the conclusion of this work, the United States Lake Survey continued the measurements in 1898, 1899, and 1900. These measurements have been reduced on the assumption that the outlet of Lake Erie is a submerged weir witth a broad, flat crest, whose upper nappe is about one mile in length and the lower one about two, with the crest section at or near the Buffalo Waterworks' Intake Pier. The Niagara River discharge formula, as derived, is:

$$D_{NIAGARA} = CbF^{\frac{1}{2}}\left(h_U + \frac{h_D}{2}\right). \qquad (31)$$

in which F = fall from Buffalo Breakwater Light-house, in Lake Erie, to Austin Street, in Niagara River,
h_U = upstream head on crest of submerged weir, determined by Buffalo Breakwater Light-house gage,
h_D = downstream head on crest of submerged weir, determined by Austin Street gage,

$C = -0.02458h_U + 2.550.$

556.35 = the average elevation of the crest of the weir above mean tide at New York,
b = width of crest section, at Waterworks' Intake, which is determined as follows: Compute the mean fall in the Niagara River from Buffalo Breakwater Light-house to Austin Street, according to the formula, $F = 0.02976X^2 - 0.4896X + 6.5828$, in which X = Lake Erie stage at Buffalo Breakwater Light-house gage above elevation 560 feet. Substitute this value for fall, or the actual fall between these two points in the equation, (Fall, Buffalo Breakwater Light-house to Waterworks' Intake = 0.4916 (Fall, Buffalo Breakwater Light-house to Austin Street) + 0.6553, and solve for fall from Buffalo Breakwater Light-house to Waterworks' Intake Section. Determine the corresponding stage of water at Waterworks' Intake Section by subtracting the fall from Buffalo Breakwater Light-house to Waterworks' Intake Section from Lake Erie stage as measured at Buffalo Breakwater Light-house. Then substitute in the equation, b = 80 (Waterworks' Intake stage above mean tide at New York) — 43598, and solve for the width of the crest section.

The monthly mean discharge values of the Niagara River, from January, 1860, to December, 1907, inclusive, are given in Table 21.

ST. LAWRENCE RIVER DISCHARGE.

67. The St. Lawrence River discharge formula has been determined from discharge measurements made by the United States Lake Survey in 1901 and 1902 at "Three Points Section," situated about 15 miles below Ogdensburg, N. Y., and 9 miles below the head of the Galop Rapids. During the measurements, no simultaneous gage readings were observed at Lock 27. Since the discharge equation is expressed in terms of Ogdensburg and Lock 27 gage heights, the latter have been computed for each measurement according to the equation, (Ogdensburg — 240) = 0.0006489 (Lock 27 — 240)^2 + 0.97085 (Lock 27 — 240) + 1.3502, which was derived from simultaneous monthly mean readings taken at the two places. This method was deemed most accurate, for, during the months when observations were taken, the slope between Ogdensburg and Lock 27 approximated very closely the mean slope computed by the above formula. It has been assumed that the submerged weir lies between Ogdensburg and Lock 27, near the head of the Galop Rapids, and the mean elevation of the crest of this weir is 230 feet above mean sea level at New York. The discharge equation, as deduced for summer flow, May to November, inclusive, before the Gut channel at the Galop Rapids was closed, is:

$$D_{\text{(summer) St. Lawrence}} = \frac{C_{oo} + C_{27}}{2} F^{\frac{1}{2}} \left(h_u + \frac{h_d}{2}\right). \quad (32)$$

in which C_{oo}, for the upstream head measured at Ogdensburg self-registering gage, is $= \frac{114430.485}{\frac{152.389}{h_u} + 1}$,

C_{27}, for the downstream head, measured at Lock 27, is $= \frac{54507.508}{\frac{59.445}{h_d} + 1}$,

F = fall, Ogdensburg to Lock 27,

h_u = upstream head on crest (elevation 230) of submerged weir, determined by Ogdensburg gage height,

h_d = downstream head on crest (elevation 230) of submerged weir, determined by Lock 27 gage height.

68. The slope in the river from Oswego and Ogdensburg to Lock 27, increases in the winter, due to the ice covering, which causes increased friction with the water and decreases the discharge for a given stage. The average increase in fall for the winter season, between Lock 27 and Ogdensburg, has

been determined as 0.31 foot. For any given stage at Lock 27, with mean summer slope to Ogdensburg, the discharge of the St. Lawrence River can be derived by formula (32). With this known river discharge and stage at Lock 27, and with Ogdensburg gage heights increased by 0.31 foot for average winter conditions, a solution for C in the submerged-weir formula has been made. This operation was repeated so as to cover the range in stage at these two gages.

69. The winter discharge equation, as deduced, covering the period from December to April, inclusive, and before the Gut channel at the Galop Rapids was closed, is:

$$D_i \text{ (WINTER) ST. LAWRENCE} = \frac{C_{oo.} + C_{27}}{2} F^{\frac{1}{2}} \left(h_U + \frac{h_D}{2}\right), \quad (33)$$

in which $C_{oo.}$, for the upstream head, measured at Ogdensburg self-registering gage in the winter season, is $= \frac{131202.913}{\frac{206.737}{h_U}+1}$,

C_{27}, for the downstream head, measured at Lock 27 in the winter season, is $= \frac{53597.993}{\frac{67.401}{h_D}+1}$,

F = fall, Ogdensburg to Lock 27,
h_U = upstream head on crest (elevation 230) of submerged weir, determined by Ogdensburg gage heights,
h_D = downstream head on crest (elevation 230) of submerged weir, determined by Lock 27 gage heights.

70. As previously stated, the winter months have been considered as December to April, inclusive. During many of these months, ice gorges have occurred in the river, above the Galop Rapids, which conditions have invalidated the winter-slope relation and caused abnormally high discharge values. Fortunately, below the Galop there are two more submerged weirs, one at the head of Rapide Plat, near Lock 24 on the Morrisburg Canal, and the other at the head of the Long Sault Rapids, near Lock 21 on the Cornwall Canal, at which points water-level observations have been made by the Canadian Government for many years.

71. Owing to lack of data, the Commission has been unable to derive a submerged-weir formula for the St. Lawrence River discharge based on the stage of water at the Rapide Plat and Long Sault Rapids, and has used the overfall-weir formula derived by the United States Lake Survey for these two locations, and has also used in a few instances the over-

fall-weir formula in terms of Lock 27, when ice gorges occurred at Lock 24 and Lock 21 and the slope in the river above the Galop was abnormal.

72. These discharge equations for the St. Lawrence River flow are:

$$D_{27\ \text{ST. LAWRENCE}} = 5732\ (2.80 + h_{27})^{\frac{1}{2}}, \tag{34}$$

$$D_{24\ \text{ST. LAWRENCE}} = 16.60\ (22.10 + h_{24})^{2.5}, \tag{35}$$

$$D_{21\ \text{ST. LAWRENCE}} = 316.0\ (8.30 + h_{21})^{2.3}, \tag{36}$$

where h_{27}, h_{24} and h_{21} are the gage readings above the old lock sill of each lock as zero.

73. In determining the monthly mean discharge of the St. Lawrence River for January, February, and March, from 1870 to 1907, inclusive, values have been deduced according to the submerged-weir and the three overfall-weir formulae. The minimum result in each case has been used as the most reliable value.

74. In 1903, the Canadian Government began work on closing the Gut channel, the smallest of the three channels at the head of the Galop Rapids. The damming of this outlet decreased the discharge of the St. Lawrence River for any given stage. According to the United States Lake Survey, this change in flow has been about 5½ per cent. less than that for the assumed original condition, January, 1860, to August, 1903, inclusive. This percentage change has been applied to the discharge equations for the period previous to September, 1903, and other discharge formulae deduced.

75. The formula as derived for summer conditions of flow of the St. Lawrence, after the Gut channel was closed, is:

$$D_{2\ (\text{SUMMER})\ \text{ST. LAWRENCE}} = \frac{C_{os.} + C_{27}}{2}\ F^{\frac{1}{2}}\left(h_v + \frac{h_o}{2}\right) \tag{37}$$

in which C for the upstream head, measured at Ogdensburg self-registering gage, is: $C_{os.} = \dfrac{104112.068}{\dfrac{146.326}{h_v} + 1}$,

C for the downstream head, measured at Lock 27, is:

$$_{27} = \frac{55685.721}{\dfrac{65.075}{h_p} + 1},$$

F = fall from Ogdensburg self-registering gage to Lock 27,
h_o = upstream head on crest (elevation 230) of submerged weir, determined by Ogdensburg gage heights,

h_D = downstream head on crest, determined by Lock 27 gage heights.

76. The St. Lawrence River winter discharge formula, after the Gut channel was closed, as deduced, is:

$$D_2 \text{ (WINTER) ST. LAWRENCE} = \frac{C_{og.} + C_{27}}{2} F l \left(h_v + \frac{h_D}{2}\right). \quad (38)$$

in which C for Ogdensburg self-registering gage is:

$$C_{og} = \frac{135093.09}{\frac{226.492}{h_v} + 1},$$

C for Lock 27 is: $C_{27} = \frac{52177.516}{\frac{69.799}{h_D} + 1}$.

The remaining factors are the same as for summer flow.

The monthly mean discharge values of the St. Lawrence River, from January, 1860, to December, 1907, inclusive, are given in Table 22.

DISCHARGE INCREMENTS OF THE RIVER OUTLETS OF THE GREAT LAKES SYSTEM.

77. The discharge increment, or rate of change of river flow per unit change in stage, varies in the several river outlets of the Great Lakes. It is not only different for each river but it also changes with the section and the stage. In general, the increment at mean stage increases with each river lower in this series. The Detroit River increment is greater than the St. Clair; likewise, the St. Lawrence River increment is greater than the Niagara. It also increases as each river is descended. On the Niagara River, the increment at Buffalo Light-house, Buffalo, for mean stage of Lake Erie, is 23400 cubic feet per second per foot, while at Grass Island, near the intake of the Niagara Falls Power Company, at Niagara Falls, N. Y., the increment is about 43000 cubic feet per second per foot. There are exceptions to this rule when the river section is contracted. At the head of the Whirlpool Rapids, in the Niagara River, a contracted section reduces the increment to about 9000 cubic feet per second per foot. In the St. Lawrence River, contracted sections occur at the head of the Rapide Plat and the head of the Long Sault Rapids. At the former, the increment is about 22500 cubic feet per second per foot, while at Lake Ontario it is 28100 cubic feet per second per foot. Table 23 gives the discharge increments, expressed in cubic feet per second per foot change in stage, of the several river outlets of the Great Lakes.

TABLE 23.

INCREMENTS OF DISCHARGE OF THE SEVERAL RIVER OUTLETS OF THE GREAT LAKES, EXPRESSED IN CUBIC FEET PER SECOND PER FOOT CHANGE IN STAGE.

River.	Location of Gage.	Stage.	Increment.
St. Marys.....	Sault Ste. Marie, Mich.,	601.91 (Mean)	18,500
		601—602	18,500
		602—603	18,500
St. Clair.....	Harbor Beach, Mich.,	581.44 (Mean)	18,900
		579—580	16,300
		580—581	17,500
		581—582	19,100
		582—583	20,900
Detroit.....	Windmill Point, Mich.,	575.40 (Mean)	20,600
		574—575	18,300
		575—576	20,900
		576—577	22,500
Niagara.....	Buffalo, N. Y.,	572.67 (Mean)	23,400
		570—571	19,600
		571—572	21,400
		572—573	23,200
		573—574	25,100
St. Lawrence....	Ogdensburg, N. Y.,	245.28 (Mean)	28,100
		244—245	26,800
		245—246	27,600
		246—247	29,300
		247—248	29,800

SUPPLY FACTORS OF GREAT LAKES.

78. The total supply (S) of water to a reservoir or lake depends on the inflow (I) or transmitted supply from another watershed, the precipitation (P) on the surface of the lake, the run-off (R) from the lake's watershed, and evaporation (E) from the lake's surface; or the outflow or discharge (D) from and storage (s) in the lake. Of these factors, for the Great Lakes, the transmitted supply (I), the discharge (D), and the storage (s), are known singly, while the value of precipitation (P), run-off (R), and evaporation (E), is known collectively.

79. The following equation expresses the total supply to any lake:

$$S = I + R + P - E = D \pm s. \qquad (39)$$

Now, $s = Ah$, where A is the area of the lake and h the depth in feet above any datum. Transposing and substituting in (39) the value of s, we have:

$$S - D = Ah \qquad (40)$$

80. The following equation shows the rate of change in the depth (dh) at any instant of time (dt):

$$(S - D)\,dt = A\,dh \tag{41}$$

Integrating with respect to t and h between the limits o and t and o and h, respectively, we have:

$$(S - D)\int_o^t dt = A\int_o^h dh \tag{42}$$

$$(S - D)\,t = Ah \tag{43}$$

81. An inspection of equation (43) shows that when S is greater than D the lake surface is rising and the storage is increasing, when S is less than D the lake surface is falling and the storage is decreasing; and when S is equal to D the lake surface remains at the same level and there is no change in the storage.

82. The local supply (L) to a reservoir or lake has been assumed as the water-yield from its own watershed. It is also, in a series of connecting watersheds, equal to the total supply (S) minus the transmitted supply or inflow (I) from the watersheds situated above.

83. The following equation expresses the local supply to any lake:

$$L = S - I = (D \pm s) - I = R + P - E \tag{44}$$

84. The known supply factors have been deduced for Lakes Superior, Michigan-Huron, Erie, and Ontario for the period of 48 years, from 1860 to 1907, inclusive. These results are shown in Tables 24, 25, 26, and 27, and Plates 2-17, inclusive.

85. For Lake Superior, the water levels at Marquette, Mich., have been assumed to represent the mean lake surface, and those at Sault Ste. Marie, Mich., (above the locks) have been used in computing the discharge of the lake's outlet. The stage readings on the first of the month for this lake and those lower in the series have been interpolated from the monthly mean readings. For Lake Michigan-Huron, the mean of the stage values for Milwaukee, Wis., and Harbor Beach, Mich., has been used for the mean lake surface. Lake St. Clair has been treated as a part of the Michigan-Huron watershed, and the Detroit River, as the natural lake outlet. Since 1900, water has been diverted from Lake Michigan through the Chicago Drainage Canal. The St. Clair River is the outlet to Lake Michigan-Huron, but, owing to the apparent changes in regimen prior to the first accurate discharge measurements in

1899, it became necessary to eliminate this river and use the Detroit, regardless of the fact that there have been many more discharge measurements of the St. Clair. The regimen of the Detroit River has, apparently, remained nearly constant during the period from 1860 to 1907, inclusive. For Lake Erie, the water levels at Cleveland, Ohio, have been used to represent the mean lake surface, and those at Buffalo, N. Y., to govern the outflow through the Niagara River. The volume of water diverted from the natural outlet of Lake Erie through the Erie and Welland canals has been estimated at 1000 and 1100 cubic feet per second, respectively. These amounts, added to the Niagara River discharge values represent the total outflow from Lake Erie. For Lake Ontario, the Oswego, N. Y., stage readings have been assumed to represent the mean water level of the lake. During periods in the spring, when the Oswego River was at flood stage, these water levels may be slightly in error. The outflow through the St. Lawrence River has been derived from the values of the Ogdensburg and Lock 27 gage heights, used collectively, except as heretofore noted.

86. Lake Superior Supply Factors. An inspection of Plates 2-5, inclusive, shows that Lake Superior had a maximum monthly mean stage of 604.08, in September, 1869, and a minimum of 600.76, in February, 1871. During the high water of 1876, Superior rose, in August, to 603.93. On several occasions, the lake level has fallen to about 601.0, or lower, as in 1879, 1880, 1892, and 1893. Since 1894, Superior has fluctuated between 601.46 and 603.54, a range of 2.08 feet, while the maximum fluctuation since 1860 has been 3.32 feet. The mean water level for the 48 years, 1860 to 1907, inclusive, was 602.32. The storage capacity of Superior is enormous, one foot depth on the lake surface being equivalent in volume to a constant inflow of 340100 cubic feet per second for one month. During the period which this investigation covers, the storage has been over + 200000 cubic feet per second, for a month, on several occasions. In May, 1876, May, 1888, and May, 1899, Superior stored + 207500, + 212600, and + 204100 cubic feet per second, respectively. In August, 1869, the lake stage increased 0.655 foot, equivalent to + 222800 cubic feet per second storage. The occurrence of the maximum storage in the month of August is most unusual. At other times, the lake surface has fallen almost as rapidly. In November, 1869, November, 1870, December, 1870, December, 1871, and December, 1897, the storage was — 168400, — 188800, — 173400, — 161600, and — 137700 cubic feet per second, respectively. The corresponding feet depths on lake surface are: — 0.495,

— 0.555, — 0.510, — 0.475, and — 0.405. For the three months of November and December, 1870, and January, 1871, Lake Superior fell from 602.47, on November 1st, to 601.06, on February 1st, a storage of — 1.41 feet. The outflow from Lake Superior through the St. Marys River has not shown the fluctuations so noticeable in the storage. In September, 1869, the river discharged 128700 cubic feet per second, and in September, 1876, 121800 cubic feet per second. These two values represent the maximum monthly mean discharge to date. On only two occasions has the monthly mean discharge fallen below 50000 cubic feet per second, and that occurred during February and March, 1893, when it reached 48200 and 48400 cubic feet per second, respectively. The total monthly mean supply or water-yield to Lake Superior has ranged between 333300 cubic feet per second, in August, 1869, and — 106600, in December, 1870, equivalent to 0.980 and — 0.313 foot depth on lake surface, respectively. A maximum monthly mean supply of + 200000 cubic feet per second, or more, has occurred in 21 of the 48 years. A minus monthly mean supply has occurred in 42 of the 48 years. Minus values have occurred in each month between October and April, inclusive, although December has been the prevailing one.

87. Lake Michigan-Huron Supply Factors. As shown on Plates 6-9, inclusive, the monthly mean stage of Lake Michigan-Huron has fluctuated between 583.58 and 583.60, in July, 1876, and June, 1886, respectively, and 579.00, in December, 1895, a range of 4.6 feet. Previous to 1886, the lake level had fallen to about 580.2, or 1.2 feet above the low water of 1895 and 1896, on only three occasions, March, 1869, March, 1872, and January and February, 1873. Since September, 1890, the monthly mean stage has not exceeded 581.5, except in July and August, 1905, and July, 1907, when it was 581.56, 581.54, and 581.56, respectively. The mean stage of Lake Michigan-Huron for the 48 years, 1860 to 1907, inclusive, was 581.38. As previously stated, in Table 1, the area of Lake Michigan-Huron is 45314 square miles. An increase in depth of one foot on this surface is equivalent to a constant inflow of 480700 cubic feet per second for one month. The storage on this lake, in May, 1873, and May, 1876, amounted to + 251400 and + 254800 cubic feet per second, respectively, with corresponding depths on surface of 0.523 and 0.530 foot. A monthly storage of + 150000 cubic feet per second is quite common. Occasionally, the high rate of storage extends over several months, as in April, May and June, 1876, when the average monthly increase for this period had a value of + 220300,

equivalent to a total change in stage of + 1.37 feet in three months. On the other hand, when the lake stage had fallen, as in August, September, October, November, and December, 1871, the average monthly decrease in storage had a value of — 183600 cubic feet per second, equivalent to a total decrease in stage of 1.91 feet in the five months. The minimum storage occurred in September, 1871, when it had a value of — 261500 cubic feet per second, equivalent to a depth on lake of — 0.544 foot. Values of — 150000 to — 200000 cubic feet per second have occurred frequently. The outflow through the Detroit River has ranged from about 275400, in July, 1883, to 105300, in February, 1874. The discharge of this river is dependent not only upon the stage of Lake St. Clair but also upon the fall to Lake Erie. The stage of Lake St. Clair is, in turn, dependent on the discharge from Michigan-Huron and on its outflow to Erie. A large discharge from Michigan-Huron raises Lake St. Clair quickly, while a high stage of Erie decreases the discharge of the Detroit River and raises Lake St. Clair by backwater. An increasing stage of Lake St. Clair with constant fall to Erie, or an increasing fall with the same St. Clair stage, gives increased discharge through the Detroit River.

88. Lakes Michigan-Huron and Erie do not rise and fall simultaneously. In some cases, the former will be rising and the latter falling. This is usually what occurs during the winter months of January, February, and March, and sometimes in December, April, and May. Ice gorges in the St. Clair or Detroit River hold back the water, thus depleting the supply to Erie and storing it in Michigan-Huron. When the gorge occurs in the St. Clair River, Lake St. Clair falls and the slope to Lake Erie becomes less than normal and that to Michigan-Huron greater. When the gorge occurs in the Detroit River, Lake St. Clair rises and the slope to Michigan-Huron is less than normal and that to Erie greater. If ice gorges of the same intensity should occur in the St. Clair and the Detroit rivers simultaneously, Lake St. Clair would probably not indicate the gorged condition, since the discharge increments of the two rivers would be decreased and the lake would remain at its normal level. By an inspection of the hydrograph of the Great Lakes, as shown on Plate 1, the effect of ice gorges in the St. Clair and Detroit rivers is seen. Attention is called particularly to the following months as indicating large gorges in the St. Clair River: February, 1865; March, 1877; January, 1884; February, 1886; April, 1901, and February, 1902. In each case, the stage of Lake St. Clair dropped and Michigan-

Huron rose. Large ice gorges in the Detroit River occurred in January, 1870, December, 1876, December, 1880, January, 1889, and February, 1895. This fact is substantiated by the extreme rise in Lake St. Clair and by the fall in Lake Erie. The total monthly mean supply to Lake Michigan-Huron has fluctuated between + 470800 cubic feet per second, in June, 1883, and — 32000 cubic feet per second, in September, 1871, equivalent to a depth on the lake of + 0.979 and — 0.067 foot, respectively. In May, 1873, and May and June, 1876, the total supply exceeded + 450000 cubic feet per second. In 10 of the 48 years, the monthly supply has been over + 400000 cubic feet per second. Monthly values of + 350000 cubic feet per second have occurred in over 60 per cent. of the years. Other months show a total supply of less than + 25000 cubic feet per second in many of these years. In April and May, 1873, May, 1876, and June, 1883, the local supply to Michigan-Huron was + 373000, + 365100, + 356400, and + 389100 cubic feet per second, respectively, corresponding to depth on lake of 0.776, 0.759, 0.741, and 0.809 foot, respectively. In September, 1871, the lake lost by evaporation 125700 cubic feet per second more than the actual precipitation on the lake surface and run-off of the tributary watershed. During the months from August to December, inclusive, a minus local supply has been common, in some cases extending over several months. From August to December, 1894, inclusive, evaporation on the lake surface exceeded the precipitation on the lake surface and run-off from the tributary watershed, and the stage of Lake Michigan-Huron dropped 1.3 feet.

89. Lake Erie Supply Factors. The monthly mean stage of Lake Erie (see Plates 10-13, inclusive,) during the period covered in this report, has risen to 574.52, in June, 1876. The minimum stage occurred in February, 1902, when Erie fell to 570.63. During the latter month, an extensive ice gorge occurred in the St. Clair River, which explains the extreme low stage of Erie at that time. Prior to that time, the minimum stage of Erie occurred in November, 1895, when it fell to 570.70. The monthly mean level has fluctuated through an extreme range of 3.89 feet, while the annual mean oscillation in lake level has been 2.53 feet. The mean stage of Erie, from 1860 to 1907, inclusive, was 572.60. The amount of storage, for a rise of one foot in the level of Lake Erie, is equivalent to a flow of 105700 cubic feet per second for one month. On but one occasion has the storage exceeded + 100000 cubic feet per second. In April, 1873, it had a value of + 103600, equivalent to a depth on lake surface of 0.98 foot. During the month

of January, 1865, the storage reached a minimum of —52900 cubic feet per second, corresponding to —0.50 foot on lake surface. A value nearly as small as the latter occurred in November, 1903, when the storage had a value of —49700, equivalent to —0.47 foot. The maximum monthly mean discharge from Lake Erie, 257800 cubic feet per second, equivalent to a depth of 2.44 feet on Lake Erie, occurred in June, 1876. The minimum, 168700 cubic feet per second, equivalent to a depth of 1.60 feet on lake surface, occurred in March, 1896. Ice gorges in the Niagara River, apparently, have had comparatively little effect on the outflow from Lake Erie. The maximum total supply of +314700 cubic feet per second to Erie, corresponding to a depth of +2.98 feet on lake, occurred in April, 1861. Large positive total supply values occurred in April, 1862, April, 1873, March and April, 1876, and June, 1883. The values for the several months are: +307,400, +309700, +295600, +289000, and +290300 cubic feet per second, respectively. In 16 out of the 48 years, a total monthly means supply of +275000 cubic feet per second has been exceeded. During the five-month period from February to June, 1876, inclusive, Erie had a monthly mean total supply greater than +250000 cubic feet per second, and the stage increased 1.82 feet. At other times, the total supply has decreased to less than half the maximum. The minimum, +146900 cubic feet per second, occurred in October, 1891, and November, 1903. The supply was nearly as low in January, 1865, and October, 1895, with values of +149300 and +148500 cubic feet per second, respectively. The local supply to Erie, apparently, has been very much less than to the lakes above. In April, 1873, January and February, 1874, and May, 1892, it exceeded +100000 cubic feet per second by 10600, 3200, 21600, and 9200, respectively. Minus values occur very frequently. In many years, the last six months give a minus local supply. From June, 1884, to March, 1885, inclusive, a minus local supply occurred during the entire period with an average monthly value of —40400. During this period, the lake fell from 574.14, in June, to 571.92, in March, a change in stage of —2.22 feet. The minimum monthly local supply to Erie of —63600 cubic feet per second, corresponding to a depth on lake surface of —0.60 foot, occurred in December, 1871. From August to November, 1867, inclusive, the monthly local supply was —57700, —60500, —61700, and —56500 cubic feet per second, respectively. Collectively, these values are equivalent to a depth on Lake Erie of 2.23 feet. During September, October and November, 1874, large successive local supply values of

— 50600, — 56100, and — 51200 cubic feet per second, respectively, occurred, equivalent to a total depth on Lake Erie of 1.49 feet. For September, October, and November, 1884, the monthly local supply was — 53100, — 57500, and — 50600 cubic feet per second, respectively. These values are, collectively, equivalent to 1.52 feet depth on Lake Erie.

90. Lake Ontario Supply Factors. Referring to Plates 14-17, inclusive, the maximum stage of Lake Ontario occurred in May, 1870, when the lake level had a value of 248.95. In 1861, 1862, 1863, 1864, 1867, 1876, 1883, 1884, 1886, 1887, and 1890, the stage exceeded 248.00. In November, 1895, the lake level dropped to 243.41, which has been the minimum stage during the 48 years from 1860 to 1907, inclusive. In two other years, the stage has fallen below 244.00. This condition occurred in January, November, and December, 1896, and January and February, 1897. This monthly fluctuation of Ontario is greater than that in any of the other Great Lakes. The maximum range in stage is 5.54 feet. Ontario fell from 248.48, in June, 1867, to 244.51, in January, 1868, a change in level of 3.97 feet. The mean stage of Lake Ontario, for the period from 1860 to 1907, inclusive, was 246.19. A foot depth on Lake Ontario is equivalent to a monthly flow of 76800 cubic feet per second. During March and April, 1873, and March, 1904, the monthly storage equalled or exceeded one foot depth on the lake surface, with corresponding storage values of + 79900, + 96000, and + 76800 cubic feet per second, respectively. Twelve of the 48 years had a monthly storage of + 50000 cubic feet per second, or more. During October and November, 1867, the minus storage exceeded — 50000 cubic feet per second, the values being — 53800, and — 57600 cubic feet per second, respectively. The discharge of the St. Lawrence River shows an extreme variation of about 130 per cent. This change in flow is small compared with rivers not having immense storage reservoirs at their sources. The maximum flow has been computed at 351200 and 350500 cubic feet per second, and occurred in May, 1862, and May, 1870, respectively. These values may be slightly too great on account of floods in the Oswego River causing abnormal gage readings for lake stage. These maximum discharge values have been approached in June and July, 1870, when there was little likelihood of the stage being affected by these local floods. In these two months, the flow has been computed at 344100 and 343200 cubic feet per second, respectively. The minimum flow has approximated 155000 cubic feet per second. In February, 1875, March, 1900, and, February, 1902, the discharge was

157900, 156600, and 152200 cubic feet per second, respectively. These extreme low discharges have been caused by ice gorges in the river. The minimum outflow, not caused by ice gorges, occurred in December, 1895, and December, 1896, when the discharge was 162500 and 164800 cubic feet per second, respectively. The total supply to Ontario has fluctuated between the maximum of + 382400 cubic feet per second, in April, 1870, and the minimum of + 154100 cubic feet per second, in February, 1875, a range of 228300 cubic feet per second. The equivalent depths on lake surface are 4.98 and 2.01 feet, respectively. In May, 1861, and April, 1862, the total supply was + 377400 and + 375600 cubic feet per second, respectively. Values of 325000 cubic feet per second have occurred in 17 of the 48 years. Since May, 1893, the total monthly supply has exceeded + 300000 cubic feet per second in but two years, 1903 and 1904. In 10 of the 48 years, the yield, or total supply, varied between + 155000 and + 175000 cubic feet per second during some months of the winter season. The Ontario local supply had a maximum of + 151800 cubic feet per second, in April, 1870. In January, 1881, the minimum value of — 34300 cubic feet per second occurred. In 7 years, the monthly mean local supply exceeded + 125000 cubic feet per second. In 17 of the 48 years, it exceeded + 100000 cubic feet per second. Minus values occurred frequently. The prevailing months for such values have been November, December, January, and February, although a minus local supply has occurred during all the months from August to February, inclusive.

MEAN MONTHLY SUPPLY FACTORS OF GREAT LAKES.

91. The mean monthly supply factors covering the period from 1860 to 1907, inclusive, have been derived from the monthly mean supply values of the several lakes for the 48-year period. Table 28 and Plate 18 give the results in numerical and graphical form. These curves show the mean monthly condition on Lakes Superior, Michigan-Huron, Erie, and Ontario. From Plate 18, Table 29 has been compiled, which shows the approximate date of maximum and minimum mean monthly values of stage, storage, outflow, total supply, and local supply of Lakes Superior, Michigan-Huron, Erie, and Ontario.

TABLE 29.

DATE OF MAXIMUM AND MINIMUM VALUES OF MEAN MONTHLY SUPPLY FACTORS OF THE GREAT LAKES.

LAKE.	Stage.	Storage.	Outflow.	Total Supply.	Local Supply.
Superior, maximum	Sep. 20	May 20	Sep. 1	May 25	May 25
Superior, minimum	Mar. 20	Dec. 10	Mar. 15	Dec. 15	Dec. 15
Michigan-Huron, maximum	Jul. 20	May 5	Aug. 1	May 10	May 5
Michigan-Huron, minimum	Feb. 1	Nov. 1	Feb. 20	Nov. 10	Oct. 25
Erie, maximum	Jun. 25	Apr. 5	Jul. 5	Apr. 20	Apr. 5
Erie, minimum	Feb. 10	Oct. 1	Feb. 20	Oct. 10	Oct. 1
Ontario, maximum	Jul. 1	Apr. 5	Jul. 1	May 5	Apr. 25
Ontario, minimum	Dec. 10	Sep. 5	Feb. 10	Jan. 20	Sep. 25

92. The mean monthly stage cycle on Lake Superior has fluctuated between 602.79, in September, and 601.77, in March, a change of 1.02 feet. A plus storage has occurred during the months of April to September, inclusive, while a minus storage has occurred during the months of October to March, inclusive. The maximum mean monthly storage has been 95900 cubic feet per second, while the minimum has been —91100. The discharge, or outflow, has increased from March 15th to September 1st, while it has decreased from September 1st to March 15th. The mean monthly outflow has ranged between 92800 and 68000 cubic feet per second. The total supply has increased values from December to May, and has decreased values from May to December. The mean monthly total supply has had a maximum value of 175700 cubic feet per second, and a minimum value of —10700 cubic feet per second. This minus value, which occurs in December, shows conclusively that the evaporation from Superior may be greater than the precipitation on lake surface and run-off from its watershed. The mean monthly supply, to Superior, in January, has been only 2300 cubic feet per second, which proves that evaporation on lake surface is nearly equal to the precipitation on lake surface and run-off from the tributary watershed for that month.

93. The mean monthly stage of Lake Michigan-Huron has fluctuated between 581.90, in July, and 580.93, in January and February, a range of 0.98 foot. The storage on Michigan-Huron has been positive from February to July, inclusive, while it has been negative from August to January, inclusive. The maximum and minimum mean monthly storage values have been +132300 and —112200 cubic feet per second, respectively. The mean monthly outflow through the Detroit River has fluctuated from 219700, in August, to 175600 cubic

feet per second, in February. This minimum discharge value is probably too large. The mean monthly total supply has had a maximum value of + 337700 cubic feet per second, in May, and a minimum value of + 96200, in November. The mean monthly local supply to Michigan-Huron has fluctuated between + 257800 cubic feet per second, in May, and + 8200 cubic feet per second, in October. During October and November, the local supply has been so small that the evaporation from the lake surface has been about equal to the precipitation on lake surface and run-off from the tributary watershed.

94. The mean monthly stage on Lake Erie has ranged from 573.24, in June, to 572.03, in February, a fluctuation of 1.21 feet. The storage on Erie has had a positive value from February to June, inclusive, and a negative value from July to January, inclusive. The mean monthly storage has had a maximum value of + 44100 cubic feet per second, in April, and a minimum value of — 31100 cubic feet per second, in September. The outflow has fluctuated between 225700 cubic feet per second, in July, and 198100 cubic feet per second, in February. The mean monthly total supply has had a maximum value of + 255700 cubic feet per second, in April, while it has fallen to a minimum value of +179200 cubic feet per second, in October. The mean monthly local supply on Erie has had a positive value from January to June, inclusive, and a negative value from July to December, inclusive. During these last six months, July to December, inclusive, the evaporation on the surface of Lake Erie has been greater than the precipitation on the lake surface and run-off from the tributary watershed. The maximum mean monthly local supply of + 56100 cubic feet per second occurred in April, while the minimum of — 31800 cubic feet per second occurred in October.

95. The mean monthly stage of Lake Ontario has ranged from 246.95, in June, to 245.57, in December, a fluctuation of 1.38 feet. The storage has shown a positive value from January to June, inclusive, and a negative value from July to December, inclusive. The mean monthly storage has had a maximum value of + 34800 cubic feet per second, in April, and a minimum value of — 28700 cubic feet per second, in September. The mean monthly outflow through the St. Lawrence River has fluctuated between 283600 cubic feet per second, in July, and 219300 cubic feet per second, in February. The mean monthly total supply has had a maximum value of + 297500 cubic feet per second, in May, and a minimum value of + 225500 cubic feet per second, in January. The mean monthly local supply to Ontario has ranged from + 83800

cubic feet per second, in April, to +18000 cubic feet per second, in September.

96. The maximum mean monthly stage of each lake of the Great Lakes has occurred at different times in the different lakes. This has been equally true with respect to the minimum stage. The maximum discharge of any lake does not occur at the time of the maximum total supply. The minimum discharge of any lake does not occur at the time of the minimum total supply. The maximum local supply of any lake does not occur at the same time as the maximum total supply; neither does the minimum local supply of any lake occur at the same time as the minimum total supply.

97. Table 30 shows the ratios, $R_{MAX.}$, between the maximum value of mean monthly discharge and the maximum value of mean monthly total supply for each lake in the system; the time interval in days, $T_{MAX.}$, which elapsed between the date of the occurrence of the maximum value of mean monthly total supply to any lake and that of the maximum value of mean monthly discharge from that lake; and the time interval, in days, $T_{MIN.}$, which elapsed between the date of the occurrence of the minimum value of mean monthly total supply to any lake and that of the minimum value of mean monthly discharge from that lake.

TABLE 30.

RATIOS—$R_{MAX.}$, $T_{MAX.}$, and $T_{MIN.}$

LAKE.	$R_{MAX.}$	$T_{MAX.}$	$T_{MIN.}$
Superior	0.524	98 days	91 days
Michigan-Huron	0.647	82 days	101 days
Erie	0.884	76 days	132 days
Ontario	0.955	56 days	20 days

98. The ratio, $R_{MAX.}$, increases with each succeeding lake in the Great Lakes system. The maximum mean monthly outflow from Superior has been about 52 per cent. of the maximum mean monthly total supply to that lake, while the maximum mean monthly outflow from Ontario has been about 96 per cent. of the maximum mean monthly total supply to that lake.

99. In order that a comparison of the several supply factors of the several lakes can be intelligently made, part of the data given in Table 28 has been expressed in cubic feet per second per square mile of watershed. Table 31 gives the mean

monthly values of storage, outflow, and total supply of Lakes Superior, Michigan-Huron, Erie, and Ontario in terms of the total watershed area, including lake surface, above the lake's outlet, and of local supply of the same lakes in terms of the tributary local watershed area including lake surface. An inspection of this table shows that the mean monthly outflow from these several lakes of the Great Lakes system has been remarkably uniform. The maximum value for Superior has been 1.22 cubic feet per second per square mile, while the minimum value has been 0.89 cubic foot per second per square mile. The maximum value for Michigan-Huron has been 1.00 cubic foot per second per square mile, while the minimum value has been 0.80 cubic foot per second per square mile. The maximum value for Erie has been 0.89 cubic foot per second per square mile, while the minimum value has been 0.78 cubic foot per second per square mile. The maximum value for Ontario has been 0.99 cubic feet per second per square mile, while the minimum value has been 0.76 cubic foot per second per square mile.

100. The mean monthly total supply to Superior has fluctuated between 2.31 cubic feet per second per square mile and —0.14 cubic foot per second per square mile. That to Michigan-Huron has fluctuated between 1.53 cubic feet per second per square mile and 0.44 cubic foot per second per square mile. That to Erie has fluctuated between 1.00 cubic foot per second per square mile and 0.70 cubic foot per second per square mile. That to Ontario has fluctuated between 1.03 cubic feet per second per square mile and 0.78 cubic foot per second per square mile.

101. The mean monthly local supply to Superior has fluctuated between 2.31 cubic feet per second per square mile and —0.14 cubic foot per second per square mile. That to Michigan-Huron has fluctuated between 1.79 cubic feet per second per square mile and 0.06 cubic foot per second per square mile. That to Erie has fluctuated between +1.62 cubic feet per second per square mile and —0.92 cubic foot per second per square mile. That to Ontario has fluctuated between +1.62 cubic feet per second per square mile and 0.55 cubic foot per second per square mile. The average local supply to Erie is considerably less than that to the other lakes. This is explained in part by the southerly position of the lake in the chain, the general direction of its principal axis coinciding with the direction of the prevailing winds, its shallow depth, and errors in winter discharge values of Detroit River,—all of which tend to decrease the local supply factor.

102. A comparison of the total supply values with the outflow or discharge values, expressed in cubic feet per second per square mile, shows the regulating effect of reservoirs on stream flow. Without reservoirs, the run-off from the lake's watershed is discharged immediately, while, with reservoirs, the run-off is stored and discharged at an approximate uniform rate.

THE REGULATION OF LAKE ERIE AS PROPOSED BY THE UNITED STATES BOARD OF ENGINEERS ON DEEP WATERWAYS.

103. The United States Board of Engineers on Deep Waterways, in 1900, reported on the regulation of Lake Erie, in appendix 6 of their report. The scheme, as proposed by them, consisted of a submerged weir, with regulating sluices, at the outlet of Lake Erie near the angle in the Bird Island Pier, by which the level of the lake might be held at or near some fixed stage. The report says:

"The regulation of the level of the lake implies the maintenance of its surface at or near some fixed stage, to accomplish which the discharge must be so controlled that it will be at all times approximately equal to the difference between the supply of water to the lake and evaporation from the lake surface."

And further, in relation particularly to Lake Erie, the report states:

"To regulate the level of Lake Erie so as to maintain its surface near some fixed place of reference will require such control of the outflow through Niagara River that the storage which would naturally occur in the lake will be discharged during the first half of the year and the outflow will be diminished a like amount during the last half of the year. This modification of outflow will not materially change the total volume of discharge for any entire year and will amount to only one-fifth of the variation of discharge of the river for different years under present conditions. The effect of this modification of flow through Niagara River, on the level of Lake Ontario, will be to slightly increase the rate of rise in the spring and make the date of maximum stage a little earlier."

104. The scheme of regulation, as proposed by the Board of Engineers on Deep Waterways, is to not allow the monthly mean stage of Lake Erie, at Buffalo, to rise above 574.5 feet, old levels, or 574.7 feet, 1903 levels, above mean tide at New York. The minimum monthly stage of lake surface, under regulation, is not definitely stated, but it is intimated to be about 573.7 feet, 1903 levels, in the following paragraphs taken from their report:

(1) "The three months in which the supply was materially in excess of the discharge for proposed regulated stage were February, March, and April, during which the excess averaged 19000 cubic feet per second, corresponding to a rise of 0.2 foot in February, 0.2 foot in March, and 0.15 foot in April. Hence, if the level of the lake, when regulated, should be allowed to fall 0.6 foot every year after the close of navigation, it is probable that the excess of supply over discharge would never cause the surface to rise above the plane of regulation."

(2) "In the fall of 1875, the discharge of Niagara River was 60000 cubic feet per second less than the capacity of the regulating works; and, if the lake had been regulated, with the sluices of the regulating works all open, the surface would have been lowered one foot in about two months, or sufficient to have stored the excessive supply which occurred in the spring of 1876, with a margin of 0.4 foot for contingencies."

105. According to the discharge equation determined by the Board of Engineers on Deep Waterways, the maximum discharge of Niagara River was 277270 cubic feet per second, with the lake regulated at stage 574.70, 1903 levels, and the minimum discharge was 178000 cubic feet per second at stage 570.70, 1903 levels. The discharge formula of Niagara River, deduced by the International Waterways Commission, is based upon more complete data and gives the maximum discharge as 261500 cubic feet per second at 574.7, 1903 levels, and the minimum as 166700 cubic feet per second at stage 570.7, 1903 levels. In this report, the latter discharge values are used instead of those of the Board of Engineers on Deep Waterways.

PRACTICAL REGULATION OF LAKE ERIE BETWEEN STAGES 573.7 AND 574.7, 1903 LEVELS.

106. In working out a practical scheme for regulation, it is quite necessary to set a definite elevation for the regulated stage of Lake Erie at the beginning of each month. The stage values used in this investigation are given in Table 32.

TABLE 32.

STAGE OF LAKE ERIE DESIRED ON FIRST OF MONTH, WITH REGULATED CONDITIONS.

MONTH.	Stage Desired at Beginning of each Month.	MONTH.	Stage Desired at Beginning of each Month.
January 1,	573.8	August 1,	574.0
February 1,	573.7	September 1,	574.0
March 1,	573.7	October 1,	574.0
April 1,	573.8	November 1,	574.0
May 1,	573.9	December 1,	573.9
June 1,	574.0	January 1,	573.8
July 1,	574.0		

107. The maximum desired stage of water from June 1st to November 1st, inclusive, as shown in the above table, allows 0.7 foot for contingencies, which, as will be seen, is not adequate. The regulation of the elevation of the level of Lake Erie between stages 573.7 and 574.7 is a difficult proposition on account of the variation in total supply. It is impossible

to estimate this factor with any degree of accuracy on account of the fluctuation of inflow, precipitation, run-off, and evaporation. This fact is very strongly brought out in the data and results shown in Table 33 and Plate 19, "Regulation of Lake Erie between stages 573.7 and 574.7." The difference between the expected total supply and the actual total supply for any one month has been as great as +47800 cubic feet per second, in April, 1891, and —40200 cubic feet per second, in April, 1892, which would have caused a difference in the expected change in stage of Lake Erie of 0.4 to 0.5 foot. In June, 1892, (see Table 33) the lake level is supposed to have reached 574.0 on the 1st of July, and regulating works are assumed to have been set to give a discharge that would bring the lake to this stage by the first of the following month, but, owing to the increase in the actual total supply over the expected total supply, the lake would have risen to 574.64, which is 0.64 foot more than the desired and estimated stage. This unlooked-for variation in a high-water year, such as 1876, might prove disastrous if the lake level were at or near stage 574.7. By examining Table 33, it is also seen that the regulated level of Lake Erie would have fallen, in most years, during some of the winter months, to 573.3, approximately, or 0.4 foot below the minimum stage set by the Board of Engineers on Deep Waterways, but would have risen above 573.7 by the opening of the season of navigation. With the proposed scheme of regulation, for the period from 1890 to 1906, inclusive, the level of Lake Erie would have risen 0.04 foot above 574.7, in June, 1892.

108. The period from 1890 to 1906, inclusive, does not include an extreme high-water year. If the proposed scheme of regulation had occurred in 1876, when the monthly mean stage of Lake Erie reached 574.5, in June, then the assumed maximum level (574.7) would have been exceeded, during April to July, inclusive, by 0.03, 0.19, 0.20, and 0.05 foot, respectively, (see Table 33).

109. During the period from 1890 to 1906, inclusive, with regulation, the mean level of Lake Erie would have been raised from 572.1 to about 573.9, an increase in mean stage of 1.8 feet. During the low-water year of 1895, the mean annual level, with regulation, would have been 2.57 feet higher than the actual stage. The extreme low monthly mean stage of 570.71, in November, 1895, would have been raised by regulation to 573.59, an increase of 2.88 feet. The actual oscillation in monthly mean water level of Lake Erie has been about 3.89 feet. With regulation as proposed, the range of monthly

mean oscillation would have been reduced to 1.43 feet during the year, and to 1.14 feet during the navigation season.

110. Perfect regulation is impossible. The monthly increase in stage of Lake Erie, with natural conditions, is frequently 0.4 to 0.5 foot; occassionally exceeds 0.8 foot; and has been as great as 0.98 foot. Daily oscillations in the stage are occasionally as large as 7 or 8 feet, and hourly variations sometimes exceed 2 feet. Southwesterly storms on the lake raise the water level at Buffalo and lower it at Amherstburg by several feet from the normal. This difference of level has been as large as 15 feet with the severest storms. To control this daily and hourly variation in stage of Lake Erie within small limits is impossible.

EFFECT OF REGULATION OF LAKE ERIE, BETWEEN STAGES 573.7 AND 574.7, ON WATER LEVELS OF LAKE ONTARIO AND ST. LAWRENCE CANALS.

111. The effect of the regulation of the stage of Lake Erie, between 573.7 and 574.7, on the water levels of Lake Ontario, for the period from 1890 to 1906, inclusive, is shown on Plate 20, which illustrates the increased range in stage of Lake Ontario and the detrimental effect to navigation in the St. Lawrence canals due to the proposed regulation of Lake Erie under the scheme proposed by the Board of Engineers on Deep Waterways.

PRACTICAL REGULATION OF LAKE ERIE BETWEEN STAGES 572.0 AND 574.5, 1903 LEVELS.

112. Inasmuch as it is deemed impracticable to regulate the monthly mean stage of Lake Erie between stages 573.7 and 574.7 feet above mean tide at New York, as proposed in the plan of the Board of Engineers on Deep Waterways, the investigation was continued to determine the limits between which the regulation of the monthly mean stage of Lake Erie would be practicable.

113. As in the previous plan of lake regulation, a definite elevation for the stage of the lake on the first of each month has been assumed. These values represent the limits within which it would be necessary to attempt to hold the stage of Lake Erie so that the maximum and minimum monthly mean water levels of 574.5 and 572.0, respectively, would not be exceeded. Table 34 shows the assumed elevations desired on the first of month, of the water surface of Lake Erie, for regulation of its monthly mean stage between 572.0 and 574.5.

TABLE 34.

STAGE OF LAKE ERIE DESIRED ON FIRST OF MONTH WITH LAKE REGULATED BETWEEN 572.0 AND 574.5.

MONTH.	Stage Desired at Beginning of each Month.	MONTH.	Stage Desired at Beginning of each Month.
January 1,	572.3	August 1,	572.5
February 1,	572.2	September 1,	572.5
March 1,	572.2	October 1,	572.5
April 1,	572.2	November 1,	572.5
May 1,	572.3	December 1,	572.4
June 1,	572.4	January 1,	572.3
July 1,	572.5		

114. An inspection of Table 34 shows that 2.0 feet and 0.2 foot have been allowed for the actual fluctuations from the desired maximum and minimum monthly mean stages, respectively, of Lake Erie, with regulation. This extreme allowable fluctuation from the desired maximum is necessitated by the extreme high water of 1876, during which year the surface of Lake Erie, at Buffalo, reached a mean level of 574.49, in June, or but 0.01 foot less than the maximum monthly mean stage allowable with regulation.

115. As 1876 is the controlling high-water year, so 1895 is the controlling low-water year. Computations have been made for these two extreme years instead of for the period from 1890 to 1906, inclusive, as in the investigation of the scheme outlined by the Board of Engineers on Deep Waterways.

116. Table 35 and Plate 21 show that, with regulation, the water levels of Lake Erie, at Buffalo, differ but slightly from the actual levels for the year 1876, while for the low-water year of 1895 the annual mean level would be increased from 571.26 to 572.33, a change of + 1.07 feet, and the mean level for the extreme low-water months of November and December (both in the navigation season) would be increased from 570.71 and 570.97 to 572.09 and 572.34, respectively, or a change of + 1.38 feet and + 1.37 feet, respectively.

EFFECT OF REGULATION OF LAKE ERIE, BETWEEN STAGES 572.0 AND 574.5, ON WATER LEVELS OF LAKE ONTARIO AND ST. LAWRENCE CANALS.

117. Any change in the outflow of Lake Erie will change the water levels of Lake Ontario. If the inflow to Ontario is increased, the lake level will rise, and with decreased inflow the

level will fall. Table 36 and Plate 21 show the effect on the water levels of Lake Ontario for the years of 1876 and 1895, if Lake Erie stage had been regulated between stages 572.0 and 574.5 for those years. The effect of the regulation of Lake Erie would have been to increase the fluctuation in stage of Lake Ontario, causing higher stage in spring and lower stage in the autumn than under actual conditions.

118. For the high-water year of 1876, during which time the regulated inflow would have differed but slightly from the actual, there would have been no appreciable increase in the fluctuation in stage on Lake Ontario, and at no time during the year would the regulated stage differ from the actual by more than 0.12 foot. In 1895, however, a low-water year on Lake Ontario as well as on Lake Erie, the fluctuation would have increased with the result that during the months from September to December, inclusive, the regulated stages would have fallen to 243.70, 243.26, 243.08, and 243.33, respectively, or 0.34, 0.38, 0.33, and 0.18 foot, respectively, below the actual stages for those months.

119. During an extended period, such as from 1890 to 1906, inclusive, differences of 0.4 to 0.5 foot between the actual stage of Lake Ontario and the stage that would have prevailed under regulated conditions on Lake Erie would be of frequent occurrence. Unfortunately, these variations, with respect to actual stage, are generally negative during the period of low water and positive during the period of high water. Such conditions, caused by regulating Lake Erie, would injuriously affect navigation in the St. Lawrence canals and would decrease the draft of vessels by 0.4 to 0.5 foot, in the Galop canals, and 0.7 to 0.8 foot, in the Morrisburg canals. Barges and tows that now load to 14 feet draft would be compelled to load to not more than 13.2 or 13.3 feet draft during September, October, and November, in most years, and in some years, during the entire season of navigation.

EFFECT OF REGULATION OF LAKE ERIE, BETWEEN STAGES 572.0 AND 574.5, ON WATER LEVELS OF NIAGARA RIVER.

120. By the proposed system of regulation, the stage of water in the Niagara River would not fluctuate through any greater range than under actual conditions. During the winter months, more frequent low water would probably occur under regulation than under actual conditions, in which case the power companies at Niagara Falls would probably have more difficulty in keeping the channels to their intakes free

from ice. During the fall months, navigation in the river might be slightly interfered with owing to the storage in the lake of a part of the natural discharge.

EFFECT OF REGULATION OF LAKE ERIE, BETWEEN STAGES 572.0 AND 574.5, ON WATER LEVELS OF LAKE ST. CLAIR, LAKE MICHIGAN-HURON AND CONNECTING WATERS.

121. By the proposed regulation of Lake Erie between stages 572.0 and 574.5, the mean level of this lake would have been raised about 1 foot. This increase in stage would have decreased the mean slope in the Detroit River and would have caused Lake St. Clair to rise until the discharge through the Detroit River had a value equal to the discharge under natural conditions for the same period. An examination of Tables 8 and 9 shows that the mean stage of Lake St. Clair, at Windmill Point, was 575.40, and that of the lower end of the Detroit River, at Amherstburg, was 572.84. From equation 30, the discharge of the Detroit River is computed to be 204900 cubic feet per second for mean stages of 575.40, at Windmill Point, and 572.84, at Amherstburg. For this river-discharge value and with the stage at Amherstburg increased by 1.0 foot, the amount that mean level of Lake Erie would have been raised by regulation, it is found that the stage of Lake St. Clair, at Windmill Point, would eventually rise 0.61 foot. This value represents the effect on the stage of Lake St. Clair due to the increase of 1.0 foot in mean stage of Lake Erie under regulation.

122. The rise between actual and regulated low-water stage of Lake Erie would be greater than the corresponding rise between actual and regulated high-water stage. The effect of this would be to slightly lessen the discharge of the Detroit River at low stage and to slightly increase it at high stage.

123. As backwater from Lake Erie raises the water level of Lake St. Clair, so backwater from Lake St. Clair raises the water level of Lake Michigan-Huron. For a given flow in the Detroit River, an increase in the stage of Lake Erie causes an increase in the stage of Lake St. Clair; likewise, for a given flow in the St. Clair River, an increase in the stage of Lake St. Clair causes an increase in the stage of Lake Michigan-Huron. By the method used above, the effect on the water level of Lake Michigan-Huron, caused by 0.61 foot backwater on Lake St. Clair, due to the regulation of Lake Erie, has been computed to be 0.27 foot rise.

124. A study of Plate 21 shows that for a year of excessive, or above-normal supply, such as 1876, the regulation of Lake Erie would not materially improve navigation. In 1895, a year of deficient supply, the mean level during the eight-month season of navigation would have been increased from 571.31 feet, under natural conditions, to 572.41, under regulated conditions, and navigation on Erie would have been improved by an increased stage of 1.1 feet. The regulation of Lake Erie, between stages 572.0 and 574.5, would raise extreme low stage for the navigation season by at least 1 foot, without an appreciable increase in the extreme high stage. This increase in low stage is equivalent to deepening every harbor and channel in Lake Erie by that amount; in the Detroit River and Lake St. Clair, by at least 0.61 foot; and in the St. Clair River and Lake Michigan-Huron by at least 0.27 foot.

REGULATION OF LAKE SUPERIOR.

125. The regulation of the stage of Lake Superior has been suggested as a means (first) for improving navigation on that lake, and (second) to compensate for the diversion of water from Lake Michigan-Huron through the Chicago Drainage Canal.

126. This Commission has already recommended in its report upon the conditions existing at Sault Ste. Marie that "the level of St. Marys River, above the rapids, shall be maintained between the elevations 601.7 and 603.2 above mean tide at New York." The monthly mean stage of St. Marys River, above the rapids, has not risen above 603.2 since 1860, except in September and October, 1869, and July, August, and September, 1876. It has fallen below 601.7 on numerous occasions, generally during the winter months. In 1879 and 1891, the monthly mean stage did not exceed 601.5, while in 1892 it exceeded 601.7 in only one month. The fall in the water level of the St. Marys River above the rapids, below 601.7, for the ice months of January to April, inclusive, does not interfere with navigation on Lake Superior. The monthly mean water level of Lake Superior was below 601.7 about 20 per cent. of the navigation season (May to December, inclusive), from 1860 to 1888, inclusive. For this cycle of years, the regimen of the St. Marys River had not been materially altered by artificial works. With the completion of the International Bridge piers and approaches in 1888, and the shutting off of spans 1 and 2 of this bridge from the rapids by the Chandler-Dunbar Water Power Company, in 1892, these two principal obstructions to the natural outflow from Lake Superior have

raised the water level so that it has not fallen below 601.7 more than about 2 per cent. of the navigation season from 1893 to 1907, inclusive. The difference cannot be attributed to the variation in the total supply, or water-yield, to Lake Superior; for, as a matter of fact, the average total supply for the period from 1860 to 1888, inclusive, was about 4400 cubic feet per second greater than for the period from 1893 to 1907, inclusive.

127. The construction of the compensating works at the head of the St. Mary's Rapids by the Michigan Lake Superior Power Company, in 1901 and 1902, cut off a flow of about 9900 cubic feet per second. The 8500 cubic feet per second of water used by this company since 1905 nearly neutralizes the effect of these works.

128. The regulation of Lake Superior during the navigation season, between the elevations 601.7 and 603.2, as measured by the level of the St. Marys River above the rapids, has been accomplished under the conditions that did exist, and no further works seem to be necessary until a change in the artificial diversions at Sault Ste. Marie is made.

129. If the monthly mean level of Lake Superior were to be controlled during the navigation season within a smaller fluctuation than 1.5 feet, then the outflow through the St. Marys River would have to be artificially controlled. In order to eliminate the monthly mean fluctuation in large natural reservoirs, such as Lake Superior and the other lakes in this system, it would be necessary to increase the fluctuations of outflow to correspond to the fluctuations of total supply to that reservoir. To accomplish this result on Lake Superior, the monthly mean outflow would have had a maximum value of 333300 cubic feet per second, in August, 1869, and a minimum value of —106600 cubic feet per second, in December, 1870. Such fluctuations in outflow are impossible, since the minimum discharge of any stream is zero. When the total supply is minus, the level of the lake or reservoir will fall even if the outflow is entirely shut off.

130. The question that now presents itself, since perfect regulation of Superior is impossible, is: Can the fluctuations in stage of Lake Superior be materially reduced; and if so, what would be the effect on the lower lakes. An examination of Table 24 shows that during November and December, 1870, and January, 1871, the total monthly supply to Lake Superior for these three consecutive months was —99500, —106600, and —42900 cubic feet per second, respectively, equivalent, collectively, to a total depth on the lake surface of —0.732 foot.

The level of Lake Superior actually fell 1.41 feet during this period, but, even if the outflow through the St. Marys River had been entirely shut off, the lake would still have fallen over eight and three-quarters inches. During May, June, and July, in the high-water year of 1876, the total monthly supply to Lake Superior was 303300, 291200, and 205000 cubic feet per second, respectively,—a total of 799500 cubic feet per second, equivalent to a depth on lake surface of +2.351 feet. The outflow through the St. Marys River for the corresponding period was 95800, 109200, and 120000 cubic feet per second, respectively, or an average monthly flow of 108300 cubic feet per second. Granting that this enormous supply of water could have been predicted,—an impossibility—and that the St. Marys River could have discharged twice the average monthly outflow, or 216600 cubic feet per second, for three months, through artificial works and channels, which would be very costly to construct, Lake Superior would still have risen over 5¼ inches.

131. If the monthly oscillations in stage of Lake Superior could be materially reduced, then the monthly mean flow through the St. Marys River would fluctuate more than it actually does. Under present conditions, the outflow through the St. Marys River is the greatest during August, September, and October, when the stage of Lake Michigan-Huron is falling very rapidly. Under these natural conditions, the water from Lake Superior aids in the attempt of nature to hold the stage of Lake Michigan-Huron at a fixed elevation. If the outflow from Lake Superior in an average year were increased as much as 50 per cent. during August, September, and October, the level of Lake Michigan-Huron would be raised only about 0.1 foot per month for these months, since the discharge through the St. Marys River is not the supply factor that produces the principal effect on the stage of Lake Michigan-Huron.

132. These cases show, first that the artificial regulation of Lake Superior would not materially decrease the present fluctuation of water level; second, that Lake Superior is one of the best naturally regulated bodies of water in the world; and third, that the effect of the artificial regulation of the level of Lake Superior on the level of Lake Michigan-Huron would produce only insignificant results.

DIVERSION OF WATER THROUGH CHICAGO DRAINAGE CANAL, THE EFFECT OF DIVERSION ON LAKES MICHIGAN-HURON, ERIE, AND ONTARIO, AND THE REGULATION OF LAKE SUPERIOR TO COMPENSATE FOR DIVERSION AT CHICAGO.

133. The Chicago Drainage Canal has diverted water from Lake Michigan-Huron since 1900. This has lowered the level of Lakes Michigan-Huron, St. Clair, Erie, and Ontario, regardless of the fact that these lakes are at higher stages than they were when the canal was opened. These higher stages are due to the increase in the quantity of water supplied since 1900. If this supply had not been increased, then the stages of the lakes would have been actually less. Plates 22, 23, and 24 show the monthly loss of level on Lakes Michigan-Huron, Erie, and Ontario, respectively, under the actual diversion through the Chicago Drainage Canal, and also under assumed diversions of 10000 and 14000 cubic feet per second.

TABLE 37.

LOSS OF LEVEL ON LAKES MICHIGAN-HURON, ERIE, AND ONTARIO UNDER THE ACTUAL DIVERSION AND UNDER ASSUMED DIVERSIONS OF 10000 AND 14000 C. F. S. THROUGH THE CHICAGO DRAINAGE CANAL, 1900-1907, INCLUSIVE.

LAKE.	LOSS OF LEVEL IN INCHES.		
	Actual Diversion.	Assumed Diversion of	
		10000 c. f. s.	14000 c. f. s.
Michigan-Huron	2-5/8	6-1/2	9-3/8
Erie	2-1/2	5-7/8	8
Ontario	1-7/8	4-1/4	6

134. The stage of Lake Michigan-Huron is 2⅝ inches lower than it would have been if there had not been any water diverted through the Chicago Drainage Canal. Likewise, the stages of Lake Erie and Lake Ontario are 2½ and 1⅞ inches lower, respectively, than they would have been with no diversion at Chicago. If the quantity of water diverted through the canal had been as much as 10000 or 14000 cubic feet per second, then the effect would have been proportionately greater.

135. Since the effect of the diversion is to lower the level of the lakes and connecting channels of the Great Lakes system, with the exception of Lake Superior and the upper St. Marys River, and as this effect will increase with the increase in the quantity of water diverted, therefore, the ques-

tion presents itself: Can the present diversion or future diversions through the Chicago Drainage Canal be compensated for by the use of Lake Superior as a storage reservoir, so that the level of the lakes below Superior will not be lowered?

136. The longest low-stage period of outflow from Lake Superior has been selected in order to obtain a solution to the question. An examination of Plates 2 to 5, inclusive, shows that such a period occurred between June, 1888, and August, 1893. The average flow for the low-water year of 1892 was 65700 cubic feet per second. Assuming a continuous discharge from Superior of the average flow for that year, and, in addition, first, 4000 and, second, 14000 cubic feet per second, respectively, to compensate for a diversion of these amounts through the Chicago Drainage Canal, or a total continuous discharge of, first, 69700 cubic feet per second, and, second, 79700 cubic feet per second, respectively, between June 1, 1888, and August 31, 1893, then the regulated stages of all the lakes in the Great Lakes system would have differed materially from the actual stages. Plate 25 and Tables 38, 39, 40, 41, and 42 show these changes in stage of Lakes Superior, Michigan-Huron, Erie, and Ontario, due to regulation of outflow from Lake Superior to compensate for diversions through the Chicago Drainage Canal of 4000 and 14000 cubic feet per second.

137. To compensate for a diversion of 4000 cubic feet per second through the Chicago Drainage Canal, with the continuous discharge of water from Lake Superior of 69700 cubic feet per second between June 1, 1888, and August 31, 1893, the stage of the St. Marys River, as measured at Sault Ste. Marie, (above the locks) would have been higher than it was actually. In August, 1893, the level of Superior would have returned to approximately the actual stage. Under assumed conditions, the mean stage of Lake Superior would have been increased during the period from June, 1888, to August, 1893, at the expense of the decrease in stage of Lakes Michigan-Huron, Erie, and Ontario. The cumulative effect of the constant discharge of 69700 cubic feet per second from Lake Superior during this five-year period would have been to lower the monthly mean stage of Lake Michigan-Huron from 579.88 to 579.53, and from 579.82 to 579.48, in November and December, 1891, respectively. These stages would have been only 0.36 and 0.48 foot higher, respectively, than the actual stages for the corresponding months of November and December in the extreme low-water year of 1895, and would have

been 0.23 and 0.28 foot lower, respectively, than the mean stage for the entire navigation season of 1895, when the shipping interests were so seriously affected. This constant discharge of water from Lake Superior would also have lowered the monthly mean stage of Lake Erie from 571.21 to 570.89, and from 571.28 to 570.96, in November and December, 1891, respectively, which would have been only 0.19 and 0.19 foot higher, respectively, than the actual stages in November and December, 1895. The monthly mean stage of Lake Ontario would have been decreased by this discharge from Lake Superior from 244.44 to 244.19, and from 244.41 to 244.16, in November and December, 1891, respectively.

138. At the end of August, 1893, the water stored in Lake Superior would have been delivered to the lower lakes, and no storage water would have been available, in addition to the actual supply, to compensate for the diversion of water through the Chicago Drainage Canal, and prevent the mean levels of Lakes Michigan-Huron, Erie, and Ontario falling below the actual stages.

139. The monthly mean discharge of the St. Marys River was greater than 69700 cubic feet per second in September, October, and November, 1893. This excess would have allowed 6900, 5800, and 4800 cubic feet per second of water, respectively, to have been stored in Lake Superior in these months. The storage of this volume of water would have temporarily taken it away from the supply to Lake Michigan-Huron, and would have lowered the level of that lake temporarily. Later, when this stored water would have been discharged into the lakes below, their stages would have been the same as under natural conditions, and during the interval between the storage and discharge of this water the diversion of water through the Chicago Drainage Canal would have lowered the mean level of Lakes Michigan-Huron, Erie, and Ontario as it has under actual conditions. If the outlet were to have been artificially changed so that the St. Marys River could have discharged 4000 cubic feet per second in addition to the actual discharge, beginning with September, 1893, in order to compensate for an assumed diversion of this amount at Chicago, then it would have been only a few years before Lake Superior would have fallen so low in stage that navigation would have been seriously interfered with.

140. To compensate for a diversion of 14000 cubic feet per second through the Chicago Drainage Canal, with the continuous discharge of water from Lake Superior of 79700 cubic feet per second between June 1, 1888, and August 31, 1893,

the stage of the St. Marys River, as measured at Sault Ste. Marie, (above the locks) would have been lower by 1.4 feet than it was actually. This increased discharge from Lake Superior would produce the same effect on the lower lakes as the effect of the previous discharge of 69700 cubic feet per second, since the increased outflow from Lake Superior would be taken by the additional diversion through the Chicago Drainage Canal. The stage of the St. Marys River, at Sault Ste. Marie, (above the locks) would have fallen, in May, 1893, to slightly below 600.0, which would have seriously interfered with the navigation of Lake Superior by the present lake vessels. At the end of this five-year period, the level of Lake Superior would have been extremely low and water would not have been available for storage in Lake Superior for the next low-water period.

141. The annual mean stage of the St. Marys River, above the locks, fell to 600.96, in 1879. This minimum value must not be taken as a criterion for permissible low water for navigation purposes; neither should it be assumed that the minimum annual mean stage on the remaining lakes, as a permanent level, would be satisfactory to navigation.

142. The artificial storage of water in Lake Superior must be commenced by shutting off the transmitted supply to the lakes below Superior in the Great Lakes system. When the stored water is allowed to flow from Lake Superior, the total supply to Lakes Michigan-Huron, Erie, and Ontario will be the same as under actual conditions, and the mean level of these lakes will remain unchanged.

143. An artificial storage of water in Lake Superior has taken place, beginning with the construction of the International Bridge and its approaches in 1888. The storing of this water in Superior has withheld it temporarily from the lakes below, and, as a result, the stages of the latter have been changed from what they would have been if there had been no artificial changes in the outlet to Lake Superior. Plates 26, 27, 28, and 29 show the monthly mean stages of the Great Lakes under actual conditions and as they would have been if no artificial works had been built in the upper St. Marys River.

144. An inspection of Plate 26 shows that the artificial storage of water in Lake Superior, created by the building in the upper St. Marys River of the International Bridge and approaches in 1888, of cutting off from the rapids the flow through spans 1 and 2 of this bridge from the American shore by the Chandler-Dunbar Water Power Company in 1892, and

of building the compensating works immediately above the bridge, on the Canadian side, by the Michigan Lake Superior Power Company in 1901, has raised the monthly mean level of Lake Superior approximately 1 foot (0.966) in August, 1904. Owing to diversions of water at Sault Ste. Marie for power and other purposes, this effect is less by about 0.4 foot than the computed ultimate rise due to these obstructions. Since January, 1905, when the Michigan Lake Superior Power Company began to divert approximately 8500 cubic feet per second of water from the river for power purposes, the difference between the actual and original efflux stages has decreased to approximately 0.6 foot, a loss in level between 1904 and 1907 of 0.4 foot. Under original efflux conditions, the monthly mean level of Lake Superior would have fallen from 601.02 to 600.76, in April, 1892; from 601.01 to 600.82, in February, 1893; from 601.46, to 600.92, in March, 1898, and from 601.88 to 601.02, in March, 1903. The annual mean stage of Lake Superior, for 1904, would have been 601.84 under original conditions, while it was 602.71 under actual conditions. This artificial storage of water, due to the obstructions at the controlling section of the upper St. Marys River, partly explains why the stage of Lake Superior has been gradually rising while the stages of the lower lakes have not followed the same general upward trend.

145. The storing of water in Lake Superior has had its effect on the stage of the lower lakes. An increase in the transmitted supply from Lake Superior raises the stage of Lake Michigan-Huron an amount equal to the increase divided by the increment of discharge through the St. Clair River. The amount of additional water from Lake Superior that would have flowed into Lake Michigan-Huron between December, 1888, and December, 1904, is equivalent to the decrease in storage on Superior. This quantity represents a slice 0.87 foot thick over the entire surface of Lake Superior, equivalent to an average monthly increase in discharge of 1530 cubic feet per second through the St. Marys River between December, 1888, and December, 1904, inclusive. Under actual conditions this increase in discharge would not be a constant quantity but would change according to the effect of the obstruction or the diversion. Plate 27 shows a comparison of the monthly mean water levels of Lake Michigan-Huron under actual and original efflux conditions of the St. Marys River. The effect of storing water in Lake Superior by cutting off of spans 1 and 2 of the International Bridge at Sault Ste. Marie, in 1892, by the Chandler-Dunbar Water Power Company, was to lower

Lake Michigan-Huron by about 0.15 foot in 1894 and 1895. In 1896, the Lake Superior Power Company began to use water for power purposes on a large scale, which partially counteracted the effect of the obstructions. In 1902, the effect of the compensating works of the Michigan Lake Superior Power Company was to lower Lake Michigan-Huron by about 0.15 foot. In 1905 the Michigan Lake Superior Power Company began the diversion of water through their canal on the American side, which has, apparently, raised the stage of Lake Michigan-Huron about 0.1 foot, but in so doing it has been done at the expense of lowering Lake Superior by about 0.4 foot.

146. The effect on Lakes Erie and Ontario of the artificial storage of water in Lake Superior is slightly less than the effect on Lake Michigan-Huron. This decrease in effect is due to the increase in the increment of discharge of the outlets of Lakes Erie and Ontario. Plates 28 and 29 show a comparison of the monthly mean water levels of Lake Erie and of Lake Ontario, respectively, under actual and original efflux conditions of St. Marys River. While the effect of the cutting off of the flow through spans 1 and 2 from the rapids of the St. Marys River occurred about December, 1892, it was not materially felt on Lake Michigan-Huron until the latter part of 1893; not in Lake Erie until the middle of 1894, and not in Lake Ontario until the end of 1894. The effect of the construction of the compensating works at Sault Ste. Marie by the Michigan Lake Superior Power Company is also noticeable on these lakes. All the other changes in stage on Lake Michigan-Huron are faithfully reproduced on the stage of Lakes Erie and Ontario, the only difference being that they occur a little later and the effect becomes slightly less on each lake lower in the series. Where the maximum effect on Lake Michigan-Huron was about 0.15 foot, it was about 0.12 foot on Lake Erie, and about 0.10 foot on Lake Ontario.

147. The artificial storage of water in Lake Superior between December, 1888, and December, 1907, inclusive, by the placing of obstructions in the upper St. Marys River, has had the effect of raising the mean stage of Lage Superior by about 0.87 foot in 1904, and of lowering Lake Michigan-Huron, Lake Erie, and Lake Ontario by a maximum of 0.15, 0.12, and 0.10 foot, respectively. This hydraulic experiment, which has been carried on since 1888, shows that the use of Lake Superior as a storage reservoir can not be successful

if navigation is to be maintained unimpaired on Lake Superior and the St. Marys River.

REGULATION OF LAKE MICHIGAN-HURON.

148. To regulate the level of Lake Michigan-Huron near some fixed plane of reference would require regulating works at or near the head of the St. Clair River. The storage in the lake, that occurs in the first part of the year, could then be discharged through these works, while the outflow from the lake during the last half of the year could be diminished by an amount equal to the negative storage. An examination of Table 28 and Plate 18 shows that the monthly mean total supply to Lake Michigan-Huron for an average year has been as great as 237700 cubic feet per second, in May, and as small as 96200 cubic feet per second, in November. Plates 7 and 6 show that the maximum and minimum monthly mean total supply has been 470800 cubic feet per second, in June, 1883, and —32000 cubic feet per second, in September, 1871, respectively. The maximum monthly mean discharge from this lake, which occurred in July, 1883, has been determined as 275400 cubic feet per second. On the basis of the above extremes for total supply, to accomplish perfect regulation of this lake would necessitate provision for a maximum outflow of 470800 cubic feet per second, and a minimum of —32000 cubic feet per second. This required maximum outflow is 195400 cubic feet per second, or 71 per cent., greater than the actual maximum. If the outflow from Lake Michigan-Huron had been entirely shut off in September, 1871, the lake would still have fallen about 0.07 foot during that month. For the period of five months, August to December, 1871, inclusive, the average outflow from Lake Michigan-Huron, with perfect regulation, would have been only 43500 cubic feet per second; likewise, for the period of five months, August to December, 1894, inclusive, and for the months of September, October, and November, in the low-water year of 1895, the average outflow with perfect regulation would have been only 71700 and 46600 cubic feet per second, respectively. On account of the small quantity of water that would have flowed in the St. Clair and Detroit rivers during these three periods, the stage of these rivers, of Lake St. Clair and of Lake Erie would have been lowered several feet below the lowest known monthly water levels, and present navigation on the Great Lakes, below Lake Michigan-Huron, would have been entirely suspended.

149. These examples that have been cited show that the perfect regulation of Lake Michigan-Huron at a fixed plane of reference is not feasible even if it were possible to predict the quantity of water that nature would supply to any lake in any month.

150. The discharges of the St. Clair and Detroit rivers during the navigation season are comparitively uniform owing to the effect of the increased slopes in the rivers counteracting the effect of the decreased stages in the lakes. With the regulation of Lake Michigan-Huron, the discharge would be greatly increased during April, May, June, and July, and greatly decreased during August, September, October, and November. The latter are the critical months for the navigators. Any change in the flow of these two rivers, whereby the fluctuation in discharge would be increased, would prove a detriment to navigation.

151. Granting that the regulation of Lake Michigan-Huron could be accomplished by artificial works, the effect on the stage of water in the St. Clair River, Lake St. Clair and Detroit River would be so serious that any benefit derived from the increased depths in Lake Michigan-Huron would be more than offset by the decreased depths in the St. Clair River, Lake St. Clair, Detroit River, and the western end of Lake Erie.

152. At the present time, the stage of Lake Michigan-Huron is partially regulated by natural agencies. Nearly every winter, nature forms a regulating works in the St. Clair or Detroit river. These works consist of ice gorges, which retard the outflow from Lake Michigan-Huron, thereby storing water to be let out during the navigation season when it is so greatly needed in the lakes and connecting channels below Lake Michigan-Huron.

REGULATION OF LAKE ONTARIO.

153. To control the stage of Lake Ontario near some fixed level, regulating works could be constructed at the head of the Galop Rapids in the St. Lawrence River. These works would control the outflow from Lake Ontario and maintain the levels of the lake within definite limits. For perfect regulation, the storage in the lake must be discharged during the first half of the year and the outflow must be diminished by the amount of the negative storage during the last half of the year. An examination of Table 28 and Plate 18, shows that, for an average year, the monthly mean total supply to Lake Ontario has fluctuated between 297500 cubic feet per

second, in May, and 225500 cubic feet per second in January, while the monthly mean outflow has varied from 283600 cubic feet per second, in July, to 219300 cubic feet per second, in February. The maximum monthly mean total supply has been as large as 382400 cubic feet per second, in April, 1870, and as small as 154100 cubic feet per second, in February, 1875, while the maximum monthly mean discharge has been as large as 351200 cubic feet per second, in May, 1862, and as small as 152200 cubic feet per second, in February, 1902. In order to accomplish perfect regulation without enlarging the river cross section, the stage of Lake Ontario must be held at such a level that the outflow can be as great as 382400 cubic feet per second, or 31200 cubic feet per second greater than the maximum discharge to date. This required maximum outflow is only 9 per cent. greater than the actual maximum. For the low-water year of 1895, the average total supply was 185700 cubic feet per second, while the average outflow was 191600 cubic feet per second. If the oscillations in the levels of Lake Ontario are to be decreased without exceeding the extreme high water of 248.95, then the level of the lake should be held at such a stage that it will never exceed this maximum limit in months of excessive supply. Two consecutive months of excessive supply occurred in April and May of 1862, when the water-yield was 375600 and 372000 cubic feet per second, respectively. The outflow through the St. Lawrence River at regulated stage 248.95 would be about 350500 cubic feet per second. With a maximum discharge through the regulating works, there would still have been an excess in supply of 25100 and 21500 cubic feet per second, corresponding to a rise in lake surface of 0.33 foot, in April, and 0.28 foot, in May, or a total of 0.61 foot in the two months. Hence, if the level of the lake, under regulation, were allowed to fall 0.6 foot, or to 248.35, after the close of the season of navigation, then the plane of regulation of Lake Ontario would probably never be exceeded.

154. Regulating works, designed to discharge about 150000 cubic feet per second, as a minimum, and 350500 cubic feet per second, as a maximum, could be located at the head of the Galop Rapids and would control the monthly mean level of Lake Ontario between 246.95 and 248.95, a range of 2 feet. This scheme of regulation would reduce the fluctuations in lake level from 5½ feet to within 2 feet, and would raise the mean level of Lake Ontario about 2 feet.

155. The effect on the stage of water in the St. Lawrence canals with this scheme of regulation of Lake Ontario

would be to cause higher water in the first part and lower water in the last part of the navigation season. Such results would injuriously affect navigation.

COMPENSATING WORKS IN THE NIAGARA RIVER.

156. Your committee had hoped to present a discussion of a project for compensating Lake Erie for the loss of level due to diversions, by works placed above the rapids approaching Niagrara Falls. A preliminary examination, however, revealed a lack of data, which prevents consideration of the question at this time.

E. E. HASKELL,
Member, American Section.

LOUIS COSTE,
Member, Canadian Section.

ATTEST: W. EDWARD WILSON, C. E.,
Secretary, American Section.

TABLE 2.

WATER LEVELS OF LAKE SUPERIOR.

Monthly mean elevations of water surface of Lake Superior, at Superior, Wis., and Marquette, Mich., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
a1860	602.69	602.44	602.42	602.99	602.92	603.09	603.05	603.10	603.08	603.13	602.95	602.69	602.81
a 61	b 2.40	2.15	2.01	2.42	3.05	3.20	3.36	3.32	3.23	3.26	3.02	2.84	2.89
a 62	2.19	2.00	2.03	2.09	2.77	2.76	2.73	2.90	3.02	2.93	2.62	2.25	2.49
a 63	2.16	2.03	1.86	1.90	2.03	1.85	2.09	2.71	2.73	2.56	2.21	2.10	2.19
a 64	1.81	1.60	1.67	1.69	1.85	2.03	2.09	2.10	2.25	1.99	1.80	1.65	1.89
a 65	1.47	1.46	1.33	1.77	2.26	2.67	2.90	3.07	3.06	2.87	2.34	2.09	2.28
a 66	1.74	1.53	1.53	1.98	2.23	2.43	2.71	2.94	2.67	2.68	2.36	2.47	2.27
a 67	2.20	2.09	1.90	2.13	2.12	2.72	3.05	3.03	3.01	2.99	2.58	2.34	2.59
a 68	2.08	1.49	1.85	2.04	2.44	2.35	2.57	2.49	2.62	2.80	2.73	2.32	2.30
a 69	2.10	1.86	1.41	1.99	2.39	2.49	2.77	3.23	4.05	3.56	3.22	2.57	2.83
a1870	2.32	2.11	2.12	2.22	2.85	2.86	2.85	2.72	2.56	2.38	1.45	1.23	2.22
a 71	1.36	0.76	1.18	1.66	2.21	2.53	2.40	2.46	2.86	2.40	2.42	1.66	1.96
72	1.47	1.36	1.24	1.14	1.79	2.17	2.44	2.61	2.77	2.67	2.52	2.22	2.09
73	2.12 c	1.80 c	1.82 c	1.88	2.31	2.61	2.90	3.08	3.14	3.04	2.90	2.60	2.53
74 c	2.14	2.13	2.09	2.19	2.26	2.48	2.84	2.93	3.03	3.00	2.91	2.60	2.56
75	2.28	2.24	2.28	2.28	2.50	2.88	2.85	2.94	3.17	3.02	2.88	2.66	2.69
76	2.48	2.27	2.18	2.21	2.73	3.43	3.82	3.93	3.82	3.49	3.32	3.05	3.00
77	2.69	2.45	2.19	2.11	2.10	2.32	2.70	2.76	2.90	2.60	2.39	2.22	2.44
78	2.20	2.32	1.85	1.52	1.79	2.07	2.14	2.02	1.85	1.92	1.72	1.40	1.89
79 c	1.49	1.48	1.76	1.37	1.01	1.24	1.48	1.60	1.49	1.58	1.50 c	1.14	1.42
1880 c	0.99 c	0.98 c	0.89 c	0.92 e	1.52	2.30	2.45	2.44	2.44	2.39	2.33	2.07	1.81
81	1.81	1.71	1.62	1.53	1.53	2.27	2.33	2.35	2.61	2.95	2.86	2.60	2.21
82	2.25	2.00	1.89	1.81	1.97	1.99	2.44	2.56	2.60	2.45	2.41	2.22	2.21
83	1.99	1.70	1.70	1.95	1.96	2.06	2.31	2.33	2.39	2.09	1.94	1.82	2.05
84 e	1.80 e	1.63 e	1.54	1.32	1.84	1.74	1.88	1.89	2.16	2.52	2.42	2.21	1.99
85	1.98	1.80	1.72	1.67	2.00	2.28	2.52	2.64	2.57	2.40	2.25	1.92	2.11
86	1.72	1.59	1.53	1.62	1.67	2.01	2.08	1.99	1.97	2.07	1.92	1.78	1.85
87	1.67	1.49	1.50	1.97	1.75	1.92	2.20	2.25	2.14	2.07	1.83	1.61	1.89
88	1.50	1.31	1.44	1.44	1.91	2.09	2.88	3.02	2.97	2.88	2.74	2.39	2.23
89	2.07	1.85	1.68	1.89	2.04	2.16	2.35	2.54	2.67	2.51	2.33	1.90	2.14
1890	1.76	1.63	1.39	1.36	1.57	2.02	2.32	2.47	2.60	2.57	2.36	2.00	2.09
91	1.64	1.51	1.47	1.43	1.63	1.98	1.88d	1.88d	1.82d	1.91d	1.79	1.43	1.67
92	1.42	1.14	1.01	1.02	1.35	1.73	1.76	1.88	1.93	1.82	1.66	1.38	1.61
93	1.16	1.01	1.06	1.16	1.66	2.18	2.48	2.54	2.48	2.42	2.26	2.03	1.89
94	1.85	1.67	1.76	1.91	2.06	2.91	2.97	3.10	3.02	3.04	2.99	2.86	2.54
95	2.80	2.98	2.11	2.01	2.28	2.76	2.90	2.95	3.09	3.14	2.85	2.53	2.63
96	2.32	2.12	1.92	2.01	2.66	3.04	3.10	3.12	2.95	2.93	2.70	2.55	2.80
97	2.39	2.16	2.08	2.11	2.43	2.78	3.06	3.20	3.14	2.94	2.64	2.21	2.66
98	1.83	1.68	1.46	1.46	1.70	2.18	2.59	2.72	2.82	2.76	2.66	2.32	2.17
99	1.98	1.76	1.79	1.76	2.47	2.95	3.19	3.35	3.51	3.32	3.21	3.00	2.96
1900	2.63	2.45	2.22	2.13	2.30	2.86	2.88	2.94	3.46	3.54	3.51	3.13	2.77
01	2.78	2.46	2.26	2.22	2.51	2.61	2.90	3.22	3.04	3.07	3.00	2.68	2.73
02	2.32	2.11	1.97	2.02	2.34	2.64	2.88	2.89	3.03	2.81e	2.81e	2.58	2.53
a 03	2.34	1.98	1.85	2.07	2.56	2.94	3.14	3.25	3.27	3.46	3.18	2.91	2.72
a 04	2.66	2.34	2.23	2.17	2.47	2.77	2.86	2.95	3.06	2.98	3.14	2.76	2.71
a 05	2.47	2.13	2.04	2.25	2.49	2.67	2.97	3.10	3.32	3.33	3.17	2.96	2.74
a 06	2.72	2.43	2.22	2.15	2.45	2.78	2.90	2.93	2.95	2.84	2.66	2.43	2.59
a 07	2.32	2.06	1.94	1.94	2.17	2.53	2.70	2.93	3.17	3.15	2.86	2.53	2.51
Mean	602.08	601.83	601.77	601.84	602.16	602.42	602.62	602.73	602.79	602.74	602.56	602.26	602.31

Authority, U. S. Lake Survey, except for supplied values.

a.—Gage readings taken at Superior, Wis.

b.—Supplied by applying to the mean reading, for the following or preceding month, the mean rise or fall in stage between such months for the years 1861 or 1862 to 1871, inclusive.

c.—Supplied by adding to the Sault Ste. Marie readings the mean fall in the water surface between Marquette and Sault Ste. Marie for the years 1871 to 1898, inclusive.

d.—Supplied in like manner from years 1899 to 1901, inclusive.

e.—From self-registering gage.

NOTE.—Elevations depend on zero of gage 601.75 ft. and B. M. 3,009.91 ft., U. S. Lake Survey, 1903 Levels.

TABLE 3.

WATER LEVELS OF ST. MARYS RIVER.

Monthly mean elevations of water surface of St. Marys River, at Southwest pier (above the locks) Sault Ste. Marie, Mich., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
a1860	602.22	601.95	601.93	602.13	602.55	602.74	602.74	602.80	602.72	602.76	602.88	602.18	602.45
a 61	1.93	1.68	1.52	1.91	2.48	2.85	3.05	3.02	2.87	2.90	2.55	2.12	2.42
a 62	1.72	1.51	1.54	1.58	2.40	2.41	2.42	2.60	2.66	2.59	2.25	1.91	2.13
a 63	1.69	1.54	1.37	1.39	1.66	1.93	1.78	2.41	2.37	2.20	1.84	1.68	1.79
a 64	1.34	1.11	1.13	1.13	1.43	1.65	1.72	1.80	1.89	1.63	1.43	1.23	1.48
a 65	1.00	0.97	0.84	1.26	1.89	2.32	2.66	2.77	2.72	2.51	1.97	1.61	1.85
a 66	1.27	1.04	1.04	1.47	1.86	2.07	2.46	2.64	2.31	2.33	1.99	2.06	1.87
a 67	1.73	1.60	1.41	1.61	1.75	2.37	2.74	2.63	2.65	2.63	2.19	1.82	2.09
a 68	1.61	1.60	1.36	1.53	2.07	2.00	2.26	2.19	2.26	2.22	2.35	1.90	1.99
a 69	1.63	1.37	0.92	1.42	2.02	2.05	2.46	2.93	2.72	3.20	2.85	2.15	2.23
1870 c	1.85 c	1.62 c	1.63 c	1.71 c	2.18 c	2.01 c	2.24 c	2.25 c	2.36 c	2.20	2.01	1.63	1.92
71	1.36	1.20	0.93	1.07	1.64	2.08	2.28	2.18	2.20	2.03	1.78	1.39	1.67
72	1.14	1.06	0.82	0.78	1.67	1.84	2.24	2.56	2.63	2.48	2.32	1.88	1.79
73	1.48	1.31	1.33	1.35	1.91	2.04	2.48	2.73	2.80	2.68	2.46	2.22	2.07
74	1.67	1.51	1.40	1.28	1.70	2.13	2.50	2.56	2.54	2.67	2.43	2.35	2.06
75	1.89	1.64	1.60	1.55	2.16	2.46	2.54	2.56	2.84	2.71	2.43	1.87	2.21
76	1.84	1.79	1.53	1.57	2.29	2.57	3.34	3.39	3.42	3.09	2.81	2.32	2.52
77	2.08	2.06	1.94	1.62	1.82	2.04	2.37	2.49	2.25	2.39	2.05	1.89	2.09
78	1.67	1.41	1.31	1.29	1.57	1.83	1.94	1.90	1.61	1.72	1.64	1.42	1.61
79	1.02	0.62	0.38	0.61	0.88	1.02	1.32	1.35	1.27	1.30	1.12	0.72	0.96
1880	0.52	0.49	0.40	0.41	1.15	1.91	2.15	2.02	2.19	1.98	1.90	1.71	1.41
81	1.48	1.30	1.32	1.21	1.63	1.86	2.06	1.98	2.17	2.63	2.53	2.20	1.86
82	1.69	1.47	1.35	1.30	1.71	1.80	2.15	2.25	2.19	2.10	2.04	1.77	1.82
83	1.34	1.25	1.25	1.32	1.31	1.68	1.86	2.26	1.95	1.80	1.60	1.43	1.60
84	1.23	1.14	1.05	0.88	1.25	1.35	1.57	1.61	1.68	1.77	1.57	1.61	1.43
85	1.44	1.23	1.19	1.02	1.66	1.94	2.12	2.34	2.10	1.92	1.83	1.55	1.70
86	1.20	1.04	1.04	1.02	1.50	1.66	1.83	1.97	1.82	1.86	1.79	1.36	1.51
87	1.14	1.00	0.97	0.83	1.19	1.64	2.01	1.89	1.73	1.93	1.70	1.39	1.44
88	1.13	0.79	0.84	0.83	1.43	2.28	2.44	2.43	2.35	2.34	2.14	1.80	1.73
89	1.52	1.23	1.26	1.25	1.81	1.99	2.26	2.27	2.26	2.11	1.81	1.43	1.77
1890	1.48	0.93	0.92	0.85	1.32	1.90	2.29	2.17	2.06	1.99	1.88	1.55	1.61
91	0.86	0.97	0.82	1.00	1.43	1.28	1.49	1.50	1.43	1.49	1.28	1.07	1.24
92	1.01	0.68	0.47	0.93	1.14	1.52	1.64	1.65	1.71	1.60	1.32	1.04	1.20
93	0.79	0.59	0.60	0.85	1.42	1.95	2.15	2.23	2.10	2.04	1.90	1.45	1.51
94	1.23	1.15	1.04	1.42	2.40	2.64	2.78	2.79	2.66	2.70	2.60	2.30	2.14
95	2.00	1.86	1.68	1.64	2.04	2.42	2.57	2.66	2.65	2.97	2.48	2.24	2.29
96	1.60	1.68	1.46	1.57	2.18	2.59	2.72	2.74	2.61	2.18	2.21	2.15	2.15
97	1.92	1.61	1.63	1.76	2.11	2.47	2.69	2.85	2.66	2.47	2.36	1.87	2.20
98	1.58	1.16	1.00	1.13	1.43	1.83	2.17	2.26	2.49	2.26	2.00	2.01	1.76
99	1.53	1.37	1.26	1.26	2.12	2.56	2.76	2.91	2.16	2.77 b	2.86 b	2.64	2.25
b1900	2.03	1.90	1.64	1.68	1.87	1.94	2.17	2.26	2.90	2.85	3.04	2.62	2.24
b 01	2.17	1.87	1.63	1.76	2.06	2.15	2.59	2.74	2.63	2.73	2.82	2.27	2.27
b 02	2.00	1.61	1.53	1.66	1.86	2.39	2.48	2.46	2.54	2.39	2.48	2.29	2.13
b 03	1.83	1.90	1.51	1.76	2.15	2.57	2.70	2.80	2.83	2.98	2.86	2.41	2.33
b 04	1.87	1.64	1.40	1.76	2.06	2.34	2.48	2.55	2.65	2.83	2.71	2.30	2.21
b 05	2.00	2.59	1.38	1.73	2.07	2.35	2.60	2.72	2.92	2.96	2.72	2.52	2.39
b 06	2.18	1.58	1.63	1.70	2.02	2.20	2.50	2.46	2.46	2.38	2.13	1.96	2.13
b 07	1.62	1.43	1.34	1.69	1.71	2.13	2.33	2.50	2.70	2.71	2.54	2.08	2.08
Mean	601.58	601.34	601.24	601.35	601.80	602.06	602.31	602.40	602.41	602.33	602.15	601.86	601.91

Authority, U. S. Lake Survey, except for supplied values.

a.—Values supplied by subtracting from the Superior, Wis., readings the mean fall in water surface between Superior and Sault Ste. Marie for the years 1860 to November, 1870, inclusive.

b.—From self-registering gage.

Note.—Elevations depend on B. M. "A" 606.089 ft., U. S. Lake Survey, 1903 Levels.

TABLE 4.

WATER LEVELS OF LAKE MICHIGAN.

Monthly mean elevations of water surface of Lake Michigan, at Milwaukee, Wis., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	581.51	581.60	581.73	581.85	581.97	581.60	581.13	581.94	581.74	581.43	581.10	581.04	581.63
61	1.30	1.02	2.31	2.41	2.52	2.90	2.13	2.26	2.06	2.06	2.70	2.52	2.40
62	2.33	2.18	2.48	2.64	2.80	3.02	2.92	2.91	2.84	2.73	2.84	2.80	2.73
63	2.13	2.18	2.17	2.17	2.32	2.47	2.43	2.29	2.11	2.05	1.85	1.92	2.15
64	1.90	1.85	1.80	1.81	2.00	2.01	1.91	1.79	1.48	1.07	0.90	0.77	1.56
65	0.56	0.65	0.82	1.21	1.47	1.81	1.94	1.96	1.88	1.03	1.04	0.72	1.39
66	0.47	0.29	0.38	0.79	0.91	1.20	1.43	1.62	1.27	1.16	1.17	0.91	0.96
67	0.80	0.94	1.13	1.41	1.68	1.94	2.09	2.06	1.73	1.42	0.96	0.61	1.40
68	0.45	0.41	1.00	0.99	1.37	1.42	1.51	1.17	0.62	0.70	0.62	0.32	0.92
69	0.36	0.32	0.06	0.48	0.78	1.20	1.37	1.05	1.02	1.46	1.34	1.06	0.93
1870	1.12	1.31	1.51	1.95	2.27	2.41	2.45	2.42	2.27	2.17	1.77	1.42	1.96
71	1.37	1.49	2.09	2.20	2.64	2.66	2.71	2.46	1.81	1.12	1.03	0.46	1.87
72	0.35	0.25	0.13	0.35	0.63	1.03	1.03	1.01	0.94	0.82	0.33	579.87	0.59
73	579.87	579.91	0.33	0.79	1.35	1.80	1.94	2.04	1.85	1.79	1.36	581.33	1.25
74	581.48	581.77	1.92	1.82	1.81	2.17	2.16	2.11	1.89	1.51	1.31	0.97	1.75
75	0.77	0.70	0.76	1.12	1.66	1.96	1.99	2.06	1.99	1.94	1.62	1.44	1.49
76	1.39	1.49	1.63	2.13	2.74	3.15	3.40	3.42	3.27	2.72	2.36	2.43	2.62
77	2.28	2.29	2.39	2.67	2.84	3.05	3.04	3.40	3.27	3.26	2.16	2.10	2.80
78	1.96	1.91	2.07	2.09	2.29	2.53	2.64	2.32	2.03	1.91	1.75	1.46	2.05
79	1.15	1.18	1.50	1.19	1.21	1.39	1.46	1.28	1.17	0.93	0.73	0.76	1.15
1880	0.80	0.71	0.73	0.93	1.26	1.77	1.99	2.05	1.73	1.35	1.06	0.98	1.29
81	0.90	1.11	1.40	1.31	1.62	2.02	2.05	2.05	1.78	1.12	1.03	1.02	1.53
82	1.63	1.62	1.80	2.12	2.52	2.89	2.93	2.91	2.66	2.36	2.07	1.76	2.13
83	1.48	1.62	1.61	1.82	2.30	2.64	2.56	2.52	2.04	2.02	2.37	2.30	2.07
84	2.07	2.19	2.44	2.62	2.85	3.06	2.93	3.06	2.44	2.44	2.06	2.05	2.57
85	2.00	2.09	2.25	2.44	2.80	3.01	3.15	3.31	3.17	3.06	2.72	2.44	2.72
86	2.57	2.60	2.97	3.21	3.61	3.87	3.88	3.13	2.91	2.81	2.47	2.14	3.00
87	2.00	2.43	2.89	2.64	2.74	2.97	2.81	2.67	2.23	1.86	1.55	1.42	2.23
88	1.25	1.20	1.33	1.50	1.97	2.54	2.32	2.13	1.96	1.72	1.46	1.16	1.71
89	1.08	1.05	1.05	1.04	1.15	1.88	1.79	1.85	1.53	1.10	0.75	0.57	1.24
1890	0.45	0.61	0.89	0.91	1.14	1.65	1.62	1.54	1.34	1.26	0.96	0.84	1.09
91	0.59	0.38	0.47	0.78	0.89	1.03	0.96	0.78	0.56	0.20	579.96	579.74	0.69
92	579.86	0.06	579.96	0.01	0.43	0.80	0.85	0.97	0.77	0.53	580.26	0.99	0.56
93	0.96	0.12	580.23	0.66	0.90	1.23	1.34	1.17	0.93	0.71	0.33	580.20	0.84
94	580.10	0.29	0.55	0.70	1.04	1.45	1.43	1.38	0.92	0.72	0.44	0.06	0.77
95	579.91	579.80	579.77	579.97	0.12	0.18	0.07	579.96	579.66	579.51	579.05	578.96	579.78
96	9.06	9.10	9.11	9.26	579.87	579.89	579.82	9.76	9.66	9.51	9.30	9.24	9.47
97	9.23	9.41	9.72	9.89	580.25	580.45	580.34	580.78	580.53	580.24	9.96	9.78	580.13
98	9.72	9.96	580.18	580.30	0.76	0.91	0.69	0.66	0.34	0.32	9.92	9.58	9.81
99	9.33	9.61	579.81	0.06	0.53	0.83	1.04	0.96	0.83	0.46	580.31	9.81	0.52
1900	9.00	9.77	9.96	0.07	0.31	0.45	0.53	0.79	0.46	0.46	0.53	580.10	0.29
01	9.94	9.92	580.24	0.49	0.92	0.97	1.06	1.11	0.93	0.84	0.22	579.98	0.64
02	9.76	9.61	579.64	579.91	0.20	0.50	0.82	0.45	0.32	0.33	0.03	9.91	0.22
03	9.66	9.39	580.06	580.33	0.42	0.61	0.79	0.72	0.77e	0.94e	0.14e	9.86	0.31
e 04	9.90	9.96	0.14	0.60	0.96	1.35	1.36	1.20	1.19	1.06	0.75	580.44	0.74
e 05	580.27	580.21	0.33	0.71	0.97	1.36	1.54	1.51	1.41	0.97	0.71	0.53	0.86
06e	0.52e	0.86e	0.92e	1.01	1.37	1.39	1.44	1.41	1.09	0.96	0.85	0.66	0.99
07	0.60	0.64	0.70	0.96	1.15	1.46	1.48	1.38	1.37	1.16	0.74	0.62	1.00
Mean	580.94	580.87	581.04	581.24	581.45	581.77	581.84	581.79	581.66	581.37	581.13	580.96	581.32

Authority, U. S. Lake Survey.

e.—Self-registering gage on harbor pier.

Note.—Elevations depend on check point (1876) on Chestnut St. Bridge (destroyed) as 595.58 ft. and check point (1902) on same bridge as 584.47 ft., U. S. Lake Survey, 1903 Levels.

TABLE 5.

WATER LEVELS OF LAKE HURON.

Monthly mean elevations of water surface of Lake Huron, at Harbor Beach, Mich., in feet above mean tide at New York.

Year.	Jan.	Feb.	Mar.	April.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	582.32	582.73	582.93	582.96	582.94	582.15	582.27	582.19	582.00	582.42	582.50	582.20	582.56
61	1.98	2.05	2.17	2.37	2.09	2.23	2.45	2.56	2.48	2.96	2.95	2.82	2.57
62	2.44	2.42	2.84	2.55	2.92	2.91	2.99	3.07	2.85	3.13	2.81	2.82	2.77
63	2.76	2.21	2.16	2.32	2.55	2.68	2.89	2.60	2.46	2.20	2.18	1.93	2.34
64	1.78	1.78	1.75	1.93	2.35	2.39	2.24	2.23	1.91	1.86	1.21	1.06	1.85
65	0.72	0.81	0.92	1.47	1.68	1.67	2.10	2.12	2.00	1.76	1.20	0.89	1.45
66	0.62	0.39	0.44	0.88	1.07	1.36	1.62	1.68	1.53	1.42	1.33	1.07	1.12
67	1.00	1.10	1.23	1.57	1.79	2.10	2.22	2.19	1.91	1.58	1.12	0.77	1.56
68	0.61	0.57	1.25	1.13	1.42	1.64	1.67	1.33	1.09	0.86	0.79	0.51	1.06
69	0.41	0.45	0.22	0.58	0.92	1.45	1.82	2.09	1.96	1.62	1.50	1.22	1.19
1870	1.28	1.37	1.67	2.00	2.43	2.87	2.98	3.59	2.73	2.33	1.93	1.86	2.10
71	1.73	1.68	2.25	2.43	2.90	2.84	2.87	2.56	2.21	1.74	1.53	1.16	2.15
72	0.96	0.79	0.39	0.71	1.11	1.51	1.61	1.58	1.46	1.36	1.06	0.77	1.10
73	0.60	0.57	0.64	1.06	1.55	1.95	2.15	2.16	1.99	1.96	1.80	1.70	1.62
74	1.72	1.98	2.00	1.82	1.90	2.26	2.40	2.29	2.11	1.84	1.30	1.46	1.91
75	1.16	1.15	1.14	1.32	1.66	1.90	2.18	2.15	2.19	2.00	1.80	1.62	1.70
76	1.74	1.72	1.85	2.13	2.73	3.22	3.06	3.80	3.49	3.09	2.94	2.75	2.74
77	2.46	2.45	2.38	2.46	2.62	2.89	2.77	2.67	2.40	2.36	2.21	2.16	2.45
78	2.06	1.96	2.00	1.99	2.30	2.58	2.60	2.50	2.21	2.22	2.05	1.83	2.20
79	1.53	1.26	1.28	1.26	1.41	1.55	1.59	1.46	1.38	1.14	1.02	1.00	1.32
1880	1.05	0.99	0.96	0.99	1.39	1.88	2.19	2.08	1.97	1.61	1.49	1.39	1.49
81	1.16	1.55	1.56	1.55	1.90	2.07	2.22	2.05	1.89	2.14	2.27	2.10	1.87
82	1.93	1.72	1.88	2.08	2.25	2.48	2.62	2.66	2.56	2.23	2.08	1.93	2.21
83	1.73	1.66	1.72	1.73	2.30	2.72	2.53	2.40	2.08	2.75	2.80	2.75	2.40
84	2.56	2.41	2.45	2.76	2.96	3.04	3.12	3.00	2.85	2.81	2.46	2.30	2.70
85	2.47	2.38	2.28	2.49	2.89	3.19	3.26	3.39	3.39	3.06	2.87	2.67	2.86
86	2.67	2.74	2.95	3.22	3.55	3.64	3.46	3.53	3.15	3.02	2.75	2.43	3.08
87	2.26	2.45	2.66	2.57	2.77	2.80	2.97	2.76	2.41	2.19	1.74	1.45	2.43
88	1.36	1.25	1.42	1.56	2.00	2.30	2.33	2.27	2.08	1.78	1.60	1.98	1.78
89	1.23	1.17	1.15	1.06	1.32	1.58	1.81	1.75	1.58	1.31	0.97	0.71	1.30
1890	0.78	0.66	0.64	0.78	1.08	1.53	1.71	1.71	1.44	1.23	1.03	0.73	1.11
91	0.53	0.42	0.39	0.72	0.96	0.91	0.94	0.84	0.65	0.36	579.97	579.91	0.64
92	579.90	579.87	579.89	0.05	0.14	0.67	0.96	1.01	0.87	0.66	580.23	580.09	0.55
93	9.84	9.79	9.87	0.25	0.86	1.21	1.33	1.21	0.91	0.73	0.47	0.30	0.87
94	580.22	580.24	580.30	0.62	1.05	1.32	1.47	1.30	1.01	0.77	0.58	0.38	0.76
95	579.96	579.94	579.85	579.95	0.12	0.19	0.16	0.07	579.94	579.65	579.36	579.09	579.83
96	9.00	9.31	9.11	9.14	579.84	579.91	579.97	0.01	9.82	9.62	9.49	9.35	9.83
97	9.45	9.36	9.47	9.84	580.41	580.65	580.82	0.84	580.53	580.23	580.07	9.81	580.13
98	9.66	9.72	9.95	580.44	0.86	0.72	0.82	0.71	0.53	0.31	0.13	9.94	0.38
99	9.96	9.84	9.98	579.36	0.40	0.79	1.06	0.98	0.79	0.58	0.34	580.03	0.39
1900	9.83	9.83	9.96	9.98	0.13	0.20	0.85	0.64	0.72	0.46	0.26	0.04	0.30
01	580.22	580.06	580.07	a580.55	0.81 a	0.91 a	1.06 a	1.11 a	0.85 a	0.66 a	0.43 a	0.16	0.57
a 02	0.00	579.81	579.73	579.91	0.16	0.46	0.78	0.82	0.61	0.27	0.17	579.93	0.22
a 03	579.74	9.78	9.93	580.27	0.39	0.56	0.75	0.75	0.60	0.63	0.41	580.13	0.36
a 04	9.91	9.91	580.05	0.62	0.96	1.45	1.55	1.53	1.38	1.26	0.95	0.80	0.84
a 05	580.38	580.30	0.39	0.66	0.95	1.40	1.57	1.56	1.45	1.23	0.93	0.67	0.95
a 06	0.53	0.46	0.76	0.94	1.30	1.52	1.42	1.36	1.12	0.87	0.66	0.48	0.96
a 07	0.46	0.46	0.66	0.94	1.08	1.39	1.64	1.40	1.42	1.31	0.83	0.62	1.05
Mean.	581.02	580.99	581.06	581.26	581.57	581.83	581.97	581.92	581.75	581.53	581.31	581.09	581.44

Authority, U. S. Lake Survey (see page 4105, appendix EEE, Annual Report of the Chief of Engineers for 1904).

a—Self-registering gage.

Note.—Elevations depend on gage bolt "E" 583.21 ft., B. M. "Jenks" 610.56 ft., U. S. Lake Survey, 1900 Levels.

TABLE 6.

WATER LEVELS OF ST. CLAIR RIVER.

Monthly mean elevations of water surface of St. Clair River, at Grand Trunk Railway (G. T. R.), in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mea
a1860	583.06	582.92	582.14	581.82	581.86	582.09	582.16	582.06	581.92	581.58	581.47	581.20	581.87
a 61	1.31	1.35	1.47	1.36	1.91	2.21	2.32	2.41	2.34	2.15	1.87	1.76	1.97
a 62	1.71	1.70	1.62	1.52	1.84	1.95	2.00	1.98	1.79	2.03	1.75	1.49	1.79
a 63	1.04	1.51	..66	1.23	1.52	1.63	1.55	1.56	1.44	1.20	1.17	0.98	1.41
a 64	1.14	1.10	1.10	0.98	1.36	1.37	1.32	1.32	0.95	0.48	0.32	0.31	0.96
a 65	0.18	0.20	0.42	0.56	0.70	0.73	1.13	1.13	1.09	0.81	0.32	0.04	0.61
a 66	0 10	579.89	579.93	0 03	0.20	0.46	0.69	0.74	0.61	0.51	0.43	0.32	0.53
a 67	0.48	580.52	580.68	0.64	0.84	1.12	1.25	1.19	0.95	0.65	0.24	579.93	0.71
a 68	0.08	0.08	0.56	0.27	0.52	0.71	0.73	0.43	0.22	0.01	579.94	9.70	0.37
a 69	579.91	579.97	579.74	579.77	0.07	0.54	0.88	1.11	1.01	0.99	580.58	580.33	0.98
a1870	580.68	580.78	581.03	581.11	1.41	1.53	1.63	1.55	1.08	1.32	0.96	0.80	1.19
a 71	1.06	1.01	1.84	1.43	1.74	1.77	1.80	1.52	1.24	0.80	0.61	0.26	1.34
a 72	0.42	0.25	579.80	579.88	0.24	0.56	0.66	0.65	0.56	0.46	0.19	579.95	0.39
a 73	0.08	0.05	580.11	580.18	0.63	0.95	1.16	1.17	1.02	0.99	0.90	580.76	0.67
a 74	1.07	1.20	1.25	0.89	0.94	1.34	1.38	1.25	1.12	0.88	0.40	0.34	1.02
a 75	0.57	0.52	0.56	0.43	0.74	1.05	1.19	1.16	1.20	1.05	0.65	0.62	0.84
a 76	1.09	1.07	1.10	1.14	1.66	2.11	2.50	2.48	2.25	2.09	1.66	1.69	1.79
a 77	1.73	1.72	1.66	1.44	1.59	1.85	1.71	1.62	1.38	1.26	1.21	1.17	1.59
a 78	1.38	1.32	1.38	1.02	1.37	1.52	1.56	1.47	1.21	1.22	1.05	0.88	1.27
a 79	0.90	0.89	0.66	0.38	0.80	0.63	0.66	0.55	0.49	0.28	0.16	0.14	0.59
a1880	0.48	0.42	0.42	0.13	0.46	0.92	1.20	1.10	1.00	0.66	0.57	0.40	0.65
a 81	0.58	0.92	0.93	0.65	0.94	1.06	1.22	1.07	0.93	1.15	1.27	1.12	0.99
a 82	1.26	1.07	1.20	1.10	1.25	1.43	1.55	1.63	1.52	1.23	1.10	0.92	1.29
a 83	1.06	1.04	1.07	0.79	1.20	1.67	2.09	2.27	1.99	1.69	1.79	1.69	1.61
a 84	1.82	1.88	1.72	1.70	1.90	1.95	2.02	1.92	1.60	1.75	1.44	1.26	1.78
a 85	1.74	1.86	1.66	1.46	1.85	2.08	2.13	2.26	2.17	1.97	1.80	1.63	1.88
a 86	1.92	1.98	2.18	2.11	2.41	2.49	2.34	2.24	2.08	1.93	1.80	1.41	2.08
a 87	1.55	1.72	1.91	1.53	1.71	1.82	1.99	1.70	1.39	1.20	0.80	0.54	1.48
a 88	0.76	0.96	0.81	0.64	1.05	1.29	1.32	1.36	1.09	0.83	0.67	0.48	0.91
a 89	0.66	0.88	0.57	0.21	0.33	0.63	0.88	0.80	0.55	0.33	0.02	579.88	0.45
a1890	0.24	0.13	0.11	579.94	0.22	0.60	0.77	0.77	0.53	0.34	0.16	9.90	0.21
a 91	0.01	579.93	579.89	9.89	0.10	0.06	0.06	0.00	579.83	579.80	579.53	9.17	579.91
a 92	579.48	9.42	9.46	9.36	579.37	579.84	0.10	0.17	580.09	9.84	9.84	9.39	9.68
a 93	9.40	9.36	9.42	9.47	580.03	580.70	0.48	0.33	0.07	0.88	9.68	9.80	9.88
a 94	9.78	9.76	9.86	9.80	0.16	0.42	0.58	0.33	0.15	9.93	9.76	9.87	580.00
a 95	9.87	9.48	9.47	9.37	579.46	579.48	579.45	579.37	579.26	9.00	8.65	8.44	579.38
a 96	8.80	8.90	8.81	8.58	8.90	9.22	9.26	9.22	9.16	8.98	8.86	8.78	8.96
a 97	9.12	9.04	9.16	9.17	9.66	9.90	580.05	580.06	9.82	9.42	9.41	9.14	9.51
a 98	9.30	9.36	9.56	9.70	9.81	9.95	0.04	579.94	9.77	9.50	9.42	9.26	9.68
Yea	9.32a	9.20b	9.33b	9.21b	9.58	580.02b	0.20	580.24	580.05b	9.90b	9.47b	9.28	9.62
b1900	9.39	9.47	9.47	9.22	9.42	579.56	579.80	579.87	579.85	9.77	9.73	9.82	9.69
b 01	9.87	9.76	9.88	580.05	9.99	9.96	580.17	580.26	580.02	9.79	9.88	9.82	9.94
b 02	9.83	9.84	9.95	579.11	9.22	9.63	579.95	0.01	579.73	9.55	9.35	9.16	9.47
b 03	9.37	9.44	9.26	9.52	9.86	9.77	9.90	579.93	9.96	9.94	9.84	9.41	9.64
b 04	9.46	9.56	9.34	9.09	580.12	580.33	580.56	580.55	580.46	580.32	580.07	9.77	580.06
b 05	580.16	580.07	9.79	9.52	9.07	9.56	9.76	9.70	9.57	9.31	9.04	580.78	9.80
b 06	579.75	9.30	580.23	580.11	9.39	9.38	9.57	9.49	9.27	9.04	579.86	9.07	9.39
b 07	580.13	9.89	9.12	9.06	9.22	9.49	9.66	9.63	9.53	9.33	9.90	579.74	9.77
Mean	580.46	580.42	580.46	580.38	580.66	580.86	581.00	580.97	580.81	580.61	580.41	580.26	580.61

Authority, U. S. Lake Survey, except for supplied values.

a.—Supplied from Harbor Beach readings for the summer months, April to December, inclusive, by formula (G. T. R.—578)—0.880 (Harbor Beach—578)—0.530; and for winter months January to March, inclusive, by formula (G. T. R.—578)—0.880 (Harbor Beach—578)—0.235.

b.—Self-registering gage.

Note.—Elevations depend on B. M. Fort Gratiot Light-house (1877) as 860.343 ft., U. S. Lake Survey, 1903 Levels.

TABLE 7.

WATER LEVELS OF LAKE ST. CLAIR.

Monthly mean elevations of water surface of Lake St. Clair, at the St. Clair Flats Canal, in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
a1860	576.31	574.86	575.94	576.80	576.98	577.03	576.40	576.30	575.90	576.20	575.66	576.20	576.22
b 61	6.37	4.92	6.02	6.77	6.82	7.03	7.00	7.17	6.98	6.78	6.64	6.64	6.90
b 62	6.29	5.14	6.07	7.24	7.24	7.26	7.27	7.15	6.94	6.74	6.43	6.30	6.87
b 63	6.45	6.41	6.16	6.83	6.90	6.77	6.83	6.79	6.61	6.11	5.94	5.90	6.46
b 64	6.14	5.80	5.61	6.30	6.70	6.90	6.87	6.47	6.29	5.80	5.72	5.83	6.16
65b	4.53b	3.78b	4.48b	5.04b	6.17b	6.31b	6.40c	6.38c	6.32c	6.11c	5.66c	5.62	5.80
66b	5.43c	4.91c	4.96c	5.72c	5.84c	6.12c	6.20c	6.24c	6.18c	6.16c	6.03c	6.30	5.85
c 67	5.30	5.26	5.52	6.06	6.46	6.84	6.70	6.61	6.25	5.90	5.42	5.30	5.91
68d	5.37d	4.15d	5.43c	5.64c	6.10c	6.41c	6.34c	6.00c	5.78c	5.40c	5.15c	5.12	5.57
69d	4.81d	4.20d	4.88c	5.35c	5.66c	6.00c	6.48c	6.49c	6.26c	5.87c	5.60d	5.93	5.60
1870d	6.70d	5.52d	5.52c	6.26c	6.74c	6.86c	7.04c	6.96c	6.74c	6.34c	6.11c	6.10	6.42
71d	5.71d	4.71c	5.40c	5.45c	6.72c	6.76c	6.82c	6.62c	6.36c	5.76c	5.60d	5.83	6.15
72d	5.00d	4.86d	4.70c	5.12c	5.32c	5.74	5.47	5.61	5.47	5.48	4.96	4.92	5.24
73	4.42	4.62	4.99	5.57	5.99	6.16	6.20	6.26	6.06	5.61	5.52	5.83	5.66
74	5.05	4.41	5.84	6.07	6.02	6.26	6.43	6.31	6.10	5.86	5.57	5.26	5.76
75	5.11	5.04	5.20	5.71	5.78	5.94	6.12	6.11	5.96	5.79	5.61	5.51	5.82
76	5.66	5.11	6.00	6.05	6.03	7.13	7.08	7.51	7.04	6.71	6.80	7.45	6.69
77	6.98	5.52	6.24	6.30	6.43	6.26	6.53	6.44	6.19c	6.13	6.24	6.08	6.24
78	5.96	5.00	5.16b	5.47b	6.03	6.06	6.03	6.71	6.37	6.18	5.85	5.61	6.12
79	5.30	4.51	5.20	5.75	5.93b	5.94b	6.01b	5.80b	5.61b	5.33b	5.03b	5.25	5.43
b1880	5.52	5.07	5.00	5.66	5.84	6.03	6.19	6.27	6.03	5.68	5.51	6.18	5.81
81b	4.60b	5.05b	5.05b	5.67b	6.01b	6.31b	6.23b	6.20	6.07	5.87c	6.00c	6.13	5.77
82c	6.40c	6.05c	6.53c	6.87	6.96c	6.81	7.41	7.40c	6.78c	6.48	6.17c	6.67	6.66
83c	6.26c	6.00c	5.96c	6.05	6.34	7.07	7.74	7.66	7.20	6.82	6.39	6.34	6.60
84	4.93	5.35	6.75	6.96	7.18	7.23	7.36	7.09	6.73	6.31	6.14	6.23	6.56
85	6.52	6.02	6.86	6.86	6.73	7.10	7.01	7.12	6.97	6.65	6.61	6.59	6.75
86	6.75	6.46	6.64	6.80	6.99	7.04	7.05	6.98	6.78	6.62	6.28	6.55	6.80
87	6.34	6.35	6.33	6.55	6.77	6.86	6.66	6.68	6.40	6.07	5.65	5.61	6.37
88	5.67	5.45	5.16	5.81	5.83	6.04	6.33	6.23	5.99	5.71	5.58	5.47	5.77
89	5.71	4.77	4.63	4.96	5.38	5.91	6.03	5.90	5.70	5.31	5.03	4.96	5.36
1890	5.44	5.36	5.38	5.68	5.91	6.34	6.27	6.03	5.79	5.57	5.34	5.30	5.71
91	4.97	5.07	4.68	5.23	5.12	5.39	5.36	5.23	5.12	4.80	4.56	4.64	5.03
92	4.58	3.81	3.70	4.53	5.07	5.60	5.68	5.71	5.60	5.15	4.76	4.54	4.87
93	3.70	3.90	4.04	5.07	5.45	5.82	5.86	5.66	5.42	5.16	4.88	4.96	5.04
94	4.99	4.49	4.86	5.01	5.44	5.69	5.72	5.23	5.35	5.12	4.86	4.82	5.16
95	5.23	5.20	4.96	4.19	4.46	4.52	4.66	4.66	4.53	4.12	3.84	4.12	4.54
96	4.17	3.23	3.57	4.00	4.34	4.70	4.87	5.03	4.71	4.61	4.15	4.13	4.31
97	4.43	4.77	4.72	4.77	5.18	5.26	5.43	5.40	5.14	4.78	4.61	4.64	4.93
98	4.38	4.10	4.72	5.17	5.26	5.49	5.54	5.40	5.13	4.87	4.82	4.90	5.00
99	4.90	4.87	4.53	4.68	5.07	5.34	5.51	5.45	5.14	4.84	4.71	4.65	4.94
1900	4.18	4.29	4.77	4.87	4.96	5.16	5.23	5.28	5.16	5.01	4.88	4.74	4.88
01	4.80	3.62	3.96	3.17	4.27	4.05	3.36	3.24	3.22	4.90	4.51	4.64	4.55
02f	5.70f	5.30f	4.26	4.46	4.70	5.07	5.70	5.80	5.28	5.18	4.89	4.99	4.76
03	5.19f	4.72f	5.06f	5.57	5.34	5.46	5.65	5.54	5.53	5.29	4.89	5.30	5.30
04	4.13	4.44	3.68	5.03	5.03	5.12	5.16	5.09	5.02	5.05	5.28	5.29	5.04
05	4.44	4.14	4.78	5.06	5.38	5.52	6.01	5.95	5.78	5.54	5.26	5.11	5.27
06f	5.25f	4.32f	4.20f	5.26f	5.40f	5.61f	5.81f	5.76f	5.55f	5.37	5.44	5.33	5.27
07	5.40	4.96	5.02	5.64	5.78	6.11	6.27f	5.96f	5.76f	5.66f	5.35f	5.32	5.62
Mean	576.30	574.85	575.20	575.64	576.00	576.17	576.28	576.19	575.96	575.72	575.46	575.89	755.66

Authority, U. S. Lake Survey, except for supplied values.

a.—Deduced by subtracting 0.67 foot from St. Clair Flats values (U. S. L. S. Report, 1904), to obtain original values at Old Detroit Water Works, then supplying by formula (Fall St. Clair Flats to Amherstburg) — 0.9878 (Fall Old Detroit Waterworks to Amherstburg) + 0.883.

b.—Supplied by formula (Fall St. Clair Flats to Amherstburg) — 1.0357 (Fall Light-house Depot to Amherstburg) + 0.377.

c.—Supplied by using mean of two values derived from equations (Fall St. Clair Flats to Amherstburg) — 0.9878 (Fall Old Detroit Waterworks to Amherstburg) + 0.883; and (Fall St. Clair Flats to Amherstburg) — 1.0357 (Fall Light-house Depot to Amherstburg) + 0.377.

d.—Supplied by formula (Fall St. Clair Flats to Amherstburg) — 0.9878 (Fall Old Detroit Waterworks to Amherstburg) + 0.883.

e.—Derived by first subtracting 0.477 foot from New Detroit Waterworks' readings and then applying the mean monthly fall from St. Clair Flats to New Detroit Waterworks, as deduced from observations taken at those points from January, 1899, to June, 1901, inclusive.

f.—Derived from observations taken at Windmill Point by applying the mean monthly fall from St. Clair Flats Canal to Windmill Point as determined from simultaneous observations taken at those points from January, 1897, to July, 1907, inclusive.

Note.—Elevations depend on zero of gage 573.36 ft., and P. B. M., "Upper Light," 581.76 ft., U. S. Lake Survey, 1903 Levels.

TABLE 8.

WATER LEVELS OF LAKE ST. CLAIR.

Monthly mean elevations of water surface of Lake St. Clair, at Windmill Point, near the outlet of Lake St. Clair, in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
a1860	574.92	574.51	575.04	576.24	576.69	576.64	576.17	576.06	575.66	576.30	575.98	575.93	575.96
a 61	5.96	4.60	5.72	6.51	6.63	6.84	6.77	6.95	6.72	6.49	6.34	6.26	6.72
a 62	5.90	4.81	5.77	6.98	7.04	7.09	7.04	6.93	6.69	6.45	6.13	5.94	6.49
a 63	6.09	6.08	5.84	6.27	6.70	6.82	6.90	6.67	6.38	5.62	5.64	5.54	6.13
a 64	5.73	5.17	5.51	6.04	6.50	6.71	6.44	6.25	6.04	5.51	5.49	5.47	5.93
a 65	4.14	3.48	4.12	5.32	5.97	6.02	6.17	6.16	6.07	5.52	5.36	5.16	5.33
a 66	5.03	4.58	4.86	5.43	5.64	5.94	6.16	6.02	5.93	5.60	5.73	5.54	5.57
a 67	4.91	4.96	4.83	5.89	6.28	6.63	6.47	6.39	6.00	5.61	5.13	4.94	5.84
a 68	4.88	3.83	5.14	5.38	5.89	6.23	6.11	5.78	5.53	5.11	4.83	4.78	5.39
a 69	4.42	4.06	4.26	5.09	5.25	5.81	6.26	6.26	6.08	5.58	5.30	5.30	5.53
a1870	6.60	5.19	5.72	6.13	6.54	6.61	6.81	6.76	6.49	6.05	5.81	5.74	6.14
a 71	5.52	4.28	5.10	6.32	6.53	6.89	6.89	6.41	6.11	5.49	5.30	5.47	5.96
a 72	4.70	4.65	4.69	4.94	5.13	5.85	6.34	6.39	5.22	5.16	4.96	4.80	5.29
a 73	4.98	4.23	4.99	5.61	5.99	6.37	6.07	6.07	5.81	5.32	5.32	5.47	5.59
a 74	4.66	4.66	5.24	5.80	5.82	6.04	6.17	6.09	5.86	5.37	5.27	4.90	5.56
a 75	4.72	4.71	4.90	5.66	5.88	5.78	5.95	5.89	5.71	5.50	5.31	5.15	5.51
a 76	5.27	5.78	6.89	6.60	6.43	7.23	7.48	7.20	6.79	6.42	6.30	7.09	6.61
a 77	6.88	6.19	5.94	4.94	5.26	6.09	6.30	6.22	5.94	5.83	5.84	5.67	5.96
a 78	5.82	4.67	4.62	5.21	5.43	6.49	6.57	6.49	6.12	5.89	5.56	5.26	5.66
a 79	4.81	4.18	4.90	5.49	5.43	5.71	5.78	5.58	5.36	5.03	4.72	4.89	5.16
a1880	5.13	4.74	5.20	5.60	5.94	6.04	5.96	6.05	5.77	5.39	5.21	5.83	5.58
a 81	4.21	4.72	4.76	5.41	5.81	6.13	6.09	5.96	5.83	5.52	5.70	5.77	5.50
a 82	6.01	5.60	6.22	6.31	6.79	6.62	7.18	7.18	6.81	6.16	5.87	6.31	6.40
a 83	5.89	5.67	5.69	5.89	6.14	6.82	7.81	7.44	6.95	6.54	6.09	6.00	6.33
a 84	4.54	5.06	5.43	6.72	6.96	7.14	7.15	6.87	6.48	6.22	5.84	5.64	6.28
a 85	6.42	5.89	5.86	6.02	6.23	6.91	6.73	6.90	6.72	6.30	6.31	6.25	6.50
a 86	5.36	4.25	5.34	6.04	6.79	6.85	6.82	6.71	6.53	6.23	5.96	6.19	6.13
a 87	5.85	6.03	6.05	6.39	6.57	6.67	6.62	6.46	6.15	5.78	5.35	5.28	6.09
a 88	5.28	5.13	4.86	5.16	5.69	5.85	6.10	6.01	5.74	5.43	5.26	5.11	5.49
a 89	5.33	4.84	4.86	4.72	5.16	5.72	5.82	5.66	5.45	5.02	4.73	4.60	5.09
a1890	5.05	4.96	4.96	5.39	5.71	6.13	6.04	5.81	5.54	5.28	5.24	5.05	5.42
a 91	4.88	4.74	4.46	4.97	4.98	5.10	5.12	5.08	4.87	4.61	4.28	4.28	4.75
a 92	3.87	3.18	3.40	4.27	4.87	5.20	5.09	5.49	5.35	4.86	4.48	4.18	4.49
a 93	3.31	3.47	4.34	4.81	5.26	5.48	5.48	5.46	5.17	4.87	4.68	4.63	4.76
a 94	4.69	4.16	4.56	4.73	5.26	5.50	5.50	5.31	5.13	4.82	4.56	4.44	4.89
a 95	4.69	4.96	4.39	3.98	4.39	4.44	4.46	4.43	4.26	3.94	3.84	3.78	4.27
a 96	3.78	3.60	3.27	3.53	4.14	4.51	4.64	4.51	4.46	4.23	3.92	3.77	4.03
97	4.38	4.64	4.57	4.75	5.30	5.11	5.22	5.15	4.93	4.68	4.47	4.39	4.77
98	4.30	a 3.77	4.75	5.01	5.11	5.26	5.30	5.10	4.90	4.64	4.53	4.68	4.78
99	4.46	4.57	3.99	4.32	4.86	5.15	5.30	5.22	4.93	4.65	4.49	4.10	4.69
1900	4.02	4.24	4.07	4.44	4.79	4.99	5.01	5.06	4.89	4.74	4.53	4.41	4.67
01	4.01	3.98	3.93	3.99	3.94	4.61	5.06	5.07	4.89	4.86	4.90	4.67	4.48
02	3.31	2.84	3.96	4.22	a 4.80	a 4.86	5.50	5.41	5.08	4.92	4.62	4.64	4.48
03	4.09	4.40	4.75	5.31	5.27	5.38	5.44	5.36	5.29	5.04	4.84	4.94	5.05
04	3.76	3.23	4.02	5.04	5.01	5.02	5.07	5.02	5.00	5.01	4.94	4.90	4.79
05	3.78	3.80	3.97	4.73	5.11	5.09	5.00	5.74	5.52	5.18	4.84	4.73	4.87
06	4.86	3.99	4.00	4.88	5.30	5.43	5.38	5.54	5.30	5.09	4.90	4.80	4.99
07	4.94	4.46	4.90	5.24	5.44	5.75	5.90	5.76	5.51	5.40	5.06	4.96	5.27
Mean	574.91	574.53	574.97	575.38	575.69	575.98	576.05	575.97	575.71	575.43	575.10	575.17	575.46

Authority, U. S Lake Survey, except for supplied values.

a.—Supplied by applying to the St. Clair Flats readings, the mean monthly fall from St. Clair Flats to Windmill Point, as deduced from observations taken between the years 1897 and 1907, inclusive.

Note.—Elevations depend on P. B. M., 12, 584.22 ft., U. S. Lake Survey, 1903 Levels.

TABLE 9.

WATER LEVELS OF DETROIT RIVER.

Monthly mean elevations of water surface of Detroit River, at Amherstburg, Ont., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
a1860	573.48	573.12	573.84	574.19	574.40	574.48	574.20	574.06	573.66	573.37	573.15	573.11	573.74
a 61	2.83	2.55	3.01	4.00	4.52	4.56	4.34	4.42	4.18	3.94	3.70	3.68	3.82
a 62	3.65	3.36	3.62	4.37	4.70	4.66	4.67	4.33	3.96	3.57	3.10	3.28	3.93
a 63	3.68	3.97	3.93	4.00	4.27	4.12	4.01	3.97	3.82	3.97	3.83	3.62	3.84
a 64	3.31	2.46	2.98	3.14	3.93	3.87	3.62	3.39	3.11	2.70	2.40	2.68	3.04
a 65	2.23	1.65	1.99	2.66	3.33	3.30	3.27	3.23	3.13	2.82	2.31	2.29	2.68
a 66	2.00	1.84	2.25	2.78	3.09	3.34	3.46	3.35	3.13	2.11	2.74	2.87	2.82
a 67	2.56	2.34	2.66	2.93	3.54	3.84	3.66	3.39	2.94	2.80	1.96	1.86	2.85
a 68	1.64	1.26	1.57	2.65	3.19	3.57	3.55	3.07	2.74	2.28	1.90	1.90	2.48
a 69	1.87	1.80	2.30	2.85	3.19	3.67	3.66	3.80	3.47	2.91	2.42	2.89	2.89
a1870	2.11	2.34	2.13	2.73	4.03	3.90	4.05	4.03	3.72	3.33	2.90	2.90	3.32
a 71	2.67	2.34	2.81	3.24	3.80	3.62	3.61	3.44	3.31	2.53	2.22	1.90	2.93
a 72	1.80	1.56	1.49	1.64	2.17	2.53	2.53	2.54	2.35	2.07	1.61	1.50	1.97
a 73	1.38	1.39	1.48	2.71	3.47	3.54	3.53	3.51	3.05	2.74	2.41	2.90	2.66
a 74	3.27	3.32	3.37	3.49	3.67	3.73	3.77	3.65	3.13	2.68	2.13	2.04	3.19
a 75	1.79	1.63	1.78	2.13	2.69	3.11	3.26	3.26	3.05	2.58	2.20	2.64	2.53
a 76	2.58	3.14	3.31	4.26	4.69	4.79	4.69	4.42	4.20	3.96	3.61	3.39	3.94
a 77	2.97	2.61	2.60	2.96	3.33	3.39	3.64	3.54	3.40	2.96	2.78	2.68	3.12
a 78	3.04	3.18	3.33	3.70	4.03	4.03	4.03	3.85	3.66	3.30	2.97	3.17	3.52
a 79	2.73	2.39	2.64	2.95	3.19	3.27	3.31	3.13	2.74	2.50	1.90	2.38	2.77
a1880	2.76	2.80	2.96	3.07	3.43	3.53	3.65	3.43	3.14	2.90	2.48	2.26	3.02
a 81	1.83	1.94	2.28	2.93	3.42	3.65	3.61	3.33	2.92	2.86	2.55	2.68	2.83
a 82	3.33	3.33	3.50	3.97	4.36	4.40	4.34	4.24	3.91	3.45	3.00	2.61	3.73
a 83	2.50	2.71	2.92	3.99	3.54	4.28	4.44	4.42	4.05	3.72	3.21	3.38	3.51
a 84	3.01	3.27	3.48	3.96	4.34	4.41	4.30	4.08	3.89	3.33	2.94	2.89	3.58
a 85	2.49	2.28	2.16	2.98	3.75	4.26	4.22	4.27	4.06	3.68	3.70	3.77	3.49
a 86	3.77	3.04	2.87	3.70	4.09	4.18	4.17	4.01	3.70	3.46	3.04	3.07	3.59
a 87	2.83	3.26	4.06	4.06	4.33	4.34	4.13	3.84	3.53	2.95	2.55	2.68	3.55
a 88	2.49	2.22	2.34	2.92	3.36	3.38	3.54	3.48	3.06	2.60	2.53	2.51	2.94
a 89	2.53	2.37	2.39	2.53	2.80	3.23	3.43	3.16	2.71	2.28	1.86	2.26	2.62
a1890	2.60	2.80	3.05	3.47	3.90	4.26	3.89	3.47	3.24	3.04	2.80	2.77	3.29
a 91	2.53	2.51	2.99	2.81	2.72	2.68	2.76	2.62	2.39	1.90	1.39	1.52	2.40
a 92	1.53	1.32	1.36	1.96	2.76	3.51	3.66	3.35	2.97	2.40	1.94	1.75	2.38
a 93	1.39	1.47	1.71	2.39	2.53	2.80	3.28	2.98	2.49	2.13	1.90	1.90	2.22
a 94	2.06	1.94	1.99	2.34	2.82	3.03	3.01	2.66	2.45	2.13	1.78	1.80	2.33
a 95	1.45	1.23	1.25	1.45	1.76	1.84	1.74	1.70	1.54	1.05	0.82	1.10	1.41
a 96	1.16	1.10	1.07	1.47	1.94	2.20	2.09	2.24	1.93	1.71	1.21	1.38	1.64
a 97	1.31	1.51	1.90	2.40	2.83	2.91	2.91	2.79	2.45	1.98	1.69	1.78	2.20
a 98	1.81	2.01	2.29	2.82	3.06	3.08	2.87	2.71	2.27	2.06	1.81	1.78	2.38
99	a 1.88	a 1.86	a 2.07	a 2.23	a 2.72	a 2.82	b 2.76	b 2.80	b 2.14	b 1.96	b 1.85	b 1.40	2.19
1900	1.60	1.80	2.19	2.44	2.85	2.75	2.85	2.86	2.30	2.03	1.55	1.80	2.10
01	1.62	1.19	1.12	1.39	1.56	2.05	2.20	2.14	2.08	1.89	1.19	1.83	1.64
02	1.90	0.88	1.13	1.62	2.09	2.32	2.99	3.00	2.84	2.50	2.20	1.98	2.05
03	1.81	1.81	2.44	2.30	2.84	3.23	3.15	2.99	2.52	2.22	1.84	1.67	2.50
04	1.66	1.61	2.20	2.38	2.80	2.78	2.96	2.98	3.06	2.75	2.24	2.05	2.70
05	1.73	1.45	1.85	2.08	2.75	2.82	2.80	3.18	2.90	2.48	2.09	2.08	2.39
06	2.10	2.14	2.00	2.43	2.96	2.98	3.02	2.97	2.70	2.53	2.13	2.48	2.51
07	b 2.91	b 2.66	b 2.47	b 2.94	b 3.17	b 3.63	c 3.89	c 3.35	c 3.01	c 2.94	c 2.53	c 2.41	2.97
Mean	573.33	573.25	573.46	573.91	573.33	573.53	573.50	573.36	573.06	572.70	573.33	573.37	573.34

Authority, U. S. Lake Survey, except for supplied values.

c.—Supplied by applying to the Cleveland, O., readings, the mean monthly fall between Cleveland and Amherstburg, as deduced from observations taken during the period from July, 1900, to December, 1904, inclusive.

b.—Self-registering gage.

Note.—Elevations depend on Gage B. M., 579.327 ft., U. S. Lake Survey, 1903 Levels.

TABLE 10.

WATER LEVELS OF LAKE ERIE.

Monthly mean elevations of water surface of Lake Erie, at Cleveland, O., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	573.26	572.90	573.30	574.00	574.21	574.18	573.92	573.76	573.42	573.12	573.03	572.87	573.30
61	2.61	2.33	2.77	3.81	4.34	4.31	4.06	4.10	3.92	3.69	3.67	3.44	3.86
62	3.43	3.14	3.38	4.18	4.42	4.42	4.39	4.01	3.70	3.33	2.98	3.01	3.69
63	3.46	3.75	3.89	3.81	3.99	3.85	3.73	3.65	3.26	2.83	2.41	2.38	3.40
64	2.09	2.24	2.45	2.95	3.05	3.00	3.34	3.07	2.85	2.84	2.37	2.44	2.80
65	2.01	1.43	1.75	2.47	2.05	2.03	2.99	2.91	2.87	2.57	2.19	2.05	2.41
66	1.78	1.42	2.01	2.89	2.81	2.07	3.16	2.93	2.87	2.86	2.83	2.62	2.53
67	2.34	2.02	2.42	2.74	3.36	3.57	3.38	3.07	3.05	3.34	1.84	1.63	2.81
68	1.42	1.04	1.95	2.46	2.91	3.30	3.27	2.75	2.48	2.03	1.57	1.66	2.78
69	1.65	1.58	2.06	2.86	2.91	3.30	3.58	3.43	3.21	2.78	2.30	2.65	2.62
1870	2.80	3.12	2.89	3.54	3.75	3.72	3.76	3.71	3.46	3.06	2.73	2.66	3.29
71	2.45	2.12	2.57	3.05	3.32	3.35	3.33	3.13	2.95	2.33	2.10	1.66	2.69
72	1.58	1.34	1.25	1.45	1.89	2.26	2.25	2.22	1.99	1.83	1.49	1.26	1.73
73	1.16	1.17	1.34	2.52	3.10	3.27	3.25	3.19	2.79	2.49	2.29	2.66	2.44
74	3.05	3.10	3.13	3.30	3.39	3.46	3.49	3.33	2.87	2.43	2.01	1.80	2.96
75	1.57	1.40	1.34	1.94	2.41	2.84	2.97	2.96	2.83	2.33	2.19	2.40	2.26
76	2.34	2.92	3.57	4.09	4.41	4.53	4.41	4.11	3.94	3.41	3.49	3.15	3.79
77	2.75	2.89	2.96	2.79	3.04	3.12	3.26	3.32	3.14	2.74	2.93	2.74	2.98
78	2.83	2.96	3.09	3.61	3.75	3.75	3.75	3.53	3.40	3.05	2.85	2.95	3.23
79	2.51	2.37	2.40	2.75	2.91	3.00	3.03	2.81	2.48	2.22	1.78	2.04	2.52
1880	2.84	2.88	2.72	2.88	3.18	3.26	3.33	3.11	2.86	2.44	2.20	2.02	2.77
81	1.61	1.72	2.04	2.74	3.14	3.38	3.32	3.01	2.66	2.61	2.43	2.64	2.63
82	3.11	3.11	3.86	3.78	3.98	4.13	4.00	3.92	3.65	3.20	3.85	2.37	3.69
83	2.26	2.49	2.95	2.80	3.26	3.96	4.16	4.10	3.79	3.47	3.09	3.13	3.37
84	2.79	3.05	3.34	3.79	4.06	4.14	3.92	3.76	3.33	3.00	2.62	2.45	3.34
85	2.27	2.06	1.92	2.74	3.47	3.98	3.94	3.95	3.80	3.70	3.58	3.58	3.24
86	3.85	3.82	3.93	3.81	3.81	3.91	3.89	3.99	3.44	3.21	2.92	2.83	3.53
87	2.61	3.04	3.83	3.87	4.06	4.07	3.84	3.83	3.29	2.76	2.43	2.45	3.31
88	2.27	2.00	2.10	2.73	2.98	3.11	3.26	3.16	2.73	2.35	2.41	2.39	2.69
89	3.31	3.15	1.96	2.34	2.83	3.00	3.15	2.84	2.45	2.03	1.76	2.02	2.58
1890	2.26	2.47	2.79	3.28	3.62	3.89	3.61	3.15	2.96	2.70	2.76	2.33	3.00
91	3.21	3.29	2.75	2.62	2.44	2.53	2.43	2.21	2.03	1.65	1.21	1.26	2.15
92	1.31	1.10	1.14	1.70	2.50	3.26	3.36	3.08	2.71	2.15	1.82	1.55	2.14
93	1.17	1.25	1.47	2.30	3.04	3.23	3.26	3.01	2.23	1.82	1.48	1.56	2.09
94	1.84	1.72	1.73	2.15	2.84	2.75	2.72	2.36	2.19	1.87	1.63	1.66	2.09
95	1.23	1.00	1.01	1.30	1.48	1.67	1.46	1.36	1.26	0.80	0.70	0.86	1.17
96	0.69	0.95	0.83	1.23	1.66	1.93	1.81	2.02	1.70	1.46	1.09	1.12	1.40
97	1.09	1.29	1.66	2.21	2.84	2.64	2.63	2.47	2.19	1.70	1.57	1.54	1.96
98	1.89	1.79	2.03	2.63	2.75	2.61	2.59	2.39	2.01	1.81	1.69	1.59	2.14
99	1.67	1.46	1.83	2.13	2.44	2.84	2.36	2.06	1.85	1.61	1.62	1.34	1.91
1900	1.38	1.87	1.92	2.22	2.39	2.47	2.34	2.31	1.99	1.75	1.49	1.45	1.96
01	1.36	1.00	0.88	1.39	1.31	1.73	1.91	1.78	1.71	1.33	1.16	1.19	1.39
02	1.03	0.62	0.94	1.49	1.86	2.12	2.74	2.73	2.38	2.29	2.02	1.83	1.86
03	1.72	1.70	2.38	3.05	3.09	3.05	2.98	2.76	2.50	2.25	1.77	1.91	2.39
04	1.19	1.28	1.86	2.91	3.17	3.32	3.41	3.10	2.84	2.49	2.12	1.77	2.44
05	1.52	1.31	1.18	1.82	2.46	2.98	3.05	2.87	2.63	2.31	1.93	1.92	2.17
06	1.94	1.98	1.71	2.13	2.40	2.90	2.64	2.63	2.35	2.21	2.18	2.43	2.25
07	2.76	2.48	2.34	2.71	2.95	3.27	3.31	3.06	2.77	2.89	2.41	2.26	2.75
Mean	573.10	572.93	572.22	572.70	573.05	573.34	573.22	573.04	573.78	572.45	572.21	572.14	572.80

Authority, U. S. Lake Survey.

From January, 1860, to December, 1903, inclusive, data from U. S. Lake Survey Report for 1901, page 4097.

Readings from 1904 to 1907, inclusive, from U. S. Lake Survey Annual Reports.

Note.—Elevations depend on B. M. "I" 581.41 ft., U. S. Lake Survey, 1903 Levels.

TABLE 11.

WATER LEVELS OF LAKE ERIE.

Monthly mean elevations of water surface of Lake Erie, at Buffalo Breakwater Light-house, in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
a1860	573.51	573.03	573.28	573.91	574.11	574.15	573.96	573.72	573.44	573.20	573.22	573.35	573.56
a 61	2.86	2.36	2.75	3.73	4.14	4.26	4.10	4.06	3.94	3.77	3.86	3.62	3.64
a 62	3.66	3.17	3.20	4.00	4.23	4.39	4.43	3.97	3.73	3.40	3.17	3.39	3.75
a 63	3.71	3.78	3.67	3.73	3.89	3.82	3.77	3.61	3.26	2.90	2.90	2.76	3.46
a 64	2.34	2.27	2.43	2.84	3.55	3.57	3.38	3.06	2.87	2.63	2.56	2.53	2.86
a 65	2.26	1.46	1.73	2.38	2.95	3.00	3.00	2.67	2.89	2.65	2.38	2.48	2.50
a 66	2.03	1.65	1.99	2.50	2.71	3.04	3.22	2.89	2.89	2.94	2.81	3.01	2.64
a 67	2.59	2.05	2.40	2.65	3.16	3.54	3.43	3.03	2.70	2.42	2.03	2.00	2.67
a 68	1.67	1.07	1.61	2.37	2.81	3.27	3.31	2.71	2.50	2.11	2.06	2.06	2.39
a 69	1.90	1.61	2.04	2.27	2.81	3.27	3.63	3.44	3.23	2.84	2.49	2.08	2.71
a1870	3.14	3.15	2.87	3.45	3.46	3.69	3.80	3.67	3.43	3.16	2.97	3.04	3.34
a 71	2.70	2.15	2.53	2.96	3.23	3.32	3.37	3.06	2.97	2.86	2.39	2.04	2.75
a 72	1.83	1.37	1.23	1.38	1.79	2.23	2.29	2.13	2.01	1.90	1.69	1.84	1.79
a 73	1.41	1.20	1.22	2.43	3.09	3.24	3.29	3.15	2.81	2.57	2.43	2.04	2.49
a 74	3.30	3.13	3.11	3.21	3.30	3.43	3.53	3.29	2.89	2.51	2.20	2.13	3.01
a 75	1.82	1.43	1.52	1.85	2.21	2.81	3.01	2.93	2.84	2.41	2.37	2.78	2.34
a 76	2.61	2.95	2.55	4.00	4.31	4.49	4.45	4.07	3.96	3.49	3.05	2.53	3.76
a 77	3.00	2.62	2.34	3.70	3.94	3.09	3.40	3.18	3.16	2.83	2.65	2.12	2.94
a 78	3.07	2.99	3.07	3.43	3.65	3.72	3.79	3.49	3.42	3.13	3.04	3.21	3.34
a 79	2.76	2.40	2.38	2.67	2.81	2.97	3.07	2.77	2.80	2.33	1.97	2.42	2.59
a1880	2.79	2.61	2.70	2.79	3.05	3.23	3.29	3.07	2.90	2.53	2.55	2.40	2.82
a 81	1.86	1.75	2.02	2.65	3.04	3.25	3.37	2.97	2.68	2.60	2.62	2.02	2.67
a 82	3.39	3.14	3.54	3.66	3.85	4.10	4.10	3.86	3.67	3.28	3.07	2.75	3.64
a 83	3.33	3.32	2.66	3.71	3.18	3.98	4.20	4.06	3.61	3.56	3.28	3.50	3.33
a 84	3.04	3.05	3.22	3.70	3.96	4.11	3.96	3.72	3.35	3.08	2.71	2.53	3.40
a 85	2.83	2.09	1.90	2.65	3.37	3.95	3.96	3.91	3.82	3.78	3.77	3.91	3.30
a 86	3.80	2.83	2.61	2.42	2.71	2.89	2.93	3.06	2.46	2.29	2.11	2.21	2.61
87	e 2.86	e 3.07	2.75	2.71	2.98	4.07	3.91	3.81	3.20	3.26	2.71	2.89	3.41
b 88	2.57	1.96	2.09	2.09	2.24	3.01	3.22	3.13	2.78	2.89	2.44	2.74	2.67
b 89	2.56	2.24	1.86	2.23	2.69	2.96	3.00	2.91	2.53	2.03	2.03	2.36	2.48
b1890	2.93	2.74	2.96	2.21	2.89	2.92	2.84	3.17	2.83	2.81	3.00	2.74	2.13
b 91	2.48	2.36	2.50	2.62	2.40	2.33	2.56	3.27	2.10	1.73	1.67	1.70	2.22
b 92	1.61	0.93	1.13	1.96	2.40	2.21	2.42	3.05	2.73	2.45	2.07	2.04	2.35
b 93	1.27	1.23	1.53	2.19	2.91	2.96	2.13	2.54	2.39	2.19	2.17	2.12	2.24
b 94	2.13	1.75	1.86	2.05	2.85	2.94	2.81	2.34	2.17	2.17	1.96	1.82	2.22
b 95	1.69	1.00	0.93	1.13	1.46	1.86	1.86	1.42	1.44	1.20	0.71	0.97	1.28
b 96	1.13	1.05	0.90	1.32	1.67	1.98	1.96	2.09	1.67	1.41	1.44	1.32	1.43
b 97	1.69	1.15	1.08	2.16	2.60	2.89	2.97	3.45	2.99	1.66	1.69	1.81	2.00
b 98	1.69	1.57	1.95	2.55	2.98	2.73	2.50	2.48	2.08	1.91	2.01	2.07	2.16
99	2.08	1.89	c 1.85	c 2.04	c 2.23	c 2.51	c 2.45	c 2.09	c 1.90	c 1.48	c 1.35	c 1.96	1.96
a1900	1.67	1.61	1.83	2.16	2.83	2.41	2.43	2.21	2.07	1.68	1.64	1.77	2.01
c 01	c 1.00	c 1.03	0.62	1.05	1.17	1.99	1.85	1.70	1.75	1.53	1.39	1.37	1.42
c 02	1.41	0.79	0.95	1.40	1.74	2.05	2.73	2.64	2.20	2.28	2.16	c 2.20	1.99
c 03	1.99	1.70	2.13	2.83	2.85	2.96	2.99	2.84	2.35	2.24	2.01	2.02	2.43
c 04	1.06	1.20	1.86	2.89	3.23	3.49	3.41	3.12	2.84	2.61	2.31	2.13	2.59
c 05	1.74	1.35	1.13	1.79	2.38	2.87	2.93	2.68	2.68	2.56	2.20	2.45	2.24
c 06	2.28	1.88	1.66	2.06	2.27	2.49	2.65	2.51	2.37	2.25	2.23	2.45	2.25
c 07	2.96	2.47	2.22	2.62	2.94	3.13	2.83	2.62	2.30	2.70	2.71	2.68	2.80
Mean	573.36	573.08	573.19	573.94	573.97	573.31	573.36	573.02	573.80	573.56	573.43	573.52	573.57

Authority, U. S. Lake Survey, except for supplied values.

a.—Supplied by applying to the Cleveland, O., readings, the mean monthly rise or fall between Cleveland, O., and Buffalo, N. Y., from June, 1899, to December, 1906, inclusive.

b.—Derived from U. S. Lake Survey tables by subtracting 0.1 foot from records there given.

c.—Self-registering gage.

Note.—Elevations depend on B. M. "Light-house," 580.101 ft., U. S. Lake Survey, 1903 Levels.

TABLE 12.

WATER LEVELS OF LAKE ONTARIO.

Monthly mean elevations of water surface of Lake Ontario, at Charlotte, N. Y., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	246.88	246.41	246.52	246.64	246.78	246.97	247.09	247.06	246.97	246.61	246.49	246.50	246.67
61	6.26	6.29	6.72	7.27	8.04	8.26	8.26	8.00	7.84	7.09	7.09	7.40	7.46
62	7.06	6.73	6.89	7.73	8.56	8.43	8.32	7.98	7.46	6.98	6.88	6.45	7.44
63	6.53	6.71	6.83	7.47	7.97	7.97	7.73	7.43	6.97	6.44	6.25	6.23	7.06
64	6.10	6.06	6.15	6.99	7.74	8.07	7.67	7.39	6.78	6.47	6.36	6.78	6.99
65	6.51	6.17	6.86	7.21	7.47	7.44	7.24	6.75	6.29	6.04	5.72	5.84	6.59
66	5.45	5.32	5.52	5.98	6.84	7.03	6.85	6.63	6.49	6.27	6.29	6.81	6.29
67	6.79	6.77	6.90	7.31	8.10	8.40	8.05	8.09	7.80	7.35	5.86	5.34	7.31
68	5.16	4.80	5.16	5.83	6.36	6.70	6.87	6.26	6.13	5.43	5.84	5.83	5.91
69	5.82	5.51	5.70	6.44	7.00	7.20	7.47	7.43	7.27	6.97	6.86	6.71	6.78
1870	7.34	7.39	7.32	8.23	9.05	9.61	8.54	8.09	7.49	7.14	6.72	6.13	7.91
71	6.30	6.03	6.27	7.08	7.32	7.25	7.06	6.64	6.30	5.73	5.35	4.78	6.31
72	4.62	4.42	4.30	4.72	4.96	5.26	5.34	5.19	4.94	4.84	4.72	4.54	4.85
73	4.47	4.35	4.25	6.32	6.91	6.94	6.90	6.66	6.32	5.86	5.70	5.53	5.89
74	5.30	5.04	7.06	7.10	7.23	7.26	7.20	7.14	6.64	6.03	5.50	5.20	6.64
75	4.83	4.53	4.98	5.46	5.81	5.96	6.01	5.82	5.60	5.35	5.17	5.07	5.44
76	5.43	6.11	6.70	7.68	8.20	8.42	8.44	8.09	7.25	7.00	6.68	6.39	7.31
77	5.98	5.74	5.88	6.46	6.60	6.41	6.54	6.27	5.86	5.46	5.23	5.46	5.98
78	5.00	5.85	6.34	6.74	7.06	7.06	7.06	6.97	6.82	6.38	6.25	7.02	6.60
79	6.80	6.45	6.47	6.73	6.84	6.91	6.72	6.34	5.94	5.80	5.10	5.12	6.23
1880	5.34	5.05	5.06	6.23	6.96	6.83	6.65	6.16	5.88	5.27	5.27	5.07	5.85
81	4.70	4.66	4.43	5.79	6.06	6.06	6.23	6.00	5.58	5.24	5.24	5.25	5.51
82	5.74	5.94	6.51	6.83	7.06	7.09	7.09	7.23	6.83	6.35	6.06	6.06	6.60
83	6.23	6.20	6.60	6.16	6.79	7.26	7.35	7.70	7.28	6.84	6.69	6.49	6.80
84	6.44	6.35	7.25	8.03	8.16	8.05	7.91	7.66	7.15	6.75	6.23	6.09	7.23
85	6.03	5.76	5.84	6.26	7.07	7.40	7.35	7.26	7.17	6.97	7.00	7.13	6.79
86	7.35	7.56	7.68	8.04	8.09	8.24	7.95	7.80	7.00	6.72	6.43	6.36	7.39
87	6.15	6.84	7.27	7.84	8.08	8.07	7.78	7.29	6.90	6.31	5.73	5.27	6.93
88	5.45	5.28	5.48	5.96	6.22	6.24	6.18	6.01	5.78	5.48	5.31	5.20	5.73
89	5.20	5.09	5.76	5.98	6.12	6.02	6.76	6.59	5.97	5.46	5.25	5.25	5.79
1890	5.18	5.47	5.78	6.09	7.06	7.06	7.09	7.23	6.85	6.42	6.17	6.04	6.46
91	6.02	6.10	6.06	7.27	7.19	6.78	6.47	6.10	5.68	5.04	4.84	4.36	5.98
92	4.57	4.31	4.60	4.90	5.15	5.73	6.26	6.17	5.90	5.46	5.16	5.07	5.28
93	5.08	4.78	5.11	5.61	7.06	7.31	7.09	6.69	6.21	5.77	5.27	5.03	6.09
94	5.61	5.97	6.02	6.09	6.26	6.75	6.52	6.26	6.44	5.75	5.27	6.24	6.13
95	4.86	4.80	4.40	4.74	4.96	4.70	4.52	4.26	4.34	3.94	3.41	3.51	4.27
96	3.77	4.06	4.36	5.15	5.44	5.23	5.12	4.89	4.51	4.28	4.08	3.96	4.57
97	3.94	3.86	4.30	4.94	5.32	5.49	5.49	5.03	5.17	4.68	4.39	4.47	4.82
98	4.70	5.00	5.46	5.90	6.12	5.76	5.56	5.47	5.11	4.85	4.75	4.74	5.18
99	4.80	4.75	5.07	5.51	6.01	6.15	5.95	5.56	5.04	4.71	4.59	4.59	5.19
1900	4.82	4.64	5.06	5.27	6.02	6.09	6.06	5.51	5.17	4.85	4.62	4.57	5.24
01	4.82	4.75	4.80	5.51	5.95	6.07	5.99	5.53	5.31	4.76	4.53	4.55	5.18
02	4.62	4.67	5.05	5.96	6.45	6.67	6.60	6.22	5.81	5.54	5.19	4.96	5.70
03	4.96	5.09	5.66	6.06	6.99	6.99	6.96	6.43	6.09	5.80	5.44	5.26	5.99
a 04	4.87	5.06	5.66	6.06	7.06	7.06	6.96	7.79	7.27	6.96	6.33	6.06	6.61
a 05	5.93	5.89	6.35	6.19	6.33	6.74	7.10	7.08	6.71	6.27	6.03	6.06	6.41
06	a 6.24	a 6.34	a 6.14	a 6.33	a 6.81	a 6.90	a 6.75	a 6.45	a 6.06	5.84	5.79	5.91	6.26
07	6.43	6.68	6.62	6.96	7.31	7.27	7.80	7.08	6.60	6.24			
Mean	265.61	265.69	265.85	266.44	266.84	266.96	266.93	266.96	266.76	266.43	266.23	265.86	266.36

Authority, U. S. Lake Survey.

a.—From self-registering gage.

Note.—Elevations depend on B. M. "I," 263.186 ft., U. S. Lake Survey, 1903 Levels.

TABLE 13.

WATER LEVELS OF LAKE ONTARIO.

Monthly mean elevations of water surface of Lake Ontario, at Oswego, N. Y., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	246.58	246.72	246.77	246.80	247.03	247.57	247.82	247.26	246.86	246.67	246.73	246.73	246.96
61	6.44	6.56	7.01	7.23	8.18	8.54	8.32	8.07	7.80	7.81	7.82	7.61	7.80
62	7.11	6.69	7.18	8.06	8.88	8.63	8.72	8.26	7.61	7.08	6.73	6.62	7.63
63	6.77	6.83	6.91	7.83	8.03	8.18	7.77	7.31	6.93	6.74	6.56	6.57	7.19
64	6.33	6.17	6.26	6.83	7.82	8.13	7.80	7.34	6.81	6.58	6.55	6.65	6.94
65	7.08	7.23	7.38	7.46	7.62	7.86	7.51	6.90	6.39	6.07	5.82	5.96	6.80
66	5.46	5.47	5.48	5.94	6.02	5.92	6.84	6.74	6.65	6.52	6.28	6.20	6.13
67	5.96	5.92	6.02	7.52	8.21	8.46	8.11	7.48	6.98	6.33	5.59	4.83	6.84
68	4.51	4.91	4.88	5.33	6.13	6.54	6.42	6.13	5.94	5.35	5.20	5.37	5.55
69	5.23	5.34	5.56	6.00	6.73	6.97	7.20	7.35	7.17	7.06	6.68	6.85	6.52
1870	7.38	7.41	7.41	7.35	8.06	8.63	8.31	7.97	7.38	6.96	6.38	6.13	7.59
71	6.06	5.89	6.10	6.70	7.12	7.06	6.90	6.46	6.13	5.63	5.31	4.90	6.18
72	4.73	4.51	4.35	4.84	4.96	5.29	5.35	5.19	4.90	4.74	4.69	4.33	4.83
73	4.31	4.35	4.50	6.46	7.00	6.92	6.88	6.60	6.18	5.78	5.80	5.79	5.96
74	6.33	6.75	7.30	7.19	7.17	7.26	7.31	6.96	6.34	5.94	5.37	5.06	6.57
75	4.73	4.35	4.64	5.44	5.71	5.87	5.90	5.76	5.55	5.27	5.08	4.90	5.27
76	5.31	5.97	6.52	7.50	8.06	8.30	8.37	7.91	7.30	6.96	6.60	6.42	7.10
77	5.99	5.82	5.77	6.46	6.83	6.43	6.47	6.20	5.77	5.34	5.25	5.35	5.98
78	5.48	5.98	6.39	6.94	6.98	6.97	6.93	6.53	6.39	6.23	6.21	7.03	6.51
79	6.81	6.45	6.30	6.71	6.80	6.83	6.67	6.32	5.90	5.46	5.07	5.10	6.20
1880	5.32	5.60	5.94	6.12	6.27	6.51	6.53	6.00	5.72	5.31	5.27	5.10	5.81
81	4.74	4.73	5.39	5.81	5.99	6.21	6.28	5.96	5.40	5.18	5.16	5.18	5.80
82	6.72	5.90	6.50	6.83	7.02	7.53	7.82	7.19	6.81	6.30	5.86	5.89	6.57
83	5.32	5.38	5.62	6.14	6.79	7.49	8.02	7.84	7.36	6.93	6.69	6.55	6.88
84	6.61	6.88	7.56	8.17	8.19	8.09	7.85	7.65	7.22	6.80	6.30	6.15	7.28
85	6.14	5.87	5.89	6.27	7.07	7.44	7.56	7.43	7.21	7.02	7.07	7.26	6.83
86	7.00	7.07	7.81	8.43	8.64	8.44	8.04	7.60	7.24	6.98	6.81	6.43	7.61
87	6.17	6.92	7.43	7.64	8.20	8.16	7.98	7.57	6.76	6.27	6.02	5.75	7.09
88	5.44	5.30	5.54	6.17	6.24	6.26	6.24	6.34	5.85	5.49	5.43	5.41	5.81
89	5.62	5.76	5.96	6.17	6.32	6.62	6.63	6.57	6.01	5.87	5.17	5.74	6.03
1890	6.25	6.60	6.95	7.17	7.53	8.16	7.99	7.32	6.97	6.64	6.72	6.81	7.07
91	6.19	6.45	6.90	7.47	7.25	6.83	6.55	6.11	5.68	5.04	4.44	4.41	6.12
92	4.51	4.48	4.61	5.19	5.25	5.61	6.33	6.36	6.04	5.80	5.33	5.20	5.38
93	4.87	4.76	5.34	5.99	7.15	7.37	7.11	6.57	6.30	5.78	5.37	5.22	5.98
94	5.56	5.74	6.04	6.09	6.27	6.80	6.60	6.02	5.51	5.26	4.93	4.88	5.78
95	4.49	4.43	4.33	4.86	5.00	4.88	4.89	4.54	4.00	3.86	3.41	3.44	4.29
96	3.80	4.26	4.49	5.41	5.43	5.23	6.08	4.94	4.48	4.23	3.97	3.97	4.62
97	3.88	3.82	4.32	4.96	5.40	5.61	5.61	5.00	5.10	4.47	4.41	4.47	4.80
98	4.64	5.08	5.48	5.92	6.08	6.13	5.85	5.50	5.09	4.84	4.80	4.90	5.37
99	4.96	4.86	5.13	5.69	5.94	6.07	5.93	5.46	e 4.95	e 4.56	e 4.42	e 4.36	5.20
e1900	4.43	4.85	5.19	5.80	5.99	5.91	5.82	5.54	5.13	4.72	4.55	4.54	5.23
e 01	4.68	4.42	4.39	5.03	5.91	5.99	5.74	5.43	5.10	4.68	4.38	4.26	5.06
e 02	4.42	4.30	4.95	5.40	5.47	5.53	5.97	6.11	5.68	5.42	5.05	4.89	5.27
e 03	4.93	5.16	5.75	6.44	6.56	6.44	6.39	6.25	6.07	5.72	5.36	5.11	5.87
04	4.73	5.00	5.63	7.00	7.61	7.87	7.79	7.64	7.25	6.87	6.38	5.81	6.84
05	5.79	5.49	5.39	6.13	6.35	6.89	6.96	6.90	6.75	6.45	6.07	5.88	6.21
06	6.13	6.09	5.91	6.25	6.36	6.41	6.37	6.26	5.81	5.49	5.58	5.74	6.03
07	6.34	6.48	6.47	6.85	7.08	7.11	7.13	6.90	6.50	6.46	6.33	6.33	6.66
Mean	245.18	245.55	245.91	246.49	246.83	246.96	246.93	246.63	246.22	245.88	245.63	245.57	246.19

Authority, U. S. Lake Survey.

e.—Self-registering gage.

Floods in Oswego River during the spring may cause abnormal gage readings from 0.2 to 0.3 foot above the true mean stage of Lake Ontario.

Note.—Elevations depend on zero of gage, 244.13 ft., and B. M. "A", 251.90 ft., U. S. Lake Survey, 1903 Levels.

TABLE 14.

WATER LEVELS OF ST. LAWRENCE RIVER.

Monthly mean elevation of water surface of St. Lawrence River, at Ogdensburg, N. Y., in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
a 1860	245.65	245.73	245.83	245.86	246.07	246.86	246.83	246.20	245.91	245.73	245.81	245.79	246.01
a 61	5.52	5.63	6.05	6.26	7.16	7.50	7.29	7.05	6.81	6.81	6.82	6.62	6.61
a 62	6.15	5.75	6.21	7.06	7.82	7.57	7.67	7.23	6.62	6.12	5.70	5.60	6.64
a 63	5.82	5.88	5.96	6.04	7.03	7.16	6.77	6.34	5.96	5.80	5.63	5.64	6.22
a 64	5.41	5.26	5.35	5.88	6.82	7.10	6.90	6.37	5.87	5.65	5.62	5.72	5.99
a 65	6.12	6.26	6.40	6.48	6.63	6.67	6.53	5.95	5.38	5.17	4.93	4.78	5.94
a 66	4.80	4.60	4.61	5.06	5.12	5.03	5.89	5.80	5.72	5.89	5.37	5.20	5.22
a 67	5.08	5.03	5.60	6.54	7.19	7.44	7.09	6.50	6.03	5.41	4.72	4.00	5.89
a 68	3.70	3.79	4.05	4.65	5.22	5.61	5.50	5.23	5.05	4.49	4.35	4.51	4.89
69	a 4.27	a 4.43	a 4.60	a 5.19	a 5.81	6.18	6.41	6.41	6.16	6.08	5.70	6.04	5.65
1870	6.32	6.36	6.18	7.35	7.87	7.60	7.30	7.03	6.19	5.87	5.64	a 5.23	6.56
71	a 5.16	a 5.00	a 5.20	a 5.76	6.03	6.26	6.01	5.66	5.34	4.99	4.39	a 4.07	5.32
72	a 3.91	a 3.70	a 3.55	a 4.01	4.31	4.53	4.77	4.66	4.59	4.09	a 3.87	a 3.55	4.13
73	a 3.51	a 3.53	a 3.60	a 5.44	6.15	6.18	6.20	a 5.67	a 5.27	a 4.85	a 4.73	a 4.90	5.07
74	a 5.43	a 5.81	a 6.33	a 6.32	a 6.21	a 6.20	a 6.24	6.16	a 5.42	a 5.06	a 4.51	a 4.19	5.66
a 75	3.91	3.88	3.82	4.57	4.82	4.98	5.01	4.86	4.65	4.41	4.24	4.07	4.43
a 76	4.46	5.07	5.59	6.53	7.06	7.27	7.24	6.90	6.33	6.01	5.67	5.50	6.14
a 77	5.00	4.74	4.89	5.54	5.60	5.51	5.55	5.29	4.89	4.48	4.40	4.52	5.08
a 78	4.61	4.51	5.47	5.71	6.03	6.02	5.96	5.90	5.66	5.41	5.30	6.06	5.65
a 79	5.87	5.53	5.39	5.77	5.86	5.88	5.73	5.40	5.01	4.59	4.23	4.25	5.29
a 1880	4.46	4.73	5.05	5.32	5.36	5.56	5.59	5.19	4.84	4.45	4.41	4.25	4.98
a 81	3.91	3.91	3.83	4.92	5.09	5.20	5.37	5.06	4.54	4.23	4.23	4.32	4.64
a 82	4.85	5.01	5.57	5.88	6.06	6.54	6.54	6.22	5.87	5.39	4.99	4.72	5.64
a 83	4.46	4.52	4.74	5.23	5.85	6.51	7.01	6.84	6.38	5.97	5.75	5.63	5.74
84	a 5.58	a 5.98	a 6.37	a 7.15	a 7.17	a 7.07	a 6.87	a 6.06	6.29	5.97	5.85	a 5.24	6.35
85	a 5.23	a 4.96	a 4.72	a 5.36	a 6.11	6.47	a 6.59	a 6.45	a 6.24	6.05	a 6.11	a 6.27	5.88
a 86	6.61	6.68	6.81	7.39	7.59	7.40	7.03	6.61	6.27	6.00	5.86	5.80	6.63
87	a 5.26	a 5.97	a 6.45	a 6.65	7.14	7.08	6.90	a 6.39	a 5.83	a 5.45	a 5.12	a 4.87	6.09
a 88	4.57	4.44	4.67	5.26	5.33	5.37	5.42	5.23	4.96	4.62	4.56	4.45	4.92
a 89	4.74	4.88	5.06	5.26	5.40	5.70	5.88	5.64	5.11	4.70	4.32	4.60	5.13
1890	a 5.34	a 5.67	a 5.96	a 6.21	6.89	7.00	6.97	6.13	a 6.02	a 5.71	a 5.78	a 5.58	6.06
91	a 5.28	a 5.53	a 6.04	a 6.49	a 6.26	5.73	5.49	5.07	4.71	4.20	3.99	a 3.80	5.21
92	a 3.70	a 3.67	a 3.79	a 4.34	a 4.40	a 4.02	5.36	5.15	5.21	4.67	4.36	a 4.25	4.43
a 93	4.04	3.93	4.20	5.09	6.19	6.39	6.15	5.64	5.39	4.90	4.51	4.27	5.08
a 94	4.69	4.96	5.14	5.19	5.36	5.88	5.67	5.13	4.64	4.40	4.08	3.76	4.99
a 95	3.68	3.69	3.82	4.06	4.16	4.06	3.77	3.54	3.22	2.90	2.66	2.60	3.40
a 96	3.08	3.46	3.66	4.55	4.57	4.49	4.34	4.10	3.68	3.43	3.19	3.12	3.89
a 97	3.10	3.05	3.32	4.12	4.54	4.73	4.72	4.73	4.36	3.88	3.60	3.55	3.97
a 98	3.83	4.34	4.61	5.08	5.18	5.33	4.95	4.66	4.34	4.01	4.06	4.07	4.51
a 99	4.14	4.05	4.29	4.81	5.08	5.17	5.08	4.80	4.11	3.74	3.61	3.59	4.34
1900	a 3.81	a 4.05	a 4.34	a 4.91	a 5.09	a 5.02	a 4.93	a 4.67	b 4.14	b 3.84	b 3.86	b 3.66	4.37
b 01	3.78	3.85	3.98	4.36	4.83	4.90	4.81	4.53	4.26	3.84	3.44	3.54	4.11
02	b 3.87	b 3.87	b 4.14	b 4.67	b 4.62	b 4.71	b 5.06	b 5.13	b 4.80	b 4.51	b 4.21	a 4.00	4.42
b 03	3.97	4.00	4.06	5.45	5.60	5.43	5.47	5.34	5.13	4.79	4.47	4.34	4.96
04	a 3.90	b 4.04	b 4.47	b 5.50	b 6.45	b 6.75	b 6.63	b 6.54	b 6.23	b 5.90	b 5.30	b 4.81	5.60
a 05	4.91	4.83	4.24	5.00	5.23	5.67	5.96	5.65	5.70	5.43	5.34	5.03	5.35
a 06	5.30	5.11	4.95	5.21	5.33	5.42	5.36	5.21	4.93	4.66	4.62	4.64	5.09
a 07	5.30	5.43	5.32	5.74	6.03	6.05	6.12	5.90	5.51	5.43	5.31	5.24	5.61
Mean	244.70	244.75	244.99	245.54	245.86	246.00	245.96	245.69	245.23	244.90	244.76	244.69	245.37

Authority, U. S. Lake Survey, except for supplied values.

a.—Supplied from Oswego, N. Y., readings by formula (Ogdensburg—340) = 0.9426 (Oswego—340)—0.553.

b.—Self-registering gage.

Note.—Elevations depend on zero of gage, 244.87 ft. and B. M. "O," 247.126 ft., U. S. Lake Survey, 1903 Levels.

TABLE 15.

WATER LEVELS OF ST. LAWRENCE RIVER.

Monthly mean elevations of water surface of St. Lawrence River, at Lock No. 27, Galop Canal, head of Galop Rapids, in feet above mean tide at New York.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	244.08	244.22	244.26	244.29	244.80	245.31	245.55	245.02	244.64	244.46	244.54	244.22	244.62
61	3.95	4.07	4.49	4.70	5.89	6.23	6.02	5.79	5.34	5.54	5.55	5.06	5.22
62	4.59	4.19	4.65	5.50	6.55	6.31	6.40	5.97	5.35	4.85	4.53	4.13	5.25
63	4.26	4.32	4.40	5.08	5.75	5.89	5.50	5.07	4.71	4.52	4.36	4.06	4.83
64	3.85	3.70	3.78	4.32	5.55	5.83	5.53	5.10	4.80	4.38	4.35	4.15	4.60
65	4.56	4.70	4.84	4.92	5.36	5.40	5.26	4.88	4.10	3.90	3.66	3.21	4.55
66	3.08	3.04	3.04	3.50	3.85	3.75	4.62	4.53	4.44	4.32	4.09	3.73	3.83
67	3.49	3.46	4.12	4.97	5.92	6.17	5.82	5.23	4.76	4.14	3.44	2.43	4.50
68	2.93	2.22	2.48	3.08	3.94	4.34	4.22	3.95	3.77	3.21	3.07	2.94	3.35
69	2.80	2.91	3.12	3.63	4.54	4.75	5.05	5.11	4.94	4.85	4.47	4.34	4.21
1870	4.73	4.87	4.87	5.78	6.63	6.32	6.01	5.60	5.04	4.73	4.19	3.66	5.21
71	3.50	3.43	3.62	4.20	4.89	4.83	4.66	4.38	3.94	3.47	3.08	2.50	3.88
72	2.34	2.13	1.96	2.44	2.85	3.16	3.21	3.06	2.79	2.64	2.50	1.98	2.60
73	1.94	2.00	2.12	2.97	4.77	4.70	4.66	4.40	4.00	3.57	3.45	3.34	3.58
74	3.37	4.24	4.77	4.66	4.94	5.02	4.97	4.76	4.13	3.77	3.23	2.62	4.26
75	1.45	0.46	1.77	3.24	3.61	3.80	3.79	3.63	3.53	3.15	2.81	2.77	2.83
76	2.91	2.73	4.02	5.35	5.95	b 5.23	6.25	5.64	4.99	4.02	4.20	3.67	4.82
77	2.37	2.17	2.57	3.80	4.81	4.38	4.56	4.05	3.81	2.90	3.00	2.99	3.57
78	2.97	3.20	4.01	4.63	5.20	b 4.74	4.62	4.53	4.31	3.99	3.84	4.95	4.26
79	3.39	3.75	3.81	4.38	4.44	4.84	4.50	3.86	3.45	2.88	2.94	2.90	3.73
1880	3.03	b 3.48	3.60	4.04	4.14	4.35	4.33	3.91	3.60	3.27	3.29	2.74	3.65
81	1.02	1.56	2.82	3.53	3.72	3.98	4.04	3.73	3.39	3.02	3.06	3.10	3.06
82	3.30	3.44	4.07	4.84	4.80	5.40	5.34	4.95	4.46	4.10	3.67	3.51	4.31
83	1.57	2.01	2.76	3.78	4.56	5.37	5.77	5.55	5.10	4.66	4.59	4.42	4.21
84	3.20	3.76	4.46	5.71	5.92	b 5.81	b 5.61	5.53	5.15	4.67	4.33	4.13	4.86
85	3.73	3.83	3.73	3.60	4.96	5.35	5.45	5.30	5.11	4.87	4.86	5.07	4.47
86	5.15	5.06	5.02	5.00	6.40	6.38	5.83	5.47	5.16	4.76	4.63	4.31	5.34
87	3.97	4.22	4.60	5.39	5.91	5.95	5.67	5.17	4.72	4.40	3.90	3.64	4.80
88	3.49	3.27	3.27	4.05	4.20	4.22	4.28	4.08	3.91	3.26	3.17	3.20	3.64
89	3.51	2.87	3.43	4.01	4.19	4.51	4.61	4.25	3.83	3.12	3.15	3.46	3.75
1890	4.10	4.13	4.64	4.98	5.28	5.09	5.74	b 5.00	b 4.79	4.28	4.22	3.44	4.73
91	3.41	3.48	4.30	5.13	4.93	4.82	4.38	3.99	3.50	2.83	2.80	2.42	3.79
92	3.23	1.83	1.98	2.97	3.16	3.80	4.21	4.08	b 3.67	3.44	3.09	3.10	3.11
93	2.27	1.71	2.29	3.06	4.80	5.12	4.81	4.27	4.17	3.60	3.20	3.06	3.55
94	3.16	3.44	3.49	3.83	4.04	4.61	4.40	3.51	3.27	3.18	2.95	2.39	3.47
95	2.16	1.33	1.59	2.64	2.97	2.81	2.51	2.36	2.11	1.77	1.56	1.72	2.13
96	1.80	1.96	1.86	3.06	3.46	3.29	3.17	3.02	2.84	2.32	2.22	2.04	2.56
97	1.91	1.75	2.25	3.19	3.34	3.73	3.64	3.62	3.07	2.87	2.30	2.37	2.81
98	2.44	2.52	2.53	3.21	3.54	3.59	3.32	3.24	2.85	2.53	2.56	2.61	3.00
99	2.70	2.56	2.72	3.25	3.66	3.54	3.66	3.27	2.81	2.40	2.26	2.25	2.94
1900	2.30	2.25	2.25	3.28	3.64	3.70	3.64	3.26	3.01	2.62	2.37	2.65	2.93
01	2.48	2.13	1.88	3.02	3.66	3.70	3.80	3.21	2.97	2.46	2.00	2.18	2.76
02	c 1.24	c 0.24	c 2.44	c 3.24	c 3.24	c 3.44	c 3.74	c 3.54	c 3.54	b 2.28	c 2.04	c 2.74	2.80
03	2.54	2.54	3.24	4.14	4.34	4.14	4.24	4.04	3.54	3.44	3.14	2.04	3.53
04	c 2.54	c 2.54	c 3.04	c 4.54	b 5.35	c 5.54	c 5.74	c 5.38	c 5.00	b 4.65	c 4.06	c 3.34	4.31
05	3.08	2.78	2.44	3.68	4.04	4.28	4.70	4.44	4.44	4.28	3.88	3.58	3.80
06	3.98	3.96	3.51	3.96	4.01	4.14	4.24	3.96	3.53	3.43	3.38	3.29	3.75
07	3.33	3.47	3.48	4.42	4.73	4.78	4.58	4.62	4.19	4.16	4.06	3.93	4.18
Mean	243.07	242.96	243.25	244.12	244.60	244.75	244.73	244.41	244.04	243.70	243.48	243.26	243.87

Authority, U. S. Lake Survey, except for supplied values.

a—Supplied from Oswego readings by formula, (Lock 27—240) = 0.9457 (Oswego—240)—1.845 assuming a mean fall during entire period.

b—Supplied from Oswego readings by formula, (Lock 27—240) = 0.9457 (Oswego—240)—1.845.

c—Deduced from the water records of the St. Lawrence canals furnished the International Waterways Commission.

Note.—Elevations depend on zero of gage, sill of Lock No. 27, 234.144 ft.

TABLE 16.

WATER LEVELS OF ST. LAWRENCE RIVER.

Monthly mean elevations of water surface of St. Lawrence River, at Lock No. 24, Morrisburg Canal, head of Rapide Plat, in feet above upper sill of old lock.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1880	8.32		8.70	9.49	9.74	9.95	9.89	9.26	8.84	8.34	8.61	7.83	9.01
81	8.09	6.74	7.94	8.77	9.03	9.36	9.86	9.17	8.53	7.89	8.48	8.35	8.31
82	8.54	8.89	9.55			10.77	10.53	10.22	9.89	9.46	8.63	8.53	9.47
83	7.57	5.90	7.66	9.14	9.90	10.78	11.15	11.05	11.06	10.12	9.53	9.38	9.48
84	7.49	8.15	12.41	10.90	11.78	11.61	11.31	11.15	10.85	9.83	9.20	8.64	10.21
85	7.90	7.18	7.53	8.61	10.21	10.91	10.74	10.58	10.09	10.05	9.94	10.39	9.48
86	10.18	10.09	10.32	11.55	11.84	11.71	11.22	10.62	10.40	10.09	9.86	9.60	10.91
87	8.77	10.40	11.13	11.13	11.44	11.41	11.06	10.46	10.07	9.65	8.99	8.48	10.23
88	7.79	6.85	7.80	9.38	9.87	9.83	9.46	9.28	8.97	8.43	8.41	8.26	8.98
89	8.71	8.16	7.96	9.80	9.46	9.93	10.05	9.79	9.13	8.32	7.96	8.77	8.98
1890	9.34	9.84	10.09	10.46		11.47	11.42	10.81	10.21	9.73	9.70	9.36	10.16
91	8.64	8.74	9.60	9.40	10.64	9.97	9.86	9.26	8.68	7.82	7.36	7.30	8.94
92	7.02	5.82	6.44	7.74	7.98	8.74	9.53	9.30	9.22	8.51	8.13	7.98	8.03
93	5.25	7.80	8.63	8.92	10.26	10.80	10.52	9.82	9.48	8.87	8.33	8.06	8.96
94	7.98	6.61	8.71	9.13	9.25	10.13	9.88	9.01	8.60	8.06	7.77	7.32	8.53
95	6.61	5.45	6.09	9.47	7.82	7.05	7.23	7.10	6.84	6.16	5.89	5.81	6.61
96	5.85	6.35	7.72	7.99	8.22	8.28	7.99	7.73	7.09	6.66	6.45	6.33	7.28
97	6.02	5.42	6.45	7.38	8.42	8.78	8.52	8.55	7.81	7.07	6.76	7.07	7.40
98	7.04	7.61	8.25	8.74	9.04	9.10	8.74	8.38	7.83	7.44	7.40	7.35	8.10
99	7.00	6.68	7.83	8.54	8.86	9.16	8.82	8.15	7.55	7.08	7.04	7.01	7.79
1900	6.91	6.89	7.16	8.50	8.88	8.98	8.84	8.22	7.90	7.40	7.12	7.39	7.87
01	7.29	7.00	7.14	8.14	8.65	9.03	8.73	8.37	8.18	7.65	7.09	7.04	7.86
e 02	7.00	5.80	7.80	8.60	8.70	8.90	9.10	9.40	8.11	8.00	8.30	7.10	8.13
e 03	8.00	7.70	8.90	8.90	9.11	9.80	9.11	9.80	9.10	8.90	8.00	7.70	8.84
e 04	6.90	7.10	7.80	9.80	10.50	10.10	11.00	10.96	10.26	10.00	9.26	8.20	9.31
e 05	7.10	10.40	9.20	9.10	9.10	9.46	9.90	9.90	9.70	9.40	9.00	8.90	9.27
e 06	9.08	8.78	9.57	9.00	9.35	9.41	9.53	9.18	8.65	8.44	8.25	8.22	8.96
e 07	8.05	8.45	9.39	10.30	10.07	10.17	10.34	10.00	10.02	9.90	9.19	9.17	9.88
Mean	7.87	7.84	8.44	9.26	9.55	9.85	9.79	9.47	9.02	8.58	8.22	8.09	8.75

Authority, U. S. Lake Survey, except for supplied values.

e.—Deduced from the water records of the St. Lawrence canals furnished the International Waterways Commission.

TABLE 17.

WATER LEVELS OF ST. LAWRENCE RIVER.

Monthly mean elevations of water surface of St. Lawrence River, at Lock No. 21, Cornwall Canal, head of Long Sault Rapids, in feet above upper sill of old lock.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1870	10.99	10.94	10.70	12.00	12.54	12.43	12.25	11.85	11.20	11.07	10.63	10.36	11.41
71	9.89	9.71	10.32	10.74	11.06	11.08	10.91	10.54	10.24	9.87	9.34	9.08	10.23
72	8.44	7.75	8.02	8.78	9.21	9.53	9.67	9.37	9.11	8.97	9.06	8.67	8.88
73	9.80	8.98	9.20	10.10	10.81	10.97	10.90	10.58	10.34	9.92	9.74	10.02	10.09
74	10.30	10.31	11.06	11.08	11.19	11.30	11.23	10.96	10.41	10.13	9.74	9.33	10.59
75	8.41	7.42	8.53	9.41	9.88	10.06	10.12	9.92	9.65	9.37	9.20	9.11	9.26
76	9.46	9.83	10.16	11.43	11.91	12.11	12.15	11.71	11.18	11.02	10.87	10.64	11.01
77	10.04	10.06	10.17	10.41	10.89	10.51	10.56	10.27	9.87	9.43	9.27	9.50	10.06
78	9.44	9.40	10.21	10.92	10.92	10.92	10.85	10.84	10.73	10.41	10.33	11.00	10.47
79	10.44	9.51	9.52	10.00	10.86	10.84	10.98	10.39	9.99	9.58	9.21	9.10	10.09
1880	9.40	9.38	9.32	10.32	10.45	10.61	10.55	10.09	9.82	9.46	9.39	9.24	9.94
81	8.18	7.18	9.02	9.77	10.01	10.25	10.29	9.96	9.50	9.33	9.35	9.30	9.35
82	9.60	9.54	10.40	10.93	10.80	11.28	11.38	11.01		10.21	9.75	9.63	10.39
83	9.11	8.91	9.97	9.99	10.64	11.20	11.47	11.35	11.21	10.63	10.06	10.42	10.43
84	10.59	10.70	10.43	11.73	11.82	11.86	11.80	11.37	10.96	10.54	10.22	9.94	10.99
85	9.90	9.93	9.50	9.87	10.63	11.24	11.22	11.02	10.54	10.06	10.76	10.99	10.56
86	10.80	9.57	10.50	11.91	12.17	12.02	11.70	11.32	11.02	10.86	10.53	10.42	11.05
87	11.08	11.79	11.81	11.82	11.80	11.77	11.82	11.05	10.54	10.26	9.72	9.62	11.04
88	9.52	8.81	9.62	10.09	10.18	10.23	10.24	10.20	9.88	9.55	9.48	9.53	9.78
89	9.68	8.94	9.30	10.23	10.24	10.61	10.75	10.48	10.00	9.51	9.21	9.80	9.90
1890	10.24	10.22	10.72	11.07	11.42	11.88	11.78	11.21	10.94	10.83	10.62	10.39	10.91
91	10.08	9.80	10.55	11.33	11.18	10.66	10.50	10.15	9.75	9.06	8.75	8.79	10.05
92	8.66	7.67	8.37	9.29	9.20	9.86	10.40	10.18	10.14	9.73	9.48	15.52	9.85
93	14.80	15.20	15.20	16.32	10.90	11.12	10.94	10.20	10.33	9.78	9.51	9.21	11.98
94	9.32	8.18	9.73	9.99	10.15	10.66	10.44	9.94	9.55	9.26	9.04	8.62	9.57
95	8.46	6.95	7.28	8.86	8.97	8.92	8.84	8.62	8.23	7.84	7.64	7.57	8.18
96	8.20	8.05	8.54	9.28	9.42	9.38	9.19	9.02	8.64	8.10	8.32	7.99	8.73
97	7.55	7.46	8.40	9.07	9.48	9.06	9.59	9.16	9.01	8.45	8.32	8.48	8.79
98	8.48	9.59	9.51	9.66	9.82	9.84	9.64	9.37	9.01	8.82	8.67	8.77	9.25
99	8.70	8.54	9.62	9.48	9.73	9.92	9.72	9.25	8.85	8.42	8.38	8.54	9.10
1900	8.39	8.89	8.55	9.66	9.87	9.91	9.86	9.58	9.30	8.83	8.71	9.00	9.02
01	8.86	9.21	9.02	9.57	9.88	10.02	9.75	9.50	9.27	8.93	8.44	8.61	9.26
c 02	8.80	12.40	9.00	9.40	9.70	9.90	10.10	10.20	9.10	9.00	9.00	9.00	9.77
c 03	8.11	8.80	9.00	10.40	10.00	10.10	10.00	10.50	10.20	9.70	9.10	8.10	9.65
c 04	8.12	10.10	9.30	10.40	9.70	11.20	11.20	11.40	10.90	10.20	9.10	9.10	10.06
c 05	8.10	7.40	7.80	9.80	9.80	10.00	10.22	10.21	10.13	9.88	9.88	9.28	9.35
c 06	9.80	9.18	9.25	9.50	9.88	9.88	9.75	9.53	9.12	8.82	8.86	9.12	9.36
c 07	9.14	8.94	9.32	10.12	10.37	10.30	10.20	10.26	9.87	9.89	9.78	9.82	9.83
Mean	9.44	9.41	9.62	10.33	10.46	10.62	10.60	10.35	9.97	9.65	9.42	9.52	9.96

Authority, U. S. Lake Survey, except for supplied values.

c.—Deduced from the water records of the St. Lawrence canals furnished the International Waterways Commission.

TABLE 19.

DISCHARGE FROM LAKE SUPERIOR.

Monthly mean outflow from Lake Superior, through St. Mary's River, in 100 cubic feet per second.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	942	880	875	932	1015	1062	1062	1075	1057	1066	1035	932	[illegible]
61	875	813	780	870	1040	1067	1122	1126	1092	1098	1018	919	[illegible]
62	836	778	785	794	962	986	968	1020	1042	1027	940	875	[illegible]
63	820	785	746	780	813	799	840	986	976	957	864	817	[illegible]
64	739	686	702	702	771	810	840	845	886	808	760	714	[illegible]
65	661	654	634	721	866	965	1045	1068	1057	1009	884	801	[illegible]
66	723	670	670	769	859	907	962	1038	962	947	889	905	[illegible]
67	839	799	735	801	834	978	1062	1096	1041	1094	935	850	[illegible]
68	801	861	744	783	907	891	951	955	981	944	979	846	[illegible]
69	808	746	642	771	906	908	997	1105	1287	1186	1057	924	[illegible]
1870	854	804	806	834	912	982	945	949	974	957	903	886	[illegible]
71	744	707	644	677	808	903	944	926	937	891	840	780	[illegible]
72	693	674	619	610	615	834	946	1020	1086	1002	907	843	[illegible]
73	771	732	737	741	870	900	1002	1089	1075	1046	907	942	[illegible]
74	815	778	783	725	822	931	1006	1020	1016	1045	985	972	[illegible]
75	886	806	790	856	928	907	1016	1020	1065	1055	990	961	[illegible]
76	854	843	782	793	955	1083	1200	1211	1218	1142	1078	986	[illegible]
77	896	908	877	860	850	980	976	1004	949	955	908	886	[illegible]
78	815	785	732	725	792	852	877	868	891	826	808	787	[illegible]
79	685	679	616	646	693	695	734	741	723	730	688	696	[illegible]
1880	650	643	622	625	695	670	828	866	883	882	809	824	[illegible]
81	783	730	734	709	906	880	935	986	950	1036	1013	957	[illegible]
82	830	789	741	730	834	845	926	949	935	914	900	898	[illegible]
83	799	716	718	734	782	917	889	956	880	845	830	780	[illegible]
84	737	698	672	653	715	761	792	801	817	838	841	801	[illegible]
85	762	737	704	695	799	877	919	949	914	873	856	797	[illegible]
86	707	670	670	666	776	913	952	954	952	960	842	744	[illegible]
87	698	661	654	623	704	806	863	986	934	875	832	728	[illegible]
88	691	813	634	622	760	864	962	990	973	960	923	776	[illegible]
89	723	664	670	668	780	916	870	872	870	840	780	704	[illegible]
1890	714	695	682	658	682	736	870	852	830	816	788	726	[illegible]
91	680	612	582	616	704	694	716	716	704	716	694	638	[illegible]
92	620	648	612	544	646	718	748	748	760	736	652	626	[illegible]
93	519	492	464	531	692	728	778	790	786	755	748	644	[illegible]
94	602	587	564	538	623	686	804	866	871	779	680	604	[illegible]
95	747	721	682	679	744	833	873	875	907	890	832	820	[illegible]
96	727	697	648	701	810	886	918	931	907	916	822	810	[illegible]
97	767	709	712	737	803	871	912	943	910	871	840	788	[illegible]
98	670	627	590	620	686	725	810	841	886	836	804	780	[illegible]
99	699	666	648	657	819	903	940	968	1004	942	926	917	[illegible]
1900	782	770	722	720	764	777	818	857	948	954	974	900	[illegible]
01	818	764	725	742	798	814	888	920	885	798	788	728	[illegible]
02	670	625	613	625	687	728	760	782	770	746	757	731	[illegible]
03	660	624	610	640	709	774	795	810	812	838	819	780	[illegible]
04	666	630	588	645	700	738	760	771	787	813	796	752	[illegible]
05	738	712	670	747	801	834	899	923	958	965	923	904	[illegible]
06	831	760	720	723	792	843	880	873	878	885	823	779	[illegible]
07	715	683	668	712	754	810	840	880	917	919	891	848	[illegible]
Mean	745	701	665	700	796	857	906	937	926	913	875	804	[illegible]

TABLE 20.

DISCHARGE FROM LAKE MICHIGAN-HURON.

Monthly mean outflow from Lake Michigan-Huron, through Detroit River, in 100 cubic feet per second.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	2125	1447	1942	3051	2214	2326	2002	1995	1894	2176	1935	2250	2046
61	e2206	1723	2168	2260	2164	2374	2234	2409	2358	2399	2262	2264	2237
62	2053	1521	2024	2442	2358	2393	2270	2438	2411	2398	2362	2212	2248
63	2153	2040	1878	2122	2207	2304	2240	2238	2263	2302	2283	2187	2200
64	e2378	2043	2049	e2201	2309	2453	2276	2241	2310	2121	2162	2133	2231
65	1894	1446	1693	2052	2204	2341	2323	2240	2321	2276	2179	2067	2067
66	e2028	1928	1850	e1964	2098	2182	2268	2256	2243	2228	2295	2272	2134
67	1881	1906	1641	e2118	2289	2427	2331	2420	2237	2231	2154	2096	2165
68	e2062	1733	2179	2095	2209	2366	2211	2180	2146	2064	2016	1998	2095
69	1844	1662	1907	1976	1848	2020	2184	2211	2192	2091	2121	2133	1994
1870	e2021	1757	1853	2154	2212	2254	2456	2451	2373	2248	2248	2310	2193
71	2089	1670	e2257	2170	2420	2448	2466	2415	2319	2186	2174	2234	2263
72	1995	2052	1934	e1998	2100	2217	2059	2132	2126	2146	2094	2005	2064
73	1796	1924	2099	e1991	1997	2133	2195	2201	2202	2141	2134	2067	2071
74	1470	1953	1947	2053	1996	2108	2168	2164	2200	2185	2183	2027	1988
75	2006	2045	2022	2027	2157	2157	2218	2175	2140	2177	2158	1980	2114
76	2060	2160	e2188	2240	1965	2311	2627	2618	2389	2252	2300	e2283	2307
77	e2271	1947	1942	1783	1799	2251	2300	2277	2164	2232	1943	2149	2043
78	2064	1518	1546	2217	2231	2271	2216	2230	2178	2168	2086	1855	2066
79	1771	1482	1849	2052	1940	2078	2104	2052	2068	1961	1978	1984	1943
1880	1931	1709	1903	1974	1963	2176	2005	2216	2183	2089	2053	2054	2028
81	1756	1998	1891	2035	2053	2182	2178	2209	2247	2137	2266	2232	2100
82	2225	2045	2194	2152	2268	2206	2380	2615	2321	2271	2251	e2139	2263
83	e2238	2226	1856	2155	2230	2434	2784	2716	2538	2402	2307	2211	2330
84	1514	1703	2426	2426	2444	2531	2611	2489	2410	2307	2336	2284	2230
85	e2208	2352	e2264	e2267	2288	2445	2276	2432	2296	2217	2276	2304	2304
86	1677	1490	2008	2116	2425	2432	2618	2405	2403	2364	2296	2403	2244
87	2289	2223	1985	2123	2202	2361	2319	2216	2233	2217	2109	2018	2204
88	2090	2086	1922	2104	2004	2130	2308	2177	2186	2131	2079	1992	2194
89	2089	1701	1716	1792	1934	2100	2086	2097	2113	2020	1998	1817	2004
1890	1940	1797	1745	1832	1839	1964	2046	2066	1994	1919	1880	1875	1955
91	1718	1809	1834	1830	1945	1885	1861	1982	1943	1878	1912	1873	1913
92	1683	1425	1508	1767	1787	1864	1908	1936	1951	1905	1843	1783	1844
93	1464	1514	1851	1883	1817	1950	2047	2052	2034	1988	1990	1955	1879
94	1676	1656	1877	1867	1981	2045	2048	2051	2026	1971	1952	1882	1940
95	e1878	e1942	1985	1733	1814	1861	1896	1895	1868	1794	1722	1748	1837
96	1736	1410	1840	1981	1985	1791	1885	1866	1837	1942	1940	1882	1736
97	1925	e1784	1907	1849	1850	1871	1991	1932	1926	1886	1916	1907	1891
98	1756	1482	1386	1946	1818	1899	1946	1931	1904	1899	1909	1904	1889
99	1947	e1836	1366	1685	1812	1925	2022	2031	2015	1923	1953	1922	1856
1900	1736	1778	1874	1780	1796	1868	1912	1957	1978	1953	1974	1911	1878
01	1719	1410	1548	1181	1706	1899	2052	2084	2039	1982	1993	1935	1798
02	1822	1464	1827	1816	1818	1926	2064	2005	1944	1905	1846	1919	1838
03	1966	1851	1857	1879	1909	1911	1968	1978	1967	1900	1910	2138	1937
04	1812	1663	e1825	2035	1909	2031	2063	2103	2079	2035	1992	2019	1950
05	1840	1534	1676	1947	1922	2066	2118	2134	2064	2052	2004	1942	1922
06	1991	1846	1600	1905	1990	2024	2089	2083	2030	2021	1994	1895	1933
07	1779	1711	1749	1931	1982	1990	2075	2026	2047	2017	1961	1983	1934
Mean	1916	1786	1865	1996	2047	2143	2196	2197	2157	2110	2075	2042	2043

e—St. Clair River discharge used.

TABLE 21.

DISCHARGE FROM LAKE ERIE.

Monthly mean outflow from Lake Erie, through Niagara River, in 100 cubic feet per second.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	2321	2178	2365	2423	2475	2486	2426	2375	2304	2244	2248	2256	2324
61	2161	2045	2126	2275	2485	2521	2474	2436	2431	2387	2410	2401	2347
62	2245	2237	2259	2471	2521	2551	2562	2439	2378	2294	2287	2291	2394
63	2272	2290	2261	2375	2418	2400	2367	2346	2264	2173	2101	2137	2311
64	2041	2035	2061	2157	2332	2257	2268	2205	2165	2105	2091	2153	2162
65	2022	1846	1904	2060	2183	2195	2201	2165	2171	2112	2060	2061	2080
66	1971	1887	1942	2077	2125	2206	2245	2189	2160	2151	2150	2197	2112
67	2005	1975	2055	2112	2224	2230	2206	2203	2123	2068	1970	1964	2119
68	1891	1765	1878	2048	2149	2261	2270	2125	2077	1987	1976	1973	2035
69	1941	1878	1973	2025	2149	2261	2242	2204	2251	2187	2078	2203	2150
1870	2239	2231	2164	2206	2256	2285	2294	2251	2214	2234	2188	2206	2279
71	2123	1967	2068	2185	2243	2273	2263	2215	2188	2045	2039	1973	2137
72	1935	1838	1796	1835	1917	2016	2026	2005	1995	1941	1883	1885	1919
73	1835	1792	1796	2061	2217	2265	2267	2231	2180	2094	2072	2206	2081
74	2209	2237	2221	2246	2267	2301	2327	2267	2170	2079	2009	2005	2199
75	1922	1840	1860	1939	2052	2149	2187	2176	2157	2056	2047	2143	2042
76	2102	2183	2332	2446	2538	2578	2547	2495	2435	2317	2285	2237	2387
77	2196	2105	2041	2124	2181	2217	2204	2209	2234	2152	2159	2235	2161
78	2213	2106	2213	2286	2256	2275	2286	2217	2266	2227	2206	2271	2250
79	2137	2065	2051	2118	2149	2167	2212	2140	2077	2033	1966	2010	2068
1880	2148	2103	2134	2145	2207	2251	2291	2213	2172	2061	2066	2043	2154
81	1931	1905	1966	2112	2205	2201	2264	2182	2119	2121	2105	2200	2118
82	2262	2220	2230	2267	2416	2474	2474	2416	2262	2265	2213	2125	2330
83	2064	2061	2115	2136	2234	2437	2500	2462	2397	2332	2265	2230	2279
84	2209	2215	2246	2270	2426	2475	2426	2375	2261	2215	2126	2155	2296
85	2061	1984	1941	2112	2286	2434	2441	2438	2400	2290	2267	2422	2213
86	2286	2159	2103	2256	2372	2416	2436	2357	2267	2287	2232	2246	2290
87	2161	2212	2263	2272	2427	2465	2423	2322	2264	2256	2135	2170	2297
88	2094	1964	1971	2131	2187	2197	2251	2225	2142	2098	2064	2133	2117
89	2081	2041	1963	2088	2075	2186	2196	2174	2084	1970	1970	2041	2066
1890	2178	2138	2191	2261	2342	2436	2384	2327	2152	2130	2196	2133	2233
91	2072	2046	2077	2106	2084	2060	2091	2025	1966	1903	1891	1897	2014
92	1878	1733	1775	1864	2054	2246	2280	2205	2143	2065	1978	1973	2035
93	1906	1796	1861	2006	2174	2258	2234	2096	2038	2006	2001	1963	2025
94	1903	1906	1931	1974	2088	2181	2180	2040	2002	2003	1962	1923	2013
95	1896	1749	1733	1777	1860	1873	1867	1838	1842	1792	1691	1744	1804
96	1775	1760	1667	1796	1891	1896	1933	1983	1891	1838	1842	1797	1840
97	1875	1761	1886	2004	2101	2097	2088	2066	1984	1886	1395	1921	1946
98	1893	1870	1951	2088	2119	2138	2077	2088	1981	1943	1945	1978	2005
99	1974	1875	1939	1973	2016	2079	2066	1983	1941	1880	1866	1964	1951
1900	1891	1878	1923	1999	2086	2064	2081	2094	1978	1893	1927	1912	1966
01	1876	1755	1712	1760	1796	1896	1936	1897	1906	1881	1831	1837	1837
02	1836	1706	1739	1855	1908	1975	2130	2110	2051	2052	1995	2009	1945
03	1961	1887	1993	2154	2139	2184	2194	2110	2068	2045	1946	1995	2040
04	1762	1813	1991	2170	2252	2217	2264	2225	2157	2108	2053	1993	2035
05	1908	1797	1816	1917	2049	2186	2264	2209	2161	2112	2089	2086	2042
06	2028	1936	1980	1977	2025	2075	2091	2078	2028	2020	2086	2068	2021
07	2185	2070	2014	2106	2157	2220	2276	2200	2148	2145	2126	2108	2148
Mean	2060	1981	2012	2116	2192	2251	2283	2203	2152	2095	2063	2063	2122

Discharge values include a flow of 1000 c. f. s. through Erie Canal, and one of 1100 c. f. s. through Welland Canal.

TABLE 22.

DISCHARGE FROM LAKE ONTARIO.

Monthly mean outflow from Lake Ontario, through St. Lawrence River, in 100 cubic feet per second.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
1860	2630	2681	2699	2690	3583	3062	3148	3060	3027	2767	2794	2678	2916
61	2567	2515	2754	2836	3267	3390	3313	3215	3072	3141	3147	2949	3022
62	2789	2656	2908	3103	3512	3404	3484	3330	3075	2900	2788	2642	3094
63	2699	2696	2725	2956	3218	3267	3128	3077	2850	2790	2722	2619	2887
64	2544	2496	2522	2696	3146	3346	3140	3089	2834	2740	2730	2652	2811
65	2778	2626	2872	3000	3079	3083	3040	3042	2889	2584	2501	2350	2794
66	2396	2288	2397	2432	2665	2643	2832	2791	2772	2720	2655	2505	2556
67	2433	2426	2642	2629	2278	2370	2243	2090	2896	2689	2445	2111	2787
68	1689	2040	2126	2300	2605	2725	2699	2909	2552	2370	2536	2266	2361
69	2223	2257	2323	2480	2794	3076	3091	3029	2983	2845	2717	2652	2712
1870	2748	[2]3040	[2]2760	3232	3505	3441	3432	3296	2706	2681	2586	2400	2944
71	2471	2619	2463	2668	2722	3131	3021	2957	2749	2722	2561	2132	2636
72	[2]2662	[2]1873	[2]1945	2114	2448	2453	2675	2665	2788	2566	2177	1978	2294
73	1967	1902	2019	2592	3016	3121	3183	2746	2613	2466	2447	2351	2547
74	2351	[2]2623	2549	2612	2933	2960	3045	3039	2962	2851	2877	2166	2707
75	[2]1549	[2]1579	[2]1631	2435	2438	2440	2484	2478	2230	2329	2402	2363	2344
76	2389	[2]2478	[2]2563	2861	3041	3033	3112	3164	3042	2672	2638	2748	2820
77	[2]2100	2337	[2]2452	2706	2546	2560	2424	2394	2380	2686	2433	2345	2464
78	[2]2273	[2]2342	2493	2670	2270	2678	2990	2920	2816	2792	2786	2711	2656
79	[2]2396	[2]2278	[2]2361	2650	2950	2882	2737	2584	2739	2734	2597	2946	2696
1880	2184	2424	2355	2513	2399	2896	2710	2597	2449	2276	2312	2152	2429
81	[2]1736	[2]1722	[2]2230	2646	2841	2710	2899	2805	2278	2345	2313	2261	2446
82	[2]2042	[2]2267	2553	2579	2975	2901	2970	2907	2948	2670	2596	2355	2684
83	[2]1950	[2]1872	[2]2313	2411	2527	2862	2180	2141	2001	2986	2884	2802	2342
84	[2]2184	[2]2234	[2]2726	3039	3348	3294	3153	2944	2962	2876	2857	2454	2915
85	[2]2270	[2]2131	[2]2197	2600	2771	2885	2920	2854	2792	2764	2677	2570	2642
86	[2]2767	[2]2397	[2]2983	3159	3206	3172	3140	2928	2780	2539	2350	2614	2942
87	[2]2460	[2]2650	[2]2796	3075	3312	3074	3[illegible]5	2842	2694	2685	2519	2449	2782
88	2235	[2]1996	[2]2072	2555	2500	2835	2599	2615	2311	2473	2473	2266	2393
89	2405	[2]2307	[2]2263	2594	2801	2878	2619	2764	2571	2664	2228	2264	2506
1890	[2]2589	2614	[2]2743	2890	3128	3030	3158	2643	2966	2816	2856	2501	2835
91	[2]2404	[2]2425	[2]2649	3122	3083	2986	3530	2374	2282	2440	2399	2093	2531
92	[2]2089	[2]1951	[2]1974	2392	2710	2549	2400	2436	2655	2287	2232	2304	2306
93	[2]1752	[2]1915	[2]2077	2353	2040	2894	2980	2826	2605	2519	2400	2230	2434
94	2297	[2]1990	[2]2426	2672	2867	2796	2746	2500	2410	2319	2136	2206	2440
95	1980	[2]1859	[2]1774	2034	2197	2302	2134	2006	1666	1794	1710	1625	1916
96	[2]1825	1923	[2]1956	2230	2252	2305	2130	2083	1985	1994	1754	1645	2002
97	1890	[2]1783	[2]1976	2022	2321	2198	2280	2200	2215	1972	2105	2120	2096
98	[2]2074	[2]2143	2191	2560	2878	2886	2801	2501	2572	2527	2390	2069	2435
99	2078	[2]2063	2100	2389	2644	2634	2808	2434	2294	2180	2133	2034	2306
1900	2023	[2]2063	[2]1566	2005	2781	2578	2530	2530	2141	2135	2151	2226	2286
01	[2]2151	1896	1998	2384	2442	2535	2404	2414	2305	2235	2182	2133	2260
02	[2]1780	[2]1522	[2]2130	2227	2411	2434	2590	2573	2451	2527	2196	2265	2242
03	[2]2070	2049	2236	2746	2711	2661	2789	2673	2672	2389	2272	2176	2437
04	[2]1973	1940	2043	2260	2675	2668	2767	2604	2726	2640	2605	2160	2470
05	[2]1966	[2]1779	[2]1886	2211	2449	2066	2643	2776	2671	2475	2536	2220	2350
06	[2]2403	2344	2191	2518	2529	2527	2606	2551	2464	2263	2249	2239	2414
07	[2]2366	[2]2307	[2]2291	2664	2741	2730	2743	2672	2590	2609	2467	2294	2513
Mean	2250	2188	2333	2606	2795	2835	2836	2750	2621	2536	2450	2341	2544

Note—21, 24 and 27 indicate that St. Lawrence River discharges were derived from gage observations taken at Locks 21, 24 and 27, respectively.

WILLIAMS EXHIBIT 34.

CONSISTING OF

A series of Tables, Charts and Plates based on Williams Exhibits 1 to 33 incl., and 35 in this case, and the Records of United States Lake Survey, Reports of the Chief of Engineers, U. S. A., of the United States Geological Survey and of the United States Weather Bureau; and of Officials of certain States and Municipalities.

Compiled under the direction of
GARDNER S. WILLIAMS.

Sheet No. 1.

CHICAGO SANITARY DISTRICT.

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Williams Ex. 34. Table 1

Chicago Sanitary District

St. Clair Discharge Observations

Showing variation of Q for same elevations.
Huron by Harbor Beach Gage.
St. Clair by St. Clair Flats Gage

No.	Huron Elevation	St. Clair Elevation	Discharge	Difference	Per. cent Variation from Mean
29 57	581.19	575.36	206600 205300	1300	0.364
32 41	581.22		210300 209300	1000	0.237
19 117	580.68	575.36	193900 192900	1000	0.258
113 207	580.69		199200 192800	3400	0.890
16 53	580.91		206700 200700	6000	1.473
12 153 124	580.62	575.26	199000 191600 190400	7400 9600 1200	1.834 4.209 0.314
119 120	580.81		197900 197000	1900	0.496
222 233	580.59	575.21	190100 188000	2100	0.555
96 279	580.30	575.16	182400 179000	3400	0.940
99 100	580.31		188200 182200	6000	1.619
237 236	580.32		189500 184700	4800	1.307
47 36	581.02		206400 204300	2100	0.511
179 181 183	580.92	574.96	207900 206100 203600	1200 1300 2500	0.289 0.413 0.601
133 136	580.60	574.86	198400 197200	1200	0.304
138 140 142	580.48	574.81	196600 190000 190200	600 6700 3800	0.134 1.633 1.302
Mean			195900	3305	

1632 Aver. variation from mean discharge = 0.844 %.

Williams Ex. 34 — Chicago Sanitary District. — Table II

St. Clair Discharge Observations

Showing variation of Q for same elevations.

Huron by Grand Trunk Gage

St Clair by St Clair Flats Gage

1899, 1900, 1901 App. EEE Page 2835 1902

Nos.	Huron Elevation	St. Clair Elevation	Discharge	Diff.	Percent Variation from Mean
33	579.362	575.20	191600		
34	.359		190400	1200	0.314
15a	579.379	575.30	196400		
19a	.376		193300	3100	0.796
29	579.493	575.20	192900		
30	.486		191000	1900	0.496
17a	579.558	575.30	205900		
52a	.560		199900	6000	1.478
21	579.656	575.30	199300		
23a	.655		205100	5800	1.433
27a	579.709	575.50	205300		
35a	.786		196700	8600	2.140
33a	579.847	575.50	206000		
34a	.850		206800	800	0.194
24a	d579.850	575.40	207100		
45a	d .850		210900	3800	0.909
37a	579.883	575.50	205300		
38a	.883		208200	2900	0.702
29a	579.890	575.50	206800		
42a	d .890		208300	1500	0.361
30a	579.951	575.50	207200		
41a	d 950		209900	2700	0.647
3	579.081	575.10	188200		
8	.076		182400	5800	1.565
6	579.398	575.10	192900	1800	0.469
11	403		191100	400	0.104
56a	402		192500	1400	0.364
44	579.483	574.80	203400		
64a	484		209200	5800	1.407
133	579.484	574.75	212400		
135	484		213900	1500	0.352
75a	579.595	574.80	207200		
76a	596		212500	5300	1.263
Page 2832 1900 EEE Sandusky Gage	579.209 .20	575.10	*185000 178900		
Mean			201515	3350	

*Readings not used in getting mean.

*1875 Aver. variation from mean discharge = 0.631%

Williams Ex. 34 *Chicago Sanitary District* *Table III.*

Niagara Discharge Observations

Showing Variations of Q at Bridge Section

for Same Elevation of Lake Erie by Buffalo Gage

Nos	Erie Elevation	Discharge	Difference.	Percent Variation from Mean.
79 P	573.01	221,200 214,400	6800	1.561'
30 I	572.64	212,600 200,700	11800	2.835'
70 J	572.52	208,500 207,600	900	216'
~~28~~ ~~116~~	~~572.50~~	~~215,400~~ ~~193,000~~	~~21500~~	~~5.32~~
~~19~~ 121	~~572.36~~	~~208,000~~ ~~196,600~~	11300	~~2.810~~
6 36	572.03	195,800 193,500	2300	592'
7 12	571.96	195,000 195,000	000	000'
67 13	571.79	191,700 191,300	400	104'
73 10	571.74	192,400 188,500	3900	1.023'
69 45	571.66	193,500 189,000	4500	1.178'
64 24	571.65	190,000 188,700	1300	343'
42 41	571.61	189,700 184,900	4800	1.280'
~~119~~ ~~48~~	~~571.58~~	~~186,100~~ ~~180,500~~	~~5600~~	~~1.537'~~
~~114~~ 5	~~571.43~~	~~181,000~~ ~~180,600~~	~~400~~	~~111'~~
55 71 ~~90~~	571.44	185,700 184,900 ~~178,200~~	7100 2800 ~~7500~~	1.946 767 ~~1.989~~
56 40	571.41	182,200 180,200	2000	552'
~~120~~ ~~120~~ ~~95~~	~~571.38~~	~~181,000~~ ~~177,700~~ ~~177,100~~	~~3300~~ ~~1300~~ ~~3900~~	~~1.088~~ ~~428~~ ~~1.285~~
86 93	~~571.32~~	~~173,000~~ ~~165,700~~	~~7300~~	~~4.217'~~
~~99~~ ~~98~~	~~571.24~~	~~149,000~~ ~~137,400~~	~~500~~	~~1.137'~~
		4,674,900	81,500	
		~~4,618,300~~	~~196,300~~	
		~~190,330'~~	~~3700~~ ~~3,710~~	

94,787 Aver. variation from mean discharge of the mean discharge. 1,729 = 0.883%

Williams Ex 34 *Table III (a)*
Sheet 1

Chicago Sanitary District
Niagara Discharge Observations
Showing Variation of Q at Bridge Section For
Same Elevation of Lake Erie by Buffalo Gage

Nos	Erie Elevation	Discharge C.F.S.	Difference	Percent Variation from Mean
71'	573.69	234300		
84	69	234500	200	0.043
64'	573.54	228470	830	0.202
60'	54	230400	7370	1.632
58'	54	222100	6130	1.320
3'	54	235600	6300	1.833
			5200	1.116
			13300	2.950
46'	573.39	227050	1770	0.388
41'	39	226620	4700	1.025
70'	39	231750	7700	1.669
111'	39	234750	2930	0.636
			5830	1.280
			3000	0.644
65'	573.30	223360		
67'	30	230220	6840	1.510
42'	573.28	219030		
30'	28	219980	950	0.216
66'	573.27	220520		
116'	27	225050	4530	1.017
57'	573.23	220590		
68'	23	222770	2180	0.492
72'	573.21	221470		
98'	21	224840	3370	0.755
62'	573.20	226780	6370	1.425
91'	20	220410	1090	0.240
101'	20	227870	3960	0.880
102'	20	222020	7460	1.665
			2410	0.544
			5050	1.121
97'	573.18	226680	6310	1.413
107'	18	220370	7970	1.788
108'	18	218710	1660	0.370
99'	573.15	221770		
100'	15	226800	5030	1.121
2'	573.12	225850		
85'	12	222880	2970	0.668
74'	573.10	222480		
96'	10	221010	1470	0.332
78'	573.08	215200	6750	1.540
84'	08	221950	9810	2.229
93'	08	225010	4120	1.850
103'	08	223320	3060	0.686
			1370	0.308
			1690	0.377
58'	573.07	217380		
109'	07	221310	3930	0.895
79	573.01	221200		
p	01	214400	6800	1.581

* Indicates 1907-1908

Williams Ex. 34. Table III a
Sheet 2

Chicago Sanitary District.
Niagara Discharge Observations
Showing Variation of Q at Bridge Section for Same Elevation of Lake Erie by Buffalo Gage.

No.	Erie Elevation	Discharge C.F.S.	Difference	Percent Variation from Mean
87	573.00	218800	3920	1.335
37	.00	224720	3540	0.602
75*	.00	222340	2810	0.630
83*	.00	221610	460	0.105
92*	00	219340	2100	0.482
95*	00	216700	2380	0.532
			3170	0.697
			6360	1.440
			8020	1.820
			730	0.164
			4000	0.908
			5640	1.284
			3270	0.744
			4910	1.121
			1640	0.377
1*	57298	224070		
110*	98	223180	1110	0.248
42*	57291	218670		
77*	91	213930	4740	1.095
36*	57287	213380		
88*	87	208520	4860	1.152
53*	57285	206410		
89*	85	198760	7650	1.801
35*	57284	216660		
87*	84	213180	3540	0.824
23*	57282	213770		
81	82	212300	1430	0.333
39*	57281	213230		
7	81	211600	1570	0.367
90*	57272	213990		
122	72	213300	310	0.073
105*	57267	212960		
C	67	211900	1040	0.244
24*	57264	210540	1960	0.463
30	.64	212500	9840	2.360
7	64	200700	11800	2.855
7*	57261	211320		
48	61	209600	1720	0.408
3*	57257	216140	3590	0.860
12*	.57	205550	13040	3.125
4	.57	208100	9450	0.847
10*	57254	209230		
14*	54	207120	2110	0.506
70	57252	208500		
J	.52	207600	900	0.216
16*	57248	208220		
19*	48	208370	150	0.036
5*	57242	202510		
8	42	206200	3690	0.904

*Indicates 1907-1908.

Williams Ex. 34 Chicago Sanitary District. Table III
Niagara Discharge Observations Sheet 3
Showing Variation of Q at Bridge Section For
Same Elevation of Lake Erie by Buffalo Gage.

Nos	Erie Elevation	Discharge C.F.S.	Difference	Percent Variation from Mean
31*	57240	211080		
d	40	201600	9480	2.299
6*	57239	202870	7350	1.780
32*	39	210220	3230	0790
b	39	206100	4120	0990
28*	57238	208650	1130	0270
33*	38	209780	350	0.084
19	38	208300	1480	0.354
13*	57235	198900	5320	1.320
21*	35	204220	8000	1.971
18	35	206900	2680	0652
30*	572.32	208330		
47	32	201000	7330	1.791
6	572.03	195800		
35	03	193500	2300	0591
7	57196	195000		
12	96	195000	000	0.000
13	571.79	191300		
67	.79	191700	400	0104
10	571.74	188500		
73	.74	192400	3900	1024
21	571.73	187400		
29	.73	188800	1400	0372
27	57166	188000	1000	0265
45	66	189000	5500	1.442
68	66	193500	4500	1175
24	57165	186700		
66	65	190000	1300	0343
41	57161	184900		
42	61	189700	4800	1.280
71	57144	182900		
56	44	185700	2800	0760
26	57141	182200		
40	41	180200	2000	0552
		23,604,330		
		204,385	4,151	

* Indicates 1907-1908 2,076 Aver. variation from Mean = 1.016 % of the mean discharge

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Table IX

Chicago Sanitary District.
Niagara Discharge Observations
Showing Variations of Q at Open Section
For Same Elevation of Lake Erie by Buffalo Gage

N° Observation	Erie Elevation.	Discharge	Difference	Percent Variation from Mean
92	573.04	218,500		
108	.04	213,100	5400	1.25
64	572.89	216,400		
95	.89	215,200	1200	.278
83	.41	216,600		
98	.41	203,900	2700	.658
103	.28	200,700		
120	.28	199,600	1100	.275
6	.22	203,600		
121	.22	200,200	3400	.842
21	571.92	191,600		
28	.92	187,200	4400	1.162
5	.87	198,100		
20	.87	190,300	7800	2.007
27	.83	186,400		
86	.83	186,200	200	.054
14	.79	188,400		
16	.79	185,800	2600	.695
7	.77	189,900		
26	.77	188,800	1100	.290
80	.75	190,200		
15	.75	185,200	5000	1.33
19	.75	185,000	200	.054
10	.75	184,300	700	.190
85	.73	189,000	5700	1.58
12	.73	188,200	800	.212
77	.72	191,000		
25	.72	186,000	5000	1.335
53	.63	190,400		
13	.63	185,600	4800	1.276
42	.60	186,600		
22	.60	183,300	3300	.892
56	.57	183,400		
30	.57	183,400	000	.000
76	.56	188,400		
67	.56	184,200	4200	1.126
46	.53	183,200		
33	.53	181,600	1600	.438
53	.49	185,700		
18	.49	180,600	5100	1.392
45	.48	182,500		
69	.48	181,700	800	.220
78	.48	185,500		
84	.45	182,100	3400	.915
74	.43	182,200		
24	.43	178,100	4100	1.138
48	.42	183,100		
36	.42	181,600	1500	.411
52	.35	183,300		
41	.35	181,600	1700	.465
44	.33	180,200		
23	.33	176,000	4200	1.179
49	.32	179,600		
39	.28	176,700	2900	.814
		14,225,200	85900	
		189,356	2962	

1481 Aver. variation from Mean = 0.78 or 1% of the mean discharge

Williams Ex. 34. Table I

Chicago Sanitary District
St. Lawrence Discharge Observations.
Lake Ontario at Sarnia Elevation
Showing Variation in Q.

No Observations	Ontario Elev Ogdensburg	Discharge	Difference	Percent * Variation from Mean
75	245.09	249700		
78	.09	246100	3600	0.726
88	.06	253100		
61	.08	250700	2400	.476
85	.05	251500		
84	.05	251400	100	.020
82	.01	251900		
95	.01	250700	1200	.239
80	.01	249800	900	.179
05	.00	251100	2100	.419
63	.00	247300	3800	.702
07	244.99	251200		
86	.99	251700	900	.179
50	.97	252100		
68	.97	250400	1700	.339
64	.97	249400	1000	.200
92	.97	249300	100	.020
90	.94	250700	2800	.557
49	.94	249900	1800	.360
71	.94	249700	200	.040
96	.94	249700	0	.000
89	.93	251200	2000	.400
41	.93	250800	400	.080
48	.93	249000	1800	.360
72	.93	248800	200	.040
87	.92	248500	2400	.480
54	.92	248100	2400	.485
45	.92	245100	1000	.203
79	.91	250500	3400	.683
43	.91	248000	2500	.502
83	.90	251100		
42	.90	246900	4200	.844
70	.88	250000		
47	.88	249200	800	.160
77	.87	248900		
74	.87	245400	3500	.708
73	.84	249800		
60	.84	247700	2100	.424
76	.84	246000	1700	.342
55	.80	249800	2800	.566
58	.80	244.800	3700	.751
29	.04	221700		
31	.04	219400	2300	.522
12	243.94	219400		
6	.94	218300	1100	.251
10	.90	217700		
25	.90	215800	1900	.438
35	.91	218500		
30	.91	216700	1800	.413
11	.90	216500		
37	.90	215300	900	.209
		12398500	64500	
		243108	1792	

896 Aver. variation from Mean = 0.37 of 1% of the mean discharge

* Taken in pairs

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Table VI

Chicago Sanitary District
St. Clair River Observations.

Discharges measured at Gorge and Dry Dock Sections for similar Stages of Lakes Huron and St. Clair.

No.	Date	Huron	St. Clair	Gorge	Dry Dock
103	1910-6-23	580.35	575.67	193600	
104	6-23	.43	.66	192530	
93	6-18	.43	.67	191410	
101	6-20	.40	.66	190620	
95	6-18	.41	.67	190390	
97	6-18	.38	.67	189080	
113	7-1	.30	.59	188760	
102	6-20	.35	.66	188320	
84	6-18	.43	.67	187030	
106	6-30	.27	.66	186940	
100	6-20	.36	.66	186740	
105	6-29	.31	.66	186710	
112	7-1	.30	.66	186580	
92	6-17	.33	.66	186280	
91	6-17	.32	.67	185860	
108	7-30	.28	.63	185770	
96	6-18	.31	.66	185620	
107	7-30	.28	.67	185200	
115	7-1	.30	.67	185090	
99	6-20	.33	.66	184600	
110	6-30	.28	.66	184400	
111	7-1	.32	.64	184330	
114	7-1	.22	.64	183560	
109	6-30	.28	.66	182940	
98	6-20	.28	.66	179840	
Mean		580.338	575.661	186836	
296	1910-6-24	580.46	575.66		199060
287	6-24	.41	.67		195380
285	6-24	.42	.66		193480
304	6-28	.30	.64		192300
280	6-21	.30	.64		192230
284	6-23	.43	.63		190240
307	6-29	.33	.64		189460
281	6-21	.41	.66		189260
283	6-23	.41	.66		188200
297	6-27	.30	.66		187580
279	6-21	.34	.63		187360
291	6-22	.27	.65		186230
301	6-27	.32	.63		185900
303	6-27	.28	.64		184860
318	7-2	.26	.64		183280
290	6-22	.29	.63		182870
Mean		580.378	575.659		189393
67	1910-5-18	580.41	.57	190920	
119	7-3	.27	.64	188740	
63	5-18	.43	.59	188070	
82	5-28	.34	.59	186610	
116	7-3	.28	.64	186240	
118	7-3	.26	.64	183960	
117	7-3	.28	.66	183010	
Mean		580.280	.616	186516	
300	1910-6-25	.32	.68		193080
289	6-25	.37	.67		186670
311	7-22	.23	.67		186900
310	7-21	.16	.62		178570
Mean		.280	.648		186280

Williams Ex. 34. Table VI (con)

Chicago Sanitary District
St. Clair River Observations.

Discharges measured at Gorge and Dry Dock Sections for similar Stages of Lakes Huron and St. Clair.

No.	Date	Huron	St. Clair	Gorge	Dry Dock
314	1910-8-2	580.31	575.62		187660
311	7-27	.25	.62		186900
308	7-9	.26	.63		185980
313	7-23	.29	.62		185980
312	7-23	.21	.60		185380
315	8-2	.29	.62		185120
307	7-9	.19	.64		181460
310	7-21	.16	.62		178520
Mean		580.247	575.624		183875
120	1910-7-3	.33	.65	190280	
121	7-3	.36	.65	189120	
122	7-3	.25	.65	184910	
		.313	.650	188103	
44	1909-11-6	580.00	575.09	183700	
42	11-6	.01	.08	181000	
43	11-6	579.97	.09	180800	
45	11-6	.97	575.10	180600	
Mean		579.988	575.090	181525	
09-3	1909-11-16	579.92	5.17		187600
09-6	11-19	9.88	5.03		183800
09-22	11-30	9.82	5.12		178700
09-23	11-30	9.80	5.11		178700
09-5	11-19	9.78	5.10		176600
09-21	11-30	9.79	5.12		176100
09-4	11-16	9.56	5.13		171000
Mean		579.807	5.111		178929

Williams Ex. 34. Chicago Sanitary District Table VII

St. Clair River Observations

Comparison of Discharge at Gorge and Dry Dock Sections in 1908-9 and 10 for similar stages of Lakes Huron and St. Clair

Increment due 1 foot Huron Change 36000 c.f.s

Increment due 1 foot St. Clair Change 12000 c.f.s

BY GROUPS

No. Obs.	Huron Elevation	St. Clair Elevation	Observed Gorge Discharge c.f.s.	Observed Dry Dock Discharge c.f.s.	Correction to Dry Dock Sect.	Corrected Dry Dock	Difference c.f.s.
25 10	580.332 0.378	573.661 3.639	186836	189393	-1404-24 = -1428	187965	-1109
7 4	580.280 0.280	573.616 3.648	186316	186280	-288+384 = +96	186376	+140
8 3	580.310 0.242	573.630 3.624	188103	183879	+2358-312 = +2244	186119	+1984
4 1	579.988 5.601	573.090 3.111	181525	178929	+6516+252 =6768	185697	-4172
		Arithmetic mean difference					1851

BY SINGLE OBSERVATIONS

Obs.	Huron Elevation	St. Clair Elevation	Observed Gorge Discharge c.f.s.	Observed Dry Dock Discharge c.f.s.	Correction to Dry Dock	Corrected Dry Dock Discharge	Difference c.f.s.
1	580.40 Jun 40	573.66 573.63	190620	192300	0-120 =-120	192180	-1560
2	580.30 0.30	573.63 3.63	188760	188380	0	188380	+380
3	580.29 0.29	573.67 3.67	183860	184860	0	184860	+1000
4	580.28 0.29	573.66 3.63	184400	182870	-360-120 =-480	182390	+2010
5	580.43 0.43	573.66 3.63	192530	190240	0-120 =-120	190120	+2410
6	580.27 0.27	573.64 3.63	188780	188250	0+120 =+120	188330	+450

Table VIII

Chicago Sanitary District
Niagara River

Comparison of Gagings at Bridge and Open Sections, for same Stages of Lake Erie by Buffalo Gage.

Bridge Section		Open Section		Difference		Diff. %	
No.	Discharge	No.	Discharge	+	−	+	−
			I-1899 only.				
110	176200	69	174400	1800		1.03	
109	178600	50	179400		800		0.45
108	176400	49	179600		3200		1.78
101	177500	75	181900		4400		2.42
~~97~~	~~177100~~	~~28~~	~~176000~~				
~~100~~	~~179700~~	~~44~~	~~180200~~				
~~102~~	~~181000~~		~~178100~~	~~1167~~		~~0.66~~	
	179267						
113	174900	52	183500		8600		4.69
~~91~~	~~178600~~	~~37~~	~~181400~~		~~2800~~		~~1.54~~
~~114~~	~~181000~~	~~73~~	~~185600~~				
		~~54~~	~~182100~~				
			~~183800~~		~~2800~~		~~1.52~~
~~119~~	~~185200~~	~~6~~	~~203600~~		~~18400~~		~~9.94~~
			Mean	~~1484~~	~~5867~~	~~0.81~~	~~3.66~~
			Algebraic Mean	-166	~~-4382~~		

Williams Ex. 34. Chicago Sanitary District Table IX
Niagara River

Comparison of Gagings at Bridge and Open Sections, for some stages of Lake Erie by Buffalo Gage

Bridge Section		Open Section		Difference		Diff %	
No.	Discharge	No.	Discharge	+	−	+	−
		II 1898-1899					
26	182200						
40	180200						
Mean	181200	51	185000		3800		2.06
22	181900	56	181600	300		0.17	
		53	178100				
72	183500	74	182200				
Mean	183500		180150	3350		1.86	
56	185700	57	181400	4300		2.37	
		75	183900				
5	180600	64	182100				
Mean	180600		183000		2400		1.31
		45	182900				
23	184800	60	181700				
Mean	184800		182300	2500		1.35	
		46	183200				
54	186200	33	181400				
Mean	186200		181800	4400		2.37	
		67	184200				
77	186800	76	188400				
Mean	186800		186300	500		0.27	
		38	183400				
32	188300	36	185400				
Mean	188300		184400	3900		2.07	
		22	183300				
59	188000	42	186600				
Mean	188000		184950	3050		1.65	
78	188100	13	183600	4500		2.44	
11	190400	86	183200	7200		3.78	
24	188700						
86	190800						
Mean	189350	17	182500	6850		3.78	
27	188000						
45	189000						
68	189200						
Mean	190067	54	186300	3767		2.00	
46	192200	61	184700	7500		4.06	
12	189100	9	184700	4400		2.38	
		25	186000				
28	188800	77	191800				
Mean	188800		188900	00		0.00	
21	187400	12	186200				
29	192800	65	189000				
Mean	190100		186600		500		0.27
17	190400	10	182300				
		18	185200				
		19	185000				
		80	190200				
Mean	190400		186175	4225		2.27	
18	191700	7	189900				
		66	184800				
Mean	191100		189350	1750		0.92	
73	191300	14	186200				
67	191700	16	186800				
Mean	191500		187100	4401		2.35	
34	186500	1	191300		5000		2.32
82	193000	87	186200				
		86	186200				
Mean	189600		186300	4700		2.60	
65	191700	5	191700				
		20	190300				
Mean	191700		190800	2900		1.49	
20	193600	78	192500	1500		0.67	
			Mean	3445	2626	1.86	1.41
			*Algebraic Mean			1.26	

Williams Ex. 34 Table X

Chicago Sanitary District
Niagara River

Comparison of Gagings at Bridge and Open Sections, for same Stages of Lake Erie by Buffalo Gage

Bridge Section		Open Section		Difference		Diff. %	
No.	Discharge	No.	Discharge	+	−	+	−
		III	1898-1900				
9	203700	106	195800				
		111	194400	8600		4.41	
			193100				
47	201000	97	201600		600		0.30
1	202400	112	200700	1700		0.85	
18	206900	116	201300	5600		2.70	
19	208300	109	199300	9000		4.50	
6	206100	118	201600	4500		2.24	
79	208300	110	203200				
J	207600						
	206030			4830		2.38	
82	218000	102	203900	9100		4.42	
0	207900	105	205000	2300		1.12	
			Mean	5706	600	2.84	0.30
			Algebraic Mean			249	

		IV	1899-1900				
~~119~~	~~193200~~	~~121~~	~~200200~~		~~13000~~		~~7.50~~
121	195600	116	201300		5700		2.89
124	212500	91	215900		3400		1.50
			Mean		~~4350~~ 4533		~~2.70~~ 2.97
			Algebraic Mean				~~2.97~~ 2.81

Williams Ex. 34

Chicago Sanitary District

Q for Niagara River, Bridge Section

(H=571, Q=175,000, A=21900)

Table XI

Date Year	Date Month	Gage Height Buffalo	Discharge C.F.S.	Date Year	Date Month	Gage Height Buffalo	Discharge C.F.S.	Date Year	Date Month	Gage Height Buffalo	Discharge C.F.S.
1900	Jan.	571.67	197,675	1901	Jan.	571.99	199,140	1902	Jan.	571.41	194,200
	Feb.	571.67	197,675		Feb.	571.99	199,140		Feb.	571.41	194,200
	March	571.67	197,675		March	571.99	199,140		March	571.41	194,200
	April	571.67	197,675		April	571.99	199,140		April	571.41	194,200
	May	571.67	197,675		May	571.99	199,140		May	571.41	194,200
	June	571.67	197,675		June	571.99	199,140		June	571.41	194,200
	July	571.67	197,675		July	571.99	199,140		July	571.41	194,200
	Aug.	571.67	197,675		Aug.	571.99	199,140		Aug.	571.41	194,200
	Sept.	571.67	197,675		Sept.	571.99	199,140		Sept.	571.41	194,200
	Oct.	571.67	197,675		Oct.	571.99	199,140		Oct.	571.41	194,200
	Nov.	571.67	197,675		Nov.	571.99	199,140		Nov.	571.41	194,200
	Dec.	571.67	197,675		Dec.	571.99	199,140		Dec.	571.41	194,200
		572.01	197,090			572.42	206,000			572.32	208,300
1903	Jan.	571.80	195,675	1904	Jan.	571.00	178,315	1905	Jan.	571.74	191,233
	Feb.	571.80	195,675		Feb.	571.00	178,315		Feb.	571.74	191,233
	March	571.80	195,675		March	571.00	178,315		March	571.74	191,233
	April	571.80	195,675		April	571.00	178,315		April	571.74	191,233
	May	571.80	195,675		May	571.00	178,315		May	571.74	191,233
	June	571.80	195,675		June	571.00	178,315		June	571.74	191,233
	July	571.80	195,675		July	571.00	178,315		July	571.74	191,233
	Aug.	571.80	195,675		Aug.	571.00	178,315		Aug.	571.74	191,233
	Sept.	571.80	195,675		Sept.	571.00	178,315		Sept.	571.74	191,233
	Oct.	571.80	195,675		Oct.	571.00	178,315		Oct.	571.74	191,233
	Nov.	571.80	195,675		Nov.	571.00	178,315		Nov.	571.74	191,233
	Dec.	571.80	195,675		Dec.	571.00	178,315		Dec.	571.74	191,233
		571.90	194,780			572.33	204,220			572.33	204,220

Mean Q, 1900 to 1904 = 198,068 c.f.s.

Mean Q, 1900 to 1907 = 201,436 c.f.s.

Date Year	Date Month	Gage Height Buffalo	Discharge C.F.S.	Date Year	Date Month	Gage Height Buffalo	Discharge C.F.S.	Date Year	Date Month	Gage Height Buffalo	Discharge C.F.S.
1906	Jan.	572.33	204,125	1907	Jan.	572.20	202,465	1908	Jan.	572.80	214,365
	Feb.	572.33	204,125		Feb.	572.20	202,465		Feb.	572.80	214,365
	March	572.33	204,125		March	572.20	202,465		March	572.80	214,365
	April	572.33	204,125		April	572.20	202,465		April	572.80	214,365
	May	572.33	204,125		May	572.20	202,465		May	572.80	214,365
	June	572.33	204,125		June	572.20	202,465		June	572.80	214,365
	July	572.33	204,125		July	572.20	202,465		July	572.80	214,365
	Aug.	572.33	204,125		Aug.	572.20	202,465		Aug.	572.80	214,365
	Sept.	572.33	204,125		Sept.	572.20	202,465		Sept.	572.80	214,365
	Oct.	572.33	204,125		Oct.	572.20	202,465		Oct.	572.80	214,365
	Nov.	572.33	204,125		Nov.	572.20	202,465		Nov.	572.80	214,365
	Dec.	572.33	204,125		Dec.	572.20	202,465		Dec.	572.80	214,365

Williams Ex. 34. Chicago Sanitary District Table III

Q for Niagara River Open Section

H=571, Q=172600, Δ=21,840

Lake Erie Elevations from Report of International Waterways Comm. 910

Date Year	Month	Gage Height Buffalo	Discharge C.F.S.
1900	Jan.	571.67	187100
	Feb.	571.67	187100
	March	571.67	187100
	April	571.67	187100
	May	571.67	187100
	June	571.67	187100
	July	571.67	187100
	Aug.	571.67	187100
	Sept.	571.67	187100
	Oct.	571.67	187100
	Nov.	571.67	187100
	Dec.	571.67	187100
1901	Jan.	572.01	194415
	Feb.	571.91	192600
	March	571.91	192600
	April	571.91	192600
	May	571.91	192600
	June	571.91	192600
	July	571.91	192600
	Aug.	571.91	192600
	Sept.	571.91	192600
	Oct.	571.91	192600
	Nov.	571.91	192600
	Dec.	571.91	192600
1902	Jan.	571.41	187380
	Feb.	571.41	187380
	March	571.41	187380
	April	571.41	187380
	May	571.41	187380
	June	571.41	187380
	July	571.41	187380
	Aug.	571.41	187380
	Sept.	571.41	187380
	Oct.	571.41	187380
	Nov.	571.41	187380
	Dec.	571.41	187380
1903	Jan.	571.99	194020
	Feb.	571.99	194020
	March	571.99	194020
	April	571.99	194020
	May	571.99	194020
	June	571.99	194020
	July	571.99	194020
	Aug.	571.99	194020
	Sept.	571.99	194020
	Oct.	571.99	194020
	Nov.	571.99	194020
	Dec.	571.99	194020
1904	Jan.	572.42	203295
	Feb.	572.13	199800
	March	572.13	199800
	April	572.13	199800
	May	572.13	199800
	June	572.13	199800
	July	572.13	199800
	Aug.	572.13	199800
	Sept.	572.13	199800
	Oct.	572.13	199800
	Nov.	572.13	199800
	Dec.	572.13	199800
1905	Jan.	571.78	197000
	Feb.	571.78	197000
	March	571.78	197000
	April	571.78	197000
	May	571.78	197000
	June	571.78	197000
	July	571.78	197000
	Aug.	571.78	197000
	Sept.	571.78	197000
	Oct.	571.78	197000
	Nov.	571.78	197000
	Dec.	571.78	197000
1906	Jan.	571.28	193570
	Feb.	571.74	196610
	March	571.74	196610
	April	571.74	196610
	May	571.74	196610
	June	571.74	196610
	July	571.74	196610
	Aug.	571.74	196610
	Sept.	571.74	196610
	Oct.	571.74	196610
	Nov.	571.74	196610
	Dec.	571.74	196610
1907	Jan.	572.33	201470
	Feb.	572.33	201470
	March	572.33	201470
	April	572.33	201470
	May	572.33	201470
	June	572.33	201470
	July	572.33	201470
	Aug.	572.33	201470
	Sept.	572.33	201470
	Oct.	572.33	201470
	Nov.	572.33	201470
	Dec.	572.33	201470
1908	Jan.	572.28	211500
	Feb.	572.28	211500
	March	572.28	211500
	April	572.28	211500
	May	572.28	211500
	June	572.28	211500
	July	572.28	211500
	Aug.	572.28	211500
	Sept.	572.28	211500
	Oct.	572.28	211500
	Nov.	572.28	211500
	Dec.	572.28	211500

Mean Q, 1900 to 1904 = 195,390 c.f.s. Mean Q, 1900 to 1907 = 198,708 c.f.s.

Williams Ex. 34. Chicago Sanitary District Table XLII

St. Clair River Equation
1899, 1900 and 1902
By Complainant's Groups

Letter	Huron	Coordinate Elevation	Q	Coordinate Q
A	579.93		179,200	
B	580.15		183,200	
C	27		184,900	
D	34	580.39	189,100	188,380
E	41		186,300	
F	46		186,600	
G	50		194,200	
H	57		191,100	
I	61		194,200	
J	65	580.69	195,000	195,719
K	70		196,200	
L	74		197,000	
M	78		198,000	
N	82		195,600	
O	88		198,900	
P	95	580.97	201,800	202,391
Q	581.01		203,400	
R	07		206,400	
S	13		207,600	
T	21		207,800	
U	34		213,600	

$X = 24,157Y - 13,832,100$

Williams Ex. 34. Table XIV

Chicago Sanitary District.

St. Clair River Equation.
1899, 1900, 1902 and 1908
By Complainant's Groups

Letter.	Huron	Coordinate Elev.	Q	Coordinate Q
A	579.93		179,200	
B	580.15		183,200	
Z	.17		182,500	
C	.27		184,900	
D	.34		189,100	
E	.41	580.36	186,300	187482
F	.46		186,600	
G	.50		194,200	
H	.57		194,100	
K	.59		194,000	
I	.61		194,200	
J	.65	580.66	195,000	194,939
R	.70		196,200	
L	.74		197,800	
M	.78		198,800	
N	.82		195,600	
O	.88		198,900	
P	.95		201,800	
Q	581.01	580.94	203,400	201775
R	.07		204,400	
S	.13		207,600	
T	.21		207,800	
U	.34		211,600	

X = 24,643Y - 14,114,330

Williams Ex. 34 *Table XV*

Chicago Sanitary District
St. Clair River Equation.
1899, 1900, 1901, 1902 and 1908
By Complainant's Groups

Letter	Huron	Coordinate Elevation.	Q Corr. Value 1901.	Coordinate Q	Observed Q	Coordinate Observed Q
A	579.93		179,200		179,200	
B	580.15		183,200		183,200	
Z	.17		182,500		182,500	
C	.27		184,900		184,900	
D	.34	580.388	189,100	188,108	189,100	188,731
E	.41	580.412	186,300		186,300	
F	.46		186,600		186,600	
G	.50		194,200		194,200	
H	.57		191,100		191,100	
α	.59		191,000		191,000	
I	.61		194,200		194,200	
J	.65	580.703	195,000	195,826	195,000	196,907
K	.70		196,200		196,200	
V	.69	580.709	196,200		202,800	
L	.74		197,000		197,000	
M	.78		198,000		198,000	
N	.82		195,600		195,600	
O	.88		198,900		198,900	
W	.88		201,300		202,700	
P	.95	580.956	201,800	202,000	201,800	204,300
X	.98	580.974	202,500		209,000	
Q	581.01		203,400		203,400	
R	.07		206,400		206,400	
S	.13		207,600		207,600	
Y	.16		203,700		213,400	
T	.21		207,800		207,800	
U	.34		213,600		213,600	

$X = 24,438y - 14,007,000$ Corrected values of 1901.

$X' = 28,059y - 16,097,050$ Measured values of 1901.

Williams Ex 34 Table XVI

Chicago Sanitary District.

Weighted Elevations, and Differences

For Lakes Huron and Erie During Discharge Measurements

Monthly Mean Elevation Used

1899-1908 inclusive

Year	Mo.	Huron Elevation	Erie Elevation	Diff	No. Gagings	Weighted Difference	Mean Diff.	Weighted Huron Elevation	Weighted Erie Elevation
1899	May	580.40	572.44	7.96	10	79.60		5804.00	5724.40
	June	0.79	2.56	8.23	13	106.99		7550.27	7443.28
	July	1.08	2.46	8.62	16	137.92		9297.28	9159.36
	Aug.	0.99	2.21	8.78	15	131.70		8714.85	8583.15
	Sept	0.79	1.85	8.94	7	62.58		4005.53	4002.95
	Oct.	0.33	1.61	8.77	14	122.78		8125.32	8002.54
	Nov.	0.24	1.62	8.62	16	137.92		9283.84	9145.92
					91	779.49	8.57	52841.09 580.671	52061.60 572.105
1900	June	580.30	572.47	7.83	7	54.81		4062.10	4007.29
	July	0.55	2.34	8.21	13	106.73		7547.15	7440.42
	Aug.	0.64	2.31	8.33	9	74.97		5225.76	5150.79
	Sept.	0.72	1.99	8.73	10	87.30		5807.20	5719.90
	Nov.	0.66	1.49	9.17	7	64.19		4064.62	4000.43
	Dec.	0.46	1.45	9.01	19	171.19		11028.74	10857.55
					65	559.19	8.60	37735.57 580.547	37176.38 571.944
1901	May	580.81	571.31	9.50	16	152.00		9292.96	9140.96
	June	0.91	1.72	9.19	20	183.80		11618.20	11434.40
					36	335.80	9.33	20911.16 580.866	20575.36 571.538
1902	Aug.	580.83	572.72	8.11	18	145.98		10454.94	10308.96
	Sept	0.51	2.38	8.13	30	243.90		17415.30	17171.40
					48	389.88	8.12	27870.24 580.630	27480.36 572.508
1908	Nov	580.46	571.71	8.75	12	105.00		6965.52	6860.52
	Dec.	0.23	1.42	8.81	3	26.43		1740.09	1714.26
					15	131.43	8.76	8706.21 580.414	8574.78 571.652
Totals Means		580.62	572.00	8.62	255	2195.79	8.61	148004.27 580.644	145808.48 572.093
Totals, Means Omitting Nov		580.59	572.06	8.53	219	1835.79	8.49	127153.11 580.608	125293.32 572.115

Williams Ex. 34. Table XVII

Chicago Sanitary District
Weighted Elevations and Differences
For Lakes Huron and St. Clair During Discharge Measurements
Monthly Mean Elevations Used.
1899-1908 Inclusive

Year	Mo.	Huron Elevation	St. Clair Elevation	Diff	No. Gagings	Weighted Difference	Mean Diff.	Weighted Huron Elevation	Weighted St. Clair Elevation
1899	May	580.40	575.13	527	10	52.70		5804.00	5751.30
	June	0.79	5.40	539	13	70.07		7550.27	7480.20
	July	1.08	5.57	551	16	88.16		9297.28	9209.12
	Aug.	0.99	5.51	548	15	82.20		8714.85	8632.65
	Sept.	0.79	5.20	559	7	39.13		4065.33	4026.40
	Oct.	0.38	4.90	548	14	76.72		8125.32	8048.60
	Nov.	0.24	4.77	547	16	87.52		9283.84	9196.32
					91	496.50	546	52784.09 580.611	52344.59 575.215
1900	June	580.30	575.21	509	7	35.63		4062.10	4026.47
	July	0.55	5.29	526	13	68.38		7547.15	7478.77
	Aug.	0.64	5.34	530	9	47.70		5225.76	5178.06
	Sept.	0.72	5.22	550	10	55.00		5807.20	5752.20
	Nov.	0.66	5.07	559	7	39.13		4064.62	4025.49
	Dec.	0.46	4.94	552	19	104.88		11028.74	10923.86
					65	350.72	540	37735.57 580.547	37384.85 575.152
1901	May	580.81	574.33	648	16	103.68		9292.96	9189.28
	June	0.91	5.09	582	20	116.40		11618.20	11501.80
					36	220.08	611	20911.16 580.866	20691.08 574.752
1902	Aug.	580.83	575.62	521	18	93.78		10454.94	10361.16
	Sept.	0.51	5.34	517	30	156.10		17415.30	17260.20
					48	249.88	518	27870.24 580.63	27620.36 575.445
1908	Nov.	580.46	575.23	523	12	62.76		6965.52	6902.76
	Dec.	0.23	4.98	525	3	15.75		1740.69	1724.94
					15	78.51	523	8706.21 580.414	8627.70 575.180
Totals Means		580.62	575.17	545	235	1394.67	547	140066.27 580.644	139671.60 578.713
Totals Means omitting 1901		580.59	575.22	537	219	1174.61	536	127533.11 580.606	127158.50 578.244

Williams Ex. 34. *Table XVIII*

Chicago Sanitary District

Differences in Elevation between

Huron - St. Clair (Open Season)
St. Clair - Erie Apr. - Nov. (incl.)
Huron - Erie

Year	Elevation Huron	Huron St. Clair	Elevation St. Clair	St. Clair Erie	Elevation Erie	Huron Erie
1860	582.70	6.32	576.26	2.55	573.71	9.07
1	2.92	5.09	7.03	3.05	3.98	8.94
2	2.79	5.51	7.28	3.36	3.93	8.86
3	2.18	5.48	6.70	3.26	3.44	8.74
4	1.58	5.10	6.48	3.43	3.05	8.53
5	1.38	6.38	6.20	3.44	2.76	8.82
	582.305	5.65	576.650	3.18	573.478	8.83
1866	581.20	5.00	576.20	3.33	572.87	8.33
7	1.65	5.28	6.37	3.51	2.86	8.79
8	1.09	5.07	6.02	3.39	2.63	8.46
9	1.34	5.20	6.14	3.15	2.99	8.35
1870	2.26	5.35	6.91	3.43	3.48	8.78
1	2.10	6.56	6.56	3.61	2.94	9.18
	581.607	5.84	576.365	3.40	572.962	8.84
1872	580.79	5.36	575.43	3.51	571.92	8.87
3	1.68	5.60	6.08	3.19	2.87	8.79
4	1.84	5.71	6.13	3.09	3.04	8.80
5	1.93	6.05	5.88	3.32	2.56	9.37
6	3.11	5.98	7.13	3.08	4.05	9.03
7	2.50	6.37	6.13	3.12	3.01	9.49
	581.971	5.84	576.187	3.22	572.908	9.06
1878	582.31	5.76	576.56	3.10	573.46	8.85
9	1.35	5.55	5.80	3.17	2.63	8.72
1880	1.70	5.55	6.15	3.22	2.93	8.77
1	2.02	5.87	6.15	3.24	2.91	9.11
2	2.39	5.52	6.87	3.17	3.70	8.69
3	2.76	5.80	6.96	3.38	3.58	9.18
	582.098	5.67	576.415	3.21	573.202	8.89
1884	583.25	5.81	576.98	3.42	573.56	9.23
5	3.05	6.10	6.95	3.51	3.64	9.41
6	3.27	6.46	6.81	3.26	3.53	9.74
7	2.54	6.00	6.54	3.07	3.47	9.07
8	2.00	6.00	6.00	3.16	2.84	9.16
9	1.38	5.79	4.99	3.09	2.60	8.88
	582.518	6.04	576.478	3.22	573.257	9.26
1860-1887	582.10	5.89	576.41	3.25	573.16	8.94

Williams Ex. 34 Table XVIII, con

Chicago Sanitary District

Differences in Elevation between Huron - St. Clair St. Clair - Erie Huron - Erie

(Open Season) Apr. - Nov. incl

Year	Elevation Huron	Huron St. Clair	Elevation St. Clair	St. Clair Erie	Elevation Erie	Huron Erie
1860-1889	582.10	3.69	576.41	3.23	573.16	8.94
1890	581.31	3.35	575.96	2.68	573.28	8.03
1	0.66	3.50	5.16	3.01	2.15	2.51
2	0.39	3.23	5.39	2.79	2.57	8.02
3	0.27	3.39	5.48	2.90	2.58	8.29
4	1.00	3.59	5.41	3.15	2.26	8.71
5	579.92	3.47	5.43	3.21	1.24	8.68
	580.72	3.42	575.30	2.95	572.35	8.37
1896	579.69	3.08	576.61	2.98	1.63	8.01
7	580.43	3.30	5.13	2.85	2.28	8.15
8	0.31	3.23	5.26	2.94	2.32	8.17
9	0.37	3.42	5.13	3.04	2.11	8.46
1900	0.46	3.33	5.13	3.01	2.12	8.46
1	0.80	6.03	4.77	3.24	1.53	8.27
	580.41	3.40	575.01	3.01	572.00	8.41
1902	580.39	3.23	575.16	2.96	572.20	8.19
3	0.59	3.42	5.17	2.98	2.19	8.40
4	1.21	3.29	5.31	2.82	2.49	8.02
5	1.51	3.42	5.33	3.13	2.20	8.51
6	1.23	3.38	5.38	3.13	2.25	8.51
7	1.16	3.39	5.38	3.14	2.24	8.53
	1.28	3.42	5.42	2.94	2.48	8.36
	580.96	3.37	5.60	2.99	2.61	8.35
1908	1.22	3.21	6.01	3.08	2.93	8.22
9	0.68	3.87	5.71	3.25	2.46	8.33
10	0.28	3.83	5.41	3.28	2.13	8.09
11	579.67	4.79	4.88	3.28	1.60	8.05
12	580.30	4.91	5.39	3.00	2.39	7.91
	80.42	4.94	5.48	3.17	2.31	8.11
1890-1901	580.70	3.40	575.30	2.98	572.32	8.38
1890-1908	580.73	3.39	575.34	2.99	572.35	8.38
1890-1910	580.70	3.34	575.36	3.01	572.35	8.35
1890-1912	580.64	3.30	575.34	3.02	572.32	8.32
1860-1908	581.57	3.38	575.99	3.14	572.85	8.72
1860-1910	581.52	3.34	575.98	3.13	572.85	8.69
1860-1912	581.46	3.31	575.95	3.13	572.80	8.66

Williams Ex. 34

Table XVIII-a
Sheet 1

Chicago Sanitary District

Differences in Elevation between Huron - St. Clair St. Clair - Erie Huron - Erie

(Closed Season Dec.-Mar. inc.)

Year	Elevation Huron	Huron St. Clair	Elevation St. Clair	St. Clair Erie	Elevation Erie	Huron Erie
1861	582.10	6.14	575.96	3.31	572.65	9.45
2	2.31	6.41	6.10	2.78	3.32	9.10
3	2.31	3.91	6.40	2.92	3.48	8.83
4	2.01	3.96	5.85	3.56	2.29	9.32
5	0.80	6.18	4.72	2.81	1.91	8.99
	581.93	6.12	575.81	3.08	572.73	9.20
1866	580.39	3.33	577.26	3.39	571.87	8.72
7	1.13	3.67	3.46	3.11	2.35	8.78
8	0.80	3.70	5.10	3.67	1.43	9.37
9	0.91	3.62	4.79	3.05	1.74	8.67
1870	1.39	3.38	6.01	3.12	2.89	8.50
1	1.80	6.07	3.79	3.34	2.45	9.35
	581.02	5.62	575.40	3.28	572.12	8.90
1872	580.81	5.60	575.21	3.75	571.46	9.35
3	0.65	5.84	4.81	3.60	1.21	9.44
4	1.82	6.48	5.34	2.95	2.39	8.83
5	1.41	6.00	3.21	3.63	1.58	9.63
6	1.79	5.88	6.10	3.29	2.81	8.98
7	2.51	6.40	6.11	3.40	2.71	9.80
	581.46	6.00	575.46	3.84	572.13	9.33
1878	582.09	6.48	575.56	2.66	572.90	9.14
9	1.48	6.29	3.19	2.64	2.55	9.93
1880	1.00	3.61	5.40	2.93	2.47	8.53
1	1.39	6.11	3.28	3.43	1.85	9.54
2	1.91	5.18	6.33	3.22	3.11	8.80
3	1.76	3.62	6.13	3.69	2.46	9.30
	581.60	5.95	575.65	3.09	572.56	9.04
1884	582.34	6.62	575.92	2.87	573.05	9.49
5	2.36	6.70	6.57	3.39	2.18	10.18
6	2.75	6.98	3.77	3.64	3.13	9.62
7	2.45	6.02	6.43	3.35	3.09	9.37
8	1.37	5.89	3.54	3.32	2.21	9.10
9	1.29	6.02	3.22	3.03	2.19	9.03
	582.12	6.21	575.91	3.26	572.64	9.48
1861-85	581.61	5.97	575.64	3.22	572.42	9.19

Williams Ex. 34 — Table XVIII c
Sheet 2

Chicago Sanitary District.

Differences in Elevation between Huron - St. Clair, St. Clair - Erie, Huron - Erie

(Closed Season Dec. - Mar. incl)

Year	Elevation Huron	Huron St. Clair	Elevation St. Clair	St. Clair Erie	Elevation Erie	Huron Erie
1861-89	581.61	5.97	575.64	3.22	572.42	9.19
1890	580.70	5.40	575.30	2.83	572.47	8.23
91	80.37	5.39	5.13	2.66	2.47	8.05
92	79.91	5.02	4.89	2.98	1.91	7.90
93	79.90	5.07	4.83	2.97	1.86	7.93
94	80.29	5.40	4.89	3.17	1.72	8.57
95	79.96	4.90	5.08	3.80	1.28	8.78
	580.22	5.43	574.79	3.05	571.74	8.48
1896	579.11	5.25	573.86	2.98	570.88	8.23
97	78.42	4.83	2.57	3.28	1.29	8.13
98	79.19	5.22	4.37	2.83	1.54	8.05
99	79.71	4.95	4.76	3.14	1.62	8.09
1900	79.89	5.36	4.53	2.98	1.55	8.34
01	80.21	5.91	4.30	3.13	1.17	9.04
	579.69	5.26	574.43	3.06	571.38	8.31
1902	579.91	5.66	574.03	3.07	570.96	8.95
03	3.84	4.79	3.05	3.12	1.93	7.98
04	80.01	5.09	4.92	3.37	1.55	8.46
05	0.37	5.62	4.75	3.30	1.45	8.92
06	0.66	6.06	4.60	2.93	1.67	9.76
07	0.67	5.37	5.10	2.63	2.47	8.20
	580.24	5.47	574.78	3.00	571.70	8.55
1908	580.34	5.39	575.15	2.73	572.42	8.12
09	0.01	5.63	4.39	2.81	1.58	8.20
10	0.07	5.73	4.60	3.05	1.55	8.78
11	79.80	5.39	4.41	2.67	1.74	8.06
12	79.30	4.92	4.86	3.61	1.25	8.03
	579.85	5.23	574.62	3.10	571.51	8.34
1890-1907	580.05	5.39	574.66	3.06	571.60	8.45
1890-1908	580.08	5.39	574.69	3.04	571.65	8.43
1890-1910	580.07	5.38	574.69	3.07	571.62	8.45
1890-1912	580.01	5.36	574.65	3.07	571.58	8.43
1861-1908	581.00	5.74	575.26	3.14	572.12	8.88
1861-1910	580.97	5.73	575.24	3.15	572.09	8.88
1861-1912	580.90	5.70	575.20	3.15	572.05	8.85

Williams Ex. 34. Table XIII

Chicago Sanitary District

Differences in Elevation
between
Huron - St Clair
St Clair - Erie
Huron - Erie
(Full Year)

Year	Elevation Huron	Huron St.Clair	Elevation St.Clair	St Clair Erie	Elevation Erie	Huron Erie
1860	582.68	6.47	576.21	2.71	573.50	9.18
1	2.66	5.93	6.73	3.15	3.58	9.08
2	2.62	5.80	6.82	3.13	3.69	8.93
3	2.15	5.56	6.59	3.19	3.40	8.75
4	581.53	5.25	6.28	3.48	2.80	8.73
5	1.29	5.54	5.75	3.31	2.44	8.85
	582.155	5.76	576.397	3.16	573.235	8.92
1866	580.96	5.00	575.96	3.38	572.58	8.38
7	1.40	5.38	6.02	3.41	2.61	8.79
8	0.91	5.20	5.71	3.48	2.23	8.68
9	1.03	5.30	5.73	3.08	2.65	8.38
1870	1.94	5.30	6.64	3.36	3.28	8.66
1	1.87	5.55	6.32	3.63	2.69	9.18
	581.351	5.29	576.003	3.39	572.673	8.68
1872	580.59	5.31	575.28	3.55	571.73	8.86
3	1.24	5.52	5.72	3.28	2.44	8.80
4	1.73	5.91	5.82	2.87	2.95	8.78
5	1.70	6.02	5.68	3.40	2.28	9.42
6	2.74	5.79	6.95	3.25	3.70	9.04
7	2.45	6.45	6.00	3.12	2.88	9.57
	581.741	5.83	575.908	3.25	572.663	9.08
1878	582.20	5.95	576.25	2.96	573.29	8.91
9	1.32	5.74	5.58	3.05	2.53	8.79
1880	1.49	5.47	6.02	3.25	2.77	8.72
1	1.87	6.00	5.87	3.26	2.61	9.26
2	2.21	5.51	6.70	3.22	3.48	8.73
3	2.49	5.86	6.63	3.36	3.27	9.22
	581.93	5.76	576.175	3.18	572.992	8.94
1884	582.70	6.08	576.62	3.28	573.34	9.36
5	2.86	6.02	6.84	3.60	3.24	9.62
6	3.08	6.62	6.46	3.12	3.34	9.74
7	2.43	6.00	6.43	3.12	3.31	9.12
8	1.78	5.95	5.83	3.22	2.61	9.17
9	1.28	5.86	5.42	3.04	2.38	8.90
	582.359	6.09	576.267	3.23	573.037	9.32
1860-1889	581.91	5.75	576.14	3.24	572.92	8.99

Williams Ex. 34 Table XIX con

Chicago Sanitary District.

Differences in Elevation between Huron - St. Clair St. Clair - Erie Huron - Erie (Full Year)

Year	Elevation Huron	Huron St. Clair	Elevation St. Clair	St. Clair Erie	Elevation Erie	Huron Erie
1860-1889	581.91	5.75	576.16	3.24	572.92	8.99
1890	581.11	5.34	575.77	2.72	573.05	8.06
1	0.54	5.45	5.09	2.94	2.15	8.39
2	0.38	5.45	4.93	2.79	2.14	8.24
3	0.37	5.47	5.10	3.01	2.09	8.48
4	0.76	5.54	5.22	3.12	2.10	8.66
5	579.85	5.73	4.60	3.43	1.17	8.66
	580.53	5.42	575.12	3.00	572.12	8.41
1896	579.53	5.16	574.37	2.98	571.39	8.14
7	580.13	5.14	4.99	3.09	1.90	8.17
8	0.28	5.22	5.06	2.92	2.14	8.14
9	0.29	5.29	5.00	3.01	1.99	8.30
1900	0.30	5.36	4.94	3.00	1.94	8.30
1	0.37	5.36	4.61	3.22	1.39	9.18
	580.18	5.36	574.83	3.04	571.79	8.39
1902	580.71	5.39	574.82	2.98	571.84	8.37
3	0.36	5.00	5.36	2.97	2.39	8.27
4	0.81	5.24	5.60	3.06	2.54	8.30
5	0.93	5.62	5.33	3.16	2.17	8.32
6	0.96	5.67	5.29	3.09	2.20	8.76
7	1.03	5.45	5.60	2.81	2.79	8.32
	580.73	5.40	575.33	3.01	572.32	8.41
1908	580.96	5.28	573.68	2.99	2.69	8.27
9	0.45	5.15	5.30	3.17	2.13	8.30
10	0.12	5.02	3.10	3.23	1.87	8.23
11	579.57	5.03	4.54	3.01	1.47	8.10
12	0.04	4.80	3.24	3.22	2.02	8.02
	580.23	5.05	575.18	3.14	572.04	8.19
1890-1907	580.48	5.39	573.09	3.01	572.08	8.40
1890-1908	580.51	5.39	573.12	3.01	572.11	8.40
1890-1910	580.48	5.35	575.13	3.03	572.10	8.38
1890-1912	580.43	5.32	575.11	3.04	572.07	8.36
1860-1908	581.36	5.60	575.76	3.15	572.61	8.75
1860-1910	581.32	5.58	575.74	3.16	572.58	8.74
1860-1912	581.26	5.53	575.73	3.10	572.35	8.71

Williams Ex. 34 *Table XI*

Chicago Sanitary District
Q for St. Clair River
(H=380. Q=177900, δ=23 820)
By Complainant's Equation

Date		Gage Height	Discharge	Date		Gage Height	Discharge	Date		Gage Height	Discharge
Year	Month	Harbor Datum	C.F.S.	Year	Month	Harbor Datum	C.F.S.	Year	Month	Harbor Datum	C.F.S.
1900	Jan.	379.74	174700	1903	Jan.	379.74	174700	1905	Jan.	380.53	200320
	Feb.		173600		Feb.		173600		Feb.		199330
	Mar.		174300		Mar.		174300		Mar.		200030
	Apr.	380	177900		Apr.	380	177900		Apr.	381	203700
	May		181000		May		181000		May		206900
	June		181000		June		181000		June		206900
	July		183000		July		183000		July		208400
	Aug.		183000		Aug.		183000		Aug.		208400
	Sept.		183000		Sept.		183000		Sept.		208400
	Oct.		183000		Oct.		183000		Oct.		208400
	Nov.		183000		Nov.		183000		Nov.		208400
	Dec.	379.72	180700		Dec.	380.53	183000		Dec.	380.36	200863
1901	Jan.	379.74	180700	1904	Jan.	379.91	179765	1906	Jan.	380.65	193320
	Feb.		179600		Feb.		179765		Feb.		193320
	Mar.		180300		Mar.		180410		Mar.		194100
	Apr.	380	183000		Apr.	380.06	182300		Apr.	381	196700
	May		186000		May		186000		May		200000
	June		186000		June		186000		June		200000
	July		187500		July		187500		July		201700
	Aug.		187500		Aug.		187500		Aug.		201700
	Sept.		187500		Sept.		187500		Sept.		201700
	Oct.		187500		Oct.		187500		Oct.		201700
	Nov.		187500		Nov.		187500		Nov.		201700
	Dec.	380.30	187500		Dec.	380.06	187500		Dec.	380.21	201700
1902	Jan.	379.91	187500	1905	Jan.	380.24	187900	1907	Jan.	380.65	193320
	Feb.		187500		Feb.		187900		Feb.		193320
	Mar.		187500		Mar.		187900		Mar.		193320
	Apr.	380	187500		Apr.	380.38	188000		Apr.	381	196700
	May		187500		May		188000		May		196700
	June		187500		June		188000		June		196700
	July		187500		July		188000		July		196700
	Aug.		187500		Aug.		188000		Aug.		196700
	Sept.		187500		Sept.		188000		Sept.		196700
	Oct.		187500		Oct.		188000		Oct.		196700
	Nov.		187500		Nov.		188000		Nov.		196700
	Dec.	380.57	187500		Dec.	380.38	188000		Dec.	380.21	196700
1903	Jan.	379.91	187500	1906	Jan.	380.38	188000	1908	Jan.	381.03	202880
	Feb.		187500		Feb.		188000		Feb.		
	Mar.		187500		Mar.		188000		Mar.		
	Apr.	380.06	187500		Apr.	380.38	188000		Apr.		
	May		187500		May		188000		May		
	June		187500		June		188000		June		
	July		187500		July		188000		July		
	Aug.		187500		Aug.		188000		Aug.		
	Sept.		187500		Sept.		188000		Sept.		
	Oct.		187500		Oct.		188000		Oct.		
	Nov.		187500		Nov.		188000		Nov.		
	Dec.	380.06	187500		Dec.	380.38	188000		Dec.		
1904	Jan.	379.91	187500	1907	Jan.	380.65	193320				
	Feb.		187500		Feb.		193320				
	Mar.		187500		Mar.		193320				
	Apr.	380	187500		Apr.	381	196700				
	May		187500		May		196700				
	June		187500		June		196700				
	July		187500		July		196700				
	Aug.		187500		Aug.		196700				
	Sept.		187500		Sept.		196700				
	Oct.		187500		Oct.		196700				
	Nov.		187500		Nov.		196700				
	Dec.	380.06	187500		Dec.	381	196700				

Mean Q 1900 to 1904 = 185,787 c.f.s. Mean Q 1900 to 1907 = 193,528 c.f.s.

Williams Ex. 34 Table XXI

Chicago Sanitary District
Relative Fluctuation of Lakes

St. Clair - Huron
Erie - Huron

Huron Elevation Decreasing

1	2	3	4	5	6	7	8	9	10	11
	Year	Huron		St. Clair		Year	Huron		Erie	
		Elevation	C. of G.	Elevation	C. of G.		Elevation	C. of G.	Elevation	C. of G.
1860-1889	1886	583.08		576.46					573.34	
	85	2.86		6.84					3.24	
	76	2.74		6.95					3.70	
	84	2.70		6.62					3.34	
	60	2.68		6.21					3.50	
	61	2.66		6.73					3.58	
	62	2.62		6.82				582.515	3.69	573.378
	83	2.49	582.472	6.63	576.546				3.27	
	77	2.45		6.00					2.88	
	87	2.43		6.43					3.31	
	82	2.21		6.70					3.48	
	78	2.20		6.25					3.29	
	63	2.15		6.59					3.40	
	70	1.94	581.907	6.64	576.162			581.907	3.28	572.920
	71	1.87		6.32					2.69	
	81	1.87		5.87					2.61	
	88	1.78		5.83					2.61	
	74	1.73		5.82					2.95	
	75	1.70		5.68					2.80	
	64	1.53		6.28					2.80	
	80	1.49		6.02					2.77	
	67	1.40	581.341	6.02	575.779			581.374	2.61	572.519
	79	1.32		5.58					2.53	
	65	1.29		5.75					2.44	
	89	1.28		5.42					2.39	
	73	1.24		5.72					2.44	
	69	1.03		5.73					2.65	
	66	0.96		5.96					2.58	
	68	0.91		5.71					2.23	
	72	0.59		5.28					1.73	
1891-1910	1907	581.05		575.60		1907	581.05		572.73	
	06	580.96		.29		06	580.96		2.26	
	08	.98		.68		08	.98		2.69	
	05	.95		.33		05	.95		2.17	
	04	.84		.60		04	.84	580.741	2.54	572.327
	1894	.76	580.741	.25	575.361	1894	.76		2.10	
	93	.57		.10		93	.47		2.09	
	91	.54		.09		91	.54		2.15	
	1909	.42		.33		1909	.42		2.13	
	03	.36	580.452	.37	575.103	1903	.36	580.448	2.39	572.076
	01	.57		574.61		1901	.57		1.39	
	1892	.38		.93		1892	.38		2.14	
	1900	.30		.54		00	.30		1.94	
	1899	.29		575.00		1899	.29		1.93	
	98	.28		.08		98	.28	580.133	2.14	571.807
	1902	.21	580.164	574.81	574.868	1902	.21		1.84	
	1897	.13		.99		1897	.13		1.96	
	1910	.12		575.14		1910	.12		1.87	
	1895	579.83		574.60		1895	579.83		1.17	
	96	.53		.37		96	.53		1.39	

1860-89	582.472	576.546	0.767			582.515	573.378	0.459			
	581.341	575.779	1.131			581.374	572.519	1.141			
	1.131	0.767		67.8%		1.141	0.859		= 75.3%		
1891-1910	580.741	575.361	0.516			580.741	572.327	0.520			
	580.164	574.868	0.377			580.133	571.807	0.608			
	0.577	0.516		89.4%		0.608	0.520		85.5%		

*Given a weight of 03

Williams Ex. 34. Table XXII

Chicago Sanitary District

Equations of Discharge of St Clair River and Increment due to Lake Huron.

From simultaneous readings of slope and discharge, Lake St Clair gauges.

1899, 1900, 1901, 1902 and 1908

1	2	3	4	5	6	7	8	9	10
No Observation	Duration St Clair	Coef G "C"		Coef G "A"		Coef G "B"		Equation	Increment
		Elev Huron	Discharge	Elev Huron	Discharge	Elev Huron	Discharge		
15	57858	581.20	180480	581.275	210347	581.151	225322	X=39473Y-2258[illegible]	39493
11	.48	0.91	180900	1.070	206535	0.714	190400	33000 Y-3018[illegible]	38018
31	.36	0.83	178800	0.99	204400	0.670	189800	39390 Y-2268[illegible]	39398
4	.31	0.96	180885	1.01	199800	0.73	187400	35387Y+2038[illegible]	35387
25	.25	0.85	179012	0.83	198000	0.68	186600	38586 Y-2219[illegible]	38586
9	.21	0.80	179111	0.895	203350	0.77	193800	32400 Y-1847[illegible]	32400
28	.16	0.58	179164	0.85	199387	0.61	186500	30918 Y+1433[illegible]	30918
6	.10	0.85	179325	0.895	203350	0.77	193300	32400 Y-1847[illegible]	32400
17	57826	0.81	179871	0.914	204650	0.64	185500	41600 Y-2394[illegible]	41600
6	.91	1.03	180450	0.92	186900	0.02	169800	18600 Y-1060[illegible]	18600
19	.86	0.82	178847	0.981	202300	0.847	191800	33300 Y-1914[illegible]	33300
11	.81	0.[illegible]	178871	0.748	204700	0.577	190300	36814 Y-2137[illegible]	36814
13	.76	0.88	179138	0.984	211400	0.819	194800	33340 Y-1922[illegible]	33340
4	.71	0.18	184178	0.33	179000	0.095	168800	22286 Y-1360[illegible]	22286
14	.66	0.11	184800	0.318	178440	57.1899	177400	64325 Y-4[illegible]	64325
								Mean of Increments 34,385	

Mean Equation:

X = 34,385 Y - 19,771,889

Williams Ex. 34

Table XXIII

Chicago Sanitary District
Equations of Discharge of St. Clair River
and Increments due to Lake St. Clair.

From simultaneous readings of stage and discharge - Lake Huron constant.
1899, 1900, 1901, 1902 and 1908

1	2	3	4	5	6	7	8	9	10
No. Pairs	Elevation Huron	C of G "C" Elev. St. Clair	C of G "C" Discharge	C of G "A" Elev. St. Clair	C of G "A" Discharge	C of G "B" Elev. St. Clair	C of G "B" Discharge	Equation	Increment
8	581.11	575.23	208840	575.44	206770	574.91	211950	$x = -9775y + 2999198$	-9775
4	1.08	5.31	207850	5.48	203200	4.86	221800	-31000 + 10991800	-31000
5	1.02	5.22	204500	.33	203000	5.14	205500	-13160 + 7770500	-13160
4	0.96	5.41	201180	.66	199500	.35	201600	-6790 + 4100600	-6790
5	0.95	5.30	205150	.54	201600	.06	208700	-14800 + 8718700	-14800
5	0.92	5.06	206280	.21	203850	4.98	207870	-16080 + 9452870	-16080
4	0.87	5.32	201150	.41	199900	5.08	204900	-14290 + 8419900	-14290
4	0.85	5.27	195625	.38	193400	4.96	202200	-20950 + 12332200	-20950
5	0.82	5.15	201680	.41	198080	.75	207650	-14580 + 8587650	-14580
7	0.81	5.29	195114	.39	196970	5.22	194180	+12890 - 8875320	+12890
4	0.79	5.12	195800	.38	191350	4.49	200850	-10600 + 6282250	-10600
4	0.70	4.98	199575	.49	198000	.48	201430	- 7580 + 4813430	- 7580
3	0.69	5.18	194533	4.81	201800	5.34	190900	-19818 + 11593380	-19818
4	0.64	5.17	197775	5.31	195450	5.035	200100	-16910 + 10185100	-16910
5	0.62	5.10	195220	4.86	197520	.26	193667	- 9707 + 5719000	- 9707
3	0.61	4.99	194867	4.61	198200	.36	188200	-18182 + 10849400	-18182
3	0.60	5.00	197800	4.86	197800	.27	196000	- 4390 + 2784935	- 4390
3	0.51	5.04	191500	4.86	194400	.139	190050	-15240 + 9807535	-15240
2	0.48	4.90	198650	4.81	194267	.16	187800	-18477 + 10815031	-18477
5	0.39	5.06	187620	5.21	185370	4.84	191000	-15216 + 9189000	-15216
4	0.32	4.98	189400	5.16	184100	4.81	194700	-30290 + 17549700	-30290

-14072 = Mean of Increment.

Mean Equation:

$X = -14,072\,Y + 9,487,163$

Williams Ex. 34. Table XXIII

Chicago Sanitary District

Equations of Discharge of St Clair River

Weighting of Increments.
in Tables XXII and XXIII

Lake Huron				Lake St. Clair.			
Elevation of St. Clair	No of Obser.	Increment	Product	Elevation of Huron	No of Obser.	Increment	Product
575.56	15	39073	586095	581 11	5	- 9775	- 48875
.46	11	35000	385000	08	4	-31000	-124000
.36	31	39390	1221090	.02	5	-13160	- 65800
.31	4	35957	141428	580.96	5	-6780	-33900
.26	25	38580	964500	95	4	-14800	-59200.
.21	9	32400	291600	.92	5	-16080	-80400
.16	28	30518	854504	.87	4	-14290	-57160
.06	4	32400	129600	.85	4	-20950	-83800
574 96	17	41600	707200	.82	5	-14560	-72900
.91	4	18600	74400	.81	7	+12890	+90230
.86	19	33300	632700	.73	4	-10600	-42400
.81	11	38814	426954	.70	4	- 7580	-30320
.76	13	33540	436020	.69	3	-19818	-59454
71	4	22880	91520	.64	4	-16910	- 67640
66	14	44325	620550	.62	5	- 9707	-48535
				.61	3	-18182	-54546
				.60	3	-4390	-13170
				.51	3	-15818	-47454
				.48	4	-18477	-73908
				.39	5	-15216	-76080
				.32	4	-30290	-121160
	209		+7563161.		90		1170,472
Weighted Mean			+36187.				-13,005

Net Increment St. Clair Change = 66⅔% of Huron Change
36187 - ⅔ × 13,005 = 27,517
St. Clair Change = 89% of Huron Change
36187 - 0.89 × 13005 = 24,613

Williams Ex. 34. Table XXV

Chicago Sanitary District
Equations of Discharge of St. Clair River
and Increments due to Lake Huron
1908 to 1910
From simultaneous readings of stage
and discharge Lake St. Clair constant

1	2	3	4	5	6	7	8	9	10
No. Observation	Duration	C of G "C"		C of G "A"		C of G "B"		Equation	Increment
	St. Clair	Elev. Huron	Discharge	Elev. Huron	Discharge	Elev. Huron	Discharge		
1	573.71	580.36	184,480	580.35	183,810	580.32	182,900	X= 33830Y-19,444,900	33830
2	.70	.36	184,310	.41	185,510	.36	183,870	29540Y-16,986,610	29540
3	.69	.36	184,310	.37	184,160	.34	183,460	27170Y-15,663,300	27170
4	.67	.36	184,140	.44	187,000	.32	182,410	25380Y-14,670,700	25380
5	.66	.36	184,140	.41	185,940	.36	183,700	24230Y-13,956,970	24230
6	.63	.36	183,960	.40	185,540	.34	183,300	22810Y-13,126,970	22810
7	.62	.36	183,790	.42	186,370	.33	182,850	21940Y-12,632,760	21940
8	.61	.36	183,790	.38	184,340	.33	182,850	21240Y-12,217,000	21240
9	.60	.37	183,960	.38	184,340	.34	183,300	20840Y-11,971,040	20840
10	.59	.37	184,140	.37	184,160	573.98	171,370	21310Y-12,327,840	21310
11	573.58	580.37	177,810	.35	183,340	.36	183,360	23100Y-13,423,200	23100
12	.57	580.37	184,140	.41	185,940	580.34	183,040	23180Y-13,423,200	23180
13	.55	580.10	184,140	.17	183,780	580.04	178,740	27510Y-15,838,640	27510
14	.54	.12	184,310	.19	183,100	579.97	178,510	28200Y-16,231,160	28200
15	.53	.12	184,310	.18	183,440	580.06	179,010	28430Y-16,373,240	28430
16	.52	.10	184,310	.15	183,940	.08	180,010	28980Y-16,691,800	28980
17	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
18	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
19	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
20	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
21	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
22	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
23	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
24	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
25	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
26	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
27	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
28	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
29	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
30	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
31	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
32	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
33	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
34	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
35	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
36	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
37	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
38	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
39	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
40	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
41	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
42	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
43	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
44	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
45	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
46	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
47	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
48	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
49	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
50	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
51	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
52	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
53	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
54	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
55	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
56	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
57	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
58	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
59	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
60	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
61	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
62	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
63	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
64	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
65	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
66	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
67	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
68	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
69	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
70	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
71	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
72	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
73	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
74	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
75	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
76	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
77	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
78	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
79	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
80	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
81	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
82	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
83	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
84	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
85	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
86	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
87	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
88	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
89	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
90	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
91	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
92	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
93	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
94	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
95	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
96	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
97	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
98	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
99	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
100	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
101	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
102	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
103	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
104	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
105	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
106	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
107	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
108	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
109	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
110	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
111	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
112	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
113	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
114	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
115	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
116	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
117	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
118	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
119	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
120	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
121	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
122	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
123	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
124	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
125	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
126	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
127	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
128	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
129	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
130	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
131	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
132	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
133	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
134	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
135	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
136	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
137	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
138	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
139	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
140	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
141	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
142	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
143	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
144	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
145	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
146	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
147	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
148	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
149	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
150	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
151	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
152	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
153	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
154	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
155	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
156	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
157	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
158	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
159	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
160	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
161	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
162	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
163	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
164	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
165	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
166	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
167	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
168	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
169	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
170	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
171	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
172	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
173	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
174	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
175	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
176	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
177	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
178	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
179	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
180	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
181	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
182	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
183	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
184	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
185	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
186	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
187	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
188	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
189	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
190	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
191	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
192	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
193	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
194	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
195	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
196	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
197	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
198	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
199	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
200	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
201	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
202	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
203	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
204	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
205	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
206	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
207	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
208	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
209	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
210	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
211	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
212	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
213	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
214	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
215	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
216	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
217	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
218	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
219	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
220	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
221	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
222	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
223	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
224	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
225	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
226	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
227	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
228	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
229	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
230	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
231	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
232	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
233	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
234	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
235	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
236	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
237	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
238	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
239	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
240	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
241	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
242	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
243	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
244	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
245	573.96	580.10	177,810	579.98	179,080	579.90	176,740	40600Y-23,419,000	40600
246	580.16	580.10	184,480	580.26	187,430	.08	180,010	40600Y-23,419,000	40600
247	573.98	580.10	184,310	.07	183,440	579.82	177,170	33280Y-19,709,100	33280
248	580.18	580.10	184,480	.28	187,740	580.10	184,250	41610Y-23,994,170	41610
249	.17	.10	184,480	.26	187,430	.10	184,080	41400Y-23,880,000	41400
250	573.96	580.10	177,

Williams Ex 34 Table XXXI

Chicago Sanitary District
Equations of Discharge of St. Clair River
and Increments due to Lake St. Clair
1908 to 1910.

From simultaneous readings of stage
and discharge Lake Huron Constant.

1	2	3	4	5	6	7	8	9	10
Mid-month in Period	Elevation Huron	C. of G "C" Fall St. Clair	Discharge	C. of G "A" Fall St. Clair	Discharge	C. of G "B" Fall St. Clair	Discharge	Equation	Increment
	580.45	573.38	198810	573.66	198480	573.24	197500	X=-11950Y+7071630	-11950
	.53	.31	198080	.80	197760	.48	197400	-9110Y+5454780	-9110
	.41	.19	197600	.67	197280	.36	196930	-7340Y+4743360	-7340
	.32	.11	197200	.57	196880	.03	196100	-13320Y+9204070	-13320
	.17	.42	196600	.41	196170	.14	196070	-3330Y+2412000	-3330
	.34	.19	197200	.58	196830	.30	196400	-13320Y+9086880	-13320
	.13	.38	196400	.37	196050	.10	196310	+4882Y-3478830	+12310
	.11	.36	196300	.35	196030	.08	196310	-5770Y+3989850	-5770
	.11	.36	196300	.35	196030	.07	196300	-5770Y+3989850	-5770
	.19	.44	196600	.43	196260	.01	196100	-7340Y+5160600	-7340
	.29	.54	196900	.53	196560	.11	196400	+4882Y-3478830	+12310
	.26	.51	196800	.50	196450	.08	196300	-7770Y+5498850	-12450
	.12	.37	196400	.36	196140	.07	196300	-4440Y+3173430	-6140

Ex 34

Table XXVII

Chicago Sanitary District
Equations of Discharge of St. Clair River
Weighting of Increments
1908 to 1910.

Lake Huron				Lake St. Clair			
Elevation of St. Clair	No. of Obser.	Increment	Product	Elevation of Huron	No. of Obser.	Increment	Product
573.71	3	33830	101490	580.45	9	11950	35850
.70	3	19240	57720	.43	2	9110	18220
.68	4	27370	109480	.41	4	20940	83760
.67	11	56480	621280	.39	4	13860	55440
.66	16	60430	967000	.37	4	13330	53320
.63	17	32310	549270	.35	4	13480	53920
.64	9	24240	218160	.33	11	1805	19855
.63	7	30560	213920	.32	2	5770	11540
.62	3	41310	123930	.31	4	9610	38440
.61	3	49100	147300	.29	2	13330	26660
.59	2	25180	50360	.28	2	12250	24500
.58	8	67810	542480	.27	2	6145	12290
.56	9	56200	505800	.25	2	9005	18010
.55	7	40430	283010	.24	9	12490	112410
.54	3	50290	150870	.23	2	5380	10760
.53	3	53260	159780	.21	6	16002	96012
.52	3	21210	63630	.18	6	37430	224580
.51	3	74060	222180	.17	2	11330	22660
.50	4	16080	64320	.16	3	20960	62880
.49	5	27540	137700	.14	2	12780	25560
.48	3	27520	109560	.11	2	3900	7800
.47	2	49000	98000	.10	2	3270	6540
.46	2	29700	118800	.08	2	10360	41440
.45	2	38730	77500	.06	2	8280	33120
.44	3	39780	219450	.04	2	13700	54800
.43	7	19970	139790	.02	2	13350	53400
.42	2	40000	80000	.01	2	12250	49000
.41	2	13620	27240	.03	2	5190	10380
.40	3	41800	209400	.05	2	14600	58400
.39	3	11790	35370	.07	2	9350	37400
.38	3	32770	123080	79.98	2	10020	40080
.37	4	44160	176120	.96	2	25970	103880
.36	4	38570	154280	.94	2	19200	77200
.35	4	7500	30000	.92	2	13855	41565
.34	10	24540	245400	.90	2	21820	87280
.33	8	30250	241500	.88	2	9000	18000
.32	10	29920	299200	.86	2	18250	91250
.31	8	28020	224160	.84	2	20440	81760
.30	6	21300	127800	.82	2	8500	17000
.29	6	23640	141840				
.28	5	25390	126950				
.27	2	24200	48400				
.26	3	23150	69450				
.25	3	40000	120000				
.24	3	17500	52500				
.23	3	36500	109500				
574.97	2	17270	34540				
.96	3	21250	63750				
	241		8627060		178		210540
Weighted Mean 35797				Weighted Mean = 11817			

Net Increment - St Clair Change = 66⅔% of Huron Change
35,797 - ⅔ × 11,817 = 27919
St Clair Change = 89% of Huron Change
35,797 - .89 × 11,817 = 26280

Table XIII
Sheet 1

Chicago Sanitary District
St. Clair River.
Discharge at Constant Stages
Gagings Weighted by Days in Periods
1899-1902

Group	Date	Lake Surfaces				Observed Discharge	Weight by Time Interval	Weighted Discharge
		Observed Huron	Observed St. Clair	Huron Mean Daily	St. Clair Mean Daily			
						C.F.S.		C.F.S.
	1899-6-7				575.42			
	8	580.91	575.36	580.78	.42	206,700	1.5	310,050
	9			.89	.42			
	10	580.92		.71	.42	205,900	2.0	411,800
	11			.71	.42			
I	12	580.58		.63	.42	194,400	1.5	291,600
	13	.68		.65	.42	193,900	1.0	193,900
	14	.84		.78	.42	194,200	1.0	194,200
	15	.96		.75	.42	202,300	1.0	202,300
	16	581.13		.81	.42	210,800	1.0	210,800
	17	.02		581.05		203,100	1.0	203,100
		580.880	575.36	580.777	575.42	201,640	10.0	201,975
	1899-7-14				575.62			
	15	581.09	575.56	581.04	.62	205,300	1.5	307,950
	16			.18	.62			
	17	.39		.18	.62	218,900	1.5	328,350
	18	.19		.18	.62	204,800	1.0	206,800
	19	.28		.07	.62	207,200	1.0	207,200
	20	.09		.08	.59	203,900	1.5	305,850
	21			.11	.62			
II	22	.22		.14		210,900	1.5	316,350
		581.21	575.56	581.115	575.616	208,830	8.0	209,080
	1899-7-23				575.62			
	24	581.14	575.56	580.98	.62	206,000	1.0	206,000
	25	.15		581.04	.62	206,800	1.0	206,800
	26	.08		.01	.62	196,700	1.0	196,700
	27	.33		.21	.62	209,300	1.0	209,300
	28	.19		.08	.62	203,300	1.0	203,300
III	29	.18		.11		208,200	1.0	208,200
		581.178	575.56	581.072	575.62	205,380	6.0	205,380
	1899-8-17				575.42			
	29	580.96	575.36	580.91	.42	206,900	1.0	206,900
	29	.98		.61	.42	204,100	1.0	204,100
	30	.87		.91	.42	199,900	1.0	199,900
IV	31	.91		.84		200,700	1.0	200,700
		580.93	575.36	580.842	575.42	202,900	4.0	202,900
	1899-10-9				574.92			
	10	580.16	574.86	580.14	.92	180,900	1.0	180,900
	11	.34		.54	.92	190,000	1.5	285,000
	12			.31	.92			
	13	.17		.21	.92	184,900	1.5	276,750
	14	.60		.61	.92	209,200	1.5	313,800
	15			.31	.92			
V	16	.03		.11	.92	180,800	1.5	270,450
	17	.70		.18	.92	198,700	1.0	198,700
	18	.51		.54	.92	194,400	1.0	194,400
	19	.61		.31		197,600	1.0	197,600
		580.415	574.86	580.304	574.92	191,950	10.0	191,760

Williams Ex 34. Table XXIII Sheet 2

Chicago Sanitary District
St. Clair River.
Discharge at Constant Stages
Sagings Weighted by Days in Periods
1899 - 1902

Group	Date	Lake Surfaces: Observed Huron	Observed St. Clair.	Huron Mean Daily	St. Clair Mean Daily	Observed Discharge	Weight by Time Interval	Weighted Discharge
	1899-11-21				574.72	C.F.S.		C.F.S.
	22	579.71	574.66	580.24	.72	180300	1.0	180300
	23	.97		.21	.72	195200	1.0	195200
	24	580.32		.21	.72	192900	2.0	385800
VI	25			.24	.72			
	26			.21	.72			
	27	580.26		.14	.72	186500	2.0	373000
	28	.16		.11	574.72	185400	1.0	185400
	29	.18		.01		181400	1.0	181400
		580.10	574.66	580.171	574.72	186950	8.0	187640
	1900-7-1				575.22			
	2	580.30	575.16	580.18	.22	182400	1.0	182400
	3	.34		.28	.22	182500	1.5	273750
	4			.41	.22			
VII	5	580.31		.38	.22	182200	2.0	364400
	6			.34	575.22			
	7	580.66		.41		191100	0.75	143320
	7	.54				190700	0.75	143030
		580.43	575.16	580.333	575.22	185780	6.00	184480
	1900-7-30				575.42			
	31	580.96	575.36	580.78	.42	199300	1.0	199300
	8-1	.85		.68	.42	195000	1.0	195000
	2	.69		.61	.42	189200	0.75	141900
VIII	2	.81				196400	0.75	147300
	3			.64	.42			
	4	.81		.54	.42	188200	1.50	282300
	5	.57		.61	.42	186900	1.00	186900
	6	.68		.61		192900	1.00	192900
		580.739	575.36	580.639	575.42	192560	7.00	192230
	1900-11-29				574.87			
	30	580.22	574.81	580.58	.87	182500	1.0	182500
	12-1	.48		.58	.87	196000	1.5	294900
	2			.48	.87			
IX	3	.37		.41	.87	191200	1.5	286800
	4	.48		.51	.87	196000	1.0	196000
	5	.70		.81	.87	201100	1.0	201100
	6	.48		.64	.87	190200	1.0	190200
	7	.75		.61	574.87	202400	1.0	202400
	8	.21		.38		185600	1.0	183600
		580.461	574.81	580.355	574.87	193200	9.0	193280

Williams Ex 34 *Table XIII*
Sheet 3

Chicago Sanitary District.
St. Clair River.
Discharge at Constant Stages
Gagings Weighted by Days in Periods
1899 - 1902.

Group	Date	Lake Surfaces				Observed Discharge	Weight by Time Interval	Weighted Discharge
		Observed Huron	Observed St Clair	Huron Mean Daily	St. Clair Mean Daily			
						C.F.S.		C.F.S.
	1901-6-6				575.02			
	7	681.13	574.96	580.68	.02	203800	0.5	101900
	7	.14				211300	0.5	105650
	8	.24		.78	.02	215100	0.75	161320
	8	.11				213500	0.75	160130
	9			.79	.02			
X	10	580.92		.74	.02	207900	0.75	155930
	10	.85				202200	0.75	151650
	11	.83		.81	.02	208100	0.75	156070
	11	.62				200500	0.75	150370
	12			.78	.02			
	13	580.86		.92	575.02	206100	1.5	309150
	14	.92		.83		209100	0.5	104550
	14	.92				206600	0.5	103300
		580.958	574.96	580.794	575.02	207830	8.00	207580
	1902-9-6				575.22			
	17	580.30	575.18	580.29	.22	179000	0.5	89500
	17	.32	.16			181700	0.5	90860
	18	.45	.18	.44	.22	183500	1.0	183500
	19	.78	.21	.58	.27	194800	1.0	194800
	20	.59	.21	.42	.27	188000	1.5	282000
XI	21			.40	.22			
	22	.48	.16	.45	.22	187800	0.75	140850
	22	.48	.16			184100	0.75	138075
	23	.54	.21	.49	.27	187900	0.5	93950
	23	.63	.21			190600	0.5	95300
	24	.57	.21	.44		190800	1.0	190800
		580.811	575.185	580.459	575.239	184820	8.0	187430

Ex 34. Table XXIX

Chicago Sanitary District

St. Clair River Observations.

Elevations of Lake Surfaces and Variations from Means, during Selected Gaging Periods of 1899 to 1902 inclusive

Mean Elevations for Open Season

Lake Huron - 1890 to 1910 580.70

Lake St. Clair - 1890 to 1910 575.36

				Lake Huron		Lake St. Clair	
Gaging	Group	Days	Period	Elevation	Change from Mean	Elevation	Change from Mean
6	II	8	1899-7 $\frac{13}{22}$	581.115	+ .42	575.616	+ .26
6	III	6	1899-7 $\frac{24}{29}$	.072	+ .37	.620	+ .26
4	IV	4	1899-8 $\frac{28}{31}$	580.842	+ .14	.420	+ .06
11	X	8	1901-6 $\frac{7}{14}$	.794	+ .09	.020	- .34
8	I	10	1899-6 $\frac{8}{17}$	.777	+ .08	.420	+ .06
7	VIII	7	1900-7 $\frac{31}{6}$	.639	- .06	5.420	+ .06
8	IX	9	1900-11 $\frac{22}{3}$	.555	- .14	4.870	- .49
10	XI	8	1902-9 $\frac{17}{24}$	.439	- .26	5.239	- .12
5	VII	6	1900-7 $\frac{2}{7}$	.333	- .37	5.220	- .14
8	V	10	1899-10 $\frac{8}{18}$	.304	- .40	4.920	- .44
6	VI	8	1899-11 $\frac{12}{19}$	.171	- .53	4.720	- .64

Williams Ex 34. Table XII

Chicago Sanitary District.

St. Clair River Observations

Normal Change of Lake St. Clair from Mean of 1830 to 1910 for Gaging Periods of 1899 to 1902, assuming St. Clair Change to be 66⅔ % of Huron Change, and observed Variation from such Normal Change, and discharges corrected to Normal Stage for Increment of Lake St. Clair = -13000 c.f.s.

1	2	3	4	5	6	7	8
Group	Change from Mean				Correction due St. Clair	Discharge	
	Huron	St. Clair				Observed	Corrected to Normal Stage
	Normal	Observed	Normal	Diff			
II	+ .42	+ .26	+ .28	- .02	- 260	209060	208800
III	+ .37	+ .26	+ .25	+ .01	+ 130	205330	205480
IV	+ .14	+ .06	+ .09	- .03	- 390	202900	202510
X	+ .09	- .34	+ .06	- .40	- 5200	207500	202300
I	+ .07	+ .06	+ .05	+ .01	+ 130	201975	202105
VIII	- .06	+ .06	- .04	+ .10	+ 1300	192230	193530
IX	- .14	- .49	- .09	- .40	- 5200	193280	188080
XI	- .26	- .12	- .17	+ .05	+ 650	187430	188080
VII	- .37	- .14	- .25	+ .11	+ 1430	184480	185910
V	- .40	- .44	- .27	- .17	- 2210	191760	189550
VI	- .53	- .64	- .35	- .29	- 3770	187640	183870

Williams Ex 34 Table XXII

Chicago Sanitary District

St. Clair River Observations
Weighted Increment of Discharge for Normal Stage of Lake St. Clair assuming Normal Change of Lake St. Clair to be 66⅔% of Huron Change, and Lake St. Clair Increment to be -13000 c.f.s

1899 - 1902
Normal St. Clair 66⅔% Huron
Δ St. Clair 13000

1	2	3	4	5	6	7	8	9
Year & Month	St. Clair Mean Daily	Corrected Discharge	Multiplier	Weighted Discharge Col. 3 · Col. 4	Huron Mean Daily	Weighted Elevation Col. 6 · Col. 4	Weighted Centers of Gravity Col. 3	Weighted Centers of Gravity of Col. 6
II	575.618	208800	8	1670400	581.115	4648.920		
III	.620	205480	6	1232880	.072	3486.432		
IV	420	202510	4	810040	580.842	2323.368	204244	580.912
X	020	202300	8	1618400	.794	4646.352		
I	420	202105	10	2021050	77.7	5807.770		
XII	420	193530	7	1354710	.639	4064.473	195080	580622
IX	574.870	188080	9	1692720	.535	5224.995		
II	575.239	188080	8	1504640	439	4643.512		
VIII	.220	185910	6	1115460	.333	3481.998	188208	580404
V	574.920	189550	10	1895500	.304	5803.040		
VI	.720	183870	8	1470960	.171	4641.368		
			84					

$$\text{Increment} = \frac{204244}{188208} \Big/ \frac{16036}{508} \div \frac{580912}{580404} = 31370 \text{ c.f.s.}$$

Williams Ex. 34. Table XXXII

Chicago Sanitary District

St. Clair River Observations

Normal Change of Lake St. Clair from Mean of 1890 to 1910 for Gaging Periods of 1899 to 1902, assuming St. Clair Change to be 89% of Huron Change, and observed Variation from such Normal Change, and discharges corrected to Normal Stage for Increment of Lake St. Clair = -13000 c.f.s

1	2	3	4	5	6	7	8
Group	Change from Mean.				Discharge		
	Huron	St. Clair Observ'd	St. Clair Normal	Diff.	Correction due St. Clair.	Observed	Corrected
II	+ .42	+ .26	+ .37	- .10	- 1430	209060	207630
III	+ .31	+ .26	+ .33	- .07	- 910	205330	204440
IV	+ .14	+ .06	+ .12	- .06	- 780	202900	202120
V	+ .09	- .34	+ .08	- .42	- 5460	207300	202040
J	+ .07	+ .00	+ .06	- .00		201975	201975
VII	- .06	+ .06	- .05	+ .11	+ 1430	192230	193660
IX	- .14	- .49	- .12	- .37	- 4810	193280	188470
XI	- .26	- .12	- .23	+ .11	+ 1430	187430	188860
XII	- .37	- .14	- .33	+ .19	+ 2470	184480	186950
X	- .40	- .44	- .36	- .08	- 1040	191760	190720
VI	- .53	- .64	- .47	- .17	- 2210	187640	185430

Williams Ex. 34.

Table XXXIII

Chicago Sanitary District

St. Clair River Observations.
Weighted Increment of Discharge for Normal Stage of Lake St. Clair assuming Normal Change of Lake St. Clair to be 89 % of Huron Change, and Lake St. Clair Increment to be -13000 cfs

1899-1902
Normal St. Clair 89% Huron
& St. Clair = 13000

1	2	3	4	5	6	7	8	9
Stage	St. Clair Mean Daily	Corrected Discharge	Multiplier	Weighted Discharge Col. 3 × Col. 4	Huron Mean Daily	Weighted Elevation Col. 6 × Col. 4	Weighted Centers of Gravity of Col. 3	Weighted Centers of Gravity of Col. 6
II	575.516	207630	8	1661040	581.115	4648920		
III	.620	204440	6	1226640	.072	3480432		
IV	.420	202120	4	808480	580.842	2373368	203,673	580.912
X	.000	202040	8	1616320	.794	4646352		
I	.420	201975	10	2019750	.777	5807770		
IX	.120	193660	7	1355620	.639	4064473	195,325	580.622
IX	574.870	188470	9	1696230	.555	5224995		
II	575.239	188860	8	1510880	.439	4643512		
IX	.220	186950	6	1121700	.333	3481998	189,064	580.406
V	574.930	190720	10	1907200	.304	5803040		
VI	.720	185430	8	1483440	.171	4641368		
			84					

Increment. $\frac{203673}{189064} \quad 14,609 \div \frac{580912}{580404} \quad .508 = 28,758$ c.f.s..

Williams Ex. 34. Chicago Sanitary District Table XXXII
St. Clair River Sheet 1
Discharge at Constant Stages
Gagings Weighted by Days in Periods
1908 - 1910

Group	Date	Lake Surfaces Huron Mean Daily	Lake Surfaces St Clair Mean Daily	Date	Observed Discharge	Weight by Time Interval	Weighted Discharge
					C.F.S.		C.F.S.
	1908-11-6		575.43				
	7	580.70	.37	1908-11-7	190420	0.50	95210
				7	187780	0.50	93890
XII				7	186930	0.50	93465
	8	.58	.36				
	9	.59	.37				
				9	191380	0.75	143535
				9	197460	0.75	148095
	10	51	32	10	191160	0.33	63720
				10	192570	0.33	64190
				10	190160	0.33	63387
	11	50		11	191870	0.50	95935
				11	195090	0.50	97545
		580.576	575.37		191480	5.0	191792
	1908-12-8		575.04				
	9	580.33	4.97	1908-12-9	186800	.5	93400
				9	183700	.5	91850
	10	.10	4.97	10	181600	.5	90800
XIII				10	179300	.5	89650
	11	.14	4.99	11	179600	1.0	179600
Observations	12	.35	5.00	12	179600	.75	134700
	13	.22	5.00	12	181200	.75	135900
	14	.17	5.00	14	168000	.75	126000
9.9 to				14	173300	.75	129975
22	15	.25	4.35	15	182500	1.0	182500
	16	.27	4.92	16	183900	.5	91950
0813				16	185900	.5	92950
to	17	.05	4.92	17	191000	1.0	191000
0815	18	.03		18	181500	1.0	181500
		580.191	574.976		181279	10.0	181178
	1909-11-4		575.09				
	5	580.17	.09	1909-11-5	184600	.25	46150
				5	183400	.25	45850
				5	182900	.25	45725
XIV				5	177800	.25	44450
	6	.07	.09	6	181000	.625	113125
	7	579.96	.08	6	180800	.625	113000
Observations	8	580.29	.05	6	183700	.625	114812
	9	.02	.09	6	180600	.625	112875
	10	579.94	.08	10	169000	1.75	295750
9.37 to	11	.98	.08	10	174500	1.75	305375
98	12	580.26	.04	13	175200	2.5	438000
	13	579.99	.06	15	183700	.75	137775
0.91 to	14	.91	.06	15	199100	.75	149325
0.98	15	580.33	.05	16	187600	1.0	187600
	16	.00	.16	16	171000	1.0	171000
	17	.05	.09	19	176600	1.0	176600
	18	.35	.02	19	183800	1.0	183800
	19	.06	.08	20	163300	.5	81650
	20	.02		20	178500	.5	89250
		580.085	575.076		180374	18.00	179040

Williams Ex 34. Table XXXIV
Sheet 2

Chicago Sanitary District
St. Clair River
Discharge at Constant Stages
Gagings Weighted by Days in Periods
1908 - 1910

Group	Date	Lake Surfaces Huron Mean Daily	Lake Surfaces St. Clair Mean Daily	Date	Observed Discharge	Weight by Time Interval	Weighted Discharge
	1909-11-25		575.23		C.F.S.		C.F.S.
	26	580.05	.21	1909-11-26	179800	.5	89900
	27	579.90	.15	26	181200	.5	90600
	28	580.26	.10	27	169400	.67	112934
XV				27	168500	.67	112334
	29	.15	.12	27	169700	.66	113134
Observations				30	176100	.83	146750
	30	.08	.12	30	178700	.83	148917
949				30	178700	.83	148917
to	12-1	.03	.11	12-2	178200	.375	66825
957	2	579.90	.10	2	174200	.375	65325
				2	175000	.375	65625
	3	.98	.08	2	176000	.375	66000
0903	4	580.01	.06	3	178600	1.0	178600
to				4	175300	.75	131475
0923	5	579.78	.16	4	172300	.75	129225
	6	.99		6	161100	.75	120825
				6	179000	.75	134250
		580.012	575.131		174812	11.00	174694
	1910-5-16		575.54				
	17	580.13	.59	1910-5-17	165560	1.0	165560
				18	188020	.33	62673
XVI	8	.45	.58	18	186640	.33	62213
				18	190920	.33	63640
Observations				19	179040	.2	35808
	19	.35	.55	19	186240	.2	37248
963				19	182660	.2	36532
to				19	177190	.2	35438
979				19	174720	.2	34944
	20	.24	.55	20	179640	.2	35928
				20	179850	.2	35970
				20	180940	.2	36188
				20	178300	.2	35660
				20	187220	.2	37444
	21	.36		21	188150	.5	94075
				21	187630	.5	93815
		580.306	575.562		182045	5.00	180627

Williams Ex. 34. Table XXXIV Sheet 3

Chicago Sanitary District.
St. Clair River.
Discharge at Constant Stages
Gagings Weighted by Days in Periods
1908 - 1910.

Group	Date	Lake Surfaces Huron Mean Daily	Lake Surfaces St. Clair Mean Daily	Date	Observed Discharge	Weight by Time Interval	Weighted Discharge
					C.F.S.		C.F.S.
	1910-6-12		575.70				
	13	580.55	.70	1910-6-13	189370	.2	37874
				13	190510	.2	38102
				13	188380	.2	37676
				13	187800	.2	37560
				13	187720	.2	37544
	14	.56	.69	14	189910	.33	63303
				14	187480	.33	62493
				14	189330	.33	63299
				14	189290	.33	63097
				14	184720	.33	61573
	15	.57	.68	14	186560	.33	62187
				15	185860	1.0	185860
				17	186280	1.0	186280
	16	.53	.67	18	191410	3	57423
				18	187030	3	56109
				18	190390	3	57117
				18	185620	3	55686
	17	.48	.66	18	189080	3	56724
				17	185860	1.0	185860
				17	186280	1.0	186280
	18	.55	.68	18	191410	3	57423
				18	187030	3	56109
				18	190390	3	57117
				18	185620	3	55686
	19	.51	.65	18	189080	3	56724
				20	179640	.4	71936
				20	184600	.4	73840
				20	186740	.4	74696
				20	190620	.4	76248
				20	188320	.4	75328
				22	182870	.5	91435
				22	183230	.5	91615
				22	182380	.5	91190
	20	.54	.68	23	189260	.333	63087
				23	190240	.333	63413
				23	189200	.333	63067
				24	199060	.333	66353
				24	193580	.333	64527
				24	192480	.333	64160
	21	.54	.66	25	186620	.75	139965
				25	193080	.75	144810
				27	185900	.5	92950
				27	184460	.5	92230
				27	184860	.5	92430
	22	.51	.65	28	192300	1.0	192300
				29	193400	.333	64533
				29	192530	.333	64177
				29	186710	.333	62237
	23	.55	.65	30	186940	.2	37388
				30	185200	.2	37040
				30	182340	.2	36468
				30	185770	.2	37154
				30	184400	.2	36880
	24	.52	.66	1910-7-1	184330	.2	36866
				1	183560	.2	36712
				1	188760	.2	37752
				1	186360	.2	37272
				1	185090	.2	37018
	25	.48	.67	2	184780	.25	46195
	26	.48	.67	2	183460	.25	45865
	27	.52	.66	2	183010	.25	45753
				2	188780	.25	47195
		580.58	575.64		187792	20.000	187999

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Table XXXIV
Sheet 4

Chicago Sanitary District
St. Clair River
Discharge at Constant Stages
Gagings Weighted by Days in Periods
1908 - 1910

Group	Date	Lake Surfaces Huron Mean Daily	Lake Surfaces St. Clair Mean Daily	Date	Observed Discharge	Weight by Time Interval	Weighted Discharge
	1910-8-7		575.63		C.F.S.		C.F.S.
	8	580.30	.54	1910-8-8	186260	.25	46565
				8	185060	.25	46265
				8	183740	.25	45935
				8	181570	.25	45392
	9	25	56	9	176100	.2	35220
XVIII				9	173300	.2	34660
				9	168130	.2	33626
Observations				9	171370	.2	34274
				9	175440	.2	35088
	10	39	5	10	187310	.167	31218
9423				10	184530	.167	30755
To				10	186390	.166	31065
152				10	185390	.167	30898
				10	186260	.167	31043
				10	185710	.166	30951
	11	36	.51	11	183980	.2	36796
				11	184870	.2	36974
				11	186820	.2	37364
				11	183020	.2	36604
				11	184510	.2	36902
	12	29	.51	12	179010	.2	35802
				12	176260	.2	35252
				12	177650	.2	35530
				12	181000	.2	36200
	13	21		13	180340	.2	36068
				13	181920	.2	36384
				13	178380	.2	35676
				13	183940	.2	36788
				13	179420	.2	35884
				13	181420	.2	36284
		580.29	575.535		181130	6.00	181071

Williams Ex. 34. Table XXXI

Chicago Sanitary District

St. Clair River Observations
Elevations of Lake Surfaces and Variations from Means, during selected Gaging Periods of 1908 to 1910 inclusive.

Mean Elevations for Open Season

Lake Huron.	1890 to 1910	580.70
Lake St. Clair	1890 to 1910	575.36

Gaging	Group	Days	Period	Lake Huron		Lake St. Clair.	
				Elevation	Change from Mean	Elevation	Change from Mean
10	XII	5	1908-11-7/11	580.576	- .12	575.370	+ .01
55	XVII	20	1910-6-9/2	.520	- .18	.664	+ .30
16	XVI	5	1910-5-17/21	.306	- .39	.562	+ .20
30	XVIII	6	1910-8-8/13	-.290	- .41	.533	+ .17
14	XIII	10	1908-12-9/18	.191	- .51	574.976	- .38
19	XIV	16	1909-11-1/26	.085	- .62	575.076	- .28
17	XV	11	1909-11-26/C	.012	- .69	.131	- .23

Williams Ex. 34. Table XXXVI

Chicago Sanitary District

St. Clair River Observations

Normal Change at Lake St. Clair from Mean of 1890 to 1910 for Gaging Periods from 1908 to 1910, assuming St. Clair Change to be 66⅔% of Huron Change, and observed variation from such Normal Change, and discharges corrected to Normal Stage for Increment of Lake St. Clair = 12000 c.f.s

1	2	3	4	5	6	7	8
Gage	Change from Mean					Discharge	
	Huron Observed	St. Clair Observed	St. Clair Normal	Diff	Correction due St. Clair	Observed	Corrected to Normal Stage
XII	- .12	+ .01	- .08	+ .09	+ 1080	191 792	192872
XIII	- .18	+ .30	- .12	+ .42	+ 5040	187999	193039
XVI	- .39	+ .20	- .26	+ .46	+ 5520	180627	186147
XVIII	- .41	+ .17	- .27	+ .44	+ 5280	181071	186351
XIII	- .51	- .38	- .34	- .04	- 480	181178	180698
XIV	- .62	- .28	- .41	+ .13	+ 1560	179040	180600
XV	- .69	- .23	- .46	+ .23	+ 2760	174694	177454

Williams Ex. 34 *Table XXXVII*

Chicago Sanitary District

St. Clair River Observations
Weighted Increment of Discharge for Normal Stage of Lake St. Clair assuming Normal Change of Lake St. Clair to be 66⅔% of Huron Change and Lake St. Clair Increment to be -12000 c.f.s.

1908 to 1910
Normal St. Clair - 66⅔% Huron
Δ St. Clair 12000

1	2	3	4	5	6	7	8	9
Group	St. Clair Mean Daily	Corrected Discharge	Multiplier	Weighted Discharge Col. 3 · Col. 4	Huron Mean Daily	Weighted Elevation Col. 6 · Col. 4	Weighted Centers of Gravity of Col. 5	Weighted Centers of Gravity of Col. 5
XII	575.370	192872	5	964300	580.570	2902.880		
XIII	.664	193039	20	3800780	.520	11610.400	190944	580.460
XVI	.562	186147	5	930735	.306	2901.530		
XVIII	.533	186351	6	1118106	.290	3481.740	185240	580.273
XIII	574.976	180698	10	1806980	.191	5801.910		
XIV	573.076	180600	10	2889600	.083	9281.360	179691	580.092
XV	.131	177454	11	1951994	.012	6380.132		
			73					

$$\text{Increment} = \frac{190944 - 179691}{11253} \div \frac{580.460 - 580.092}{.368} = 30,579$$

Williams Ex. 34. Table XXXVIII

Chicago Sanitary District

St. Clair River Observations

Normal Change at Lake St. Clair from Mean of 1890 to 1910 for Gaging Periods from 1908 to 1910, assuming St. Clair Change to be 89% of Huron Change, and observed variation from such Normal Change, and discharges corrected to Normal Stage for Increment of Lake St. Clair = 12000 c.f.s.

1	2	3	4	5	6	7	8
Group.	Change from Mean				Discharge		
	Huron Observ.	St. Clair Observ.	St. Clair Normal	Diff.	Correction due St. Clair.	Observed	Corrected to Normal Stage
XII	-.12	+.01	-.11	+.12	+1440	191792	193232
XVII	-.18	+.30	-.16	+.46	+5520	187999	193519
XVI	-.39	+.20	-.35	+.55	+6600	180627	187227
XVIII	-.41	+.17	-.36	+.53	+6360	181071	187431
XIII	-.51	-.38	-.45	+.07	+840	181178	182018
XIV	-.62	-.28	-.55	+.27	+3240	179040	182280
XV	-.69	-.23	-.61	+.38	+4560	174694	179254

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Chicago Sanitary District

Table XXXIII

St. Clair River Observations
Weighted Increment of Discharge for Normal Stage of Lake St. Clair assuming Normal Change of Lake St. Clair to be 89% of Huron Change and Lake St. Clair Increment to be -12000 c.f.s

1908 to 1910
Normal St. Clair 89% Huron
Δ St. Clair 12000

1	2	3	4	5	6	7	8	9
Group	St. Clair Mean Daily	Corrected Discharge	Multiplier	Weighted Discharge Col. 3 · Col. 4	Huron Mean Daily	Weighted Elevation Col. 6 · Col. 4	Weighted Centers of Gravity of Col. 3	Weighted Centers of Gravity of Col. 6
XII	575.370	193232	5	966160	580.576	2902.880		
XVII	.664	193519	20	3870380	.520	11610.400	191,591	580.460
XVI	.562	187227	5	936135	.306	2901.530		
XVIII	.533	187431	6	1124586	.290	3481.740	180,380	580.273
XIII	574.976	182018	10	1820180	.191	5801.910		
XIV	575.076	182280	16	2916480	.085	9281.360	181,310	580.092
XV	.131	179254	11	1971794	.012	6380.132		
			73					

$$\text{Increment} = \frac{\frac{191591}{181310}}{16281} \div \frac{\frac{580.460}{580.092}}{.368} = 27{,}938$$

Williams Ex. 34

Table XL
Sheet 1

Chicago Sanitary District

Q for St Clair River
By Defendant's Equation

Q = (Huron Elev. - 582.70) 40,442 - (St Clair Elev. - 575.36) 13000 + 197,610

Date		Huron	Huron	Huron	St. Clair	St. Clair	St. Clair	Net	Discharge
Year	Month	Elevation	Rise	Increase	Elevation	Rise	Decrease	Increase	
1900	Jan.	579.82	0.08	35589	574.24	1.12	14560	21029	176581
	Feb.	579.93	0.04	13691	574.28	0.04	3900	9791	175322
	Mar.	579.80	0.02	5410	574.24	0.04	1300	4110	175012
	Apr.	579.78	0.02	1080	574.22	0.02	1300	780	174232
	May	579.80	0.02	1080	574.24	0.02	1300	780	173452
	June	579.83	0.03	1620	574.26	0.02	1300	320	173132
	July	579.86	0.03	1620	574.28	0.02	1300	320	172812
	Aug.	579.90	0.04	2160	574.30	0.02	1300	860	171952
	Sept.	579.94	0.04	2160	574.32	0.02	1300	860	171092
	Oct.	579.98	0.04	2160	574.34	0.02	1300	860	170232
	Nov.	580.00	0.02	1080	574.36	0.02	1300	220	170012
	Dec.	580.02	0.02	1080	574.38	0.02	1300	220	169792
	Av. Q = 184,949								
1901	Jan.	580.22	0.20	19412	574.63	0.25	23000	10182	179974
	Feb.	580.03	0.19	18446	574.74	0.11	12650	18796	178178
	Mar.	579.91	0.12	11646	574.74	0.00	0	11646	176532
	Apr.	579.85	0.06	5823	574.70	0.04	4600	2223	176309
	May	579.85	0.00	0	574.70	0.00	0	0	176309
	June	579.85	0.00	0	574.70	0.00	0	0	176309
	July	579.85	0.00	0	574.70	0.00	0	0	176309
	Aug.	579.85	0.00	0	574.70	0.00	0	0	176309
	Sept.	579.85	0.00	0	574.70	0.00	0	0	176309
	Oct.	579.85	0.00	0	574.70	0.00	0	0	176309
	Nov.	579.85	0.00	0	574.70	0.00	0	0	176309
	Dec.	579.93	0.08	7764	574.74	0.04	4600	7524	175833
	Av. Q = 202,292								
1902	Jan.	580.00	0.07	6794	574.76	0.02	2600	9394	175833
	Feb.	579.93	0.07	6794	574.74	0.02	2600	7594	175033
	Mar.	579.91	0.02	1942	574.74	0.00	0	1942	174940
	Apr.	579.89	0.02	1942	574.74	0.00	0	1942	174940
	May	579.87	0.02	1942	574.74	0.00	0	1942	174940
	June	579.85	0.02	1942	574.74	0.00	0	1942	174940
	July	579.85	0.00	0	574.74	0.00	0	0	174940
	Aug.	579.85	0.00	0	574.74	0.00	0	0	174940
	Sept.	579.85	0.00	0	574.74	0.00	0	0	174940
	Oct.	579.85	0.00	0	574.74	0.00	0	0	174940
	Nov.	579.85	0.00	0	574.74	0.00	0	0	174940
	Dec.	579.85	0.00	0	574.74	0.00	0	0	174940
	Av. Q = 184,992								

Williams Ex 34

Table XL
Sheet 1

Chicago Sanitory District

Q for St Clair River
By Defendant's Equation

$Q = (Huron\ Elev. - 580.70)40,442 - (St.\ Clair\ Elev. - 575.36)/3000 + 197,610$

Date		Huron		Huron		St. Clair		St. Clair		Net	
Year	Month	Elevation		Rise		Elevation		Rise		Increase	Discharge
1926											
	Jan.										
	Feb.										
	Mar.										
	Apr.										
	May										
	June										
	July										
	Aug.										
	Sept.										
	Oct.										
	Nov.										
	Dec.										
											$Av.\ Q = 183,738$
1927											
	Jan.										
	Feb.										
	Mar.										
	Apr.										
	May										
	June										
	July										
	Aug.										
	Sept.										
	Oct.										
	Nov.										
	Dec.										
											$Av.\ Q = 200,106$
1928											
	Jan.										
	Feb.										
	Mar.										
	Apr.										
	May										
	June										
	July										
	Aug.										
	Sept.										
	Oct.										
	Nov.										
	Dec.										
											$Av.\ Q = 208,021$

Williams Ex. 34.

Table XL
Sheet 3

Chicago Sanitary District

Q for St. Clair River
By Defendant's Equation

Q = (Huron Elev. - 580.70) 40,442 - (St. Clair Elev. - 573.36) 13,000 + 197,610

Date		Huron		Huron	St. Clair	St. Clair	St. Clair	Net	
Year	Month	Elevation		Rise	Increase	Elevation	Rise	Decrease	Increase	Discharge
1906	Jan	580.33		0.17	6873	573.40	0.04	520	7392	190315
	Feb	580.50		0.01	24266	573.36	1.00	13000	13266	203581
	Mar	580.51		0.00	9702	573.36	1.00	1300	8402	211983
	Apr	580.51		0.00	20433	573.45	0.09	11700	8733	220716
	May	580.51		0.00	6609	573.45	0.00	0	6609	227325
	June	580.57		0.06	2178	573.45	0.00	0	2178	229503
	July	580.61		0.04	1742	573.45	0.00	0	1742	231245
	Aug	580.63		0.02	871	573.45	0.00	0	871	232116
	Sept	580.63		0.00	0	573.45	0.00	0	0	232116
	Oct	580.63		0.00	0	573.45	0.00	0	0	232116
	Nov	580.63		0.00	0	573.45	0.00	0	0	232116
	Dec	580.63		0.00	0	573.45	0.00	0	0	232116
Av. Q - 209248										
1907	Jan	580.63		0.00	2022	573.40	0.02	260	2287	194328
	Feb	580.63		0.00	8000	573.48	0.08	10400	2431	203045
	Mar	580.63		0.00	3000	573.51	0.03	3900	5031	208076
	Apr	580.63		0.00	9000	573.60	0.09	11700	2331	210407
	May	580.63		0.00	3000	573.63	0.03	3900	5031	215438
	June	580.63		0.00	0	573.63	0.00	0	0	215438
	July	580.63		0.00	0	573.63	0.00	0	0	215438
	Aug	580.63		0.00	0	573.63	0.00	0	0	215438
	Sept	580.63		0.00	0	573.63	0.00	0	0	215438
	Oct	580.63		0.00	0	573.63	0.00	0	0	215438
	Nov	580.62		0.01	0	573.63	0.00	0	0	215438
	Dec	580.62		0.00	0	573.40	0.04	520	3755	219193
Av. Q - 208576										

Mean Q 1900 to 1907 = 198002 c.f.s.

Williams Ex. 34.

Table XLI
Sheet

Chicago Sanitary District
Discharge Data
of
St. Lawrence River

1	2	3	4	5	6	7	8	9
Group No	No Observ.	Date	Observed Elevation	Observed Discharge	Optimizing Mean Daily	Multiplier	Weighted Discharge	Corrected Mean Daily
		1930-9-25			244.06			244.97
	1	26	244.14	222800	4.13	1.5	334200	4.96
	2	27	4.08	223000	4.13	.5	111500	5.01
	3	27	4.10	223300		.5	111650	
	4	28	3.99	219700	4.04	1.0	219700	4.96
I	5	29	4.02	221100		1.0	221100	
		29			4.02			4.91
		30			4.01			4.86
	6	10-1	3.94	218300	3.98	2.5	545750	4.90
		2			3.97			4.84
	7	3	4.04	219400	4.07	1.5	329100	4.83
	8	4	4.12	223800	4.06	1.0	223800	4.83
	9	5		223000		.5	111500	
			1952.43	1994,400	244.047	10.0	2308300	2449.14
			244.05	221,600	244.047		230830	244.914
		1930-10-8			244.02			244.95
	10	9	243.90	217700	3.87	1.0	217,700	4.84
	11	10	3.80	216200	3.87	1.0	216200	4.81
II	12	11	3.94	219400	4.04	1.0	219400	4.88
	13	12		221100		1.0	221100	
			731.64	874,400	975.80	4.0	874,400	979.62
			243.88	218,600	243.950		218,600	244.905
		1930-10-18			243.83			244.29
	14	17	243.84	217600	3.99	1.0	217600	4.76
	15	18	4.05	223800	4.02	1.0	223800	4.81
	16	19	3.88	209400	3.82	2.0	418800	4.49
		20			3.84			4.60
		21			3.94			4.69
III	17	22	3.81	215000	3.77	2.0	430000	4.57
	18	23	3.71	213300	3.79	1.0	213300	4.88
	19	24	3.89	217700	3.84	1.0	217700	4.61
	20	25	3.82	208300	3.59	1.0	208300	4.34
	21	26	3.70	212700		1.0	212700	
			1980.40	1,717,800	2438.22	10.0	2142,200	2446.67
			243.80	214,725	243.822		214220	244.467
		1930-10-29			243.78			244.29
	22	29	243.78	210800	3.72	1.0	210800	4.23
	23	30	3.86	189300	3.67	1.0	189300	4.26
	24	31	3.69	209900	3.70	1.0	209900	4.23
III	25	11-1	3.90	213800	3.98	1.0	213800	4.40
	26	2	4.07	225700	4.12	1.0	225700	4.60
	27	3		211700		1.0	211700	
			1818.20	1264900	1462.27	6.0	1260900	1466.98
			243.88	210,150	243.712		210,150	244.497

Williams Ex 34.

Table XLI
Sheet 2

Chicago Sanitary District
Discharge Data
of
St. Lawrence River

1	2	3	4	5	6	7	8	9
Group No.	No. Obsn.	Date	Observed Elevation	Observed Discharge	Conservancy Mean Daily	Multiplier	Weighted Discharge	Corrego Mean Daily
I	46	1901-5-5			244.91			246.06
	47	6	244.83	243400	4.86	.333	81133	6.02
	48	6	4.88	249100		"	83067	
	49	6	4.93	249000		"	83000	
	50	7	4.94	248900	4.93	"	82967	6.00
	51	7	4.97	252100		"	84033	
	52	7	5.04	251700		"	83900	
	53	8	4.80	244500	4.86	"	81500	5.96
	54	8	4.89	243900		"	81300	
	55	9	4.92	246100		"	82033	
	56	9	4.80	248200	4.82	"	82733	5.95
	57	9	4.78	248500		"	82833	
	58	9	4.85	246700		"	82233	
	59	10	4.66	242400		"	80800	
	60	10	4.77	245600		"	81867	
	61	10	4.84	246700		"	82233	
			3672.90	3,706,900	122.438	5.00	1,234,632 ✓	1279.99
			244.86	247,127	244.878		247,126	245.998
II	70	1901-6-17			244.83			245.93
	71	18	244.88	250000	4.88	.333	83333	5.93
	72	18	4.92	249700		"	82900	
	73	18	4.93	248800		"	82933	
	74	19	4.84	248600	4.92	"	82933	5.95
	75	19	4.95	250600		"	83533	
	76	19	5.09	249700		"	83233	
	77	20	4.84	246000	4.89	"	82000	5.96
	78	20	4.87	248900		"	82967	
	79	20	5.09	246100		"	82033	
	80	21	4.91	250500	4.98	"	83500	5.98
	81	21	5.01	249800		"	83267	
	82	21	5.08	252600		.333	84200	
	83	22	4.82	246800	4.91	.75	185100	5.94
		22	4.90	251100		.25	188325	
		23			5.05			6.03
	84	24	5.05	281400	5.07	.5	125700	6.04
	85	24	5.05	251500		.5	125750	
	86	24	5.12	252700		.5	126350	
	87	25	4.99	252800	5.01	.333	84200	6.01
	88	25	5.00	253100		"	84367	
	89	25	5.02	252600		"	84200	
	90	25	4.94	250700		"	83567	
	91	26	5.02	250200		"	83400	
	92	26	4.97	249300		.333	83100	
			563457	5,762,300	220.431	9.00	2258,859 ✓	2213.83
			244.98 ✓	250,109	244.948		250,649 ~	245.981

Williams Ex. 34

Table XLII

Chicago Sanitary District
INCREMENT OF DISCHARGE
OF
St. Lawrence River
(Three Points Section)

Computed for 1 foot rise at Ogdensburg

1	2	3	4	5	6	7	8	9	10	11
Sequence	Group	Days	Preceding Mean Daily	Multiplier	Weighted Elevations	Centers of Gravity Elevation	Discharge	Multiplier	Weighted Discharge	Centers of Gravity Discharge
23	VI	9	244.946	9	2204.51	244.921	250099	9	2,250,891	249,837
15	V	5	876	5	1224.38	244.219	247126	5	1,235,630	226,644
9	I	10	047	10	2440.47		220830	10	2,208,300	
4	II	4	3.950	4	975.80	243892	218600	4	874,400	216,193
8	III	10	3.832	10	2438.22		214220	10	2,142,200	
6	IV	6	3.712	6	1462.27		210130	6	1260,900	
63		44		44	10745.65			44	9,972,325	
					244.219				226,644	

244.921 − 243.892 = 1.029

249.837 − 218,193 = 31,644

31,918 = Increment

Equation:

$X = 31,918\,Y - 7,568,368$

Williams Ex. 34. Chicago Sanitary District
Q for St. Lawrence River
(H-243, Q-192,400, A 28870)
By Complainant's Equation

Table XLIII

Date		Lake Height	Discharge	Date		Lake Height	Discharge	Date		Lake Height	Discharge
Year	Month	Quarterday	C.F.S.	Year	Month	Quarterday	C.F.S.	Year	Month	Quarterday	C.F.S.
1900	Jan	243.97	220400	1903	Jan	243.61	215785	1906	Jan	245.30	258800
	Feb		211200		Feb		212715		Feb		253300
	Mar		204000		Mar		210880		Mar		252000
	April		196800		April		207200		April		251300
	May		189600		May		203320		May		250600
	June		182400		June		199440		June		249900
	July		175200		July		195560		July		249200
	August		168000		August		191680		August		248500
	Sept		160800		Sept		187800		Sept		247800
	Oct		153600		Oct		183920		Oct		247100
	Nov		146400		Nov		180040		Nov		246400
	Dec		139200		Dec		176160		Dec		245700
1901	Jan	244.24	228200	1904	Jan	244.37	232000	1907	Jan	245.09	252785
	Feb		221200		Feb		228920		Feb		252320
	Mar		214200		Mar		225840		Mar		251855
	April		207200		April		222760		April		251390
	May		200200		May		219680		May		250925
	June		193200		June		216600		June		250460
	July		186200		July		213520		July		249995
	August		179200		August		210440		August		249530
	Sept		172200		Sept		207360		Sept		249065
	Oct		165200		Oct		204280		Oct		248600
	Nov		158200		Nov		201200		Nov		248135
	Dec		151200		Dec		198120		Dec		247670
1902	Jan	244.42	233400	1905	Jan	244.11	224399	1908	Jan	245.61	267850
	Feb		226400		Feb		221320		Feb		
	Mar		219400		Mar		218240		Mar		
	April		212400		April		215160		April		
	May		205400		May		212080		May		
	June		198400		June		209000		June		
	July		191400		July		205920		July		
	August		184400		August		202840		August		
	Sept		177400		Sept		199760		Sept		
	Oct		170400		Oct		196680		Oct		
	Nov		163400		Nov		193600		Nov		
	Dec		156400		Dec		190520		Dec		

Mean Q 1900 to 1902 = 240,818 c/s.

Mean Q 1900 to 1908 = 247,762 c/s.

Williams Ex. 34. Table XLIIe

Chicago Sanitary District
Q for St. Lawrence River
(H = 244.22, Q = 226644, Δ = 31920
By Defendant's Equation

Date	Gage Height	Discharge
Year	Hour	Quarterday	C.F.S.
1900			
1901			
1902			

Mean Q 1900 to 1907 = 241908

Mean Q 1900, 1901, 1902 = 242277

Table XLIV.

Chicago Sanitary District.

Relative Fluctuations of Lakes.

Ontario-Erie.

Erie Elevation Decreasing.

1	2	3	4	5	6
Period	Year	Erie		Ontario	
		Elevation	C of G	Elevation	C of G
1860–1903	1876	573.70		247.10	
	62	369		263	
	61	358		760	
	60	350		696	
	59	348		657	
	58	340		719	
	57	334		730	
	56	334		760	
	55	351		706	
	54	329		650	
	53	328		759	
	52	327		668	
	51	324	573.180	685	246.982
	50	305		707	
	49	296		658	
	48	290		694	
	47	289		618	
	46	265		653	
	45	281		694	
	44	244	572.620	689	246.172
	43	268		693	
	42	277		733	
	41	261		682	
	40	261		651	
	39	268		619	
	38	253		621	
	37	244		594	
	36	253		647	
	35	236		608	
	34	228		577	
	33	220	572.153	553	245.497
	32	215		612	
	31	214		638	
	30	214		587	
	29	210		573	
	28	209		598	
	27	196		620	
	26	194		526	
	25	193		620	
	24	184		627	
	23	173		602	
	22	139		506	
	21	139		562	
	20	117		529	

572.180 246.982 4445 = 1444.5 Outlook
572.153 245.497 1.029 2.16
.027 1.485

Williams Ex. 34 Table XII

Chicago Sanitary District
Niagara Discharge

1 ft. rise in Lake Erie
All groups considered
Buffalo Gage

1	2	3	4	5	6	7	8	9	10	11
Sequence	Group	Days	Buffalo Mean Daily	Multiplier	Weighted Elevations	Coef. of Elev.	Discharge	Multiplier	Weighted Discharge	Coef. of Discharge
6	XIII	3	57268	3	171786		217787	3	653301	
19	XIII	13	254	13	744302	572296	202942	13	2638246	199868
8	IV	4	209	4	2288.36		193238	4	772952	
6	I	5	202	5	2860.10		194355	5	971675	
8	XI	6	196	6	3431 76	63	193289	6	1139734	1220
22	VII	10	194	10	5719.40	571992	186405	10	1864050	199088
10	III	7	189	7	4003.29		184471	7	1291297	
6	II	6	184	6	3431.04	25	186567	6	1119402	4304
11	X	6	181	6	3429.66	571768	184333	6	1105998	184334
3	IX	3	155	3	1714.65		185787	3	557301	
12	XI	7	151	7	4000.57		184511	7	1291577	
[illegible]										
8	VIII	4	141	4	2286.64		182688	4	730752	
[illegible]										

572296
4725
569

199868
199986
14002

Increment = [illegible] per sec
14002 ÷ 8.569 = 2665.
Equation: X = 2665Y − 14,778,972
X = [illegible]

115		74	6862.58	78	42325.29		2294313	74	14130285	

Williams Ex. 34

Table XLVa
Sheet 1
(5 Sheets)

Chicago Sanitary District
Niagara River
Discharge at Constant Stages

Gagings Weighted by Days in Periods
1898-1900

1	2	3	4	5	6	7	8
Group	No. of Obsn.	Date	Observed		Buffalo Mean Daily	Multiplier	Weighted Discharge
			Elevation	Discharge			
	6	1898-9-12			571.75		
	7	13	572.08	195800	1.93	0.75	146850
	13	13	1.96	195000		0.75	146250
	14	14			2.05		
I	15	15	2.01	195500	2.13	1.00	195500
	8	15	2.16	198900		1.00	198900
	9	16			2.15		
	10	17	1.74	188500	2.05	0.75	141375
	11	17	1.75	190400		0.75	142800
6			3431.65	1164100	3432.10	5.00	971675
Mean			571.94	194017	572.02		194335
	20	1898-9-28			571.85		
	21	29	571.85	188900	1.85	0.75	141675
	30	29	1.73	187400		0.75	140550
	22	30			1.85		
II	23	10-1	1.42	181900	1.75	1.25	227375
		1	1.48	184800		1.25	231000
		3			1.85		
	24	4	1.65	188700	1.85	1.00	188700
	25	4	1.76	190100		1.00	190100
6			3429.89	1121800	400285	6.00	1119400
Mean			571.65	186967	571.84		186567
	32	1898-10-12			572.15		
	33	13	571.47	188500	1.75	0.75	141375
		13	1.84	190400		0.75	142800
	34	14			2.25		
	35	15	1.80	188900	2.23	1.00	188900
		15	2.03	193300		1.00	193300
III	36	16			1.75		
	37	17	1.14	183200	1.13	0.50	91600
	38	17	1.05	173600		0.50	87000
	39	17	0.75	173800		0.50	86900
		17	0.62	169200		0.50	84600
	40	18			1.65		
	41	19	1.41	180200	2.13	0.75	135150
		19	1.61	184900		0.75	138675
10			5713.65	1828200	4575.10	7.00	1291300
Mean			571.36	182820	571.89		184471

Williams Ex. 34

Table XLV
Sheet 2

Chicago Sanitary District
Niagara River
Discharge at Constant Stages

Gagings Weighted by Days in Periods
1898-1900

1	2	3	4	5	6	7	8
Group	No of Obsn.	Date	Observed Elevation	Observed Discharge	Buffalo Mean Daily	Multiplier	Weighted Discharge
IV	49	1898-10-31	572.29	207100	571.95		
	50	11-1	1.27	195800	2.13	0.50	103550
	51	2	1.26	194900		0.50	97900
	52	3	1.83	193000	2.55	0.75	146175
		4				0.75	144750
	53		1.60	188000	1.95		
	54		1.33	186900	1.83	0.375	70500
	55		1.47	187600		0.375	70088
	56		1.24	183700		0.375	70350
						0.375	69638
	8		457.99	1539000	2860.45	4.00	772951
Mean			571.75	192375	572.09		193238
V	98	1899-2-13	571.94	161300	571.55		
	99	14	1.99	160800	1.33	1.00	161500
	100	15	1.92	160700	1.23	0.25	42700
	101	16	1.91	159900		0.25	42175
	102	17	1.91	158700		0.25	41475
	103	18	1.91	158400		0.25	44275
	104	19	1.90	159400	1.45	0.50	84700
	105	20	1.90	160900		0.50	84050
	106	21	1.89	159700	1.45	0.50	84800
	107	22	1.90	157500		0.25	39187
	108	23	1.93	161000		0.25	40833
	10		19.10	1597000	5.03	4.00	690523
Mean			571.91	159700	571.51		172631
VI	1	1899-8-29	571.80	191900	571.95		
	2	30	2.14	200300	1.93	1.00	191900
	3	31	1.93	193800	2.03	0.25	46787
	4	9-1	1.85	192600		0.25	48267
	5	1	1.87	191100	1.95	0.25	48150
	6	2	2.25	201600		0.50	99050
	7	3	1.77	189900	1.95	0.50	101800
		4			2.13	1.50	284850
	8		1.89	190600	7.73	1.50	285900
	8		457.547	1582800	400375	6.00	1159734
Mean			571.93	195350	571.96		193289

Williams Ex 34

Table XLVa
Sheet 3

Chicago Sanitary District
Niagara River
Discharge at Constant Stages

Gagings Weighted by Days in Periods
1898-1900

1	2	3	4	5	6	7	8
Group	No. of Obsns.	Date	Observed Elevation	Observed Discharge	Buffalo Mean Daily	Multiplier	Weighted Discharge
	12	1899-9-13			572.05		
	13	14	571.73	188200	1.85	1.00	188200
	14	15	1.63	184600	1.75	0.33	61567
	15	16	1.75	188400		0.33	62800
	16	17	1.75	188200		0.33	61733
	17	18	1.79	189800	1.85	0.50	92900
	18	19	1.63	182300		0.50	91250
		16	1.49	180600		0.50	90300
		17			1.85		
	19	18	1.75	185000	1.85	0.50	92500
	20	19	1.67	180300		0.50	90150
	21	20	1.92	191600		0.50	95800
III	22	19	1.80	183300	1.55	0.33	61100
	23	19	1.33	176000		0.33	58667
	24	19	1.29	175100		0.33	57867
	25	20	1.78	186000	1.85	0.33	62000
	26	20	1.77	188800		0.33	62933
	27	20	1.63	186400		0.33	62133
	28	21	1.92	187200	2.25	0.50	93600
	29	21	2.32	201000		0.50	100500
	30	22	1.55	181800	2.05	0.50	90900
	31	23	2.06	193600		0.50	96800
	32	23	1.50	183300	2.45	0.50	91650
	33	23	1.33	181800		0.50	90800
	22		12577.95	4092500	629.35	10.00	1864050
Mean			571.72	186023	571.94		186405
	34	1899-10-3			571.45		
	35	4	571.66	186300	1.55	1.00	186300
	36	5	1.39	181200	1.40	1.00	181200
III	37	6	1.42	181600	1.45	0.50	90800
	38	6	1.42	181400		0.50	90700
	39	7	1.37	178400	1.15	0.50	89200
	39	7	1.28	176700		0.50	88350
	6		3428.76	1093300	2857.05	4.00	730750
Mean			571.46	182217	571.41		182688

Williams Ex. 34. Table XLVa Sheet 4

Chicago Sanitary District
Niagara River
Discharge at Constant Stages

Gagings Weighted by Days in Periods
1898-1900

1	2	3	4	5	6	7	8
Group	No. of Obsn.	Date	Observed Elevation	Observed Discharge	Buffalo Mean Daily	Multiplier	Weighted Discharge
IX	41	1899-10-10			571.55		
	42	11	571.35	181800	1.35	0.50	90900
	43	11	1.60	186600		0.50	93300
	44	12	1.39	189000	1.55	0.50	94500
	45	12	1.33	180200		0.50	90100
		13	1.48	182300	1.55	1.00	182500
	5		2857.35	920100	2286.20	3.00	551300
Mean			571.47	184020	571.55		183767
X	55	1899-10-29			571.85		
	56	30	571.63	190400	1.35	0.50	95200
	57	30	1.57	185400		0.50	92700
	58	31	1.22	180600	1.15	0.50	90300
	59	31	1.13	170400		0.50	85200
	60	11- 1	1.61	183800	1.35	1.00	183800
	61	2	0.78	169400	0.85	0.50	84700
	62	3	0.82	168800		0.50	84400
	63	3	1.16	175800	1.95	0.50	87900
	64	3	0.67	165200		0.50	82600
	65	4	2.89	216400	2.55	0.50	108200
		4	3.29	222000		0.50	111000
	11		6286.67	2028200	4001.25	6.00	1106000
Mean			571.52	184382	571.61		184333
XI	70	1899-11-22			571.45		
	71	23	570.73	167500	0.85	0.50	83750
	72	23	0.54	164300		0.50	82150
	73	24	1.32	182700	1.45	0.50	91350
	74	24	1.45	185500		0.50	92750
	75	25	1.43	182200	1.45	0.75	136650
		25	1.30	181900		0.75	136425
	76	26			1.55		
	77	27	1.56	188400	1.55	0.75	141300
	78	27	1.72	191800		0.75	143850
	79	28	1.64	194500	1.95	0.50	97250
	80	28	1.88	193800		0.50	96850
	81	29	1.72	190200	1.85	0.50	95100
		29	1.68	188700		0.50	94350
	12		6857.33	2211000	4572.10	7.00	1291575
Mean			571.44	184250	571.51		184511

Williams Ex. 34. Table XLVO
Sheet 5

Chicago Sanitary District
Niagara River
Discharge at Constant Stages

Gagings Weighted by Days in Periods
1898-1900

1	2	3	4	5	6	7	8
Group	No. of Obser.	Date	Observed		Buffalo Mean Daily	Multiplier	Weighted Discharge
			Elevation	Discharge			
		1900-6-27			572.55		
	91	28	572.73	215900	2.65	0.50	107950
	92	29	3.04	218500		0.50	109250
XII	93	29	3.41	228800	2.65	0.50	114400
	94	29	2.94	214100		0.50	107050
	95	30	2.99	215200	2.65	0.50	107600
	96	30	2.95	214100		0.50	107050
	6		3437.96	1306600	229.050	3.00	653300
Mean			572.99	217767	572.62		217767
		1900-7-8			573.15		
	101	9	573.15	221400	2.75	0.50	110700
	102	9	2.69	205900		0.50	102950
	103	10	2.28	200700	2.45	0.50	100350
	104	10	2.71	214300		0.50	107150
	105	11	2.71	205000	2.65	0.50	102500
	106	11	2.26	193800		0.50	97900
	107	12	3.21	216900	2.75	0.50	108450
	108	12	3.04	213100		0.50	106550
XIII	109	13	2.30	199300	2.65	1.00	199300
	110	14	2.52	203200	2.35	0.75	152400
	111	14	2.26	194400		0.75	145800
		15			2.35		
	112	16	2.33	200700	2.45	0.75	150525
	113	16	2.15	196500		0.75	147375
	114	17	2.88	213200	2.35	0.50	107600
	115	17	2.36	201600		0.50	100800
	116	18	2.35	201300	2.35	1.00	201300
	117	19	2.11	201100	2.25	1.00	201100
	118	20	2.39	201600	2.35	1.00	201600
	119	21	2.25	193900	2.65	1.00	193900
	19		1087.09	3881900	801.5.50	13.00	2638250
Mean			572.53	204311	572.54		202942

Williams Ex 34 *Table XLII*

Chicago Sanitary District
Niagara Discharge

1 Ft rise in Lake Erie
All groups considered

$\frac{\text{Buffalo Mean Daily} + \text{Amherstburg Mean Daily}}{2}$ *gives governing elev*

1	2	3	4	5	6	7	8	9	10	11
Group	Group	Days	Buffalo Mean Daily	Multiplier	Weighted Elevations	Coef of Elev.	Discharge	Multiplier	Weighted Discharge	Coef of Discharge
6	XII	3	572.55	3	1717.65		217767	3	653300	
19	XIII	13	2.51	13	7442.63		202942	13	2638250	
6	I	5	2.25	5	2861.25	572.354	194335	5	971675	199868
8	II	6	2.24	6	3433.44		193289	6	1159734	
8	IV	4	200	4	2288.00		193238	4	772952	1290
10	III	6	2.08	6	3432.48	572.0[illegible]	184217	6	1105300	19[illegible]
22	VIII	10	203	10	5720.30		186405	10	1864050	
6	II	7	213	7	4004.91		187314	7	1311200	5120
11	X	6	1.77	6	3430.62	571.[illegible] 909	184333	6	1106000	18[illegible]
5	IX	5	1.74	5	1718.22		189767	5	551300	
6	VIII	4	1.72	4	2286.88		182600	4	730750	
12	XI	7	1.67	7	4001.69		184511	7	1291575	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]		[illegible]	[illegible]	—		[illegible]	[illegible]	
119		74		74	42335.07				[illegible]600.5	

2153210 *360175*

572.354
571.[illegible] 909
0.445

199868 5120

Increment = [illegible] = [illegible] *cu ft per sec.*
19763 + 0.445 = 33492

Equation:

$X = [illegible] - [illegible]$

$X = 33492\,Y - 19763.108$

Williams Ex. 34 Chicago Sanitary District Table XLVIII
Niagara Discharge
1 Ft. rise in Lake Erie
All groups considered

$$\frac{\text{Buffalo Mean Daily} + \text{Amherstburg Mean Daily}}{2} = \text{governing elevation}$$

1	2	3	4	5	6	7	8	9	10	11
Groups	Group	Days	Buffalo & Amherstburg Mean Daily	Multiplier	Weighted Elevations	C of G Elevs	Discharge	Multiplier	Weighted Discharge	C of G Discharge
6	XII	3	57255	3	171765		217767	3	653301	
19	XIII	13	57251	13	744263	572.354	202942	13	2,638,246	
6	I	5	57225	5	286125		194335	5	971,675	199868
8	III	6	57224	6	343344		193269	6	1,159,734	
8	IV	4	57200	4	228800	92	193238	4	772952	1220
6	II	6	572.12	6	343272	572.[illegible]	186567	6	1,119,[illegible]	190[illegible]
22	VII	10	572.03	10	5720.03		186405	10	1,864,050	
10	III	7	572.10	7	400470	905	184471	7	1,291,297	4986
11	X	6	571.78	6	343068	571[illegible]	184333	6	1,105,998	181[illegible]
5	IX	3	571.74	3	171522		183767	3	551,301	
6	VIII	4	571.72	4	228688		182688	4	730,752	
12	XI	7	571.67	7	400169		184511	7	1,291,577	
[illegible]										
		24			[illegible]				[illegible]	

572354
[illegible]
[illegible]
469

190882
[illegible] = [illegible] - 33145
449

190868
[illegible]
[illegible]
190882

$X = 33145\,Y - 18770769$

Williams Ex 34. Table XLVIb

Chicago Sanitary District.
Niagara Discharge

Amherstburg Mean Daily

1 Ft rise in Lake Erie

Sagitto	Group	Days	Amherstburg Mean Daily	Multiplier	Weighted Elevation	C of G Elevation	Discharge	Multiplier	Weighted Discharge	C of G Discharge
6	XII	3	572.46	3	171744		217767	3	653301	
19	XIII	13	572.46	13	744224	572.412	202942	13	2638246	199868
6	I	5	572.48	5	286240		194335	5	971675	
8	VI	6	572.51	6	3435.06		193285	6	1159734	
8	IV	4	571.91	4	2287.64	31	193238	4	772952	1220
6	II	6	572.41	6	343446	572.2[illegible]	186567	6	1119 402	196[illegible]
10	III	7	572.32	7	400624		184471	7	1291 297	
22	VII	10	572.13	10	572130		186405	10	1864050	
11	X	6	571.94	6	3431.64	101	184333	6	1105998	4996
12	XI	7	571.83	7	4002.81	572.[illegible]	184511	7	1291577	183[illegible]
5	IX	3	571.92	3	1715.76		183767	3	651301	
6	VIII	4	572.03	4	2288.12		182688	4	730752	
[illegible]										
		[illegible]			[illegible]				[illegible]	
					31				1220	
					572.2[illegible]				196[illegible]	

572.412 + 101/311

16882/311 = 97052

199868 + 4996/311 = 14882

Williams Ex 34

Chicago Sanitary District
Niagara Discharge

Table XLVII

Cleveland Mean Daily

1 Ft. rise in Lake Erie.

Year	Group	Days	Cleveland Mean Daily	Multiplier	Weighted Elevation	C of G of Elev.	Discharge	Multiplier	Weighted Discharge	C of G of Discharge
17	I	11	572.32	11	6291.72		206480	11	2271280	
11	VI	7	2.09	7	4004.63	572.127	192860	7	1350020	197229
22	II	11	1.97	11	6291.67		192710	11	2119810	
16	IV	6	1.74	6	3430.44	571.[illegible]	193650	6	1161900	[illegible]
22	VII	9	1.87	9	5146.83		186450	9	1678050	
14	III	5	1.69	5	2858.45		179500	5	897500	
2	VIII	8	1.62	8	4572.96	571.63	184360	8	1474880	183766
8	X	4	1.57	4	2286.28		180538	4	722150	
8	IX	4	1.51	4	2286.04		185100	4	740400	
[illegible]										

572.127
571.6[illegible]83 197229 [illegible] 3766
[illegible]
492 13463

Increment = 13463 / 492 = 30459 cu. ft. per sec.

Equation: 30459Y - 17229166
X - [illegible]

Williams Ex 34.

Chicago Sanitary District.
Niagara Discharge.

Table XLVII B

Cleveland Mean Daily

If rise in Lake Erie.

Engineer	Group	Days	Cleveland Mean Daily	Multiplier	Weighted Elevation	C of G Elevs	Discharge	Multiplier	Weighted Discharge	C of G Discharge
17	I	14	572.52	14	801528	572.068	206611	14	2892554	196,168
22	II	25	571.96	25	14299.00		192851	25	4821275	
11	VI	10	572.00	10	5720.00		191543	10	1915430	
14	IV	9	571.74	9	5145.66	205	194221	9	1747989	911
22	VII	10	571.84	10	5718.40	571	186405	10	1864050	190,918
8	IX	5	571.88	5	2857.90		186145	5	930725	
12	VIII	10	571.60	10	5716.00	570	185028	10	1850280	3,301
8	X	5	571.70	5	2858.50	571	181645	5	908225	185,329
14	III	10	571.80	10	5716.00		177878	10	1778780	
[illegible]										
		350			572068				19702311	

572.068
570
571
350

196,168
12858
196,168
12,007
12858

Williams Ex. 34

Table XLVIII
Sheet 1

Chicago Sanitary District
Precipitation

Superior : Marquette
Mich. Huron: Milwaukee, Detroit
Erie St. Clair : Detroit, Cleveland, Buffalo
Ontario : Buffalo, Oswego, Rochester, Toronto

Year	Superior	Mich. Huron	Erie-St. Clair	Ontario
1860	29.79	25.15	31.83	29.66
61	28.58	33.53	36.70	37.76
62	30.24	36.44	38.79	38.86
63	33.60	34.06	37.73	37.41
64	22.32	27.84	34.33	41.38
65	26.00	28.98	28.82	36.27
	28.83	30.58	33.04	37.24
1866	29.49	33.93	39.57	38.64
● 67		27.04	30.51	32.11
● 68		31.08	38.79	38.64
● 69		35.83	38.58	42.53
70		30.37	41.23	40.43
71		37.15	39.96	38.87
	29.49	31.58	36.57	37.75
1872	30.23	33.16	37.44	38.58
73	26.36	33.31	40.85	39.64
74	34.94	34.34	41.01	41.37
75	30.22	34.93	34.68	38.83
76	31.44	33.97	40.22	38.42
77	27.29	40.29	34.70	36.67
	28.46	33.50	35.61	33.05
1878	36.19	40.24	42.38	42.06
79	40.72	31.05	38.38	37.25
80	33.48	34.82	41.44	38.78
81	42.91	42.26	38.78	38.61
82	37.08	39.37	34.77	38.81
83	30.50	31.22	37.28	38.15
	36.81	39.36	40.16	36.12
1884	41.74	38.37	42.58	39.05
85	30.56	30.41	38.13	38.04
86	38.27	29.08	37.25	38.27
87	33.62	29.71	37.82	38.31
88	35.46	28.25	37.88	37.41 *
89	30.37	28.38	37.73	38.62
	32.11	28.33	33.49	32.45
1860-1889	31.71	32.35	35.77	35.32

* Toronto Missing
● Detroit taken as mean of Lansing and Monroe

Williams Ex. 34 Table XLVIII

Chicago Sanitary District Sheet 2

Precipitation

Superior : Marquette
Mich. Huron: Milwaukee, Detroit
Erie St. Clair : Detroit, Cleveland, Buffalo
Ontario : Buffalo, Oswego, Rochester, Toronto

Year	Superior	Mich-Huron	Erie-St.Clair	Ontario
1860-1889	31.71	32.35	35.77	35.32
1890	34.47	32.54	43.12	43.50*
91	33.78	29.35	37.45	37.82*
92	33.78	32.07	36.45	36.37*
93	35.68	35.85	38.43	38.31*
94	33.98	29.78	30.62	30.03
95	33.04	29.98	37.97	36.74
	33.34	31.36	34.75	36.01
1896	29.39	32.59	36.72	35.58
97	30.03	30.61	30.87	34.23
98	27.48	33.18	33.46	33.49
99	36.43	29.81	36.74	35.93
1900	32.32	30.77	31.01	35.20
11	37.15	29.44	34.33	37.49
	32.17	29.25	32.20	34.62
1903	26.77	32.08	36.11	32.89
03	35.84	32.64	36.41	34.42
04	33.74	29.00	36.91	36.47
05	28.18	27.03	33.25	34.68
06	37.43	34.33	32.97	32.73
07	31.62	32.76	33.25	33.05
	32.86	32.10	34.18	34.05
1908	30.29	28.43	30.74	31.32
09	29.27	28.08	37.27	34.23
10	30.24	25.04	33.65	31.73
11	37.22			34.00
12	30.35			32.41*
	31.38	29.19	33.67	34.23
1890-1907	32.79	30.90	33.71	34.90
1890-1908	32.66	30.77	33.53	34.71
1890-1910	32.39	30.66	33.71	34.80
1860-1908	32.12	31.74	34.90	35.08
1860-1910	32.02	31.69	34.93	35.11

* Toronto Missing

Williams Ex 34

Table XLVIII(a)
Sheet 1

Chicago Sanitary District
Annual Precipitation

Year	Annual Precipitation													
	Evanston	Lombard	Downers Grove	Florence	Wilmette	Chicago	Cicero	Blue Island	Buffalo Grove	Glenview	Barrington	Bensenville	Bromley
1860	23.79		28.77	30.40	22.02	(34.40)	37.18		30.03			30.38	28.00
61	30.98		37.59	31.78	33.48	(38.30)	33.90	40.67	38.61	32.05	44.59	33.99	34.45
62	30.24		31.43	33.46	41.45	(40.12)	38.29	44.65	30.67	32.05	44.59	40.21	34.05
63	33.60		30.57	32.29	33.16	(33.60)	34.67	33.92	29.15	30.16	44.79	31.22	32.77
64	22.32	27.95	29.88	29.01	29.50	(28.90)	33.18	37.17	40.96	43.79	43.97	40.24	30.94
65	26.08	29.92	27.10	30.82	31.86	(40.20)	32.02	39.55	33.53	43.37	43.29	33.77	32.93
66	29.49	30.62	31.72	29.67	34.18	(36.30)	38.65	40.67	38.96	43.29	46.03	30.07	39.42
67		24.98		32.97	24.10	22.41	31.13	31.36	31.44	33.22	31.66	31.66	30.11
68		30.10		32.68	29.27	30.98	33.82	42.16	38.54	42.51	39.22	34.28	34.38
69		32.04		30.36	31.51	30.57	37.86	42.44	40.68	47.08	44.35	39.64	39.64
1870		36.04	34.07	34.70	29.61	29.84	41.70		41.91	34.10	39.61	46.18	46.18
71		26.51	33.35	27.22	29.04	(33.61)	32.75	(36.08)	34.68	31.07	33.41	32.73	
72	(30.03)	27.74	32.11	24.74	(30.29)	31.22	36.31	(37.56)	28.57	31.74	(30.39)	25.35	
73	28.38	28.23	34.01	29.05	30.01	34.16	42.12	33.35	43.32	33.29	49.84	31.01	
74	24.04	23.09	26.69		31.00	29.32	33.91	22.81	30.41	34.91	35.51	24.34	
75	30.22		35.71		33.36	38.08	30.91	28.03	31.44	31.41	29.91	27.23	
76	31.44		40.40		30.34	30.51	41.70	34.35	39.25	34.19	33.82	31.41	
77	27.54		32.23		40.15	41.01	33.89	33.77	34.48	32.20	34.12	21.99	
78	36.19		41.39		33.89	41.35	33.51	37.61	60.24	35.83	40.80	40.35	

Continuation from Williams Exhibit 5 consisting of private data, Federal Office and Commission data.

Observations at Chicago 1871-1884 inclusive are from Chicago Weather Service Report, 1884, p. 5.

Observations at Chicago 1885-1891 inclusive are from Chicago Weather Service Report, 1891, p. 5.

Observations at Chicago 1892-1911 inclusive are from Chicago Weather Service Report, 1911, p. 5.

Observations at Chicago 1912-1916 inclusive are from Chicago Weather Service Report, 1916, p. 5.

Observations at Chicago 1917-1919 inclusive are from Chicago Weather Service Report, 1919, p. 5.

Observations at Chicago 1920-1922 inclusive are from Chicago Weather Service Report, 1922, p. 5.

Observations at Chicago 1923-1924 inclusive are from Chicago Weather Service Report, 1924, p. 5.

Observations at Chicago 1925-1926 inclusive are from Chicago Weather Service Report, 1926, p. 5.

Observations at Chicago 1927-1928 inclusive are from Chicago Weather Service Report, 1928, p. 5.

Observations at Chicago 1929-1930 inclusive are from Chicago Weather Service Report, 1930, p. 5.

Observations at Chicago 1931-1932 inclusive are from Chicago Weather Service Report, 1932, p. 5.

Observations at Chicago 1933-1934 inclusive are from Chicago Weather Service Report, 1934, p. 5.

Observations at Chicago 1935-1936 inclusive are from Chicago Weather Service Report, 1936, p. 5.

Observations at Chicago 1937-1938 inclusive are from Chicago Weather Service Report, 1938, p. 5.

Observations at Chicago 1939-1940 inclusive are from Chicago Weather Service Report, 1940, p. 5.

Observations at Chicago 1941-1942 inclusive are from Chicago Weather Service Report, 1942, p. 5.

Observations at Chicago 1943-1944 inclusive are from Chicago Weather Service Report, 1944, p. 5.

Observations at Chicago 1945-1946 inclusive are from Chicago Weather Service Report, 1946, p. 5.

Observations at Chicago 1947-1948 inclusive are from Chicago Weather Service Report, 1948, p. 5.

Observations at Chicago 1949-1950 inclusive are from Chicago Weather Service Report, 1950, p. 5.

Observations at Chicago 1951-1952 inclusive are from Chicago Weather Service Report, 1952, p. 5.

Observations at Chicago 1953-1954 inclusive are from Chicago Weather Service Report, 1954, p. 5.

Observations at Chicago 1955-1956 inclusive are from Chicago Weather Service Report, 1956, p. 5.

Observations at Chicago 1957-1958 inclusive are from Chicago Weather Service Report, 1958, p. 5.

Observations at Chicago 1959-1960 inclusive are from Chicago Weather Service Report, 1960, p. 5.

Observations at Chicago 1961-1962 inclusive are from Chicago Weather Service Report, 1962, p. 5.

Observations at Chicago 1963-1964 inclusive are from Chicago Weather Service Report, 1964, p. 5.

Observations at Chicago 1965-1966 inclusive are from Chicago Weather Service Report, 1966, p. 5.

Observations at Chicago 1967-1968 inclusive are from Chicago Weather Service Report, 1968, p. 5.

Observations at Chicago 1969-1970 inclusive are from Chicago Weather Service Report, 1970, p. 5.

Observations at Chicago 1971-1972 inclusive are from Chicago Weather Service Report, 1972, p. 5.

Observations at Chicago 1973-1974 inclusive are from Chicago Weather Service Report, 1974, p. 5.

Observations at Chicago 1975-1976 inclusive are from Chicago Weather Service Report, 1976, p. 5.

Observations at Chicago 1977-1978 inclusive are from Chicago Weather Service Report, 1978, p. 5.

Observations at Chicago 1979-1980 inclusive are from Chicago Weather Service Report, 1980, p. 5.

Observations at Chicago 1981-1982 inclusive are from Chicago Weather Service Report, 1982, p. 5.

Observations at Chicago 1983-1984 inclusive are from Chicago Weather Service Report, 1984, p. 5.

Observations at Chicago 1985-1986 inclusive are from Chicago Weather Service Report, 1986, p. 5.

Observations at Chicago 1987-1988 inclusive are from Chicago Weather Service Report, 1988, p. 5.

Observations at Chicago 1989-1990 inclusive are from Chicago Weather Service Report, 1990, p. 5.

Observations at Chicago 1991-1992 inclusive are from Chicago Weather Service Report, 1992, p. 5.

Observations at Chicago 1993-1994 inclusive are from Chicago Weather Service Report, 1994, p. 5.

Observations at Chicago 1995-1996 inclusive are from Chicago Weather Service Report, 1996, p. 5.

Observations at Chicago 1997-1998 inclusive are from Chicago Weather Service Report, 1998, p. 5.

Observations at Chicago 1999-2000 inclusive are from Chicago Weather Service Report, 2000, p. 5.

Observations at Chicago 2001-2002 inclusive are from Chicago Weather Service Report, 2002, p. 5.

Observations at Chicago 2003-2004 inclusive are from Chicago Weather Service Report, 2004, p. 5.

Observations at Chicago 2005-2006 inclusive are from Chicago Weather Service Report, 2006, p. 5.

Observations at Chicago 2007-2008 inclusive are from Chicago Weather Service Report, 2008, p. 5.

Observations at Chicago 2009-2010 inclusive are from Chicago Weather Service Report, 2010, p. 5.

Observations at Chicago 2011-2012 inclusive are from Chicago Weather Service Report, 2012, p. 5.

Observations at Chicago 2013-2014 inclusive are from Chicago Weather Service Report, 2014, p. 5.

Observations at Chicago 2015-2016 inclusive are from Chicago Weather Service Report, 2016, p. 5.

Observations at Chicago 2017-2018 inclusive are from Chicago Weather Service Report, 2018, p. 5.

Observations at Chicago 2019-2020 inclusive are from Chicago Weather Service Report, 2020, p. 5.

Observations at Chicago 2021-2022 inclusive are from Chicago Weather Service Report, 2022, p. 5.

Observations at Chicago 2023-2024 inclusive are from Chicago Weather Service Report, 2024, p. 5.

Observations at Chicago 2025-2026 inclusive are from Chicago Weather Service Report, 2026, p. 5.

Observations at Chicago 2027-2028 inclusive are from Chicago Weather Service Report, 2028, p. 5.

Observations at Chicago 2029-2030 inclusive are from Chicago Weather Service Report, 2030, p. 5.

Observations at Chicago 2031-2032 inclusive are from Chicago Weather Service Report, 2032, p. 5.

Observations at Chicago 2033-2034 inclusive are from Chicago Weather Service Report, 2034, p. 5.

Observations at Chicago 2035-2036 inclusive are from Chicago Weather Service Report, 2036, p. 5.

Observations at Chicago 2037-2038 inclusive are from Chicago Weather Service Report, 2038, p. 5.

Observations at Chicago 2039-2040 inclusive are from Chicago Weather Service Report, 2040, p. 5.

Observations at Chicago 2041-2042 inclusive are from Chicago Weather Service Report, 2042, p. 5.

Observations at Chicago 2043-2044 inclusive are from Chicago Weather Service Report, 2044, p. 5.

Observations at Chicago 2045-2046 inclusive are from Chicago Weather Service Report, 2046, p. 5.

Observations at Chicago 2047-2048 inclusive are from Chicago Weather Service Report, 2048, p. 5.

Observations at Chicago 2049-2050 inclusive are from Chicago Weather Service Report, 2050, p. 5.

Observations at Chicago 2051-2052 inclusive are from Chicago Weather Service Report, 2052, p. 5.

Observations at Chicago 2053-2054 inclusive are from Chicago Weather Service Report, 2054, p. 5.

Observations at Chicago 2055-2056 inclusive are from Chicago Weather Service Report, 2056, p. 5.

Observations at Chicago 2057-2058 inclusive are from Chicago Weather Service Report, 2058, p. 5.

Observations at Chicago 2059-2060 inclusive are from Chicago Weather Service Report, 2060, p. 5.

Observations at Chicago 2061-2062 inclusive are from Chicago Weather Service Report, 2062, p. 5.

Observations at Chicago 2063-2064 inclusive are from Chicago Weather Service Report, 2064, p. 5.

Observations at Chicago 2065-2066 inclusive are from Chicago Weather Service Report, 2066, p. 5.

Observations at Chicago 2067-2068 inclusive are from Chicago Weather Service Report, 2068, p. 5.

Observations at Chicago 2069-2070 inclusive are from Chicago Weather Service Report, 2070, p. 5.

Observations at Chicago 2071-2072 inclusive are from Chicago Weather Service Report, 2072, p. 5.

Observations at Chicago 2073-2074 inclusive are from Chicago Weather Service Report, 2074, p. 5.

Observations at Chicago 2075-2076 inclusive are from Chicago Weather Service Report, 2076, p. 5.

Observations at Chicago 2077-2078 inclusive are from Chicago Weather Service Report, 2078, p. 5.

Observations at Chicago 2079-2080 inclusive are from Chicago Weather Service Report, 2080, p. 5.

Observations at Chicago 2081-2082 inclusive are from Chicago Weather Service Report, 2082, p. 5.

Observations at Chicago 2083-2084 inclusive are from Chicago Weather Service Report, 2084, p. 5.

Observations at Chicago 2085-2086 inclusive are from Chicago Weather Service Report, 2086, p. 5.

Observations at Chicago 2087-2088 inclusive are from Chicago Weather Service Report, 2088, p. 5.

Observations at Chicago 2089-2090 inclusive are from Chicago Weather Service Report, 2090, p. 5.

Observations at Chicago 2091-2092 inclusive are from Chicago Weather Service Report, 2092, p. 5.

Observations at Chicago 2093-2094 inclusive are from Chicago Weather Service Report, 2094, p. 5.

Observations at Chicago 2095-2096 inclusive are from Chicago Weather Service Report, 2096, p. 5.

Observations at Chicago 2097-2098 inclusive are from Chicago Weather Service Report, 2098, p. 5.

Observations at Chicago 2099-2100 inclusive are from Chicago Weather Service Report, 2100, p. 5.

Williams Ex 34

Table XLVIII a
Sheet 2

Chicago Sanitary District
Annual Precipitation

Year	Annual Precipitation												Riverside
	Hegewisch	Lansing	Dentral	Monroe	Hinsdale	Chicago	Cleveland	Toledo	Buffalo	Conneaut	Rochester	Riverside	
1879	40.20		37.17		24.93	30.71	41.51	30.27	30.97	36.60	33.27	22.52	
1880	33.44		47.65		23.96	37.10	37.35	35.72	39.26	43.19	41.80	32.92	
81	42.91		43.44		39.07	44.19	34.96	45.91	34.93	39.23	38.24	21.19	
82	37.48		32.32		28.49	41.34	38.98	33.03	33.82	36.13	24.73	20.60	
83	30.30		32.57		23.47	43.86	41.13	34.24	36.07	34.49		23.81	
84	41.44		28.17		30.57	34.61	33.26	28.43	37.07	31.97	31.17	20.35	
85	(30.36)		28.94		32.38	44.57	38.93	33.9	32.36	33.14	28.31	26.35	
86	28.27		26.71		31.46	28.77	27.34	32.70	44.83	33.48	36.84	27.72	
87	25.62		28.97		30.90	29.13	34.36	32.01	31.33	23.41	28.30	17.91	
88	33.46		29.02		23.49	30.86	32.57	25.86	33.87	32.79	27.76		
89	30.31		21.06		31.70	34.35	32.57	21.84	40.07	40.10	33.70		
1890	34.47		34.99		30.09	32.69	41.82	33.61	40.35	40.86	43.09		
91	33.75		28.83		28.76	26.34	34.16	22.12	30.74	31.44	33.64		
92	27.28		37.11		33.09	30.36	36.51	36.70	40.57	34.81	33.02		
93	35.86		34.18		32.87	27.47	33.88	23.81	38.64	34.78	35.50		
94	33.50		23.74		27.79	27.46	27.73	21.34	38.92	36.44	30.11	29.64	
95	33.04		23.04		24.80	32.30	28.64	23.21	32.02	32.19	30.78	28.03	
96	28.39		30.20		28.95	33.14	36.68	33.10	37.29	38.32	36.84	29.08	
97	30.03		30.34		31.05	28.85	24.54	30.36	37.72	36.61	30.12	32.36	

Williams Ex. 34

Table XLVIIIa
Sheet 3

Chicago Sanitary District
Annual Precipitation

Year	Annual Precipitation													
	Marquette	Lansing	Detroit	Monroe	Milwaukee	Chicago	Cleveland	Toledo	Buffalo	Oswego	Rochester	Toronto		
1898	27.45		34.34		32.95	33.77	32.34	28.10	33.50	40.44	37.50	30.55		
1899	36.43		28.91		22.82	26.89	24.55	27.00	29.39	34.65	26.76	28.94		
1900	32.32		31.45		30.10	28.65	23.65	29.58	34.93	37.17	38.12	29.60		
01	37.19		28.78		18.11	24.32	38.71	26.29	33.49	43.08	37.20	32.19		
02	28.77		33.33		28.63	37.57	39.89	33.31	32.91	37.87	29.73	31.07		
03	39.84		35.88		33.41	28.09	33.41	35.08	37.93	39.63	29.44	30.63		
04	33.24		28.32		29.86	28.14	34.56	27.94	33.83	39.51	34.56	35.99		
05	28.16		32.00		32.19	33.36	31.90	28.39	33.85	38.10	33.50	31.28		
06	37.49		33.67		30.18	30.87	31.62	30.27	33.63	36.23	29.74	31.91		
07	31.68		30.62		34.90	33.10	34.76	35.03	34.97	38.36	27.60	31.42		
08	30.29		28.59		28.32	34.83	27.60	33.85	34.24	33.93	27.49	29.62		
09	29.27		40.63		31.31	43.72	34.29	40.42	36.86	37.59	29.50	32.92		
1910	30.54		24.98		21.10	28.86	33.65	29.13	42.45	36.99	33.52	33.78		
11	37.22		28.63		28.23	33.55	37.37	39.11	37.03	36.90	32.88	29.18		
12	30.59		29.66		34.59	29.67	33.94	31.95	33.22	40.36	29.45			

Williams Ex. 34. Table XLIX
Sheet 1

Chicago Sanitary District.

Elevations of Lake Ontario

1860-1889

Year	Full Year		Open Season	
	Elevation Water Surface	Mean of Period.	Elevation Water Surface	Mean of Period.
1860	246.96		247.10	
1	7.40		7.45	
2	7.43	247.20	8.00	247.43
3	7.19		7.39	
4	6.94		7.23	
5	6.89		6.92	
	1483.21		1484.59	
1866	246.13		246.57	
7	6.04		7.34	
8	5.83	246.47	5.90	246.80
9	6.35		6.92	
70	7.39		7.86	
1	6.10		6.40	
	1478.82		1480.78	
1872	244.82		245.00	
3	5.04		6.40	
4	6.36	245.92	6.69	246.22
5	5.87		5.37	
6	7.10		7.63	
7	5.99		6.08	
	1475.54	~	1477.35	
1878	246.30		246.69	
9	6.21		6.22	
80	5.89	246.22	6.00	246.45
1	6.31		5.76	
2	6.67		6.88	
3	6.26		7.16	
	1477.30		1478.71	
1884	247.30		247.55	
5	6.93		7.12	
6	7.60	246.77	7.71	246.98
7	7.02		7.30	
8	5.85		6.06	
9	6.53		6.17	
	1480.64		1481.89	
[illegible]	7395.91	246.52	7405.31	246.78

Williams Ex 34

Table XLIX
Sheet 2

Chicago Sanitary District

Elevations of Lake Ontario
1890-1912

Year	Full Year		Open Season	
	Elevation water surface	Mean of Period	Elevation water surface	Mean of Period
1890	247.07	245.77	247.31	245.99
1	6.12		6.12	
2	5.38		5.42	
3	5.98		5.98	
4	5.76		5.93	
5	4.29		4.35	
	1474.63		1475.94	
1896	244.62	243.05	244.86	243.28
7	4.87		5.12	
8	4.87		5.34	
9	5.10		5.30	
1900	5.13		5.18	
1	5.06		5.34	
	1470.30		1471.70	
1902	245.27	246.12	245.38	246.47
3	5.81		6.13	
4	6.64		7.31	
5	6.71		6.32	
6	6.03		6.10	
7	5.88		6.19	
	1476.70		1478.49	
1908	247.22	246.01	247.61	246.34
9	6.12		6.31	
10	5.61		5.95	
11	5.83		5.15	
12	6.02		6.47	
	1230.18		1231.70	
1890 to 1904	3682.71	245.514	3686.72	245.781
1890 to 1907	4421.63	245.646	4426.13	245.896
1890 to 1910	5160.71	245.748	5166.18	246.009
1890 to 1912	5631.81	246.731	5637.83	245.993
1890 to 1904	11078.71	246.183	11089.92	246.443
1890 to 1910	12336.71	246.700	12363.38	246.438
1890 to 1912	13047.32	246.176	13061.03	246.435

Williams Ex. 34. Table L
Sheet 1

Chicago Sanitary District

Elevations of Lake Superior

1860-1889

	Full Year		Open Season	
Year	Elevation of Water Surface	Mean for Period	Elevation of Water Surface	Mean for Period
1860 a	602.78		603.00	
1	2.83		3.10	
2	2.53		2.73	
3	2.19		2.27	
4	1.87		1.97	
5	2.25		2.63	
	3614.48	602.41	3615.70	602.62
1866 a	602.27		602.50	
7	2.49		2.69	
8	2.30		2.49	
9	2.63		2.98	
1870	2.32		2.48	
1	2.96		2.32	
	3614.97	602.50	3615.43	602.57
1872 b	602.03		602.26	
3	2.48		2.71	
4	2.56		2.71	
5	2.67		2.81	
6	3.06		3.35	
7	2.44		2.45	
	3615.24	602.54	3616.29	602.72
1878 b	601.87		601.88	
9	1.43		1.41	
1880	1.78		2.08	
1	2.21		2.35	
2	2.31		2.28	
3	2.01		2.12	
	3611.49	601.92	3612.12	602.02
1884 b	601.90		601.93	
5	2.18		2.29	
6	1.88		1.94	
	1805.90	601.97	1806.16	602.05
1887 b	601.88		602.02	
8	2.08		2.37	
9	2.14		2.27	
	1806.10	602.03	1806.26	602.09
1860-89	18068.18	602.273	18072.56	602.417

Williams Ex. 34. Table L

Sheet 2

Chicago Sanitary District

Elevations of Lake Superior

1890-1910

	Full Year		Open Season	
Year	Elevation of water surface	Mean for Period	Elevation of water surface	Mean for Period
1890 b	602.00		602.16	
1	1.69		1.78	
2	1.51		1.64	
3	1.86		2.14	
4	2.36		2.83	
5	2.62		2.73	
	3612.24	602.04	3613.30	602.22
1896 b	602.59		602.78	
7	2.00		2.79	
8	2.17		2.35	
9	2.69		2.97	
1900	2.77		2.85	
1	2.75		2.84	
	3615.57	602.60	3616.38	602.76
1902 b	602.53		602.66	
3 b/e	2.73		2.98	
4 b/e	2.71		2.84	
5 b/e	2.74		2.91	
6 b/e	2.63		2.71	
7 b/e	2.81		2.68	
8 b/e	2.27		2.43	
9 b/e	1.93		602.05	
1910 b/e	601.78		601.84	
	3421.83	602.43	3423.12	602.57
1890 to 1910	12649.64	602.364	12653.00	602.524
1860 to 1908	29314.11	602.33	29321.67	602.483
1860 to 1910	30717.82	602.310	30725.56	602.462

Williams Ex. 34 *Table L1*

Chicago Sanitary District

Elevation of Lakes
and Differences in Periods

1	2	3	4	5	6	7	8	9	10	11
Period	Superior	Huron-Mich.	Michigan-Huron	Huron-Mich.	St. Clair	St. Clair-Erie	Erie	Erie-Ontario	Ontario	Huron-Erie
1860-1899	602.41	2020	582.10	5.76	576.40	3.16	573.24	326.04	247.20	8.92
60 - 71	2.50	21.15	1.35	5.29	6.08	3.39	2.67	326.20	6.47	8.65
72 - 77	2.34	20.80	1.74	5.83	5.91	3.29	2.60	326.20	5.92	9.08
78 - 83	1.92	19.99	1.93	5.73	6.18	3.19	2.99	326.17	6.22	8.94
84 - 86	1.97	19.09	2.86	6.36	6.64	3.33	3.31	326.01	7.24	9.57
87 - 99	2.03	20.20	1.81	5.94	5.89	3.12	2.77	326.41	6.30	9.06
1860-1899	602.27	2036	581.91	5.75	576.16	3.24	572.92	326.16	246.52	8.99
90 - 95	602.04	21.51	580.53	5.41	575.12	3.00	572.12	326.35	245.77	8.41
96 - 01	2.80	22.42	0.41	3.35	4.53	3.04	1.79	326.34	5.03	8.39
02 - 04	2.66	22.19	0.47	5.21	5.26	3.02	2.24	326.33	5.93	8.21
05 - 10	2.31	21.36	0.75	5.36	5.35	3.06	2.31	325.98	6.33	8.44
1890-1910	602.30	21.83	580.49	5.35	575.13	3.04	572.10	326.16	245.75	8.36
1860-1910	602.31	20.99	581.32	5.58	575.74	3.16	572.58	326.16	246.20	8.74

Note: Mean Elevation of Ontario, 1860-1904 - 245.51, 1860-1901-246.18

Williams Ex. 34. Table LII

Chicago Sanitary District

Elevations and Differences of Elevation of the Great Lakes.

Full Year				Open Season			
Lake	1860 to 1889	1890 to 1910	Diff.	Lake	1860 to 1889	1890 to 1910	Diff.
	Elevations				Elevations		
Michigan Huron	581.91	580.48	1.43	Michigan Huron	582.10	580.70	1.40
St. Clair	576.16	575.13	1.03	St. Clair	576.41	575.36	1.05
Erie	572.92	572.10	0.82	Erie	573.16	572.35	0.81
Ontario	246.52	245.75	0.77	Ontario	246.78	246.01	0.77
		245.66*	0.86*			245.96*	0.82*
Differences.							
Huron to St. Clair	5.75	5.35	0.40	Huron to St. Clair	5.69	5.34	0.35
St. Clair to Erie	3.24	3.03	0.20	St. Clair to Erie	3.25	3.01	0.24
Huron to Erie	8.99	8.38	0.61	Huron to Erie	8.94	8.35	0.59
Erie to Ontario	326.40	326.35	0.05	Erie to Ontario	326.38	326.34	0.04
		326.44*	0.01*			326.46*	0.05*

* Elevation of Lake Ontario corrected for effect of Out Dam since 1905

Williams Ex 34

Chicago Sanitary District Dredging

Table LIII
Sheet 1

St. Clair River — Detroit River

Cubic yards Removed.

Date	St. Clair River and Lake St. Clair						Detroit River					
	Lower End Lake Huron	South Channel River	St. Clair River	St. Clair Flats Canal	Gross Reinf. Cur.	Total	Bailey Ave.	Lime Kiln Basin	Outer	Living Stone Chan.	Total	Grand Total.
1870				289756		289756						289756
71				40316		40316						40316
73		30000		10000		60000						60000
74		33074		214657		247731						247731
75		35000				35000						35000
76		6700				6700						6700
77		21796				21796		2632			2632	24428
78												
79								630			630	630
80				3626		3626		8401			8401	12027
81								17089			17089	17089
82								6797			6797	6797
83								6334			6334	6334
84								636			636	636
85								8369			8369	8369
86				64580		64580		13189			13189	79769
87								14698			14698	14698
88								1095			1095	1095
89		20800		50117		70917		8538			8538	85455
90		25439				25439		18344			18344	43783
91		17504		43496		61000		2797			2797	63797
92		40011		142765		182776						182976
		210344		841823		1113837		111769			111769	1225606

Cubic yards Removed

Williams Ex 34

Table LIII
Sheet 2

Chicago Sanitary District
Dredging

St. Clair River — Detroit River

Date	St. Clair River and Lake St. Clair						Detroit River					
	Lower End Lake Huron	South Black River	St. Clair Flats Canal	Gross Reinf. Curb	Total.	Bailed River	Lime Kiln Crossing	Outer	Living Stone Chan	Total.	Grand Total.
1893	3836		39517	104471	64984	140804			4677	4677	145541
94	29435		43837		539910	1202898			178565	178565	1381463
95	39401		120617		1805382	2349949	2230		460874	463104	2813053
96	10395				1870739	2731132	13867		332791	346158	2377290
97	3264	729			1219258	1252991	3174		40354	45528	1298119
98		45729	55379			101308	24620		89189	113809	215117
99			44636			44636	60035		14778	74813	121449
1900							26052	360		26412	26412
1			76258			76258	42354	30483	27507	100744	177002
2			86753			86753	77234	63791	105269	245694	332447
3		82368	60997			143966	70370	39020	174428	216484	360050
4	60312		337511	76469		469498	775	1570	26391	28736	518234
5	48350		328789		72374	444019		332264	631935	516421	960440
6			93848		41660	974128		113493	1104035	1217586	2251716
7		14405	78324			792969		86996	646390	733386	1526355
8		9101				9101		132640	2231132	2363772	2872873
9								54984	4390	59374	2922247
10									228946	228946	3151193
	107124	132135	3370128	8896	5644263	9344670	284479	5559639	39762	5883880	15228550
		270381		845513		1115837		111769		111769	1227606
	107124	402516	3370128	854409	5644263	10460507	284479	5671408	39762	5995650	16456156

1903 to 1910 14,975,331

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Book LIV
Sheet 118

Chicago Sanitary District

Relative Fluctuation of Lakes

St. Clair - Erie.

Full Year

Year	Month	Group	Huron Elevation	St. Clair Elevation	St. Clair C of G	Erie Elevation	Erie C of G	St. Clair Change / Erie Change
1860	July	1	581.71	578.33	578.33	573.94	573.94	
	Aug.				0.00		0.00	
	Sept.							0.44 ÷ 0.44 = 100%
1861	July	2	581.32	576.32	578.23	573.71	573.71	
	Aug.		581.36	576.81	576.14	573.87	573.67	
	Sept.				0.91		0.20	0.21 ÷ 0.20 = 110%
1862	July	3	581.41	575.82	575.82	572.88	572.88	
	Aug.		581.49	575.84	575.84	572.83	572.83	
	Sept.				0.02		0.05	0.02 ÷ 0.05 = 120%
1863	July	4	581.36	576.42	576.42	573.32	573.32	
	Aug.		581.28	576.48	576.48	573.26	573.26	
	Sept.				0.06		0.06	0.22 ÷ 0.06 = 110%
1864	July	5	581.32	575.80	575.80	572.88	572.88	
	Aug.		581.32	575.82	575.82	572.83	572.83	
	Sept.				0.02		0.05	0.02 ÷ 0.05 = 57.75%
1865	July	6	581.24	575.79	575.79	572.84	572.84	
	Aug.		581.22	575.67	575.67	572.60	572.60	
	Sept.				0.12		0.24	0.12 ÷ 0.24 = 500%
1866	July	7	581.26	575.45	575.45	572.36	572.36	
	Aug.		581.22	575.43	575.43	572.31	572.31	
	Sept.				0.02		0.05	0.02 ÷ 0.05 = 40%
1867	July		581.26	574.97	574.97	572.25	572.25	
	Aug.		581.22	574.83	574.83	572.42	572.42	
	Sept.				0.14		0.17	0.14 ÷ 0.17 = 82.35%
1868	July		581.22	575.47	575.47	572.12	572.12	
	Aug.		581.11	575.38	575.38	571.98	571.98	
	Sept.				0.09		0.14	0.09 ÷ 0.14 = 64.28%
							1.06	0.32 ÷ 1.06 = 32.05%

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Table LIV
Sheet 2

Chicago Sanitary District

Relative Fluctuation of Lakes

St. Clair - Erie

Full Year

Year	Month	Group	Number Elevations	St. Clair		Erie		St. Clair Change / Erie Change
				Elevation	C. of G.	Elevation	C. of G.	
1872	Aug	8	38/04	575.77	575.77	573.03	573.03	
1873	May		1.03	3.62	579.39	2.36	575.39	
1874				3.52	582.91	2.64	578.03	
					0.21		0.30	0.21 - 33.25 %
1875	July	9	380.96	575.25	575.91	573.38	573.35	
1876	July			3.43	579.34	2.48	575.83	
1877	July			3.29	582.63	2.44	578.27	
1878	Aug			3.19	585.82	2.13	580.40	
1879	Nov			3.14	588.96	1.93	582.33	
					0.38		1.09	0.38 - 33.20 %
1880	Nov	10	380.88	575.54	575.52	573.04	573.76	
1881				3.33	578.85	2.71	576.47	
1882				3.33	582.18	2.56	579.03	
1883				3.24	585.42	2.33	581.36	
1884	June		0.88	3.28	588.70	1.72	583.08	
					0.19		0.79	0.19 - 24.05 %
1885	Aug	11	380.83	575.63	575.67	573.22	573.64	
1886	July			3.30	578.97	2.35	575.99	
1887				3.30	582.27	2.41	578.40	
1888	Nov			3.22	585.49	2.25	580.65	
1889	May		0.84	3.31	588.80	1.77	582.42	
					0.15		0.39	0.15 - 42.90 %
1890	Apr	12	380.78	575.71	575.55	573.28	573.70	
1891	Sept		0.80	3.29	578.84	2.39	576.09	
1892				3.30	582.14	2.38	578.47	
1893				3.30	585.44	2.35	580.82	
1901	May		0.81	3.33	588.77	1.31	582.13	
					0.16		1.12	0.16 - 69.60 %

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Table LIV
Sheet 3

Chicago Sanitary District

Relative Fluctuation of Lakes

St. Clair - Erie

Full Year

Year	Month	Group	Huron Elevation	St. Clair		Erie		St. Clair Change Erie Change
				Elevation	C of S	Elevation	C of S	
1903	July	13	580.75	575.68	573.73	572.90	572.86	.835 - 88.60 %
1902	Aug.		.77	.78	573.72	.74		
1901	Sept.		.76	.86	573.72	1.71	572.33	1.37
					.015			
1896	June	14	580.72	575.55	573.67	572.81	572.60	.839 - 28.80 %
1895	July		.73	.60	573.66	.76		
1894	Aug.		.73	.53	573.65	.76	572.43	1.17
1893	Sept.		.73	.44	573.65	2.30		
			.73	.32	.014	1.54	572.09	.034
1923	June	15	580.67	575.78	573.54	573.26	572.72	.834 - 125.80 %
1922	July		.68	.81		.28		
1921	Aug.		.68	.33	573.53	2.27	572.33	1.39
1920	Sept.		.68	.26		1.97		
1919	Oct.		.67	.17	573.51		572.14	.138
					.015		.138	
1898	June	16	580.66	575.33	573.50	572.67	572.41	.826 - 32.10 %
1897	July		.66	.31		2.03		
1896	Aug.		.66	.07	573.11	1.36	571.87	1.33
1895	Sept.		.66	.04		1.33		
1894	Oct.		.66	.96	573.02		571.60	.881
					.026		.881	
1900	June	17	580.63	575.91	573.49	573.13	572.83	.826 - 41.70 %
1899	July		.63	.83		2.76		
1898	Aug.		.63	.54	573.35	2.42	572.50	1.33
1897	Sept.		.63	.20		2.31		
1896	Oct.		.63	.40		2.13		
1895	Nov.		.63	.18	573.24	2.09	572.33	.826
					.035		.826	

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Table LIV
Sheet 4

Chicago Sanitary District
Relative Fluctuation of Lakes
St. Clair - Erie
Full Year

Year	Month	Group	Mean Elevation	St. Clair Elevations	St. Clair C.of G.	Erie Elevations	Erie C.of G.	Range
1898	June	18	580.56	576.53	576.53	573.03	572.57	
1899	July		580.56	576.53		572.78		
1899	Aug.		580.56	576.49		572.48		
1899	Sept.		580.56	576.50		572.43		
1901	Oct.		580.55	576.53		571.93		
	Nov.			576.54	576.51		571.46	1.13
				.17				
1902	June	19	580.51	576.54	576.36	572.36	572.34	
1899	July		0.53	5.03	5.18	2.31	2.01	
1898	Sept.		0.52	5.19	5.40	2.01	1.94	
1904	Oct.		0.56	5.40	5.53	1.94	1.77	
	Dec.			5.43		1.77		
				-0.17				0.45
1902	June	20	580.48	576.43	576.43	572.46	572.43	
1900	July		0.47	5.43	5.46	2.43	2.03	
	Aug.		0.46	5.46	5.48	2.29	1.98	
					0.05			0.45
1906	May	21	580.44	576.53	576.520	572.43	572.43	
1897	June		0.41	5.54	5.53	2.43	2.29	
1903	July		0.42	5.53	5.54	2.29	1.98	
1901	Aug.		0.43	5.55	5.481	1.72	1.78	
	Nov.			5.47		1.78		
				0.14	0.039		1.00	
1902	May	22	580.33	576.42	576.413	572.03	572.02	
1894	June		0.31	5.42	5.44	2.03	2.26	
1894	July		0.33	5.44	5.470	2.26	1.91	
1908	Aug.		0.38	5.50	5.52	1.91	1.52	
					0.039		1.24	
1903	May	23	580.27	Not given	Not given	(573.03)	(572.57	
1902	June		0.30	576.54	576.522	2.27	2.27	
1902	July		0.27	5.54	5.493	2.27	1.72	
1902	Aug.		0.28	5.44	5.476	1.38	1.45	
1902	Sept.		0.30	5.50		1.38		
1902	Oct.		0.29	5.51		1.36		
					0.046		0.90	

$\frac{1.13}{1.73} = 112.30\%$

$\frac{-0.17}{0.43} = -39.55\%$

$\frac{0.45}{0.88} = 39.40\%$

$\frac{0.45}{1.20} = 37.85\%$

$\frac{0.39}{1.24} = 30.22\%$

$\frac{0.90}{2.03} = 44.50\%$

Williams Ex 34 Chicago Sanitary District — Table LIV Sheet 3

Relative Fluctuation of Lakes

St Clair - Erie

Full Year

Year	Month	Basis	Hourly Fluctuations	St. Clair		Erie			St Clair - Erie Change
				Elevations	C & G S Datum	Elevations	C & G S Datum		
1900	Jan	24	3.0025	573.13	573.04	571.20	571.95		
1900	Feb		0.21	573.13	573.04	571.24	571.95		
1900	Mar		0.23	573.05	572.96	571.22	571.93		
1900	Apr		0.24	573.04	572.95	571.20	571.91		
1900	May		0.22	573.77	573.68	571.40	572.11		
1900				573.24	573.15	571.45	572.16		0.99 = 9120%
1901	Jan	25	3.0015	573.13	573.04	572.30	572.01		
1901	Feb		0.13	573.13	573.04	572.36	572.07		
1901	Mar		0.12	573.24	573.15	572.34	572.05		
1901	Apr		0.13	573.40	573.31	572.39	572.10		
1901	May		0.14	573.60	573.51	572.45	572.16		
1901			0.12	573.30	573.21	572.37	572.08		0.86 = 1945%
1902	Jan	26	3.0008	573.41	573.32	572.01	571.72		
1902	Feb		0.07	573.46	573.37	571.97	571.68		
1902	Mar		0.10	573.50	573.41	571.71	571.42		
1902	Apr		0.08	573.38	573.29	571.58	571.29		
1902	May		0.07	573.02	572.93	571.30	571.01		
1902				573.37	573.28	571.71	571.42		0.86 = 14430%
1903	Jan	27	3.0045	573.23	573.14	572.23	571.94		
1903	Dec		0.05	573.23	573.14	572.28	571.99		
1903				573.23	573.14	572.26	571.97		0.83 = -9333%
1904	Jan	28	3.0038	573.23	573.14	572.23	571.94		
1904			0.32	573.23	573.14	572.29	572.00		
1904			0.32	573.36	573.27	572.40	572.11		
1904			0.32	573.45	573.36	572.46	572.17		
1904			0.32	573.55	573.46	572.52	572.23		
1904			0.32	573.62	573.53	572.56	572.27		
1904				573.41	573.32	572.41	572.12		0.80 = 1720%

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Table LIV
Sheet 6

Chicago Sanitary District

Relative Fluctuation of Lakes

St. Clair - Erie

Full Year

Year	Month	Group	Huron Elevation	St. Clair Elevation	St. Clair C of G	Erie Elevation	Erie C of G	St. Clair Change / Erie Change
1918	Apr.	29	579.86	574.76	+374.11	571.39	+571.39	
1918	May		579.81	574.86		571.33		
1918	June		579.81	574.80		571.33		
1918	July		579.81	574.80		571.32		
1918	Aug.		579.81	574.80		571.31		
1918	Sept.		579.81	574.80		571.31		
1918	Oct.		579.81	574.80		571.31		
1918	Nov.		579.81	574.80		571.31		
1918	Dec.		579.81	574.80		571.31		
1919	Jan.		579.81	574.80		571.31		
1919	Feb.		579.81	574.80		571.31		
1919	Mar.		579.81	574.80		571.31		
1919	Apr.	30	579.84	574.83	+374.14	571.34	+571.42	.03 = 37.50%
1919	May		579.86	574.85		571.36		
1919	June		579.86	574.85		571.36		
1919	July		579.86	574.85		571.36		
1919	Aug.		579.86	574.85		571.36		
1919	Sept.		579.86	574.85		571.36		
1919	Oct.		579.86	574.85		571.36		
1919	Nov.		579.86	574.85		571.36		
1919	Dec.		579.86	574.85		571.36		
1920	Jan.		579.86	574.85		571.36		
1920	Feb.		579.86	574.85		571.36		
1920	Mar.		579.86	574.85		571.36		
1920	Apr.	31	579.78	574.77	+374.07	571.29	+571.31	.07 = 87.50%
1920	May		579.78	574.77		571.29		
1920	June		579.78	574.77		571.29		
1920	July		579.78	574.77		571.29		
1920	Aug.		579.78	574.77		571.29		
1920	Sept.		579.78	574.77		571.29		
1920	Oct.		579.78	574.77		571.29		
1920	Nov.		579.78	574.77		571.29		
1920	Dec.		579.78	574.77		571.29		
1921	Jan.		579.78	574.77		571.29		
1921	Feb.		579.78	574.77		571.29		
1921	Mar.		579.78	574.77		571.29		
1921	Apr.	32	579.72	574.71	+374.01	571.23	+571.23	.06 = 75.00%
1921	May		579.72	574.71		571.23		
1921	June		579.72	574.71		571.23		
1921	July		579.72	574.71		571.23		
1921	Aug.		579.72	574.71		571.23		
1921	Sept.		579.72	574.71		571.23		
1921	Oct.		579.72	574.71		571.23		
1921	Nov.		579.72	574.71		571.23		
1921	Dec.		579.72	574.71		571.23		
1922	Jan.		579.72	574.71		571.23		
1922	Feb.		579.72	574.71		571.23		
1922	Mar.		579.72	574.71		571.23		
1922	Apr.	33	579.62	574.61	+374.01	571.13	+571.13	.10 = 125.00%
1922	May		579.62	574.61		571.13		
1922	June		579.62	574.61		571.13		
1922	July		579.62	574.61		571.13		
1922	Aug.		579.62	574.61		571.13		
1922	Sept.		579.62	574.61		571.13		
1922	Oct.		579.62	574.61		571.13		
1922	Nov.		579.62	574.61		571.13		
1922	Dec.		579.62	574.61		571.13		
1923	Jan.		579.62	574.61		571.13		
1923	Feb.		579.62	574.61		571.13		
1923	Mar.		579.62	574.61		571.13		
1923	Apr.	34	579.54	574.53	+374.00	571.05	+571.05	.08 = 100.00%
1923	May		579.54	574.53		571.05		
1923	June		579.54	574.53		571.05		
1923	July		579.54	574.53		571.05		
1923	Aug.		579.54	574.53		571.05		
1923	Sept.		579.54	574.53		571.05		
1923	Oct.		579.54	574.53		571.05		
1923	Nov.		579.54	574.53		571.05		
1923	Dec.		579.54	574.53		571.05		
1924	Jan.		579.54	574.53		571.05		
1924	Feb.		579.54	574.53		571.05		
1924	Mar.		579.54	574.53		571.05		
1924	Apr.	35	579.46	574.45	+373.92	570.97	+570.97	.08 = 100.00%
1924	May		579.46	574.45		570.97		
1924	June		579.46	574.45		570.97		
1924	July		579.46	574.45		570.97		
1924	Aug.		579.46	574.45		570.97		
1924	Sept.		579.46	574.45		570.97		
1924	Oct.		579.46	574.45		570.97		
1924	Nov.		579.46	574.45		570.97		
1924	Dec.		579.46	574.45		570.97		
1925	Jan.		579.46	574.45		570.97		
1925	Feb.		579.46	574.45		570.97		
1925	Mar.		579.46	574.45		570.97		
1925	Apr.	36	579.38	574.37	+373.84	570.89	+570.89	.08 = 100.00%
1925	May		579.38	574.37		570.89		
1925	June		579.38	574.37		570.89		
1925	July		579.38	574.37		570.89		
1925	Aug.		579.38	574.37		570.89		
1925	Sept.		579.38	574.37		570.89		
1925	Oct.		579.38	574.37		570.89		
1925	Nov.		579.38	574.37		570.89		
1925	Dec.		579.38	574.37		570.89		
1926	Jan.		579.38	574.37		570.89		
1926	Feb.		579.38	574.37		570.89		
1926	Mar.		579.38	574.37		570.89		
1926	Apr.	37	579.30	574.29	+373.76	570.81	+570.81	.08 = 100.00%
1926	May		579.30	574.29		570.81		
1926	June		579.30	574.29		570.81		
1926	July		579.30	574.29		570.81		
1926	Aug.		579.30	574.29		570.81		
1926	Sept.		579.30	574.29		570.81		
1926	Oct.		579.30	574.29		570.81		
1926	Nov.		579.30	574.29		570.81		
1926	Dec.		579.30	574.29		570.81		
1927	Jan.		579.30	574.29		570.81		
1927	Feb.		579.30	574.29		570.81		
1927	Mar.		579.30	574.29		570.81		
1927	Apr.	38	579.22	574.21	+373.68	570.73	+570.73	.08 = 100.00%
1927	May		579.22	574.21		570.73		
1927	June		579.22	574.21		570.73		
1927	July		579.22	574.21		570.73		
1927	Aug.		579.22	574.21		570.73		
1927	Sept.		579.22	574.21		570.73		
1927	Oct.		579.22	574.21		570.73		
1927	Nov.		579.22	574.21		570.73		
1927	Dec.		579.22	574.21		570.73		
1928	Jan.		579.22	574.21		570.73		
1928	Feb.		579.22	574.21		570.73		
1928	Mar.		579.22	574.21		570.73		
1928	Apr.	39	579.14	574.13	+373.60	570.65	+570.65	.08 = 100.00%
1928	May		579.14	574.13		570.65		
1928	June		579.14	574.13		570.65		
1928	July		579.14	574.13		570.65		
1928	Aug.		579.14	574.13		570.65		
1928	Sept.		579.14	574.13		570.65		
1928	Oct.		579.14	574.13		570.65		
1928	Nov.		579.14	574.13		570.65		
1928	Dec.		579.14	574.13		570.65		
1929	Jan.		579.14	574.13		570.65		
1929	Feb.		579.14	574.13		570.65		
1929	Mar.		579.14	574.13		570.65		
1929	Apr.	40	579.06	574.05	+373.52	570.57	+570.57	.08 = 100.00%
1929	May		579.06	574.05		570.57		
1929	June		579.06	574.05		570.57		
1929	July		579.06	574.05		570.57		
1929	Aug.		579.06	574.05		570.57		
1929	Sept.		579.06	574.05		570.57		
1929	Oct.		579.06	574.05		570.57		
1929	Nov.		579.06	574.05		570.57		
1929	Dec.		579.06	574.05		570.57		
1930	Jan.		579.06	574.05		570.57		
1930	Feb.		579.06	574.05		570.57		
1930	Mar.		579.06	574.05		570.57		
1930	Apr.	41	578.98	573.97	+373.44	570.49	+570.49	.08 = 100.00%
1930	May		578.98	573.97		570.49		
1930	June		578.98	573.97		570.49		
1930	July		578.98	573.97		570.49		
1930	Aug.		578.98	573.97		570.49		
1930	Sept.		578.98	573.97		570.49		
1930	Oct.		578.98	573.97		570.49		
1930	Nov.		578.98	573.97		570.49		
1930	Dec.		578.98	573.97		570.49		
1931	Jan.		578.98	573.97		570.49		
1931	Feb.		578.98	573.97		570.49		
1931	Mar.		578.98	573.97		570.49		
1931	Apr.	42	578.90	573.89	+373.36	570.41	+570.41	.08 = 100.00%
1931	May		578.90	573.89		570.41		
1931	June		578.90	573.89		570.41		
1931	July		578.90	573.89		570.41		
1931	Aug.		578.90	573.89		570.41		
1931	Sept.		578.90	573.89		570.41		
1931	Oct.		578.90	573.89		570.41		
1931	Nov.		578.90	573.89		570.41		
1931	Dec.		578.90	573.89		570.41		
1932	Jan.		578.90	573.89		570.41		
1932	Feb.		578.90	573.89		570.41		
1932	Mar.		578.90	573.89		570.41		
1932	Apr.	43	578.82	573.81	+373.28	570.33	+570.33	.08 = 100.00%
1932	May		578.82	573.81		570.33		
1932	June		578.82	573.81		570.33		
1932	July		578.82	573.81		570.33		
1932	Aug.		578.82	573.81		570.33		
1932	Sept.		578.82	573.81		570.33		
1932	Oct.		578.82	573.81		570.33		
1932	Nov.		578.82	573.81		570.33		
1932	Dec.		578.82	573.81		570.33		
1933	Jan.		578.82	573.81		570.33		
1933	Feb.		578.82	573.81		570.33		
1933	Mar.		578.82	573.81		570.33		
1933	Apr.	44	578.74	573.73	+373.20	570.25	+570.25	.08 = 100.00%
1933	May		578.74	573.73		570.25		
1933	June		578.74	573.73		570.25		
1933	July		578.74	573.73		570.25		
1933	Aug.		578.74	573.73		570.25		
1933	Sept.		578.74	573.73		570.25		
1933	Oct.		578.74	573.73		570.25		
1933	Nov.		578.74	573.73		570.25		
1933	Dec.		578.74	573.73		570.25		
1934	Jan.		578.74	573.73		570.25		
1934	Feb.		578.74	573.73		570.25		
1934	Mar.		578.74	573.73		570.25		
1934	Apr.	45	578.66	573.65	+373.12	570.17	+570.17	.08 = 100.00%
1934	May		578.66	573.65		570.17		
1934	June		578.66	573.65		570.17		
1934	July		578.66	573.65		570.17		
1934	Aug.		578.66	573.65		570.17		
1934	Sept.		578.66	573.65		570.17		
1934	Oct.		578.66	573.65		570.17		
1934	Nov.		578.66	573.65		570.17		
1934	Dec.		578.66	573.65		570.17		
1935	Jan.		578.66	573.65		570.17		
1935	Feb.		578.66	573.65		570.17		
1935	Mar.		578.66	573.65		570.17		
1935	Apr.	46	578.58	573.57	+373.04	570.09	+570.09	.08 = 100.00%
1935	May		578.58	573.57		570.09		
1935	June		578.58	573.57		570.09		
1935	July		578.58	573.57		570.09		
1935	Aug.		578.58	573.57		570.09		
1935	Sept.		578.58	573.57		570.09		
1935	Oct.		578.58	573.57		570.09		
1935	Nov.		578.58	573.57		570.09		
1935	Dec.		578.58	573.57		570.09		
1936	Jan.		578.58	573.57		570.09		
1936	Feb.		578.58	573.57		570.09		
1936	Mar.		578.58	573.57		570.09		
1936	Apr.	47	578.50	573.49	+372.96	570.01	+570.01	.08 = 100.00%
1936	May		578.50	573.49		570.01		
1936	June		578.50	573.49		570.01		
1936	July		578.50	573.49		570.01		
1936	Aug.		578.50	573.49		570.01		
1936	Sept.		578.50	573.49		570.01		
1936	Oct.		578.50	573.49		570.01		
1936	Nov.		578.50	573.49		570.01		
1936	Dec.		578.50	573.49		570.01		
1937	Jan.		578.50	573.49		570.01		
1937	Feb.		578.50	573.49		570.01		
1937	Mar.		578.50	573.49		570.01		
1937	Apr.	48	578.42	573.41	+372.88	569.93	+569.93	.08 = 100.00%
1937	May		578.42	573.41		569.93		
1937	June		578.42	573.41		569.93		
1937	July		578.42	573.41		569.93		
1937	Aug.		578.42	573.41		569.93		
1937	Sept.		578.42	573.41		569.93		
1937	Oct.		578.42	573.41		569.93		
1937	Nov.		578.42	573.41		569.93		
1937	Dec.		578.42	573.41		569.93		
1938	Jan.		578.42	573.41		569.93		
1938	Feb.		578.42	573.41		569.93		
1938	Mar.		578.42	573.41		569.93		
1938	Apr.	49	578.34	573.33	+372.80	569.85	+569.85	.08 = 100.00%
1938	May		578.34	573.33		569.85		
1938	June		578.34	573.33		569.85		
1938	July		578.34	573.33		569.85		
1938	Aug.		578.34	573.33		569.85		
1938	Sept.		578.34	573.33		569.85		
1938	Oct.		578.34	573.33		569.85		
1938	Nov.		578.34	573.33		569.85		
1938	Dec.		578.34	573.33		569.85		
1939	Jan.		578.34	573.33		569.85		
1939	Feb.		578.34	573.33		569.85		
1939	Mar.		578.34	573.33		569.85		
1939	Apr.	50	578.26	573.25	+372.72	569.77	+569.77	.08 = 100.00%
1939	May		578.26	573.25		569.77		
1939	June		578.26	573.25		569.77		
1939	July		578.26	573.25		569.77		
1939	Aug.		578.26	573.25		569.77		
1939	Sept.		578.26	573.25		569.77		
1939	Oct.		578.26	573.25		569.77		
1939	Nov.		578.26	573.25		569.77		
1939	Dec.		578.26	573.25		569.77		
1940	Jan.		578.26	573.25		569.77		
1940	Feb.		578.26	573.25		569.77		
1940	Mar.		578.26	573.25		569.77		
1940	Apr.	51	578.18	573.17	+372.64	569.69	+569.69	.08 = 100.00%
1940	May		578.18	573.17		569.69		
1940	June		578.18	573.17		569.69		
1940	July		578.18	573.17		569.69		
1940	Aug.		578.18	573.17		569.69		
1940	Sept.		578.18	573.17		569.69		
1940	Oct.		578.18	573.17		569.69		
1940	Nov.		578.18	573.17		569.69		
1940	Dec.		578.18	573.17		569.69		
1941	Jan.		578.18	573.17		569.69		
1941	Feb.		578.18	573.17		569.69		
1941	Mar.		578.18	573.17		569.69		
1941	Apr.	52	578.10	573.09	+372.56	569.61	+569.61	.08 = 100.00%
1941	May		578.10	573.09		569.61		
1941	June		578.10	573.09		569.61		
1941	July		578.10	573.09		569.61		
1941	Aug.		578.10	573.09		569.61		
1941	Sept.		578.10	573.09		569.61		
1941	Oct.		578.10	573.09		569.61		
1941	Nov.		578.10	573.09		569.61		
1941	Dec.		578.10	573.09		569.61		
1942	Jan.		578.10	573.09		569.61		
1942	Feb.		578.10	573.09		569.61		
1942	Mar.		578.10	573.09		569.61		
1942	Apr.	53	578.02	573.01	+372.48	569.53	+569.53	.08 = 100.00%
1942	May		578.02	573.01		569.53		
1942	June		578.02	573.01		569.53		
1942	July		578.02	573.01		569.53		
1942	Aug.		578.02	573.01		569.53		
1942	Sept.		578.02	573.01		569.53		
1942	Oct.		578.02	573.01		569.53		
1942	Nov.		578.02	573.01		569.53		
1942	Dec.		578.02	573.01		569.53		
1943	Jan.		578.02	573.01		569.53		
1943	Feb.		578.02	573.01		569.53		
1943	Mar.		578.02	573.01		569.53		
1943	Apr.	54	577.94	572.93	+372.40	569.45	+569.45	.08 = 100.00%
1943	May		577.94	572.93		569.45		
1943	June		577.94	572.93		569.45		
1943	July		577.94	572.93		569.45		
1943	Aug.		577.94	572.93		569.45		
1943	Sept.		577.94	572.93		569.45		
1943	Oct.		577.94	572.93		569.45		
1943	Nov.		577.94	572.93		569.45		
1943	Dec.		577.94	572.93		569.45		
1944	Jan.		577.94	572.93		569.45		
1944	Feb.		577.94	572.93		569.45		
1944	Mar.		577.94	572.93		569.45		
1944	Apr.	55	577.86	572.85	+372.32	569.37	+569.37	.08 = 100.00%
1944	May		577.86	572.85		569.37		
1944	June		577.86	572.85		569.37		
1944	July		577.86	572.85		569.37		
1944	Aug.		577.86	572.85		569.37		
1944	Sept.		577.86	572.85		569.37		
1944	Oct.		577.86	572.85		569.37		
1944	Nov.		577.86	572.85		569.37		
1944	Dec.		577.86	572.85		569.37		
1945	Jan.		577.86	572.85		569.37		
1945	Feb.		577.86	572.85		569.37		
1945	Mar.		577.86	572.85		569.37		
1945	Apr.	56	577.78	572.77	+372.24	569.29	+569.29	.08 = 100.00%
1945	May		577.78	572.77		569.29		
1945	June		577.78	572.77		569.29		
1945	July		577.78	572.77		569.29		
1945	Aug.		577.78	572.77		569.29		
1945	Sept.		577.78	572.77		569.29		
1945	Oct.		577.78	572.77		569.29		
1945	Nov.		577.78	572.77		569.29		
1945	Dec.		577.78	572.77		569.29		
1946	Jan.		577.78	572.77		569.29		
1946	Feb.		577.78	572.77		569.29		
1946	Mar.		577.78	572.77		569.29		
1946	Apr.	57	577.70	572.69	+372.16	569.21	+569.21	.08 = 100.00%
1946	May		577.70	572.69		569.21		
1946	June		577.70	572.69		569.21		
1946	July		577.70	572.69		569.21		
1946	Aug.		577.70	572.69		569.21		
1946	Sept.		577.70	572.69		569.21		
1946	Oct.		577.70	572.69		569.21		
1946	Nov.		577.70	572.69		569.21		
1946	Dec.		577.70	572.69		569.21		
1947	Jan.		577.70	572.69		569.21		
1947	Feb.		577.70	572.69		569.21		
1947	Mar.		577.70	572.69		569.21		
1947	Apr.	58	577.62	572.61	+372.08	569.13	+569.13	.08 = 100.00%
1947	May		577.62	572.61		569.13		
1947	June		577.62	572.61		569.13		
1947	July		577.62	572.61		569.13		
1947	Aug.		577.62	572.61		569.13		
1947	Sept.		577.62	572.61		569.13		
1947	Oct.		577.62	572.61		569.13		
1947	Nov.		577.62	572.61		569.13		
1947	Dec.		577.62	572.61		569.13		
1948	Jan.		577.62	572.61		569.13		
1948	Feb.		577.62	572.61		569.13		
1948	Mar.		577.62	572.61		569.13		
1948	Apr.	59	577.54	572.53	+372.00	569.05	+569.05	.08 = 100.00%
1948	May		577.54	572.53		569.05		
1948	June		577.54	572.53		569.05		
1948	July		577.54	572.53		569.05		
1948	Aug.		577.54	572.53		569.05		
1948	Sept.		577.54	572.53		569.05		
1948	Oct.		577.54	572.53		569.05		
1948	Nov.		577.54	572.53		569.05		
1948	Dec.		577.54	572.53		569.05		
1949	Jan.		577.54	572.53		569.05		
1949	Feb.		577.54	572.53		569.05		
1949	Mar.		577.54	572.53		569.05		
1949	Apr.	60	577.46	572.45	+371.92	568.97	+568.97	.08 = 100.00%
1949	May		577.46	572.45		568.97		
1949	June		577.46	572.45		568.97		
1949	July		577.46	572.45		568.97		
1949	Aug.		577.46	572.45		568.97		
1949	Sept.		577.46	572.45		568.97		
1949	Oct.		577.46	572.45		568.97		
1949	Nov.		577.46	572.45		568.97		
1949	Dec.		577.46	572.45		568.97		
1950	Jan.		577.46	572.45		568.97		
1950	Feb.		577.46	572.45		568.97		
1950	Mar.		577.46	572.45		568.97		
1950	Apr.	61	577.38	572.37	+371.84	568.89	+568.89	.08 = 100.00%
1950	May		577.38	572.37		568.89		
1950	June		577.38	572.37		568.89		
1950	July		577.38	572.37		568.89		
1950	Aug.		577.38	572.37		568.89		
1950	Sept.		577.38	572.37		568.89		
1950	Oct.		577.38	572.37		568.89		
1950	Nov.		577.38	572.37		568.89		
1950	Dec.		577.38	572.37		568.89		
1951	Jan.		577.38	572.37		568.89		
1951	Feb.		577.38	572.37		568.89		
1951	Mar.		577.38	572.37		568.89		
1951	Apr.	62	577.30	572.29	+371.76	568.81	+568.81	.08 = 100.00%
1951	May		577.30	572.29		568.81		
1951	June		577.30	572.29		568.81		
1951	July		577.30	572.29		568.81		
1951	Aug.		577.30	572.29		568.81		
1951	Sept.		577.30	572.29		568.81		
1951	Oct.		577.30	572.29		568.81		
1951	Nov.		577.30	572.29		568.81		
1951	Dec.		577.30	572.29		568.81		
1952	Jan.		577.30	572.29		568.81		
1952	Feb.		577.30	572.29		568.81		
1952	Mar.		577.30	572.29		568.81		
1952	Apr.	63	577.22	572.21	+371.68	568.73	+568.73	.08 = 100.00%
1952	May		577.22	572.21		568.73		
1952	June		577.22	572.21		568.73		
1952	July		577.22	572.21		568.73		
1952	Aug.		577.22	572.21		568.73		
1952	Sept.		577.22	572.21		568.73		
1952	Oct.		577.22	572.21		568.73		
1952	Nov.		577.22	572.21		568.73		
1952	Dec.		577.22	572.21		568.73		
1953	Jan.		577.22	572.21		568.73		
1953	Feb.		577.22	572.21		568.73		
1953	Mar.		577.22	572.21		568.73		
1953	Apr.	64	577.14	572.13	+371.60	568.65	+568.65	.08 = 100.00%
1953	May		577.14	572.13		568.65		
1953	June		577.14	572.13		568.65		
1953	July		577.14	572.13		568.65		
1953	Aug.		577.14	572.13		568.65		
1953	Sept.		577.14	572.13		568.65		
1953	Oct.		577.14	572.13		568.65		
1953	Nov.		577.14	572.13		568.65		
1953	Dec.		577.14	572.13		568.65		
1954	Jan.		577.14	572.13		568.65		
1954	Feb.		577.14	572.13		568.65		
1954	Mar.		577.14	572.13		568.65		
1954	Apr.	65	577.06	572.05	+371.52	568.57	+568.57	.08 = 100.00%
1954	May		577.06	572.05		568.57		
1954	June		577.06	572.05		568.57		
1954	July		577.06	572.05		568.57		
1954	Aug.		577.06	572.05		568.57		
1954	Sept.		577.06	572.05		568.57		
1954	Oct.		577.06	572.05		568.57		
1954	Nov.		577.06	572.05		568.57		
1954	Dec.		577.06	572.05		568.57		
1955	Jan.		577.06	572.05		568.57		
1955	Feb.		577.06	572.05		568.57		
1955	Mar.		577.06	572.05		568.57		
1955	Apr.	66	576.98	571.97	+371.44	568.49	+568.49	.08 = 100.00%
1955	May		576.98	571.97		568.49		
1955	June		576.98	571.97		568.49		
1955	July		576.98	571.97		568.49		
1955	Aug.		576.98	571.97		568.49		
1955	Sept.		576.98	571.97		568.49		
1955	Oct.		576.98	571.97

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Table LV
Sheet 1

Chicago Sanitary District
Relative Fluctuation of Lakes
St. Clair - Erie
Open Season, Apr - Nov Incl

Year	Month	Group	Huron Elev/Diff	St Clair Elev/Diff	C. & G. Diff	Erie Elev/Diff	C. & G. Diff	St Clair Change / Erie Change
1900	July	1	581.71	576.33	0.33	573.67	0.32	033 = 344%
1900	Aug		581.54	576.00		573.35		096
1900	Sept		581.38	575.91		573.27		
1905	July	2	581.55	576.25	0.24	573.41	0.24	044 = 417%.
1905	Aug		581.32	576.01		573.17		106
1905	Sept		581.36	575.95		573.07		
1902	August	3	581.44	575.83	0.24	572.96	0.24	044 = 1250%
1902	July		581.41	575.59		572.73		008
1902	Sept		581.43	575.84		572.83		
1907	June	4	581.42	576.19	0.24	573.40	0.24	044 = 4040%
1907	July		581.30	576.00		573.18		001
1907	Sept		581.30	575.90		573.16		
1903	July	5	581.32	575.92	0.24	572.88	0.24	044 = 5775%
1903	June		581.35	575.75		572.77		008
1903	Sept		581.30	575.80		572.80		
1906	July	6	581.32	575.88	0.24	572.84	0.24	044 = 5000%
1906	June		581.21	575.64		572.60		008
1906	Sept		581.20	575.69		572.36		
1904	June	7	581.09	575.92	0.24	573.25	0.24	044 = 3205%
1904	July		581.00	575.68		573.02		008
1904	Aug		581.02	575.44		572.78		

Weighted Mean of Relative Fluctuations = 1902% (See sheet 2)

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Table L V.
Sheet 2

Chicago Sanitary District
Relative Fluctuation of Lakes.
St. Clair - Erie
Open Season, Apr. to Nov. inc.

Year	Month	Group	Huron Elevations	St. Clair		Erie		St. Clair Change
				Elevation	Col 6	Elevation	Col 6	Erie Change
1892	Aug.	8	581.04	575.77		573.03		
1893	Nov.		1.02	3.50		2.34		
1894				579.27	0.37		0.58	0.21 = 35.25 %
1895	July	9	580.32	579.95		573.38		
1896	July			576.45		573.33		
1897	July			579.91		573.46		
1898	Sept.			576.47		574.44		
1899	Sept.			579.79		574.13		
1900	Nov		0.83	575.33		572.20		
1901				579.27	0.38		1.08	0.38 = 35.20 %
1902	May	10	580.80	574.34		573.04		
1903	Sept.			576.88		574.11		
1904	Sept.			579.22		573.36		
1905	Sept.			575.42		573.36		
1906	Sept.			579.08		573.27		
1907	Nov.		0.80	575.33		571.71		
1908				579.12	0.79		0.79	0.79 = 24.05 %
1909	Aug.	11	580.83	575.65		572.72		
1910	July			576.90		573.68		
1911	July			579.57		574.17		
1912	Sept.			575.79		573.41		
1913	Sept.			579.49		574.29		
1914	Aug.		0.83	575.42		572.89		
1915				579.31	0.73		0.30	0.43 = 42.90 %
1916	Sept.	12	580.78	574.76		573.38		
1917	Sept.			576.80		574.26		
1918	Sept.			579.25		574.33		
1919	Nov.			575.79		573.31		
1920				579.30	0.80		1.23	0.43 = 65.04 %

Williams Ex. 84.

Table L V.
Sheet 3

Chicago Sanitary District
Relative Fluctuation of Lakes
St. Clair - Erie
Open Season Apr. to Nov. inc.

Year	Month	Group	Huron Elevation	St. Clair Elevation	St. Clair C of G	Erie Elevation	Erie C of G	St. Clair Change / Erie Change
1903	July	13	580.72	575.68	575.72	573.85	573.86	
1904	Oct.		8.98	3.78	3.84	1.87	1.80	2.04 = 54.54 %
					575.56		573.66	
					8.68		8.67	
1898	June	14	580.72	575.50	575.46	573.91	573.85	
1899	July		8.98	3.60	3.58	2.05	2.05	
1900	Aug.		8.72	3.38	3.39	1.83	1.83	
1903	Sept.		8.74	3.35	3.32	1.88	1.88	
1904	Oct.				575.32		573.68	
1905	Nov.				8.46		8.71	2.64 = 56.64 %
1898	Apr.	16	580.66	575.13	575.13	572.45	571.91	
1899	May		8.92	3.03	3.05	1.83	1.71	
1900	June		8.86	3.06	3.06	1.83	1.78	
1901	July		8.81	4.86	4.86	1.83	1.83	
1903	Aug.				574.94		571.41	2.48 = 56.00 %
1904	Sept.				8.76		8.50	
1905	Oct.				575.42		573.94	
1906	Nov.				8.54		8.53	
1898	Apr.	17	580.63	575.84	575.63	573.13	572.68	
1899	May		8.89	3.34	3.37	2.67	2.43	
1900	June		8.83	3.07	3.07	2.13	2.03	
1901	July		8.83	3.18	3.22	2.03	2.18	
1903	Aug.				575.22		572.43	2.79 = 59.75 %
1904	Sept.				8.45		8.18	
1905	Oct.				575.41		573.62	
1906	Nov.				8.33		8.11	
1898	June	18	580.58	575.33	575.33	573.08	572.59	
1899	July		8.84	3.28	3.28	2.53	2.21	
1900	Aug.		8.68	3.03	3.03	1.83	1.79	1.27 = 112.50 %
1901	Sept.		8.68	3.15	3.15	1.89	1.79	
1903	Oct.				574.93		572.21	
1904	Nov.				8.25		8.00	
1898	Apr.	21	580.44	575.23	575.23	573.03	572.58	
1899	May		8.71	3.23	3.23	2.53	2.38	
1900	June		8.43	3.07	3.02	1.78	1.78	1.15 = 37.50 %
					574.82		572.03	
					8.82		8.18	

Williams Ex. 34.

Table L.K.
Sheet 4

Chicago Sanitary District
Relative Fluctuation of Lakes
St. Clair - Erie
Open Season Apr. to Nov. inc.

Year	Month	Gage	Huron Elevation	St. Clair Elevation	St. Clair C of D	St. Clair Recession	Erie (573.00)	Erie C of D	St. Clair-Erie Change
1903	Apr.	23	580.27	Not Given	573.23			Not Given	
1902	May		0.30	573.21	573.10		2.29	573.72	
1901	Oct.		0.28	1.28	0.34		1.83	0.61	0.27 = 30.65%
1901	Apr.	24	580.25	573.43	573.43		572.20	573.20	
1902	May		0.27	1.21	572.92		1.30	0.30	
1899	Oct.		0.24	1.11	0.51		1.22	0.49	0.21 = 37.5%
1897	Apr.	23	580.14	573.13	573.04		572.30	572.30	
1902	May		0.14	1.20	572.93		1.39	0.39	
1902	Oct.		0.16	1.20	0.41		1.39	0.39	
1899	Nov.		0.18	1.20	573.34		1.39	571.91	
1880	July		0.18	1.25	0.31		1.48	571.62	0.28 = 46.6%
1900	Apr.	25	579.96	574.93	574.93		572.30	0.00	
1900	July		0.04	1.20	573.73		1.39	572.02	
1900	Sept.		0.04	1.20	574.66		1.39	571.30	
1891	Nov.		0.07	1.82	574.77		1.39	571.23	0.11 = 57.14%
					0.74			0.77	

Weighted Mean Recession of Erie = 1.39 ± 0.02 ft.

Williams Ex. 34. Table LVI

Chicago Sanitary District.

Winter Temperatures.

Closed Season; Dec-Mar. Incl.

Year	Detroit Fahrenheit	Buffalo Fahrenheit	Oswego Fahrenheit
1889-90	33.9	32.7	30.4
90-91	29.8	28.7	25.6
1-2	29.1	29.0	27.3
2-3	24.2	23.9	22.4
3-4	30.4	30.0	27.7
4-5	24.7	24.6	24.1
	28.7	28.2	26.3
1895-96	27.2	27.0	24.8
6-7	28.8	29.1	27.0
7-8	30.6	31.7	30.5
8-9	25.0	26.9	25.6
9-0	26.1	26.9	25.8
1900-01	26.0	27.1	25.1
	27.3	28.1	26.5
1901-02	28.0	28.8	27.5
02-03	29.6	31.1	28.7
03-04	22.3	23.5	21.2
04-05	25.4	23.6	21.8
05-06	29.9	29.6	27.9
06-07	28.9	26.7	26.0
	27.3	27.2	25.4
1907-08	28.6	28.4	27.1
08-09	30.1	29.6	28.0
09-10	28.6	28.6	27.8
10-11	28.3	27.3	25.3
11-12	22.9	24.6	24.1
	27.7	27.7	26.5

Williams Ex. 34 Table LVII

Chicago Sanitary District

Great Lakes Drainage Areas

Drainage Areas

River	Total Land & Lake Sq. Mi.	Total Lake Sq. Mi.	Total Land Sq. Mi.	Local Land & Lake Sq. Mi.	Local Lake	Local Land	Pop. per Sq. Mi. Local Land
St. Lawrence	287688	95088	192600	32980	7243	25737	534
Niagara	234708	67845	166863	34573	9968	24605	734
Detroit	220135	77877	142258	6194	303	5691	37
Niagara & Detroit	474843	163722	309121	40767	10471	30296	171
St. Clair	213941	77374	136567	137807	45314	92493	3338
Detroit & St. Clair	434076	155251	278825	144001	45817	98184	3375
St. Marys	76134	32060	44074	76134	32060	44074	2353

Table LVIII

Chicago Sanitary District

Comparisons of River Discharges

River	Discharges		Runoff per Square Mile				
			Total		Local		Stream
	Total C.F.S.	Local C.F.S.	Land and Lake C.F.S.	Land C.F.S.	Land and Lake C.F.S.	Land C.F.S.	C.F.S.
	By Complainant's Equation 1900-1907						
St. Lawrence	247762	47690	0.86	1.29	1.45	1.35	1.44
Niagara	200072	6344	0.78	1.20	0.19	0.27	0.86
St. Clair	193528	115328	0.90	1.42	0.84	1.25	0.87
St. Mary's	78200	78200	1.03	1.77	1.03	1.77	
	By E.S. Wheeler Rep. 1882-1898 Rep. Ch. Eng. 1908						
St. Lawrence	249075	31973	0.87	1.29	0.97	1.24	
Niagara	217102	24391	0.85	1.30	0.71	1.00	
St. Clair	192511	122148	0.90	1.41	0.89	1.32	
St. Mary's	70363	70363	0.92	1.60	0.92	1.60	
	By International Waterways Comm. 1890-1904						
St. Lawrence	233320	34812	0.81	1.21	1.06	1.35	
Niagara	198507	12207	0.78	1.19	0.35	0.80	
Detroit	186300	110920	0.85	1.31	0.77	1.13	
St. Mary's	75380	75380	0.99	1.71	0.99	1.71	

Williams Ex. 34. Table LIX o

Chicago Sanitary District

Runoff From Drainage Basins

By Local Stream Gagings

Month	C.F.S. Per Square Mile		
	Huron-Michigan	Erie	Ontario
January	0.779	1.023	1.480
February	0.858	0.912	1.446
March	1.377	2.101	2.435
April	1.735	1.199	3.162
May	1.177	0.613	2.005
June	0.930	0.566	1.254
July	0651	0.303	0.881
August	0.515	0.168	0.735
September	0.515	0.139	0.648
October	0.591	0.126	0.912
November	0.635	0.207	1.116
December	0.629	0.605	1.201
Full Year	0.866	0.664	1.440
Apr.-Nov Inc.	0.844	0.415	1339
June-Nov "	0.640	0.252	0.924

Williams Ex 34. Table LIX

Chicago Sanitary District

Runoff from Huron-Michigan Drainage

Summary

Huron-Michigan Drainage

Drainage	January		February		March		April		May		June	
	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Lake Michigan	157613	69777	139995	69721	172357	216373	191163	327868	190457	217301	185291	189339
Lake Huron	28709	20488	23868	19689	23582	61895	34244	65338	34244	46933	34244	28949
Total	186322	90265	163864	89410	202139	278268	225407	393206	224701	264234	229535	218288
C.F.S./Sq.Mi.		0.779		0.858		1.377		1.735		1.177		0.930

Drainage	July		August		September		October		November		December	
	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Lake Michigan	189971	104383	189313	102965	202356	103388	202356	120956	189320	121002	183774	120637
Lake Huron	34244	17988	31783	15993	33208	16218	33208	18866	35669	22066	32819	18795
Total	224215	122371	221096	118960	236164	121606	236166	139822	225189	143068	221993	139432
C.F.S./Sq.Mi.		0.631		0.545		0.515		0.591		0.635		0.629

Williams Ex. 34. Chicago Sanitary District Table LIXc
Sheet 1
Runoff from Lake Michigan Drainage (14 Sheets)

Summary
Lake Michigan Drainage

Drainage	River	Year	January		February		March		April		May		June	
			Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Lake Michigan	Escanaba	1903-09							3200	15378	3200	11002	4800	7887
"	Fox	1895-04	35800	24954	53800	25738	62000	29674	62000	108002	62000	50867	62000	52513
"	Grand	1897-09	33900	57738	33900	71412	33900	113666	28900	96031	28800	60465	28800	50719
"	Iron	1900-02	75	64	75	62	130	144	130	282	130	194	130	134
"	Kalamazoo	1901-07	8824	7870	8824	7400	8824	14258	10295	12793	10295	9103	10295	8229
"	Manistee	1903-09	5400	6280	5400	5783	5400	7079	5400	10480	5400	8750	5400	6840
"	Menominee	1898-09	9975	9910	9975	5700	9975	9970	13872	33333	18304	42913	20724	32464
"	Muskegon	1901-06	4702	2937	7054	4202	9406	9333	9406	9673	9406	8643	9406	6288
"	Oconto	1906-09	1628	610	1628	626	1628	217	1628	2210	1628	2680	2442	2195
"	St. Joseph	1901-06	13745	17424	13745	17949	19680	34525	23615	33606	19680	19737	19680	15319
"	Wolf	1907-09	1394	930	1394	847	1394	1039	797	1360	1394	2930	1394	1709
		Totals	157643	124717	139779	139721	172557	216513	191163	322868	190457	217301	195291	184339
		C.F.S. per Sq. Mi.		0.792		0.873		1.255		1.689		1.140		0.944

Williams Ex 34

Chicago Sanitary District

Table L IXc
Sheet 2

Runoff from Lake Michigan Drainage

Summary
Lake Michigan Drainage

Drainage	River	Year	July		August		September		October		November		December	
			Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.
Lake Michigan	Escanaba	1903-09	4800	3000	4800	2385	5800	3483	5400	5311	5400	3827	5200	3074
"	Fox	1885-04	2000	1200	2000	1192	2300	1776	2300	2793	2300	2445	2300	2436
"	Grand	1891-09	3800	3148	3800	2725	3800	2545	3800	3245	3800	3004	3800	3220
"	Iron	1900-02	130	116	130	99					79	72	79	89
"	Kalamazoo	1901-04	4275	681	4275	3889	4275	614	4275	6006	4275	6735	4275	735
"	Manistee	1903-09	6300	7218	6300	6769	6300	6740	6300	6894	6300	7257	6300	718
"	Menominee	1885-09	2400	1601	2400	2045	2487	2144	2487	2534	2012	2017	2640	1587
"	Muskegon	1901-06	1405	1206	1758	343	1758	1068	1758	612	1758	645	1758	686
"	Ocanto	1906-09	342	1737	342	1033	342	1337	342	1303	342	1737	428	600
"	St. Joseph	1901-06	1800	3510	1576	1809	1800	942	1800	1638	1800	2740	1800	1796
"	Wolf	1907-09	1394	1733	1394	1238	1394	1460	1394	1307	1394	1218	1394	1200
		Totals	31711	24050	31584	22446	32487	23144	32487	23534	32012	30171	32640	25087
		Run-off		0.872		0.59		0.59		0.496		0.638		0.637

Williams Ex. 34

Table LIXc
Sheet 3

Chicago Sanitary District

Runoff from Lake Michigan Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Sanitary	Canals	43 G.S. 43 "29	1903											800	1571
"	"	"	1904											800	1512
"	"	" 770	1905							800	2468	800	2322	800	1730
"	"	" 726	1906							800	5170	800	1870	800	1160
"	"	" 744	1907							800	2420	800	4390	800	1100
"	"	" 744	1908							800	3320	800	2420	800	839
"	"	" 781	1909							3200	17745	3200	11062	800	1887
											4.81		3.44		1.441
River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Sanitary	Canals	43 G.S. 43 "29	1903	800	663	800	454	800	1617	800	1625	800	985		
"	"	" 770	1904	800	669	800	565	800	741	800	1145	800	657		
"	"	" 726	1905	800	669	800	411	800	708	800	623	800	699	800	491
"	"	" 744	1906	800	579	800	413	800	714	800	485	800	1000	800	964
"	"	" 744	1907	800	351	800	406	800	779	800	829	800	544	800	446
"	"	" 781	1908	800	617	800	342	800	220	800	294	800	243		
"	"		1909	800	734	800	2538	800	274	800	310	800	891	800	773
				4800	3856	4800	2538	5600	5383	5600	5311	5600	5019	3200	3674
					.804		.341		.908		.948		.897		.961

Williams Ex 34

Table L
Sheet

Chicago Sanitary District

Runoff from Lake Michigan Drainage

Lake Michigan Discharge

River	Location	Authority	Year	January	February	March	April	May	June
				Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.
Fox	Chicago Drainage Canal	U.S.G.S. W.S.P. 345	1895	6300 3531	6300 4320	6300 3417	6300 6540	6300 3610	6300 4700
"	"	"	1896		6300	6300 1894	6300 918	6300 3140	6300 3776
"	"	"	1897	6300 2102	6300 2705	6300 2711	6300 6432	6300 406	6300 3916
"	"	"	1898	6300 2249	6300 2239	6300 2968	6300 4091	6300 1743	6300 3110
"	"	"	1899	6300 1405	6300 2013	6300 2222	6300 3337	6300 609	6300 638
"	"	"	1900	6300 2174	6300 2847	6300 2705	6300 344	6300 2576	6300 810
"	"	"	1901	6300 3316	6300 3773	6300 3639	6300 2960	6300 1194	6300 3173
"	"	"	1902	6300 2263	6300 2142	6300 2982	6300 2235	6300 1435	6300 1810
"	"	"	1903	6300 1740	6300 2249	6300 3827	6300 6300	6300 5537	6300 3041
"	"	"	1904	6300 2677	6300 3301	6300 3138	6300 6444	6300 5707	6300 4482
				July	August	September	October	November	December
River	Location	Authority	Year	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.	Area Disch. Sq. Mi. C.F.S.
Fox	Chicago Drainage Canal	U.S.G.S. W.S.P. 345	1895	6300 7612	6300 4428	6300 3808	6300 3417	6300 2007	6300 2361
"	"	"	1896	6300 2787	6300 1410	6300 446	6300 1065	6300 892	6300 2314
"	"	"	1897	6300 3300	6300 891	6300 533	6300 1434	6300 892	6300 2314
"	"	"	1898	6300 1571	6300 187	6300 188	6300 1701	6300 2213	6300 2175
"	"	"	1899	6300 3196	6300 1306	6300 308	6300 1144	6300 2118	6300 2087
"	"	"	1900	6300 358	6300 189	6300 2271	6300 3220	6300 4062	6300 4533

Williams Ex. 34

Table LIX c
Sheet 5

Chicago Sanitary District

Runoff from Lake Michigan Drainage

River	Location	Authority	Year	July.		August.		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Fox	Bridge Above Dam.	U.S. Eng. Rpt.	1901	600	3301	600	2178	600	1721	600	2351	600	3286	600	2768
"	"	"	1902	600	4304	600	2856	600	1766	600	1818	600	2294	600	2774
"	"	"	1903	600	4124	600	3446	600	4321	600	4588	600	3696	600	2785
"	"	"	1904	600	3105	600	2085	600	1434	600	3411	600	4078	600	3348
				2400	12916	2400	10286	2400	9326	2400	12163	2400	12424	2400	11675
					241		339		286		419		532		.445
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Grand	Grand Rapids	U.S. Eng. Rpt.	1897									400	2892	400	1761
"	"	"	1898	400	3007	400	2892			400	4815	400	2203	400	1735
"	"	"	1899	400	6965	400	4773	400	3649	400	10708	400	3088	400	2236
"	"	"	1900	400	2520	400	2324	400	3545	400	1991				
"	"	Sylvania Electric	1901	400	2230	400	2102	400	13564	400	6076	400	3344	400	2613
"	"	"	1902	400	6530	400	3340	400	8140	400	4730	400	1412	400	3652
"	"	"	1903	400	4418	400	2383	400	12830	400	8818	400	3344	400	2821
"	"	"	1904	400	3449	400	3418	400	3044	400	6530	400	4091	400	2719
"	"	"	1905	400	8288	400	6991	400	6963	400	6116	400	3359	400	4412
"	"	"	1906	400	2300	400	1270	400	4080	400	9300	400	6344	400	3860
"	"	"	1907	400	2300	400	1270	400	4080	400	9300	400	6344	400	3860

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Table LI
Sheet

Chicago Sanitary District

Runoff from Lake Michigan Drainage

Lake Michigan Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Grand	Grand Rapids	U.S.G.S.	1908	4300	4714	4300	6534	4300	17430	4300	8314	4300	3574	4300	4328
"	"	Mich. Public Service Co.	1909	3960	3753	3960	7282	3960	19225	3960	7685	3960	2210	3960	3079
					1.071		1.325		2.10		1.637		1.079		.863
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Grand	Grand Rapids	U.S.G.S. W.S.P.	1897	4300	692	4300	571	4300	1370	4300	1181	4300	1453	4300	2382
"	"	"	1898	4300	1491	4300	861	4300	1694	4300	1853	4300	2645	4300	3614
"	"	"	1899	4300	1719	4300	1617	4300	1741	4300	1715	4300	1795	4300	2059
"	"	"	1900												
"	"	Grd. Rapids Power Co.	1901	4300	4266	4300	2087	4300	2015	4300	2318	4300	2258	4300	3221
"	"	"	1902	4300	6085	4300	2908	4300	3187	4300	3330	4300	4419	4300	4525
"	"	"	1903	4300	2675	4300	2361	4300	1791	4300	5118	4300	2999	4300	3308
"	"	"	1904	4300	1835	4300	1438	4300	2282	4300	3210	4300	1815	4300	2079
"	"	"	1905	4300	4254	4300	3230	4300	3055	4300	3366	4300	3835	4300	3350
"	"	"	1906	4300	1821	4300	1574	4300	1391	4300	2015	4300	3344	4300	4112
"	"	"	1907	4300	2867	4300	2179	4300	2432	4300	2820			4300	3567
"	"	"	1908	4300	2710	4300	2096	4300	3220	4300	2498	4300	2811	4300	2713
"	"	"	1909	4300	1910	4300	1370	4300	1120	4300	1428	4300	2507	4300	4419
				3960	3753	3960	7282	3960	19225	3960	7685	3960	4419	3960	3726
				4300	1071	4300	1325	4300	2110	4300	1637	4300	1079	4300	863

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Table LIXc
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Chicago Sanitary District

Runoff from Lake Michigan Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S.	Area Sq Ft	Discharge C.F.S	Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S
Iron	Iron River	U.S.G.S. W.S. 97	1900												
"	"	"	1901	75	64	75	62	75	67	75	169	75	94	75	73
			1902					75	77	75	93	75	100	75	81
				75	64	75	62	150	144	150	262	150	194	150	154
					.854		.827		.960		1.346		1.291		1.027

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S
Iron	Iron River	U.S.G.S. W.S. 97	1900												
"	"	"	1901	75	116							79	72	79	69
			1902	75	60	75	59								
				150	176	75	59					79	72	79	69
					1.172		.786						.911		.814

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq Mi	Discharge C.F.S	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S.
Kalamazoo	Allegan	U.S.G.S. W.S. 83	1901	1471	881	1471	683	1471	932	1471	940	1471	776	1471	837
"	"	"	1902	1471	1308	1471	1704	1471	2700	1471	812	1471	816	1471	828
"	"	"	1903	1471	1308	1471	1704	1471	2700	1471	2399	1471	1118	1471	1094
"	"	"	1904	1471	1215	1471	1443	1471	3007	1471	3062	1471	1513	1471	1019

Chicago Sanitary District

Runoff from Lake Michigan Drainage

Table LI
Sheet

Lake Michigan Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.
Nippersink Lake	Antioch	U.S.G.S. W.S. #270	1905	1411	976	1411	880	1411	849	1411	1120	1411	1020	1411	1060
"	"	" #308	1906	1410	1810	1410	1810	1410	1740	1410	1930	1410	1740	1410	1610
"	"	" #44	1907	1410	1920	1410	1320	1410	1700	1410	2230	1410	1530	1410	1110
				2824	7650	2824	7400	2824	4428	2820	6299	2820	5105	2820	5824
					382		309		1016		1493		1806		1989
River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.	Area Sq.mi.	Discharge C.F.S.
Nippersink Lake	Antioch	U.S.G.S. W.S. #8	1901	1411	722	1411	768	1411	741	1411	741	1411	847	1411	799
			1902	1411	918	1411	797	1411	761	1411	900	1411	923	1411	938
			1903	1411	908	1411	1012	1411	1236	1411	1158	1411	1008	1411	1171
			1904	1411	973	1411	911	1411	894	1411	1046	1411	894	1411	827
			1905	1411	1392	1411	957	1411	938	1411	924	1411	1093	1411	1130
			1906	1410	844	1410	808	1410	996	1410	977	1410	1100	1410	1270
			1907	1410	894	1410	736	1410	828	1410	1000	1410	1020	1410	1340
				11295	6781	11295	5899	11295	6114	11295	6906	11295	7395	11295	7515
					599		511		594		830		960		715

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Chicago Sanitary District — Table LIXc, Sheet 9

Runoff from Lake Michigan Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.
Hanisville	Sherman	U.S.G.S. W.S. Pap.	1904	900	1100	900	1000	900	1100	900	1200	900	1740	900	1240
"	"	"	1905	900	901	900	855	900	1000	900	1080	900	1310	900	1120
"	"	"	1906	900	1200	900	1100	900	1110	900	1240	900	1320	900	1060
"	"	"	1907	900	1140	900	900	900	1040	900	1420	900	1370	900	1240
"	"	"	1908	900	943	900	910	900	1230	900	1330	900	1330	900	1080
"	"	"	1909	900	996	900	1110	900	993	900	1320	900	1620	900	1100
				5400	6080	5400	5765	5400	7075	5400	10080	5400	8720	5400	6840
					1101		1067		1340		1940		1618		1267
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.
Hanisville	Sherman	U.S.G.S. W.S. Pap.	1903	900	1040	900	1200	900	1200	900	1150	900	1100	900	1210
"	"	"	1904	900	1050	900	999	900	942	900	1010	900	926	900	910
"	"	"	1905	900	1110	900	952	900	934	900	943	900	1080	900	1000
"	"	"	1906	900	1000	900	920	900	878	900	905	900	1000	900	1000
"	"	"	1907	900	936	900	944	900	971	900	1030	900	1030	900	1200
"	"	"	1908	900	1030	900	892	900	843	900	885	900	908	900	945
"	"	"	1909	900	982	900	891	900	935	900	898	900	973	900	993
				6300	7218	6300	6765	6300	6746	6300	6944	6300	7037	6300	7185
					1145		1074		1070		1086		1120		1130

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Chicago Sanitary District

Runoff from Lake Michigan Drainage

Lake Michigan Drainage

River	Location	Authority	Year	February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Hennepin Canal	Lower Summit Reach	U.S.E.D. H.D. 83	1898					2432	4011	2432	3080	2432	2459
"	Iron Mt.	U.S.E.D. W.S. 129	1899					2415	3175	2415	7496	2415	3417
"	"	"	1902					2415	3995	2415	7879	2415	4791
"	"	"	1903					2415	3282	2415	6810	2415	3011
"	"	"	1904					2415	8040	2415	5610	2415	3040
"	"	U.S.E.D. W.S. 336	1905	2415	2370	2415	2250	2415	7050	2415	7920	2415	3040
"	"	"	1906	2415	2370	2415	2250	2415	7050	2415	7920	2415	3040
"	"	"	1907	3780	1980	3780	1800	3780	7050	3780	7920	3780	3040
"	Rock	"	1908	3780	1980	3780	1800	3780	7050	3780	7920	3780	3040
"	"	"	1909	3780	1260	3780	1310	3780	1820			2430	3230
"	Iron Mt.	"	1909										
"	Rock	"	1909	9975	9910	9975	3100	9975	3970	15872	33695	48304	42913	20224	32461
					392		511		2981		2111		2341		1568

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Hennepin Canal	Lower Summit Reach	U.S.E.D. H.D. 83	1898	2432	1139	2432	2282	2432	2366	2432	3248	2432	2166		
"	Iron Mt.	U.S.E.D. W.S. 129	1899	2432	1819	2432	1573								
"	"	U.S.E.D. W.S. 336	1902					2415	1735	2415	1596	2415	2829	2415	1909
"	"	"	1903	2415	3393	2415	1049	2415	2091	2415	1057	2415	2505	2415	2150

Chicago Sanitary District Table LIXc Sheet 11

Runoff from Lake Michigan Drainage

Lake Michigan Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Menominee.	Iron Mt.	U.S.G.S. W.S. #129	1904	2415	2196	2415	2125	2415	2488	2415	3650	2415	2293	2415	1838
"	" "	" #156	1905	2415	3850	2415	2130	2415	3284	2415	2163	2415	2704	2415	2043
"	" "	" #206	1906	2415	3500	2415	2400	2415	2160	2415	2140				
"	Koss	" #244	1907	3780	3220	3780	2170	3780	4240	3780	2860	3780	2430	3780	2350
"	"	" "	1908	3780	3740	3780	2100	3780	1440	3780	2200	3780	1880	3780	2270
"	Iron Mt.	" #264	1909	2420	2740	2420	1920	2420	1580	2420	1400	2420	3270	2420	2480
"	" "	" "		24504	26057	24504	20749	24487	24144	24487	28314	22072	20177	19640	15082
					1.069		.846		.985		.951		.914		.769

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Muskegon.	Newaygo	U.S.G.S. W.S. #129	1901											2352	1073
"	"	"	1902	2352	717	2352	773	2352	1348	2352	2430	2352	3149	2352	1809
"	"	"	1903			2352	1579	2352	3715	2352	3244	2352	2153		
"	"	"	1904												
"	"	" #170	1905					2352	2812	2352	2129	2352	2091	2352	2286
"	"	" #206	1906	2350	2220	2350	1830	2350	1480	2350	1810	2350	1250	2350	1120
				4702	2937	7054	4202	9406	9355	9406	9673	9406	8643	9406	6288
					.625		.596		.995		1.028		.919		.669

Williams Ex. 34 Chicago Sanitary District Table LIXC
Sheet 12

Runoff from Lake Michigan Drainage

Lake Michigan Drainage

River	Location	Aumsville	Year	July		August		September		October		November		December	
				Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.
Hudson	Nawanga	USGS WS 29	1901	2332	1064	2332	939	2332	886	2332	1175	2332	898	2332	904
			1902	2332	1488	2332	1085	2332	1078	2332	1572	2332	1338	2332	1281
			1904			2332	1015	2332	778	2332	1061	2332	993	2332	920
			1905	2332	1284	2332	1082	2332	1129	2332	1154	2332	1266	2332	1161
			1906	2350	1080	2350	914	2330	997	2330	1250	2330	1900	2330	1920
				9400	4900	11738	3415	11738	4866	11738	6212	11738	6433	11736	6186
					321		456		414		329		349		320
River	Location	Aumsville	Year	January		February		March		April		May		June	
				Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.	Area Sq.mi.	Discharge c.f.s.
Ohio	Gilbert	USGS WS 34	1906							814	1160	814	1230	814	776
			1907							814	1120	814	1450	814	575
			1908	814	317	814	337	814	486	814	1120	814	1450	814	575
			1909	814	293	814	289	814	331						
				1628	610	1628	626	1628	817	1628	2210	1628	2680	2442	2195
					374		364		301		1338		1815		899

Williams Ex. 34. Chicago Sanitary District Table LIXc Sheet 13.

Runoff from Lake Michigan Drainage

Lake Michigan Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Oconto	Gillett	U.S.G.S. W.S. #244	1906	814	504	814	501	814	570	814	682	814	957		
"	"	"	1907	814	520	814	291	814	682	814	474	814	476	814	331
"	"	"	1908	814	733	814	261	814	285	814	347	814	364	814	275
				2442	1757	2442	1053	2442	1537	2442	1503	2442	1797	1628	606
					.720		.431		.630		.616		.736		.372
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
St. Joseph	Berrien	U.S.G.S. W.S. #89	1901							3935	3074	3935	2790	3935	2057
"	"	"	1902	3935	2721	3935	2446	3935	5197	3935	3560	3935	3863	3935	3629
"	"	" #89	1903	3935	4450	3935	3973	3935	8084	3935	6933				
"	"	"	1904	3935	5853	3935	5830	3935	12010	3935	8801	3935	3744	3935	2669
"	"	" #110	1905					3935	4784	3935	4688	3935	6080	3935	3534
"	"	" #208	1906	3940	4400	3940	3700	3940	4390	3940	4330	3940	3060	3940	3460
				15745	17424	15745	17949	19680	34525	23615	33606	19680	19737	19680	15349
					1.106		1.14		1.751		1.421		1.002		.780

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Table LIXc
Sheet 14

Chicago Sanitary District.

Runoff from Lake Michigan Drainage

Lake Michigan Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
St Joseph	Buchanan	U.S.G.S. W.S. 385	1901	3935	1730	3935	1507	3935	1774	3935	2804	3935	2785	3935	3220
"	"	"	1902	3935	4947	3935	2377	3935	2268	3935	3791	3935	3284	3935	3714
"	"	"	1904	3935	2639			3935	1292	3935	1870	3935	1844	3935	1594
"	"	"	1905	3935	2994	3935	2015	3935	2308	3935	2223	3935	2617	3935	3035
"	"	"	1906	3940	1780	3940	2030	3940	1300	3940	1470	3940	2370	3940	4170
				19880	13410	15745	7909	19680	9147	19680	11638	19700	12740	19680	15796
					687		502		465		592		648		803
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Wolf	Kesherra	U.S.G.S. W.S. 384	1907									797	1630	797	796
"	"	"	1908	797	510	797	399	797	608	797	1360	797	1300	797	911
"	"	"	1909	797	420	797	448	797	431						
				1594	930	1594	847	1594	1039	797	1360	1594	2930	1594	1709
					583		531		652		1.71		1.85		1.071
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Wolf	Kesherra	U.S.G.S. W.S. 384	1907	797	811	797	694	797	988	797	685	797	640	797	600
"	"	"	1908	797	942	797	564	797	472	797	612	797	578	797	450
				1594	1753	1594	1238	1594	1460	1594	1307	1594	1218	1594	1030
					1.10		.789		.915		.820		.764		.638

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Table LIX d
Sheet 1
5 Sheets

Chicago Sanitary District

Runoff from Lake Huron Drainage

Summary
Lake Huron Drainage

Drainage	River	Year	January		February		March		April		May		June	
			Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.
Lake Huron	Au Sable	1902-08	4260	4340	1420	1830	4270	5083	8335	13284	8335	10993	8335	9682
"	Cass	1908-09	863	193	863	818	1726	7600	863	1500	863	1400	863	140
"	Thunder Bay	1901-06	8320	4093	8320	4541	8320	9987	10080	20016	10080	11945	10080	7796
"	Tittabawassee	1903-09	14766	10860	14766	12490	14766	31925	14766	33838	14766	22593	14766	11831
		Totals	28109	20486	25869	19689	29582	61875	34244	68938	34244	46933	34244	29949
		C.F.S. per Sq. Mi.		0.714		0.761		2.092		2.003		1.373		0.845
			July		August		September		October		November		December	
Drainage	River	Year	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.	Area Sq. Mi.	Disch. in c.f.s.
Lake Huron	Au Sable	1902-08	8335	7337	8335	7311	9960	8026	9960	8099	9960	8685	7110	7364
	Cass	1908-09	863	109	863	819	863	401	863	334	863	472	863	780
	Thunder Bay	1901-06	10080	3003	10080	4320	10080	3564	10080	4717	10080	3667	10080	4873
	Tittabawassee	1903-09	14766	5339	12305	3722	12305	4538	12305	6017	14766	7667	14766	6279
		Totals	34244	17788	31783	15492	33208	16218	33208	18866	35669	22006	32819	18795
		C.F.S. per Sq. Mi.		0.525		0.487		0.488		0.568		0.619		0.572

Williams Et. al. vs. Chicago Sanitary District

Table LIX d Sheet 2

Runoff from Lake Huron Drainage

Lake Huron Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Au Sable	Bamfield	U.S.G.S. W.S. #29	1903					1425	2030	1425	1938	1425	1380	1425	1117
"	"	"	1904							1425	2698	1425	2142	1425	1506
"	"	" #110	1905					1425	1703	1425	1478	1425	1631	1425	1379
"	"	" #206	1906	1420	1270	1420	1850	1420	1350	1420	2780	1420	1610	1420	1570
"	"	" #244	1907	1420	2090					1420	2550	1420	2280	1420	2450
"	"	"	1908	1420	1180					1420	2440	1420	1950	1420	1660
				4260	4540	1420	1850	4270	5083	8533	13384	8533	10993	8533	9857
					1.06		1.30		1.19		1.57		1.29		1.13

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Au Sable	Bamfield	U.S.G.S. W.S. #29	1902					1425	1008	1425	1067	1425	1352	1425	1299
"	"	"	1903	1425	1124	1425	1465	1425	1436	1425	1228	1425	1107		
"	"	"	1904	1425	1290	1425	1212	1425	1108	1425	1175	1425	1094		
"	"	" #110	1905	1425	1133	1425	1134	1425	1114	1425	1069	1425	1202	1425	1175
"	"	" #206	1906	1420	1320	1420	1210	1420	1120	1420	1180	1420	1580	1420	2660
"	"	" #244	1907	1420	1370	1420	1140	1420	1210	1420	1260	1420	1280	1420	1170
"	"	"	1908	1420	1300	1420	1150	1420	1060	1420	1170	1420	1130	1420	1260
				8535	7337	8535	7311	9960	8036	9960	8099	9960	8685	7110	7561
					.883		.856		.808		.813		.870		1.06

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Table LIXd

Chicago Sanitary District. Sheet 3

Runoff from Lake Huron Drainage

Lake Huron Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.
Cass	Frankfort	U.S.G.S. W.S. 284	1908	863	193	863	818	863	3910	863	1300	863	1400	863	140
"	"	"	1909	863	193	863	818	1776	7600	863	1300	863	1400	863	140
					2.24		.948		4.40		1.74		1.62		.162
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S.	Area Sq Mi	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.
Cass	Frankfort	U.S.G.S. W.S. 284	1908	863	109	863	819	863	40.1	863	33.4	863	47.2	863	78.8
				863	109	863	819	863	40.1	863	33.4	863	47.2	863	78.8
					.126		.095		.0465		.0387		.0546		.0913
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.	Area Sq Mi.	Discharge C.F.S.
Huron Bay	Alpena	U.S.G.S. W.S. 85	1901	1260	344	1260	306	1260	1237	1260	2987	1260	1236	1260	736
"	"	"	1902	1260	365	1260	699	1260	2117	1260	1089	1260	1111	1260	810
"	"	"	1903	1260	478	1260	574	1260	900	1260	1482	1260	792	1260	331
"	"	"	1904	1260	497	1260	431	1260	1268	1260	1391	1260	2254	1260	474
"	"	"	1905	1260	936	1260	919	1260	1323	1260	1911	1260	1262	1260	905
"	"	"	1906	1260	936	1260	919	1260	1323	1260	3297	1260	1551	1260	723

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Table 1

Chicago Sanitary District.

Runoff from Lake Huron Drainage

Lake Huron Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Thunder Bay.	Alpena	U.S.G.S. W.S. "214	1907	1260	1321	1260	833	1260	1840	1260	1629	1260	1686	1260	1136
			1908	1260	564	1260	699	1260	1310	1260	3275	1260	2053	1260	961
				8820	4395'	8820	4541'	8820	9887.	10080	20018	10080	11945	10080	7296
					.555'		.515'		1.12		1.99		1.19'		.725

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Thunder Bay.	Alpena	U.S.G.S. W.S. "83	1901	1260	673	1260	611	1260	684	1260	788	1260	700	1260	536
"	"	"	1902	1260	699	1260	689	1260	183	1260	559	1260	925	1260	483
"	"	"	1903	1260	616	1260	1038	1260	1002	1260	868	1260	546	1260	480
"	"	"	1904	1260	461	1260	461	1260	428	1260	476	1260	444	1260	441
"	"	"	1905	1260	492	1260	479	1260	371	1260	440	1260	633	1260	559
"	"	"	1906	1260	812	1260	409	1260	247	1260	631	1260	1125	1260	982
"	"	"	1907	1260	523	1260	451	1260	466	1260	442	1260	633	1260	669
"	"	"	1908	1260	727	1260	222	1260	183	1260	513	1260	661	1260	703
				10080	5003'	10080	4340'	10080	3364'	10080	4717	10080	5667'	10080	4873'
					.497'		.431'		.334'		.468'		.562'		.484'

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Table LIX d
Sheet 5

Chicago Sanitary District.

Runoff from Lake Huron Drainage

Lake Huron Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Thornton Reservoir	Freeland	G.S.W. Report	1904	2461	856	2461	1100	2461	600	2461	3364	2461	2300	2461	1305
"	"	"	1905	2461	740	2461	852	2461	4341	2461	3423	2461	4639	2461	4445
"	"	"	1906	2461	3340	2461	4745	2461	9011	2461	3339	2461	2083	2461	1125
"	"	"	1907	2461	3332	2461	2079	2461	6890	2461	3090	2461	3139	2461	1931
"	"	"	1908	2461	1054	2461	1157	2461	8373	2461	5302	2461	4865	2461	2873
"	"	"	1909.	2461	1788	2461	2317	2461	4700	2461	6724	2461	3019	2461	2149
				14766	10800	14766	12400	14766	39825	14765	33698	14766	22395	14766	11834
					.735		.845		2.46		2.28		1.53		.801
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Thornton Reservoir	Freeland	G.S.W. Report	1903			2461	*843	2461	1518	2461	2236	2461	1183	2461	801
"	"	"	1904	2461	774	2461	690	2461	615	2461	903	2461	667	2461	609
"	"	"	1905	2461	1334	2461	981	2461	1034	2461	1232	2461	1795	2461	1220
"	"	"	1906	2461	732							2461	2429	2461	2040
"	"	"	1907	2461	884	2461	633	2461	803	2461	853	2461	1180	2461	840
"	"	"	1908	2461	832	2461	825	2461	983	2461	703	2461	731	2461	783
"	"	"	1909	2461	873										
				14766	3339	12305	3722	12305	4238	12305	6017	14765	7697	14760	6279
					.361		.302		.371		.489		.520		.420

*10days

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Table LIX
Sheet 1
(7 Sheets)

Chicago Sanitary District

Runoff from Lake Erie Drainage

Summary

Lake Erie Drainage

Drainage	River	Year	January		February		March		April		May		June	
			Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Lake Erie	Black	1905 - 06	834	1134	417	269	1251	2825	1251	1457	1251	7018	1668	10716
"	Cuyahoga	1903 - 03	1396	992	1396	657	1396	4730	1396	2231	1396	4599	1396	1627
"	Huron	1904 - 09	3780	2819	4342	3236	4342	7085	4342	3708	4342	14771	4342	5973
"	Maumee	1898 - 06	20373	21152	21023	18891	21023	32744	21023	23612	21023	123141	21023	13312
"	Sandusky	1894 - 00	1532	2178	1532	1525	1532	3278	1532	1286	1532	715	1532	370
"	Thames	1894-97					1228	789	1228	817	3604	2267	3604	2132
"	Tiffin	1903-05					1496	3017	1496	2672	1496	1782	2744	1866
	Totals		26404	27273	27744	24601	34651	61519	34651	43595	35204	157172	37012	37901
	Other Sq. Mi.				1293	2182		2182		1749		2871		2360
			July		August		September		October		November		December	
Drainage	River	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Lake Erie	Black	1905 - 06	1668	3942	1251	4328	1251	1492	1251	1392	1251	2378	1251	341
"	Cuyahoga	1903-03	1396	992	1396	657	1396	414	2234	1036	2004	1015	695	762
"	Huron	1904-09	4342	2227	3789	831	3785	814.6	3789	1010	3785	1382	3028	1339
"	Maumee	1898-06	21081	7844	20903	2820	20903	7137	20903	1130	24901	4208	20834	16317
"	Sandusky	1894-00	1532	111	1532	287	1532	41	1532	19	770	54	1532	896
"	Thames	1894-97	3604	1369	1228	345			2436	1119				
"	Tiffin	1903-03	2744	431	2744	4348	2744	128.7	2744	3042	2744	5347	1496	871
	Totals		40173	18768	36537	13718	34111	10722	40008	8698	40811	15005	29465	20239
	Other Sq. Mi.			2308		2308		2308		2178		2308		2225

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Chicago Sanitary District

Runoff from Lake Erie Drainage

Table LIXe
Sheet 2

Lake Erie Drainage

River	Location	Authority	Year	January			February			March			April			May			June		
				Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches
Black	Elyria	U.S.G.S.	1903																		
"	"	"	1904	417	608	1.68	417	869	2.39	417	1210	3.32	417	676	1.86	417	227	.62	417	536	1.47
"	"	"	1905							417	799	2.19	417	571	1.57	417	440	1.21	417	300	.82
"	"	"	1906	417	346	.95				417	616	1.69	417	410	1.13	417	409	1.12	417	206	.57
				834	1154		417	869	12.51	1251	3325	12.51	1251	1457	12.51	1251	1076	12.51	1251	1042	12.51
					1.38			2.08			2.10			1.16			.86			.83
				July			August			September			October			November			December	
River	Location	Authority	Year	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches	Area Sq.Mi.	Discharge C.F.S.	Depth in Inches
Black	Elyria	U.S.G.S.	1903	417	94	.26	417	272	.75	417	82	.23	417	95	.26	417	48	.13	417	174	.48
"	"	"	1904	417	255	.71	417	68.8	.19	417	11	.03	417	12.1	.03	417	75.1	.21	417	45	.12
"	"	"	1905	417	16.5	.05	417	112	.31	417	36.2	.10	417	32.1	.09	417	94.7	.26	417	319	.88
"	"	"	1906	417	28.7	.08															
				1668	394.2	12.51	1251	452.5	12.51	1668	129.2	12.51	1251	139.2	12.51	1251	237.8	12.51	1251	541	12.51
					.236			.362			.119			.111			.190			.432	

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Table LIXe
Sheet 3

Chicago Sanitary District

Runoff from Lake Erie Drainage

Lake Erie Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.
Grand Kalamazoo	Kalamazoo Mich	U.S.G.S. W.S.P.P. 170	1903. 1904 1905					698	2342	698	641	698	959	698	1094
								698	2408	698	596	698	740	698	533
								1396	4750	1396	1237	1396	1439	1396	817
									340		150		122		117
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.
Grand Kalamazoo	Kalamazoo Mich	U.S.G.S. W.S.P.P. 170	1903 1904 1905	698	546	698	285	698	927	698	472	698	337		
				698	416	698	329	698	467	698	104	698	109		
				1396	992	1396	657	1396	1414	2094	1036	2094	1018	698	782
					711		492		101		495		486		109
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.	Area Sq.Mi.	Disch. Cu.Ft.S.
Huron	Geddes	U.S.G.S. W.S.P.P. 170	1904 1905 1906 1907 1908	757	525	757	2381	757	1684	757	458	757	394
				757	204	757	170	757	750	757	646	757	606	757	1106
				757	696	757	426	757	515	757	620	757	454	757	322
				757	980	757	386	757	720	757	859	757	604	757	410
				757	479	757	965	757	2065	757	877	757	627	757	246

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Table LIX a
Sheet 4

Chicago Sanitary District
Runoff from Lake Erie Drainage

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.
Huron	Chicago	U.S.E.D. H.S. 1924	1909	757	302	757	524	757	663	757	494	757	1130	757	485
				3785	2845	4542	3296	4542	7095	4542	5202	4542	4277	4542	2923
					751.		.726		1.56		1.145		.941		.644
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.
Huron	Chicago	U.S.E.D. H.S. 1924	1904	757	169	757	180	757	250	757	290	757	239		
			1905	757	399										
			1906	757	145	757	156	757	836	757	139	757	272	757	447
			1907	757	240	757	138	757	221	757	316	757	362	757	452
			1908	757	96	757	269	757	143	757	141	757	153	757	237
			1909	757	175	757	114	757	114	757	124	757	356	757	409
				4542	1227	3785	857	3785	811.6	3785	1010	3785	1382	3028	1539
					.270		.226		.214		.267		.365		.507
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.	Area Sq.Mi.	Disch. Sec.Ft. C.F.S.
Missis-sippi	Mississ. Hdw.	U.S.E.D. Rep. 1911	1898	6111	10979	6111	6301	6111	9989	6111	6028	6111	9950	6111	1057
			1899	6111	5054	6111	7946	6111	5810	6111	11439	6111	9355	6111	3449
			1900	6111	2309	6111	5716	6111	1207	6111	3646	6111	9147	6111	3599
			1901												

Williams Ex. 34 Chicago Sanitary District Table LIXE Sheet 5

Runoff from Lake Erie Drainage

Lake Erie Drainage

River	Location	Authority	Year	January Area Sq Mi.	January Discharge C.F.S.	February Area Sq Mi.	February Discharge C.F.S.	March Area Sq Mi.	March Discharge C.F.S.	April Area Sq Mi.	April Discharge C.F.S.	May Area Sq Mi.	May Discharge C.F.S.	June Area Sq Mi.	June Discharge C.F.S.
Maumee	Sherwood	U.S.G.S. W.S. #129	1903											2190	1313
"	"	"	1904					2190	10400	2190	6645	2190	1130	2190	860
"	"	" #170	1905					2190	3796	2190	2471	2190	4582	2190	2709
"	"	" #206	1906	2190	2130	2190	1030	2190	2400	2190	2980	2190	527	2190	930
				20523	21152	20529	18971	24903	52844	24903	29977	24903	12314	27095	13912
					1.03		.926		2.12		1.20		.495		.514

River	Location	Authority	Year	July Area Sq Mi.	July Discharge C.F.S.	August Area Sq Mi.	August Discharge C.F.S.	September Area Sq Mi.	September Discharge C.F.S.	October Area Sq Mi.	October Discharge C.F.S.	November Area Sq Mi.	November Discharge C.F.S.	December Area Sq Mi.	December Discharge C.F.S.
Maumee	Waterville	U.S.G.S. Rep. 22	1898											6111	8205
"	"	"	1899	6111	285	6111	1362	6111	259	6111	48	6111	521	6111	2323
"	"	"	1900	6111	2094	6111	563	6111	27	6111	41	6111	2619	6111	1509
"	"	U.S.G.S. W.S. #125	1901	6111	2503	6111	47	6111	42	6111	246	6111	98	6111	2585
"	Sherwood	" #129	1903	2190	287	2190	255	2190	689	2190	287	2190	261		
"	"	"	1904	2190	1354	2190	313	2190	232	2190	229	2190	113		
"	"	" #170	1905	2190	534	2190	280	2190	508	2190	307	2190	596	2190	1727
"	"	" #206	1906	2190	787										
				27083	7844	24903	2820	24903	1757	24903	1158	24903	4208	26634	16947
					.289		.113		.0705		.0465		.169		.614

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Chicago Sanitary District

Runoff from Lake Erie Drainage

Table LIXe
Sheet 6

Lake Erie Drainage

River	Location	Authority	Year	January				February				March				April				May				June			
				Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.
Senaca	Mexico	U.S.G.S.	1898	776	1516	776	636	776	1871	776	600	776	657	776	776												
Riv.	"	Rec. 22	1899	776	656	776	889	776	1407	776	686	776	88	776	776												
	"	"	1900	776	2172	776	1525	776	3279	776	1286	776	715	776	1552												
				1552		1552		1552		1552		1552		1552													
					1.40		.904		2.11		.827		.461		.458												
				July		August		September		October		November		December													
River	Location	Authority	Year	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.
Senaca	Mexico	U.S.G.S.	1898	776	32	776	44	776	3	776	9	776	24	776	727												
Riv.	"	Rec. 22	1899	776	32	776	44	776	3	776	9	776	24	776	171												
	"	"	1900	776	79	776	743	776	38	776	70	776	24	776	1552												
				1552	111	1552	287	1552	41	1552	79	1552	776	1552	898												
					.0715		.185		.026		.0508		.0155		.578												
				January		February		March		April		May		June													
River	Location	Authority	Year	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.
Thames	London	U.S.G.S.	1894					1225	709					1225	626	1225	730										
	"	Rec. 22	1895											1225	422	1225	531										
	"	"	1896									1225	817	1225	1119	1225	871										
	"	"	1897					1225	709	1225	817	1225	2267	1225	3484	1225	2132										
									.642		.666		.846		.534												

Williams Ex. 34 — Chicago Sanitary District — Table L1 Sheet

Runoff from Lake Erie Drainage

Lake Erie Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.
Thames	London	U.S.G.S. W.S.P.#4	1895	1228	486					1228	453				
"	"	"	1896	1228	418	1228	545			1228	662				
"	"	"	1897	1228	486										
				3684	1390	1228	545			2456	1115				
					377		444				454				

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.
Tiffin	Defiance	U.S.G.S. W.S.#27	1903											748	740
"	"	" #129	1904					748	3730	748	1865	748	328	748	209
"	"	" #170	1905					748	1287	748	807	748	1494	748	917
								1496	5017	1496	2672	1496	1782	2244	1866
									3.36		1.79		1.19		.831

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.	Area Sq.M.	Disch. in cfs C.F.S.
Tiffin	Defiance	U.S.G.S. W.S.#27	1903	748	311	748	238	748	607	748	159	748	141	748	464
"	"	" #129	1904	748	270	748	109	748	491	748	69.6	748	367		
"	"	" #170	1905	748	250	748	378	748	62	748	76.6	748	197	748	407
				2244	831	2244	454.8	2244	78.7	2244	304.2	2244	974.7	1496	871

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Table LIX f
Sheet 1
(11 Sheets)

Chicago Sanitary District
Runoff from Lake Ontario Drainage

Summary
Lake Ontario Drainage

Drainage	River	Year	January		February		March		April		May		June	
			Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.
Lake Ontario	Black	1897-1909	18809	30669	18809	30669	18809	30669	18809	30669	18809	30669	18809	30669
"	Genesee	1892-1909	23340	34399	23340	34399	23340	34399	23340	34399	23340	34399	23340	34399
"	Moose	(See Black)												
"	Oneida	1903-1909	9336	15317	9336	15317	9336	15317	9336	15317	9336	15317	9336	15317
"	Oswego	1897-1905	24930	38273	24930	38273	24930	38273	24930	38273	24930	38273	24930	38273
"	Salmon	1901-1905	348	2300	259	640	259	640	259	640	259	640	259	640
"	Seneca	1903-1905	8603	22316	8603	22316	8603	22316	8603	22316	8603	22316	8603	22316
		Totals	96052	145208	96123	145355	96143	145355	96143	145355	96143	145355	96143	145355
		c.f.s. per Sq. Mi.		1.480		1.446		2.435		3.161		2.005		1.254
Drainage	River	Year	July		August		September		October		November		December	
			Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.	Area Sq. Mi.	Discharge c.f.s.
Lake Ontario	Black	1897-1909	18744	17476	18744	11673	18744	22306	18744	20693	18744	34709	18744	48119
"	Genesee	1892-1909	23333	8706	23333	10042	23333	23538	23333	7686	23333	26550	23333	47263
"	Moose	(See Black)												
"	Oneida	1903-1909	6810	6854	6810	6452	6810	6810	6810	3088	6810	6810	6810	9657
"	Oswego	1897-1905	24930	16178	24930	29315	24930	39910	24930	45238	24930	39910	24930	38854
"	Salmon	1901-1905	259	2363	259	2407	259	2402	259	2775	259	2402	259	2402
"	Seneca	1903-1905	8603	13027	8603	12277	8603	12603	8603	10684	8603	13777	8603	12403
		Totals	82161	76348	82161	74166	82161	110556	82161	71160	82161	127446	82161	176469
		c.f.s. per Sq. Mi.		0.881		0.795		0.446		0.912		1.116		1.201

Williams Ex. 34. *Table LIX f*
Sheet 2

Chicago Sanitary District

Runoff from Lake Ontario Drainage

Lake Ontario Drainage

*** 3 days

River	Location	Autocl	Nor-	January		February		March		April		May		June	
				Area Sq Mi	Disch. Cu Ft per Sec	Area Sq Mi	Disch. Cu Ft per Sec	Area Sq Mi	Disch. Cu Ft per Sec	Area Sq Mi	Disch. Cu Ft per Sec	Area Sq Mi	Disch. Cu Ft per Sec	Area Sq Mi	Disch. Cu Ft per Sec
Black	Hammond Whiting	N.S.Y.D.	1917			609	2160	609	6317	609	9494	609	9494	609	273
"	"	N.S.Y.D.	1918	609	3402	609	3906	609	3901	609	4654	609	4654	609	1018
"	"	N.S.Y.D.	1919	609	1712	609	2336	609	3031	609	13194	609	13194	609	218
"	"	N.S.Y.D.	1920	609	2334	609	4704	609	2670	609	13576	609	3711	609	1632
"	"	N.S.Y.D.	1921	609	2044	609	2401	609	6014	609	4004	609	2387	609	396
(Head Calumet)	Thornton Riverdale	N.S.Y.D.	1922	631	2100	631	4743	631	27100	346	1957	346	912	346	721
"	"	N.S.Y.D.	1923	631	2100	631	4743	631	27100			631	1231	631	2208
"	"	N.S.Y.D.	1924	631	1438	631	3007	631	5944	631	10160	631	4323	631	2277
"	"	N.S.Y.D.	1925	631	2279	631	2024	631	3416	631	10110	631	3161	631	3983
"	"	N.S.Y.D.	1926	630	2010	631	3220	631	5330	630	7110	630	2611	630	2170
"	"	N.S.Y.D.	1927							630	6270	630	2430	630	2130
"	"	N.S.Y.D.	1928					630	6280	630	6280	630	6280	630	2268
"	"	N.S.Y.D.	1929	630	3480	630	3300	630	3480	630	6300	630	1980	630	2268
				6309	30668	6309	47677	5758	110196	6309	113360	6309	62744	6309	21719
					1.38		1.51		3.17		5.44		2.00		1.71

* Diverted to Illinois River Canal at Summit via Sanitary & Ship Canal Nov. 1, 1900

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Table LIXf
Sheet 3

Chicago Sanitary District

Runoff from Lake Ontario Drainage

Lake Ontario Drainage

*1895-3

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
				2274	386	2274	335	2274	384	2274	345	2274	163		1.61
Black	Whitehall	U.S.G.S.	1897	1851	283	1851	220	1851		1851	243	1851	483	1851	1165
"	"	N.S.G.S.	1898	1851	283	1851	175	1851	483	1851	348	1851	398	1851	2110
"	"	N.S.G.S.	1899	1851	415	1851	287	1851	938	1851	1018	1851	438	1851	3501
"	"	N.S.G.S.	1900	1851	736	1851	1134	1851	1418	1851	1478	1851	394	1851	4230
"	"	N.S.G.S.	1901	1851	413	1851	233	1851	548	1851	338	1851	213		
"	Fairhills	N.S.G.S.	1902					1851	783	1851	2418	1851	2488	1851	3088
Mosic (Black)	Newerkirk	N.S.G.S.	1902	346	614	346	486								
"	Fairhills	N.S.G.S.	1903	1851	278	1851	2735	1851	1917	1851	3937	1851	1878	1851	7229
"	"	N.S.G.S.	1904	1851	488	1851	1178	1851	2751	1851	4713	1851	1713	1851	4714
"	"	N.S.G.S.	1905	1851	333	1851	2328	1851	2783	1851	2335	1851	3088	1851	3607
"	"	N.S.G.S.	1906	1850	238	1850	1208	1850	1783	1850	2280	1850	2780	1850	2110
"	"	N.S.G.S.	1907	1850	328	1850	785	1850	1848	1850	3488	1850	1780	1850	3570
"	"	N.S.G.S.	1908	1850	483	1850	1088	1850	748	1850	1100	1850	478	1850	1470
"	"	N.S.G.S.	1909	1850	1168	1850	1030	1850	1783	1850	1810	1850	730	1850	1110

*Directed to Black River Canal at Mooresville August Canal Rec. 1896, p. 466.

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Chicago Sanitary District

Runoff from Lake Ontario Drainage

Table LIX
Sheet 2

Lake Ontario Drainage

* See note bottom Sheet 5

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Genesee	Mt. Morris	Drainage Basin used 1883 Dunlap Waterways	1892	1070	724	1070	1624	1070	1808	1070	2119	1070	1624	1070	1352
"	" "		1893	1070	1810	1070	1325	1070	2144	1070	2387	1070	2413	1070	336
"	Rochester	N.3°24 Correction	1894	2363	2841	2363	2384	2363	6008	2363	3616	2363	6308 75	2363	2800 75
"	"	N.3°24 Correction	1895	2363	1200	2363	700	2363	4033	2363	3083	2363	900 75	2363	533 75
"	"	N.3°24 Correction	1896	2363	1400	2363	2702	2363	3725	2363	7623	2363	1300 75	2363	1000 75
"	Mt. Morris	Drainage Basin used 1883	1898	1070	1810	1070	1900	1070	2552	1070	1582	1070	1160	1070	767
"	Rochester	" F803 Correction	1899	2363	3660	2363	1650	2363	3400	2363	3080	2363	1200 75		
"	Mt. Morris	N.3°10	1903											1070	626
"	Rochester	N.3°206 Correction	1904					2360	18900	2360	7460	2360	3160 75	2360	2230 75
"	Mt. Morris	N.3°10	1904	1070	2764	1070	4983								
"	Rochester	N.3°206 Correction	1905	2360	2800					2360	4150	2360	1460 75	2360	1670 75
"	"	N.3°206 Correction	1906	2360	3250	2360	1320	2360	7680	2360	5110	2360	2130 75	2360	1300 75
"	"	N.3°244 Correction	1907	2360	6330	2360	1500	2360	5400	2360	4210	2360	2810 75	2360	1830 75
"	"	N.3°241 Correction	1908	2360	3790	2360	5940	2360	9080	2360	4000	2360	6020 75	2360	2420 75
"	"	N.3°184 Correction	1909	2360	2700	2360	6000	2360	4200	2360	4350	2360	3850 75	2360	1280 75
				25510	34599	23160	32228	24470	57967	26650	54810	26630	37141	25335	19841
					1.3557		1.3918		2.363		2.044		1.394		.777

Chicago Sanitary District

Runoff from Lake Ontario Drainage

Lake Ontario Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Genesee	Mt. Morris	Drainage Water Supply Paper 183	1892	1070	1912	1070	1327	1070	230	1070	306	1070	547	1070	1346
"	"	"	1893	1070	228	1070	325	1070	316	1070	373	1070	518		
"	Rochester	W.S. Paper 184	1893											2365	3914
"	"	W.S. Paper 184 Correction	1894	2365	792 / 73	2365	732 / 73	2365	1300 / 73	2365	920 / 73	2365	1600 / 73	2365	1100
"	"	W.S. Paper 184 Correction	1895	2365	390 / 73	2365	400 / 73	2365	250 / 73	2365	220 / 73	2365	300 / 73	2365	1700
"	"	W.S. Paper 184 Correction	1896	2365	645 / 73	2365	440 / 73	2365	240 / 73	2365	2000 / 73	2365	745 / 73		
"	Mt. Morris	Drainage Water Supply Paper 183	1897											1070	882
"	Rochester	Drainage Water Supply Paper 184 Correction	1898					2365	642 / 73	2365	1180 / 73	2365	2235 / 73	2365	2400
"	Mt. Morris	Drainage Water Supply Paper 183	1898	1070	418	1070	742								
"	"	W.S. Paper 170	1903	1070	470	1070	1208	1070	757	1070	982	1070	1061	1070	1006
"	Rochester	W.S. Paper 206 Correction	1904	2360	1310 / 73	2360	634 / 73	2360	323 / 73	2365	986 / 73	2365	362 / 73	2365	1370
"	"	W.S. Paper 206 Correction	1905	2360	1340 / 73	2360	1230 / 73	2360	680 / 73	2360	583 / 73	2360	1400 / 73	2360	2690
"	"	W.S. Paper 206 Correction	1906	2360	783 / 73	2360	878 / 73	2360	484 / 73	2360	2280 / 73	2360	3650 / 73	2360	4070
"	"	W.S. Paper 244 Correction	1907	2360	1470 / 73	2360	323 / 73	2360	362 / 73	2360	1070 / 73	2360	1340 / 73	2360	4930
"	"	W.S. Paper 244 Correction	1908	2360	1780 / 73	2360	733 / 73	2360	280 / 73	2360	260 / 73	2360	350 / 73	2360	380

* Diverted to Erie Canal at Rochester 122 cfs. Rep. N.Y.S.E. 1890 p. 419
less seepage 47 cfs. Barge Canal Rep. 1901, p. 930. Net correction 73 c.f.s.

Williams Ex. 34

Table LIII
Sheet 2

Chicago Sanitary District.

Runoff from Lake Ontario Drainage

Lake Ontario Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Genesee	Rochester	U.S.G.S. W.S. 221 Correction	1909	2360	487 73	2360	325 73	2360	293 73	2360	377 73	2360	439 73	2360	493
				25933	42700	25933	40012	26600	7686	26830	12243	26830	13931	26830	26481
					.497		.393		.268		.457		.329		.389
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Oneida	Euclid	U.S.G.S. W.S. 97 Correction	1903	1400	4186	1400	6179	1400	10619	1400	9143	1400	2035 221	1400	1833 221
"	"	W.S. 189	1904	1313	2162	1313	3403	1313	5934						
"	"	W.S. 170	1905	1313	2499	1313	1592	1313	2977						
"	"	W.S. 236 Correction	1906	1310	4240	1310	3170	1310	3200	1310	5970	1310	3330 221	1310	2390 221
"	"	W.S. 211 Correction	1907	1400	5980	1400	2510	1400	2940	1400	4020	1400	4360 221	1400	1470 221
"	"	W.S. 241 Correction	1908	1400	4130	1400	4620	1400	5610	1400	6630	1400	5310 221	1400	2680 221
"	"	W.S. 281 Correction	1909	1400	2090	1400	3840	1400	6090	1400	7360	1400	6330 221	1400	3660 221
				9336	25247	9336	25644	9336	37370	6910	33143	6910	23310	6910	13108
					2.65		2.70		3.92		4.79		3.37		1.90

* Diversions to Oswego Canal 333 c.f.s. Rep. N.Y.S.E. 1893, p. 120 less seepage 112 c.f.s. Barge Canal Rept. 1901, p. 930. Net correction 221 c.f.s.

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Chicago Sanitary District. Table LIX f Sheet 7

Runoff from Lake Ontario Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.
Oswego	Euclid	B.S.D.S. N.S.S.S. Diversion	1903	1400	827 221	1400	1412 221	1400	1230 221	1400	2930 221	1400	2712 221	1400	2207
"	"	N.S.S.S. Diversion	1906	1310	1780 221	1310	1080 221	1310	744 221	1310	962 221	1310	1080 221	1310	2370
"	"	N.S.S.S.	1904											1313	1344
"	"	N.S.S.S. Diversion	1907	1400	1580 221	1400	930 221	1400	914 221	1400	973 221	1400	2190 221	1400	2360
"	"	N.S.S.S. Diversion	1908	1400	1720 221	1400	1288 221	1400	728 221	1400	837 221	1400	1230 221	1400	1030
"	"	N.S.S.S. Diversion	1909	1400	1820 221	1400	672 221	1400	667 221	1400	922 221	1400	1140 221	1400	1210
				2910	8834	2910	6902	2910	5088	2910	7215	2910	9657	2723	10351
					1.25		.931		.737		1.09		1.10		1.26
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.	Area Sq. mi.	Discharge c.f.s.
Chicago	High Dam	U.S.E.D. N.S.S.S. Diversion	1897							3000	1006	3000	1586	3000	3201
"	"	N.S.S.S. Diversion	1898	3000	1896	3000	1238	3000	3818	3000	2578	3000	1963	3000	1311
"	"	N.S.S.S. Diversion	1899	3000	1232	3000	1473	3000	1874	3000	1694	3000	1734	3000	1985
"	"	N.S.S.S. Diversion	1900	3000	3077	3000	1835	3000	1991	3000	1825	3000	1845	3000	3132
"	"	N.S.S.S. Diversion	1901	3000	3376	3000	1874	3000	2710	3000	1857	3000	1938	3000	2632

Williams Ex. 34.

Table LIX(1)

Chicago Sanitary District Sheet 6

Runoff from Lake Ontario Drainage

Lake Ontario Drainage

River	Location	Authority	Year	January Area Sq.Mi.	January Discharge C.F.S.	February Area Sq.Mi.	February Discharge C.F.S.	March Area Sq.Mi.	March Discharge C.F.S.	April Area Sq.Mi.	April Discharge C.F.S.	May Area Sq.Mi.	May Discharge C.F.S.	June Area Sq.Mi.	June Discharge C.F.S.
Oswego	Minetto	U.S.G.S. W.S. 82 Correction	1902	4990	8722	4990	6238	4990	18340	4990	12345	4990	5567 983	4990	6216 983
"	Battle Island	W.S. 129 Correction	1904							4990	19330	4990	13320 983	4990	7497 983
"	" "	W.S. 170 Correction	1905							4990	16370	4990	7978 983	4990	6748 983
				24990	26273	24990	21478	24990	45573	39970	104331	39970	73461	39970	49743
					1.05		.860		1.82		2.61		1.84		1.24

River	Location	Authority	Year	July Area Sq.Mi.	July Discharge C.F.S.	August Area Sq.Mi.	August Discharge C.F.S.	September Area Sq.Mi.	September Discharge C.F.S.	October Area Sq.Mi.	October Discharge C.F.S.	November Area Sq.Mi.	November Discharge C.F.S.	December Area Sq.Mi.	December Discharge C.F.S.
Oswego	High Dam	U.S.G.S. W.S. 49 Correction	1897	3000	2174 983	3000	2370 983	3000	1248 983	3000	1076 983	3000	1821 983	3000	4168
"	" "	W.S. 65 Correction	1898	3000	1834 983	3000	925 983	3000	1377 983	3000	2018 983	3000	4152 983	3000	3899
"	" "	W.S. 65 Correction	1899	3000	748 983	3000	612 983	3000	615 983	3000	585 983	3000	1095 983	3000	1612
"	" "	W.S. 65 Correction	1900	3000	966 983	3000	669 983	3000	670 983	3000	853 983	3000	2418 983	3000	9077
"	" "	W.S. 65 Correction	1901	3000	3740 983	3000	1978 983	3000	1871 983	3000	2130 983	3000	2901 983	3000	6806
"	Minetto	W.S. 82 Correction	1902	4990	8338 983	4990	6998 983	4990	3057 983	4990	4618 983	4990	5797 983	4990	3116

Williams Ex 34.

Table LIXf
Sheet 9

Chicago Sanitary District.

Runoff from Lake Ontario Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Chicago	Drainage Canal	U.S.E.& W.S. Commission	1904	4990	4418	4990	3231	4990	3223	4990	4904	4990	4719		
"	"	U.S.E.& W.S. Commission	1905	4990	7777	4990	4668	4990	5145	4990	4731	4990	6130	4990	8387
				5970	46575	5970	27315	5970	25233	5970	28859	5970	37777	5970	39040
					925		734		630		.720		.944		1.113
				January		February		March		April		May		June	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Salmon	Pulaski	U.S.E.& W.S. W.S.#3	1901							264	2894	264	859	264	1065
"	"	W.S.#7	1903							264	1381	264	232	264	382
"	"	W.S.#9	1904							264	3173	264	2143	264	411
"	"	W.S.#10	1905							264	2927	264	935	264	1043
"	"	W.S.#26	1906	239	1340	239	640	259	880	239	2330	239	943	239	570
"	"	W.S.#44	1907	239	1160					259	1040	239	894	239	836
				318	2500	239	610	259	880	1374	13978	1374	5974	1374	3907
					482		247		3.40		8.88		3.81		2.45
				July		August		September		October		November		December	
River	Location	Authority	Year	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Salmon	Pulaski	U.S.E.& W.S. W.S.#3	1900					264	219	264	343	264	1267	264	641
"	"	W.S.#5	1901	264	281	264	460	264	287	264	943	264	748	264	930

Williams Dr. Jr. Chicago Sanitary District Table LIX Sheet 10

Runoff from Lake Ontario Drainage

Lake Ontario Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.
Salmon	Fulaski	U.S.G.S. W.S.°82	1902	264	394	264	611	264	373	264	615	264	796	264	934
"	"	W.S.°97	1903	264	367	264	570	264	214	264	1120	264	486		
"	"	W.S.°129	1904	264	443	264	430	264	581	264	874	264	317		
"	"	W.S.°170	1905	264	488	264	411	264	374	264	972	264	1048	264	1131
"	"	W.S.°206	1906	259	390	259	125	259	104	259	519	259	606	264	334
"	"	W.S.°244	1908					259	121	259	153	259	507		
				1579	2563	1579	2407	2102	2775	2102	5339	2102	5805	1320	4190
					1.62		1.52		1.32		2.64		2.76		3.18

River	Location	Authority	Year	January		February		March		April		May		June	
				Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.	Area Sq.Mi.	Discharge C.F.S.
Seneca	Baldwinsville	U.S.G.S. W.S.°97 Correction	1903	3103	3427	3103	5311	3103	7546	3103	8051	3103	4194 762	3103	2799 762
"	"	W.S.°129	1904	3103	2594	3103	4490	3103	6986						
"	"	W.S.°170	1905	3103	3467	3103	2793	3103	4165						
"	"	W.S.°206 Correction	1906	3100	3680	3100	2790	3100	3420	3100	5680	3100	3840 762	3100	3490 762
"	"	W.S.°244 Correction	1907	3100	5580	3100	3460	3100	4370	3100	4560	3100	4610 762	3100	3270 762
"	"	W.S.°291 Correction	1908	3100	4170	3100	3970	3100	5950	3100	5140	3100	5470 762	3100	3590 762
				18609	22918	18609	22814	18609	32437	12403	23431	12403	21162	12403	16157
					1.23		1.225		1.74		1.89		1.705		1.303

*Diversion to Oswego Canal 300 c/s Rept. NYS E. 1893, p 120. 1893 seepage from Erie Canal
Lake Ontario Canal Rept. 1901, p 950 Net correction 762 c/s

Williams Ex. 34. Chicago Sanitary District Table LIXf

Runoff from Lake Ontario Drainage Sheet 11

Lake Ontario Drainage

River	Location	Authority	Year	July		August		September		October		November		December	
				Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.	Area Sq. Mi.	Discharge C.F.S.
Seneca	Baldwinsville	U.S.G.S. N.Y. '97 Correction	1903	3103	2094 / 162	3103	1819 / 162	3103	2976 / 162	3103	4108 / 162	3103	4277 / 162	3103	2837
"	"	N.Y. '09	1904											3103	2411
"	"	N.Y. 1906 Correction	1906	3100	3000 / 162	3100	2210 / 162	3100	1930 / 162	3100	2770 / 162	3100	3870 / 162	3100	3960
"	"	N.Y. 1914 Correction	1907	3100	2410 / 162	3100	1530 / 162	3100	1470 / 162	3100	2240 / 162	3100	3340 / 162	3100	3800
"	"	N.Y. 1914 Correction	1908	3100	2480 / 162	3100	1670 / 162	3100	1780 / 162	3100	1860 / 162	3100	1930 / 162	3100	1590
				12403	13022	12403	10277	12403	10684	12403	13777	12403	16115	13506	14678
					1.05		.828		.860		1.11		1.30		946

Williams Ex 34 Toble LX
Sheet 1

Chicago Sanitary District
Summary Rainfall

Month	Year	Inches of Rainfall		
		Huron-Michigan	Erie	Ontai
January	1900	1.32	2.35	3.6
	01	1.73	2.10	2.4
	02	0.90	1.89	2.3
	03	1.93	2.41	3.2
	04	1.75	4.39	2.7
	Mean	1.55	2.64	2.9
February	1900	3.48	5.04	4.3
	01	1.46	2.06	1.3
	02	1.40	1.42	1.5
	03	2.26	3.43	2.8
	04	2.14	3.24	2.3
	Mean	2.15	3.04	2.8
March	1900	1.62	3.19	3.7
	01	3.01	2.84	3.7
	02	2.87	2.30	2.6
	03	2.02	2.68	3.4
	04	3.10	4.13	3.1
	Mean	2.32	3.03	3.3
April	1900	1.37	1.76	1.3
	01	1.30	2.30	2.0
	02	1.34	1.71	2.0
	03	2.41	4.08	3.1
	04	2.10	2.78	3.1
	Mean	1.82	2.53	2.8
May	1900	2.41	1.63	1.6
	01	3.57	3.99	3.3
	02	3.90	3.23	2.5
	03	3.43	1.84	0.7
	04	3.07	3.18	3.4
	Mean	2.98	2.46	2.3
June	1900	2.00	2.30	1.9
	01	1.80	2.17	3.3
	02	4.91	3.60	4.2
	03	3.64	3.87	4.1
	04	2.23	1.81	3.5
	Mean	2.68	3.11	3.5

Williams Ex. 34. Table LX a
Sheet 2

Chicago Sanitary District
Summary Rainfall

Month	Year	Inches of Rainfall		
		Huron-Michigan	Erie	Ontario
July	1900	4.29	4.38	2.91
	01	3.78	3.82	3.33
	02	3.98	3.93	3.63
	03	3.97	3.69	3.81
	04	2.72	3.50	4.47
	Mean	4.01	4.58	3.83
August	1900	3.98	2.30	1.84
	01	2.79	3.07	3.89
	02	1.70	1.43	2.09
	03	4.03	3.52	3.49
	04	2.93	3.43	3.43
	Mean	2.98	3.12	2.90
September	1900	2.80	2.20	2.61
	01	2.32	3.31	3.23
	02	3.38	4.32	3.33
	03	3.03	1.72	1.76
	04	3.02	2.69	4.38
	Mean	3.11	2.80	2.76
October	1900	2.32	2.01	2.90
	01	2.98	0.33	2.09
	02	2.34	2.37	2.84
	03	2.17	2.41	3.53
	04	2.19	1.88	2.92
	Mean	2.42	1.92	2.96
November	1900	3.79	3.88	3.45
	01	1.33	2.27	3.08
	02	2.33	1.33	1.80
	03	1.71	1.46	1.80
	04	0.47	0.28	0.30
	Mean	1.93	1.87	2.48
December	1900	1.01	0.87	2.31
	01	2.42	4.42	4.01
	02	2.32	3.03	3.20
	03	2.01	2.60	2.63
	04	2.12	2.41	2.94
	Mean	2.10	2.67	3.04
Full Year		30.25	33.77	35.76
Apr.-Nov.		21.93	23.39	23.65
June-Nov.		17.13	17.40	18.48

Williams Ex 34

Table LXb
Sheet 1

Chicago Sanitary District.
Precipitation on
Lakes Huron and Michigan

Stations	1900												
	Jan	Feb.	Mar	Apr	May	June	July	Aug	Sept.	Oct	Nov.	Dec.	Annual
Port Huron	1.26	3.06	2.17	1.30	3.85	2.60	3.86	4.12	1.32	1.14	3.71	0.34	28.73
Harbor Beach	0.60	2.37	2.25	1.63	2.11	2.22	1.60	4.36	0.94	2.13	3.99	0.50	25.34
Port Austin	T	3.13	0.30	1.09	1.19	1.67	1.65	4.17	1.15	3.10	3.65	T	21.32
Harrisville	1.24	4.19	2.03	1.36	2.64	0.53	4.34	5.23	2.25	2.90	3.01	1.37	31.11
Alpena	0.77	2.07	0.76	1.14	1.60	2.41	3.33	2.97	3.23	1.62	2.56	0.37	23.03
Mackinaw	0.88	2.33	0.60	3.15	1.64	4.41	8.96	4.77	12.44	2.28	3.78	1.20	46.46
Manistee	1.22	3.65	1.25	1.50	2.27	1.73	•	•	•	1.50	2.52	1.10	•
Ludington	0.97	3.15	0.63	0.00	2.56	1.55	4.53	2.69	1.85	2.61	3.64	1.50	25.70
Grand Haven	2.71	3.73	2.06	1.59	2.96	1.43	3.73	4.36	2.15	2.35	4.69	0.57	32.33
South Haven	1.38	4.70	2.80	1.76	2.07	1.79	7.24	8.31	1.78	2.33	5.75	0.99	40.00
St. Joseph	1.47	5.24	1.52	1.45	3.50	1.25	4.67	7.73	0.00	2.97	3.86	0.01	34.17
Menominee	0.90	0.00	0.60	0.00	1.72	1.75	6.87	4.13	4.86	5.12	1.31	0.79	27.75
Manitowoc	0.88	1.89	0.98	2.70	1.12	2.43	4.99	3.12	3.27	4.84	2.46	1.06	29.34
Milwaukee	1.63	3.05	1.72	1.74	2.57	1.88	4.93	3.76	3.51	2.22	2.23	0.84	30.10
Chicago	1.21	3.52	1.58	1.07	3.59	2.06	4.64	4.24	1.56	1.35	3.30	0.58	28.65
Goderich (Ont.)	1.10	2.50	2.40	1.20	1.94	3.62	3.00	1.10	1.33	2.03	1.70	0.00	21.92
Snow water	1.85	2.90	1.60	0.10							1.29	1.03	8.35
Wiarton (Ont.)	0.60	2.10	0.24	0.83	2.32	1.20	•	2.99	2.10	2.28	5.15	0.61	•
Snow water	2.40	2.30	1.33	0.10							1.13	2.30	9.80
Collingwood (Ont.)	0.00	0.00	0.00	•	1.96	1.41	2.12	1.92	2.65	2.34	3.38		15.78
Snow water	•	•	•	•							1.85		
Parry Sound (Ont.)	0.38	2.67	0.62	0.89	4.78	2.07	2.81	1.11	4.54	2.85	5.09	0.80	28.11
Snow water	4.62	3.84	1.34	0.12							1.98	2.47	14.77
Sum	27.37	62.73	29.34	24.69	43.89	38.03	72.87	71.68	50.43	47.38	77.03	18.25	
Averages													
The Year	1.52	3.48	1.62	1.37	2.41	2.00	4.29	3.98	2.80	2.52	3.79	1.01	30.79
Apr.-Nov.													23.16
June-Nov													1938

Williams Ex. 34 Table LXb Sheet 2

Chicago Sanitary District
Precipitation on
Lakes Huron and Michigan.

Stations	1901												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Port Huron	1.10	1.38	1.37	1.78	2.93	1.26	2.67	0.34	2.13	1.14	1.19	2.85	20.36
Harbor Beach	0.99	0.62	1.75	1.38	2.18	0.63	2.41	1.35	1.33	2.38	0.89	1.15	17.46
Port Austin	0.65	0.60	1.44	1.68	1.30	0.00	3.10	1.18	0.66	1.82	0.68	0.00	13.61
Harrisville	2.01	0.77	4.44	2.93	3.26	1.62	3.50	4.36	3.19	3.44	0.80	1.31	31.71
Alpena	1.20	0.35	3.23	1.51	2.10	1.11	3.95	2.23	3.36	3.08	0.85	1.64	23.23
Mackinaw	1.37	0.30	0.82	1.41	1.71	3.42	6.63	6.16	3.93	4.36	1.47	1.83	33.91
Manistee	2.78	2.00	4.10	0.41	2.21	1.78	4.67	1.60	3.18	3.40	1.73	4.06	32.17
Ludington	1.46	1.05	2.25	0.10	0.76	0.36	1.97	0.25	1.16	1.93	0.79	1.90	14.98
Grand Haven	1.96	1.30	3.71	0.65	1.62	2.16	3.90	0.17	2.98	2.33	1.75	3.07	26.45
South Haven	1.39	0.80	2.37	0.80	2.82	3.06	1.73	1.40	2.02	4.44	1.16	3.01	23.60
St. Joseph	1.01	2.10	3.24	0.20	1.12	1.30	2.40	2.38	2.86	4.72	1.10	3.96	27.05
Menominee	0.85	0.80	3.45	0.35	3.22	2.26	4.64	3.02	2.17	4.47	1.72	0.30	27.85
Manitowoc	1.27	0.73	2.14	0.16	1.80	2.91	4.22	1.42	2.65	2.66	0.67	1.73	25.91
Milwaukee	1.33	1.97	3.62	0.47	1.75	1.12	2.03	1.50	1.86	0.63	0.73	1.69	18.69
Chicago	1.15	2.05	3.38	0.33	2.18	2.47	4.25	2.00	2.92	1.29	0.85	1.70	24.52
Goderich (rain)	0.73		1.80	1.10	2.70	1.60	2.75	1.40	1.33	1.50	1.20	1.50	17.39
Goderich (snow melted)	2.60	2.40	0.80	0.40						0.25	0.30	1.80	8.75
Kincardine (rain)	0.36		1.02	1.79	4.05	2.16	5.09	3.61	3.47	0.37	1.40	1.84	25.16
Kincardine (snow melted)	3.30	2.25	1.89	0.43						0.10	0.30	2.40	10.65
Collingwood (rain)	*	*	*	3.48	3.14	1.39	3.11	2.40	2.89	1.69	*	*	18.10
Collingwood (snow melted)	*	*	*							0.18	*	*	
Parry Sound (rain)	0.47		1.28	1.74	3.33	3.44	7.90	4.08	3.54	4.66	1.87	2.28	34.99
Parry Sound (snow melted)	3.30	4.24	2.23	0.10							1.94	3.76	15.71
Sum	31.33	26.22	54.21	24.26	45.0	34.83	70.89	47.62	47.85	58.96	24.33	40.62	
Averages													
The Year	1.75	1.46	3.01	1.30	2.37	1.80	3.73	2.24	2.57	2.68	1.35	2.42	26.63
Apr.-Nov.													17.99
June-Nov													14.32

Williams Ex. 34. Table LX b
Sheet 3

Chicago Sanitary District
Precipitation on
Lakes Huron and Michigan.

Stations	1902												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Port Huron	0.52	0.76	2.05	1.25	4.53	3.30	5.29	4.05	6.27	2.57	1.73	1.43	33.77
Harbor Beach	0.87	0.33	4.32	1.35	2.91	4.71	7.34	2.48	3.91	3.00	1.60	1.65	34.69
Port Austin	0.20	0.60	1.00	1.00	3.80	4.32	5.60	0.00	2.79	2.18	1.45	1.18	24.72
Harrisville	1.37	0.93	3.43	1.87	2.81	4.11	6.78	1.79	1.81	3.44	1.94	4.09	34.39
Alpena	0.77	0.56	1.51	2.54	2.98	3.14	5.60	2.33	2.44	2.34	2.80	1.75	29.02
Mackinaw	0.39	0.37	1.29	3.58	2.64	4.36	2.21	2.95	1.71	3.32	5.87	2.14	31.43
Manistee	0.90	1.80	4.31	1.93	3.74	5.93	9.01	0.97	0.00	0.55	0.53	1.75	33.22
Ludington	0.23	1.10	2.11	1.70	3.97	6.68	4.93	0.00	0.00	0.30	0.92	1.25	23.79
Grand Haven	0.33	1.48	3.64	1.39	4.30	3.85	4.85	0.53	3.23	3.17	2.76	2.60	34.81
South Haven	0.61	1.25	4.30	2.13	4.19	3.07	3.90	0.65	6.25	1.87	3.92	2.32	36.46
St. Joseph	0.94	1.77	4.24	3.93	5.51	7.38	4.66	1.59	4.37	3.43	3.75	4.03	45.12
Menominee	0.73	1.00	0.46	2.49	2.62	4.99	4.41	1.41	2.38	1.60	2.03	0.85	24.99
Manitowoc	0.26	2.27	2.05	0.91	3.70	3.81	8.89	1.69	2.60	1.81	2.09	2.43	32.97
Milwaukee	0.31	1.13	1.91	0.87	4.66	4.71	4.82	0.53	4.27	1.45	1.83	1.89	28.27
Chicago	2.66	1.33	4.10	2.26	5.08	6.45	3.78	1.44	4.83	2.14	2.03	1.90	38.76
Goderich (Ont.)	0.20	0.06	1.30	1.10	2.70	2.24	2.60	1.03	4.83	2.92	1.45	0.60	21.51
Snow water	2.00	3.30	0.00	0.70							0.45	1.35	7.30
Wiarton (Ont.)	0.11		3.47	2.26	3.81	3.80	3.52	2.70	4.89	4.47	2.32	1.41	34.97
Snow water	1.80	2.30	0.30	0.20							0.20	2.30	7.30
Collingwood (Ont.)	*	*	*	*	3.13	3.73	4.87	3.76	4.03	4.18	1.61	*	*
Snow water	*	*	*	*							0.60	*	*
Parry Sound (Ont.)	0.04	0.34	4.13	2.03	4.86	4.70	5.07	2.70	3.51	3.61	2.64	1.48	37.16
Snow water	2.09	1.39	0.60	0.07							0.28	3.72	8.01
Sum	10.13	18.33	51.64	34.95	74.18	89.34	108.15	32.39	68.27	48.35	44.61	41.70	
Averages													
The Year	0.90	1.40	2.87	1.94	3.90	4.71	5.38	1.70	3.38	2.54	2.35	2.32	33.39
Apr.-Nov.													26.10
June-Nov.													20.26

Williams Ex. 34.

Table LXb
Sheet 4

Chicago Sanitary District
Precipitation on
Lakes Huron and Michigan.

Stations	1903												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Port Huron	1.36	2.46	1.54	2.19	3.68	2.47	4.89	4.26	3.23	2.16	2.78	1.87	32.91
Harbor Beach	1.44	1.31	1.06	1.75	3.33	2.28	2.81	4.52	3.78	2.58	2.27	1.32	28.87
Port Austin	0.87	1.24	0.00	0.81	3.03	2.47	2.67	2.44	3.30	2.03	1.69	1.13	21.67
Harrisville	2.08	2.88	1.86	2.19	2.95	3.32	3.52	5.47	3.63	2.27	1.66	2.22	36.03
Alpena	1.52	2.63	1.51	2.00	2.39	2.57	3.08	3.68	3.02	2.73	1.36	1.07	31.34
Mackinaw	1.60	0.84	4.26	1.56	2.75	2.51	3.73	7.40	4.70	4.22	1.80	3.57	40.96
Manistee	1.80	1.30	3.00	*	*	*	*	0.08	0.90	0.23	*	3.45	*
Ludington	2.60	2.40	0.00	2.61	0.84	2.36	1.30	0.00	0.27	0.33	0.00	3.16	15.87
Grand Haven	1.66	2.31	1.64	4.52	3.06	2.40	2.05	3.83	3.49	1.04	1.24	1.37	33.16
South Haven	2.37	2.23	2.97	3.80	2.39	1.73	3.28	4.74	2.39	1.26	1.18	4.14	34.70
St. Joseph	2.41	2.10	2.01	3.85	1.43	3.70	4.45	3.50	2.05	0.83	1.10	3.00	32.47
Menominee	0.25	0.00	3.23	1.67	4.07	4.76	1.34	3.92	4.68	1.39	1.42	0.97	27.30
Manitowoc	0.70	1.10	2.18	4.01	2.73	0.92	7.92	4.24	2.39	3.41	1.12	0.44	32.16
Milwaukee	0.60	2.01	3.20	2.68	3.03	1.51	4.53	3.56	3.07	2.13	1.49	1.65	33.41
Chicago	1.09	3.03	1.67	3.77	0.93	1.62	4.78	3.49	4.00	1.09	0.34	2.25	28.09
Goderich (Snow water)	0.90 1.55	2.10 2.90	0.80 0.10	1.40 0.95	1.37	3.60	2.40	4.37	3.72	2.82	1.20 1.35	0.80 4.50	25.48 17.25
Wiarton (Snow water)	0.74 3.95	1.34 2.25	2.03 0.10	0.91 T	2.34	3.08	3.24	3.61	5.07	2.26	1.09 0.92	0.53 3.03	26.85 12.27
Collingwood (Snow water)	0.00 *	0.00 *	0.00 *	0.81 0.05	1.99	3.38	3.30	3.85	6.13	3.36	0.00 4.80	0.00 *	23.42 *
Parry Sound (Snow water)	1.14 2.33	1.66 2.21	2.38 0.85	1.88	2.79	2.57	2.89	3.56	4.35	4.89 0.70	0.91 1.18	T 2.99	28.32 9.24
Sum	33.38	48.7	36.6	41.31	45.9	47.47	70.35	76.52	68.82	41.13	30.2	46.95	
Averages													
The Year	1.83	2.86	2.02	2.41	2.55	2.64	3.91	4.03	3.63	2.17	1.71	2.61	31.79
Apr.-Nov													23.05
June-Nov													18.09

Williams Ex. 34. Table LX6
Sheet 5

Chicago Sanitary District
Precipitation on
Lakes Huron and Michigan

Stations	1904												
	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Port Huron	1.76	1.43	2.62	2.23	1.82	3.12	2.34	3.56	2.72	1.89	0.43	1.33	24.97
Harbor Beach	0.80	1.20	1.05	1.40	2.17	1.26	3.66	1.37	1.90	2.48	0.09	1.27	18.^3
Port Austin	2.25	3.00	2.30	0.90	3.70	*	*	*	*	*	*	*	*
Harrisville	2.13	3.82	2.50	2.54	4.43	3.68	2.61	1.73	1.78	1.57	0.52	2.38	31.71
Alpena	0.97	1.99	2.65	2.64	3.77	3.45	1.04	1.30	1.99	1.63	0.89	1.74	24.68
Mackinaw	0.80	1.35	2.90	2.40	3.63	0.00	2.10	4.30	6.10	3.30	0.45	2.80	35.75
Manistee	1.45	4.70	1.30	*	*	*	2.30	*	*	*	0.40	*	*
Ludington	*	*	*	*	*	1.05	*	*	1.16	2.09	T	*	*
Grand Haven	0.78	0.80	2.18	1.94	4.20	1.24	2.40	2.68	3.29	3.28	T	0.00	22.77
South Haven	2.42	1.43	7.32	1.90	1.05	0.76	3.71	5.18	2.79	2.17	0.22	1.99	30.99
St. Joseph	3.30	1.20	2.40	1.13	*	1.00	*	*	3.90	1.25	0.02	*	*
Menominee	0.35	1.81	2.09	1.63	6.28	1.67	2.43	2.57	4.46	2.15	0.20	0.75	26.18
Manitowoc	0.85	1.89	3.66	2.01	3.21	2.63	2.52	2.22	3.19	3.63	0.09	2.40	30.29
Milwaukee	1.30	1.39	3.46	1.79	2.38	3.65	1.89	3.96	2.64	2.56	0.11	2.67	29.86
Chicago	2.25	1.71	4.57	3.01	1.34	0.33	2.78	4.00	2.63	1.38	0.31	1.21	26.14
Goderich (Imp. Stand. Meter)	0.30 / 2.53	1.00 / 2.10	2.80 / 1.20	2.10 / 0.90	1.70	2.36	2.57	2.10	2.13	1.42 / 0.10	0.80 / 0.83	0.30 / 2.80	19.88 / 11.36
Wiarton (Imp. Stand. Meter)	0.00 / 1.38	0.28 / 2.63	1.64 / 0.63	2.29 / 0.17	2.71	2.67	2.25	1.01	3.13	2.00 / T	0.74 / 0.30	0.63 / 2.38	20.14 / 8.15
Collingwood (Imp. Stand. Meter)	0.00 / *	0.00 / *	0.00 / *	1.34 / *	3.61	3.84	4.88	3.63	3.22	2.74 / *	0.00 / *	0.00 / *	23.46 / *
Parry Sound (Imp. Stand. Meter)	0.00 / 3.30	R / 2.30	1.99 / 1.60	2.17 / 0.93	3.43 / T	3.30	3.82	3.45	4.84	1.34 / T	0.99 / 0.40	1.00 / 2.80	27.27 / 11.36
Sum	22.00	36.79	52.77	33.68	58.61	38.24	43.50	44.28	51.41	37.39	8.01	23.64	
Averages													
The Year	1.73	2.16	3.10	2.10	3.07	2.25	2.72	2.93	3.02	2.19	0.47	2.12	28.98
Apr.-Nov.													19.37
June-Nov.													13.60

Williams Ex. 34 Table LXC
Sheet 1

Chicago Sanitary District
Precipitation on
Lake Erie.

Stations	1900												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Toledo	0.73	4.42	1.57	2.73	2.45	3.41	3.43	2.25	0.82	2.29	2.67	0.78	29.58
Cleveland	2.23	3.61	2.06	1.32	1.26	1.53	4.85	1.79	1.94	1.16	3.01	0.81	25.57
Buffalo	3.82	3.21	3.80	1.13	1.22	1.22	2.97	2.69	3.90	3.39	3.32	1.26	33.93
Brt Down (Snow Meter.)	1.60 1.97	1.33 3.89	0.81 3.96	1.62 0.26	1.21	2.47	3.84	2.30	2.54	1.47	2.90 1.63	0.53 0.46	23.39 12.17
Brt Dunwell (Snow meter)	0.88 0.30	2.81 3.30	0.96 2.80	1.33 0.18	1.99	2.91	4.87	2.27	1.80	1.80	3.68 0.39	0.25 0.23	25.70 7.21
Sum	11.73	23.19	13.30	8.80	8.16	11.49	21.91	11.20	11.00	10.00	19.41	4.34	159.35
Averages													
The Year	2.35	3.04	3.19	1.76	1.63	2.30	4.38	2.30	2.20	2.01	3.85	0.87	31.91
Apr.-Nov.													20.46
June-Nov.													17.07

Stations	1901												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Toledo	1.30	1.13	1.94	2.97	2.85	3.32	2.68	3.91	0.87	1.06	1.25	3.53	26.79
Cleveland	1.18	1.28	2.93	2.10	2.78	3.55	3.77	0.31	7.38	0.80	2.42	4.21	36.71
Buffalo	3.31	3.20	3.03	3.13	3.28	1.39	3.05	2.07	3.29	1.29	2.87	5.52	39.49
Brt Down (Snow meter)	1.20 1.40	0 2.30	2.47 0.35	0.48 1.25	2.94	1.43	2.50	1.54	2.39	0.49	1.33 0.48	2.63 1.81	19.39 8.87
Brt Dunwell (Snow meter)	1.25 1.11	0 1.89	1.90 1.03	1.81 0.70	1.10	1.14	2.72	1.53	7.40	0.97 0.07	2.05 0.70	2.39 1.83	19.17 7.26
Sum.	10.89	10.32	14.72	11.86	12.95	10.83	14.72	12.36	16.53	4.63	11.11	22.17	159.98
Averages.													
The Year	2.18	2.06	2.84	2.36	2.59	2.17	2.94	3.07	3.31	0.93	2.22	4.42	31.09
Apr.-Nov.													19.59
June-Nov.													14.64

Williams Ex. 34. Table LXI. Sheet 2

Chicago Sanitary District
Precipitation on
Lake Erie

Stations	1902												
	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Toledo	0.72	0.62	2.76	0.86	4.72	6.19	4.01	1.79	6.31	1.98	1.40	2.25	33.31
Cleveland	1.25	0.83	2.34	1.85	3.60	9.77	3.14	1.60	5.36	2.41	2.07	3.67	39.89
Buffalo	4.01	2.33	1.81	2.04	1.85	4.20	4.53	1.72	2.73	3.09	1.03	3.57	32.91
Port Dover, Ont.	0.33	0.66	2.02	1.87	2.38	3.42	8.02	1.28	2.34	2.86	1.13	1.52	28.05
Snow meter	1.42	1.08	0.01	0.26							0.62	1.29	4.74
Port Dunnville, Ont.	0.11	0.34	2.30	1.25	3.69	5.41	6.71	1.25	4.60	1.52	1.20	1.44	30.02
Snow meter	1.38	1.23	0.02	0.40							0.20	1.40	4.83
Sum	9.44	7.11	11.57	8.33	16.24	28.99	22.41	7.14	21.74	11.86	7.65	13.14	173.77
Averages													
The Year	1.89	1.42	2.30	1.71	3.25	5.80	3.68	1.43	4.35	2.37	1.53	3.03	34.76
Apr.-Nov.													20.12
June-Nov.													21.10

Stations	1903												
	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Toledo	1.10	3.37	1.87	3.67	1.43	3.87	5.54	6.63	2.71	2.32	1.01	1.74	35.08
Cleveland	1.88	3.87	2.40	3.85	1.46	3.17	3.23	4.13	2.46	3.48	1.91	1.90	33.44
Buffalo	4.23	7.90	3.32	4.48	1.69	3.95	4.07	3.29	0.81	2.13	1.36	3.70	37.93
Port Dover, Ont.	0.81	2.18	3.37	4.27	1.57	3.79	8.62	4.73	0.38	1.31	1.50	1.34	33.97
Snow meter	1.33	1.61	0.82	0.2							0.0	1.31	4.95
Port Dunnville, Ont.	0.32	2.30	2.80	3.99	2.06	3.30	8.37	3.83	0.93	2.37	1.49	1.37	36.34
Snow meter	1.60	1.00	0.10	0.09							0.63	1.50	4.28
Sum	12.07	17.23	13.38	20.36	8.21	18.34	34.25	26.68	7.29	12.03	7.30	13.01	187.30
Averages													
The Year	2.41	3.45	2.68	4.08	1.64	3.67	6.40	5.34	1.46	2.41	1.46	2.60	37.60
Apr.-Nov.													26.46
June-Nov.													20.74

Williams Ex. 34. Table LXc
Sheet 3

Chicago Sanitary District
Precipitation on
Lake Erie

Stations	1904												
	Jan	Feb.	Mar	Apr.	May	June	July	Aug	Sept	Oct.	Nov.	Dec	Annual
Toledo	3.51	2.53	4.35	1.77	2.69	0.51	2.83	3.20	2.94	1.22	0.04	2.33	27.94
Cleveland	4.69	2.95	4.01	2.76	3.70	1.17	4.63	2.29	3.62	1.24	0.41	2.49	34.56
Buffalo	4.78	4.32	3.51	2.79	3.12	2.83	3.87	3.41	2.11	1.93	0.51	2.65	35.83
Port Dover	1.36	1.10	3.56	2.92	3.11	1.89	3.13	4.51	2.52	2.79	0.04	0.84	27.77
Snow water	3.00	1.57	1.04	0.92							0.14	1.53	8.00
Port Burwell	1.18	2.63	2.82	1.79	3.30	1.65	3.00	3.82	2.78	2.23	0.11	1.30	26.00
Snow water	3.33	1.10	0.23	0.90							0.03	1.08	7.31
Sum	21.93	16.20	20.76	13.80	15.92	8.05	17.45	17.23	13.97	9.41	1.28	12.04	167.55
Averages													
The Year	4.39	3.24	4.15	2.76	3.18	1.61	3.50	3.45	2.69	1.88	0.26	2.41	33.52
Apr - Nov													19.33
June - Nov.													13.39

Williams Ex. 34 Table LXd Sheet 1

Chicago Sanitary District
Precipitation on
Lake Ontario

Stations	1900												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kingston rain	1.57	2.19	0.26	1.01	2.35	2.08	2.21	1.23	4.13	2.87	2.62	0.38	23.10
Snow water	1.93	1.63	2.11	0.13							1.08	0.81	7.73
Rochester	4.31	4.44	3.14	1.68	1.31	2.43	3.98	2.03	1.93	3.16	4.45	2.96	38.12
Watertown	4.59	4.01	3.87	0.61	2.37	1.62	2.34	1.10	3.05	3.09	8.70	2.67	38.00
Oswego	4.03	4.19	3.16	1.54	1.24	1.29	3.30	2.10	2.53	3.26	6.53	3.70	37.17
Toronto rain	0.97	2.14	1.67	1.83	0.95	2.43	2.73	2.75	1.42	2.12	3.02	0.61	22.13
Snow water	1.47	3.07	1.83	T	T						0.87	0.22	7.46
Sum	18.39	21.69	18.54	6.85	8.26	9.85	14.56	9.21	13.06	14.50	27.27	11.35	173.73
Averages													
The Year	3.68	4.34	3.71	1.37	1.65	1.97	2.91	1.84	2.61	2.90	5.45	2.31	34.74
Apr-Nov.													20.70
June-Nov.													17.68

Stations	1901												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kingston rain	0.77	0.0	2.83	3.08	3.73	4.14	3.36	3.21	3.11	1.80	1.62	2.97	30.23
Snow water	1.06	1.09	0.84	0.55						T	0.74	0.84	5.12
Rochester	3.83	3.69	3.75	4.26	3.06	2.46	2.87	2.19	3.08	1.41	2.63	4.17	37.20
Watertown	1.85	2.07	4.71	3.78	3.17	3.75	3.73	4.26	3.80	3.23	4.90	3.43	44.70
Oswego	2.73	1.35	3.66	4.35	3.18	4.23	3.08	4.90	3.13	3.43	3.87	6.08	45.09
Toronto rain	0.78	0.00	1.38	3.69	3.47	2.07	3.37	3.87	3.05	0.56	1.33	2.23	25.20
Snow water	1.69	1.44	1.36	0.88							0.32	1.38	7.07
Sum	12.21	9.84	18.53	20.35	16.91	16.45	16.63	18.43	16.17	10.43	15.11	23.45	194.61
Averages													
The Year	2.44	1.97	3.71	4.07	3.38	3.33	3.33	3.69	3.23	2.09	3.08	4.61	38.93
Apr-Nov.													26.11
June-Nov.													18.78

Williams Ex 34. Table LXd Sheet 2

Chicago Sanitary District
Precipitation on
Lake Ontario

Stations	1902												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kingston rain	0.44	0.28	2.47	3.30	1.96	4.17	4.52	2.09	1.34	3.46	1.34	1.22	26.54
Snow water	1.10	0.81	0.12	0.01						T	0.19	1.55	3.90
Rochester	2.5	2.31	1.48	2.48	1.67	4.08	4.43	1.90	1.99	2.22	1.01	3.46	29.73
Watertown	2.41	2.70	3.93	2.81	3.05	5.84	3.48	1.91	2.40	4.00	1.90	2.81	37.24
Oswego	2.49	1.78	3.80	2.21	3.02	4.34	6.48	2.23	2.57	2.24	1.78	4.73	37.87
Toronto rain	0.06	0.92	2.17	2.15	1.89	3.57	4.35	2.38	3.35	2.78	0.98	1.91	26.11
Snow water	2.34	0.58	0.35	0.02						T	0.72	0.71	4.920
Sum	11.60	9.64	14.32	12.98	11.59	22.20	23.26	10.76	11.65	14.70	7.92	15.99	166.31
Averages													
The Year	2.32	1.93	2.86	2.60	2.32	4.44	4.65	2.09	2.33	2.94	1.58	3.20	33.26
Apr. - Nov.													22.93
June - Nov.													18.03

Stations	1903												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kingston rain	0.87	1.05	2.43	3.11	0.32	6.16	4.01	3.8	1.11	3.08	1.10	1.08	28.37
Snow water	1.78	1.45	0.33	0.11						0.14	0.31	1.94	6.06
Rochester	2.54	2.62	3.88	2.81	0.53	3.66	2.55	3.45	1.11	2.93	1.58	1.83	29.44
Watertown	3.01	3.15	3.82	2.70	0.49	4.78	5.52	3.15	1.44	3.94	2.37	2.54	40.91
Oswego	3.49	3.08	4.82	3.25	0.32	5.57	2.61	3.08	2.21	4.88	2.46	3.88	39.65
Toronto rain	0.66	1.50	1.81	3.44	1.79	3.33	4.34	3.65	0.41	2.66	1.00	1.04	25.83
Snow water	2.04	1.30	0.02	0.30	0.01					0.12	0.26	0.33	3.00
Sum	16.39	14.13	17.11	13.77	3.68	23.5	19.03	17.31	6.28	13.75	9.00	13.26	175.06
Averages													
The Year	3.28	2.83	3.47	3.14	0.73	4.70	3.81	3.44	1.26	3.95	1.80	2.65	35.01
Apr. - Nov.													22.83
June - Nov.													18.96

Williams Ex 34. Table LXd
Sheet 3

Chicago Sanitary District
Precipitation on
Lake Ontario

Stations	1904												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Kingston rain	0.08	1.30	2.70	3.90	1.92	3.89	3.31	4.07	4.26	2.43	0.33	0.97	28.41
Snow melter	2.07	1.29	0.60	0.32						0.83	0.46	1.43	6.20
Rochester	3.39	2.65	2.93	3.30	3.86	2.71	4.70	2.56	3.95	2.02	0.33	2.46	34.56
Watertown	2.41	3.27	3.08	2.53	5.17	3.53	3.75	3.16	6.48	3.96	0.82	2.32	40.48
Oswego	3.68	3.11	3.69	2.81	2.98	3.72	3.75	2.92	3.24	3.69	0.45	4.12	39.51
Toronto rain	0.32	1.09	2.32	2.64	3.79	2.77	5.13	4.53	3.99	2.42	0.88	0.74	30.04
Snow melter	1.87	1.91	0.60	0.47						0.06	0.03	0.71	3.63
Sum	13.92	14.63	15.87	15.71	17.72	16.62	22.34	17.26	23.92	14.61	2.50	17.20	184.23
Averages													
The Year	2.78	2.92	3.17	3.13	3.44	3.32	4.47	3.43	4.38	2.92	0.50	2.44	36.94
Apr-Nov.													25.63
June-Nov.													19.04

Williams Ex. 34. Chicago Sanitary District Table LXI a Sheet 1

Summary of Mean Temperatures.

Summary
Mean Temperatures of Air and Water
of the
Great Lakes.

Month	Records	Lake Superior		Lake Michigan				Lake Huron		Lake St. Clair		Lake Erie		Lake Ontario	
				Chicago		Milwaukee				Detroit		Cleveland		Toronto	
		Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
Jan.	Water Works			28.0	32.2	23.2	34.8			26.6		29.3	33.5	24.9	35.2
	U.S. Lake Survey*			31.0	32.8							27.0	32.2		
Feb.	Water Works			26.5	32.1	24.6	33.4			24.7		27.7	32.9	22.2	34.36
	U.S. Lake Survey			27.0	32.5							21.5	32.0		
Mar.	Water Works			41.4	34.6	37.5	35.4			37.2		39.0	34.1	32.8	34.8
	U.S. Lake Survey			34.7	33.8							41.3	36.7		
Apr.	Water Works			46.2	41.1	42.4	39.3			44.6	41.6	46.8	40.2	48.3	38.3
	U.S. Lake Survey	42.9	35.1	45.7	40.6			44.9	40.4	47.8	41.6	46.9	39.2	46.2	40.7
May	Water Works			57.1	48.2	53.1	43.6			56.9	51.8	58.8	51.1	54.4	42.6
	U.S. Lake Survey	45.1	37.5	51.3	45.4			52.3	46.1	58.8	51.2	58.9	50.6	53.6	00.6
Jun.	Water Works			68.4	57.5	65.4	47.9			67.2	65.1	68.3	62.3	65.1	45.8
	U.S. Lake Survey	52.0	41.6	62.8	54.8			65.1	58.7	67.2	62.4	69.5	64.1	64.0	50.5
July	Water Works			74.4	65.1	71.4	50.1			72.5	70.6	74.0	78.0	70.1	45.1
	U.S. Lake Survey	60.2	49.3	69.5	63.1			72.6	67.6	73.4	69.7	74.8	71.9	69.1	64.6
Aug.	Water Works			72.9	68.3	69.7	54.4			70.1	71.1	72.0	71.4	67.7	52.8
	U.S. Lake Survey	65.7	56.7	72.8	67.8			75.5	70.0	74.6	72.6	75.1	72.9	70.9	67.0

*U.S. Lake Survey temperatures are the mean of readings at several stations. See Table LXI c.
Water Works temperatures are the mean from 1907 to 1911.

Williams Ex. 34.

Table LXI e
Sheet 2

Chicago Sanitary District

Summary of Mean Temperatures

Summary
Mean Temperatures of Air and Water
of the
Great Lakes

Month	Records	Lake Superior		Lake Michigan				Lake Huron		Lake St. Clair		Lake Erie		Lake Ontario	
				Chicago		Milwaukee				Detroit		Cleveland		Toronto	
		Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
Sept	Water Works			66.3	69.5	63.0	63.8			64.1	67.0	67.8	67.9	64.2	64.3
	U.S. Lake Survey*	60.3	53.8	66.4	62.1			68.0	66.2	69.6	67.9	69.7	68.8	66.4	65.1
Oct	Water Works			54.6	55.3	50.6	50.5			50.7	53.2	55.1	53.2	48.7	47.4
	U.S. Lake Survey	46.4	48.4	51.7	53.0			53.4	54.1	54.2	54.0	55.5	53.2	54.3	55.8
Nov	Water Works			40.9	42.8	37.3	44.5			38.9	43.3	43.4	47.1	37.8	41.4
	U.S. Lake Survey	35.7	41.3	39.9	43.1			41.4	43.5	42.1	43.8	42.7	43.8	38.5	42.1
Dec	Water Works			29.4	33.9	25.6	37.9			28.1	38.1	33.6	37.6	27.9	37.36
	U.S. Lake Survey	21.6	36.5	29.6	34.8			30.5	37.6	30.8	38.6	31.7	38.7	26.6	38.7

*U.S. Lake Survey temperatures are the mean of readings at several stations.
Water Works temperatures are the mean from 1907 to 1911.

Williams Ex. 34.

Table LX1 b
Sheet 1

Chicago Sanitary District

Temperatures of Air and Water of Lake Michigan at Chicago Water Works Pumping Station

Year	Temperature in Degrees Fahrenheit											
	January		February		March		April		May		June	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	27.8	32.3	26.4	32.0	42.6	34.9	39.8	39.5	51.6	45.6	66.2	53.8
1908	28.6	32.0	26.7	32.0	40.6	34.6	49.0	41.3	58.7	48.5	68.4	57.6
1909	28.8	32.5	32.4	32.2	36.0	33.3	45.1	39.8	55.9	48.2	66.6	56.3
1910	25.7	32.0	24.7	32.0	48.6	35.9	51.2	45.0	53.4	48.0	68.2	57.6
1911	29.2	32.2	32.4	32.5	39.2	34.5	46.1	39.7	66.0	50.6	72.4	62.2
Mean	28.0	32.2	28.5	32.1	41.4	34.6	46.2	41.1	57.1	48.2	68.4	57.5

Year	July		August		September		October		November		December	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	73.3	61.7	71.2	63.7	64.6	61.9	52.6	52.4	41.0	42.2	32.8	34.2
1908	74.3	66.4	73.4	71.8	70.6	65.8	55.2	55.0	43.5	42.1	31.3	33.2
1909	72.3	65.4	74.8	70.6	64.0	64.1	50.6	52.6	48.5	46.4	21.7	34.8
1910	76.0	66.7	73.3	70.2	65.2	64.2	58.4	59.3	36.0	42.3	26.4	32.9
1911	76.0	65.4	71.8	65.0	67.0	66.6	53.3	57.2	35.4	41.0	35.0	34.2
Mean	74.4	65.1	72.9	68.3	66.3	64.8	54.0	55.3	40.9	42.8	29.4	33.9

Williams Ex. 34

Table L X10
Sheet 2

Chicago Sanitary District

Temperatures of Air and Water
of
Lake Michigan at Milwaukee
Water Works Pumping Station

Year	Temperature in Degrees Fahrenheit											
	January		February		March		April		May		June	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	22.4	34.9	23.6	33.2	38.6	34.2	37.2	37.7	48.2	41.6	63.2	45.3
1908	24.5	34.9	23.8	33.3	36.0	35.3	45.2	38.6	54.3	43.1	64.4	46.3
1909	24.4	35.5	27.4	32.4	33.0	35.0	40.5	38.5	52.5	44.2	63.2	48.5
1910	21.1	34.0	19.3	34.0	44.2	36.6	46.9	43.1	50.6	44.7	66.8	48.6
1911	23.8	34.6	28.7	34.0	35.8	35.7	42.4	38.5	59.9	44.5	69.4	51.0
Mean	23.24	34.78	24.36	33.38	37.52	33.36	42.44	39.28	53.10	43.62	65.40	47.94

Year	July		August		September		October		November		December	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	70.1	45.7	67.0	45.4	61.0	48.6	48.8	45.9	37.6	43.1	28.2	38.8
1908	70.8	48.0	70.2	60.3	67.8	48.4	51.6	44.0	39.3	43.9	26.1	38.0
1909	70.2	50.7	71.9	54.4	61.6	55.3	47.6	52.0	44.9	45.9	18.8	37.6
1910	73.5	56.4	70.6	56.1	61.4	57.1	54.8	53.8	32.6	45.2	23.0	32.2
1911	72.6	47.8	68.6	55.6	63.4	59.7	50.3	56.9	37.2	44.4	32.4	38.1
Mean	71.44	50.72	69.66	54.36	63.04	53.82	50.62	50.52	37.52	44.50	25.86	37.94

Williams Ex. 34.

Table LXIb
Sheet 3

Chicago Sanitary District

Temperatures of Air and Water
of
Lake St. Clair at Detroit
Water Works Pumping Station

Year	Temperature in Degrees Fahrenheit											
	January		February		March		April		May		June	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	26.0		21.2		39.2		39.1		51.1		64.8	
1908	25.9		21.8		36.1		43.9		59.2	51.6	68.2	63.9
1909	28.6		29.7		32.9		43.9	39.3	53.7	50.7	67.1	63.5
1910	23.0		22.4		44.0		48.0	44.0	53.8	53.0	66.3	64.0
1911	27.4		28.8		33.6		46.0		64.7		69.4	
Mean	26.38		24.68		37.16		44.38	41.65	56.90	51.77	67.20	63.13

Year	July		August		September		October		November		December	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	71.0	69.5	68.0	69.1	62.8	66.2	47.3	52.4	38.2	42.0	30.5	39.1
1908	72.8	72.3	69.7	72.4	68.6	68.6	53.8	56.2	40.3	43.4	29.8	
1909	71.7	70.0	71.3	71.9	61.4	66.2	47.2	50.9	44.9	44.3	23.0	
1910	73.9		70.6		63.3		54.6		35.7		22.7	
1911	73.6		70.6		64.7		50.8		33.6		33.9	
Mean	72.50	70.60	70.08	71.13	64.06	67.0	50.74	53.17	38.94	43.30	28.08	39.10

Williams Ex 34

Table LXIb
Sheet 2

Chicago Sanitary District

Temperatures of Air and Water of Lake Erie at Cleveland Water Works Pumping Station

Year	Temperature in Degrees Fahrenheit											
	January		February		March		April		May		June	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	23.1	33.8	21.4	32.5	39.5	33.9	40.7	40.3	52.5	48.2	63.5	58.0
1908	26.8	33.8	22.7	33.1	34.8	34.7	44.4	41.3	56.3	49.8	64.6	64.5
1909	34.2	34.4	33.3	33.2	35.5	33.8	47.6	40.2	59.7	50.2	70.2	63.2
1910	26.8	31.9	24.1	31.9	43.3	34.0	49.3	39.4	54.9	51.9	65.5	58.4
1911	33.8	33.7	36.8	34.0	39.8	34.3	51.6	39.8	70.5	53.2	73.5	67.4
Mean	29.3	33.5	27.7	32.9	39.0	34.1	46.8	40.2	58.8	51.1	68.3	62.3

Year	July		August		September		October		November		December	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	71.8	70.4	69.1	70.7	66.0	68.8	50.3	58.3	41.2	46.8	33.1	38.9
1908	67.9	71.2	65.7	71.5	64.2	66.3	52.0	59.0	39.3	47.7	29.9	38.1
1909	76.0	68.9	76.1	72.4	68.9	68.5	56.0	57.6	52.8	49.7	32.5	39.9
1910	74.6	66.2	72.3	70.8	67.3	67.7	58.9	61.9	39.9	48.4	28.3	33.8
1911	73.9	72.2	76.7	71.4	72.8	68.1	58.4	58.0	43.6	46.1	42.3	38.2
Mean	74.0	70.0	72.0	71.4	67.8	67.9	55.1	58.2	43.4	47.1	33.6	37.8

Williams Ex 34. Table LXIb
Sheet 5

Chicago Sanitary District
Temperatures of Air and Water
of
Lake Ontario at Toronto
Water Works Pumping Station

Year	Temperature in Degrees Fahrenheit											
	January		February		March		April		May		June	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	22.1	35.3	18.3	35.1	33.8	34.8	28.4	35.8	48.3	39.1	63.8	41.8
1908	24.4	36.3	19.3	34.4	31.4	34.0	41.8	35.9	56.2	40.7	66.2	41.8
1909	26.4	36.0	26.7	35.0	29.9	34.5	40.9	37.5	53.7	40.6	63.3	44.4
1910	25.5	34.3	21.0	34.2	38.8	37.2	46.9	42.3	52.5	44.2	64.6	47.7
1911	23.9	33.7	23.5	33.1	30.1	33.4	43.3	39.9	61.2	48.5	63.6	53.2
Mean	24.86	33.30	22.20	34.36	32.8	34.78	40.76	38.28	54.38	42.62	64.14	45.78

Year	July		August		September		October		November		December	
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
1907	69.3	41.9	63.3	46.5	61.7	49.7	43.0	42.4	36.9	41.2	29.5	37.7
1908	70.7	44.8	67.0	48.6	63.7	53.7	51.4	48.1	39.6	41.1	29.1	38.2
1909	67.7	43.5	69.1	57.8	60.3	54.1	46.2	43.2	40.6	42.3	29.9	36.8
1910	71.1	49.3	67.8	56.6	59.9	61.6	51.2	52.9	36.0	41.8	21.1	33.3
1911	71.6	43.8	69.2	54.6	60.5	52.2	49.5	50.3	33.9	40.8	33.9	38.8
Mean	70.08	43.06	67.88	52.82	61.22	54.26	48.66	47.38	37.80	41.44	27.90	37.36

Williams E. 34.

Chicago Sanitary District
Temperatures of Air and Water
Lake Michigan
From U.S. Lake Survey Records

Table LXIc
Sheet 1
(6 Sheets)

Station and Year	Temperature in Degrees Fahrenheit											
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
	January		February		March		April		May		June	
Milwaukee Lt. Pier Station												
1904					36.8	34.2	43.8	40.1	52.9	46.4	61.6	53.9
1905					30.6	33.4	40.6	40.7	54.3	47.4	64.4	53.1
1906	31.0	32.8	27.0	32.5								
Mean	31.0	32.8	27.0	32.5	33.7	33.8	42.2	40.4	53.7	46.9	63.0	53.5
Grand Haven Pier Lt. Sta.												
1904							45.4	42.8	56.8	51.1	66.7	57.9
1905					36.6*	33.8*	43.6	43.2	57.9	51.5	67.3	59.0
1906												
Mean					36.6	33.8	47.5	43.3	56.6	51.9	67.0	58.4
Eleven Ft. Shoal Light Vessel												
1905									45.4	41.8	57.2	53.1
1906							44.8	38.0*	47.5	44.3	60.3	56.1
Mean							44.8	38.0	46.4	43.0	59.2	55.2
Lansing Shoal Light Vessel												
1904									47.5	32.6	37.4	50.1
1905									29.6	40.8	64.5	54.3
1906							44.1*	36.8				
Mean							44.1	36.8	48.6	40.2	61.8	52.2
Mean of Lake	31.0	32.8	27.0	32.5	34.7	33.8	45.7	40.4	51.3	45.4	62.0	54.8
	July		August		September		October		November		December	
Milwaukee Lt. Pier Station												
1904	64.4	61.4	72.8	67.0	64.1	56.8	48.7	45.0	40.1*	43.1*	25.8*	34.1
1905	66.0	61.9	70.8	69.5	64.3	58.8	52.4	51.3	40.2	38.6	32.4	34.5
1906									40.9	42.7	30.9	36.6
Mean	66.6	61.6	71.7	67.0	64.2	57.7	50.6	49.2	40.6	41.8	29.5	35.0
Grand Haven Pier Lt. Sta.												
1904									40.1*	42.8*	28.4	33.2
1905	71.4	62.7	74.6	67.4	69.1	63.5	55.7	53.8	42.1	41.8	34.4	34.8
1906	73.6	64.3	74.7	70.5	72.2	64.6	53.5	51.8	43.0	44.2	32.6	33.9
Mean	73.5	63.5	77.2	69.0	70.6	64.0	53.6	53.7	42.6	42.8	32.5	33.7
Eleven Ft. Shoal Light Vessel												
1905	65.6	62.5	68.7	66.9	63.5	62.8	49.7	45.6	37.3	43.8		
1906	68.4	68.9	69.5	69.7	64.2	61.5	50.0	54.5	39.6	44.1		
Mean	67.0	64.7	69.1	68.2	64.0	62.2	49.8	55.0	38.0	44.0		
Lansing Shoal Light Vessel												
1904									37.8	44.7		
1905	68.3	57.5	73.0	64.3	66.0	62.2	51.8	53.3	37.3	44.3		
1906	71.8	65.5	73.5	68.8	68.7	62.7	50.0	51.5	39.4	43.6	21.8	37.3
Mean	71.0	62.5	73.2	66.0	68.8	62.4	50.9	54.1	37.9	44.2	21.8	37.3
Mean of Lake	69.5	63.1	72.8	67.8	68.4	62.1	51.7	53.0	39.9	43.1	29.6	34.8

* Partial Months

Williams Ex. 34

Table LXIa
Sheet 2

Chicago Sanitary District

Temperatures of Air and Water
of
Lake Superior

From U.S. Lake Survey Records

Station and Year	Temperature in Degrees Fahrenheit											
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
	January		February		March		April		May		June	
Devil's Island Light Station 1905							43.8	36.1	47.7	40.1	54.6	47.2
1906							47.9	38.2	48.3	39.4	61.2	44.3
Mean							45.8	36.2	48.0	39.8	57.9	44.8
Passage Isl. Light Station 1905							37.8	33.0	44.0	38.4	50.9	39.7
1906							42.4	35.5	45.2	37.1	51.1	39.8
Mean							39.7	34.2	44.6	38.8	51.0	39.8
Stannard Rock Light Station 1905									42.0	35.8	45.9	38.3
1906							43.8	34.9	43.6	36.3	48.4	38.3
Mean							43.4	34.9	42.8	36.0	47.2	38.3
Mean for Lake							42.9	35.1	45.1	37.5	52.0	41.6
	July		August		September		October		November		December	
Devil's Island Light Station 1905	69.1	56.4	72.6	64.3	62.2	56.4	48.2	50.0	34.9	42.3	23.8	36.7
1906	71.8	60.6	72.9	63.0	59.1	53.0	50.7	51.4	36.2	41.5		
Mean	70.4	58.5	72.8	63.2	60.6	54.7	49.4	50.7	35.6	41.8	23.0	36.7
Passage Isl. Light Station 1905	56.3	44.4	63.2	54.8	56.5	51.6	44.9	47.5	32.0	40.5	22.8*	37.1*
1906	54.9	42.9	62.3	55.9	58.1	52.9	44.5	46.5	33.3	39.4	17.9*	35.6*
Mean	56.6	44.6	63.2	55.3	57.3	52.2	44.7	47.0	33.8	40.0	20.9	36.4
Stannard Rock Light Station 1905	52.2	42.2	60.3	51.4	54.2	50.3	45.6	48.0	37.4	41.9		
1906	53.2	47.6	61.9	54.1	57.7	53.0	44.8	47.1	37.9	42.2		
Mean	52.7	44.9	61.1	52.7	56.0	51.6	45.2	47.6	37.6	42.0		
Mean for Lake	60.2	49.3	65.7	56.7	60.3	53.8	46.4	48.4	35.7	41.3	21.6	36.5

* Partial Months

Williams Ex. 34. Chicago Sanitary District Table LXIc Sheet 3

Temperatures of Air and Water of Lake Huron

From U.S. Lake Survey Records

* Partial Months

Station and Year	Temperature in Degrees Fahrenheit											
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
	January		February		March		April		May		June	
Spectacle Reef Light Station 1905							40.2*	34.6	42.9	37.0	54.5	47.6
1906							40.7	33.7	48.3	38.3	60.7	51.6
Mean							40.6	34.9	43.6	37.6	57.3	49.6
Charity Island Light Station 1905							47.2*	43.2	56.5	54.6	68.1	67.1
1906							46.2	42.6	54.7	54.6	67.9	67.5
Mean							46.9	47.4	55.6	54.6	69.0	67.3
Lake Huron Lt. Vessel No. 61 1904							45.2*	38.6	60.0	45.4	68.6	57.6
1905							48.7	39.8	56.6	46.6	69.2	59.8
1906												
Mean							47.0	39.0	57.8	46.0	68.9	58.3
Mean for Lake							44.9	40.4	52.3	46.1	65.1	58.7
	July		August		September		October		November		December	
Spectacle Reef Light Station 1904	65.6	62.5	70.3	65.0	63.8	62.7	49.1	50.3	36.4	41.3		
1905	71.3	62.3	71.1	66.7	64.5	61.7	49.5	49.7	37.8	42.6		
Mean	68.6	62.0	70.7	65.8	64.0	62.2	49.3	50.0	37.1	42.0		
Charity Island Light Station 1905	73.6	72.4	73.2	72.7	66.7	67.1	52.5	53.3	40.8	41.9		
1906	73.9	73.1	72.2	73.2	70.2	70.0	52.8	53.3	43.7	42.8		
Mean	73.7	72.8	73.7	74.0	68.4	68.5	52.6	54.3	41.8	42.2		
Lake Huron Lt. Vessel No. 61 1904									41.3	44.6	77.5	36.4
1905	74.5	66.1	72.4	67.7	72.3	63.7	52.3	52.9	44.9	44.5	58.0	39.4
1906	78.6	68.5	81.8	72.3	78.2	70.0	57.0	57.5	43.0	43.7	30.9	31.9
Mean	75.6	67.3	80.1	70.1	77.8	68.0	56.2	58.1	43.9	45.4	30.5	37.6
Mean for Lake	72.6	67.4	73.5	70.0	62.4	66.2	53.4	54.1	41.4	43.5	30.5	37.6

Williams Ex. 34. *Table LXLL*
Sheet 2.

Chicago Sanitary District

Temperatures of Air and Water
of
Lake St. Clair
from U. S. Lake Survey Records

Station and Year	Temperature in Degrees Fahrenheit											
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
	January		February		March		April		May		June	
Depot Pt. Lt. House No. 13												
1904							45.8	41.0	53.2	51.5	67.2	62.4
1905							50.7	42.7	52.3	50.9	67.3	62.5
1906												
Mean							47.8	41.6	52.8	51.2	67.2	62.4
	July		August		September		October		November		December	
Depot Pt. Lt. House No. 13												
1904	73.3	69.7	72.7	70.6	68.6	66.1	55.3	56.5	42.8	42.1	27.6	32.5
1905	73.3	70.9	74.4	74.2	70.5	69.7	53.7	53.4	42.2	43.4	31.6	34.8
1906												
Mean	73.4	69.7	74.6	72.4	69.6	67.9	54.2	54.0	42.0	42.8	30.8	34.6

a. Partial Months

Williams Ex. 34

Chicago Sanitary District
Temperatures of Air and Water
Lake Erie
From U.S. Lake Survey Records

Table L X I c
Sheet 5

Station and Year	Temperature in Degrees Fahrenheit											
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
	January		February		March		April		May		June	
Toledo Harbor Light Station												
1904			16.4*	32.0*			47.6*	43.1*	62.0	57.5	73.8	69.2
1905	24.2	32.0					51.4	43.7	60.7	57.0	73.7	68.9
1906												
1907	29.9	32.3	26.6	32.1	41.3	36.7	41.2	39.1	54.9	49.4	67.1	63.3
Mean	27.0	32.2	21.5	32.0	41.3	36.7	46.7	42.2	59.9	54.6	71.5	66.7
S.E. Shoal Light Vessel												
1905											70.9*	70.3*
1906							56.7*	41.6*	61.5	51.2	72.2	63.0
Mean							56.7	41.6	61.5	51.2	71.6	67.6
Horseshoe Reef Light Station												
1904							40.9*	42.6*	54.0	45.0	63.5	60.3
1905							43.4	34.9	54.7	48.9	65.1	59.0
1906											68.1	57.3
1907									59.0	45.7	70.9	65.1
1908												
Mean							42.2	33.4	55.9	45.9	66.9	60.5
Mean for Lake	27.0	32.2	21.5	32.0	41.3	36.7	46.9	39.2	58.4	50.4	69.5	64.1
	July		August		September		October		November		December	
Toledo Harbor Light Station												
1904									40.9*	40.8*	28.9	32.2
1905	77.8	76.4	75.6	73.2	71.8	68.2	57.4	55.8	41.3	40.1	32.1*	33.8
1906	78.2	73.0	80.0	77.2	73.7	72.2	54.9	53.3	44.3	40.3	31.5	33.7
1907	76.5	72.0	74.6	72.1	69.5	67.0	52.7	53.3	42.6	41.7	33.7	34.1
Mean	76.5	73.8	76.7	74.2	71.5	69.5	55.3	54.5	41.9	41.4	31.5	33.4
S.E. Shoal Light Vessel												
1904	77.3	73.5	78.1	77.4	70.2	68.7	57.4	60.1	45.1	42.4	37.5*	34.6
1905	76.7	73.5	80.3	76.2	74.9	72.1	58.5	59.2	47.0	44.8	34.9*	38.2
Mean	77.0	72.9	79.2	76.8	72.6	70.4	58.0	59.2	46.0	45.1	36.2	37.0
Horseshoe Reef Light Station												
1904									37.8*	43.6*	32.8*	34.6
1905	71.6	69.6	71.5	69.8	65.3	66.8	53.6	57.9	39.8	40.7	31.5*	38.1
1906	73.7	69.4	74.7	69.2	68.2	67.3	53.3	55.1	40.2	42.2	34.0*	38.3
1907	70.2	69.1	69.6	69.8	64.5	66.9	51.0	55.9	43.1	43.3	33.7*	36.9
1908	74.1	71.3	73.3	70.9	69.2	68.3	59.3	58.8	44.7	45.4	32.5*	37.7
Mean	72.4	69.9	72.3	71.0	66.8	67.4	54.3	58.2	42.1	45.3	30.1	37.0
Mean for Lake	74.8	71.9	75.1	72.9	69.7	68.8	55.5	57.2	42.7	43.8	31.7	35.7

* Partial Month

Williams Ex. 34

Table LXI c
Sheet 6

Chicago Sanitary District

Temperatures of Air and Water
of
Lake Ontario

From U.S. Lake Survey Records

Station and Year	Temperature in Degrees Fahrenheit											
	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water	Air	Water
	January		February		March		April		May		June	
Charlotte Light Station												
1904							45.0	42.3	52.4	48.5	63.2	59.0
1905							44.6	42.9	53.0	50.3	63.9	59.3
1906												
Mean							45.8	42.6	53.7	49.4	64.6	59.8
Gallop Island Light Station												
1904							46.5	37.6	51.1	45.6	62.1	56.4
1905							48.1	40.2	56.1	49.3	64.7	60.2
1906												
Mean							46.6	38.9	53.6	47.4	63.4	58.3
Mean for Lake							46.2	40.7	53.6	48.4	64.0	58.5
	July		August		September		October		November		December	
Charlotte Light Station												
1904									41.8	40.8	36.3	32.6
1905	70.7	64.5	69.4	64.9	64.8	62.6	55.3	55.3	40.1	40.0	34.4	33.9
1906	60.3	57.2	67.5	67.5	67.9	67.2	54.0	54.0	41.9	42.3	36.7	35.8
Mean	65.5	60.8	68.4	63.2	66.3	64.9	54.6	54.6	41.2	41.7	36.8	33.4
Gallop Island Light Station												
1904									42.8	40.6	30.4	32.4
1905	71.6	66.5	71.0	68.7	66.3	65.4	55.6	56.2	38.6	42.0	29.4	31.6
1906	74.0	70.3	73.6	72.9	66.7	65.4	53.2	54.3	33.6	41.1	17.8	32.0
Mean	72.8	68.4	72.3	70.8	66.5	65.4	53.9	56.2	37.8	42.5	22.4	34.0
Mean for Lake	69.1	64.6	70.9	67.0	66.4	65.1	54.3	55.4	39.5	42.1	26.6	33.7

* Partial Months

Williams Ex. 34. Table LXId
Sheet 1 (3)

Chicago Sanitary District
Surface Water Temperatures
1905

Route	Date	Max.	Min.	Mean
Lake Superior				
300 to Ashland & return	July 31 - Aug. 3	64.3	39.4	51.6
	Aug. 25 - Aug. 27	62.8	50.6	57.4
	Oct. 13 - Oct. 16	53.8	44.7	49.7
300 to Duluth and return	June 24 - June 27	56.0	38.7	42.6
	Aug. 19 - Aug. 23	71.3	53.1	61.1
	Sept. 12 - Sept. 15	61.6	41.2	51.8
300 to Otter Is. & return				
" " Duluth " "	Nov. 27 - Dec. 7	43.2	38.2	40.3
Portage Lake & River	Dec. 2 - Dec. 4	33.5	32.0	33.1
St. Mary's River	June 23 - June 28	64.7	52.8	57.0
	July 31 - Aug. 3	65.0	58.5	62.1
	Aug. 24 - Aug. 28	65.8	62.0	63.8
	Aug. 18 - Sept. 1	73.3	54.5	63.4
	Sept. 11 - Sept. 17	64.9	58.6	61.6
	Oct. 8 - Oct. 18	56.6	50.3	53.4
	Nov. 27 - Dec. 8	41.4	33.4	38.2
Lake Michigan				
Mackinac to Chicago				
To Escanaba to "				
To Mackinac	Aug. 24 - Aug. 31	75.9	64.0	70.3
Mackinac to Green Bay	Sept. 22 - Sept. 24	62.7	58.9	61.3
Traverse Bay to Chicago				
to Mackinac	Oct. 10 - Oct. 13	62.3	42.9	57.1
Mackinac to Milwaukee				
to Mackinac	Nov. 17 - Nov. 27	46.4	38.0	42.6
Grand Haven to Milw-				
aukee to Ludington	Feb. 21 - Feb. 22	37.7	32.3	30.0

Williams Ex. 34.

Table LXI d
Sheet 2

Chicago Sanitary District
Surface Water Temperatures
1905

Route	Date	Max.	Min.	Mean
Lake Huron				
Port Huron to Detour to Port Huron	June 22 - June 29	64.9	49.3	57.2
Port Huron to Detour to Mackinac to Port Huron	Aug. 18 - Sept. 1	74.4	47.1	67.9
Port Huron to Goderich	July 7	69.3	63.9	68.3
Goderich to Harbor Beach	July 11	72.0	67.3	69.97
Harbor Beach to Tawas City	July 14	71.3	60.5	68.94
Tawas City to Bay City	July 16	74.8	65.8	71.26
Bay City to Tawas City	July 19	72.9	66.0	69.47
Tawas City to Kincardine	July 20	68.7	63.3	63.79
Kincardine to Southampton	July 26	64.3	30.1	37.54
Southampton to South Pt.	July 27	62.0	47.2	57.8
Alpena to Presque Isle	July 31	60.7	39.0	60.0
Presque Isle to Cove Isl.	Aug. 2	64.8	37.2	59.2
Cove Isle. to Southampton	Aug. 5	68.0	60.3	63.86
Southampton to Stokes' Bay.	Aug. 7	75.2	72.0	73.87
Stokes' Bay to Alpena	Aug. 10	69.7	60.8	64.62
Alpena to Duck Island	Aug. 12	65.7	39.5	62.71
Duck Isle. to Stokes' Bay	Aug. 13	67.2	61.2	63.64
Stokes' Bay to Providence Bay	Aug. 20	65.2	32.0	62.97
Providence Bay to Presque Isle.	Aug. 23	63.0	33.3	38.00
Presque Island to Cheboygan	Aug. 24	64.0	61.3	62.64

Williams Ex. 34 Table LXIII Sheet 3

Chicago Sanitary District

Surface Water Temperatures

1905

Route	Date	Max.	Min.	Mean
Lake Huron				
Cheboygan to Mackinac Island	Aug. 25	63.0	62.5	63.72
Detour S.E. and then W to Cheboygan	Aug. 30	61.7	53.8	59.02
Detour to Cheboygan	Sept. 4	60.0	53.3	56.97
Mackinac Isle to Detour	Sept. 9	58.2	56.9	57.53
Detour to Mississaqe Straits	Sept. 13	58.3	54.0	56.3
Mississaqe Straits to Rogers Isle and thence to Cheboygan	Sept. 16	58.3	53.0	57.5
Cheboygan to Duck Isle.	Sept. 19	58.5	56.5	57.47
Duck Isle. to South Pt.	Sept. 20	61.1	56.0	58.98
Alpena to Harbor Beach	Sept. 22	64.8	59.2	61.10
Harbor Beach to Bay City	Sept. 23	66.1	62.2	63.89
Bay City to Gravelly Pt.	Sept. 26	64.0	63.3	63.71
Harbor Beach to Port Sanilac thence to Goderich	Oct. 9	58.2	54.0	56.03
Clark Pt. to Goderich	Oct. 10	53.2	51.0	52.33
Goderich to Port Huron	Oct. 11	57.8	54.0	56.33
Port Huron to Detroit	Oct. 12	57.2	53.9	56.39
Port Huron to Detour	July 30 - Aug. 4	67.9	59.5	63.76
	Aug. 24 - Aug. 28	67.3	63.3	65.93
Port Huron to Detour to Port Huron to Mackinac to Port Hu	Sept. 11 - Sept. 25	60.9	51.8	62.48

Williams Ex. 34. Table LXI d Sheet 4

Chicago Sanitary District
Surface Water Temperatures
1903

Route	Date	Max.	Min.	Mean
Lake Huron				
Port Huron to Mackinac to Detour to Port Huron Port Huron to Mackinac to Port Huron. Port Huron to Detour to Port Huron	Oct. 7 - Oct. 19 Nov. 16. - Dec. 10	61.8 45.9	46.7 38.9	50.14 42.28
St. Clair River				
St. Clair River	June 22 - June 29	63	37.6	50.49
	July 30 - Aug. 4	67.2	66.5	66.72
	Sept. 3	69.8	69.7	69.73
	Sept. 18 - Sept. 25	66.3	62.0	64.57
	Oct. 7 - Oct. 19	62	58.6	59.34
	Nov. 16 - Dec. 10	44.9	40.2	43.11
Lake St. Clair.				
Lake St. Clair	June 22 - June 29	71	63.4	67.20
	July 30 - Aug. 4	69.9	68.4	69.13
	Aug. 29	68.4	67.3	67.85
	Sept. 3	69.8	69.4	69.67
	Sept. 10 - Sept. 25	67.4	63.2	65.86
	Oct. 7 - Oct. 19	62.4	57.7	60.0
	Nov. 13 - Dec. 10	42.7	38.9	40.30
Detroit River				
Detroit River	June 20 - June 22	66.3	63.3	66.03
	June 26	68.4	66.0	67.20

Williams Ex 34. Table LXIa Sheet 5

Chicago Sanitary District
Surface Water Temperatures
1903

Route	Date	Max.	Min.	Mean
Detroit River				
Detroit River	July 24	71.2	70.4	70.80
	Aug. 4	69.3	69.3	69.30
	Aug. 15 - Aug. 17	75.4	74.8	75.10
	Aug. 29 - Sept. 1	70.5	69.5	69.97
	Sept. 18 - Sept. 21	66.2	66.1	66.13
	Sept. 28	64.7	64.4	64.53
	Oct. 19 - Oct. 23	57.5	50.4	53.62
	Nov. 13 - Dec. 10	41.5	34.8	39.43
Lake Erie				
Detroit to Erie Erie to Detroit	June 20 - June 21	66.5	61.3	63.3
	June 26 - June 27	70.0	57.0	62.69
Buffalo to Detroit	July 9	67.6	64.5	66.67
	July 24 - July 25	74.3	63.5	70.57
Detroit to Ashtabula to Detroit Detroit to Buffalo. Buffalo to Cleveland Cleveland to Detroit	Aug. 15 - Aug. 17	78.3	74.6	75.33
	Aug. 29 - Sept. 1	72.7	69.5	71.13
	Sept. 18 - Sept. 20	69.3	67.8	68.40
	Sept. 28 - Sept. 29	67.6	63.2	66.83
Detroit to Cleveland to Detroit Detroit to Cleveland to Detroit to Erie to Detroit	Oct. 20 - Oct. 23	53.9	52.6	53.40
	Nov. 13 - Nov. 26	47.5	38.5	43.22

Williams Ex 34. Table. LXII.

Chicago Sanitary District

Meteorological Records at Rochester

Averages of Results Obtained Since Beginning of Experiments in 1891.

Period		Records Made at Mt. Hope Reservoir						
		Depth of evaporation		Mean temperature				Precipitation
Years	Month	Depth in inches from Pan	Depth in inches from Tank	Mean of Maximum	Mean of Minimum	Mean of Month	Mean of Day	Depth in inches
1896-1907	Jan.		0.75		32.6	32.7	24.7	1.867
1896-1907	Feb.		2.79		32.6	32.9	24.9	1.930
1896-1907	Mar.		4.42		34.0	34.0	26.0	2.000
1896-1907	Apr.	4.69	4.67	47.4	34.0	40.7	30.7	2.241
1896-1907	May	6.47	5.54	58.5	43.9	51.2	40.4	2.767
1896-1907	June	6.35	4.54	68.5	53.9	61.2	50.6	3.117
1896-1907	July	6.68	3.44	74.6	61.2	67.9	57.6	3.346
1896-1907	Aug.	5.68	2.84	74.0	60.5	67.3	57.0	3.146
1896-1907	Sept.	4.58	2.03	69.0	55.6	62.3	52.1	3.117
1896-1907	Oct.	2.58	1.33	57.4	45.0	51.2	41.2	2.770
1896-1907	Nov.	1.81	1.34	47.4	34.3	40.9	31.9	2.806
1896-1907	Dec.		1.16		34.3	34.9	28.7	1.966
Totals and Means		44.51	33.13	60.6	51.2	49.5	40.6	27.627

Period		Records of U.S. Weather Bureau					
		Precipitation		Temperature of air in shade		Humidity of air	
Years	Month	Depth in inches from Gauge	Depth in inches from Snow	Mean of Maximum	Mean of Minimum	Mean of Month	Mean of Day
1896-1907	Jan.	2.08	5.13	34.9	24.1	74.7	79.
1896-1907	Feb.	2.20	4.73	36.7	25.0	78.0	79.
1896-1907	Mar.	2.42	3.94	44.7	31.5	80.7	78.
1896-1907	Apr.	2.68	2.84	57.5	41.0	80.7	76.
1896-1907	May	3.08	0.44	68.8	50.0	80.8	74.
1896-1907	June	3.28	0.12	77.2	59.1	80.8	74.
1896-1907	July	3.58	0.00	80.1	63.4	80.8	74.
1896-1907	Aug.	3.38	0.00	78.7	62.1	80.8	74.
1896-1907	Sept.	3.08	0.00	73.1	56.1	80.8	74.
1896-1907	Oct.	2.88	0.00	62.1	45.1	80.8	74.
1896-1907	Nov.	2.68	0.00	50.5	34.7	79.3	77.
1896-1907	Dec.	2.01	2.36	39.6	28.7	79.2	77.
Totals and Means		33.15	34.07	47.8	47.7	73.8	72.

Williams Ex 34 Chicago Sanitary District Table LXIII

Effect of Livingstone Channel

Effect of Livingstone Channel

Year	Huron Elevations				Mich St Clair Flats Elevations				St Clair	Erie Elevations				Mich Erie
	Oct.	Nov	Dec	Mean	Fall	Oct	Nov	Dec	Mean	Fall	Oct.	Nov	Dec	Mean	Fall
1900	580.08	0.66	0.45	580.39	5.65	575.01	574	4.80	574.94	3.38	571.75	1.49	1.45	571.56	9.03
01	.56	.43	.10	.40	.62	4.96	.67	.70	.76	.55	.33	.16	.19	.23	9.17
02	.27	.17	9.93	.12	.04	5.26	.90	5.05	5.08	.04	2.29	2.02	.82	2.04	8.00
03	.53	.41	0.12	.45	.20	.45	.55	.35	.25	.43	.25	1.77	.43	1.82	8.63
04	1.26	.96	.50	.90	.39	.74	.34	.45	.51	.38	.49	2.12	.77	2.13	8.77
05	.22	.93	.67	.94	.58	.60	.32	.17	.36	.31	.31	1.93	.91	.85	8.89
06	0.87	.66	.65	.73	.40	.45	.33	.21	.33	.06	.21	2.17	2.42	.27	8.46
07	1.21	.81	.62	.89	.35	.76	.47	.60	.56	.09	.69	2.81	.26	.85	8.46
Mean				580.63	5.41-6.22%				575.22	3.28-3.78%				571.94	8.69
1908	580.08	0.46	0.23	580.52	5.24	575.64	5.23	4.96	575.28	3.47	572.31	1.71	1.62	571.81	8.71
09	.46	.12		.26	.06	.31	.08		.20	.51	1.76	.51		.69	8.57
10	.66	9.83	9.52	9.81	4.97	.20	4.89	4.44	.84	.28	.88	.46	.34	.56	8.25
11	9.56	.44	.39	.46	.72	4.83	.69	.70	.74	.38	.53	.13	.42	.36	8.10
Mean				580.01	5.00-5.95%				575.01	3.41-4.05%				571.60	8.41
1912	580.04	0.03	0.28	580.45	5.23	575.31	5.23	5.02	575.19	3.32	572.15	1.92	1.55	571.87	8.55
					6.28					3.94					

Changes in Feet

From	to	Huron	St. Clair	Erie	Huron to St. Clair	St. Clair to Erie	Huron to Erie
1900-7	08-11	-0.62	-0.21	-0.36	-0.41	+0.13	-0.28
1908-11	12	+0.41	+0.15	+0.27	+0.23	-0.09	+0.14

Williams Ex. 34. Table LXIV

Chicago Sanitary District

Comparison of Results obtained
With a Haskell Current Meter on Rigid
Support for Regular and Irregular Velocities.

Regular Velocity					Irregular Velocity				Irreg. ratio / Reg. ratio
Group	No. of Observ.	Rev.	Val	Val / Rev.	No. of Observ.	Rev.	Val.	Val / Rev.	
I	69	.536	1.260		137	.533	1.369		
	70	.434	1.075		136	.388	1.027		
	71	.273	.796		133	.221	.663		
	72	.169	.479		134	.115	.330		
	Mean	.363	.928	2.629	Mean	.423	7.082	2.558	.972
II	68	1.019	2.240		128	.956	2.145		
					138				
	Mean	1.019	2.240	2.198	Mean	.989	2.178	2.200	1.000
III	73	1.287	2.574		127	1.368	2.960		
	75	1.297	2.594		135	1.429	3.086		
	81	1.335	2.758						
	90	1.253	2.574						
	Mean	1.293	2.660	2.057	Mean	7.408	3.078	2.143	1.040
II	66	1.761	3.671		140	1.584	3.540		
	84	1.796	3.810						
	88	1.767	3.720						
	89	1.633	3.410						
	Mean	1.733	3.652	2.107	Mean	1.584	3.540	2.235	1.060
I	64	1.964	4.016		135	1.870	4.137		
	65	1.805	3.748		139	2.003	4.292		
	76	1.848	3.741						
	Mean	1.979	4.169	2.106	Mean	1.934	4.212	2.178	1.030
II	78	2.778	5.949		138	2.865	6.135		
	83	2.778	5.737						
	86	2.822	5.934						
	Mean	2.789	5.870	2.141	Mean	2.865	6.135	2.141	1.000

Williams Ex. 34. Table LXV

Chicago Sanitary District
Elevations and Mean Elevations of Lakes for Ten Years Prior and Ten Years Subsequent to Opening of Chicago Drainage Canal

Year	Michigan Elevation	St. Clair Elevation	Erie Elevation
1890	581.11	575.77	573.05
1	0.54	5.09	2.15
2	0.35	4.93	2.18
3	0.37	5.10	2.09
4	0.76	5.22	2.10
5	79.83	4.60	1.17
6	79.93	4.37	1.99
7	80.73	4.39	1.96
8	0.28	5.06	2.19
9	0.29	5.00	7.93
Mean	580.342	575.013	572.012
1900	580.30	574.94	571.94
1	0.37	4.61	1.39
2	0.21	4.82	1.64
3	0.36	5.36	2.39
4	0.82	5.60	2.32
5	0.55	5.33	2.17
6	0.96	5.29	2.26
7	1.03	5.20	2.29
8	- 0.98	5.08	2.69
9	0.21	5.32	2.13
Mean	580.665	575.255	572.210

Gain in Elevation of Subsequent over Prior Decade	580.665 − 580.342 = .323	575.255 − 575.013 = .242	572.210 − 572.012 = .198
	4"	2.8"	2.3"

Williams Ex. 34. *Chart I*

Chicago Sanitary District
Discharge of Lower Detroit River
Gage Relations

Gaging	Mamajuda	Section	Gibraltar	Amherstburg	Ouellette	Width Section	Area	Velocity	Discharge
1. May 8-10, 1909	574.35	573.48	572.65	572.87	(574.17)	1625	27200	2.20	59420
2. June 28-9, 1909	4.72	4.19		3.55	(574.55)	1680	28900	1.80	49880
3. Aug. 29, 1912	4.17	3.69		3.10	573.83	1680	27753	1.40	38868
4. Aug. 30, 1912	4.00	3.43		2.78	573.57	1680	27236	1.48	40498
5. Dec. 5, 1912	3.46	2.84	572.17	2.10	(573.01)	1680	26296	1.58	44300
Average 1-5		3.53		2.88	573.83				46593
" 2,3,4,5		3.54		2.88	573.75				43386
" 3,4,5	573.88	3.32		2.66	573.47				41222

To interpolate Ouellette (1) and (2)
Mean fall Mamajuda to Amherstburg Apr. 24 to May 20
= 574.29-572.99 = 1.30

By statement of Report of C.Y. Dixon p. 11, the fall from Ouellette's to Amherstburg = 1.14
Fall Mamajuda to Ouellette = $\frac{16}{130}$ Mamajuda to Amherstburg

Gaging 1 M = Mamajuda, A = Amherstburg, O = Ouellette
M-A = 574.35-572.87 = 1.48
$1.48 \times \frac{16}{130} = 0.182$ ∴ Ouellette = 574.35-0.18 = 574.17

Gaging 2
M-A = 574.72-573.55 = 1.17
$1.17 \times \frac{16}{130} = 0.14$ ∴ Ouellette = 574.72-0.14 = 574.58

To interpolate Ouellette (5) S = Section
By 3 O-A = 573.83-573.10 = 0.73
S-A = 573.69-573.10 = 0.59
O-A = $\frac{73}{59}$ S-A = 1.237

By 4 O-A = 573.57-572.78 = 0.79
S-A = 573.43-572.78 = 0.65
O-A = $\frac{79}{65}$ S-A = 1.216

Mean (O-A)+(S-A) = 1.226
By 5 S-A = 572.84-572.10 = 0.74
∴ Ouellette's = 0.74 × 1.226 + 572.10 = 573.01

Williams Ex. 34. Chart I

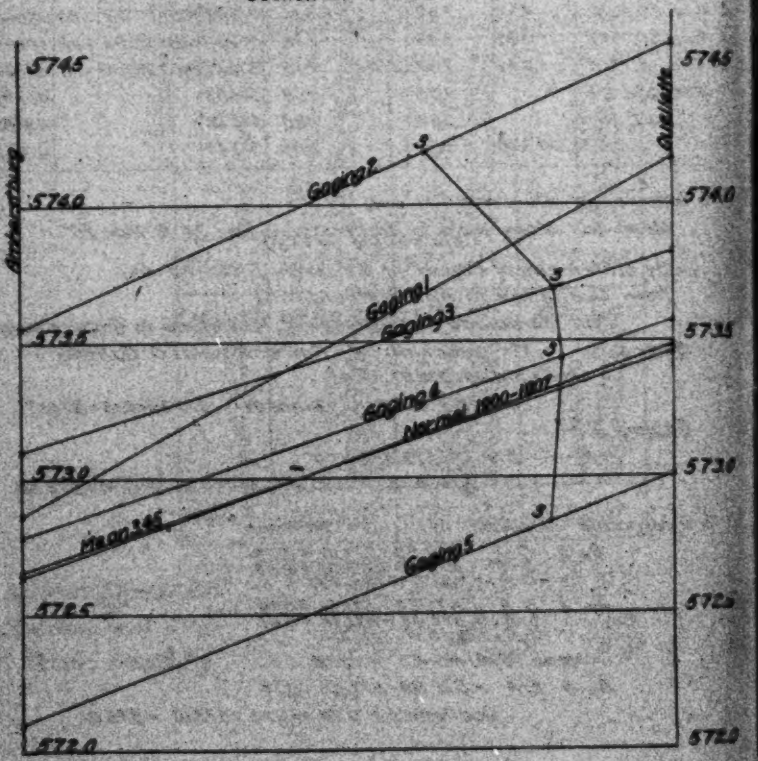
Chicago Sanitary District
Discharge of Lower Detroit River
Gage Relations

Mean St Clair Flats (1900-1907 Open Season) = 575.43
Amherstburg . . . . . = 572.65

$$\frac{\text{Fall St Clair Flats to Ouellette}}{\text{Fall St Clair Flats to Amherstburg}} = 0.703$$

$$\frac{575.43 - \text{Ouellettes}}{575.43 - 572.65} = 0.703$$

Ouellettes = 573.48



Williams Ex 34 *Chart III*

Chicago Sanitary District

Discharge of Lower Detroit River

Trenton Channel

1912

	Monroe	Amherstburg	Fall	Section	w	A	$\frac{A}{w}$	V	Q
Mean 3 days	573.88	572.66	1.22	573.32	1680	26112	15.54	1.579	41,222
Normal Fall	573.60	572.65	0.95	573.16	1680	25843	15.38	1.386	35,818

$$\frac{V_{normal}}{V_{mean}} = \left[\sqrt{\frac{0.95}{1.22}} = 0.882\right]\left[\sqrt{\frac{15.38}{15.54}} = 0.995\right] = 0.878$$

$V_{normal} = .878 \times 1.579 = 1.386$

$Q = 1.386 \times 25,843 = 35,818$ c.f.s.

$M-O = \frac{fl}{150}(M-A)$ or $M-573.48 = \frac{fl}{150}(M-572.65)$ $\therefore M = 573.60$

$M-S = \frac{fl}{150}(M-A)$ or $573.60-S = \frac{fl}{150}(573.60-572.65)$ $\therefore S = 573.16$

Williams Ex 34. Chart II

Chicago Sanitary District

Discharge of Lower Detroit River

Stony Island Channel

1912

	Ouellette	Amherstburg	Fall	Section	w	A	$\frac{A}{w}$	V	Q
Aug 20-21	573.50	572.74	0.84	573.24	1240	7699	6.21	1.500	11549
Normal	573.48	572.65	0.83	573.14	1240	7575	6.11	1.479	11203

$$\frac{V_{normal}}{V_{mean}} = \left[\sqrt{\frac{0.83}{0.84}} = .994\right]\left[\sqrt{\frac{6.11}{6.21}} = 0.992\right] = 0.986$$

$V_{normal} = 0.986 \times 1.500 = 1.479$

$Q = 1.479 \times 7575 = 11203$ c.f.s.

* $S = O - \frac{1}{11}(O-A) = 573.48 - \frac{1}{11} \times 0.83 = 573.48 - 0.34 = 573.14$

Williams E. 34. Chart K

Chicago Sanitary District

Discharge of Lower Detroit River

Livingstone Channel

1912

	Ouellette	Amherstburg	Fall	Section	w	A	$\frac{A}{w}$	V	Q
Dec 17	573.10	572.35	0.75	572.73	500	11883	23.77	2.93	34,838
Normal	573.48	572.65	0.83	573.07	500	12053	24.11	3.103	37,400

$$\frac{V_{normal}}{V_{mean}} = \left[\sqrt{\frac{0.83}{0.75}} = 1.052\right]\left[\sqrt{\frac{24.11}{23.77}} = 1.007\right] = 1.059$$

$V_{normal} = 1.059 \times 2.93 = 3.103$

$Q = 3.103 \times 12053 = 37,400$ c.f.s.

$S = O - \frac{17}{17}(O-A) = 573.48 - \frac{17}{17} \times 0.83 = 573.48 - 0.41 = 573.07$

Williams Ex. 34. *Chart VI*

Chicago Sanitary District

Discharge of Lower Detroit River

Lime Kiln Channel

1912

	Gualette	Anderson	Fall	Section	w	A	$\frac{A}{w}$	V	Q
Dec. 18	572.95	572.17	0.78	572.58	2670	38840	14.55	2.55	99128
Normal	573.48	572.65	0.83	573.09	2670	40282	15.06	2.67	107,339
Oct. 24	573.02	572.06	0.96	572.56	2670	38787	14.51	2.76	106,975
Normal	573.48	572.65	0.83	573.08	2670	40175	15.05	2.61	104,857

Mean for Normal = 106,098

(Dec. 18)

$$\frac{V_{normal}}{V_{mean}} = \left[\sqrt{\frac{0.83}{0.78}} = 1.031\right]\left[\sqrt{\frac{15.06}{14.55}} = 1.017\right] = 1.048$$

$$V_{normal} = 1.048 \times 2.55 = 2.67$$

$$Q = 2.67 \times 40282 = 107,339 \text{ c.f.s.}$$

(Oct. 24)

$$\frac{V_{normal}}{V_{mean}} = \left[\sqrt{\frac{0.83}{0.96}} = .930\right]\left[\sqrt{\frac{15.05}{14.51}} = 1.018\right] = .947$$

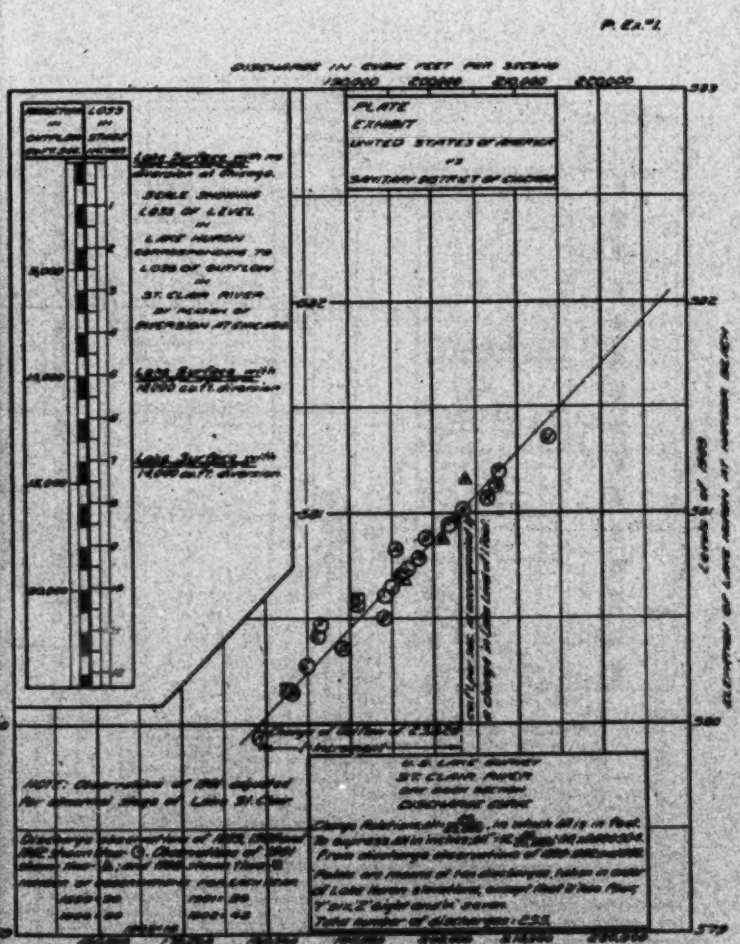
$$V_{normal} = .947 \times 2.76 = 2.610$$

$$Q = 2.610 \times 40875 = 104857 \text{ c.f.s.}$$

Dec. 18 $S = O - \frac{11}{12}(O - A) = 573.48 - \frac{11}{12} \times 0.83 = 573.48 - 0.39 = 573.09$

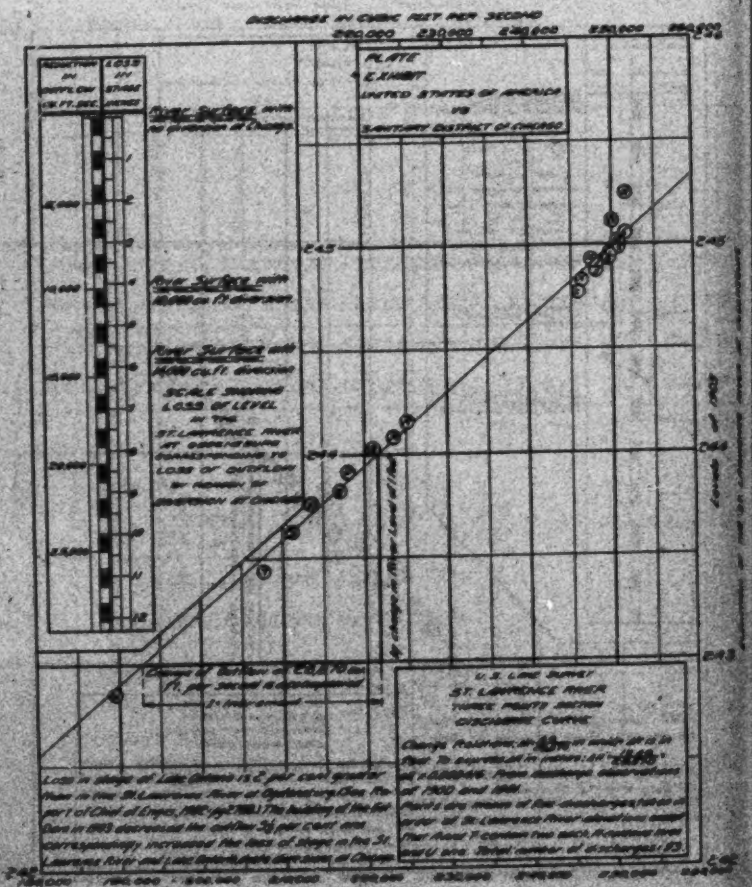
Oct. 24 $S = O - \frac{11}{12}(O - A) = 573.48 - \frac{11}{12} \times 0.83 = 573.48 - 0.40 = 573.08$

Williams Ex. 34. *Plate 1*



Williams Ex. 34. Plate II

Pl. Ex. No. 2.



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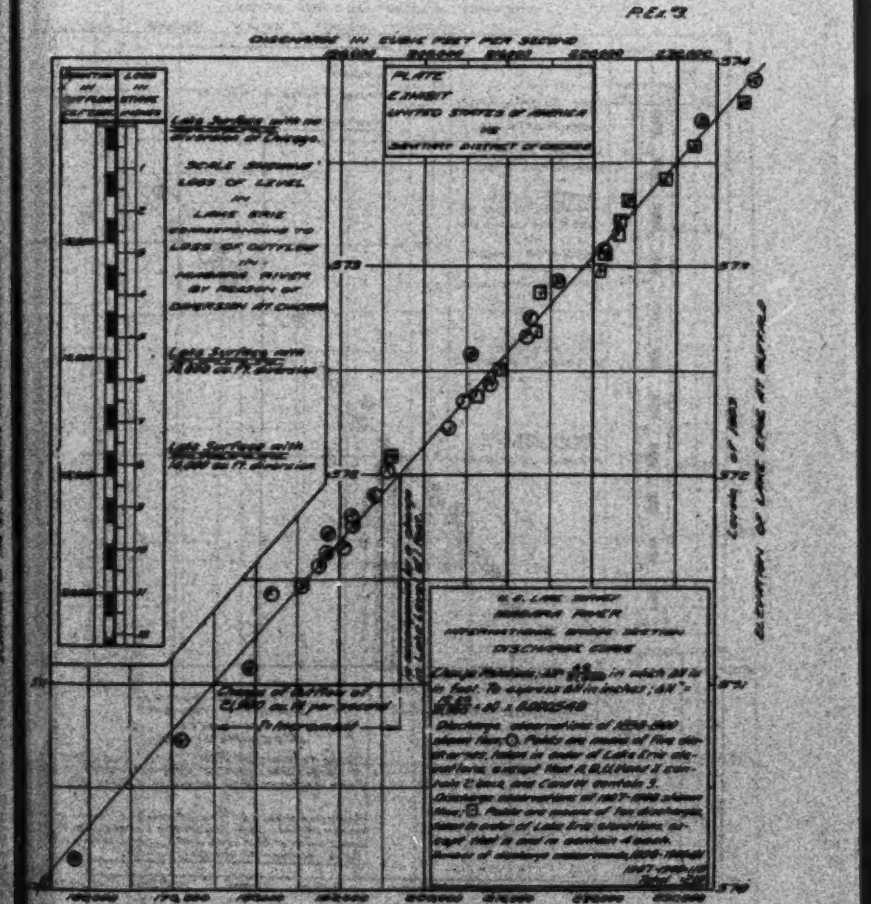

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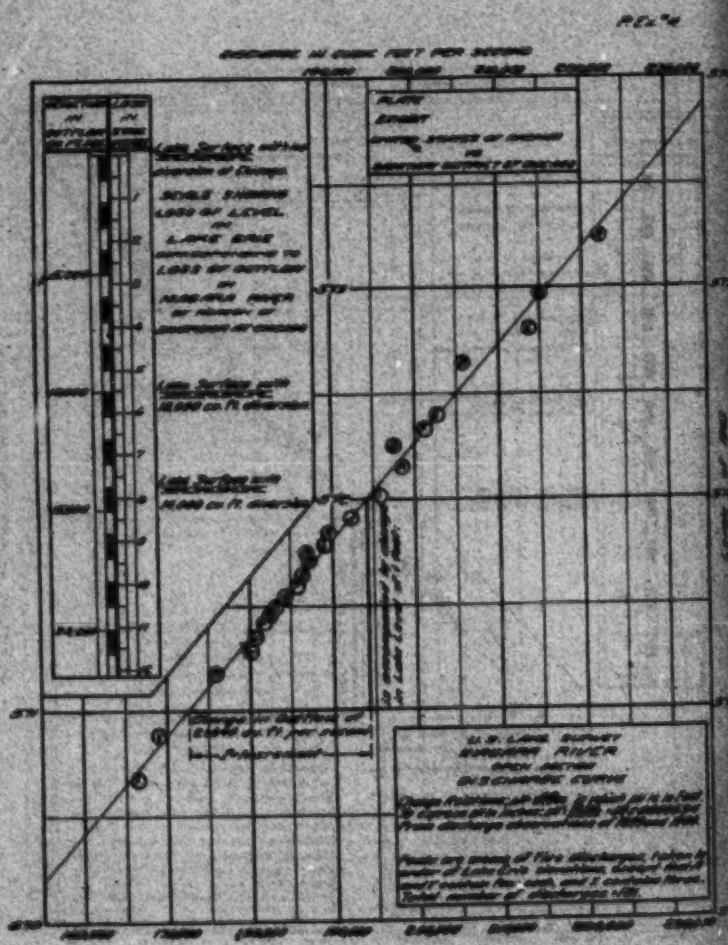
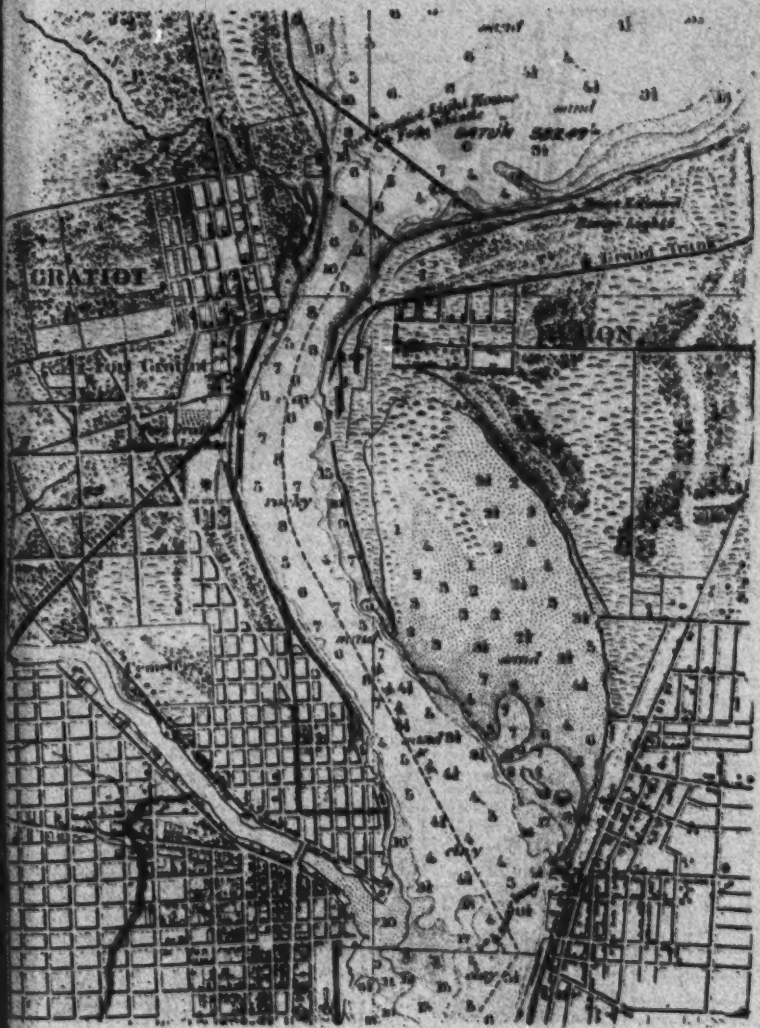


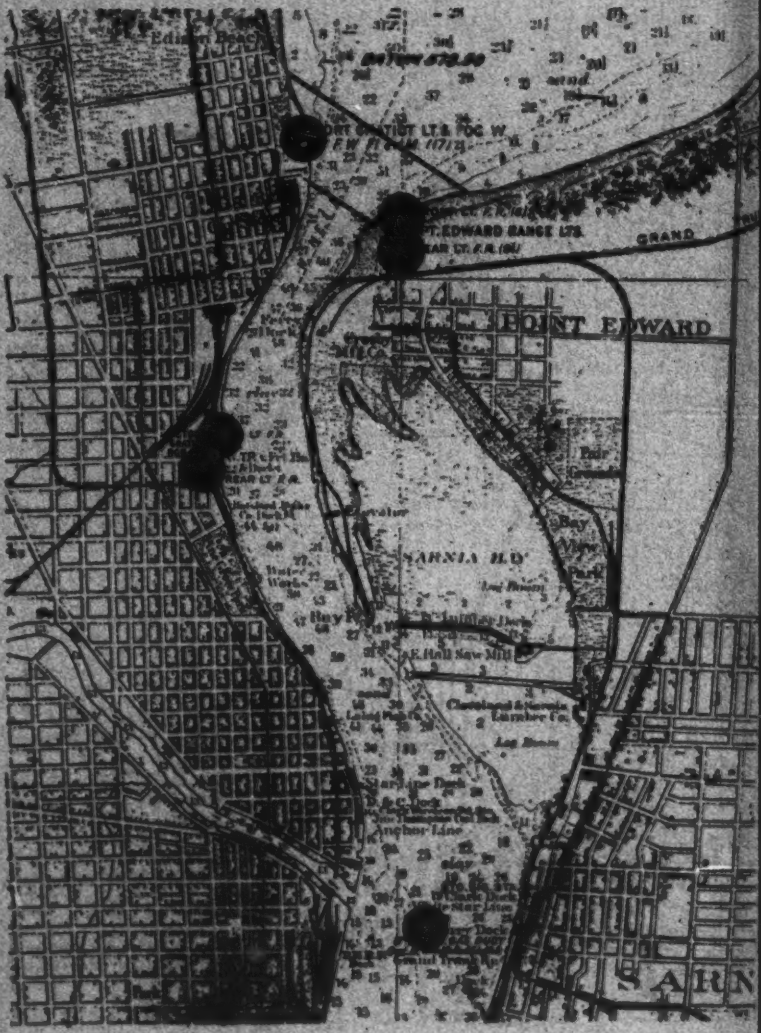
Williams Ex 34. Plate V

Williams Ex. 34. Plate II

Williams Ex. 34. Plate III.



Williams Ex 34 Plate III



Williams Ex. 34.

Plate IX

Chicago Sanitary District

CROSS SECTIONS

St. Clair River

Niagara River
Bridge Section

Niagara River
Open Section

St. Lawrence River

Sanitary District Canal

Scale 1" = 250'

Williams Ex. 34

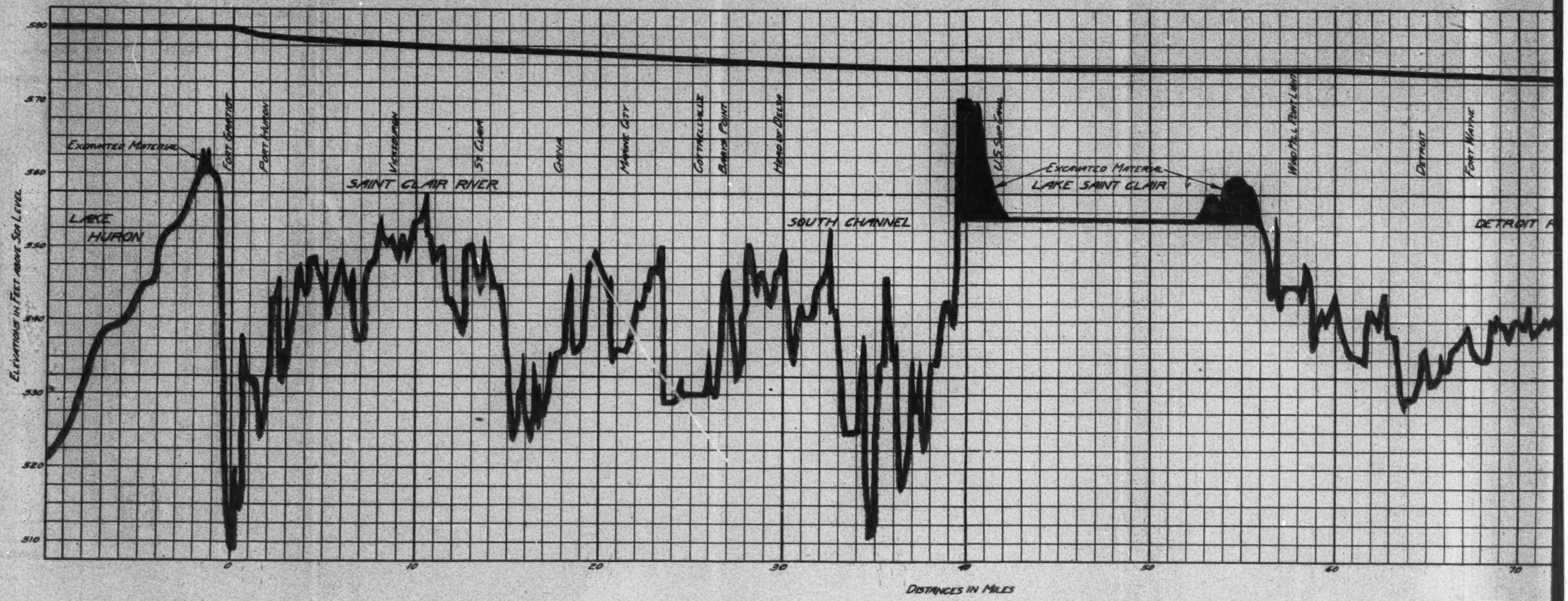
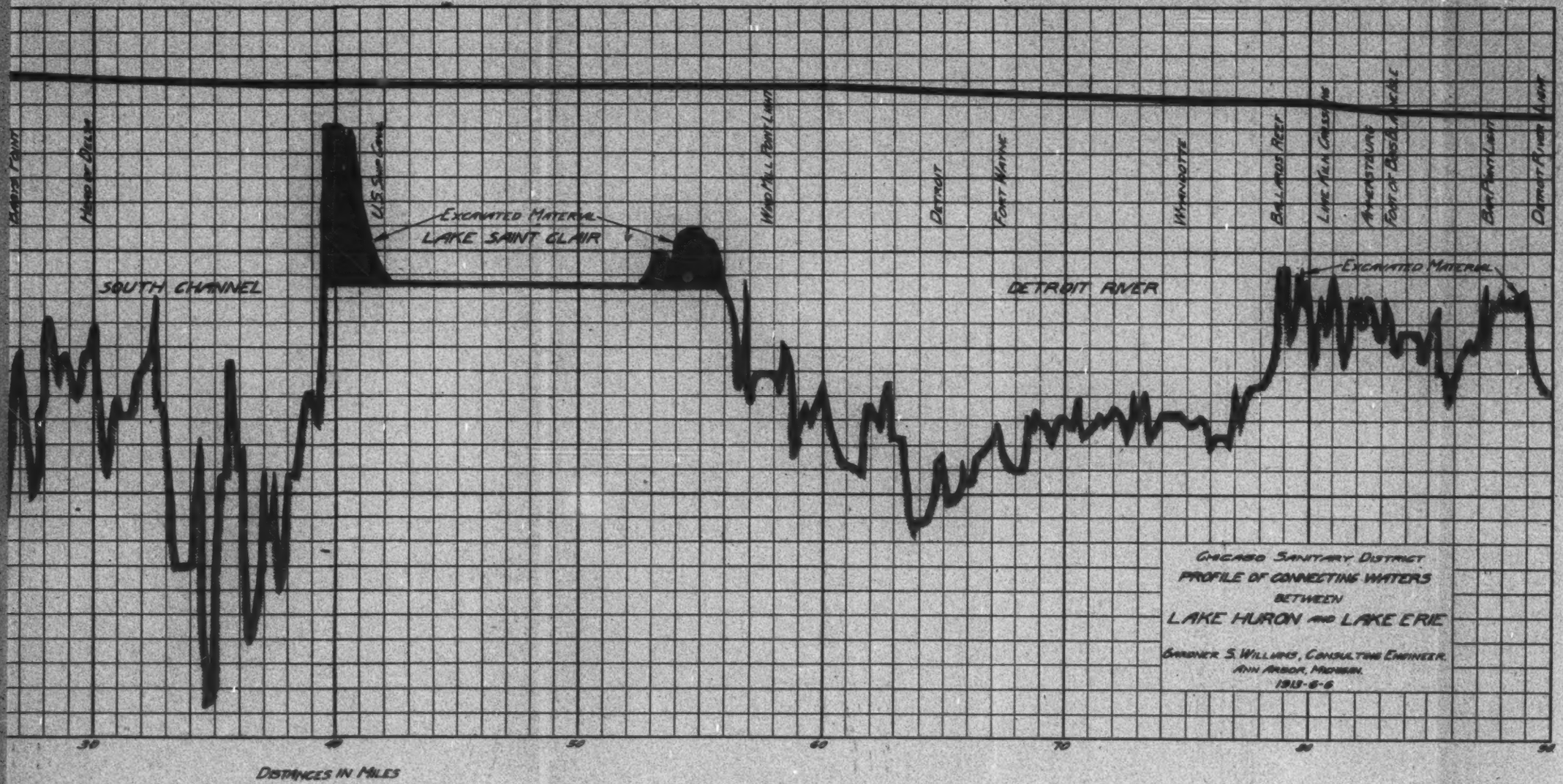


Plate X.

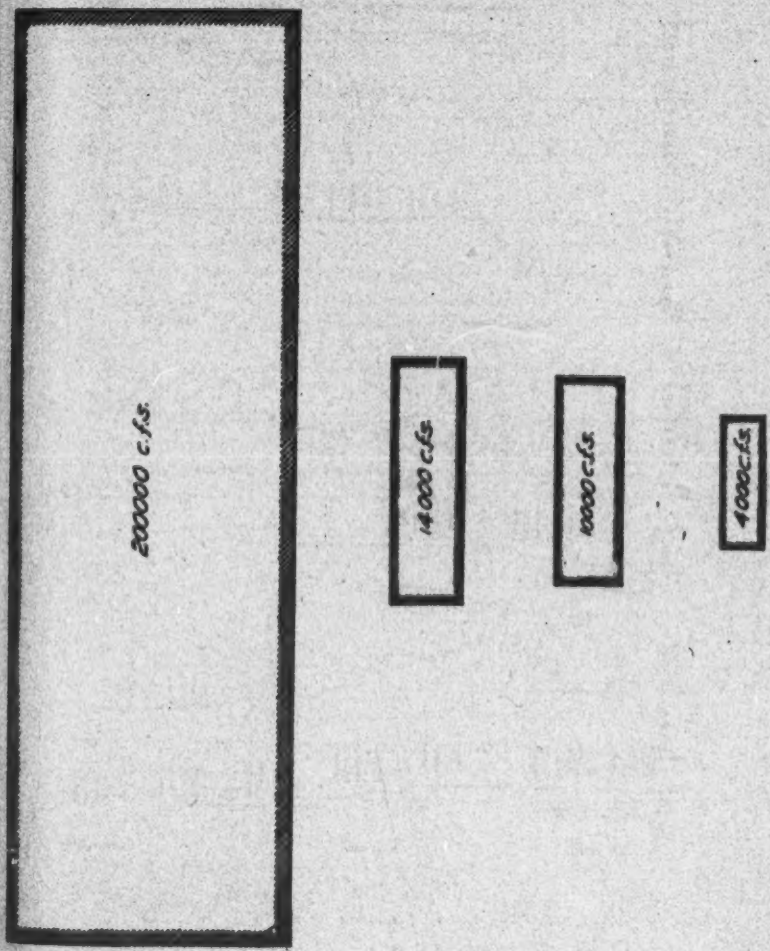


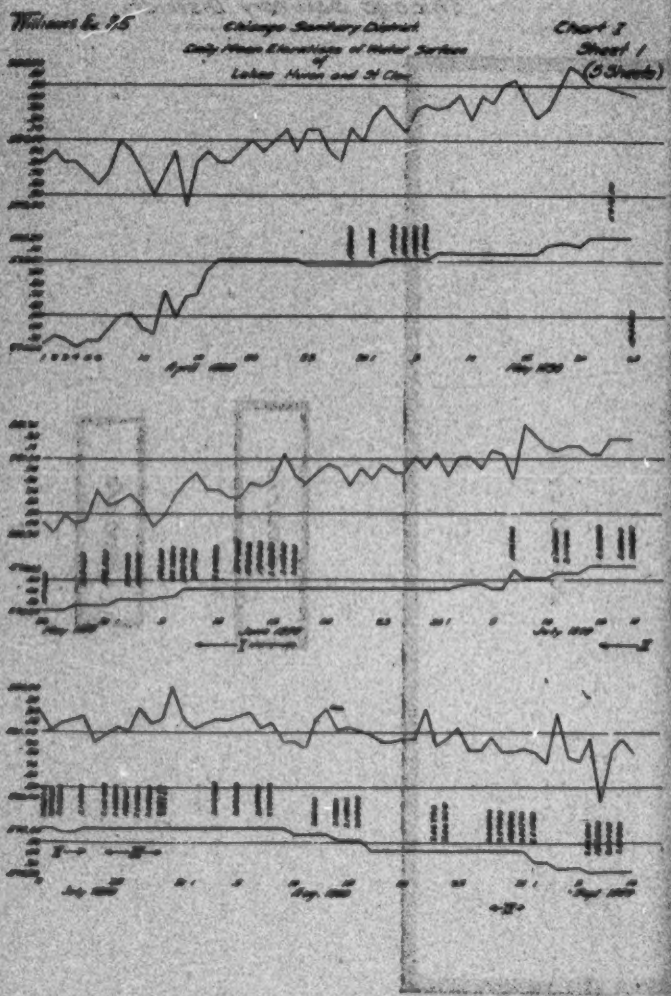
Chicago Sanitary District
PROFILE OF CONNECTING WATERS
BETWEEN
LAKE HURON AND LAKE ERIE

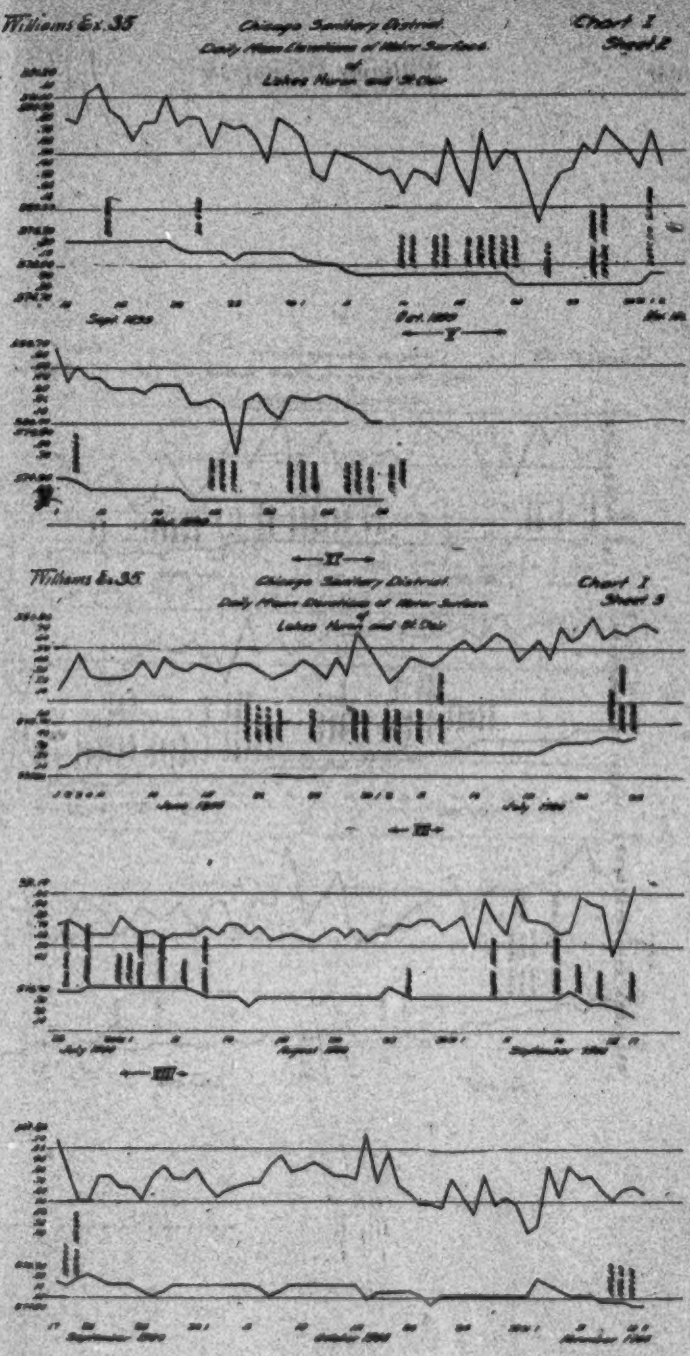
Gardner S. Williams, Consulting Engineer.
Ann Arbor, Michigan.
1913-6-6

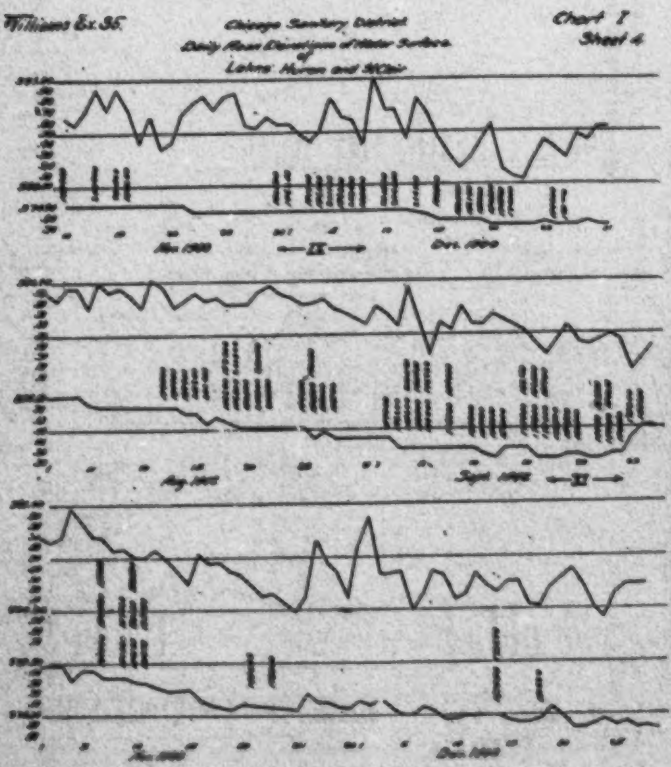
Plate XI

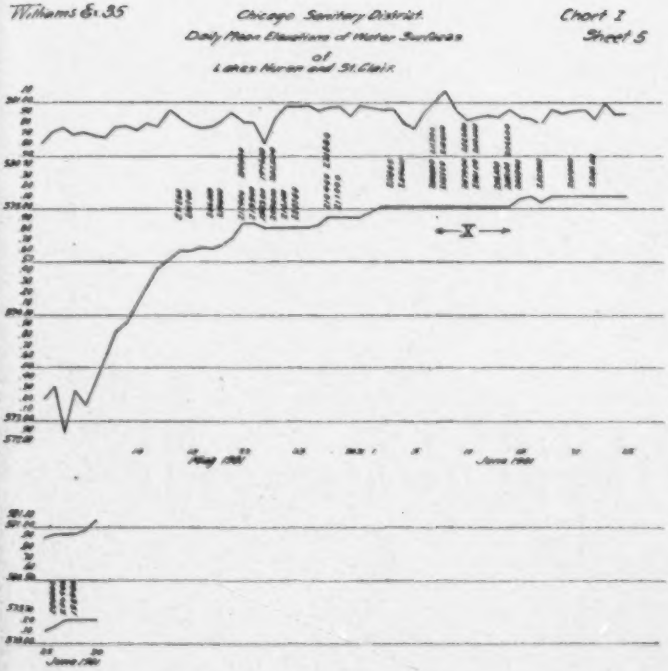
Chicago Sanitary District

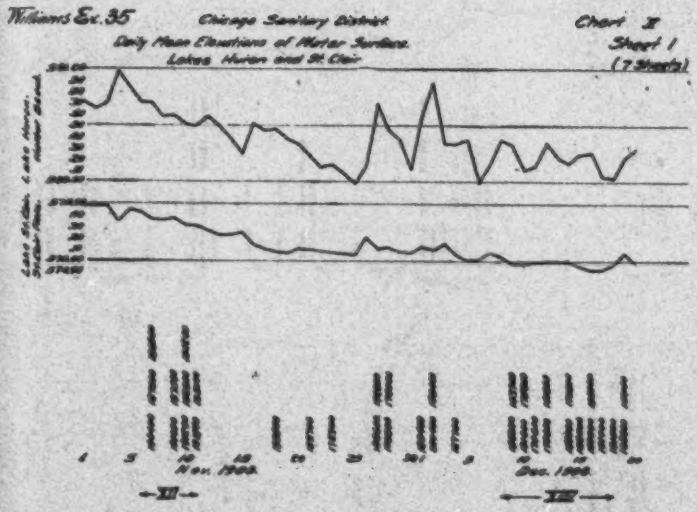


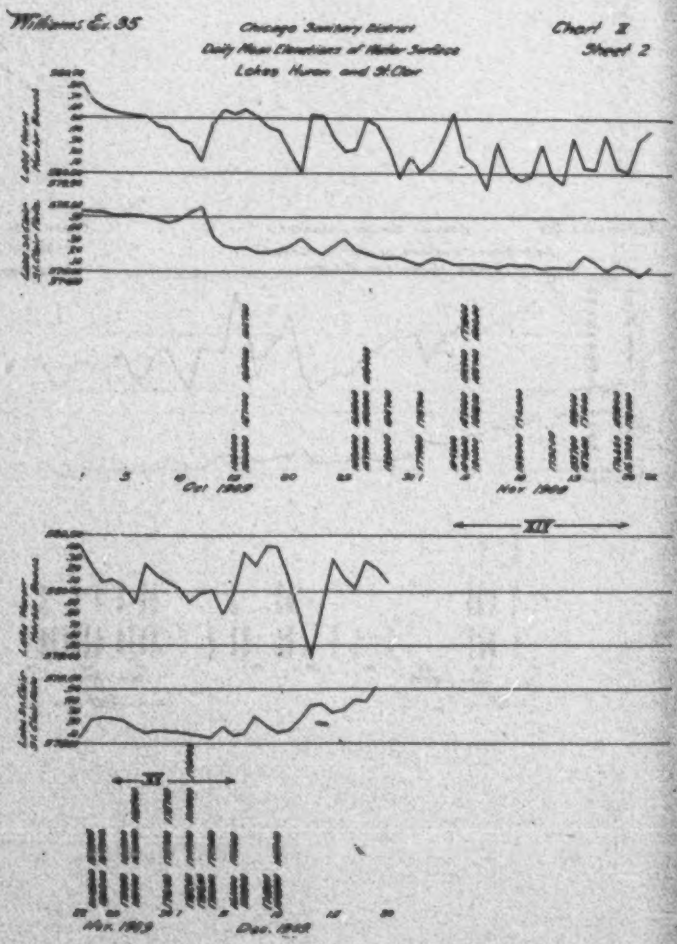

Williams Ex. 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface
of
Lakes Huron and St Clair
Chart I
Sheet 1
(3 Sheets)

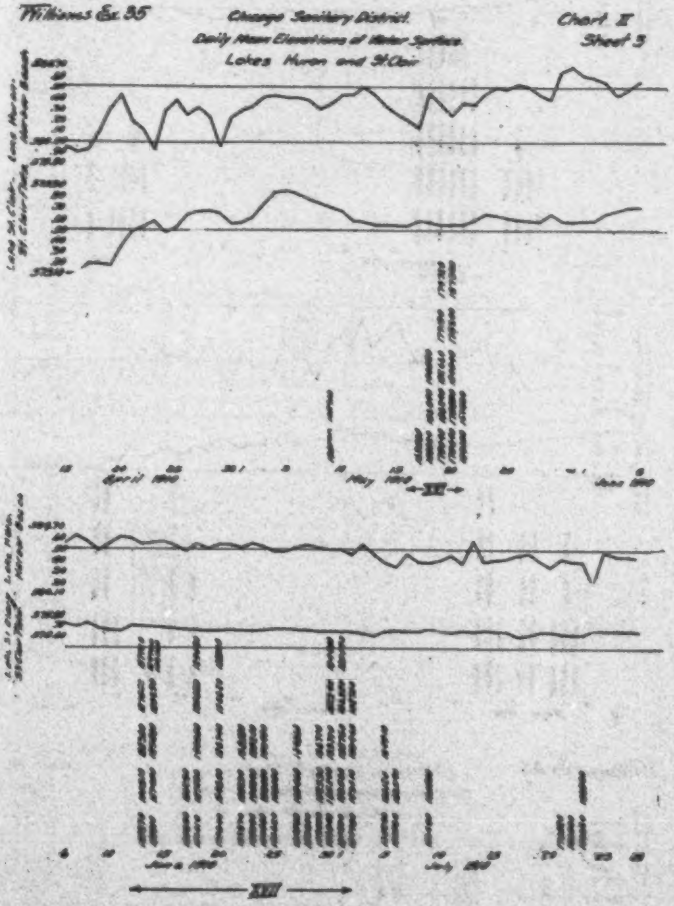

Williams Ex. 35
Chicago Sanitary District
Chart I
Sheet 2
Lakes Huron and St Clair
Williams Ex. 35
Chicago Sanitary District
Chart I
Sheet 3
Lakes Huron and St Clair

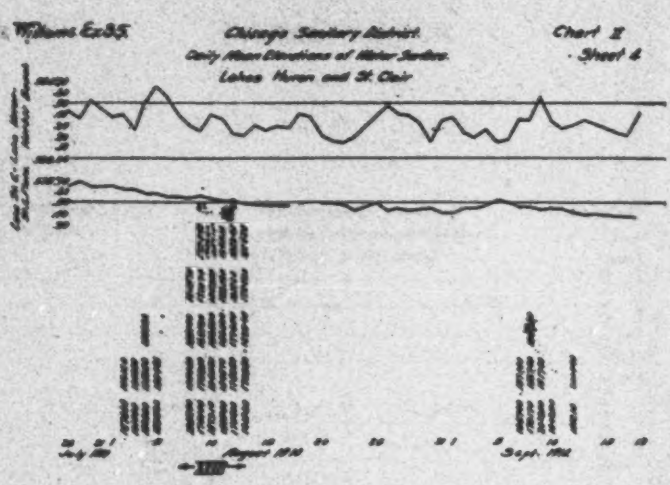

Williams Ex. 35.
Chicago Sanitary District
Chart 1
Sheet 4
of
Lakes Huron and Michigan

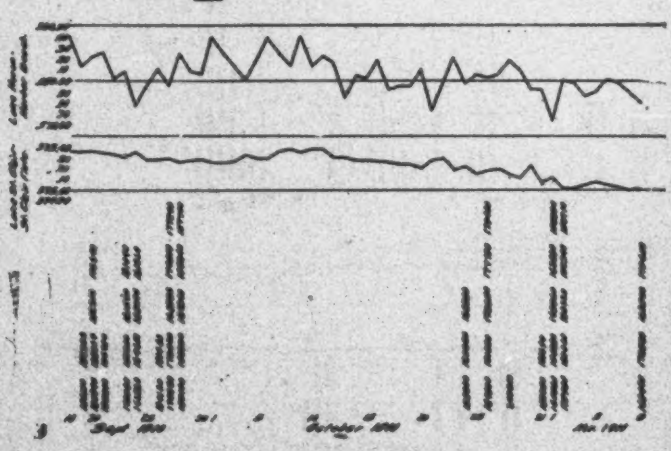

Williams Ex. 35
Chicago Sanitary District
Daily Mean Elevations of Water Surfaces
of
Lakes Huron and St. Clair
Chart 1
Sheet 5
X
May 1911
June 1911
June 1911

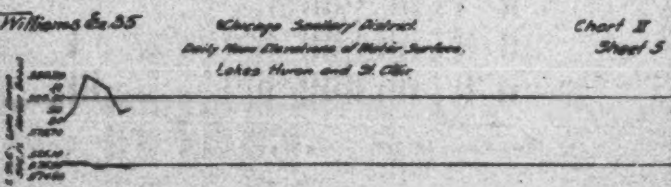

Williams Ex. 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface.
Lakes Huron and St. Clair
Chart X
Sheet 1
(7 Sheets)
Nov. 1900.
Dec. 1900.
XII
XIII

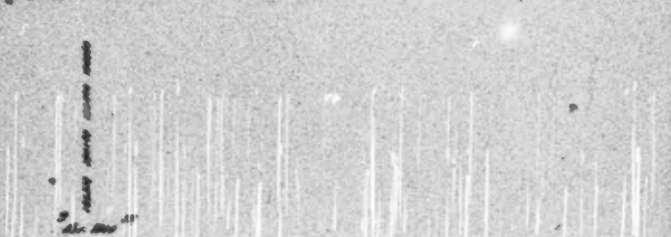

Williams Ex. 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface
Lakes Huron and St. Clair
Chart X
Sheet 2
Oct. 1909
Nov. 1909
XII
XII
Nov. 1909
Dec. 1909

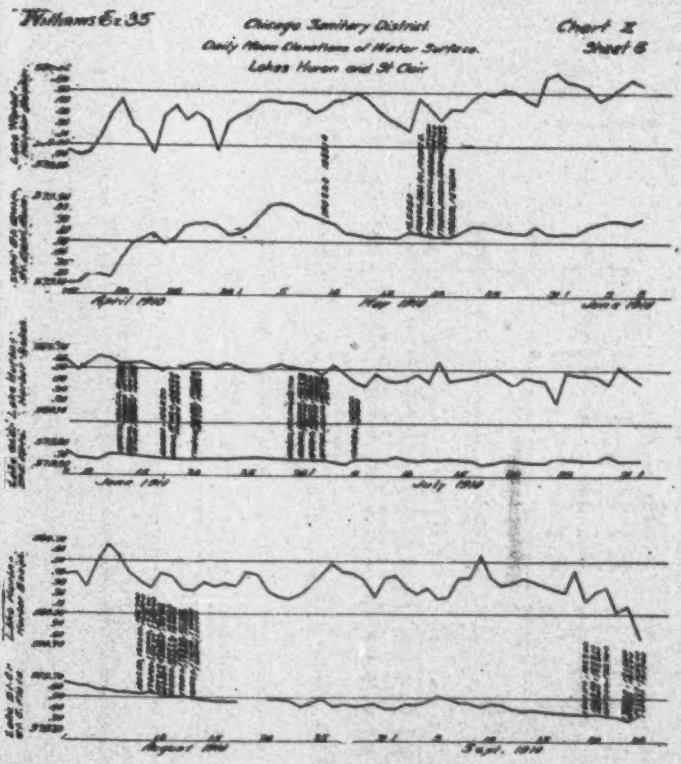

Williams Ex. 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface
Lakes Huron and St. Clair
Chart II
Sheet 3
XII
XIII


Williams Ex 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface
Lakes Huron and St. Clair
Chart II
Sheet 4




Williams Ex 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface
Lakes Huron and St. Clair
Chart II
Sheet 5




Williams Ex 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface.
Lakes Huron and St Clair
Chart II
Sheet 6
April 1910
May 1910
June 1910
June 1910
July 1910
August 1910
Sept. 1910
Williams Ex 35
Chicago Sanitary District
Daily Mean Elevations of Water Surface.
Lakes Huron and St Clair
Chart II
Sheet 7
Sept 1910
October 1910

Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Cleveland
Chart III
Sheet 1
(4 Sheets)
III
II
I
II
III
Sept 1838
Nov 1838
Dec 1838
July 1838
Aug 1838
Sept 1838
Oct 1838
July 1838
Aug 1838
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
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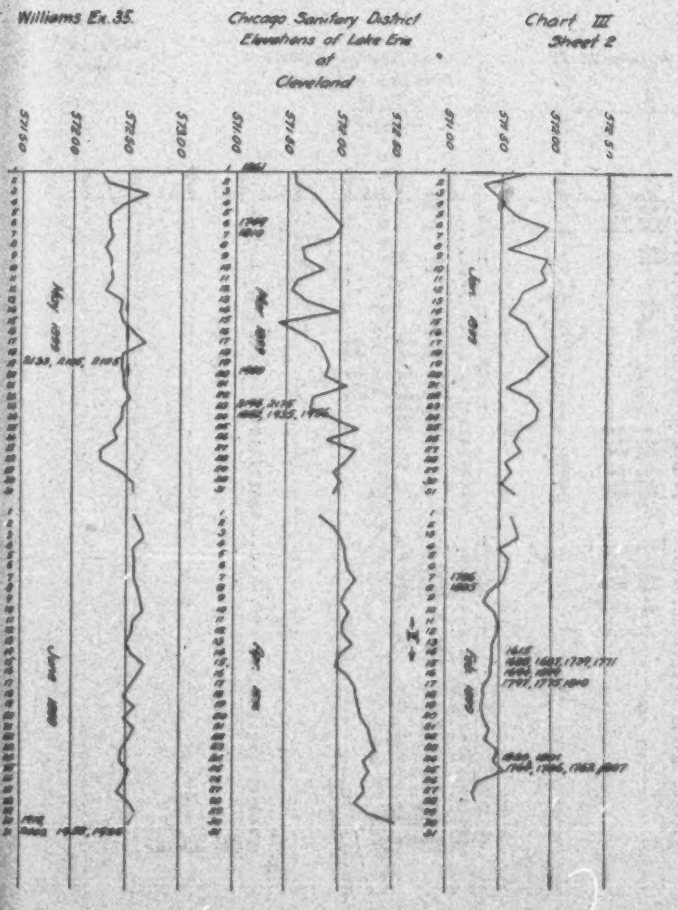
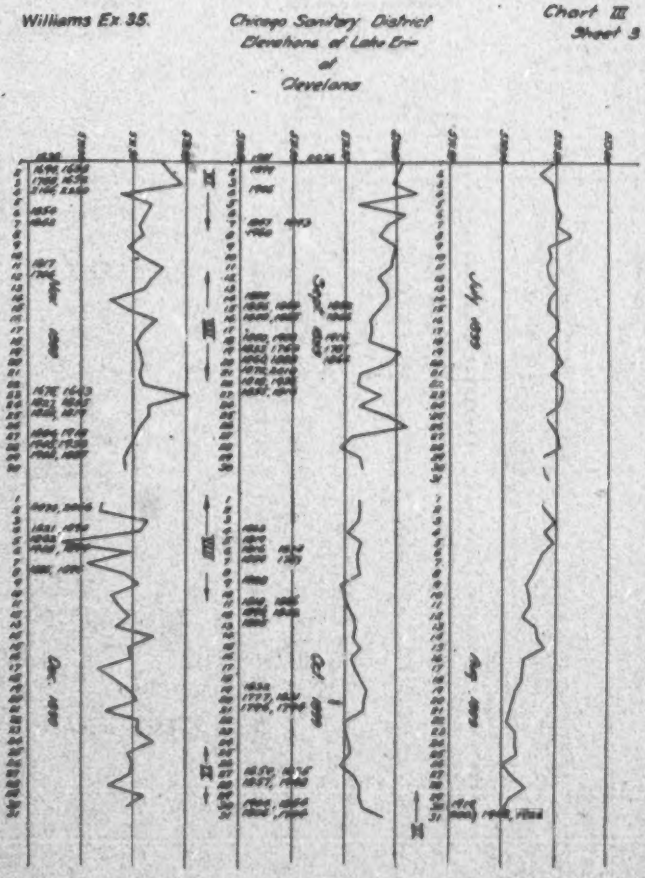
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972


Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Cleveland
Chart III
Sheet 2
574.0
573.0
572.0
571.0
570.0
569.0
568.0
567.0
566.0
565.0


Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Cleveland
Chart III
Sheet 3

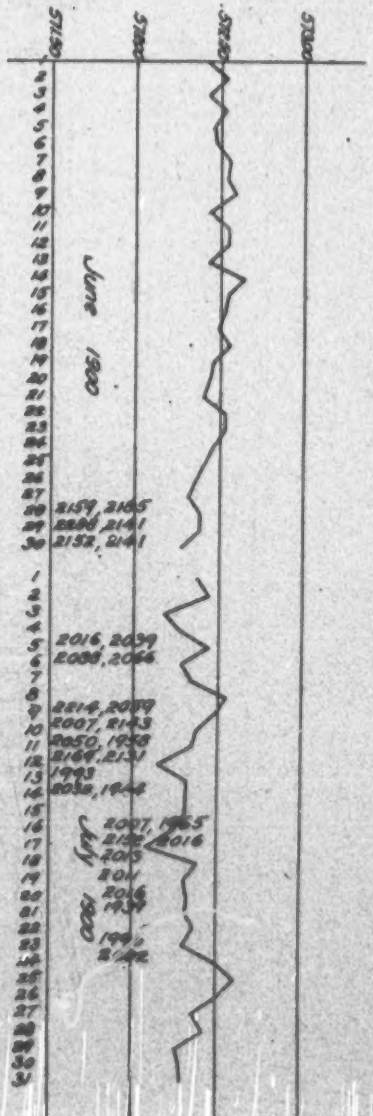
Williams Exhibit 35.

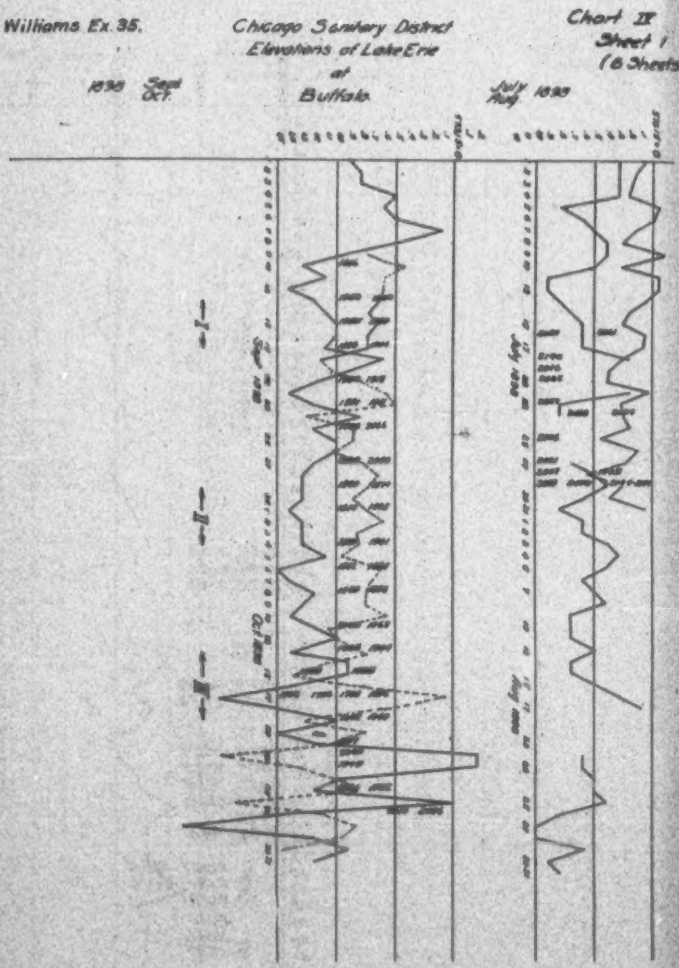
Chicago Sanitary District

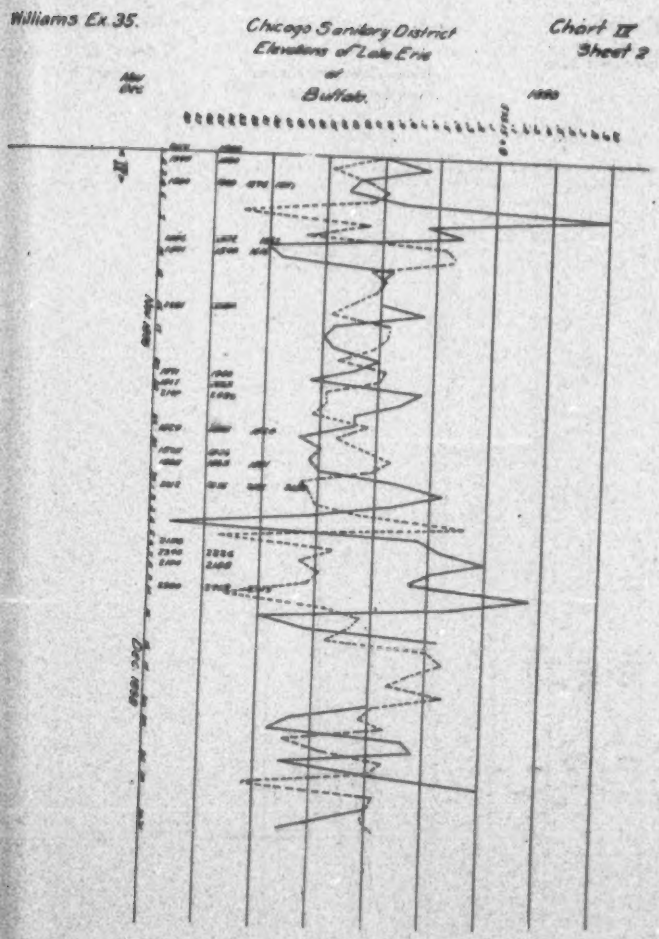
Williams Ex. 35. Elevations of Lake Erie at Cleveland

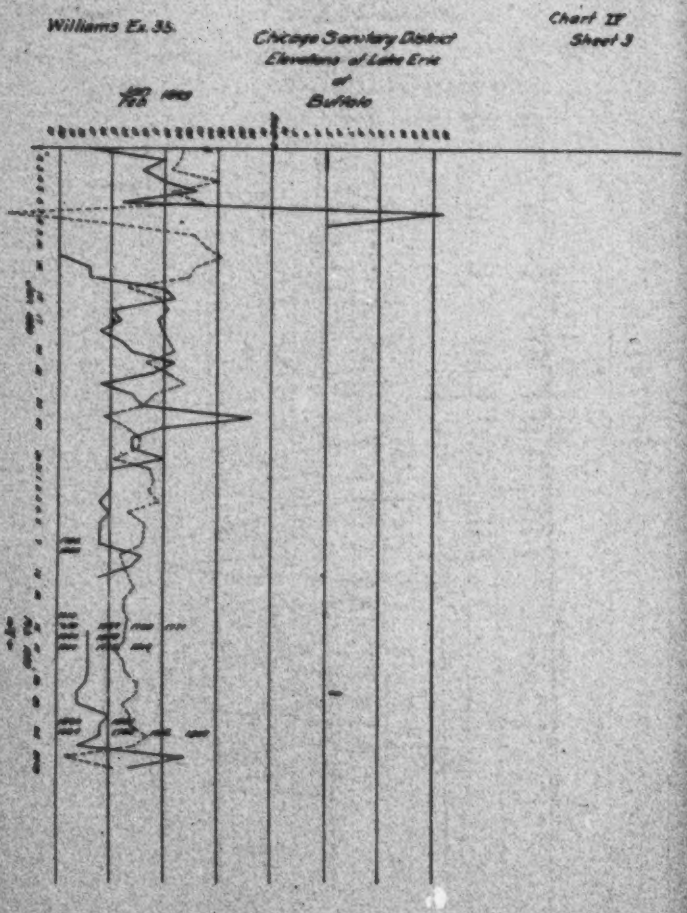
Chart III

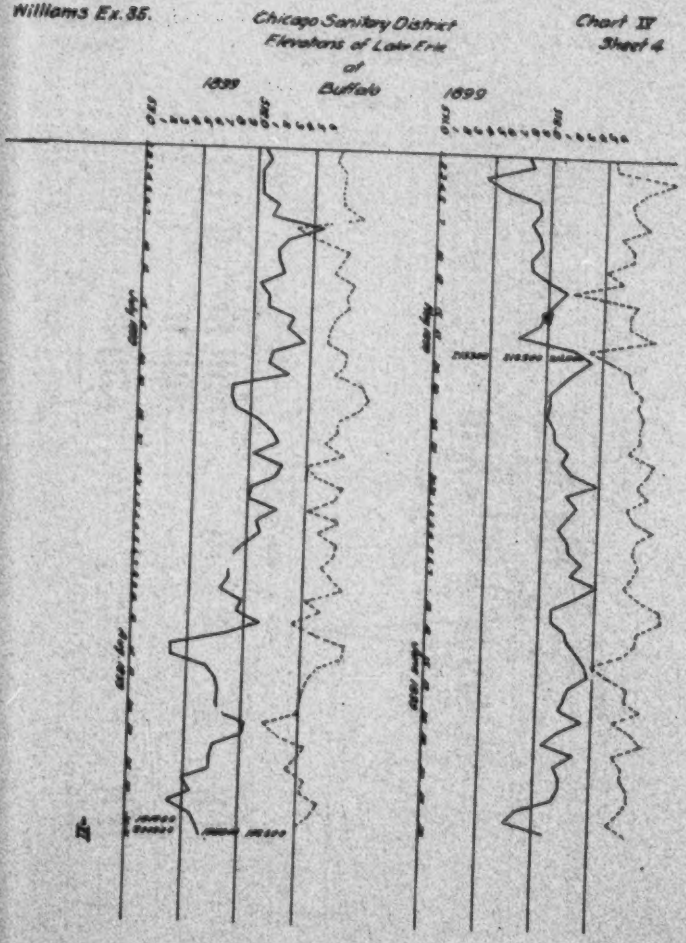
Sheet 4

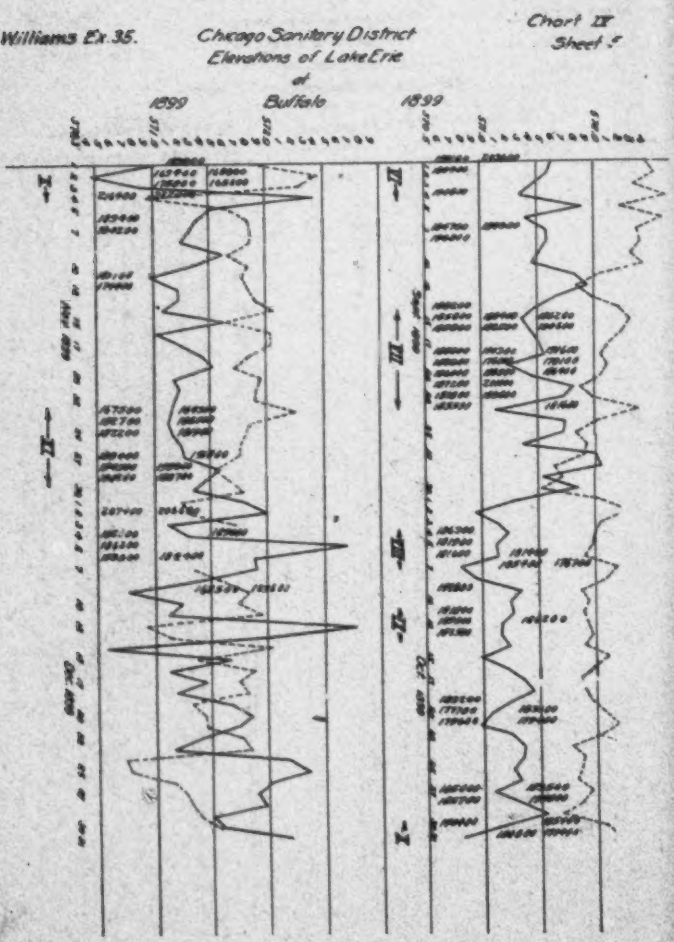


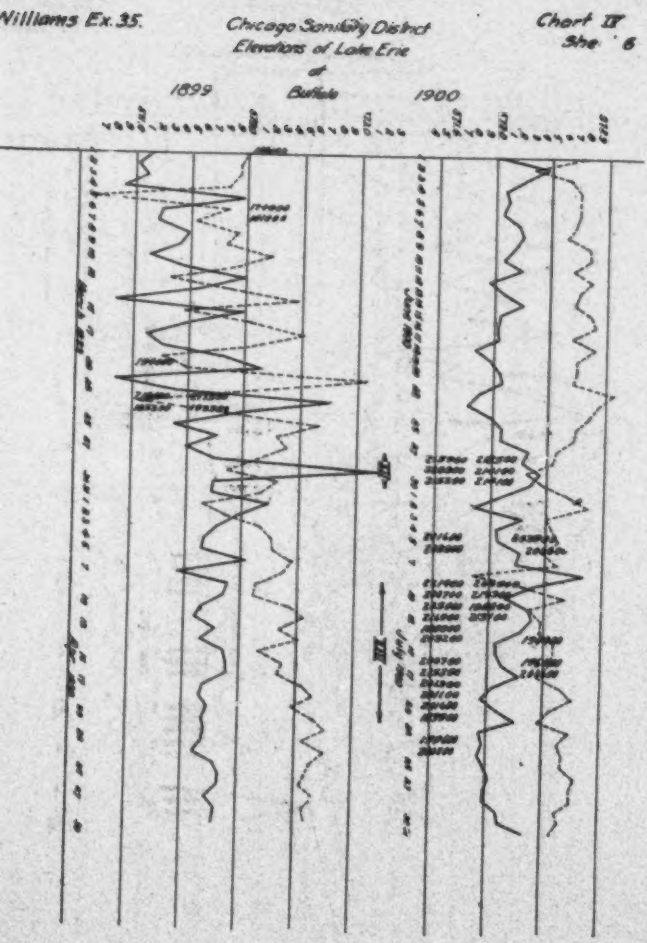

Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Buffalo.
Chart II
Sheet 1
(6 Sheets)
1896 Sept Oct.
July Aug. 1899
I
II
III


Williams Ex 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Buffalo.
Chart II
Sheet 2


Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Buffalo
Chart II
Sheet 3


Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Buffalo
Chart IV
Sheet 4
1839
1899

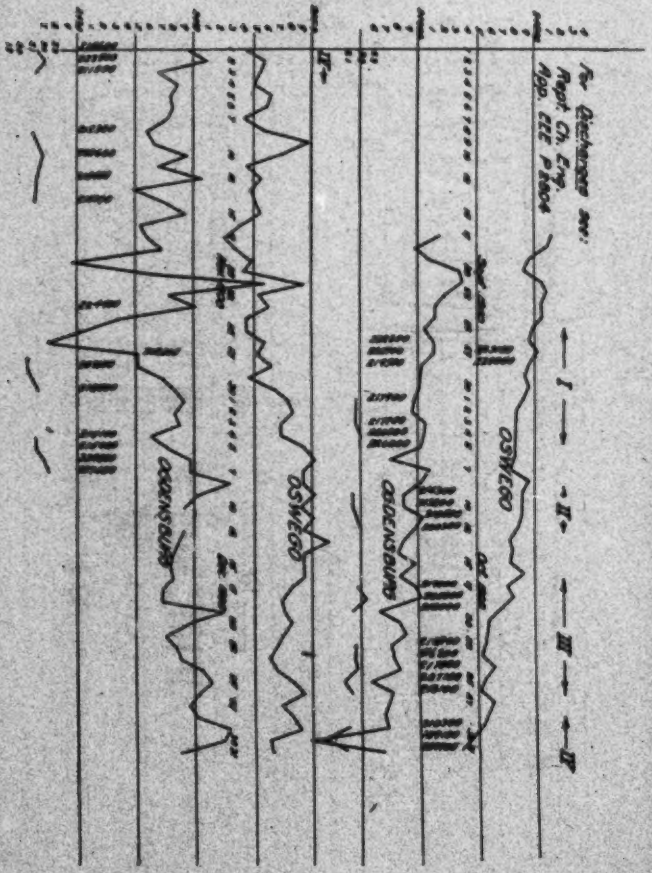

Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Buffalo
1899
1899
Chart IX
Sheet 5

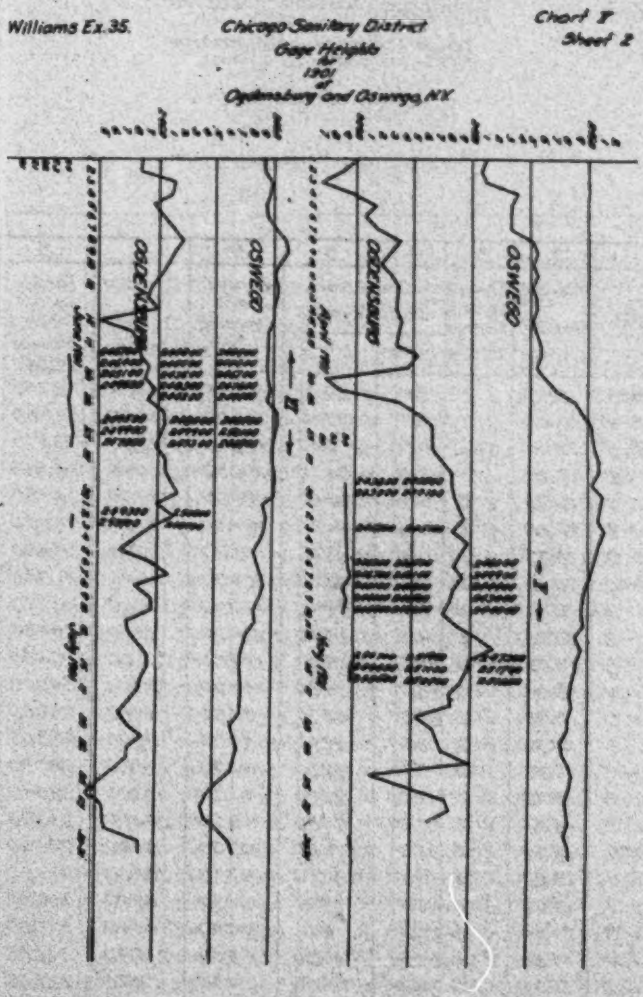

Williams Ex. 35.
Chicago Sanitary District
Elevations of Lake Erie
at
Buffalo
Chart II
Sheet 6
1899
1900

Williams Ex. 35.

The Chicago Sanitary District
Gage Heights
at
Oswego and Oswego, N.Y.

Chart I
Sheet 1
(2 Sheets)




Williams Ex. 35.
Chicago Sanitary District
Gage Heights
for
1901
at
Oakwood and Oswego, N.Y.
Chart I
Sheet 2
OSWEGO
OSWEGO
OSWEGO

Steam's Exhibit 9,
Table A

Chicago Sanitary District
Local Supply and Storage
Lake Ontario

June - Nov. 1883 - 1906

1	2	3	4	5	6	7	8
Year	Rainfall Ontario Inches	Evaporation Ontario Inches	Excess of Evaporation Inches	Excess of Evaporation C.F.S.	Runoff into Ontario C.F.S.	Storage Ontario C.F.S.	Total Local Supply & Storage C.F.S.
1883	18.96	21.8	+2.82	+ 3010	-13100	- 6660	-18750
4	16.43	21.8	+5.37	+ 5740	-13100	-24600	-31960
5	22.36	21.8	-0.56	- 597	-17800	- 1280	-19670
6	18.89	21.8	+2.91	+ 3110	-15050	-26640	-38580
7	15.36	21.8	+6.44	+ 6860	-12200	-29440	-34780
8	20.68	21.8	+1.12	+ 1195	-16450	-10760	-26000
9	23.75	21.8	-3.95	- 4215	-20500	-13080	-37800
1890	26.32	21.8	-4.52	- 4820	-20900	-13640	-41360
1	18.78	21.8	+3.02	+ 3240	-14950	-33360	-45270
2	23.20	21.8	-1.40	- 1490	-18450	- 3460	-23400
3	19.08	21.8	+2.72	+ 2905	-13200	-25100	-37400
4	18.54	21.8	+3.26	+ 3480	-14750	-22800	-34070
5	15.93	21.8	+5.87	+ 6270	-12680	-19480	-25900
6	18.76	21.8	+3.04	+ 3245	-14900	-18200	-29860
7	17.82	21.8	+3.98	+ 4250	-14200	-13380	-23330
8	19.72	21.8	+2.08	+ 2220	-15700	-15360	-28840
9	14.51	21.8	+7.29	+ 7780	-11550	-20620	-24390
1900	19.74	21.8	+2.06	+ 2200	-15700	-16000	-29500
1	18.03	21.8	+3.77	+ 4020	-14350	-20860	-31190
2	21.03	21.8	+0.77	+ 822	-16750	- 6920	-22830
3	21.04	21.8	+0.76	+ 811	-16750	-16140	-32080
4	17.88	21.8	+3.92	+ 4180	-14200	-21240	-31260
5	21.56	21.8	+0.24	+ 256	-17150	- 3620	-22500
6	21.20	21.8	+0.54	+ 576	-16900	- 9480	-25800

Chicago Sanitary District Stearns Exhibit
Local Supply and Storage Table B
Lakes St. Clair and Erie

June - Nov. 1883 - 1906

1	2	3	4	5	6	7	8
Year	Rainfall St. Clair Erie Inches	Evaporation St. Clair Erie Inches	Excess of Evaporation Inches	Excess of Evaporation C.F.S.	Runoff St. Clair and Erie C.F.S.	Storage St. Clair and Erie C.F.S.	Total Local Supply & Storage C.F.S.
1883	20.90	24.4	+3.50	+ 5400	- 18600	- 9400	- 22600
4	14.78	24.4	+9.62	+14800	- 13160	- 29540	- 27900
5	22.57	24.4	+ 1.83	+ 2800	- 20060	- 3140	- 20400
6	17.06	24.4	+7.34	+11300	- 15200	- 17900	- 21800
7	14.87	24.4	+9.53	+14650	- 13240	- 29510	- 28100
8	16.38	24.4	+8.02	+12320	- 14590	- 12730	- 15000
9	14.91	24.4	+9.49	+14600	- 13300	- 15700	- 14400
1890	20.06	24.4	+4.34	+ 6680	- 17900	- 21080	- 32300
1	18.47	24.4	+5.93	+ 9130	- 16430	- 23100	- 30400
2	19.95	24.4	+4.45	+ 6850	- 17760	- 21790	- 32700
3	13.84	24.4	+8.56	+13180	- 14110	- 29170	- 30100
4	14.02	24.4	+10.38	+13930	- 12300	- 19050	- 15800
5	14.93	24.4	+9.47	+14380	- 13300	- 13480	- 12200
6	21.56	24.4	+2.84	+ 4370	- 19210	- 12760	- 27600
7	17.45	24.4	+6.95	+10690	- 15540	- 18850	- 23700
8	19.98	24.4	+4.42	+ 6810	- 17790	- 21420	- 32400
9	14.01	24.4	+10.39	+16040	- 12490	- 18650	- 15100
1900	19.50	24.4	+4.90	+ 7540	- 17370	- 17170	- 27000
1	15.79	24.4	+8.61	+13250	- 14050	- 5900	- 6700
2	23.57	24.4	+0.83	+ 1260	- 21000	- 1260	- 21000
3	19.79	24.4	+4.61	+ 7100	- 17620	- 27380	- 37900
4	14.89	24.4	+9.55	+14700	- 13240	- 23560	- 22100
5	21.08	24.4	+3.32	+5100	- 18800	- 14600	- 28300
6	20.78	24.4	+3.62	+ 5570	- 18500	- 3870	- 16800

Stearns Exhibit 1
Table C

Chicago Sanitary District

Comparison of Discharges
Niagara River
June - Nov. 1883-1900

Comparison of Niagara River Discharge as deduced from St. Lawrence River with Tabulated Discharge, using at both places the Discharge of the International Waterways Comm.

1	2	3	4	5	6	7
Year	St. Lawrence River Discharge I.W.W.C. C.F.S.	Total Local Supply Lake Ontario C.F.S.	Deduced Niagara Discharge C.F.S.	Niagara Discharge I.W.W.C C.F.S.	Col. 4 minus Col. 3	
1883	296100	18700	277400	239700	37700	
4	297000	32000	265000	231800	33200	
5	285200	19700	265500	241200	24300	
6	287500	38600	248900	235300	13600	
7	279100	34800	244300	230600	13700	
8	230000	26000	224000	216300	7700	
9	261900	37800	224100	209700	14400	
1890	290900	41400	249500	225200	24300	
1	243300	43300	200000	199100	900	
2	245800	23400	222400	215700	6700	
3	272100	37400	234700	210000	24700	
4	230100	34100	216000	205600	10400	
5	195200	25900	169300	181700	-12400	
6	203000	29900	173100	189600	-16500	
7	217700	23300	194200	200400	-6200	
8	234800	28800	226000	202700	23300	
9	237500	24400	213400	196400	17300	
1900	234200	29300	204700	199200	5500	
1	235700	31900	204500	188800	15700	
2	243000	22800	220700	206900	13300	
3	235900	32100	223800	209800	14000	
4	273900	31300	242600	218800	23800	
5	263200	22500	240700	216000	24700	
6	244700	25800	218900	205400	13500	

Average excluding years 1895-96 16390

Stearns Exhibit 7.
Table D

Chicago Sanitary District
Comparison of Discharges
Niagara River
June - Nov. 1883 - 1908

Comparison of Niagara River Discharge as deduced from St. Lawrence River with Tabulated Discharge, using for St. Lawrence Defendant's Equation, for Niagara International Waterways Comm.

1	2	3	4	5	6
Year	St. Lawrence River Discharge Defendant's Equation C.F.S.	Total Local Supply Stmr. Ontario C.F.S.	Deduced, Niagara Discharge C.F.S.	Niagara Discharge I.W.W.C. C.F.S.	Col. 4 minus Col. 5 C.F.S.
1883	296500	- 18700	277800	239700	38100
4	296900	- 32000	264900	231800	33100
5	293700	- 19700	274000	241200	32800
6	298800	- 38600	260200	233300	26900
7	287600	- 34800	252800	230600	22200
8	252800	- 28000	226800	216300	10500
9	258600	- 37800	220800	209700	11100
1890	292100	- 41400	250700	225200	25500
1	247700	- 43300	202400	199100	3300
2	249300	- 23400	225900	215700	10200
3	267500	- 37400	230100	210000	20100
4	230300	- 34100	216200	205600	10600
5	199200	- 25900	173300	181700	- 8400*
6	214800	- 29900	184900	189600	- 4700*
7	228600	- 23500	205100	200400	4700
8	236200	- 28800	207400	202700	4700
9	231400	- 24400	207000	196400	10600
1900	231800	- 29300	202300	199200	3100
1	229500	- 31200	198300	188800	9500
2	242900	- 22800	220100	204900	15200
3	255100	- 32100	223000	209800	13200
4	282400	- 31300	251100	218800	42300*
5	272300	- 22900	249800	216000	33800*
6	234100	- 25800	228300	205400	27900*
				Mean	16070

* Defective due to low stages of lakes in 1895-98 and to Cut Dam in 1904-5-6 and therefore omitted from mean.

Stearns Exhibit 1.
Table E

Chicago Sanitary District
Comparison of Discharges
St. Clair River
June-Nov. 1883-1906

Comparison of St. Clair River Discharges as deduced from Niagara River with Computed Discharge, Using International Waterways Comm. Niagara Discharge, Complainant's Equation St. Clair River

1	2	3	4	5	6	7
Year	Niagara Discharge I.W.W.C. C.F.S.	Total Local Supply and Storage St. Clair Erie C.F.S.	Deduced St. Clair Discharge C.F.S.	St. Clair Discharge Complainant's Equation C.F.S.	Col. 5 minus Col. 4 C.F.S.	
1883	239700	-22600	217100	249400	32300	
4	231800	-27900	203900	245800	41900	
5	241200	-20400	220800	253400	32600	
6	233300	-21800	211500	254800	43300	
7	230600	-28100	202500	237200	34700	
8	216500	-13000	201300	227400	26100	
9	209700	-14400	195300	212700	17400	
1890	225200	-32300	192900	212200	19300	
1	199100	-30400	168700	192200	23500	
2	213700	-32700	183000	195800	12800	
3	210000	-30100	179900	201200	21300	
4	205600	-13600	190000	203100	13100	
5	181700	-12200	169500	173000	3500	
6	189600	-27600	162000	173400	11400	
7	200400	-23700	176700	190500	13800	
8	202700	-32400	170300	190300	20000	
9	196400	-13100	181300	194800	13500	
1900	199200	-27000	172200	191700	19500	
1	188800	-6700	182100	197900	15800	
2	204900	-21000	183900	189800	5900	
3	209800	-37900	171900	194100	22200	
4	216800	-22100	196700	209900	13200	
5	216000	-28300	187700	210100	22400	
6	205400	-16800	188600	204800	16200	

Stearns Exhibit #1
Table F

Chicago Sanitary District.
Comparison of Discharges
St. Clair River
June - Nov. 1883 - 1906

Comparison of St. Clair River Discharges as deduced from Niagara River with Computed Discharge, using International Waterways Commission Niagara Discharge, Defendant's Equation St. Clair River.

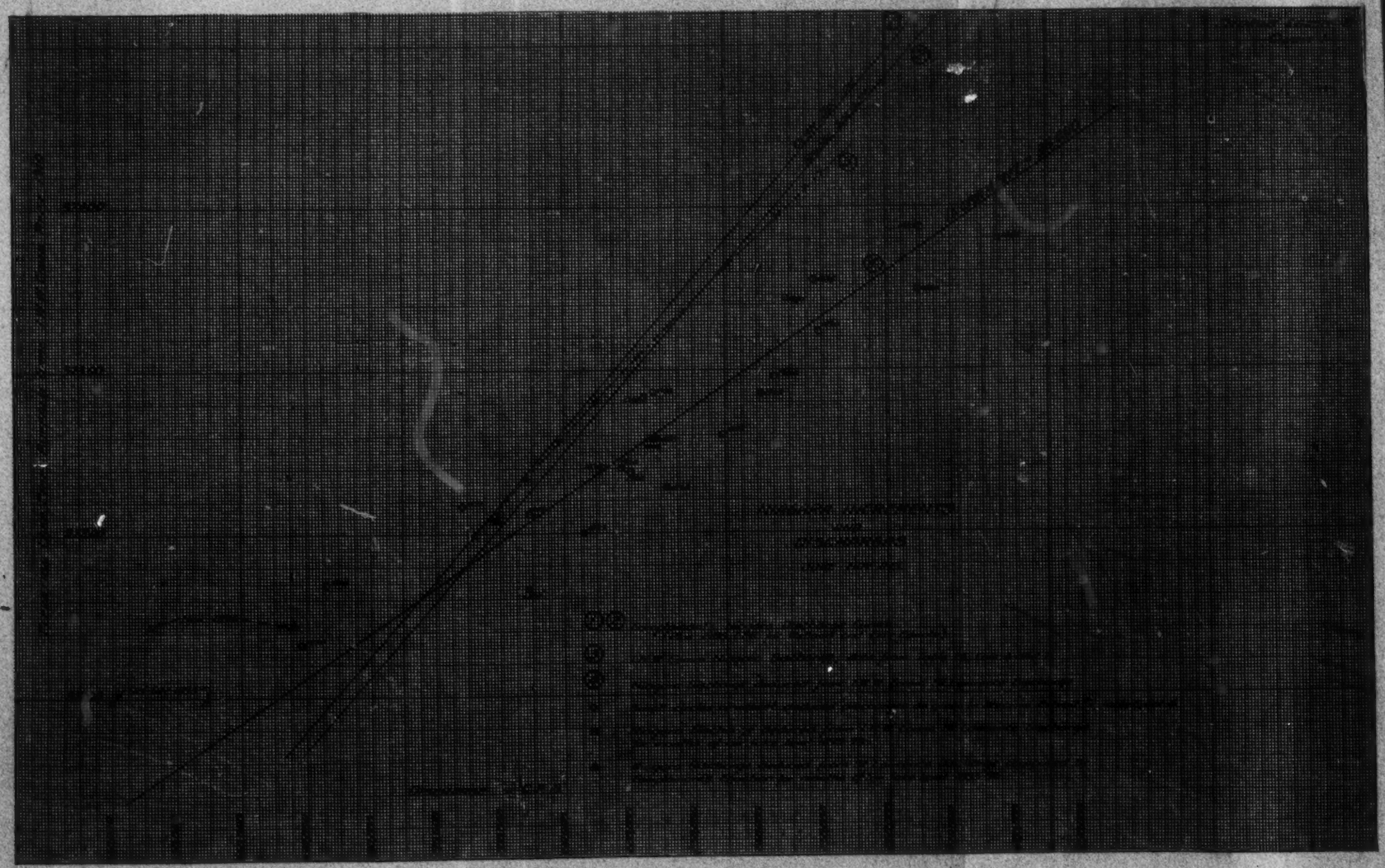
1	2	3	4	5	6	7
Year	Niagara Discharge I.W.W.C. C.F.S.	Total Local Supply and Storage St. Clair Erie C.F.S.	Deduced St. Clair Discharge C.F.S.	St. Clair Discharge Defendant's Equation C.F.S.	Col. 4 minus Col. 5 C.F.S.	Means.
1883	239700	-22600	217100	266600	49500	
4	231800	-27900	203900	264300	60400	
5	241200	-20400	220800	276600	55800	
6	233300	-21800	211500	280700	69200	
7	230600	-28100	202500	235400	32900	
8	216300	-15000	201300	244600	43300	55200
9	209700	-14400	195300	223800	28500	
1890	223200	-32300	192900	219500	26600	
1	199100	-30400	168700	196700	28000	
2	213700	-32700	183000	197400	14400	
3	210000	-30100	179900	206700	26800	
4	205600	-13600	190000	211000	21000	24200
5	181700	-12200	169500	176000	6500*	
6	189600	-27600	162000	169700	7700*	
7	200400	-23700	176700	193200	16500	
8	202700	-32400	170300	191500	21200	
9	196400	-13100	181300	199800	18500	
1900	199200	-27000	172200	195500	23300	
1	188800	- 6700	182100	206700	24600	
2	204900	-21000	183900	189800	5900	
3	209800	-37900	171900	195400	23500	
4	218800	-22100	196700	216000	19300	
5	216000	-28300	187700	218300	30600	
6	205400	-18800	188600	211900	23300	20700

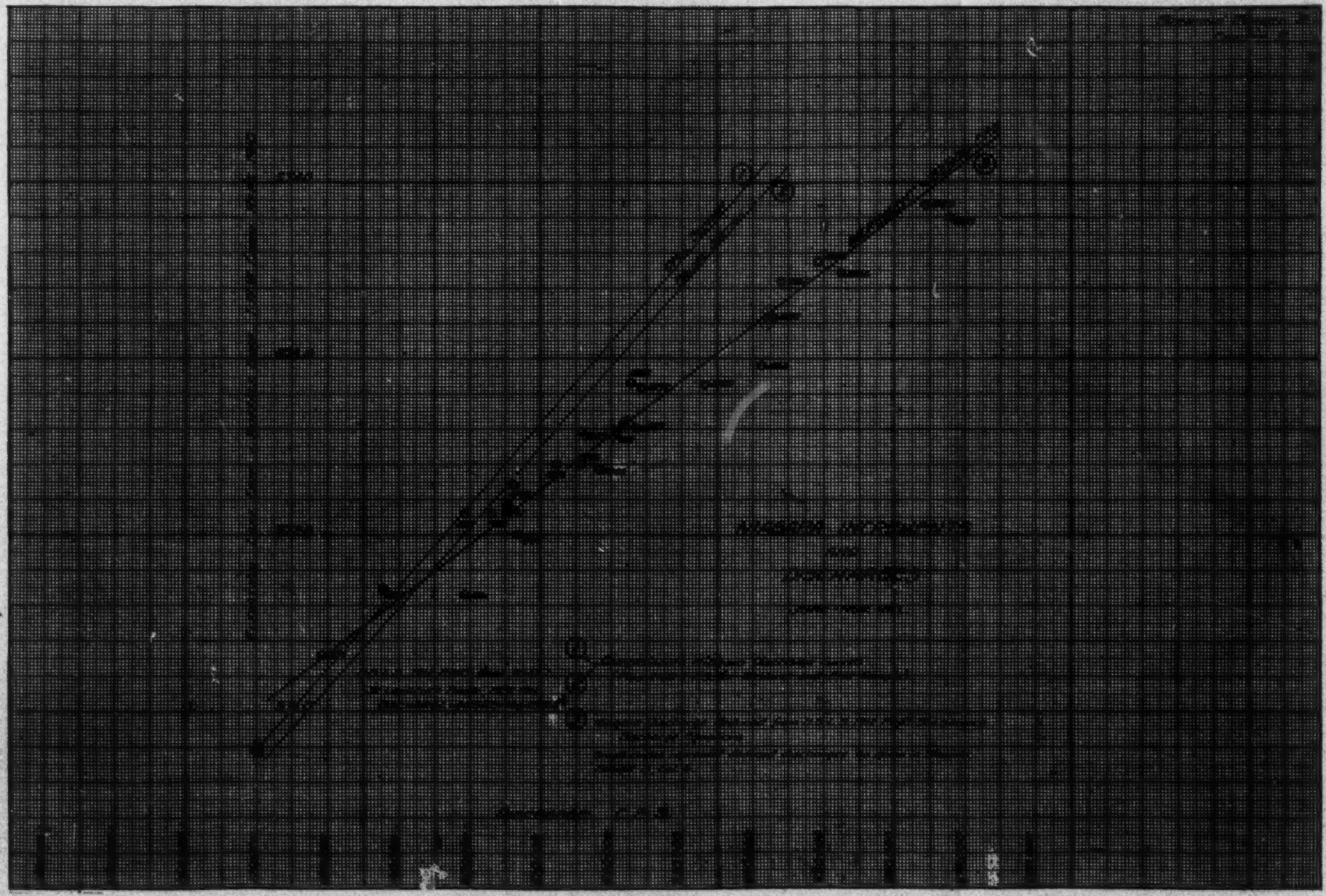
* Defective due to low stage of Lakes.

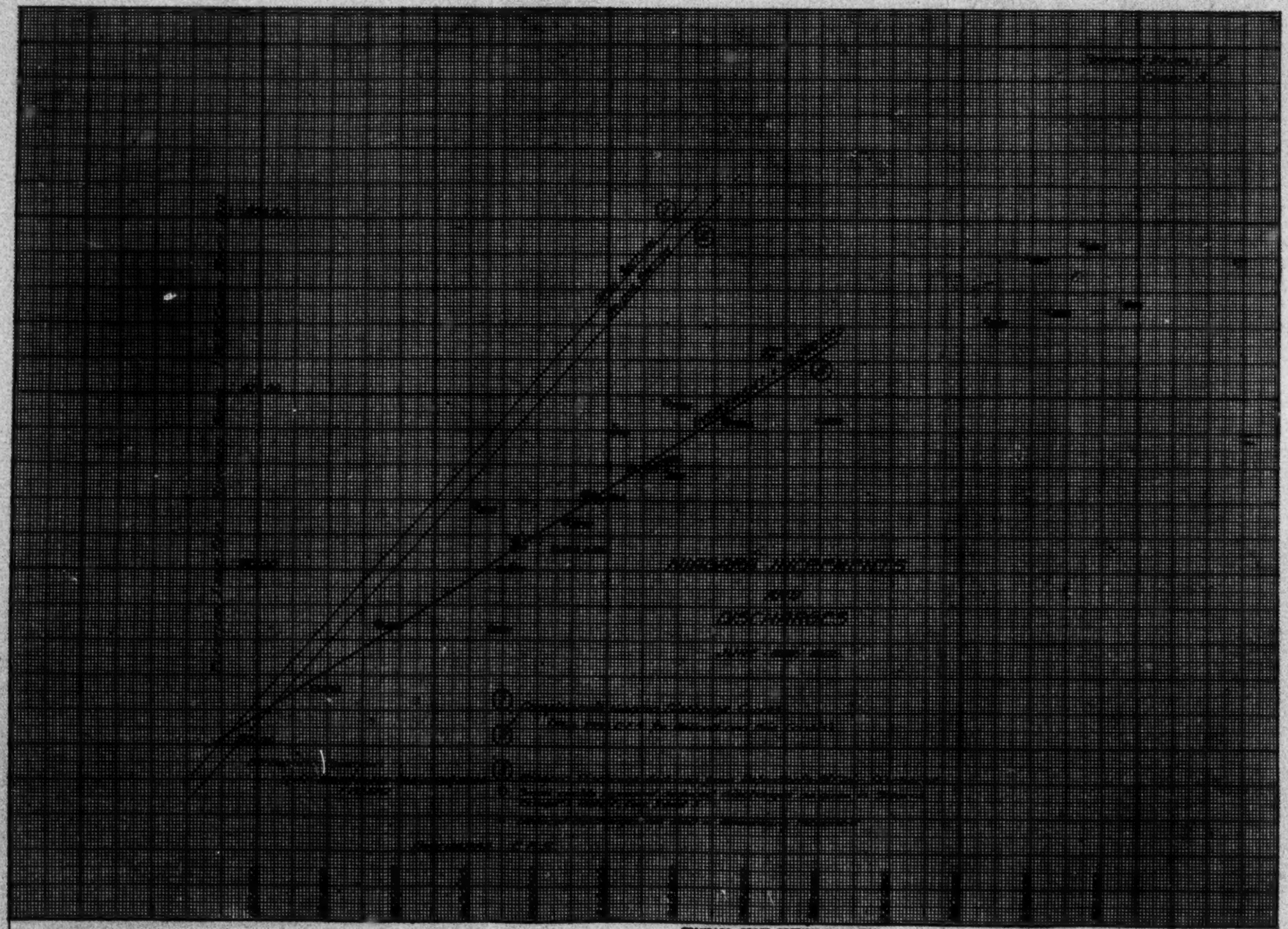
Stearn's Exhibit #1
Table 6
Chicago Sanitary District

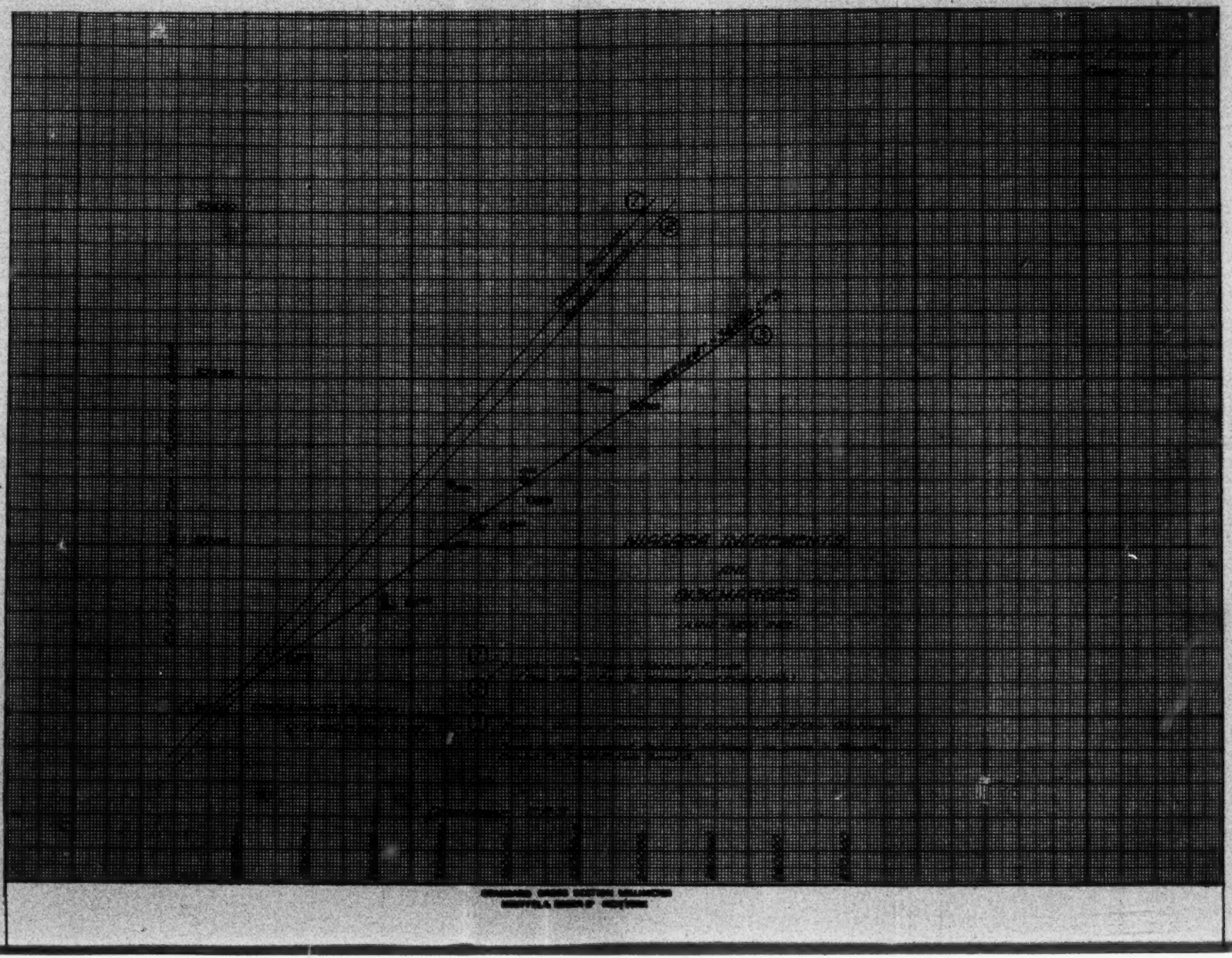
Comparisons of Discharge
St. Lawrence & St. Clair
June - Nov. Incl.

1	2	3	4	5	6	7
Period	Saint Lawrence Defendants Equation c.f.s.	Ontario Supply Old Storage c.f.s.	Erie St. Clair Supply Old Storage c.f.s.	Reduced St. Clair c.f.s.	St. Clair Defendants Equation c.f.s.	Col. 6 less Col. 5 c.f.s.
1883 } 1888 }	287700	-20290	-22630	236800	264700	27900
1889 } 1891 }	266100	-41480	-25700	198900	213300	14400
1892 } 1903 }	236400	-28580	-23500	184300	194400	10100









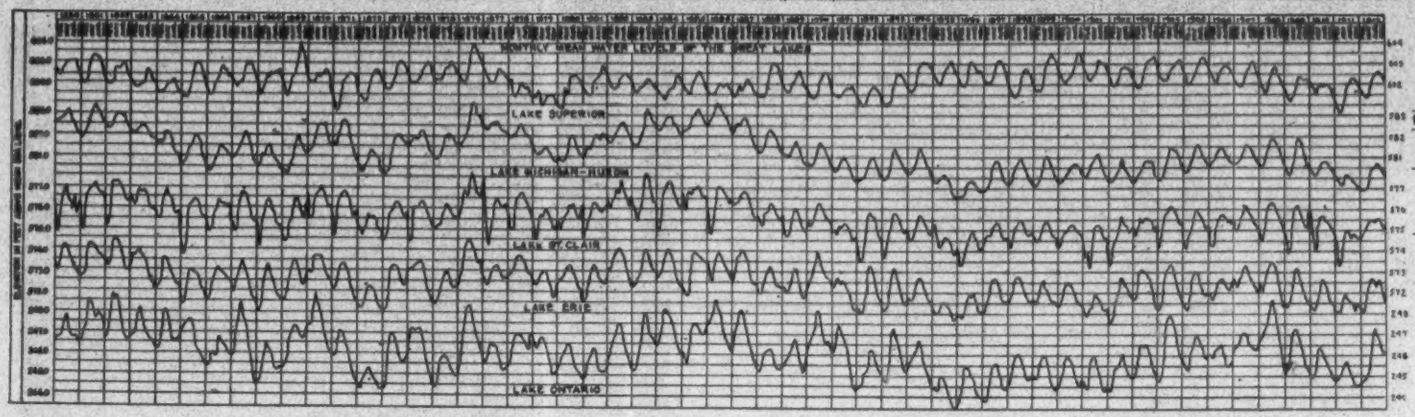
Chicago Sanitary District Stearns' Exhibit #3
Comparison of Discharges
Niagara River
June - Nov. 1883-1906

*St. Lawrence Discharge based on 1912 Discharge Curves prepared by Sherman Moore

1	2	3	4	5*	6	7
June to Nov. Year	Discharge* St Lawrence C.F.S.	Local Supply and Storage Chicago C.F.S.	Deduced Niagara C.F.S	Niagara Discharge Complaint Location C.F.S.	Col. 4 Minus Col. 3 C.F.S.	Buffalo Gage I.W.W. Comm. Ft.
1883	286500	18800	267700	238500	29200	573.80
4	284500	32000	252500	231600	20900	3.49
5	284000	19700	264300	240000	24300	3.87
6	289000	38600	249400	232900	16500	3.55
7	278800	34800	244000	230000	13400	3.44
8	248900	26000	222900	217800	5100	2.86
9	253500	37800	215700	211700	4000	2.58
1890	284200	41400	242800	225900	16900	3.23
1	244600	45300	199300	201600	- 2300	2.12
2	247500	23400	224100	217200	6900	2.83
3	261200	37400	223800	212100	11700	2.60
4	246500	34100	212400	207800	4600	2.40
5	203200	25900	177300	184100	- 4800	1.32
6	217500	29900	187600	192300	- 4700	1.69
7	226900	23500	203400	206100	2700	2.17
8	235000	26800	208200	209300	1100	2.28
9	231200	24400	206800	199000	7800	2.00
1900	232300	29500	203000	201700	1300	2.12
1	230800	31200	199300	191600	7700	1.66
2	241200	22800	218400	207300	11100	2.38
3	252700	32100	220600	211700	8900	2.58
4	272500	31300	241200	220000	21200	2.96
5	255700	22500	233200	217600	15600	2.85
6	241700	25000	216900	208800	8100	2.40

* Column 5 includes 2100 C.F.S. diversion thru Erie and Welland Canals.

FREEMANS EX. 1

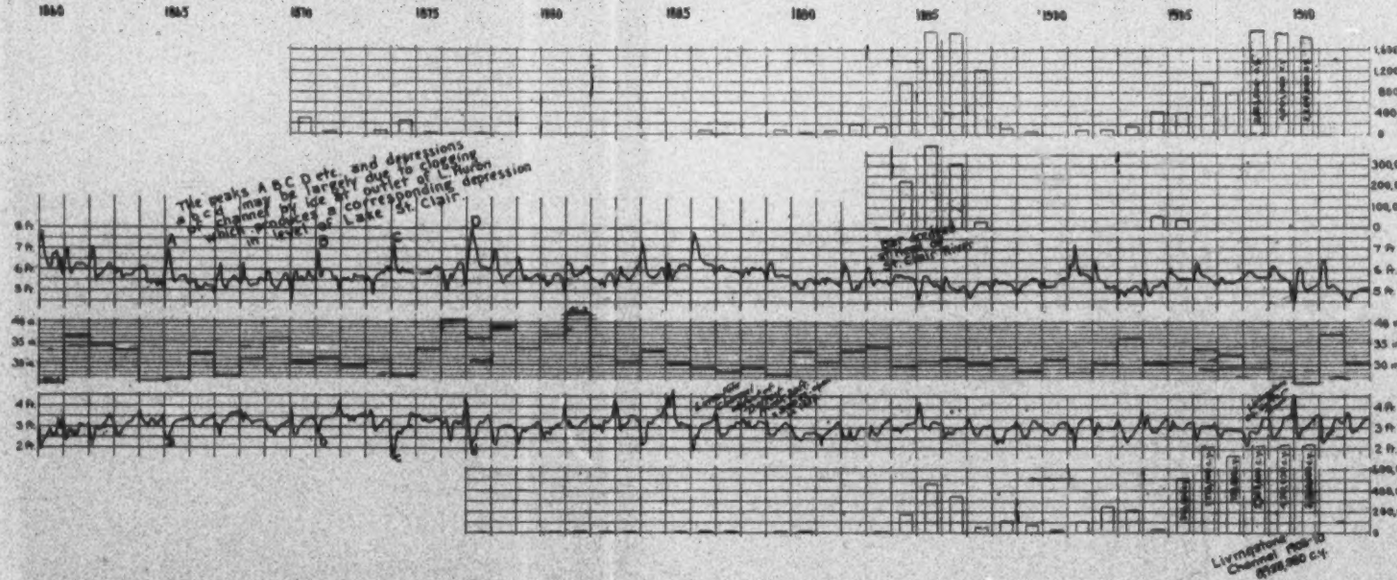


Computed effect of Diversion by Drainage Canal, in lowering lakes. Based on Defendants reductions of Complainants observations: Lowering of lakes regardless of any compensation works

For Diversion of	4000 c.f.s.	10000 c.f.s.	14000 c.f.s.
Huron	0.14 ft.	0.35 ft.	0.49 ft.
Erie		0.30 ft.	0.42 ft.
Ontario		0.33 ft.	0.46 ft.

LAKE LEVELS

1860 1865 1870 1875 1880 1885 1890 1895 1900 1905 1910

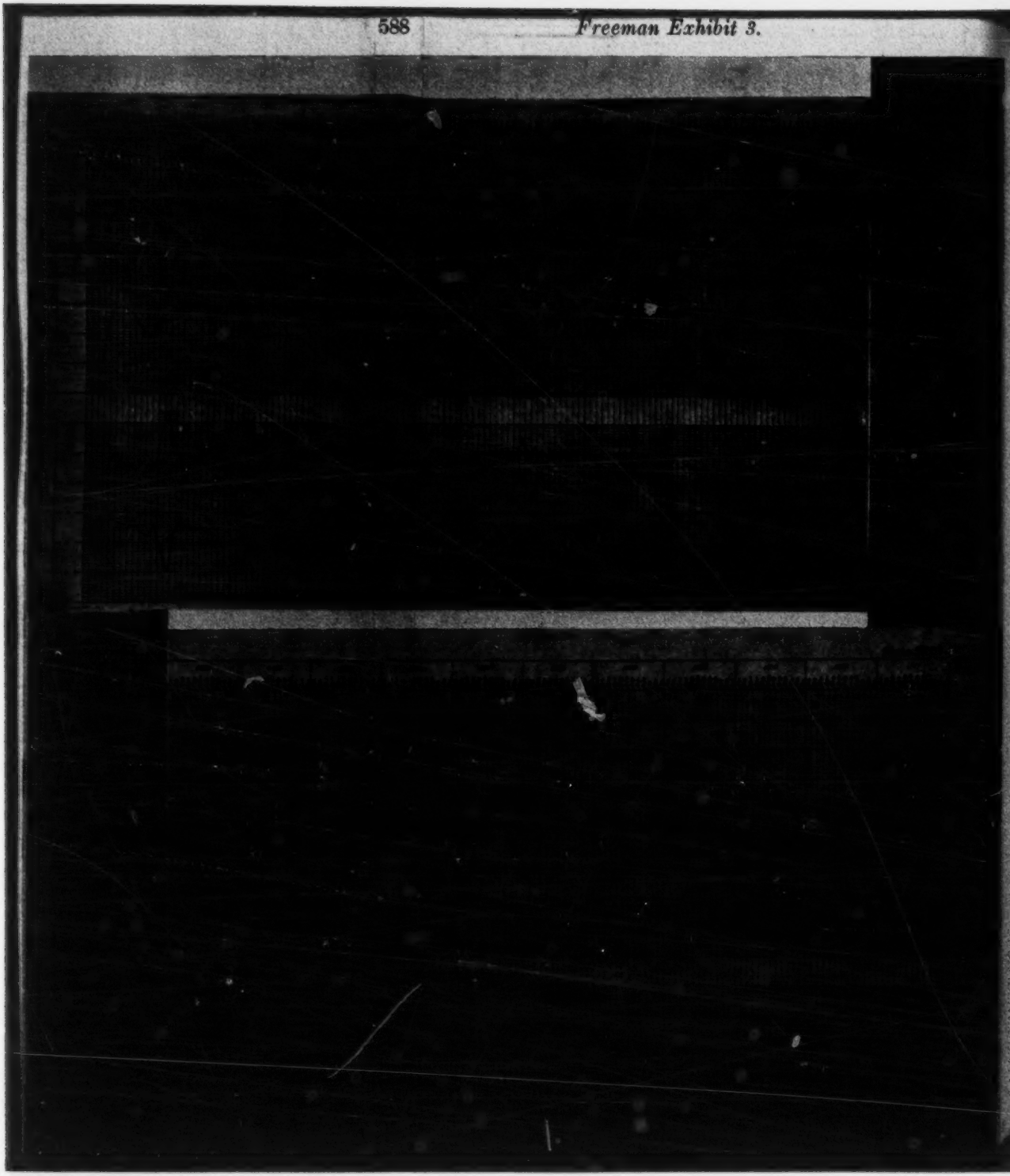


Studies Relative to

CHICAGO DRAINAGE CANAL

John R. Freeman, C.E.
Providence, R.I.

Mar. 17, 1910.



FREEMAN EXHIBIT 4.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

Paper No. 1259.

CHARACTERISTICS OF CUP AND SCREW CURRENT METERS; PERFORMANCE OF THESE METERS IN TAIL-RACES AND LARGE MOUNTAIN STREAMS; STATISTICAL SYNTHESIS OF DISCHARGE CURVES.*

BY B. F. GROAT, ASSOC. M. AM. SOC. C. E.

WITH DISCUSSION BY MESSRS. W. G. PRICE, E. E. HASKELL, CHARLES H. MILLER, JOHN C. HOYT, C. W. STANIFORD, AND B. F. GROAT.

During the summer and autumn of 1911 the writer ran a number of efficiency tests on two of the 6,000-h. p. hydraulic turbine units recently installed in the power-house of the St. Lawrence River Power Company, at Massena, N. Y. On one of the units, two sets of tests were run, one prior, and one subsequent, to cutting off several feet of the draft-tubes. On the other unit, one set of tests was run after the draft-tubes had been shortened, as had been done in the case of the other turbine unit.

In all, about 40,000 instrumental readings, including gauge readings, were made. Of these, 7,000 were complete velocity observations by current meters, and 4,000 additional readings on a Pitot tube furnished about 100 complete velocity observations for comparison with simultaneous readings by the current meters.

Owing to the nature of the tail-races, which discharge into the Grasse River, a weir test was out of the question. Before beginning the tests, therefore, it became necessary to decide between the current meter and Pitot tube as instruments for measuring the flow.

*Presented at the meeting of February 5th, 1913.

In favor of the current meter is its simplicity and the f
cility with which it may be used in tail-races. Against it
the fact that, notwithstanding the large number of observe
who have experimented with it and the large number of re
ords which have been made by it, there is still a great deal
well-founded skeptical discussion as to the accuracy of t
instrument when the records are based solely on the sti
water rating.

The Pitot tube has been not only a subject of adverse cr
cism but also an instrument about which much positive i
norance seems to exist. It would seem, however, that t
recent demonstrations of the accuracy of Darcy and Basi
experiments, 1865, by Messrs. William Monroe White,* F
F. Moody, Gardner S. Williams, John R. Freeman, and other
should sufficiently dispel all doubts as to the reliability
the instrument. On the other hand, where the velocity of t
water is variable from moment to moment, a large number
readings must be taken and reduced to a mean square roo
in order to obtain sufficiently close approximations to th
average in any one velocity determination.

After a final summary of advantages and disadvantage
it was decided to use both the screw and cup types of curre
meter, and to check their records, if necessary, with a Pit
tube.

E. E. Haskell, M. Am. Soc. C. E., Director of the College o
Civil Engineering Cornell University, made up one of h
screw type meters especially for the series of tests to be u
dertaken, and a new Gurley-Price meter of the cup type (No
600) was purchased from the makers at Troy. Master Me
chanic D. J. Jones, of the Power Company, made up a Pito
tube, following as nearly as possible the description of Tub
N given in Mr. White's paper, mentioned above.

The following are the general conclusions concerning cu
rent meters which have been drawn from the tests with th
foregoing equipment:

1.—†When a cup meter is run in perturbed water it wi
register a larger number of revolutions per second than
perfect still-water rating would indicate.

2.—†When a screw meter is run in pertubed water it wi
register a smaller number of revolutions per second than
perfect still-water rating would indicate.

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*"The Pitot Tube: Its Formula," by William Monroe White, *Jour*
Association of Engineering Societies, Vol. XXVII, 1901, p. 35.

For other reference marks see following page.

3.—†In the foregoing sense, a cup meter is affected relatively to a much greater extent than a screw meter. In the tail-races at Massena, as an average, the cup meter was affected to the extent of 6%, while the Haskell meter was affected mostly by less than 1 per cent. In boilers of considerable violence the cup meter may easily over-register by 25%, while the screw meter will under-register by not more than 3 or 4 per cent.

4.—Either type of meter when run in perturbed water will give uniform records in equal times, provided these times are sufficiently long, the flow of the water itself being subject to an established regimen.

5.—If both types of meter are used simultaneously in perturbed water, the disparity between the discrepant velocities thus determined by the still-water rating may be taken as a basis for correcting the discrepant velocities.

6.—The average corrections thus obtained for the Haskell meter when run with the Gurley-Price meter in the tail-races at Massena varied from 0.5 to 0.9 of 1%, while the corresponding corrections for the Gurley-Price meter were about six times larger. Comparisons with the Pitot tube furnished substantially the same corrections as those obtained by comparison of the meters.

7.—It would seem to follow that current-meter observations based on still-water ratings without further correction should

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†In a discussion of a paper on current meter and weir discharge comparisons by Edward C. Murphy, Assoc. M. Am. Soc. C. E. *Transactions*, Am. Soc. C. E., Vol. XLVII, 1902, p. 370, Charles H. Miller, M. Am. Soc. C. E., describes certain experiments on screw and cup meters in the following language:

"The Haskell meter was lowered from one side of the skiff and one of the Price meters from the other side, both to the same depth (about 5 ft.). The registrations or revolutions of each, for periods of from 5 to 10 minutes, were noted; then, for similar periods of time, the skiff was caused to rock from one side to the other at short intervals, and the registrations recorded, the movement of the skiff giving to the meters a vertical motion of from 1 to 2 ft. Under this motion the revolutions of the Price meter increased, while those of the Haskell meter decreased, but in a less proportion than the increase of the Price meter, showing that the error due to instability of support is greater in the Price than in the Haskell meter. Lack of time prevented more extended observations, and in different velocities of current, which probably would have evolved some fixed difference due to the different construction of the meters in question."

Conclusions 1, 2 and 3, of the present paper seem to have been fairly stated by Mr. Miller, but as applied only to instability of support. They are here advanced as inherent characteristics of these different types of meter, and extended to apply, not only to cases of instability of support, but also to these current meters generally, however supported, in flowing water.

be made with great caution. On the other hand, it seems certain that the correction for a cup meter when run at a good meter station on an open river is not large, while the corresponding correction for a screw meter may be negligible.

Plate XXIII shows the results of a number of ratings of the Haskell meter. The general method was similar to that adopted by the United States Lake Survey, as described in the reports by F. C. Shenehon, M. Am. Soc. C. E.,* covering his current-meter observations. The meter was suspended either by cable or rod from a bowsprit at the head of a light skiff. The skiff, with an observer, was then towed back and forth over a 200-ft. base at a given velocity, one such double run constituting a velocity observation. The total time and total number of revolutions then stand for the transit of a 400-ft. base in perfectly still water.

The first four ratings, on June 29th and 30th, 1911, were made along the longitudinal center line of Lock No. 15 in the old Cornwall Canal, at Cornwall, Ont. Both lock gates were open, but the north miter leaf of the lower gate, opening into the St. Lawrence River was not fully into its recess in the north wall. The meter was about 4 ft. below the surface of the water, and the depth in the lock was 9 or 10 ft. The water in the lock had a tendency to surge at times. Sometimes there was considerable velocity through the lock, and at other times very little.

The ratings of August 12th and October 3d, 1911, were made in a bay of the Grasse River, opposite the power-house of the St. Lawrence River Power Company, at Massena, N. Y. The meter was about 2.25 ft. below the surface of the water, and the average depth under the base line was about 7 ft., with a shallow spot near the east end about 5 ft. deep. There was very little current, but at times there were surges due to the operation of the power-house just across the river.

The ratings of July, 1912, were made under the direction of Professor Arthur M. Greene, Jr., at the rating station of Rensselaer Polytechnic Institute, Troy, N. Y., after the meter had been used extensively at Massena and in North Carolina and Tennessee. The meter had been overhauled twice at Cornell University before these ratings, but long after those at Massena. The meter was also provided with a new shaft. After running a complete set of tests at Troy, the new shaft was put in and another set of tests was made.

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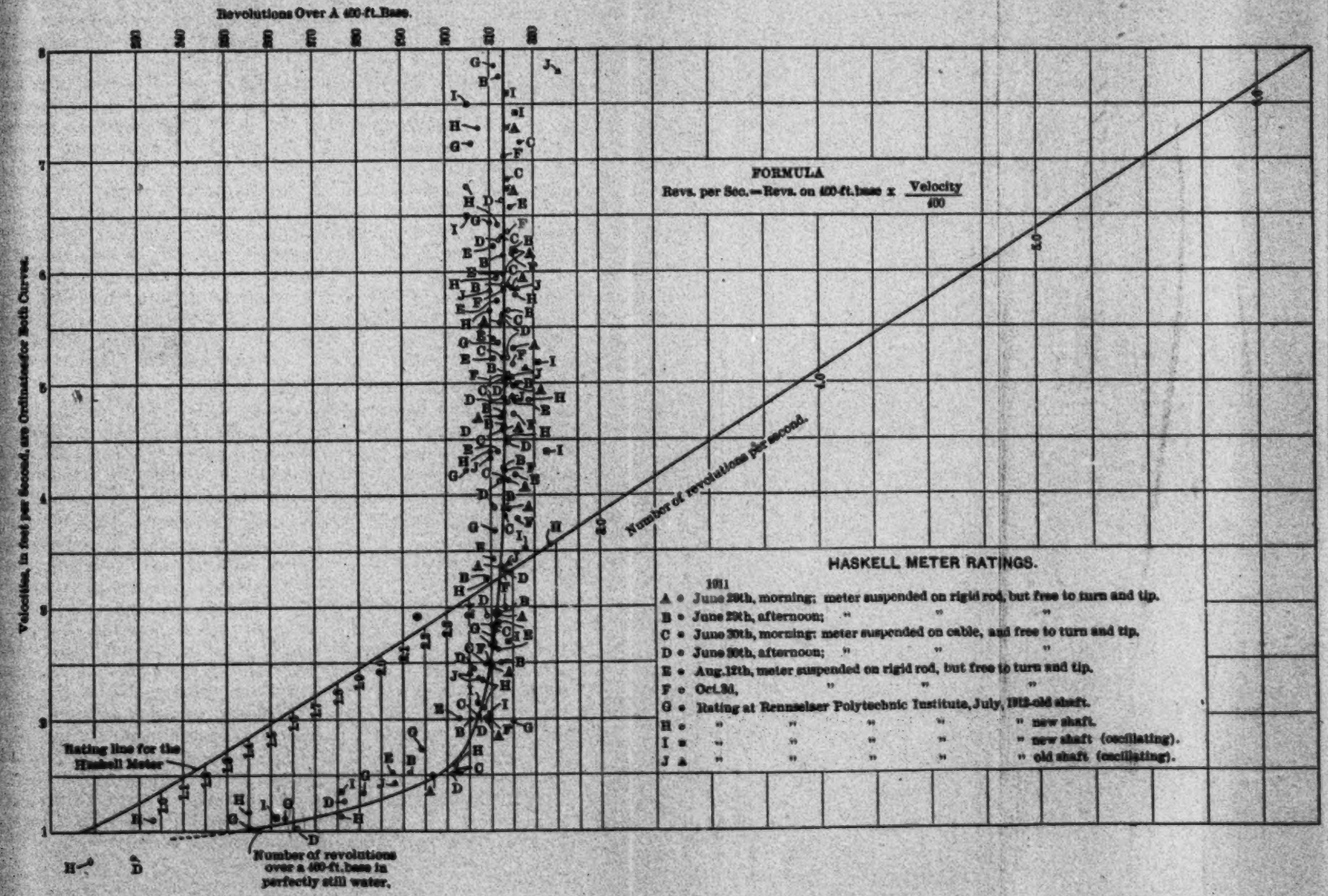
*As described in Reports, Chief of Engineers, U. S. Army, 1900 to 1904, inclusive.

PLATE XXIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXVI, No. 1289.
GROAT ON
CUP AND SCREW CURRENT METERS.



The curve of revolutions over a 400-ft. base was plotted from the first four ratings in the Cornwall Canal. It will be seen from Plate XXIII, however, that the subsequent ratings do not materially alter the position of this line, up to velocities of 5 or 6 ft. per sec. If the correction were made, the number of revolutions, as shown by the line, would be increased only ¼% at 4 ft. per sec., and reduced only ¼% at about 8 ft. per sec. In fact, it may be seen that, out of about 100 double runs in the canal lock and Grasse River, not one plotted point differs by more than 1% from the line of revolutions as determined from the first four ratings for velocities of more than 1½ ft. per sec. For velocities of less than 1½ ft. per sec. the line of revolutions is so steep that errors of somewhat larger magnitude are to be expected. In the oscillating tests, the meter was oscillated parallel to the motion of the car, and covered an amplitude of 5¾ in. for every 8-ft. advance of the car. Transverse oscillations reduce the number of revolutions over a given base. The relations between velocity and revolutions over a 400-ft. base were then plotted, as shown on Plate XXIII, and from the resulting curve the rating line for still water was located and drawn, also as shown on that plate.

After having drawn the rate line, a reduction diagram, Plate XXIV, may be prepared, from which velocities may be read directly when referred to time and revolutions. This obviates either the necessity for reducing revolutions to revolutions per second, or of taking a fixed time for observing velocities, which is inexpedient where velocities are variant.

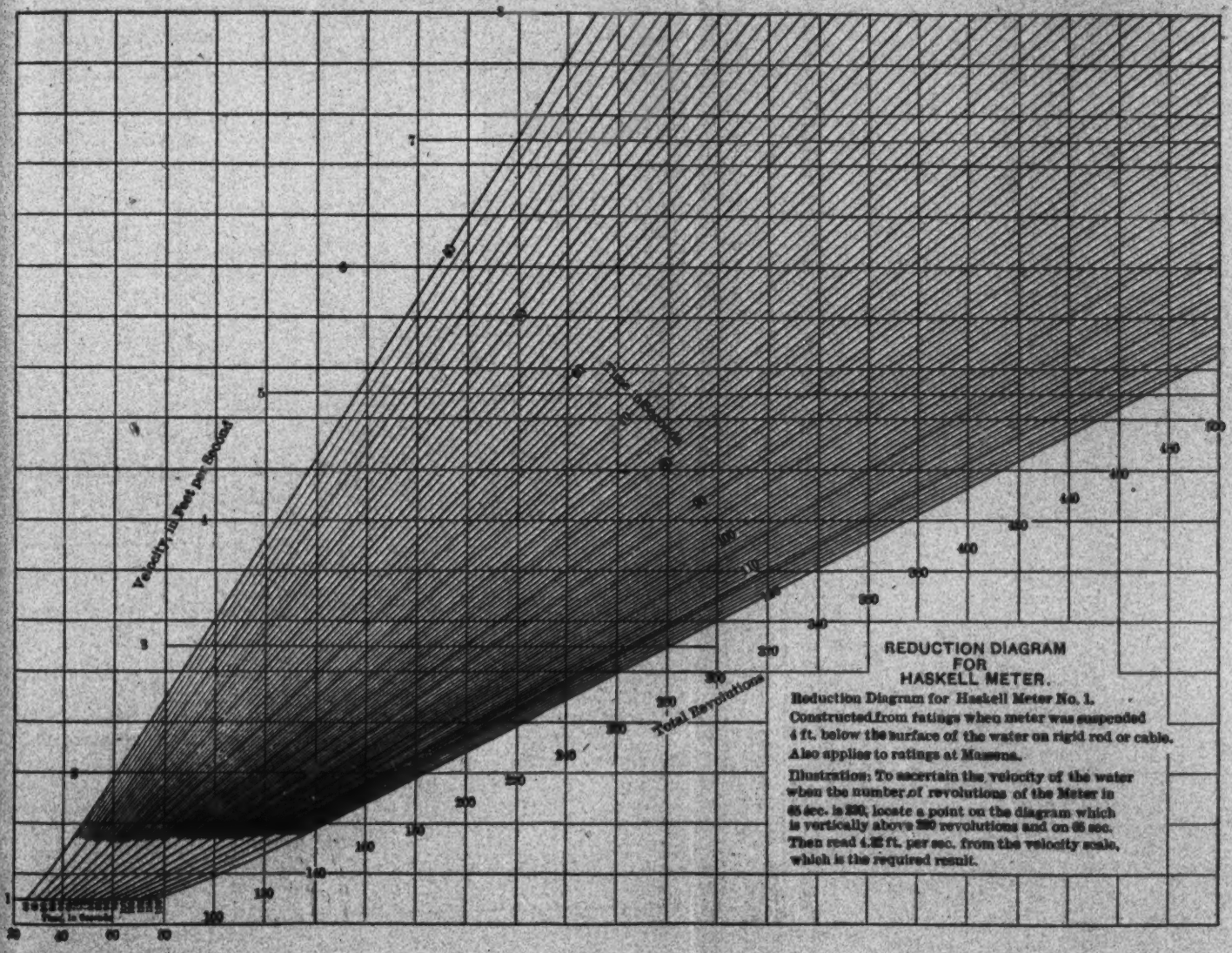
Plate XXV shows the Gurley-Price meter rating curves, obtained in a manner precisely similar to that used for the Haskell meter. In fact, the ratings were frequently made on the same day as for the Haskell meter.

In order that there may be no misundertanding concerning these ratings, it may be stated that the tests were severe, when considered as a whole. Some of the ratings were made at a depth of 4 ft., some at a depth of 2 ft. 3 in., some in windy weather, some in calm weather, and several different observers acted at different times.

Under all these diverse conditions, it may be seen that the Haskell meter, in the Massena and Cornwall ratings, never varied by more than 1% in any individual observation, and that rating lines drawn for different ratings would differ by only 0.2 or 0.3 of 1% at the greatest.

The Gurley-Price meter exhibits a much greater range of

PLATE XXIV.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXVI, No. 1255.
GROAT ON
CUP AND SCREW CURRENT METERS.

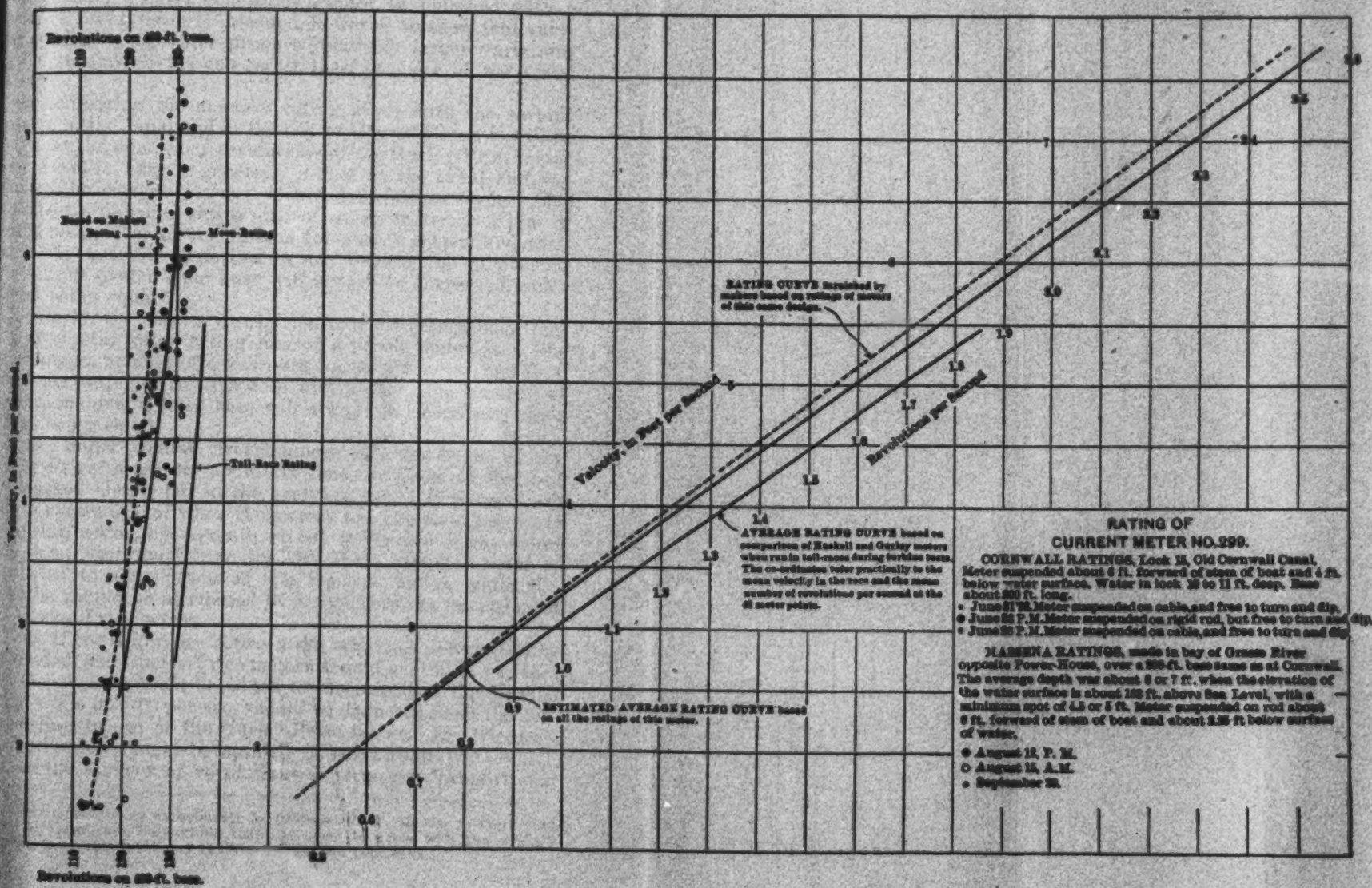


REDUCTION DIAGRAM FOR HASKELL METER.

Reduction Diagram for Haskell Meter No. 1.
Constructed from ratings when meter was suspended 4 ft. below the surface of the water on rigid rod or cable.
Also applies to ratings at Massena.

Illustration: To ascertain the velocity of the water when the number of revolutions of the Meter is 65 sec. is 230, locate a point on the diagram which is vertically above 230 revolutions and on 65 sec. Then read 4.32 ft. per sec. from the velocity scale, which is the required result.

PLATE XXV.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXVI, No. 1259.
GROAT ON
CUP AND SCREW CURRENT METERS.



RATING OF CURRENT METER NO. 299.

CORNWALL RATINGS, Lock 18, Old Cornwall Canal. Meter suspended about 6 ft. forward of stem of boat and 4 ft. below water surface. Water in lock 10 to 11 ft. deep. Base about 200 ft. long.

- June 21 P.M. Meter suspended on cable, and free to turn and dip.
- June 22 P.M. Meter suspended on rigid rod, but free to turn and dip.
- June 23 P.M. Meter suspended on cable, and free to turn and dip.

MASSENA RATINGS, made in bay of Grasse River opposite Power-House, over a 500-ft. base same as at Cornwall. The average depth was about 6 or 7 ft., when the elevation of the water surface is about 192 ft. above Sea Level, with a minimum spot of 4.5 or 5 ft. Meter suspended on rod about 6 ft. forward of stem of boat and about 2.25 ft. below surface of water.

- August 12, P. M.
- August 15, A.M.
- September 20.

variations, 5 or 6% up to velocities of 5 ft. per sec., which were considerably in excess of the mean velocities in the tail-races where the meter was used.

It is not contended here that a satisfactory still-water rating under perfect conditions cannot be obtained with a meter of this type; it is intended, however, to show that varying conditions of water produce relatively larger variations in the records of the cup meter than in those of the screw meter.

On comparing the maker's rating curve with the several ratings in the canal and in the bay of Grasse River, it will be seen that the number of revolutions of the Gurley-Price meter over a 400-ft. base is generally higher in the canal and bay than in the maker's rating. Hence it is fair to suspect that a perfect still-water rating line of a cup meter is a line of minimum number of revolutions for such a meter, and that, when the water is disturbed in any degree, the number of revolutions over a fixed base will always be increased, other things being equal.*

Similarly, the contrary suspicion may be entertained, that a perfect still-water rating line of a screw meter is a line of maximum number of revolutions for such a meter, and that, when the water is disturbed in any degree, the number of revolutions over a fixed base will always be decreased, other things being equal.

Since, under similar circumstances, the deviations of the Gurley-Price meter are about six times as large as those of the Haskell meter, but in the contrary sense, it would seem fair to conclude that when the meters are run simultaneously in flowing water, one-seventh of any difference in the velocities thus determined from the still-water ratings should be attributed to a deviation of the Haskell meter, while six-sevenths should be attributed to a simultaneous deviation of the Gurley-Price meter.

Thus, if the difference between the velocities determined by the Haskell and Gurley-Price meters should be 0.42 ft. per sec., 0.06 ft. per sec. should be added to the record of the Haskell meter, while 0.36 ft. per sec. should be deducted from the corresponding record of the Gurley-Price meter. In strictness, this correction should be applied to revolutions per second, but, as the number of revolutions is so nearly proportional

*Certain interesting experiments by Professor L. F. Moody, in the rating station at Rensselaer Polytechnic Institute, seem to agree with the writer's experiments on this point and confirm the general conclusion.

to the velocity, and as the corrections are relatively small, no serious error results. The particular ratio here determined, of course, applies only to the two individual meters as used in the tail-races at Massena by the writer.

In order to establish more satisfactorily the principle mentioned above, the boat was rocked during several of the runs of a rating, imparting to the meter which was being rated an oscillation in an arc about 3 ft. long and about 2½ ft. in radius, and at right angles to the direction in which the meter was being drawn through the water. The result was that the Gurley meter was found to increase its number of revolutions by 15% while the Haskell meter reduced its number of revolutions by 2½%, practically the same ratio as that deduced above from the rating curves. The effect of longitudinal oscillations was tested also. The result of special tests of this character at Rensselaer Polytechnic Institute may be seen on Plate XXIII. Subsequently, other tests on a new Haskell meter showed that longitudinal oscillations of 22 in. in 6 ft. advance of car retarded the meter slightly, up to velocities of about 2 ft. per sec., above which the meter was accelerated, the error being less than 2% at 9 ft. per sec. The net result in perturbed water, however, seems to be slight retardation in all cases.

It is now desirable to show how these principles have been used to correct the current-meter records actually observed in the tail-races during the turbines tests referred to at the outset. In order to do this properly, it will be necessary to state another conclusion, based on the current-meter records, which the writer hopes to take up more fully in the future under another title. The conclusion is as follows:

Under an established regimen, the distribution of the flow of water in a tail-race obstructed by tilling racks is fixed in character, the ratio of the average velocity at any given point to that at any other given point in the race being constant. This proposition applies over a considerable range in the total amount of discharge, but supposes the actual wetted cross-section of the race to remain the same.

The foregoing proposition was proven from a number of the turbine tests by computing and compiling the relative velocities at the 84 meter points in the races where velocity observations were taken. A turbine unit discharged through two tail-races, each about 15 ft. wide, while the depth of the water varied from 15 to 16 ft. The meter section of each race was divided into six equal vertical, and seven equal horizontal

strips, and the meter points were the forty-two intersections of the median lines of the strips. The verticals were numbered 1 to 6 from west to east, while the depths were numbered 1 to 7 downward.

To demonstrate the truth of the principle of a fixed distribution of flow in tail-races, and also as a verification of Conclusion No. 4, Tables 1 to 4 are given:

TABLE 1—GURLEY-PRICE METER IN WEST RACE, SHOWING CONSTANCY OF VELOCITIES TAKEN IN QUICK SUCCESSION. VELOCITIES WERE OBSERVED WITH A SINGLE STOP-WATCH PROVIDED WITH TWO SECOND HANDS.

Test of September 9th, at 0.82 gate.
The numbers are of revolutions per second.

Depths.	Verticals.						Totals of lower set.
	1	2	3	4	5	6	
1	1.38	1.40	1.15	0.88	0.90	0.94	6.69
	1.36	1.43	1.16	0.89	0.87	0.95	
2	1.39	1.44	1.40	1.26	1.20	1.16	7.70
	1.34	1.44	1.40	1.24	1.22	1.16	
3	1.36	1.44	1.42	1.40	1.34	1.31	8.46
	1.36	1.44	1.39	1.41	1.35	1.31	
4	1.37	1.44	1.43	1.39	1.31	1.27	8.41
	1.36	1.44	1.43	1.39	1.32	1.26	
5	1.38	1.47	1.38	1.40	1.35	1.28	8.57
	1.40	1.46	1.38	1.40	1.37	1.28	
6	1.70	1.78	1.80	1.77	1.61	1.06	10.09
	1.66	1.78	1.80	1.78	1.60	1.06	
7	1.60	1.81	1.84	1.78	1.78	1.06	10.84
	1.66	1.80	1.84	1.78	1.79	1.06	
Totals of lower set.	10.07	10.74	10.75	9.76	9.58	9.64	60.56

The register was started first and the observer noted the pointer as it clicked from revolution to revolution of the meter. By synchronizing with the rythm of the register, it was possible for the observer to start the stop-watch almost exactly at the moment the register clicked to zero. Similarly, the primary second hand could be stopped after any desired number of revolutions while the secondary hand could be stopped at, say, twice that number. Thus, two or more velocities in immediate succession could be determined for each meter point in the tail-races.

In support of the principle of fixed distribution, it may be stated that the percentages corresponding to the figures of

Tables 1 and 2 at the 84 meter points agree remarkably well with the corresponding ones of Tables 3 and 4 after applying certain necessary small corrections. Tables 1 and 2 each represent an individual set of double discharge measurements in one of the races, while Tables 3 and 4 have been compiled as average percentages from a number of such sets of observations.

In Verification of Conclusion No. 4, it may be seen that each pair of velocities determined at the same point by either meter consists practically of two equal velocities. This truth has been found to apply throughout the turbine tests.

TABLE 2.—HASKELL METER IN EAST RACE, SHOWING CONSTANCY OF VELOCITIES TAKEN IN QUICK SUCCESSION. THE COMPARISONS ARE NOT AS GOOD AS WITH THE GURLEY-PRICE METER, BECAUSE THE VELOCITIES WERE TAKEN WITH TWO DIFFERENT WATCHES, ONE OF WHICH WAS NOT VERY RELIABLE.

Test of September 9th, at 0.82 gate.
The numbers are of feet per second.

Depths.	Verticals.						Totals of lower set.
	1	2	3	4	5	6	
1.....	3.75	3.74	3.68	3.61	3.94	3.75	
	3.73	3.75	3.80	3.80	3.97	3.73	17.40
2.....	3.68	....	....	....	....	....	
	3.67	3.69	3.86	3.97	3.76	4.01	21.40
3.....	4.13	3.96	3.92	3.91	4.13	4.09	
	4.08	3.99	3.78	3.98	4.17	4.10	24.34
4.....	4.21	3.98	3.94	3.77	3.98	4.07	
	4.03	3.95	3.94	3.70	3.91	4.05	23.45
5.....	4.09	3.90	3.73	3.68	3.91	4.03	
	4.05	3.94	3.73	3.67	3.94	4.20	23.27
6.....	4.17	4.00	3.74	3.61	4.13	4.44	
	4.30	4.01	3.73	3.68	4.13	4.49	24.35
7.....	3.97	3.97	3.86	3.85	4.06	4.01	
	3.93	3.97	3.86	3.91	4.06	4.01	23.37
Totals of lower set.	23.51	23.89	23.56	23.46	23.99	23.92	142.33

The two velocities at each meter point were taken in immediate succession in a manner similar to that described in the foot-note under Table 1, except that two stop-watches were used. The observations were about 1 min. in duration for the first velocity and twice as long for the second velocity.

TABLE 3.—RELATIVE DISTRIBUTION OF FLOW IN WEST RACE OF UNIT NO. 3 DURING TESTS OF JULY AND AUGUST. WATER SURFACE AT ELEVATION 162.85.

Depths.	Verticals.						Totals.
	1	2	3	4	5	6	
1	2.16	2.16	1.84	1.88	1.80	1.97	11.10
2	2.11	2.41	2.32	2.07	2.02	2.22	13.15
3	2.04	2.37	2.46	2.21	2.15	2.14	13.30
4	2.13	2.30	2.34	2.20	2.05	2.36	13.53
5	2.19	2.41	2.37	2.20	2.27	2.07	14.40
6	2.05	2.37	2.00	2.05	2.42	2.05	16.47
7	2.72	2.37	2.00	2.00	2.00	2.00	17.70
Totals	16.00	17.40	17.53	16.21	15.66	17.06	99.96

The numbers are percentages of the sum of the velocities at the 42 meter points in the race. Thus, in Vertical 1, Depth 1, the velocity is 2.16% of the sum of all the velocities at the meter points.

TABLE 4.—RELATIVE DISTRIBUTION OF FLOW IN EAST RACE OF UNIT NO. 3 DURING TESTS OF JULY AND AUGUST. WATER SURFACE AT ELEVATION 162.85.

Depths.	Verticals.						Totals.
	1	2	3	4	5	6	
1	1.72	1.80	1.86	1.65	2.16	2.24	11.20
2	2.08	2.24	2.00	2.16	2.24	2.24	12.70
3	2.48	2.51	2.19	2.20	2.51	2.20	13.70
4	2.60	2.24	2.36	2.12	2.17	2.41	14.30
5	2.36	2.41	2.15	2.10	2.12	2.46	13.80
6	2.72	2.40	2.40	2.02	2.40	2.72	15.80
7	3.00	2.24	2.11	2.00	2.00	2.72	16.60
Totals	17.12	16.88	16.91	16.25	16.97	17.22	100.00

The percentages of Tables 3 and 4 are computed by dividing the velocity at any meter point by the sum of the velocities at all the meter points.

Attention should be directed to the fact that while water discharged from a turbine will be much quieted by stilling racks, yet the latter themselves are sources of disturbance, and that the violent agitation caused by the turbines is merely supplanted by an entirely different type of disturbance produced by the racks. The effect of the racks is to render the flow parallel to the side-walls of the race, but the body of the water is full of small eddies and boilers of more or less violence. The parallelism of flow at each meter point was tested by a kind of inverted weather vane, which the writer understands was first used by John R. Freeman, M. Am. Soc. C. E. The indications of parallelism of flow by this vane were extremely satisfactory at all points.

The meter section was about 30 ft. down stream from the racks. The effect of the disturbance from the racks, however, was plainly indicated by the divergence of the velocity records, based on the still-water ratings, when the two meters were run in quick succession at any meter point. It is well to note here that the velocity was greater near the bottom of the race than at the top, and that the agitation by the racks was greater near the top than at the bottom, where the flow was extremely steady and subject to little or no agitation. This is clearly shown by the records, and especially by the fact that the clicking of the register was almost absolutely uniform when the meters were near the bottom. It is also shown by the fact that there was always a greater disparity between the meter records near the surface than at the bottom.

To be precise, the corrections for the meters should be computed for each of the 84 meter points in the races. Practically, the corrections may be made for the average velocities in the seven horizontals, because the velocities along any horizontal do not vary widely.

An example of the computation of corrections for the Haskell and Gurley-Price meters is given in Table 5.

TABLE 5.—COMPUTATION OF VELOCITY CORRECTIONS.

Horizontal in which meter was run.	Velocities Based on the Still-Water Ratings.		Difference.	One seventh of difference + Haskell = true velocity.	Velocity excessive by Gurley. Percentage.	Velocity deficient by Haskell. Percentage.
	Gurley.	Haskell.				
1.....	3.04	3.26	0.22	3.04	14.5	2.4
2.....	4.40	4.50	0.10	4.50	12.0	2.0
3.....	4.74	4.44	0.30	4.46	5.8	0.96
4.....	4.66	4.62	0.04	4.66	4.3	0.72
5.....	5.08	4.89	0.19	4.98	3.1	0.55
6.....	5.09	5.35	0.13	5.37	2.0	0.34
7.....	6.29	6.75	0.17	6.17	2.3	0.39
Totals..	33.07	33.91	2.16	33.21		

$$\text{Average error of Gurley meter} = \frac{6}{7} \times \frac{2.16}{33.21} = 5.6 \text{ per cent.}$$

$$\text{Average error of Haskell meter} = \frac{1}{7} \times \frac{2.16}{33.21} = 0.93 \text{ " "}$$

The method given in Table 5 for computing the corrections for the velocities is based solely on the current-meter ratings and the rocking experiments in conjunction with the fundamental propositions before stated. It is desirable, therefore, to have independent means of checking the methods and the numerical results.

Accordingly, a Pitot tube was operated at the meter points, in Depths 2, 3, 5, 6, and 7, simultaneously with the Haskell meter. While the meter was recording in Vertical 3 the Pitot was recording in Vertical 2. After the record was taken, both the meter and Pitot were advanced to the next succeeding verticals, so that the meter would then record in Vertical 4 while the Pitot was in Vertical 3. Depths 1 and 4 were omitted because the tail of the Pitot was out of water in Depth 1, and the construction of the piping of the Pitot did not conform with the staging for the observers in such a way as to admit of readings in Depth 4. This might have been remedied, but no great importance was attached to these facts.

The results of these tests are given in Table 6.

It should be noticed in Table 6 that the velocities given in Verticals 1 and 6 were not taken in quick succession. The meter and tube were traversed across each horizontal, beginning with the Pitot tube in Vertical 1 and the meter in Vertical 2, and ending with the Pitot tube in Vertical 5 and the meter in Vertical 6. After the five horizontals were traversed in this manner, the Pitot tube and meter were interchanged in

relative position, and readings were taken at the five dept with the Pitot tube in Vertical 6 and the meter in Vertical All other readings by the meter or Pitot tube were follow immediately by a reading of the other instrument.

The writer does not wish to make too much of these Pi tube tests. The experimenters were not familiar with the i strument, as they had used it on only one other occasion. T dynamic and static columns were drawn up on a scale gra uated to single tenths and half tenths of a foot and the di ferences in head were merely estimated to the nearest hu dredths of a foot. This may seem crude, but when it is co sidered that the water columns are both vibrating, sometim violently, that twenty or thirty readings are taken for ea velocity, and that all percentage errors are nearly split two by the process of extracting the square root of the hea it will be seen that the method is probably as accurate as ne be for the purpose at hand. Indeed, the results seem to justi this conclusion.

Attention may be directed to three general facts shown the summary of Table 6. The ratios for the verticals increa toward the right in the west race. They increase toward t left in the east race. The ratios for the horizontals increa upward in both races. On the whole, the tendency is for th ratio of the Pitot velocity to the meter velocity to increase u ward, as it should, as it has been shown that the meter retarded toward the surface.

TABLE 6.—COMPARISONS BETWEEN VELOCITIES DETERMINED BY PITOT TUBE AND HASKELL METER AT VARIOUS POINTS IN THE TAIL-RACES OF UNIT NO. 5.

Depth.		Verticals.														Ratios.
		1		2		3		4		5		6		Totals.		
		Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	
2	A	....	....	4.03	4.06	3.94	3.99	3.76	3.78	3.80	3.85	....	....	15.59	14.47	1.072
	A	....	....	4.15	4.09	3.96	3.11	3.80	3.86	3.85	3.89	....	....	15.15	15.80	1.046
	A	....	....	3.72	3.84	3.58	3.48	4.10	3.80	4.40	4.40	....	....	16.21	14.97	1.083
	A	....	....	3.80	3.84	3.98	3.77	4.30	4.30	4.40	4.40	....	....	16.50	16.09	1.030
	A&C	2.66	2.69	3.84	3.84	3.80	3.80	3.60	3.81	3.92	3.17	1.66	1.77	15.30	15.30	1.001
		2.66	2.69	23.00	17.86	17.76	15.62	17.04	17.09	18.62	17.90	1.66	1.77	76.55	72.50	1.055
3	A	....	....	4.06	4.03	4.14	4.09	4.05	3.96	4.26	4.20	....	....	16.75	16.41	1.020
	A	....	....	4.06	4.19	4.11	4.19	4.15	4.16	4.40	4.36	....	....	17.01	16.46	1.033
	A	....	....	4.06	4.16	4.06	4.04	4.01	4.00	4.40	4.36	....	....	17.13	17.43	0.983
	A&C	2.66	2.71	4.84	4.81	4.62	4.43	4.40	4.36	4.46	4.46	....	....	17.80	17.43	0.981
		2.66	2.71	3.96	3.96	3.94	3.41	3.16	3.10	3.96	3.80	2.66	2.66	15.30	14.26	0.972
		2.66	2.71	19.06	19.19	19.26	19.40	19.06	19.06	20.02	19.86	2.66	2.66	80.00	81.96	1.001
5	A	....	....	5.26	5.41	4.97	4.97	4.27	4.41	4.26	4.26	....	....	19.50	18.81	0.964
	A	....	....	5.27	5.26	4.96	4.96	4.46	4.47	4.23	4.29	....	....	19.74	19.12	0.960
	A	....	....	4.91	4.13	4.62	4.60	4.06	4.10	4.46	4.44	....	....	18.75	18.07	1.006
	A&C	2.61	2.66	4.46	4.14	4.06	3.96	4.11	4.00	4.04	4.00	....	....	16.96	16.46	1.030
		2.61	2.66	3.91	3.90	3.46	3.33	3.61	3.64	3.94	3.46	2.16	2.14	15.11	15.06	0.986
		2.61	2.66	23.10	21.94	19.31	20.04	19.39	19.60	19.73	19.94	2.16	2.14	89.11	86.97	0.969
8	A	....	....	5.26	5.26	5.47	5.46	5.41	5.35	4.26	4.21	....	....	21.17	21.08	0.976
	A	....	....	5.26	5.07	5.47	5.70	5.26	5.26	4.26	4.26	....	....	21.41	21.95	0.976
	A&C	2.74	2.66	3.86	3.87	3.07	3.10	3.06	3.00	3.80	3.87	2.02	2.17	16.53	16.60	0.996
		2.74	2.66	19.38	19.26	14.01	14.26	13.73	14.06	12.48	12.34	2.02	2.17	80.11	80.17	0.999

REMARKS: *A*—tests in W. race at 0.7 gate; *B*—tests in E. race at 0.7 gate; *C*—tests in W. race at 0.37 gate.

TABLE 6.—(Continued.)

Depth.		1		2		3		4		5		6		Totals.		Ratio.
		Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	Pitot.	Meter.	
Verticals.	A	....	....	5.93	5.91	6.06	6.08	6.12	6.19	5.90	5.79	....	....	35.96	34.11	0.948
	B	5.11	5.07	5.45	5.79	6.19	6.33	6.81	6.96	5.68	5.60	....	....	35.24	36.95	0.955
	C	5.08	5.07	5.12	5.14	5.90	5.93	5.90	5.16	5.68	5.60	....	....	32.68	32.89	1.006
		....	....	5.04	5.05	5.96	5.98	5.94	5.19	5.90	5.60	5.76	5.68	33.34	33.79	0.986
		5.14	5.14	17.52	17.90	18.72	18.99	18.78	18.97	17.11	17.00	5.76	5.68	99.76	98.09	0.964
Totals.	A	....	....	94.98	95.36	94.07	95.06	93.72	93.44	93.06	90.05	....	....	95.96	95.45	0.995
	B	....	....	94.79	93.01	94.85	95.83	95.83	95.63	93.90	92.66	....	....	95.96	96.96	1.010
	C	....	....	12.07	11.57	12.86	11.97	13.52	13.06	12.85	13.17	....	....	50.11	49.07	1.021
		12.51	12.50	12.80	13.00	13.00	12.13	12.99	12.65	12.13	12.94	....	....	50.61	49.91	1.014
		16.66	16.36	16.77	17.04	16.71	16.97	16.10	16.90	15.47	15.00	11.00	10.77	98.66	98.51	0.991
		16.66	16.66	96.96	90.77	99.86	99.96	99.07	98.13	97.96	97.72	11.00	10.77	394.69	389.17	1.004
Ratio.	A	.....		0.995		1.010		1.010		1.010		.....		.....		
	B	.....		0.979		1.026		1.018		1.012		.....		.....		
	C	.....		1.046		1.080		1.066		0.981		.....		.....		
		.....		1.028		1.012		1.015		0.986		.....		.....		
		.....		0.995		0.988		0.988		0.968		.....		.....		
		0.999		0.969		1.007		1.011		1.009		1.021		1.004		

Remarks: *A*—tests in W. race at 0.7 gate; *B*—tests in E. race at 0.7 gate; *C*—tests in W. race at 0.87 gate.

It is not wholly clear to the writer, however, why the Pitot tube velocity should be in the neighborhood of 1½% less than the meter velocity at the greater depths. It is not improbable that this would have been partly compensated for, had the observations in the east race been continued to Depths 5 and 6, but probably not entirely. In fact, there seems to be a reciprocal relation, as noted above, between the readings in the two races. This would follow naturally, owing to the symmetry of the flow in the races as to the central dividing wall, and the fact that the meters always rotate in the same direction. Thus, if there is an eddy clockwise at a certain position in either race, there should be a symmetrically located eddy counter-clockwise in the other race, and these might have opposite effects on the meter, the Pitot tube not being affected in the same way.

It is not impossible that the Haskell meter was running a trifle faster near the bottom of the race than the actual still-water ratings would indicate that it should. This would result from the fact that the rating boat was not a rigid support, nor was the water absolutely still during the ratings. This would necessitate shifting the rate line of the Haskell meter toward its ideal position of a maximum number of revolutions. This, in turn, would diminish all discharge records based on still-water ratings. On the other hand, to be consistent, it would follow that the rate line of the Gurley-Price meter would have to be shifted toward the maker's rate line, which would make for a larger correction to be added to velocities by the Haskell meter when based on still-water ratings, thus leaving true velocities in Table 5 practically unchanged. In corresponding manner, all the ratios of Tables 6 and 7 would be increased, while the meter velocities would be less in the same proportion, the effect of which would be to leave the corrected true velocities corresponding to the tables unaltered, they being in fact those of the Pitot tube. Thus, discharge estimates would not be affected materially in either case. The most reasonable explanation, however, is that the Pitot tube itself is variously affected by small amounts in different parts of the raceways.

The object, however, is not to speculate on such matters, but simply to check the computation of a small correction to the velocity, which correction may be in error by 50% and yet not affect the discharge measurements by the meter by more than three or four tenths of 1 per cent.

Interpolating a percentage for Depth 1, which was not ob-

served in the tests, equal to the mean given for Depth 2, 1.055, and another in Depth 4, taking an average between the means for Depths 3 and 5, practically 1.000, there may be arranged the figures in Table 7.

TABLE 7.—AVERAGE CORRECTION FOR HASKELL METER, BASED ON COMPARISON OF CURRENT METER AND PITOT TUBE RECORDS.

Depths.	Ratio of velocity by Pitot tube to that by current meter, from Table 6.	Relative velocity in each horizontal, being a mean for Haskell meter.	Corrected relative meter velocity.
1.....	*1.055	10.30	10.76
2.....	1.055	11.98	12.51
3.....	1.001	13.50	13.51
4.....	*1.000	14.04	14.04
5.....	0.998	14.06	14.04
6.....	0.955	15.86	15.86
7.....	0.904	19.96	18.39
		100.00	100.61

*Interpolated velocity ratio.

It follows from Table 7 that an approximate correction of 0.61% should be applied to discharges determined by the Haskell meter when used in these tail-races, and basing velocities on the still-water rating.

As a matter of fact, no direct use whatever was made of the still-water rating curves of the Gurley-Price meter, except to compute the corrections for the meters, which seem to be substantially verified by the Pitot tube tests. In reality, the Gurley-Price meter was rated relatively to the Haskell by comparisons of the simultaneous records taken by the meters in the two races during the numerous turbine tests.

While the Haskell meter runs in the west race, the Gurley-Price meter runs in the east race, and *vice versa*. If a pair of turbine tests be selected where the conditions are substantially the same, the Haskell meter being in the west race during one of the tests and in the east race during the other test, the total sum of the 84 velocities by the Haskell meter may be plotted to the total sum of the 84 numbers of revolutions per second by the Gurley-Price meter. If a number of such points be plotted, the curve drawn through them will represent the functional relation between the sum of the 84 velocities by the Haskell meter and the corresponding total sum of the numbers of revolutions per second by the Gurley-Price meter at the 84 meter points in the two races.

PLATE XXVI.
TRANS. AM. SOC. CIV. ENGRS.
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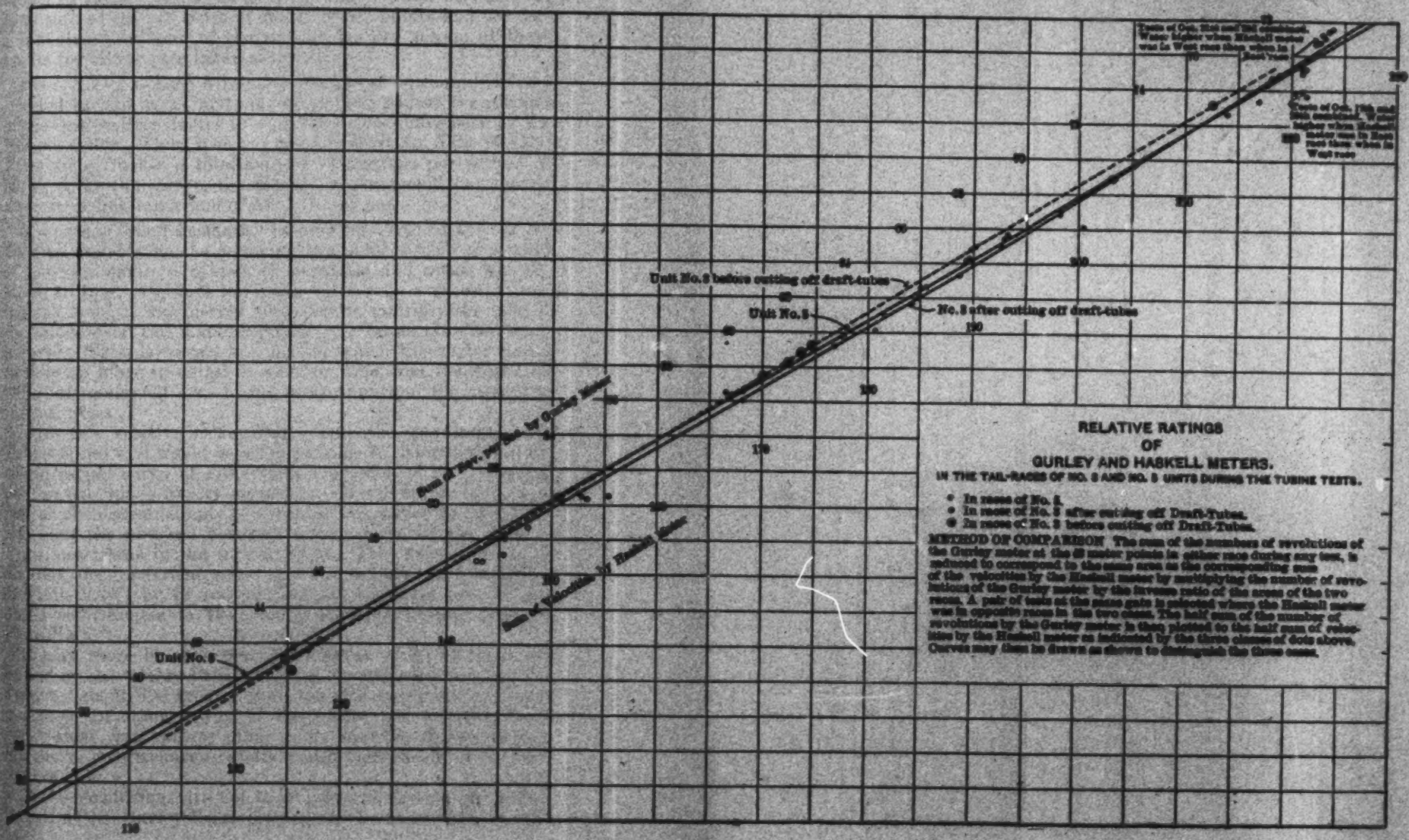
BROAT ON
CUP AND SCREW CURRENT METERS.



RELATIVE RATINGS
OF
GURLEY AND HASKELL METERS.
IN THE TAIL-RACES OF NO. 3 AND NO. 5 UNITS DURING THE TURBINE TESTS.

- In races of No. 5.
- In races of No. 3 after cutting off Draft-Tubes.
- In races of No. 3 before cutting off Draft-Tubes.

METHOD OF COMPARISON. The sum of the numbers of revolutions of the Gurley meter at the 48 meter points in either race during any test, is reduced to correspond to the same area as the corresponding sum of the velocities by the Haskell meter by multiplying the number of revolutions of the Gurley meter by the inverse ratio of the areas of the two races. A pair of tests at the same gate is selected where the Haskell meter was in opposite races in the two cases. The half sum of the number of revolutions by the Gurley meter is then plotted to the half sum of velocities by the Haskell meter as indicated by the three classes of dots above. Curves may then be drawn as shown to distinguish the three cases.

As the two races are so nearly alike, it may be accepted that, on the average, half the total sum of the 84 velocities will correspond to half the total number of revolutions per second at the 84 meter points, as a functional relation between the total sum of the velocities at the 42 meter points and the corresponding total sum of the revolutions per second at these points for either race taken separately.

Plate XXVI is such a relative rating curve, compiled from selected turbine tests, and may be used to reduce the records of the Gurley-Price meter to what they would have been by the Haskell meter. Thus, if in any tests on Unit No. 5 the Gurley-Price meter makes a total sum of revolutions per second of 50, then, by this curve, the Haskell meter would have made a record indicating a sum of 149.3 ft. per sec.

It was not found necessary to have any regard for the individual velocity by the meter at any point, except as a part of the total sum. A system of constants and ratios was devised, so that, to obtain the mean velocity in a raceway during any tests, it was merely necessary to multiply the sum of the velocities at the 42 meter points by a factor obtained from a curve. This, however, is a matter which the writer hopes to take up more in detail at another time, and therefore, he will confine himself here to the performance of the meters in the tail-races.

With this relative rating curve and the percentages of Tables 3 and 4, it would be quite possible to determine the absolute rating curve of either meter at each of the 84 meter points; but this is hardly necessary. It will suffice here, as a matter of interest, simply to conclude this paper by determining what the average absolute rating curve of the Gurley-Price meter was in the turbine tests. This may be done by dividing the numerical value of the abscissas and ordinates of Plate XXVI by 42 and plotting the resulting pairs of reduced co-ordinates to the corresponding reference lines in Plate XXV.

It may there be seen that the number of revolutions per second by the Gurley-Price meter in the tail-races was, on the average, about 6% greater than the still-water rating would indicate. In other words, if the writer had relied on this meter alone, without any other guide than the still-water rating curve, his discharge results would undoubtedly have been 6% too high.

These conclusions are not to be taken as casting any reflections on the Gurley-Price meter, which according to the

writer's experience, is an admirably constructed instrument. In fact, the results could not have been obtained without it. The rating of the meter was perfectly definite at each of the 84 meter points in the races, but could not be determined directly by the still-water rating, which, in reality, is the only thing at fault. The still-water rating should never be applied without regard to the probable deviations of the speed of revolution due to disturbances in the water. An excellent check on the meters is to rate them where operated with a Pitot tube.

ADDENDA.

Since the foregoing was written, the writer has had a very instructive experience with several types of meter used simultaneously on a complicated network of mountain streams. The results of oscillating the meters have confirmed the general conclusion that in all cases, relatively, cups are accelerated considerably, while screws are retarded slightly, in turbulent water. The errors of the cup meter, based on still-water ratings, were from 3 to 6 times greater than those of the screw, and in the contrary sense.

Design of Meters.—The principal desideratum of a current meter is that it should give the resolved component of velocity in a direction fixed relatively to the meter. The fact that a cup over-registers in turbulent water while a screw under-registers, gives a basis of design which may be used to produce a meter possessing this characteristic more or less rigidly. If the blades of a screw are "cupped" to the proper extent, and in the right sense, the effect may thus be toward neutralizing the retardation which the screw would otherwise suffer.

There are other ways of producing such a meter. Professors Greene and Moody, of Rensselaer Polytechnic Institute, have conducted a series of experiments there which resulted in the production of a meter practically giving only the resolved components of velocity.

A conclusion to be drawn from these experiences is that a tail, or rudder, is a useless appendage to a meter used in stream gauging. The meter should be held rigidly in the stream or conduit, giving only the component of velocity perpendicular to the cross-section. A cup meter would give better results in turbulent water if it had no tail, but was simply allowed to run at the end of a vertical rod like an inverted cup anemometer.

The recording device for a meter designed to be held rigidly n the current should register positively for down-stream cur- ent and negatively for up-stream current. There are cases here the current beneath the surface is up-stream; and the ld forms of meter make no distinction, as they should.

Accuracy of Velocity Determinations by Current Meters.— Under given conditions, the current meter is a very accurate nstrument. To prove this, it is only necessary to take a series f observations at a given meter point, or better, at a given et of meter points, when conditions at the gauging section are onstant. Repetitions of these observations will give results hecking within 1 per cent.

It is not even necessary to take observations under constant onditions, as is shown by the writer's plottings of the sums f the metered velocities at selected sets of meter points t various gauging stations. These curves are drawn through he plottings of points the co-ordinates of which are the ele- ation of the water surface at the given gauging station and he sum of the velocities at a selected number (25 to 100) of eter points in the cross-section. In shallow streams the eter points should be at mid-depth.

Even in the case of shallow, turbulent stony streams, such lotted points all lie within 1% of the finally determined curve, hus showing that the performance of the meter, be it of rew or cup type, is uniform and reliable.

The main sources of error are in the application of the still- ater rating, the determination of the section area, and the termination of the distribution of flow through the cross- ection. The errors due to an erroneous determination of the istribution of velocities are frequently styled the "errors due the method of calculation."

Distribution Factor.—If the discharge and section area are termined accurately for any one gauging, the mean velocity the section may be divided by the sum of the velocities at selected set of meter points. This ratio may be called the istribution factor for the corresponding stage of the water. this way, corresponding values of the distribution factor nd stage of the river may be determined and plotted, the co- rdinates being the elevation of the water surface and corre- ponding value of the distribution factor. If the work has en good, the points will plot as close to a smooth curve as e plotting of points representing the sums of velocities at e selected set of meter points.

Section Area.—The section area, next to the error in applying the still-water rating, is probably the most uncertain element of a discharge determination, where the stream is shallow and stony. Nevertheless, it has been ascertained that the surface profile of such streams at reasonably good stations is a function of the stage of the water, in many cases being simply a horizontal line. By taking a minutely accurate profile of the bottom of such a stream along the cross-section, and a number of surface profiles at various stages, the section area may be plotted to the corresponding elevation of water surface. This is another element for the accurate determination of a discharge curve.

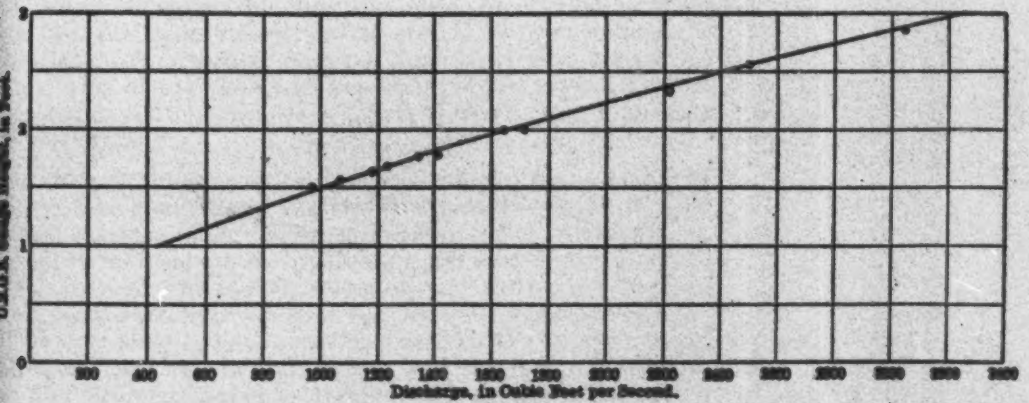
Statistical Synthesis of a Discharge Curve by Means of its Generating Elements.—According to the definitions given above, there are three principal generating elements of a discharge curve, all of which may be exhibited as curves plotted to the elevation of the water surface at the cross-section. These generating elements are, respectively, the sum of the velocities at a selected set of meter points, the distribution factor, and the area of cross-section.

If, for any given stage of water, the corresponding values taken from the curve of sums of velocities and the curve of distribution factors be multiplied together, the result is the mean velocity in the section for that stage. The product of this mean velocity and the section area taken from the area curve for the same stage is the discharge for that stage. In this way the discharges of the stream may be computed for all stages and plotted as a finally determined discharge curve.

The method is as strictly statistical as though the laws of probability had been applied formally, and the result is practically as satisfactory and infinitely easier to obtain. Moreover, errors are immediately detected and located.

Good work on the mountain streams of North Carolina and Tennessee has shown that individual discharge determinations based on the foregoing processes will plot within 1 or 2%, as extreme errors, of the final discharge curve.

PLATE XXVII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. LXXVI, No. 1288.
SMOAT ON
CUP AND SCREW CURRENT METERS.

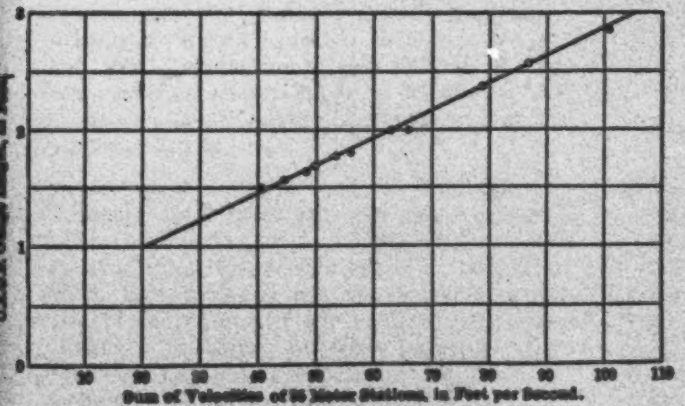


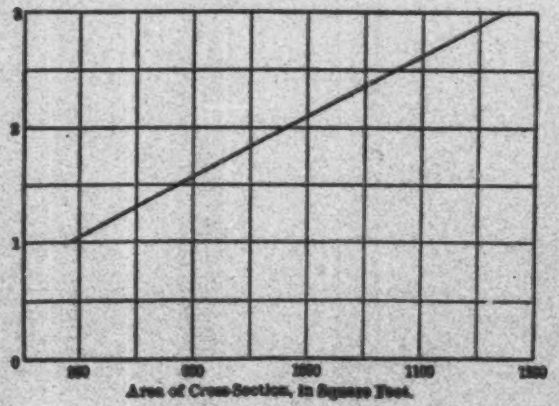
DISCHARGE CURVE FOR TUCKASEGEE RIVER AT BRYSON, N. C.

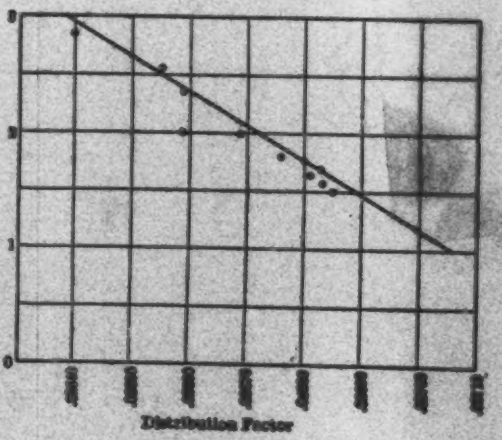
- Observations with Gurley Meter
- Observations with Haskell Meter

The discharge curve has been computed from the elementary curves obtained from observations with the Haskell Meter.

The points spotted on the discharge curve indicate the individual discharge obtained from each gauging.







Distribution of Flow.—The distribution of flow is determined in the ordinary manner by vertical velocity curves. It is best, however, to be systematic. A good system is to determine the ratio of the mid-depth velocity to the mean velocity in each vertical for the whole range of stages of the river. The writer has used an average value of these ratios for each stage of the river, by which the mean mid-depth velocity for the corresponding stage is to be divided, in order to obtain the mean velocity in the section before computing a discharge. In practice, a curve may be drawn giving the mean value of the ratio for each stage of the river. The determination of this ratio is a different thing from a gauging for discharge.

Discharge Gauging.—As described above, the writer prefers to take gaugings of shallow rivers at mid-depth at equidistant stations along the cross-sections. The individual discharge is then computed by dividing the sum of the products of the corrected mid-depth velocities and their corresponding areas by the average value of the before-mentioned ratio for the proper stage. The discharges at the ends of the section, below obstructions in the stream and around and through piers of bridges, should be treated separately under the title "end discharges" or "additional discharges." This additional discharge may be plotted as a function of the stage of the river. Such a plotting shows whether the calculation has been made on a consistent basis by forming a well-determined curve. Otherwise, the computer has varied his method of attack inconsistently.

Error in Using Average Ratios.—Undoubtedly, an error is made in using an average ratio of any sort, unless that average be determined properly. Thus a time average and a space average of a quantity are two entirely different things. It is important, therefore, to use the correct form of averages. However, if the values of the ratio of mid-depth velocity to mean velocity in thirty or forty verticals at a station of fairly uniform depth and velocity all lie between 1.10 and 1.18 as extremes, with an arithmetical average of about 1.14, no serious error can result in using such an average value. In fact, in this particular case, a detailed computation and one based on the average value of 1.14 differed by only one-seventh of 1 per cent.

Room for Research.—In the writer's opinion, it would pay scientific investigators to develop a meter which under all con-

ditions would give the resolved component of velocity in a given direction, rather than to attempt to determine any functional relation between the deviations of cup and screw meters from their still-water ratings. In the foregoing studies of the results at Massena it was thought sufficiently accurate to consider the error of the cup meter about six times the error, in the contrary sense, of the screw meter. This ratio is undoubtedly a variable, but no serious error can result by assuming it to be constant where the extremes observed would make less than 1% difference in the discharge, as was the case in the turbine tests at Massena.

Practical Application of the Methods.—Table 8 exhibits the results of a number of discharge determinations at a station where the turbulence of flow is at a minimum. In fact, the disparity between the records of the Haskell and Gurley meters is less in these observations than for those at any of the other stations operated in North Carolina and Tennessee. The average ratio of mid-depth velocity to mean velocity in the vertical, for 45 vertical velocity curves, is 1.055. The curve has not been drawn.

TABLE 8.—Results of a Number of Discharge Observations Taken at the Station at the Wagon Bridge, Bryson, N. C.

Meter.	Gauge height.	*Sum of velocities in 25 verticals.	Section area.	Distribution factor.	Discharge.	Mean velocity.
Gurley	1.80	40.38	686.0	0.03[illegible]	[illegible]	1.[illegible]
Gurley	1.67	44.81	690.8	0.03824	1 [illegible]	1.[illegible]
Gurley	1.64	46.10	811.7	0.03831	1 170	1.[illegible]
Haskell	1.66	46.66	821.3	0.03848	1 [illegible]	1.[illegible]
Haskell	1.77	48.25	866.4	0.03850	1 [illegible]	1.[illegible]
Gurley	1.69	46.97	842.1	0.03870	1 [illegible]	1.[illegible]
Gurley	1.89	48.73	880.3	0.03880	1 [illegible]	1.[illegible]
Gurley	2.09	50.94	920.3	0.03888	1 [illegible]	1.[illegible]
Haskell	2.27	52.96	1 [illegible]	0.03888	[illegible]	[illegible]
Haskell	2.16	52.[illegible]	1 [illegible]	0.03888	[illegible]	[illegible]
Gurley	2.09	[illegible]	1 144.3	0.03840	[illegible]	[illegible]

*The velocities are here based solely on the still-water ratings of the meters.

Plate XXVII shows the plottings of the main elements of the discharge observations of Table 8, according to the statistical methods described herein. The discharge curve is determined by the three elementary curves, as already explained. The elementary curves are plotted from the records of the Haskell meter.

DISCUSSION.

W. G. Price, M. Am. Soc. C. E. (by letter).—This paper gives the results obtained from a very large number of observations, and should be of much value. Before accepting these results as perfectly reliable, the writer would be pleased to know if the meters, in both the rating and stream tests, were suspended in precisely the same way and by supports of the same size?

Were weights used in both cases; and were they always the same distance from the wheel?

Was the skiff so far from the wheel that it did not push the water ahead of itself a trifle and thus reduce the rate of revolution of the wheel? In some cases, a steamer ascending the Upper Mississippi will check slightly the flow of the water some hundreds of feet ahead of itself.

The writer has had an extensive experience with current meters during a period of seventeen years, beginning with 1879, during which time he measured the flow in the Mississippi, Missouri, and Ohio Rivers, and their large and small tributaries, many times, and in many places. The following propositions are the result of his experience:

The thread of a perturbed current, of course, is longer than that of a steady current. A meter of the cup type, without a vane, measures the thread of the horizontal current perturbations, but when provided with a vane, it measures a trifle more than the thread of the horizontal perturbed current. This is due to the effect on the vane of the perturbed current which swings the wheel transversely to the current. If a cup meter with no vane is fixed on a vertical rod, the current perturbations moving up and down in the vertical plane will decrease the revolutions of the wheel and thus offset the increase due to the horizontal perturbations. This action is due to the fact that the top and bottom faces of the meter wheel present a propeller-shaped surface to the water, and when vertical currents strike the wheel they tend to turn it in the opposite direction from that produced by the water flowing against the cups. For this reason the vane should not be used in streams shallow enough to permit of it being omitted, if there are perturbed currents. Larger streams, when the gauging station is carefully selected, are not perturbed to such an extent as to cause a serious error in meter measurements.

A meter of the propeller type will measure less than the thread of the perturbed current, because of the inability of the

vane to keep the face of the wheel at all times precisely normal to the current. A current striking a propeller wheel sidewise does not increase its revolutions, as is the case with the cup meter. Each type of meter, in clear, straight, running water, will give the same accurate results, provided it has been accurately rated and is supported in the stream in precisely the same way as when rated, or by a method which does not produce an increase or decrease of current at the meter wheel.

When a weight is attached to the supporting rod under the meter, it reduces the discharge area and increases the velocity of the water in its vicinity, and thus increases the rate of revolution of the meter wheel. If the weight is placed 6 in. below the meter, the wheel, in each type, will run much faster than when the weight is 12 in. below the meter. A difference in the location of the weight, or the use of the weight in one case and not in the other, will produce all the difference, noted by the author for the Price meter, between ratings and stream measurements.

The propeller type of meter is often made to run more slowly between ratings and stream measurements by a slight quantity of grit blowing into the bearings, or being carried in by the water. This type of meter is often made to run slow by a particle of dead grass or leaf (found moving in most streams) catching on the propeller. The propeller type of meter does not free itself from such debris, as does the cup meter.

When meters are rated in still water, it is necessary to wait 10 min. or more after each passage of the meter for the water to become still again. If the wind is blowing against the surface of the water, variable and sometimes rotary currents will be produced, which will make the rating inaccurate. The surface currents will run in one direction and the under current in the opposite direction. For this reason, the meter should be rated at a depth of more than 2½ ft., and in water more than 5 ft. deep.

A rating taken in running water is likely to be the most accurate, because the running water carries away the disturbing currents produced by the movement of the meter.

When a cup meter is accurately rated in still water and in ordinarily steady running water, the two ratings will be the same within a small faction of 1%, and the rating curve can be drawn through all the plotted points obtained by the rating, so that no point will vary in revolutions as much as 1% from the curve.

The writer has used a Morse paper tape register and electric device to start and stop the register, or mark the paper tape, at the instant of passing the cross-wires suspended over the 200-ft. base, so that the fractions of revolutions of the cup meter wheel were determined at the beginning and end of the run; and such a rating in still water, with almost no wind, located all the plotted points within a very small fraction of 1% of the number of revolutions from the rating curve as drawn.

The ratings of both the Haskell and Price meters given on Plates XXIII and XXV are inaccurate, as the plotted points indicating the number of revolutions vary entirely too much. The errors in the Price ratings are apparently much greater than in the Haskell ratings.

Mr. Groat has conducted a series of observations in one tail-race where the currents were quite divergent, and the writer submits that the result of his experiment, treating as it does of one special condition, cannot be taken, either directly or by inference, to apply to general conditions of measurements of the flow of streams.

Under such peculiar conditions, where there are cross-currents, as in the Massena experiment, it is possible that the propeller type, owing to its peculiar construction, is less affected by such currents than the cup type; but if the propeller type were better for the measurement of streams where accurate measurements are impossible, owing to cross-currents, this fact would not indicate that such meters are better for general use.

A perfect still-water rating, of course, is what is required when the instrument is to be used in the measurement of straight, flowing streams. The usual rating in running water is made only to secure the same result as would be obtained by a perfect still-water rating. The small variations of the current from a straight line, as seen at the gauging section in most streams, makes only a negligible error in meter measurements.

A meter measures approximately the length of the curved thread of the current; therefore, if the thread is very divergent, inaccurate results will be obtained with any meter.

A gauging section having a perturbed current which would cause an error of 6% would give evidence to the eye by the boiling of the water, and would make the experienced observer hunt for a better section. However, better sections cannot possibly always be found.

A gauging section which has an up-stream current should never be used, and one which has very divergent currents can not give accurate results with any method of measurement.

The first meter used by the writer had a cup wheel which revolved in a horizontal plane. It was designed by Gen. Ellis, and had been used by him in the Connecticut River. This meter did good work in water which was absolutely free from grit. Floating organic matter, such as leaves and grass, did not often affect it, as the turning of the wheel caused such debris to free itself. When the attempt was made to use it in the muddy water of the rising Ohio in 1882, it gave very inaccurate results, owing to grit getting into the bearings, which made its rate variable. The writer was then furnished with two very finely constructed meters, designed by Clemens Herschel, M. Am. Soc. C. E., and made by Buff and Berger especially for this work. Each was of the propeller type, with horizontal shaft, having agate bearings, and each was provided with a vane to hold the meter in line with the current in both the vertical and horizontal planes. They were as perfect instruments of the propeller type as the writer has seen.

These meters were tested by rating them in clear water, and gave good results. They were then rated in a bayou of roily water, an overflow from the Ohio, and the results were very inaccurate, owing to grit getting into the bearings, and leaves and other debris catching on the wheel and continuing to revolve with it. They were tested in the turbid Ohio River with no better results.

It was absolutely necessary to have a meter which would do accurate work, if the great Ohio flood of 1882, which was then on its way, was to be accurately measured. In designing and constructing what is called the Price meter, on this occasion, the cup type of wheel was adopted, for three reasons: The friction of the bearings is so small that this wheel can measure sufficiently low velocities, which is not the case with the propeller type; the revolving wheel will clear itself of debris; and, by using a vertical shaft, with inverted cup bearings filled with air and oil which will stay in by capillary attraction, no water with its load of grit can enter. The friction of the bearings thus becomes a constant quantity. The well-known and successful operation of these meters is due to these three features, which the writer believes cannot be secured by any other design.

The propeller type of meter, designed by Mr. Herschel, was in service before the Price meter, but has had quite a limited use, while several thousand Price meters have gone into service. This test of time, under all kinds of conditions, indicates that the cup meter is the most efficient for general purposes.

The writer believes that with an accurately rated cup meter of the type having no vane—which is much the better design for shallow, perturbed streams—more accurate results could have been secured at Massena.

E. E. HASKELL, M. Am. Soc. C. E. (by letter).—The writer has been greatly interested in the results set forth in Mr. Groat's paper, for he has never had occasion to use current meters under just such conditions.

The current meter was designed originally to measure velocities in open channels. It has developed into two distinct types: those having screw wheels and those having cup wheels. The first current meter, "Woltman's Mill," more than 100 years old, was of the screw wheel type. This meter has undergone various changes in form and in the mounting of its wheel, and, on the whole, has proved to be very accurate and reliable. The origin of the cup wheel meter is not as definite. It has undergone various changes, and the cups have been of various forms, namely, cones, hemispheres, and combinations of cones and hemispheres. Although a great deal of good work has been done with meters of this type, they have not shown themselves to be anywhere near as reliable as those of the screw wheel type. In the writer's judgment, this is due to the fact that they do not always present the same area and form of wheel to the current pressure. The tilting of the meter, even through small angles, changes these, and consequently changes the rating curve or equation. In current meters of the screw wheel type, such tilting through small angles makes but a slight change in the area and form of wheel presented to the current pressure, and, accordingly, they follow much more closely their rating curve or equation.

In the last paragraph on page 836, the author states, as follows:

> "A conclusion to be drawn from these experiences is that a tail, or rudder, is a useless appendage to a meter used in stream gauging."

The writer's experience will not allow him to accept this conclusion. In a large river, the difficulty of holding the axis

of the meter perpendicular to the cross-section becomes so great that it is out of the question. In large streams it is necessary to measure both factors, velocity and direction, and reduce to obtain the velocity normal to the cross-section. In small streams or tail-races it is possible to hold the meter rigidly in place; but, when thus held, if the direction of the current makes an angle with the horizontal, that is, strikes the wheel of the cup meter either on the top or bottom of the cups, it will over-register as readily as if running in "eddies" or "boils." The amount of this over-registration depends on the angle which the direction of the current makes with the horizontal, and can only be determined by some check method.

It is not at all clear to the writer why a still-water rating of a current meter should not give an entirely satisfactory result. In all cases where the elements of the current in the open channel are reasonably parallel, the meter is working under almost the same conditions as when drawn through still water. In one case the meter is free and the water moving, and in the other the meter is free and moving, and the water still.

The following test of a direction current meter was made after it had been rated in still water. It was made in a large tidal channel, free from "eddies" or "boils," where the elements of the current were parallel. Each comparison was made by running the meter for 10 min., and in this time running ten large cylindrical can-floats, alternating on each side of the meter. The determined velocities are in feet per second, as follows:

Float	1.04	1.29	1.55	1.94	2.56	2.65	2.76	2.80	3.08
Meter	1.05	1.28	1.55	1.96	2.59	2.64	2.74	2.82	3.11

The greatest uncertainty in the results obtained with cup wheel meters is caused by using such meters from an unstable support, like a boat, particularly if the weather conditions are such as to give the boat any rocking or pitching motion.

The author is deserving of much credit for his work and his paper. Well planned and well executed work cannot help but make for engineering progress.

CHARLES H. MILLER, M. Am. Soc. C. E. (by letter).—Although the writer has made scarcely any current meter observations during the past twelve years, and hence has not kept up fully with the progress in such work, he is much pleased at the opportunity to read such a clear presentation

of a series of observations, evidently made with much painstaking care; and is gratified to note such a complete verification, stated, however, in a much clearer manner, of a positive difference between a cup meter and a screw meter when running in perturbed water; which difference the writer noted just a short time before leaving the Government service, and has never had opportunity to investigate further.

Although the difference was then cited as being due to instability of support, in other words, the rocking of the skiff, this rocking was done for the purpose, not only of causing conditions actually to be found in the river on account of "boils" and "eddies," but to show the effects that might be expected should the skiff or support be moved otherwise than in a straight and even course, while taking a rating in still water. That the writer was familiar with this source of error a number of years ago may be noted by referring to a letter* written by him, in which, in speaking about the rating of meters in skiffs, it is stated that "a rating should never be taken in a skiff which is being pulled with the oars," and that "the observers should be cautioned about keeping the same positions and not swinging their bodies from one side to the other while the observation is being made." This same passage was noted by the late William Starling, M. Am. Soc. C. E., and referred to in his paper entitled "The Discharge of the Mississippi River."†

Mr. Starling's paper treats in general of the many difficulties attending the taking of discharge observations on the Lower Mississippi River, and explains the reasons for some of the apparently discrepant results published in those days, he having had access, at the time, to the large mass of data gathered by the writer and others then engaged in wrestling with the problem of determining the extent of, or in eliminating, errors. It must be remembered that the possibility of error is very great when measuring the discharge of a river in which a favorable cross-section has a width of approximately ½ mile, with a maximum depth of 105 ft. at times, where velocities of 9 ft. per sec. or greater are found, and a total discharge of 1 750 000 cu. ft. per sec. may be obtained. Under such conditions, it is impossible to anchor the boat or equipment, and it must be held on one spot, as nearly as possible, by means of the rudder and the propelling power, counter-

Engineering News, January 24th, 1895, p. 58.

†*Transactions*, Am. Soc. C. E., Vol. XXXIV, p. 347.

balancing the current and wind forces. Careful observations were made to determine how much movement actually took place. In fact, a large portion of the time in the field was devoted to checking the accuracy of the observations. It may be noted that the meters then used were of the cup variety. Some checks, however, were made by a system of double floats.

As noting some of the improvements that were being made from time to time, attention is called to the fact that, at a time as recent as 1891, the meter rating was considered as following a straight line, and the proper straight-line equation was calculated by the method of least squares, often, however, not until some time after the field observations had been made. About the date just mentioned it became customary to plot the rating observations and draw the curve conforming as nearly as possible thereto, from which a rating table was taken directly. Other tables were made to cover all necessary computations in the discharge work, and each station observation was calculated while the boat or steamer was moving to the next station, so that the total discharge was known a few minutes after the last velocity observation had been made. For instance, during the morning of May 4th, 1892, at Arkansas City, Ark., the discharge was computed at 1 733 676 sec-ft. as compared with 1 532 875 sec-ft. for the day before. Another observation, made during the afternoon, gave 1 741 526 sec-ft., showing that some marked change had taken place during that time. On the following day it had dropped back to 1 589 172 sec-ft., or to about the general average at that time. Under the old methods, the observations were not computed until some time, often weeks, after the field observations had been made.

As illustrating the fact that every method that could be thought of at the time was used to eliminate errors, it will suffice to say that, in the case of a large and persistent difference in the discharge, as found at two stations 90 miles apart, new meters were purchased, later they were interchanged, frequent ratings were made, and finally the observers exchanged places with each other; all this was done without finding a satisfactory reason for the difference. This was in 1892. During the high water of 1893 these same stations were again occupied, and further efforts were put forth to get accurate results. Mr. Starling, in the paper previously cited, has this to say regarding this work:

"In 1893, the discharges at Arkansas City and Wilson's Point agree fairly well; and when checked by the results of the flanking observations, they present a very coherent mass of data, affording the most trustworthy measurement of the extreme high-water discharge ever obtained on the Mississippi."

Too much stress cannot be placed on the fact that it is just as important to avoid errors in rating meters as in taking the actual discharge observations; and the writer is strongly of the opinion, based on long experience in the field, that by far the larger part of the error is due to the fact that ratings are usually made under physical conditions which are widely variant from those under which the discharge observations are made. For instance, if the observations are to be made from a steamer, then the ratings should be made from the same or a similar steamer, and in dead water, if possible, although they can be made accurately in moving water, provided the movement is smooth, generally uniform, and slow enough to permit the taking of slow velocities in the downstream direction. Care must be exercised in keeping the meter below the influence of the "drag" occasioned by the steamer hull moving through the water.

Necessarily, the official reports, on account of limited space, as a rule, can contain but a brief explanation of methods and results; and, naturally, these reports incline toward the better showings, failing in general to recognize the fact that the publication of actual failures will often hasten the time of the final solution of the problem.

It may be of interest to know that the first forms of meters were of the wind-mill, screw, or propeller type; that is, the vanes turned, in a plane which was perpendicular to the direction of the current. These were used on South American rivers in 1871.

To eliminate the tail or rudder appears to be a move in the right direction, but a vertical rod could hardly be used with success in gauging a stream as large as the Mississippi, and it would no doubt be possible to work out a design which could be mounted concentrically on the cable which is now used to lower the meter, with its attendant lead weight, to depths of 60 ft. or more, affixing the tail or rudder to the lead weight, and placing the latter so far below the meter that it would not influence its running.

JOHN C. HOYT, M. Am. Soc. C. E.—Although more than fifty devices for measuring the velocity of water have been patented, the only meters which have had general use are the Price, Haskell, Fteley, and Ellis, or modifications of these.

Each of the various meters has first been devised to meet the requirement of some special condition, and may or may not be applicable to other conditions. Therefore, a current meter should never be used for other conditions than those for which it is designed or has been found to be applicable.

In 1888 the United States Geological Survey began gauging streams of all sizes and in all sections of the country. These streams presented an infinite variety of combinations of range in depth, width, and velocity, were often remote from railroad or other regular transportation facilities, and were consequently difficult and expensive to gauge. No adequate instruments or methods had been developed for work of this varied nature. Furthermore, elaborate equipment and methods were out of the question on account of the limited funds. It was necessary to devise or adapt a current meter which could be readily carried in the field and operated by one man, either from a bridge, boat, cable and car, or by wading.

To fulfill these requirements it was essential: (*a*) that the meter should be simple and light in construction, with no delicate parts which easily get out of order; (*b*) that it should be simple in operation, including its preparation for use under any conditions, and its dismantling, cleaning, and boxing after use; (*c*) that it should offer a small area of resistance to the action of the water; (*d*) that it should have a simple and effective device for indicating the number of revolutions of the wheel; and (*e*) that it should be adaptable for use under all conditions.

After experimenting with various types, the engineers of the Survey developed a meter combining certain essential features of the Price acoustic and the large Price electric meter. This is known as the small Price electric meter, and is now in general use in the Survey work. Modifications in its construction have been made from time to time, until now it represents the ideas of many engineers based on results of more than twenty years of experience in stream gauging.

The limitation of the Price meter pointed out in this paper, namely, that it may be effected by cross-currents, has always been recognized by its designers and users. Therefore, special care has been taken to restrict its use to work where the conditions are such that errors from this cause will not affect

the final estimates of discharge. These requisite conditions are: (*a*) a fairly smooth bed; (*b*) a measurable and steady velocity of current; and (*c*) a stationary stage during the measurement. The velocity of the current should vary gradually throughout the section, which should show no marked eddies, cross-currents, or boils, and its mean should not be less than 0.5 ft. per sec. at low stages. After visiting hundreds of gauging stations, on streams of varied character, in all sections of the United States, the speaker is convinced that only the exceptional station is not or cannot be located in accordance with these requirements. This statement is made in order to correct any impression which may be drawn from Mr. Groat's paper, that the Geological Survey records, based on measurements with the small Price meter, generally involve large errors. More than two hundred engineers have been engaged in the stream gauging work of the Survey for various periods during the last twenty years, and, as far as known, no valid criticism of the methods used has ever been made which was not fully appreciated by the Survey engineers; and they have made combined effort to correct, as far as possible, each defect in the work as soon as it is discovered. The instruments and methods have been subject to continual change, and old have been supplanted by new whenever the new have been proved the better. Constructive criticism of the work is, and has always been, welcomely received and acted upon, and this opportunity is taken to appeal to engineers who are interested in the use of stream flow records for more constructive criticism and for co-operation in raising this branch of hydraulics to the high plane for which all who are engaged in it are striving.

A few points in Mr. Groat's paper may be referred to briefly:

1.—The paper calls attention to the recognized fact that the differential meter is affected by cross-currents.

2.—It is believed by the speaker that the methods used in carrying on the work from which the conclusions in the paper were drawn, and the magnitude of the results obtained, are both open to question.

3.—Unfortunately, the methods are described only in a general way, and various factors which might affect the results materially are not adequately presented. Furthermore, sufficient data for making any exhaustive study of the results are not given. Therefore, any detailed discussion of the work is impossible.

4.—The large Price meter used in the work is of a type which has not been used for several years by engineers who are most familiar with stream gauging. In the work of the Geological Survey, it was abandoned several years ago, when fifty meters of this style, all practically new, were condemned and replaced by the small Price meter, which was found to give more satisfactory results.

5.—The reader is left in great doubt and uncertainty in regard to the standards used in the comparisons. Though the Haskell meter used may not be seriously affected by cross-currents, there are no experimental data, as far as known to the speaker, which show that this meter gives results any more accurate under the adverse conditions stated than does the Price meter.

6.—The results obtained with an unrated Pitot tube do not appear to be sufficiently conclusive for any final deductions. The Pitot tube itself has had no extended use in open channels, its behavior has not been fully investigated, and, in the limited experiments which have been made with it, many questions have come up which leave an uncertainty as to its action. It has been demonstrated that its rating does not hold near the sides of a canal, and it has also been shown that it will not measure the true velocity when the opening is not in line with the current.

7.—The paper points out a well-known defect in the Price meter, but gives no remedy, and offers no substitute which can be used under a wide variety of conditions.

8.—The assumption that the differences shown by the so-called still-water ratings of the meters apply when the meters were used in the canal is questionable. The amount of difference between the Price and Haskell meters, when rated under the conditions mentioned, will depend on the amount of disturbance introduced into the rating; as the Price meter will record, not only the horizontal motion, but also the vertical motion and the cross-currents.

9.—The experience of the Geological Survey shows that accurate ratings of the current meter cannot be made from boats, owing to the errors introduced in connection with obtaining the various factors entering into the rating. Changes in the methods of rating by the United States Geological Survey, the Bureau of Standards, and the Rensselaer Polytechnic Institute have changed the results of ratings about 3 per cent.

10.—The speaker is unable to see why one familiar with current-meter work would have attempted to use the Price

current-meter under the conditions found at Massena. Engineers of the Geological Survey have frequently refused to co-operate in work where similar conditions existed.

11.—The statistical synthesis method, as understood by the speaker, does not take into account the relative distribution of velocities and areas in various parts of the cross-section. The mean velocity in a cross-section, as defined by the Geological Survey, is obtained by dividing the discharge by the area, which will not give the same results as taking the mean of the velocities at various points in the cross-section. For example, a certain stream may have 50% of its flow in 10% of its cross-section. Furthermore, this method of computation has no apparent advantage over that ordinarily used, and has the disadvantage of being much more complicated, even if the results are of equal value.

12.—The question of the distribution of velocity in the vertical has been investigated most thoroughly by the engineers of the Geological Survey, who have found the mid-depth method to be the least desirable. The mean of the velocities at two-tenths and eight-tenths of the depth gives (without a coefficient) the velocity in the vertical, under all conditions of natural flow; and, next in value, the six-tenths depth method has been found to be the most satisfactory.

The only method yet devised for rating a current meter is by drawing it through still water. A close study indicates that no material error is introduced in the results obtained with this instrument on account of the method of rating. Large numbers of comparative measurements have been made with the Price current meter, calibrated weirs, and measuring tanks, all of which show that the meter, when properly used, will give results accurate within 1 or 2 per cent.

It has also been found that measurements at different points on a stream, where the conditions of measurement are entirely different, give results which agree closely. Many measurements have been made on two tributary streams and then on the main stream below, and the results check within the limits of accuracy necessary in work of this type.

C. W. Stanford, M. Am. Soc. C. E.—The speaker would like to ask Mr. Groat or Mr. Hoyt whether any of the current meters mentioned—the Haskell, the Price, the Ellis, or perhaps the admirable German instruments—after being rated in fresh water (still water, of course), have been used in salt water; and what percentage of accuracy can be obtained with such meters in salt water?

If such instruments have been rectified against corrosion, and against short-circuiting, can they be relied on when used in salt water?

B. F. Groat, Assoc. M. Am. Soc. C. E. (by letter).—If one will examine the papers and discussions concerning current meters published since the original study was made by Frederic P. Stearns, Past-President, Am. Soc. C. E., in 1879,* it will be found that there is much uncertainty among engineers concerning the reliability of these instruments, with which, up to the present time, there does not seem to have been any generally satisfactory and generally adopted practice. These facts are in sharp contrast to those connected with the use of other engineering instruments, such as the transit and level. No method can be deemed generally satisfactory until it meets the general approval of practitioners. So long as there is lack of agreement between various classes of current-meter observers, not only as to the general method of procedure, but also as to the reliability of various types of instruments, there can be no such thing as a satisfactory current-meter practice.

When it becomes generally realized that current meters obey their still-water ratings only when the conditions of flow are ideal, and that cup meters are affected in one sense and screw meters in the contrary sense, it will be apparent that there is a real reason for the diversity of opinion concerning the reliability of current-meter work.

The writer, therefore, was inspired by the hope that this paper might reopen the discussion and possibly put in motion an effort to improve the current meter.

Appended to the paper there is a brief description of a new system of taking discharge observations and a new method of constructing the discharge curve. This system and method have been applied most successfully in a number of cases, and are worthy of the attention of those contemplating a series of gaugings at one or more stations.

The method of synthesizing a discharge curve is not an invention of the writer which he is trying to introduce, but is a well-stablished method used by physicists and practicing engineers in determining various kinds of relations between observed magnitudes. It consists simply in separating a given investigation into its elementary parts and drawing a curve for each, the final relations being derived from the elementary curves or relations. The fact that the sum of the

*Transactions, Am. Soc. C. E., Vol. XII, 1883, p. 301.

velocities at a given set of meter points at a gauging station forms such an elementary relation, when plotted as a function of the gauge height, leads to the term "statistical."

The main advantage of the statistical method is that the entire series of gaugings, extending over a long series of years, may be connected into a consistent whole. The peculiar characteristics of a station may be studied from the elementary curves. If any change or break occurs in one or more of the elementary curves, a corresponding change or break has taken place in one or more of the physical characteristics or hidden conditions of the station. This is especially true of the sum of the velocities at a given set of meter points, because the sum forms a fixed relation between velocity and stage. The sum is chosen because, in taking a number of velocities, the accidental variations and errors in the velocities eliminate themselves. That is why, even at turbulent stations, a smooth curve can be drawn through the plotted values of the sum, with errors well within 1 or 2%, as extremes. It is not likely that changes in the hidden conditions at a station would be detected by any other method. They would be set down simply as unaccountable variations.

Another very important advantage of the statistical method is that it affords at once the most independent and most easily secured check on the velocity readings. Indeed, the sum of the velocities must plot on a definite curve, and this enables one to check the meter work at any newly observed stage with that at any other stage within 10 min. after all the velocities for the former have been recorded.

The writer is glad to know that his Conclusion 1, concerning cup meters, is generally recognized. Under certain nearly ideal conditions, such meters will give good results, but, the moment the conditions are changed in the slightest degree, the still-water rating becomes more or less inapplicable, with a resulting constant or systematic error.

Nevertheless, it would be perfectly safe to use a cup meter in turbulent water if, where used, it were rated with a Pitot tube. The fact that the meter runs with fidelity under such circumstances is another of the conclusions drawn in the paper, and one should not lose sight of this good quality. It may also be remarked that this is a fact which does not seem to have been generally recognized. Cup meters will undoubtedly have their uses, but improvements in the means for obtaining their ratings—not still-water ratings, but actual ratings at the time and place of use—are imperative. It will

do to talk about refined ratings when probable errors are reduced to values of less than from 3 to 5 per cent.

After reading the discussions one can scarcely shake off the idea that the niceties demanded for the conditions under which cup meters must be rated are altogether out of proportion to the degree of accuracy attainable with these meters in stream gauging. If a cup meter cannot be rated accurately from a boat when operated carefully, owing to changes in rating due to the slight irregularities of motion, what must be the effect on such a meter when subjected to the far greater irregularity of the motion of the water at a fairly good gauging station, to say nothing of the errors to be expected at a really turbulent station.

The writer believes that Mr. Miller made an important discovery in current-meter engineering when he noticed that cups over-register considerably and screws under-register slightly in agitated water. In due time this fact will impress itself on engineers generally, and lead to a meter which obeys its still-water rating more closely than any hitherto made.

The Haskell meter is so nearly correct under a wide range of conditions that it would seem to require only slight modification, as suggested in the paper, to render it almost independent of conditions. It would be a delightful task, for some one who has the time and means, to develop such a meter. Meantime, it cannot be too strongly urged on hydraulic engineers that a screw current meter is the most reliable kind for measuring the velocities of flowing water when using the still-water rating.

It may be well to define the terms "cup" and "screw," as the writer does not wish to apply the general propositions stated to every kind of instrument which may chance to be called a cup meter or a screw meter: A cup meter is one in which the rotating element operates on the principle of the Robinson cup anemometer, though the shape of the cups need not be limited to that of the hemisphere. A screw is a rotating element the surface of which would be generated by a straight line perpendicular to, rotating uniformly about, and moving uniformly along, the axis of rotation.

One would also hesitate to apply the propositions to meters having large or badly designed frames which would be likely to interfere with the action of the water on the runner. Although the frame of the cup meter is at the rear of the runner, it has decided and different effects on the rating of the

instrument when turned somewhat to the right and then an equal angle to the left of the line of motion.

The writer is more than pleased to have Mr. Price's open-minded discussion. The cup meter is very ingenious, and the means which Mr. Price has adopted to protect the bearings and secure uniformity of friction have probably been the cause of the continuance of this meter in the Government service.

Mr. Price may be assured that the meter was suspended in precisely the same manner during the turbine tests as in the ratings. This applies also to the stream tests. No weights were used in any case, and the meter wheel was about 7 ft. in advance of the stem of the rating boat. The reaction of the boat on the screw must have been slight indeed, as the ratings from a car at the Rensselaer Polytechnic Institute do not differ materially from those by the boat.

Fig. 1 shows the rating boat, and below it the rod used to support the meter. The hooks on this rod may be adjusted so that any desired series of depths may be secured. From the staging on which the observer stood a ⅝-in. rod extended across the tail-race at a fixed elevation. The meter was attached to one end of a ¾-in. rod, about 2 ft. long, the other end of which was screwed into the supporting rod. There were seven hooks on the supporting rod during the turbine tests, any one of which could be hooked over the ⅝-in. rod on the staging, thus immersing the meter to the corresponding depth. Six rope clips were attached to the ¾-in. rod at the verticals in which the meters were to be operated. The rope clips served as stops at which to hold the meter rod, when taking observations in the verticals.

Fig. 2 is a rough sketch of the Pitot tube and supporting rod. The Pitot tube (to the right) is a copy of "Tube *N*," as described in Mr. White's monograph, referred to in the paper. The supporting rod (to the left) was designed to be operated from the staging in the tail-race, in the same manner as the supporting rod for the meters. On Fig. 2 is shown one of the hoops to engage the ⅝-in. rod on the staging, and also the eyes on both the Pitot tube and meter supporting rods to which a guy wire was attached near their lower ends, thus holding the rods and preventing bending.

Mr. Price states that the meter of the propeller type does not free itself from such debris as dead grass and leaves. This is too broad a statement, for there is at least one meter of that type which does free itself, and that is the Haskell. This meter has been used by the writer many times in streams

carrying much dead grass, leaves, twigs, sand, and mud. On no occasion did it catch the slightest particle or give any evidence of being affected thereby.

This is due to the effective shape of the runner, which Dean Haskell has undoubtedly designed expressly for the purpose. The up-stream end of the wheel is brought down to moderately pointed or conical nose which sheds all debris carried by the water.

The question of friction in a current meter is very interesting. Throwing out the case of low velocities, the necessity seems to be, not so much for a small amount of friction as for constancy of amount. If the resisting torque is large but constant, a rating should be fixed just as exactly as in the case where the friction is small and constant. Notice, too, that there is a resisting torque caused by the hydraulic skin friction on a screw, which can be made as large as desired by lengthening the vanes along the axis. In this respect, the screw is just as much a differential meter as the cup meter.

The retarding skin friction has a much longer lever arm than the bearing friction, and has a much larger resisting torque, so that the bearing friction of a screw meter offers a resistance of secondary importance. Further, the resisting skin friction is a fixed function of the velocity, varying approximately as the square thereof. Hence it is clear that the principal portion of the resisting torque is fixed for each velocity and cannot be changed. It follows that, if the meter is kept in only fair condition, the rating is not affected seriously by moderate changes in bearing friction. The truth of this was tested in the experiments at Massena by taking part of a rating while the bearing was dirty and stiff, then completing the rating after the meter had been cleaned and oiled. Let the reader select from ratings *E* and *F* of the Haskell meter, Plate XXIII, the points taken before cleaning and oiling the meter. The Haskell meter is not sensitive to moderate changes of bearing friction.

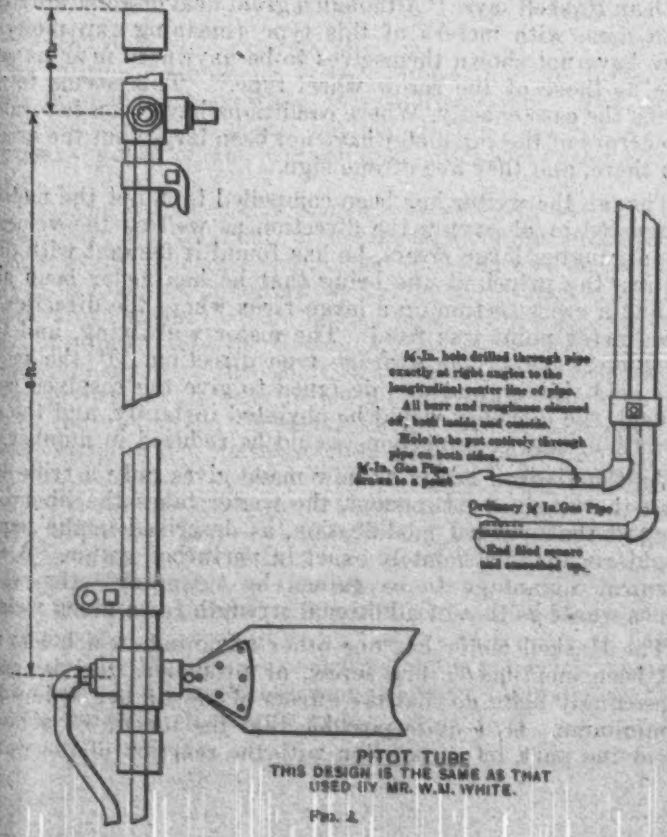
Mr. Price thinks the ratings (Plate XXIII) of the Haskell meter are inaccurate. If any one will take the pains to examine the percentage errors of the various ratings and the wide range of conditions under which these ratings were made, he will feel compelled to admit that the performance of this meter was very consistent throughout. Ratings of this kind are of more practical value than those obtained under restricted conditions, because the former afford an indication

of the degree of accuracy to be expected of the meter when in actual service, while the latter do not.

No doubt the rating line could be adjusted to the observations somewhat better. This rating line was located from a few of the earlier ratings, the later ones being plotted on the diagram subsequently. The change, if made, would be trifling, excepting for low velocities, which were not used.

The idea must not be entertained that the conditions in the Massena tail-races were bad. On the contrary, they were much better than those usually encountered in stream gauging. The flow of the water was parallel to the side-walls, and the meters might as well have been fixed rigidly to the rods, as far as concerned any tendency to swing. The errors of the meters were caused by small eddies and boils such as would certainly have to be dealt with at most gauging stations. The conditions of flow were carefully studied at each of the 84 meter points by using an inverted weather vane. An instrument was invented and used to ascertain the quantity of air in the water at each meter point. This quantity was found to be negligible.

Mr. Price states that a gauging station which has an upstream current should never be used, and one which has divergent currents cannot give accurate results with any method of measurement.



PITOT TUBE
THIS DESIGN IS THE SAME AS THAT USED BY MR. W.M. WHITE.

FIG. 2.

It may be that gauging stations with negative velocities should not be used, but do our current meters give any indication which would lead one to discard such a station when encountered? If the meter is 4 or 5 ft. under water, it cannot be seen; but it goes on recording the velocity just the same, even if the current is directed up stream, and the unsuspecting observer records a considerable positive velocity at the point, whereas it should have been recorded as negative.

As to the matter of divergent currents, the writer believes most fully that the problem may now be solved by using a screw meter held rigidly at right angles to the direction of flow. When the screw is modified, as suggested in the paper, it will increase still further the reliability of the results, even at the best of gauging sections.

Dean Haskell says: "Although a great deal of good work has been done with meters of this type (meaning cup meters), they have not shown themselves to be anywhere near as reliable as those of the screw wheel type." This seems to describe the case exactly. Where conditions have been favorable, the errors of the cup meter have not been large; but the errors are there, and they are of one sign.

Though the writer has been compelled to adopt the method suggested of observing the direction as well as the velocity, when gauging large rivers, he has found it fraught with difficulties, the principal one being that he has never been able to find a cross-section on a large river where the direction at each meter point was fixed. The meter will swing, and this completely masks the average true direction. If the meter was held rigidly, and was designed to give the resolved component, the difficulty would be obviated instantly, and the observations and computations would be reduced in number.

As the Haskell meter as now made gives only a trifle less than the resolved component, the writer takes the liberty to suggest that a slight modification, as described in the paper, might render it absolutely exact in perturbed water. A mechanical advantage to be gained by "cupping" the wheel vanes would be that of additional strength for a given weight.

The Haskell meter has one other advantage which has not yet been mentioned: The screw, or propeller, may be made exceedingly light, so that the effects of inertia are reduced to a minimum. It is quite possible that the inertia of a heavy revolving part, in conjunction with the reaction of the water,

may play an important role in changing the rating when the velocities become variable.

The still-water rating is not satisfactory at present because meters must be used in water which is more or less perturbed. Otherwise, the current meter becomes an instrument of limited use, and demands attention to a complicated system of details. As soon as a meter is produced which will resolve the momentary velocities at a meter point, the still-water rating will apply, even in perturbed water. Dean Haskell is to be congratulated on the fact that his meter almost does this very thing, so that probably only slight modification will be necessary to secure the desired result.

The float and meter comparisons are interesting. Applying the statistical method of summing the velocities in each case, the resulting comparison follows:

Sum of velocities by float	19.67
Sum of velocities by meter	19.74
Difference	0.07

Mr. Miller's discussion is very interesting, as it recounts work of unusual magnitude on the Mississippi. The writer has lived at various points on that river all his life, and remembers much of the Government work of various kinds there.

It is to be regretted that such a keen observer as Mr. Miller should have left the field of current-meter engineering. However, a useful fact once established is bound to live, and thus Mr. Miller its still potentially active in this branch of science.

Mr. Hoyt seems to fear that an impression may be drawn from the paper that the Geological Survey records, based on measurements with the small Price meter, generally involve large errors. This fear is hardly justifiable, as the writer states very definitely, "it seems certain that the correction for a cup meter when run at a good meter station on an open river is not large." On the other hand, it would certainly be on the side of safety to determine the degree of error in every important series of gaugings. One of the best ways to uncover an error of this kind is to run a cup meter and a screw meter in the section simultaneously. If the meters agree, there is no error. If they disagree materially, it will be found that the velocities by the cup meter are excessive, and those by the screw are deficient, the numerical value of such errors by the cup meter being relatively larger than those corresponding by the screw meter.

If any one wishes adminicular evidence as to the truth of this statement, beyond that afforded by the paper, he may refer to the paper, "Current Meter and Weir Discharge Measurements,"* by E. C. Murphy, M. Am. Soc. C. E. In this paper Mr. Murphy has, in the clearest manner, plotted the results of a number of comparisons of discharges by a weir with simultaneous discharges by cup and screw current meters.

In the case of the cup meters, practically all the discharges exceed the corresponding discharges by weir. This is indicated by the fact that practically all the points for the cup meters plot below the axis of abscissas in Fig. 2 of that paper.

In the case of the screw meter, the discharges are generally deficient, as the points generally plot above the axis of abscissas. Moreover, this is the more accurate meter, because the points average much closer to the axis, being in fact within 0.07% of it.

Mr. Hoyt concludes his discussion with several numbered paragraphs. They may be taken up in the same order:

1.—The paper does much more than call attention to the recognized fact that the cup meter is affected by cross-currents. It calls attention to the fact that the effect is productive of errors all on the side of excessive velocity, and that the screw meter is affected in the contrary sense, but to a relatively smaller extent. Though this was discovered by Mr. Miller years ago, it does not seem to have been recognized by anybody else since that time; but it is undoubtedly of the greatest importance to those who wish to improve the present methods of stream gauging.

Before carrying out any experiments at Massena, the writer was of the opinion that screw meters, like cup meters, would always show excessive discharges. This, he thought, would be the case because of the swinging of the meter and the consequent measurement of the thread of a sinuous, rather than of a straight, current. This, however, is incorrect. To prove it, attach a screw meter to the rating boat or rating car. Draw the meter over its course in the usual manner and count the revolutions. Then repeat the process, having all conditions the same as before, except that the meter is oscillated transversely to the direction of motion during its transit of the course. If the rating boat is used, the oscillation may be effected by rocking the boat. In the case of the car, some mechanical device may be used.

Transactions, Am. Soc. C. E., Vol. XLVII, p. 376.

Theoretically, the number of revolutions in the latter case should exceed those in the former case. Practically, the reverse is the case. The side-wash of the current has somewhat more than annulled the effect of increasing the length of the course.

2 and 3.—It is true that the methods used by the writer in making his discharge measurements were described only in a general way. Otherwise, the paper would have become so voluminous that the main facts would have been obscured. It must be remembered that the conclusions of the paper are not derived from a study of current meters *per se*, but are inductions from observations on the behavior of meters while testing turbines.

4.—The large Price meter was adopted as one type of meter to be used in the Massena tests, because the same type had been used by other engineers in the same tail-races several years before, and a comparison was desired. The results of the turbine tests would have been the same had the small Price, or any other cup meter been used instead of the large Price meter, because means were taken to correct the errors due to deviations from the still-water ratings.

5.—The standard adopted by the writer when comparing the cup and screw meters was the true velocity of the water. This appears when discussing Table 5, where it is shown that the cups over-register, on the average, by 5.6%, and the screw under-registers, on the average by 0.93 per cent.

When the Pitot tube and Haskell meter were compared, the Pitot tube was supposed to indicate, on the average, the true velocity. The result of this comparison was that the Haskell meter under-registered by about 0.6 per cent.

Thus there were two different methods of determining the discharge: (*a*) by cup and screw meters corrected through the medium of the boat-rocking tests, and (*b*) by Pitot tube and screw meter comparisons by which corrections were determined to be applied to the metered discharges.

It is worthy of note that these two methods of correcting the discharge, when applied to any given turbine test, give rise to a discrepancy of scarcely 0.3 of 1 per cent.

It is not claimed that rocking the boat is the best means for ascertaining the relative of errors of cup and screw meters. It is claimed that the nature of the case is such that extreme accuracy in this respect is not necessary. This is because the errors to be determined are not relatively large.

If it is feared that this paper is too daring in its conclusions to be credible, it may be well to search for independent verficiation. Such material may be found in Mr. Murphy's extremely valuable paper, "Current Meter and Weir Discharge Measurements," previously quoted.

Though Mr. Murphy gives an interpretation of the results of his experiments, yet he expressly states that he has "avoided in this paper a detailed comparison of results by different meters." Hence it will be permissible to analyze the results for the purpose of such a comparison.

The best method of eliminating accidental errors in comparing such a series of observations is the "statistical" method. In the case at hand, this method is particularly facile because comparable results may be obtained by the simple operation of summation.

In order the better to understand the conditions under which the tests by Mr. Murphy were conducted, it may be stated that they were made in the canal of the Hydraulic Laboratory at Cornell University. The discharge in each test was measured by weir and by two current meters. The two current meters were observed simultaneously in the same discharge section, one starting on the south side and progressing north while the other started on the north side progressing south.

There were twenty-five experiments, each made in the manner described. Ten of these were comparisons between the weir, Haskell meter No. 3, and small Price meter No. 363. Nine were comparisons between the weir, small Price meter No. 351, and small Price meter No. 363. Six were comparisons between the weir, Haskell meter No. 3, and small Price meter No. 351. Moreover, from these experiments may be selected sixteen in which the Haskell meter is compared with the weir, fifteen for Meter No. 351, and nineteen for Meter No. 363.

There are, therefore, six sets of experiments which may be compared statistically. In each case the aggregate discharge by the weir may be compared with the corresponding aggregate, or aggregates, by the meter, or meters, as the case may be. Table 9 gives the comparisons in tabular form.

TABLE 9.—STATISTICAL SUMMARY OF TWENTY-FIVE EXPERIMENTS BY E. C. MURPHY, M. AM. SOC. C. E., IN WHICH THE DISCHARGE OF A CANAL IS MEASURED SIMULTANEOUSLY BY A WEIR AND TWO CURRENT METERS, THE LATTER OPERATED IN THE SAME DISCHARGE SECTION.

Compiled from Table 1, *Transactions, Am. Soc. C. E.*, Vol. XLVII, p. 373.

No. of experiments.	Sum of all the discharges in all experiments, as shown by weir, in cubic feet per second.	SUMS OF THE DISCHARGES IN ALL THE EXPERIMENTS, AS SHOWN BY THE VARIOUS METERS.								
		Screw Type.			Cup Type.					
		Haskell Meter.			Price Meter No. 351.			Price Meter No. 363.		
		Sum, in cubic feet per second.	Error, in cubic feet per second.	Error, Percentage.	Sum, in cubic feet per second.	Error, in cubic feet per second.	Error, Percentage.	Sum, in cubic feet per second.	Error, in cubic feet per second.	Error, Percentage.
10	3 474.78	3 473.99	— 0.79	— 0.02	.....	.....	....	.....	.....	....
15	3 778.67	.....	....	....	3 480.06	+ 65.28	+ 1.94	.....	.....	....
10	4 166.17	.....	.....	.....	.....	.....	....	4 228.92	+ 62.05	+ 1.24
10	2 143.64	2 147.39	+ 3.75	+ 0.18	.....	.....	....	2 164.98	+ 20.55	+ 0.96
6	1 351.14	1 396.60	— 4.54	— 0.34	1 368.86	+ 37.19	+ 2.79	.....	.....	....
9	2 064.58	.....	....	....	2 070.77	+ 25.84	+ 1.39	2 094.01	+ 31.43	+ 1.54

The function of such a summary of aggregates is to eliminate in large measure the unavoidable accidental errors arising during the observations. Thus the remaining errors are each composed of two parts, namely, a large part, which is the net average constant error of the observations, and a small part, which is the net residual of the unequated accidental errors. From the approximate uniformity of the errors of the table, it may be concluded that accidental errors have been practically eliminated, and the computed errors for the sets of observations of greatest weight (the first three sets in the table) are the constant errors due to the meters, or due to deviations from their still-water ratings. Thus the constant error of the Haskel meter is —0.02%, that of the small Price No. 351 is +1.94% and that of the small Price No. 363 is +1.24 per cent. It may be inferred from the plottings by Mr. Murphy, on page 376 of his paper, that the average constant error of No. 351 should exceed that of No. 363. The reason for this is that the discharge by either of the meters

shows an increasing excess over the discharge by the weir with decreasing velocities, and there are relatively more observations of low velocity by Meter No. 351 than by No. 363. Had the reverse been the case, it might have been expected that the constant error of No. 363 would exceed that of No. 351.

It will be seen that the error of the Haskell meter for the ten comparisons with weir and small Price meter No. 363, is +0.18 per cent. This error, though insignificant, would have been negative had it not been for three experiments, Nos. 1-2, 3-4, and 5-6, in which this meter, for some unaccountable reason, gave discharges 4 or 5% greater than the weir. These three observations are plainly discordant, as may be seen by referring to the plottings for the Haskell meter in Fig. 2 of Mr. Murphy's paper. Had the meter run in these three experiments according to the same law as in all the other experiments, the errors for these three experiments would have been about nil. Thus the excess in discharge by the Haskell meter in the three experiments in question is about 25 cu. ft. per sec., as may be seen by consulting Table No. 1 of Mr. Murphy's paper. The aggregate for the weir from the writer's comparison, Table 9, is 3 474.78, and that for the meter would become 3 473.99—25.0=3 448.99. Thus the deficiency in the aggregate for the Haskell meter would be 3 474.78—3 448.99= 25.79. In other words, it is more than probable that the discharges by the Haskell meter are deficient by the slight percentage of 25.8÷3 475=0.75. However, it will not do to correct or reject observations simply because they are discordant.

It follows from the results shown in Table 9 that the cup meters in all cases gave excessive discharges and the Haskell meter gave relatively much smaller errors, the discharges being slightly deficient on the average. Therefore, the following general conclusions may be drawn from the results contained in Mr. Murphy's valuable paper:

(*a*) When a cup meter is run in moderately perturbed* water, it will register a larger number of revolutions per second than a perfect still-water rating would indicate.

(*b*) When a screw meter is run in moderately perturbed water, it will register a smaller number of revolutions per second than a perfect still-water rating would indicate.

*At the bottom of page 374 of Mr. Murphy's paper it is stated that there was a slight agitation of the water during the experiments.

(*c*) In the foregoing sense, a cup meter is affected relatively to a much greater extent than a screw meter.

(*d*) Either type of meter, when run in moderately perturbed water, will give uniform records in equal times, provided these times are sufficiently long, the flow of the water itself being subject to an established regimen.

(*e*) If both types of meter are used simultaneously in moderately perturbed water, the disparity between the discrepant velocities thus determined by the still-water rating may be taken as a basis for correcting the discrepant velocities.

(*f*) If the discharge by the weir be considered correct, the average error of the Haskell meter in Mr. Murphy's experiments was 0.02% on the side of deficiency, with a probability of its being slightly larger, and the average error of the cup meters was in the neighborhood of 1% on the side of excessive discharge.

(*g*) It would seem to follow that current-meter observations based on still-water ratings, without further correction, should be made with great caution. On the other hand, it seems certain that the correction for a cup meter when run at a good meter station on an open river is not large, and the corresponding correction for a screw meter may be negligible.

6.—It cannot be said that the Pitot tube used at Massena was an unrated instrument. It is an exact copy of one which was investigated as "Tube *N*" by Mr. White in the paper already referred to. It has a coefficient equal to unity.

In speaking of the accuracy of Pitot tubes, two distinct reactions must be kept in mind. One is the impulse of the moving water on the dynamic orifice, the other is the reaction of the static pressure and the moving water on the static orifice. If the static orifice is properly designed, the motion of the water, or the dynamic reaction, will have no effect on it; but the motion of the water will exert either suction or a positive pressure on an improperly designed static opening. It is this latter difficulty which has caused most of the uncertainty as to Pitot tubes.

Mr. White's experiments showed, in the most convincing manner, that the coefficients of all dynamic orifices of circular section, be they cylindrical, diverging, or converging, are exactly equal to unity. This was accomplished by towing a boat through the water with a number of different types of circular dynamic orifices attached somewhat in advance of the stem. The water stood at exactly the same level in all the risers, and the total head raised was equal to the sum of the velocity head and static head in each case.

7.—Although the paper does not essay to offer at once a complete remedy for the erratic behavior of current meters in perturbed water, it does point out the interesting fact that a close estimate of the true velocity may be made by using a screw meter of good design. If still greater accuracy is desired, both cup and screw meters may be used, the records being corrected by the observed relative deviations produced in some such manner as the rocking tests described briefly in the paper; or, even better still, the screw meter may be rated by a properly constructed and properly manipulated Pitot tube, under the exact conditions and at the exact point, or points, where the meter is to be used.

8.—The writer has oscillated a number of meters of different types, both longitudinally (up and down stream) and transversely (athwart stream and vertically). In all cases the cups were affected by increments several times as large as the decrements of the screws. This was for violent, as well as moderate, vibrations. It is true that the ratio is variable, values ranging from 3 to 6 having been noted; but, when the error between the cup and screw is not more than 7%, the application of the extreme ratios leads to corrections for the screw meter of only 1¼ and 1 per cent. Thus, an error of 100% in the true value of the ratio makes a difference in the final discharge of only ¼% for the case cited.

This method, of course, is only a practical way of getting an approximate result, but the approximation is shown to be close.

9.—A current meter which cannot be rated with sufficient accuracy from a boat will show even greater discrepancies when run at the average gauging station. The United States Lake Survey has done a great work on the Niagara and St. Lawrence Rivers, and its ratings were frequently made from a boat. The writer knows that screw meters were used extensively on this important work, but does not know whether

cup meters were also used. If the boat ratings had been unsatisfactory, it is certain that that fact would have led to a condemnation of such ratings. Possibly, if cup meters had been used, the boat ratings would have proven unsatisfactory. Of course, a rating made under laboratory conditions will plot almost exactly on a smooth curve; but a rating of a screw meter of good design will be nearly as good, if made from a boat.

It is presumed by the writer that the changes in the method of rating referred to by Mr. Hoyt were such as might be made by placing the weight too close to the wheel, or by running it near the sides, or bottom, of the tank. These are abnormal ratings, of a character which does not affect the question at hand.

10.—It has already been explained that the large Price meter was selected for the tests at Massena for the sake of comparison with the results of a former test in the same tailraces with a meter of this particular type. The writer is of the opinion that the results would have been substantially the same, even if the small Price meter had been substituted for the larger pattern. It must be emphasized that the conditions of discharge for much the greater portion of the gauging section at Massena were as good as those most frequently encountered at a good gauging station. The reliability of these tests cannot be questioned on this account.

The cup meter ran with great fidelity at any given point in the race. Its rating there, relatively to that of the Haskell meter or Pitot tube, was perfectly definite, a fact which does not seem to have been known heretofore. The trouble was not with the cup meter, but with the application of the still-water rating to the case. A raceway of uniform section can certainly be gauged within 1% of the true discharge. This statement is made because any given condition of discharge can be exactly reproduced at the observer's pleasure. This is one of the facts demonstrated at Massena.

11.—The distribution factor used in the statistical method is essentially a form factor. Its value depends on the shape of the solid constructed out of the components of velocity which are normal to the cross-section when these components are erected at their points of application. To every shape a particular value of the distribution factor attaches, but it is not true, conversely, that to every value of the distribution

factor a particular shape must attach. It is only necessary that shapes be equivalent as to discharge in order that two or more shapes may have the same value for their distribution factors. Hence it is not at all improbable that such changes of distribution actually take place at gauging sections without changing the discharge curve or rating table.

The mean velocity in the cross-section is the quotient obtained by dividing the total discharge by the area of the cross-section. The statistical method relies on this definition. In the turbine tests at Massena, the value of the distribution factor was ascertained by drawing the familiar contours of equal velocity over the cross-section of the race. The volume under these contours was computed, and, when expressed in proper units, was numerically equal to the discharge. This discharge was then divided by the area in order to ascertain the mean velocity.

By definition, the distribution factor is the ratio of the above determined mean velocity to the sum of the velocities recorded at the 42 meter points in the race. By actually computing this ratio, in the foregoing manner, for several of the turbine tests where the conditions were substantially the same, it was found that the value of the ratio—that is, of the distribution factor—was constant for given conditions. Consequently, it follows that the mean velocity in the tail-race may be ascertained simply by multiplying the sum of the observed velocities by the proper value of the distribution factor.

Though a somewhat different procedure was adopted in the Southern work, it was clearly proven that the distribution factor is a definite function of the gauge height, or stage of the river, which, when once reduced to a curve, may thereafter be used as the quickest possible means of ascertaining the mean velocity in the gauging section. This is accomplished simply by multiplying the sum of the velocities at a given set of meter points by the corresponding value of the distribution factor, as read from its locus.

In short, it has been demonstrated by these experiments that, in current-meter work, and discharge gauging in general, one may deal with aggregates of velocity area, and discharge, instead of individual values, with a gain in accuracy, time, labor, and satisfaction, to be realized in no other way.

Take, for example, the case of an observer who has just hurried to a gauging station to measure a discharge at a particular stage of the stream. He drops his meter at two or three dozen permanently established meter points (supposing the river is, say, 250 ft. wide), adds up all his velocities, compares the sum with his statistical velocity curve, finds the sum correct, and then multiplies it by a factor taken from a curve, the product being the discharge. The whole work may be done within an hour or two. Moreover, the observer knows his work is correct, because his velocity observations are checked.

12.—It is very certain that the Geological Survey has done excellent work in studying velocity curves and in formulating therefrom a few simple laws which govern the discharge of rivers. Much of this work is due to Mr. Hoyt with whose name is linked some of the most valuable hydraulic investigations.

For the most part, the writer's studies have been connected with shallow turbulent rivers, as he is frequently compelled to examine streams of this class with regard to the character of their flow. It may be of interest to know that he has arrived at two conclusions connected therewith. They are:

(*a*) A shallow turbulent stream may be gauged satisfactorily with a screw meter, or, better still, with a cup and a screw meter simultaneously.

(*b*) The proper point in a shallow turbulent section at which to take the meter readings is at mid-depth, otherwise the meter is too near the surface or too near the bottom to admit of accuracy.

Like Mr. Hoyt, the writer has summed up the measured discharges of two or more tributaries to find a good check on the discharge of the main stream. This does not prove, however, as a necessary conclusion, that the work at any of the stations is correct, as all may be, and sometimes are, affected by the same constant error.

In reply to Mr. Staniford: The writer has had only a limited experience with the current meter in salt water, in the form of a ship's log. This instrument was of the screw type, the runner being very similar to that of the Haskell meter. With care, such an instrument will give distances, and, there-

fore, velocities, well within 2%, even when the sea is agitated, assuming, of course, that there is no current or surface drift.

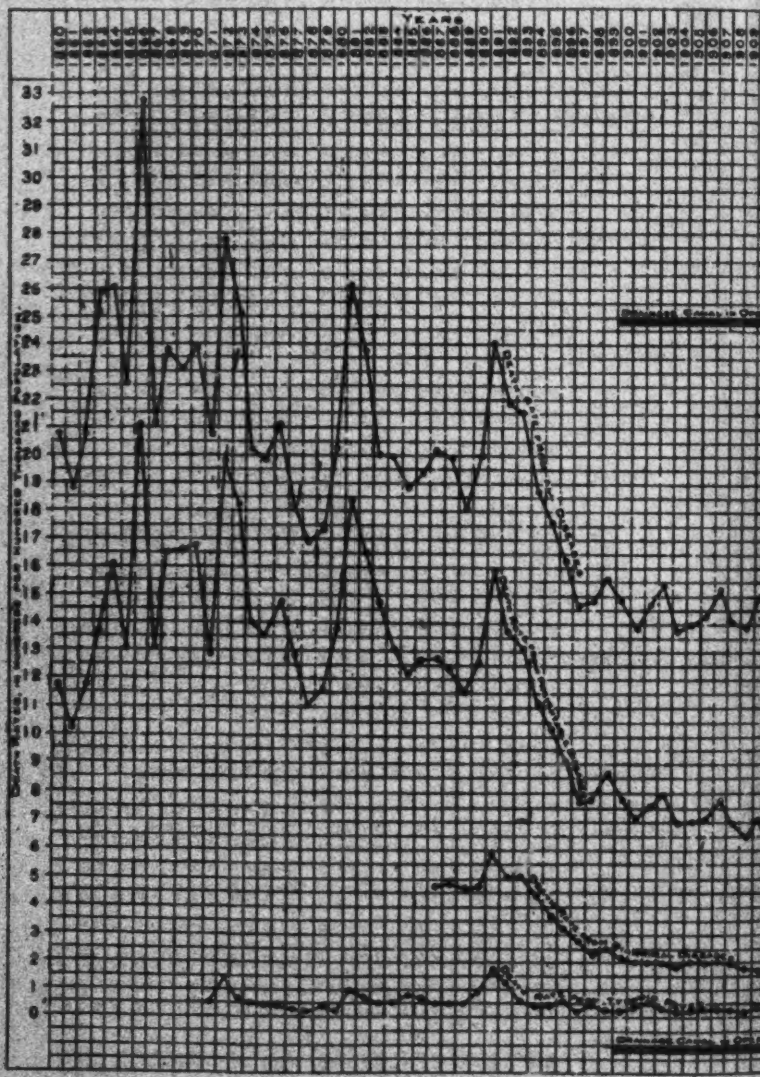
The Haskell meter was designed by Dean Haskell when he was working in salt water, and is adapted for use in both salt and fresh water. These meters have been used in coast harbors by officers of the U. S. Engineer Corps, and the Coast and Geodetic Survey; these officers would undoubtedly be able to state how fresh- and salt-water ratings compare.

ADAMS EXHIBIT ONE.

2—CHICAGO.

Death rates per 100,000 of population.

Years.	All Causes.	Typhoid Fever.	Diarrheal Diseases.	Tuberculosis.	Pneumonia.	Bronchitis.	Influenza.	Diphtheria and Croup.	Scarlet Fever.	Tuberculosis of the Lungs.	Measles.	Whooping Cough.	Small-pox.	Bright's Disease.	Heart Disease.	Cancer.	Violence.	Tuberculosis other than Pulmonary.	Children under 5 years.
1887	2027	50.3	477.6	202.6	132.6	99.2	.....	184.9	25.0	180.7	44.9	13.9	.3	42.1	72.2	39.6	126.8	22.0	996
1888	1965	46.7	487.2	201.3	137.7	102.5	.....	161.6	22.9	182.1	16.8	22.8	.....	41.1	77.1	45.0	110.5	19.2	939
1889	1812	48.4	465.6	181.0	125.0	87.3	0.1	161.4	19.8	164.9	21.8	10.3	.2	39.9	71.0	40.5	104.4	16.0	878
1890	1967	91.6	471.5	201.9	188.5	108.1	10.2	114.7	17.5	182.8	6.1	18.3	.....	46.3	74.2	41.9	130.4	19.2	899
1891	2416	173.8	585.3	208.9	251.8	130.1	1.7	118.2	43.4	184.5	23.1	16.9	.....	51.7	80.9	47.4	128.8	24.4	1097
1892	2185	124.1	508.6	198.6	190.8	108.6	8.6	129.0	31.8	182.3	15.4	13.7	.2	50.8	88.2	44.9	138.4	16.3	972
1893	2161	63.5	512.6	211.2	196.1	111.4	7.0	117.1	26.3	185.5	18.7	16.8	1.8	60.1	88.3	48.6	151.7	22.7	986
1894	1826	37.5	445.5	191.0	116.1	90.5	3.9	106.4	14.5	167.4	13.9	16.0	78.9	52.0	79.3	48.8	118.4	23.5	842
1895	1772	37.9	372.7	180.2	172.6	82.9	12.1	120.1	5.6	159.1	11.4	8.9	11.5	51.3	99.8	49.9	106.3	21.1	765
1896	1629	53.6	357.2	186.8	150.0	81.6	1.2	76.2	3.8	162.4	5.1	13.1	.....	57.3	90.3	51.4	103.7	24.4	680
1897	1463	29.8	278.2	172.6	144.3	68.8	1.0	51.9	5.4	146.4	9.3	10.7	.....	62.8	91.6	49.8	99.7	28.3	574
1898	1404	40.8	241.5	181.7	169.1	63.9	18.0	43.7	4.3	155.2	3.5	13.4	.....	67.5	89.8	50.6	97.4	26.5	523
1899	1503	27.2	253.5	178.9	211.4	62.3	19.1	55.4	32.9	154.7	10.3	4.7	.1	72.6	91.7	54.7	97.5	24.2	546
1900	1468	19.8	216.2	173.9	199.5	66.1	9.4	49.5	13.3	153.0	11.4	16.8	.1	65.7	111.4	56.2	97.3	20.8	487
1901	1397	29.1	211.3	164.0	178.5	49.4	11.5	29.4	9.4	142.4	9.0	11.8	.2	57.9	111.1	57.2	99.9	21.6	428
1902	1473	44.5	201.0	165.4	190.6	54.3	6.6	34.8	24.7	141.9	6.8	14.8	.3	60.8	116.5	59.6	104.9	23.5	446
1903	1562	31.8	194.6	182.5	250.1	54.3	9.0	34.4	16.0	135.0	14.9	14.6	2.5	81.9	113.0	57.4	130.9	27.5	447
1904	1410	19.6	177.7	186.5	217.8	44.0	6.0	21.5	7.5	164.8	2.5	5.9	1.5	97.3	107.5	59.2	106.0	21.7	371
1905	1413	16.9	192.5	188.8	184.1	43.5	7.9	22.2	4.1	164.6	11.9	18.4	3.1	103.5	108.3	61.1	108.3	24.2	438
1906	1453	18.5	197.0	192.0	202.5	36.3	6.0	27.7	24.7	161.3	6.4	8.4	.....	106.5	109.8	66.5	111.6	20.7	440
1907	1572	18.2	195.4	197.2	232.1	38.4	11.6	27.1	35.1	171.5	12.8	12.0	.03	121.9	113.2	75.1	121.6	25.7	402
1908	1449	15.8	202.3	186.7	167.4	37.6	15.9	26.5	19.6	163.0	8.1	6.4	.....	102.0	128.1	74.9	118.1	23.7	459
1909	1458	12.6	171.1	181.0	219.6	6.8	8.7	31.7	17.2	155.9	7.7	6.5	.....	105.9	147.4	76.7	126.5	25.1	436
1910	1514	13.7	177.2	178.0	240.8	7.8	6.6	37.4	18.4	153.3	8.7	7.9	.03	113.9	151.4	82.3	116.2	24.7	461
1911	1455	10.9	147.0	166.0	219.6	4.0	5.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	409
1912	1492	7.5	149.7	163.5	220.4	4.7	2.8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	436



ADAM'S EXHIBIT 2.

ADAMS' EXHIBIT 3

6.

COURSE OF THE DEATH RATES FROM IMPURE WATER DISEASES AND IMPURE AIR DISEASES: CHICAGO, 1887-1912.

COMPARISON OF TWO THIRTEEN-YEAR PERIODS.

Death-Rates per 100,000 Population.

Year	IMPURE AIR DISEASES (Tuberculosis. Influenza.) (Pneumonia. Bronchitis.) Total	IMPURE WATER DISEASES Typhoid and Diarrheal Diseases.
1887	434.5	527.6
1888	441.5	533.9
1889	393.4	514.0
1890	508.7	563.1
1891	593.1	758.1
1892	515.6	623.7
1893	525.7	566.1
1894	401.5	483.0
1895	447.8	410.6
1896	419.6	389.8
1897	386.8	307.5
1898	422.7	282.3
1899	471.8	280.7
1900	447.8	236.0
1901	403.4	240.4
1902	416.8	245.5
1903	495.9	226.4
1904	454.3	197.3
1905	424.3	209.4
1906	436.8	215.5
1907	479.4	213.6
1908	407.6	218.1
1909	416.1	183.7
1910	433.2	190.9
1911	394.8	157.9
1912	391.4	157.2
Average Rate.		Average Rate.
1887-1899	458.7	480.7
1900-1912	430.9	207.1
Decrease	27.8	237.6
Per Cent Decrease	6.1%	56.9%

ADAMS' EXHIBIT 4

Distribution of Deaths from Typhoid Fever, by sex and age.
Chicago, 1912.

Age	Males	Per Cent of all Deaths of Males	Females	Per Cent of all Deaths of Females	Both Males and Females	Per Cent of all Deaths
1- 5	5	4.27%	4	6.8	9	5.1
5-10	5	4.27	7	11.9	12	6.8
10-20	18	15.4	13	22.0	31	17.6
20-30	42	35.9	20	33.9	62	35.2
30-40	22	18.8	10	16.9	32	18.2
40-50	18	15.4	2	3.4	20	11.4
50-60	5	4.27	1	1.7	6	3.4
60-70	2	1.7	1	1.7	3	1.7
70-80			1	1.7	1	.6
All ages	117	100.0	59	100.0	176	100.0

Males constitute 66.5% of all deaths, females, 33.5%.
(Data taken from the records of the Chicago Department of Health.)

ADAMS' EXHIBIT 5.

II.

DECREASE IN VARIOUS DEATH-RATES SINCE THE DRAINAGE CANAL WENT INTO OPERATION.

Comparison of Two Thirteen Year Periods: (1887-1899) and (1900-1912)
Death-rates per 100,000 Population.

CAUSE	Decrease in Death-rate (1887-1899) (1900-1912)	Per Cent Decrease (1887-1899) (1900-1912)	Number of Deaths Prevented from cause named for every death Prevented from Typhoid.
All Causes	398	21.3	9.3
Preventable Diseases	418	36.9	9.8
Impure Water Diseases (as recognized by Chicago Dept. of Health)	274	56.9	6.4
Impure Water Diseases (as recognized by Sedgwick and MacNutt)	‡290	31.8	6.8
Diarrheal Diseases	231	55.2	5.4
Typhoid Fever	42.7	68.2	...

‡1887-1899 compared with 1900-1912.

ADAMS EXHIBIT 6.

ADAMS' EXHIBIT 7.
(Public—No. 92.)

An act to facilitate the collection of commercial statistics required by section 2 of the river and harbor appropriation acts of eighteen hundred and sixty-six and eighteen hundred and sixty-seven.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That owners, agents, masters and clerks of vessels arriving and departing from localities where works of river and harbor improvements are carried on shall furnish, on application of the persons in local charge of the works, a comprehensive statement of vessels, passengers, freight and tonnage.

Sec. 2. That every person or persons offending against the provisions of this act shall, for each and every offense, be liable to a fine of one hundred dollars, or imprisonment not exceeding two months, to be enforced in any district court in the United States within whose territorial jurisdiction such offense may have been committed.

Approved February 21st, 1891.

Trip No. _____

Statement of Traffic
Passing Through
St. Mary's Falls Canal

_____ 190____

From _____

To _____

Bound Down
(East)

Name and Class of Vessel _____

Draft of Water _____ feet _____ inches

Copper, tons _____

Grain, bushels (Corn, Oats, Rye, Barley, Flax Seed) _____

_____

Building Stone, tons _____

Flour bbls. _____

Iron Ore, tons _____

Iron, Pig, tons _____

Lumber, M ft. _____

Silver Ore, tons _____

Wheat, bushels _____

Unclassified Freight, tons _____

Total Cargo, tons _____

Passengers, number _____

_____

Clerk Master

N. B.—(All tons are "net" tons of 2,000 pounds except where otherwise specified.) Detroit March, 1905—30,000.

E31(b)

ADAMS' EXHIBIT 8.
(Public—No. 92.)

An act to facilitate the collection of commercial statistics required by section 2 of the river and harbor appropriation acts of eighteen hundred and sixty-six and eighteen hundred and sixty-seven.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That owners, agents, masters and clerks of vessels arriving and departing from localities where works of river and harbor improvements are carried on shall furnish, on application of the persons in local charge of the works, a comprehensive statement of vessels, passengers, freight and tonnage.

Sec. 2. That every person or persons offending against the provisions of this act shall, for each and every offense, be liable to a fine of one hundred dollars, or imprisonment not exceeding two months, to be enforced in any district court in the United States within whose territorial jurisdiction such offense may have been committed.

Approved February 21st, 1891.

Trip No. _____

Statement of Traffic
Passing Through
St. Mary's Falls Canal

_____ 191__

From _____

To _____

Bound Up
(West)

Name and Class of Vessel _____

Draft of Water _____ feet _____ inches

Coal, tons Soft _____ Hard _____

Grain, bushels (Corn, Oats, Seeds, Cut Feed) _____

Flour, bbls. _____

Manufactured Iron, tons _____

Salt, bbls. _____

Unclassified Freight, tons _____

Total Cargo, tons _____

Passengers, number _____

_____ Clerk _____ Master

N. B.—All tons are "net" tons of 2,000 pounds, except where otherwise specified.

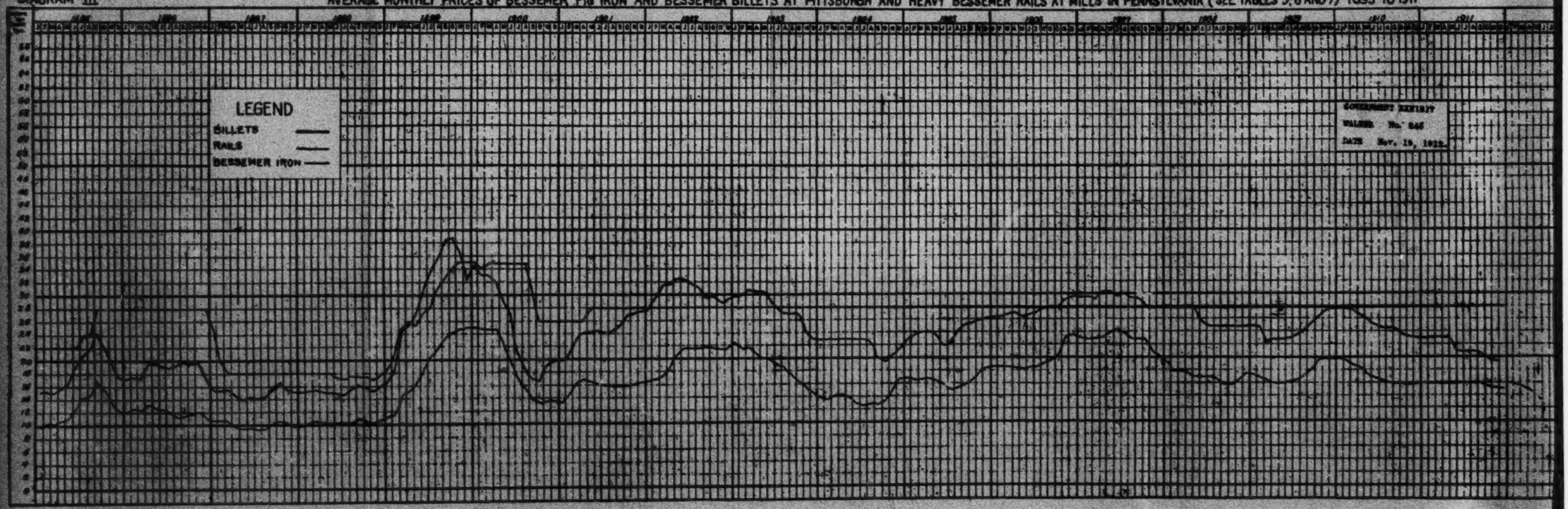
Detroit, April 12, 20,000.

Adams Exhibit 9.

Adams' Exhibit

DIAGRAM III

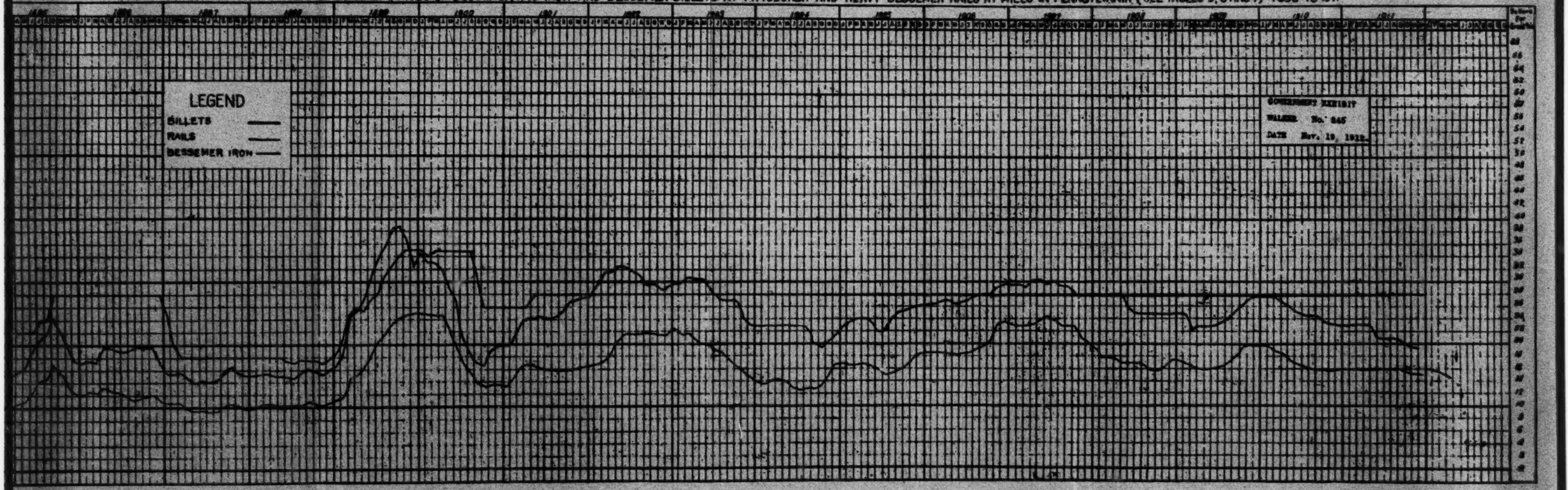
AVERAGE MONTHLY PRICES OF BESSEMER PIG IRON AND BESSEMER BILLETS AT PITTSBURGH AND HEAVY BESSEMER RAILS AT MILLS IN PENNSYLVANIA (SEE TABLES 5, 6 AND 7) 1895 TO 1911



Adams' Exhibit 9

AM III

AVERAGE MONTHLY PRICES OF BESSEMER PIG IRON AND BESSEMER BILLETS AT PITTSBURGH AND HEAVY BESSEMER RAILS AT MILLS IN PENNSYLVANIA (SEE TABLES 5, 6 AND 7) 1895 TO 1911



ADAMS' EXHIBIT 10. 1675
Government Exhibit Walker No. 268
Date, Nov. 20, 1912

TABLE 52. Average Price of Heavy Steel Rails in England and in the United States, 1895 to 1911, by months (Dollars per Gross Ton).

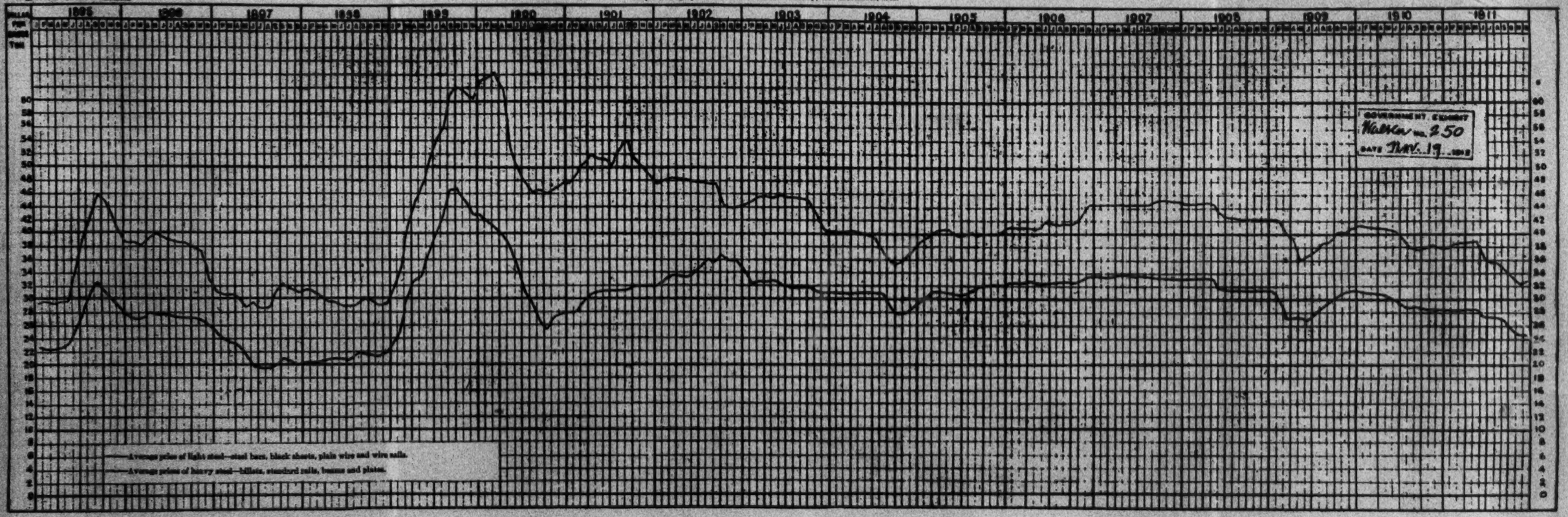
	1895		1896		1897		1898		1899		1900	
	England	United States	England	United States	England	United States	England	United States	England	United States	England	United States
January	17.18	22.00	23.11	28.00	22.38	25.00	21.90	18.00	22.96	18.50	34.06	35.00
February	17.03	22.00	23.11	28.00	22.50	20.00	21.90	18.00	23.11	20.25	34.37	34.20
March	17.27	22.00	23.11	28.00	22.05	18.00	21.90	18.00	23.23	24.80	36.01	35.00
April	17.64	22.00	22.50	28.00	21.90	18.00	21.90	18.00	24.48	25.75	37.40	35.00
May	17.64	22.00	22.14	28.00	21.90	18.00	21.90	18.00	24.94	25.20	37.71	35.00
June	17.64	22.00	21.90	28.00	21.90	18.00	21.90	17.50	25.30	27.25	37.10	35.00
July	17.64	24.00	21.90	28.00	21.90	18.00	22.14	17.00	30.26	28.25	36.50	35.00
August	18.25	24.00	21.90	28.00	21.90	18.00	22.50	17.50	30.41	31.00	35.16	35.00
September	19.31	28.00	21.90	28.00	21.90	18.00	22.50	17.50	32.36	32.50	34.06	30.25
October	21.13	28.00	21.90	28.00	21.90	18.00	22.50	17.50	32.85	34.00	34.06	26.00
November	22.87	28.00	21.90	28.00	21.90	18.00	22.50	17.50	33.76	35.00	30.66	26.00
December	23.11	28.00	21.90	28.00	21.90	18.00	22.50	17.50	34.06	35.00	28.89	26.00
Average	18.89	24.33	22.27	28.00	22.00	18.75	22.17	17.63	28.14	28.13	34.67	32.29

	1901		1902		1903		1904		1905		1906	
	England	United States	England	United States	England	United States	England	United States	England	United States	England	United States
January	28.50	26.00	26.28	28.00	26.76	28.00	22.87	28.00	21.90	28.00	29.35	28.00
February	27.67	26.00	24.63	28.00	26.76	28.00	21.90	28.00	23.72	28.00	30.11	28.00
March	25.79	26.00	25.70	28.00	26.76	28.00	21.90	28.00	24.45	28.00	30.41	28.00
April	25.55	26.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	30.41	28.00
May	25.06	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	30.87	28.00
June	25.24	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	31.02	28.00
July	26.76	28.00	26.76	28.00	26.76	28.00	21.90	28.00	25.55	28.00	31.02	28.00
August	26.76	28.00	26.76	28.00	25.55	28.00	21.90	28.00	25.55	28.00	31.02	28.00
September	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	25.55	28.00	30.72	28.00
October	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	25.55	28.00	30.41	28.00
November	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	28.13	28.00	30.53	28.00
December	26.76	28.00	26.76	28.00	24.33	28.00	21.90	28.00	28.95	28.00	31.63	28.00
Average	26.54	27.33	26.45	28.00	25.85	28.00	21.98	28.00	25.50	28.00	30.63	28.00

	1907		1908		1909		1910		1911	
	England	United States	England	United States	England	United States	England	United States	England	United States
January	32.08	28.00	29.80	28.00	26.15	28.00	25.55	28.00	27.52	28.00
February	32.69	28.00	29.20	28.00	25.55	28.00	26.00	28.00	27.98	28.00
March	32.85	28.00	29.20	28.00	25.55	28.00	26.15	28.00	27.86	28.00
April	32.85	28.00	28.50	28.00	25.55	28.00	26.28	28.00	27.37	28.00
May	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
June	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
July	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
August	32.85	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
September	32.08	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
October	31.63	28.00	27.98	28.00	25.55	28.00	26.76	28.00	27.37	28.00
November	30.66	28.00	27.67	28.00	25.55	28.00	26.76	28.00	27.37	28.00
December	30.41	28.00	26.76	28.00	25.55	28.00	26.76	28.00	27.37	28.00
Average	32.22	28.00	28.26	28.00	25.60	28.00	26.51	28.00	27.47	28.00

DIAGRAM VIII

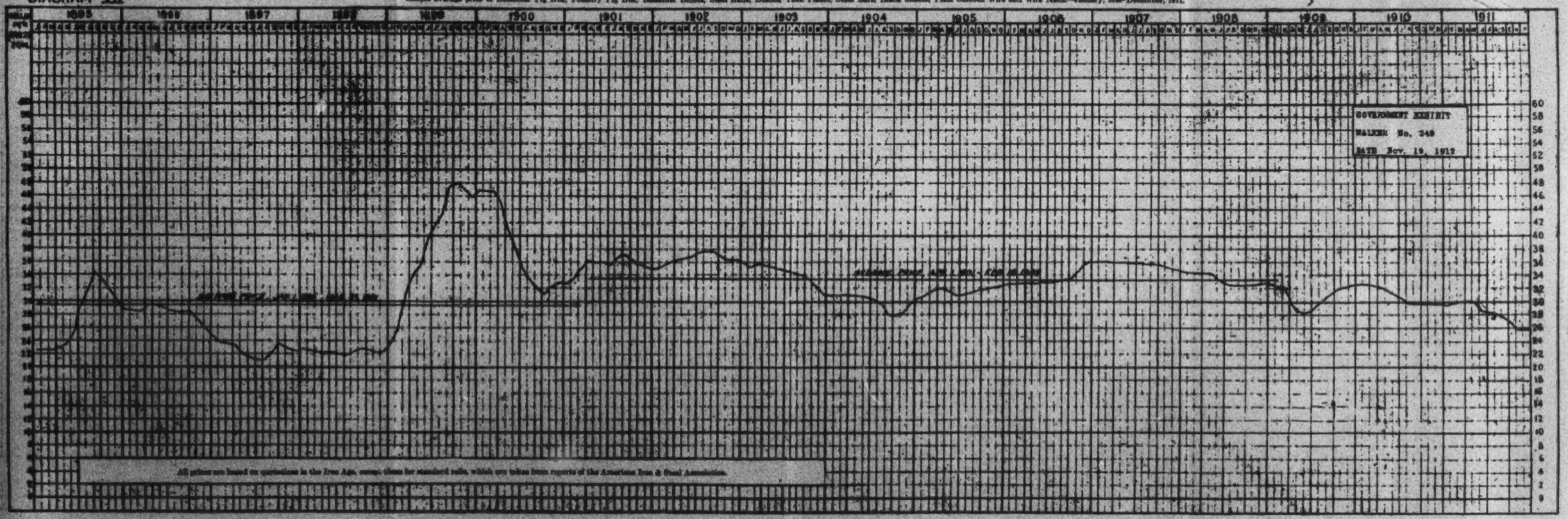
Simple average prices of Steel Products.—January, 1895-December, 1911.



Adam's Exhibit 12.

DIAGRAM VII

Simple average price of Bessemer Pig Iron, Foundry Pig Iron, Bessemer Billets, Steel Rails, Beams, Tank Plates, Steel Bars, Black Sheets, Plain Smooth Wire and Wire Nails.—January, 1895–December, 1911.



ADAMS' EXHIBIT 13.

19

Loss that would be sustained by the City of Chicago and dependent populations were the present facilities for obtaining an adequate supply of pure water impaired or destroyed, based upon a comparative study of health statistics of the city for 13 years before and 13 years after the opening of the Chicago Drainage Canal.

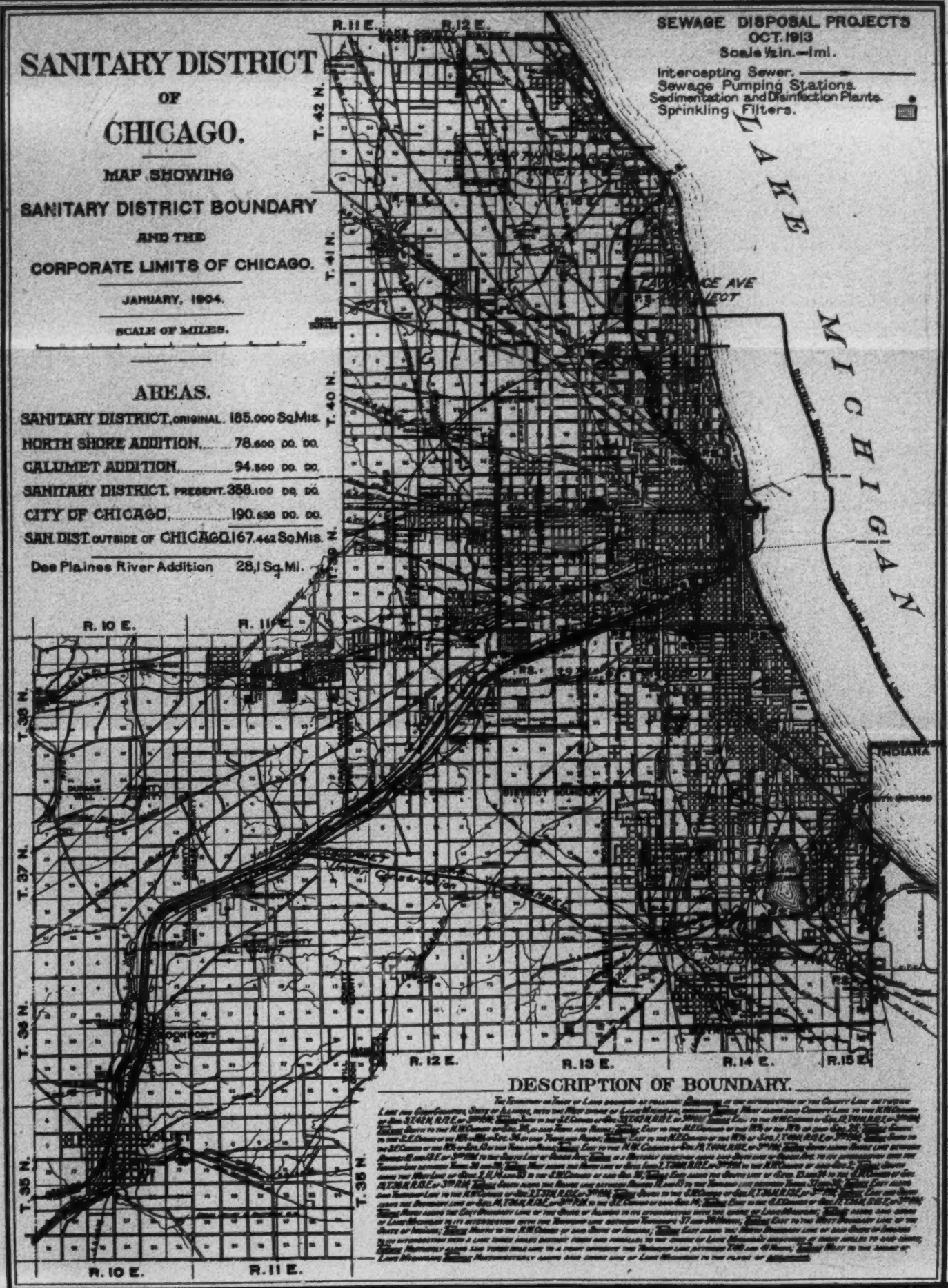
Per Annum.

Per 100,000 of the Population.

Kinds of Loss.	From Increase in Typhoid Fever	From Increase in Other Diseases
I. By Loss of Contributions to Maintenance:		
a. Through premature death of male workers, 83% of 28.39x36x300	$254,488	$636,220
b. Through sickness, 83% of (483x10) + (28.39x2) + 52x300	23,400	23,400
II. By Decrease in Capital Building:		
a. Through premature death, 42.7x 36x40	28,256	70,640
b. Through sickness (726x10) + 52x40	5,581	5,581
III. By Unnecessary Dissipation of Resources: 483x58.41	42,405	42,405
	$354,130	$778,246

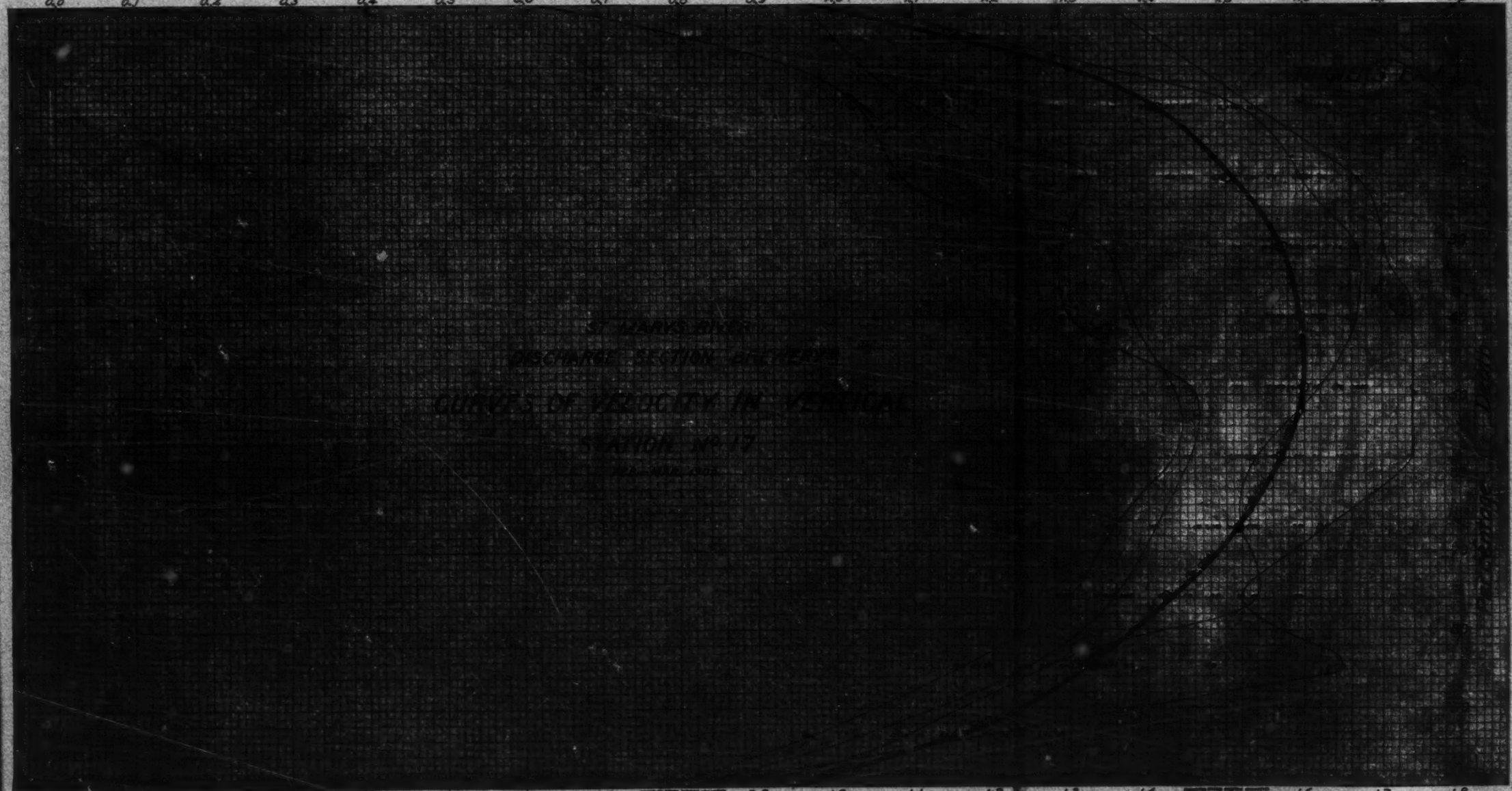
$354,130x23 = $8,144,900.

$778,246x23 = $17,899,658, which is the annual loss to the City of Chicago.


SANITARY DISTRICT
OF
CHICAGO.
MAP SHOWING
SANITARY DISTRICT BOUNDARY
AND THE
CORPORATE LIMITS OF CHICAGO.
JANUARY, 1904.
SCALE OF MILES.
AREAS.
SANITARY DISTRICT, ORIGINAL. 185.000 Sq. Mls.
NORTH SHORE ADDITION, 78.600 DO. DO.
CALUMET ADDITION, 94.500 DO. DO.
SANITARY DISTRICT, PRESENT. 358.100 DO. DO.
CITY OF CHICAGO, 190.638 DO. DO.
SAN. DIST. OUTSIDE OF CHICAGO. 167.462 Sq. Mls.
Des Plaines River Addition 28.1 Sq. Mi.
SEWAGE DISPOSAL PROJECTS
OCT. 1913
Scale 1/2 in. = 1 mi.
Intercepting Sewer.
Sewage Pumping Stations.
Sedimentation and Disinfection Plants.
Sprinkling Filters.
LAKE MICHIGAN
INDIANA
R. 10 E.
R. 11 E.
R. 12 E.
R. 13 E.
R. 14 E.
R. 15 E.
T. 42 N.
T. 41 N.
T. 40 N.
T. 39 N.
T. 38 N.
T. 37 N.
T. 36 N.
DESCRIPTION OF BOUNDARY.

Velocity in Feet per Second

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8



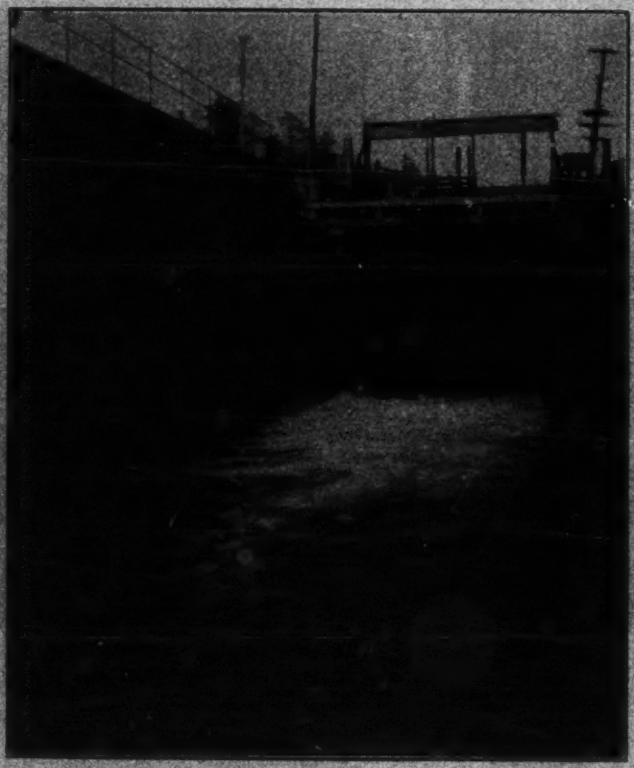
0.0 0.2 0.3 0.4 0.5 0.6 0.7 0.9 1.0 1.1 1.2 1.3 1.4 1.6 1.7 1.8

Velocity in Feet per Second

SCHODER EXHIBIT 1.
Dec. 13, 1913.

SCHODER EXHIBIT 2.

Dec. 13, 1913.

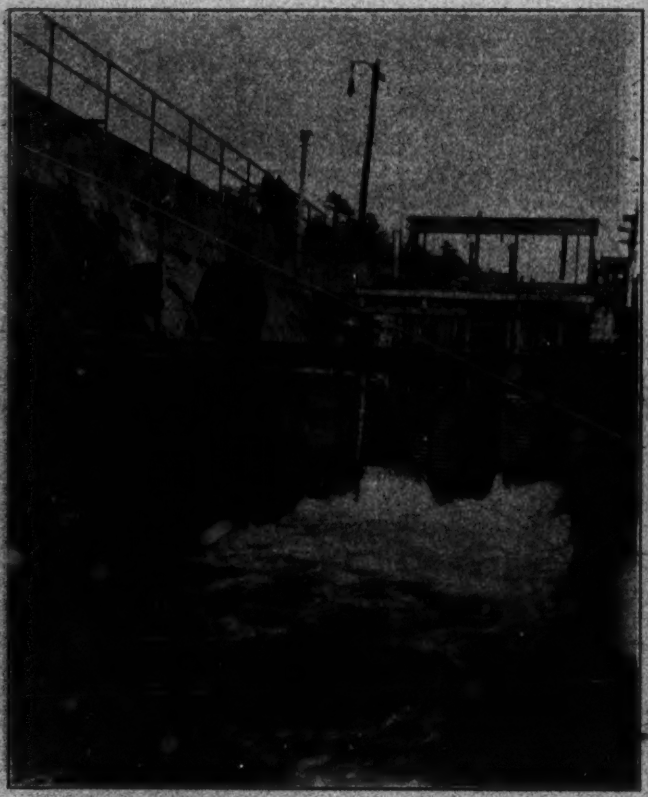


SCHODER EXHIBIT 3.

Dec. 13, 1913.

SCHODER EXHIBIT 4.

Dec. 13, 1913.



SCHODER EXHIBIT 5.

Dec. 13, 1913.

SCHODER EXHIBIT 6.
Dec. 13, 1913.

SCHODER EXHIBIT 7.

Dec. 13, 1913.

SCHODER EXHIBIT 8.
Dec. 13, 1913.

SCHODER EXHIBIT 9.

Dec. 13, 1913.

SCHODER EXHIBIT 10.
Dec. 13, 1913.

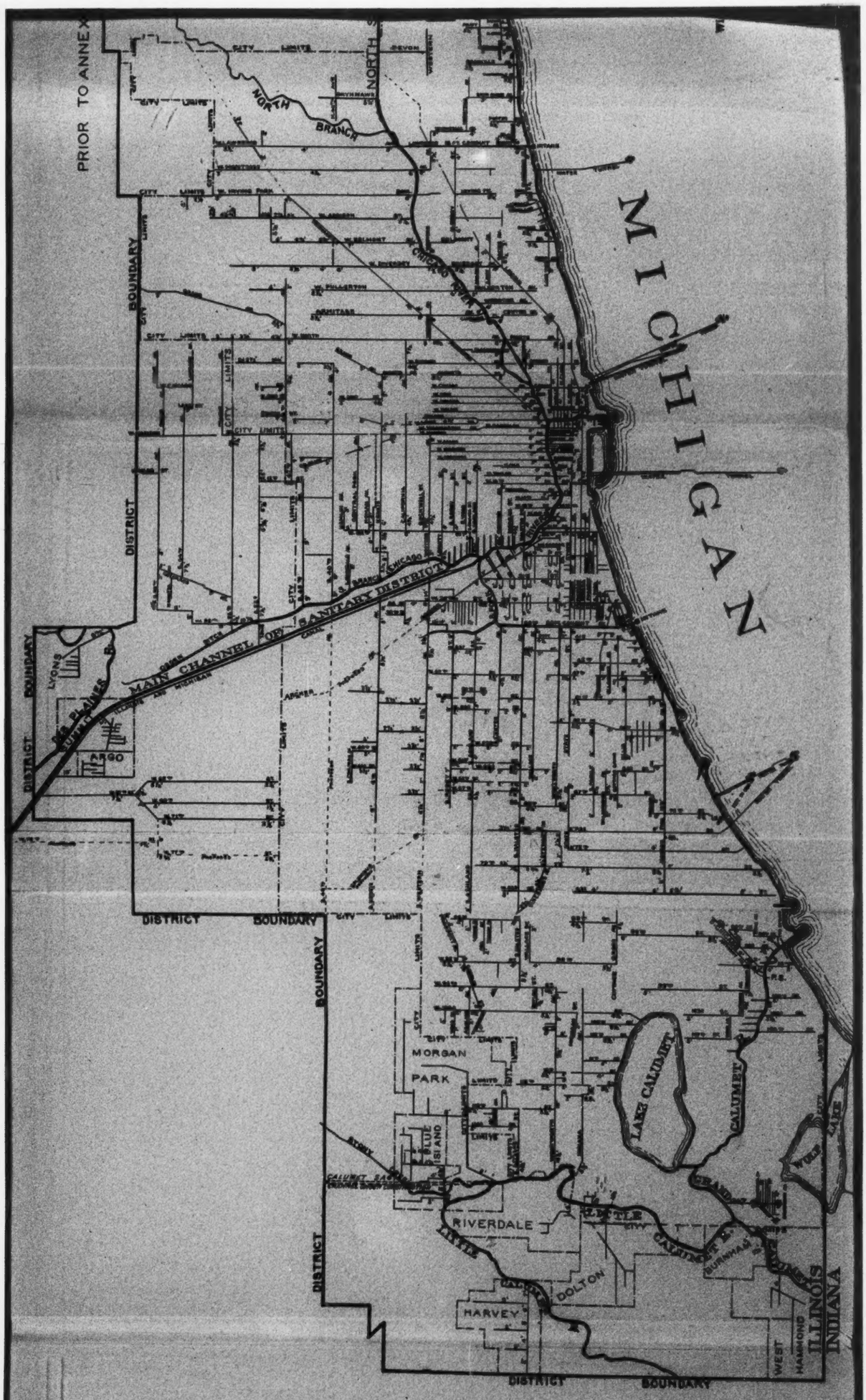
SCHODER EXHIBIT 11.

Dec. 13, 1913.

SCHODER EXHIBIT 12.
Dec. 13, 1913.

CORNELL UNIVERSITY HYDRAULIC LABORATORY CANAL DISCHARGE MEASUREMENTS BY HASKELL CURRENT METER

No. of Meas.	Distance down stream from Baffles, feet	Mean depth of water in feet	Discharge by meter c. f. s.	Discharge by Weir c. f. s.	Deficiency in discharge by meter c. f. s.	% Deficiency of meter meas.
1	51	3.96	159.4	170.6	11.2	6.6
2	260	4.40	161.9	170.6	8.7	5.1
3	51	2.62	164.3	170.6	6.3	3.7
4	88	2.73	161.6	170.6	9.0	5.3
5	208	2.91	165.0	169.6	4.6	2.7
6	41	7.12	166.3	170.5	4.2	2.5
7	67½	7.19	160.3	169.5	9.2	5.4
8	208	7.44	160.4	168.0	7.6	4.5
9	41	7.00	152.3	168.3	16.0	9.5



SANITARY DISTRICT OF CHICAGO

MAP OF THE

CITY OF CHICAGO AND VICINITY

SHOWING

MAIN OUTFALL SEWERS.

CHICAGO JANUARY, 1914.

SCALE IN STATUTE MILES

PRIOR TO ANNEXATION 1913

DISTRICT BOUNDARY

LYONS

DES PLAINES

MAIN CHANNEL OF SANITARY DISTRICT

CITY LIMITS

NORTH BRANCH

MORTON GROVE

NILES CENTER

NORTH SHORE CHANNEL

WINNETKA

GLENCOE

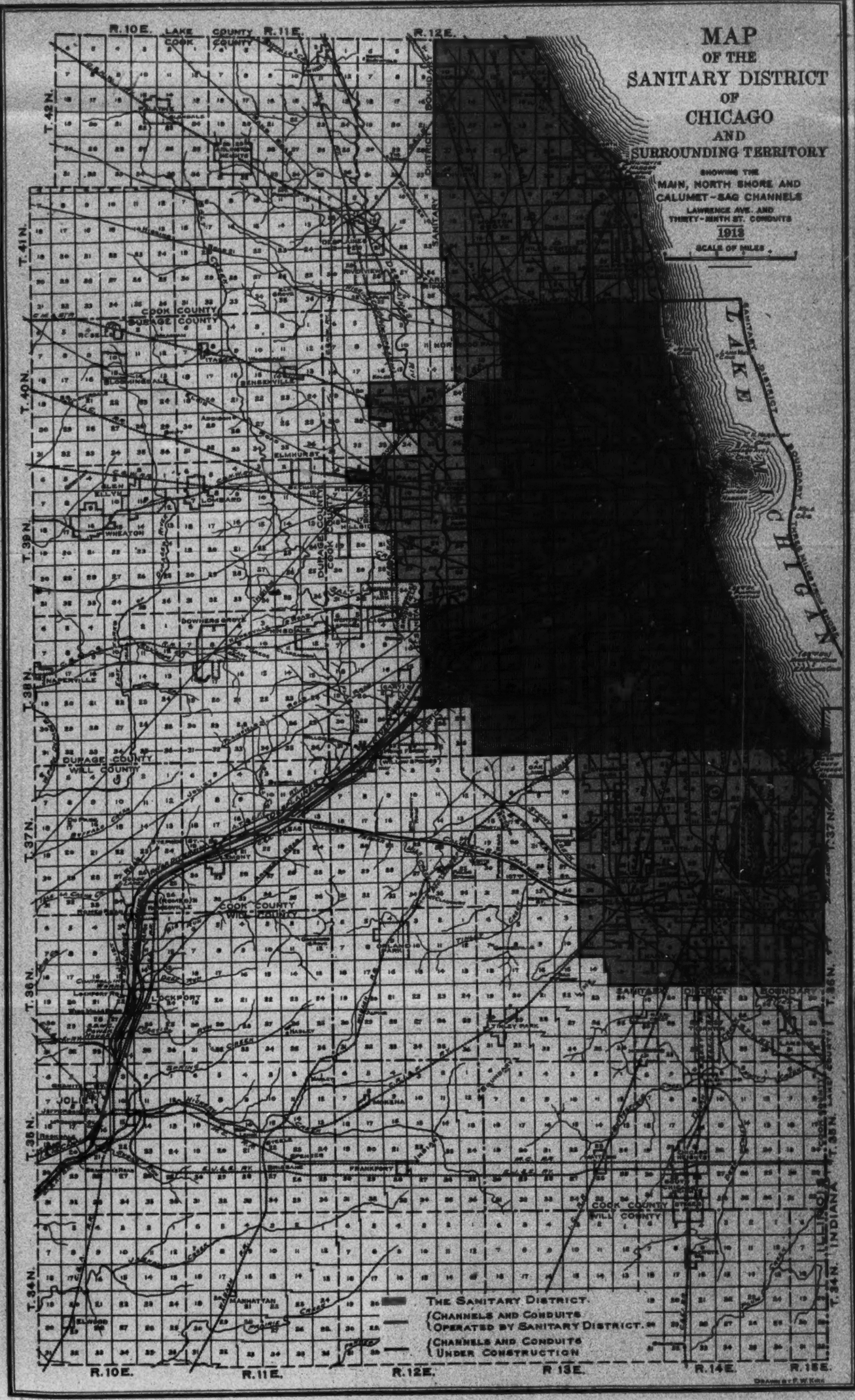
GROSS POINT

LAKE MICHIGAN

Wisner Exhibit 1, January 20, 1914.

Wisner Exhibit 2.

Wisner Exhibit 2.



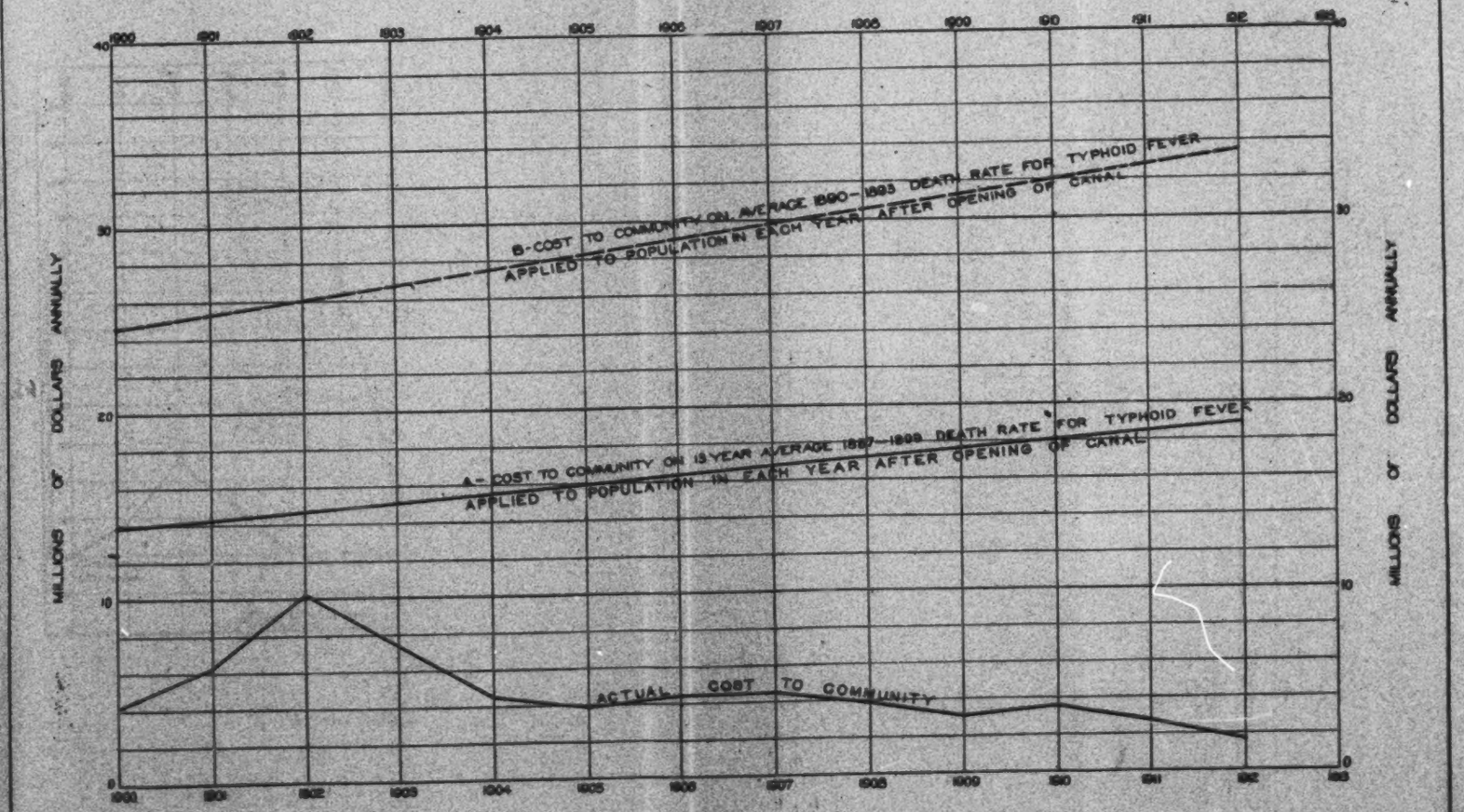
ORIGINAL SANITARY DISTRICT SHOWN IN GREEN.

THE SANITARY DISTRICT OF CHICAGO

CHART SHOWING SAVING TO COMMUNITY BY REDUCTION OF TYPHOID FEVER

SINCE OPENING OF DRAINAGE CANAL

JANUARY 2, 1900.



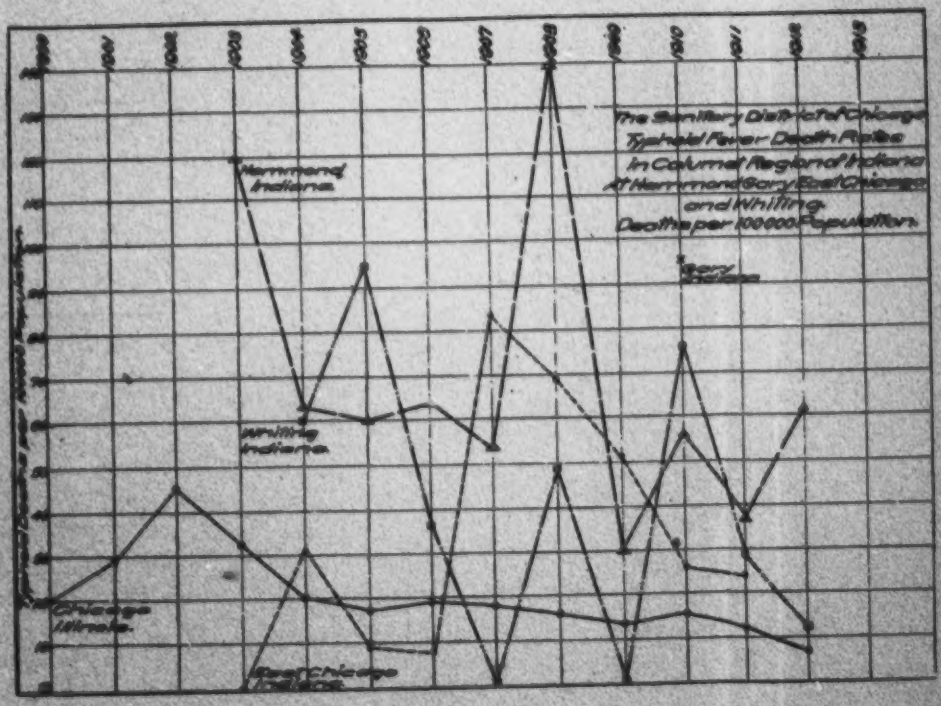

The Sanitary District of Chicago
Typhoid Fever Death Rate
In Calumet Region of Indiana
At Hammond Gary East Chicago
and Whiting.
Deaths per 100000 Population.
Hammond Indiana.
Whiting Indiana.
Chicago Illinois.
East Chicago Indiana.
Gary Indiana.

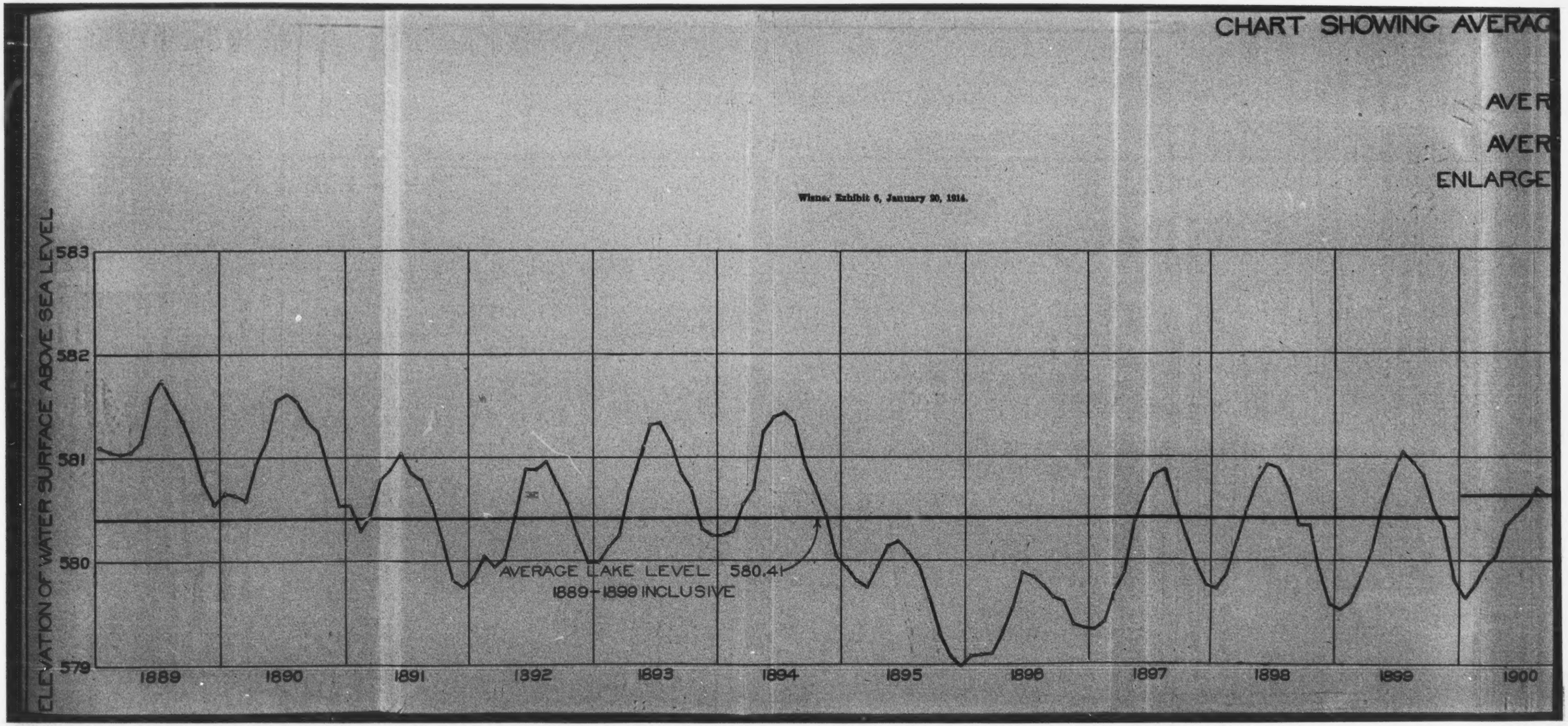
CHART SHOWING AVERAG

AVER

AVER

ENLARGE

Wisner Exhibit 6, January 20, 1914.



VERAGE MONTHLY LEVEL OF LAKE MICHIGAN FROM 1889 TO DATE

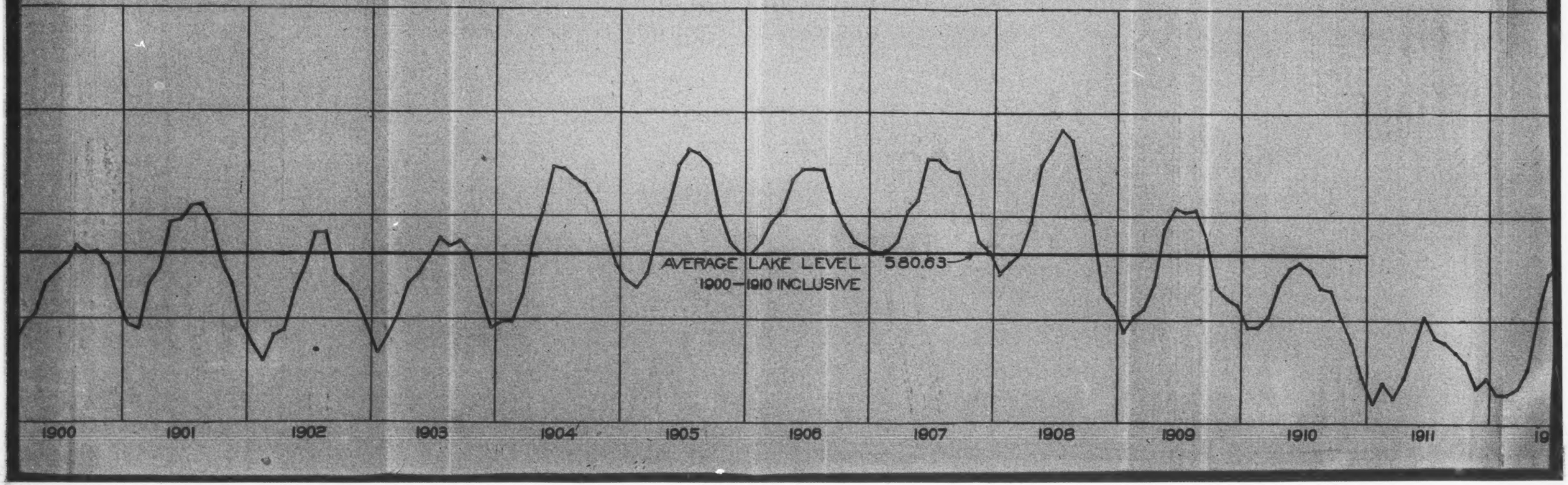
AND

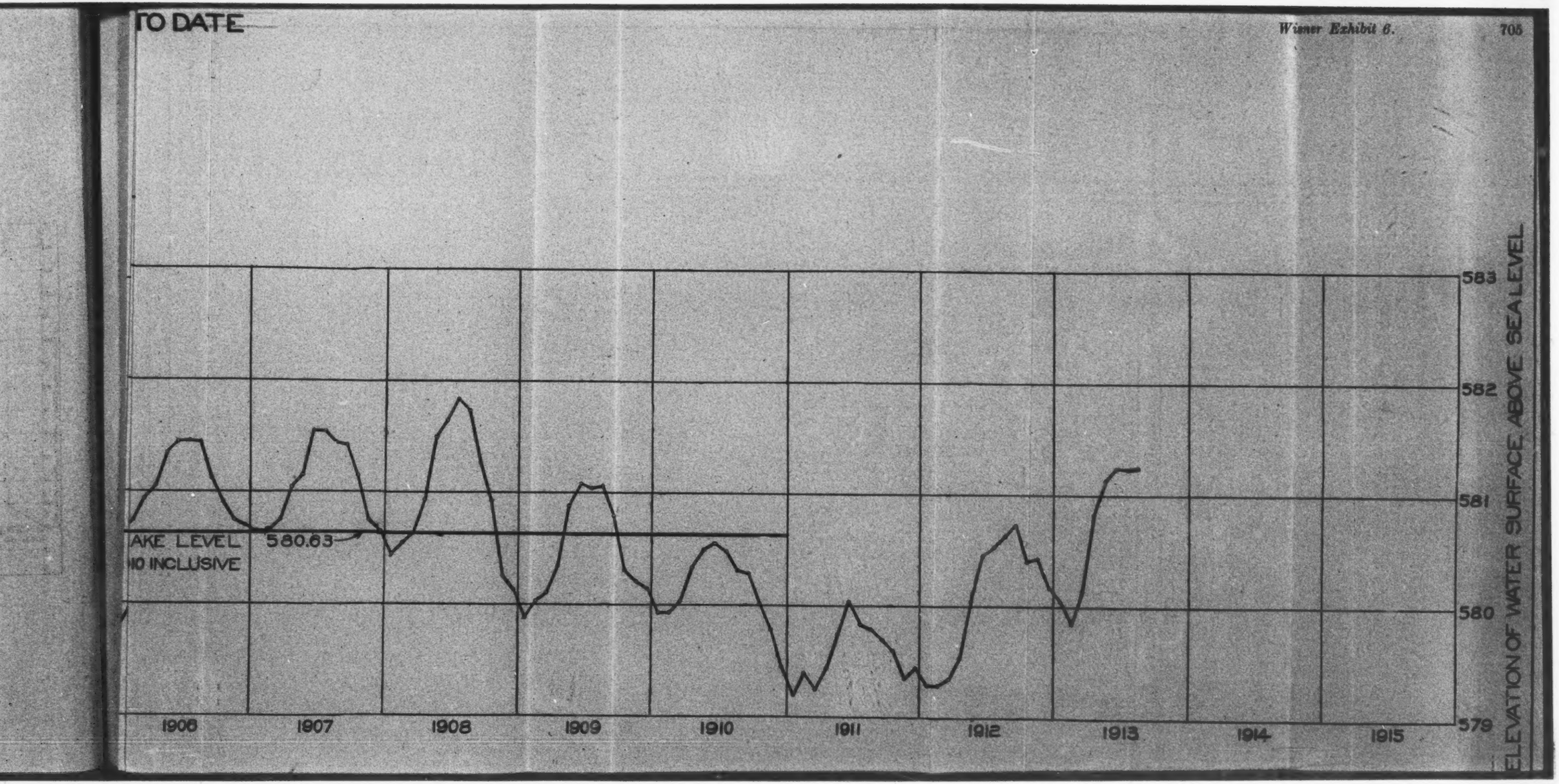
AVERAGE LAKE LEVEL 1889 TO 1899 INCLUSIVE

AVERAGE LAKE LEVEL 1900 TO 1910 INCLUSIVE

ARGED FROM UNITED STATES LAKE SURVEY CHART

AUGUST 1913




TO DATE
AKE LEVEL
10 INCLUSIVE
580.63
583
582
581
580
579
ELEVATION OF WATER SURFACE ABOVE SEA LEVEL
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915

COMPLAINANTS EXHIBITS.

IN

REBUTTAL.

Address: Iroquois, Ontario.

U. S. Lake Survey Detroit, Mich., Sept. 16, 1913.		
Rep.	5	103

UNITED STATES LAKE SURVEY.

Ogdensburg, N. Y., Sept. 15, 1913.

From W. S. Richmond, Junior Engineer.

To District Engineer Officer, U. S. Lake Survey, Old Custom House, Detroit, Mich.

Subject: Preliminary Report, Hydraulics of Niagara River, 1913.

1. In accordance with your instructions, contained in letters dated June 13th and 30th, July 5th, August 12th and 22nd and September 3rd, hydraulic measurements of the Niagara River were made between July 5th and September 4th, inclusive.

2. Measurements of the volume of flow were made at two sections, one on each side of Grand Island, each section being about 4¼ miles below the foot of Squaw Island. Although, from the standpoint of configuration of the channel, slightly better sections might have been obtained further down stream, the adopted sections were selected because of the facilities they offered for range systems, and because of their nearness to a proper base of supplies.

3. The section in the west channel was called Oakfield, that in east channel, Wickwire. The field sheets of the upper Niagara River show the channels to be sufficiently smooth for some distance above and below the sections. There was no boiling or eddying of the water past or near the sections, and the average velocity was less than three feet per second. An inspection of the profiles and transverse and vertical curves, shows that good conditions for gaging obtained.

4. Practically the same equipment was used as on the St. Clair River in 1910, and on the St. Lawrence River in 1911. The personnel of the party was likewise much the same. Almost all the observing was done by the writer, or by Junior Engineer Albert B. Jones, who has been his ranking assistant for the past three years. In general, the same methods were used and standards of accuracy observed as in preceding years and set forth in various reports by the writer and others. Practically nothing in the line of field or office work was left unchecked. It was not expected, however, that the few measurements of current velocity which could be made in the brief time allotted to this work, would give final results quite as accurate as could be obtained from a much longer series of observations.

5. To one familiar with such work the procedure followed in field work and computations will, for the most part, be evident upon inspection of the field notes and the computations and sketches submitted.

6. At each section the horizontal distances depend on a base line measured with a good 100 foot steel tape, the length of base line being checked from the triangulation of 1909 of the International Waterways Commission.

7. The setting of the cut-off ranges was carefully checked.

RICHMOND'S EXHIBIT No. 1.
Feb. 4, 1914.

8. The rod floats were of rough hemlock, 2 inches square and 14 feet long, weighted at the bottom with scraps of lead to make them float vertically, with the tops projecting about 4 inches out of water. A piece of lath, about a foot long, extended 8 inches higher, and carried a flag 5 inches square.

9. The Buffalo gage was carefully and thoroughly inspected on July 9th and 29th, duplicate wye levels being run between P. B. M. Buffalo lighthouse, and the reference gages on the former date. The gage was also inspected August 18th and September 4th.

10. Small-type self-registering gages were established and maintained at Austin Street, Buffalo, and Chippewa, Ontario, in the exact locations of former gages. Unfortunately, the dock at Chippewa burned August 7th, destroying the gage, but the record was later rescued from the water, practically uninjured.

11. At the sections box gages were installed. Distances were measured with a wooden staff from a point on the top of the box down to the water inside.

12. Levels in duplicate were run to the reference points of all gages, from neighboring benchmarks, when the gages were installed, and when they were removed. All staffs were carefully tested.

13. Soundings were made exactly on section with a 140 pound cast iron weight suspended by number 30 steel piano wire. Locations were by cut-off angles read with a transit on shore, and were computed to the nearest foot.

14. Four Haskell current meters were used on their 40 pound weights. During current measurements for discharge or coefficient determination, two meters at a time were suspended 4 feet apart in the central forward part of the catamaran, 4 feet forward of the line joining the points at which the pontoon bows cut the water. The steering wheel, which was 15 feet astern of the port meter, was held on station.

15. Meters were rated two at a time, suspended from a cross-boom, so that each meter was 3½ feet from the side of the rating boat and 6 feet under water. The working draft of the rating boat was one foot.

16. No observations of current velocity were made when a passing vessel was on or near the section. During still-water ratings runs were seldom made when a boat was passing the mouth of the slip at the foot of Hertel Avenue, where the ratings were made, or for several minutes thereafter.

17. The results of rating number 2 are a valuable check on those of rating number 1, but were not used because they differed so very slightly from the first rating. The use of rating 1 for the discharge measurements is logical, and it is perfectly proper for the coefficient observations, where the meters were so used as to tend to eliminate errors of rating.

18. In gaging the flow through the areas at the ends of each section observations were taken while wading, or from the yawl, distances being obtained with tapes and tag-lines, depths with a sounding pole, and velocities with a small Price meter.

19. Water surface elevations at the various gages during discharge measurements were scaled directly from the records, allowing time intervals of −20, −10 and +60 minutes for the Buffalo, Austin St. and Chippewa gages, respectively. These time intervals were estimated from a consideration of carefully determined time intervals on the St. Clair River.

20. A brief summary of the results is as follows:

SECTION WICKWIRE.

No.	Date 1913	Inclusive Time	Water Surface Elev.			Wind	Meters	Disch.
			Buff.	Austin	Chip.			
1	July 30	9:12–11:35	573.35	568.01	563.08	NW 2	1B & 10B	95,200
2	" 30	13:30–16:23	573.01	567.82	563.01	NE 10	10B & 14B	92,800
3	Aug. 1	14:16–16:02	573.19	567.87	563.01	N 15	10B & 14B	93,700
4	" 6	8:56–10:53	573.02	567.82	563.00	0	1B & 10B	93,300
5	" 6	11:06–14:15	573.02	567.76	562.98	NE 3	10B & 15B	91,800
6	" 6	14:29–16:10	573.04	567.77	562.93	0	1B & 15B	92,100
7	" 7	7:47– 9:44	572.85	567.71	562.94	NE 10	1B & 14B	91,900
8	" 7	9:59–11:47	572.84	567.67	562.92	0	1B & 10B	90,800
9	" 7	13:12–15:46	572.88	567.64	562.89	N 10	10B & 15B	90,300
10	" 9	9:17–11:27	572.53	567.09	.....	SW 15	14B & 15B	87,400
Means			573.06					91,900

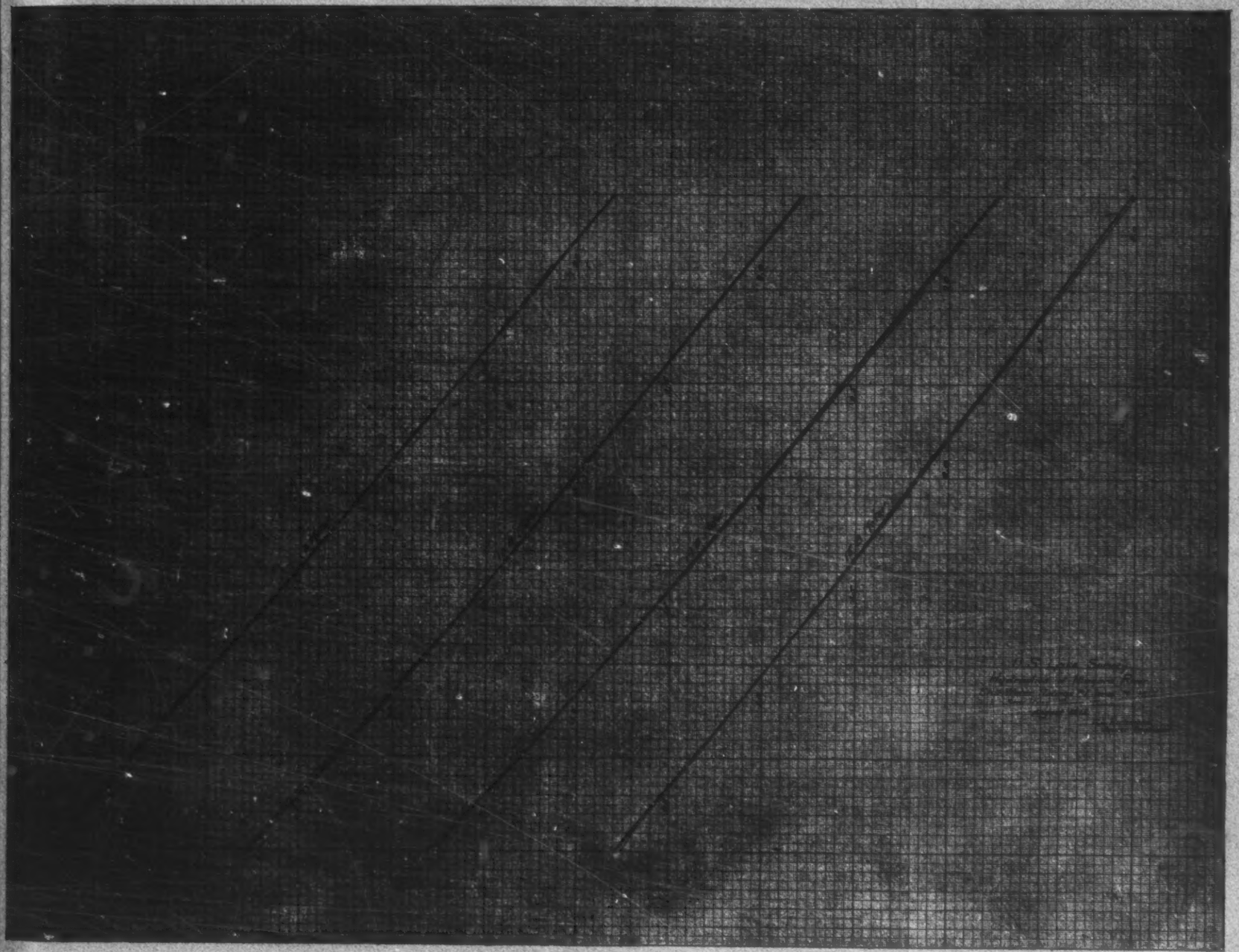
SECTION OAKFIELD.

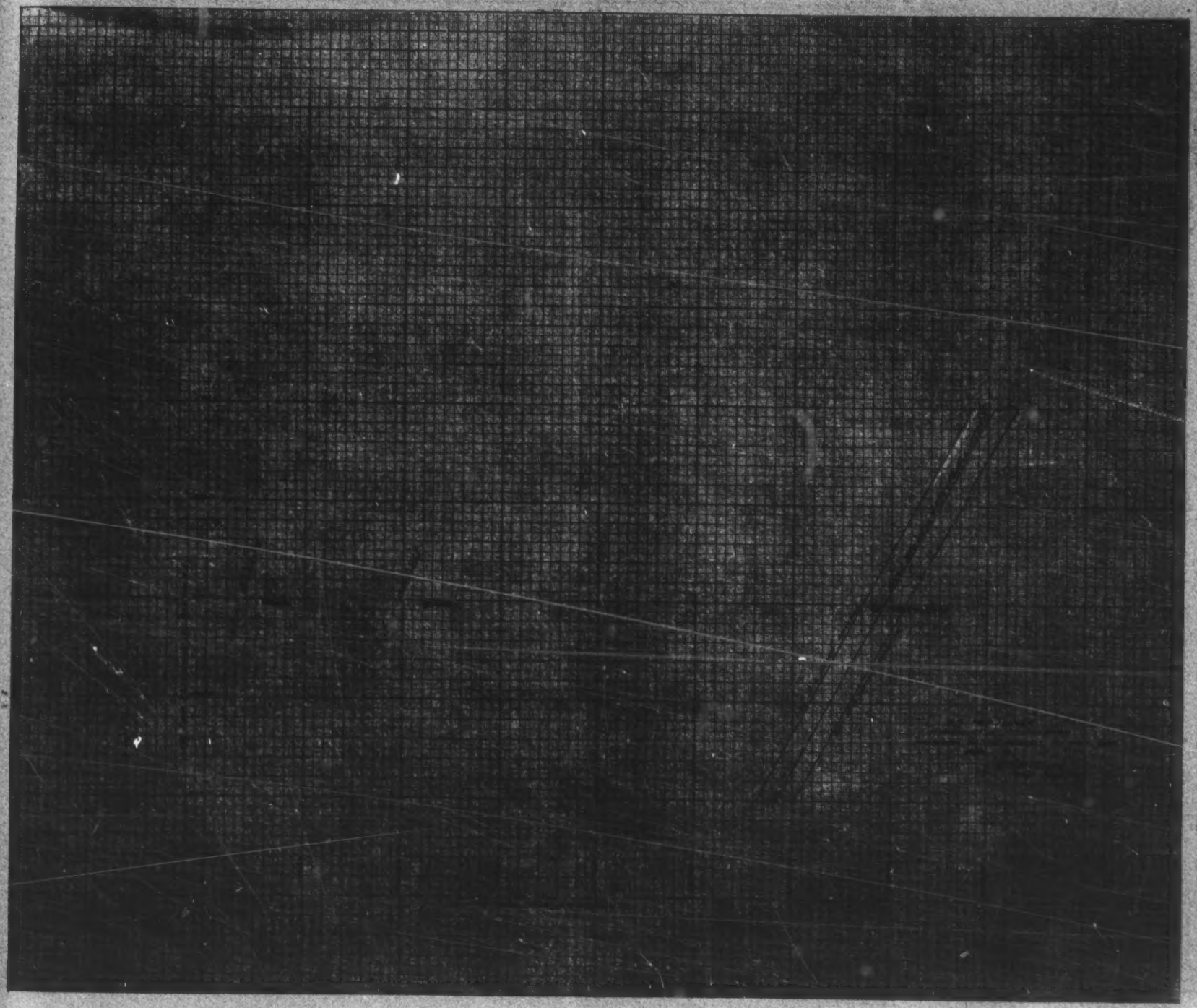
No.	Date 1913	Inclusive Time	Water Surface Elev.			Wind	Meters	Disch.
			Buff.	Austin	Chip.			
1	July 31	8:34–10:53	573.19	567.83	562.98	S 5	14B & 15B	127,900
2	" 31	11:08–14:22	573.23	567.86	563.01	S 2	1B & 15B	126,700
3	" 31	14:41–16:18	573.23	567.92	563.04	0	1B & 10B	129,100
4	Aug. 2	8:37–10:37	573.51	568.06	563.09	NW 11	14B & 15B	130,400
5	" 11	9:00–11:01	572.72	567.23	.....	E 10	1B & 10B	119,600
6	" 11	11:19–14:55	572.77	567.47	.....	E 27	10B & 14B	121,900
7	" 11	15:13–16:56	572.30	567.26	.....	E 10	14B & 15B	118,500
8	" 12	8:00–10:03	573.11	567.78	.....	E 5	10B & 15B	125,500
9	" 12	10:21–13:43	572.96	567.75	.....	0	10B & 14B	124,200
10	" 12	14:00–15:40	572.78	567.62	.....	S 6	14B & 15B	123,100
Means			573.06					124,900

Combining the above means, the final result becomes:

Buffalo Gage.	RIVER DISCHARGE. Observed.	Computed.	RESIDUAL C. F. S.	Per cent.
572.98	216,800	218,000	−1200	−0.6

W. S. RICHMOND.





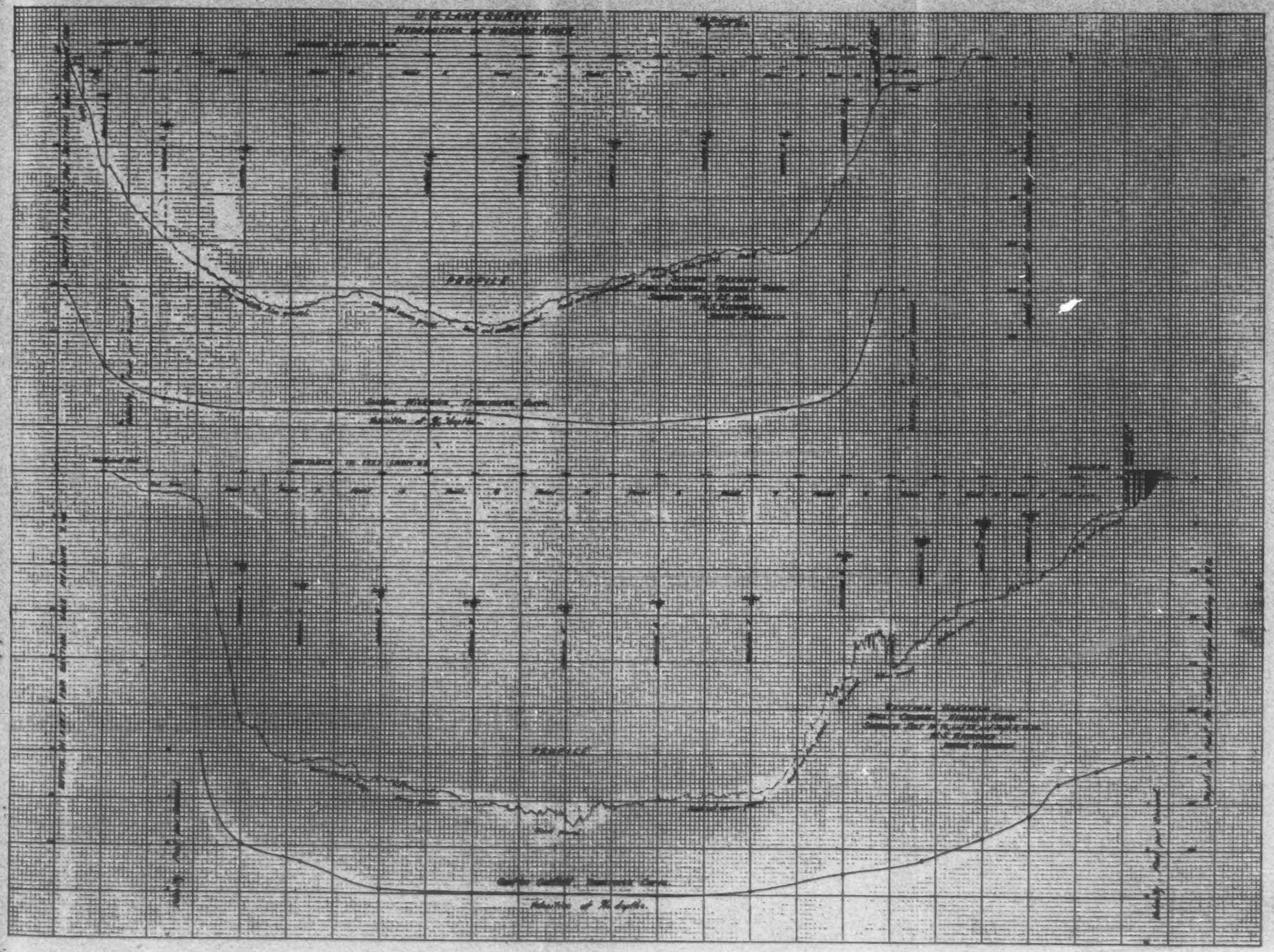


Table 2.
In 4 Sheets.
Sheet 1.

U. S. LAKE SURVEY.

CHICAGO DRAINAGE CANAL.

Measurements of Flow by Index Meter.

LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.569
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
1	Dec. 16	15:22-15:46	15-B	1.64	1.49	4015	5963	580.04		576.99	3.05		SW	8
2		15:47-16:18	15-B	1.71	1.55	4023	6236	580.04		577.04	3.00			
3		16:18-16:46	15-B	1.65	1.49	4024	5998	580.04		577.05	2.99			
4	Dec. 17	10:05-10:30	10-B	1.88	1.66	3585	5957	579.84		576.19	3.65			
5		10:36-10:57	10-B	1.67	1.53	3553	5453	579.84		576.21	3.63		W	20
6		11:37-11:57	10-B	1.62	1.45	3901	5657	579.74		576.29	3.45		W	20
7		13:14-13:34	15-B	1.68	1.52	3964	6025	579.73		576.68	3.10			
8		13:35-14:00	15-B	1.65	1.49	3974	5921	579.84		576.74	3.10			
9		14:00-14:44	15-B	1.70	1.54	3923	6122	579.85		576.79	3.16			
10		15:10-15:39	10-B	1.68	1.52	4013	6100	580.04		576.96	3.04		W	8
11		15:40-16:05	10-B	1.82	1.63	4023	6438	580.04		577.04	3.00			
12		16:07-16:27	10-B	1.68	1.52	4029	6134	580.04		577.05	2.98			
13		16:27-16:47	10-B	1.60	1.45	4032	5846	580.04		577.10	2.94			
14	Dec. 18	9:21- 9:43	10-B	2.06	1.87	2726	6966	580.19		575.20	4.99		N	6
15		9:50-10:13	10-B	1.97	1.78	2751	6677	580.24		575.36	4.88			
16		10:16-10:39	10-B	1.93	1.77	2772	6676	580.25		575.40	4.76			
17		10:47-11:08	10-B	1.89	1.71	2793	6488	580.24		575.62	4.62		NW	2
18		11:09-11:26	10-B	1.83	1.66	2813	6328	580.20	576.21	575.74	4.46	0.47		
19		11:37-12:01	10-B	1.78	1.61	2841	6099	580.15	576.32	575.92	4.23	0.40		
20		12:02-12:22	10-B	1.71	1.55	3967	5994	580.10	576.40	576.08	4.02	0.32		
21		13:31-13:56	15-B	1.65	1.49	3940	5871	580.20	576.80	576.53	3.67	0.27	N	4
22		13:57-14:21	15-B	1.71	1.55	3961	6140	580.36	576.96	576.66	3.80	0.33		
23		14:35-14:57	15-B	1.76	1.59	3976	6322	580.22	577.06	576.73	3.57	0.33		
24		14:58-15:20	15-B	1.70	1.54	3983	6142	580.25	577.17	576.83	3.55	0.34		

MOORE'S EXHIBIT 2, FEB. 5, 1914.

Table 2.
In 4 Sheets.
Sheet 2.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.569
U. S. P. B. M. 114—594.121
U. S. P. B. M. 130—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
25	Dec. 18	15:23-15:45	15-B	1.67	1.51	4010	6055	580.40	577.24	576.96	3.44	0.28	N	4
26		15:46-16:06	15-B	1.64	1.49	4023	5994	580.44	577.33	577.04	3.40	0.29		
27		16:08-16:24	15-B	1.62	1.47	4022	5923	580.44	577.38	577.08	3.36	0.30		
28		16:34-16:45	15-B	1.62	1.47	4036	5933	580.44	577.46	577.12	3.32	0.34		
29	Dec. 19	9:58-10:23	10-B	1.70	1.53	3917	6346	579.96	576.79	576.39	3.80	0.40	SW	12
30		10:33-10:49	10-B	1.71	1.55	3960	6143	580.03	576.96	576.62	3.80	0.34		
31		10:50-11:27	10-B	1.70	1.61	3943	6346	580.04	576.98	576.63	3.81	0.43		
32		11:28-11:56	10-B	1.78	1.61	3940	6343	579.88	576.97	576.55	3.33	0.42		
33		13:06-13:36	15-B			4011	5896	579.78	577.27	576.97	2.81	0.30		
34		[illegible]	15-B				5901	579.74	577.28	577.00	2.74	0.28		
35		[illegible]	15-B			4032	5894	579.78	577.37	577.10	2.68	0.27		
36		[illegible]	15-B			4057	5871	579.90	577.42	577.13	2.77	0.29		
37		[illegible]	15-B	1.52	1.39	4047	5622	579.94	577.46	577.19	2.75	0.27	SW	8
38		15:01-15:20	15-B	1.48	1.34	4063	5443	579.94	577.53	577.28	2.66	0.25		
39		15:21-15:56	15-B	1.45	1.34	4073	5530	579.94	577.60	577.35	2.59	0.25		
40		15:56-16:21	15-B	1.50	1.36	4079	5803	579.94	577.64	577.37	2.57	0.27	SW	4
41		16:22-16:33	15-B	1.49	1.35	4039	5525	580.16	576.37	575.90	4.26	0.47		
42	Dec. 20	9:10- 9:33	10-B	1.88	1.70	3884	6706	580.22	576.44	576.00	4.23	0.44		
43		9:34-10:01	10-B	1.92	1.74	3875	6836	580.31	576.57	576.13	4.18	0.44		
44		10:14-10:29	10-B	1.89	1.71	3876	6412	580.40	576.64	576.20	4.20	0.44		
45		10:30-11:05	10-B	1.82	1.65	3898	7124	580.44	576.73	576.18	4.26	0.55		
46		11:14-11:47	15-B	2.04	1.85	3853	7129	580.44	576.74	576.20	4.24	0.54		
47		11:50-12:24	15-B	2.04	1.85	3898	7189	580.44	577.25	577.18	3.26	0.07		
48		12:44-14:16	10-B	1.37	1.24	4045	5016	580.39	577.45	577.31	3.08	0.14		
49		14:17-14:46	10-B	1.26	1.23	3986	5001							

Moore's Exhibit 2.

Table 2. In 4 Sheets. Sheet 3.

U. S. LAKE SURVEY.

CHICAGO DRAINAGE CANAL.

Measurements of Flow by Index Meter.

LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.589
U. S. " 114—594.131
U. S. " 4. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
49	Dec. 20	14:40-15:07	10-B	1.32	1.30	4097	4916	580.34	577.62	577.50	2.84	0.12	N	6
50		15:07-15:34	10-B	1.30	1.18	4122	4864	580.34	577.77	577.65	2.69	0.12	N	6
51		15:35-15:59	10-B	1.49	1.35	4123	5566	580.34	577.91	577.66	2.43	0.25		
52		16:01-16:25	10-B	1.46	1.33	4131	5483	580.34	577.93	577.71	2.63	0.22	N	10
53		16:25-16:51	10-B	1.44	1.30	4156	5402		577.98	577.86		0.12		
54		16:55-17:00	10-B	1.38	1.70	4117	6999		578.06	577.62		0.44		
55		17:33-18:06	15-B	1.97	1.78	4071	7246		577.98	577.34		0.64	N	8
56		18:06-18:37	15-B	2.06	1.87	4065	7602		577.80	577.30		0.50		
57		18:37-19:13	15-B	2.03	1.84	4045	7443		577.75	577.18		0.57		
58		19:13-19:44	15-B	1.99	1.80	4031	7256		577.59	577.09		0.50		
59		19:44-20:15	15-B	2.03	1.84	4021	7399		577.56	577.03		0.53		
60		20:15-21:08	15-B	2.04	1.85	4005	7409		577.45	576.93		0.53		
61		21:28-21:58	10-B	2.15	1.96	3973	7745		577.30	576.73		0.57		
62		21:58-22:21	10-B	2.14	1.94	3961	7684		577.26	576.66		0.60		
63		22:21-22:04	10-B	2.11	1.91	3951	7546		577.20	576.60		0.60		
64		22:04-23:33	10-B	2.10	1.90	3941	7488		577.11	576.54		0.57		
65		23:33-24:04	10-B	2.08	1.88	3923	7394		577.05	576.49		0.56		
66	Dec. 21	0:04- 0:35	10-B	2.09	1.87	3923	7344		577.01	576.46		0.55		
67		0:35- 1:05	10-B	2.08	1.87	3919	7329		576.95	576.40		0.55		
68		3:04- 3:35	15-B	2.13	1.97	3390	7663		576.80	576.22		0.58	N	16
69		3:35- 4:06	15-B	2.14	1.94	3385	7537		576.79	576.19		0.60		
70		4:06- 4:37	15-B	2.17	1.97	3385	7653		576.77	576.19		0.58		
71		4:37- 5:08	15-B	2.12	1.92	3878	7442		576.74	576.14		0.60		
72		5:08- 5:39	15-B	2.14	1.94	3878	7518		576.73	576.13		0.60		

Moore's Exhibit 3.

MOORE'S EXHIBIT 4, FEB. 5, 1914.

Table 2. In 4 Sheets. Sheet 4.

U. S. LAKE SURVEY.
CHICAGO DRAINAGE CANAL.
Measurements of Flow by Index Meter.
LEMONT, ILL.

Elevations depend on
U. S. P. B. M. 99—591.560
U. S. P. B. M. 114—594.121
U. S. P. B. M. 120—592.133

Sherman Moore, Jun. Engr.
Jan. 1914.

No.	Date 1913	Time	Meter	Index Velocity Ft. per Sec.	Mean Velocity Ft. per Sec.	Area Sq. Ft.	Flow C. F. S.	Water Surface Elevations			Fall to Lemont from		Wind	
								Lake Mich.	Willow Springs	Lemont	Lake	Willow Springs	Dir.	Vel.
									576.72	576.11		0.61		0
73	Dec. 21	5:30– 6:10	15-B	2.13	1.93	3873	7473		576.69	576.09		0.60		
74		6:10– 6:42	15-B	2.12	1.93	3868	7463		576.68	576.08		0.60		
75		6:42– 7:03	15-B	2.12	1.92	3867	7425		576.70	576.46		0.24		
76		7:03– 7:14	15-B	1.70	1.54	3928	6049		576.70	576.78		0.08		
77		7:14– 7:24	15-B	1.48	1.34	3980	5333		576.92	577.05		0.11		0
78		7:24– 7:46	15-B	1.18	1.07	4024	4306	580.43	577.09	576.66	3.77	0.43		
79	Dec. 22	9:46–10:12	15-B	1.86	1.68	2961	6654	580.45	577.12	576.61	3.84	0.51		
80		10:13–10:29	15-B	1.95	1.77	3953	6997	580.44	577.12	576.80	3.84	0.32		
81		10:29–11:05	15-B	1.95	1.77	3951	6993	580.42	577.13	576.61	3.81	0.52		
82		11:07–11:31	15-B	1.98	1.79	3953	7076	580.38	577.12	576.61	3.77	0.51		
83		11:31–11:56	15-B	1.98	1.79	3953	7076	580.20	577.45	577.18	3.02	0.27	S	4
84		13:03–13:24	15-B	1.56	1.41	4045	5703	580.17	577.48	577.15	3.02	0.33		
85		13:25–13:43	15-B	1.58	1.43	4040	5777	580.14	577.53	577.21	2.93	0.32		
86		13:47–14:08	15-B	1.62	1.47	4050	5954	580.14	577.59	577.27	2.87	0.32		
87		14:09–14:40	15-B	1.66	1.50	4060	6090	580.14	577.62	577.30	2.84	0.32	S	4
88		14:44–15:03	15-B	1.64	1.49	4065	6057	580.14	577.66	577.35	2.79	0.31		
89		15:04–15:37	15-B	1.57	1.42	4073	5784	580.14	577.75	577.46	2.68	0.29		
90		15:50–16:16	10-B	1.60	1.45	4091	5932	580.14	577.80	577.53	2.61	0.27		
91		16:17–16:47	10-B	1.55	1.40	4102	5743	580.14	577.86	577.53	2.61	0.33	NNE	8
92		16:49–17:03	10-B	1.53	1.39	4102	5702		577.87	577.53		0.35		
93		17:03–17:16	10-B	1.73	1.57	4100	6537		577.74	576.96		0.78		
94		17:17–17:49	10-B	2.29	2.07	4010	8301		577.45	576.71		0.74		
		12:40–18:21	10-B	2.26	2.16	3969	8573		577.94	576.66		0.68		

MOORE'S EXHIBIT 5 FEB. 5, 1914

U S LAKE SURVEY

Plate 4.

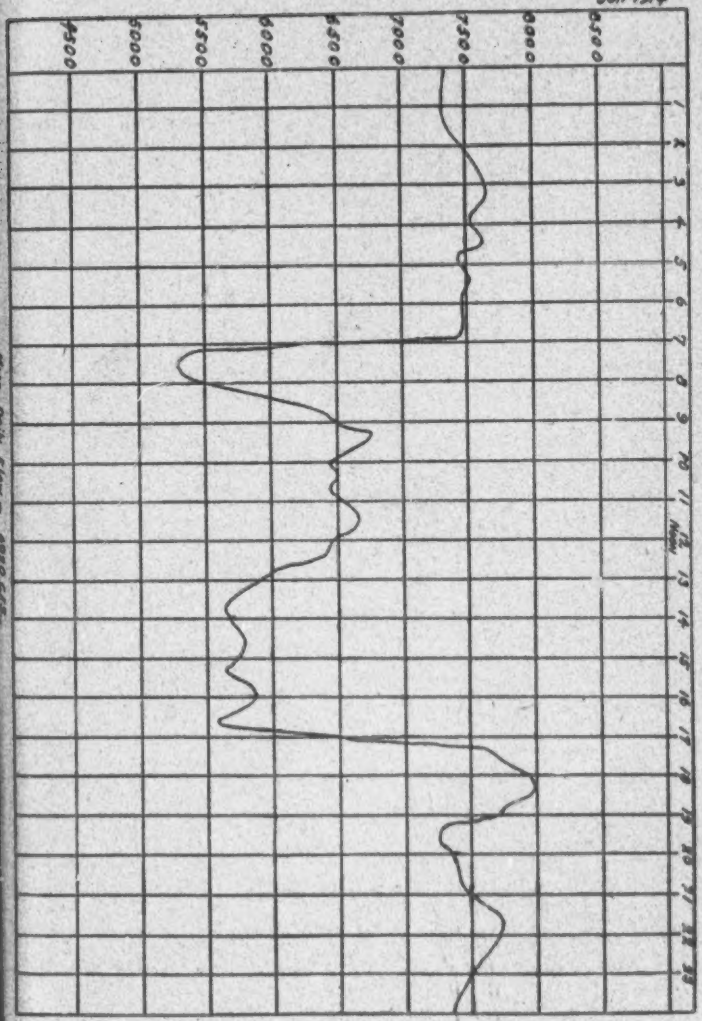
CHICAGO DRAINAGE CANAL

Mean 24 Hour Curve of Flow

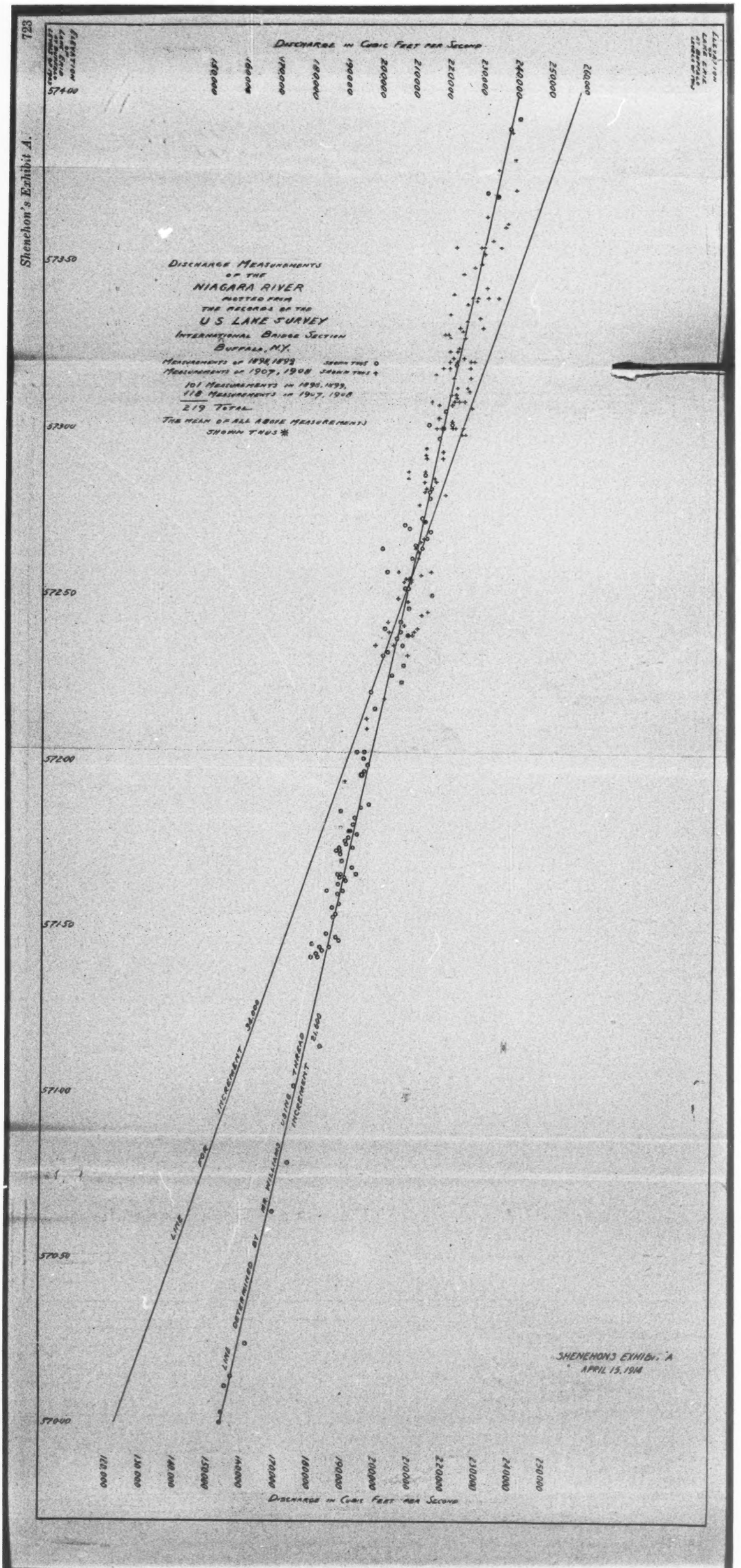
Lemont, Ill

SHERMAN MOORE, Jun. Engr

Jan 1914.

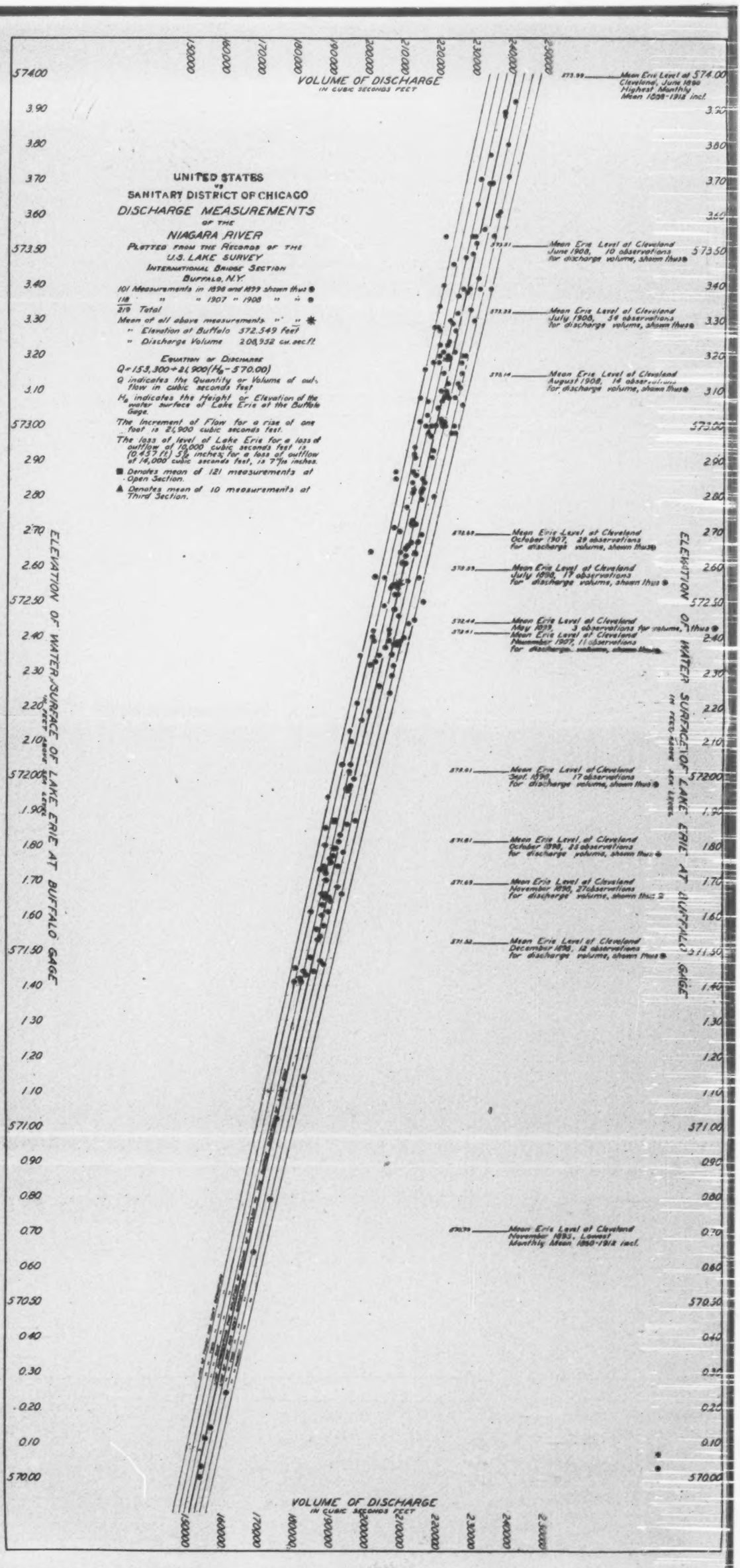


Shenehon's Exhibit A.



Shenehon's Exhibit B.

Shenehon's Exhibit B, April 15, 1914.



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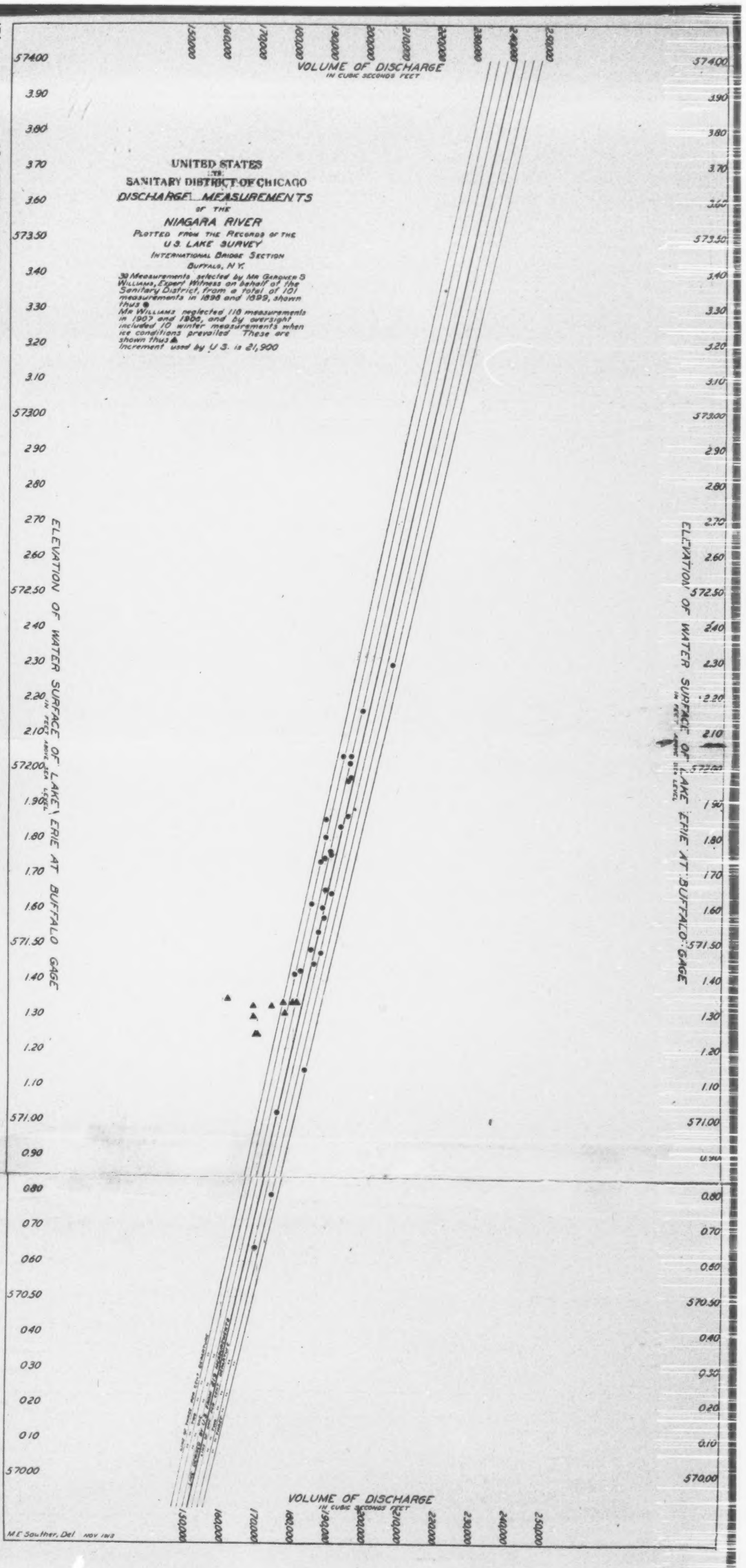
Shenehon's Exhibit C.

Shenehon's Exhibit C, April 16, 1914.



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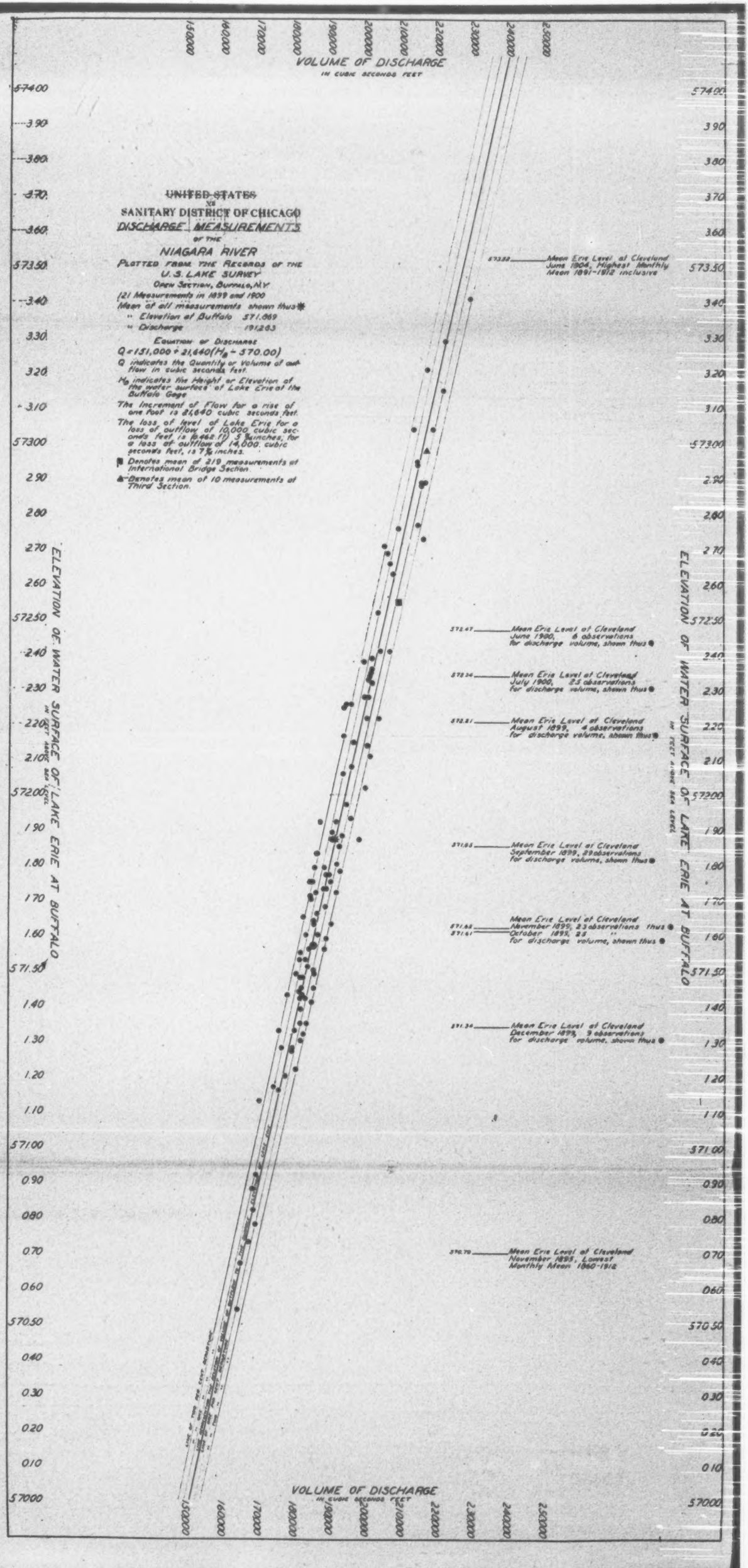
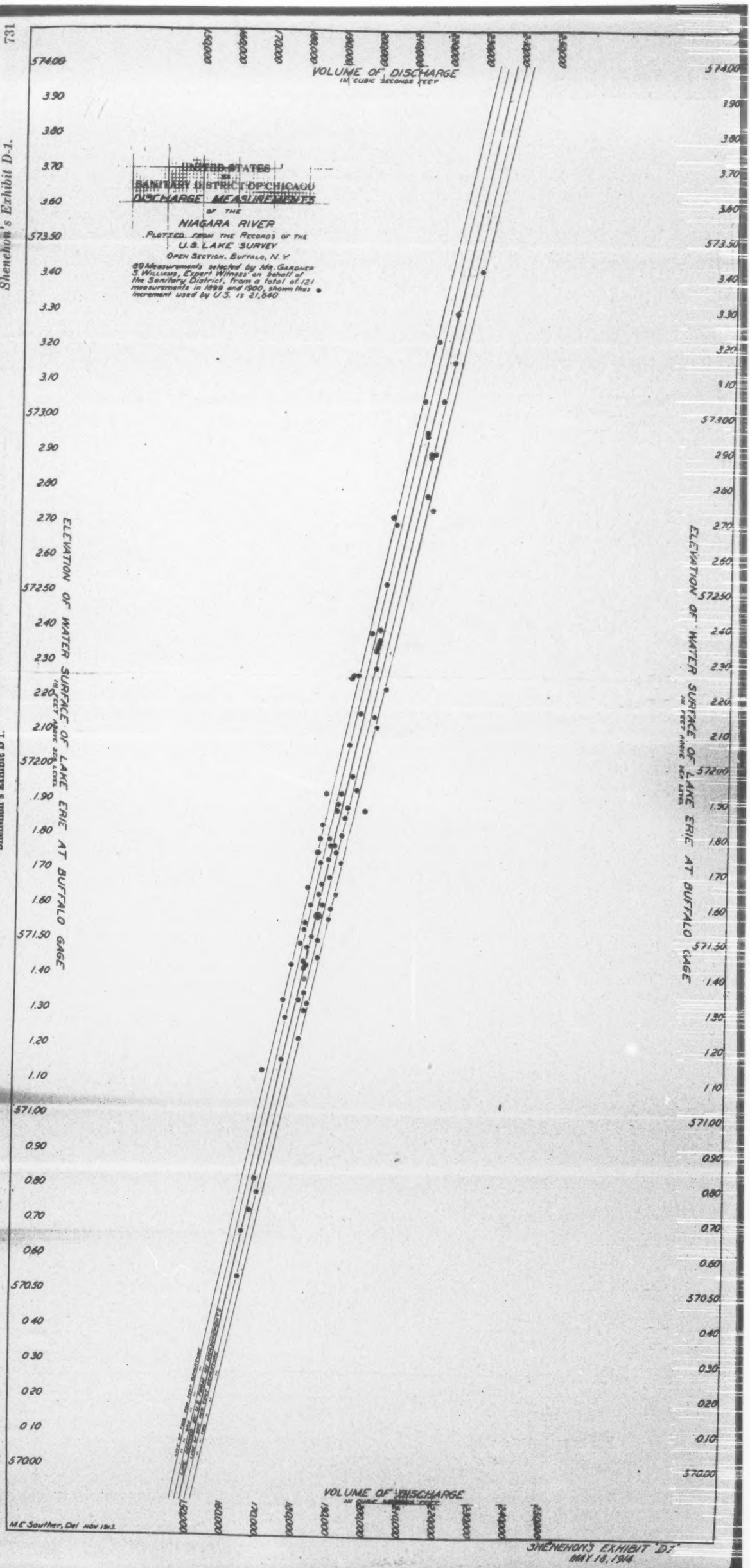
Shenehon's Exhibit D.

Shenehon's Exhibit D' April 15, 1914.



731

Shenehon's Exhibit D-1.

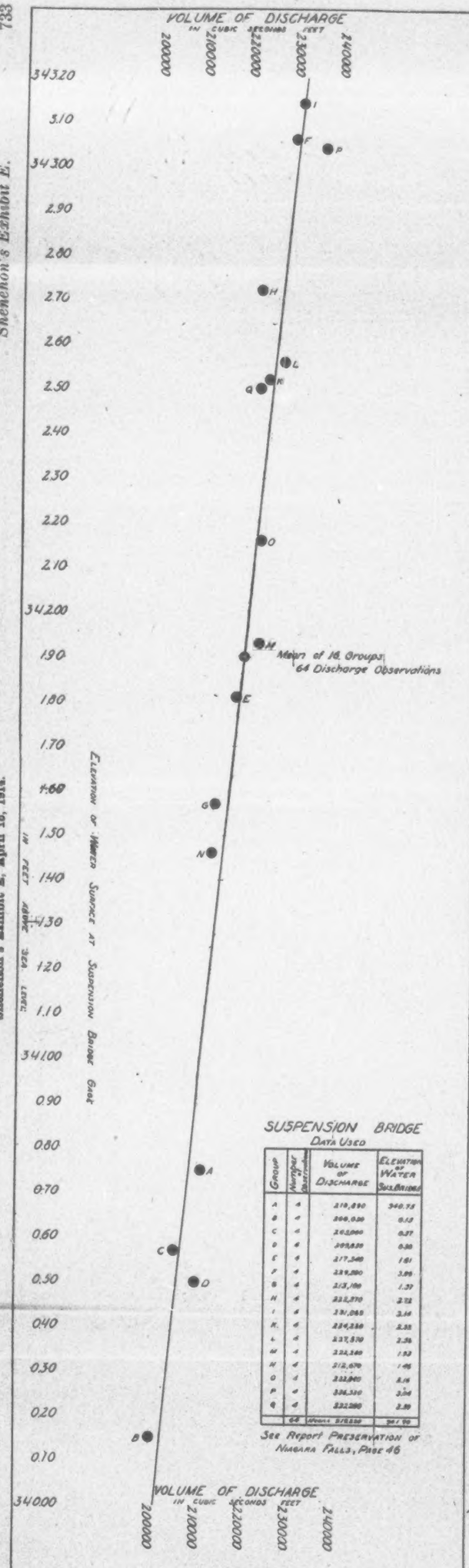


Shenehon's Exhibit D 1.

SHENEHON'S EXHIBIT "D-1"
MAY 18, 1914.

Shenehon's Exhibit E.

Shenehon's Exhibit E, April 16, 1914.



SUSPENSION BRIDGE
Data Used

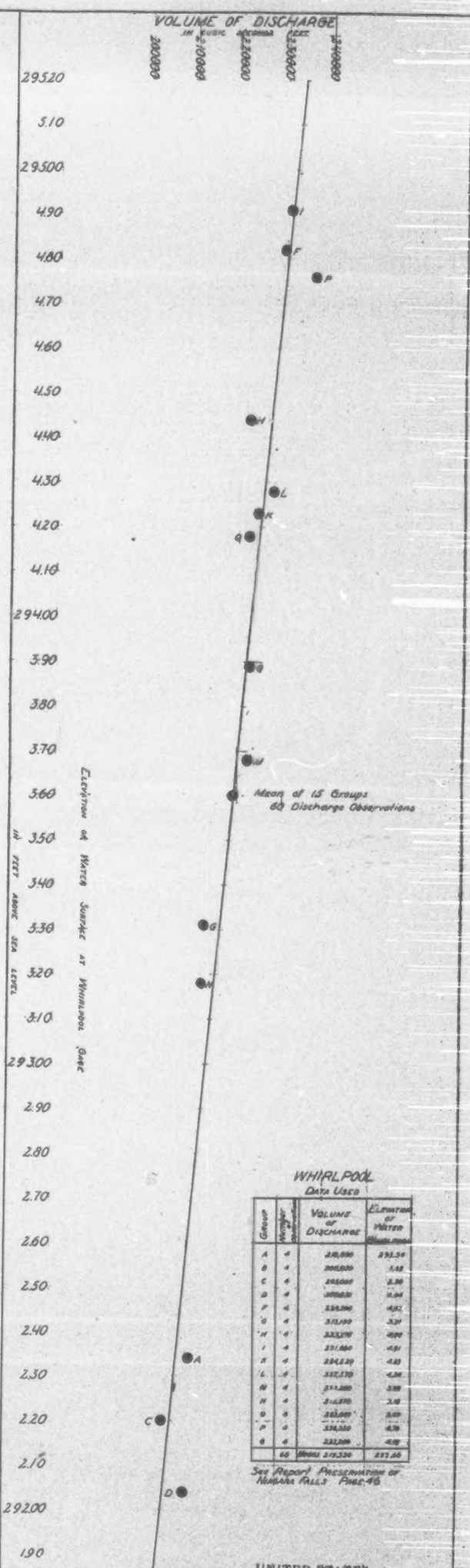
Group	Number Observations	Volume of Discharge	Elevation of Water Surface
A	4	218,690	340.75
B	4	209,030	0.13
C	4	203,000	0.27
D	4	209,830	0.38
E	4	217,340	1.61
F	4	229,290	3.06
G	4	213,190	1.37
H	4	232,270	2.72
I	4	231,060	3.14
K	4	234,230	2.55
L	4	237,570	2.76
M	4	232,340	1.92
N	4	212,070	1.16
O	4	232,840	2.16
P	4	236,330	3.24
Q	4	232,280	2.39
	64	Means 219,330	341.99

See Report Preservation of Niagara Falls, Page 46

UNITED STATES
vs.
SANITARY DISTRICT OF CHICAGO

THE VOLUME OF DISCHARGE OF THE NIAGARA RIVER
PLOTTED WITH RESPECT TO THE ELEVATION OF THE WATER SURFACE AT THE
SUSPENSION BRIDGE GAGE

Equation of Discharge: $Q = 201060 + 9547(H_s - 340.00)$
Increment at Suspension Bridge is 9547
Derived Increment for Lake Erie is $9547 \times 229 = 21860$



WHIRLPOOL
Data Used

Group	Number Observations	Volume of Discharge	Elevation of Water Surface
A	4	218,690	293.34
B	4	209,030	1.88
C	4	203,000	2.36
D	4	209,830	2.84
F	4	229,290	4.61
G	4	213,190	3.31
H	4	232,270	4.19
I	4	231,060	4.91
K	4	234,230	4.33
L	4	237,570	4.56
M	4	232,340	3.99
N	4	212,070	3.18
O	4	232,840	3.69
P	4	236,330	4.79
Q	4	232,280	4.19
	60	Means 219,330	293.80

See Report Preservation of Niagara Falls Page 46

UNITED STATES
vs
SANITARY DISTRICT OF CHICAGO

THE VOLUME OF DISCHARGE OF THE NIAGARA RIVER
PLOTTED WITH RESPECT TO THE ELEVATION OF THE WATER SURFACE AT THE
WHIRLPOOL GAGE

Equation of Discharge $Q = 186,670 + 9083(H_w - 290.00)$
Increment at Whirlpool is 9083
Derived Increment for Lake Erie is $9083 \times 2.47 = 22440$

735

Shenehon's Exhibit F.

Shenehon's Exhibit F, April 15, 1914.

VOLUME OF DISCHARGE.
IN CUBIC SECONDS FEET

200000 210000 220000 230000 240000

ELEVATION OF WATER SURFACE OF NIAGARA RIVER AT SUSPENSION BRIDGE GAGE
IN FEET ABOVE SEA LEVEL

343.50 3.40 3.30 3.20 3.10 343.00 2.90 2.80 2.70 2.60 2.50 2.40 2.30 2.20 2.10 342.00 1.90 1.80 1.70 1.60 1.50 1.40 1.30 1.20 1.10 341.00 0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 340.00

SUSPENSION BRIDGE

DATA USED

Group	Number Observations	Elevation of Water Suspension Bridge Gage	Volume of Discharge
1	10	343.36	234,240
2	10	2.96	228,660
3	10	2.78	225,466
4	10	2.60	223,590
5	10	2.58	224,310
6	10	2.11	221,060
7	10	1.98	219,660
8	10	1.74	218,140
9	10	1.27	213,810
10	10	0.77	210,830
11	10	0.48	207,730
12	8	0.32	201,320
	118	Mean 1.83	219,060

See Report, "PRESERVATION OF NIAGARA FALLS," Page 46, also Page 31.

Note: Group No. 1 contains the ten observations showing the highest elevation of the Suspension Bridge Gage.
Group No. 2 is made up of the ten next lower observations.
Group No 12 contains the eight observations with lowest gage reading.
Others are intermediate in order of gage height.

Mean of 12 groups
118 discharge observations

UNITED STATES
SANITARY DISTRICT OF CHICAGO
THE VOLUME OF DISCHARGE
OF THE NIAGARA RIVER
PLOTTED WITH RESPECT TO
THE ELEVATION OF THE
WATER SURFACE
AT THE
SUSPENSION BRIDGE
GAGE

Equation of Discharge $Q = 201,560 + 3445(H_s - 340.00)$
Increment at Suspension Bridge is 3445
Derived Increment for Lake Erie is $3445 \times 2.33 = 22,000$
The multiplier 2.33 is the ratio of fluctuation of the Suspension Bridge compared with Lake Erie at Cleveland, Ohio. See Exhibit H, Shenehon, April 15, 1914.
Lowerings of Lake Erie indicated by Derived Increment are as follows:
For Diversion of Chicago of 10,000 cu sec ft 5 3/16 inches
4,000 " " " 2 1/16 "
14,000 " " " 7 1/16 "
These conclusions are entirely independent of the Buffalo Gage readings during the observations for Volume of Discharge.

M. E. Shaffner, Del. Dec. 1913.

200000 210000 220000 230000 240000
VOLUME OF DISCHARGE
IN CUBIC SECONDS FEET

Shenehon's Exhibit G.

Shenehon's Exhibit G, April 15, 1914.

VOLUME OF DISCHARGE
IN CUBIC SECONDS FEET

200,000 210,000 220,000 230,000 240,000

ELEVATION OF WATER SURFACE OF NIAGARA RIVER AT WHIRLPOOL GAGE
IN FEET ABOVE SEA LEVEL

295.20 5.10 295.00 4.90 4.80 4.70 4.60 4.50 4.40 4.30 4.20 4.10 294.00 3.90 3.80 3.70 3.60 3.50 3.40 3.30 3.20 3.10 293.00 2.90 2.80 2.70 2.60 2.50 2.40 2.30 2.20 2.10 292.00 1.90 1.80 291.70

WHIRLPOOL
DATA USED

Group	Number of observations	Elevation of Water Whirlpool Gage	Volume of Discharge
1	10	295.08	233,640
2	10	4.70	226,580
3	10	4.41	224,470
4	10	4.14	223,670
5	10	3.93	224 170
6	10	3.79	221,360
7	10	3.44	218,730
8	10	3.14	214,960
9	10	2.80	210,690
10	10	2.10	207,130
11	8	1.77	203,930
	108	Mean 3.36	219,300

See Report, "PRESERVATION OF NIAGARA FALLS," Page 46, also Page 31.

Note: Group No. 1 contains the ten observations showing the highest elevation of the Whirlpool Gage
Group No. 2 is made up of the next lower ten observations
Group No. 11 contains the eight observations with lowest gage reading
Others are intermediate in order of gage height.

Mean of 11 groups
108 discharge observations

UNITED STATES
vs
SANITARY DISTRICT OF CHICAGO
THE VOLUME OF DISCHARGE
OF THE NIAGARA RIVER
PLOTTED WITH RESPECT TO
THE ELEVATION OF THE
WATER SURFACE
AT THE
WHIRLPOOL
GAGE

Equation of Discharge: $Q = 188,740.8585(R_w - 290.00)$
Increment at Whirlpool is 8585.
Derived Increment for Lake Erie is $8585 \times 2.61 = 22,400$
The multiplier 2.61 is the ratio of fluctuation of the Whirlpool compared with Lake Erie at Cleveland, Ohio. See Exhibit H, Shenehon, April 15, 1914.
Lowerings of Lake Erie indicated by Derived Increment, are as follows

For Diversion at Chicago of 10,000 cu. sec ft. 5 3/4 inches
4,000 " " " 2 1/2 "
14,000 " " " 7 3/4 "

These conclusions are entirely independent of the Buffalo Gage readings during the observations for Volume of Discharge

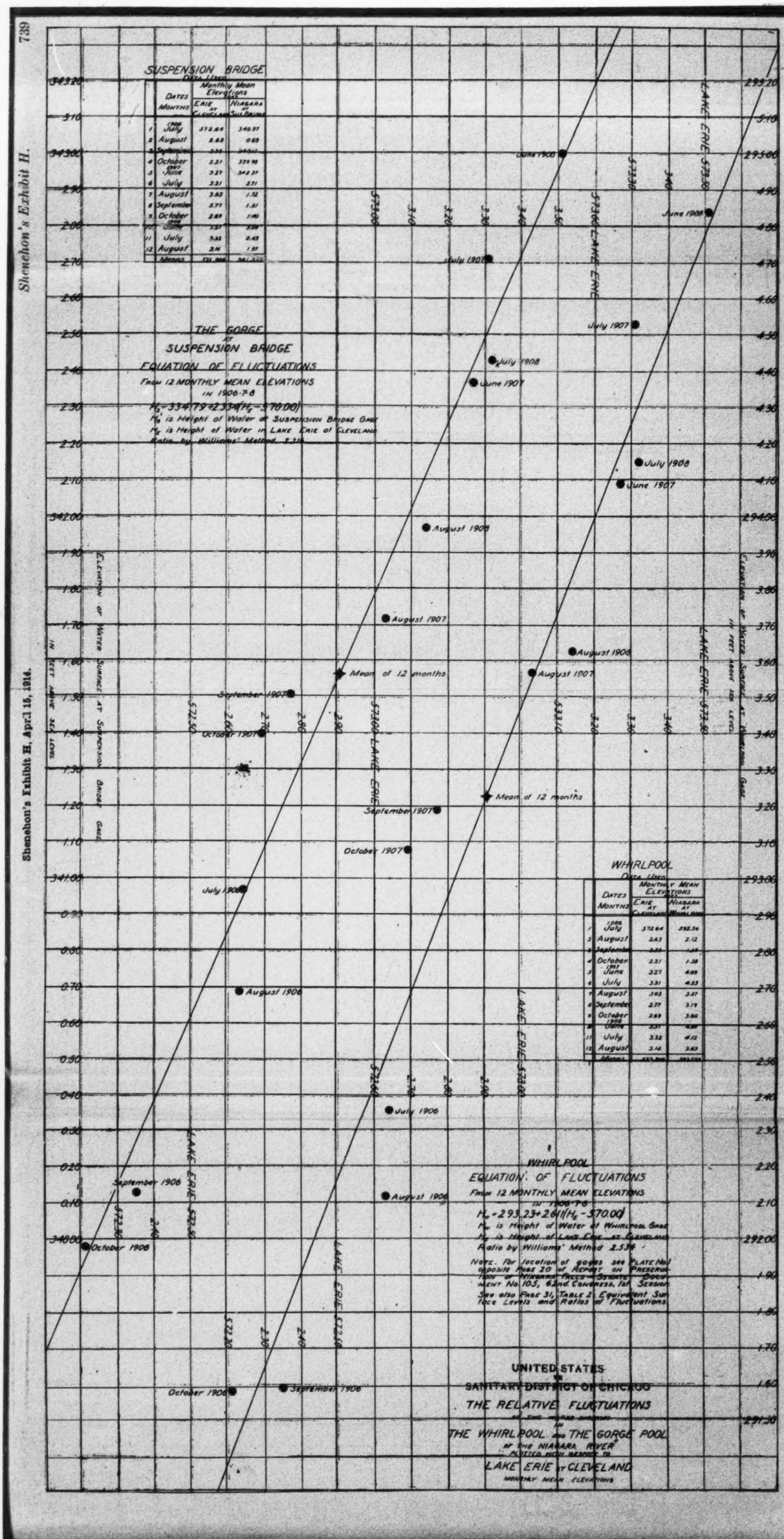
M.E. Souther, Del
DEC 1913

VOLUME OF DISCHARGE
IN CUBIC SECONDS FEET

739

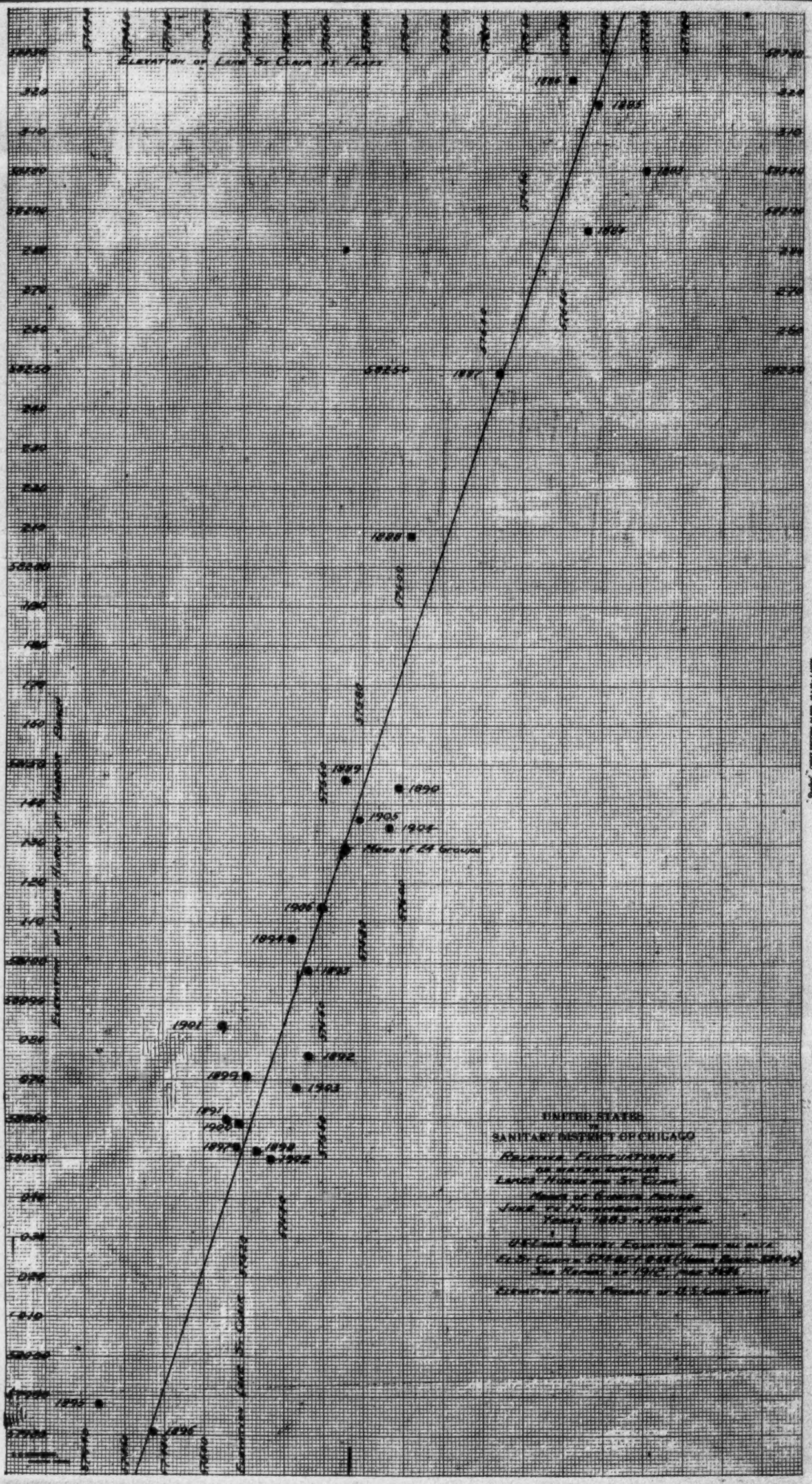
Shenehon's Exhibit H.

Shenehon's Exhibit H, April 15, 1914.

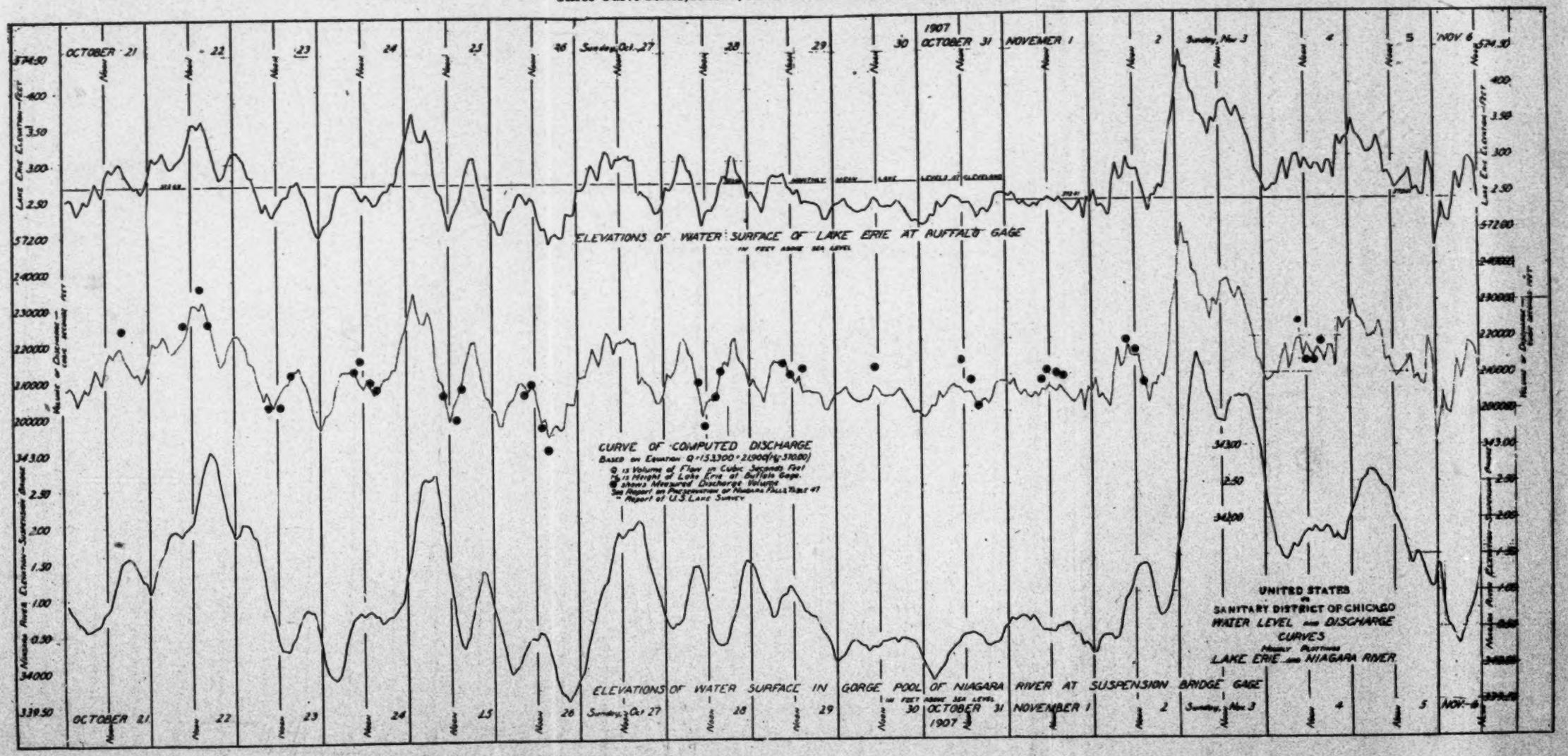


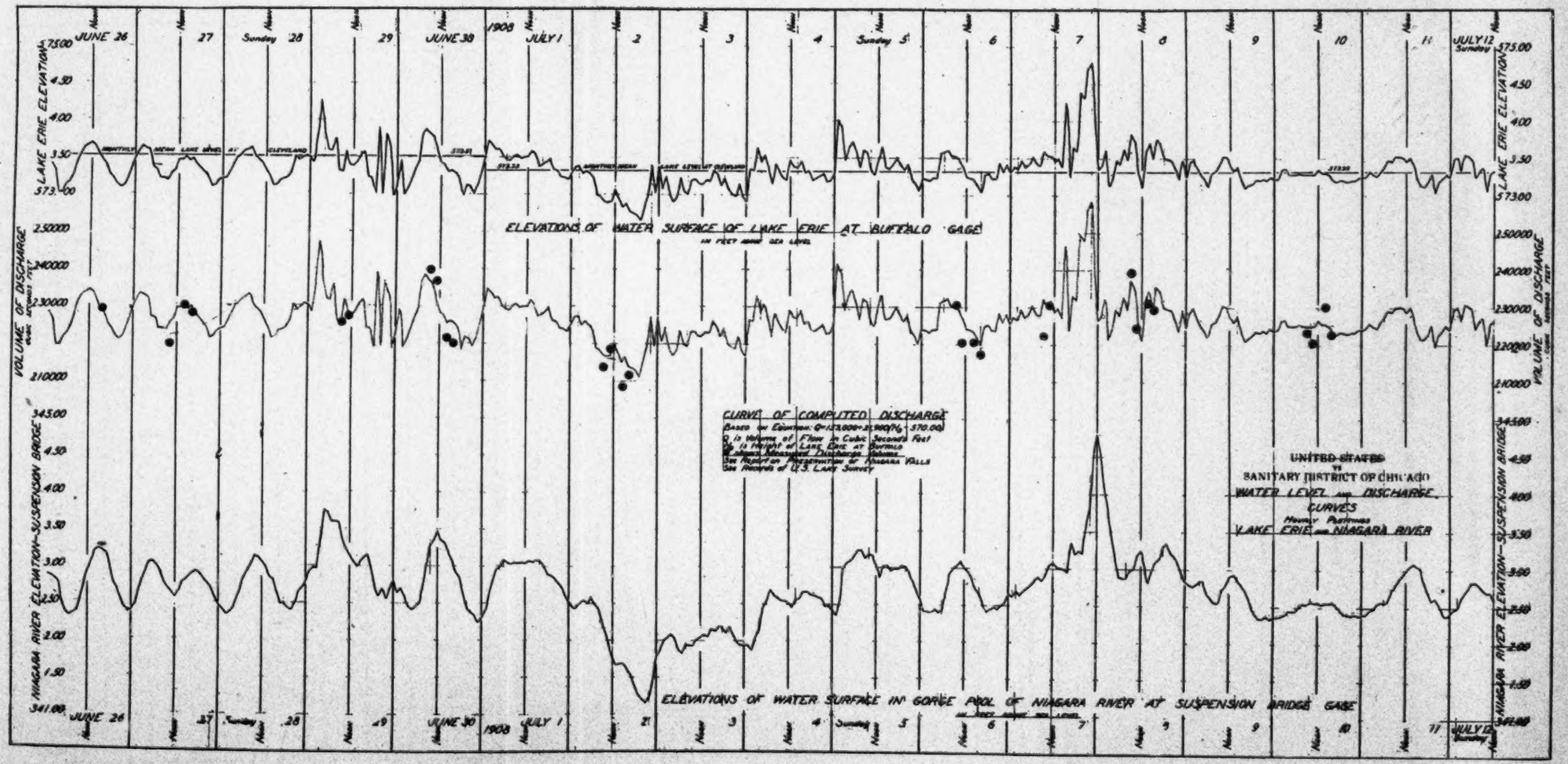
Shenehon's Exhibit I.

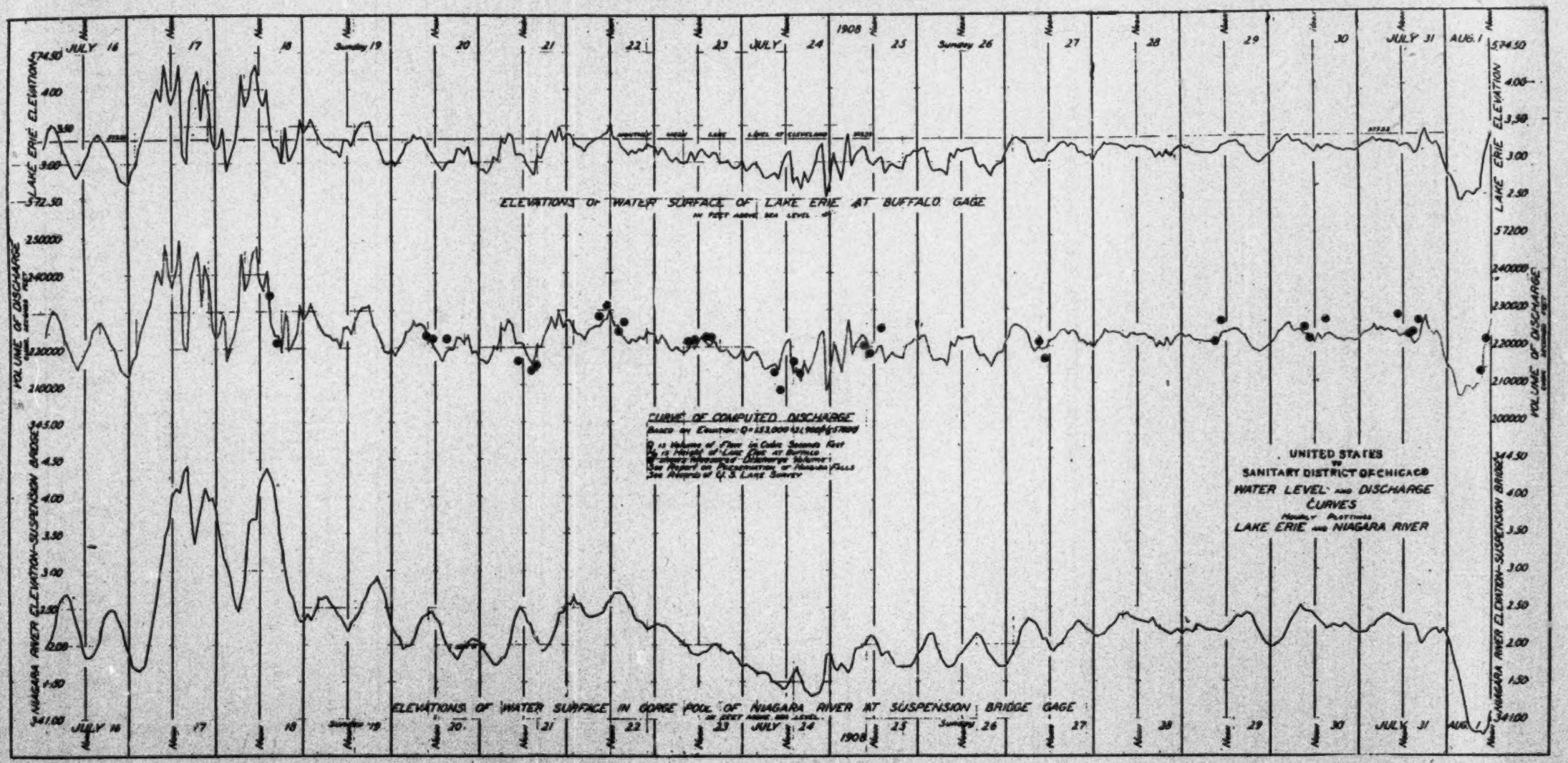
Shenehon's Exhibit I, April 15, 1914.



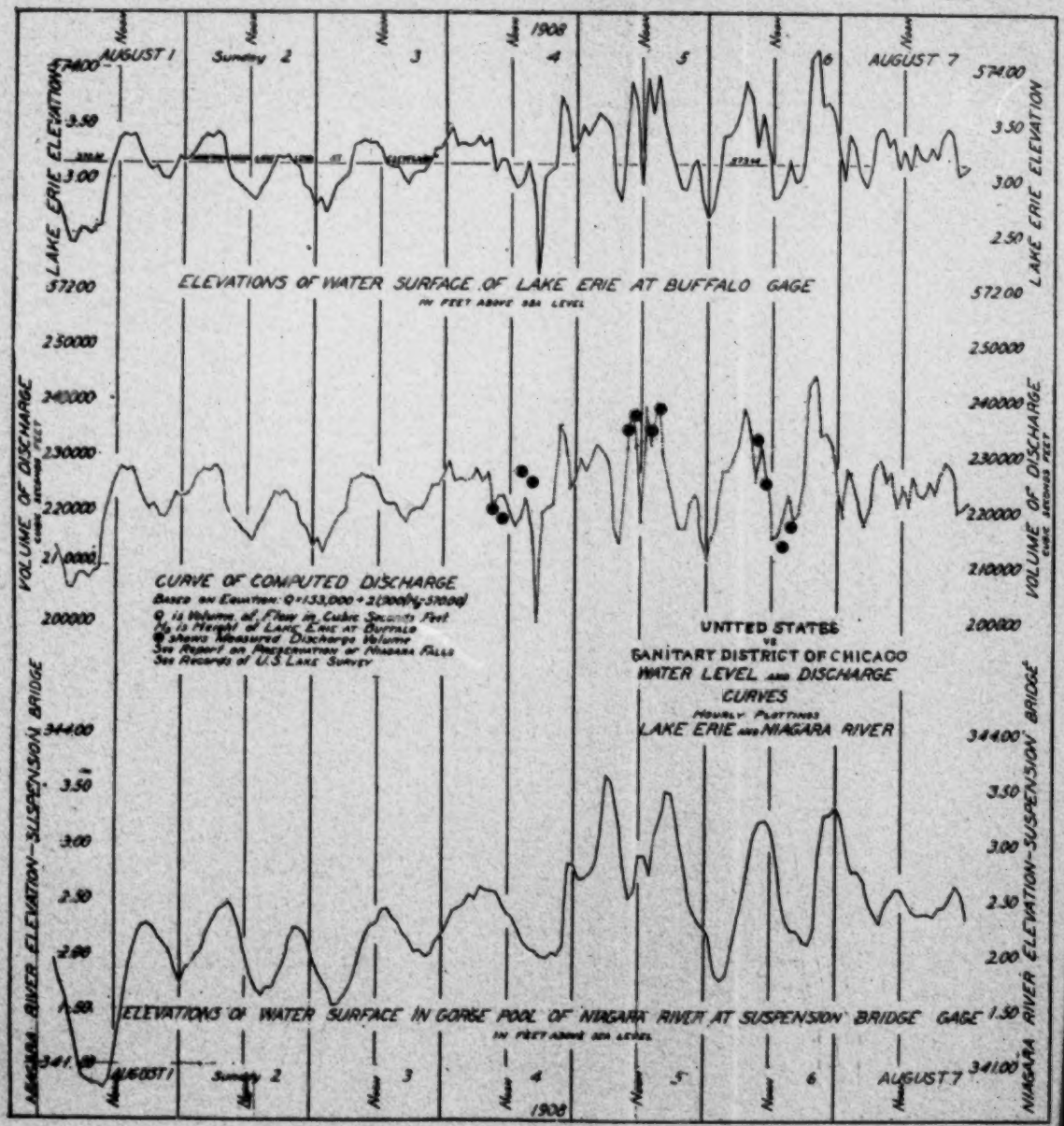
Three-Curve Series, Sheet 1, Shenehon's Exhibit K, April 15, 1914.

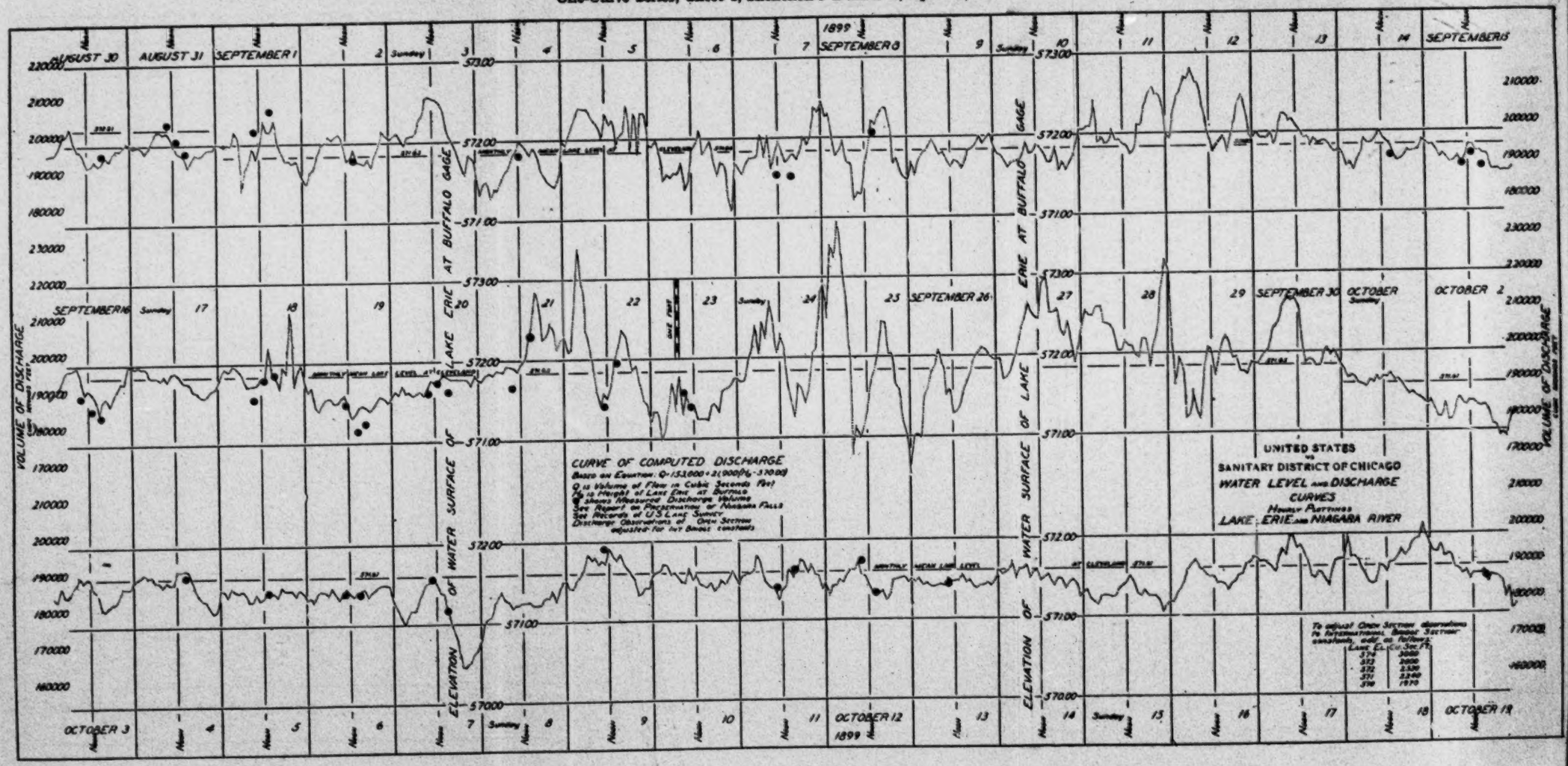


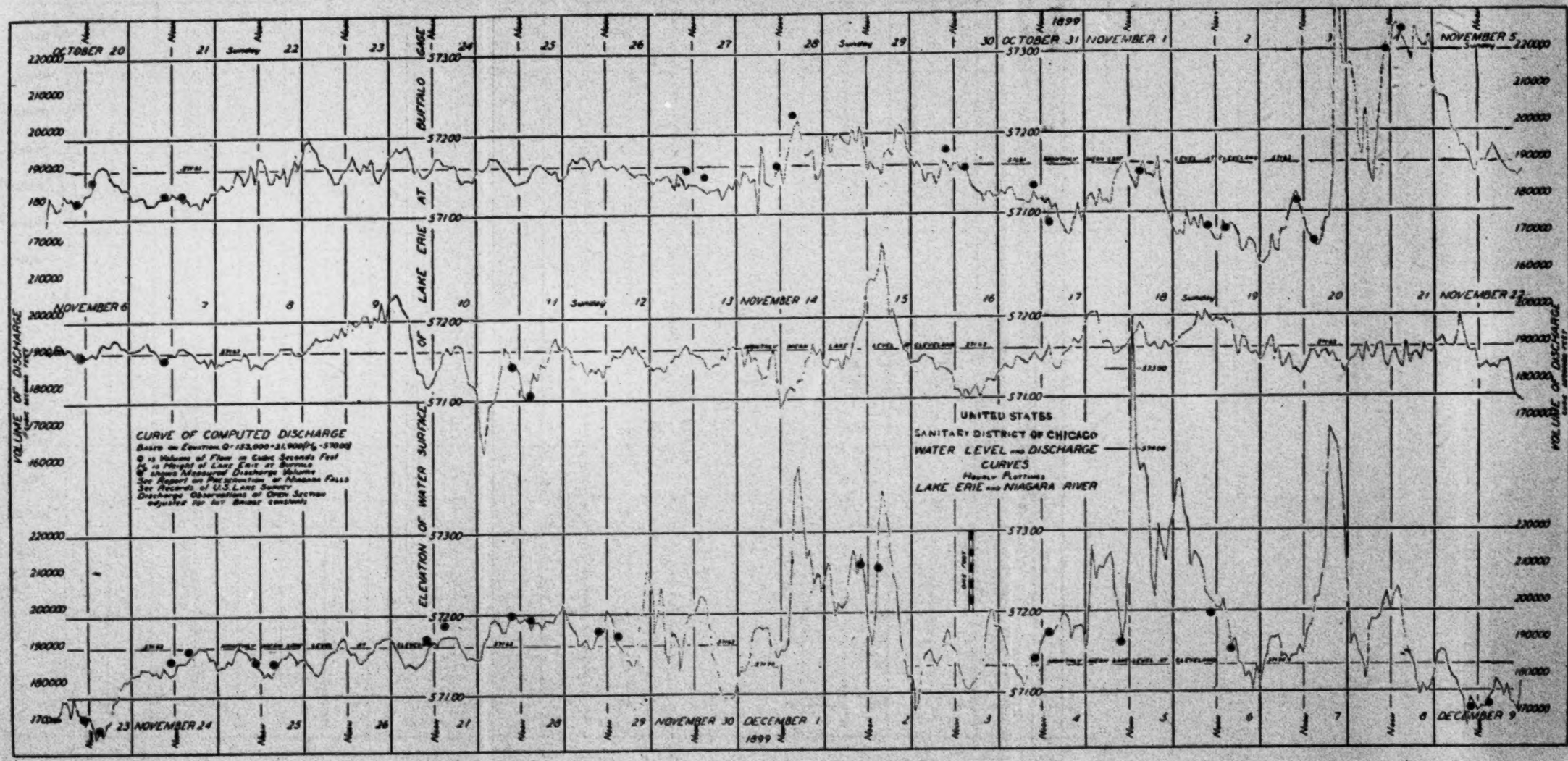

JUNE 26
27
Sunday 28
29
JUNE 30
1908
JULY 1
2
3
4
Sunday 5
6
7
8
9
10
11
JULY 12
Sunday
LAKE ERIE ELEVATION
573.00
VOLUME OF DISCHARGE
250000
240000
230000
220000
210000
NIAGARA RIVER ELEVATION-SUSPENSION BRIDGE
345.00
341.00
ELEVATIONS OF WATER SURFACE OF LAKE ERIE AT BUFFALO GAGE
CURVE OF COMPUTED DISCHARGE
UNITED STATES
vs
SANITARY DISTRICT OF CHICAGO
WATER LEVEL and DISCHARGE
CURVES
Hourly Postings
LAKE ERIE and NIAGARA RIVER
ELEVATIONS OF WATER SURFACE IN GORGE POOL OF NIAGARA RIVER AT SUSPENSION BRIDGE GAGE

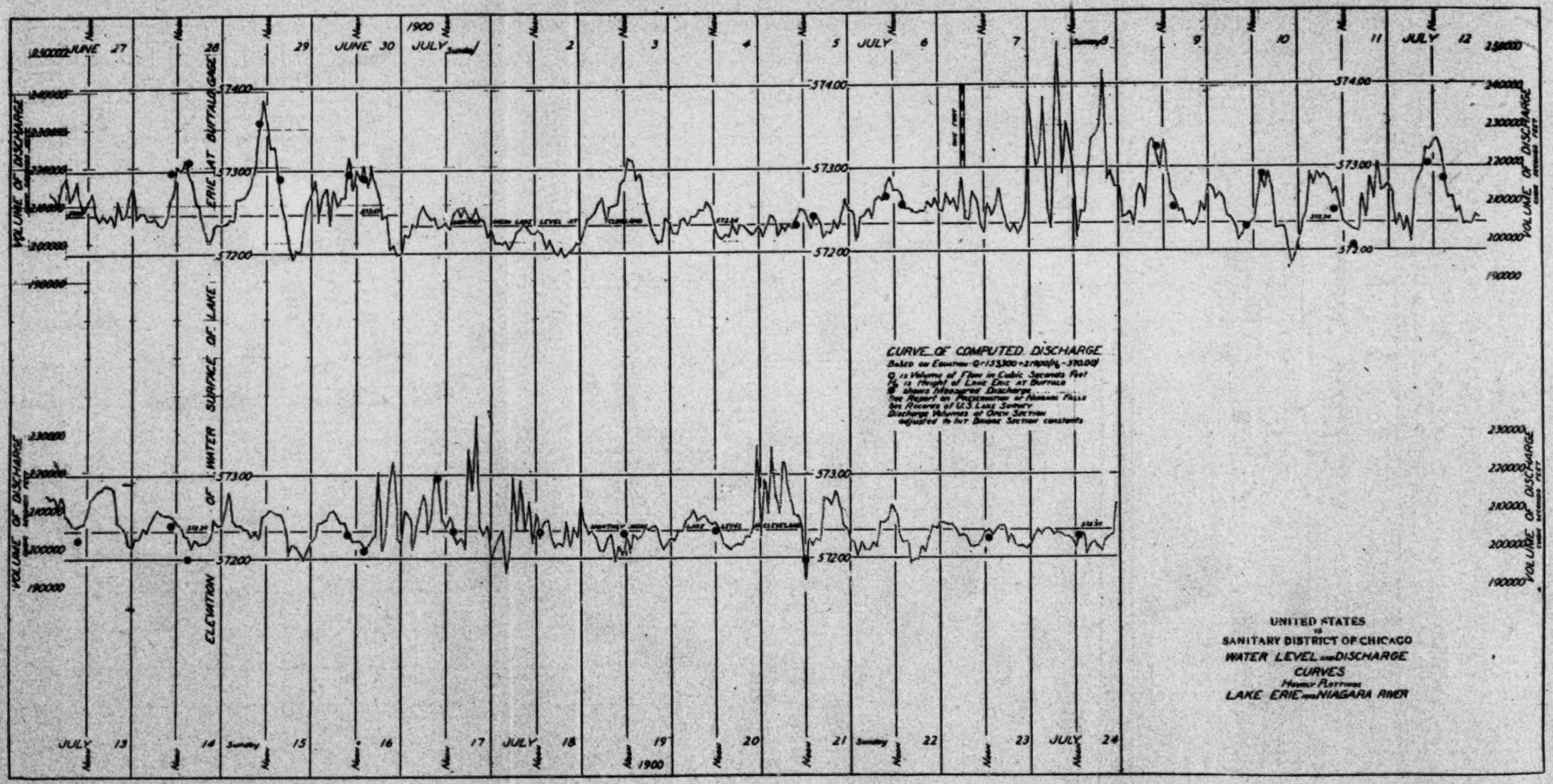

ELEVATIONS OF WATER SURFACE OF LAKE ERIE AT BUFFALO GAGE
CURVE OF COMPUTED DISCHARGE
ELEVATIONS OF WATER SURFACE IN GORGE POOL OF NIAGARA RIVER AT SUSPENSION BRIDGE GAGE
UNITED STATES
vs
SANITARY DISTRICT OF CHICAGO
WATER LEVEL and DISCHARGE
CURVES
Hourly Plottings
LAKE ERIE and NIAGARA RIVER
LAKE ERIE ELEVATION
VOLUME OF DISCHARGE
NIAGARA RIVER ELEVATION-SUSPENSION BRIDGE
JULY 16
17
18
19
20
21
22
23
JULY 24
1908
25
26
27
28
29
30
JULY 31
AUG. 1

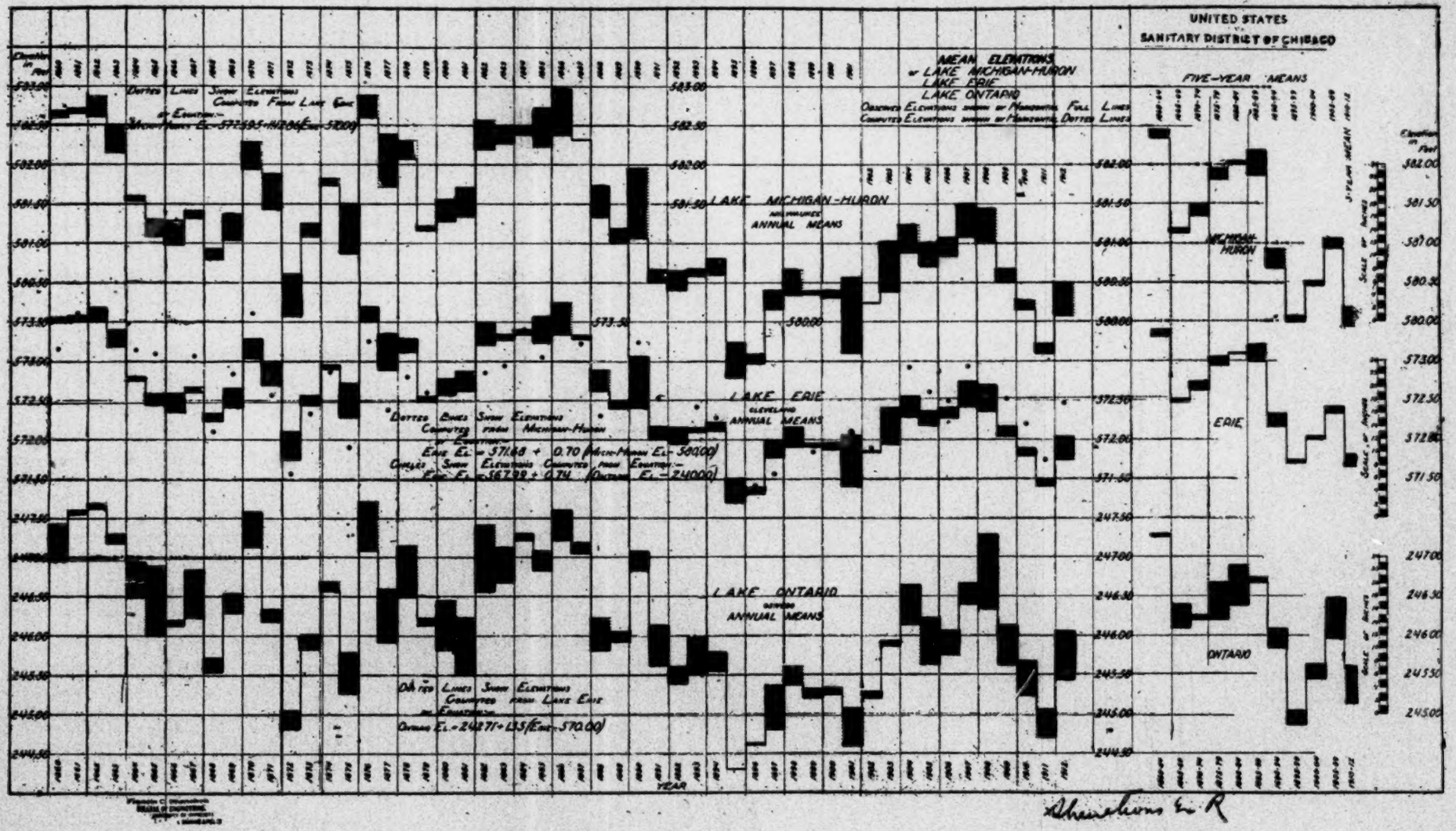
Three-Curve Series, Sheet 4, Shenehon's Exhibit N, April 15, 1914.

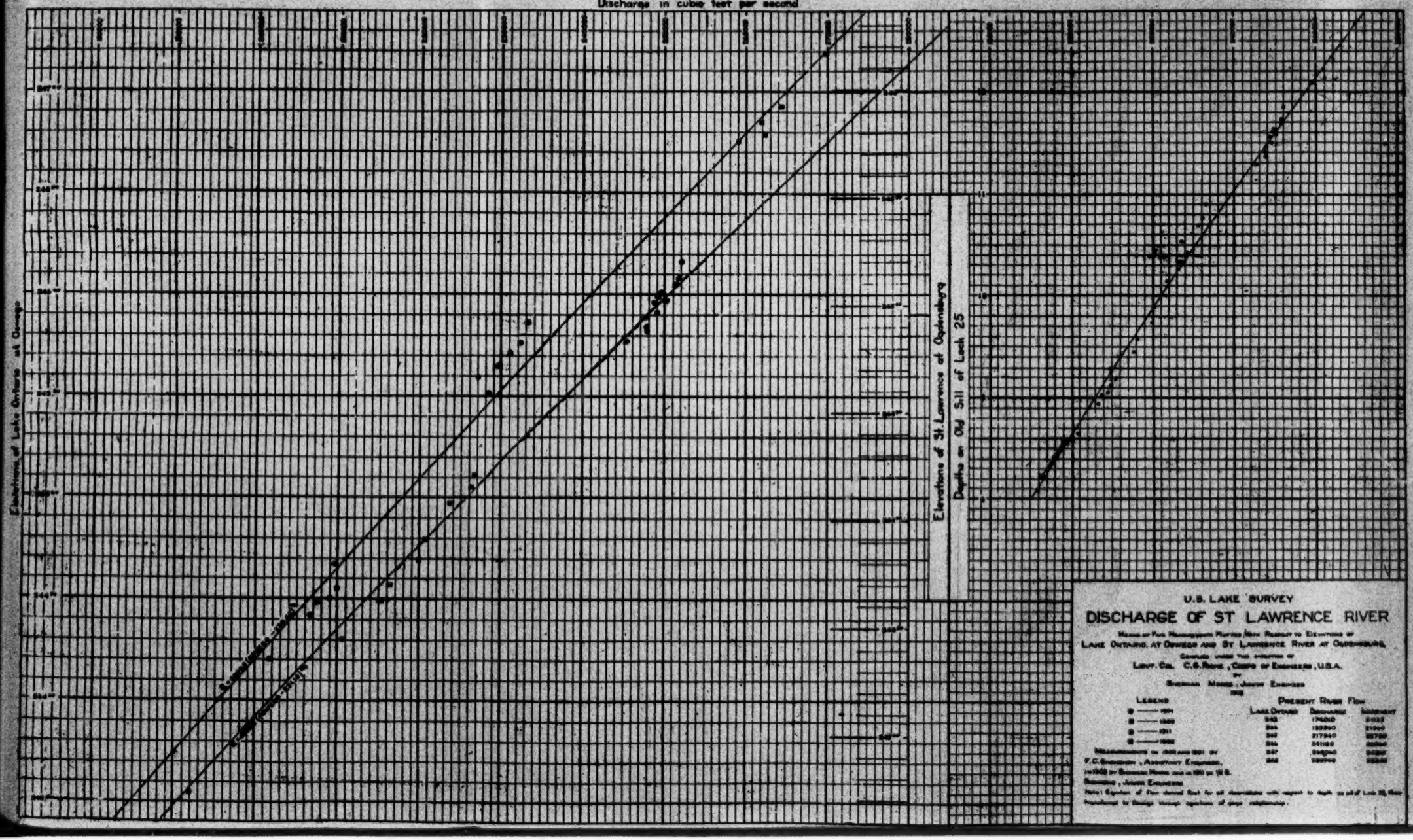



VOLUME OF DISCHARGE
ELEVATION OF WATER SURFACE OF LAKE ERIE AT BUFFALO GAGE
AUGUST 30
AUGUST 31
SEPTEMBER 1
SEPTEMBER 16
SEPTEMBER 26
SEPTEMBER 30
OCTOBER 2
OCTOBER 3
OCTOBER 12
OCTOBER 19
1899
CURVE OF COMPUTED DISCHARGE
Based on Equation: Q=153,000+2(900Ph-3900)
Q is Volume of Flow in Cubic Seconds Feet
Ph is Height of Lake Erie at Buffalo
Above Measured Discharge Volume
See Report on Preservation of Niagara Falls
See Records of U.S. Lake Survey
Discharge Observations of Open Section adjusted for Ice Sheet conditions
UNITED STATES
vs
SANITARY DISTRICT OF CHICAGO
WATER LEVEL and DISCHARGE CURVES
Hourly Plottings
LAKE ERIE and NIAGARA RIVER


VOLUME OF DISCHARGE
ELEVATION OF WATER SURFACE OF LAKE ERIE AT BUFFALO GAGE
OCTOBER 20
NOVEMBER 6
NOVEMBER 23
NOVEMBER 24
NOVEMBER 30
DECEMBER 1
1899
OCTOBER 31
NOVEMBER 1
NOVEMBER 5
NOVEMBER 22
DECEMBER 9
CURVE OF COMPUTED DISCHARGE
UNITED STATES
SANITARY DISTRICT OF CHICAGO
WATER LEVEL and DISCHARGE CURVES
Hourly Plottings
LAKE ERIE and NIAGARA RIVER


JUNE 27
28
29
JUNE 30
JULY
2
3
4
5
JULY 6
7
9
10
11
JULY 12
1900
574.00
573.00
572.00
VOLUME OF DISCHARGE
ELEVATION OF WATER SURFACE OF LAKE ERIE AT BUFFALO GAGE
CURVE OF COMPUTED DISCHARGE
Based on Equation: Q=13,300 (H-570.00)²
Q is Volume of Flow in Cubic Seconds Feet
H is Height of Lake Erie at Buffalo
● shows Measured Discharge
See Report on Regulation of Niagara Falls
See Records of U.S. Lake Survey
Discharge Volumes of Open Section
adjusted to Int Bridge Section constants
JULY 13
14
15
16
17
JULY 18
19
20
21
22
23
JULY 24
UNITED STATES
vs
SANITARY DISTRICT OF CHICAGO
WATER LEVEL and DISCHARGE
CURVES
Hourly Readings
LAKE ERIE and NIAGARA RIVER


UNITED STATES
SANITARY DISTRICT OF CHICAGO
MEAN ELEVATIONS
OF LAKE MICHIGAN-HURON
LAKE ERIE
LAKE ONTARIO
FIVE-YEAR MEANS
LAKE MICHIGAN-HURON
ANNUAL MEANS
LAKE ERIE
ANNUAL MEANS
LAKE ONTARIO
ANNUAL MEANS
MICHIGAN-HURON
ERIE
ONTARIO
YEAR


Discharge in cubic feet per second
Elevations of Lake Ontario at Oswego
Elevations of St. Lawrence at Ogdensburg
Depths on Obj Sill of Lock 25
U.S. LAKE SURVEY
DISCHARGE OF ST LAWRENCE RIVER
LEGEND
PRESENT RIVER FLOW

Shenehon's Exhibit T, April 15, 1914.

U.S. vs SANITARY DISTRICT
COMPARISON OF
ST LAWRENCE AND NIAGARA RIVER DISCHARGES
WITH INTERMEDIATE SUPPLY
COMPUTED BY DEFENDANT'S WITNESS STEARNS

1	2	3	4	5	6	7
JUNE TO NOV YEAR	DISCHARGE BY ST LAWRENCE RIVER C.S.F.	LOCAL SUPPLY AND STORAGE ONTARIO C.S.F.	REDUCED NIAGARA DISCHARGE C.S.F.	ACTUAL NIAGARA DISCHARGE C.S.F.	Col 4 minus Col 5	
1891	244800	45300	199500	204300	− 4800	
2	247600	23400	224200	219800	+ 4400	
3	261300	37400	223900	214700	+ 9200	
4	246700	34100	212600	210400	+ 2200	
1895	205200	25900	179300	186800	− 7500	
6	217500	29900	187600	194800	− 7200	
7	229000	23500	205500	205300	+ 200	
8	235000	28800	206200	207800	− 1600	
9	231300	24400	206900	199400	+ 7500	
1900	232500	29500	203000	202000	+ 1000	
1	230400	31200	199200	192000	+ 7200	
2	241200	22800	218400	207800	+10600	
3	252700	32100	220600	212100	+ 8500	
4	272500	31300	241200	220500	+20700	
1905	253700	22500	233200	218100	+15100	
6	241700	25800	215900	208200	+ 7700	
16 YEARS	240300	29200	211100	206500	+ 4600	

COLUMN 2 ST. LAWRENCE RIVER OUTFLOW BY U.S. LAKE SURVEY 1912 REPORT

COLUMN 3 TOTAL LOCAL SUPPLY AND STORAGE COMPUTED BY MR FREDERIC P. STEARNS SEE HIS TABLE D, COLUMN 3.

COLUMN 5 NIAGARA INFLOW BY U.S. EXHIBIT No 3 TO VOLUME OF RIVER FLOW IS 4000 TO 2300 C.S.F. FOR INFLOW BY ERIE AND WELLAND CANALS.

SHENEHON'S EXHIBIT U 1 April 16, 1914 [5 sheets (1)]

Also HAYFORD'S EXHIBIT 1 for identification of April 10, 1914

FRANCIS C. SHENEHON
Member American Society of Civil Engineers
Consulting Engineer
Minneapolis

NIAGARA RIVER—DISCHARGE

Solution of Straight Line Eq. by Williams 3-point Method

Center of Gravity of 219 observations
Buffalo Gage = 572,549 Thoroughly
Q = 208,952 checked
F.C.S.

See Special Sheet

Center of Gravity of 121 observations

$$\text{Gage} = \frac{377.16}{121} + 570.00 = 573.117$$

$$Q = \frac{26787200}{121} = 221,380$$

Log 377.16 = 2.5765256
Log 121 = 2.0827854
Log 3.117 = 0.4937402

Log 26787200 = 7.4279273
Log 121 = 2.0827854
221,380 = 5.3451419

Center of Gravity of 98 observations

$$\text{Gage} = \frac{180.98}{98} + 570 = 571.847$$

$$Q = \frac{18973400}{98} = 193606$$

Log 180.98 = 2.2576306
Log 98 = 1.9912261
Log 1.847 = 0.2664045

Log 18973400 = 7.2781452
Log 98 = 1.9912261
Log 193,606 = 5.2869191

SHENEHON'S EXHIBIT U 2 April 16, 1914 [5 sheets (2)]

Also HAYFORD'S EXHIBIT 2 for identification of April 10, 1914

FRANCIS C. SHENEHON
Member American Society of Civil Engineers
Consulting Engineer
Minneapolis

Three Point Method
Niagara Discharge

	Gage	Q = Volume		Increment
Upper	573,117	221,380		
c =	0.568	12428	=	21,880
Mean	572,549	208,952		
	0.702	15,346	=	21,860
Lower	571,847	193,606		
		Upper Minus lower =		21,870

Log 12428 = 4.0944012
Log 0.568 = 9.7543483 — 10

Log Inc. 21,880 = 4.3400529

Log 15346 = 4.1859952
Log 0.702 = 9.8463371 — 10

21.860 = 4.3306581

Full Length Upper Minus Lower
Log 27774 = 4.4436384
Log 1.270 = 0.1039037 — 10

21870 = 4.3396347

SHENEHON'S EXHIBIT U 3, April 16, 1914. [5 sheets (3)]
Also HAYFORD EXHIBIT 3, for identification of April 10, 1914

FRANCIS C. SHENEHON

Member American Society of Civil Engineers
Consulting Engineer
Minneapolis

	No. of Dis		
1898—1899—1.01		202.90	198,762.00
1907—1908—1.18		355.24	258,844.00
2.19		558.14	457,606.00
Mean	=	572.55	209000

Log 558.14 = 2.7467431
Log 219 = 2.3404441

Log Gage 2.5486 = 0.4062990
572.549
Log 45760600 = 7.6604917
Log 219 = 2.3404441

Log Q = 208,952 = 5.3200476

Result
Center of Gravity of 219 Observations for Discharge Int. Bridge Niagara River
Gage = 572.549
Q = 208,952

SHENEHON'S EXHIBIT U 4, April 16, 1914. [5 sheets (4)]
Also HAYFORD EXHIBIT 4 for identification of April 10, 1914
FRANCIS C. SHENEHON
Member American Society of Civil Engineers
Consulting Engineer
Minneapolis

3.92	24.09	3.16	21.64		
3.80	23.80	3.15	22.18	2.66	21.39
3.88	23.86	3.15	22.68	2.65	21.05
3.80	23.94	3.12	22.64	2.64	20.07
3.77	23.46	3.12	22.58	2.64	21.08
3.71	23.98	3.11	22.64	2.64	21.25
3.70	23.13	3.10	22.10	2.63	21.14
3.69	23.43	3.10	22.25	2.61	20.96
3.69	23.45	3.09	22.27	2.61	21.12
3.63	23.11	3.08	21.52	2.57	20.21
3.61	23.73	3.08	22.20	2.57	20.58
3.60	23.67	3.08	22.33	2.57	21.51
3.56	23.30	3.08	22.50	2.56	21.37
3.54	22.21	3.07	21.74		
3.54	22.95	3.07	22.13		
3.54	23.04	3.06	22.71		
3.54	23.56	3.05	21.94		
3.52	23.07	3.03	21.72		
3.49	22.98	3.02	22.12		
3.48	22.78	3.01	21.44		
3.46	22.43	3.01	22.12		
3.42	23.12	3.00	21.67		
3.40	22.15	3.00	21.83		
3.39	22.70	3.00	21.88		
3.39	22.88	3.00	22.16		
3.39	23.18	3.00	22.23		
3.39	23.48	3.00	22.47		
3.38	22.82	2.98	22.41		
3.37	22.57	2.98	22.52		
3.34	22.04				
3.33	22.92	2.97	21.76		
3.32	22.55	2.94	21.38		
3.30	22.34	2.93	21.58		
3.30	23.02	2.92	21.36		
3.29	22.41	2.91	21.39		
3.28	21.90	2.91	21.87		
3.28	22.00	2.87	20.85		
3.27	22.05	2.87	21.34		
3.27	22.50	2.86	21.34		
3.24	22.31	2.85	20.84		
3.23	22.66	2.85	21.61		
3.23	22.28	2.84	21.31		
3.21	22.15	2.84	21.67		
3.21	22.48	2.82	21.36		
3.20	22.04	2.82	21.52		
3.20	22.28	2.81	21.32		
3.20	22.68	2.81	21.48		
3.20	22.79	2.80	21.94		
3.19	22.26	2.79	21.49		
3.18	21.87	2.77	21.17		
3.18	22.04	2.73	21.25		
3.18	22.67	2.72	21.30		
		2.72	21.33		
		2.71	20.73		
		2.70	20.80		
		2.69	21.50		
		2.67	21.30		
		2.67	21.40		
			21.20		
			21.05		
			21.25		
			21.05		
			20.67		

8mm Gage = 377.16
Volume = 267862
N = 121

SHENEHON'S EXHIBIT U 5, April 16, 1914. [5 sheets (5).]

Also HAYFORD EXHIBIT 5 for identification of April 10, 1914.

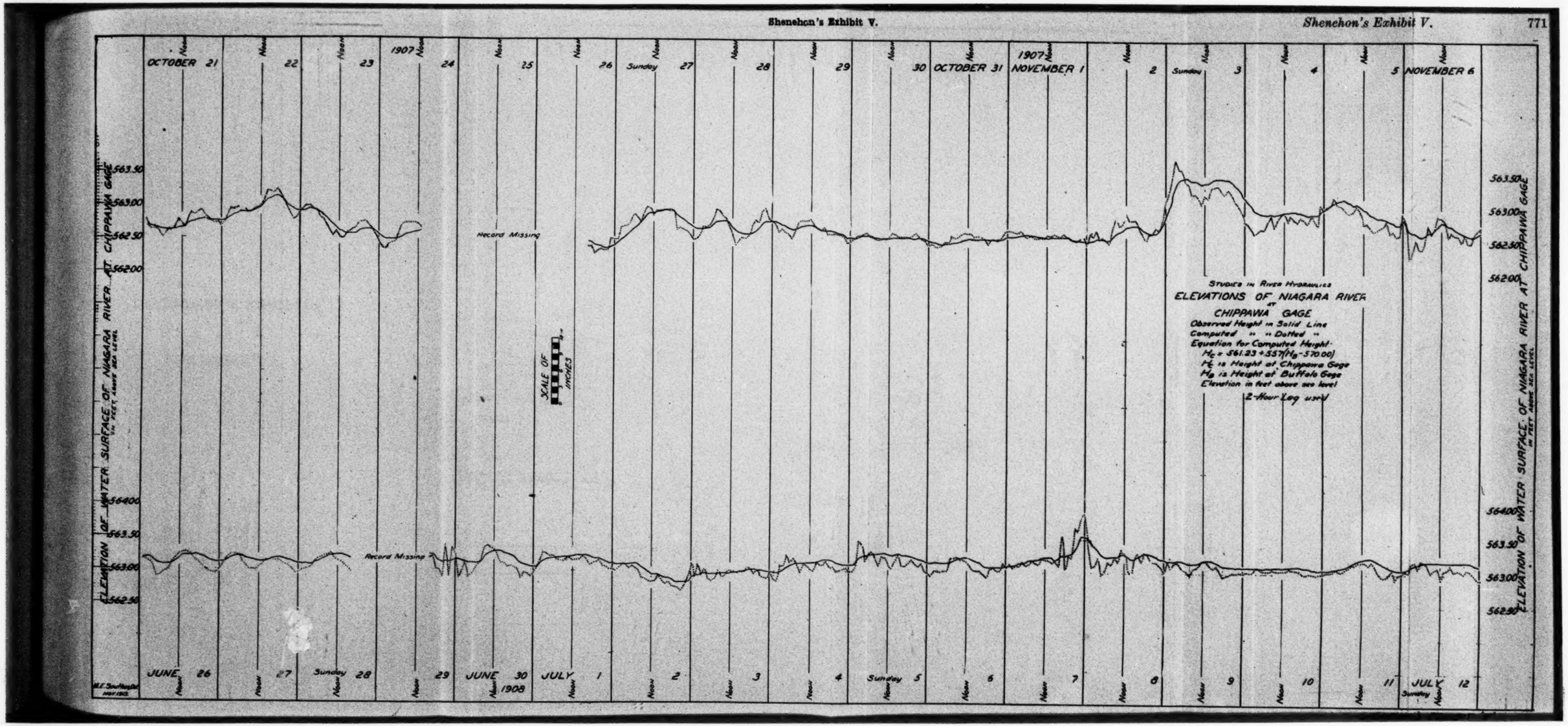
NIAGARA DISCHARGE.

1898-99

FRANCIS C. SHENEHON
Member American Society of Civil Engineers
Consulting Engineer, Minneapolis.

uffalo Gage*	Q*	Gage	Q
2.55	20.78	1.76	19.01
2.54	20.71	1.75	19.04
2.54	20.92	1.74	19.24
2.52	20.76	1.74	18.85
2.52	20.85	1.73	18.74
2.50	21.56	1.73	18.88
2.49	20.55	1.72	18.89
2.48	20.82	1.70	18.91
2.48	20.84	1.68	19.22
2.46	20.88	1.66	18.80
2.45	21.41	1.66	18.90
2.44	21.24	1.66	19.35
2.42	20.25	1.65	18.87
2.42	20.62	1.65	19.00
2.41	20.72	1.64	19.04
2.40	20.16	1.63	18.81
2.40	21.11	1.61	18.49
2.39	20.29	1.61	18.97
2.39	20.61	1.60	18.80
2.39	21.02	1.57	18.85
2.38	20.83	1.56	18.65
2.38	20.86	1.54	18.75
2.38	20.98	1.53	18.69
2.37	20.51	1.48	18.48
2.35	19.89	1.47	18.76
2.35	20.42	1.46	18.85
2.35	20.69	1.45	18.06
2.33	20.24	1.44	18.29
2.32	20.10	1.44	18.57
2.32	20.83	1.43	18.35
2.29	20.71	1.42	18.19
2.26	20.37	1.41	18.02
2.24	20.66	1.41	18.22
2.21	19.75	1.14	18.32
2.19	20.16	1.02	17.56
2.16	19.89	.79	17.38
2.13	19.62	.64	16.92
2.10	19.64	.24	16.16
2.03	19.35	.14	15.72
2.03	19.58	.11	15.56
2.01	19.55	.3	15.45
1.99	19.68	570.00	15.41
1.97	19.58		
1.96	19.50		
1.96	19.50		
1.94	19.00		
1.87	19.71		
1.86	19.49		
1.85	18.89		
1.83	19.30		
1.81	19.26		
1.80	18.89		
1.79	19.13		
1.79	19.17		
1.78	19.38		
1.77	19.11		

Sum Gage = 180.98
* Volume = 18973400
N = 98


OCTOBER 21
22
23
1907
24
25
26
Sunday 27
28
29
30
OCTOBER 31
1907
NOVEMBER 1
2
Sunday 3
4
5
NOVEMBER 6
Noon
Record Missing
Record Missing
SCALE OF INCHES
STUDIES IN RIVER HYDRAULICS
ELEVATIONS OF NIAGARA RIVER AT CHIPPAWA GAGE
Observed Height in Solid Line
Computed " " Dotted "
Equation for Computed Height:
$H_C = 561.23 + .557(H_B - 570.00)$
H_C is Height at Chippawa Gage
H_B is Height at Buffalo Gage
Elevation in feet above sea level
2-Hour Log w.s.w.
ELEVATION OF WATER SURFACE OF NIAGARA RIVER AT CHIPPAWA GAGE
IN FEET ABOVE SEA LEVEL
563.50
563.00
562.50
562.00
564.00
563.50
563.00
562.50
JUNE 26
27
Sunday 28
29
JUNE 30
1908
JULY 1
2
3
4
Sunday 5
6
7
8
9
10
11
JULY 12
Sunday
M.E. Southgate
NOV 1913

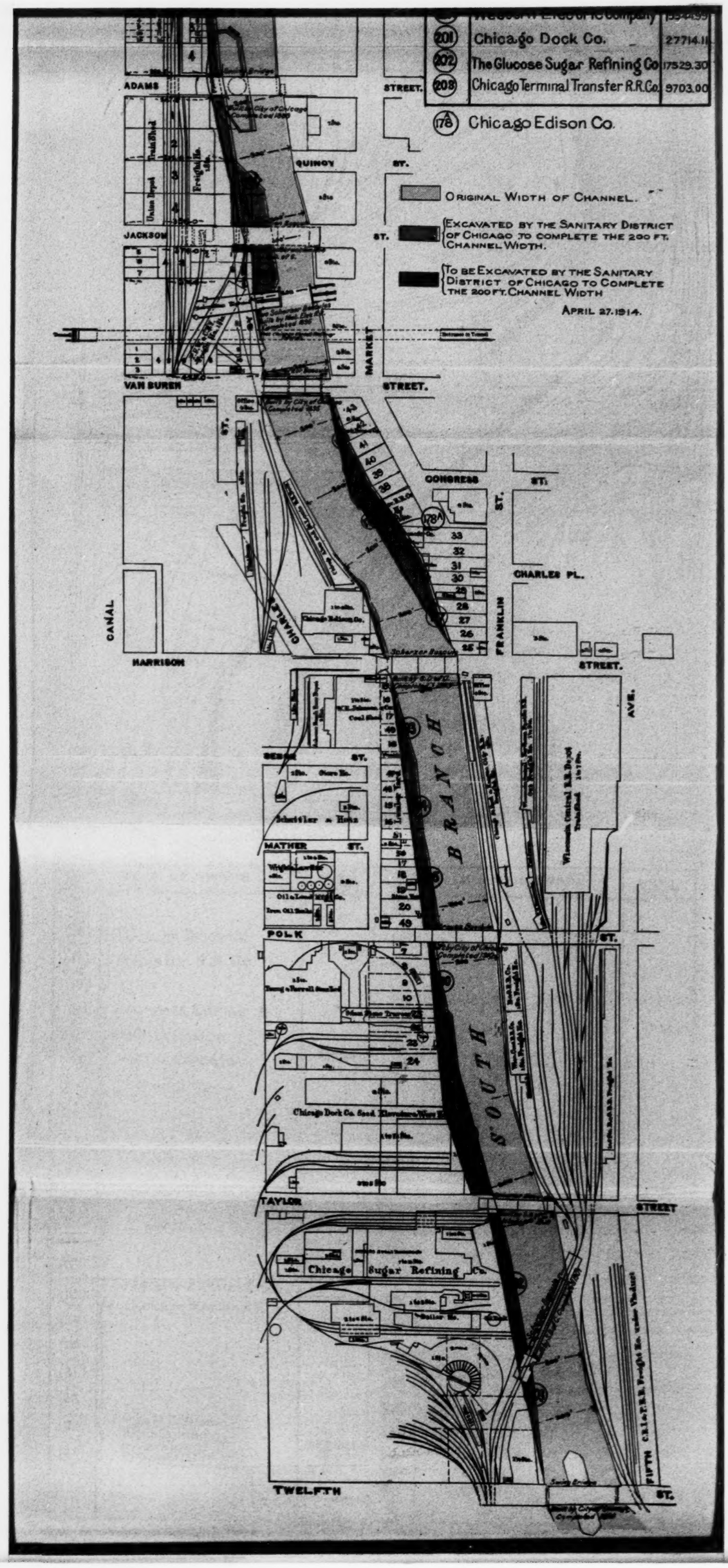
DEFENDANT'S EXHIBITS

IN

SUR-REBUTTAL.

RIVER
WABASH AV
STATE
DEARBORN
CLARK
LASALLE
MICHIGAN AVE.
RUSH
STREET

Wisner's Exhibit 7
May 20. 1914.
WABASH AV.
STATE
DEARBORN
CLARK
LASALLE
FIFTH AVE.
FRANKLIN
SOUTH WATER
WELLS ST.
LAKE
CARROLL
KINZIE
RIVER
CHICAGO
MICHIGAN AVE.
RUSH STREET
STREET


201 Chicago Dock Co. 27714.11
202 The Glucose Sugar Refining Co 17529.30
208 Chicago Terminal Transfer R.R.Co. 9703.00
178 Chicago Edison Co.
ORIGINAL WIDTH OF CHANNEL.
EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.
TO BE EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH
APRIL 27. 1914.
ADAMS
QUINCY
JACKSON
VAN BUREN
MARKET
STREET.
CONGRESS
CHARLES PL.
FRANKLIN
CANAL
HARRISON
SOUTH BRANCH
MATHER
POLK
TAYLOR
Chicago Sugar Refining Co.
TWELFTH
FIFTH AVE.

775

Wisner's Exhibit 8.

SANITARY DISTRICT OF CHICAGO

MAP

Showing

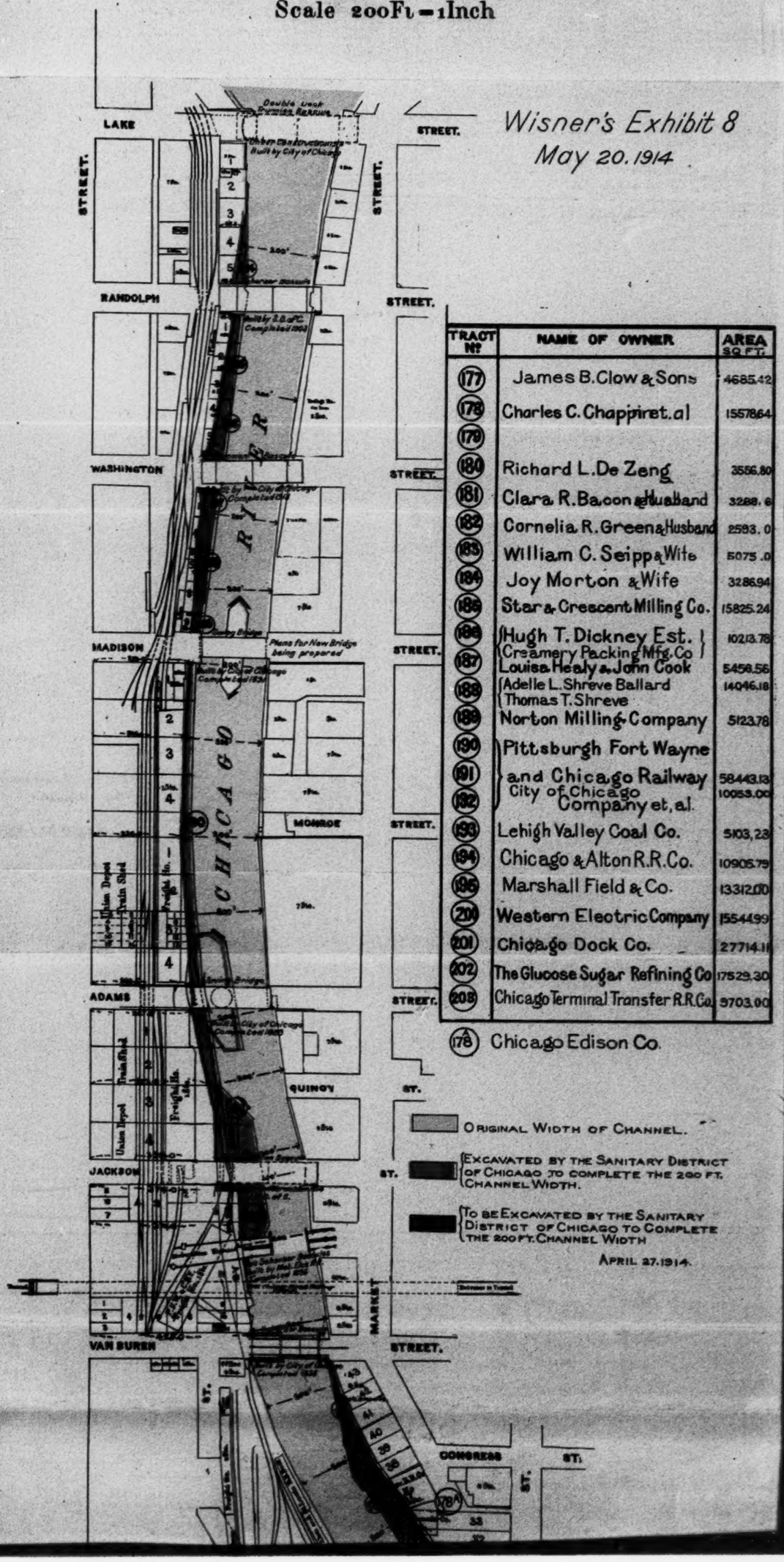
CHICAGO RIVER IMPROVEMENT

From

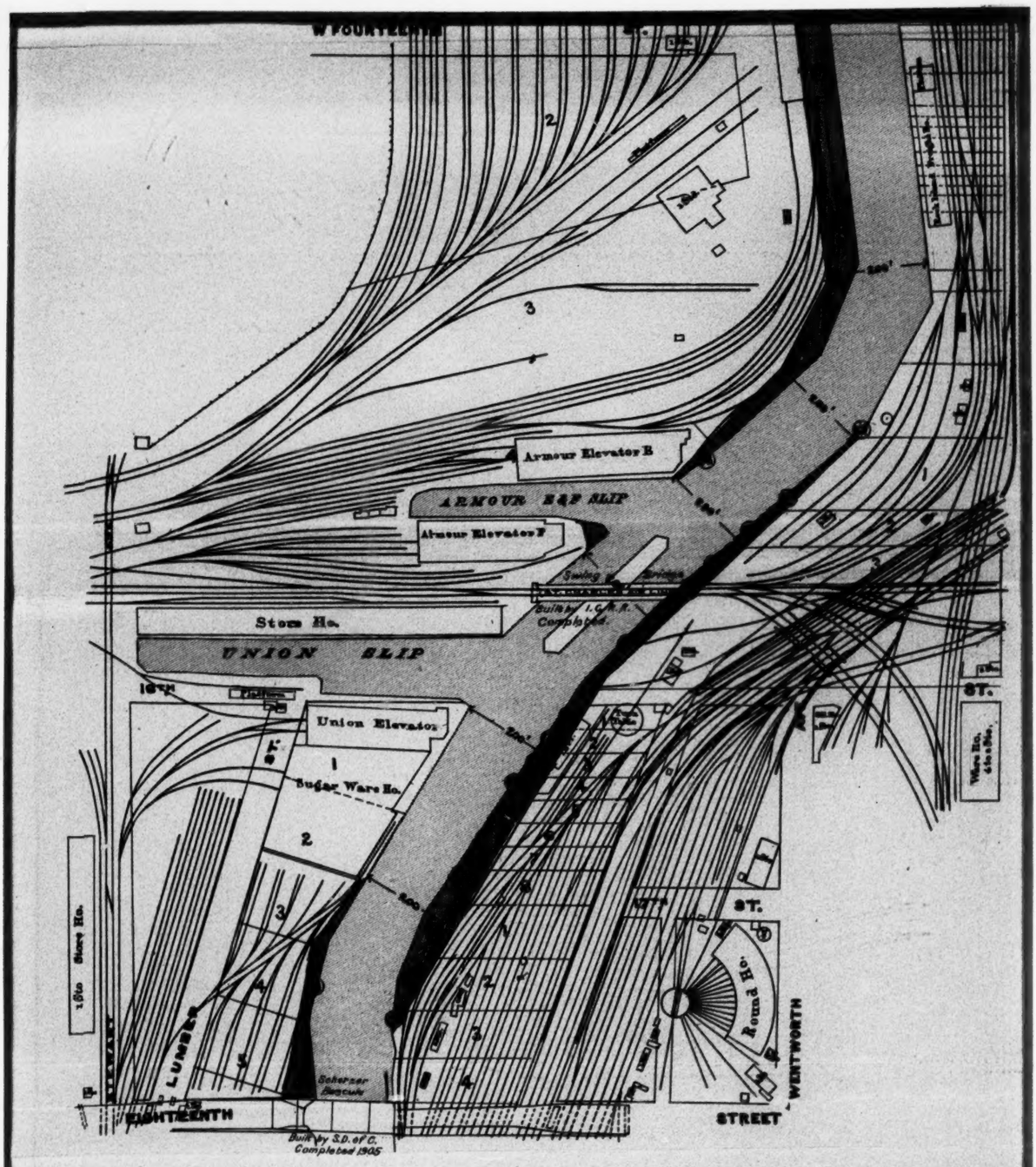
LAKE STREET TO 12TH STREET

Scale 200 Ft = 1 Inch

Wisner's Exhibit 8
May 20. 1914.



TRACT №	NAME OF OWNER	AREA SQ FT.
177	James B. Clow & Sons	4685.42
178	Charles C. Chappiret. al	1557864
179		
180	Richard L. De Zeng	3556.80
181	Clara R. Bacon & Husband	3288. 6
182	Cornelia R. Green & Husband	2583. 0
183	William C. Seipp & Wife	5075 .0
184	Joy Morton & Wife	3286.94
186	Star & Crescent Milling Co.	15825.24
186	Hugh T. Dickney Est.	10213.78
187	Creamery Packing Mfg. Co	
188	Louisa Healy & John Cook	5456.56
	Adelle L. Shreve Ballard	14046.18
	Thomas T. Shreve	
189	Norton Milling Company	5123.78
190	Pittsburgh Fort Wayne	
191	and Chicago Railway	58443.13
192	City of Chicago	10053.00
	Company et. al.	
193	Lehigh Valley Coal Co.	5103.23
194	Chicago & Alton R.R. Co.	10905.79
195	Marshall Field & Co.	13312.00
200	Western Electric Company	1554499
201	Chicago Dock Co.	27714.11
202	The Glucose Sugar Refining Co	17529.30
203	Chicago Terminal Transfer R.R. Co.	9703.00



TRACT No.	NAME OF OWNER	AREA SQ. FT.	TRACT No.	NAME OF OWNER	AREA SQ. FT.
15	Chicago Terminal Transfer R.R. Co.	6,305.95	35	See Tracts 33 & 34 for Owners and Area	
16			36		
17			37A		
18			37	Chicago & North Western Ry. Co	37,772.29
18A	George M. Eckles Edith O. Eckles (City Elevator Property)	11,583.66	38		1,727.20
19			152		
20			153		
21			154		
21A	Chicago Terminal Transfer R.R. Co	12924.63	155		
22			156		
23			157	Chicago & Western Indiana R.R. Co. et al	42,606.80
24			158		
25 N.R. S.R.	Chicago & Great Western R.R. Co. B & O. Chicago Terminal R.R. Co.	31,491.65	159		
26			160		
27			161		
28			162		
29			163	C.R.I. & P.R.R. Co. L.S. & M.S.R'y. Co. & C. & W.R.R. Co	5,410.02 16.03
30			163A	M.C.R.R - I.C.R.R. - C.B. & Q.R.R.	1,768.50
31			164		
32			165	C.R.I. & P.R.R. Co. L.S. & M.S.R'y. Co. C. & W.R.R. Co.	8960.37
33	George M. Eckles Edith O. Eckles (Iowa Elevator Property)	24,004.56	166		
34			167	L.S. & M.S.R.R. Co.	00.78
			39 40	Wm. A. Havemeyer & Rosa R. Havemeyer	5686.00

777

Wisner's Exhibit 9.

SANITARY DISTRICT OF CHICAGO

MAP

Showing

CHICAGO RIVER IMPROVEMENT

From

12TH STREET TO 18TH STREET

Scale 200Ft = 1Inch Wisners Exhibit 9

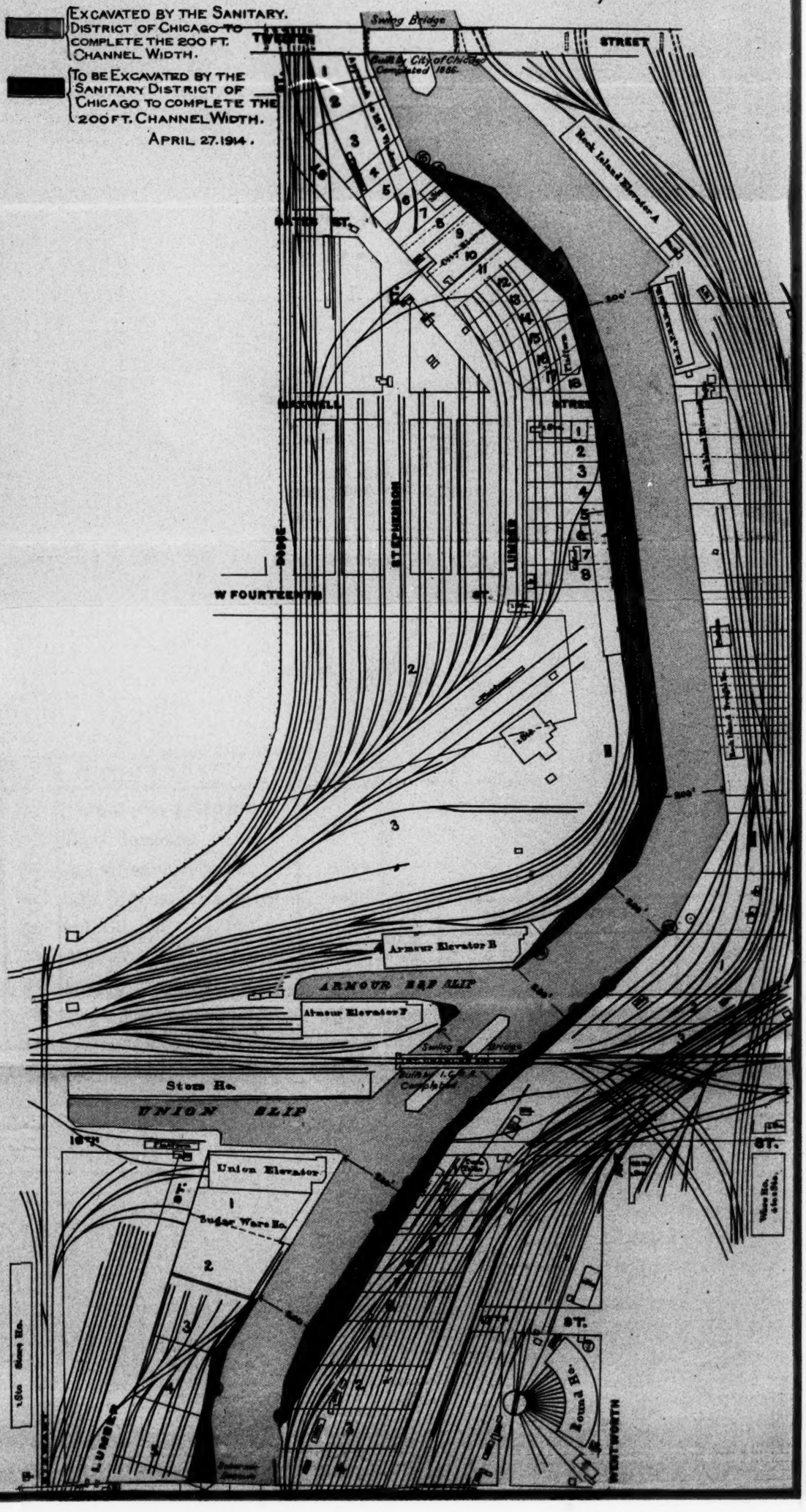
May 20 1914

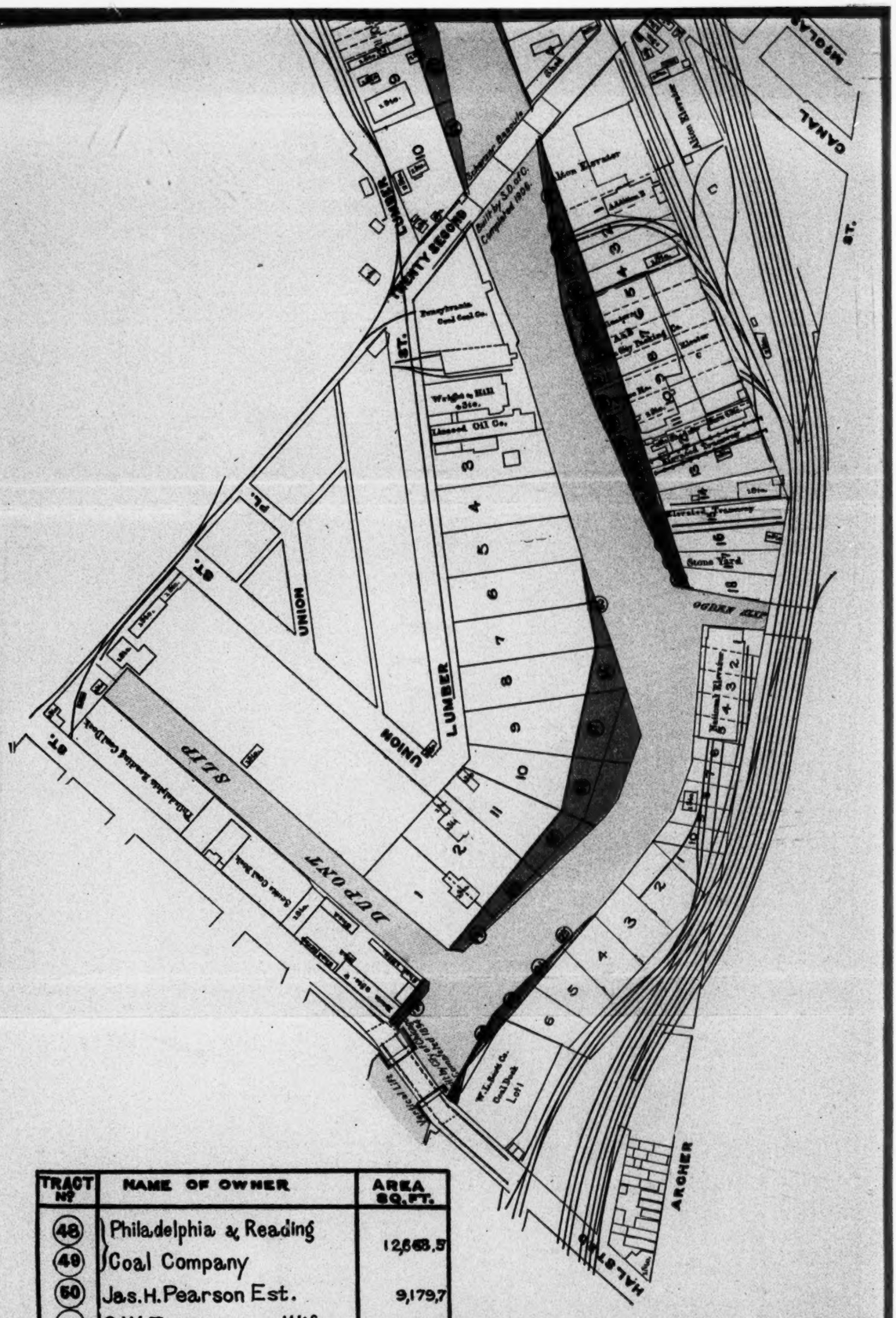
ORIGINAL WIDTH OF CHANNEL

EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

TO BE EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

APRIL 27. 1914.





TRACT Nº	NAME OF OWNER	AREA SQ. FT.
48	Philadelphia & Reading Coal Company	12,563.5
49		
50	Jas. H. Pearson Est.	9,179,7
51	C.W. Tegtmeyer & Wife	5406,0
52	H.D. Gibson	2,148,5
53	Mary C. Lilly & Husband	2,905,0
54	E. A. Lord et. al.	5,176,0
55		
56	Clarence E. Carr et. al.	6,839.0
57	W. Sherriffs	7,397.0
58	Illinois Stone Co.	4,480.0
65	B.F. Mc Connell	3,508.72
66	Mrs A. Babcock & Husband	25,570,02
67		
68		
69	Henry A. Du Pont	18,188,23
70		
71		
71A		
122	W.L. Scott & Co.	10,228,13
123		
124		

TRACT Nº	NAME OF OWNER	AREA SQ. FT.
125	C. & A. R.R. Co.	729,20
127 to 133 Incl.	Wm. B. Ogden Est. Western Stone Co.	15,593,47
134 to 140 Incl.	Nebraska City Packing Co.	27,595,80
141 to 145 Incl.	Seaverns Elevator Co.	14,836,19
149	Cosmopolitan Elec. Co.	1,912,65
150	General Chemical Co	816.41
41	Delaware Lackawanna R.R. et al	17,041.00
42		
41A	Robt. W. Hall & Wife	534.93
43	Thos. H. Hoyne et al.	7,631.03
44		
45	Jose B. King et. al.	23,133,92
46		
47		
146	Louis Hutt & Wife	7,101.9
147	Wm. R. Mamine & Wife	5,554.8
147A		

779

Wisner's Exhibit 10.

SANITARY DISTRICT OF CHICAGO

MAP

Showing

CHICAGO RIVER IMPROVEMENT

From

18TH STREET TO HALSTED STREET

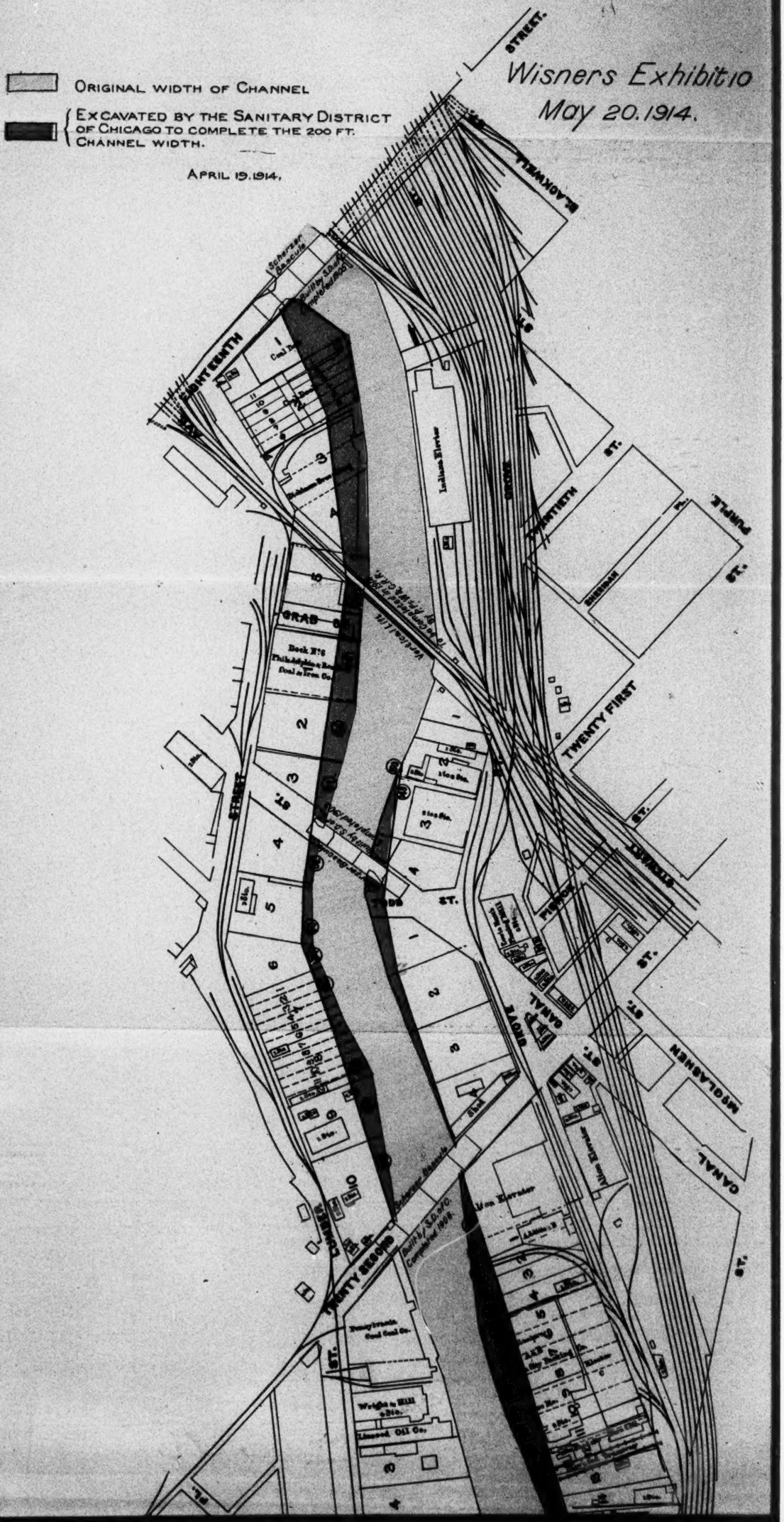
Scale 200Ft = 1Inch

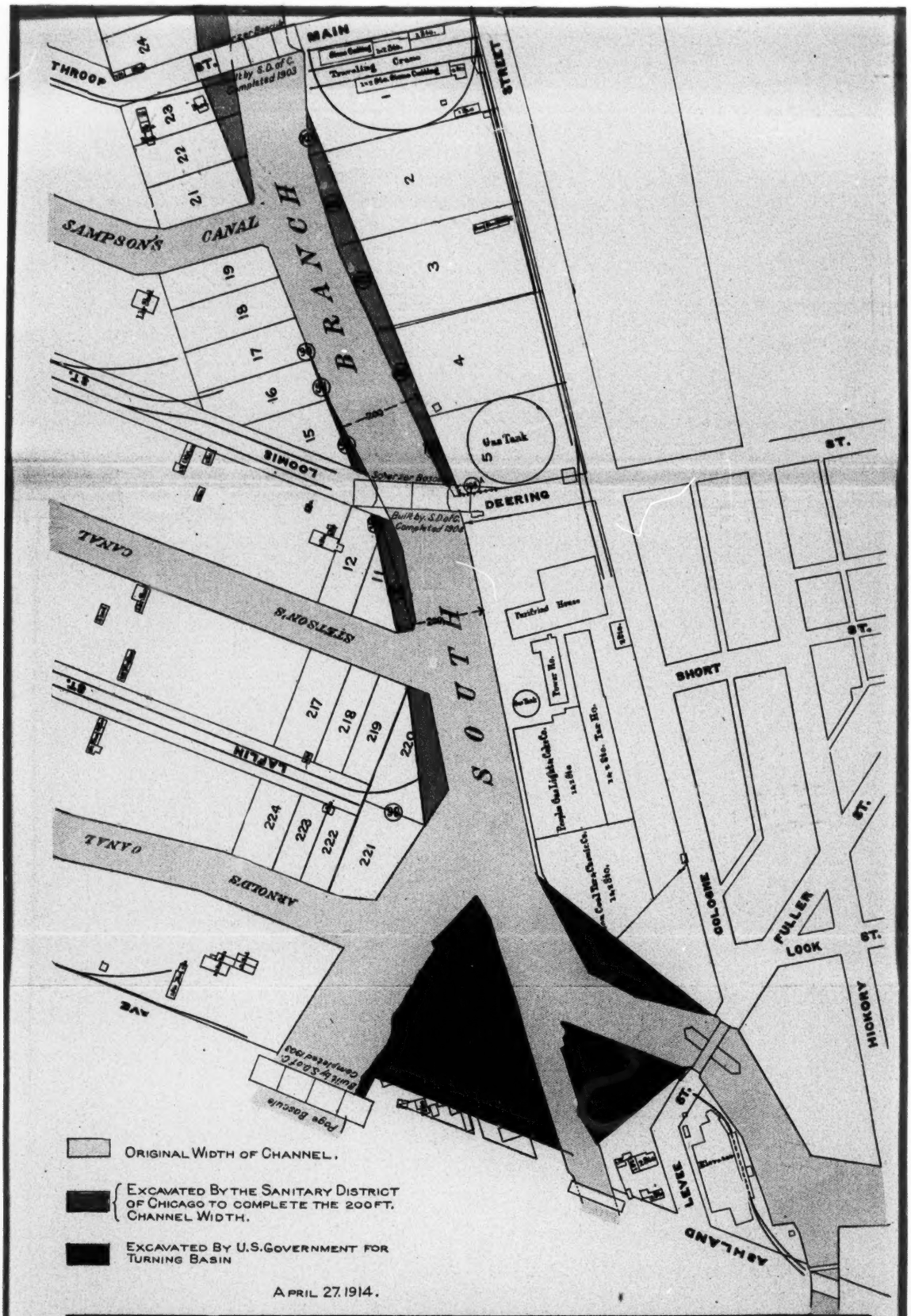
Wisners Exhibit 10
May 20. 1914.

ORIGINAL WIDTH OF CHANNEL

EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

APRIL 19. 1914.





ORIGINAL WIDTH OF CHANNEL.

EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

EXCAVATED BY U.S. GOVERNMENT FOR TURNING BASIN

APRIL 27. 1914.

TRACT Nº	NAME OF OWNER	AREA SQ. FT.
72		1,393,47
73	Omaha Packing Company	5,348,87
74	C. B & Q. R.R.	3,207,33
75		
76 to 82 inc	Commonwealth Electric Co.	20,927.85
90	L.W. Fargo	529,44
91		
92	Wm G. Roelker	1,404,80
93		
94		
96	Maxwell Bro's.	2 Lots 63,953,50
83 to 86 incl	The Peoples Gas Light & Coke Co.	4,529,00
87 to 89 incl	Henrietta A Boel & Husband	8 674.20

TRACT Nº	NAME OF OWNER	AREA SQ. FT.
105	Peoples Gas Light & Coke Co.	4,372,30
106	J.J. Mitchell et al	8,531,66
107	Francis B. Peabody Delia S. Gallup	11,255,55
108	Eliz Boyer	10,015,27
109	E. Heldmaier & Wife	
111	Estate of Benj. S. Rotch	9,580,66
112 & 112½	Commonwealth Electric Co.	5,065,70
113	Drexel Estate	1,173,42
114	North Western University	6,741.62
115	The Peoples Gas Light & Coke Co	10,422.77
116	Peoples Gas Light & Coke Co	312,97
118 to 121 inc	Estate of Edson Keith	11,598,96
110	Peoples Gas Light & Coke Co	5,110,00
105A	Peoples Gas Light & Coke Co	1,431,00

781

Wisner's Exhibit 11.

SANITARY DISTRICT OF CHICAGO

MAP

Showing

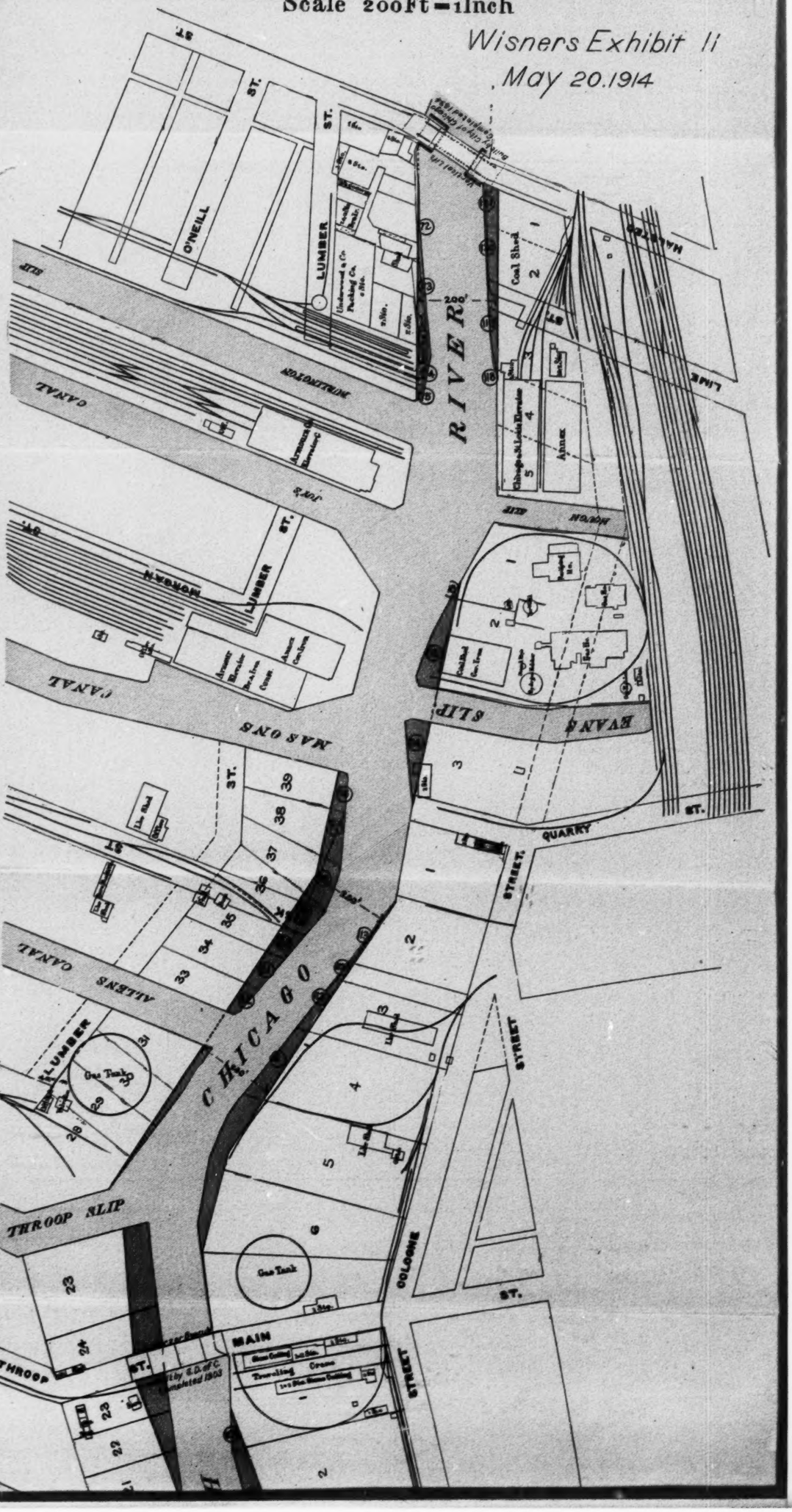
CHICAGO RIVER IMPROVEMENT

From

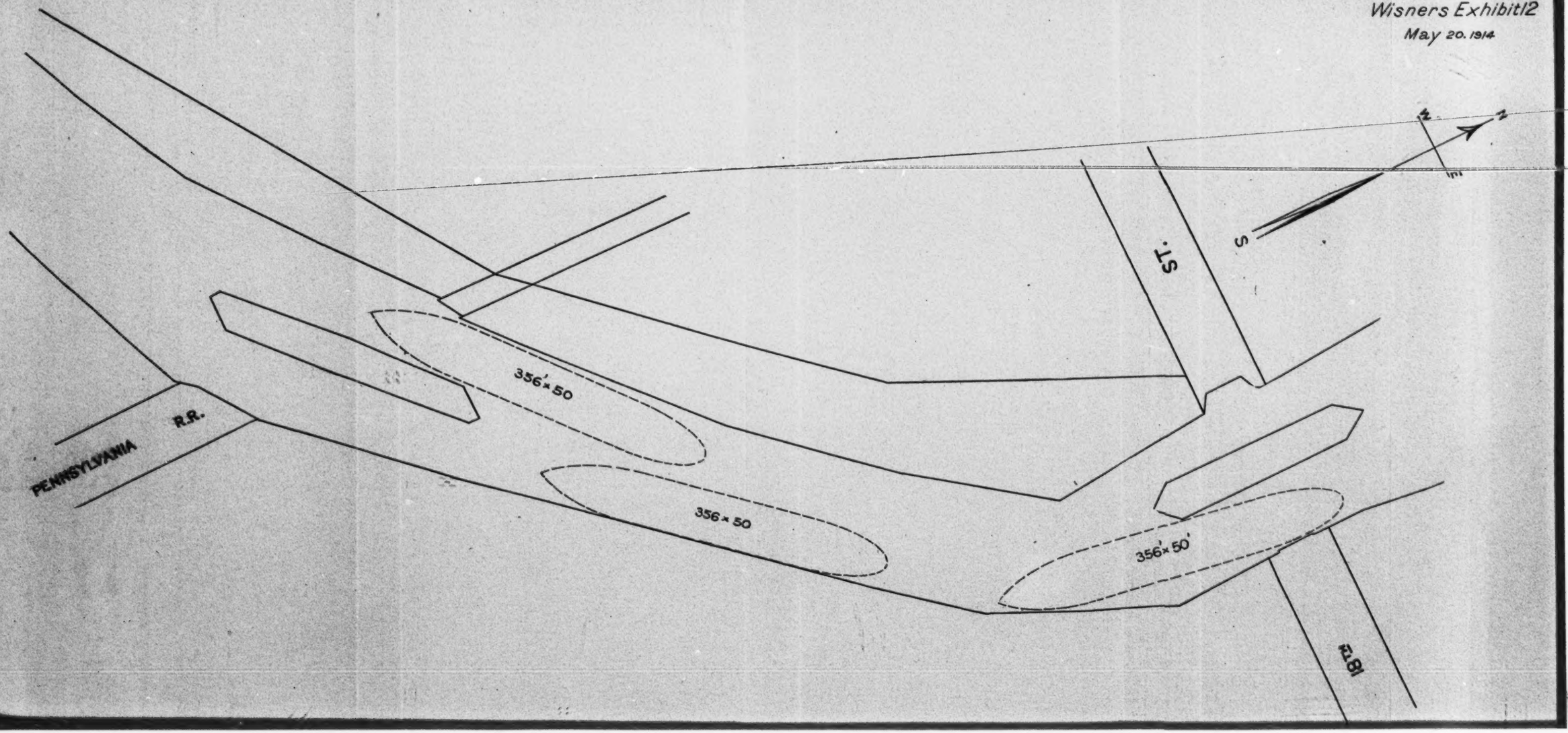
HALSTED STREET TO ASHLAND AVE

Scale 200Ft = 1Inch

Wisners Exhibit 11
May 20.1914



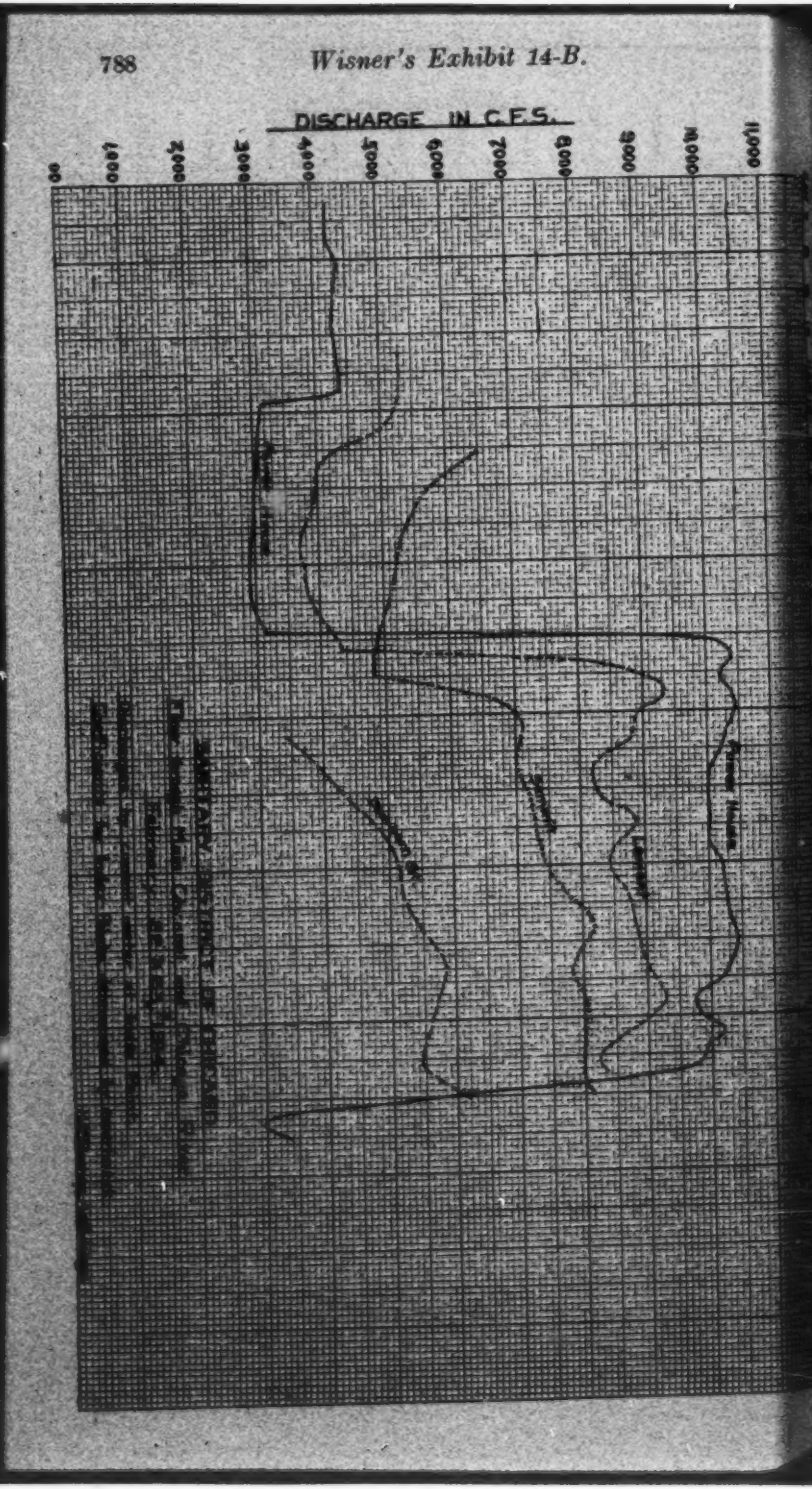
Wisners Exhibit12
May 20. 1914



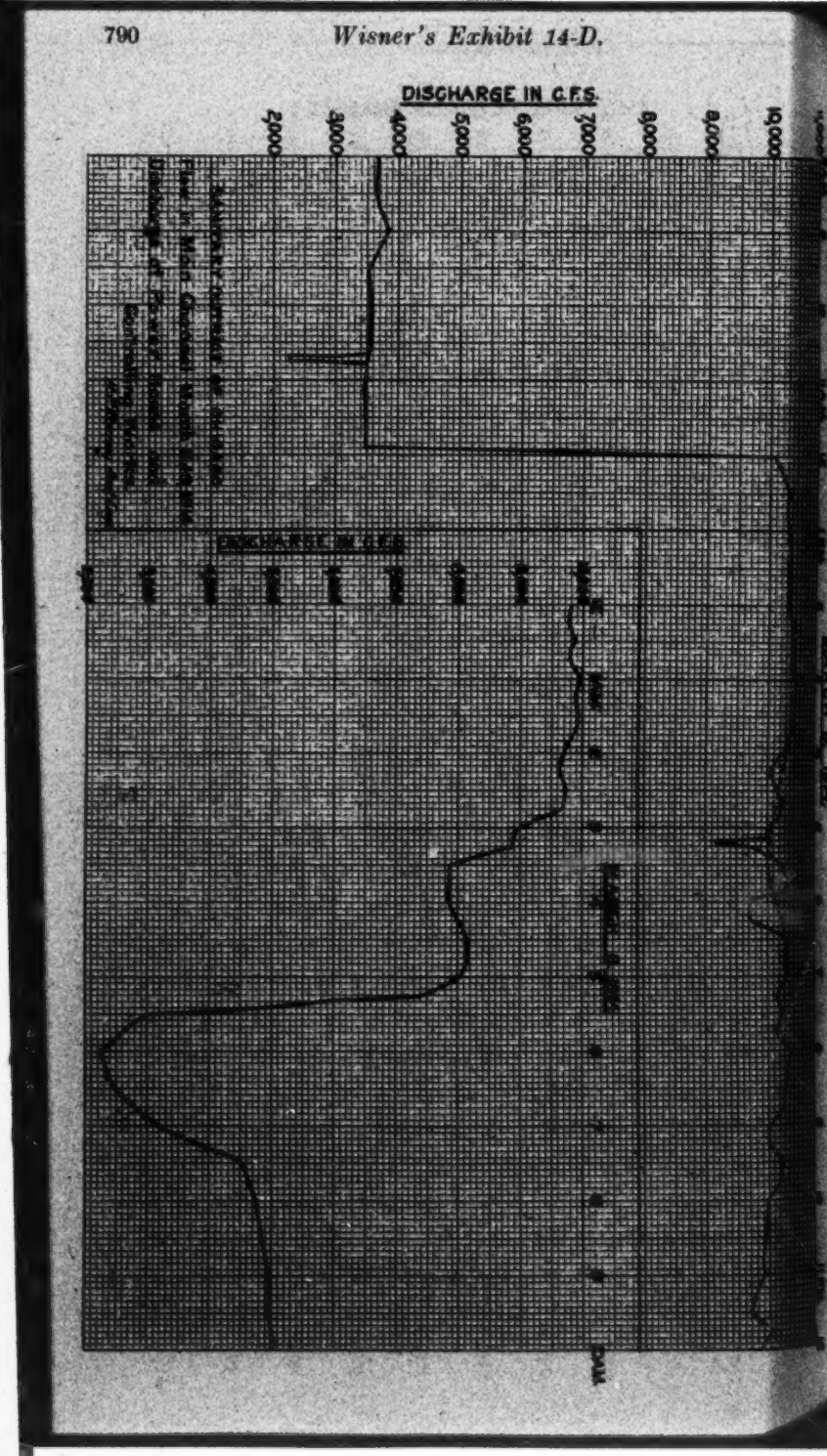
Wisners Exhibit 13
May 20. 1914

DISCHARGE IN C.F.S.
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
JPM
4
5
6
7
8
9
10
11PM
12
1AM
2
3
4
5
6
7AM
FEBRUARY 23, 1914
FEBRUARY 24, 1914

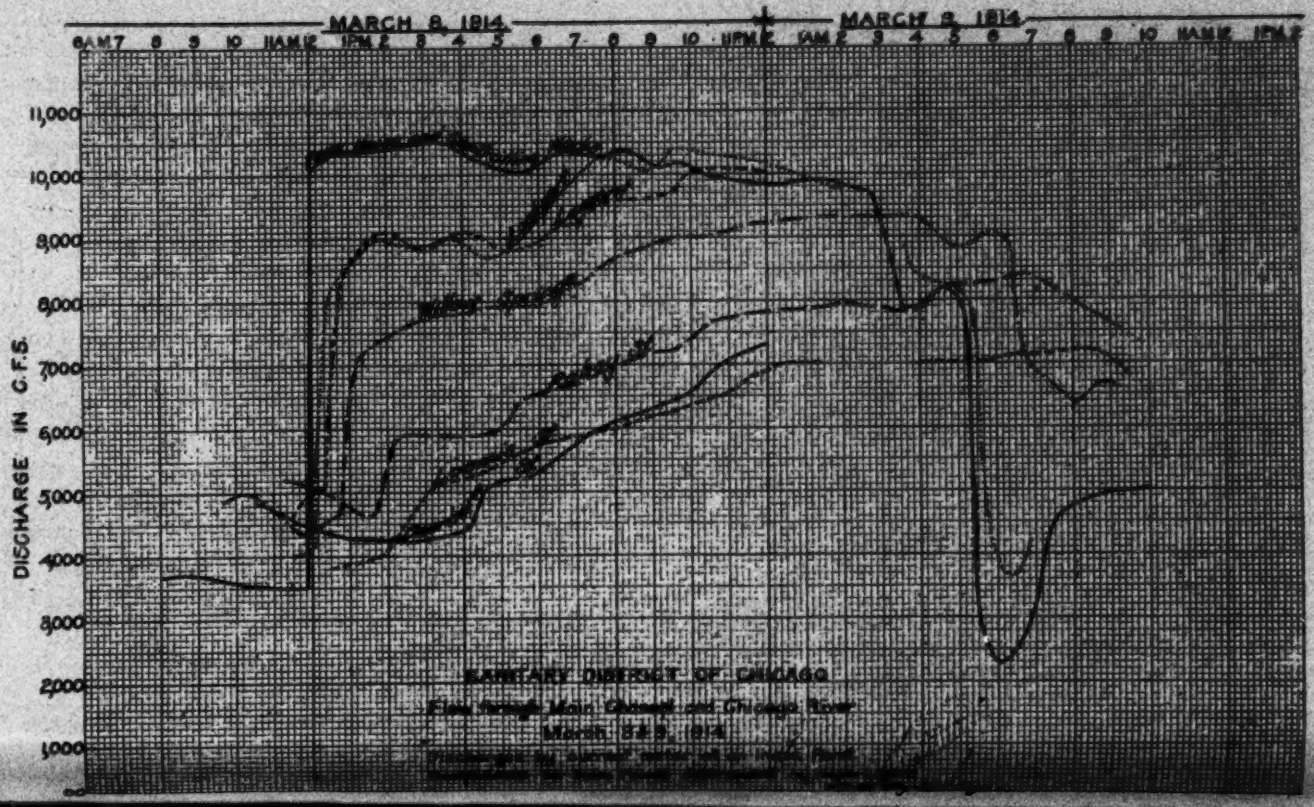
Wisner's Exhibit 14-B.

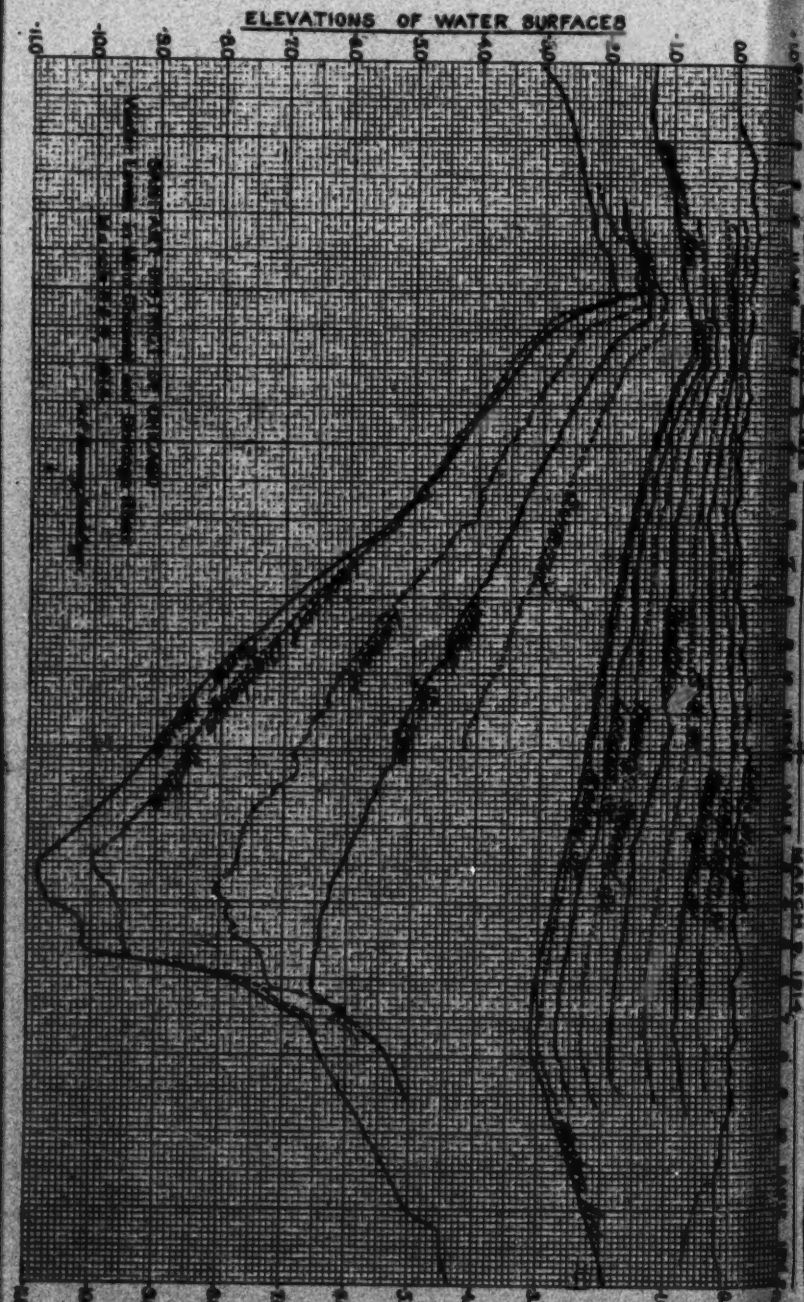


ELEVATIONS OF WATER SURFACES.
FEBRUARY 22, 1914
FEBRUARY 23, 1914


DISCHARGE IN C.F.S.
2000
3000
4000
5000
6000
7000
8000
9000
10,000
DISCHARGE IN C.F.S.

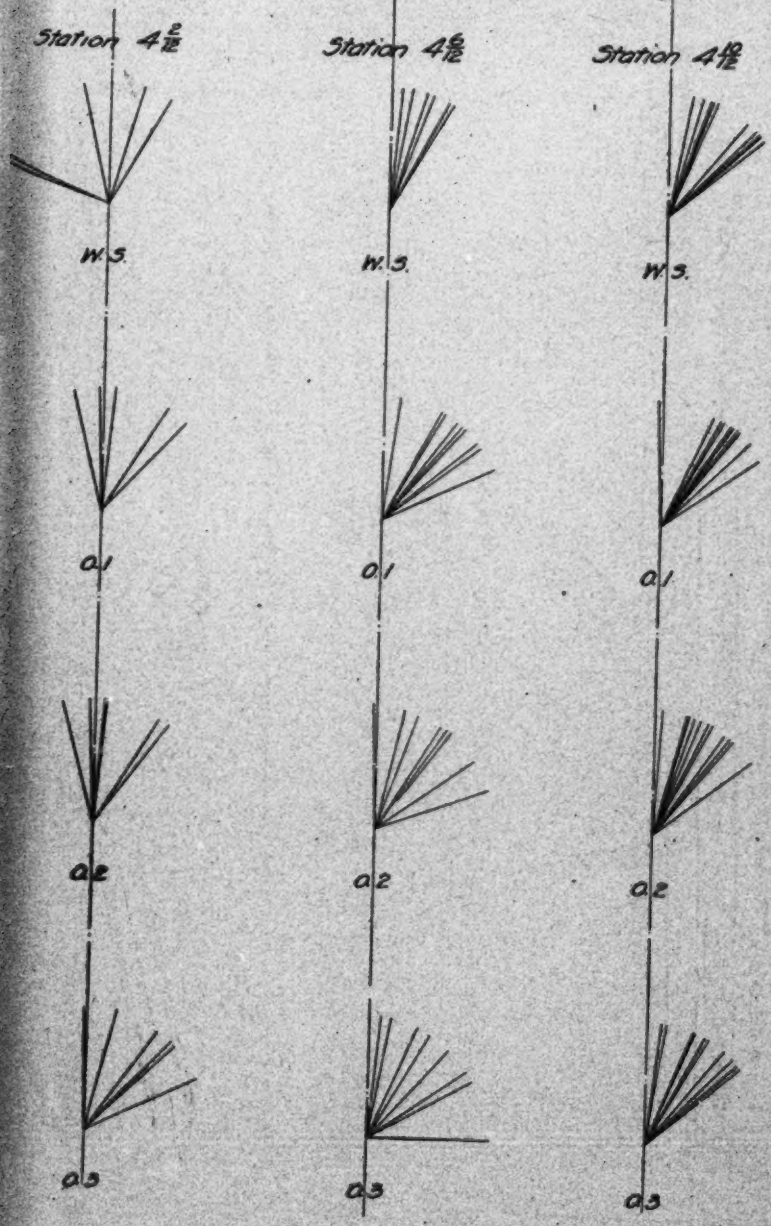
Wisner's Exhibit 14-E.




ELEVATIONS OF WATER SURFACES

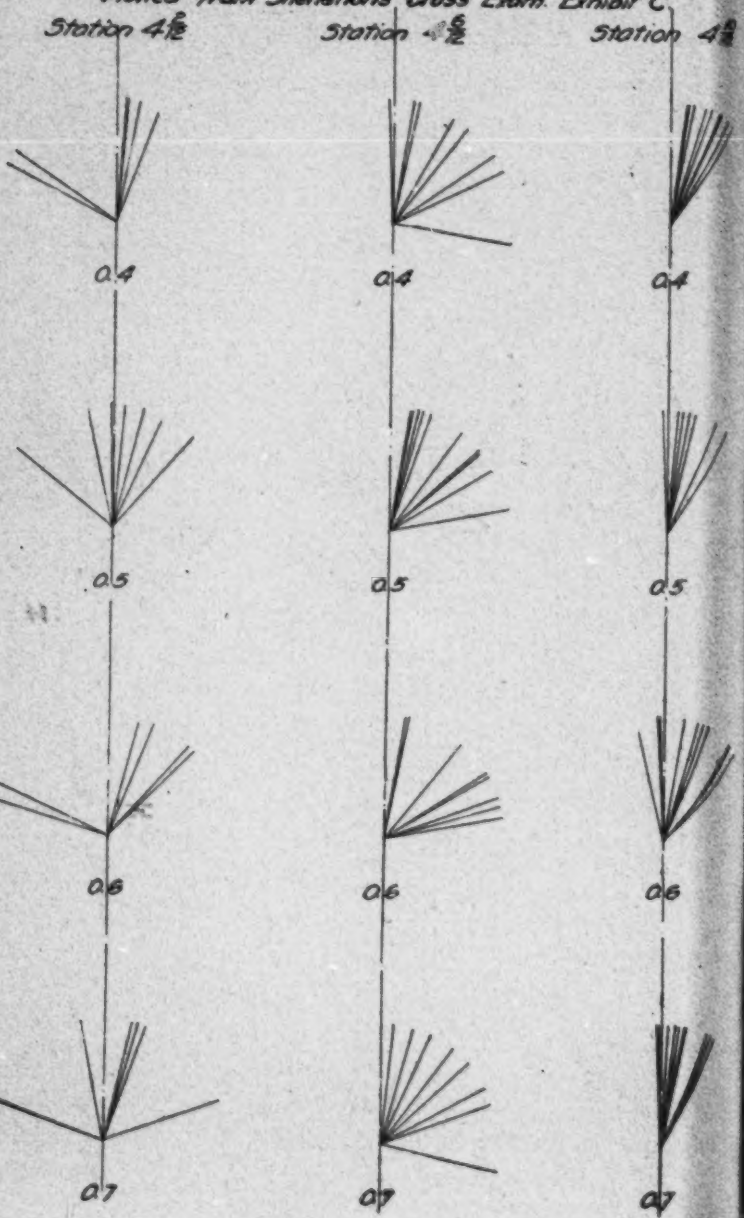
Williams Ex. 36 A

Direction Measurements of Vertical Curves
International Bridge
Plotted from Shenehon's Cross Exam. Exhibit C



Williams Ex. B

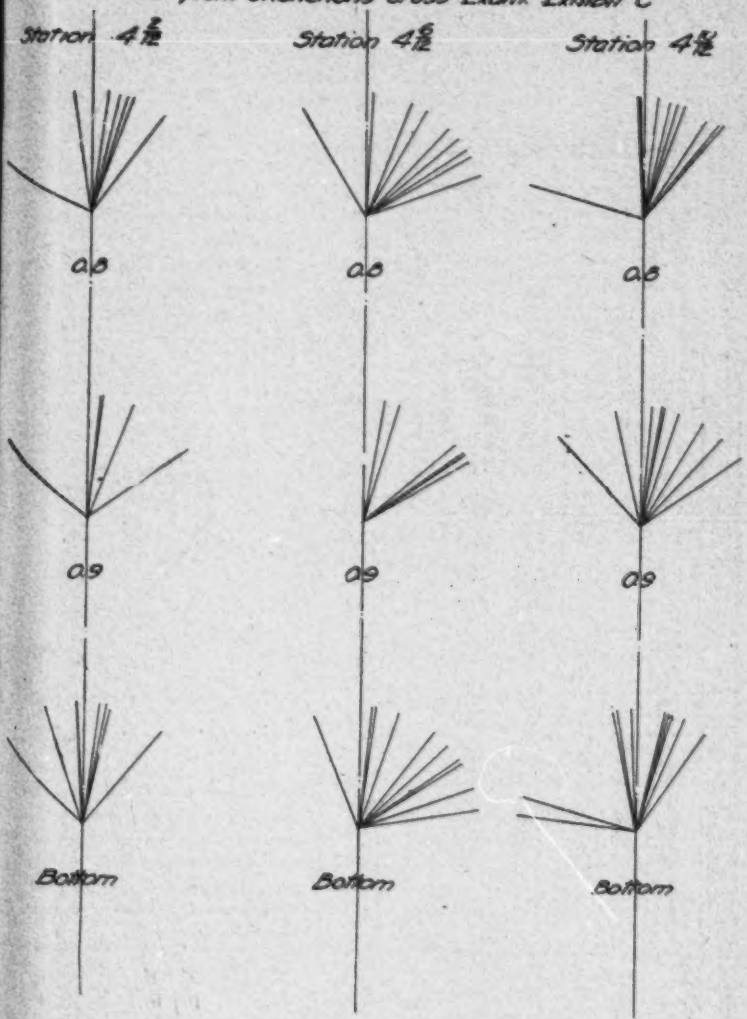
Direction Measurements of Vertical Curves
International Bridge
Plotted from Shanahan's Cross Exam. Exhibit C



Williams Ex. 36 C

Direction Measurements of Vertical Curves of International Bridge

Plotted from Shenehon's Cross Exam. Exhibit C



Williams Ex 37

LAKE LEVELS – NIAGARA RIVER

VERTICAL CURVES

SPAN 6 STATION 4/12 P.C. Sheeler

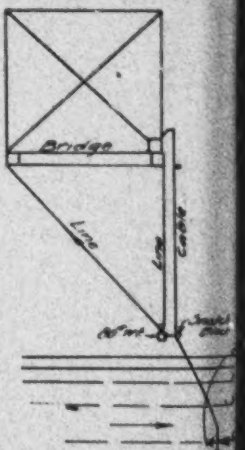
INTERNATIONAL BRIDGE SECTION Asst. Eng.

Date of Observation 1910	Number of Observation	Number of Verticals in Section	Velocity Surface Feet per Second: By 10.48 at No. Depths 3.465	By 6.328 at Three Depths 3.465	Percent Velocity at Surface to Velocity at 0.2 Depth (Large Section) m g	Weight of Obs (Proportional to Time Run)	Weighted Mean Percentages h
a	b	c	d	e	f	g	h
Feb 2	1	10	4.46	3.70	83.6	5	
" 6	1	10	3.71	3.20	91.0	5	
" 6	1	5	4.04	3.33	90.3	1	
" 6	1	5	3.88	3.31	93.7	1	
" 6	1	6	4.82	3.42	91.3	1	90.8
Feb 2	2	10	4.30	3.87	90.3	5	
" 6	2	10	3.87	3.26	90.1	5	
" 6	2	5	3.88	3.38	91.0	1	
" 6	2	5	4.24	3.50	90.0	1	
" 6	2	6	4.17	3.38	88.7	1	83.1
Feb 2	3	10	4.38	3.86	91.7	5	
" 6	3	10	3.82	3.33	90.1	5	
" 6	3	5	3.79	3.40	92.1	1	
" 6	3	5	4.13	3.51	88.9	1	
" 6	3	6	4.06	3.43	92.7	1	90.6
Feb 2	4	10	4.43	3.80	88.8	5	
" 6	4	10	3.86	3.36	91.1	5	
" 6	4	5	3.87	3.38	93.1	1	
" 6	4	5	4.16	3.47	88.6	1	
" 6	4	6	3.97	3.39	96.3	1	90.8
Feb 6	5	10	3.71	3.17	90.8	5	
" 6	5	5	3.63	3.20	94.0	1	
" 6	5	5	4.03	3.38	92.7	1	
" 6	5	6	4.06	3.48	92.2	1	91.4
Feb 6	6	10	3.96	3.40	94.7	6	
" 6	6	5	3.80	3.26	91.2	1	
" 6	6	5	3.83	3.31	97.7	1	
" 6	6	6	4.06	3.43	93.3	1	83.6
Feb 6	7	10	3.82	3.44	90.1	5	
" 6	7	5	3.83	3.30	91.6	1	
" 6	7	5	4.01	3.43	77.0	1	
" 6	7	6	3.83	3.31	96.0	1	89.6
Feb 6	8	10	3.91	3.36	70.4	5	
" 6	8	5	3.78	3.29	68.7	1	
" 6	8	5	4.00	3.38	68.7	1	
" 6	8	6	3.98	3.35	64.5	1	68.5
Feb 6	9	10	3.80	3.26	71.7	5	
" 6	9	5	3.96	3.43	67.6	1	
" 6	9	5	3.70	3.23	76.7	1	
" 6	9	6	3.92	3.36	78.5	1	
" 6	9	6	3.98	3.40	70.1	1	
" 6	9	6	4.03	3.39	77.0	1	71.2

Water Surface 567.2 0.00

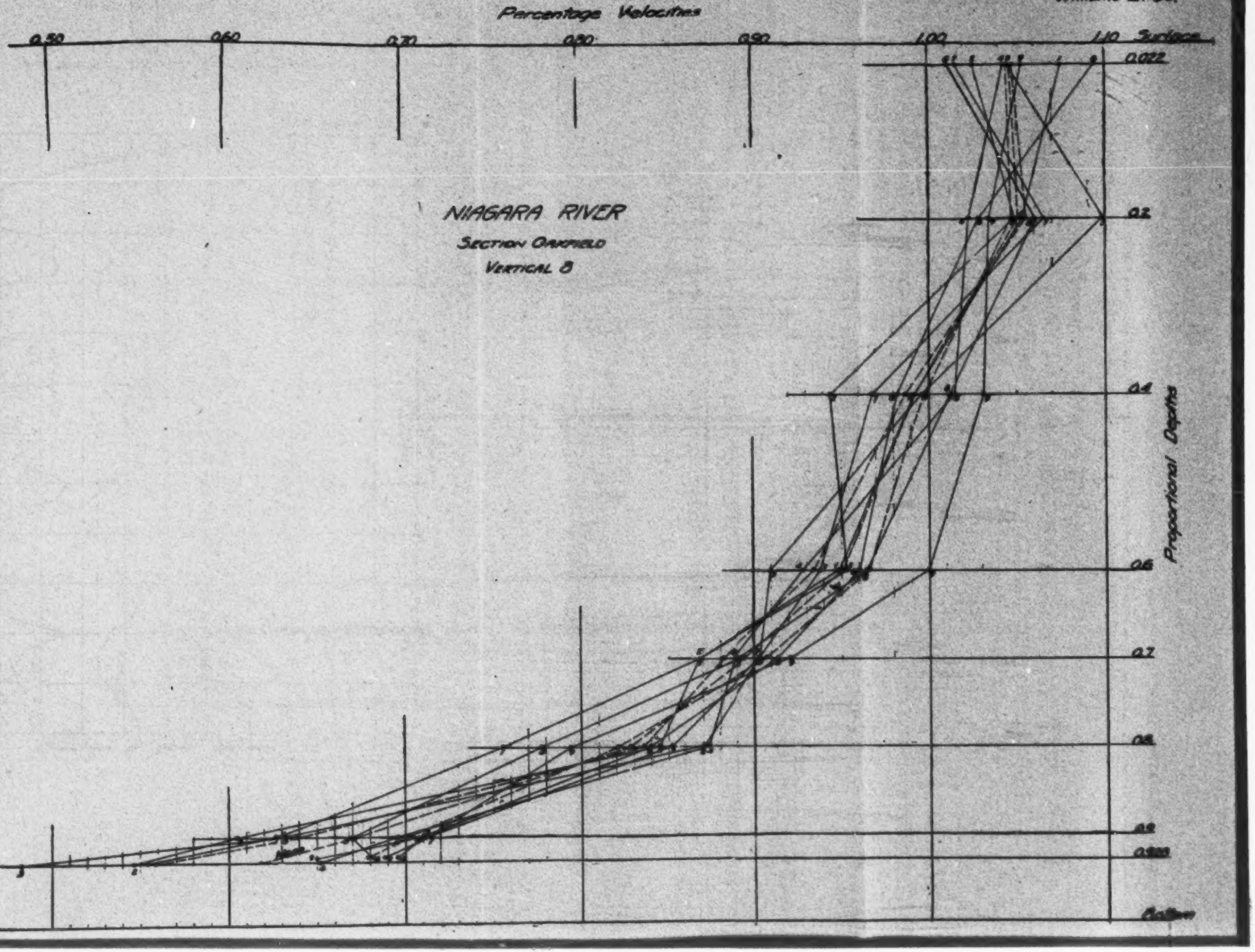
Weighted mean velocity in discharge 3.46 6.00

To obtain velocity in units corresponding to Percentages multiply h by 6.00

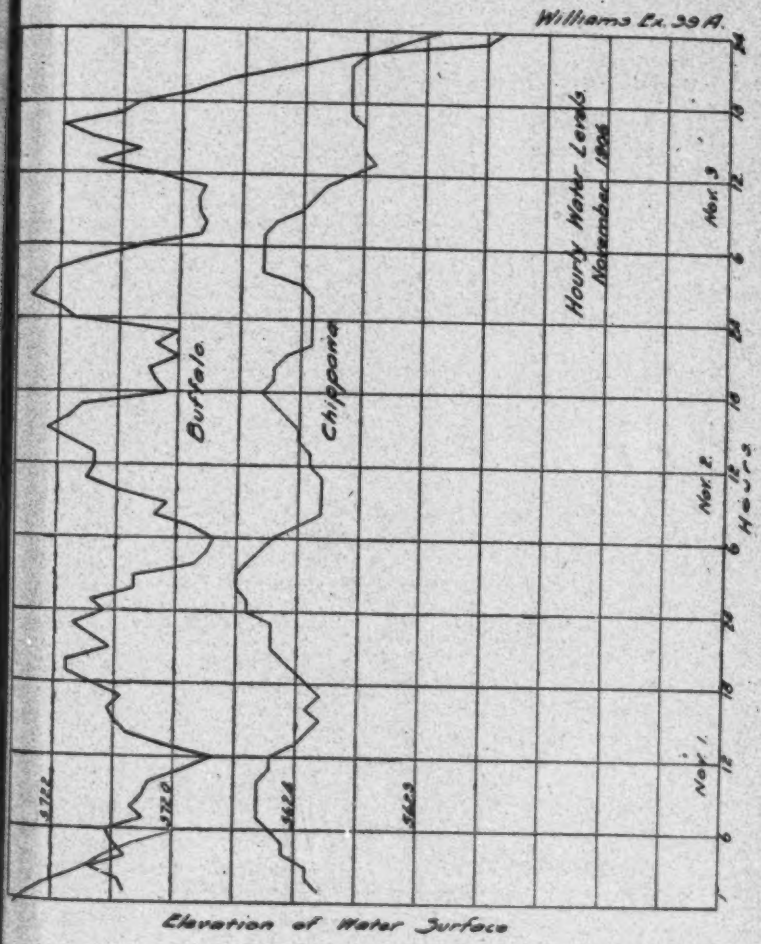


Meter was allowed to go downstream without guys at 1/4, 6 and 9/10 depths. At each depths was made to descend in a vertical line (in both planes) through its position at 8/10 Cable & sinker was used, no sinker with Cable assumed straight line below Snatch block.

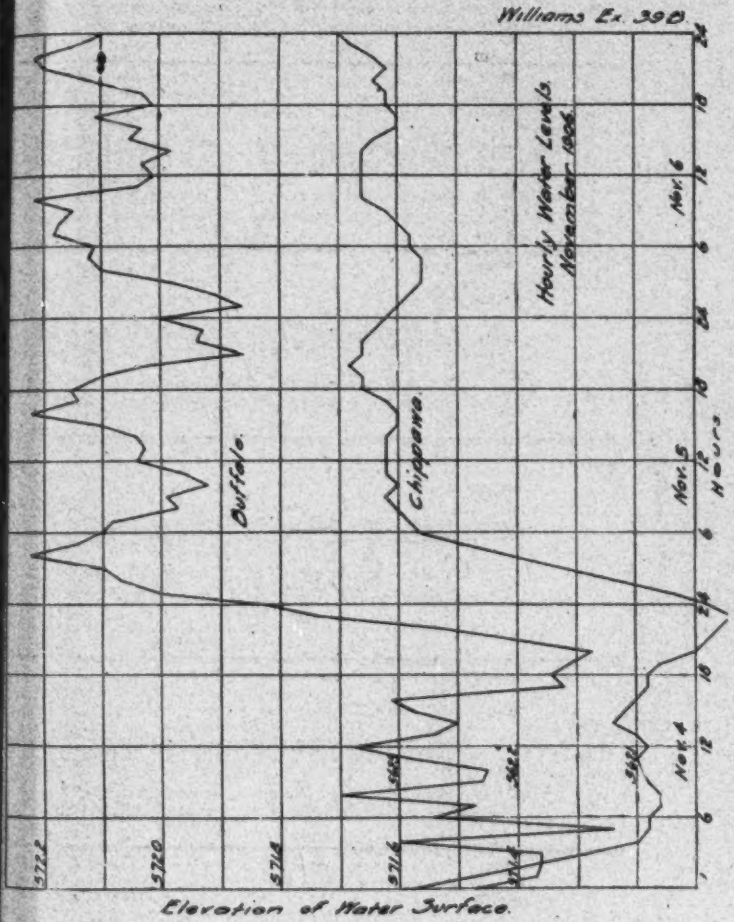
Williams Ex. 38.



(Being Shenehon's Exhibit A on Cross Examination)



(Being Shenehon's Exhibit B on Cross Examination)



WILLIAMS EXHIBIT 39-C.

(Being Shenehon's Exhibit C on Cross Examination.)

Harvey H. Atwell
Feb. 21, 1899

DIRECTION MEASUREMENTS OF VERTICAL CURVES AT INTERNATIONAL BRIDGE, BUFFALO, N. Y., 1897.

Span 3

Station 3⅛				Station 3⅝			
Depth	Register	Book	Page	Depth	Register	Book	Page
Bottom	215°	4	1	Bottom	184°	4	11
0.9	193°	"	"	0.9	184°	"	"
0.6	190°	"	"	0.8	184°	"	"
0.5	213°	"	"	0.7	185°	"	"
0.4	188°	"	"	0.6	187°	"	"
0.3	184°	"	"	0.5	185°	"	"
				0.4	184°	"	"
0.9	176°	4	10	0.3	186°	"	"
0.8	181°	"	10	0.2	184°	"	"
				0.1	185°	"	"
Bottom	184	4	10	Surface	180°	"	"
0.9	183	"	"				
0.8	185	"	"	Bottom	184°	4	12
0.7	182	"	"	0.9	185°	"	"
0.6	187	"	"	0.8	178°	"	"
0.5	184	"	"	0.7	178°	"	"
0.4	184	"	"	0.6			
0.3	185	"	"	0.5	185°	"	"
0.2	184	"	"	0.4	184°	"	"
0.1	184	"	"	0.3	184°	"	"
Surface	182	"	"	0.2	184°	"	"
				0.1	183°	"	"
Bottom	181°	4	11	Surface	183°	"	"
0.9	183°	"	"				

Span 4

Station 4$\frac{5}{16}$				Station 4$\frac{7}{16}$			
Depth	Register	Book	Page	Depth	Register	Book	Page
Bottom	176°	4	32	Bottom	199°	4	30
0.9	180°	"	"	0.9	197°	"	"
0.8	170°	"	"	0.8	230°	"	"
0.7	168°	"	"	0.7	282°	"	"
0.6	195°	"	"	0.6	260°	"	"
0.5	185°	"	"	0.5	191°	"	"
0.4	184°	"	"	0.4	178°	"	"
0.3	178°	"	"	0.3	270°	"	"
0.2	177°	"	"	0.2	250°	"	"
0.1	178°	"	"	0.1	222°	"	"
Surface	180°	"	"	Surface	200°	"	"
Bottom	132°	4	43	Bottom	260°	4	30
0.9	128°	"	"	0.9	240°	"	"
0.8	114°	"	"	0.8	183°	"	"
0.7	109°	"	"	0.7	205°	"	"
0.6	226°	"	"	0.6	255°	"	"
0.5	167°	"	"	0.5	260°	"	"
0.4	116°	"	"	0.4	245°	"	"
0.3	225°	"	"	0.3	240°	"	"
0.2	185°	"	"	0.2	178°	"	"
0.1	166°	"	"	0.1	220°	"	"
Surface	112°	"	"	Surface	210°	"	"

Station 4$\frac{9}{16}$				Station 4$\frac{11}{16}$			
Depth	Register	Book	Page	Depth	Register	Book	Page
Bottom	220°	5	47	Bottom	187°	5	44
0.9	202°	"	"	0.9	197°	"	"
0.8	200°	"	"	0.8	210°	"	"
0.7	193°	"	"	0.7	187°	"	"
0.6	223°	"	"	0.6	220°	"	"
0.5	222°	"	"	0.5	196°	"	"
0.4	202°	"	"	0.4	219°	"	"
0.3	223°	"	"	0.3	190°	"	"
0.2	212°	"	"	0.2	212°	"	"
0.1	212°	"	"	0.1	188°	"	"
Surface	196°	"	"	Surface	190°	"	"
Bottom	187°	5	48	Bottom	157°	5	45
0.9	235°	"	"	0.9	236°	"	"
0.8	217°	"	"	0.8	224°	"	"
0.7	200°	"	"	0.7	227°	"	"
0.6	195°	"	"	0.6	251°	"	"
0.5	205°	"	"	0.5	240°	"	"
				0.4	236°	"	"
				0.3	235°	"	"
				0.2	194°	"	"
				0.1	217°	"	"
				Surface	200°	"	"

Station 4$\frac{13}{16}$			
Depth	Register	Book	Page
Bottom	218	5	41
0.9	230	"	"
0.8	236	"	"

Sheet No. 1.—Continued.

| Span 3 | | | | | Span 4 | | | | |

WILLIAMS EXHIBIT 39-D.

(Being Shenehon's Exhibit D on Cross Examination.)

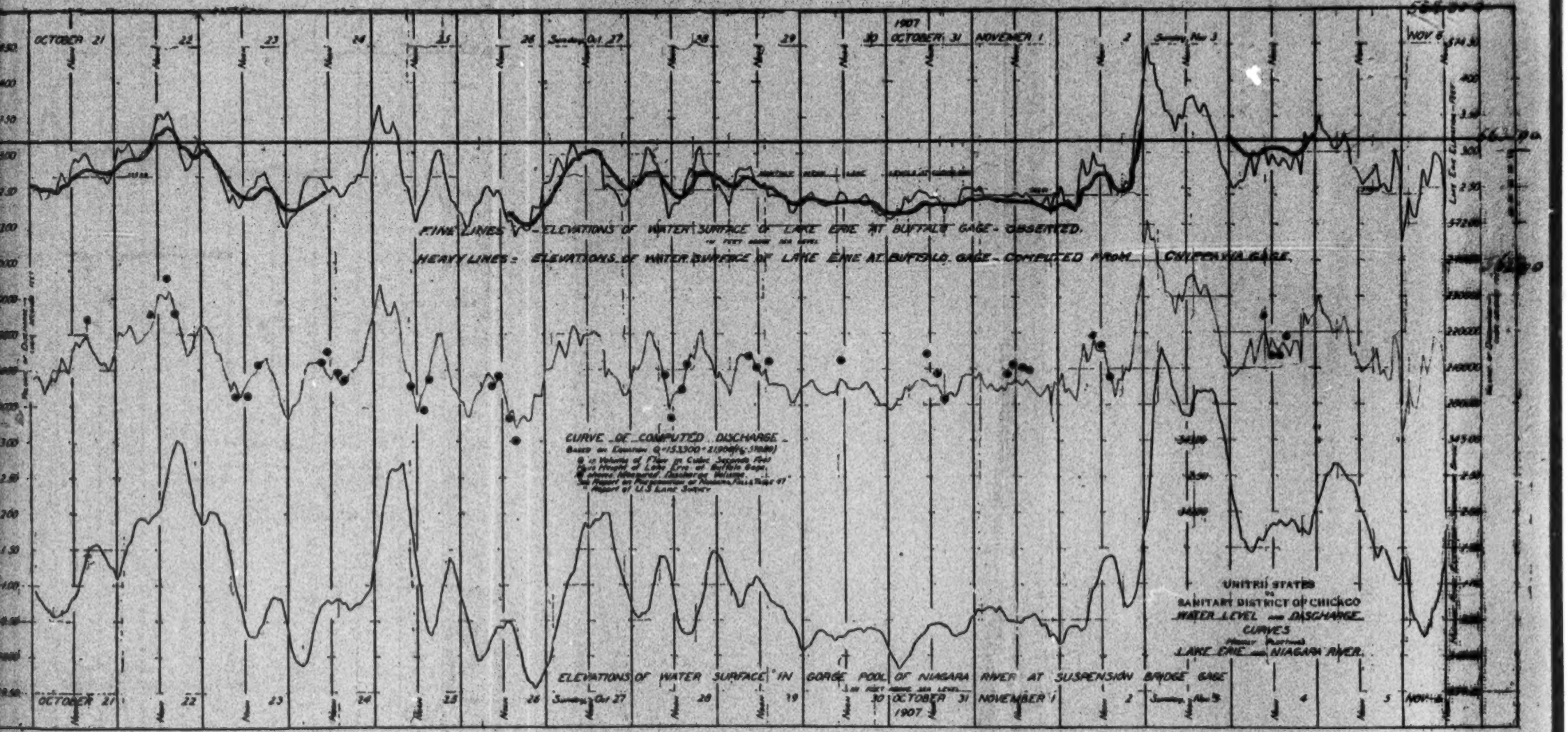
DIRECTION MEASUREMENTS OF VERTICAL CURVES AT INTERNATIONAL BRIDGE, BUFFALO, N. Y., 1897.

	Station 4 $\frac{19}{21}$				Station 4 $\frac{19}{21}$				Station 4 $\frac{19}{21}$					Station				Station				Station			
	Depth	Register	Book	Page	Depth	Register	Book	Page	Depth	Register	Book	Page		Depth	Register	Book	Page	Depth	Register	Book	Page	Depth	Register	Book	Page
Span 4	Bottom	177°	4	29	Bottom	97°	4	45	Bottom	168°	4	46	Span 5												
	0.9	166°	"	"	0.9	136°	"	"	0.9	198°	"	"													
	0.8	177°	"	"	0.8	187°	"	"	0.8	197°	"	"													
	0.7	177°	"	"	0.7	182°	"	"	0.7	190°	"	"													
	0.6	177°	"	"	0.6	221°	"	"	0.6	197°	"	"													
	0.5	185°	"	"	0.5	187°	"	"	0.5	193°	"	"													
	0.4	197°	"	"	0.4	191°	"	"	0.4	206°	"	"													
	0.3	219°	"	"	0.3	211°	"	"	0.3	203°	"	"													
	0.2	196°	"	"	0.2	208°	"	"	0.2	206°	"	"													
	0.1	210°	"	"	0.1	217°	"	"	0.1	215°	"	"													
	Surface	195°	"	"	Surface	231°	"	"	Surface	225°	"	"													
	Bottom	170°	4	29	Bottom	197°	4	45	Bottom	215°	5	39													
	0.9	235°	"	"	0.9	190°	"	"	0.9	223°	"	"													
	0.8	178°	"	"	0.8	212°	"	"	0.8	221°	"	"													
	0.7	178°	"	"	0.7	208°	"	"	0.7	206°	"	"													
	0.6	178°	"	"	0.6	166°	"	"	0.6	203°	"	"													
	0.5	178°	"	"	0.5	180°	"	"	0.5	190°	"	"													
	0.4	200°	"	"	0.4	205°	"	"	0.4	212°	"	"													
	0.3	225°	"	"	0.3	229°	"	"	0.3	189°	"	"													
	0.2	195°	"	"	0.2	199°	"	"	0.2	215°	"	"													
	0.1	205°	"	"	0.1	218°	"	"	0.1	214°	"	"													
	Surface	175°	"	"	Surface	227°	"	"	Surface	199°	"	"													

No. 3—Continued.

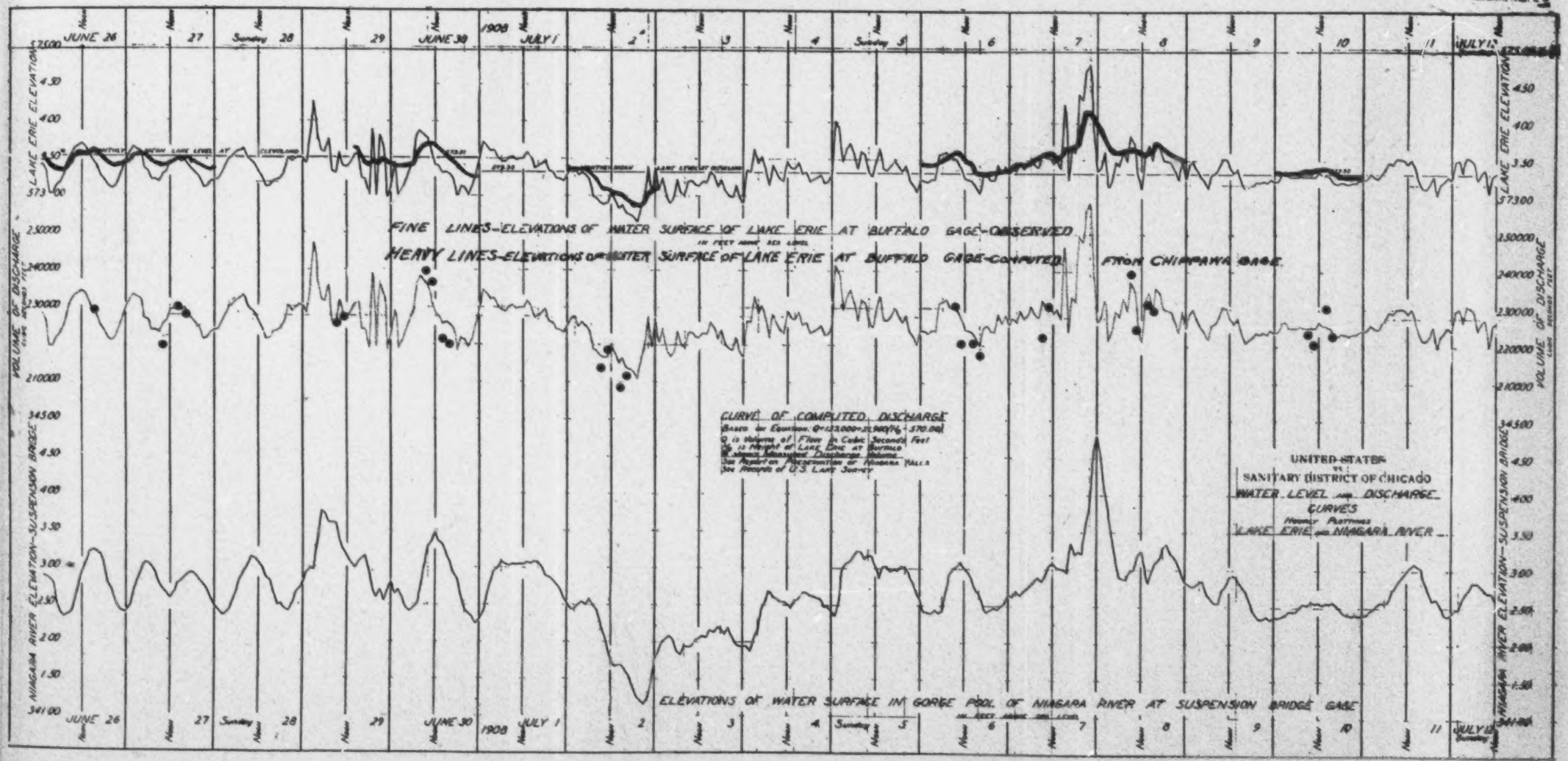
Span 4								Span 5							
Bottom	195°	4	30	Bottom		4	46	Bottom	193°	5	40				
0.9	185°	"	"	0.9	211°	"	"	0.9	191°	"	"				
0.8	200°	"	"	0.8	212°	"	"	0.8	219°	"	"				
0.7	186°	"	"	0.7	208°	"	"	0.7	191°	"	"				
0.6	190°	"	"	0.6	226°	"	"	0.6	226°	"	"				
0.5	190°	"	"	0.5	205°	"	"	0.5	213°	"	"				
0.4	205°	"	"	0.4	206°	"	"	0.4	189°	"	"				
0.3	187°	"	"	0.3	209°	"	"	0.3	231°	"	"				
0.2	184°	"	"	0.2	220°	"	"	0.2	233°	"	"				
0.1	178°	"	"	0.1	209°	"	"	0.1	235°	"	"				
Surface	190°	"	"	Surface	220°	"	"	Surface	200°						
Bottom	106°	4	44	Bottom	203°	4	46								
0.9	166°	"	"	0.9	166°	"	"								
0.8	106°	"	"	0.8	193°	"	"								
0.7	188°	"	"	0.7	203°	"	"								
0.6	220°	"	"	0.6	200°	"	"								
0.5	185°	"	"	0.5	187°	"	"								
0.4	188°	"	"	0.4	215°	"	"								
0.3	202°	"	"	0.3	229°	"	"								
0.2	202°	"	"	0.2	218°	"	"								
0.1	226°	"	"	0.1	215°	"	"								
Surface	202°	"	"	Surface	228°	"	"								

Williams Exhibit 89-E 1.
(Being Shonehon's Exhibit E 1 on Cross Examination.)

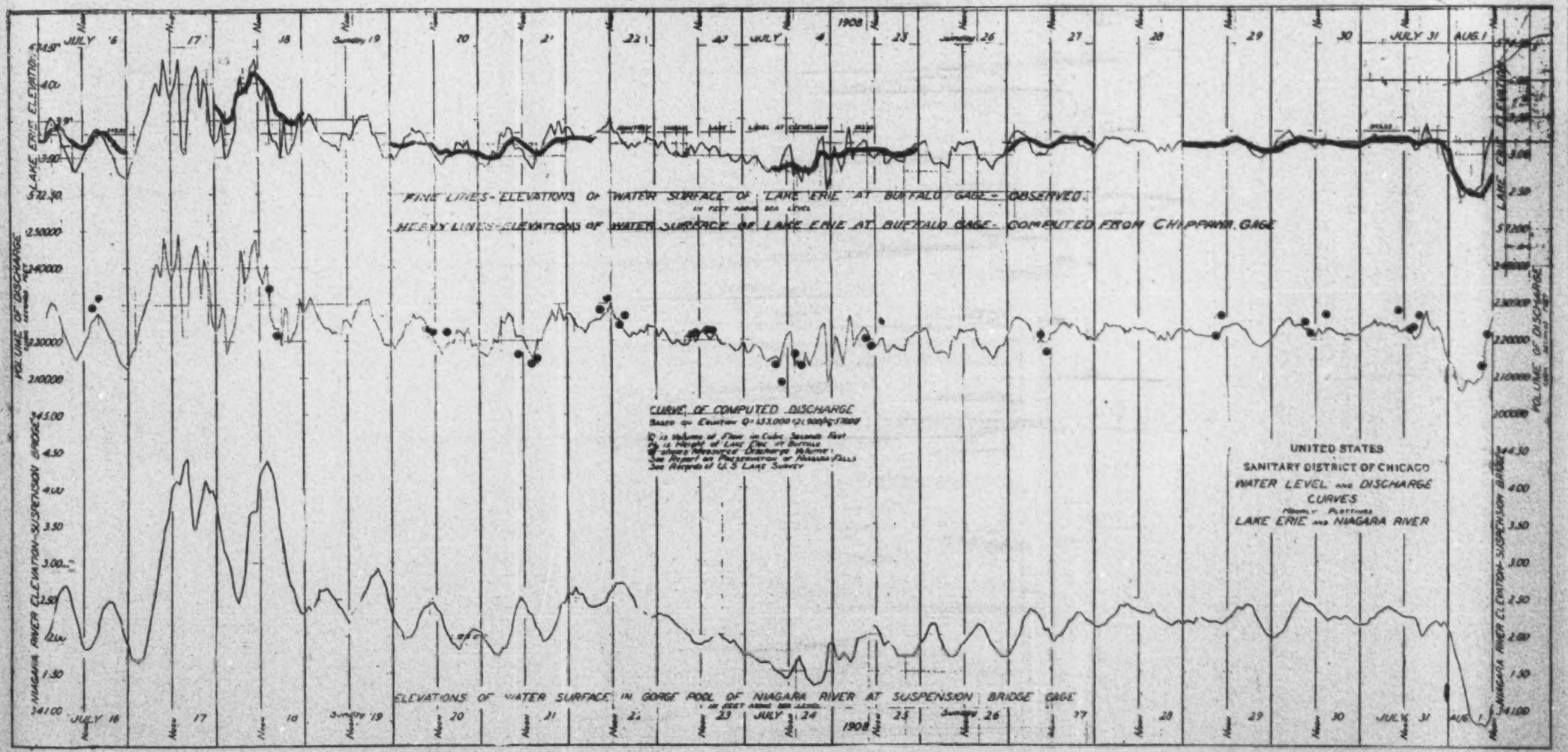


William's Exhibit 39-E 2.

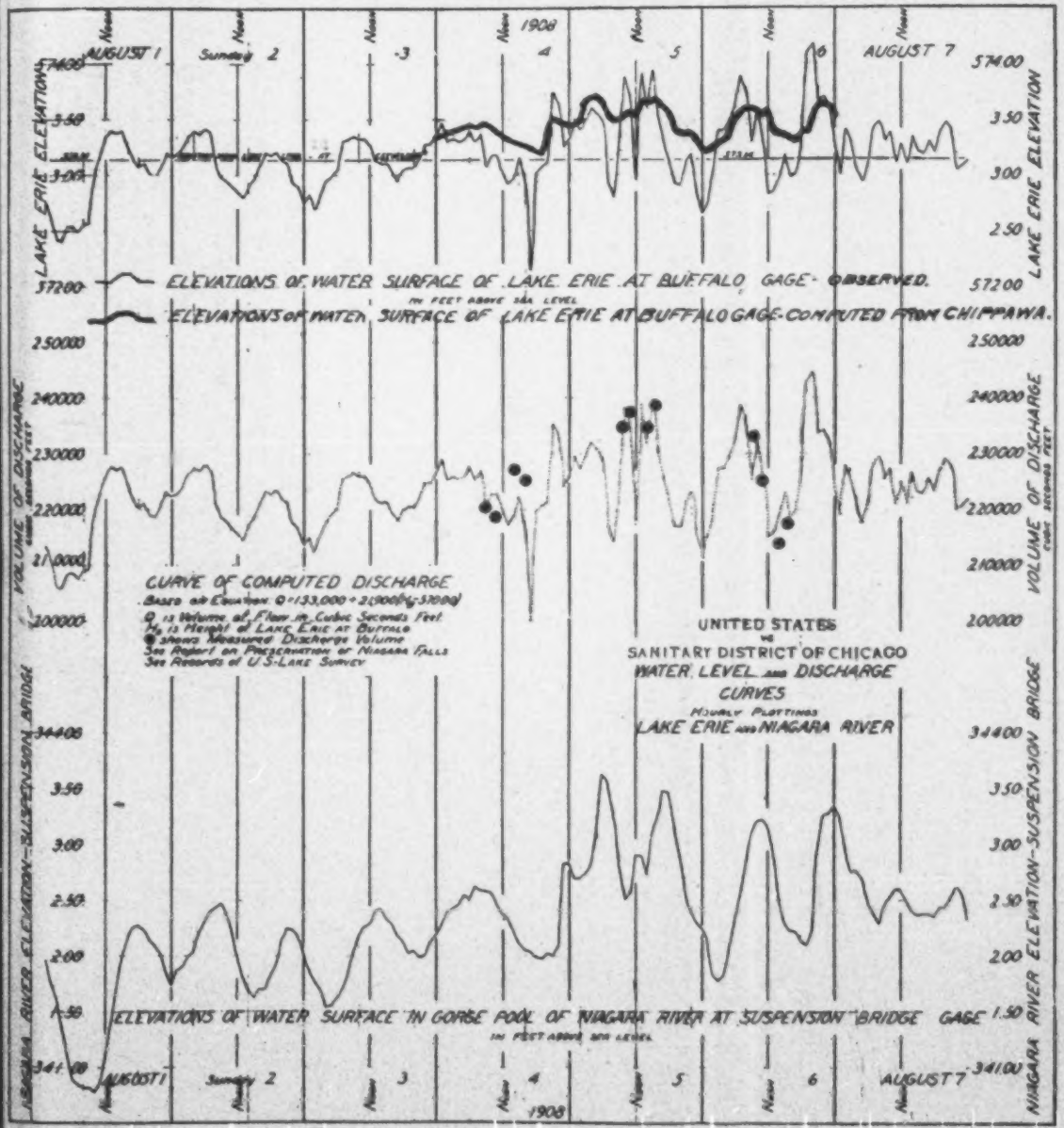
(Being Shenehon's Exhibit E-2 on Cross Examination)



Williams Exhibit 39-E 3.
(Being Shenehon's Exhibit E 3 on Cross Examination.)



(Being Shenehon's Exhibit E 4 on Cross Examination.)



WILLIAMS EX. 40.

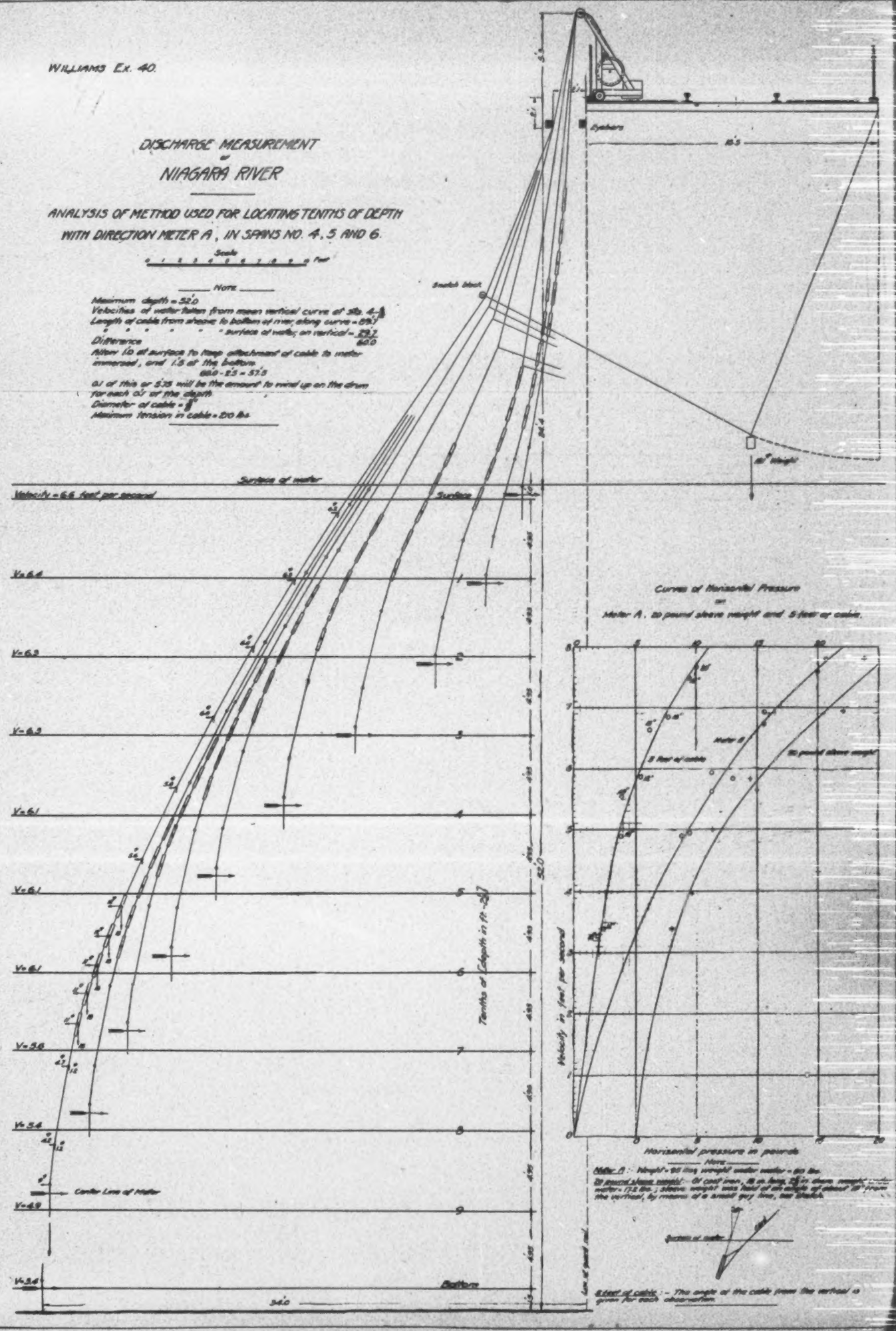
DISCHARGE MEASUREMENT
OF
NIAGARA RIVER

ANALYSIS OF METHOD USED FOR LOCATING TENTHS OF DEPTH WITH DIRECTION METER A, IN SPANS NO. 4, 5 AND 6.

Scale 0 1 2 3 4 5 6 7 8 9 10 Feet

Note

Maximum depth = 52.0
Velocities of water taken from mean vertical curve of Sts. 4-5
Length of cable from sheave to bottom of river along curve = 69.7
" " " " " surface of water, on vertical = 29.7
Difference 40.0
Allow 1.0 at surface to keep attachment of cable to meter immersed, and 1.5 at the bottom.
68.0 - 2.5 = 57.5
1/ of this or 5.75 will be the amount to wind up on the drum for each 1/ of the depth
Diameter of cable = 3/8"
Maximum tension in cable = 200 lbs.



PRESERVATION OF NIAGARA FALLS.

TABLE 47.—*Elevation of Lake Erie derived from discharge of Niagara River, International Bridge, Buffalo, N. Y.*

Number	Date	Wind		Change of Lake level during measurement		Fall Lake Erie to bridge (feet).	Meter U. S. Lake Survey	Discharge (cubic feet per second)	Lake Erie elevation (feet).		Difference (feet).	
		Direction	Estimated velocity (miles)	Rise (feet)	Fall (feet)				Computed	Observed	Lake, high	Lake, low
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*	*m*	*n*
	1907											
1	Oct. 21	.....	.....	0.02	0.13	4.95	2B	224,070	573.26	572.98	.....	0.28
2	Oct 22	SW.	25	.14	.00	4.94	2B	225,850	573.34	573.12	.....	.22
3	do	SW.	30	.09	.07	5.03	4A	235,600	573.75	573.54	.....	.21
4	do	SW.	10	.03	.41	4.93	1B	225,700	573.33	573.37	0.04	.....
5	Oct. 23	NW.	25–30	.13	.26	4.71	1B	202,510	572.26	572.42	.16	.....
6	do	NW.	30	.29	.01	4.75	1B	202,870	572.27	572.39	.12	.....
7	do	NW.	30–20	.21	.02	4.86	2B	211,320	572.67	572.61	.....	.03
8	Oct. 24	NW.	6	.03	.04	4.93	1B	212,030	572.70	572.66	.....	.04
9	do	NW	6	.00	.16	4.85	2B	215,140	572.84	572.57	.....	.27
10	do	SW.	8	.01	.11	4.84	2B	209,230	572.57	572.54	.....	.03
11	do	SW.	10	.16	.07	4.84	1B	207,170	572.47	572.41	.....	.03
12	Oct. 25	NW.	15–30	.00	.38	4.58	1B	205,550	572.40	572.57	.17	.....
13	do	NW.	20	.12	.01	4.71	2B	198,900	572.10	572.35	.25	.....
14	do	NW.	20	.31	.00	4.78	2B	207,120	572.48	572.54	.03	.....
15	Oct. 26	NE.	6	.02	.07	4.87	2B	205,470	572.40	572.49	.09	.....
16	do	NE.	6	.16	.04	4.86	1B	208,220	572.53	572.48	.....	.05
17	do	.....	.....	.06	.14	4.65	1B	196,450	571.99	572.10	.11	.....

WILLIAMS EXHIBIT 41—Continued.
Being Exhibit No. 1 of July 22, 1913.
PRESERVATION OF NIAGARA FALLS.

TABLE 47.—*Elevation of Lake Erie derived from discharge of Niagara River, International Bridge, Buffalo, N. Y.—Con.*

Number	Date	Wind		Change of Lake level during measurement		Fall Lake Erie to bridge (feet)	Meter U. S. Lake Survey	Discharge (cubic feet per second)	Lake Erie elevation (feet).		Difference (feet).	
		Direction	Estimated velocity (miles)	Rise (feet)	Fall (feet)				Computed.	Observed	Lake, high	Lake, low
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*	*m*	*n*
	1907											
18	Oct. 26			.02	.24	4.60	2B	190,050	571.72	571.94	.22	
19	Oct. 28	NW.	35	.03	.32	4.61	2B	208,370	572.53	572.48		.05
20	do	NW.	35	.07	.08	4.51	1B	196,210	571.98	572.13	.15	
21	do	NW.	35	.05	.02	4.69	1B	204,220	572.33	572.35	.02	
22	do	NW.	35	.32	.00	4.90	1B	211,430	572.67	572.63		.04
23	Oct. 29	NW.	10	.10	.04	4.92	1B	213,770	572.78	572.82	.04	
24	do	NW.	20	.03	.15	4.76	2B	210,540	572.64	572.64	.00	.00
25	do	NW.	25	.04	.29	4.74	2B	212,070	572.70	572.56		.14
26	Oct. 30	NE.	3	.14	.08	4.85	2B	212,380	572.72	572.44		.28
27	Oct. 31			.03	.06	4.84	2B	214,080	572.80	572.45		.35
28	do	NW.	2	.02	.10	4.81	2B	208,650	572.54	572.38		.16
29	do	SE.	3	.08	.16	4.67	2B	201,650	572.22	572.19		.03
30	Nov. 1	SE.	10	.13	.10	4.57	46A	208,330	572.53	572.32		.21
31	do	SE.	10	.15	.07	4.81	46A	211,080	572.66	572.40		.26
32	do	S.	2	.04	.09	4.77	46A	210,220	572.62	572.39		.23
33	do	S.	2	.05	.10	4.78	46A	209,780	572.60	572.38		.22
34	Nov. 2	S.	40	.33	.07	5.04	46A	219,360	573.04	572.80		.24
35	do	S.	40	.03	.33	4.99	46A	216,660	572.92	572.84		.08

36	do	S.	40	.02	.30	4.80	46A	207,810	572.50	572.55	.05	.....
37	Nov. 4	W.	4	.09	.01	5.01	46A	224,720	573.28	573.00	.....	.28
38	do	W.	4	.12	.20	4.85	46A	213,380	572.76	572.87	.11	.....
39	do	W.	7	.15	.02	4.79	46A	213,230	572.76	572.81	.05	.....
40	do	SW.	10	.04	.23	4.94	46A	218,840	573.02	572.93	.....	.09
	1908											
41	June 26	SE.	4	.00	.26	4.96	14B 1	228,820	573.46	573.39	.....	.07
42	June 27	SW.	3	.12	.01	5.17	14B 1	219,030	573.03	573.28	.25	.....
43	do	W.	5	.07	.03	5.23	1B 1	229,760	573.51	573.49	.....	.02
44	do	W.	5	.08	.10	5.20	1B 1	227,780	573.42	573.48	.06	.....
45	June 29	W.	8	.39	.15	4.90	1B 1	225,460	573.32	573.32	.00	.00
46	June 29	SW.	7–20	.10	.22	4.97	1B 1	227,050	573.39	573.39	.00	.00
47	June 30	SW.	8	.15	.17	5.11	14B 1	239,770	573.94	573.71	.....	.23
48	do	SW.	7–12	.08	.37	5.05	14B 1	236,730	573.80	573.60	.....	.20
49	do	SW.	15	.16	.24	4.99	1B 1	221,500	573.15	573.40	.25	.....
50	do	SW.	10	.14	.15	4.95	1B 1	219,980	573.08	573.28	.20	.....
51	July 2	E.	5	.07	.16	4.85	14B 4	213,620	572.77	572.92	.15	.....
52	do	NE.	6–25	.18	.07	4.88	14B 4	218,670	573.02	572.91	.....	.11
53	do	NE.	15	.06	.14	4.89	1B 1	208,410	572.54	572.85	.31	.....
54	do	NE.	20–7	.03	.17	4.88	1B 1	211,690	572.69	572.77	.08	.....
55	July 6	SW.	15	.06	.09	5.04	14B 4	230,740	573.54	573.52	.....	.02
56	do	SW.	12	.00	.27	4.96	14B 4	220,380	573.10	573.34	.24	.....
57	do	SW.	10	.03	.17	4.90	1B 1	220,590	573.11	573.23	.12	.....
58	do	SW.	15	.21	.12	4.85	1B 1	217,380	572.95	573.07	.12	.....
59	July 7	SW.	18	.12	.03	5.15	14B 4	222,100	573.17	573.54	.37	.....
60	do	SW.	18	.08	.19	5.20	14B 4	230,400	573.53	573.54	.01	.....
61	July 8	NW.	38	.51	.11	5.25	15B 1	239,400	573.92	573.80	.....	.12
62	do	NW.	38	.00	.66	5.00	15B 1	224,320	573.27	573.46	.19	.....
63	do	NW.	10	.12	.07	5.18	15B 1	231,060	573.55	573.63	.08	.....
64	do	SW.	25–40	.20	.13	5.06	15B 1	229,470	573.49	573.54	.05	.....
65	July 10	SW.	6	.04	.06	5.23	1B 1	223,380	573.23	573.30	.07	.....
66	do	SW.	6	.09	.07	5.20	1B 1	220,520	573.10	573.27	.17	.....
67	do	SW.	6	.01	.04	5.15	15B 3	230,220	573.52	573.30	.....	.22

WILLIAMS EXHIBIT 41—Continued.
Being Exhibit No. 1 of July 22, 1913.

PRESERVATION OF NIAGARA FALLS.

TABLE 47.—*Elevation of Lake Erie derived from discharge of Niagara River, International Bridge, Buffalo, N. Y.—Con.*

Number	Date	Wind		Change of Lake level during measurement		Fall Lake Erie to bridge (feet)	Meter U. S. Lake Survey	Discharge (cubic feet per second)	Lake Erie elevation (feet)		Difference (feet)	
		Direction	Estimated velocity (miles)	Rise (feet)	Fall (feet)				Computed.	Observed	Lake, high	Lake, low.
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*	*m*	*n*
	1908											
68	July 10	SW.	6	.05	.09	5.08	15B 3	222,770	573.20	573.23	.03	
69	July 16	SW.	5–15	.23	.02	5.04	1B 8	229,180	573.48	573.33		
70	do	SW.	8	.02	.11	5.03	1B 8	231,750	573.58	573.39		.15
71	July 18	SW.	10	.00	.03	4.88	1B 8	234,300	573.70	573.69		.19
72	do	SW.	10	.09	.31	4.69	1B 8	221,470	573.14	573.21	.07	.01
73	July 20	NW.	4	.00	.21	4.83	14B 7	223,100	573.22	573.24	.02	
74	do	SW.	8	.06	.13	4.77	14B 7	222,480	573.19	573.10		
75	do	NW.	3	.09	.02	4.83	1B 8	222,340	573.18	573.00		.09
76	July 21		0	.26	.43	4.81	14B 7	216,400	572.91	573.16	.25	.18
77	do	NW.	10	.14	.21	4.73	14B 7	213,930	572.78	572.91	.13	
78	do	NW.	10	.21	.03	4.80	14B 7	215,200	572.85	573.08	.23	
79	July 22	SW.	5	.11	.07	4.95	14B 7	228,150	573.43	573.38		
80	do	SW.	12	.10	.02	4.94	1B 8	231,250	573.56	573.42		.05
81	do	SW.	10	.05	.10	4.83	1B 8	224,090	573.26	573.29	.03	.14
82	do	NW	5	.04	.09	4.81	1B 8	226,780	573.37	573.20		
83	July 23	NW.	5	.16	.08	4.80	1B 8	221,610	573.14	573.00		.17
84	do	NW.	5	.06	.11	4.84	1B 8	221,950	573.16	573.08		.14
85	do	NE.	8	.18	.14	4.83	1B 8	222,880	573.20	573.12		.08

86	do	NE.	8	.06	.06	4.81	1B 8	222,660	573.19	573.09	.....	.10
87	July 24	NE.	5	.06	.03	4.78	14B 7	213,120	572.75	572.84	.09	.....
88	do	NE.	5	.14	.12	4.80	14B 7	208,520	572.54	572.87	.33	.....
89	do	NE.	12	.15	.65	4.70	1B 8	216,060	572.90	572.85	.....	.05
90	do	NE.	10	.18	.25	4.72	1B 8	212,990	572.74	572.72	.....	.02
91	July 25	NE.	4	.14	.12	4.86	14B 7	220,410	573.09	573.20	.11	.....
92	do	NE.	6	.15	.19	4.72	14B 7	218,340	573.00	573.00	.00	.00
93	do	NE.	10	.13	.18	4.84	1B 8	225,010	573.30	573.08	.....	.22
94	July 27	.....	0	.05	.01	4.75	1B 8	221,150	573.13	573.02	.....	.11
95	do	NE.	3	.05	.02	4.76	1B 8	216,700	572.93	573.00	.07	.....
96	July 29	SW.	5	.06	.05	4.81	14B 7	221,010	573.13	573.10	.....	.03
97	do	SW.	3	.06	.04	4.86	14B 7	226,680	573.37	573.18	.....	.19
98	July 30	SW.	8	.02	.07	4.85	14B 7	224,840	573.29	573.21	.....	.08
99	do	SW.	8	.02	.09	4.83	14B 7	221,770	573.16	573.15	.....	.01
100	do	SW.	10	.10	.03	4.83	1B 8	226,800	573.38	573.15	.....	.23
101	July 31	SW.	8	.03	.06	4.84	1B 8	227,870	573.42	573.20	.....	.22
102	do	NW	15	.00	.03	4.81	1B 8	222,820	573.20	573.20	.....	.00
103	do	NW	15	.04	.08	4.74	1B 8	223,320	573.22	573.08	.....	.14
104	do	NW.	15	.12	.00	4.78	1B 8	226,370	573.35	573.11	.....	.24
105	Aug. 1	NE	10	.26	.01	4.90	14B 7	212,960	572.74	572.67	.....	.07
106	do	NE.	18	.22	.01	5.10	14B 7	221,310	573.13	573.07	.....	.06
107	Aug. 4	SW.	15	.04	.28	4.79	14B 7	220,370	573.09	573.18	.09	.....
108	do	SW.	15- 8	.09	.07	4.82	14B 7	218,710	573.02	573.18	.16	.....
109	do	SW.	15	.17	.03	4.76	1B 8	227,110	573.39	573.06	.....	.33
110	do	SW.	8	.14	.05	4.71	1B 8	225,180	573.31	572.98	.....	.33
111	Aug. 5	SW.	8	.64	.06	4.98	1B 8	234,750	573.72	573.39	.....	.33
112	do	SW.	8	.02	.48	5.06	1B 8	237,330	573.83	573.61	.....	.22
113	do	SW.	35	.25	.80	5.05	14B 7	234,570	573.71	573.77	.06	.....
114	do	SW.	20	.30	.47	5.02	14B 7	238,630	573.89	573.88	.....	.01
115	Aug. 6	SW.	50	.06	.02	4.86	14B 7	233,020	573.64	573.56	.....	.08
116	do	SW.	20	.00	.69	4.71	14B 7	225,050	573.30	573.27	.....	.03
117	do	SW.	30	.29	.03	4.67	1B 8	213,850	572.78	572.94	.16	.....
118	do	SW.	20	.05	.26	4.77	1B 8	217,220	572.94	573.03	.09	.....

WILLIAMS EXHIBIT 42

Being Complainant's Exhibit 4 of July 22, 1913
Cross-Examination of Gardner S. Williams

TABLE 1

HOURLY WATER LEVELS AS RECORDED BY SELF-REGISTERING GAGE AT BUFFALO, N. Y., DURING MONTH OF NOVEMBER 1906.

Hour	1	2	3	4	5	6	7	8	9	10	11
1	571.86	571.92	571.98	571.15	571.78	571.64	571.88	571.87	571.63	571.77	571.69
2	1.87	1.85	2.04	1.14	1.85	1.69	1.83	1.83	1.84	1.94	1.60
3	1.92	1.85	2.01	1.14	1.87	1.76	1.70	1.84	1.77	1.93	1.62
4	1.86	1.75	1.99	1.38	2.01	1.88	1.78	1.83	1.95	2.03	1.55
5	1.88	1.73	1.93	1.02	1.92	1.90	1.77	1.90	2.12	2.32	1.49
6	1.89	1.72	1.85	1.32	1.88	1.89	1.69	1.89	1.98	2.50	1.49
7	1.83	1.75	1.75	1.25	1.86	1.96	1.71	1.63	2.03	2.28	1.50
8	1.85	1.82	1.74	1.48	1.75	1.95	1.80	1.83	1.80	2.44	1.65
9	1.83	1.80	1.75	1.24	1.77	1.93	1.81	1.78	1.76	2.55	1.73
10	1.82	1.88	1.75	1.23	1.70	2.00	1.83	1.70	1.73	2.55	1.80
11	1.77	1.93	1.74	1.36	1.74	1.82	1.82	1.61	1.63	2.62	1.88
12	1.72	1.92	1.82	1.45	1.82	1.79	1.85	1.68	1.81	2.63	1.86
13	1.80	1.92	1.92	1.32	1.81	1.81	1.86	1.74	1.92	2.66	1.70
14	1.86	1.96	1.85	1.18	1.82	1.76	1.90	1.77	1.94	2.50	1.59
15	1.88	2.00	1.93	1.25	1.88	1.83	1.87	1.83	2.41	2.88	1.72
16	1.89	1.96	1.98	1.39	2.01	1.81	1.90	1.78	2.40	3.02	1.86
17	1.87	1.94	1.88	1.10	1.92	1.89	1.95	1.91	3.28	2.47	1.83
18	1.91	1.80	1.85	1.12	1.93	1.79	1.89	1.73	3.55	2.11	1.82
19	1.96	1.82	1.76	1.09	1.88	1.81	1.80	1.75	3.12	2.21	1.85
20	1.96	1.83	1.70	1.05	1.80	1.90	1.76	1.60	2.63	2.09	1.84
21	1.89	1.78	1.60	1.18	1.64	1.98	1.75	1.51	2.35	2.00	1.72
22	1.92	1.82	1.50	1.31	1.72	2.00	1.85	1.55	2.61	1.95	1.82
23	1.95	1.78	1.28	1.51	1.71	1.92	1.80	1.47	1.88	2.08	2.00
24	571.90	571.95	571.25	571.60	571.78	571.88	571.70	571.71	571.53	571.92	571.80
Mean	572.09	572.07	572.01	571.48	572.05	572.08	572.08	571.98	572.37	572.83	571.98

Add 22 ft. to all readings from 1st to 25th, inclusive. Datum 593.81 instead of 570.08. Daily means have been corrected.

TABLE 1

HOURLY WATER LEVELS AS RECORDED BY SELF-REGISTERING GAGE AT BUFFALO, N. Y., DURING MONTH OF NOVEMBER 1906.

Hour	12	13	14	15	16	17	18	19	20	21	22
1	571.82	572.26	572.00	571.80	571.99	571.50	571.53	571.91	571.78	571.22	575.54
2	1.99	2.28	1.98	1.71	1.95	1.38	1.68	2.22	1.54	1.53	6.60
3	1.94	2.28	1.92	1.50	2.02	1.47	1.65	2.16	1.38	1.59	7.20
4	2.03	2.29	2.05	1.38	2.05	1.34	1.68	2.43	1.18	1.50	7.10
5	2.12	2.04	2.27	1.30	2.05	1.20	2.14	2.22	1.17	1.25	7.30
6	2.10	2.04	2.27	1.28	2.02	1.38	1.91	2.49	1.61	1.27	5.47
7	2.05	2.05	2.16	1.31	1.87	1.03	2.09	2.38	1.35	1.07	5.22
8	2.72	2.10	2.26	1.43	1.90	1.12	2.18	1.78	1.36	0.85	4.61
9	2.04	2.13	2.14	1.54	1.82	1.18	2.17	1.73	1.25	0.72	4.02
10	2.01	2.18	2.07	1.71	1.72	1.41	2.16	1.69	1.36	1.12	3.62
11	1.87	2.31	2.06	1.82	1.78	1.35	2.05	1.92	1.50	1.10	4.12
12	1.73	2.30	2.00	1.83	1.78	1.56	2.14	1.83	1.32	1.29	4.13
13	1.60	2.35	1.94	1.94	1.89	2.00	2.09	1.93	1.30	1.39	3.82
14	1.64	2.31	1.79	1.86	1.97	2.36	2.35	2.00	1.50	1.52	3.76
15	1.67	2.15	1.75	1.73	2.10	2.48	1.97	1.85	1.70	1.65	4.08
16	1.68	2.16	1.74	1.65	2.13	2.09	2.31	1.98	1.28	1.95	3.86
17	1.68	2.18	1.70	1.58	2.09	2.25	3.05	1.88	1.12	1.66	3.66
18	1.76	2.11	1.76	1.46	1.99	2.22	3.18	1.91	1.40	1.53	3.31
19	1.81	1.99	1.80	1.44	1.92	1.92	3.36	1.98	1.30	1.58	3.38
20	1.83	2.02	1.86	1.59	1.83	1.50	2.57	1.93	1.22	1.71	3.26
21	1.86	2.05	1.80	1.60	1.72	1.63	2.38	1.98	1.05	1.81	3.22
22	1.93	1.90	1.86	1.54	1.68	1.68	2.00	2.04	1.42	3.45	2.65
23	1.99	1.90	1.95	1.63	1.56	1.20	1.84	2.03	1.35	4.12	2.62
24	572.20	571.92	571.85	571.92	571.52	571.59	572.00	571.90	571.29	575.31	572.49
Mean	572.11	572.36	572.18	571.83	572.11	571.84	572.41	572.23	571.58	571.98	574.60

Notes on condition of record.....

WILLIAMS EXHIBIT 42

Being Complainant's Exhibit 4 of July 22, 1913
Cross-Examination of Gardner S. Williams

TABLE 1

HOURLY WATER LEVELS AS RECORDED BY SELF-REGISTERING GAGE AT BUFFALO, N. Y., DURING MONTH OF NOVEMBER 1906.

Hour	23	24	25	26	27	28	29	30	31	
1	572.00	572.53	572.99	571.87	572.50	572.56	572.33	572.72	.....	Elevation of Zero of Staff Gage, 573.09 (Levels of 1903.)
2	1.90	2.60	2.96	2.00	3.58	2.65	2.08	2.64	.....	
3	2.01	2.38	2.93	2.10	4.35	2.83	2.15	2.54	.....	
4	2.16	2.30	2.85	2.10	4.77	3.08	1.90	2.50	.....	
5	2.22	2.42	2.57	2.38	4.33	3.02	2.09	2.59	.....	Date of last inspection, Aug. 7 and Nov. 20, 1906.
6	2.42	2.41	2.66	2.24	5.12	3.20	1.96	2.61	.....	
7	2.50	2.18	2.81	2.16	4.25	3.00	1.96	2.64	.....	
8	2.64	2.30	2.50	2.25	4.04	3.37	2.09	2.60	.....	
9	2.77	2.39	2.53	1.94	3.76	3.57	2.11	2.73	.....	
10	2.77	2.27	2.74	1.63	3.68	3.37	2.16	2.98	.....	
11	2.63	2.14	2.74	1.92	3.49	3.25	2.18	3.13	.....	
12	2.55	2.27	2.55	2.13	2.70	2.67	2.27	2.92	.....	
13	2.48	2.43	2.67	2.04	2.73	2.67	2.33	2.96	.....	
14	2.26	2.73	2.64	2.23	3.18	2.54	2.36	3.10	.....	
15	2.26	2.72	2.43	2.15	3.13	2.46	2.38	3.17	.....	
16	2.33	2.68	2.30	2.53	3.10	2.46	2.12	3.29	.....	
17	2.30	2.85	2.28	3.27	2.89	2.28	2.26	3.40	.....	
18	2.37	2.95	2.17	3.46	3.02	2.35	2.30	3.19	.....	
19	2.47	2.74	2.09	3.10	2.55	2.15	2.30	3.52	.....	
20	2.61	2.60	1.85	3.11	2.27	2.17	2.22	3.55	.....	
21	2.58	2.67	1.64	3.22	2.49	2.41	2.43	3.38	.....	
22	2.63	2.74	1.60	2.75	2.66	2.45	2.47	3.39	.....	
23	2.78	2.78	1.80	2.74	2.54	2.57	2.40	3.10	.....	
24	572.51	573.03	571.55	572.54	572.35	572.34	572.45	573.35	.....	Monthly Mean
Mean	572.64	572.77	572.62	572.41	573.31	572.78	572.22	573.00	.....	572.810

WILLIAMS EXHIBIT 42
Being Complainant's Exhibit 4 of July 22, 1913
Cross-Examination of Gardner S. Williams

TABLE 1

ELEVATION OF DATUM LINE AS DERIVED FROM REFERENCE GAGE.

Date	Time	Elev. of W. S. by Ref. Gage	Scaled height above Datum	Elevation of Datum		Remarks
Nov. 2	10.25	572.09	.....	570.02	.....	.....
3	18.52	1.99	.....	0.02	.....	.....
5	16.45	2.09	.....	0.00	.....	.....
6	16.45	2.09	.....	0.04	.....	.....
7	16.30	2.09	.....	0.02	.....	.....
8	14.05	1.99	.....	0.03	.....	.....
9	16.30	2.59	.....	0.00	.....	.....
11	16.20	2.09	.....	0.04	.....	.....
12	16.45	1.89	.....	0.06	.....	.....
14	18.40	1.99	.....	570.04	.....	.....
15	16.30	1.79	.....	569.98	.....	.....
17	16.00	2.09	.....	569.83	.....	.....
20	15.50	1.69	.....	570.01	.....	.....
21	15.45	1.99	.....	569.98	.....	.....
24	16.40	2.99	.....	570.00	.....	.....
26	16.15	3.09	.....	570.35	.....	.....
27	16.04	2.89	.....	569.90	.....	.....
29	8.35	2.29	.....	570.12	.....	.....
29	9.17	572.29	.....	570.12	.....	.....
			Mean	570.03		

Max. at.....hour.....day.....
Min. at.....hour.....day.....

REDUCTION OF RECORD

Vertical Scale of Record, 1 inch = 1 foot.
Horizontal Scale of Record, 2 in. = 1 hour.
Record prepared by Lockwood.
Record scaled by Lockwood.
Water levels recorded by Lawton.
Daily and Mo. Means by.....
Means checked by.....

Elevation of Datum Line used in scaling this record, 570.03.

Williams Exhibit 42.

Cross X Wms. No. 4 x

WILLIAMS EXHIBIT 42
Being Complainant's Exhibit 4 of July 22, 1913
Cross-Examination of Gradner S. Williams

TABLE 2

HOURLY WATER LEVELS AS RECORDED BY SELF-REGISTERING GAGE AT CHIPPAWA, ONT., DURING MONTH OF NOVEMBER, 1906.

Hour	1	2	3	4	5	6	7	8	9	10	11
1	562.38	562.44	562.39	562.24	562.07	562.30	562.35	562.31	562.21	562.62	562.52
2	2.39	2.45	2.39	2.19	2.12	2.29	2.35	2.31	2.21	2.63	2.47
3	2.39	2.45	2.40	2.14	2.16	2.28	2.35	2.31	2.21	2.50	2.43
4	2.41	2.44	2.43	2.10	2.21	2.28	2.35	2.31	2.23	2.48	2.38
5	2.41	2.43	2.43	2.09	2.25	2.28	2.34	2.32	2.25	2.45	2.35
6	2.42	2.42	2.43	2.09	2.28	2.29	2.33	2.32	2.27	2.45	2.32
7	2.43	2.40	2.43	2.08	2.29	2.29	2.32	2.32	2.30	2.49	2.29
8	2.43	2.38	2.42	2.08	2.30	2.30	2.30	2.31	2.31	2.51	2.28
9	2.43	2.38	2.40	2.09	2.31	2.31	2.28	2.30	2.31	2.51	2.27
10	2.43	2.38	2.39	2.11	2.30	2.33	2.28	2.29	2.32	2.55	2.27
11	2.42	2.38	2.38	2.10	2.31	2.33	2.28	2.29	2.31	2.57	2.27
12	2.42	2.39	2.36	2.09	2.31	2.33	2.28	2.28	2.31	2.60	2.28
13	2.40	2.39	2.34	2.10	2.31	2.33	2.29	2.27	2.30	2.62	2.29
14	2.39	2.40	2.35	2.12	2.31	2.33	2.28	2.27	2.30	2.65	2.30
15	2.38	2.40	2.35	2.11	2.30	2.32	2.28	2.26	2.31	2.66	2.30
16	2.39	2.41	2.35	2.10	2.30	2.30	2.29	2.25	2.34	2.65	2.30
17	2.38	2.42	2.36	2.09	2.31	2.30	2.29	2.26	2.40	2.70	2.30
18	2.39	2.43	2.36	2.09	2.33	2.31	2.30	2.27	2.46	2.72	2.30
19	2.40	2.42	2.36	2.08	2.33	2.31	2.31	2.28	2.64	2.68	2.31
20	2.41	2.42	2.36	2.05	2.34	2.32	2.32	2.28	2.75	2.63	2.33
21	2.42	2.41	2.36	2.04	2.33	2.31	2.32	2.27	2.77	2.62	2.34
22	2.42	2.39	2.35	2.03	2.33	2.32	2.31	2.25	2.74	2.58	2.34
23	2.42	2.39	2.32	2.02	2.32	2.34	2.31	2.22	2.72	2.55	2.33
24	562.44	562.39	562.28	562.04	562.31	562.35	562.31	562.22	562.69	562.53	562.33
Mean	562.41	562.41	562.37	562.09	562.28	562.31	562.31	562.26	562.40	562.58	562.33
	2.50	2.38	2.35	2.08	2.27	2.30	2.30	2.32	2.55	2.64	2.32

TABLE 2

HOURLY WATER LEVELS AS RECORDED BY SELF-REGISTERING GAGE AT CHIPPAWA, ONT., DURING MONTH OF NOVEMBER, 1906.

Hour	12	13	14	15	16	17	18	19	20	21	22
1	562.34	562.43	562.49	562.36	562.22	561.68	561.63	562.00	561.80	561.49	562.50
2	2.35	2.48	2.48	2.36	2.27	1.67	1.63	1.97	1.80	1.49	2.87
3	2.35	2.52	2.47	2.36	2.29	1.63	1.61	1.97	1.78	1.49	3.07
4	2.35	2.54	2.47	2.33	2.32	1.61	1.62	1.95	1.74	1.52	3.63
5	2.38	2.56	2.47	2.30	2.33	1.59	1.63	1.96	1.68	1.55	3.91
6	2.40	2.58	2.48	2.25	2.35	1.55	1.67	1.97	1.62	1.55	4.05
7	2.42	2.56	2.49	2.21	2.37	1.53	1.71	1.98	1.59	1.54	4.01
8	2.42	2.55	2.50	2.17	2.37	1.50	1.74	1.98	1.57	1.53	4.01
9	2.43	2.54	2.51	2.14	2.37	1.47	1.78	1.97	1.53	1.49	3.89
10	2.43	2.54	2.52	2.14	2.37	1.46	1.82	1.89	1.51	1.48	3.67
11	2.44	2.53	2.52	2.15	561.72	1.45	1.84	1.84	1.49	1.44	3.51
12	2.43	2.53	2.51	2.19	1.71	1.45	1.85	1.82	1.49	1.46	3.41
13	2.42	2.56	2.51	2.22	1.72	1.45	1.85	1.80	1.50	1.47	3.41
14	2.38	2.58	2.49	2.25	1.70	1.50	1.89	1.79	1.50	1.49	3.35
15	2.36	2.59	2.47	2.28	1.70	1.58	1.89	1.79	1.48	1.55	3.21
16	2.34	2.60	2.43	2.27	1.71	1.68	1.90	1.79	1.51	1.61	3.17
17	2.33	2.59	2.40	2.28	1.75	1.72	1.89	1.78	1.53	1.68	3.13
18	2.30	2.58	2.38	2.27	1.78	1.74	1.95	1.78	1.51	1.73	3.19
19	2.30	2.57	2.37	2.27	1.79	1.77	2.06	1.76	1.50	1.74	3.00
20	2.32	2.55	2.37	2.24	1.79	1.79	2.17	1.76	1.49	1.74	2.95
21	2.34	2.54	2.35	2.22	1.78	1.77	2.20	1.76	1.50	1.76	2.90
22	2.34	2.53	2.35	2.21	1.77	1.73	2.14	1.75	1.47	1.75	2.85
23	2.36	2.52	2.35	2.21	1.74	1.72	2.11	1.77	1.47	1.85	2.75
24	562.40	562.50	562.35	562.21	561.71	561.68	562.05	561.79	561.47	562.13	562.65
Mean	562.37	562.54	562.45	562.25	562.34	562.23	562.48	562.48	562.18	562.23	563.92
	2.40	2.54	2.44	2.25	2.40	2.25	2.57	2.47	2.11	2.33	3.79

All readings after 10th hour, Nov. 16, are 0.62 ft. too small, except daily means, which have been corrected. The wrong elevation for zero of gage was used. S. T. H. & F. L.

Notes on condition of record.....

Williams Exhibit 42.

WILLIAMS EXHIBIT 42

Being Complainant's Exhibit 4 of July 22, 1913
Cross-Examination of Gardner S. Williams

TABLE 2

HOURLY WATER LEVELS AS RECORDED BY SELF-REGISTERING GAGE AT CHIPPAWA, ONT., DURING MONTH OF NOVEMBER, 1906.

Hour	23	24	25	26	27	28	29	30	31	
1	562.57	562.27	562.29	561.84	562.14	562.11	561.94	561.89	.....	Elevation of Zero of Staff Gage, 567.639. (Levels of 1903.)
2	2.45	2.27	2.32	1.81	2.10	2.10	1.93	1.92	.....	
3	2.31	2.27	2.34	1.80	2.13	2.08	1.91	1.96	.....	
4	2.23	2.26	2.35	1.80	2.29	2.09	1.88	1.95	.....	Date of last inspection.....
5	2.20	2.23	2.35	1.79	2.50	2.14	1.85	1.96	.....	.....
6	2.17	2.20	2.35	1.82	2.66	2.17	1.82	1.96	.....	
7	2.16	2.19	2.32	1.84	2.77	2.22	1.81	1.98	.....	
8	2.17	2.17	2.32	1.84	2.87	2.22	1.78	1.99	.....	
9	2.19	2.14	2.30	1.83	2.85	2.26	1.76	2.01	.....	
10	2.23	2.14	2.28	1.81	2.82	2.30	1.76	2.03	.....	
11	2.27	2.13	2.28	1.77	2.81	2.34	1.77	2.07	.....	
12	2.27	2.11	2.27	1.72	2.75	2.35	1.79	2.04	.....	
13	2.28	2.09	2.28	1.73	2.62	2.31	1.80	2.06	.....	
14	2.28	2.08	2.26	1.73	2.50	2.27	1.81	2.16	.....	
15	2.26	2.10	2.24	1.74	2.46	2.19	1.83	2.20	.....	
16	2.21	2.15	2.24	1.77	2.45	2.18	1.86	2.22	.....	
17	2.20	2.18	2.20	1.79	2.41	2.17	1.87	2.25	.....	
18	2.19	2.21	2.15	1.90	2.38	2.05	1.86	2.29	.....	
19	2.17	2.26	2.11	2.03	2.36	2.03	1.85	2.29	.....	
20	2.15	2.28	2.07	2.11	2.31	1.98	1.86	2.30	.....	
21	2.19	2.28	2.02	2.13	2.21	1.94	1.85	2.34	.....	
22	2.21	2.27	1.96	2.17	2.17	1.93	1.86	2.37	.....	
23	2.22	2.27	1.90	2.18	2.14	1.94	1.87	2.39	.....	
24	562.26	562.27	561.88	562.16	562.14	561.96	561.87	562.40	.....	
Mean	562.86 2.70	562.82 2.77	562.83 2.99	562.50 2.57	563.07 3.07	562.76 2.75	562.46 2.47	562.75 2.90	.....	Monthly Mean 562.510

WILLIAMS EXHIBIT 42

Being Complainant's Exhibit 4 of July 22, 1913.
Cross-Examination of Gardner S. Williams

TABLE 2

ELEVATION OF DATUM LINE AS DERIVED FROM REFERENCE GAGE.

Date	Time	Elev. of W. S. by Ref. Gage	Scaled height above Datum	Elev. of Datum 1" Scale	Elev. of Datum 3" Scale	Remarks
Nov. 16	.....	561.73	.....	555.90	560.39	.....
Nov. 23	.....	562.25	.....	555.98	560.38	.....
Nov. 24	.....	562.14	.....	556.02	560.39	.....
.....	.....	.....	Mean	555.97	560.39	.....
.....	.....	.....	.....	0.62	0.62	.....
.....	.....	.....	Corr.	556.59	561.01	.....
Nov. 30	.....	562.20	.....	556.00	560.39	.....
Dec. 1	.....	2.30	.....	556.00	560.40	.....
Dec. 3	.....	1.98	.....	555.98	560.41	.....
.....	.....	.....	Mean	555.99	560.40	.....
.....	.....	.....	.....	0.62	0.62	.....
.....	.....	.....	Corr.	556.61	561.02	.....

Max. at 6 hour, 22 day, 564.67
Min. at 11 hour, 21 day, 562.02

REDUCTION OF RECORD

Vertical Scale of Record. . . . inches=1 foot
Horizontal Scale of Record, 2 in.=1 hour.
Record prepared by Lockwood.
Record Scaled by Lockwood.
Water levels recorded by Lawton.
Daily and Monthly Means by Lockwood.
Means checked by Lawton.
Harding & Lockwood check before 16th.
Elevation of Datum Line used in scaling this record.
Nov. 16–27, 560.39.
Nov. 27–30, 560.40.

(29,839)

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, 1923

No. 529

THE SANITARY DISTRICT OF CHICAGO, APPELLANT,

vs.

THE UNITED STATES OF AMERICA

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS

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[fols. a & b] [Caption omitted]

[fol. c] IN THE

CIRCUIT COURT OF THE UNITED STATES, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

No. 29019

THE UNITED STATES OF AMERICA

vs.

THE SANITARY DISTRICT OF CHICAGO

BILL OF COMPLAINT—Filed March 23, 1908

[fol. 1] [Title omitted]

To the Honorable the Judges of the Circuit Court of the United States for the Northern District of Illinois, Eastern Division, in Chancery Sitting:

Your, orator, the United States of America, by Charles J. Bonaparte, its Attorney General, and Edwin W. Sims, its attorney for the Northern District of Illinois, brings this, its bill of complaint, against The Sanitary District of Chicago, the dlefendant, and respectfully alleges and represents unto your honors as follows:

First. That the defendant, The Sanitary District of Chicago, is a municipal corporation organized and existing under and by virtue of an act of the Legislature of the State of Illinois, approved May 29, 1889, in force July 1, 1889, and entitled, "An Act to create Sanitary Districts and to remove obstructions in the Desplaines and Illinois Rivers," that it has its principal office in the City of Chicago, in the State of Illinois, and that it is a citizen of the State of Illinois.

Second. That the Main Calumet River, situated in, and flowing, in a northeasterly direction through, the County of Cook, in the said State of Illinois, and emptying into Lake Michigan at South Chicago, [fol. 2] in said county, is a navigable river for its entire length from Lake Michigan to where it is formed by the Little and Grand Calumet rivers; that the United States has appropriated and expended large sums of money in improving the navigability of said river and in improving the harbor at the mouth of the same, that is to say, it has appropriated and expended in such improvement of said river, including its tributaries in Indiana and Illinois, between the years 1884 and 1907 inclusive, the sum of $994,218.98, and in the improvement of said harbor, since the year 1870, the sum of $1,567,230; that at the present time the largest vessels on Lake Michigan can enter said harbor and pass up said river for a distance of five miles, and small vessels can ascend the remaining three miles; that the Little Calumet

River, which, between the mouth of Stoney Creek and the mouth of said river, flows through the said County of Cook in an easterly direction, and in conjunction with the Grand Calumet River, in said county, forms the said Calumet River, is also a navigable river from its mouth to the mouth of Stoney Creek, in said county; that for all of that distance it has a depth of about 6 feet and steamboats and sailing vessels engaged in state and interstate commerce use said river for said distance; that the bridges across said river for said distance are provided with draws for the accommodation of such craft, and such bridges are under the direct supervision of the Secretary of War of the said United States; that the Grand Calumet River, an interstate stream rising in the State of Indiana and flowing in a northwesterly direction into and through the State of Illinois, to the said point of its conjunction with the Little Calumet River, is also a [fol. 3] navigable river, and the said United States has expended large sums of money in improving its navigability; that Lake Michigan and its harbor and connecting rivers and channels are navigable waters of the said United States; and that the United States has appropriated and expended large sums of money in improving the navigability of the rivers, channels and harbors connected with said Lake Michigan.

Third. That on the seventh day of December, in the year 1904, the Board of Trustees of the said The Sanitary District of Chicago duly passed an ordinance, which was afterwards duly approved by its president and which still remains in full force and effect, establishing and laying out a route for a channel and outlet of The Sanitary District of Chicago, to be known as the Calumet-Sag Channel, which said ordinance directed that said channel be constructed by the said Sanitary District from a point in the main channel of the said Sanitary District at a place called Sag, about 11 miles in a northerly direction up the said main channel from Lockport, in the State of Illinois, to a point in said Little Calumet River, at the mouth of Stoney Creek aforesaid, near the City of Blue Island (thereby connecting the said Little Calumet River with the said main channel of the said Sanitary District); that said ordinance provided that said channel should be constructed to a width of 90 feet at the bottom, with vertical sides, where the same is constructed through rock, and to a width of 70 feet on the bottom, with side slope of 3 feet vertical to 5 feet horizontal, where the same is constructed through earth, and that said channel should be constructed to a depth and on a grade sufficient to insure 22 feet depth of water flow; that the con- [fol. 4] struction and maintenance of said channel as provided for in and by the terms of said ordinance and as the defendant plans and proposes to construct and maintain the same, will result in reversing the flow of the said Little Calumet River and the said Calumet River in such a way as to make the water in those rivers flow out of Lake Michigan instead of into it, and as your orator is informed and believes, and so charges the fact to be, will result in diverting and abstracting from Lake Michigan a large quantity of water, to wit: 4,000 cubic feet of water per second and causing said water to flow through the said Calumet rivers into the said Calumet-Sag Channel,

through that channel into the main channel of said Sanitary District, and thence to the Desplaines, Illinois and Mississippi rivers, and on to the Gulf of Mexico.

Fourth. Your orator further represents, on information and belief, that such diversion and abstraction of the waters of Lake Michigan into the Mississippi River basin as aforesaid, will lower the level of the water in Lake Michigan, and thus diminish the navigable capacity and depth of the various rivers, channels and harbors connected therewith which have been deepened and improved at great expense under the authority of the Congress of the said United States. Such depths that the construction and maintenance of the said Calumet-Sag Channel and the diversion and abstraction of the proposed amount of water from Lake Michigan will have a tendency to undo and annul the orders of Congress as expressed in the various river and harbor acts appropriating funds for improving the harbors and channels connecting with Lake Michigan; that the construction and maintenance of the said Calumet-Sag Channel in [fol. 5] the manner that the defendant plans and proposes to construct and maintain the same, and the consequent and resultant diversion of the waters of Lake Michigan out of the Lake Michigan basin into the Mississippi basin as aforesaid, will alter and modify the condition and capacity of all the said harbors and of all the said channels (navigable waters of the said United States as aforesaid), and will impede, injure and obstruct navigation in many of said harbors and channels, and will create an obstruction to the navigable capacity of the last mentioned waters of the said United States.

Fifth. That the diversion of said water as herein above set forth and the creation of the said obstruction to the navigable capacity of the said navigable waters of the United States, as above described, by the defendant, has not been, and is not, affirmatively authorized by the Congress of the said United States, and has not been, and is not, authorized in any way by the said Congress.

Sixth. Your orator further represents, on information and belief, that the construction and maintenance of the said Calumet-Sag Channel, as the defendant plans and proposes to construct and maintain the same, will lower the levels of the water in the said Calumet, Little Calumet and Grand Calumet rivers, and will alter and modify the course, condition and capacity of those rivers respectively.

Seventh. Your orator further avers on information and belief, that the construction and maintenance of the said proposed Calumet-Sag Channel, as planned and proposed by the defendant, and its [fol. 6] consequent diversion of the waters of Lake Michigan out of the Lake Michigan basin into the Mississippi River basin as aforesaid, will lower the levels of the waters of said Lake Michigan and will injure and impede navigation in all of the harbors and channels in said waters.

Eighth. That in and by Section 10 of an act of Congress, approved Mar[illegible]h 3, 1899, and entitled, "An Act making appropriations

for the construction, repair and preservation of certain public works on rivers and harbors, and for other purposes," it is provided as follows:

"That the creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or other structures in any port, roadstead, haven, harbor, canal, navigable river or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to the beginning of same";

which said law has remained and been in full force and effect ever since its passage and still remains in full force and effect.

Ninth. That heretofore, to wit, on or about the twenty-eighth day [fol. 7] of November, in the year 1906, the defendant made application to the Secretary of War of the said United States, for authority to construct and maintain the said Calumet-Sag Channel, as above described, and to reverse the flow of the said Calumet rivers, as above described; that thereafter the said Secretary of War requested the Chief of Engineers of the said United States to make his recommendation concerning the said application, and that thereupon, to wit, on the twenty-third day of February, in the year 1907, the said Chief of Engineers reported to the said Secretary of War that he was unwilling to recommend favorably the said proposed work; that thereafter, to wit, on the fourteenth day of March, in the year 1907, the said Secretary of War denied the said application and refused to authorize the said proposed work; and that up to the present time, to wit, the time of the filing of this bill of complaint, the said proposed work has not been recommended by the said Chief of Engineers and has not been authorized by the said Secretary of War, and still remains and is wholly without the recommendation, permission or approval of the said Chief of Engineers and still remains and is wholly without the authority, permission or approval of the said Secretary of War.

Tenth. That the defendant has announced its intention to construct and maintain the said proposed Calumet-Sag Channel, to reverse the flow of the said Calumet River and the said Little Calumet River as aforesaid, and to divert and abstract waters from Lake Michigan as aforesaid, notwithstanding the refusal of the said Chief of Engineers to recommend the same, and notwithstanding the re-

[fol. 8] fusal of the said Secretary of War to authorize the same, unless restrained by a court having jurisdiction to restrain said action, and to that end its Board of Trustees, on the eighteenth day of September, in the year 1907, adopted and passed an order, which is still in full force and effect, and a true copy of which is hereto appended, marked Exhibit "A," and made a part hereof.

Eleventh. Your orator further represents, upon information and belief, that the defendant desires, proposes and intends to divert the waters of Lake Michigan as aforesaid, through the said Calumet rivers and the Calumet-Sag Channel as aforesaid, for sanitary purposes and for the development of valuable water power which it proposes to sell; that the Congress of the United States has not fixed any amount of such waters for such proposed diversion, and has not provided for the diversion of any of such waters through the said Calumet rivers and the said Calumet-Sag Channel, and that the Secretary of War of the United States, under the direction of Congress, or in any other way, has not fixed any amount of such waters for such proposed diversion, but, on the contrary, has refused so to do, and has refused to authorize the diversion of any of such waters through said rivers and said channel.

Twelfth. Your orator further represents that the defendant cannot lawfully construct or maintain the said proposed Calumet-Sag Channel as above described, cannot lawfully reverse the flow of the said Calumet rivers as it plans and proposes to do as aforesaid, and cannot lawfully divert and abstract the waters of Lake Michigan as it plans and proposes to do as aforesaid.

[fol. 9] Thirteenth. That the defendant, on the sixteenth day of October, 1907, actually began the excavation of the said proposed Calumet-Sag Channel, at the westerly end of the same, with a force of men under the supervision of one William M. McCartney, its asistant engineer, and your orator is informed and believes, and so charges the facts to be, that the defendant intends to, and will, continue and complete the construction of said channel, reverse the flow of the said Little Calumet and the said Calumet rivers as aforesaid, and divert and abstract the waters of Lake Michigan as aforesaid, and maintain said channel as aforesaid, to the manifest and irreparable injury of your orator and its interstate navigation and commerce, unless restrained by the injunction of this honorable court.

Forasmuch, therefore, as your orator is remediless in the premises by the rules of the common law, and can have adequate relief only in a court of equity, and to the end that the said The Sanitary District of Chicago, a municipal corporation as aforesaid, which is made defendant to this your orator's bill of complaint, may full, true and perfect answer make to all and singular the matters and things hereinbefore stated and charged, but not under oath, its answer under oath being hereby expressly waived, your orator files this bill of complaint and prays your honors forthwith to grant a provisional

or preliminary writ of injunction directed to the said defendant, its Board of Trustees, officers, agents, attorneys, representatives, employes and servants, and all other persons, acting, or claiming or assuming to act, under its authority, enjoining it, and each of its Board of Trustees, officers, agents, attorneys, representatives, em- [fol. 10] ployes and servants, and each of the other persons aforesaid, from constructing, and from beginning or attempting to construct, and from continuing the construction of, and from doing anything in, towards, or about the construction of the said proposed Calumet-Sag Channel, and from constructing, and from beginning and attempting to construct, and from continuing the construction of, and from doing anything in, towards, or about the construction of, any channel, canal, ditch or drain, connecting the main channel of the Sanitary District of Chicago and with the said Little Calumet or with the said Calumet River or with Lake Michigan, of such a kind and character as to reverse the flow of said rivers or to divert or abstract any waters from Lake Michigan, and from doing or attempting anything in any way to connect the waters of the said Calumet rivers with the main channel of the said Sanitary District, and from doing or attempting anything in any way to reverse the flow of the said Calumet rivers, and from doing or attempting anything in any way to divert or abstract any waters from Lake Michigan in any channel other than the Chicago River as already authorized by the said Secretary of War, unless, prior to beginning any of said work, or doing or attempting to do any of such things, the Chief of Engineers of the said United States shall have recommended, and the Secretary of War of the said United States shall have authorized, the doing of such work, until such time as your honors shall appoint and direct for the final hearing herein, and upon such final hearing to make such injunction perpetual.

And may it please your honors to grant such other, further and [fol. 11] different relief in the premises as equity may require, and to your honors may seem meet.

And your orator prays that a writ of subpœna may issue to the said defendant. The Sanitary District of Chicago, commanding it, under a penalty and at a time and place to be therein stated, to appear and answer all and singular the matters hereinbefore stated and charged, and abide by and perform such orders as the court may make in the premises.

And your orator will ever pray.

Charles J. Bonaparte, Attorney General of the United States; By Direction of the Attorney General: Edwin W. Sims, United States Attorney for the Northern District of Illinois; James H. Wilkerson, Special Assistant United States Attorney, Solicitors for the United States.

[fol. 12] Jurat showing the foregoing was duly sworn to by W. H. Bixby omitted in printing.

[fol. 13] EXHIBIT A TO BILL OF COMPLAINT

Whereas, heretofore, to-wit: on the 7th day of December, A. D. 1904, by an ordinance duly passed by this Board and afterwards duly approved by its President, this Board established and laid out a route for a channel and outlet of the Sanitary District of Chicago, which channel was by said ordinance to be constructed and maintained, together with the necessary additions thereto, within the limits of said route, a map or plat of said route or right of way being attached to and made a part of said ordinance, entitled: "Sanitary District of Chicago, Ordinance Map for the right of way of the Calumet-Sag Channel from the westerly preserve line of the Illinois and Michigan Canal, in section 14, T. 37 N., R. 11, E. of the third principal meridian, to the north and south center line of section 32, T. 37 north, range 14, east of the third principal meridian," upon which said map or plat is shown the boundary line of the route for said channel, said boundary line being indicated in red on said plat and marked, "Ordinance Boundary Line," and

Whereas, By the terms of said ordinance it is provided that a channel be constructed by the Sanitary District of Chicago the center line of which shall begin at the center line of the main channel of the Sanitary District of Chicago, in section 14 township 37 north, range 11, east of the third principal meridian in Cook County, Illinois, at a point 707.55 feet, measured along the center line of said channel, distant from the westerly line of said section 14; running thence south 84 degrees east to the westerly reserve line of the [fol. 14] Illinois and Michigan Canal; thence along and upon the center line of the route established in and by the said ordinance; and

Whereas, The construction and maintenance of the channel provided for in and by the terms of said ordinance will result in diverting and reversing the flow of the Calumet river, a navigable stream now flowing into Lake Michigan, and,

Whereas, Heretofore, to wit, on November 28, A. D. 1906, this Board instructed its president to transmit to the Secretary of War an application for a permit to reverse the flow of said Calumet river and thereafter, to wit, on March 14, A. D. 1907, the Secretary of War communicated to this Board his refusal to issue such permit, and

Whereas, This Board is advised that it has the right and that it is its duty under the laws of the State of Illinois to construct its said channel and reverse the flow of said Calumet river, notwithstanding the refusal of the Secretary of War to issue a permit authorizing the same, for the purpose of furnishing the proper sanitary method of disposing of the sewage of the territory and inhabitants contiguous to the said proposed channel and within the corporate limits of the Sanitary District of Chicago, and unless restrained by a court having jurisdiction of the subject matter at the instance of the United States Government, and

Wheras, The Board of Trustees of the Sanitary District of Chicago deemed the construction of such channel and the reversal of the flow of said Calumet river necessary for the preservation of the health of a large number of persons residing within the limits of the [fol. 15] Sanitary District of Chicago; and that it is in duty bound under the law to proceed with the construction thereof, first giving notice of its intention so to do to the Secretary of War and to the Attorney General, that they may, if they see fit, take such steps as they think proper to protect the rights, if any, of the general government in the premises before the expenditure by the District of any considerable portion of the eight or ten millions of dollars necessary to construct the said channel, now, therefore, it is

Ordered, By the Board of Trustees of the Sanitary District of Chicago,

First. That the Finance Committee be, and it is hereby, instructed to forthwith negotiate for the purchase, upon such terms as said Finance Committee may deem just, of any and all property lying within said route for said channel, as described in the ordinance passed and adopted by this Board December 7, 1904, and that said Finance Committee, in the event it shall be unable to purchase any portion of said right of way, immediately instruct the Attorney of this District to institute proceedings in such court as he may deem proper for the condemnation of any of such property as said Finance Committee may be unable to purchase, or otherwise acquire, and,

Second. That the Chief Engineer be, and he is hereby instructed to forthwith prepare plans and specifications for the construction of said channel, according to the terms of the ordinance passed and adopted by this Board December 7, 1904, aforesaid, and that upon the acquirement of any property by the Finance Committee, as herein [fols. 16 & 17] directed, that the Chief Engineer be, and he is hereby instructed to install such machinery and employ such labor as may be necessary to immediately begin the construction of the said channel and secure the reversal of the flow of said Calumet river, and,

Third. That the Clerk of this District be, and he is hereby, instructed to transmit a certified copy of this preamble and order, together with a certified copy of the ordinance of December 7, 1904, aforesaid, and of the "Ordinance Map" attached thereto, to the Secretary of War, to the Attorney General of the United States, to the Chief of Engineers of the United States Army, and to Lieut. Col. Wm. H. Bixby, District Engineer in charge of the Chicago District, at Chicago, Illinois, said copies to be transmitted by United States mail, and the said Clerk is directed to report to this Board the manner in which he shall have carried out the terms of this order.

[File endorsement omitted.]

[fol. 18] IN THE CIRCUIT COURT OF THE UNITED STATES

[Title omitted]

[fol. 19] THE ANSWER OF THE SANITARY DISTRICT OF CHICAGO, RESPONDENT, TO THE BILL OF COMPLAINT OF THE UNITED STATES OF AMERICA, COMPLAINANT—Filed March 23, 1908

This respondent, the Sanitary District of Chicago, now and at all times hereafter, saving and reserving unto itself all benefit and advantage of exception which can or may be had or taken to the many errors, uncertainties and other imperfections in said bill contained, for answer thereunto, or to so much and such parts thereof as this respondent is advised it is or are material or necessary for it to [fol. 20] make answer unto, answering says:

First. This defendant admits that it is a municipal corporation, organized and existing under and by virtue of the laws of the State of Illinois, as charged in the first paragraph of the bill of complaint herein. This defendant hereto attaches a map or plat, marked "Exhibit A," made a part hereof, which represents and shows the territorial boundaries of this defendant, within which there is comprised substantially 358 square miles; that within the boundaries of said District there are situated the following cities, villages and towns: Chicago, Evanston, Glencoe, Winnetka, Wilmette, Shermerville, Glenview, Morton Grove, Miles, Cicero, Stickney, Evergreen Park, Morgan Park, Blue Island, Riverdale, Dolton, Harvey, West Hammond, Worth, Bremen and Calumet; that the population of said District exceeds 2,000,000.

Second. This defendant admits that the Calumet river is a river situated in the County of Cook and State of Illinois, flowing northeasterly, substantially as charged in paragraph two of the bill of complaint; and this defendant will hereinafter more particularly describe said river and attach plats showing the exact location and direction of the same; but this defendant expressly denies that said Calumet river is a navigable river for its entire course, as charged in said bill of complaint, but, on the contrary, alleges that the length, depth and width of said stream throughout its length is substantially as is hereinafter more particularly set forth in the twenty-second paragraph hereof. This defendant admits the allegations in said [fol. 21] paragraph two contained as to the amount of moneys appropriated and expended by the Federal Government in the improvement of said river.

This defendant denies that the Little Calumet river from its mouth to the conjunction thereof with Stony Creek is a navigable river; but, on the contrary, alleges that said river between said points is of the dimensions and capacity hereinafter more fully set forth in the twenty-second paragraph hereof.

This defendant further denies that said portion of said Calumet river above mentioned is traversed by any vessels whatsoever engaged in either interstate or intrastate commerce.

This defendant denies that the Grand Calumet river from its origin in the State of Indiana to its confluence with the Little Calumet is a navigable river within the meaning of that term.

Third. This defendant admits that on, to-wit, the 7th day of December, 1904, the Board of Trustees of the Sanitary District of Chicago passed an ordinance laying out a right of way for, and providing for the construction of, a channel or waterway substantially as set forth in paragraph 3 of the bill of complaint, a copy of which said ordinance is hereto attached, marked "Exhibit G" and made a part hereof as fully as if set forth herein.

This defendant alleges that afterwards on, to-wit, the 22nd day of January, 1908, said Board of Trustees passed another ordinance extending the right of way adopted December 7th, 1904, in an easterly direction from the point where it joined with the Little Calumet river, as provided for in said original ordinance, to a point known [fol. 22] as the "Forks" and shown on "Exhibit F" hereto attached, as will more fully appear from a copy of said ordinance attached hereto, made a part hereof and marked "Exhibit H."

This defendant denies the allegations made in paragraph 3 of the bill of complaint herein: that the construction of said waterway or channel as proposed will result in diverting and abstracting from Lake Michigan four thousand cubic feet of water per second; but on the contrary alleges that the amount of water that will be diverted or abstracted from Lake Michigan by reason of the construction of said channel or waterway will be as hereinafter more fully set forth.

Fourth. This defendant expressly denies the allegation contained in paragraph 4 of the bill of complaint herein that the diversion and abstraction of the waters from Lake Michigan contemplated by this defendant through its proposed channel and waterway will lower the level of the waters of the Great Lakes and will diminish the navigable capacity of said waters or the harbors thereof.

This defendant expressly denies that interstate or any other commerce will be, to any extent, injured or interfered with by the said diversion and abstraction of waters from the Great Lakes, or by the construction and maintenance of the Calumet-Sag Channel; and denies that the construction of said channel will have a tendency to undo and annul the orders of Congress, as expressed in its various river and harbor bills, appropriating funds for improving the rivers and harbors; and expressly denies that the construction of said water- [fol. 23] way and channel will alter and modify the conditions of the rivers and harbors of the United States, or any of them, and substantially and seriously impede, injure and obstruct the navigation of the Great Lakes, and the harbors and channels thereof, or the rivers flowing thereinto, as alleged in said paragraph 4; but, on the contrary, the defendant alleges that the construction and maintenance of said waterway and channel as proposed, and the diversion of water through the same as proposed, will not in any wise effect the navigable capacity of the Great Lakes, or the harbors and channels connected therewith, or the rivers flowing into the same, and will not interfere with, or in any degree injure, interstate commerce, or any

other commerce; but, on the contrary, as hereinafter shown, will be to the interest of interstate commerce and in accordance with the policy and laws of the United States.

Fifth. This defendant expressly denies the allegation contained in paragraph 5 of said bill of complaint, that the construction of said proposed channel has not been affirmatively authorized by the Congress of the United States; but, on the contrary, this defendant alleges that the construction and maintenance of the channel and waterway, substantially as it is proposed to be constructed, is expressly and affirmatively authorized and provided for by the statutes of the United States.

Sixth. This defendant denies the allegation in paragraph 6 of the bill of complaint, that the construction and maintenance of said proposed waterway will lower the level of the Little Calumet river; but [fol. 24] alleges that the effect upon said Little Calumet river that the construction and maintenance of said proposed waterway will have is fully set forth and shown hereinafter.

Seventh. This defendant admits that the various bodies of water mentioned in paragraph 7 of the bill of complaint are each connected with the other and are, in a measure, interdependent upon each other for their respective water levels; but this defendant expressly denies the allegation in said paragraph contained that the construction and maintenance of the proposed waterway, as planned by the defendant, and its consequent diversion of the water from Lake Michigan, would lower the levels of all of said waters, or any of them; and further expressly denies that such construction and maintenance of said channel would injure or impede navigation in the harbors and channels of said waters, or in any of them.

Eighth. This defendant further answering admits that Section 10 of an Act of Congress, approved May 3rd, 1899, is substantially as set forth in paragraph 8 of the complainant's bill herein; but this defendant denies that this act has any binding force on this defendant; or that said act in anywise prohibits the construction and maintenance of the channel or waterway proposed to be constructed by this defendant; or that the same is a constitutional or valid enactment.

Ninth. This defendant further answering admits that on or about the 28th of November, A. D. 1906, this defendant made application to the Secretary of War for a permit to reverse the flow of the Calumet [fol. 25] river, and that thereafter proceedings were had substantially as alleged by the complainant in paragraph 9 of this bill; but this defendant expressly denies that by said application it admitted the jurisdiction of the Secretary of War in such matters; or that it required such permit from said Secretary of War to construct and maintain said channel; but, on the contrary, alleges that it made such application to said Secretary of War purely as a matter of comity and in order to promote and maintain the spirit of harmony which it believed should obtain between the Federal Government

and the various state and local government of the United States; all of which more fully appears from a statement filed with the Secretary of War at the time of making said application, a part of which is in words and figures as follows, to-wit:

"That while insisting upon the right as a matter of right, we are entitled, nevertheless, to a permit from the Secretary of War; to evidence that there exists between the two governments that 'spirit of harmony and concilliation' which, in the words of Chief Justice Marshall, in Gibbons v. Ogden (9 Wheaton, 1), 'ought always to characterize the conduct of governments standing in the relation which that of the Union and those of the states bear to each other'; and to further evidence on the part of said governments that 'frank and candid co-operation for the general good' spoken of by Justice Johnson in the same case, 'which should always take place where there is a seeming blending of the power of the two governments and an apparent conflict.' "

Tenth. This defendant admits that through and by its Board of Trustees it adopted and passed an order substantially as set forth in paragraph 10 of the bill of complaint, and has announced its intention to construct and maintain said waterway and channel as [fol. 26] therein alleged, because of its belief that it has a lawful right to do so.

Eleventh. This defendant admits that Section 1 of an Act of Congress, approved June 29th, 1906, is substantially as set forth in paragraph 11 of complainant's bill of complaint; but this defendant denies that said law has any application to the work contemplated by this defendant, or that it has any binding force or effect in this case.

Twelfth. This defendant denies the allegation in paragraph 12 of complainant's bill of complaint, that the Congress of the United States has not provided for the diversion of any of the waters of Lake Michigan through said proposed waterway and channel; but, on the contrary, alleges that this defendant and the State of Illinois are expressly authorized by Congressional legislation to construct and maintain a waterway such as is proposed by the defendant and to divert the waters of Lake Michigan through the same into the Illinois river.

Thirteenth. This defendant denies that it cannot lawfully construct and maintain said proposed channel as alleged in paragraph 13 of the bill of complaint herein; but, on the contrary, alleges that it is lawfully empowered so to do, and that it is its duty so to do under the laws of the State of Illinois and of the United States.

Fourteenth. This defendant admits that on the 16th day of October, 1907, it actually began the work of excavating said proposed channel and the construction thereof, as alleged in paragraph 14 of the bill of complaint herein; and that it proposes to construct said [fol. 27] channel in the manner and form and of the character,

size and dimensions as hereinafter set forth; but this defendant expressly denies that the construction and maintenance thereof will be to the manifest or irreparable injury of the United States, or to interstate and foreign commerce; but, on the contrary, alleges that the construction and maintenance of said channel and waterway will benefit both state and interstate commerce.

Fifteenth. For further answer, this defendant says that in 1822 and in 1827 the Congress of the United States enacted laws authorizing the State of Illinois to construct a waterway suitable for navigation, connecting the waters of Lake Michigan with the waters of the Illinois river and to thereafter maintain the same at all times in a condition suitable for navigation, as will more fully appear from said acts, reference to which is hereby made. That after the passage of said acts by the Congress of the United States, the State of Illinois accepted the same and thereafter, by various acts duly passed by the General Assembly of said state, and approved by the governor thereof, the said state authorized the construction of, and did construct, and has ever since maintained, a waterway connecting the waters of Lake Michigan with the waters of the Illinois river, over and through which waterway commerce has been carried on continuously since the date of the completion thereof in, to-wit, 1848.

This defendant hereby refers to each and all of the several acts of the General Assembly of the State of Illinois relating to said waterway, which said acts are generally entitled "Acts relating to the [fol. 28] Illinois and Michigan Canal," and asks for the benefit thereof as fully as if set forth herein. This defendant further says that the waterway as originally constructed for the purpose of connecting the waters of Lake Michigan with the waters of the Illinois river, connected the waters of said lake with those of the Illinois river by a channel terminating at or near the City of Peru, on the Illinois river, in the County of La Salle and State of Illinois, and beginning at a point on the Chicago river, which in turn connected with Lake Michigan, in the City of Chicago, and also by a branch terminating at or near the mouth of Stony Creek, on the Calumet river, which said channel and which said branch connecting with said Calumet river are represented and shown on the map or plat which is hereto attached, marked "Exhibit E," by lines colored yellow.

Sixteenth. This defendant for further answer says that in compliance with and pursuant to the powers and duties resting upon this defendant under and by virtue of the several acts incorporating it heretofore referred to, this defendant has constructed a channel of the character and size and dimensions provided for by the original act of its incorporation, extending from a point on the Chicago river, in the City of Chicago, near the original termination of the Illinois and Michigan Canal, parallel with said Illinois and Michigan Canal, to and through the City of Joliet, as represented and shown upon said "Exhibit E" by lines colored red; that the construction of said channel was begun in the year 1892 and work thereon has proceeded continuously from that day to this and is, as yet, not entirely completed. Said channel was completed from its said connection with

[fol. 29] the Chicago river to a point at or near Lockport, a distance of 3 or 4 miles northeasterly from the City of Joliet, in the year 1900 sufficiently to turn the waters therein for the purpose for which said canal had been constructed; and that in the year 1900, pursuant to the various laws of the State of Illinois and the laws of the United States, this defendant did divert the waters of said Chicago river and Lake Michigan to and into said waterway and discharged the same therethrough into the Desplaines river and thence into the Illinois river; that since the turning in of said waters, this defendant has prosecuted the work of extending said canal from said point in Lockport to and through the City of Joliet and has likewise continued the work of deepening and widening the Chicago river with which it connects for the purpose of making said waterway sufficient to accomplish the objects of its creation, both as an outlet for the sewage of the Sanitary District and for the purpose of commerce and navigation; that said waterway or channel has been substantially completed from its connection with said Chicago river to the City of Joliet, a distance, approximately, of thirty-two miles; that from the point of its connection with the Chicago river for a distance of 7.8 miles said waterway is 110 feet wide on the bottom and 198 feet wide at the water line, with a depth of 22 feet of water; that for the next 5.3 miles it is 202 feet wide on the bottom and 290 feet wide at the water line, with a minimum depth of 22 feet of water; for the next 14.95 miles it is 160 feet wide on the bottom and 162 feet wide at the water line, with 22 feet depth of water, the same being cut through solid rock and glacial drift; for the next 2 miles its minimum [fol. 30] width is 160 feet at the bottom and it is irregular in width from there on, varying from 160 to 500 feet in width, with a minimum depth of 22 feet and maximum depth of 24 feet.

At this point there is a lock 130 feet long and 22 feet wide and 12 feet over mitre sills. Alongside this lock, there is a reservation for a lock of ample capacity to accommodate the largest lake-going vessels. For the next one mile, running southerly from said lock, the channel is 160 feet wide with a minimum depth of 19.7 feet; and for the next mile it is 160 feet wide with a minimum depth of 10 feet. That upon the construction of a large lock, provided for as aforesaid, the largest lake-going vessels will be able to pass through this channel from Lake Michigan to the City of Joliet. That the total amount expended by this defendant so far in the construction, operation and maintenance of said waterway to September 1, 1907, exceeded the sum of $54,500.000.00, which said sum, taken in connection with the amount theretofore expended by the State of Illinois in the construction and maintenance of the Illinois and Michigan Canal, exceeds, so this defendant is informed and believes, and upon such information charges the fact to be, the sum of $61,037,254.79.

Seventeenth. This defendant, further answering, says that after the turning in of the waters as aforesaid into the waterway constructed by this defendant as aforesaid, the City of Chicago, lying wholly within the confines of the territory embraced by this defendant, has so reconstructed and built its sewerage system, by a system of intercepting sewers and trunk sewers, as to carry the sewage of that portion

[fol. 31] of said city north of 87th street and south of Fullerton avenue into said channel, thus preventing the discharge thereof into Lake Michigan as the same had been wont theretofore to do and, in this manner, the said city has prevented the pollution of Lake Michigan and partially protected the water supply of said city, which is procured from said lake through water tunnels and intakes extending out a distance of four miles into the lake. The location of the intakes through which the City of Chicago obtains its water from Lake Michigan are represented and shown upon Exhibits "A" and "D," as thereon marked and indicated; and the territory within said city which is now discharging into this defendant's channel and waterway is represented upon "Exhibit D" by that space colored pink; that there has been constructed by the City of Chicago a trunk sewer or conduit from a point near the intersection of the shore line of Lake Michigan with 39th street westward to the south fork of the south branch of the Chicago river, through which said trunk sewer or conduit water from said Lake is forced by means of a pumping system, with a maximum capacity of said trunk sewer or conduit of 120,000 cubic feet per minute.

Eighteenth. This defendant, for further answer, says that the sewage from that portion of the territory of this defendant lying south of 87th street, and embracing the towns and territories as represented and shown upon "Exhibit D," still discharges into Lake Michigan, either directly or through the Calumet river; that the same pollutes the waters of the said lake and is a constant menace to the health of the people of said district, by reason of the fact that [fol. 32] it contaminates the waters of said lake in proximity to and around and about the so-called Hyde Park or 68th street intake, through which said intake a large proportion of the water supplying the inhabitants of the City of Chicago, and other municipalities within this defendant, is obtained.

This defendant is informed and believes, and upon such information charges the fact to be, that the water mains of the City of Chicago are so interdependent that the water entering any of the same may find its way into any and all portions of said city, and that the population of any one of the intakes of said city does or may pollute the water supply of said entire city and in this manner menaces and threatens the health and welfare of all the people of said community; that there is being discharged into said Lake Michigan the sewage of substantially 200,000 people residing south of said 87th street; that within said territory there are populous and rapidly growing cities, to wit, South Chicago, Pullman, West Pullman, Kensington and Harvey, together with several smaller towns and municipalities and a considerable portion of the City of Chicago.

Nineteenth. This defendant, further answering, says that it is for the purpose of protecting the water supply of its inhabitants from contamination by the sewage of the people living south of said 87th street, and for the purpose of complying with the duty resting upon it by the several laws of the State of Illinois, that it proposes to construct and maintain a waterway or channel, the construction of

which is sought to be enjoined by the bill of complaint herein; that [fol. 33] the authority of this defendant to construct said waterway or channel, and the purposes to be served by the construction and maintenance thereof, and the duty resting upon this defendant to construct the same, all fully appear from the several acts of the State of Illinois heretofore referred to. The said proposed channel, when completed, will be located as represented and shown on Exhibits "B" and "C"; that it will be substantially 21 miles in length, measuring from the eastern shore line of Lake Calumet along the line of said proposed waterway or channel to the connection thereof with the main channel at Sag; that said defendant proposes to construct and maintain a channel of the size, character and dimensions as follows, to wit: Beginning at the easterly termination thereof at a point indicated as the "Forks" in "Exhibit C" hereto attached, the outlet of Lake Calumet as shown on said exhibit, will be dredged 14 feet so as to give a depth to said outlet of 22 feet in place of the present depth of 8 feet. The bottom of said outlet as so dredged will have a width of 72 feet; the width at the water line will be not less than 160 feet. Running thence westerly through the southern portion of Lake Calumet one mile, dredging so as to create a channel having a width at the bottom of not less than 72 feet and a depth of not less than 20 feet, in place of the present depth of 4½ feet in said portion of Lake Calumet. From the westerly shore of Lake Calumet to a point on the Little Calumet river near 129th street one and one-quarter miles, the channel will be constructed 29 feet in depth with a width of 72 feet on the bottom and 160 feet at the water line, and depth of water of 22 feet. From the intersection of said channel with said Little [fol. 34] Calumet river, the channel of said river will be utilized as a section of said proposed waterway for a distance of approximately two miles to the confluence thereof with Stony Creek. Said section of said river so utilized will be dredged 12½ feet, giving a depth of water therein of 20 feet in place of the present depth of water therein of 10 feet. The width of said section of said river as so dredged at the bottom thereof will be 72 feet and the width thereof at the water line will be not less than 160 feet, or an average of 10 feet greater than the present average width of said section of said river. From the confluence of Stony Creek and the Little Calumet river, said channel will run in a westerly direction for a distance of approximately 16 miles through alternating sections of glacial drift and rock. Through glacial drift sections, said channel will be 72 feet wide at the bottom and 162 feet wide at the surface and 22 feet deep. Through rock sections, said waterway or channel will be 93 feet wide, with vertical sides, and depth of 22 feet. There will be constructed at the confluence of Stony Creek and the Little Calumet river a guard lock and controlling works through and by means of which this defendant will be able to control absolutely the quantity of water permitted to enter said channel and flow westwardly therethrough; that by the operation of the controlling works of this defendant it will be possible to prevent the flow of any water westwardly through said channel; that the maximum amount of water that it will be able

to flow westwardly through said channel will not exceed 4,000 cubic feet per second.

Twentieth. This defendant, further answering, says that upon [fol. 35] the completion of said channel, as proposed, this defendant proposes to flow westwardly through said channel waters sufficient to reverse the flow of the Calumet river in order to carry the sewage discharging therein through said channel and away from Lake Michigan, so that the same will no longer contaminate the water supply of the inhabitants of said district; but that the quantity of water so diverted will only be sufficient to cause a reversal of said flow and to properly dilute said sewage so as to comply with the several laws under which this defendant is incorporated, but that at no time would the amount of water so diverted through said channel exceed the amount of 4,000 cubic feet per second. That the maximum amount of water that can be flowed through the main channel of this defendant westwardly from the confluence of the proposed channel therewith is 840,000 cubic feet per minute; that the amount which this defendant flows therethrough, and will flow therethrough from time to time, will only be such an amount as is required by law for the proper dilution of the sewage of the district; and that the amount that this defendant does now and will thereafter flow, whether said proposed channel be constructed or not, will be said amount sufficient to dilute said sewage; that by the construction and maintenance of said proposed channel, it is not proposed by this defendant to flow any more than sufficient to meet the requirements of law to properly dilute the sewage of the district, which said amount it would be bound by law to flow through its main channel without the construction of the channel complained of by the complainant.

Twenty-first. For a further answer, this defendant says that it ex- [fol. 36] pressly denies that the construction and maintenance of said proposed channel would in any wise affect the levels of the Great Lakes and the channels, harbors and rivers connected therewith; or that it will in anywise injure, interfere with or be to the detriment of the commerce thereon; and this defendant expressly denies that the construction and maintenance of the proposed channel will in any wise affect the navigable capacity of the Little Calumet or Grand Calumet rivers, and alleges that it will not in any wise affect, alter, modify or change said Little Calumet river other than is herein specifically set forth, which this defendant alleges is to the benefit of said river and to the commerce thereon and not to the detriment thereof.

Twenty-second. And, further answering, this defendant says that "Exhibit F," a map or plat attached hereto and made a part hereof, shows in detail the depth, channel width and top width of the Calumet and Little Calumet rivers from Lake Michigan to Stony Creek as the same now exist; that the depth of Calumet river from Lake Michigan to 106th street is 21 feet, with a channel width of 200 feet

and a top width of from 225 to 300 feet; that from 106th street to 110th street said Calumet river has a depth of 20 feet, a channel width of 200 feet and a top width of from 230 feet to 250 feet; that from 110th street to 122nd street said Calumet river has a depth of 21 feet, a channel width of 200 feet and a top width of 250 feet; that from 122nd street to a point known as "Chittenden Bridge," designated upon said "Exhibit F" as Chittenden road, the said Calumet river has a depth of 17 feet, a channel width of 180 feet and a top [fol. 37] width of from 250 to 330 feet; that from said Chittenden bridge to a point shown upon said "Exhibit F" and designated as the "Forks," the said Calumet river has a depth of from 5 feet to 8 feet, a channel width of from 50 feet to 200 feet and a top width of 250 feet; that from the forks aforesaid to a point shown upon said "Exhibit F" and designated as the "Junction," being the confluence of the Grand Calumet and the Little Calumet rivers, the said river has a depth of 8 feet, a channel width of 60 feet and a top width of 112 feet; and that the Little Calumet river from the point designated upon said "Exhibit F" as the "Junction" to the confluence of Stony Creek and said Little Calumet river has a depth varying from 4 feet to 10 feet, a channel width of from 65 feet to 140 feet and a top width of from 105 feet to 270 feet.

Twenty-third. This defendant, further answering, says that upon the completion of the said channel as proposed it will afford navigation for vessels of the said Great Lakes through the Calumet river to its main channel and from thence to the City of Joliet and will be a sufficient and valuable route for commerce, both state and interstate, from Lake Michigan to the City of Joliet; that the construction and maintenance of said channel will be to the interest of the commerce of the Great Lakes and of the Desplaines, Illinois and Mississippi rivers; that all of the waters which this defendant now diverts from Lake Michigan, and which it proposes hereafter to divert through both its main and proposed channel, is discharged by this defendant into the Desplaines river and from thence into the Illinois river and forms through and by said rivers a navigable channel from [fol. 38] Lake Michigan to the Mississippi river and is to the interest of the commerce upon said rivers and to the commerce of the State of Illinois and of the United States; and that the construction and maintenance of the same by this defendant through and by authority of the State of Illinois is in accordance with the declared and express public policy both of the United States and of the State of Illinois, to forever maintain a waterway suitable for navigation connecting the waters of Lake Michigan with the waters of the Illinois and Mississippi rivers.

Twenty-fourth. This defendant further answering says that it is the only body or municipality clothed with authority to provide for the drainage and disposal of the sewage, and the furnishing of outlets for such outlets and sewage, within its corporate limits; that by reason of the laws of the State of Illinois, under and by virtue of which it exists, it is proceeding to dispose of and provide a means

for the disposal of, by a channel and adjuncts thereto, of all the sewage arising within its corporate limits which would otherwise flow into Lake Michigan, thus polluting the water supply of the inhabitants of this defendant; that the powers of this defendant and its authority in the matter of furnishing the outlets for the sewage and drainage of its territory, and the manner thereof, are circumscribed by the laws pursuant to which it is organized and existing; and that there is no other lawful method of disposing of the sewage and drainage of the territory comprised within the corporate limits of this defendant other or different than by the construction of channels and adjuncts thereto; and that the proposed channel complained of [fol. 39] by the complainant herein is a part of the only plan for the disposal of such sewage and the furnishing of outlets therefor which this defendant is empowered to carry out.

And this defendant, further answering, denies that the complainant is entitled to the relief, or any part thereof, in the said bill of complaint demanded, and prays the same advantage of this answer as if it had pleaded or demurred to the said bill of complaint; and prays that it be dismissed with its reasonable costs and charges in this behalf most wrongfully sustained.

The Sanitary District of Chicago, by John C. Williams, Its Solicitor. E. C. Lindley, Of Counsel.

[fol. 40] EXHIBIT G TO ANSWER

An ordinance for the establishment of a right of way for a channel from the westerly reserve line of the Illinois and Michigan Canal in Section 14, T. 37 N., R. 11 E., of the 3rd P. M., to the north and south center line of Section 32, T. 37 N., R. 14 E., of the 3rd P. M., and for the construction of a channel from the center line of the main drainage channel of the Sanitary District of Chicago, in said Section 14, T. 37 N., R. 11 E., of the 3rd P. M., to said center line of Section 32, T. 37, N., R. 14 E., of the 3rd P. M., in Cook County, Illinois.

Be it ordained by the Board of Trustees of the Sanitary District of Chicago:

Section 1. That there be and is hereby laid out and established a route for a channel and outlet for the Sanitary District of Chicago, which channel is hereby directed to be constructed and maintained, together with the necessary additions thereto within the limits, of said route, which said route, shall be over, upon and through certain lands lying in the County of Cook and State of Illinois, and is described as follows, to-wit:

Beginning at the point of intersection of the westerly reserve line of the Illinois and Michigan Canal with the north and south center line of Section 14, T. 37 N., R. 11 E. of the 3d P. M.; running thence

south along said north and south center line of said Section 14 to a point 1,057.5 feet north of the center of said Section 14; thence southeasterly to the point of intersection of the east line of said Section 14 with the northerly reserve line of the Sag Feeder; thence along the northerly reserve line of said Sag Feeder to the north and south center line of Section 13, T. 37 N., R. 11 E. of the 3d P. M.; thence southeasterly to a point in the east line of Section 21, T. 37 N., R. 12 E. of the 3d P. M. 685.3 feet south of the northeast corner of said [fol. 41] Section 21; thence southeasterly to a point in the east line of Section 23, T. 37 N., R. 12 E. of the 3d P. M. 2,152.6 feet south of the northeast corner of said Section 23; thence southeasterly to the northwest corner of Section 29, T. 37 N., R. 13 E. of the 3d P. M.; thence east to the northwest corner of the N. E. ¼ of the N. W. ¼ of said Section 29; thence south along the west line of said N. E. ¼ of the N. W. ¼ of said Section 29 for a distance of 400 feet; thence southeasterly to a point in the north and south center line of said Section 29, 970 feet south of the north line of said Section 29; thence southeasterly to a point in the north line of the S. W. ¼ of the N. E. ¼ of said Section 29, 740 feet west of the northeast corner of said S. W. ¼ of the N. E. ¼ of said Section 29; thence east to the northeast corner of said S. W. ¼ of the N. E. ¼ of said Section 29; thence south along the east line of said S. W. ¼ of the N. E. ¼ of said Section 29 for a distance of 430 feet; thence southeasterly to a point in the east and west center line of the N. E. ¼ Section 33, T. 37 N., R. 13 E. of the 3d P. M. 510 feet west of the east line of said Section 33; thence south along said east line of said Section 33 for a distance of 640 feet; thence southeasterly to the northwest corner of the N. E. ¼ of the S. W. ¼ Section 34, T. 37 N., R. 13 E. of the 3d P. M.; thence southeasterly to a point in the north and south center line of said Section 34, 500 feet south of the east and west center line of said Section 34; thence southeasterly to a point in the north and south center line of the S. E. ¼ of said Section 34, 780 feet south of the east and west centre line of said Section 34; thence southeasterly to a point in the east line of said Section 34, 1,753.46 feet north of the southeast corner of said Section 34; thence east to a point in the north and south center line of Section 36, T. 37 N., R. 13 E. of the 3d P. M., 1,753.46 feet north of the south line of said Section 36; thence easterly to the northwest corner of Lot 20, Block 2, in Storz & Rhode's [fol. 42] Sub. of Lots 11, 12, 13 and 14 of Robinson's Subdivision, in the City of Blue Island; thence east along the north line of said Lot 20 to the west line of Lot 24, in said Block 2; thence north along the west line of said Lot 24 to the most northerly corner ther-of; thence southeasterly along the northe-ly line of said Lot 24; thence southeasterly along the northerly line of Lot 25 in said Block 2 for a distance of 40 feet; thence easterly to the north line of the east and west alley in Dornhecker's Sub. of Block 12, Robinson's Addition, in the City of Blue Island; thence east along the north line of said alley across Greenwood Avenue in said City of Blue Island and along the north line of the east and west alley in Dornhecker's Sub. of Block 11, Robinson's Addition to the southeast corner of Lot 1 in said Dornhecker's Sub. of Block 11; thence easterly to the most west-

erly corner of Lot 9, Block 10, Superior Court partition of Block 10, etc., in Robinson's Addition, in the City of Blue Island; thence northeasterly along the northwesterly line of said Lot 9 to the most northerly corner thereof; thence southeasterly along the northeasterly line of said Lot 9 to the most easterly corner thereof; thence northeasterly along the southeasterly lines of Lots 8 and 7 in said Block 10, to the most easterly corner of said Lot 7; thence easterly to the most northerly corner of Lot 7 in Bartelme's Sub. of Block 9, Robinson's Addition, in the City of Blue Island; thence southeasterly along the northeasterly line of said Lot 7 to the most easterly corner thereof; thence northeasterly to the northwest corner of Lot 4, Block 57, in Portland, a Subdivision in the City of Blue Island; thence east along the north line of said Lot 4, across Rexford Street, and along the north line of Lot 6, Block 56, in said City of Blue Island, to the west line of Lot 8 in said Block 56; thence north along the west line of said Lot 8 to the east and west center line of said Block 56; thence east along the east and west center line of said Block 56 across Gregory Street, along the east and west center line of Block 55, across [fol. 43] Wabash Street, along the east and west center line of Block 54, across Chatham Street, along the east and west center line of Block 53, and across Chicago Street, all in the City of Blue Island, to the east line of said Chicago Street; thence north along the east line of said Chicago Street to the southeast corner of said Chicago Street and Fulton Street; thence east along the south line of said Fulton Street and across State Street to the southeast corner of Fulton Street and State Street; thence north across said Fulton Street to the southwest corner of Keiffer's Addition to Blue Island; thence east along the south line of said Keiffer's Add. to Blue Island; to the west line of the north and south alley in said Keiffer's Add. to Blue Island; thence north along the west line of said alley to the northeast corner of Lot 12, in said Keiffer's Add.; thence east -cross said alley and along the north line of Lot 17 in said Keiffer's Addition to the west line of Robinson Street, in said City of Blue Island; thence north along said west line of Robinson Street to the south line of the east and west alley in said Keiffer's Addition; thence east across said Robinson Street to the most northerly corner of Block 49, in the City of Blue Island; thence southeasterly along the northeasterly line of said Block 49 to the most easterly corner of Lot 4 in said Block 49; thence easterly across Girard Street to the most southerly corner of Block 25 in said Portland, a Subdivision in said City of Blue Island; thence easterly to the southwest corner of Block 26, in said Portland, a Subdivision in the Town of Calumet; thence north along the west line of said Block 26 to the east and west center line thereof; thence east along the east and west center line of said Block 26 to the east line thereof; thence easterly across Colonade Row, in said Town of Calumet, to the Northwest corner of Lot 7, Block 27, in said Town of Calumet; thence east along the north line of said Lot 7 to the west line of Lot 4 in said Block 27; thence north along the west line of said Lot [fol. 44] 4 to the north line of said Block 27; thence east along the north line of said Block 27 and across Tremont Avenue to the southeast corner of Summit Street and Tremont Avenue; thence north

across Summit Street to the north line of said Summit Street; thence east along the north line of said Summit St. and across Exeter Street to the southwest corner of Block 6 in said town of Calumet; thence north along the west line of said Block 6 to the east and west center line thereof; thence east along said east and west center line of said Block 6 across Concord Street and along the north lines of Lots 6, 7 and 8, Block 5, in said Town of Calumet, to the west line of Lot 2 in said Block 5; thence north along the west line of said Lot 2 to the north line of said Block 5; thence east along the north line of said Block 5 across Portland Street to the northwest corner of Block 4 in said Town of Calumet; thence east along the north line of said Block 4 for a distance of 120 feet; thence northeasterly to a point in the west line of Section 31, T. 37 N., R. 14 E. of the 3d P. M. 160 feet north of the east ¼ corner of said Section 31; thence northeasterly to a point in the east line of the W. ½ of the S. W. ¼ of the N. W. ¼ Section 32, T. 37 N., R. 14 E. of the 3d P. M., 300 feet north of the east and west center line of said Section 32; thence east to a point in the north and south center line of said Section 32, 300 feet north of the center of said Section 32; thence south along the north and south center line of said Section 32 to the southeast corner of Block 159, in the Town of Calumet; thence southwesterly along the southeasterly line of said Block 159 to the most southerly corner thereof; thence northwesterly to the most southerly corner of Block 37, in the Town of Calumet; thence northwesterly along the southwesterly line of said Block 37, to the most westerly corner thereof; thence northwesterly to the most southerly corner of Block 36, in the Town of Calumet; thence westerly to the southeast corner of Block 38, [fol. 45] in the Town of Calumet; thence west along the south line of Block 38, across Cass Street, along the south line of Block 39, across Illinois Street, and along the south line of Block 40, all in the Town of Calumet, to the southwest corner of said Block 40; thence south across Randolph Street to the northwest corner of Block 73, in said Town of Calumet; thence west across Berrien Street to the northeast corner of Block 72 in said Town of Calumet; thence west along the north line of said Block 72 to the northwest corner thereof; thence westerly across Chadwick Street to the northeast corner of Lot 4, Block 71, in said Town of Calumet; thence south along the east line of said Lot 4 to the southeast corner thereof; thence west along the south line of said Lot 4 to the east line of Lot 6 in said Block 71; thence south along the east line of said Lot 6 to the southeast corner thereof; thence west along the south line of Lots 6, 7, 8, 9 and 10 in said Block 71 to the west line of said Block 71; thence south along the west line of said Block 71 to the southwest corner thereof; thence west across Duane Street and along the south line of Block 70 in said Town of Calumet to the southwest corner thereof; thence south across Sycamore Street to the northwest corner of Block 82, in the Town of Calumet; thence west across Portland Street to the northeast corner of Block 83, in said Town of Calumet; thence south along the east line of said Block 83 to the east and west center line thereof; thence west along said east and west center line, across Concord Street and along the east and west line of Block 45, in said

Town of Calumet, to the east line of said Block 45; thence south along the east line of said Block 45 to the southwest corner thereof; thence across Exeter Street and along the south line of Block 46, in said Town of Calumet, to the southwest corner thereof; thence south across Elm Street to the northwest corner of Block 88, in said Town of Calumet; thence west across Tremont Street and along the north line of Block 89, in said Town of Calumet, to the northwest corner [fol. 46] thereof; thence south along the west line of said Block 89 to the east and west center line thereof; thence west across Colonade Row and along the east and west center line of Block 90, in said Portland, a Subdivision in the Town of Calumet to the west line thereof; thence west to the point of intersection of the east and west center line of Block 91, in said Portland, a Subdivision in the City of Blue Island, with the east line of said Block 91; thence west along the east and west center line of said Block 91 to the west line thereof; thence south along the west line of said Block 91 to the southwest corner thereof; thence west across Robinson Street and along the south line of Block 92, in the City of Blue Island, to the southwest corner thereof; thence southwesterly to the northeast corner of Lot 4, Block 98, in the City of Blue Island; thence west along the north line of said Block 98, across Chicago Street, along the north line of Block 97, across Chatham Street, and across the north line of Rexford & Bellamy's re-sub. of Block 96, all in the City of Blue Island, to the northwest corner of said Rexford & Bellamy's re-sub.; thence south along the west line of said Rexford & Bellamy's re-sub. to the north line of the alley in said Rexford & Bellamy's re-sub.; thence westerly across Wabash Street to the point of intersection of the east and west center line of Block 95, in said City of Blue Island, with the east line of same; thence west along said east and west center line of said Block 95, across Gregory Street, and along the east and west center line of Block 94, in said City of Blue Island, to the east line of Lot 5 in said Block 94; thence north along the east line of said Lot 5 to the northeast corner thereof; thence west along the north line of said Lot 5 to the west line of said Block 94; thence westerly across Rexford Street to the northeast corner of Lot 2, in re-subdivision of Block 93, in said Portland, a subdivision in said City of Blue Island; thence west along the north line of said Lot 2 to the east line [fol. 47] of Lot 1, Block 17, in Assessor's Division of Blocks 17, 21, 22 and 25, in Robinson's Addition; thence south along said east line of said Lot 1 to the southeast corner thereof; thence east along the south line of said Lot 1 to the southwest corner thereof; thence northwesterly across Western Avenue, in the City of Blue Island, to the northeast corner of Lot 2, in subdivision of Block 18, Robinson's Addition; thence west along the north line of said Lot 2 to the northwest corner thereof; thence northwesterly to the northeast corner of Lot 2, Block 2, in Owner's Sub. of Block 20, and Lot 2, Block 19, in Robinson's Addition; thence west along the north line of said Lot 2 to the northwest corner thereof; thence westerly across Ann Street to the northeast corner of Lot 3, Block 1, in Owners' Sub. of Block 20, and Lot 2, Block 19, in Robinson's Addition; thence west along the north line of said Lot 3 across the north and south alley in said

Block 1, and along the north line of Lot 22 in said Block 1 to the west line of said Block 1; thence westerly to the northeast corner of Lot 6, in subdivision of Lot 6, Robinson's Subdivision, in City of Blue Island; thence westerly along the south line of Kott Street, across the north and south alley to the northwest corner of Lot 3 in said subdivision of Lot 6; thence westerly to the southeast corner of Block 4, Storz & Rhode's Subdivision of Lots 11, 12, 13 and 14 of Robinson's Subdivision; thence west along the south line of said Block 4, across Vine Avenue and along the south line of Block 3 in said Storz & Rhode's Sub. to the southwest corner thereof; thence westerly to a point in the north and south center line of Section 36, T. 37 N., R. 13 E. of the 3d P. M., 1093.46 feet north of the S. ¼ corner of said Section 36; thence west to a point in the west line of said Section 36, 1,093.46 feet north of the southwest corner of said Section 36; thence westerly to the southeast corner of Lot 46, Block 2; thence westerly along the south line of said Lot 46, across the alley [fol. 48] and along the south line of Lot 87, Block 2, across Sawyer Street, along the south line of Lot 168, Block 3, across the alley and along the south line of Lot 208, in said Block 3, across Spaulding Avenue, along the south line of Lot 288, Block 6, across the alley, along the south line of Lot 330 in said Block 6, across Turner Avenue along the south line of Lot 408, Block 7, across the alley, along the south line of Lot 449 in said Block 7 to the west line of said Block 7, all in Jas. J. Smith & Co.'s Second Addition to Clairmont, Lot 3 of Engelland's Sub. of E. ½, S. E. ¼, Sec. 35, T. 37 N., R. 13 E. of the 3d P. M.; thence westerly to a point in the west line of the East ½ of the S. E. ¼, Sec. 35, T. 37 N., R. 13 E. of the 3d P. M. 1,093.46 feet north of the south line of said Section 35; thence west to a point in the west line of said Section 35, 1,093.46 feet north of the southwest corner of said Section 35; thence northwesterly to the northwest corner of the S. ½ of the S. E. ¼, Section 34, T. 37 N., R. 13 E. of the 3d P. M.; thence north along the north and south center line of said Section 34 to a point 1,500 feet north of the S. ¼ corner of said Section 34; thence northwesterly to a point in the east line of the N. W. ¼ of the S. W. ¼ of said Section 34, 660 feet north of the east and west center line of said S. W. ¼ of said Section 34; thence northwesterly to the W. ¼ corner of said Section 34; thence northwesterly to a point in the north and south center line of the N. E. ¼ Section 33, T. 37 N., R. 13 E. of the 3d P. M., 2,000 feet south of the north line of said Section 34; thence northwesterly to a point in the north and south center line of the S. E. ¼ of Section 29, T. 37 N., R. 13 E. of the 3d P. M. 370 feet south of the east and west center line of said Section 29; thence northwesterly to a point in the east and west center line of said Section 29, 780 feet east of the center of said Section 29; thence west to the center of said Section 29; thence north along the north and south center line of said Section 29 for a distance of 540 feet; thence north- [fol. 49] westerly to a point in the south line of the N. W. ¼ of the N. W. ¼ of said Section 29; 900 feet east of the west line of said Section 29; thence west to the southwest corner of the N. W. ¼ of the N. W. ¼ of said Section 29; thence north on the west line of said

Section 29, 301 feet; thence northwesterly to a point in the west line of Section 24, T. 37 N., R. 12 E. of the 3d P. M. 3,162.4 feet south of the north line of said Section 24; thence northwesterly to a point in the west line of Section 22, T. 37 N., R. 12 E. of the 3d P. M. 1,702.7 feet south of the north line of said Section 22; thence northwesterly to a point in the south line of Section 17, T. 37 N., R. 12 E. of the 3d P. M. 1,441.9 feet east of the southwest corner of said Section 17; thence west to said southwest corner of said Section 17; thence north on the west line of said Section 17 for a distance of 261.8 feet; thence northwesterly to a point in the east and west center line of Section 14, T. 37 N., R. 11 E. of the 3d P. M., 200 feet east of the center of said Section 14; thence west along the east and west center line of said Section 14 to the westerly reserve line of the Illinois and Michigan Canal; thence northeasterly along said westerly reserve line of the Illinois and Michigan Canal to the point of beginning.

Section 2. That a channel be constructed by the Sanitary District of Chicago, the center line of which shall begin at the center line of the Main Channel of the Sanitary District of Chicago in Section 14, T. 37 N., R. 11 E. of the 3d P. M., in Cook County, Illinois, at a point 807.55 feet (measured along the center line of said Main Channel), distant from the westerly line of said Section 14; running thence south 84 degrees east to the westerly reserve line of the Illinois and Michigan Canal; thence along and upon the center line of the above established route. Said channel shall be constructed to a width of 90 feet at the bottom, with vertical sides—where the same is con-[fol. 50] structed through rock and said channel shall be constructed to a width of 70 feet on the bottom, *which* side slopes of three vertical to five feet horizontal, where the same is constructed through earth, and said channel shall be constructed to a depth and on a grade sufficient to insure a flow of 22 feet of water.

Section 3. The Finance Committee of the Board of Trustees of the Sanitary District of Chicago is hereby authorized and directed to negotiate for and to purchase for and on behalf of the Sanitary District of Chicago, upon such terms as said Finance Committee may deem just, any and all property, right of way and privilege within said route for said channel, as described in this ordinance; and in the event that said Finance Committee is unable to agree with any of the owners or parties in interest for any of said property or their interests therein, then, upon direction of said Finance Committee, the Attorney of the District shall institute proceedings in such court as he may deem proper for the condemnation of any such property, right of way or privilege as said Finance Committee is unable to acquire by purchase or otherwise.

Section 4. That attached hereto and made a part of this ordinance is a plat entitled "Sanitary District of Chicago, Ordinance Map for the Right of Way of the Calumet-Sag Channel, from the westerly reserve line of the Illinois and Michigan Canal, in Section 14, T. 37 N., R. 11, E. of the 3d P. M.," to the north and south center line of

Section 32, T. 37 N., R. 11, E. of the 3d P. M., upon which said plat or map is shown the boundary lines of the route for said channel, said boundary lines being indicated in red on said plat and marked "Ordinance Boundary Line."

Section 5. That an ordinance entitled "An ordinance for the establishment of a right of way for a channel from the westerly reserve line of the Illinois and Michigan Canal in Section 14, T. [fol. 51] 37 N., R. 13, E. of the 3d P. M., to the east line of the W. ½ of the N. E. ¼ of Section 23, T. 37 N., R. 13, E. of the 3d P. M., in Cook County, Illinois, and providing for the construction of such channel, passed May 4, 1904 (see pages 9908 and 9909 of Proceedings; and an ordinance entitled "An ordinance providing for the construction of a channel from the center line of the Main Channel of the Sanitary District of Chicago in Section 14, T. 37 N., R. 13, E. of the 3d P. M., to the east line of the west half of the N. E. ¼ of Section 23, T. 37 N., R. 13, E. of the 3d P. M., in Cook County, Illinois," passed July 20, 1904 (see pages 10056 and 10057 of Proceedings) be, and the same are hereby repealed.

Section 6. This ordinance shall be in force from and after its passage.

[fol. 52] EXHIBIT H TO ANSWER

An ordinance for the establishment of a right of way from the easterly end of the right of way established by the Board of Trustees December 7, 1904, to the north and south center line of section 25, T. 37 N., R. 14 E., of the 3rd P. M. and for the construction and maintenance of a channel from the north and south center line of frac. section 32, T. 37 N., R. 14 E., of the 3rd P. M. north of Indian boundary line to the north and south center line of sec. 25, T. 37 N., R. 14 E., of the 3rd P. M.

Be it ordained by the Board of Trustees of the Sanitary District of Chicago.

Section 1. That there be and is hereby laid out and established a route for a channel and outlet for the Sanitary District of Chicago, which channel is hereby directed to be constructed and maintained, together with the necessary additions thereto within the limits of said route, which said route shall be over, upon and through certain lands lying in the County of Cook and State of Illinois and is described as follows, to-wit:

Beginning at a point in the north and south center line of frac. sec. 32, T. 37 N., R. 14 E. of the 3rd P. M. north of Indian boundary line, 300 feet north of the center of said frac. sec. 32; thence northeasterly to a point in the west line of the W. ½ of the W. ½ of the N. E. ¼ of said frac. sec. 32, 680 feet north of the south line of said N. E. ¼ frac. sec. 32; thence northeasterly to a point in the west line of the E. ½ of said N. E. ¼ frac. sec. 32, 860 feet north of the

south line of said N. E. ¼ frac. sec. 32; thence northeasterly to a point in the west line of the east half of the E. ½ of said N. E. ¼ frac. sec. 32, 910 feet north of the south line of said N. E. ¼ frac. sec. 32; thence northeasterly to a point in the west line of frac. sec. [fol. 53] 33, T. 37 N., R. 14, E. of the 3rd P. M. north of the Indian boundary line, 925 feet north of the east and west center line of said frac. sec. 33; thence southeasterly to a point in the Indian boundary line 660 feet distant in southwesterly direction from the intersection of the north line of frac. sec. 33, T. 37 N., R. 14 E. of the 3rd P. M. south of Indian boundary line; thence easterly to a point in the easterly line of the right of way of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway Co. 530 feet in southeasterly direction distant from said north line of frac. sec. 33; thence northeasterly to a point in said north line of said frac. sec. 33, 500 feet west of the N. E. corner of the N. W. ¼ of said frac. sec. 33; thence northeasterly to a point in the west line of the S. E. ¼ frac. sec. 28, T. 37 N., R. 14 E. of the 3rd P. M. south of Indian boundary line 760 feet north of the S. W. corner of said S. E. ¼ frac. sec. 28; thence northeasterly to the N. W. corner of lot 1, County Clerk's division of S. E. ¼ frac. sec. 28, T. 37 N., R. 14 E. of the 3rd P. M. south of Indian boundary line; thence southeasterly and easterly along the southerly line of 127th street to its intersection with the westerly line of the right of way of the Illinois Central Railroad Co.; thence northeasterly to a point in the east line of frac, sec. 27, T. 37 N., R. 14 E. of the 3rd P. M. south of Indian boundary line 2,030 feet north of the S. E. corner of said frac. sec. 27; thence north along the east line of said frac. sec. 27 to its intersection with the east and west center line of said frac. sec. 27; thence southeasterly to a point 1,321.24 feet west and 1,545 feet north of the S. E. corner of the S. W. ¼ sec. 25, T. 37 N., R. 14 E. of the 3rd P. M.; thence northeasterly to a point in the north and south center line of said section 25, 1,650 feet north of said S. E. corner of said S. W. ¼ sec. 25; thence south along said north and south center line of said sec. 25 for a distance of 660 feet; thence southwesterly to a point 875 [fol. 54] feet north and 1,321.24 feet west of said S. E. corner of said S. W. ¼ sec. 25; thence south on a line 1,321.24 feet west of and parallel to said north and south center line of said Sec. 25, to the south line of said sec. 25; thence westerly along the south line of said sec. 25 and the south line of sec. 26, T. 37 N., R. 14 E. of the 3rd P. M. to the easterly line of the right of way of the Michigan Central Railroad Co.; thence northwesterly along said easterly line of the right of way of the Michigan Central Railroad Co. for a distance of 1,680 feet; thence southwesterly to the S. W. corner of frac. sec. 27 T. 37 N., R. 14 E. of the 3rd P. M. south of the Indian boundary line; thence southwesterly to a point in the easterly line of the right of way of the Pittsburgh, Cincinnati, Chicago & St. Louis Railway Co., 1,140 feet in northwesterly direction distant from the north and south center line of frac. sec. 33, T. 37 N., R. 14 E. of the 3rd P. M. south of Indian boundary line; thence westerly to the point of intersection of the east and west center line of frac. sec. 32,

T. 37 N., R. 14 E. of the 3rd P. M. north of the Indian boundary line with said Indian boundary line; thence along said east and west center line of frac. sec. 33 to the west line of said frac. sec. 33; thence westerly along the south line of the N. E. ¼ frac. sec. 32, T. 37 N., R. 14 E. of the 3rd P. M. north of Indian boundary line to the east line of the W. ½ of the W. ½ of the N. E. ¼ of said frac. sec. 32; thence southwesterly to a point in the north and south line of said frac. sec. 32, said point being the southeast corner of block 159 in the town of Calumet; thence north along said north and south center line of said frac. sec. 32, to the point of beginning.

Section 2. That a channel be constructed by the Sanitary District of Chicago, the center line of which shall be, approximately, the center line of the above established route. Said channel shall [fol. 55] have a width of seventy-two feet at the bottom and shall be so constructed as to have a depth and grade sufficient to insure a flow of twenty-two feet of water.

Section 3. That attached hereto, and made a part of this ordinance, is a plat entitled "Sanitary District of Chicago. Ordinance Map for the Right of Way of the Calumet-Sag Channel from the North and South Center line of Sec. 32, T. 37 N., R. 14 E. of the 3rd P. M., to the North and South Center line of sec. 25, T. N., R. 14 E. of the 3rd P. M.;" upon which said map or plat is shown the boundary lines of the route for said channel, said boundary lines being indicated in red on said plat and marked "Ordinance Boundary Line."

[File endorsement omitted.]

(Here follow exhibits to answer, marked side folio pages 56, 57, 58, 59, 60, 61, and 62)

[fol. 63] IN THE CIRCUIT COURT OF THE UNITED STATES, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

EXCEPTIONS OF COMPLAINANT TO THE ANSWER OF THE DEFENDANT—Filed June 25, 1908

Now comes the above named complainant and takes its exceptions to the answer of the defendant herein as follows, to-wit:

First. The complainant excepts to the denial contained and purported to be made by said defendant in the second paragraph of said answer, as follows, to-wit:

"This defendant expressly denies that said Calumet river is a navigable river for its entire course, as charged in said bill of com-

SANITARY DISTRICT OF CHICAGO.

MAP SHOWING

SANITARY DISTRICT BOUNDARY

AND THE

CORPORATE LIMITS OF CHICAGO,

JANUARY, 1904.

SCALE OF MILES.

Exhibit "A"
to Answer

AREAS.

SANITARY DISTRICT, ORIGINAL	185.000 Sq. Mls.
NORTH SHORE ADDITION	78.600 DO. DO.
CALUMET ADDITION	94.500 DO. DO.
SANITARY DISTRICT, PRESENT	358.100 DO. DO.
CITY OF CHICAGO	190.638 DO. DO.
SAN. DIST. OUTSIDE OF CHICAGO	167.462 Sq. Mls.

R. 10 E. R. 11 E. R. 12 E. R. 13 E. R. 14 E. R. 15 E.

T. 42 N. T. 41 N. T. 40 N. T. 39 N.

LAKE MICHIGAN

INDIANA

DESCRIPTION OF BOUNDARY.

The Territory or Tract of Land bounded as follows: Beginning at the intersection of the County Line between Lake and Cook Counties, State of Illinois, with the West Shore of Lake Michigan, thence West along said County Line to the N.W. Corner of Sec. 3 T 42 N. R 12 E. of 3rd P.M.; thence South to the S.E. Corner of Sec. 33 T 42 N. R 12 E. of 3rd P.M.; thence East to the N.W. Corner of Sec. 12 T 41 N. R 12 E. of 3rd P.M.; thence South to the N.W. Corner of Sec. 24, of said Town and Range; thence East to the N.E. Corner of the W½ of the W½ of said Sec. 25; thence South to the S.E. Corner of the W½ of said Sec. 36 of said Town and Range; thence East to the N.E. Corner of the W½ of Sec. 1 T 40 N. R 12 E. of 3rd P.M.; thence South to the S.E. Corner of the W½ of Sec. 12 of said Town and Range; thence East to the N.W. Corner of Sec. 19 T 40 N. R 13 E. of 3rd P.M.; thence South along Range Line between Ranges 12 and 13 E. of 3rd P.M. to the South Line of Grand Ave.; thence in a Westerly direction along said South Line of Grand Ave. to its intersection with the Township Line between Towns 38 and 39; thence West along the North Line of Sec. 2 T 39 N. R 12 E. of 3rd P.M. to the N.W. Corner of said Sec. 2; thence South along the West Line of Sec. 2 N.W. and 30 to the S.W. Corner of said Sec. 31; thence East along the South Line of Sec. 31 to the N.W. Corner of Sec. 19 T 39 N. R 13 E. of 3rd P.M.; thence South along the Range Line between Ranges 13 and 14 to the Township Line between Towns 37 and 38; thence East along said Township Line to the N.W. Corner of Sec. 3 T 37 N. R 13 E. of 3rd P.M.; thence South to the S.W. Corner of Sec. 9 T 37 N. R 13 E. of 3rd P.M.; thence East along the Boundary Line of Sec. 10 T 37 N. R 13 E. of 3rd P.M. to the S.E. Corner of said Sec. 10; thence East to the S.E. Corner of said Sec. 11; thence North along the East Boundary Line of the State of Illinois to the intersection with the Shore of Lake Michigan; thence along and along the Shore of Lake Michigan to its intersection with the Township Line between Townships 37 and 38 North; thence East to the West Boundary Line of the State of Indiana; thence North to the N.W. Corner of said State of Indiana; thence East along the North Boundary Line of said State of Indiana to the intersection with a Line three miles distant from and parallel to the Shore of Lake Michigan as surveyed at right angles to said Shore; thence Northwesterly along said three mile line to a point opposite the Township Line between 40 and 41 North; thence West to the Shore of Lake Michigan; thence Northwesterly along said Shore Line of Lake Michigan to the place of Beginning.

Exhibit B to Answer

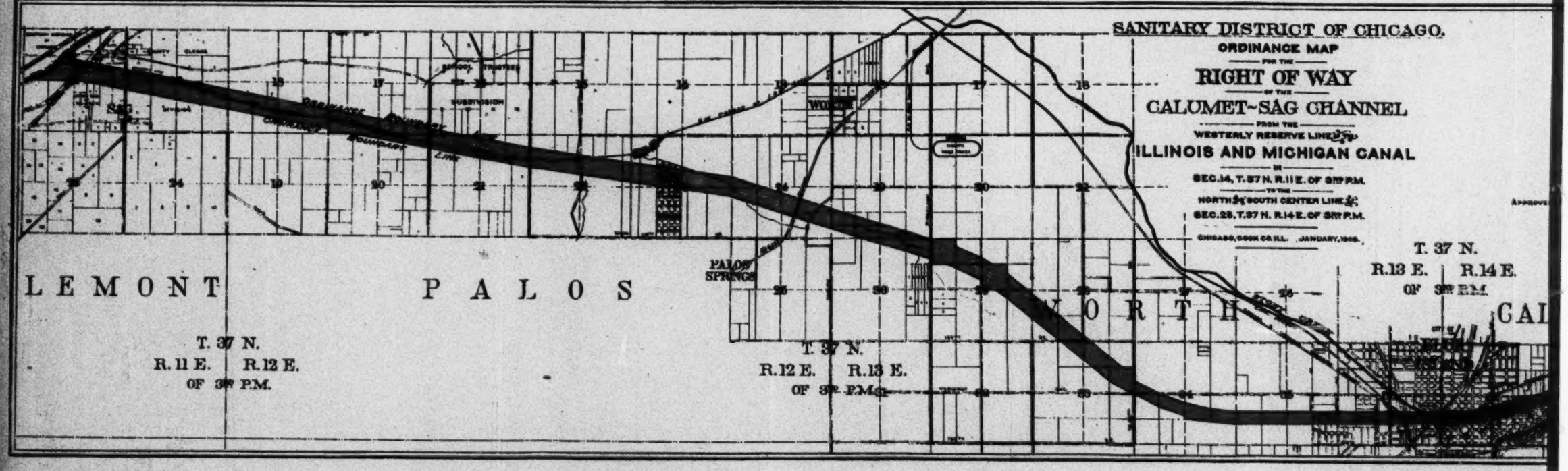
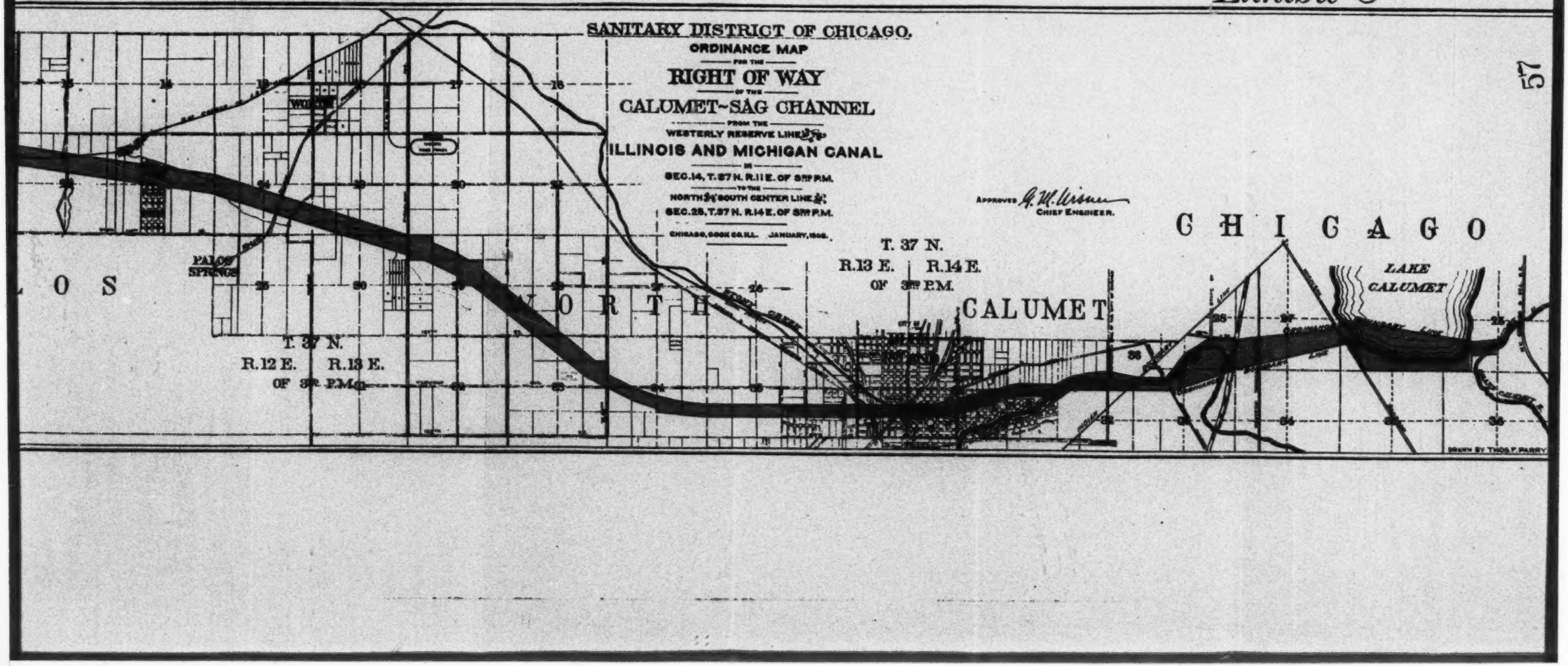
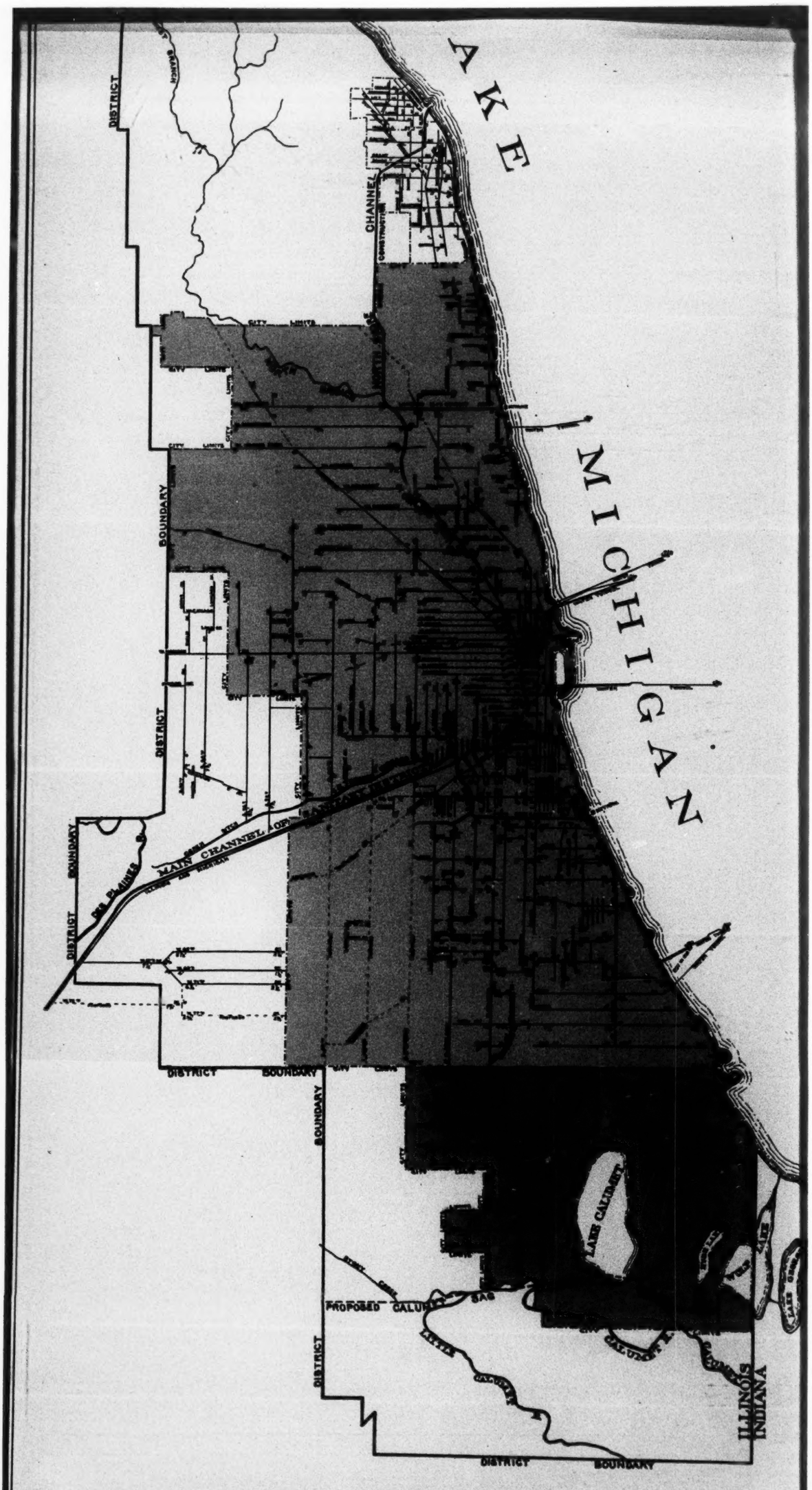


Exhibit B to Answer

Exhibit C





SANITARY DISTRICT OF CHICAGO

MAP OF THE

CITY OF CHICAGO AND VICINITY

SHOWING

MAIN OUTFALL SEWERS.

CHICAGO JAN. 23, 1908.

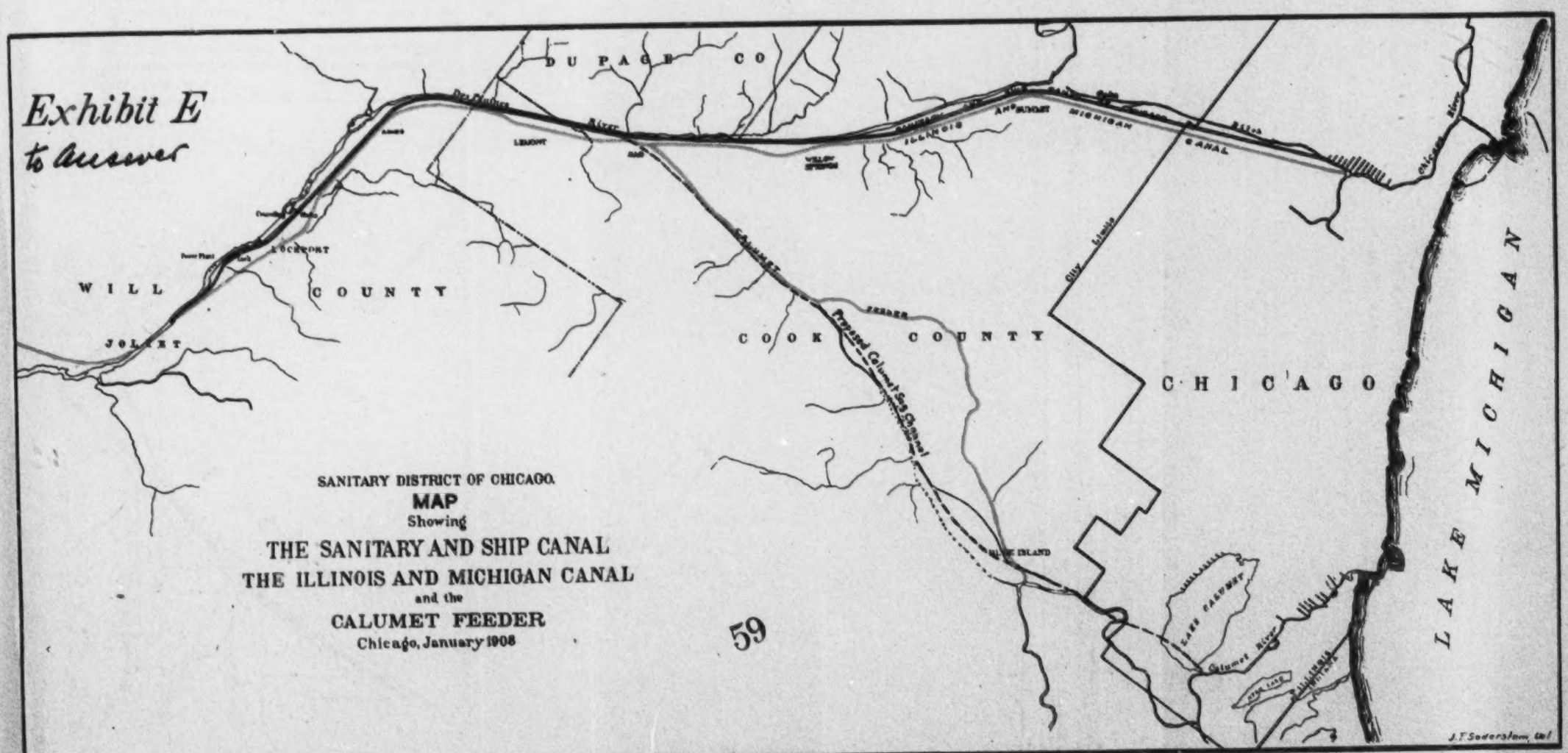
SCALE IN STATUTE MILES.

Territory draining into the Sanitary District Channel colored thus

" " " " Calumet River " "

Exhibit "D"
To Answer

Exhibit E
to Answer



SANITARY DISTRICT OF CHICAGO.

MAP

Showing

THE SANITARY AND SHIP CANAL

THE ILLINOIS AND MICHIGAN CANAL

and the

CALUMET FEEDER

Chicago, January 1908

59

EXHIBIT F.

to Answer

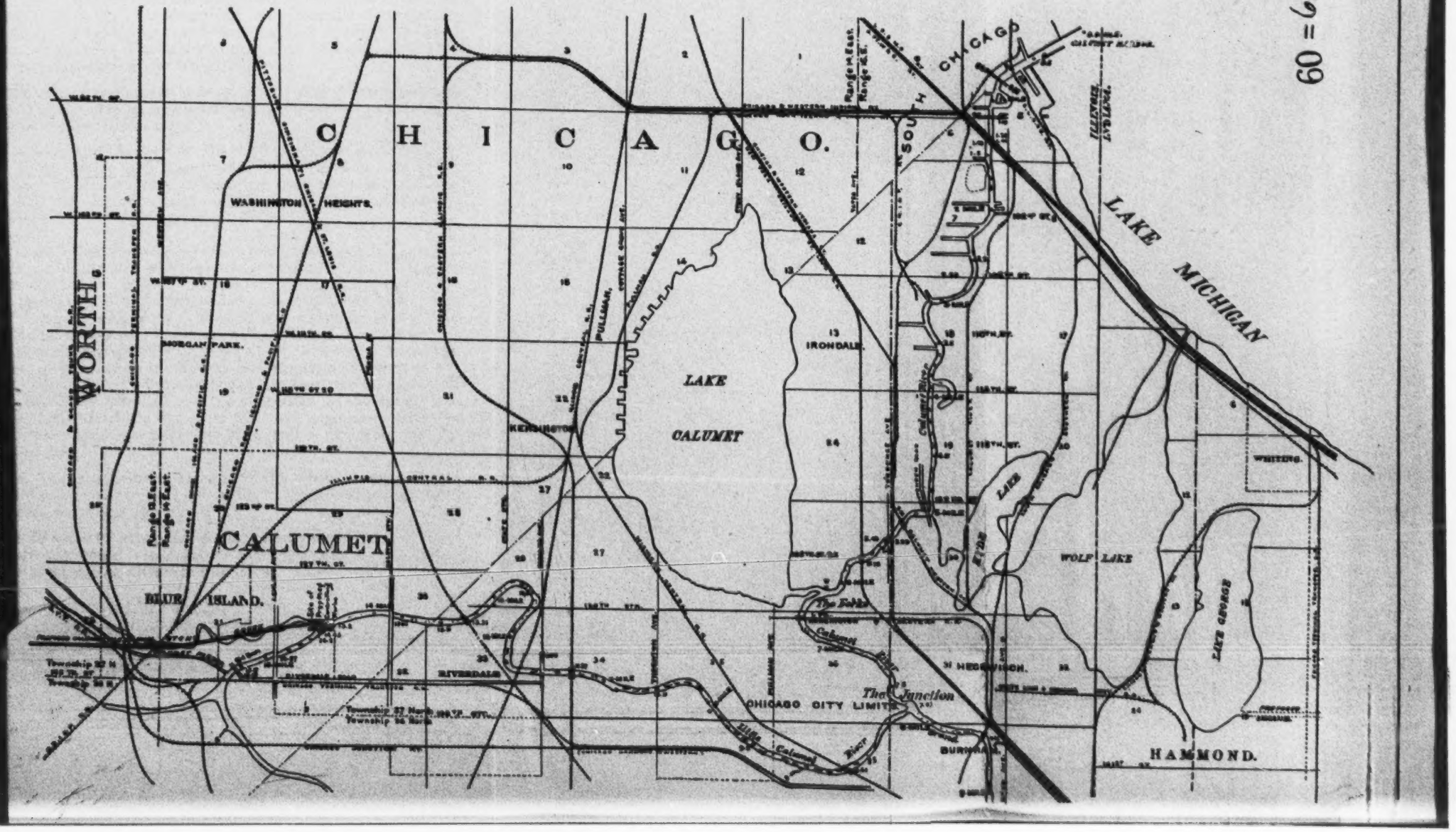
MAP
CALUMET RIVER
from
LAKE MICHIGAN TO JUNCTION
with
PROPOSED CALUMET SAG CHANNEL

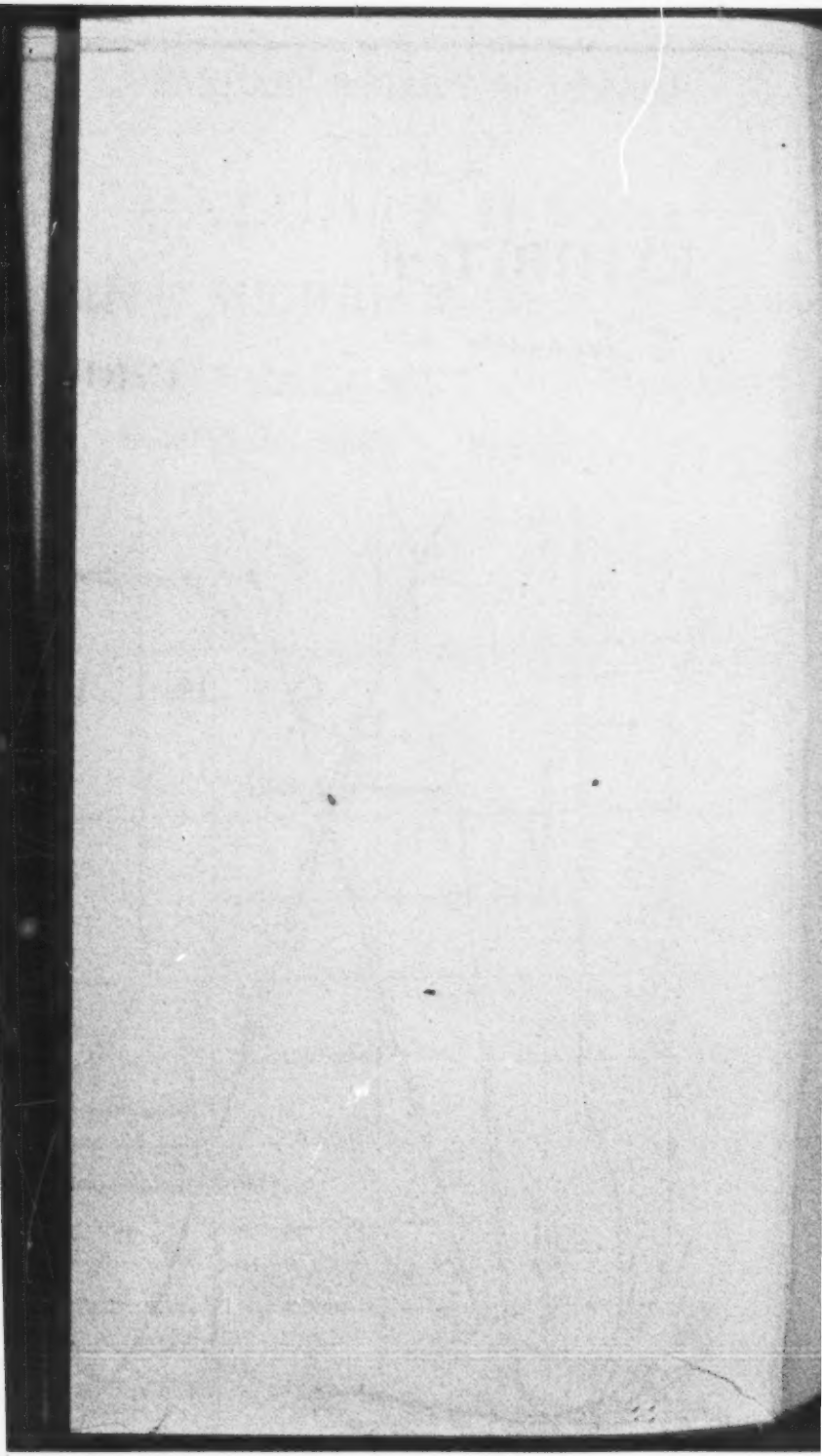
Scale ½ Mile = 1 Inch Chicago, Dec. 1907

Depth and width of the Calumet River

	Depth	Channel width	Top width
From Lake Michigan to 106th St. Bridge	21.00	200.00	225 to 300.00
" 106th St. Bridge to 110th St.	20.00	200.00	230 to 280.00
" 110th St. to 122nd St.	21.00	200.00	250.00
" 122nd St. to Chittenden Bridge	17.00	200.00	250 to 330.00
" Chittenden Bridge to the Forks	9.10 to 22	200.00	250.00
" the Forks to Junction	6.00	80.00	112.00
" Junction to prop. Calumet Sag Channel	6 feet	160 feet	165 to 210.00

60 = 62





plaint, but, on the contrary, alleges that the length, depth and width [fol. 64] of said stream throughout its length is substantially as hereinafter more particularly set forth in the twenty-second paragraph hereof,"

on the ground that the same is evasive and insufficient and does not fully, directly and completely respond to the allegations of the complainant's bill of complaint on the same subject, as contained in the second paragraph of the bill of complaint herein; and on the further ground that it appears from other portions of the answer of said defendant, to-wit, the allegations in the twenty-second paragraph of said answer, together with Exhibit F, annexed to said answer and made a part thereof, that said denial of the navigability of said Calumet river is untrue and that said portion of said answer above set forth is insufficient and impertinent; and on the further ground that it appears from the allegations in the bill of complaint, which are admitted by the defendant, and from the allegations in the answer of the defendant, and from the facts of which the court will take cognizance, that said Calumet river is a navigable river and is navigable water of the United States.

Second. The complainant excepts to the denial contained and purported to be made by said defendant in the second paragraph of its said answer, as follows, to-wit:

"This defendant denies that the Little Calumet river from its mouth to the conjunction thereof with Stony Creek is a navigable river; but, on the contrary, alleges that said river between said points is of the dimensions and capacity hereinafter more fully set forth in the twenty-second paragraph hereof,"

on the ground that the same is evasive and insufficient and does not [fol. 65] fully, directly and completely respond to the allegations of the complainant's bill on the same subject, as contained in the second paragraph of said bill; and on the further ground that it appears from the allegations in the bill of complaint which are admitted in the answer, and by the allegations in said answer, that said denial as to the navigability of said Little Calumet river is untrue, and that said denial is insufficient and impertinent; and on the further ground that it affirmatively appears from the allegations of the bill which are admitted and the allegations in the answer and from the facts of which the court will take cognizance that said Little Calumet river is a navigable river, and is navigable water of the United States.

Third. The complainant excepts to the denial contained and purported to be made by said defendant in the second paragraph of said answer, as follows, to wit:

"This defendant further denies that said portion of said Calumet river above mentioned is traversed by any vessels whatsoever engaged in either interstate or intrastate commerce,"

on the ground that same is evasive and insufficient and does not fully, directly and completely respond to the allegations of the bill of complaint on the same subject; and on the further ground that said defendant does not deny that the Calumet river is traversed by vessels engaged in interstate commerce, but on the contrary the fact that the said Calumet river is traversed by vessels engaged in interstate commerce is substantially admitted by aid answer, and that the facts with reference to the navigability and use of the Calumet river [fol. 66] as admitted by said defendant are sufficient for the purpose of granting the relief sought by the complainant.

Fourth. The complainant excepts to the denial contained and purported to be made by said defendant in the second paragraph of said answer, as follows, to-wit:

"This defendant denies that the Grand Calumet river from its origin in the State of Indiana to its confluence with the Little Calumet is a navigable river within the meaning of that term,"

on the ground that said denial is evasive, indefinite and does not completely respond to the allegations of the bill of complaint on the same subject; and on the further ground that said denial is shown by the other portions of said answer to be untrue.

Fifth. The complainant excepts to the denial contained and purported to be made by said defendant in the third paragraph of its answer, as follows, to-wit:

"This defendant denies the allegations made in paragraph 3 of the bill of complaint herein, that the construction of said waterway or channel as proposed will result in diverting and abstracting from Lake Michigan four thousand cubic feet of water per second,"

on the ground that said denial is evasive, insufficient, does not respond to the allegations of the bill of complaint on the same subject, and is shown by other portions of said answer to be untrue; and on the further ground that it affirmatively appears from other portions of said answer that a large quantity of water will be abstracted from Lake Michigan through the porposed channel, and that said statements in said answer are a practical admission of the allegations of [fol. 67] thebill of complaint as to the diversion of water from Lake Michigan.

Sixth. The complainant excepts to the denial contained and purported to be made by the defendant in the fourth paragraph of said answer, as follows, to wit:

"This defendant expressly denies the allegation contained in paragraph 4 of the bill of complaint herein, that the diversion and abstraction of the waters from Lake Michigan contemplated by this defendant through its proposed channel and waterway will lower the level of the waters of the Great Lakes and will diminish the navigable capacity of said waters or the harbors thereof,"

on the ground that said denial is evasive, insufficient, and does not fully, directly and completely respond to the allegations in the bill of complaint on the same subject, and that it appears from the allegations in the bill of complaint which are admitted by the defendant, and from the allegations in the answer of the defendant and from the facts of which the court will take cognizance, that said denial is untrue; and on the further ground that the finding and decision of the Secretary of War that the construction of said proposed channel and waterway will diminish the navigable capacity of Lake Michigan, and will alter and modify the condition and capacity thereof, is final and conclusive as against the defendant.

Seventh. The complainant excepts to the following portion of the fourth paragraph of said answer, to wit:

"This defendant expressly denies that interstate or any other commerce will be, to any extent, injured or interfered with by the [fol. 68] said diversion and abstraction of waters from the Great Lakes, or by the construction and maintenance of the Calumet-Sag Channel,"

on the ground that the same is impertinent and does not respond to any allegation in the bill of complaint, and that the matters therein set forth constitute no defense to the relief sought in the bill of complaint.

Eighth. The complainant excepts to the following portion of the fourth paragraph of said answer, as follows, to-wit:

"And denies that the construction of said channel will have a tendency to undo and annul the orders of Congress, as expressed in its various river and harbor bills appropriating funds for improving the rivers and harbors; and expressly denies that the construction of said waterway and channel will alter and modify the conditions of the rivers and harbors of the United States, or any of them, and substantially and seriously impede, injure and obstruct the navigation of the Great Lakes, and the harbors and channels thereof, or the rivers flowing thereinto, as alleged in said paragraph 4; but, on the contrary, the defendant alleges that the construction and maintenance of said waterway and channel as proposed, and the diversion of water through the same as proposed, will not in any wise affect the navigable capacity of the Great Lakes, or the harbors and channels connected therewith, or the rivers flowing into the same,"

on the ground that it appears from the other portions of said answer that each of the purported denials in the portion thereof last above set forth is untrue, and that said portion of said answer herein set forth is sham, evasive and insufficient, and does not fully and com- [fol. 69] pletely respond to the allegations of the bill of complaint on the same subject; and on the further ground that it affirmatively appears from the allegations of the bill which are admitted, and

from the allegations in the answer and from the facts of which the court will take cognizance that the construction of said proposed channel and waterway will affect the navigable capacity and condition of said Lake Michigan, and its harbors and channels, and the rivers flowing into it; and on the further ground that the finding and decision of the Secretary of War set forth in said bill and answer as to the effect of the construction and maintenance of said proposed waterway and channel is final and conclusive as against the defendant.

Ninth. The complainant excepts to the following portion of the fourth paragraph of said answer, to-wit:

"[The defendant alleges that the construction and maintenance of said water-way and channel as proposed] will not interfere with, or in any degree injure, interstate commerce, or any other commerce; but on the contary, as hereinafter shown, will be to the interest of interstate commerce and in accordance with the policy and laws of the United States,"

on the ground that the same is impertinent, does not respond to any of the allegations of the bill of complaint, is merely the statement of erroneous conclusions of law, and is shown by the allegations of the bill which are admitted and by the other allegations of the answer and by the facts of which the court will take cognizance to be untrue; and on the further ground that the finding and decision of the Secretary of War as set forth in the bill and answer are final and conclusive as against the defendant.

[fol. 70] Tenth. The complainant excepts to the allegations contained in the fifth paragraph of said answer on the ground that the purported denial therein is merely the statement of an erroneous conclusion of law; and on the further ground that there is no statute of the United States which authorizes and provides for the construction and maintenance of said channel and water-way, and that the allegation in said paragraph with reference to the existence of such a law is impertinent.

Eleventh. The complainant excepts to the allegations contained in the sixth paragraph of said answer for the reason that the same are insufficient, evasive, and do not fully and completely respond to the allegations of the bill of complaint on the same subject. The averment in the bill is that the construction and maintenance of said channel will lower the level of the Calumet, Little Calumet and Grand Calumet rivers; whereas the defendant in said answer merely denies that the construction of said channel will lower the level of the Little Calumet river. The defendant does not deny that the construction of said channel will alter and modify the course, condition and capacity of said rivers, as charged in said bill, but on the contrary it is admitted in said answer that the construction and maintenance of said channel will result in changing the course of said rivers.

Twelfth. The complainant excepts to the denial contained and purported to be made in the seventh paragraph of said answer, as follows, to-wit:

"This defendant expressly denies the allegation in said (7th) paragraph contained that the construction and maintenance of the pro- [fol. 71] posed water-way, as planned by the defendant, and its consequent diversion of the water from Lake Michigan, would lower the levels of all of said waters, or any of them; and further expressly denies that such construction and maintenance of said channel would injure or impede navigation in the harbors and channels of said waters, or in any of them,"

on the ground that the same is evasive, incomplete, and insufficient, and does not fully and completely respond to the allegations contained in the bill of complaint on the same subject; and on the further ground that it appears from the allegation of the bill which are admitted by the defendant, and from the allegations in the answer, and from the facts of which the court will take cognizance, that said purported denial is untrue, and that the effect of the construction and maintenance of said proposed channel will be necessarily to alter and modify the condition and capacity of said Lake Michigan; and on the further ground that the finding and decision of the secretary of war set forth in the bill, and answer, with reference to the effect of the construction of said proposed channel, are final and conclusive as against the defendant.

Thirteenth. The complainant excepts to the following portion of the eighth paragraph of said answer, as follows, to wit:

"This defendant denies that this act (the act of May 3, 1899) has any binding force on this defendant; or that said act in anywise prohibits the construction and maintenance of the channel or waterway proposed to be constructed by this defendant; or that the same is a constitutional or valid enactment,"

on the ground that the same is merely the statement of erroneous [fol. 72] conclusions of law, and is impertinent; and on the further ground that said act therein referred to is a valid and constitutional enactment, is binding upon the defendant, and prohibits the construction and maintenance of the channel and water-way proposed to be constructed by said defendant in the absence of the compliance by the defendant with the requirements and conditions therein set forth.

Fourteenth. The complainant excepts to the following portion of the ninth paragraph of said answer as follows, to wit:

"This defendant expressly denies that by said application it admitted the jurisdiction of the secretary of war in such matters,"

on the ground that it is merely the statement of an erroneous conclusion of law, and is impertinent; and on the further ground that

there is no proper denial of the specific allegations of the bill of complaint to the effect that said defendant did submit itself to the jurisdiction of said secretary of war for the purpose of the determination of the effect of the construction and maintenance of said proposed channel upon the condition and capacity of the navigable waters of the United States, described in said bill and answer.

Fifteenth. The complainant excepts to the following portion of the ninth paragraph of said answer, as follows, to wit:

"Or that it required such permit from said secretary of war to construct and maintain said channel,"

on the ground that the same is the statement of an erroneous conclusion of law, and is impertinent; and on the further ground that the construction of the proposed channel as described in said answer [fol. 73] would necessarily interfere with, alter and modify the condition and capacity of the navigable waters of the United States described in the bill and answer, and that the authorization by the secretary of war required by statute is a condition precedent to the lawful construction of said channel; and on the further ground that the finding and decision of said secretary of war, refusing to permit the construction of said proposed channel, are final and conclusive as against the defendant.

Sixteenth. The complainant excepts to the following portion of the ninth paragraph of said answer, to wit:

"But on the contrary, alleges that it made such application to said secretary of war purely as a matter of comity and in order to promote and maintain the spirit of harmony which it believed should obtain between the Federal Government and the various state and local governments of the United States; all of which more fully appears from a statement filed with the secretary of war at the time of making said application, a part of which is in words and figures as follows, to wit:

'That while insisting upon the right as a matter of right, we are entitled, nevertheless, to a permit from the secretary of war; to evidence that there exists between the two governments that 'spirit of harmony and conciliation' which, in the words of Chief Justice Marshal, in Gibbons v. Ogden (9 Wheaton, 1), 'ought always to characterize the conduct of governments standing in the relation which that of the Union and those of the states bear to each other'; and to further evidence on the part of said governments that 'frank and candid co-operation for the general good' spoken of by Justice [fol. 74] Johnson in the same case, 'which should always take place where there is a seeming blending of the power of the two governments and an apparent conflict,' "

on the ground that same is impertinent, and is not responsive to any of the allegations of the bill of complaint; and on the further ground that the matters therein set forth if true would not justify the wrongs alleged in the bill of complaint to have been committed

by the defendant, or in anywise constitute a defense against the relief sought by the bill of complaint.

Seventeenth. The complainant excepts to the following portion of the eleventh paragraph, to wit:

"But this defendant denies that said law has any application to the work contemplated by said defendant, or that it has any binding force or effect in this case."

on the ground that same is a mere statement of an erroneous conclusion of law and is impertinent; and on the further ground that it appears from the facts stated in the bill and admitted by the defendant, and from the allegations in the answer, and from the facts of which the court will take cognizance, that it is necessary for the construction of said channel to be authorized by the secretary of war, pursuant to statute; and on the further ground that said statute is a valid and constitutional enactment, and is applicable to the facts herein as admitted by the defendant.

Eighteenth. The complainant excepts to the allegations contained in the twelfth paragraph of the bill of complaint, on the ground that the purported denial therein involves the statement of an erroneous conclusion of law; and on the further ground that there is no congressional legislation authorizing the construction and [fol. 75] maintenance of said channel, and the diversion of the waters of said Lake Michigan, and that the averment in said paragraph to that effect is undue and impertinent.

Nineteenth. The complainant excepts to the thirteenth paragraph of said answer on the ground that it is merely the statement of an erroneous conclusion of law; and is impertinent; and on the further ground that there is no law authorizing the construction and maintenance of said proposed channel, and that the finding and decision of the secretary of war, made pursuant to statute, denying to the defendant the right to construct and maintain said proposed channel, are final and conclusive as to the defendant.

Twentieth. The complainant excepts to the following portion of the fourteenth paragraph of said answer, to wit:

"This defendant expressly denies that the construction and maintenance thereof will be to the manifest or irreparable injury of the United States, or to interstate and foreign commerce; but, on the contrary, alleges that the construction and maintenance of said channel and waterway will benefit both state and interstate commerce,"

on the ground that it appears from the allegations in the bill which are admitted by the defendant to be true, and from the allegations in the answer, that said purported denial is untrue, and that it is insufficient and impertinent; and on the further ground that the finding and decision of the secretary of war, with reference to the construction and maintenance of said channel, made pursuant to the statute, are final and conclusive against the defendant.

Twenty-first. The complainant excepts to all of the allegations [fol. 76] in the fifteenth paragraph of said answer on the ground that each of said allegations is impertinent; and on the further ground that said allegations, if true, would not justify the acts of the defendant charged in the bill, nor would they constitute a defense against the relief sought by the bill of complaint; and on the further ground that said allegations involve an erroneous construction of the statutes of the United States and erroneous conclusions of law.

Twenty-second. The complainant excepts to all of the allegations in the sixteenth paragraph of said answer on the ground that each of said allegations is impertinent, and has no relation whatever to any of the issues involved in this case, and that said allegations if true, would not justify the acts of the defendant charged in the bill of complaint, nor would they constitute any defense against the relief sought in said bill; and on the further ground that said allegations involve an erroneous construction and application of the statutes of the United States and of the State of Illinois.

Twenty-third. The complainant excepts to all of the allegations in the seventeenth paragraph of said answer on the ground that each of said allegations is impertinent and has no relation whatever to the issues involved in this case, and that said allegations if true, would not justify the acts of the defendant charged in the bill of complaint, nor would they constitute any defense to the relief sought in said bill; and on the further ground that said allegations involve an erroneous construction and application of the statutes of the United [fol. 77] States and of the State of Illinois.

Twenty-fourth. The complainant excepts to all of the allegations in the eighteenth paragraph of said answer on the ground that each of said allegations is impertinent, not responsive to any of the allegations in the bill of complaint, and in no way relates to any of the issues involved in this case; and that said allegations if true, would not justify the acts of the defendant charged in the bill of complaint, nor would they constitute any defense against the relief sought in said bill; and on the further ground that said allegations involve an erroneous construction and application of the statutes of the United States and of the State of Illinois.

Twenty-fifth. The complainant excepts to all of the allegations in the nineteenth paragraph of said answer on the ground that each of said allegations is impertinent, and is not responsive to any of the allegations in the bill of complaint, and does not relate in any way to the issues involved in this case, and that said allegations if true, would not justify the acts of the defendant charged in the bill of complaint, nor constitute a defense against the relief sought in said bill; and on the further ground that said allegations involve an erroneous construction and application of the statutes of the United States and of the State of Illinois.

Twenty-sixth. The complainant excepts to all of the allegations in the twentieth paragraph of said answer on the ground that each

of said allegations is impertinent, is not responsive to any of the [fol. 78] allegations in said bill of complaint, and does not in any way relate to the issues involved in this case, and that said allegations if true, would not justify the acts of the defendant charged in the bill of complaint, nor constitute a defense against the relief sought in said bill; and on the further ground that said allegations involve an erroneous construction and application of the statutes of the United States and of the State of Illinois.

Twenty-seventh. The complainant excepts to that portion of the twenty-first paragraph of said answer as follows, to wit:

"This defendant says that it expressly denies that the construction and maintenance of said proposed channel would in anywise affect the levels of the Great Lakes, and the channels and harbors and rivers connected therewith,"

on the ground that it appears from the allegations in the bill which are admitted by the defendant, and from the allegations in the answer herein, and from the facts of which this court will take cognizance, that said purported denial is untrue; and on the further ground that said portion of said paragraph is impertinent, insufficient and does not properly respond to any of the averments in said bill of complaint.

Twenty-eighth. The complainant excepts to the following portion of the twenty-first paragraph of said answer, to wit:

"Or that it will in anywise injure, interfere with or be to the detriment of the commerce thereon,"

on the ground that same is impertinent, is not responsive to any allegation in the bill of complaint, and is shown by the allegations [fol. 79] of the bill which are admitted, and by the allegations in the answer, to be untrue; and on the further ground that the finding and decision of the secretary of war with reference to the matters therein set forth, are final and conclusive against the defendant.

Twenty-ninth. The complainant excepts to the following portion of the twenty-first paragraph of said answer, to wit:

"And this defendant expressly denies that the construction and maintenance of the proposed channel will in anywise affect the navigable capacity of the Little Calumet, or Grand Calumet rivers, and alleges that it will not in anywise affect, alter, modify or change said Little Calumet river, other than as herein specifically set forth, which this defendant alleges is to the benefit of said river, and to the commerce thereon, and not to the detriment thereof,"

on the ground that the same is evasive, indefinite, insufficient, and does not fully respond to the allegations of the bill of complaint on the same subject; and on the further ground that it appears from the allegations of the bill which are admitted by the defendant, and from the allegations in the answer, that said purported denial is

untrue; and on the further ground that it affirmatively appears from the admissions in said answer that the effect of the construction of said channel will be to alter and modify and change the direction of the course of said Little Calumet river.

Thirtieth. The complainant excepts to all of the allegations in the twenty-third paragraph in said answer, on the ground that each of said allegations is impertinent, is not responsive to any allegation [fol. 80] in the bill of complaint, and does not relate in any way to the issues involved in this case; and on the further ground that the power to regulate commerce among the states is conferred, not upon the governments of the respective states, but upon the United States; that Congress in the exercise of its power has legislated with reference to the matters covered by the bill of complaint and the answer herein; that said legislation is valid, constitutional and binding upon the defendant, and that the effect of the construction of said proposed channel upon intestate commerce is a matter for determination, not by the authorities of the State of Illinois, but by the federal authorities, upon whom that power has been conferred by Congress.

Thirty-first. The complainant excepts to all of the allegations in the twenty-fourth paragraph of said answer, on the ground that each of said allegations is impertinent, and not responsive to any of the allegations in said bill of complaint, and that said allegations if true, would not justify any of the acts of the defendant complained of in the bill of complaint, nor constitute a defense against the relief sought in said bill; and on the further ground that it is not alleged in said paragraph, nor in any other portion of said answer, that the local government of Illinois could not make provision for the drainage and disposal of said sewerage in some adequate manner without violating the statutes of the United States, passed pursuant to the power to regulate commerce conferred upon Congress by the constitution, and without defying the lawful orders of the department of war made in the premises.

[fol. 81] Thirty-second. The complainant excepts to each and every one of the purported denials of the material allegations of the bill of complaint, on the ground that each of said purported denials is shown by the allegations of the bill which are admitted by the defendant, and by the other allegations of the answer, and by the facts of which the court will take judicial notice to be untrue, and is therefore insufficient; and on the further ground that there is no sufficient and complete denial of any one of the material allegations of said bill.

Thirty-third. The complainant excepts to said answer on the ground that there is no sufficient denial of the allegations in the bill of complaint to the effect that by the construction and maintenance of said proposed channel the defendant will divert a large quantity of water from Lake Michigan.

Thirty-fourth. The complainant excepts to said answer on the ground that there is no sufficient denial of the allegations of the bill to the effect that by the construction and maintenance of said proposed channel the defendant will alter and modify the course of the Calumet and Little Calumet rivers, and cause the water in said rivers to flow in a direction different from that in which it now flows.

Thirty-fifth. The complainant excepts to said answer on the ground that the defendant has not therein by sufficient averments denied the material allegations of said bill of complaint, entitling the complainant to the relief therein sought.

Thirty-sixth. The complainant excepts to said answer on the ground that it does not set up any matter constituting a defense to [fols. 82 & 83] the matters alleged in the bill of complaint.

Wherefore, the complainant comes and in all particulars aforesaid excepts to the answer of the said defendant on the grounds alleged, that the same is evasive, untrue, imperfect, insufficient, irrelevant, and impertinent; and prays that said irrelevant and impertinent portions of said answer hereinabove pointed out may be expunged from said answer, and that as to the remaining portions of said answer to which exceptions have been taken, said defendant may be compelled to put in a full, complete and sufficient answer with reference to the matters therein referred to; and that said complainant may have such other relief in the premises as to the court may seem proper.

Charles J. Bonaparte, Attorney-General of the United States; Edwin W. Sims, United States Attorney; James H. Wilkerson, Special Assistant United States Attorney, Solicitors for the United States.

[File endorsement omitted.]

[fol. 84] IN THE DISTRICT COURT OF THE UNITED STATES, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

BILL OF COMPLAINT—Filed October 6, 1913

[fol. 85] To the Honorable the Judges of the District Court of the United States for the Northern District of Illinois, Eastern Division, in Chancery Sitting:

Your orator, The United States of America, by James G. McReynolds, its Attorney General, and James H. Wilkerson, its attorney for the Northern District of Illinois, brings this, its bill of complaint, against The Sanitary District of Chicago, defendant, and respectfully alleges and represents unto your Honors as follows:

First: That defendant, The Sanitary District of Chicago, is a municipal corporation, organized and existing under and by virtue of an act of the Legislature of the State of Illinois, approved May 29,1889, in force July 1, 1889, and entitled, "An Act to create Sanitary Districts and to remove obstructions in the Desplaines and Illinois Rivers"; that it has its principal office in the City of Chicago, in the State of Illinois, and that it is a citizen of the State of Illinois.

Second. That the Chicago river is situated in the County of Cook and State of Illinois and consists of a main river originally flowing in a generally easterly direction emptying into Lake Michigan, said main river being formed by two branches known as the north branch and the south branch of said Chicago river, and the said south branch being divided into two forks, known as the west fork and the south fork.

Third. That the said Chicago river, including both the north branch and the south branch, and the west fork and the south fork of the south branch, is a navigable water of the United States.

Fourth. That the United States has appropriated and expended a large sum of money, to wit, $4,216,066.36, in improving the navigability of said river and the harbor at the mouth of the same.

[fol. 86] Fifth. That in and by section 10 of an act of Congress, approved March 3, 1899, and entitled "An Act making appropriations for the construction, repair and preservation of certain public works on rivers and harbors, and for other purposes," it is provided as follows:

"That the creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recom-ended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition or capacity of any port, roadstead, haven, harbor, canal, lake, harbor of refuge or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to the beginning of the same."

which said law has remained and been in full force and effect ever since its passage and still remains in full force and effect.

Sixth. That heretofore, to wit, prior to the 8th day of May, 1899, defendant applied to the Secretary of War of the United States, for permission to reverse the current and the flow of the said Chicago

river and to divert and abstract a certain quantity of water from Lake Michigan through said Chicago river and through a certain canal which was constructed and being constructed by defendant; and thereafter, to wit, on the 8th day of May, 1899, the Secretary of War issued a permit to the defendant to reverse the current and flow of the said Chicago river and to divert and abstract from Lake Michigan not to exceed 300,000 cubic feet per minute, reserving the right to make such changes as the Secretary of War should see fit in the interests of navigation and property rights. A copy of said permit is attached hereto as Exhibit "A" and is referred to and made a part hereof with like effect as if set out in full herein.

Seventh. That thereafter, on, to wit, April 9, 1901, the Secretary of War ordered defendant to reduce the flow through the Chicago [fol. 87] river to 200,000 cubic feet per minute, a copy of which order is attached hereto as Exhibit "B" and is referred to and made a part hereof with like effect as if set out in full herein.

Eighth. That thereafter, defendant applied to the Secretary of War and in compliance with said application said Secretary of War, on, to wit, July 23, 1901, modified the permit and order theretofore issued and issued a permit to defendant to flow 300,000 cubic feet of water per minute between the hours of 4:00 P. M. and 12:00 P. M. midnight, a copy of which permit is attached hereto as Exhibit "C" and is referred to and made a part hereof with like effect as if set out in full herein.

Ninth. That subsequently thereto defendant applied for and obtained from the Secretary of War, on to wit, the 5th day of December, 1901, a permit to flow 250,000 cubic feet per minute throughout the twenty-four hours of the day, copy of which permit is attached hereto as Exhibit "D" and is referred to and made a part hereof with like effect as if set out in full herein.

Tenth. That subsequently thereto, defendant applied for and obtained from the Secretary of War, on, to wit, the 17th day of January, 1903, a permit to increase the flow through the Chicago river from 250,000 to 350,000 cubic feet per minute until the 31st day of March, 1903, after which date the flow to be reduced to 250,000 cubic feet per minute as theretofore, a copy of which permit is attached hereto as Exhibit "E" and is referred to and made a part hereof with like effect as if set out in full herein.

Eleventh. That subsequently, on, to wit, the 28th day of November, 1906, defendant made application to the Secretary of War for permission to construct a canal connecting the Calumet river with the main channel of the Sanitary District canal at what is known as Sag Station, and to reverse the flow of the Calumet river, and thereafter, on, to wit, the 14th day of March, 1907, the said Secretary of War denied the said application.

Twelfth. That subsequently thereto, defendant applied for and obtained from the Secretary of War, on, to wit, the 11th day of

September, 1907, a permit to construct a canal connecting Lake Michigan at Wilmette, Illinois, with the north branch of the Chicago river upon the condition that the total diversion of water from [fol. 88] Lake Michigan through the Chicago river should not exceed the amount already authorized by the War Department, to wit, 250,000 cubic feet per minute.

Thirteenth. That subsequently thereto, defendant applied for and obtained from the Secretary of War, on, to wit, the 27th day of June, 1910, a permit authorizing it to construct a canal connecting the Calumet with the main channel of the Chicago Drainage canal at Sag Station and to divert and abstract water from Lake Michigan through said canal, and providing, among other things, that the amount of water withdrawn from Lake Michigan through the Chicago river and the Calumet river together should not exceed the total amount of 250,000 cubic feet per minute, the amount previously authorized to be withdrawn through the Chicago river alone.

Fourteenth. That thereafter, on, to wit, the 5th day of February, 1912, defendant applied to the Secretary of War for permission to withdraw and divert from Lake Michigan through the Chicago river and Calumet river, not to exceed 10,000 cubic feet of water per second, or 600,000 cubic feet per minute, copy of which application is attached hereto, as Exhibit "F" and is referred to and made a part hereof with like effect as if set out in full herein.

Fifteenth. That thereafter, on to wit, the 8th day of January, 1913, the Secretary of War of the United States, refused said application of February 5, 1912, copy of which said refusal is attached hereto as Exhibit "G" and is referred to and made a part hereof with like effect as if set out in full herein.

Sixteenth. Your orator further represents that defendant has for a long period of time diverted and abstracted from Lake Michigan and caused to flow through the Chicago river and is at the present time diverting and abstracting from Lake Michigan and causing to flow through the Chicago river from 400,000 to 600,000 cubic feet of water per minute, which amount is greatly in excess of the amount so permitted to be diverted and abstracted from Lake Michigan to flow through the Chicago river by said Secretary of War as hereinbefore set out and is in direct violation of the permits of said Secretary of War which limits the said flow to 250,000 cubic feet per minute; that defendant plans, intends and threatens to continue to divert from Lake Michigan through the Chicago river from 400,000 to 600,000 cubic feet per minute in violation of the permits and orders of the Secretary of War.

Seventeenth. Your orator further represents that the Congress of the United States has not authorized the diversion of any of such [fol. 89] waters through the Chicago river, and that the Chief of Engineers has not recommended the said diversion of waters through the Chicago river in excess of 250,000 cubic feet per minute, nor

has the Secretary of War authorized the diversion of the waters of Lake Michigan through the said Chicago river in excess of 250,000 cubic feet per minute, but on the contrary has refused so to do, and has refused to authorize the diverson of any of such waters in excess of 250,000 cubic feet per minute through said river, as is more fully set out in paragraph fifteenth, hereof, and that the total amount of water which said defendant can legally divert or abstract from Lake Michigan in any manner cannot exceed 250,000 cubic feet per minute.

Eighteenth. Your orator further represents on information and belief that the diversion and abstraction of the waters of Lake Michigan into the Chicago river in excess of 250,000 cubic feet per minute has lowered and will continue to lower the level of the water of Lake Michigan, Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Sault Ste. Marie, St. Mary's river, St. Clair river, Detroit river, Niagara river, St. Lawrence river, and all the harbors, channels, canals and rivers connected therewith, all of which are navigable waters of the said United States, and will thus injure and diminish and create an obstruction to the navigable capacity of all said waters.

Nineteenth. That said waters have been deepened and improved under great expense of the United States under authority of the Congress of the United States, and that the diversion and abstraction of the waters of Lake Michigan in excess of the permits hereinbefore set forth, will have a tendency to undo and annul the orders of Congress as expressed in the various rivers and harbors acts appropriating funds for improving harbors and channels in the above named waters and channels connected therewith.

Twentieth. That the said diversion and abstraction of the waters of Lake Michigan through the Chicago river in excess of the permits of the United States as aforesaid, will alter and modify the condition and capacity of the channel of the said Chicago river which is a channel of a navigable water of the United States.

Twenty-first. That the said diversion and abstraction of the waters of Lake Michigan through the Chicago river in excess of the permits of the United States as aforesaid, will alter and modify the condition and capacity of Lake Michigan, Lake Huron, Lake St. [fol. 90] Clair, Lake Erie, Lake Ontario, Sault Ste Marie, St. Mary's river, St. Clair river, Detroit river, Niagara rivers and St. Lawrence river and the ports, roadsteads, havens, harbors, canals and harbors of refuge connected with the above named waters.

Twenty-second. Your orator further represents that defendant cannot lawfully continue to divert and abstract the waters of Lake Michigan as it now does and threatens to do as aforesaid without the recommendation of the Chief of Engineers of the United States and permission of the Secretary of War of the United States in excess of the permits hereinbefore referred to limiting the said flow to 250,000 cubic feet per minute, yet the defendant notwithstanding it has no right so to do, plans, intends and threatens to continue the diversion

of the waters of Lake Michigan in excess of the amount so permitted and authorized by the Secretary of War, to the manifest and irreparable injury of your orator and its interstate navigation and commerce, unless restrained by the injunction of this Honorable Court.

Forasmuch, therefore, as your orator is remediless in the premises by the rules of the common law, and can have adequate relief only in a court of equity, and to the end that the said Sanitary District of Chicago, a municipal corporation as aforesaid, which is made defendant to this your orator's bill of complaint may full, true and perfect answer make to all and singular the matters and things hereinbefore stated and charged (but not under oath, its answers under oath being hereby expressly waived), your orator files this bill of complaint and prays your Honors forthwith to grant a provisional or preliminary writ of injunction directed to the said defendant, its Board of Trustees, officers, agents, attorneys, representatives, employees and servants, and all other persons, acting, or claiming or assuming to act, under its authority, enjoining it, and each of its Board of Trustees, officers, agents, attorneys, representatives, employes and servants, and each of the other persons aforesaid, from diverting or abstracting any waters from Lake Michigan over and above and in excess of 250,000 cubic feet per minute as already authorized by said Secretary of War until such time as your honors shall appoint and direct for the final hearing herein, and upon such final hearing to make such injunction perpetual.

And may it please your honors to grant such other, further and different relief in the premises as equity may require and to your honors may seem meet.

[fol. 91] And your orator prays that a writ of subpœna may issue to the said defendant, The Sanitary District of Chicago, commanding it, under a penalty and at a time and place to be therein stated, to appear and answer all and singular the matters hereinbefore stated and charged, and abide by and perform such orders as the court may make in the premises.

And your orator will ever pray.

James C. McReynolds, Attorney General of the United States.
By Direction of the Attorney General: James H. Wilkerson, United States Attorney for the Northern District of Illinois.

[fol. 92] EXHIBIT "A" TO BILL OF COMPLAINT

"Whereas, by Section 10 of an act of Congress approved March 3, 1899, entitled 'An Act making appropriations for the construction, repair and preservation of certain public works, on rivers and harbors, and for other purposes,' it is provided that it shall not be lawful to alter or modify the course, location, condition or capacity of the channel of any navigable water of the United States unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same:

And whereas, the Sanitary District of Chicago, a municipal corporation, organized under the laws of the State of Illinois, has constructed an artificial channel from Robey street, Chicago, to Lockport, and has been heretofore granted permission by the Secretary of War to make certain improvements in the Chicago river for the purpose of correcting and regulating the cross section of the river so as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles an hour, it being intended to connect the said artificial channel with the west fork of the south branch of Chicago river at Robey street in the said City of Chicago.

And whereas, The said Sanitary District of Chicago has now applied to the Secretary of War for permission to divert the waters of the said Chicago river and cause them to flow into the said artificial channel at Robey street as aforesaid;

And whereas, The said Sanitary District of Chicago represents that such movable dams and sluice gates as are necessary to, at all times, secure absolute and complete control of the volume and velocity of flow through the Chicago river have been constructed;

Now therefore, The Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the water of Chicago river to flow into the same, subject to the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and [fol. 93] final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it become apparent that the current created by such drainage works in the south and main branches of Chicago river, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago river and its South Branch.

3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago river.

Witness my hand this 8th day of May, 1899.

R. A. Alger, Secretary of War. (Seal War Office.) John M. Wilson, Brig. Genl. Chf. of Engrs. U. S. A."

EXHIBIT "B" TO BILL OF COMPLAINT

"Whereas, under date of May 8th, 1899, the Secretary of War granted permission unto The Sanitary District of Chicago to open the artificial channel from Roby Street, Chicago, to Lockport, and

cause the waters of Chicago river to flow into the same, upon the following condition, inter alia:

'2. That if, at any time, it becomes apparent that the current created by such drainage works in the south and Main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its south Branch.'

And whereas, It is alleged by various commercial and navigation interests that the present discharge from the river into the Drainage Canal sometimes exceeds three hundred thousand (300,000) cubic feet per minute, causing a velocity of nearly three (3) miles per hour, which greatly endangers navigation, in the present condition of the river.

Now, therefore, This is to certify that the Secretary of War, upon the recommendation of the Chief of Engineers, hereby directs said [fol. 94] Sanitary District to regulate the discharge from the river into the Drainage Canal so that the maximum flow through the Chicago river and its south branch shall not exceed two hundred thousand (200,000) cubic feet per minute.

Witness my hand this ninth day of April, 1901.

Elihu Root, Secretary of War."

"EXHIBIT "C" TO BILL OF COMPLAINT

"War Department, Washington

File No. 2560 of 1900.

July 23, 1901.

SIR: Referring to War Department order of April 9th last, restricting the flow of water through the Chicago River under War Department permit of May 8, 1899 to 200,000 cubic feet per minute, and replying to your letter of the 15th instant, in which you request, for reasons stated, that the said order be amended to permit a flow of 300,000 cubic feet per minute between the hours of 4 P. M. and twelve o'clock midnight, I beg to inform you that I have this day approved the modification last referred to, which approval will be subject to revocation by the Department in case the increase shall prove to be dangerous to nagivation.

Very respectfully, Elihu Root, Secretary of War. Mr. Alexander J. Jones, President Sanitary District of Chicago, Chicago, Illinois."

EXHIBIT "D" TO BILL OF COMPLAINT

"J. A. G. O. (6353)

Whereas, Under date of May 8th, 1899, the Secretary of War granted permission unto the Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, upon the following condition, inter alia;

[fol. 95] "2. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch;"

And whereas, The Secretary of War subsequently directed said Sanitary District of Chicago, to regulate the discharge of water into the Chicago Drainage Canal so that the maximum flow through the Chicago River shall not exceed 200,000 cubic feet per minute from midnight to 4 p. m., nor 300,000 cubic feet per minute from 4 p. m. to midnight;

And whereas, Said Sanitary District of Chicago has applied to the Secretary of War for permission to increase the flow between midnight and 4 p. m. daily, to 250,000 cubic feet per minute; and the Chief of Engineers has recommended that the increase applied for be granted, but that the rate of flow from 4 p. m. to midnight be reduced to 250,000 cubic feet per minute, so that flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day.

Now, therefore, This is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto the said Sanitary District of Chicago permission to regulate said discharge so that the maximum flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day, upon the following conditions:

1. That this permission shall be in lieu of the present authorized rates of flow as stated above.

2. That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

3. That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

Witness my hand this 5th day of December, 1901.

W. Cary Sanger, Assistant Secretary of War."

[fol. 96] EXHIBIT "E" TO BILL OF COMPLAINT

"J. A. G. O. (6353)

Whereas, under date of December 5, 1901, by an instrument supplementary to the original permission granted by the Secretary of War, May 8, 1899, to the Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of the Chicago River to flow into the same, the Secretary of War, pursuant to authority reserved in said permission of May 8, 1899, gave permission to the Sanitary District of Chicago to regulate said discharge so that the maximum flow per minute throughout the twenty-four hours of the day, upon the following conditions, inter alia:

"That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require";

And whereas, The said Sanitary District of Chicago has applied for permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute during the closed season of navigation, in order to carry off the accumulations of sewage deposit which line the shores along the city;

Now, therefore, This is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto said Sanitary District of Chicago permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute, until the 31st day of March, 1903, after which date it shall be reduced to 250,000 cubic feet per minute, as now authorized, upon the following conditions:

1. That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

2. That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

Witness my hand this seventeenth day of January, 1903.

W. Cary Sanger, Assistant Secretary of War."

[fol. 97] EXHIBIT "F" TO BILL OF COMPLAINT

"The Sanitary District of Chicago

Chicago, February 5th, 1912.

SIR: On behalf of the Board of Trustees of The Sanitary District of Chicago, I have the honor to apply for enlargement of the terms

of an instrument executed by The Secretary of War May 8, 1899, as modified by instruments similarly executed on December 5, 1901, and June 30, 1910, respectively, in the following particulars and in view of the facts hereinafter set forth, to wit:

The flow of water from Lake Michigan through the canal of The Sanitary District of Chicago is now limited by the said instruments to 4167 cubic feet per second.

The population of the Sanitary District, the sewage of which is to be disposed of through the channels constructed and to be constructed by the said District, exceeds 2,500,000 persons, and is rapidly increasing. The only method at present available for disposing of the sewage of this population is by diluting the same with water withdrawn from Lake Michigan and flowing through the Chicago Drainage Canal. The least amount of water necessary to render sewage innocuous by the dilution method has been estimated by well recognized sanitary experts as 1,000 feet per second for every 300,000 inhabitants; so that the amount permitted to be withdrawn by the instruments to which reference has been made is much below the amount at present needed by the District.

The Sanitary District has been for some time engaged in investigating methods and devising plans for the treatment of the sewage with a view to requiring less water for its safe dilution in the future. The methods of other states and countries for such treatment of sewage, are not as yet entirely satisfactory to all concerned, and any changes of methods for large cities must necessarily require several years.

Until these experiments are concluded and proper works installed, the use of additional water from Lake Michigan is essential to the health of the large population of the City of Chicago and of the Sanitary District and of those who live adjacent to the Des Plaines and Illinois rivers into which such waters are discharged.

Subject therefore to such restrictions as to you may seem proper [fol. 98] for the protection of the public interest, and to such a method of supervision as you may suggest to promote the general welfare, and pending the completion of the investigations now being conducted to render the use of increasing quantities of water in the future necessary; I have the honor to apply for permission for The Sanitary District of Chicago to withdraw from Lake Michigan through the Chicago river and Calumet river—not to exceed ten thousand cubic feet of water per second; such permission to be revocable at any time by The Secretary of War, and subject to such action as the Congress of the United States may see fit to take in the premises.

Respectfully submitted, George M. Wisner, Chief Engineer.
Hon. Henry L. Stimson, Secretary of War, Washington, D. C."

EXHIBIT "G" TO BILL OF COMPLAINT

In the Matter of the Application of THE TRUSTEES OF THE SANITARY DISTRICT OF CHICAGO for Permission to Divert from Lake Michigan 10,000 Cubic Feet of Water Per Second.

War Department

Washington, January 8, 1913.

The Sanitary District of Chicago applies to the War Department for permission to increase the amount of water it is authorized to withdraw from Lake Michigan from 4,167 cubic feet per second, the amount now authorized, to 10,000 cubic feet per second.

The Chicago Drainage Canal was opened in January, 1900. It reverses the flow of the Chicago River, which formerly emptied into Lake Michigan, and as a result a portion of the waters of that lake, instead of following their former course through Lakes Huron, Erie, and Ontario into the St. Lawrence, are now carried across the watershed into the Illinois River, and through that to the Mississippi and the Gulf of Mexico. The canal thus serves as a system of drainage for the City of Chicago, carrying the sewage of that city southward to the Mississippi, and thus protects the water supply of that city, which is taken from Lake Michigan.

[fol. 99] Permission to divert water from Lake Michigan was first granted by my predecessor, Secretary Alger, on May 8, 1899. He permitted a flowage of 5,000 cubic feet per second, but his permit contained the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it becomes apparent that the current created by such drainage works in the south and main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its south branch.

Subsequently, during the administration of Secretary Root, the amount of the current permitted to be taken was modified or restricted until December 5, 1901, when it was fixed at the amount now permitted, and these permits contained the condition—

that the permission herein given shall be subject to such modifications as in the opinion of the Secretary of War the public interests may from time to time require.

On March 14, 1907, an application made for permission to divert an additional 4,000 cubic feet per second for the purpose of reversing the current of the Calumet River and flowing that river also through the canal to drain the southern portion of Chicago was denied by Secretary Taft in an opinion in which he referred once more to the desirability of submitting "this question of capital and national importance to the Congress of the United States."

It is clear that even under the conditions heretofore manifested on these applications, the proposition to divert the waters of Lake Michigan into another watershed has not been entertained without hesitation and careful restriction by my predecessors. The propriety of obtaining congressional sanction for the project has been pointed out from the beginning; and the form in which the permit has been granted, even for the moderate amount of diversion permitted, has been so phrased as to indicate that the permission was predicated upon the absence of any substantial injury to commerce.

The sanitary canal has never received the direct sanction of Congress. It was built solely under the authority of the State of Illinois, as given in its 1889 general act for creating sanitary districts. And although pursuant to the suggestion of my predecessors the question of the propriety of its diversion of water from Lake Michigan was presented urgently in the reports of the Chief of Engineers for the [fol. 100] years 1899 and 1900 as transmitted to Congress, no action upon the question has ever been taken by that body. In the argument before me it was urged that the present canal represented the growth and development of a national policy expressed in two acts of Congress, 1822 and 1827, which authorized the construction of a canal "to connect the Illinois River with Lake Michigan," thus connecting the two watersheds. (Acts of Mar. 30, 1822, and Mar. 2, 1827.) But these statutes authorized a canal for the purpose of navigation and not sanitation. (Missouri v. Illinois, 200 U. S. 526.) The Illinois and Michigan Canal, actually constructed under their authority, derived its water for navigation purposes from the Calumet, Des Plaines, and Chicago Rivers, and not from the Lakes. And although in the latter part of its existence it was used to a very slight extent to help purify the waters of the Chicago River and thus sanitate the City of Chicago, such a purpose could not have been dreamed of at the time its construction was authorized by Congress, 90 years ago. I can not see that its authorization and construction offer the slightest congressional sanction for the great canal now under discussion, which was not even contemplated until much more than half a century later. Even at the time when the present canal was constructed and opened it is very evident that its ultimate possible effect upon the navigation of the Great Lakes was not clearly realized by those interested in that navigation. The evidence before me indicates that the withdrawal of water from Lake Michigan at Chicago would require about five years to produce its full effect upon the levels of the Great Lakes (see report of International Waterways Commission on Chicago Drainage Canal, p. 7) and that this effect would be still further obscured by periodic oscillations in the lake levels. These facts may easily explain any inaction on the

part of the Nation and their representatives to this withdrawal of water and make it clear that any argument of implied acquiescence must be scrutinized with unusual care.

In this respect the situation is now very different. The present application was opposed by representatives of 23 cities and 6 States interested in harbors and commerce upon the Great Lakes, notably the Cities of Duluth, Milwaukee, Toledo, Cleveland and Buffalo. It was opposed by representatives of the navigation interests engaged on the Chicago River as well as on the Great Lakes, and by the official representatives of the Canadian Government as well as private Canadian interests engaged in the navigation of the Lakes and the [fol. 101] St. Lawrence River, including representatives of the Cities of Kingston and Montreal.

A very careful consideration of the voluminous evidence and statements submitted, as well as a consideration of the reports of other commissions and boards of engineers who have investigated the subject, leaves no doubt in my mind that the withdrawal of 10,000 cubic feet per second would substantially interfere with the navigable capacity of the Great Lakes and their connecting rivers. The Chief of Engineers, whose statutory authority in passing upon this application is concurrent with and independent of my own, and whose opinion upon such a question of scientific conclusion must be given especial weight, so states in his recommendation. His conclusions are corroborated by the authority of other boards of investigation, notably the report of the International Waterways Commission of January 4, 1907.

Careful observations and calculations conducted under the offices of the United States Lake Survey and reported through the Chief of Engineers, covering observations for the last 46 years, indicate that a withdrawal of 10,000 cubic feet per second would reduce levels at various places as follows:

	Inches
Lakes Huron and Michigan	6.9
Lake St. Clair	6.3
Lake Erie	5.4
Lake Ontario	4.5
St. Lawrence River at Rapide Plat	4.8 plus.

The foregoing effects would be produced at mean lake levels; the lowering effects would be much greater at low-water periods—the precise time when any additional shortage would be most keenly felt. This reduction would create substantial injury in all of the American harbors of the Great Lakes and in the St. Marys' St. Clair, and Detroit Rivers. It would produce equal injury in Canadian harbors on the Great Lakes, and a still greater injury on the lower St. Lawrence, the Canadian officials claiming a probable lowering effect of 12 inches at Montreal at low water.

The United States has improved about 106 harbors and rivers on the Great Lakes affected by this diversion and has spent on such improvements over ninety millions of dollars. The Canadian Government has improved over 50 harbors on Georgian Bay and Lakes

Huron, St. Clair, Erie and Ontario. By treaty, American vessels are accorded equal rights of navigation with Canadian vessels in all [fol. 102] these waters, including the St. Lawrence River. The reduction of the water in these harbors and channels would diminish to just that extent the amount of these improvements, and would nullify to just that extent the effects of the moneys which have been appropriated for that purpose by the respective Governments. Connecting various portions of these waterways are the two canals at the Sault Ste. Marie, the Welland Canal, and a number of canals on the St. Lawrence River. The available depth of water over one or all sills of each of these canals would be affected, and in some cases reconstruction might even be made necessary.

The enormous lake traffic which uses these harbors and these rivers is increasing with great rapidity, both in gross volume and in the size and average draft of the vessels employed therein. The Chief of Engineers reports that to lower the water surface 6 inches would reduce the permissible load of one of the large modern vessels by from 300 to 550 tons, with a consequent loss of from $3,600 to $7,500 in freights for such vessel per season. The International Waterways Commission reported that it would be a conservative estimate which would make the loss to the navigation interests resulting from a reduction of 6 inches in the depth of water as $1,500,000 per annum, or a sum which, capitalized at 4 per cent., would amount to a loss of $37,500,000. (see third progress report of International Waterways Commission of Dec. 1, 1907, p. 24). The lowest careful estimate of injury to American vessels alone is reported by the Chief of Engineers at $1,000,000 per year.

The argument was made before me that, owing to the well-known fact that the levels of the lake vary, owing to winds and change of barometric pressure, by amounts even greater than the reduction which would be caused by this canal, therefore the proposed reduction is of no consequence. This argument is well disposed of in the report of the International Waterways Commission of January 4, 1907, on page 8, as follows:

It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they cannot see it they will not know it and will not feel it. The argument is fallacious. It is true that they cannot see it immediately, but they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be [fol. 103] diminished by the amount that the average level is lowered unless the depth be restored by remedial works.

In a word, every drop of water taken out of Chicago necessarily tends to nullify costly improvements made under direct authority of Congress throughout the Great Lakes, and a withdrawal of the amount now applied for would nullify such expenditures to the

amount of many millions of dollars, as well as inflict an even greater loss upon the navigation interests using such waters.

On the other hand, the demand for the diversion of this water at Chicago is based solely upon the needs of that city for sanitation. There is involved in this case no issue of conflicting claims of navigation. The Chief of Engineers reports that so far as the interests of navigation alone are concerned, even if we should eventually construct a deep waterway from the Great Lakes to the Mississippi over the route of the sanitary canal, the maximum amount of water to be diverted from Lake Michigan need actually be not over 1,000 feet per second, or less than a quarter of the amount already being used for sanitary purposes in the canal. This estimate is confirmed by the report of the special board of engineers on the deep waterway from Lockport, Ill., to the mouth of the Illinois River, dated January 23, 1911. It is also confirmed by the practical experience of the great Manchester Ship Canal in England. From the standpoint of navigation alone in such a waterway too great a diversion of water would be a distinct injury rather than a benefit. It would increase the velocity of the current and increase the danger of overflow and damage to adjacent lands.

We have, therefore, presented in this case claims of entirely different characters and jurisdictions—the claim of sanitation on the one side and of navigation on the other; the vital interest of a single community on the one side and the broad interest of the commerce of the nation on the other. The discretion given to the Secretary of War under sections 9 and 10 of the act of 1899 is very broad, but I have very grave doubts as to whether it was intended to authorize him to grant a permit which would inflict a substantial injury upon commerce in order to benefit sanitation. The entire purpose and scope of that legislation was to make him the guardian of commercial interests of the nation represented in their waterways. And while he sometimes under that statute must decide that the interests of one class of transportation are less important and must yield to the conflicting interests of another class, I have considerable doubt [fol. 104] whether it was intended to give him authority to sacrifice substantial interests of navigation to entirely different claims over which he normally has no jurisdiction whatever.

But however that may be, and without resting my decision upon the question of my legal authority, I am quite clear as a matter of discretion that under the facts presented by this case no further diversion of water should be permitted at Chicago without the direct sanction of the Congress of the United States. I do not for one moment minimize the importance of preserving the health of the great City of Chicago; but when a method of doing this is proposed which will materially injure a most important class of the commerce of the nation and which will also seriously affect the interests of a foreign power, it should not be done without the deliberate consideration and authority of the representatives of the entire nation. The growth of Chicago is phenomenal and its representatives are quite unwilling to put any final limit to the demand which may be made upon the waters of Lake Michigan for its sanitation under the

system now in use. I have before me the report of 1911 of the president of the sanitary district in which he says:

I am of the opinion that the presumption that our water supply is to be limited to 10,000 cubic feet per second, or 600,000 cubic feet per minute, is gratuitous and mischievous and should not be voiced by the officials of this district. I believe that we should have the volume requisite to our needs as they appear and are justified.

It is therefore quite conceivable that compliance with their sanitary needs according to this method of sanitation may eventually materially change this great natural watercourse now existing through the Lakes. The weighing of the sanitation and possibly the health of one locality over against the commerce of the rest of the Nation and the consideration of our relations and obligations to Canada in respect to a great international waterway are not matters of mere technical or scientific deduction. They are broad questions of national policy. They are quite different in character, for example, from the question of fixing the proper location of a pierhead line or the height or width of a drawbridge over a navigable stream—fair samples of the class of questions which come to the Secretary of War for decision under the above-mentioned act of 1899. While the researches and opinions of experts in the respective fields are necessary and useful as an assistance toward reaching a fair and proper policy, the final determination of that policy should belong not to an [fol. 105] administrative officer but rather to those bodies to whom we are accustomed to entrust the making of our laws and treaties.

In my view of the proper exercise of my discretion in this matter the foregoing considerations are sufficient for a decision of this case. Having reached the conclusion that the proposed diversion of the waters of Lake Michigan would substantially injure the interests of navigation on the Great Lakes which it is my legal duty to protect, it would clearly follow that the present application should be denied.

I have carefully examined, however, the evidence which both sides have introduced bearing upon the sanitary needs of the City of Chicago, and my conclusion is in no way shaken. I am not persuaded that the amount of water applied for is necessary to a proper sanitation of the City of Chicago. The evidence indicates that at bottom the issue comes down to the question of cost. Other adequate systems of sewage disposal are possible and are in use throughout the world. The problem that confronts Chicago is not different in kind but simply larger and more pressing than that which confronts all of the other cities on the Great Lakes, in which nearly 3,000,000 people of this country are living. The urban population of those cities, like that of Chicago, is rapidly increasing, and a method of disposition of their sewage which will not injure the potable character of the water of the Lakes must sooner or later be found for them all. The evidence before me satisfies me that it would be possible in one of several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition. A recent report of the engineer of the sanitary commissior (Oct. 12, 1911) proposes

eventually to use some such method, but proposes to postpone its installation for a number of years to come, relying upon the present more wasteful method in the meanwhile. It is manifest that so long as the city is permitted to increase the amount of water which it may take from the Lakes, there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage. This is particularly true in view of the fact that by so doing it may still further diminish its expenses by utilizing the water diverted from the Lakes for water power at Lockport. But it must be remembered that for every unit of horsepower realized by this water at Lockport four units of similar horsepower would be produced at Niagara, where the natural con- [fol. 106] ditions are so much more favorable. Without, therefore, going more into detail in a discussion of this question, I feel clear that no such case of necessity has been presented by the evidence before me as would justify the proposed injury to the many varied interests in the great waterways of our lakes and their appurtenant rivers.

It remains only to consider certain special arguments that have been pressed upon me. It has been urged that the levels of the lakes, even if lowered, could be restored by compensating works. To a certain extent that is true. But the very nature of this consideration offers another illustration of the importance of having the whole question passed upon by Congress. Such compensating works can only be constructed by the authority of Congress and at very considerable cost. It is not a matter which is in the hands of the Secretary of War. Permission to divert water which will at one and the same time nullify the effect of past appropriations and make necessary similar expenditures in the future, should be granted only with the express consent of the body in whose hands the making of such appropriations and the authorization of such works rest.

Furthermore, in most cases such compensating works could only be constructed with the joint consent of our neighbor Canada. The United States Government alone would be unable, even if it were willing to spend its own funds, to compensate for the damage done through the lowering of these levels unless Canada were willing to join in constructing the portion of such works which would necessarily stand upon Canadian soil.

The question therefore becomes not merely national but international, and this leads me to the consideration of the arguments which were urged by both sides in reference to the treaty with Great Britain in respect to Canada of January 11, 1909. A careful consideration of that treaty fails to indicate to me that it is in any way controlling upon the questions now before me. It gives to the citizens of both countries certain mutual rights of navigation in the waters of the Great Lakes and their connecting rive-s; but beyond that the question of the right to this diversion at Chicago seems to me to have carefully excluded. The applicants for the permit have urged upon me that article 8 of the treaty gives a preference to the uses of water of the lakes for domestic and sanitary purposes over the uses of such water for navigation. Article 8, however, applies only to future

[fol. 107] cases brought before the International Joint Commission; and furthermore I am clearly of the opinion that the domestic and sanitary purposes referred to in that article were intended to be the "ordinary" uses of such waters for domestic and sanitary purposes referred to in article 3. It would be quite contrary to our own national policy to give such a preference to an extraordinary sanitary use of such a character as to create a substantial injury to navigation. The matter has been before our own Supreme Court in the case of the United States v. the Rio Grande Dam & Irrigation Co. (174 U. S., 690). In that case the Supreme Court held that a company which proposed to take the water of the Rio Grande river for the purpose, among others, "of supplying water to cities and towns for domestic and municipal purposes" could be prevented from so doing when the result would be a substantial injury to the navigability of the Rio Grande river farther down. In its opinion the court said:

The question always is one of fact, whether such appropriation substantially interferes with the navigable capacity within the limits where navigation is a recognized fact. In the course of the argument, this suggestion was made, and it seems to us not unworthy of note, as illustrating this thought. The Hudson river runs within the limits of the State of New York. It is a navigable stream and a part of the navigable waters of the United States, so far at least as from Albany southward. One of the streams which flows into it and contributes to the volume of its waters is the Croton river, a non-navigable stream. Its waters are taken by the State of New York for domestic uses in the City of New York. Unquestionably the State of New York has a right to appropriate its waters, and the United States may not question such appropriation, unless thereby the navigability of the Hudson be disturbed. On the other hand, if the State of New York should, even at a place above the limits of navigability, by appropriation for any domestic purposes, diminish the volume of waters, which, flowing into the Hudson, make it a navigable stream, to such an extent as to destroy its navigability, undoubtedly the jurisdiction of the National Government would arise and its power to restrain such appropriation be unquestioned; and within the purview of this section (act of Sept. 19, 1890, ch. 907) it would become the right of the Attorney General to institute proceedings to restrain such appropriation.

The treaty, however, contains provisions in its article 10 by which "any questions or matters of difference arising between the high contracting parties involving the rights, obligations, or interests of the United States or of the Dominion of Canada, either in relation to each other or to their respective inhabitants, may be referred for decision" to an international joint commission established by the said treaty. The hearing before me brought forth the fact that the Government of Canada regards the proposal contained in this application as one which affects the material interests of that county. The establishment by formal treaty between the two countries of a tribunal [fol. 108 & 109] with jurisdiction to decide just such questions seems to me to afford an additional reason against the assumption of juris-

diction to decide the question by an administrative officer of one of those countries.

In short, after a careful consideration of all the facts presented, I have reached the following conclusions:

First. That the diversion of 10,000 cubic feet per second from Lake Michigan, as applied for in this petition, would substantially interfere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.

Second. That that being so, it would not be appropriate for me, without express congressional sanction, to permit such a diversion, however clearly demanded by the local interests of the sanitation of Chicago.

Third. That on the facts here presented no such case of local permanent necessity is made evident.

Fourth. That the provisions of the Candian treaty for a settlement by joint commission of "questions or matters of difference" between the United States and Canada offer a further reason why no administrative officer should authorize a further diversion of water, manifestly so injurious to Canada, against Canadian protest.

The prayer of the petition is therefore denied.

Henry L. Stimson, Secretary of War.

[File endorsement omitted.]

[fol. 110] District Court of the United States, Northern District of Illinois

United States of America, Complainant,

vs.

The Sanitary District of Chicago, Defendant.

The Answer of the Sanitary District of Chicago, Defendant, to the Bill of Complaint of the United States of America, Complainant—Filed January 16, 1914

[fol. 111] This defendant, The Sanitary District of Chicago, by Edmund D. Adcock and Alfred S. Austrain, its solicitors, now, and at all times hereinafter saving and reserving unto itself all benefit and advantage of exception which can or may be had or taken to the many errors, uncertainties and other imperfections in said bill contained for answer thereunto, or to so much or such parts thereof as this defendant is advised, it is or are material or necessary for it to make answer unto answering says:

1. This defendant admits that it is a municipal corporation, organized and existing under and by virtue of the laws of the State

of Illinois, as charged in the first paragraph of the Bill of Complaint, filed herein, and this defendant hereto attaches a copy of the Act of the General Assembly of the State of Illinois, entitled "An Act to create Sanitary Districts and to remove obstructions in the Desplaines and Illnois Rivers," approved May 29, 1889, in force July 1, 1889, [fol. 112] and all acts amendatory and supplementary thereto, marked "Exhibit A" and made a part hereof, to which reference is hereby made.

2. This defendant admits that the Chicago River is situated in the County of Cook and State of Illinois and consists of a main river, originaly flowing in a generally easterly direction, emptying into Lake Michigan; that said main river is formed by two branches, known as the North Branch and the South Branch respectively; that said South Branch is divided into two forks, known as the West Fork and the South Fork, and this defendant attaches hereto a map or plat, marked "Exhibit B" and made a part hereof, which said plat more particularly describes said river, its branches and forks and shows the exact location and direction of the same, to which said "Exhibit B" reference is hereby made.

3. This defendant admits that the said Chicago River including both the North Branch and South Branch as well as the West Fork and South Fork of the South Branch are navigable waters of the United States.

4. This defendant admits that the United States of America has appropriated and expended large sums of money to-wit: the sum of $4,216,066.33 in improving the navigable capacity of said river and the harbor at the mouth of the same, as is charged in paragraph 4 of the Bill of Complaint, filed herein, and this defendant shows that of the said sum, the said complainant expended, to wit: the sum of $2,389,527.10, in and about the improvement of the harbor at the mouth of the said Chicago River; that no part of said latter sum was expended in or about the improvement of said Chicago River; that down to the year 1896 the said complainant had expended no money whatever in the improvement of the said Chicago River; that the balance of said sum of $4,216,066.36, to wit: the sum of $1,626,539.29 was expended by the complainant in and about the improvement of the Chicago River between the year 1896 and the [fol. 113] 30th day of June, 1913; that the City of Chicago, prior to the expenditure by the United States of any money on the Chicago River, began the improvement of said river and expended large sums of money in said improvement; that the City of Chicago entered upon the improvement of the said Chicago River in the year 1861 and has expended during the period beginning in the said year, 1861, and ending the first day of January, 1913, the sum of, to wit: $6,272,574.52; that this defendant has itself expended in addition to the money expended by the City of Chicago, the sum of, to wit: $10,640,739.52, in and about the improvement of the said Chicago River, the South Branch and West Fork thereof; that the said moneys so expended by this defendant was expended for the

purpose of enabling this defendant to cause to flow the several amounts of water through the said river as provided under the Act of the General Assembly of Illinois of 1889 and all of said expenditures improved the capacity and navigability of said Chicago River and its several branches.

5. This defendant admits that the provisions of Section 10 of an Act of Congress, approved March 3, 1889, entitled "An Act making appropriations for the construction, repair and preservation of certain public works on rivers, harbors and for other purposes" are substantially as set forth in paragraph 5 of the Bill of Complaint filed herein; that the said Act of Congress has remained in full force and effect ever since its passage and still remains in full force and effect.

6. This defendant admits that the Secretary of War on, to wit, the 8th day of May, 1899, issued a permit to this defendant granting it permission to open the channel constructed and cause the waters of the Chicago River to flow into the same, that the said permit is substantially in words and figures as set forth in the said Bill of Complaint as "Exhibit A" thereto. This defendant denies that applica-[fol. 114] tion was made by this defendant for permission to abstract and divert a certain quantity of water from Lake Michigan through the said main channel of this defendant, but this defendant shows that application was made to the Secretary of War for permission to open the channel constructed and cause the waters of the Chicago River to flow into the same pursuant to and under the said Act of May 29th, 1889, hereinbefore set forth, that in the said permit the said Secretary of War stated that he reserved the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

7. This defendants admits that on, to wit: April 9, 1901, the Secretary of War ordered and directed this defendant to reduce the flow through the Chicago River to 200,000 cubic feet of water per minute as charged in paragraph 7 of said bill; that the provisions of said order are substantially as set forth in the said Bill of Complaint as "Exhibit B" thereto.

8. This defendant admits that on or about July 23, 1901, the Secretary of War modified the order theretofore issued on April 9, 1901, as aforesaid by issuing a permit to defendant to flow 300,000 cubic feet of water per minute through the Chicago River between the hours of 4:00 P. M. and 12:00 P. M. midnight; that the provisions of the said permit are set forth in the Bill of Complaint as "Exhibit C."

9. This defendant admits that on or about the 5th day of December, 1901, the Secretary of War issued a permit to defendant to cause the flow 250,000 cubic feet of water per minute throughout the twenty-four hours of the day; that the provisions of said permit are substantially as is set forth in said Bill of Complaint as "Exhibit D" thereto.

10. This defendant admits that on or about the 17th day of January, 1903, the Secretary of War issued a permit to the defendant to increase the flow of water through the Chicago River from 250,-[fol. 115] 000 to 300,000 cubic feet of water per minute until the 31st day of March, 1903, after which time the flow to be reduced to 250,000 cubic feet of water per minute; that the provisions of the said permit are substantially as is set forth in the said Bill of Complaint as "Exhibit E" thereto.

11. This defendant admits that on or about the 28th day of November, 1906, this defendant made application to the Secretary of War for permission to construct a canal connecting the Calumet River with the main channel of the defendant at what is known as Sag Station, as charged in paragraph 11 of said Bill of Complaint; that thereafter on or about the 14th day of March, 1907, the said Secretary of War denied the said application and refused to grant the permit applied for thereunder; that a copy of the said statement of the Secretary of War denying said permit is by express reference thereto, made part hereof, and marked "Exhibit C," and attached hereto.

12. This defendant admits that on or about the 11th day of September, 1907, this defendant applied for and obtained from the Secretary of War a permit to construct a canal connecting Lake Michigan at Wilmette, Illinois, with the North Branch of the Chicago River; that a copy of the said permit is by express reference thereto, made a part hereof and is attached hereto and marked "Exhibit D."

13. This defendant admits that on or about the 30th day of June, 1910, this defendant applied for and obtained permission from the Secretary of War authorizing it to construct a canal connecting the Calumet River with the main channel of this defendant at Sag, Illinois, and to reverse the flow of the Calumet River, that the said canal is known and described as the Sag Channel, that a copy of the said permit issued on said, to-wit: June 30, 1910, is by express reference thereto, made a part hereof and is attached hereto and marked "Exhibit E."

[fol. 116] 14. This defendant admits that on or about the 5th day of February, 1912, this defendant applied to the Secretary of War for a permit to withdraw and divert from Lake Michigan through the Chicago and Calumet Rivers at least the amount of 10,000 cubic feet of water per second or 600,000 cubic feet of water per minute as charged in paragraph 14 of said Bill of Complaint; copy of which said application is attached to said Bill of Complaint and marked "Exhibit F."

15. This defendant admits that on, to-wit: the 8th day of January, 1913, the Secretary of War refused said application of February 5, 1912; that the statement of the Secretary of War in refusing the said application is set forth as "Exhibit G" to said Bill of Complaint.

16. This defendant denies that it has for a long period of time diverted and abstracted from Lake Michigan and caused to flow through the Chicago River, or that it is at the present time diverting and abstracting from Lake Michigan and causing to flow through the Chicago River from 400,000 to 600,000 cubic feet of water per minute as charged in paragraph 16 of said Bill of Complaint.

17. This defendant denies that the diversion and abstraction of the waters of Lake Michigan into the Chicago River substantially in excess of the amount of 250,000 cubic feet of water per minute has lowered or will lower the levels of Lake Michigan, Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Sault Ste Marie, St. Mary's River, St. Clair River, Detroit River, Niagara River and St. Lawrence River, or any of them, or of any of the harbors, channels, canals or rivers connected therewith or will injure or diminish or create an obstruction to the navigable capacity of said waters or any of them as charged in paragraph 18 of said Bill of Complaint.

18. This defendant neither affirms nor denies that the said waters mentioned in paragraph 18 of the said Bill of Complaint have been deepened and improved under great expense to the complainant, [fol. 117] under the authority of Congress but prays for strict proof thereof; and this defendant denies that the diversion and abstraction of waters from Lake Michigan substantially in excess of the permits hereinabove set forth have, or will have a tendency to undo or annul the orders or acts of Congress as charged in paragraph 19 of said Bill of Complaint.

19. This defendant denies that the said diversion and abstraction of the waters of Lake Michigan through the Chicago River in excess of or substantially in excess of the amount provided by the permit of the Secretary of War as aforesaid will modify the condition and capacity of the channel of the said Chicago River as charged in paragraph 20 of said Bill of Complaint.

20. This defendant denies that the said diversion and abstraction of waters of Lake Michigan through the Chicago River in excess of or substantially in excess of the permits of the Secretary of War as aforesaid, will alter or modify the condition and capacity of Lake Michigan, Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Sault Ste Marie, St. Mary's River, St. Clair River, Detroit River, Niagara River and St. Lawrence River, or any of them, and the ports, roadsteads, havens, harbors, canals and harbors of refuge connected with the above named waters or any of them. This defendant denies that it cannot lawfully continue to divert and abstract without the permission of the Secretary of War, waters from Lake Michigan as it now does or that it cannot lawfully divert and abstract without the permission of the Secretary of War waters from Lake Michigan under the said Act of the General Assembly of the State of Illinois approved May 29th, 1889, and by and through the channels and works it has already constructed. And this defendant denies that the complainant will be in any manner injured by the diversion of

waters pursuant to said Act of the General Assembly of the State of [fol. 118] Illinois; and this defendant denies that the Interstate Navigation and Commerce of the United States will in any manner or to any extent be injured or destroyed by the proposed abstraction or diversion of water from Lake Michigan pursuant to and under said Act of the General Assembly of the State of Illinois of May 29, 1889, and as contemplated by the channels and works of this defendant hereinbefore and hereafter described.

21. This defendant states that the Sanitary District of Chicago is a municipal subdivision of the State of Illinois, consisting of an area of 386.2 square miles, situated on the shore of Lake Michigan at the southwestern end of said lake, with a shore line on said Lake Michigan of 33 miles and extending westward from said shore line, a distance of from 6 to 14 miles; that the land lying within the said territory is naturally drained into Lake Michigan for the most part through the Chicago and Calumet Rivers and their branches; that rising in the State of Wisconsin about 12 miles back from the shore of Lake Michigan, is the Desplaines River which flows in a southerly direction at a distance of about 10 miles from said lake and parallel to said lake until it, the said Desplaines River, reaches a point 15 miles southwest of the mouth of the Chicago River, when it turns to the southwest and at a distance of 45 miles beyond empties into the Illinois River; that at a distance of about 6 miles back from Lake Michigan and between said Lake Michigan and the Desplaines River is an elevation of land of approximately 11 feet above the low water level of Lake Michigan; that said elevation of land has been known as the Continental Divide, or the height of land on one side of which water flows into the Great Lakes thence into the Gulf of St. Lawrence, and on the other side of which water flows into the Desplaines River, thence into the Illinois and Mississippi Rivers, thence to the Gulf of Mexico; that the lowest point in said Continental Divide or elevation [fol. 119] of land was at a point about 8 miles by the water trail southwest of the mouth of the Chicago River; that at said point there was situated approximately on the summit of said divide a lake known as Portage *Land* and later as Mud Lake; that in times of high water the Desplaines River rose to the elevation of said lake and discharged itself over the divide and through the Chicago River into Lake Michigan; that the land lying to the East of said divide is low, flat, level and swampy land absolutely devoid of hills or elevations of land so that in times of high water large portions of said territory were overflowed; that the City of Chicago was established at the mouth of the Chicago River located approximately in the center of the territorial limits of this defendant; that the City of Chicago as it has expanded has stretched out over the branches of the Chicago River and over the territory of this defendant and from the time when the site where the City of Chicago is now located, was settled it has been menaced by floods and has had to contend with the natural disadvantages which it suffered by reason of the fact that the city was situated upon a flat, low, sandy soil and at the outlet or discharging point of a large drainage area; that from the various

times when this part of the territory of North America was discovered, there has existed at the mouth of the Chicago River a trading post; that from 1778, a fort, afterwards known as Fort Dearborn, was situated near the mouth of said river and on the south side thereof; that the said Fort and other buildings were practically destroyed in the Massacre of 1812; that the said Fort Dearborn was rebuilt by the United States in the year 1816; that during the early days the sewage of said Fort and the houses adjoining thereto was disposed of by cesspools and by other methods customarily used in small urban communities; that in the year 1837, the Village of Chicago was organized with 709 lawful voters; that between said year 1837 and the year 1854 when the City of Chicago was incorporated, the Village had grown with very rapid strides so that there [fol. 120] was a population of approximately 40,000 people in the City of Chicago in the year 1854; that by reason of the natural conditions which existed at Chicago as set out in detail hereinbefore, to-wit: the location of said City on a flat, low, marshy and sandy soil with only a slight elevation above the level of Lake Michigan, said City was confronted at that early day with the necessity of constructing a sewer system and was obliged to and did raise the level of its streets so as to permit the construction therein of a sewer system, and entered thereupon, upon the systematic construction and development of such a sewer system; that between the years 1854 and the year 1889 sewers were constructed in the territory of said City of Chicago north of the Chicago River, which drained into the Chicago River as far north as the boundaries of said City of Chicago; that the territory lying to the west of both the North Branch and the South Branch of the Chicago River constructed sewers draining into the Chicago River; that the territory lying south of the Chicago River and east of State Street constructed sewers draining into Lake Michigan; that is to say, said territory constructed sewers at 12th Street, 22nd Street and in 31st Street emptying directly into Lake Michigan; that the territory above described as being within the boundaries of the City of Chicago as it existed in 1889 was bounded on the north by Fullerton Avenue, at a distance of 2½ miles north of the Chicago River, on the west by Western Avenue at a distance of between 4 and 5 miles west of Lake Michigan, and on the south by 39th street, a distance of approximately 4½ miles south of the mouth of the Chicago River.

22. This defendant states that south of 39th Street and adjoining thereto was situated the flourishing village of Hyde Park with a population in 1889 of 41,000, the largest part of which had sewers emptying directly into Lake Michigan; that west of said village of Hyde Park was situated a town of considerable size known as the [fol. 121] Town of Lake, with a population of, to-wit: 58,661; that the sewage from said Town of Lake emptied into the South Fork of the Chicago River; that situated north of Fullerton Avenue, being the northern boundary of said City of Chicago was situated the Town of Lake View with a population of , to-wit: 42,339, which had several sewers emptying into Lake Michigan; that situated west of said

Town of Lake View was situated the Town of Jefferson, whose sewers emptied into the North Branch of the Chicago River, with a population in 1889 of, to-wit: 10,662; that the population of the City of Chicago in 1889 was, to-wit, 802,651; that by reason of the fact that the said City of Chicago and the towns of Lake View and Hyde Park emptied their sewage directly in to Lake Michigan, and that other portions of said City of Chicago, said Town of Jefferson and said Town of Lake emptied their sewage into the Chicago River, which in turn during portions of the year discharged itself into Lake Michigan, the said water of the Chicago River and the waters of Lake Michigan adjoining the said City of Chicago became and were badly polluted and the danger to health and condition of nuisance resulting therefrom became so aggravated as to necessitate the creation of this defendant for the purpose of abating the said pollution and nuisance thereby created, and providing a way as hereinafter more fully shown of disposing of the sewage of said City of Chicago and its adjacent towns and villages.

23. This defendant further states that the inhabitants of the Village of Chicago obtained their drinking water from shallow wells sunk into the sand, upon which said Village of Chicago was founded; that the water obtained therefrom consisted of the water of Lake Michigan or of the Chicago River which had seeped through the said sands and into said shallow wells and did not consist of natural underground water; that as the said Village grew in population to a [fol. 122] city, the said shallow wells became badly polluted by sewage and by the drainage water and refuse washed into said wells, and as a result the people of said city became obliged to obtain their water from Lake Michigan; that at first water wagons were employed to cart the water from the lake to the individual users and later a wooden pipe was laid in the streets; that subsequently a tunnel was extended out into Lake Michigan at Chicago Avenue and a crib built at the Lake extremity to prevent the end of said tunnels being injured or choked up by ice in the winter time; that the City of Chicago, and some of the towns or villages mentioned built in Lake Michigan six intakes, cribs and tunnels connected therewith for the purpose of obtaining water from Lake Michigan as follows: The Lake View Crib on the northern extremity of said city at a distance of two miles from the shore of Lake Michigan; the Carter H. Harrison Crib, situated at a distance of three miles from the shore; the Chicago Avenue Crib, situated at a distance of two miles from shore; the Four Mile Crib situated at approximately four miles from the shore and opposite the most densely populated portion of said City of Chicago, and the Hyde Park and Edward F. Dunne Cribs, two miles off shore, situated near the southern extremity of said City; that from each of the said cribs large tunnels extended in the earth under Lake Michigan to points on the shore where pumping stations are erected, by means of which water is pumped through the said tunnels and distributed through distributing pipes or water mains to the people of the City of Chicago, and adjoining towns; that the said distributing system is interconnected so that in case any one

crib or tunnel should be incapacitated, the other tunnels would furnish water to the people who would ordinarily take from that tunnel by means of inter-connecting pipes, but the said City of Chicago has spent in and about the construction of said cribs and water tunnels and in and about the construction of its distributing pipes and distributing tunnels large sums of money, in excess of, to-wit: [fol. 123] $59,042,565.00; and that said City of Chicago has no other means or source from which it could obtain a water supply of the quality and amount adequate to its needs and is therefore obliged to and will be obliged to obtain its entire drinking water supply out of said Lake Michigan.

This defendant shows that by reason of the facts hereinbefore set forth that between the years 1880 and 1900 when this defendant opened its channel, as hereinafter set forth, the said waters of Lake Michigan, from which the inhabitants of the City of Chicago and environs were obliged to obtain their water supply, were badly polluted by reason of the fact that the sewage of said City of Chicago and adjoining towns and villages thereto, as well as the drainage water of a large drainage area was discharged into Lake Michigan.

24. This defendant states that from the earliest discovery of this country, there has existed between Lake Michigan and the Mississippi River a water route used as a highway of trade and travel; that this water route originally consisted of the Chicago River, its south branch and the west fork thereof, a ditch or canal in wet seasons and a portage in dry seasons, from thence into a lake known as Mud Lake, and a ditch or canal in wet seasons and a portage in dry seasons from said Mud Lake into the Desplains River; from thence said route proceeded down the Desplaines River into the Illinois River and thence into the Mississippi River. That the said route was used for the purpose of carrying on trade and for the purpose of travel for upwards of 160 years, and that said use was prior to any improvements made by the United States or by the government then controlling the country now known as Canada.

That there existed also during the said period from the lower end of Lake Michigan through the Great Lakes and its connecting waters to the Atlantic Ocean two water routes, one by way of a portage around Niagara Falls and from thence on the St. Lawrence River [fol. 124] to the Atlantic Ocean; that the other water route consisted of a route through Georgian Bay, Lake Nipissing, and down the Ottawa River into the St. Lawrence River and thence to the Atlantic Ocean; that the said water route hereinbefore described from Lake Michigan into the Mississippi River, and the said two water routes from the lower end of Lake Michigan to the Atlantic Ocean were used for the purpose of trade and for travel prior to the year 1830 and for some time subsequently.

That about the year 1822 there was a great demand for improvement of these water routes; that on or about March 30th, 1822, the Congress of the United States passed an act granting to the State of Illinois certain public lands for the purpose of aiding the State of Illinois in constructing a canal "connecting the Illinois River

with the southern end of Lake Michigan;" that the said act of the Congress of the United States is in the words and figures as follows, to-wit:

Act of March 30, 1822

(3 U. S. Stat. at Large, p. 659)

An Act to Authorise the State of Illinois to Open a Canal Through the Public Lands to Connect the Illinois River with Lake Michigan. (Approved and in force March 30, 1822.)

Section 1. Be it enacted by the Senate and the House of Representatives of the United States of America, in Congress Assembled: That the State of Illinois be, and is hereby authorized to survey and mark, through the public lands of the United States, the route of the canal connecting the Illinois River with the southern bend of Lake Michigan; and ninety feet of land on each side of said canal shall be forever reserved from any sale to be made by the United States, except in the cases hereinafter provided for, and the use thereof forever shall be, and the same is hereby vested in the said State for a canal, and for no other purpose whatever; on condition, however, that if the said State does not survey and direct by law said canal to be opened, and return a complete map thereof to the treas-
[fol. 125] ury department, within three years from and after the passage of this act; or, if the said canal be not completed, suitable for navigation within twelve years thereafter; or, if said ground shall ever cease to be occupied by, and used for, a canal suitable for navigation; the reservation and grant hereby made shall be void and of none effect; Provided, always, and it is hereby enacted and declared, that nothing in this act contained, or that shall be done in pursuance thereof, shall be deemed or construed to imply any obligation on the part of the United States to appropriate any money to defray the expenses of surveying or opening said canal; Provided, also, and it is hereby further enacted and declared, that the said canal, when completed, shall be and forever remain a public highway for the use of the Government of the United States, free from any toll or other charge whatever, for any property of the United States, or persons in their service passing through the same.

(Sections through which the canal passes reserved until, etc.—The state may use necessary adjacent material without waste.)

2. And be it further enacted, That every section of land through which said canal route may pass, shall be, and the same is hereby reserved from future sale, until hereafter specially directed by law; and the said State is hereby authorized and permitted, without waste, to use any materials on the public lands adjacent to said canal, that may be necessary for its construction.

That the said act provided that if the State of Illinois did not make a survey and furnish a complete copy thereof to the Treasury Department within three years from and after the date of its passage, or if

the said canal be not completed suitable for navigation within twelve years thereafter, or if said ground shall ever cease to be occupied and used for a canal suitable for navigation, the reservation and grant made shall be void and of no effect; that the State of Illinois did not within the three year period provided for in the act return a complete map of the canal, and the rights granted under the said act lapsed pursuant to the terms thereof; that subsequently to the passage of the said act and prior to March 2nd, 1827, and subsequently [fol. 126] thereto, the Government of Great Britain refused to the citizens of the United States of America the free navigation of either or both of the water routes hereinbefore described, and particularly the free navigation of the St. Lawrence River; that the United States of America claimed that under the laws of nations the citizens of the United States were entitled to the use of such outlet for the purpose of carrying on trade and for travel.

That on or about the 28th day of January, 1826, a memorial was addressed to the Congress of the United States by the General Assembly of Illinois, which said memorial is attached hereto as Exhibit "F" and made a part hereof. That in and by the said memorial the General Assembly of the State of Illinois represented to the Congress that the construction of a canal "uniting the waters of Lake Michigan with the Illinois River will form an important addition to the great connecting chain of internal navigation."

That the action of the Government of Great Britain in refusing to the citizens of the United States the free navigation of the St. Lawrence River made it necessary for the United States to provide a free and unobstructed water route from the Great Lakes to the Atlantic Ocean by way of the Desplaines, Illinois and Mississippi Rivers and the Gulf of Mexico.

That thereupon on or about the 2nd day of March, 1827, the Congress of the United States passed an act granting to the State of Illinois certain public lands "for the purpose of aiding the State in opening a canal uniting the waters of the Illinois River with those of Lake Michigan." That the said Act of March 2nd, 1827, is in words and figures as follows, to-wit:

[fol. 127] **Act of March 2, 1827**

(4 U. S. Stat. at Large, p. 234)

An act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan. (Approved and in force March 2, 1827.)

Section 1. Be it enacted by the Senate and House of Representatives of the United States of America, in Congress Assembled, That there be and hereby is granted to the State of Illinois, for the purpose of aiding the said State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each side of said canal, and re-

serving each alternate section to the United States, to be selected by the Commissioner of the Land Office, under the direction of the president of the United States, from one end of the said canal to the other; and the said land shall be subject to the disposal of the Legislature of the said State, for the purpose aforesaid, and no other; Provided, That the said canal when completed, shall be and forever remain a public highway for the use of the Government of the United States, free from any toll, or other charge, whatever, for any property of the United States, or persons in their service passing through the same; Provided, That said canal shall be commenced within five years and completed in twenty years, or the State shall be bound to pay to the United States the amount of any lands previously sold, and that the title to purchasers under the State shall be valid.

(Duty of the Governor of the State when the canal is located, etc.)

2. And be it further enacted, That so soon as the route of the said canal shall be located and agreed on by the said State, it shall be the duty of the Governor thereof, or such other person or persons as may have been, or shall hereafter be, authorized to superintend the construction of said canal, to examine and ascertain the particular sections to which said State will be entitled, under the provisions of this act, and report the same to the Secretary of the Treasury of the United States.

[fol. 128] (Powers Given to the Legislature)

3. And be it further enacted, That the said State under the authority of the Legislature thereof, after the selection shall have been so made, shall have power to sell and convey the whole, or any part of the said land, and to give a title in fee simple therefor, to whomsoever shall purchase the whole or any part thereof.

That in and by the said Act of March 2nd, 1827, the Congress provided for the uniting of the waters of Lake Michigan with those of the Illinois River and made possible the establishment of an outlet from Lake Michigan, and thereby brought Chicago and its surrounding territory into the Mississippi River water-shed; that pursuant to the said Act of March 2nd, 1827, the State of Illinois by act of the General Assembly of January 9, 1836, provided for the construction of a canal of a certain depth to be supplied with water from Lake Michigan; that Section 16 of said act of the General Assembly of the State of Illinois of January 9th, 1836, entitled, "An Act for the construction of the Illinois and Michigan Canal," is as follows:

"That said canal shall not be less than forty-five feet wide at the surface, thirty feet at the base, and of sufficient depth to insure navigation of at least four feet, to be suitable for ordinary canal boat navigation, to be supplied with water from Lake Michigan and such other sources as the Canal Commissioners may think proper, and to be constructed in the manner best calculated to promote the permanent interests of the country, reserving ninety feet on each side of

said canal to enlarge its capacity whenever in the opinion of the Board of Canal Commissioners the public good shall require it."

That the plan of the said canal as originally contemplated under the act of the General Assembly of January 9th, 1836, provided for the flow of the waters of Lake Michigan by gravity into and through the canal and from thence into the Illinois River; that the plan originally proposed was known as the deep-cut plan; that on account of lack of funds the State of Illinois was unable to immediately construct the said canal upon that plan whereby the waters of Lake [fol. 129] Michigan would flow through the said canal by gravity into the Desplaines river and thence into the Illinois.

That in the year 1848 the said Illinois and Michigan canal was finally completed upon the plan known as the shallow-cut plan, by which water of Lake Michigan necessary to partly operate the said canal and its locks were caused to flow into the canal by means of pumps then installed; that from the time the said canal was opened until the construction of the main channel of the Sanitary District, it furnished a partial outlet for the sewage and drainage of the City of Chicago; that as the needs of the City of Chicago demanded, said canal was enlarged so as to provide a better and more suitable outlet for the drainage of the City of Chicago and its environs; that on or about the year 1860, to meet the demands of increased population of the City of Chicago, larger pumps were installed to pump more water from Lake Michigan through the Chicago River into the Illinois and Michigan Canal, thence into the Desplaines River, thus causing part of the drainage and sewage of the City of Chicago and its environs to flow into the Desplaines River; that in the year 1865, to meet the further needs of the City of Chicago with reference to furnishing an outlet for its drainage and sewage, the General Assembly of the State of Illinois passed an act entitled, "An Act to provide for the completion of the Illinois and Michigan Canal upon the plan adopted by the State in 183 :." (Approved February 16, 1865; in force April 16, 1865): that the said act of the General Assembly of the State of Illinois is in words and figures as follows, to-wit:

An Act to Provide for the Completion of the Illinois and Michigan Canal upon the Plan Adopted by the State in 1836. (Approved February 16, 1865, in Force April 16, 1865.)

(Preamble.)—Whereas, it has been represented that the City of Chicago, in order to purify or cleanse Chicago River, by drawing sufficient quantity of water from Lake Michigan, directly through it, [fol. 130] and through the summit division of the Illinois and Michigan Canal, would advance a sufficient amount of funds to accomplish this desirable object; and,

Whereas, the original plan of the said canal was to cut down the summit so as to draw a supply of water for navigation directly from Lake Michigan, which plan was abandoned for the time being, after a large part of the work had been executed, only in consequence of the inability of the State to procure funds for its further prosecution; and,

Whereas, under the law creating the trust the plan of the summit division of the canal was changed, the level being raised so as to require the principal supply of water to be obtained through the Calumet feeder, subject to serious contingencies, and by pumping on to the summit with the hydraulic works at Bridgeport; now, therefore,

(Summit Division to Be Completed.)—Section 1. Be it enacted by the People of the State of Illinois, represented in the General Assembly: That to secure the completion of the summit division of the Illinois and Michigan Canal, upon the original "deep cut" plan, with such modifications and changes of line, if necessary, as will most effectually secure the thorough cleansing or purification of the Chicago River, and facilitate the execution of the work, the City of Chicago, through its constituted authorities, may at once enter into an arrangement with the board of trustees of said canal, with a view to the speedy accomplishment of the work.

(Opening and Closing of Canal.)—2. The canal shall not be constructed of a less capacity than the plan adopted by the canal commissioners in 1836, nor shall the work of deepening it be prosecuted so as to materially interfere with the navigation. By consent of the board of trustees, however, the navigation may be opened later and closed earlier than usual in former years, but it shall never be diminished to a less time than six months.

(Right of Way.)—3. It shall be lawful for the City of Chicago to enter upon and use any lands which may be necessary for the right of way for said canal, if the route should in any part vary from the present line of canal, and to take and use any materials of any description, necessary for the prosecution of the work contemplated, along the line thereof; the value of the same to be determined in the mode [fol. 131] provided by the general laws of this State.

(Amount Expended to be Lien—Proviso.)—4. The amount expended by the City of Chicago in deepening the summit division of the canal, according to the plan adopted by the canal commissioners in 1836, shall be a vested lien upon the Illinois and Michigan canal and its revenues, after the payment of the present canal debt; and the net revenues of the canal shall all, thereafter, be applied to the payment of the principal and interest of the same expended in accomplishing the object of this Act, until the whole amount is reimbursed to the city; Provided, the cost shall not exceed two and a half millions of dollars.

(State May Refund.)—5. The State of Illinois may at any time relieve this lien upon the canal and revenues, by refunding to the City of Chicago the amount expended in making the contemplated improvement and the interest thereon.

That under the said Act of 1865 the City of Chicago was authorized to improve the said Illinois and Michigan Canal by deepening same and otherwise changing its cross section so that a certain amount of the waters of Lake Michigan, including the sewage and drainage of the City of Chicago, would flow into and through the Illinois and Michigan Canal by gravity, and thence into the Desplaines River.

That on or about the year 1871 the said improvement was completed; that from that time to the time hereinafter stated, to wit, the year 1884, the waters of Lake Michigan, including the sewage and drainage of the City of Chicago and its environs flowed by gravity through the said Illinois and Michigan Canal into the Desplaines River; that from the time the said pumps were installed, to wit: the year 1848, water from Lake Michigan was caused to flow through the Chicago River in various quantities into the said Illinois and Michigan Canal and from thence into the Desplaines and Illinois Rivers; that when the said Illinois and Michigan Canal was completed upon the deep cut plan, a greater amount of water was caused to flow from [fol. 132] Lake Michigan into the said canal and from thence into the Desplaines and Illinois Rivers; that by the said works and the operation of the said pumps, the Chicago River was caused to flow in a reversed direction away from Lake Michigan instead of towards the lake, its current and course was reversed during the greater portion of each year; that thereby the needs of the City of Chicago and its environs for an outlet for its sewage and drainage were partially met.

That an ordinance of the City of Chicago passed on June 5th, 1865, providing for the improvement of the said Illinois and Michigan Canal is attached hereto as Exhibit "G" and made a part hereof.

That in the year 1871 the General Assembly of the State of Illinois, by an act entitled, "An Act to relieve the lien of the City of Chicago upon the Illinois and Michigan Canal and revenues by refunding to said city the amount expended by it in making the improvement contemplated by 'An Act to provide for the completion of the Illinois and Michigan Canal upon the plan adopted by the State in 1836,' approved February 16, 1865, together with interest thereon as authorized by Section 5 of said act, and to provide for issuing bonds therefor," provided for the payment to the City of Chicago of the moneys expended by it in improving the said Illinois and Michigan Canal upon the plan provided for in the Act of 1836.

That in the year 1881 the Senate and the House of Representatives of the State of Illinois passed a joint resolution, which said resolution is in words and figures as follows, to wit:

Resolution of 1881 (Laws 1881, p. 159)

Concerning Chicago Sewage in Illinois and Michigan Canal

Whereas, The State of Illinois, in General Assembly, did, on the [fol. 133] sixteenth day of February, 1865, grant and authorize the City of Chicago in the State of Illinois, to deepen the Illinois and Michigan canal for the purpose of, and with the intent to better the system of sewage of the said City of Chicago by permitting a free flow of water from Lake Michigan through the Chicago River and said canal to the Desplaines and Illinois Rivers; and the City of Chicago did perfect said improvement in conformity with said permission; and,

Whereas, The great fire in the said City of Chicago on the eighth and ninth days of October, A. D. 1871, did so greatly damage the assessable property of a very large number of its citizens and taxpayers, and the people of the State of Illinois did, by its General Assembly, refund to the said City of Chicago the amount of the cost of deepening the Illinois and Michigan Canal said sum refunded being in gross two millions nine hundred and fifty-five thousand three hundred and forty dollars; and,

Whereas, The deepening of the canal as aforesaid has proved to be totally inadequate for the purposes intended, and the large amount of sewage of the City of Chicago, being far greater than the capacity of the canal and the water now passing through it to deodorize and render innocuous; and,

Whereas, The foulness of the water annually causes the death of millions of fish in the Desplaines and Illinois Rivers, that float to the shores and decay; and,

Whereas, Said sewage, in an entirely undecomposed and putrid mass, is carried by the current of the canal into the Desplaines River, and thence into the Illinois River, and in its foulest condition is thus transported to and below the City of Peoria, in said State, rendering the air at all points along its passage so impure and foul as to be exceedingly offensive and taking with it germs of disease of all kinds prevalent in the City of Chicago, and thus spreading them broadcast through the entire Desplaines and Illinois River valleys, causing thereby much illness as well as poisoning of the blood, and debilitating the systems of 200,000 people; and,

Whereas, Careful investigation leads our people to fear that an epidemic may spread over said section of the State of Illinois from the causes above stated; and,

Whereas, in addition to the above distress, there has been a great [fol. 134] loss of property, business industries, and to the communities in said region, by reason of the causes herein mentioned; and,

Whereas, Prior to the deepening of said Illinois and Michigan Canal, the water necessary for all purposes of navigating said canal and propelling of machinery was obtained from the Desplaines River and the Calumet feeder, through Lane's Lake; and,

Whereas, The bed of the Desplaines River, at the summit and thence westward along the line of and adjacent to the canal, is, at a low state of water, eight (8) feet above the surface level of the canal, and will average a supply of water sufficient for all canal and power purposes during the seasons of navigation; and,

Whereas, The supplying of the canal from these sources will so dilute and weaken the sewage of the City of Chicago, as to greatly relieve it of its foulness and stench to the great delight, relief and health of the people near to and bordering upon the line of the canal, the Desplaines and Illinois Rivers; therefore, be it

Resolved, By the Senate, the House of Representatives concurring herein, That the Board of Canal Commissioners of the Illinois and Michigan Canal be, and they are hereby, directed to cause sluiceways of sufficient capacity, with the proper guard-gates, to be opened from the Desplaines River to the canal, at or near the summit, in Cook

County, and at or near Lemont, in Cook County, and also to construct a dam across the former Calumet feeder at such suitable point as will cause the waters from Lane's Lake to flow into the canal; that said canal commissioners shall immediately commence, construct and improve said sluices and feeders in the order named, and pay for the same out of any moneys in their hands or control as canal commissioners, resulting from the earnings of the canal. The amount to be expended as above designated in the prosecution of said improvement shall not, however, exceed the sum of ten thousand dollars: Provided, that the Canal Commissioners shall first confer with the Mayor or other proper authorities of the City of Chicago, and if said city shall proceed without delay to cause a flow into the canal from the Chicago River sufficient to dilute and purify the waters and thus remedy the evils complained of, said flow to be not less than 60,000 cubic feet per minute, including the ordinary flow [fol. 135] into the canal from the Chicago River, or so much thereof as in their judgment said canal can carry, and if this shall be accomplished by the first day of September, 1881, the commissioners shall accept it in lieu of obtaining a supply of water from the other sources named: Provided, further, that said commissioners are hereby directed to take care of 60,000 cubic feet per minute above contemplated, if so furnished by the City of Chicago: Provided, further, that the adoption of this resolution shall not commit the State to a system of permanent drainage of Chicago sewage through either the canal or Desplaines or Illinois Rivers, but that the State reserves the right to require the City of Chicago, in future years, to take care of its sewage through other channels: And provided, further, that if the said City of Chicago shall erect pumping works for the purpose of causing such flow as aforesaid, the Canal Commissioners shall allow the said city to erect said pumping works upon the canal lands in Bridgeport; and said city shall support, control and manage said pumping works, subject to the direction of the Canal Commissioners relative to the amount of water to be received into the canal, from time to time, as the exigencies of the canal may require, but at the expense of the said City of Chicago; Provided, further, that the City of Chicago, its officers, agents or employes, shall derive from this resolution no right to control or exercise any authority over any of the gates, locks or dams of said canal.

That under the said resolution the Board of Canal Commissioners of the Illinois and Michigan Canal were directed to permit the City of Chicago, if it so desired, to install pumps or such other works so that the flow of water through the said canal from Lake Michigan should be not less than 60,000 cubic feet of water per minute; that thereafter, on or about the year 1884, the City of Chicago did install pumps and works at Bridgeport so that waters of Lake Michigan including the sewage and drainage of the City of Chicago and its environs in greater quantities was caused to flow through the Chicago River and the Illinois and Michigan Canal and thence into the Illinois River to the extent of approximately 60,000 cubic feet of water per minute.

[fol 136] 25. This defendant states that the inhabitants of the City of Chicago and its environs obtained drinking water from Lake Michigan; that Lake Michigan was, is and will be the only adequate source from which drinking water for the metropolitan population of the City of Chicago and its environs could, or may be obtained; that Lake Michigan furnishes an adequate, sufficient, and pure supply of drinking water, if unpolluted by sewage or drainage; that the said additional flow of water through the Illinois and Michigan Canal created by the pumping works installed as aforesaid in 1884 at Bridgeport did not serve to sufficiently cleanse the Chicago River of the pollution created by the sewage and drainage of the City of Chicago and its environs; that during a portion of each year the Chicago River did flow into the Lake thus carrying with its waters the sewage and drainage of the City of Chicago and its environs, thereby further polluting the water of Lake Michigan from which the inhabitants of the City of Chicago and its environs obtained their drinking water supply; that the metropolitan district comprising the City of Chicago and other cities and villages located adjacent thereto and along the shores of Lake Michigan from the Indiana State line to the north line of the County of Cook had increased in population so that the improvements made from time to time up to the year 1884 were insufficient and inadequate to prevent the pollution of the water of Lake Michigan by sewage and drainage; that on account of this rapid increase of population a greater amount of sewage and drainage each year was discharged directly into the Lake and caused a greater pollution from the flow of the Chicago River at times towards Lake Michigan; that the inhabitants of the City of Chicago and its environs were thus deprived of a pure water supply for domestic purposes; that the water used for domestic purposes became so polluted by sewage and drainage injected into Lake Michigan that pestilence ensued, and it became necessary that some further [fol. 137] and better improvements be made by which the pollution of the drinking water of the inhabitants of the City of Chicago and its environs would be prevented; that Lake Michigan at and near the points where the City of Chicago and adjacent towns obtained their water supply had become so polluted and contaminated by sewage discharged into Lake Michigan from the Chicago River and from sewers emptying directly into said Lake Michigan, along its shores in the vicinity of the said water supply intakes that the death rate from typhoid fever and other water borne diseases had become very high; that deaths from such causes were frequent through the said City of Chicago and adjacent towns; that the Chicago River and its branches was then a seething mass of septic sludge giving forth noxious and disagreeable odors which caused annoyance and danger to the people of Chicago and persons visiting or sojourning within its limits.

That thereupon the City of Chicago, through its proper corporate authorities, appointed a commission consisting of eminent sanitary experts for the purpose of making an investigation of the conditions and making a report as to the proper solution of the problem then confronting the people of Chicago and its environs who depended

upon Lake Michigan for their water supply; that the said commission was appointed in the year 1886, and after several years of investigation and study, it presented a report to the Mayor of the City of Chicago recommending the construction of a channel and works connected therewith substantially as provided for in the said Act of May 29th, 1889; that the said Act of May 29th, 1889, under which the Sanitary District of Chicago, defendant, was organized, was passed pursuant to the investigations made by the said commission and other investigations made and carried on at the same time by other persons; that the said act was passed for the purpose of providing for the organization of a sanitary district and the construction of channels and works by it so that the pollution of the [fol. 138] drinking water of the City of Chicago and its environs would be relieved and a pure water supply could be secured; thereby preventing death and pestilence among the people of the City of Chicago and adjacent towns, arising from impure water and preventing active public nuisance created by the conditions then existing in the Chicago River as hereinbefore set forth.

26. This defendant further states that by the Act of May 29th, 1889, the Sanitary District organized under said act was authorized to construct a channel of sufficient size to take care of, not only the sewage and drainage of the City of Chicago and its environs, but it was authorized also to take care of the sewage and drainage of the City of Chicago and its environs as the increase of population might require; that in and by said act it was provided that said channel should be constructed with a capacity and size to produce and maintain through the rock sections thereof an ultimate flow of not less than 600,000 cubic feet of water per minute; that said channel was to be constructed so that it would produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population within such sanitary district.

That the Chicago River drains an area of, to wit: 420 square miles; that the run-off of the said Chicago River drainage area at times of heavy rains and high flow is approximately 10,000 cubic feet of water per second; that in order to prevent the Chicago River from reversing itself in times of high flood and driving so much of said sewage into Lake Michigan, it was necessary that the channel so to be constructed should have an ultimate capacity of not less than 600,000 cubic feet of water per minute, or 10,000 cubic feet of water per second; that in order to prevent the pollution of the waters of Lake Michigan from and by way of the Calumet River, it was necessary that a channel be constructed connecting the said Calumet River with the main channel thus provided to be con- [fol. 139] structed so that the flow of the Calumet River would be reversed; that in order to prevent the pollution of the waters of Lake Michigan from the cities, villages and towns, located on the shores of Lake Michigan immediately north of the limits of the City of Chicago, it was necessary that a channel or adjunct be constructed

to provide an outlet into the main channel of the Sanitary District for the said cities, towns and villages.

That it was further provided in and by said act that the said main channel when completed should be a navigable water of the United States and that the said United States should have the authority to take over and operate said channel for navigation purposes, but not for sanitary or drainage purposes; that the said channel to be constructed pursuant to said act was intended to be an enlargement or a replacement of the channel known as the Illinois and Michigan Canal.

27. This defendant states that pursuant to said Act of May 29th, 1889, on to wit, the 15th day of August, 1889, a petition was duly filed, signed by the requisite number of legal voters, asking that the limits of the district be defined by the tribunal provided for in the act and praying that an election be held to determine whether the territory thus defined should become the Sanitary District of Chicago; that the tribunal so authorized did thereafter define the limits of this defendant; that the said election was held pursuant to the said petition and pursuant to the provisions of said act on the 5th day of November, 1889; that at the election so held on the 5th day of November, 1889, it was decided in the affirmative, that the territory so theretofore defined by the tribunal authorized as aforesaid become the Sanitary District of Chicago; that subsequently thereto and on or about the 12th day of December, 1889, a special election was held for the purpose of electing trustees of the Sanitary District of Chicago, and that as a result of said election, trustees [fol. 140] were duly elected; that subsequently thereto, on or about the 18th day of January, 1890, the Board of Trustees so elected at the election held on December 12, 1889, after duly qualifying as such trustees pursuant to the act, held a regularly organized meeting of the Board of Trustees to begin the actual work of constructing the Sanitary District channel provided for in said act. That this defendant entered upon the construction of the said main channel and other works provided for under said act long prior to September 19th, 1890; that pursuant to the said act of the General Assembly of the State of Illinois of May 29th, 1889, and long prior to September 19th, 1890, the Board of Trustees of the Sanitary District of Chicago laid out the plans for and entered upon the construction of the main channel from Robey Street in the City of Chicago to Lockport, Illinois, of a capacity of eight hundred and forty thousand cubic feet of water per minute, or 14,000 cubic feet per second; that plans were at the same time made and considered for the construction of a channel to connect the Calumet River with the said main channel; that plans were then made for the construction of intercepting sewers on the south side of the City of Chicago converging at 39th Street on the Lake Shore by which approximately 2,000 cubic feet of water per second should be pumped from Lake Michigan, together with sewage accumulated at said point, through a conduit to be constructed into the South Fork of the South Branch of the Chicago River, and from thence into the said main channel.

That the said intercepting sewers so provided for on the south side of the City of Chicago and converging at 39th Street were for the purpose of intercepting sewage that then flowed directly into Lake Michigan, and thereby divert it into the main channel.

That the North Branch of the Chicago River was then a stagnant stream into which sewage from a large portion of the north side of the City of Chicago was emptied; that in order to create a current [fol. 141] into said North Branch and thereby cleanse it and abate a public nuisance, plans were then made for the construction of a conduit extending from the Lake Shore at Lawrence Avenue in the City of Chicago to the said North Branch through which approximately 666 cubic feet of water per second from Lake Michigan should be caused to flow, and from thence into the main channel.

That plans were then made and considered for the construction of a north shore channel by which the sewage from the cities, towns and villages on the Lake Shore immediately north of the northern limits of the City of Chicago should be diverted from Lake Michigan into the North Branch of the Chicago River and from thence into the main channel; that it was contemplated that approximately 1,000 cubic feet of water per second from Lake Michigan should be caused to flow through the said channel, together with the sewage and drainage of said district.

That plans were then made and considered for enlarging the cross section of the Chicago River, South Branch, and West Fork to accommodate sufficient water so as to cause the course, current and flow of the Chicago River to be at all times reversed, in times of high water as well as in times of low water, and to provide for an ultimate flow through the Sanitary District main channel of sufficient water to dilute and purify the sewage of the City of Chicago and its environs flowing into the main channel, pursuant to the provisions of the said Act of 1889.

That at the time the defendant entered upon the construction of the said works the said complainant had knowledge of the said act and the improvements provided for under said act.

28. This defendant further states that pursuant to the said Act of 1889, and pursuant to the said plans it constructed a channel through what is known as the rock section of the route described, extending from the controlling works at Lockport north to Willow [fol. 142] Springs, a distance of 14.93 miles, with a bottom width of 160 feet, a surface width of 162 feet, with a depth of at least 24 feet, and with a declivity of to wit, 1 foot in every 20,000 feet, having a capacity of flowing 840,000 cubic feet of water per minute or 14,000 cubic feet of water per second; that from said Willow Springs to Robey Street, Chicago, Illinois, a distance of to wit, 13.1 miles, through what is known as the earth section, the defendant made plans for a channel with a bottom width of, to wit, 202 feet and a surface width of to wit, 300 feet and a depth of not less than, to wit, 24 feet, with a declivity of to wit, 1 foot in every 40,000 feet; that then said defendant constructed said channel through said earth section as planned, except in this, that for a distance of, to wit,

7.8 miles from Robey Street to Summit the defendant left unexcavated a width of 92 feet, inasmuch as said channel was out of the territory having a rock stratum and was more easily capable of progressive development as the population of the district might increase; that the capacity of said channel from Robey Street to Summit, being a portion of the earth section was, to wit, 80 per cent of the flow of the rock sections, or, to wit, 500,000 cubic feet of water per minute, or to wit, 8,000 cubic feet of water per second; that long prior to the filing of said Bill of Complaint herein, this defendant made and entered into a contract with the Great Lakes Dredge & Dock Company, under which the said main channel in the earth sections was to be enlarged by widening the same, so that through the said earth section, the said main channel would have a capacity of flowing in excess of 10,000 cubic feet of water per second; that before the filing of the said Bill of Complaint herein, the work provided for under said contract was substantially completed, so that the said main channel through the said earth sections at the time of the filing of said Bill of Complaint herein, had a capacity of flowing in excess of 10,000 cubic feet of water per second.

[fol. 143] 29. This defendant states that the aforesaid main channel from Robey Street to the controlling works at Lockport, Illinois, was completed and ready for use on or about September 21, 1898; that on or about January 11, 1899, the defendant, pursuant to the said Act of 1889, and more particularly Section 27 thereof, reported such fact to the Governor of the State of Illinois; that the Governor of the State of Illinois, pursuant to the said act, thereupon appointed a special commission to inspect and certify as to the completion of the main channel as required by the Act of 1889 aforesaid; that pursuant to the report of the said commission the then Governor of the State of Illinois did, on, to wit, January 17, 1900, authorize and direct the opening of said channel, the said commission having reported that the channel was completed in accordance with the provisions of said Act of 1889.

30. This defendant states that on, to wit, January 17th, 1900, the said channel was opened and the flow of the Chicago River, the South Branch and the West Fork thereof, as far as Robey Street, in the City of Chicago was reversed, and water was caused to flow out of Lake Michigan, through the Chicago River, the South Branch and the West Fork thereof, and down the Sanitary District channel from Robey Street and discharged into the Desplaines River at Lockport and from thence into the Illinois River, and from the Illinois River into the Mississippi River, and continuing to the Gulf of Mexico.

31. This defendant states that contemporaneously with the construction of the said main channel this defendant carried on certain construction work in the Chicago River, the South Branch thereof, and the West Fork to provide a larger cross section; that the purpose of enlarging the cross section was to enable the Chicago

River, the South Branch and the West Fork thereof to flow an increased quantity of water.

That on or about June 16, 1896, the defendant made application [fol. 144] to the Secretary of War for a permit to widen and deepen the Chicago River at certain points in accordance with a map or plan of such construction attached to the said application; that a copy of said application, together with a copy of said map or plan, is by express reference thereto, made a part hereof, and is attached hereto, marked "Exhibit H."

That on or about July 3, 1896, the Secretary of War granted a permit to the defendant to improve the Chicago River in accordance with the said application and the map accompanying the same, a copy of which said permit is, by express reference thereto made a part hereof and is attached hereto and marked Exhibit "I."

That on or about the 26th day of April, 1900, and on or about the 7th day of June, 1900, the said defendant made application to the Secretary of War for permits to make certain further changes, alterations and improvements in the South Branch of the Chicago River so as to accommodate a flow of water through the said South Branch and the West Fork thereof to the extent of the said applications, together with certain plans of the said improvement attached thereto, copies of which are by express reference thereto, made a part hereof and are attached hereto, marked Exhibit "J," and "JI," respectively, and said plans are marked K1 and K2, respectively.

That thereafter, and on or about July 11, 1900, the Secretary of War granted two permits to this defendant to make the changes, alterations and improvements in the South Branch of the Chicago River as shown upon the plans attached to said applications, that a copy of said permits are attached hereto and made a part hereof, and marked Exhibit "L" and "L1."

That pursuant to said permits of July 3, 1896, and July 11, 1900, and pursuant to certain other permits granted by the Secretary of War to this defendant at various times, to which other permits reference is hereby expressly made, this defendant improved the said [fol. 145] Chicago River, South Branch thereof and the West Fork, so that the said rivers have been enlarged sufficiently to accommodate a flow of water of at least 8,000 cubic feet per second with a velocity of not to exceed 1¼ miles per hour; that the volume of water above specified flowing as aforesaid through the said rivers and into and through the main channel of the Sanitary District, together with the 2,000 cubic feet of water per second emptying into the South Fork of the said Chicago River from the 39th Street Pumping Station will not create a current in any way injurious to navigation.

That in the course of the improvement of the said Chicago River and the widening and deepening thereof, and in the building of bridges, this defendant expended in excess of $10,000,000 as hereinbefore set forth: that a large part of the said money so expended was for the purpose of improving navigation in the said Chicago River, South Branch and West Fork: that the said Chicago River was deepened by this defendant to a depth of 26 feet from a depth

of 17 feet at all points and widened to a width of 200 feet at all points, from a width of approximately 100 feet.

That pursuant to the said Act of 1889 the said main channel or canal constructed by this defendant as aforesaid from Robey street to Lockport, Illinois, is of a depth of at least 24 feet at all points and of a width of at least 162 feet at all points; that the said Chicago River, the South Branch and the West Fork thereof as improved by this defendant, and the main channel constructed as aforesaid by this defendant, are of sufficient capacity to enable the largest vessels, freight or passenger, traversing the Great Lakes, to pass through or into same; that by virtue of the works of this defendant the largest vessels traversing the Great Lakes can pass through the said Chicago River and its branches as aforesaid to the City of Joliet; that the said main channel of this defendant as heretofore constructed is an enlargement, or takes the place of the old Illinois and Michigan Canal; [fol. 146] that since the completion of the said main channel the said Illinois and Michigan Canal has been abandoned; that the said improvement of the Chicago River and its branches, for the purpose of improving navigation was in accordance with the plans of the complainant in connection with the improvement of navigation upon the said rivers.

32. This defendant states that pursuant to an Act of the General Assembly of the State of Illinois entitled "An Act in relation to the Sanitary District of Chicago to enlarge the corporate limits of said district and to provide for the navigation of the channels created by said District, and to construct dams, water-wheels and other works necessary to develop and render valuable power arising from the water passing through its channels, and levying taxes therefor," approved May 14th, 1903, in force July 1, 1903, attached hereto as part of Exhibit "A," this defendant extended its main channel to the City of Joliet; that the said work was completed on or about the year 1907; that the portion of the said main channel constructed pursuant to said act was of the same depth and width as the portion of the main channel constructed pursuant to the Act of 1889; that under said act the said defendant constructed also certain works for utilization of water power at Joliet; that the water power so developed is approximately 30,000 horse power; that each horse power is worth approximately $30.00 per year net as developed at Joliet; that this defendant expended in the construction of the said water power development approximately $5,000,000; that if the flow of the said main channel of the Sanitary District were limited to 4,167 feet there would be little, if any, power developed or available at Joliet. That this defendant now sells and disposes of the electrical energy developed as aforesaid by its works at Joliet, Illinois; that such revenue is used for the purpose of partially defraying the other expenses of this defendant; that the hydro-electric plant constructed [fol. 147] as heretofore set forth near Joliet, Illinois, was constructed to utilize the water power incidentally developed by the flow through the main channel of this defendant for the purpose of diluting sew-

age arising from the population within the limits of the Sanitary District of Chicago; that the operation of the said hydro-electric plant and the development and sale of electrical energy does not in any way increase the amount of water caused to flow through the said main channel; that this defendant pursuant to the said Act of 1889 and the acts amendatory and supplementary thereto constructed the said North Shore Channel as an adjunct or addition to its main channel to furnish an outlet for the sewage and drainage of the District immediately north of the northern limits of the City of Chicago, comprising certain cities, towns and villages located along the shore of Lake Michigan and immediately north, as aforesaid, of the northern limits of the City of Chicago; that the said North Shore channel was completed on or about the year 1910; that there was also constructed at the point where the said North Shore channel intersects with Lake Michigan pumping works of sufficient capacity to cause approximately 1,000 cubic feet of water per second to flow into and through the said North Shore channel for the purpose of diluting the sewage and drainage of the said district.

34. This defendant states that pursuant to the said act of 1889 there was constructed by this defendant and the City of Chicago certain intercepting sewers and pumping works at Lawrence avenue, in Chicago, and the Lake, and at 39th Street, Chicago, and the Lake, by which all the sewage formerly flowing directly into Lake Michigan is diverted into the main channel aforesaid of this defendant.

That in the year 1910 this defendant entered upon the construction of an adjunct or addition to its main channel known or called the Calumet-Sag Channel extending from a point on the Little Calumet River at Blue Island to a point on the main channel of [fol. 148] this defendant at Sag, Illinois; that the said channel is now in the course of construction; that it is being constructed of a capacity to flow approximately 2,000 cubic feet of water per second, and is capable of enlargement, so that it will accommodate a flow of 4,000 cubic feet per second of water; that the said Calumet Sag Channel is designed to furnish an outlet for the sewage and drainage arising in what is called the Calumet district lying immediately south of the southern limits of the City of Chicago and thus prevent the pollution of the drinking water of the City of Chicago and environs by and through the Calumet River; that the said Calumet Sag Channel is also designed to furnish a certain amount of water by which to dilute sewage and drainage flowing through the main channel of the Sanitary District, and arising in that portion of the Sanitary District tributary to the Chicago River and its branches and the main channel of this defendant.

35. This defendant states that the said works constructed or being constructed and the said improvements made upon the Chicago River and its branches as hereinbefore described were made necessary by virtue of the said Act of the General Assembly of Illinois of 1889 and acts amendatory and supplementary thereto; that the

said works and improvements provide a complete and comprehensive system by which an outlet is provided for the sewage accumulating in the Metropolitan district comprised within the limits of the Sanitary District of Chicago, and for the drainage arising therein; that the said works so constructed and being constructed does and will prevent the pollution of the drinking water of the inhabitants of the Sanitary District and provide pure water for drinking and domestic purposes for the inhabitants of the District; that the said Act of 1889 and acts amendatory and supplementary thereto were passed and adopted by the General Assembly of the State of Illinois pursuant to and under the police power existing in the State for the purpose of protecting the health and lives of the people within [fol. 149] said district and within the State of Illinois as well as persons sojourning or visiting within the limits of this defendant.

That the channels and works constructed and to be constructed provides the only method by which the sewage and drainage of the inhabitants of the Sanitary District could be diverted from Lake Michigan and a pure water supply for domestic purposes secured for such inhabitants; that the drainage basin of the Great Lakes and that of the Mississippi River is divided by a ridge of ground within approximately 8 miles of the shore of Lake Michigan; that the summit of the said divide, known as the Continental Divide, was but a few feet above the level of Lake Michigan or Chicago City datum; that the City of Chicago and its environs is located in this regard differently from any other city on the Great Lakes; that by virtue of the nearness of the Mississippi River drainage basin and the insignificance of this so-called Divide it was possible to provide in the manner above set forth an outlet for the sewage and drainage of the City of Chicago and its environs so that the water of Lake Michigan could be maintained pure and undefiled by any pollution from sewage or drainage arising within the City of Chicago and other cities and villages located upon the shore of Lake Michigan near the said City of Chicago.

That this defendant and the City of Chicago have expended in and about the construction of the works and in making the improvements above mentioned the sum of to-wit, $82,000,000 to protect the said water supply; that of this amount the City of Chicago has expended approximately $6,500,000 in and about building intercepting sewers, pumping stations and other works.

36. This defendant further states that the said works constructed and the improvements made by this defendant hereinbefore set out and the works being constructed, were, and are necessary to preserve the health of the people within The Sanitary District of Chicago [fol. 150] and to protect the lives of the people therein; that the said The Sanitary District of Chicago comprises a large Metropolitan district within the County of Cook and various cities and villages located in said county; that this defendant attaches thereto a map or plat marked Exhibit "M," which is by express reference made a part hereof and attached hereto, which represents and shows the territorial boundaries of this defendant within which there is

comprised substantially three hundred eight-six square miles; that within the boundaries of said District there are situated the following cities, villages and towns: Chicago, Evanston, Glencoe, Winnetka, Wilmette, Shermerville, Glenview, Morton Grove, Niles, Cicero, Stickney, Evergreen Park, Morgan Park, Blue Island, Riverdale, Oak Park, Berwyn, Forest Park, River Forest, Maywood, Riverside, Brookfield, Bellwood, Franklin Park, Melrose Park, River Grove, Dolton, Harvey, West Hammond, Worth, Bremen and Calumet; that the population within the limits of the said The Sanitary District of Chicago exceeds two million five hundred thousand.

37. This defendant states that the Congress of the United States has at various times appropriated moneys for the improvements of the Illinois River and for the making of surveys and investigations to determine the best method by which the navigation upon the said Illinois and Desplaines rivers could be improved in connection with the Main Channel heretofore constructed by this defendant; that the said complainant built in the lower Illinois River certain dams at La Grange and Kampsville for the purpose of improving navigation upon the said Illinois River; that the said dams were built and constructed in connection with and for the purpose of supplementing the improvement of navigation made by the State of Illinois by the construction of two dams, one at Henry, Illinois, and the other opposite Copperas Creek on the Illinois River; that the said dams constructed by the complainant and by the State of Illinois were provided with locks by which vessels could pass from [fol. 151] the level of the water created by the dam at the lock to the level below, or vice versa; that during the period when the said main channel of this defendant was under construction, prior thereto and since the opening of same, the Congress has appropriated moneys for the purpose of making surveys and investigations for a Deep Waterway, extending from the terminus of the Main Channel of this defendant, at or near Lockport, Illinois, on the Desplaines and Illinois Rivers to the Mississippi River and from thence to the Gulf of Mexico; that all Boards of Engineers and all Engineer Officers of the Corps of Engineers of the United States Army, who have made reports in regard to such Deep Waterway pursuant to the appropriations made by the Congress have recommended the improvement of the Desplaines and Illinois Rivers to provide Deep Water navigation, and the plans and recommendations made by such engineers contemplate the use of the said Main Channel of this defendant as part of, and a link in such Deep Waterway and the use of the water flowing through and contemplated to be passed through the Main Channel of this defendant in the Desplaines and Illinois Rivers for the purpose of such navigation; that the International Waterways Commission created by an Act of Congress and by an Act of the Parliament of the Dominion of Canada by report made on January 11th, 1909, recommended that 10,000 cubic feet of water per second should be allowed to be diverted by this defendant from Lake Michigan; that this defendant constructed its said Main Channel, with a capacity of not less than Ten Thousand

(10,000) cubic feet of water per second, with the intended purpose to comply with the plans and purposes of the United States; that the United States approved of the said plans and purposes and the Congress of the United States co-operated with this defendant and invited this defendant to co-operate with complainant and joined with this defendant in the improvement of the Chicago River, as has [fol. 152] been more fully set out; that the Attorney General of the United States, on December 14, 1909, caused suit to be instituted in the name of the United States against the Economy Light & Power Company, in the Circuit Court of the United States, Eastern Division, Northern District of Illinois; that the said suit was instituted by way of a bill of complaint filed in said court to enjoin the said defendant, the Economy Light & Power Company, from constructing a dam in the Desplaines River; that in and by said bill of complaint, the said complainant further recognized the right of this defendant to divert the amount of water contemplated in and by its said work and in and by the said Act of May 29, 1889; that in and by said bill of complaint the said United States of America alleged:

"That in connection with the construction of said Sanitary District Canal, and in creating the system of waterways resulting from the construction of said canal, said State of Illinois has caused the quantity of water flowing through said Desplaines River below the point at which it connects with said canal to be largely increased, and that said portion of said river has been continuously since the opening of said canal, and is now, water navigable in fact and a part of the navigable waters of the United States and subject to the jurisdiction and control of the Federal Government. * * *

That in connection with and as a result of the construction of said Sanitary District Canal and the diversion of said water from Lake Michigan, said Sanitary District of Chicago, acting under authority of said State of Illinois, has largely increased the navigability of said Des Plaines River and that continuously since the opening of said canal there has been, and is, in said portion of said Des Plaines River below the point at which it connects with said canal, a body of water navigable in fact and which, by virtue of its connection with other navigable waters is to be deemed a part of the navigable waters of the United States and subject to the jurisdiction and control of said United States."

That the said complainant, in and by its said bill of complaint in the said cause wherein the Economy Light & Power Company is [fol. 153] defendant, based its right to an injunction enjoining the construction of the said dam upon the fact that the State of Illinois had, in and by and pursuant to the Act of May 29, 1889, created a navigable waterway in the Desplaines River at the points described in the said bill of complaint; that the said navigable water thus created and connected with and a part of the system of navigable waterways created by The Sanitary District of Chicago pursuant to the said Act of 1889 and which said waterways thus created were

connected with and a part of the other navigable waters of the United States; that, inasmuch as the said Act of 1889 provided for the recovery of damages of all and every kind sustained to land by virtue of the construction, operation and continuance of said main channel, that the Economy Light & Power Company had the right to obtain compensation for any damage that might have resulted to it by virtue of its being deprived of rights in the said Desplaines River at the points mentioned in the said bill of complaint which existed prior to the said Desplaines River becoming a navigable waterway pursuant to the said Act of 1889.

38. This defendant states that, at the time the said Act of 1889 was passed by the General Assembly of Illinois, and at the time the plans for construction of the said Main Channel were completed, and during the construction thereof, and before the opening of the said channel, the said United States had knowledge of and knew of the passage of the said Act, the making of the plans and the opening of the channel; that, at or about the time of the opening of the said channel, various measurements were made upon the St. Clair River to determine the increment thereof, by which the effect of a diversion of a certain number of feet of water from Lake Michigan outside of the regular outlet could be ascertained; that the measurements were made also, in the Niagara and St. Lawrence Rivers to determine the increment of such rivers respectively; that the said measurements [fol. 154] were made by the United States Lake Survey, under the direction of the Corps of Engineers of the United States Army; that, after the said measurements were made to determine the increments of the said rivers, it was claimed by various of the Engineer officers that the levels of Lake Michigan, Lake St. Clair, Lake Erie and Lake Ontario, and the channels connecting them, would be affected by the diversion of approximately ten thousand (10,000) cubic feet of water per second to the extent of approximately six (6) inches; that, thereafter, the United States, in providing for the improvement of the St. Mary's, St. Clair and Detroit Rivers and other channels connecting the Great Lakes with one another, determined upon a reference plane for such improvements at approximately six (6) inches below the reference plane that had theretofore been adopted, and the said United States did thereby acquiesce in and agree to such diversion.

And this defendant states that if the diversion of water from Lake Michigan has or will lower the levels of the water of either or all of the following named waters: Lake Michigan, Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Sault Ste. Marie, St. Mary's River, St. Clair River, Detroit River, Niagara River, and St. Lawrence River and of all or any of the harbors, channels, canals or rivers connected therewith, it is feasible and practicable to compensate for the lowering of such levels by the building of proper works at either the St. Clair River, Detroit River, Niagara River, St. Lawrence River or of all of them; that the International Waterways Commission in their report on the regulation of Lake Erie issued in the year 1910, recommended the building of regulation works to regulate the levels of Lake Erie and thereby raise such levels approximately one foot at

low water times; that the said International Waterways Commission estimated the cost of building such regulation works at approximately seven hundred ninety-six thousand dollars; that the said International Waterways Commission has recently made a further report [fol. 155] upon the building of compensating or regulating works to regulate the levels of the various lakes in order to raise the level of Lake Erie approximately one foot; that the estimate made for said works by the said Commission as the cost of said work is approximately three million dollars; that such regulation works would more than offset any alleged lowering of the levels of Lake Michigan, Lake Huron and Lake Erie by the diversion of water through the Chicago Drainage Canal as contemplated under the said Act of 1889 and as proposed by the works of this defendant already constructed and in the process of construction; that the levels of the water of Lake Michigan, Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Sault Ste. Marie, St. Mary's River, St. Clair River, Detroit River, Niagara River, St. Lawrence River and all the harbors, channels, canals and rivers connected therewith, have been lowered by the works constructed by the United States, by Canada, by private individuals and corporations, by and with the consent and acquiescence of the said United States; that the level of said waters has not been lowered by this defendant.

39. This defendant states that the said complainant, by consenting to the improvement of the Chicago River to accommodate the flow of water through the Main Channel of this defendant as contemplated under the Act of 1889, by the appropriation of money for the purpose of determining the feasibilty of improving waterways to connect with the navigable waterways created by this defendant, by acquiescing in and acknowledging the right to use the said works and to abstract the water from Lake Michigan contemplated by said Act of 1889, solemnly asserted in the said case of the United States vs. The Economy Light & Power Company, above referred to, by allowing this defendant to proceed with the construction of said works with the knowledge of the said complainant, without making any objection thereto, but on the contrary, consenting to and agreeing to [fol. 156] various improvements made necessary by virtue of the said system of works provided for under said Act of 1889, has estopped itself from making any objection to or attempting to prevent further use and continuance of the said works for the purpose for which they were created; that, after the initiation of the said work of the said Sanitary District upon its said system of drainage, the said United States adopted the improvements contemplated and being then carried on by the Sanitary District in the Chicago River and its various branches and supplementing said improvements so being made by this defendant, and inviting further improvements, itself expended approximately one million dollars ($1,000,000.00) in the improvement of the Chicago River from Rush street to the head of the West Fork.

40. This defendant states that this defendant has never recognized the right of the United States in any manner to interfere with the

construction, operation or use of the Main Channel of the Sanitary District or any of its adjuncts or additions; that it has never recognized the right of the United States in any manner to determine or direct how the said Main Channel or its adjuncts or additions, as hereinbefore mentioned, should be operated or used, or the amount of water that should be abstracted from Lake Michigan through its various channels or adjuncts or additions thereto to carry out the provisions of said Act of May 29, 1889; that this defendant made application for the permits mentioned and described in the Bill of Complaint, copies of which are attached to the Bill of Complaints as exhibits, by reason of the close blending or association of the two governments, namely, the Governments of the State of Illinois and the United States of America; that this defendant desired, if possible, to obtain the consent of the Secretary of War to the construction, operation and use of its works but this defendant never has admitted and does not admit, but on the contrary denies the right of the United States to determine the amount of water that should be [fol. 157] caused to flow through the said Main Channel or its additions or adjuncts, or the manner of such flow; that the permit of May 8, 1899, granted to this defendant the right to open the said Main Channel and use the same for the purposes and to cause the amounts of water to flow therein as contemplated and provided for under the Act of May 29, 1889; that the only condition mentioned in the said permit limiting the amount of water which the Secretary of War consented should be allowed to flow through the said Main Channel, was the preservation of suitable conditions of navigation upon the Chicago River itself; that the said condition was inserted in the said permit and made necessary by virtue of the fact that, at that time, the said Chicago River had not been widened and deepened to the extent that it was proposed to be; that the orders subsequently given by the Secretary of War to reduce the flow or to increase the flow of water through the Chicago River were based entirely upon the conditions of the Chicago River for the purpose of navigation; that in and by the said permit of May 8, 1899, and the subsequent orders and permits issued by the Secretary of War, the said United States recognized the right of this defendant to abstract water from Lake Michigan and only limited the amount of such abstraction by the amount that the Chicago River could carry without injury to navigation thereon; that, subsequently to the issuance of the said permits, the said project of this defendant, for the widening and deepening of the said Chicago River, for a capacity of at least eight thousand (8,000) cubic feet of water per second, was carried out pursuant to the consent of the Secretary of War, as evidenced by the permits hereinbefore mentioned; that, before the filing of the bill of complaint herein, this defendant improved the said Chicago River by widening and deepening the same, so that at least eight thousand (8,000) cubic feet of water per second could flow and was flowing into and through the said Chicago River, the South [fol. 158] Branch and West Fork thereof, without creating a current of more than one and one-quarter (1¼) miles per hour and without creating a condition which would be or was injurious to navigation,

but on the contrary, the condition so created by this defendant greatly improved the navigation in all respects of said Chicago River and all its branches.

41. This defendant states that the said water discharged from the said main channel into the Desplaines River, flows through said Desplaines River and empties into the Illinois River; that, as a result of the discharge of water into the said Illinois River, the said Illinois River has become navigable without the use of the Government dams or the State dams heretofore constructed, so that the Illinois River may be traversed by boats of a deeper draft than could have traversed the said Illinois River by the use of the locks and dams constructed by the United States Government and the State of Illinois, namely, the Kampsville and La Grange dams by the United States and the Henry and Copperas Creek dams by the State of Illinois; that the Illinois River has become clear, which prior to the opening of the said main channel was a sluggish, slow moving body of water, badly polluted by sewage discharged by the City of Chicago and many towns and villages situated along said Illinois River; that by reason of the said increased flow of water in said river, fish life in said river has increased very rapidly, and the said Illinois River has become more healthful to the people living thereon; that the cities and towns located on the said Illinois and Desplaines Rivers are enabled, by virtue of the said flow of water, created by this defendant, to discharge their sewage into the said river without creating an offensive condition or public nuisance; that, if the said flow of the said Illinois River had not been increased by the waters caused to flow therein by this defendant, or, if the flow through the main channel of this defendant were limited to four thousand one [fol. 159] hundred and sixty-seven (4,167) cubic feet of water per second, or to any amount materially less than required by said Act of May 29, 1889, it would be necessary for the cities and towns located on the said Illinois and Desplaines Rivers to expend vast sums of money in treating the sewage now discharged into the said Illinois River, in order to prevent an offensive condition or public nuisance.

42. This defendant states that, since the opening of the said main channel and the completion and opening of additions and adjuncts thereto, including the intercepting sewers hereinbefore described, the health conditions in the City of Chicago and other towns and villages located within the limits of The Sanitary District of Chicago have greatly improved; that the death rate from water borne diseases has greatly diminished; that in and by the said works created by this defendant pursuant to the said Act of 1889 and acts amendatory and supplementary thereto, persons living or sojourning within the district have acquired a pure water supply for drinking and other domestic purposes; that the City of Chicago is a great railroad and commercial center, and is a primal market; that a great many persons who do not reside within the limits of the Sanitary District come each year from all parts of the United States and the world to the City of Chicago and remain therein for various periods; that the total number of persons coming into and leaving the City of Chi-

cago each year approximates twenty-seven million (27,000,000) people; that there are, in addition, approximately forty-seven million (47,000,000) persons who do not reside within the City of Chicago who come to the City from nearby or suburban towns and villages during the course of each year; that all such persons traveling through said City of Chicago or sojourning therein for any length of time, are interested in the better health conditions produced by a pure and unpolluted or undefiled drinking water supply.

[fol. 160] 43. This defendant states that, if the injunction prayed for by the complainant herein is granted, and this defendant is obliged thereby to limit its flow of water to four thousand, one hundred sixty-seven (4,167) cubic feet per second, a large portion of the moneys already expended by this defendant and the City of Chicago in and about the construction and installation of the works hereinbefore mentioned and described, will have been used for no purpose and the said works will become practically useless and of no substantial efficiency or value; that the said City of Chicago and other cities, towns and villages within the boundaries of this defendant have constructed their sewers, water mains, and other sewage disposal works and water supply works upon the basis that the works of this defendant were and are permanent, to endure for all time, and could be used and operated as contemplated by the said Act of May 29, 1889, and acts amendatory and supplementary thereto; that, if the said flow of water through the said main channel of this defendant and its adjuncts and additions should be limited to four thousand one hundred sixty-seven (4,167) cubic feet of water per second, it will be necessary, in order to prevent said sewage from becoming a public nuisance, to construct a plant or plants for the disposal of sewage by some other method or methods; that the construction of such plant or plants would cost upwards of one hundred millions of dollars ($100,000,000) and the annual operation of such a system would cost over seven million dollars ($7,000,000) which capitalized at five per cent (5%) would mean a total investment of two hundred and forty million dollars ($240,000,000); that it would be necessary, also, to construct, in connection with the said sewage disposal works, filtration works to filter all the drinking water and water used for domestic purposes of the inhabitants of said District and the floating population thereof, which would cost upwards of twenty-five millions of dollars ($25,000,000) and which would [fol. 161] require an annual operation charge of at least two million dollars ($2,000,000), which, capitalized at five per cent (5%) would be equal to an original investment of forty million dollars ($40,000,000); that the City of Chicago and the other cities, towns and villages located within the boundaries of the Sanitary District, would be thus damaged to the extent of approximately three hundred million dollars ($300,000,000) and the works of this defendant already completed and in operation would become useless and the moneys expended by this defendant in the construction thereof, approximately eighty-two million dollars ($82,000,000), would be expended for no practical purpose so far as taking care of the sanitary condi-

tions of this defendant are concerned; that the only method by which this defendant can efficiently take care of and remove the sewage and drainage arising within its limits and thereby protect the water supply of the inhabitants of the City of Chicago and its environs is the one laid out under the said Act of May 29, 1889, and acts amendatory and supplementary thereto; that the method or methods which it would be necessary for this defendant to adopt, if the flow of water through its main channel were limited to four thousand, one hundred sixty-seven (4,167) cubic feet per second would not accomplish the purpose now secured by the works of this defendant constructed as hereinbefore set forth, nor would such works constructed under a plan made necessary by such limitation of flow of water in any manner equal the efficiency of the works already constructed to be operated pursuant to the provisions of the said Act of 1889.

44. This defendant states that the State of Illinois under the said Act of 1889 and acts amendatory and supplementary thereto, provided a comprehensive and effective method to dispose of the sewage of the metropolitan district comprised within the boundaries of this defendant, and to provide pure drinking water [fol. 162] for the inhabitants thereof and its floating population, to wit: the method of treating the said sewage by dilution and diverting the same from Lake Michigan; that this defendant is without power to dispose of sewage and to provide a pure drinking water supply by any other method than the one provided for under the said Act of 1889 and acts amendatory and supplementary thereto; that, if it were given power to dispose of the sewage by some other method and to procure a pure drinking water supply in some other manner, the constitutional limitation of the State of Illinois upon the creation of indebtedness by municipalities would prevent this defendant from providing the moneys with which to build sewage disposal works and filtering plants to meet the conditions which would be created by the decrease of the flow of water to four thousand, one hundred sixty-seven (4,167) cubic feet per second, and it would be impossible for this defendant, if it had the power, to provide sufficient funds to build such sewage disposal and filtration works, either by taxation or by the issuance of bonds; that neither the City of Chicago nor the other cities, villages or towns within the limits of The Sanitary District of Chicago, have the power to raise sufficient moneys by the sale of bonds or by taxation, by reason of the constitutional limitation aforesaid, to build sewage disposal or water purification and filtration works which would be necessary to be constructed within the limits of the respective cities, towns and villages, if this defendant were compelled to limit the flow of water to four thousand, one hundred and sixty-seven (4,167) cubic feet per second.

45. This defendant states that, if the said injunction is granted, and this defendant is restrained from withdrawing more than four thousand, one hundred sixty-seven (4,167) cubic feet per second from Lake Michigan, it will be unable to keep the drainage water,

which will flow from said territory, from reversing the Chicago [fol. 163] River at various times during each year, so that the said drainage and sewage arising tributary to the Chicago River will flow into Lake Michigan and thereby pollute the water supply of the City of Chicago and other cities, towns and villages within the limits of the Sanitary District; that, at other times of the year, the said Chicago River will become polluted so that there would be thereby created an offensive condition and a public nuisance, increasing the spread of water-borne diseases, endangering the health and lives of the entire population of this defendant and its floating population.

46. This defendant states that the sewage disposal works and water filtration plants that would be made necessary to be constructed if the said injunction were granted and the flow of water through the main channel were limited to four thousand, one hundred and sixty-seven (4,167) cubic feet per second, would be inadequate, ineffective and impracticable to provide for the disposition of the sewage aforesaid and to provide pure drinking water for the inhabitants of the said District; that purification of sewage artifically and the filtration of water polluted by sewage or an effluent arising from sewage purification work is a method for providing a water supply used only where the method provided for under the Act of 1889, to wit: the dilution method and diverting sewage and drainage from the water supply, is impossible.

47. This defendant denies that the complainant is entitled to the relief, or any part thereof, as in the said Bill of Complaint demanded, and this defendant states that said Bill of Complaint is inadequate, and insufficient in law and does not on its face entitle the said complainant to the relief prayed for in and by said Bill of Complaint; and this defendant furthermore moves that the Bill of Complaint be dismissed for want of equity and this defendant, as to [fol. 164] each and every allegation of the said Bill of Complaint not herein admitted, answered or specifically denied hereby expressly denies, and this defendant prays the same advantage of this answer as if it had pleaded or demurred to the said Bill of Complaint and prays that it be dismissed with its reasonable costs and charges, in this behalf most wrongfully sustained.

Edmund D. Adcock, Alfred S. Austrian, Solicitors for Defendant.

[fol. 165] EXHIBIT A TO ANSWER

An Act to Create Sanitary Districts and to Remove Obstructions in the Desplaines and Illinois Rivers. (Approved May 29th, 1889. In force July 1, 1889, L. 1889, P. 126; Legal News Ed. p. 85.)

343. Incorporating Sanitary District—Question, How Submitted—Commissioners—Report as to Expenditures.

1. That whenever any area of contiguous territory within the limits of a single county shall contain two or more incorporated

cities, towns or villages, and shall be so situated that the maintenance of a common outlet for the drainage thereof will conduce to the preservation of the public health, the same may be incorporated as a sanitary district under this act, in the manner following: Any 5,000 legal voters resident within the limits of such proposed sanitary district may petition the county judge of the county in which they reside to cause the question to be submitted to the legal voters of such proposed district whether they will organize as a sanitary district under this act. Such petition shall be addressed to the county judge, and shall contain a definite description of the territory intended to be embraced in such district, and the name of such proposed sanitary district: Provided, however, that no territory shall be included in any municipal corporation formed hereunder which is not situated within the limits of a city, incorporated town or village, or within three miles thereof, and no territory shall be included within more than one sanitary district under this Act. Upon the filing of such petition in the office of the county clerk of the county in which such territory is situated it shall be the duty of the county judge to call to his assistance two judges of the circuit court and such judges shall constitute a board of commissioners who shall have [fol. 166] power and authority to consider the boundaries of any such proposed sanitary district, whether the same shall be described in such petition or otherwise. Notice shall be given by such county judge of the time and place where such commissioners will meet, by a publication inserted in one or more daily papers published in such county, at least twenty days prior to such meeting. At such meeting the county judge shall preside and all persons in such proposed sanitary district shall have an opportunity to be heard touching the location and boundary of such proposed district and make suggestions regarding the same, and such commissioners, after hearing statements, evidence and suggestions, shall fix and determine the limits and boundaries of such proposed district, and for that purpose and to that extent, may alter and amend such petition. After such determination by said commissioners, or a majority of them, the county judge shall submit to the legal voters of the proposed sanitary district the question of the organization and establishment of the proposed sanitary district, as determined by said commissioners, at an election to be held on the first Tuesday after the first Monday in November thence next ensuing, notice whereof shall be given by said commissioners, at least twenty days prior thereto, by publication in one or more daily papers published within such proposed sanitary district, such notice to specify briefly the purpose of such election, with a description of such proposed district. Each legal voter resident within such proposed sanitary district shall have the right to cast a ballot at such election, with the words thereon "For Sanitary District," or "Against Sanitary District." The ballots so cast shall be received, returned and canvassed in the same manner and by the same officers as is provided by law in the case of ballots cast for county officers. The County judge shall cause a statement of the result of such election to be spread upon the records of the County Court. If a majority of the votes

cast upon the question of the incorporation of the proposed sanitary [fol. 167] district shall be in favor of the proposed sanitary district such proposed district shall thenceforth be deemed an organized sanitary district under this act:* Provided, that the Trustees of all Sanitary Districts heretofore created under this act and all Sanitary Districts hereafter to be created under this act, whenever the expenditures of any such District shall have amounted to the sum of one million dollars and such sum shall have been raised; by taxation upon the assessable property in any such Sanitary District or shall have been raised by the sale of bonds of said district or otherwise, shall on or before September 1, A. D. 1905, report to the Governor of this State and to the two branches of the Legislature thereof separately all of the items of expenditures theretofore made by them as such Trustees, of the moneys so belonging to said Sanitary District, together with all items of receipts from all sources and shall furnish with all such reports copies of all contracts entered into by them for the expenditure of moneys so belonging to said District and upon November 30, A. D. 1906, and biennally thereafter the Trustees of any such District shall make full, complete, accurate and itemized reports of all receipts and expenditures of such moneys to be hereafter made by them respectively, together with a copy of all contracts for the expenditures of moneys hereafter to be made by such Trustees to the Governor and the two branches of the State Legislature of this State separately and the Governor and either branch of the said Legislature of this State shall have the right to examine the books of said Trustees and all Expenditures made by or in any such District, by committee or otherwise, and to call for further reports, accounts, items and copies of all contracts made by or documents held in the possession of any such Trustees; and upon the failure, refusal or neglect of any such Trustees to accurately and completely furnish any and all such items, accounts, documents and reports of contracts as provided in this Act, any and all Trustees of any such [fol. 168] Sanitary District shall forfeit their office and by writ of quo warranto be ousted and removed therefrom; all such actions to be brought in the county where any such Trustees may reside or wherein the major portion of any such Sanitary District may be situated. (That part following the star was added by the Act of 1905 entitled "An Act to amend and revise section 1 of an act entitled, 'An Act to create Sanitary Districts and to remove obstructions in the Desplaines and Illinois Rivers.'" (Approved May 29th, 1889, in force July 1, 1889. Approved May 13, 1905. In force July 1, 1905.)

344. Judicial Notice of District — Organization — Election — County Judge.

2. All courts in this state shall take judicial notice of the existence of all Sanitary Districts organized under this act. Upon the organization of any sanitary district under this act the county judge shall call an election to elect officers and cause notice thereof to be posted or published, and perform all other acts in reference to such election in like manner as nearly as may be, as he is required to perform in

reference to the election of officers in newly organized cities under the provisions of an act entitled "An Act to provide for the incorporation of cities and villages." Approved April 10th, 1872.

345. Trustees—Election and Terms of—Vacancy.

3. In each Sanitary District organized under this act, there shall be elected at the November election 1905, nine trustees, three of which trustees shall hold their office for a term of one year, three for a term of three years, and three for a term of five years, and until their successors shall be elected and qualified.

At every regular county election occurring after the year 1905, there shall be elected three trustees who shall hold their office for six [fol. 169] years, and until their successors shall be elected and qualified, to succeed those whose terms of office shall expire that year. In all elections for trustees each elector may vote for as many candidates as there are trustees to be elected, but no elector may give to such candidates more than one vote, it being the intent and purpose of this act to prohibit cumulative voting in the selection of members of the Board of Trustees of the Sanitary District.

Each elector in such Sanitary District may vote for and designate (upon his ballot cast for Trustees for said Sanitary District) one of the candidates for Trustees to be President of said Board, and the person so designated who shall receive the highest number of such votes shall be declared elected President of such board. The person so elected, President of such Board at the November election of 1905, shall hold office for a term of five years and until his successor shall be elected and qualified. When a vacancy shall occur in the office of president of such board, the board of trustees shall elect one of their number, who shall perform the duties of president until such vacancy shall be filled by an election. When a vacancy shall occur in the office of trustees of any sanitary district organized under the provisions hereof within one year before the expiration of the term of such vacant office, the vacancy shall be filled by appointment by the board of trustees of such sanitary district, but if such unexpired term exceeds one year, the Governor shall appoint the time for an election to fill such vacancy, and shall file a notice of such time with the county clerk of each of the counties in which (such) sanitary district shall be situated.

Such sanitary district shall from the time of the first election held by it under this act be construed in law and equity a body corporate and politic, and by the name and style of the Sanitary District of —— and by such name and style may sue and be sued, contract and be contracted with, acquire and hold real estate and personal property necessary for corporate purposes, and adopt a com- [fol. 170] mon seal and alter the same at pleasure. (As amended by act approved and in force February 27, 1907. L. 1907, p. 287.

346. Trustees Constitute a Board—Duties and Powers of—Ordinances, etc. (How Approved).

4. The trustees elected in pursuance of the foregoing provisions of this act shall constitute a board of trustees for the district by which

they are elected, which board of trustees is hereby declared to be the corporate authorities of such sanitary district, and shall exercise all the powers and manage and control all the affairs and property of such district. Said board of trustees shall have the right to elect a clerk, treasurer, chief engineer and attorney for such municipality, who shall hold their respective offices during the pleasure of the board, who shall give bond as may be required by said board. Said board may prescribe the duties and fix the compensation of all the officers and employees of said sanitary district: Provided, however, that the salary of the president of said board of trustees who shall be elected at any election held subsequent to the year 1910 shall in no case exceed seven thousand five hundred dollars ($7,500.00) per annum and the salary of each of the other trustees elected subequent to the year 1910, shall not exceed five thousand dollars ($5,000.00) per annum. Any incumbent of the office of trustee (excepting said president) whose term is now running and does not expire until after the passage of this act may appoint a private secretary, and such appointment shall remain in force until revoked by the trustee making the same, and such secretary shall receive a salary at the rate of two thousand dollars ($2,000.00) per annum, payable monthly. No trustee (excepting the president) shall be entitled to appoint such private secretary during such time as he shall receive the maximum salary herein authorized. Any incumbent of the office of president heretofore or hereafter elected may appoint a private secretary, which secretary shall receive a salary [fol. 171] not to exceed three thousand five hundred ($3,500.00) dollars per annum, payable monthly. Any such appointment made by the president shall remain in force until revoked by such president or until the expiration of his term of office.

Said board of trustees shall have full power to pass all necessary ordinances, orders, rules, resolutions and regulations for the proper management and conduct of the business of said board of trustees and of said corporation and for carrying into effect the object for which such sanitary district is formed. All ordinances, orders, rules, resolutions and regulations passed by said board of trustees shall, before they take effect, be approved by the president of said board of trustees, and if he shall approve thereof, he shall sign the same, and such as he shall not approve he shall return to the board of trustees with his objections thereto in writing at the next regular meeting of said board of trustees occurring after the passage thereof. Such veto may extent (extend) to any one or more items or appropriations contained in any ordinance making an appropriation, or to the entire ordinance; and in case the veto extends to a part of such ordinance, the residue thereof shall take effect and be in force, but in case the president of such board of trustees shall fail to return any ordinance, order, rule, resolution or regulation with his objections thereto by the time aforesaid, he shall be deemed to have approved the same, and the same shall take effect accordingly. Upon the return of any ordinance, order, rule, resolution or regulation by the president, the vote by which the same was passed shall

be reconsidered by the board of trustees, and if upon such reconsideration two-thirds of all the members elect shall agree by yeas and nays to pass the same it shall go into effect notwithstanding the president may refuse to approve thereof. (As amended by act approved May 27, 1911. In force July 1, 1911. L. 1911, p. 307.)

[fol. 172] 347. Ordinances Making Appropriaton—Publication of.

5. All ordinances making any appropriations shall, within one month after they are passed, be published at least once in a newspaper published in such district, or if no such newspaper of general circulation is published therein, by posting copies of the same in three public places in the district; and no such ordinance shall take effect until ten days after it is so published, and all other ordinances, orders and resolutions, shall take effect from and after their passage unless otherwise provided therein.

348. Ordinances and Resolutions—Evidence.

6. All ordinances, orders and resolutions, and the date of publication thereof, may be proven by the certificate of the clerk, under the seal of the corporation, and when printed in book or pamphlet form, and purporting to be published by the board of trustees and such book or pamphlet shall be received as evidence of the passage and legal publication of such ordinances, orders and resolution, as of the dates mentioned in such book, or pamphlet in all courts and places without further proof.

349. Board of Trustees—Powers of.

7. The board of trustees of any sanitary district organized under this act shall have power to provide for the drainage of such district by laying out, establishing, constructing and maintaining one or more main channels, drains, ditches, and outlets for carrying off and disposing of the drainage (including the sewage) of such district, together with such adjuncts and additions thereto as may be necessary or proper to cause such channels or outlets to accomplish the end for which they are designed in a satisfactory manner; also to make and establish docks adjacent to any navigable channel made under the provisions hereof for drainage purposes, and to lease, [fol. 173] manage and control such docks, and also to control and dispose of any water power which may be incidentally created in the construction and use of said channels or outlets, but in no case shall said board have any power to control water after it passes beyond its channel, waterways, races or structures into a river or natural waterway or channel, or water-power or docks situated on such river or natural waterway or channel: Provided, however, nothing in this act shall be construed to abridge or prevent the State from hereafter requiring a portion of the funds derived from such water-power, dockage or wharfage to be paid into the State Treasury to be used for State purposes. Such channels or outlets may extend outside of the territory included within such sanitary dis-

trict and the rights and powers of said board of trustees over the portion of such channel or outlet lying outside of such district shall be the same as those vested in said board over that portion of such channels or outlets within the said district.

350. May Purchase and Sell Real Estate, etc.

8. Such sanitary district may acquire by purchase, condemnation or otherwise any and all real and personal property, right of way and privilege, either within or without its corporate limits, that may be required for its corporate purposes: Provided, all moneys for the purchase and condemnation of any property shall be paid before possession is taken, or any work done on the premises damaged by the construction of such channel or outlet, and in case of an appeal from the court in which such condemnation proceedings shall be pending, taken by either party, whereby the amount of damages is not finally determined, the amount of the judgment in such court shall be deposited with the county treasurer of the county in which such judgment shall be rendered subject to the payment of such damages on orders signed by such judge whenever the amount of damages is finally determined; and when not longer required for such purposes, [fol. 174] to sell, convey, vacate, and release the same, subject to the reservation contained in section 7 relating to water-power and docks. (As amended by act approved May 25, 1907. In force, July 1, 1907; L. 1907; p. 284.)

351. May Borrow Money—Limitation.

9. The corporation may borrow money for corporate purposes, and may issue bonds therefor, but shall not become indebted in any manner, or for any purpose to an amount in the aggregate to exceed three (3) per centum of the valuation of taxable property therein, to be ascertained by the last assessment for State and county taxes previous to incurring of such indebtedness. (As amended by act approved June 14, 1909. In force July 1, 1909. L. 1909, P. 196.)

352. To Provide for Direct Annual Tax—Net Earnings.

10. At the time or before incurring any indebtedness, the board of trustees shall provide for the collection of a direct annual tax sufficient to pay the interest on such debt as it falls due, and also to pay and discharge the principal thereof as the same shall fall due, and at least within twenty years from the time of contracting the same: Provided, that the net earnings from water-power and docks may be appropriated and applied to the purpose of paying the interest or principal of such indebtedness, or both, and to the extent that they will suffice, the direct tax may be remitted.

353. Contracts—How Let.

11. All contracts for work to be done by such municipality, the expense of which will exceed five hundred dollars, shall be let to the lowest responsible bidder therefor upon not less that ten days' public notice of the terms and conditions upon which the contract is to be

let having been given by publication in a newspaper of general circulation published in said district, and the said board shall have the [fol. 175] power and authority to reject any and all bids and readvertise: Provided, no person shall be employed on said work unless he be a citizen of the United States, or has in good faith declared his intention to become such citizen. In all cases where an alien, after filing his declaration of intention to become a citizen of the United States, shall for the space of three months after he could lawfully do so, fail to take out his final papers and complete his citizenship, such failure shall be prima facie evidence that his declaration of intentions was not made in good faith. And that eight hours shall constitute a day's work. (As amended by act approved May 25, 1907. In force July 1, 1907. L. 1907, p. 284.)

354. Trustees—Levy and Collect Taxes—Movable Bridges.

12. The board of trustees may levy and collect taxes for corporate purposes upon property within the territorial limits of such sanitary district, the aggregate amount of which in any one year shall not exceed one per centum of the value of the taxable property within the corporate limits as the same shall be assessed and equalized for the county taxes for the year in which the levy is made. Said board shall cause the amount to be raised by taxation in each year, to be certified to the county clerk on or before the second Tuesday in August as provided in section one hundred and twenty-two of the general revenue law. All taxes so levied and certified shall be collected and enforced in the same manner and by the same officers as state and county taxes, and shall be paid over by the officer collecting the same to the treasurer of the sanitary district, in the manner and at the time provided by the general revenue law: Provided, that no part of the taxes hereby authorized shall be used by such drainage district for the construction of permanent fixed, immovable bridges across any channel constructed under the provisions of this act; And provided further, that all bridges built across such channel shall not necessarily interfere with or obstruct the navigation of such channel. [fol. 176] when the same becomes a navigable stream, as provided in section 24 of this act, but such bridges shall be so constructed that they can be raised, swung, or moved out of the way of vessels, tugs, boats, or other water craft navigating such channel; And provided further that nothing in this act shall be so construed as to compel said district to maintain or operate said bridges, as movable bridges, for a period of nine years from and after the time when the water has been turned into said channel pursuant to law, unless the needs of general navigation on the Des Plaines and Illinois rivers, when connected by said channel, sooner require it. (As amended by act approved May 25, 1907. In force July 1, 1907. L. 1907, p. 284.)

355. Expenses of Improvement—Special Assessments—General Tax.

13. The board of trustees shall have power to defray the expenses of any improvement made by it in the execution of the powers

hereby granted to such incorporation, by special assessment or by general taxation, or partly by special assessment and partly by general taxation, as they shall by ordinance prescribe. It shall constitute no objection to any special assessment; that the improvement for which the same is levied is partly outside the limits of such incorporation, but no special assessment shall be made upon property situated outside of such sanitary district, and in no case shall any property be assessed more than it will be benefited by the improvement for which the assessment is levied. The proceedings for making, levying, collecting and enforcing of any special assessment levied hereunder, shall be the same as nearly as may be as is prescribed by article nine of an act entitled "An act to provide for the incorporation of cities and villages," approved April 10, 1872. Whenever in said act the words "city council" are used, the same shall apply to the board of trustees constituted by this act, and the words applying to the city or its officers in that article shall be held [fol. 177] to apply to the corporation hereby created and to its officers.

356. Assessment—Installments—Interest.

14. When any assessment is made under this act, the ordinance authorizing such assessment may provide that it be divided into equal annual installments, not more than twenty in number, and fix the amount and time of payment of each installment, and that the installments shall bear interest at a rate not exceeding six per cent per annum, payable annually, from the date fixed in said ordinance, and the several installments and interests thereon may be collected and enforced, as they shall become due, in the manner provided for the enforcement of assessments under said Article 9. No more of any assessment need be returned or certified to the county collector than will show the amount due and unpaid at the time of such return, and no sale of any parcel of land for any installment of an assessment shall discharge the premises from any subsequent installment of the same or any other assessment. Any one or all of the installments may be paid any time after the assessment is confirmed, with accrued interest, if any, to the date of payment.

357. When Assessments Payable by Installments—Bonds May Be Issued.

15. Where any assessment is made payable in installments the board of trustees may issue bonds or certificates not exceeding in amount eighty per centum of the unpaid portion of such assessment at the date of the issue thereof, payable only out of such assessment, and bearing interest at a rate not exceeding the rate of interest upon the installments of such assessments. The board of trustees shall have the right to call in and pay off said bonds or certificates as fast as there is money received into the treasury from the assessment against which the same are issued, and all moneys received upon [fol. 178] such assessment shall be applied to the payment of said certificates or bonds until they are fully satisfied.

358. Private Property—How Taken for Improvement.

16. Whenever the board of trustees of any sanitary district shall pass an ordinance for the making of any improvement which such district is authorized to make, the making of which will require that private property should be taken or damaged, such district may cause compensation therefor to be ascertained, and condemn and acquire possession thereof in the same manner as nearly as may be as is provided in an act entitled "An act to provide for the exercise of the right of eminent domain," approved April 10, 1872: Provided, however, that proceedings to ascertain the compensation to be paid for taking or damaging private property shall in all cases, be instituted in the county where the property sought to be taken or damaged is situated; And, provided, that all damages to property whether determined by agreement or by final judgment of court shall be paid out of the annual district tax, prior to the payment of any other debt or obligation.

359. May Acquire Right of Way.

17. When it shall be necessary in making any improvements which any district is authorized by this act to make, to enter upon any public property or property held for public use, such district shall have the power so to do and may acquire the necessary right of way over such property held for public use in the same manner as is above provided for acquiring private property, and may enter upon, use, widen, deepen and improve any navigable or other waters, waterways, canal or lake: Provided, the public use thereof shall not be unnecessarily interrupted or interfered with, and that the same shall be restored to its former usefulness as soon as practicable: Provided, however, that no such district shall occupy any portion of [fol. 179] the Illinois and Michigan canal outside of the limits of the county in which such district is situated for the site of any such improvement, except to cross the same, and then only in such a way as not to impair the usefulness of said canal, or to the injury of the right of the State therein, and only under the direction and supervision of the canal commissioners: And, provided further, that no district shall be required to make any compensation for the use of so much of said canal as lies within the limits of the county in which said district is situated except for transportation purposes.

360. Special Assessment—Damage to Property and Cost of Acquiring.

18. In making any special assessment for any improvement which requires the taking or damaging of property, the cost of acquiring the right to damage or take such property may be estimated and included in the assessment as a part of the cost of making such improvement.

361. Liability of Sanitary District for Damages.

19. Every sanitary district shall be liable for all damages to real estate within or without such district which shall be overflowed or

otherwise damaged by reason of the construction, enlargement or use of any channel, ditch, drain, outlet or other improvement under the provisions of this act; and actions to recover such damages may be brought in the county where such real estate is situated, or in the county where such sanitary district is located, at the option of the party claiming to be injured. And in case judgment is rendered against such district for damage, the plaintiff shall also recover his reasonable attorneys' fees to be taxed as costs of suit: Provided, however, it shall appear on the hearing of plaintiff's motion to tax such attorney's fees, that the plaintiff notified the trustees of such district, in writing, at least 60 days before suit was commenced by leaving a copy of such notice with some one of the trustees of such [fol. 180] district, stating that he claims damages to the amount of — dollars by reason of (here insert the cause of damage) and intends to sue for the same: And, provided further, that the amount recovered shall be larger than the amount offered by said trustees (if anything) as a compromise for damages sustained. (As amended by act approved May 25, 1907. In force July 1, 1907. L. 1907, p. 284.)

361a. Inhabitant May Be Competent as Judge, Justice, or Juror.

19a. No person shall be an incompetent judge, justice or juror by reason of his being an inhabitant or freeholder in any sanitary district formed under the provisions hereof in any action in which such sanitary district may be a party in interest. (Added by act approved May 25, 1907. In force July 1, 1907. L. 1907, p. 284.)

362. Capacity of Channel or Outlet.

20. Any channel or outlet constructed under the provisions of this act which shall cause the discharge of sewage into or through any river or stream of water beyond or without the limits of the district constructing the same shall be of sufficient size and capacity to produce a continuous flow of water of at least two hundred cubic feet per minute for each one thousand of the population of the district drained thereby, and the same shall be kept and maintained of such size and in such condition that the water thereof shall be neither offensive or injurious to the health of any of the people of this State; and before any sewage shall be discharged into such channel or outlet, all garbage, dead animals and parts thereof, and other solids shall be taken therefrom, and said district shall, at the time any sewage is turned into or through any such channel or channels, turn into said channel or channels not less than twenty thousand cubic feet of water per minute for every one hundred [fol. 181] thousand inhabitants of said district, and shall thereafter maintain the flow of such quantity of water. (As amended by Act which became a law June 10, 1895. In force July 1, 1895: L. 1895, p. 168; Legal News Ed. p. 81.)

363. Sanitary District—Failure to Comply with Act—Remedy Penalty—Emergency Tax.

21. In case any sanitary district in this State formed under the provisions of this act shall introduce sewage into any river or stream of water, or natural or artificial water course, beyond or without the limits of such district, without conforming to the provisions of this act, or having introduced such sewage into such water course, shall fail to comply with any of the provisions of this act, an action to enforce compliance shall be brought by the Attorney General of this State in the courts of any county wherein such water course is situated, or he may authorize the State's Attorney of any such county to commence and prosecute such action in any such county: Provided, that nothing in this section contained shall be construed to prevent the prosecution of any action or proceedings by individuals or bodies corporate or politic against such district: And, provided further, that if any individual or the authorities of any municipal corporation shall file with the Attorney General a verified statement, in writing, setting forth wherein said sanitary district has failed to comply with any of the provisions of this act, it shall be the duty of the Attorney General forthwith to file in the Supreme Court of this State a petition for mandamus, setting forth wherein said sanitary district has failed to comply with the provisions of this act, and said court shall thereupon hear and determine such cause and proceed to enforce compliance with the provisions of this act, as in other cases of mandamus.

And, in order to comply with the provisions of this act, such sanitary district is hereby authorized and empowered to levy and collect such tax, as an emergency tax, upon the taxable property [fol. 182] of such sanitary district as may be necessary to carry into effect any order, judgment or decree of said court relating to the requisite flowage of water, capacity of the channel or outlet and the construction, maintenance and operation of movable bridges, as required by this act. (As amended by act approved May 15, 1897. In force July 1, 1897; L. 1897 p. 210; Legal News Ed. p. 76.)

364. Act—How Construed.

22. Nothing in this act contained shall be so construed as to constitute a contract or grant between the State of Illinois and any sanitary district formed under its provisions, or to prevent, debar or deprive the State of Illinois from, at any time in the future, altering, amending or repealing this act, or imposing any conditions, restrictions or requirements other, different or additional to any herein contained upon any sanitary district which may be formed hereunder.

365. Channel—How to Be Constructed.

23. If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Desplaines or Illinois river such channel shall be

constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than fourteen feet, and a current not exceeding three miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan, of not less than eighteen feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than one hundred and sixty feet at the bottom capable of producing a depth of not less than eighteen feet of water. If the population of [fol. 183] the district draining into such channel shall at any time exceed 1,500,000 such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than three miles per hour, and if at any time the general government shall improve the Desplaines or Illinois rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter, enlarge the entire channel leading into said Desplaines or Illinois rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom. In case a channel is constructed to the Desplaines river as contemplated in this section it shall be carried down the slope between Lockport and Joliet to the pool commonly known as the upper basin of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act, may correct, modify and remove obstructions in the Desplaines and Illinois rivers wherever it shall be necessary so to do to prevent overflow or damage along said river, and shall remove the dams at Henry and Copperas Creek in the Illinois river, be- [fol. 184] fore any water shall be turned into the said channel. And the canal commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said canal commissioners to cause such dam or dams to be removed. This act

shall not be construed to authorize the injury or destruction of existing water power rights. (Canal Comrs. v. Sanitary District, 184 Ill. 597.)

366. Channel, When Completed—Control of.

24. When such channel shall be completed, and the water turned therein, to the amount of three hundred thousand cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the general government shall improve the Desplaines and Illinois rivers for navigation, to connect with this channel, said general government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary or drainage purposes.

367. May Permit Territories Outside to Drain, etc.

25. Any district formed hereunder shall have the right to permit territory lying outside its limits and within the same county to drain into and use any channel or drain made by it, upon such payments, terms and conditions as may be mutually agreed upon, and any district formed hereunder is hereby given full power and authority to contract for the right to use any drain or channel which may be made by any other sanitary district, upon such terms as may be mutually agreed upon, and to raise the money called for by any such contract in the same way and to the same extent as such district is authorized to raise money for any other corporate purposes: Pro- [fol. 185] vided, that where the united flow of any sanitary districts thus co-operating shall pass into any channel constructed within the limits of the county wherein such districts are located, and which passes into the Desplaines or Illinois rivers, such united flow shall in no case and at no time be less than 20,000 cubic feet of water per minute for each one hundred thousand of the aggregate of the population of the districts co-operating: Provided, nothing in this act shall in any wise be so construed as to diminish, impair or remove any right or rights of any city, village, township or corporation, body politic or individual situated on the Desplaines or Illinois rivers or their tributaries and within the valleys of the same to use the channel for drainage or otherwise not inconsistent with the rights of the district constructing the same as expressed in this act.

368. When City or Village Owns Waterworks, etc.

26. Whenever in any such sanitary district there shall be a city, incorporated town or village, which owns a system of waterworks and supplies water from a lake or other source which will be saved and preserved from sewage pollution, by the construction of the main channel, drain, ditch or outlet herein provided for, and the turning of the sewage of such city and district therein, and there shall be in such sanitary district any territory bordering on any such city, incorporated town or village within the limits of another city, incorporated town or village, which does not own any system of waterworks, at the time of the creation of such sanitary district, then

upon application by the corporate authorities of such latter named city, incorporated town or village the corporate authorities of such city, incorporated town or village having such system of waterworks shall furnish water at the boundary line between such municipalities by means of its waterworks to the corporate authorities asking for the same in such quantities as may be required to supply [fol. 186] consumers within said territory, at no greater price or charge than it charges and collects of consumers, within its limits for water furnished through meters in like large quantities.

369. When Channel Constructed—Commissioners to be appointed to inspect its work.

27. If any channel shall be constructed under the provisions of section 23 of this act, it shall be the duty of the trustees of such district, when such channel shall be completed, and before any water or sewage shall be admitted therein, to duly notify, in writing, the Governor of this State of such fact; and the Governor shall thereupon appoint three discreet persons as commissioners, one of whom shall be a resident of the city of Joliet, or between said city and the city of La Salle, and one a resident of the city of La Salle, or between said city and the city of Peoria, and one a resident of the city of Peoria, or between said city and the mouth of the Illinois river, to inspect said work. The said commissioners shall, within ten days after such appointment meet at the city of Chicago, and shall appoint a competent civil engineer, and they may employ such other assistance as they may require to expeditiously perform their duties. The said commission shall take as their datum line for the survey the datum established by the Illinois and Michigan Canal Trustees in 1847, and shall make such examination and surveys of Chicago river and of the channel or channels authorized by this act as shall enable them to ascertain whether said channel is of the character and capacity required by this act. And in case they shall find the work in all respects in accordance with the provisions of section 23, of this act, they shall so certify to the Governor, who shall thereupon authorize the water and sewage to be let into said channel. But in case said commissioners shall find said channel is not constructed in accordance with the provisions of this act, it shall be their [fol. 187] duty to file in any court of competent jurisdiction, on the chancery side thereof, in their name as such commissioners, a bill against said corporation, which bill shall set forth wherein said work is deficient and fails to comply with the provisions of this act; and said court shall thereupon issue an injunction without bond against said defendant, enjoining and restraining it from admitting water or sewage into said channel until the final order of the court. And in case said court, upon hearing, shall determine that said channel is not constructed in accordance with the provisions of this act, said injunction shall be continued until the provisions of this act shall have been fully complied with.

Such commissioners and engineers shall receive for their services ten dollars per day each, and their reasonable expenses and outlays for the time by them necessarily employed in the discharge of their

duties, which shall be paid to them from the State Treasury; and the said sanitary district shall reimburse the State for all expenses and disbursements on account of said commission.

If any channel is constructed under the provisions of this act which shall discharge the sewage of a population of more than 300,000 into or through any river beyond or without the limits of the district constructing it, the same shall be constructed in accordance with the provisions of section 23 of this act, and if any such channel receives its supply of water from any river or channel connecting with Lake Michigan it shall be construed as receiving its supply of waters from Lake Michigan.

An Act Concerning Police Power upon the Sanitary District of Chicago. (Approved June 16, 1893. In Force July 1, 1893. L. 1893, p. 96; Legal News Ed., p. 56.)

369a. Power to Appoint Force.

1. Be it enacted by the People of the State of Illinois, represented in the General Assembly, That the sanitary district of Chicago shall [fol. 188] have the right and power to appoint and support a police force, the members of which may have and exercise police powers over and within its right of way and for a distance of one and one-half miles on each side of its main drainage channel, such police powers as are conferred upon and exercised by the police of organized cities and villages; but such police force when acting within the limits of such city or village, shall act in aid of the regular police force of such city or village, and shall then be subject to the direction of its chief of police, city or village marshals or other head thereof.

An Act extending the powers of sanitary districts organized under an act entitled "An act to create sanitary district and to remove obstructions in the Desplaines and Illinois rivers," approved May 29, 1889, in force July 1, 1889, to enable such districts to improve certain navigable streams within or auxiliary to such district and to build bridges across such streams. (Approved May 13, 1901. In force July 1, 1901. L. 1901, p. 164; Legal News Ed., p. 94.)

369b. May Acquire Land, etc., by Purchase or under the Eminent Domain Laws.

1. Be it enacted by the People of the State of Illinois represented in the General Assembly: That any Sanitary district organized under an act entitled "An act to create Sanitary Districts and remove obstructions in the Des Plaines and Illinois rivers," approved May 29, 1889, in force July 1, 1889, which heretofore has or may hereafter use any navigable stream or river for a portion of its channel, or as an adjunct thereto or auxiliary to its main channel, may for the purpose of widening, deepening or improving the same, for purposes set forth in the act aforesaid, acquire by purchase, or under and pursuant to the eminent domain laws of this state, or otherwise,

sufficient land for the purpose of making such improvements by [fol. 189] widening and deepening said stream, as aforesaid.

369c. When District May Construct Bridge or Bridges.

2. That wherever it has or may become necessary by reason of the widening, deepening or improving of such river, to construct bridges to meet the altered or changed condition of such stream or river, such Sanitary District or districts may construct such bridge, or bridges as such improvement, heretofore made or hereafter to be made, may require.

369 D. Act, How Construed.

3. Nothing herein contained shall be construed as depriving any city, village or town, situated wholly or partly within the limits of said Sanitary District, of any power now exercised in the operation of said bridges; and any bridges built under the provisions of this act to supply or replace a public street or highway bridge, now or hereafter existing, shall, after the construction of said bridge, be operated and controlled for municipal purposes by said city, village or town within which it is located.

An act in relation to the Sanitary District of Chicago to enlarge the corporate limits of said district and to provide for the navigation of the channels created by such district and to construct dams, water-wheels and other works necessary to develop and render available the power arising from the water passing through its channels and to levy taxes therefor. (Approved May 14, 1903; in force July 1, 1903, L. 1903, p. 113; Legal News Ed., p. 92.)

369 E. Sanitary District of Chicago Extended.

1. Be it enacted by the people of the State of Illinois represented in the General Assembly: That the corporate limits of the sanitary district of Chicago, be, and the same are hereby extended so as to [fol. 190] embrace and include within the same, the territory and tracts of land situated in the County of Cook and State of Illinois, hereinafter described as follows, viz.:

First. The territory or tract of land bounded as follows: Beginning at the intersection of the county line between Lake and Cook counties, State of Illinois, with the west shore of Lake Michigan, running thence west along said county line to the northwest corner of Section three (3) Township forty-two (42) north, Range twelve (12), east of the third principal meridian; thence south to the southeast corner of Section thirty-three (33), Township forty-two (42) north, Range twelve (12) east of the third principal meridian; thence east to the northwest corner of section twelve (12) Township forty-one (41) north, Range twelve (12) east of the third principal meridian; thence south to the northwest corner of Section twenty-five (25), in said town and range; thence east to the northeast corner of the west half (½) of the west half (½) of said Section (twenty-five) 25; thence south to the southeast corner of the west half (½)

of the west half (½) of Section thirty-six (36) in said town and range; thence east to the northeast corner of the west half (½) of Section one (1), Township forty (40) north, Range twelve (12), east of the third principal meridian; thence south to the southeast corner of the west half (½) of Section thirteen (13) in said township and range; thence east to the southeast corner of Section thirteen (13) thence east, north, northwest and east along the present boundary line of said sanitary district of Chicago to the shore of Lake Michigan; thence northwesterly along the shore of Lake Michigan to the place of beginning.

Second. The territory or tract of land bounded as follows to-wit: Commencing at the northeast corner of Section three (3) in Township thirty-seven (37) north, Range thirteen (13) east of the third principal meridian; running thence south to the southwest corner [fol. 191] of section eleven (11), township thirty-six (36) north, range thirteen (13) east of the third principal meridian; thence east and south along the boundary lines of Section fourteen (14) in said Township thirty-six (36) to the southeast corner of said Section fourteen (14), thence east to the southeast corner of Section seventeen (17) in Township thirty-six (36) north, Range fifteen (15), east of the third principal meridian; thence north along the east boundary line of the State of Illinois to its intersection with the shore of Lake Michigan, thence along the shore of Lake Michigan to the south boundary line of the present sanitary district of Chicago; thence west along the present south boundary line of the said sanitary district of Chicago to the place of beginning.

369 F. Drainage of Added Territory—Use Calumet Feeder—Illinois and Michigan Canal—Connection with Land for Use of Canal Commissioners.

2. The board of trustees of said sanitary district shall have the right to provide for the drainage of the additional territory added to said sanitary district by this act by laying out, establishing, constructng and maintaining one or more channels, drains, ditches and outlets for carrying off and deposing of the drainage (including the sewage) of such district, together with such adjuncts and additions thereto as may be necessary or proper to cause such channels or outlets to accomplish the end for which they are designed in a satisfactory manner and shall have the right to use what is known as the "Calumet feeder" of the Illinois and Michigan canal and lands adjacent to such feeder belonging to the State of Illinois for the site of any such channel, within the limits of the county in which such district is situated, in such manner as said district may elect, and shall also have the right to construct a channel across said Illinois and Michigan canal, without being required to restore said Illinois and Michigan canal or said feeder to its former usefulness. If, [fol. 192] by reason of said abandonment, a stagnant stream or pool of water shall remain upon the deposits of Chicago sewage, accumulated in said Illinois and Michigan Canal by reason of its years of usefulness by the city of Chicago as a sewage outlet, said

sanitary district shall fill up said canal to a depth sufficient to remove said condition and prevent the spread of pestilence and disease throughout the territory in which said Illinois and Michigan Canal is abandoned; and the other powers and jurisdiction of said sanitary district of Chicago over and in connection with such added territory shall be the same as that vested in it over the territory included within the limits of said sanitary district as originally organized. Before said Calumet channel is connected with the present main sanitary channel, gates of suitable pattern for shutting off the flow of water into said Calumet channel shall be installed at or near the connection of said Calumet channel with the Calumet river and forever maintained for use in case of an emergency, and for the protection of the property and lives of residents of the Illinois valley, and shall maintain the same proportion of dilution of sewage through such auxilliary channels as it may construct and join to its main channel as is now required by the act creating said sanitary district: Provided however, that before any such channel is constructed across said Illinois and Michigan Canal, or the navigation of said canal in any manner interfered with, said sanitary district of Chicago shall connect its present main channel from the controlling works at Lockport with the upper basin of the Illinois and Michigan Canal at Joliet by a channel of a depth of not less than ten (10) feet and a width of not less than one hundred and sixty (160) feet through its entire length, in which channel so to be constructed said sanitary district shall provide and construct a lock or locks of the size of at least twenty-two (22) feet in width by one hundred and thirty (130) feet in length between mitre sills, connecting upper [fol. 193] and lower levels, and provide suitable protection for water craft in using said locks and channel. Said locks shall be constructed of the most approved pattern of their size, and be perfectly safe for use and be equipped with machinery to operate the same; and if only one lock is constructed it shall be provided with double gates to prevent accident, and said sanitary district shall forever maintain and operate the same. Provided, further, that said sanitary district shall furnish and provide at said lock a site of the dimensions of at least twenty by thirty feet upon which the State through the Canal Commissioners shall have the right to erect a suitable office building and keep an agent therein, and the Canal Commissioners shall have such authority in and about said lock as is necessary to enforce the rules and regulations prescribed by them pertaining to and governing navigation on the Illinois and Michigan Canal: Provided, further: That said sanitary district shall furnish, free of all expense, for the perpetual use of the Canal Commissioners, at some point in the township of Lockport to be agreed upon by the Canal Commissioners and the sanitary district trustees, a strip or parcel of land bordering upon said sanitary channel, eight hundred (800) feet in length and one hundred and thirty (130) feet in width, filling the same to a suitable depth to provide suitable roadways for approaches, whereon may be located, constructed and operated docks, shops, barns and other buildings controlled by the Canal Commis-

sioners and used in connection with the operation of the Illinois and Michigan Canal.

369 G. Navigation on Sanitary District Channels

3. Said sanitary district shall permit all water craft navigating or proposing to navigate said Illinois and Michigan Canal to navigate the water of all said channels of said sanitary district promptly, without delay and without payment of any tolls or lockage charges for so navigating in said channels. The rules of the United States government now in force, regulating navigation on the Chicago [fol. 194] river shall govern navigation on the channels of said sanitary district of Chicago; Provided however, that the speed of all vessels while passing through the earth sections shall not exceed eight (8) miles per hour.

369 H. No Special Tax or Assessment for Work Heretofore Done on Main Channel Added Territory.

4. Said sanitary district of Chicago, shall have no power to levy and collect any special assessment or special tax upon any part of said added territory to defray or pay any part of the cost, either of the work heretofore done by said sanitary district or any main channel hereafter to be constructed in said added territory.

369 I. Authority to Develop Water Power.

5. That the said sanitary district of Chicago is hereby authorized to construct all such dams, waterwheels and other works north of the upper basin of the Illinois and Michigan Canal as may be necessary or appropriate to develop and render available the power arising from the water passing through its main channel and any anuxiliary channels now or hereafter constructed by said district.

369 J. How Such Power May Be Utilized.

6. That the power made available by the works constructed under the provisions of this act shall be converted into electrical energy and shall be transmitted to the various cities, villages and towns within said sanitary district or adjacent to the main channel of said sanitary district and may be used in the lighting of said cities, villages and towns, or parts thereof, or for the operation of pumping plants or machinery used for municipal purposes or for public service, or may be disposed of to any other person or corporation, upon such terms and conditions as may be agreed to by the said sanitary district; Provided, however, that it shall be the duty [fol. 195] of said sanitary district to utilize so much of said power as may be required for that purpose to operate the pumping stations, bridges and other machinery of said sanitary district.

369 K. Authority to Levy Tax.

7. That for the purpose of meeting the expenditures arising from the exercise of the powers conferred by sections five and six of this act upon the said sanitary district, the said sanitary district of Chi-

cago is hereby authorized to levy and collect in each year, for a period of three years (in addition to the taxes which said district is now by law authorized to levy and collect) a tax of not exceeding one-fourth of one per cent of the value of the taxable property within the corporate limits of said district, as the same shall be assessed and equalized for the State and county taxes of the year in which the levy is made; Provided, further, that the county clerk, in extending said one-fourth of one per cent tax upon the taxable property within said sanitary district, shall not in any event reduce the same, but in that rspect said one-fourth of one per cent shall not be subject to the provisions of an act entitled, "An act concerning the levy and extension of taxes," approved May 9, 1901.

369 L. Comply with Acts of Congress as to Illinois and Michigan Canal.

8. The said sanitary district shall at the expense of said district, in all respects comply with the provisions of the acts of Congress of March 22, 1822, and March 2, 1827, as construed by the courts of last resort of the State of Illinois and of the United States, in relation to the Illinois and Michigan Canal, so far as it affects that portion of the Illinois and Michigan Canal vacated or abandoned by the terms of this act.

[fol. 196] 369 M. Petition for Question to be Submitted—Election.

9. If within sixty (60) days after the passage of this act a petition signed by not less than three per cent of the legal voters of the territory within the limits of the sanitary district of Chicago, as the same are enlarged by the terms of this act, praying that the question of the adoption of this act shall be submitted to a vote of the electors of the territory within the said limits of the said sanitary district of Chicago, shall be filed with the clerk of said sanitary district, then and in such case the question of the adoption of this act shall be submitted to a vote of the said electors as in said petition prayed, at the general election to be held in the County of Cook in November 1904, and in such case this act shall not be in force unless a majority of the votes cast at said election upon the question of the adoption of this act shall be in favor of the adoption thereof. It shall be the duty of the election officers having charge of the preparation of the ballots and the giving of the notices of election and of the counting, canvassing and making return of the ballots to take all necessary steps and do all necessary acts to cause the said question of the adoption of this act to be submitted to a vote as hereinbefore provided, and to cause the result of such election to be canvassed and certified, as provided by law in other similar cases.

(Here follows Exhibit B to answer, marked side folio page 197.)

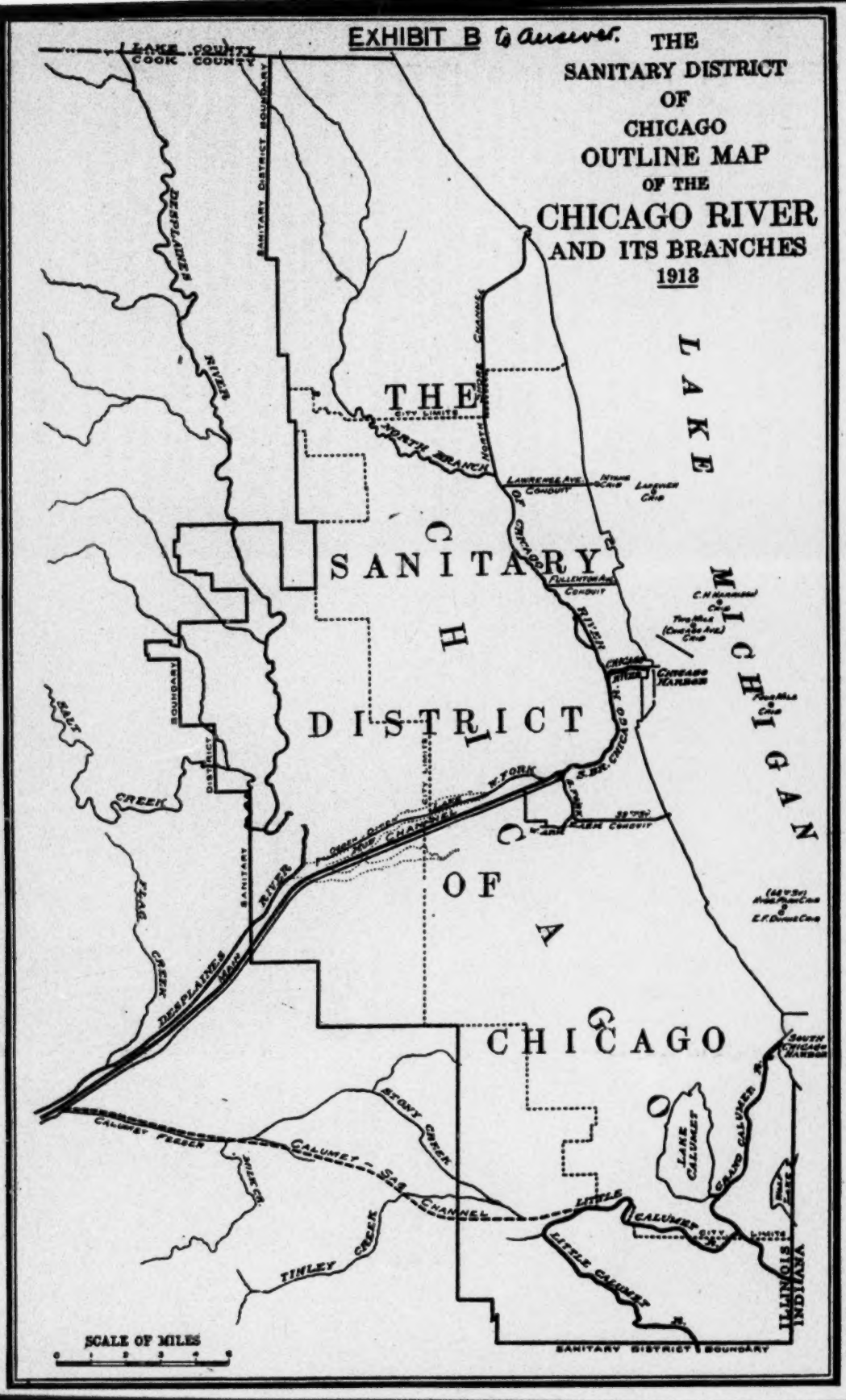


EXHIBIT B to answer.
THE SANITARY DISTRICT OF CHICAGO
OUTLINE MAP OF THE
CHICAGO RIVER AND ITS BRANCHES
1913
LAKE COUNTY
COOK COUNTY
SANITARY DISTRICT BOUNDARY
DES PLAINES RIVER
THE SANITARY DISTRICT OF CHICAGO
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NORTH BRANCH
NORTH BRANCH CHANNEL
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FULLERTON AVE. CONDUIT
CHICAGO RIVER
CHICAGO HARBOR
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[fol. 198] EXHIBIT "C" TO ANSWER

War Department, Washington

March 14, 1907.

In the Matter of the Application of THE SANITARY DISTRICT OF CHICAGO to Reverse the Flow of the Calumet River

This application is made under Section 10 of the act of March 3, 1899 (30 Stat. L., 1151), which provides as follows:

"Sec. 10. That the creation of any obstruction, not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same."

The application of the Sanitary District is for leave to reverse the flow in the Calumet River in such a way as to make the water to flow out of the lake instead of to flow into it and to discharge the water from the Calumet River into the Drainage Canal. The Chief of Engineers was at first of opinion that such a change in the flow of the river *it* was not within the power of the Chief of Engineers to recommend, or within the power of the Secretary of War to permit. This expression of opinion as to the construction of the stat-
[fol. 199] ute was submitted to the Judge Advocate General, who holds that Section 10, as quoted above, applies to this case and that it is one in which work could be allowed under the recommendation of the Chief of Engineers and the permission of the Secretary of War. Upon the construction of the Judge Advocate General I requested the Chief of Engineers to make his recommendation, which he has done as follows:

"February 23, 1907.

1. Respectfully returned to the Secretary of War.

2. The subject of the abstraction of water from Lake Michigan has been elaborately investigated by the Lake Survey Office at Detroit, and the results are published in the annual reports of the Chief

of Engineers for the years 1900, 1902 and 1904. The international Waterways Commission has also given it careful consideration, and its conclusions are set forth in report of January 4, 1907, printed as War Department Document No. 293.

3. In my opinion, this abstraction will undoubtedly lower the levels of all the waters of the Great Lakes, except those of Lake Superior, and thus diminish the navigable capacity and depth of the various channels and harbors which have been deepened and improved under authority of Congress.

4. Leaving out Lake Superior, there are more than 100 works of river and harbor improvements on the Great Lakes and their connecting waters, for which appropriations aggregating more than $80,000,000 have been made. The application of this vast sum has resulted in securing and maintaining specified depths and widths of channel, which Congress has decided to be required for the accommodation of the traffic using those waters.

5. To diminish these depths even to a slight extent, would not only prove a serious injury to the traffc, but would practically undo the work which has been accomplished by Congressional direction, and necessitate the expenditure of further large sums of money for restoration. Any project that tends, in a measure, to annul or reverse the orders of Congress, as expressed in the various river and harbor acts appropriating funds for improving the harbors and [fol. 200] channels connecting with the Great Lakes, should meet the disfavor of the Department, unless it has been sanctioned by that body. In my judgment, such a project is the one under consideration, and for this reason I am unwilling to recommend favorable action thereon, assuming that the Department is empowered to take such action, as is held by the Judge Advocate General.

A. Mackenzie, Brig. Gen., Chief of Engineers, U. S. Army."

It is quite evident from the reading of the statute that Congress intended in this statute, as in many others, to give the Chief of Engineers authority, independent of the Secretary of War, in reaching a conclusion as to the wisdom and propriety of granting a permit under the section, and that unless the Chief of Engineers shall recommend the granting of the permit, the Secretary of War is without power to give the requested authority. It follows, therefore, that the application must be denied whatever my view of the case.

The decision of the Chief of Engineers and its final character has made it unnecessary for me to consider the merits of the question, but I may say this much, that the application for a change in the Calumet River is to be made the basis for the withdrawal of a large amount of water from Lake Michigan and that all interested in the enormous lake traffic view the settlement of the question with grave apprehension. Added to this, is the international complication which is likely to arise in the threatened lowering of the lake level in the ports and harbors and canals of Canada. On the other hand, it is maintained with great emphasis and elaboration of detail

that the change in the Calumet River, is essential to the healthful sanitation of Chicago, and that the threatened injury to navigation is so small as to be negligible.

Between too such great interests, the decision must be affected more or less by large public policy and expediency, and while I [fol. 201] agree in the construction of the Judge Advocate General that the issue is left by statutes to the recommendation of the Chief of Engineers and the concurrent decision of the Secretary of War, it may be fortunate that circumstances now require submission of this question of capital and national importance to the Congress of the United States.

Wm. H. Taft, Secretary of War.

(Reprinted from proceedings of Board of Trustees, March 27, 1907, pages 211-12.)

[fol. 202] EXHIBIT "D" TO ANSWER

"War Department,
Washington, September 11, 1907.

SIR: Referring to your letter of 2nd instant, in which you request approval of proposed drainage channel to connect Lake Michigan at Wilmette, Ill., with the North Branch of the Chicago River; also permission to construct a pile crib in Lake Michigan at mouth of same, and to deposit filling within the limits of such crib, I beg to inform you that the War Department will interpose no objection to the project as set forth in your letter and indicated on drawing submitted, provided the following conditions are complied with:

1. That the pier constructions, the filling behind the same, and the excavation of the proposed channel shall be done subject to the supervision and approval of the local officer of the Corps of Engineers, U. S. Army, at Chicago, so far as to see that the work authorized is not exceeded;

2. That the total diversion of water from Lake Michigan through the Chicago River into the Illinois River shall be no greater than already authorized by past War department permits;

3. That the work shall be commenced before December 31, 1908, and completed within five years thereafter.

Very respectfully, Robert Shaw Oliver, Acting Secretary of War. G. M. Wisner, Esq., Chief Engineer the Sanitary District of Chicago, American Trust Building, Chicago, Illinois."

[fol. 203] EXHIBIT E TO ANSWER

Permit

War Department,
Washington, June 30, 1910.

SIR: Referring to your application of the 27th instant on behalf of the Board of Trustees of The Sanitary District of Chicago to open a channel from the Calumet River to its existing Main Channel so as to substitute two routes instead of one between Lake Michigan and its canal, I have the honor to advise you to the following effect:

It appears from the records of the Department that by an instrument executed May 8, 1899, The Sanitary District of Chicago was given permission to connect its Drainage Canal with the South Branch of the Chicago River at Robey Street, in the City of Chicago, and to divert the waters of Lake Michigan through the Chicago River into said canal, subject to certain specified conditions designed to limit the amount of such diversion and in other ways to protect the public interest. The permission so granted was subsequently modified at various times, and by an instrument executed December 5, 1901, the amount of flow was fixed at not exceeding 250,000 cubic feet per minute, equivalent to 4,167 cubic feet per second, which is the present rate allowed. At the time the original permit was given a connection with the Calumet River was not mentioned but if it had been it is probable that a connection with that river as well as with the Chicago River would have been allowed.

So long as the water-flow remains unchanged there seems to be no special objections to its extension to both rivers instead of confining it to a single one, especially since if the new (Calumet) route be developed later to a navigable state the double route will be ad-
[fol. 204] vantageous to navigation interests. Accordingly, in view of the favorable recommendation of the Chief of Engineers and of the consent thereto by the Attorney General, under the conditions hereinafter prescribed, the Department hereby modifies the existing permission so as to allow the division of the already permitted water-flow in such manner as to reach the Sanitary District Canal by way of the Calumet River and a connecting channel, as well as by way of its present route through the Chicago River, subject to all pertinent conditions of the existing permissions and to other express conditions, as follows:

(a) That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of The Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

(b) That if at any time it become apparent that the current created by such drainage work in the Calumet, as well as Chicago rivers, be unreasonably obstructive to navigation, or injurious to property, the Secretary of War reserves the right to close the discharge through

said channel or rivers, or to modify it to such an extent as may be demanded by navigation and property interests along said rivers.

(c) That The Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in the Calumet as well as Chicago river.

(d) That the amount of water withdrawn from Lake Michigan, through the Chicago and Calumet rivers together, shall not exceed the total amount of 250,000 cubic feet per minute (4,167 cubic feet per second) already authorized to be withdrawn through the Chicago River alone.

(e) That the permission herein given shall be subject to such [fol. 205] modification as in the opinion of the Secretary of War the public interests may from time to time require.

(f) That this permission shall in nowise affect or in any manner be used in the friendly suit now pending in the Circuit Court of the United States for the Northern District of Illinois brought by the United States of America against the Sanitary District of Chicago, to determine the right of the said Sanitary District to divert from Lake Michigan for sanitary purposes an amount of water in excess of that now being diverted, without having first obtained a permit from the Secretary of War.

(g) That the War Department shall have free access at all times to the waterflow records of The Sanitary District of Chicago and free access also to the regulating works and all other parts of its canals for the purpose of checking records or making water-flow measurements.

(h) That the plans for the proposed work shall be submitted to and approved by the Chief of Engineers and the Secretary of War.

(i) That the work shall be subject to the supervision and approval of the Engineers Officer of the United States Army in charge of the locality.

Very respectfully, Robert Shaw Oliver, Acting Secretary of War. Mr. George M. Wisner, Chief Engineer Sanitary District of Chicago, Chicago, Ill.

(Reprinted from the proceedings of the Board of Trustees, November 2, 1911, pages 1323-25.)

[fol. 206] EXHIBIT "F" TO ANSWER

Memorial to Congress on the Subject of the Illinois and Michigan Canal

(Laws Extra Session, 1826, p. 97)

To the Honorable the Senate and House of Representatives of the United States of America in Congress assembled:

The memorial of the General Assembly of the State of Illinois respectfully represents that the construction of a canal uniting the waters of Lake Michigan with the Illinois river, will form an important addition to the connecting links in the chain of internal navigation, which will effectually secure the indissoluble union of the confederate members of this great and powerful Republic. By the completion of this great and valuable work, the connection between the north and the south, the east and the west, would be strengthened by the ties of commercial intercourse and social neighborhood, and the union of the states might bid defiance to internal commotion, sectional jealousy and foreign invasion. All the states of the Union would then feel the most powerful motives to resist every attempt at dissolution. To effect so great and desirable an object, your memorialists believe to be of sufficient importance to engage the attention and awaken the munificent patronage of a government whose principle of action is the promotion of the general welfare. Your memorialists are sensibly alive to the spirit of improvement that manifests itself in almost every section of our extensive country, and would fain lend a helping hand in so great and good a cause; their situation, however, forbids their doing much, without the aid of the federal government; into whose treasury almost all the funds whether brought hither by emigrants or earned by the industry of their citizens, are paid for the purchase of the public lands. While this state [fol. 207] of things shall continue and the money thus paid into the treasury of the Union is taken out of our State, our people will not be able to engage in the glorious work of improving our common country. Ought the people of this State to stand by with folded arms and behold the great work of internal improvement progress in other states without making an effort to improve their own conditions, and at the same time advance the interest of our beloved country? A condition thus paralyzed, is at war, not only with our interests, but with the best feelings of our hearts. Did this State possess the public domain lying within its bounds, as in the case with the older members of this confederacy, your memorialists would not appear before your honorable body to solicit aid in this important work. If, as your memorialists believe, the construction of this canal would be highly beneficial to the Union at large; if the receipts into the treasury of the United States would be augmented by the increased sales of public lands; and if the interest of this State would be also advanced thereby; is it unreasonable to apply to a paternal government for assistance in the promotion of such beneficial ends? It is un-

necessary for your memorialists to enlarge on the great advantages of this canal to the Union, in the facilities to be afforded in the event of a war with either the Indian tribes inhabiting our frontier, or the British nation. Your honorable body is aware that this State is situated on the borders of an Indian country, filled with numerous and powerful tribes of the sons of the forest. If our country should be again engaged in war, the saving of expense in the transportation of munitions of war, would alone defray the expense of the contemplated canal, and justify the United States in making a liberal appropriation for its construction. Your memorialists do not, however, ask your honorable body to appropriate money out of the treasury to aid them in this work; they only ask for a tract of land, [fol. 208] through which the contemplated canal may pass, and which, for a series of years, will be wholly unproductive to the government unless the canal shall be commenced under auspices favorable to its completion; in which event all the land in the vicinity would immediately become available to the United States. Your memorialists sincerely believe that a liberal appropriation of land for this object, would, even in a pecuniary point of view be of immense importance to the treasury of the Union. The public lands in the vicinity would not only sell, but at a considerable advance upon the minimum price. Should this opinion be correct (and does not experience justify it?) the United States would be gainers by the proposed donation to the State. Your memorialists further state that at their last session, they passed an act of incorporation, upon very liberal terms, authorizing a company to construct the projected canal; but the remoteness of the country from the residence of capitalists, has prevented them from engaging in the work. At their present session, your memorialists have repealed the charter; and their only hope of soon beginning the work depends upon the liberality of your honorable body. Your memorialists have caused the route to be explored and estimates to be made of the probable expense of the work; from which it appears that the cost of constructing the canal will not be less than $600,000 and may possibly amount to $700,000. To the end, therefore, that your memorialists may be enabled to commence and complete this great and useful work, we pray your honorable body to grant to this State the respective townships of land through which the contemplated canal may pass; the avails of which, to be appropriated exclusively, to the construction of said canal, upon such terms and conditions as to your honorable body may seem proper.

[fol. 209] EXHIBIT "G" TO ANSWER

"An Ordinance for Cleansing the Chicago River and Appropriating the Proceeds of Two Hundred and Fifty Bonds Therefor.

Section 1. Be it ordained by the Common Council of the City of Chicago (June 5, 1865), That the plan of the board of public works for cleansing the Chicago River and its branches by cutting down

the summit of the Illinois and Michigan Canal below the level of Lake Michigan so as to draw from it at a low stage of water in the lake not less than twenty-four thousand (24,000) cubic feet of water per minute, is hereby approved, and said board are hereby authorized to execute said work.

Section 2. That the board of public works are hereby authorized and empowered for the purpose of prosecuting the work described in the previous section, to make any contract necessary to carry into effect such purpose with the trustees of the Illinois and Michigan Canal, in conformity with and subject to the general provisions of the city charter.

Section 3. That as a temporary expedient for cleansing the South Branch of the Chicago River, the said board are hereby authorized and empowered to contract with the said trustees for the pumping from the river into the canal, by the hydraulic works at Bridgeport, and discharging through the canal of such amount of water as shall be found necessary and practicable for such purpose.

Section 4. That for the purpose of carrying out the improvement specified in the foregoing sections, the board of public works be and they are hereby authorized to issue 250 bonds of the denomination of $1,000 each, to be dated July 1, 1865, and payable in New York, twenty-five years after the date thereof, with coupons for interest, at the rate of seven per centum per annum, payable semi-annually in New York; the said bonds to be issued in conformity with the provisions of an act of the General Assembly of the State of Illinois, approved February 15, 1865, and entitled 'An act to amend an act entitled an act to reduce the charter of the City of Chicago, and the several acts amendatory thereof, into one act, and to revise the same,' approved February 13, 1863."

[fol. 210] EXHIBIT H TO ANSWER

Application of the Sanitary District for the Improvement of the Chicago River

Chicago, June 16, 1896.

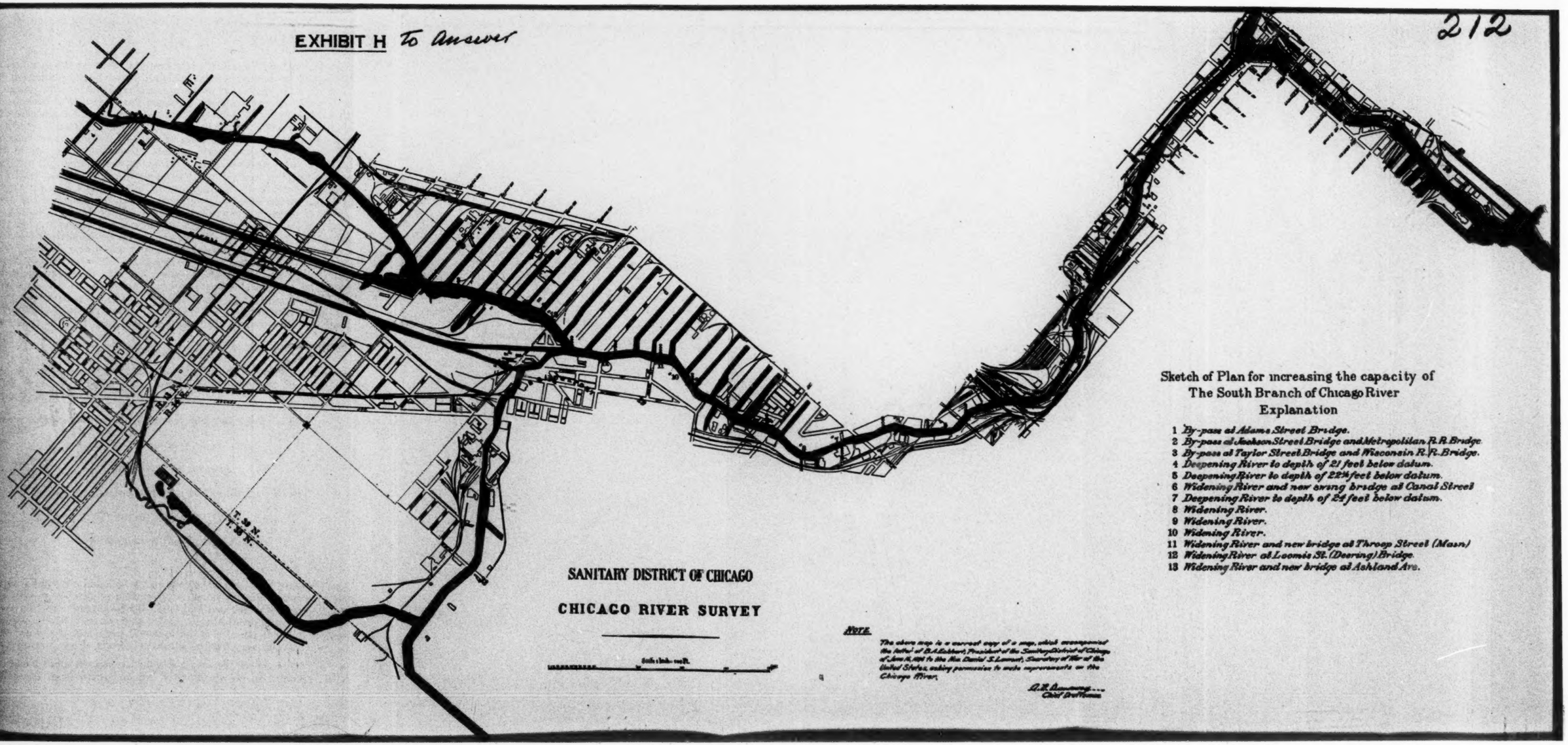
To the Honorable Daniel S. Lamont, Secretary of War, Washington, D. C.

DEAR SIR: The work of The Sanitary District of Chicago has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport in Will County, twenty-eight miles distant.

Our connection with Lake Michigan must be through the Chicago river with the West Fork of the South Branch of which we make a junction at Robey Street. We send herewith a map showing in a

EXHIBIT H To Answer

212



SANITARY DISTRICT OF CHICAGO

CHICAGO RIVER SURVEY

Sketch of Plan for increasing the capacity of
The South Branch of Chicago River
Explanation

1 By-pass at Adams Street Bridge.
2 By-pass at Jackson Street Bridge and Metropolitan R.R. Bridge.
3 By-pass at Taylor Street Bridge and Wisconsin R.R. Bridge.
4 Deepening River to depth of 21 feet below datum.
5 Deepening River to depth of 22½ feet below datum.
6 Widening River and new swing bridge at Canal Street
7 Deepening River to depth of 24 feet below datum.
8 Widening River.
9 Widening River.
10 Widening River.
11 Widening River and new bridge at Throop Street (Main)
12 Widening River at Loomis St. (Deering) Bridge.
13 Widening River and new bridge at Ashland Ave.

NOTE.

The above map is a correct copy of a map, which accompanied the letter of R.A. Lidstone, President of the Sanitary District of Chicago, of June 8, 1911 to the Hon. Dewitt S. Lamont, Secretary of War of the United States, asking permission to make improvements on the Chicago River.

R.E. Armstrong
Chief Draftsman

general way our plans for improving the Chicago River by widening and deepening at the points indicated thereon by red hatchings and by figures which refer to explanation, given in the legend on the map. It is desired to so correct and regularize the cross section of the river as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles per hour. The cross section necessary to accomplish this can be obtained throughout the greater part of the distance between Monroe Street and Robey Street, by dredging the river to a depth of 20 ft. at mid stream, with 12 ft. at dock lines and a uniform slope away from docks of one foot in five, so that the full depth would be reached forty feet from the dock lines; but there are places so narrow that this cross section can only be obtained by widening the river; and again the depth to be ob-
[fol. 211] tained in the vicinity of Van Buren Street is limited by the height of the crown of the tunnel. To obviate this difficulty it is purposed to secure the requisite cross section by constructing a by-pass to the west of the bridges at Adams, Jackson and Van Buren Streets, as indicated. We ask your permission to proceed with the work upon the lines indicated and so far as is consistent with propriety the co-operation of the United States Engineering Department.

Awaiting your favorable reply, and holding ourselves ready to respond to any call from you for fuller information as to our plans, I am

Yours respectfully, (Signed) B. A. Eckhart, President.

A copy of the above letter is found at Page 297 of the Clerk's Copy Letter Book "C," being letter book from September 20, 1895, to January 11, 1897.

(Here follows Exhibit H to Answer, marked side folio page 212)

[fol. 213] EXHIBIT I TO ANSWER

Permit for the Improvement of the Chicago River

(Permit of July 3rd, 1896)

Improvement of the Chicago River

July 3, 1896.

SIR: I have the honor to acknowledge the receipt of your letter of 16th ultimo, requesting permission to make certain changes in the capacity of the channel of the Chicago River for drainage purposes at points indicated on the map accompanying the application, and in reply beg to say that upon investigation it is found that the permission requested can be granted upon the following conditions:

1. That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale

showing each proposed new bridge, each by-pass and each new dock or wharf proposed to be built, in order that the Secretary of War may act intelligently in each case.

2. That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submitted for consideration.

3. That it will not cover obstructions to navigation by reason of this work while in progress or when completed.

4. That the United States shall not be put to expense by reason of this work.

5. That this authority will expire by limitation in two years from date unless extended.

Very respectfully, (Signed) Joseph B. Doe, Acting Secretary of War. B. A. Eckhart, Esq., President the Sanitary District of Chicago, Rialto Building, Chicago, Ill.

[fol. 214] EXHIBIT J TO ANSWER

The Sanitary District of Chicago

Security Building

Chicago, April 26, 1900.

To the Honorable the Secretary of War.

SIR: The Sanitary District of Chicago, a municipal corporation organized and existing under the laws of the State of Illinois, respectfully represents that, by the laws of the State of Illinois and the charter of this petitioner, it is authorized to enter upon, widen, deepen and otherwise improve any navigable stream, river or other water-way. That in pursuance of the power conferred upon it by the statutes of the State of Illinios, and in the performance of the duties enjoined upon it by the act of the Legislature authorizing its creation, and under which it is acting, it has been determined to improve the Chicago River by widening and deepening the same and to the end that such action on the part of your petitioner may be conformable to law and the statutes of the United States in that behalf, it hereby makes application for permission to make the changes, alterations and improvements in said Chicago River from or near Lake Street in the City of Chicago to or near Ashland Avenue in the City of Chicago, said work to conform to the plan and specifications as follows:

(a) A map herewith exhibits the existing boundaries of that part of the South Branch of the Chicago River which it purposes and desires to improve.

(b) The work to be done contemplates widening the river to a width of two hundred (200) feet between dock lines, except in so far as bridge abutments may project into the stream outside of the new [fol. 215] dock lines; said widening in all cases to be made with a view of improving the navigability of the stream.

(c) The work to be so done as to ultimately permit excavation of the river bed to a depth of thirty (30) feet below water surface throughout the central portion of the stream.

(d) The widening of the river is to be so disposed that the effect will be to produce a straighter channel than now exists and, furthermore, to result in a continuous dock line having straighter alignment and being better disposed for navigation than the docks which now exist.

(e) The work to be done is to be prosecuted progressively as to time. The rate of progress being limited by the rapidity with which right of way may be acquired and the resources for the execution of the work to be made available. The modification and alteration of said river as above indicated will greatly benefit navigation in said river. Your petitioner, therefore, respectfully requests that the plan of improvement as above outlined be approved by you.

Awaiting as early a reply as practicable under the circumstances, your petitioner has the honor, to be.

Very respectfully yours, The Sanitary District of Chicago, by William Boldenweck, President. Attest: Joseph H. Haas, Clerk.

[fol. 216] EXHIBIT J-1 TO ANSWER

Chicago, June 7, 1900.

To the Honorable, the Secretary of War.

SIR: Under date of April 26, 1900, the Sanitary District of Chicago had the honor to address a communication to you containing an outline of the proposed improvement of a portion of the South Branch of the Chicago River. Accompanying the letter was a map showing the location of the South Branch of the Chicago River, the bridges spanning said river and, also, the width of the stream along the entire course of the South Branch of the river. Since that date the Sanitary District of Chicago passed an ordinance for the improvement of the South Branch of the Chicago River from the south line of Twelfth Street to the east line of Ashland Avenue, so as to make said South Branch, between the lines aforesaid, of a uniform width of two hundred (200) feet; the work to be done so as to ultimately permit excavation of the river bed to a depth of thirty (30) feet below water surface throughout the central of said stream, in accordance with the plans adopted by the Board of Trustees of the Sanitary District of Chicago, a copy of which plans is hereto annexed. The

ordinance referred to being marked Exhibit "A," with this letter; and the maps showing the plans of the proposed improvement being marked Exhibit "B." The maps are in two sections, known respectively as No. 2 and No. 3.

The Sanitary District of Chicago is a municipal corporation, organized and existing under the laws of the State of Illinois and by the laws of said State and the charter of said Sanitary District, it is authorized to enter upon, deepen, widen and otherwise improve [fols. 217 & 218] any navigable stream, river, or other water-way; and that in pursuance of the power conferred upon it by the statutes of the State of Illinois and in performance of the duties enjoyed upon it by the act of the legislature authorizing its creation, and under which it is acting, it determined upon said plans outlined in the enclosed ordinance and further illustrated by the maps hereto annexed; and the said Sanitary District, in compliance with the Statutes of the United States, hereby makes application to you for permission to make the changes, alterations and improvements in said South Branch of the Chicago River, from the south line of Twelfth Street to the east line of Ashland Avenue.

Awaiting as early a reply as practicable under the circumstances, your petitioner has the honor to be,

Very respectfully yours, The Sanitary District of Chicago, by William Boldenweck, President. Attest: Joseph F. Haas, Clerk.

(Here follows Exhibits K^1 and K^2 to Answer, marked side folio pages 219 and 220)

[fol. 221] EXHIBIT L TO ANSWER

War Department,
Washington, July 11, 1900.

SIR: I have the honor to acknowledge the receipt of your letter of April 26th last, requesting, in behalf of the Sanitary District of Chicago, permission to change, alter and improve the Chicago River, from Lake Street to Ashland Avenue, in Chicago, as shown on maps which accompanied your said letter.

Replying thereto I beg to inform you that there is no objection on the part of the War Department to the prosecution of work of improvement of Chicago River, specified in the above mentioned letter and delineated on the maps which accompanied the same, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the general government in any way with the expense incident to the carrying out of the project, and does not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago River and cause them to flow into

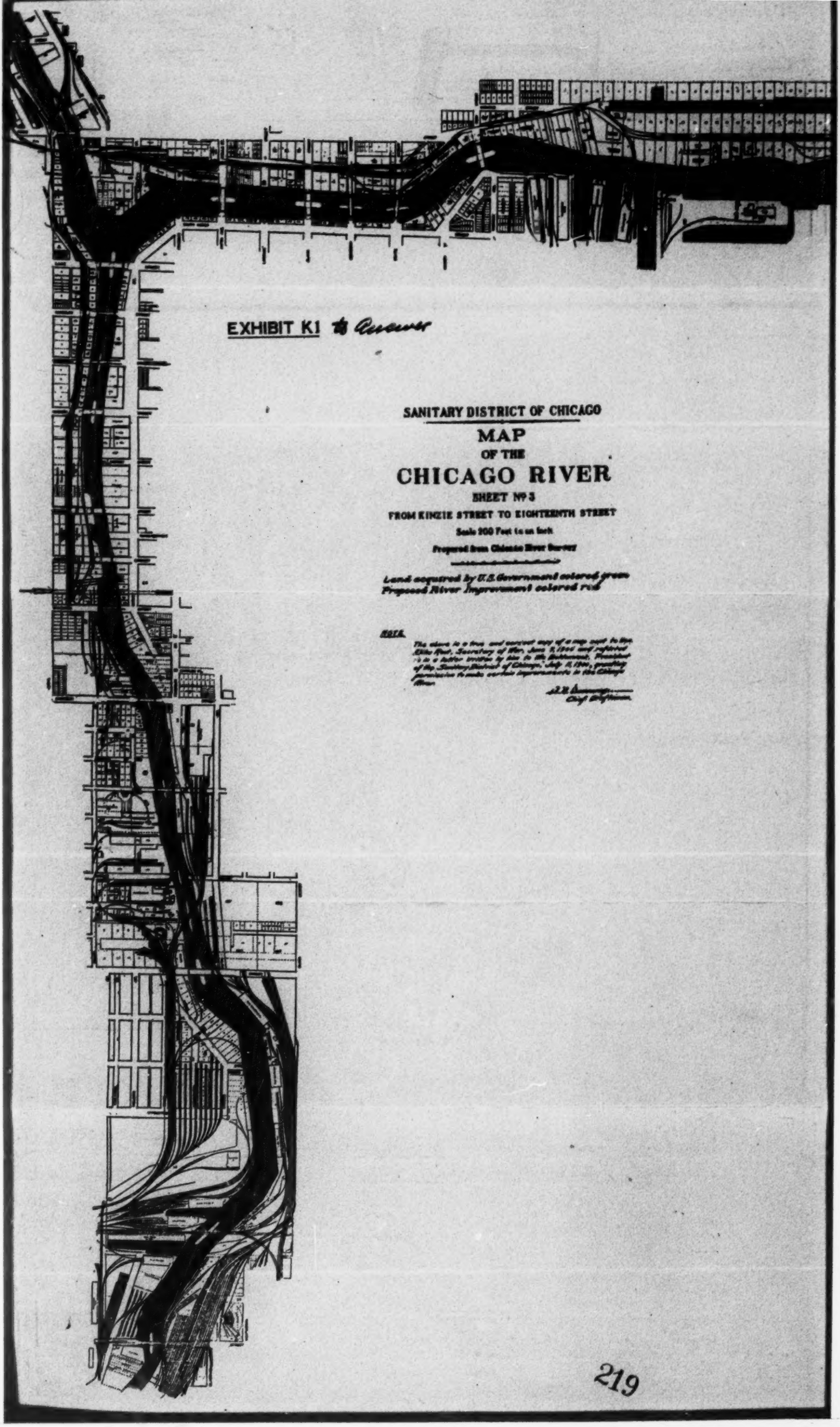


EXHIBIT K1 to Answer

SANITARY DISTRICT OF CHICAGO

MAP
OF THE
CHICAGO RIVER

SHEET № 3

FROM KINZIE STREET TO EIGHTEENTH STREET

Scale 200 Feet to an Inch

Prepared from Chicago River Survey

Land acquired by U.S. Government colored green
Proposed River Improvement colored red

NOTE.

This sheet is a true and correct copy of a map sent to the Hon. Jesse Root, Secretary of War, June 9, 1911 and referred to in a letter written by him to the Sanitary District of Chicago, July 8, 1911, granting permission to make certain improvements in the Chicago River.

J.D. Cunningham
Chief Engineer.

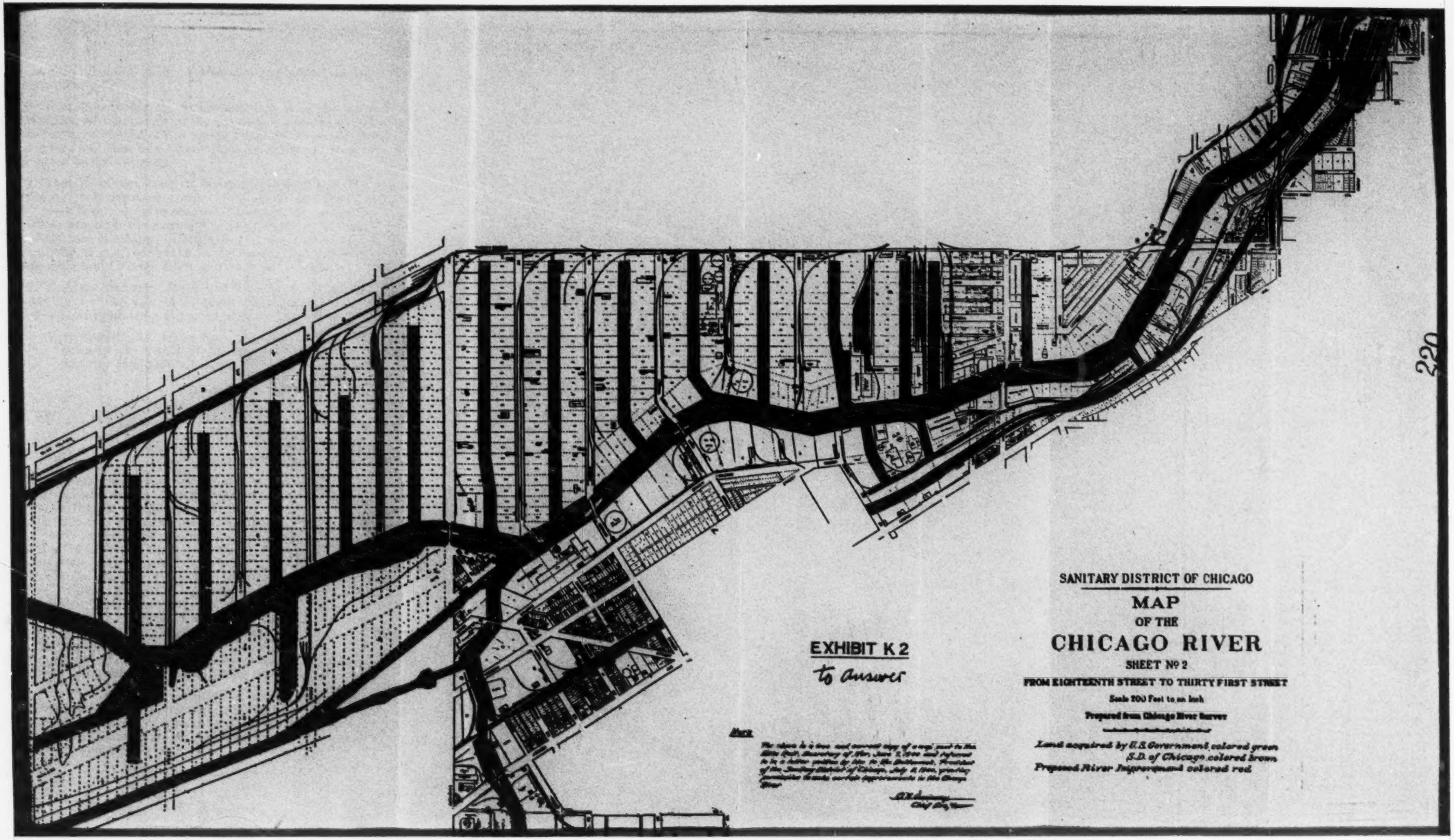


EXHIBIT K 2
to Answer

SANITARY DISTRICT OF CHICAGO

MAP
OF THE
CHICAGO RIVER
SHEET № 2

FROM EIGHTEENTH STREET TO THIRTY FIRST STREET

Scale 200 Feet to an Inch

Prepared from Chicago River Survey

Lands acquired by U.S. Government colored green
S.D. of Chicago colored brown
Proposed River Improvement colored red

the artificial channel, such permission being subject to the following conditions, viz:

"1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action and that this permit shall be subject to such action as may be taken by Congress.

"2. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close [fol. 222] said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

"3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River.

Very respectfully, Elihu Root, Secretary of War. Mr. Wm. Boldenweck, President the Sanitary District of Chicago, Security Building, Chicago, Ill."

[fol. 223] EXHIBIT L-1

War Department,
Washington, July 11, 1900.

SIR: In response to your application of the 7th ultimo, for permission to make certain changes, alterations and improvements in the South Branch of the Chicago River, from the south line of Twelfth Street to the east line of Ashland Avenue, as shown on plans which accompanied said application, I beg to inform you that there is no objection on the part of the War Department to the prosecution of the work as specified, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the general government in any way with the expense incident to the carrying out of the project, and does not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted, under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago River and cause them to flow into the artificial channel such permission being subject to the following conditions, viz:

"1. That it be distinctly understood that it is the intention of the Secretary of War to submit the question connected with the work of the Sanitary District of Chicago to Congress for consideration and final action and that this permit shall be subject to such action as may be taken by Congress.

"2. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

"3. That the Sanitary District of Chicago must assume all re-[fol. 224] sponsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River.

Very respectfully, Elihu Root, Secretary of War. Mr. Wm. Boldenweck, President the Sanitary District of Chicago, Security Building, Chicago, Ill."

[File endorsement omitted.]

(Here follows Exhibit M to answer, marked side folio pages 225 and 226.)

[fols. 227–228] In the District Court of the United States for the Northern District of Illinois, Eastern Division

[Title omitted]

Notice of Motion to Strike from Answer—Filed February 28, 1914

To Edmund D. Adcock, Karpen Building, and Alfred S. Austrian, American Trust Building, Chicago, Solicitors for Defendant:

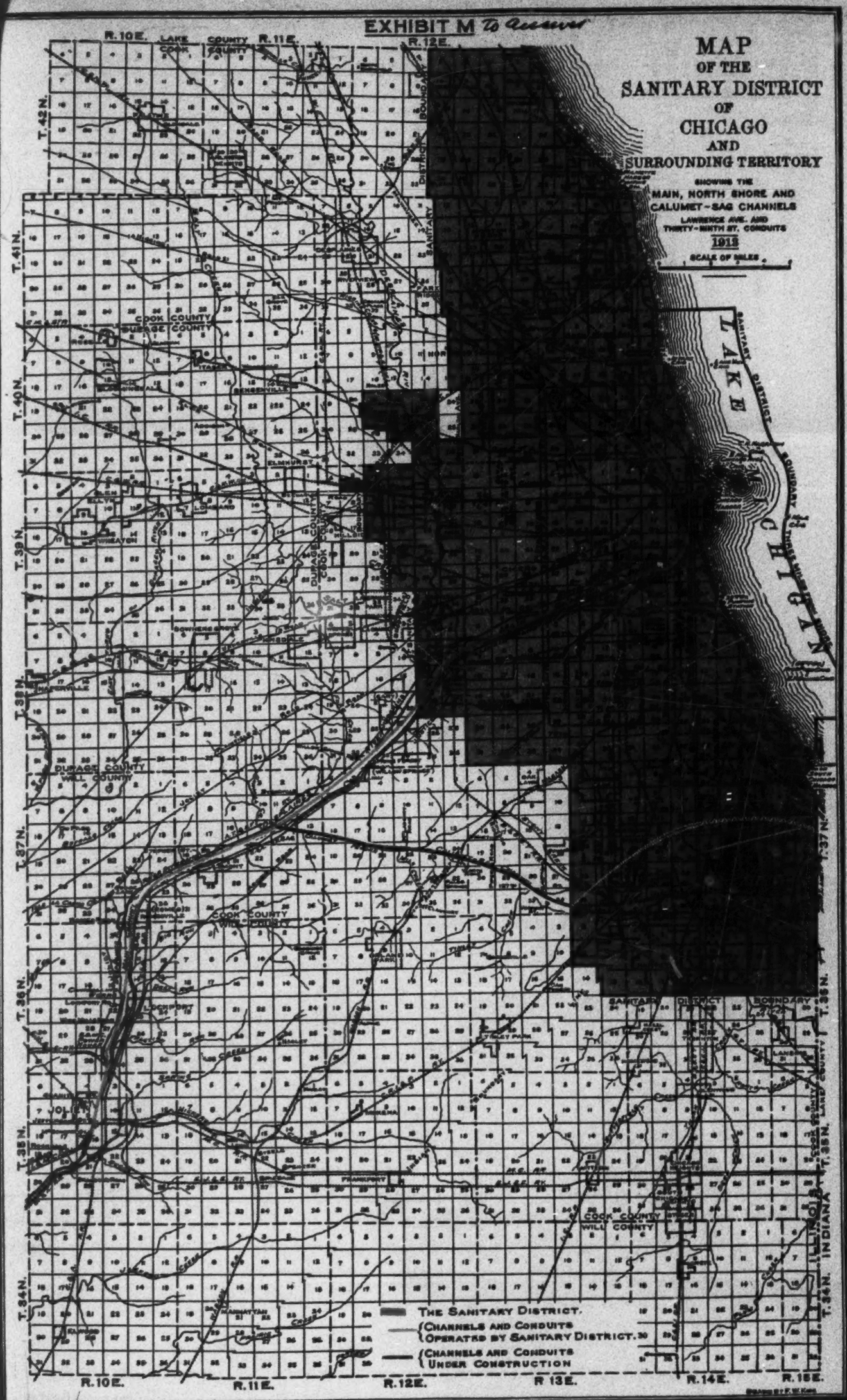
Please take notice that on Saturday, February 28th, 1914, at the opening of court on that day, or as soon thereafter as counsel can be heard, before Honorable Kenesaw M. Landis, Judge of the United States District Court for the Northern District of Illinois, at his court room in the city of Chicago, I shall move to strike from the answer herein each of the allegations in paragraphs 20–46, inclusive.

And for grounds for this motion, the complainant states as to each of said allegations, that it is not responsive to any averment in the bill of complaint; that it sets forth affirmative matters not proper to be proved as a defense in this case, and that evidence offered at the hearing in support thereof would necessarily be excluded as incompetent, irrelevant, immaterial and not pertinent to any issue in this case.

The complainant, at the time above stated, will enter said motion and ask to have the same set for hearing in accordance with Equity Rule thirty-three.

James H. Wilkerson, United States Attorney.

EXHIBIT M To Answer



225 + 226

Received copy of the above notice this 27th day of February, A. D. 1914.

Alfred S. Austrian, Edmund D. Adcock.

[File endorsement omitted.]

[fols. 229 & 230] IN THE UNITED STATES DISTRICT COURT FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

ORDER CONSOLIDATING CAUSES—Entered June 18, 1923

This cause came on at this term and was argued by counsel, and thereupon, upon consideration thereof, it was ordered, adjudged and decreed as follows:

That the case of United States, Complainant, vs. Sanitary District of Chicago, Defendant, Number C C 29019 upon the docket of this court, and instituted on March 23, 1908, be and the same is hereby consolidated with this cause, and the orders, proceedings and evidence presented and testimony taken or depositions filed in said cause, are hereby made orders, proceedings, evidence, testimony and depositions in this cause, the consolidated cause to proceed under the title of this cause.

Enter:

Carpenter, Judge. 18 June, 1923.

[fol. 231] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

OPINION—Filed June 18, 1923

CARPENTER, District Judge (orally): It is needless to say that this litigation is of vital interest to the people of the State of Illinois. It was started nearly fifteen years ago by bill filed in behalf of the United States of America against the Sanitary District of Chicago to restrain the defendant from diverting from the waters of Lake Michigan in excess of approximately 4,500 feet per second.

The parties used the better part of six years in putting in the proof. The matter was then presented with appropriate briefs to my distinguished colleague, Judge Landis, for final determination. Judge Landis kept the matter under advisement for another six years, moved undoubtedly by the thought that the State of Illinois was being benefitted all of the time by the withdrawal of 10,000

cubic feet a second by the defendant, and that the Government was not in any way actually harmed.

On June 19th, 1920, Judge Landis rendered an oral opinion, finding in effect that the withdrawal in excess of 4,167 cubic feet a second by the Sanitary District of Chicago was without authority of law; that the withdrawals then being made reduced the level [fol. 232] of Lake Michigan, and other of the navigable waters of the United States, to such an extent as to be an interference with navigation; that the Secretary of War, acting under Congressional powers, had never given his consent to such excessive withdrawals; that the diversion by the Sanitary District was therefore unlawful, and an injunction should issue.

A motion was made thereafter not for a reconsideration of the findings of the Court, but for the purpose of settling the terms of the final decree.

Attorneys for the Sanitary District urged the evidence showed clearly that by the construction of weirs and other compensating works at a relatively small expense, the Government could restore the various water levels which had been reduced by the flow into the drainage canal. They also urged that the State of Illinois, by appropriate legislation, had authorized the Sanitary District to agree with the United States Government to stand the cost of such weirs and compensating works and their annual maintenance, and strenuously urged upon the Court that as a condition to the entry of any injunction, the plaintiff Government should agree to erect and maintain such works at the expense of the defendant.

Counsel for the Drainage District have also urged upon the Court at this time to reconsider entirely the case upon the evidence presented.

[fol. 233] This Court is very much disinclined to interfere with the judgment of Judge Landis. At least it is entitled to the weight that would be given to the report of a Master in Chancery or Special Commissioner. In addition, this Court has gone over the entire record, and is able to say that it agrees with Judge Landis in every respect, although from a legal standpoint, with some reluctance.

It is not necessary to go into the duties of the Secretary of War with respect to navigable waters. It is not necessary to discuss the question of whether when the State of Illinois entered the Union in 1818 it joined with special reservations with respect to its own police powers. A reading of the Federal decisions from Gibbons vs. Ogden, 9 Wheat, 1, down to the present date leaves no escape from the thought that the States in adopting the Constitution surrendered to the central government everything, without stint or reservation, so far as the terms of the Constitution are concerned. The right to regulate commerce was conferred with many other things, and that right imposed upon the central government to see to it that navigation was not interfered with, either by individuals, the several States, or any foreign power. It is very true that it is the duty of the State of Illinois, in the exercise of its police power, to provide for the safety and welfare of its own people. On the other hand, if that

safety and welfare depends upon the operation of the things granted to the central government, the State of Illinois must look to Congress for eventual aid or relief.

[fol. 234] The evidence shows, and Judge Landis found and I find that the waters of Lake Michigan and other navigable waters of the Great Lakes have been reduced in level by the amount of water in excess of 4,167 cubic feet per second withdrawn from Lake Michigan by the defendant. From the standpoint of the practical mariner the testimony may not be satisfactory. It was given by engineers more or less highly technical, but thoroughly equipped in their profession. In fact no Lake captain testified that by reason of the lowering of the level of Lake Michigan was navigation interfered with. I have grave doubts whether any boat has been stranded or delayed by reason of the action of the Sanitary District.

On the other hand, the water levels have been reduced, and the Secretary of War, in whom is reposed the sole authority in matters of this kind, has determined that there was an interference with navigation, and a permit to the Sanitary District to continue in its present withdrawals was refused.

The jurisdiction of the Court has not and could not be challenged, and an injunction must issue against the defendant.

The record shows that the Sanitary District of Chicago has expended in its work some hundreds of millions of dollars; and the evidence shows rather conclusively that no other system of disposing of the sewerage in the great district covered would work so well as that devised by the Sanitary District. The City of Chicago, since the Drainage District began to operate, has practically doubled in population. The district served by the Sanitary District holds more people than over forty states in the Union. The rate of typhoid fever since the completion of the Drainage Canal has been reduced [fol. 235] from seventy-five per hundred thousand to a negligible number.

The testimony of Government engineers shows that it would take from ten to twenty-five years for the Drainage District to erect sewerage treatment and disposal works to handle the sewerage within the Drainage District, if the flow of water was reduced from 10,000 to 4,167 cubic feet per second.

This matter is a subject which needs the consideration of thinking people, not only in the State of Illinois, but in the whole United States. The Treaty with Canada entered into some years ago seemed to contemplate an acquiescence on the part of the Canadian Government to the withdrawal of 10,000 cubic feet a second by the Drainage District. However that may be, the Secretary of War has not given his official consent. Whether the increased withdrawal should or should not be made is properly a political and not a legal question, in the absence of consent by the Secretary of War. The Legislature of the State of Illinois, the various civic bodies, the Association of Commerce, and senators and representatives should see to it that at the earliest possible moment the situation here is brought to the attention of Congress, so that by appropriate legisla-

tion the health and welfare of this great community may be safeguarded. I have no doubt that when the maatter is properly presented it will be taken up by Congress and by the State Department, and some plan devised which will bring about adequate and the desired results.

It goes without saying that this Court will not issue an injunction to be effective forthwith. It cannot impose the conditions so [fols. 236 & 237] strenuously urged by the attorneys for the Sanitary District. It is doubtful whether the State of Illinois could authorize expenditures to be made in foreign states and foreign countries to restore the water levels.

On the testimony of the Government engineers the Court might, in the exercise of a sound discretion, delay the effectiveness of its injunction for from fifteen to twenty-five years to enable the Sanitary District or the State of Illinois to arrange for other means of disposing of the sewerage now handled by the Sanitary District.

Believing as I do that it is a matter for the immediate action of Congress, a decree may be prepared finding the facts as stated in the Bill and enjoining the defendant from withdrawing from Lake Michigan in excess of 4,167 cubic feet a second; the decree, however, not to go into effect for six months.

The matter must necesarily go to the Supreme Court of the United States for final settlement, and no doubt, if need be, when the record is there filed, application may be made to that Court for a supersedeas or further stay.

Carpenter, Dist. Judge. 18 June, 1923.

[File endorsement omitted.]

[fol. 238 & 239] IN THE UNITED STATES DISTRICT COURT FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

ORDER REFUSING OFFER OF SANITARY DISTRICT TO CONSTRUCT CERTAIN WORKS—Entered June 18, 1923

This cause came on to be further heard at this term and was argued by counsel, and thereupon, upon consideration thereof, it was ordered, adjudged and decreed, as follows:

(1) The motion presented herein on the 12th day of July, 1920, by the defendant, asking that the defendant be not enjoined or restrained from withdrawing from Lake Michigan less than ten thousend (10,000) cubic seconds feet of water, and in connection with which said motion an offer was made to pay cost of constructing and maintaining such works as might be provided by complainant to off-set for the lowering of the surface elevations of Lakes Michigan, Huron, St. Claire, Erie and Ontario, due to a diversion of said

amount by the defendant at Chicago, is hereby denied, and the said offer is refused.

Enter.

Carpenter, Judge. 18 June, 1923.

[fols. 240 & 241] Copy

IN THE DISTRICT COURT OF THE UNITED STATES, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

Consolidated Causes

DECREE FOR INJUNCTIONS

This cause came on to be further heard at this term, and was argued by counsel; and thereupon, upon consideration thereof, it was ordered, adjudged and decreed as follows, viz:

That the defendant, the Sanitary District of Chicago, its Board of Trustees, officers, agents, attorneys, representatives, employees and servants, and all other persons acting or claiming or assuming to act under its authority, be, and they hereby are, and each of them hereby is, enjoined from diverting or abstracting any waters from Lake Michigan over and above or in excess of 250,000 cubic feet per minute.

The operation of this injunction is hereby stayed for a period of six months to enable the defendant to present the record herein to the Supreme Court of the United States.

Enter:

Carpenter, Judge. June 18th, A. D. 1923.

[fol. 242] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

PETITION FOR APPEAL—Filed June 29, 1923

The Sanitary District of Chicago, defendant herein, respectfully shows:

Defendant is aggrieved by the judgment and decree herein rendered on June 18, 1923, in favor of the plaintiff and against the defendant, enjoining and restraining the defendant, its Board of Trustees, officers, agents, attorneys, representatives, employees and servants, and all persons acting or claiming or assuming to act under its authority, as prayed in the plaintiff's complaint, from diverting or abstracting water from Lake Michigan in excess of

250,000 cubic feet per minute; and the defendant, for the reasons specified in the assignment of errors filed herewith, desires to appeal from said decree to the Supreme Court of the United States, and desires that said appeal shall operate as a supersedeas and may suspend during the pendency of said appeal, the effect of said injunction.

Wherefore, defendant prays that the said appeal may be allowed and that the said appeal may operate as a supersedeas and may suspend during the pendency of said appeal the effect of said in-
[fols. 243–245] junction and decree; that said appeal be made returnable to the Supreme Court of the United States according to law, and that a transcript of the record, proceedings, papers and exhibits upon which said decree was rendered, duly authenticated, be sent to said Supreme Court of the United States, and defendant prays for all general and equitable relief.

Clyde L. Day, Edmund D. Adcock, Solicitors for Defendant.

[File endorsement omitted.]

[fol. 246] In the District Court of the United States, Northern District of Illinois, Eastern Division

[Title omitted]

Assignment of Errors—Filed June 29, 1923

Now comes the above named defendant, the Sanitary District of Chicago, and says that the final order or decree made and entered herein on the eighteenth day of June, 1923, granting the injunction prayed in the bill of complaint, is erroneous and against the just rights of said defendant, for the following reasons:

(1) Because, as appears from the record in this cause, the plaintiff was not entitled to the injunction granted in said order or decree enjoining the defendant, its Board of Trustees, officers, agents, attorneys, representatives, employes and servants, and all other persons acting or claiming or assuming to act under its authority, from diverting or abstracting any waters from Lake Michigan over and above or in excess of 250,000 cubic feet per minute, and the Court should have refused to enter any order or decree enjoining and restraining the defendant concerning or in respect to the subject matter of said complaint, and should have dismissed plaintiff's
[fol. 247] complaint for want of equity.

(2) Because under the Commerce Clause of the Constitution of the United States, Article I, Section 8, Clause Third, wherein Congress is given power to regulate commerce with foreign nations and among the several states and with the Indian tribes, neither Congress nor any officer of the United States has power or authority to regulate or limit the State of Illinois or the Sanitary District of

Chicago, a municipal corporation created under its authority, in abstracting or diverting water from Lake Michigan for public welfare and in exercise of the state's police power within the limits proposed by defendant, and as and in the manner abstracted or diverted or proposed to be abstracted or diverted.

(3) Because the diversion of water from Lake Michigan by defendant to the Desplaines and Illinois Rivers by means of a canal, called herein for convenience "Main Channel," and the reversal of the flow of the Chicago River and certain of its branches, including diversion works supplementary thereto, as appears by the record, has been, is being, and is proposed to be done in the exercise of the police powers of the State of Illinois for the benefit of public health and welfare.

(4) Because the diversion of water from Lake Michigan by defendant to the Desplaines and Illinois Rivers by means of its Main Channel and the reversal of the flow of the Chicago River and certain of its branches, including diversion works supplementary thereto, as appears by the record, has been, is being, and is proposed to be [fol. 248] done in the exercise of the police powers of the State of Illinois, and has been and is the only means by which the sewage of Chicago and its surrounding territory within the territorial limits of the Sanitary District of Chicago may be diverted from Lake Michigan, the only drinking water supply for the population of said area, to protect health and preserve lives.

(5) Because the diversion of water from Lake Michigan by defendant to the Desplaines and Illinois Rivers by means of its Main Channel and the reversal of the flow of the Chicago River and certain of its branches, including diversion works supplementary thereto, as appears by the record, has been, is being and is proposed to be done in the exercise of the police powers of the State of Illinois, and is necessary for the public health and welfare and to protect health and preserve lives.

(6) Because the diversion of water from Lake Michigan by defendant to the Desplaines and Illinois Rivers by means of its Main Channel and the reversal of the flow of the Chicago River and certain of its branches, including diversion works supplementary thereto, as appears by the record, has been, is being and is proposed to be done in the exercise of the police powers of the State of Illinois, and is necessary to prevent public nuisances and the breeding of diseases.

(7) Because the defendant, as appears by the record, in diverting water from Lake Michigan in excess of 250,000 cubic feet of water per minute, and in proposing to continue to do so, has been and proposes to continue so doing pursuant to and under an Act of the General Assembly of the State of Illinois passed May 29, 1889, and [fol. 249] in force July 1, 1889, which said Act expressly directs the defendant to divert and abstract through its diversion works water from Lake Michigan at the rate of 20,000 cubic feet of water per

minute for each one hundred thousand of the population of the defendant, such population being now approximately three million people, requiring a diversion of six hundred thousand cubic feet per minute, and said Act of the General Assembly of May 29, 1889, was passed in exercise of the police powers of the State for the public health and welfare, and the acts of the defendant taken thereunder have been, are, and are proposed to be for such purposes.

(8) Because said Act of May 29, 1889, of the General Assembly of Illinois, and Acts amendatory thereof and supplementary thereto, were passed for the sole and only purpose of preserving health and protecting life under the State's police power, and the operation of the defendant's diversion works has been and is for the same purpose, and neither Congress nor any officer of the United States can interfere under the Constitution of the United States with the reasonable exercise of such power.

(9) Because the operation and maintenance of defendant's diversion works under the authority of the State of Illinois for the public health and welfare, as appears by the record, cannot be interfered with by the United States, and particularly if the alleged interference with navigation or impairment thereof is only an indirect result of the operation of said works, the primary and sole purpose of the operation of said works being for the public health and welfare [fol. 250] of the people of the State. The power and authority under which said works have been built and are operated and maintained is a power reserved to the states and not delegated to the United States or Congress under the Constitution.

(10) Because as appears by the record a pure, wholesome, potable drinking water supply for the people of Chicago and its environs and for the people residing within the territorial limits of the Sanitary District of Chicago, cannot be obtained or provided except by the operation and maintenance of the diversion works of defendant and the abstraction from Lake Michigan of 20,000 cubic feet per minute for each hundred thousand of the population thereof, such population being now in excess of three million people requiring water diversion, much greater than 250,000 cubic feet per minute.

(11) Because as appears by the record no works can or may be constructed to take the place of the diversion works operated and maintained by the defendant whereby a pure, wholesome, potable drinking water supply may be provided for said population within the territorial limits of defendant, and whereby the abstraction or diversion of water from Lake Michigan may be reduced to 250,000 cubic feet per minute or to any amount approximately said volume of water.

(12) Because, as appears by the record, no works or means may be constructed or provided supplementary to or to be operated in conjunction with the diversion works built, operated and maintained by defendant whereby the diversion and abstraction of water from Lake Michigan may be reduced or limited to 250,000 cubic feet of

[fol. 251] water per minute or to any amount of water approximating said volume and whereby a wholesome drinking water supply may be provided for the people residing within the limits of the Sanitary District of Chicago.

(13) Because, as appears by the record, the reduction of or limitation of the abstraction and diversion of water from Lake Michigan to 250,000 cubic feet per minute by defendant or any amount approximating said volume as provided by said injunctional decree and within the time provided by said injunctional decree, would immediately cause a great public nuisance to exist in the Chicago River, the Desplaines and Illinois Rivers, and the waters of Lake Michigan at Chicago would become contaminated by sewage, breeding typhoid and other water-born diseases in the people whose only drinking water supply is obtained from Lake Michigan.

(14) Because, as appears from the record, works cannot be constructed to supplement the diversion works built, operated and maintained by defendant which will provide a reasonably pure drinking water supply for Chicago and whereby the abstraction and diversion of water from Lake Michigan may be reduced to 250,000 cubic feet of water per minute within any period less than twenty years.

(15) Because, as appears by the record, it will be necessary in order to supplement the diversion works of defendant with a diversion from Lake Michigan limited to 250,000 cubic feet of water per minute to construct what are known and called artificial sewage purification works, the cost of which is upwards of One Hundred Million Dollars ($100,000,000), and, further, the construction and [fol. 252] maintenance of works to filter the water supply of Chicago costing upwards of Sixty Million Dollars ($60,000,000), which works cannot be built, constructed and placed in operation within any period of less than twenty years.

(16) Because, as appears by the record, the total amount of money that may be devoted to construction work that defendant can raise from taxation and by the issuance of bonds within the limits of the Constitutional requirements of the State within the period of twenty years does not exceed One Hundred and Six Million Dollars ($106,000,000), and such amount can only be raised and provided by such means from time to time during said period, and the last portion of such amount can only be raised at substantially the end of said twenty year period.

(17) Because, as appears by the record, the diversion works constructed, maintained and operated by defendant were built, constructed and maintained to divert from Lake Michigan a total ultimate volume of 600,000 cubic feet of water per minute in order to keep the Chicago River and certain of its branches to its Main Channel flowing in a reverse direction from its original flow and away from Lake Michigan, so that none of the sewage emptied into said river by means of many sewers, could find its way to Lake Michigan

from the Chicago River when it is at flood stages which occurs many times during the year, and such flood stage run-off of the Chicago River drainage area is 600,000 cubic feet of water per minute; and also so that the sewage thus diverted into the Chicago River and to the Desplaines and Illinois Rivers will be diluted and free from nuisance or from danger of injury or impairment to [fol. 253] the public health and fish life in the Desplaines and Illinois Rivers.

(18) Because the Act of Congress of March 2, 1827, entitled "An Act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan," granting among other things to the State certain land to aid the State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, authorized and empowered the State of Illinois directly or through any municipal agency to divert and abstract from Lake Michigan water to the extent of 600,000 cubic feet per minute as provided and proposed by defendant's works constructed, operated and maintained, and, as appears by the record, defendant in constructing and operating said works has been and is so acting under authority of the State expressly granted by Congress.

(19) Because, as appears by the record, the State immediately commenced to exercise the authority granted by said Act of Congress of March 2, 1827, and built a canal whereby water of Lake Michigan was diverted for the purpose of its operation; and thereafter enlarged said canal for navigation purposes, diverting a greater amount of water from Lake Michigan for such purposes; and thereafter in further exercise of said power and authority, created the defendant and caused it to build a canal of greater dimensions in depth and width than the original canal, to replace the old one called the Illinois and Michigan Canal, which new canal was designed to and does abstract water to the amount of 600,000 cubic feet per minute for navigation as well as sanitary purposes; and has replaced for all navigation pur- [fol. 254] poses the old Illinois-Michigan Canal between Joliet and Chicago, and has further united the waters of the Illinois River with those of Lake Michigan; and the said canal built and maintained by defendant as aforesaid is one of the navigable waters of the United States connecting various other navigable waters.

(20) Because the said Main Channel and defendant's other diversion works were built and are maintained and operated under the authority of the State of Illinois as expressly authorized by said Act of Congress of March 2, 1827.

(21) Because the State of Illinois by merely constructing the old Illinois-Michigan Canal did not exhaust its power and authority under said Act of March 2, 1827, but had the further power and authority under said Act to create the Sanitary District of Chicago and provide that it should build and construct said canal and diversion works to abstract and divert from Lake Michigan up to 600,000 cubic feet of water per minute, and in excess of 250,000

cubic feet per minute for navigation on said canal, Desplaines and Illinois Rivers, and for purposes of protecting the health and lives of part of the people of the State.

(22) Because, as appears by the record, the United States during the course of the enlargement of the old Illinois-Michigan Canal and the replacement thereof by the defendant as aforesaid through Congress and its executive officers not only acquiesced in the enlargement of said Illinois-Michigan Canal and the construction of the canal built and operated by the Sanitary District of Chicago requiring the diversion of water from Lake Michigan to the amount of 600,000 cubic feet per minute for navigation and sanitary purposes, [fol. 255] but also invited such enlargement of said Illinois-Michigan Canal and the construction and operation of said canal of the defendant to divert from Lake Michigan an amount of water ultimately equal to 600,000 cubic feet per minute.

(23) Because, as appears by the record, the Secretary of War and Congress through the Secretary of War transmitting annual report of the Chief of Engineers of the United States Army, had full and complete knowledge of the passage of the Act of the General Assembly of the State of Illinois of May 29, 1889, expressly providing for the construction of the Main Channel and diversion works of the defendant and the abstraction of water from Lake Michigan to the ultimate amount of 600,000 cubic feet per minute; and they also had knowledge by the same means of the commencement immediately thereafter of the construction of such works, the progress of the construction, and their completion on or about the year 1898, which said diversion works so provided to be constructed and constructed during said period could only be operated for the purposes intended, with a diversion and abstraction of water from Lake Michigan to the ultimate amount of 600,000 cubic feet per minute; and Congress has not only not legislated in any manner to interfere with the operation of said works of defendant but, on the contrary, has passed many Acts indicating its recognition of said diversion to the ultimate amount of water mentioned.

(24) Because, as appears by the record, Congress has by Acts passed fixed project depths for substantially all the harbors and [fol. 256] connecting waters of Lakes Superior, Michigan, Huron, Erie and Ontario since the completion and commencement of the operation of the defendant's diversion works and the diversion of water to the ultimate amount of 600,000 cubic feet per minute, and said project depths in said harbors and connecting waters have at all times existed and have always been the depths of waters in said harbors and connecting waters so provided by Congress, notwithstanding the claimed lowering of the elevations of the surface of Lakes Michigan, Huron, Erie and Ontario and their connecting waters by said abstraction to said ultimate amount of 600,000 cubic feet per minute.

(25) Because Congress under the Commerce Clause of the Constitution has power for the improvement of navigation to improve the

harbors, connecting channels and waters of the Great Lakes by deepening such channels and harbors or otherwise improving same and by fixing the depth of water that shall be provided in said harbors and channels through such improvement of nagivation; and, as appears by the record, in the exercise of such power Congress has so fixed said project depths; and, as it further appears by the record, at no time has the actual depth of water in such channels and harbors been less than the project depths so fixed by said Acts of Congress, and the diversion of water from Lake Michigan has not to the ultimate amount above mentioned impaired or lessened said depths or caused the depth of water to be less than the project depths so fixed by Congress.

(26) Because, as appears by the record, the cost and financial burden to defendant of building works which would approach the [fol. 257] proper protection of the water supply of the people within the territorial limits of the defendant, to take the place of the diversion in excess of 250,000 cubic feet per minute and up to 600,000 cubic feet per minute, would be, including increased cost of operation, upwards of $250,000,000., whereas the damage to plaintiff claimed by reason of the alleged injury to navigation by such diversion is slight.

(27) Because, as appears by the record, all the claimed damage to navigation by the diversion made and proposed by defendant can be offset or compensated for by the construction of works whose cost would not exceed $475,000.

(28) Because it is an uncontroverted fact, as appears by the record, that submerged weirs or dams may be constructed in the St. Clair and Niagara Rivers under the authority of the United States at a cost estimated by the United States Army Engineers to be not in excess of $475,000, which will have the effect of raising the surface elevations of the waters of Lake Michigan, Lake Huron and Lake Erie and their connecting waters to an amount equal to the alleged lowering of the surface elevations of said Lakes and their connecting waters by the diversion of water from Lake Michigan by defendant to the amount of 600,000 cubic feet per minute, and pursuant to the Rivers and Harbors Act of Congress of June 25, 1910, a report was made to Congress by the commission thereunder appointed, approved by the Secretary of War, recommending that such works be constructed, providing the State of Illinois or some agency of the State should provide the funds therefor, and as it further appears by the record the construction of the Gut dam in the Galops [fol. 258] rapids has already caused surface elevation of the water of Lake Ontario to be raised an amount equal to the claimed lowering due to defendant's diversion.

(29) Because, as appears by the record, the defendant in this case has offered, pursuant to ordinance of its Board of Trustees, to pay not only the cost of the construction, but also the maintenance of any works that may be provided by the authority of the United States to offset or compensate for alleged lowering of the surface

elevations of waters of the Great Lakes system due to the diversion of water from Lake Michigan to the amount of 600,000 cubic feet per minute.

(30) Because, as appears by the record, the defendant presented said offer by a motion and asked that the defendant be not enjoined from taking an amount of water less than 600,000 cubic feet per minute, on condition that the defendant be decreed to pay such cost, and the Court by order denied said motion.

(31) Because Congress by the Rivers and Harbors Act of March 3, 1899, March 2, 1907, and June 25, 1910, provided and appropriated for survey and estimate of costs of waterway from and connecting with the southern terminus of the Sanitary District's diversion canal replacing the Illinois-Michigan Canal along the Desplaines and Illinois Rivers, which said proposed waterway for which survey and estimate of cost was made under said Acts contemplated the use of water from Lake Michigan diverted by the Sanitary District to the amount of 600,000 cubic feet per minute.

(32) Because by Acts of Congress of March 3, 1909, June 25, 1910, August 24, 1912, and June 30, 1917, providing for the in-
[fol. 259] vestigation and report upon the best means of compensating for the lowering of the surface elevations of the Great Lakes and their connecting waters, due not only to the alleged diversion of water by the defendant to the amount of 600,000 cubic feet per minute, but also to diversions from other sources, Congress has expressly indicated its recognition of such diversions as existing lawful diversions and necessary to be continued, and Congress thereby proposes in connection therewith to take means by which the alleged or claimed injury to navigation may be taken care of without impairing the usefulness of said diversion works for the purposes for which they have been created and are being maintained.

(33) Because the Act of Congress of June 29, 1906, relating to the diversion of water from the Niagara River expressly states it shall not in any manner affect diversions for sanitary or domestic purposes, the diversion by defendant to 600,000 cubic feet per minute being the principal one for sanitary and domestic purposes, and said Act is in part as follows:

"That the diversion of water from Niagara River or its tributaries in the State of New York is hereby prohibited except with the consent of the Secretary of War as hereinafter authorized in Section 2 of this Act, provided that this prohibition shall not be interpreted as forbidding the diversion of the waters of the Great Lakes or of the Niagara River for sanitary or domestic purposes or for navigation, the amount of which may be fixed from time to time by the Congress of the United States or by the Secretary of War of the United States under its direction,"

and said Act expressly indicates that such diversions for sanitary or
[fol. 260] domestic purposes from the Great Lakes was not, and

should not be limited except by future Acts of Congress or by the Secretary of War under some future Act or Acts.

(34) Because the construction of the works of Sanitary District of Chicago to divert from Lake Michigan an ultimate amount of 600,000 cubic feet of water per minute was authorized by law of the State of Illinois and was, therefore, works expressly recognized as valid by Section 10 of the Rivers and Harbors Act of Congress of September 19, 1890, wherein it was provided only "that the creation of my obstruction not affirmatively authorized by law to the navigable capacity of any waters in respect of which the United States has jurisdiction is hereby prohibited," and Section 10 of the Rivers and Harbors Act of March 3, 1899, providing "that the creation of any obstruction not affirmatively authorized by Congress to the navigable capacity of any waters of the United States is hereby prohibited", was not intended to affect obstructions theretofore constructed or created pursuant to Acts of the General Assembly of the State of Illinois under the exercise of police power.

(35) Because the Acts of Congress passed contemporaneously with, during and after the construction of the diversion works of the defendant to the amount of 600,000 cubic feet of water per minute indicate that it was and is not the intention of Congress that the Rivers and Harbors Act of March 3, 1899, and particularly Sections 9, 10 and 12 thereof, should authorize or empower the Secretary of War or the Chief of Engineers to in any way prohibit, modify or control the diversion of water from Lake Michigan by defend- [fol. 261] ant through its various works to the ultimate amount of 600,000 cubic feet per minute.

(36) Because Sections 9 and 10 of the Rivers and Harbors Act of March 3, 1899, only authorize the Secretary of War acting in conjunction with the Chief of Engineers of the United States Army to grant or refuse a permit to build, construct or operate works affecting navigable waters of the United States.

(37) Because the Secretary of War under said Rivers and Harbors Act of March 3, 1899, Sections 9 and 10 thereof, is not authorized to control or in any manner supervise the operation of such works.

(38) Because, as appears by the record, on May 8, 1899, the Secretary of War acting in conjunction with the Chief of Engineers of the United States Army issued a permit to the defendant to open and operate its canal to divert water to the ultimate amount of 600,000 cubic feet per minute, and said permit was subject to the conditions that if Congress acted on the subject matter then the permit should be subject thereto, and also if at any time it should become apparent that the current in the Chicago River should be unreasonably obstructive to navigation then the Secretary of War might modify the amount of the diversion; and the Chicago River and its south branch and west fork was to and does furnish the connection between Lake Michigan and the northern terminus of defendant's

Main Channel extending from Chicago to Joliet, and thus the supply channel for the main channel of water from Lake Michigan, and said Chicago River and its south branch and west fork was [fol. 262] narrow, shallow and tortuous and thereby its flowage capacity was small; and by reason of the condition of the Chicago River and because of objections to the current therein as so expressly stated the Secretary of War attempted to modify or limit the diversion authorized under said permit of May 8, 1899, to 250,000 cubic feet per minute, which was done under a supposed permit dated May 5, 1901; and the defendant in view of such limitation of the amount of withdrawal and because of the shallowness and narrowness of the said Chicago River and its south branch and west fork thereof, made application to the Secretary of War for authority to increase the flowage capacity of the channel of said Chicago River and the south branch and west fork thereof by deepening it from its then depth of seventeen feet to the depth of twenty-six feet and widening at all points to two hundred feet for the purpose of providing an enlarged supply channel and the amount of water necessary for its Main Channel, so that the required amount of water to operate said diversion works taken through the Chicago River and the south branch and west fork thereof would not create a current in the channel of said rivers in excess of one and one-quarter mile per hour fixed by the Secretary of War; and said improvement of said Chicago River was made, as expressly stated in the application for permit therefor in order that the waters of Lake Michigan might be diverted to the amount of 600,000 cubic feet per minute, without creating a current in the Chicago River in excess of one and one-quarter miles per hour; and thereafter the defendant did improve the said Chicago River by deepening and widening it as above stated, at an expense of upwards of $13,000,000; and there has not been, is, and will not be, any [fol. 263] current in the Chicago River in excess of a mile and a quarter an hour by reason of abstraction of water from Lake Michigan in excess of 250,000 cubic feet per minute and to the ultimate amount of 600,000; and the so-called limitation of flow attempted to be made by the Secretary of War under said supposed permit of May 5, 1901, has ceased to have any force or effect, as the reason therefor has been removed.

(39) Because the Secretary of War and the Attorney General of the United States, in causing the institution of this suit and the filing of the complaint herein, and the prosecution of the said suit, have taken an unreasonable and arbitrary course and have thereby arbitrarily sought to enforce the provisions of the so-called permit of May 5, 1901, limiting the abstraction and withdrawal to 250,000 cubic feet of water per minute from Lake Michigan, when said limitation of flow was made solely because of the current in the Chicago River and the United States has not sought in this suit by its complaint to base its right to an injunction upon the conditions of navigation on the Chicago River but solely upon the condition of navigation on the Great Lakes, their connecting waters and harbors other than the Chicago River and its harbor.

(40) Because, as appears by the record, the Secretary of War has authorized the withdrawal of water from Lake Michigan to the amount of 600,000 cubic feet of water per minute and any limitation of withdrawal thereafter made under the conditions of the original permit of May 8, 1899, has ceased to have any force or effect, as [fol. 264] the express reason for such limitation of withdrawal has been removed by the defendant's constructing works and making improvements in the Chicago River and south branch and west fork thereof pursuant to the permit of the Secretary of War and for the purpose of removing the reason for such limitation of the amount of withdrawal.

(41) Because, as appears by the record, the abstraction and withdrawal of water from Lake Michigan to the amount of 600,000 cubic feet per minute has not and will not impair the navigable capacity of any of the navigable waters of the United States.

(42) Because, as appears by the record, the abstraction and withdrawal of water from Lake Michigan by the defendant to the amount of 600,000 cubic feet of water per minute has not and will not substantially impair or affect the navigable capacity of any of the navigable waters of the United States.

(43) Because, as appears by the record, no effect of such withdrawal or abstraction of water has been observed.

(44) Because, as appears by the record, no lay witness or navigator or captain of any ship or any one engaged in navigation upon the Great Lakes has testified as to any effect upon the navigable capacity of any of the harbors or connecting waters of the Great Lakes by the diversion of water by the defendant to the amount of 600,000 cubic feet per minute.

(45) Because, as appears by the record, the only basis upon which [fol. 265] plaintiff sought the injunctional decree or upon which the injunctional decree was or could be based was the testimony of expert witnesses and analyses made by them.

(46) Because, as appears by the record, the injunctional decree herein is only based upon the analyses of expert witnesses.

(47) Because, as it appears from the record, the evidence herein does not show that the surface elevations of the waters of the Great Lakes or their harbors, or connecting channels, or any of such waters, have been or will be lowered or affected in any manner by the diversion of water at Chicago.

(48) Because, as it appears from the record, the evidence herein does not show that the surface elevations of the waters of the Great Lakes or their harbors, or connecting channels, or any of such waters, have been materially or substantially lowered, or have been materially or substantially affected by the diversion of water at Chicago.

(49) Because, as appears by the record, the injury and damage to the defendant resulting from and by reason of the injunctional de-

cree entered herein will be financially great, whereas the benefit to the plaintiff resulting from and by reason of said decree will be slight.

(50) Because, as appears by the record, it will be impossible for [fol. 266] the defendant to provide adequate means to protect the water supply of the people of Chicago and within the territorial limits of the defendant with the diversion of water from Lake Michigan reduced to 250,000 cubic feet per minute, whereas the benefit to navigation upon the Great Lakes, their harbors and connecting waters, will be slight and scarcely appreciable.

(51) Because, as appears from the record, the defendant could not observe the injunction granted by said decree of June 18, 1923, without causing contamination of the drinking water supply of a population of upwards of 3,000,000 people within the territorial limits of the defendant, which contamination of drinking water supply would cause epidemics of typhoid fever and other water-borne diseases.

(52) Because, as appears from the record, the said injunctional decree entered herein in effect holds unconstitutional the Act of the General Assembly of the State of Illinois of May 29, 1889, wherein the defendant is directed to withdraw from Lake Michigan not less than 20,000 cubic feet of water per minute for each 100,000 of population within its territorial limits, which said act was passed under a power reserved to and in the State of Illinois under the Constitution.

(53) Because, as appears from the record, the Rivers and Harbors Act of June 13, 1902, Section 4 thereof, provided that the President of the United States might invite the Government of Great Britain to join in the formation of an International Commission to [fol. 267] be composed of three members from the United States and three who should represent the interests of the Dominion of Canada, whose duties should be to investigate and report on conditions and uses of the waters adjacent to the boundary line between the United States and Canada, upon the maintenance and regulation of suitable levels, the effect of diversions therefrom and the necessary measures to regulate such diversions; and, it was further provided, that the Commission should make recommendations as to the terms of a treaty concerning said boundary waters; and said Commission, known as International Waterways Commission, contemplated by said Act, was thereafter formed in the manner described; and the said Commission made special investigation of the diversion of water by the defendant, the amount thereof, the necessities for same, and recommended that the diversion of 600,000 cubic feet per minute by defendant should not be disturbed; and the said International Waterways Commission made an investigation of the uses of the waters of the Great Lakes, the priority of the different uses and what use should take precedence of all other uses, and found that the use of said waters for sanitary and domestic purposes should take precedence of all other uses, including use for navigation; and the said

International Waterways Commission also made reports and recommendations concerning the terms of the treaty with reference to boundary waters made January 11, 1909, and by said treaty it was provided that existing uses of water should not be disturbed; that use for domestic and sanitary purposes should take precedence of all other uses; that at Niagara Falls there might be diverted 36,000 cubic seconds feet of water on the Canadian side and on the American side 20,000 cubic seconds feet, and such difference was due principally [fol. 268] to the fact that the United States was charged with 10,000 cubic seconds feet, or 600,000 cubic minutes feet, diversion by defendant.

(54) Because, as appears from the record, the treaty between the United States and Great Britain of January 11, 1909, relating to and concerning the boundary waters between the United States and Canada expressly recognizes and authorizes the diversion by the defendant to the amount of 600,000 cubic feet per minute from Lake Michigan and the Great Lakes System.

(55) Because, as appears from the record, the treaty of January 11, 1909, precludes the plaintiff's obtaining an injunction with reference to withdrawal of water from Lake Michigan by defendant as to any amount less than 600,000 cubic feet per minute.

(56) Because the Court should have granted and allowed the motion presented on July 12, 1920, containing the offer of defendant to defray the cost of constructing and maintaining any compensating works the United States might determine to build to offset for the alleged lowering of the surfaces of the Great Lakes and their connecting channels and harbors, and should have entered a decree only enjoining the defendant from diverting water from Lake Michigan in excess of 600,000 cubic feet per minute on condition that such cost of constructing and maintaining said works should be paid when demanded by the plaintiff.

(57) Because it does not appear from the record that the diversion of water from Lake Michigan to the amount of 600,000 cubic feet per minute is under all the facts and circumstances an unreasonable obstruction to navigation.

[fol. 269] (58) Because, as appears from the record, the decree herein in effect permits the Secretary of War and the Attorney General to pursue an unreasonable and arbitrary course with reference to the defendant's diversion of water from Lake Michigan.

(59) Because, as appears from the record, the Court should have balanced the equities and entered a decree which would do complete justice between the parties, and should have refused to enter the injunctional decree herein causing unreasonable damage and injury to the defendant.

(60) Because, as appears from the record, the plaintiff did not show that the abstraction of water from Lake Michigan by the de-

fendant to the amount of 600,000 cubic feet per minute under all the circumstances would amount to an unreasonable obstruction to navigation, having consideration for not only the effect upon navigation but also the purpose of the withdrawal—the public benefit inuring to the people as compared to injury to or interference with navigation.

(61) Because Congress will not be deemed to have acted concerning a matter of local regulation such as is embraced in the Act of the General Assembly of Illinois of May 29, 1889, providing for the construction and operation of defendant's diversion works unless it has passed a special law with reference to the particular alleged obstruction or regulation.

[fol. 270] (62) Because, as appears from the record, the plaintiff is estopped or is in no position to assert that the works of the defendant were erected and were operated, and are being operated, without authority or constitute a nuisance; and when the United States comes in to a court of equity it stands in no different position than any other plaintiff in equity.

Wherefore, the defendant, the Sanitary District of Chicago, prays that said decree of the District Court of the United States, for the Northern District of Illinois, Eastern Division, be reversed, and that the said District Court of the United States, for the Northern District of Illinois, Eastern Division, may be directed to enter a decree dissolving and vacating the injunction granted by it on said June 18, 1923.

The Sanitary District of Chicago, by Clyde L. Day, Edmund D. Adcock, Its Solicitors.

[File endorsement omitted.]

[fols. 271 & 271½] [File endorsement omitted.]

[fol. 272] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

ORDER ALLOWING APPEAL

Considering the petition for appeal of the defendant, the Sanitary District of Chicago, this day presented.

It is ordered that an appeal be allowed to said defendant herein from the decree of June 18, 1923, rendered against said defendant in the above entitled and numbered cause, and that said appeal shall be returnable to the Supreme Court of the United States, and that, upon the execution, filing and approval of a bond in the penal sum of Five Thousand Dollars ($5,000), said appeal shall operate as a

supersedeas of said decree and shall suspend during the pendency of said appeal, the effect and operation of the injunction herein.

Enter.

Carpenter, Judge. 29th June, 1923.

[fols. 273 & 274] [File endorsement omitted.]

[fol. 275] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

ORDER RE TRANSCRIPT OF EVIDENCE

This cause came on at this term and was argued by counsel, and thereupon, upon consideration thereof, it was ordered, adjudged and decreed, as follows:

(1) The evidence taken in this cause in the exact words of the witnesses as it appears in certain printed bound volumes numbered 1 to 7, including also typewritten transcript of evidence taken on, towit, April 25th and 26th, 1923, together with exhibits, is practically impossible to put into narrative form which will disclose the vital merits of the cause. Said evidence is in printed form and consists principally of statements and evidence of expert witnesses whose testimony appearing in the record cannot be materially condensed, and of documentary evidence, which in the form they now appear in the record, are sufficiently condensed.

(2) The said evidence shall be set out in the exact words of the witnesses as it appears in the said printed documents and in the said typewritten testimony taken on April 25th and 26th, 1923, and the said seven printed volumes which are identified by the signature of the Clerk of the Court on the title page of each of said volumes numbered from 1 to 7, inclusive, and entitled on the back thereof "United States of America vs. Sanitary District of Chicago—Record," including said typewritten transcript taken April 25th and 26th, 1923, identified by the Clerk's signature, shall be incorporated [fol. 276] in the transcript of record on the appeal of said cause.

Enter.

Carpenter, Judge. 29th June, 1923.

[fol. 277] [File endorsement omitted.]

[fols. 278–281] BOND ON APPEAL FOR $5,000—Approved to Operate as a Supersedeas and Filed June 29, 1923

[fol. 282] IN THE UNITED STATES DISTRICT COURT FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

ORDER RE TRANSCRIPT OF EVIDENCE

This cause came on to be further heard at this term and was argued by counsel, and thereupon, upon consideration thereof, it was ordered, adjudged and decreed, as follows:

(1) The testimony of all witnesses herein and various documentary evidence and exhibits was taken, offered or introduced, and the objections and exceptions to said evidence or testimony were made before Samuel M. Morgan, heretofore appointed as Commissioner to take and transcribe said testimony and evidence, and a transcript of all of said testimony and evidence before said Commissioner has been filed by him in this Court and certain other documentary evidence, offered, introduced or presented has been filed herein pursuant to stipulation of counsel, and all of said testimony and evidence offered, introduced or presented in the manner aforesaid, prior to February 15, 1915, has been printed and consists of seven printed volumes, including exhibits, which said seven volumes, including exhibits, is a correct and true copy as is agreed [fol. 283] by counsel for both parties of all of said testimony, evidence or exhibits offered, introduced and filed prior to said February 15, 1915, which said volumes are now here in open court and for identification bear the signature on the initial page of each volume of the clerk of this Court.

(2) The said printed volumes above described and identified as aforesaid, shall be treated and accepted in all respects the same as the original documents or depositions taken and filed prior to said February 15, 1915, and said printed volumes shall be substituted for said typewritten transcript of said testimony and evidence and stipulations as to facts, and shall be the record thereof, and said printed volumes so identified shall be filed by the Clerk of this Court for the purposes aforesaid.

Enter.

Carpenter, Judge. 29th June, 1923.

[fols. 284 & 285] [File endorsement omitted.]

[fol. 286] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

ORDER EXTENDING TIME

The parties in the above entitled cause appearing here in open court by their respective solicitors, and for satisfactory reasons appearing to the Court, the time for filing the record in this cause in the Supreme Court of the United States pursuant to the appeal sued out is hereby extended until and including the 20th day of September, A. D. 1923.

Enter.

Carpenter, Judge of said Court. 29th June, 1923.

[fols. 286½ & 287] [File endorsement omitted.]

[fols. 288–290] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

Consolidated Cause No. 114.

UNITED STATES OF AMERICA

vs.

SANITARY DISTRICT OF CHICAGO

STIPULATION AS TO INCORPORATING ORIGINAL CERTIFICATE OF EVIDENCE IN THE TRANSCRIPT OF RECORD IN PLACE OF A COPY THEREOF—Filed June 29, 1923

It is hereby stipulated and agreed, by and between the parties hereto, represented by their respective solicitors, that the original certificate of evidence filed herein may be incorporated as a part of the transcript of record to be filed with the Clerk of the United States Supreme Court pursuant to the appeal herein, in place of a copy of said certificate of evidence.

Edwin A. Olson, United States Attorney; Joseph B. Fleming, Special Assistant Attorney General, Solicitors for Plaintiff.
Clyde L. Day, Edmund D. Adcock, Solicitors for Defendant.

[File endorsement omitted.]

[fol. 291] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

Certificate of Evidence—Filed June 29, 1923

Be it remembered and certified, that on the hearing of this cause, the same being originally cause number 29019 and equity number 114, upon the said respective bills of complaint and answers, the following evidence was introduced by the parties hereto, to wit—the evidence as contained in the printed and bound volumes numbered 1 to 7, respectively, marked on the back thereof "United States of America vs. Sanitary District—Record," further identified by the signature of the Clerk of the Court on the title page of each of said seven volumes, and including typewritten testimony taken before the Commissioner on April 25th and 26th, 1923, entitled "United States of America vs. Sanitary District of Chicago," also further identified by the signature of the Clerk of this Court on the first page of said testimony, and said printed volumes identified as aforesaid including the said typewritten volume, are made a part hereof, the same as if attached hereto.

The following is a copy of the stenographic transcript of the opinion of Judge Landis delivered orally on June 19, 1920:

[fol. 292] OPINION OF JUDGE LANDIS IN SANITARY DISTRICT CASES

June 19, 1920.

I have sent for you gentlemen to dispose of the Sanitary District cases. Before taking up these cases, just a word about time and delay. Six years was spent after these cases were filed in taking testimony, and about six years has passed since the cases were submitted to me on briefs. The six years that was taken up while taking testimony was all necessary. The delay that has occurred since the matters have been submittetd to me have been the result of the exercise of my judgment. First, that during the war period, in view of the international questions possible, I thought it was better that this matter should continue just as it was, and secondly, since the war I have deferred entering this order with the understanding that there was a possibility of a composition of differences here that would enable the questions to be permanently adjusted along lines which I have been told were suggested by the Sanitary District to the War Department and the Canadian Government. I have held the matter, however, as long as I think proper on that theory and shall enter an order.

The bills were filed under legislation authorizing the United States to receive the injunctive power of the court as against obstruction of navigable waters and impairment of the navigable capacity of navigable waters. The averments, so far as I need to deal with the averments here now, are that the Sanitary District proposes to take an

amount of water—is taking an amount of water—proposing to take more, the taking of which will result in such impairment and such obstruction. Specifically, the impairment complained of most im- [fol. 293] portant in my view, is the impairment of the navigable capacity of the Great Lakes, excepting Lake Superior. The theory of the bills is—the charge is that such impairment by the district as is charged in the bills, without the consent of the Federal authorities at Washington, which consent is authorized and provided for by the Federal legislation, as I said before, entitles the government to an injunction. The defense of the Sanitary District is, first, that there is no impairment and no obstruction, and primarily, secondly, if there is an impairment or an obstruction, that it is necessary for the sanitation of this great populative territory. An examination of the proofs on the question of whether there is an impairment or not, an obstruction or not, that is to say, whether the taking of this water is felt or not, leads me to the conclusion that there is a lowering of the surface of this lake. In making that statement I have in mind the variation of the lake levels, traditional variation of the lake levels, known to all men that know anything about it. All that time finding that there is a lowering of the lake level, yes. That the taking of this vast volume of water each minute of each hour of each day of each month of each year continued unceasingly, no evidence in this case discrediting the fact, and has entirely resulted in the lowering of the level of the lake, and has resulted in changing the current of the Chicago River and reversing the current of the Chicago River. Now that the variation is only a matter of inches in the level of Lake Michigan, it is without doubt in my judgment, on the evidence in the matter, a matter of inches, and being a matter of inches, even though it be no more than three or four, having in mind the state of proof as to the depth of the harbors in the Great Lakes, [fol. 294] it is directly an impairment of navigable capacity, and by leaving the bottom of the harbors that much closer, the water is the creation of an obstruction to the navigable waters of the United States; in other words, the question of fact—whether there is an impairment or obstruction here, are beyond controversy and beyond question, but the fact is clearly established that there is such a change in this lake level, in my judgment, so that in low lake level time the level is lower and in high lake level time it is less than it would be but for this diversion.

Q. How many cubic feet per minute now?

A. Just at present I think about 8,500 per second. 480,000 cubic feet per minute, that is approximately. The diversion is 480,000 cubic feet per minute. The finding of the court is, on the evidence in this case, that that has resulted in the lowering of the lake level and the reversal of these currents, which latter fact is not controverted, and on the evidence in the case that the lowering is an impairment, as I said before, an impairment of navigable capacity, even though it amounts to no more than three or four inches, and as to the lowering to that extent there could be no controversy on the record, so on that fact the court's finding is against the contention

of the defendant on the proposition that this is a necessary thing for the salvation of this community, that is, without this water this community will be at the mercy of diseases and germs from which it suffered before this diversion began and from which it has by this diversion been practically relieved of, as shown by statistics. The court has complied with the rule of law, that navigable rights are [fol. 295] paramount, and even though the district is driven to the necessity of making some other provision, granting that the War Department and Congress should refuse to give that contention to this question of sanitation, it is entitled to the law which is in force in this room on me, which I must obey, that a navigable right is paramount, and that in the last analysis should Congress and the War Department in consideration of all these matters decline to permit the necessary diversion, the burden is on the District of providing some other method of relief; in other words, the defense that is necessary for the purposes of sanitation as against the rule that a navigable right and navigation right is a paramount right, is immaterial.

I had hoped, as I stated at the beginning, that there might be a composition of this thing. The Judge has no right to have personal feelings, but I live in this community, and it was my hope that there could be devised a program that would enable this district to have the benefit of this water, as much as it needs, that will give to the country this water in the solving of this problem of navigation.

There will be an order striking or sustaining the exceptions of the plaintiff, certain paragraphs of your answer setting up this sanitation defense. There will also be another sustaining the operation of this order which I am entering here this morning until 30 days after the Sanitary District has an opportunity to present to the Supreme Court of the United States an application for a supersedeas against high water, that is 30 days after the date fixed for the meeting of the Supreme Court in October. The order will not go into effect, it [fol. 296] will be suspended until 30 days after the Supreme Court meets in October. That is plenty of time, is it not? A. Yes, sir. I think that is plenty of time. I have considered that is enough. I wanted to make no mistake. You can form it in a way so that you will have a final order to appeal from. You have got to have that in mind. You may draw an order effective 30 days after the Spureme Court meets.

I omitted to mention one matter here which is not important, except the control of the Federal Government over this question has been recognized from the beginning by the Sanitary District itself before the diversion began and continuously down until what was that year when they attached that order, 1909? A. I think 1907 or 1908.

From the beginning, prior to the beginning of the diversion and down to 1907 or 1908, the constant attitude of the Sanitary District was a recognition of the control of the Federal Government over this whole question, everything that was done by the Sanitary Dis-

trict in the way of diversion being in a permit granted by the War Department on application of the Sanitary District to that end. The Sanitary District shall have an opportunity to apply for further relief to the War Department at Washington. Under no circumstances does this order go into effect now. Make that 60 days, and you may put in it, if it does not destroy the appealability of the order, you may put in a provision retaining me in control. The thing that the Government wants, at least the court wants, being a citizen of Chicago, the thing I want is water without microbes. That is why I have held your lawsuit.

[fol. 297] The following is motion presented on July 12, 1920, and filed herein:

[fol. 298] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

C. C. No. 29019 and Equity No. 114

UNITED STATES OF AMERICA, Complainant,

vs.

THE SANITARY DISTRICT OF CHICAGO, Defendant.

MOTION FOR RECONSIDERATION OF ORAL OPINION AND ORAL DIRECTION OF THE COURT CONCERNING THE FORM OF DECREE IN SAID TWO CAUSES, TOGETHER WITH GROUNDS OF SAID MOTION

C. Arch Williams, Attorney for Defendant. Edmund D. Adcock, of Counsel.

[fol. 299] [Title omitted]

Now comes The Sanitary District of Chicago, defendant, in said two causes, by C. Arch Williams and Edmund D. Adcock, its attorneys, and moves the court that it reconsider its oral opinion and oral direction heretofore announced concerning the form of decree to be entered in the said causes, and that the court direct that The Sanitary District of Chicago, defendant, be enjoined, only, from withdrawing or diverting from Lake Michigan, through its various works now constructed or under construction, more than ten thousand cubic feet of water per second from Lake Michigan on condition that if the Congress of the United States, or other competent [fol. 300] governmental authority, provides for the construction of, in the St. Clair, Niagara or St. Lawrence rivers, or in one or all of them, works to compensate for any diminishing levels of the Great Lakes and connecting waters, due to the diversion or with-

drawal of ten thousand cubic feet of water per second from Lake Michigan by The Sanitary District of Chicago, then The Sanitary District of Chicago shall defray the expense and pay the cost of the construction and maintenance of any such works upon request therefor by the United States of America. In connection with said motion, and as a part thereof, the defendant hereby offers and agrees to defray the expense or pay to the United States upon demand the cost of the construction and maintenance of the works of the character above described in accordance with an ordinance of the Board of Trustees of The Sanitary District of Chicago passed and approved by said Board on the 8th day of July, A. D. 1920, a copy of which said ordinance is hereto attached and marked Exhibit "A," a certified copy of which is here ready to be produced in court. In support of said motion, and as grounds therefor, the defendant alleges and shows the following:

(1) The first of said suits was instituted in the Circuit Court of the United States for the Northern District of Illinois, Eastern Division, in the year 1908 and particularly seeks to enjoin the construction and operation of the Calumet Sag Channel, then and now under construction, through which channel it was and is proposed to divert approximately two thousand cubic feet of water per second from Lake Michigan into the main channel of said district at Sag, [fol. 301] Illinois. The second of said suits was instituted in the District Court of the United States, for the Northern District of Illinois, Eastern Division, on October 6, 1913, by bill of complaint filed on said date wherein it was prayed that The Sanitary District be enjoined and restrained

"from diverting or abstracting any waters from Lake Michigan over and above and in excess of two hundred and fifty thousand cubic feet of water per minute, as already authorized by said Secretary of War * * *."

The said suit instituted in the said District Court therefore sought to enjoin the abstraction of waters by the District, not only through the main channel, but also through or by means of any other works then constructed, under construction, or to be constructed. The latter suit, therefore, embraces and covers the subject matter of the first suit. It was agreed by stipulation that any evidence introduced in any one of the said suits that would be material in the other might be used by either party.

(2) The ground upon which the complainant sought injunction, as shown by the evidence and the allegations of said bill of complaint, was that the diversion of water in excess of two hundred and fifty thousand cubic feet per minute, or four thousand one hundred sixty-seven cubic feet per second, would lower the levels of the Great Lakes and connecting waters, thereby injuring navigation and changing the navigable capacity of the navigable waters of the United States.

(3) It is an admitted and undisputed fact on the record in said causes that works may be installed in the St. Clair, Niagara and St. Lawrence rivers which will compensate for the lowering of the lake [fol. 302] levels due to a diversion at Chicago of ten thousand cubic feet of water per second. Witnesses for both the United States and The Sanitary District in said causes so testified. There was introduced in evidence in said cause a document entitled "Final Report Waterway from Lockport, Illinois, to the Mouth of the Illinois River, H. R. Document No. 762, Sixty-third Congress, Second Session." The said report was made pursuant to the River and Harbor Act of Congress of June 25, 1910, which provided:

"The Secretary of War shall appoint a board of five members, to be composed of four engineer officers of the army and one civil engineer, taken from civil life. * * * Said Board shall report upon * * * such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, as far as practicable for the diminishing level in said lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway herein described, or diversion for any other purpose."

The Board of Engineers, provided for by said Act of Congress, so appointed, made an investigation and its report was submitted to the Board of Engineers for Rivers and Harbors on August 15, 1913. The Board of Engineers for Rivers and Harbors report, reviewing the report of the special board, is dated December 16, 1913. It is signed by General William M. Black, then senior member of the Board, who was later and for a number of years Chief of Engineers of the United States army. Concerning the Chicago diversion, the Board of Engineers for Rivers and Harbors, in its report stated:

"Further, the Board believes that the total volume of water to be [fol. 303] diverted from the natural discharge channels of the lakes should be definitely fixed by Congress; that a project with estimate of cost for works necessary to compensate for such diversion should be prepared to the satisfaction of the Chief of Engineers, and the Secretary of War; that before any diversion is made beyond that at present existing, the State of Illinois shall transfer to the Secretary of War the funds necessary for such works as given by approved estimate of cost that the work shall be built by the United States with the funds so provided and that the control and maintenance of such works shall be in and at the cost of the United States."

The Special Board's report upon the subject of compensating for diminished or diminishing lake levels is as follows:

"To restore the diminished levels in the lakes by constructing contracting works in their outlets does not however present any serious difficulties. A careful discussion of the proper locations and dimensions of such works is also given in Appendix A.

At the foot of Lake Ontario the closure of the Gut channel of the Galops Rapids by the Canadian Government has had the effect

of raising the level of Lake Ontario an amount nearly equal to the computed lowering of the lake by a diversion of 10,000 second feet at Chicago, and no compensation is at present deemed necessary to restore former conditions in this lake.

In Appendix A it is proposed to diminish the outflow of Lake Erie by the construction of three submerged weirs in Niagara River in the vicinity of Squaw Island, which would average about 4.2 feet in height and would contain about 15,000 cubic yards of masonry. The estimated cost is $150,000.

To raise the level of Lakes Michigan and Huron submerged weirs [fol. 304] are proposed in St. Clair River, covering 3 miles of river below the mouth of Black River at Port Huron. The weirs as suggested in Appendix A have a height of from 5 to 6 feet above the river bed, contain about 65,000 cubic yards of material, and their estimated cost is $325,000. It is computed that these weirs will increase the velocity of the water flowing over them slightly (from a mean of 3.28 feet to 3.89 feet per second), but, on the other hand, above the mouth of Black River the river slopes and velocities which are now excessive will be diminished, and navigation on the whole will be considerably benefited.

The Chicago diversion has no effect on Lake Superior.

Compensation for the loss of elevation on Lakes Michigan, Huron and Erie, and their connecting waters, due to an assumed diversion from Lake Michigan of 10,000 second feet, will by the plan above outlined involve an expenditure of about $475,000, to which should be added an amount for the maintenance of the weirs, estimated at about $15,000 per year, the total cost being much less than the cost of restoration of depths by dredging. It is the opinion of the board that while other plans have been proposed compensation by fixed contraction works similar in general to those above described affords the cheapest and most satisfactory method of preserving the levels of the Great Lakes."

Said report is signed by W. H. Bixby, Brigadier General, U. S. Army, retired, President of the Board; C. McD. Townsend, Colonel, Corps of Engineers, U. S. Army; C. Keller, Major, Corps of Engineers, U. S. Army; J. B. Cavanaugh, Major, Corps of Engineers, U. S. Army; and John Bogart, Civil Engineer.

The Appendix A to said report is signed by C. Keller, Major, Corps [fol. 305] of Engineers, and is dated August 13, 1913. Concerning construction and effect of compensating works, Col. Keller states in his report as follows:

"The loss of depth on Lake Ontario, due to a diversion of 10,000 second-feet, would be 0.431 foot, or 5.2 inches. The closure of the Gut Channel of the Galops Rapids by the Canadian Government in 1903 has had the effect of raising the level of Lake Ontario by about the same amount. No further compensation is therefore at present necessary on Lake Ontario to restore its natural levels. The head of Galops Rapids will probably afford an advantageous site for a submerged dam or weir to obstract further the area of the channel through which Lake Ontario discharges, and no great

engineering difficulty should be experienced in securing any reasonable increase of level on this lake, but storage in this lake would, temporarily at least, diminish depths in the St. Lawrence River. * * *

For the channels and lakes from the foot of Lake Erie to the St. Marys Locks, so far as affected by the Chicago diversion, a plan of compensation seems feasible which will not disturb natural conditions.

To compensate for the reduction of level in Lake Erie, the outflow capacity of the Niagara River must be diminished. By building submerged weirs or contraction works a short distance below its head, this may be done without altering the range and the periods of the natural oscillations of the lake. At the same time, the free flow down the Niagara River will remain practically unchanged. A proper location of the weirs, which will be of moderate height, or of the contracting dikes will not increase the danger of ice gorges in the upper Niagara River. * * *

It is known that when the surface of Lake Erie is elevated there [fol. 306] will be some backwater effect on Lakes Michigan and Huron, estimated to be slightly more than one-third the rise of Lake Erie. Assuming the surface of Lake Erie raised 0.45 foot, it is estimated that the backwater rise of Lakes Michigan and Huron may be as much as 0.16. A diversion of 10,000 second-feet at Chicago would lower Lakes Michigan and Huron 0.47 foot, and the difference between this and the above backwater effect, or 0.31 foot, represents the additional amount which the surface of Lakes Michigan and Huron must be raised to compensate for such diversion. The St. Clair River is a main artery of the highly important lake traffic, and if submerged weirs are to be built in this river to raise the level of Lakes Michigan and Huron, sites must be chosen and the weirs built to such height that the depth over them will be ample and that navigation may remain convenient and unobstructed. The average depth of the St. Clair River for a considerable distance below the mouth of Black River at Port Huron is 30 feet, and six weirs may be built below that point, at distances averaging half a mile apart, which will raise the surface of Lakes Michigan and Huron the desired amount and will not reduce the depth over the weirs and elsewhere below 24 to 25 feet. The mean velocity of the current in this vicinity would be increased from about 3.28 feet to about 3.89 feet per second, or to about 2 2/3 miles per hour, and the effect of this increase would be felt over a distance of about 3 miles below the upper weir, while above it the river slopes and velocities, now excessive, will be diminished and navigation will be benefited. The weirs, located as above, should have a height of about 5 to 6 feet above the river bed, and six weirs would require about 65,000 cubic yards of stone, which, at $5 per cubic yard, will cost about $325,000. Contraction works in the same locality will, at higher cost, produce the same result, but they must, as previously noted, be restricted in height to mean stage.

[fol. 307] The Chicago diversion, nor any from the lower lakes, will have no effect upon Lake Superior.

The plan of compensation herein proposed has the advantage of simplicity and relative economy. Moreover, the submerged weirs may be systematically and progressively built, so as to permit close observation of their effect and such changes in plan as experience gained during construction may suggest. On the other hand, the Niagara River weirs, so long as they exist, would certainly interfere with the navigation of the main channel of the Niagara River, and at some future time might thereby interfere with the deepening of the channel. Present navigation would, however, be sufficiently served by the new lock at Black Rock. A further minor criticism of the proposed Niagara River weirs is that they do not, as would a high weir close to Niagara Falls, prevent the power diversions at Niagara from slightly lowering the level of Lake Erie; but the weirs are designed to compensate for the effects of diversions from Lake Michigan only. The consideration of compensation for the effects of diversions from the Niagara River is not included in the board's duties, but such compensation could readily be provided by slight modification of the weirs proposed.

Compensation for the loss of elevation on Lakes Michigan, Huron and Erie and connecting waters, due to an assumed diversion from Lake Michigan of 10,000 second-feet will, by the plan above outlined, involve a total expenditure of at least $475,000, to which must be added a small amount, possibly $15,000, annually, for the maintenance of the remedial works. This volume of 10,000 cubic feet per second has been assumed merely as a basis for computation. The cost of compensation for a diversion of different volume may be determined in the same manner."

[fol. 308] 4. On June 30, 1917, the Congress of the United States by joint resolution authorized and directed the Secretary of War to

"Make a comprehensive and thorough investigation, including all necessary surveys and maps, of the entire subject of water diversion from the Great Lakes and Niagara River, including navigation, sanitary and power purposes, and the preservation of the scenic beauty of Niagara Falls and the rapids of Niagara River, and to report to Congress thereon at the earliest practicable date."

Accordingly, the Chief of Engineers, by direction of the Secretary of War, authorized the Division Engineer, Lakes Division (Col. J. G. Warren, Corps of Engineers, U. S. Army), to make and prepare a report upon all the diversions of the Great Lakes. This report was recently submitted to the Board of Engineers on Rivers and Harbors, and, on June 3, 1920, the said Board had a hearing concerning the subject matter of said report at Niagara Falls, New York. At said hearing, representatives of persons, firms and corporations diverting water from the Great Lakes were present, including representatives of the various power companies and interests using the water of the Niagara River at or near Niagara Falls to develop for sale, for commercial purposes, electricity. Representatives of The Sanitary District of Chicago were present as were those of organizations desiring

to protect the scenic beauty of Niagara Falls. The said report has not yet been printed and is in typewritten form, and it is understood there are only two copies in existence—one is located at the office [fol. 309] of the Division Engineer at Buffalo and another at the office of the Board of Engineers for Rivers and Harbors, at Washington, D. C. The report, however, has been examined by representatives of The Sanitary District and the substance of same, with reference to the Chicago diversion and compensation therefor, can be stated, and the defendant asks the opportunity, at such time as the court may direct, to offer said report, or portions thereof, in evidence. The said report found that there were many diversions of the waters of the Great Lakes which effected the lowering of lake levels, and particularly the level of Lake Erie—such as the diversions at Niagara for power purposes, the diversion of 4,500 cubic-seconds feet for power purposes through the Welland Canal and other diversions, including the Chicago diversion; that the Chicago diversion of 10,000 cubic feet per second would produce approximately 55 per cent of the entire lowering of Lake Erie. The report further finds that any diminished or diminishing levels of the lakes due to the Chicago diversion, or any other diversion, may be compensated for by the construction of works in the St. Clair and Niagara rivers of the character described in said report entitled "Final Report, Waterway from Lockport, Ill., to the Mouth of the Illinois River," or by the construction and operation of so-called "regulating works" in the Niagara River, which said works would consist of dams which may be moved at will to regulate the levels of Lake Erie. It was recommended that The Sanitary District be allowed and permitted to withdraw from Lake Michigan 10,000 cubic second-feet of water and that works to [fol. 310] compensate for any diminished or diminishing lake levels should be built at the expense of The Sanitary District.

5. The treaty between the United States and Great Britain of 1909, relating to Canadian boundary waters, provided that there may be diverted from the Niagara River above Niagara Falls, on the Canadian side, water to the extent of 36,000 cubic feet per second and on the American side 20,000 cubic feet of water per second. The reason that the United States was only permitted to divert 20,000 cubic second-feet as compared with the Canadian right of 36,000 second-feet was because the United States was charged with the diversion of 10,000 second-feet at Chicago. Canada, therefore, can make no objection. The International Waterways Commission was organized and appointed pursuant to the joint action of the Congress of the United States and the Parliament of Canada. Canada and the United States each appointed three members thereof. The purpose of the orgnization of the International Waterways Commission was, among other things, to recommend the form of a treaty between the United States and Great Britain concerning the Canadian boundary waters. On April 25, 1906, the Canadian section of the International Waterways Commission made a report to the Commissioner of Public Works of Canada, as follows (proceedings I. W. C., page 333):

"At Chicago the Americans had built a drainage canal which, when in full operation will use about 10,000 cubic feet of water per second.

The quantity of water required for the purposes of a ship canal is comparatively small, but the character of this drainage canal at [fol. 311] Chicago is such as to involve the continuous flow of water, which will have the effect of lowering Lake Michigan, by over 6 inches and Lake Erie by 4½ inches. The nature of this work may be judged when we state that the expenditure will be over $40,000,000 and that power works are in the course of construction on the canal which will generate some 30,000 H. P.

As the diversion from Lake Michigan to the Mississippi River is of a much more serious character than the temporary diversions from the Niagara River, it is felt that the amount of water taken on the American side of the Niagara River should be limited to 18,500 cubic feet per second. * * * It is exceedingly important in the interest of navigation, both to ourselves and the people of the United States, that the diversion by way of the Chicago drainage canal should be limited. * * * If our proposal is carried out, the diversions will be about as follows:

Diversions on the American Side

	Per second cubic feet
Niagara Falls	18,500
Chicago Drainage Canal	10,000
Total	28,500

Diversions on the Canadian Side

Niagara Falls and on the Niagara Peninsula	36,000

It is quite apparent that no further diversion can be made on the Niagara River without injury to the scenic effect of the Falls as a whole, and there should be no further diversion from Lake Erie or any other of the waters of the Great Lakes system, which will be [fol. 312] injurious to navigation. Your Commission is, therefore, of opinion that the time has come when it is desirable to make a treaty limiting these diversions. * * * Therefore this Commission recommends that a treaty be had between the United States and Great Britain, in framing which, it should be recognized that * * *

Permanent or complete diversions of such waters are wrong in principal, and, therefore, should hereafter be absolutely prohibited. The diversions by the Chicago drainage canal should be limited to the use of not more than 10,000 cubic feet per second. * * * This would give an apparent advantage to Canadian interests, but as the diversion is not of serious injury to the Falls and does not materially affect the interests of navigation, it is more than counter-

balanced by the complete diversion of 10,000 cubic feet by way of the Chicago drainage canal to the Mississippi River.

On May 3, 1906, the International Waterways Commission, by report signed by all members, made a report as follows (proceedings I. C. W., 339):

"The Commission has made a thorough investigation of conditions existing at Niagara Falls and the two sections have presented reports to their respective governments setting forth these conditions, to which attention is invited. The following views and recommendations are based upon a careful study of the facts and conditions set forth in these reports. * * *

2. While the Commission are not fully agreed as to the effect of diversions of water from Niagara Falls, all are of the opinion that more than 36,000 cubic feet per second on the Canadian side of the Niagara River, or on the Niagara Peninsula, and 18,500 cubic feet per second on the American side of the Niagara River, including diversions for power purposes on the Erie Canal, cannot be diverted without injury to Niagara Falls as a whole.

[fol. 313] 3. The Commission, therefore, recommends that such diversions, inclusive of water required for domestic use or the service of locks in navigation canals, be limited on the Canadian side to 36,000 cubic feet per second, and on the United States side to 18,500 cubic feet per second (and in addition thereto, a diversion for sanitary purposes, not to exceed 10,000 cubic feet per second, be authorized for the Chicago drainage canal), and that a treaty or legislation be had limiting these diversions to the quantities mentioned.

The effect of the diversion of water by the Chicago drainage canal upon general navigation interests of the Great Lakes' system will be considered in a separate report. * * * The following principles are suggested * * *:

Permanent or complete diversions of navigable waters or their tributary streams should only be permitted for domestic purposes and for the use of locks in navigation canals."

On January 4, 1907, the International Waterways Commission made a special report, signed by all the members, entitled:

"The Chicago Drainage Canal—Joint Report of the International Waterways Commission."

Among other things in said report, the said Commission stated:

"There appears to be a tacit general agreement that Chicago needs, or will need about 10,000 cubic feet of water per second for sanitary purposes and that the city should have it without further question. * * * We therefore recommend that the government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago drainage canal."

[fol. 314] After the evidence was presented in this case, the representatives of The Sanitary District succeeded in obtaining an inspection of the papers showing the negotiations between the United States and Great Britain, which led up to the treaty. The Secretary of State gave The Sanitary District copies of certain of the papers but would not allow copies of all the papers to be obtained. It appears that there was before the Secretary of State the various reports of the International Waterways Commission concerning the diversion of waters at Niagara Falls. The Secretary of State gave the Foreign Relations Committee of the United States Senate a memorandum concerning the treaty when it was before the Senate for ratification with reference to the diversion of waters at Niagara Falls and the diversion at Chicago. The said memorandum stated:

"The waters of Lake Michigan do not come within the definition of boundary waters, as defined in the preliminary article of the treaty, and it will be noted that in Article 1 of the treaty the waters of this lake are not included among the boundary waters of the Great Lakes system but are covered by special provision in the second paragraph of that article. * * * Attention is called to the express provision in this article that it shall not apply to cases already existing which would seem to cover, and was certainly intended to cover, the Canal system at Chicago. * * * The treaty, therefore, recognizes that the settlement of the question of the use of waters of Lake Michigan is purely a domestic question and leaves undisturbed the governmental rights of the United States with respect to it."

We are also advised that the Secretary of State, when he appeared [fol. 315] before the Foreign Relations Committee of the Senate, stated that the reason for allowing Canada 36,000 cubic second-feet of diversion of water at Niagara Falls, was because of the 10,000 second-feet of diversion at Chicago. This may be verified by reference to the proceedings of the Foreign Relations Committee of the United States Senate.

(6) The United States, by the Secretary of War, has consented to the reversal of the current and flow of the Chicago River, the south branch thereof and the west fork, and to the changing, if any, of the navigable capacity of the Chicago River and its branches in the respect and to the entire extent which has been or will be accomplished by the withdrawal of ten thousand cubic second feet of water from Lake Michigan. The main channel of the Sanitary District was opened and placed in operation on January 17, 1900. The waters of Lake Michigan were then drawn through it by way of the Chicago River and the branches mentioned. The channel was opened pursuant to consent of the Secretary of War by permit dated May 8, 1899. This permit was without limitation as to the amount of withdrawal or diversion, except that the limitation thereon would be the flowage capacity of the main channel of the District, which is in excess of ten thousand second feet. The permit of May 8, 1899, without the preambles thereto, is as follows:

"Now, therefore, the Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the water of Chicago River to flow into the same, subject to the following conditions:

[fol. 316] 1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action and that this permit shall be subject to such action as may be taken by Congress.

2. That if at any time it becomes apparent that the current created by said drainage work in the south and main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its south branch.

3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River."

The conditions, it will be observed, of said permit related only to the future action of Congress, current in the Chicago River and the payment of damage to property resulting from any current in said river. Work was commenced upon the construction of the main channel of the District in 1891. The District was organized in 1889. The Sanitary District Act specifies the sort of a channel which should be constructed across the continental divide to form an outlet for the sewage and drainage within the territorial limits of the District. Congress was notified by reports of the Chief of Engineers in each year, from the beginning of the construction of the channel, not only of the plans of the District for the construction of said channel and its operation and withdrawal of water for such purposes, but also [fol. 317] of the progress of the work. In 1895 the Secretary of War appointed a commission of engineers, of which General Poe was chairman, to investigate the subject of the effect of the withdrawal upon lake levels of ten thousand cubic seconds feet of water. This commission made a report in the year 1895 to the effect that the levels of the lakes would be lowered approximately six inches by said diversion. In 1896, and from that time on, various permits were issued by the Secretary of War to the Sanitary District for the construction of various works in the Chicago River, necessary to carry out the District's plans for the diversion. Finally, as before stated, after thorough investigation by the Chief of Engineers and his assistants and the recommendation of the Chief of Engineers, the permit of May 8, 1899, was issued. Thereafter the channel was opened. The condition of the permit of May 8, 1899, concerning the current in the Chicago River, was inserted because of the then tortuous narrow and shallow Chicago River channel.

It was considered that it would be necessary, in order for the District to withdraw the amount of water desired through the river channel, that the flowage capacity of same would have to be enlarged. It was therefore not long after the channel was opened that it was found that an excessive current was created. Therefore, the District made plans in the year 1900 for the widening of the Chicago River, the south branch and west fork thereof to its junction with the northern terminus of the main channel, so that the channel would have a width through the entire course of not less than two hundred feet and a depth of not less than twenty-six feet in the center. The channel at that time was only seventeen feet deep. It [fol. 318] was necessary also to reconstruct and replace bridges across the river. These plans were submitted to the Secretary of War and the purpose of The Sanitary District to deepen and widen the Chicago River was stated and a permit was issued by the Secretary of War to The Sanitary District to make all changes necessary and the specific changes above set forth. Prior to the time when the said work of deepening and widening the river was commenced and after the channel was opened and placed in operation, the Secretary of War had limited the permit of May 8, 1899, by specifying that the flow or withdrawal should not exceed two hundred and fifty thousand cubic feet per minute. This limitation was placed solely because of the current in the Chicago River and it was so expressed in the permit. It is upon this permit that the Government is now seeking the injunction. Thereafter, The Sanitary District deepened and widened the river, rebuilt and replaced bridges pursuant to the permit of the Secretary of War, and has expended, in order to remove the cause for the limitation of two hundred and fifty thousand cubic feet per minute, upwards of thirteen million dollars. The cause and the reason for the limitation of the flow to the amount named has been removed and, therefore, the limitation becomes ineffective.

April 21, 1891, the Board of Trustees of The Sanitary District passed a resolution in regard to the use of the Chicago River and a certified copy thereof was sent to the Secretary of War. The resolution is as follows:

"Resolved that this Board hereby ordains that The Sanitary Dis- [fol. 319] trict of Chicago, do, forthwith, enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the south branch thereof and also the south branch thereof together with the south and west forks thereof so as to make the same a proper and sufficient supply channel for the main channel heretofore surveyed from the Chicago River to Joliet and further, that the acting Chief Engineer be and he is hereby directed immediately to investigate and report upon the capacity of said river and its said south branch and forks for that purpose, and also as to any changes that should be made therein and that a copy of this resolution, certified by the clerk be, forthwith, transmitted to the mayor and common council of the City of Chicago and the Secretary of War of the United States."

Congress, the Secretary of War, Chief of Engineers and his various assistants have had knowledge and notice of the plans and purposes of The Sanitary District in the construction of its works for diversion purposes and in the use of the waters of Lake Michigan for the operation of such works. There has been an acquiescence and at least a tacit agreement that the amount which The District needs, up to ten thousand second feet, would not be limited and that the diversion for sanitary purposes was recognized as being a paramount and primary use. The treaty between the United States and Great Britain with reference to Canadian boundary waters recognizes that the use for sanitary purposes is first and paramount to the use for all other purposes.

The Illinois and Michigan canal was constructed pursuant to Act of Congress of March 2, 1827, "to unite the waters of the Illinois River with those of Lake Michigan." Section 16 of the Act of Jan-
[fol. 320] uary 9, 1836, the General Assembly of Illinois provided that the canal should "be supplied with water from Lake Michigan and such other sources as the Canal Commissioners may think proper." The Supreme Court of the United States, in Missouri v. Illinois, 200 U. S. 495, 526, concerning the effect of the Congressional and State Acts, said:

"Some stress is laid on the proposition that Chicago is not on the natural watershed of the Mississippi, because of a rise of a few feet between the Desplaines and the Chicago rivers. We perceive no reason for distinction on this ground. The natural features relied upon are of the smallest. And if, under any circumstances, they could affect the case, it is enough to say that Illinois brought Chicago into the Mississippi watershed in pursuance not only of its own statutes but also of the acts of Congress of March 30, 1822, * * * and March 2, 1827, * * * the validity of which is not disputed."

From the time the Illinois and Michigan canal was placed in operation, water has been withdrawn through it from Lake Michigan, not only for navigation purposes, but also for sanitary purposes. The withdrawal for sanitary purposes increased as the sanitation needs of Chicago required it. In 1873 the channel of the Illinois and Michigan canal was deepened at the expense to Chicago of three million dollars in order to increase the withdrawal and thereby cleanse the Chicago River. In 1884 pumps were installed at Bridgeport to accomplish a greater withdrawal. The Sanitary District Act and the works constructed thereunder accomplished the replacement of the old Illinois and Michigan canal by the main channel of The Sanitary
[fol. 321] District. This was so held in the case of Mortell v. Clark, 272 Ill. 201, 213.

(7) The diversion of at least 10,000 cubic second-feet of water from Lake Michigan is essential for the sanitary needs and requirements of the population within the limits of The Sanitary District, which includes that of the City of Chicago and its suburbs, comprising a population of approximately 3,000,000 people. The primary

purpose of The Sanitary District is to construct and operate works to provide a pure drinking water supply for this population. The plans for the works of The Sanitary District were formulated and recommended by a commission of engineers, pursuant to an ordinance of the City of Chicago, known as "Drainage and Water Supply Commission." This commission studied the matter for two or three years and finally recommended the diversion of the drainage and sewage of Chicago and its environs to the Desplaines River, together with a sufficient amount of water from Lake Michigan (20,000 cubic feet per minute for each 100,000 population) to oxidize the sewage and waste. This Commission's report was made in 1887 and The Sanitary District Act was passed pursuant to the recommendations of that Commission at the next session of the Legislature, and the District has expended upwards of $100,000,000 in the construction of these works. They have accomplished practical results. There was not at the time the Commission made its report, and there has not been since that time, any other practical method that could have been adopted to accomplish the purpose of these works—namely, the protection of the water supply. The record in this case [fol. 322] shows that the art of artificially purifying sewage has been for years, and is now, in a state of uncertainty, and there is no plan for artificially purifying sewage that engineers agree is feasible and practical, and will with any certainty serve for a considerable period of time in the future—and this is particularly true when dealing with great metropolitan populations.

The basis, therefore, of The Sanitary District's diversion works is the reversal at all times of the Chicago River, into which a large amount of sewage is emptied from sewers serving the people of Chicago and its suburbs. The maximum run-off of the Chicago River drainage area is 10,000 cubic second-feet. Obviously, if the capacity of the main channel of the District were less than 10,000 second-feet, the Chicago River would flow into Lake Michigan at certain flood times. The withdrawal of water from Lake Michigan must, therefore, be the same amount, because it would be impossible, if the flow were limited to 4,167 feet, or any amount materially below the 10,000 second-feet, to change the flow from the limited amount to the maximum run-off of the drainage area in time to keep the water from going into Lake Michigan. This is demonstrated by testimony of witnesses in this case and it is recognized as a fact by the report of Col. Warren, Division Engineer of the Lakes Division, above mentioned. The limitation of the flow to 4,167 second-feet, or any amount materially less than 10,000 second-feet, would, therefore, require the absolute and complete purification of all sewage within the limits of the District, so that if any effluent found its way into Lake Michigan, it would not affect the water supply.

[fol. 323] There was presented in this case estimates of the cost of constructing artificial purification works to completely purify the sewage and drainage. These estimates were made in the year 1913. The total cost of constructing these works, which would require a great number of years to complete, was from $75,000 000 to $100,-

000,000. The figures were made with reference to the cost of materials, labor, etc., as of the year 1913. Since that time the cost of labor and materials for similar works has increased approximately 100 per cent, so that to install the works which would be made necessary by reason of the limitation of the flow to 4,167 second-feet, would be from $150,000,000 to $200,000,000. The cost of operating and maintaining these works annually was also estimated, and the estimates were upwards of $5,000,000 per annum. The annual operating and maintenance cost would now, according to present prices of labor and materials, much exceed that amount.

It is also shown in the record in this case that it would be impossible for the District or this community to raise the money necessary to construct these works within any reasonable time, unless constitutional amendment should permit greater bonding power.

In addition to the amount which the District would be compelled to expend by virtue of the limitation of flow to 4,167 second-feet, it would lose the greater portion of the investment that it has already made in the present diversion works.

Furthermore, it is probable that any works which the District might install for the purification of sewage and drainage would, within a very short time, have to be discarded and thrown aside for [fol. 324] some other works upon a different plan. Indicative of the changes in the art of artificially purifying sewage that have taken place we refer to the fact that it was only five years ago that most sanitary engineers believed that the best method to be used was the Imhoff Tank system. In these tanks a certain amount of sewage was allowed to settle and the effluent drawn off to run through what are called "sprinkling filters," by which the effluent from the Imhoff tank was, by means of a nozzle, sprayed over crushed rock of several feet in thickness. Lately, sanitary engineers have reached the conclusion that such method is not proper but that what is known as the "activated sludge" system should be used. This system contemplates the passing of the sewage and drainage at low velocities through tanks, which tanks are provided at the bottom with perforations so that a vast amount of air may be pumped through the sewage and thereby the sewage be purified.

If the District were limited now to the withdrawal of 4,167 second-feet, at many times during the year the Chicago River would flow into Lake Michigan, carrying with it a vast amount of sewage. At and prior to the time the Drainage Canal was opened and placed in operation, the death rate per year from typhoid fever was 75 per 100,000 population. Occasionally there would be epidemics, when the rate would be 190 per 100,000. Since the opening of the Drainage Canal there has been a steady reduction in the death rate per year from typhoid fever, with no epidemics, so that now the death rate from typhoid fever is less than 1 per annum per 100,000 of population. According to Hazen's theorem, where there is an increase of 1 per annum in death rate from typhoid fever, there is an increase of 3 from other kindred disease; and the same theorem applies con- [fol. 325] versely to a decrease. The limitation to 4,167 second-feet

would produce intolerable conditions in the Illinois River, because of the fact that the principal amount of the sewage of Chicago and its suburbs would be delivered to the Desplaines and Illinois Rivers without the necessary pure water for oxidization and purification purposes. All fish life would be destroyed throughout the entire course of said river and the fish industry along the Illinois River is one of the principal industries of the state. The conditions above mentioned that would result from the limitation of flow to 4,167 second-feet would continue until works were installed to practically purify a very large portion of the sewage and drainage arising within the limits of The Sanitary District, and it would continue to a certain extent until the works were installed to purify all sewage and drainage.

8. Since the drainage Canal was opened, January 17, 1900, all boats that were then navigating the Great Lakes and its connecting waters are not interfered with in any respect, by a less depth due to lowering of lake levels. All boats which the United States claims are affected—those owned by the Pittsburgh Steamship Co., a subsidiary of the United States Steel Corporation—were constructed since that time. All the critical points of navigation of the Great Lakes have been, since the opening of the Drainage Canal, deepened or improved, and the record in this case shows that the reference plane for the improvement of 1903, which included practically all the connecting channels, was made approximately 6 inches lower because of the diversion at Chicago—so that, the navigation interests have not been injured. They have the same depth of water that they would have had if the diversion had not existed.

[fol. 326] 9. The Sanitary District here and now offers and agrees to pay to the United States the amount of money necessary to construct, operate and maintain the compensating works which will off-set or compensate for any damage due to the diversion at Chicago. These works the Federal engineers have said may be installed and will accomplish the purpose named. If they were installed and placed in operation, the only ground of the Government for seeking the injunction here would be removed. The expense would be practically nothing as compared with the financial burden that would be placed upon the District if it is enjoined from withdrawing more than 4,167 second-feet of water, or any amount materially less than 10,000 second-feet. The only thing that the Government would have to do in order to accomplish the installation of the works would be to provide for their construction, operation and maintenance. The suggestion for modification of the opinion and direction of the court with reference to the decree in these cases herein made points out the plain practical solution of this problem.

The facts above mentioned are all found in the record, except those that have arisen since the closing of the taking of testimony (1914) or those discovered since—negotiations leading up to Canadian Boundry water treaty.

Respectfully submitted, —— ——, Attorney for the Sanitary District of Chicago. —— ——, of Counsel.

[fol. 327] EXHIBIT A TO MOTION

An ordinance of the Board of Trustees of the Sanitary District of Chicago offering and agreeing to defray the expense of the construction of works in one or more of the outlets of the Great Lakes to compensate for any diminishing levels of the Great Lakes and connecting waters due to the diversion of 10,000 cubic feet of water per second from Lake Michigan by the Sanitary District of Chicago and authorizing the attorneys of the Sanitary District in the suits pertaining to said diversions now pending in the District Court of the United States for the Northern District of Illinois, Eastern Division, to make and present such offer and agreement in open court.

Whereas, there are now pending in the District Court of the United States, for the Northern District of Illinois, Eastern Division, two suits in equity instituted by the United States against The Sanitary District concerning the withdrawal of water from Lake Michigan by The Sanitary District of Chicago. The first suit was instituted in the year 1908 and pertains particularly to the construction and operation and withdrawal of water for the operation of the Calumet Sag Channel, an adjunct of the main channel of The Sanitary District of Chicago. The second suit was instituted in the year 1913 and seeks to enjoin The Sanitary District from withdrawing from Lake Michigan, through its various channels, including the Calumet Sag Channel then and now under construction, [fol. 328] more than 4,167 cubic feet of water per second. The said suits have been tried together and submitted together upon briefs; and,

Whereas, the Honorable Kenesaw M. Landis, one of the Judges of said District Court of the United States, for the Northern District of Illinois, Eastern Division, before whom said cases have been pending, did recently render an opinion or direction for the entry of a decree in said cases, in substance, to enjoin The Sanitary District of Chicago, defendant in said cases, from withdrawing from Lake Michigan more than 4,167 cubic feet of water per second; and

Whereas, various reports have been submitted purusuant to acts of The Congress of the United States by the Engineer Corps of the U. S. A., finding that the claim of injury to navigation arising from the lowering of lake levels because of the diversion from Lake Michigan of water at Chicago to the extent of 10,000 cubic feet of water per second, may be compensated for by the construction of fixed weirs or works of similar character, or by the construction and operation of movable dams in the St. Clair, Niagara and St. Lawrence Rivers, or one or all of them, and that the expense of constructing said fixed weirs would, at the time the report was made, not exceed $475,000; and it was recommended that if The Sanitary District of Chicago should defray the expense of constructing such works, then they should be maintained by and at the expense of the

United States; and, if such works were constructed and placed in operation, thereby the ground of the United States for securing the injunction herein would be removed; and,

[fol. 329] Whereas, it is the opinion of the Board of Trustees that if The Sanitary District is enjoined from taking more than 4,167 cubic feet of water per second from Lake Michigan for sanitary purposes, it will be necessary to expend, in the construction of works to artificially purify sewage, supplement and aid the works diverting 4,167 cubic second feet of water upwards of $150,000,000, and the operation and maintenance of the same will exceed upwards of $5,000,000 per annum; and it is, further, the belief of the Board of Trustees of The Sanitary District of Chicago that it is doubtful whether such works, with said limited withdrawal of 4,167 cubic second feet of water will provide for the people of The Sanitary District of Chicago, which includes the population of Chicago and its environs, a safe drinking water supply, for the reason that it would be impossible, with said limited withdrawal, to keep the Chicago River at all times reversed so that it would not flow into Lake Michigan, carrying with it a large amount of sewage and drainage, and it is doubtful whether such purification works would accomplish practical results.

Now, therefore, be it ordained by the Board of Trustees of the Sanitary District of Chicago:

Section 1. The Sanitary District of Chicago does hereby offer and agree to defray the expense, and pay to the United States Government the cost, of constructing and maintaining works to be installed at the outlet or outlets of any of the Great Lakes to compensate for any diminishing levels of the Great Lakes and connecting [fol. 330] waters, due to a diversion or withdrawal from Lake Michigan of 10,000 cubic feet of water per second by The Sanitary District of Chicago through its various channels and diversion works in the event The Sanitary District is not enjoined from diverting from Lake Michigan less than 10,000 cubic seconds feet of water.

Section 2. The said offer and agreement contained in Section 1 hereof is intended to embrace and cover not only the expense of constructing and maintaining fixed weirs or dams described in the report entitled "Final Report of Waterways from Lockport to the Mouth of the Illinois River," House of Representative's Document No. 762, 63rd Congress, 2d Ses-ion, but also any other works of similar character that may be planned or provided for by the Congress of the United States or by competent Governmental authority, or works known as "regulating works," consisting of movable dams or dams that may be moved from time to time, that may be planned or provided for by The Congress or other competent authority—such works having for their purpose compensation for any diminishing levels of the Great Lakes or connecting waters due to a diversion at Chicago of 10,000 cubic second feet of water; and the said The Sanitary District of Chicago offers and agrees to pay to the United States the expense of constructing and maintaining such works when-

ever the United States shall provide for such construction and make request for the payment of the amount of money necessary to construct and maintain the same.

Section 3. The attorneys for The Sanitary District of Chicago in [fol. 331] said two suits above described, wherein the United States is complainant and The Sanitary District of Chicago is defendant, on behalf of The Sanitary District of Chicago, are hereby authorized, empowered and directed to present and make said offer in open court in said causes, or in any other manner that the said attorneys may deem proper.

Section 4. The preambles to this Ordinance are hereby made a part of same and this Ordinance shall take effect and be in force from and after its passage.

Approved:
William J. Healy, President of the Sanitary District of Chicago.

[Title omitted]

NOTICE

To Honorable Charles F. Clyne, United States District Attorney for the Northern District of Illinois, attorney for the complainant:

Please take notice, That on Monday morning, the 12th day of [fol. 332] July, A. D. 1920, at the opening of court, or as soon thereafter as counsel can be heard, we shall appear before Honorable Kenesaw M. Landis, one of the judges of said court, in the Federal building, Chicago, Ill. in the room usually occupied by him as a court room and present the foregoing motion for modification of oral opinion of said court and oral direction of the court with reference to the entry of the decree herein, at which time and place you may be present if you see fit.

——— ———, Attorney for Defendant.

[fol. 333] And the following is an amendment to said motion, filed herein:

[fol. 334] [Title omitted]

[fol. 335] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

AMENDMENT TO MOTION FOR RECONSIDERATION OF ORAL OPINION AND ORAL DIRECTION OF THE COURT CONCERNING THE FORM OF DECREE IN SAID TWO CAUSES, TOGETHER WITH GROUNDS OF SAID MOTION

Now comes the Sanitary District of Chicago, by William F. Mulvihill, Morton S. Cressy and Edmund D. Adcock, its attorneys and amends its "Motion for Reconsideration of Oral Opinion and Oral Direction of the Court Concerning the Form of Decree in said two Causes, together with Grounds of said Motion," by inserting, at page 27 of said printed motion, and at the end of paragraph No. 7 thereof, a new paragraph known and called paragraph No. 7½ as follows:

"7½. On, to wit, August 7, 1919, the Board of Trustees of the Sanitary District of Chicago duly adopted an ordinance, which ordinance was approved by the President of said Board, entitled: [fol. 336] 'An ordinance of the Board of Trustees of the Sanitary District of Chicago laying out and adopting a program for the construction and operation of works for the purification of or the removal of solids and organic and inorganic matter from sewage, trade waste, offall and other organic and inorganic matter so that within the period of the next twenty-five years not more than fifty per ceht of the amount of said sewage and waste that is now passing into the Desplaines River from the main channel of the Sanitary District will at the end of such period find its way into said river. Such works are to supplement those constructed or in process of construction for the diversion of sewage and drainage arising within the limits of the Sanitary District of Chicago.'"

The said ordinance, exclusive of the preambles, is as follows:

"Be it ordained by the Board of Trustees of the Sanitary District of Chicago:

Section 1. To supplement the works of the Sanitary District of Chicago now constructed or in the process of construction for the diversion of sewage or drainage, and to aid said works in better accomplishing the purpose for which they were constructed, the Sanitary District does hereby lay out and adopt a program for the construction and operation of works for the purification of sewage or the removal of organic or inorganic matter from human sewage

and the removal of trade wastes and other wastes and for the carrying on of such work at such a rate as continuously after the lapse of four years to diminish the amount of sewage including all wastes passing into the Desplaines River by way of the Main Channel of the Sanitary District of Chicago, so that within the period of twenty-five years such purification works shall be constructed and in operation, that the amount of such raw sewage and wastes so passing into [fol. 337] said Desplaines River shall be at least fifty per cent less than that passing now.

Sec. 2. The Chief Engineer and the Attorney of the Sanitary District are hereby directed to take such steps as may be necessary to carry forward the foregoing program, and the Chief Engineer is directed to report to such officers of the United States and the State of Illinois as may be interested, the progress made from time to time in carrying out said program.

Sec. 3. The foregoing preamble to this ordinance is hereby adopted and made a part of same.

Sec. 4. This ordinance shall be in full force and effect from and after its passage and adoption."

In 1921 the General Assembly of Illinois amended the Sanitary District Act so as to specifically authorize the Board of Trustees to construct the works and carry out the program for sewage purification, as set forth in the foregoing ordinance. The said ordinance was passed by the Board of Trustees of the Sanitary District of Chicago after negotiations with the Division Engineer at Chicago, representing the Chief of Engineers of the United States Army, and a draft of said ordinance was submitted to said Division Engineer at Chicago before it was passed, and said draft of ordinance was approved. It was stated by the said Division Engineer that the passage of said ordinance, and the carrying out of the program for sewage treatment, so mentioned in said ordinance, would be satisfactory to the United States, as the final solution of the problems involved in the controversy between the United States and the Sanitary District. The Sanitary District of Chicago has, since the adoption of said ordinance by its Board, carried out the program in said ordinance mentioned, as laid out, and is now constructing sewage treatment [fol. 338] works. Said sewage treatment works now constructed, or under construction have, or will cost many millions of dollars and the Sanitary District has planned the construction of further works to carry out in good faith the program for sewage treatment, so outlined in said ordinance.

William F. Mulvihill, Attorney for the Sanitary District of Chicago, Defendant. Morton S. Cressy, Edmund D. Adcock, of Counsel.

[fol. 339] Thereupon, on July 12, 1920, the said motion entitled "Motion for Reconsideration of Oral Opinion and Oral Direction of

the Court Concerning the Form of Decree in said two Causes, together with Grounds of Said Motion" was presented to the Honorable Kenesaw Mountain Landis, Judge of the District Court of the United States, for the Northern District of Illinois, Eastern Division, and partly heard and argued; and thereafter Judge Landis resigned his position as Judge of said Court and ceased to become Judge thereof on March 1, 1922. No further proceedings were had before Judge Landis in said cause between the date of the presentation of said motion and its being partly heard and argued before him and said March 1, 1922, when Judge Landis left the bench; and, thereafter, the cause was assigned to Honorable George A. Carpenter, Judge of [fol. 340] said Court. Thereafter, on June 18, 1923, the Court entered the following order:

ORDER REFUSING OFFER TO CONSTRUCT CERTAIN WORKS

"The motion presented herein on the 12th day of July, 1920, by the defendant, asking that the defendant be not enjoined or restrained from withdrawing from Lake Michigan less than ten thousand (10,000) cubic seconds feet of water, and in connection with said motion an offer was made to pay cost of constructing and maintaining such works and might be provided by complainant to off-set for the lowering of the surface elevations of Lakes Michigan, Huron, St. Claire, Erie and Ontario, due to a diversion of said amount by the defendant at Chicago, is hereby denied, and the said offer is refused."

To the entry of which order the defendant duly excepted.

Thereupon, on June 18, 1923, the Court entered the following order and decree:

DECREE FOR INJUNCTION

"That the defendant, the Sanitary District of Chicago, its Board of Trustees, officers, agents, attorneys, representatives, employees and servants, and all other persons acting or claiming or assuming to act under its authority, be, and they hereby are, and each of them hereby is, enjoined from diverting or abstracting any waters from Lake Michigan over and above or in excess of 250,000 cubic feet per minute.

The operation of this injunction is hereby stayed for a period of [fol. 341] six months to enable the defendant to present the record herein to the Supreme Court of the United States."

To the entry of which order and decree the defendant duly excepted.

ORDER SETTLING CERTIFICATE OF EVIDENCE

The foregoing is all the evidence and proceedings had in the above entitled consolidated cause, and inasmuch as the matters above set forth do not fully appear of record in this suit, the defendant tenders this certificate of evidence and prays that the same may be certified under the hand and seal of the Judge of this Court and thereupon made a part of the record in such cause, and it is certified accordingly, this 29th day of June, A. D. 1923.

George A. Carpenter, Judge. (Seal.)

[fol. 342] [File endorsement omitted.]

[fol. 343] IN THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

[Title omitted]

PRÆCIPE FOR TRANSCRIPT OF RECORD—Filed June 29, 1923

To the Clerk of said District Court:

Please prepare transcript of record in the above entitled cause and insert therein the following:

1. The bill of complaint in case number 29019.

2. The answer of the defendant thereto.

3. Exceptions of the complainant to answer of the defendant.

4. Bill of complainant in case number 114.

5. Answer of the defendant to said bill.

6. Certificate of evidence.

8. Stipulation of June 29, 1923.

9. Order of June 18, 1923, consolidating two causes number 114 and 29019.

10. Order of June 18, 1923, denying defendant's motion of July 12, 1920.

11. Final decree entered June 18, 1923.

12. Petition and order for appeal to the Supreme Court of the United States.

13. Assignment of Errors.

14. Order to make part of the record all of the evidence taken in [fols. 344 & 345] the case in the exact words of the witnesses.

15. Appeal bond.

16. Copy of this præcipe.

17. Order entered substituting printed record for typewritten record as filed by the Commissioner.

18. Order extending time to file transcript of record.

19. Copy of Motion to strike part of answer Feb. 18, 1914.

20. Opinion of Judge Carpenter June 18, 1923.

Clyde L. Day, Edmund D. Adcock, Attorneys for Defendant.

[File endorsements omitted.]

[fols. 346 & 347] Northern District of Illinois,
Eastern Division, ss:

Clerk's Certificate

I, John H. R. Jamar, Clerk of the District Court of the United States for the Northern District of Illinois, do hereby certify the above and foregoing to be a true and complete transcript of the proceedings had of record made in accordance with Præcipe filed in this Court in the cause entitled The United States of America vs. The Sanitary District of Chicago, No. 114, in Equity, as the same appear from the original records and files thereof now remaining in my custody and control.

In testimony whereof, I have hereunto set my hand and affixed the seal of said Court at my office, in the City of Chicago, in said District, this 15th day of August, A. D. 1923.

John H. R. Jamar, Clerk. (Seal of Dist. Court U. S., Northern Dist. Illinois.

[fol. 348] In the District Court of the United States

[Title omitted]

Certificate of Evidence

Further proceedings in the above-entitled cause before Samuel M. Morgan, Commissioner, on Wednesday April 25, 1923, at 10.30 o'clock a. m., at the Rookery Building, Chicago, Illinois, pursuant to stipulation.

Appearances: Mr. Edwin A. Olson, U. S. Attorney; Mr. Joseph B. Fleming, Special Assistant to the Attorney General, on behalf of the Complainant, Mr. Clyde L. Day, Mr. George F. Barrett, Mr.

Louis J. Behan, and Mr. Edmund D. Adcock, on behalf of the Defendant.

[fol. 349] Mr. Adcock: I will offer in evidence a certified copy of an ordinance passed by the Board of Trustees of The Sanitary District on August 7, 1919.

Mr. Fleming: The record will show my objection.

Mr. Adcock: I think there is a stipulation in the record to the effect that objections as to materiality, relevancy and competency may be preserved, without making the formal objection at the time. It may be presented at the hearing or any other time. Proper objections to the form of question and answer are to be taken at the time the testimony or evidence is presented, in order to avoid the necessity of taking it over again.

Mr. Fleming: If that is preserved, that is all I want.

Mr. Adcock: I offer that copy as Pearse Exhibit 1 of this date.

(Certified copy of ordinance passed by the Board of Trustees of The Sanitary District on August 7, 1919, offered in evidence, was marked Pearse Exhibit 1, April 25, 1923, and is hereto attached.)

Mr. Adcock: I offer a certified copy of an ordinance of the Board of Trustees of the Sanitary District of Chicago, passed by the Board [fol. 350] at a meeting held on July 8, 1920, as Pearse Exhibit 2 of this date.

(Certified copy of ordinance of Sanitary District offered in evidence, was marked Pearse Exhibit 2, April 25, 1923, and is attached hereto.)

Mr. Adcock: I offer in evidence as Pearse Exhibit 3 of this date a copy of a letter dated May 24, 1921, from the Division Engineer at Chicago, Colonel William V. Judson, Corps of Engineers, to the Chief of Engineers of the United States Army at Washington D. C. This is subject to verification as to correctness of the copy that is offered.

(Letter of Colonel William V. Judson dated May 24, 1921, offered in evidence was marked Pearse Exhibit 3, April 25, 1923, and is hereto attached.)

[fol. 351] LANGDON PEARSE, a witness called on behalf of the defendant, was first duly sworn by the Commissioner, and testified as follows:

Direct examination.

By Mr. Adcock:

Q. Your name is Langdon Pearse?
A. Yes, sir.
Q. You reside where?
A. In Winnetka, Illinois.

Q. What connection if any have you with the defendant, the Sanitary District of Chicago?

A. I have been employed with The Sanitary District of Chicago in various capacities since March 1st, 1909; at present in the position of Sanitary Engineer, in charge of the sanitary engineering work of the District.

Q. Will you state your education, and generally your experience; what you have done in the engineering world?

A. I am a graduate of Harvard College with the degree of A. B. in 1899; and from the Massachusetts Institute of Technology, with a degree of Bachelor of Science in Civil Engineering; also Master of Science in Civil Engineering, of date 1902.

In the period between 1901 and 1909, at which time I became [fol. 352] connected with the Sanitary District, I was successively Levelman for the Massachusetts Harbor and Land Commission, on the Brockton Ship Canal; Assistant Engineer to the Charles River Dam Commission, under John R. Freeman; Assistant Engineer for the Commission on Additional Water Supply in New York City, known as the Herring-Burr-Freeman Commission; also as Personal Assistant to George C. Whipple in work for the Augusta Water District, Me., Cleveland and Jersey City; and also in connection with the suit of Missouri vs. Illinois.

From there, I was Assistant Engineer for the Improved Water and Sewage Works at Columbus, Ohio, involving the construction of a water filtration and softening plant; also sewage treatment; and also Assistant Engineer on the Greater Water Supply for the People's Water Company of Oakland, California, a water filtration project.

From 1909 to date, I have been successively assistant engineer, division engineer, and since 1907, sanitary engineer with the Sanitary District of Chicago, in charge of all sanitary work, involving the laboratory work covering chemistry and bacteriology, in connection with our testing stations, studies of the Canal and River, [fol. 353] as well as industrial wastes; the construction and operation of four Testing stations, respectively on domestic sewage at 39th Street and the Lake, packinghouse waste, tannery sewage and Corn Products sewage; the design and construction of intercepting sewers in size from six inches to twenty-two feet in diameter, including the North Shore Intercepting Sewer, the Stockyards Intercepting Sewer, the Calumet Intercepting Sewer, and the 52nd Avenue Sewer Outlet; the design of sewage pumping stations, known as the Evanston, Desplaines, Calumet, 95th treet stations, and also the remodeling of Lawrence Avenue and 39th Street; the design of sewage treatment works and other construction at Morton Grove, the so-called Calumet works at 125th Street and Cottage Grove Avenue, the Desplaines River Treatment Works, near the Subway Hospital in Broad view; Glenview Sewage Treatment Works, and the designs for the North Side Sewage Treatment Works.

I have further been in charge of the general operation of the Sewage Treatment Works, of which we now have three in operation, one at Morton Grove, one at Calumet, and one known as the Desplaines River.

In addition to these technical duties, I have also been in charge [fol. 354] of preparing special reports and data for the use of the Chief Engineer and others in different suits.

In addition to my duties with The Sanitary District, I have further served as a Consultant for the U. S. Public Health Service on stream pullution for the last three years; and in that connection served for the Sanitary District on a joint survey with the U. S. Public Health Service of the Illinois River, extending over a period of one year.

In my private capacity as a Consulting Engineer, I have executed the following works, in special partnership with George W. Fuller; designed and built the Evanston Water Filtration plant. As a member of the firm of Pearse, Greeley & Hansen, we designed and built the Decatur, Illinois Dam & Sewage Treatment Works; the Whiting, Indiana Water Filtration plant, and the Winnetka, Illinois Water Filtration plant.

And further, as engineer, have made reports for, designed and built works for the Sanitary District of Decatur, the North Shore Sanitary District, the Downers Grove Sanitary District, the Sanitary District of Champaign and Urbana; and in addition have made miscellaneous reports on industrial wastes for the Holland-St. Louis [fol. 355] Sugar Company, the Standard Oil Company of Indiana and others.

I am also a member of the American Society of Civil Engineers, and the American Institutute of Consulting Engineers.

Q. What studies have you made in regard to the sewage disposal problem of The Sanitary District?

A. I was first employed on the work in 1909, with the intent of making a complete and thorough investigation of the sewage treatment problem of The Sanitary District. I have been at that ever since.

I first went into the engineering details in the so-called 1911 report of Mr. Wisner, who was then Chief Engineer; and later in 1912 and 1914, I went into the matter again in connection with this particular law suit for Mr. Wisner. And further in 1919 and 1920, in connection with the report of the so-called Expert Commission composed of Eddy, Fuller and Hatton.

It was early evident that to unravel the sewage treatment problem, a close study was required, not only of the sewage from the human sources, but also of the wastes of industrial origin.

The study of the domestic sewage was begun by a testing station [fol. 356] at 39th Street and the Lake, operating on sewage coming from an area of over twenty-two square miles, and from a population of 270,000 and up. This was very free from industrial wastes. In this Station were tried all the practical methods of sewage treatment then known, including septic tanks, Imhoff tanks, biolytic tanks, sprinkling filters, etc.

Q. Just explain those different terms, what the methods are?

A. The difference between the different tanks mentioned is essentially one of construction as well as operation. By septic tanks, I mean the single story tank in which the solids deposited from the

sewage are allowed to accumulate, with cleaning at infrequent intervals.

By the Imhoff tank, I mean a double deck type of tank in which the upper chamber serves as a settling chamber, the solids passing through a trap into the lower chamber where they digest at leisure, the gases passing off through a separate vent, in order not to contaminate the sewage flowing through, which is settling.

The sludge from this tank may be drawn at intervals of two weeks, [fol. 357] in the warm weather; the storage capacity provided being from four to six months, according to the design.

The biolytic tank is a special device, in which all the sewage entering the tank comes in at the bottom and passes through the sludge deposit. This tank has been used only experimentally, and while it gave a remarkable reduction of sludge, it produced offensive odors and was therefore discontinued.

The sprinkling filters mentioned are beds of crushed stone, in the experimental work ranging from five to ten feet in depth, but usually in active work around six feet and a half, the stone being composed of one and a half to two inches in size. These beds are placed upon prepared underdrains to permit free drainage of the liquid trickling down through. The liquid is sprinkled upon the surface by nozzles spaced up 13½ feet on centers, operating intermittantly and dosing the beds at a rate of from two to five million gallons per acre per twenty-four hours.

Q. How was the station operated there at 39th Street?

A. The 39th Street Testing Station was operated from October 1909 to January 1915. The results that were obtained there indicated that with the more dilute sewage found in Chicago, liberal [fol. 358] provision for treatment, loadings, was required.

The value of the Imhoff tanks and sprinkling filters was clearly demonstrated.

Following the study of the domestic sewage, we entered upon an extended study of the Packingtown situation in January 1911. The preliminary investigation showed the lack of knowledge for handling such waste. Consequently a Testing Station was established in 1912, and operated until September 1918. These studies showed that the activated sludge process was the most promising of success on Packinghouse waste.

I might explain that the activated sludge process is a process in which the solids settling from the sewage are held back and conditioned by the blowing of air, so that in a period of about two weeks it has acquired the property of changing from the organic matter coming in the sewage to a more mineral form. It is essentially a biological process, involving the same principles as in the sprinkling filter, except that the films which are active and doing the work are held in suspension by air blown in at the bottom of the tanks, instead of the films being around the periphery of the stones in a bed above ground. The sludge is retained by settling tanks, returned to the [fol. 359] incoming sewage and then held in contact and in thorough mixture by the air blown in at the bottom of the tanks.

From day to day a certain amount of sludge can be removed from

the system, about one thousand pounds per million gallons of domestic sewage, and in the case of Packingtown about between three and four thousand pounds of dry solids per million gallons.

This sludge is higher in nitrogen than the usual sludge from Imhoff tanks or other processes.

Q. The activated sludge method is substantially a reversal of the sprinkling filter, isn't it? In the one you pump the air in, while in the other you disseminate it, so the air can get to it?

A. Yes, in that sense.

In connection with our packinghouse investigation, a thorough inspection was made of every packinghouse in the Sanitary District, the flow from each being gaged and analyzed before entering the sewer.

In 1911, all the packinghouses were examined. In 1917, the work was repeated, the flow of thirty-one houses being measured and analyzed in a period of about three months.

[fol. 360] The study of the tannery situation was begun in 1912. A recent investigation showed twenty houses all located on the North Branch of the Chicago River. After a number of inspections, a tannery testing station was established in December 1919, and operated up to December 31, 1922. In this the various processes applicable to handling tannery wastes were tried, including sprinkling filters and activated sludge. A survey of the industry was also made, house by house.

The Corn Products Refining Company plant at Argo was early recognized as an outstanding source of organic pollution. After some preliminary work, a testing station was established in 1921, by which the experiments have been conducted to date, using activated sludge and also a sprinkling filter. The flow of the plant has been measured, analyzed and correlated to the grind. This plant manufactures primarily starch and glucose, and is the largest of its kind in the world, grinding upwards of 75,000 bushels of corn every twenty-four hours.

Q. Are there any other sources of pollution than the ones you have mentioned; that is outside of the human sewage?

A. Yes, sir, there are other sources of pollution, which we have [fol. 361] investigated in a cursory way, which add to the load, but are not so important as those listed. Among these may be mentioned the Pope Beet Sugar factory, miscellaneous butterine factories, paint and glue works, gas works, paper mills and wire mills.

Q. Have you reached any conclusion as to the method to pursue in artificially treating these wastes and sewage?

A. Yes, sir.

Q. What is that conclusion?

A. The study I have made in the last fourteen years has led me to divide the Sanitary District into five main geographical projects, namely:

The Calumet, South of 87th Street.

The Southwest, South of the Canal and the river and North of 87th Street.

The West, north of the canal and river, and south of Fullerton Avenue in general, and the

North Side project, North of Fullerton Avenue.

In addition, there is the Desplaines River project.

Besides these five main projects, there are the Packingtown, Corn Products and Tannery industrial projects. The first two require [fol. 362] separate treatment plants distinct from the human sewage plants, whereas the tannery situation is to be combined with the North and West Side projects.

Besides the major projects outlined, there are and will be for many years small treatment units, plants for isolated villages such as Morton Grove, Glenview, Shermerville and the like, where the population is small and the distances are too great to warrant the construction of an intercepting sewer at present.

Q. Have you made any estimate of the population of the Sanitary District as it probably will be at different times in the future?

A. Yes, sir, I have made a careful study of the population in the Sanitary District from the United States census figures from the component parts of the census of 1890, 1900, 1910 and 1920. From the figures an estimate has been made of the future population of the District up to 1960. The growth of the various sewage treatment project areas has also been worked out in detail.

Q. Just state how you make those estimates of the future population.

A. We have plotted the populations as they have existed, with the [fol. 363] correction for the date, on paper, and then projected a curve on that.

We have further tested the ten year increment by the actual differences, taking into account the growth of the territory of the Sanitary District, and have arrived at the figures given in the table.

Q. Is that a usual method adopted by engineers in determining populations of the future in a metropolitan area?

A. Yes, sir, this method has been used and is one that is usual among engineers.

Q. You have there a table showing the population for the years 1890, 1900, 1910 and 1920.

A. Yes.

Mr. Adcock: I offer that in evidence as Pearse Exhibit 4 of this date.

(Table produced by witness for the years 1890, 1900, 1910 and 1920, offered in evidence, was marked Pearse Exhibit 4, April 25, 1923, and is hereto attached.)

Q. Have you a table which shows the populations for the future, 1930, 1940, 1945, 1950, 1955 and 1960, including also the year 1920?

A. Yes, sir, that table has been prepared. (Producing same).

[fol. 364] Mr. Adcock: I offer that in evidence as Pearse Exhibit 5 of this date.

(Table for the years 1920, '30, '40, '45, '50, '55 and '60, offered in evidence was marked Pearse Exhibit 5, April 25, 1923, and is hereto attached.)

Q. What was the total load upon the Main Channel in 1920, expressed in population, and what was the human population and the industrial load expressed in equivalent human population?

A. These loads are shown in the table which I have prepared based on the census populations and the projected population for the human load, and based upon our surveys for the industrial load expressed in equivalent population.

Q. And you have prepared an exhibit showing that?

A. Yes.

Mr. Adcock: I offer that in evidence as Pearse Exhibit 6 of this date.

(Table described by witness, offered in evidence, was marked Pearse Exhibit 6, April 25, 1923, and is attached hereto.)

Q. What estimates have you made covering the same propositions for the years 1930, 1940, 1945, 1950 and 1955? Have you prepared a table covering that?

[fol. 365] A. The estimates for the years following 1930, and up are given in the Exhibit 6, following the figures given for 1920, for the totals there expressed.

Q. How did you get at this proposition, what method did you use as shown on those tables?

A. The method by which I have arrived at the population equivalent of the industrial wastes is based on the dissolved oxygen required to oxidize the putrescible matter in sewage. Continued research over many years in the laboratory of the Sanitary District has shown this to be a reliable and accurate measure of the strength of sewage, inasmuch as it utilizes exactly the same biological activities which are effective in the stream. By stream I mean the Canal, Desplaines and Illinois Rivers.

Essentially, the test depends on mixing with the sample sufficient standard water saturated with dissolved oxygen to supply enough dissolved oxygen to oxidize the organic or putrescible material, in five, ten or twenty days, as the case may be, and leave a small amount of oxygen over at the end of a period.

The amount of dissolved oxygen required is expressed in parts per [fol. 366] million. For purposes of comparison, a ten day period has been chosen in our work, inasmuch as 90 per cent of the oxidation of the putrescible material is generally completed in sewage within that period. Such a test is called the Biochemical oxygen demand, and has been widely used by the U. S. Public Health Service, the Sanitary District and other research workers, as being more delicate and expressive than the old line chemical determinations. In some instances we have used nitrate of soda, added in known amounts, in place of dissolved oxygen.

The first step in the study of our sewage was to determine the amount of dissolved oxygen required per capita to oxidize the putrescible matter in human sewage. Prior to the work of the Sanitary District this figure had never been determined. Experiments were made on the sewage at 39th Street Pumping Station during

the year 1914. This sewage was chosen because a thorough inspection of the area tributary showed no industrial wastes likely to upset the tests.

On 179 days, hourly portions were collected during the twenty-four hours and daily composites were made. These were analyzed. The flow of the sewage was measured. The population tributary was [fol. 367] estimated. From the data the average figure was determined that 100 grams of oxygen are required per capita to properly oxidize the human sewage, or 0.22 pounds. Subsequently other research chemists confirmed this figure to me personally.

The next step was to determine the amount of putrescible material requiring oxidation from the different industries. This was done from time to time as follows:

The Packingtown and Union Stock Yards situation was investigated in the summer of 1917 between July 9, and October 6. At that time thirty firms were actively engaged in the packing and allied industries, in addition to the Stockyards. All of these houses were examined, and the flow gaged and analyzed from forty-one outlets, besides the public sewers, and certain outlets from the Stockyards. In all cases (except three of the smaller houses where the examination lasted two days) the sampling and gaging continued a week, night as well as day.

The flow was read as frequently as every ten minutes in most cases. For analysis, individual portions were taken every ten minutes and combined into hourly composites, which in turn were combined into [fol. 368] day or night composites, weighted according to the flow.

I mentioned the fact we made day and night composites, because there was a marked difference in the flow, in the strength day and night, as well as in the quantity.

From the determination of the biological oxygen demand and the flow, the total oxygen requirement was calculated. Based on the 0.22 pound per capita, the effect of the Stockyards and Packingtown was found to be practically 1,000,000 people. This investigation alone cost $5,661.97, an amount which was reimbursed to the Sanitary District by the packers.

For the Tannery industry, the investigations made between 1911 and 1919, gave a rough indication of the equivalent. However, the most detailed survey was made in the summer of 1921, when twenty tanning houses were inspected. For each house, the flow was gaged and analyzed, the work being done substantially in the same manner as for the Packinghouse survey. The determination of the biological oxygen demand and the flow from the houses showed a total oxygen requirement equivalent to 70,000 people, on a normal hides capacity rating. In addition, seven wool pulleries and three [fol. 369] wool scouring houses were examined.

For the Corn Products Refining Company, the investigations were made in December 1921, and January and February 1922, in connection with the testing station then operated on the Corn Products wastes. The flow was gaged and sampled throughout the twenty-four hours, analyses being made on twenty-four composites. The result-

ing oxygen demand showed that the population equivalent was 411,000 people, at that time when a grind of 64,500 bushels was being made. Since that time the grind has increased.

Q. What was the designed capacity of the Main Channel of the Sanitary District?

A. The Sanitary District Channel in the main section was designed upon the assumption that the runoff of the Chicago River would not exceed 10,000 cubic feet per second, and could therefore be diverted from the Lake by a channel having that hydraulic capacity.

Q. That is reversed at all times?

A. Reversed at all times, yes, sir.

Q. If the diversion from the Lake is limited to 4,167 cubic feet per second, what effect will this have upon the problem of protecting the water supply?

A. The likelihood of overflow into the lake is very much increased, [fol. 370] with a result that pollution of the water supply is likely to occur, which will be severe. This is due to the fact that the intercepting sewers as designed cannot be made large enough to carry more than twice the dry flow in 1950; hence overflows will come into service, at times of storm, spilling sewage into the branches of the Chicago River. Consequently, with any reversal of the flow, storm water and sewage mixed will fill the river and be swept into the Lake.

Q. What methods would be necessary to pursue, in order to protect the water supply, in the event of the reduction of diversion?

A. It does not seem safe to me to rely entirely upon chlorination of the water supply for protection, where a water would be exposed to sudden and so-called explosive pollution. In my experience, the only adequate and certain protection would be filtration, accompanied by chlorination, as a finishing process.

Q. What is the extent of the use of water for domestic purposes now, and what do you estimate it in the future?

A. I have prepared an estimate of the use of water at the present time in the city of Chicago, that is as of 1920; and also for 1945 and 1955. These estimates have been checked with those of the Water [fol. 371] Bureau of the City of Chicago, and are in substantial agreement.

Q. That is the pumpage practically, isn't it, Mr. Pearse?

A. Yes, sir, that is practically the pumping.

Q. That has nothing to do with the diversion from the lake by the Sanitary District?

A. It has nothing to do with that.

Mr. Adcock: I offer in evidence this table that the witness has just presented, as Exhibit 7 of this date.

(Table of water consumption for 1920, 1945 and 1955, offered in evidence, was marked Pearse Exhibit 7, April 25, 1923, and is hereto attached.)

Q. Have you made any estimate of the cost of the construction and operation of plants for filtering the water supply of Chicago?

A. I have made a rough estimate of the cost of filtration, basing the capacity of the plant on the maximum daily rate, and including in round figures the low lift pumping stations.

In 1945, the cost would be for construction approximately $90,000,000, or by 1955, a cost of $106,500,000. These costs are in [fol. 372] round figures, and undoubtedly would require some additional expansions to increase the figures in a detailed survey, because of the necessity of the connections to the intake tunnels and other incidental work, which at present it is difficult to estimate. I present them as an indication of figures based on the cost of works in the past and present, to show the magnitude of the filtration expenditure.

Q. You say "a rough estimate," what do you mean by that?

A. I mean an estimate that may be within 15 or 20 per cent, based on round figures, calculated per million gallons for plants of like nature. They are figures that perhaps are not accurate enough to predicate a bond issue upon for a public vote, but are accurate enough to indicate the magnitude of the expenditure for handling the filtration of a city of the size of Chicago. Such a plant would be the largest filtration plant of its kind in the world, and would necessitate special designs and lay-out, so that the figures necessarily at the present moment are not contractors' estimates of what the work could actually be built for, but they are what we call preliminary estimates which may be accurate within 15 or 20 per cent, [fol. 373] thereabouts.

Q. What would be the probable annual cost of maintenance and operation of such works?

A. I believe that in 1945, the cost of maintaining and operating such filter plants for the city would exceed three million dollars, and that by 1955, the cost would have probably reached $3,526,000, the additional cost being due to the additional service required for the population, and increased pumpage.

To these figures necessarily should be added interest charges and depreciation, to give the total annual costs. These costs cover labor, chemicals, supplies and general repairs necessary and incidental to the operation of such filtration plants.

Q. Based upon the project, the plan outlined by the ordinance of August 7, 1919, what populations would require treatment?

A. I have made a calculation based on the so-called "Colonel Judson plan,"—if I understand the question.

Q. Yes.

A. Which was designed to outline the program for the Sanitary District for the twenty-five years following 1920, to construct works which would reduce the load on the channel to one-half that exist-[fol. 374] ing in 1920. The figures are presented as follows:

For Conditions in 1920

By census, S. D. C. in 1920	2,986,000
Estimated Industrial Wastes	1,500,000
Total	4,486,000
One-half	2,243,000

Q. That is an equivalent population, human population?

A. Equivalent population expressed in the equivalent sewage from human beings.

Q. That is that represents, according to such estimates, half the waste passing from the southern terminus of the Main Channel of the Desplaines River?

A. Yes, sir. The figure of 2,243,000 is in round figures to the nearest thousand.

The equivalent population, under the Colonel Judson plan that would be required to reduce the sewage pollution to in 1945, outlined In 1945, the conditions are as follows:

For Conditions in 1945

Estimated S. D. C. in 1945	4,782,000
Estimated Industrial Wastes	2,000,000
Total	6,782,000
Deduct residual one half	2,243,000
Requiring treatment by	4,539,000

[fol. 375] 4,539,000 is the population which I understand would have to be provided for by treatment works, under this so-called Colonel Judson plan.

Q. That is during the period from 1920 to 1945?

A. Yes, sir.

Q. What flow of dilution water does this plan provide, or would this plan provide in 1945?

A. I have based the figures on the minimum legal dilution expressed in the Act of the Sanitary District, namely 3 1/3 cubic feet per second per thousand population, and on that base I find the population of 2,243,000 requires 7,500,000 cubic feet per second, in round figures, for dilution. From the sewers there may come a flow which we have assumed to be 346 gallons per capita per 24 hours for a population of 4,782,000 in 1945, which would give a flow of 2,482 cubic feet per second, making a total flow through the channel of diversion from the lake, and of water supply coming through the sewers of practically 10,000 second feet; a difference of only a few unit second feet, so that it rounds out to the 10,000 second feet.

Q. If by the year 1945 the flow were reduced to 4,167 second feet, on this basis, what population would that flow accom-odate, or equivalent population?

[fol. 376] A. On the assumed basis of the minimum legal dilution of 4,167 cubic feet per second, at 3½ cubic feet per second per thousand population, is equivalent to 1,250,000 people. In 1945, the total population equivalent, both human and industrial is estimated at 6,782,000. The difference, or 5,532,000 people would require treatment. In 1945, this means 993,000 more people than would be required under the Colonel Judson plan.

Mr. Fleming: The testimony now being presented, as I understand it, is presented merely for the enlightenment of the court in connection with the character of the decree he shall enter.

Mr. Adcock: Yes, and they are matters that were brought out in the argument of the motions; and are pursuant to the written motion presented.

Mr. Fleming: My objection specifically is this: I object to the reopening of the case on any of the issues; the elaboration of any of the testimony on any of the issues in the original case. In that case the record has been made, the testimony heard, and an informal opinion rendered by the trial court. And to all intents and purposes, disposition has been made of this case, and the only matter pending now is the question of the form of the decree which should [fol. 377] be entered.

It is my understanding it was Judge Carpenter's suggestion that there was no objection to taking testimony insofar as the presentation into this record of the ordinances of the Sanitary District was concerned, and the testimony, moreover, on the subject of the construction of these plants. My stipulation, in any event, was limited to those two propositions. I could not stipulate nor agree to any further testimony at this time; testimony introduced as to the merits of this case.

Mr. Adcock: I want to say in behalf of the defendant, there isn't any attempt to re-open any of the issues that were presented in the original case. This testimony is in connection with the motions that were made, the form of the decree to be presented, in order to give the court the facts upon which he may act in determining the decree that he shall enter, and it is only for that purpose.

Mr. Fleming: I reserve the right to present objections to this, and to strike this——

Mr. Adcock: Strike any portions you want to under the terms of the stipulation, anything that is objected to on the ground of mate- [fol. 378] riality, relevancy and competency; also under any other stipulation.

Mr. Fleming: That was the original stipulation.

Mr. Adcock: Yes.

Mr. Fleming: But this matter is something that is outside; the issues have been settled, the matters submitted to the court. This testimony of Mr. Pearse with respect to the back flow of the river, the flowing of the river into Lake Michigan in the event of reduction to 4,167, testimony of that character is something not within the authorization of the court, and certainly not within the stipulation between yourself and me.

Mr. Adcock: That we believe to be material in connection with the issues that we believe are now before the court, on the motions that were recently argued, and upon the question as to the decree that the court may enter; and it is for that purpose only we are offering the evidence. As far as I am concerned, I agree that the objections which counsel wishes to make may be presented to this testimony now, or at any time that he desires.

Whereupon an adjournment was taken to Thursday April 26th, two o'clock P. M.

[fol. 379] Thursday, April 26, 1923—two o'clock p. m.

Parties met pursuant to adjournment.
Present as before.

Langdon Pearse resumed the stand for further direct examination by Mr. Adcock and testified as follows:

Q. How long would it take, probably, to build these additional works for the 993,000 people?

A. I estimate not over ten years.

Q. According to your estimates, what would be the human population and the equivalent in industrial wastes?

A. The human population would amount to 5,500,000 in 1955, and the industrial wastes 2,200,000, making a total of 7,700,000.

Q. What population would require treatment then by 1955 on the reduction of flow to 4,167 second feet; also the increase over 1945?

A. The figures given previously may be developed as follows: The total population in 1955 we have estimated at 7,700,000; the total [fol. 380] population in 1945, at 6,782,000, making a difference of 918,000 population, as the growth in the ten years.

If you take the total in 1955, namely 7,700,000 and from this deduct the population equivalent to the 4,167 cubic feet per second, namely 1,250,000, you have as a difference as of 1955 a population of 6,450,000.

Under the Colonel Judson plan as mentioned before, the population requiring treatment in 1955 would be 5,457,000, the difference then between the two being 993,000 people.

Q. What is the cost of the artificial sewage treatment program, under the plan of the ordinance of August 7, 1919, which we will call the Colonel Judson plan for convenience? Have you made an estimate of that.

A. We have made an estimate of the cost. The sewage treatment program based on this plan was estimated in 1920 to require directly an expenditure for sewage treatment of $104,335,000, out of a total program of over 106,000,000. I say over $106,000,000 because in addition to the $104,000,000 would be the other items such as regulating works, bridges over the Main Channel, and dredging of the [fol. 381] Calumet River, which amount to $7,250,000. Of the total as estimated, over $9,490,000 has been spent or put under con-

tract to date, thus leaving a total of about $94,845,000 still to be expended.

Q. The amount of approximately $9,000,000 there which you have stated, has been expended since 1919 or 1920, has it, or been contracted for?

A. Has been either expended or contracted for since 1920.

Q. That is when you say "contracted for" that means under actual contract?

A. Yes.

Q. That is contracts let and in performance?

A. Yes.

Mr. Fleming:

Q. How much was that?

A. $9,490,000, that is under contract or completed, during the period from 1920 to date. The cost of each project is indicated in the exhibit, as well as the year.

Mr. Adcock:

Q. Indicated on an exhibit or tabulation, which you have prepared here?

A. Yes, sir.

Q. And which you hand me?

[fol. 382] A. Which I hand you, yes.

Q. You have made up these figures, or they have been made under your direction, have they?

A. These figures were made up under my direction, and represent the combined judgment of our office.

Mr. Adcock: The tabulation which you have handed me bears the legend, "The Sanitary District of Chicago estimated costs of sewage treatment projects and necessary construction work for period 1922-1845", and I will offer that in evidence as Pearse Exhibit 1 of this date.

(Blue print, estimated cost of sewage treatment projects and necessary construction work 1922-1945, offered in evidence, was marked Pearse Exhibit 1, April 26, 1923, and is hereto attached:)

Q. What progress does this schedule of progress call for or contemplate, both on new work and extension of existing works?

A. We based this schedule on the following assumptions as to the progress that might be made. I would make this explanation, however, that this general program was worked up in 1922, that is not 1923, and we estimated then that the North Side work would [fol. 383] be started in 1922. The plans were practically ready last fall for the first contract of that plant, but owing to the discussion with Evanston over the location of the site, the work has not actually been put under contract, but the program is outlined to start on the North Side plant in 1922, and completed by 1928.

Q. You say "discussion with Evanston," do you mean then that there were objectors as to the site? You have a site there now?

A. The District has acquired approximately 200 acres at Oakton Avenue and the North Shore Channel for the purpose of a site. This site was acquired about two years ago. Last year, when it was announced that we were prepared to start work on the plant, objections were raised by various Evanstonians, and only to-day a large delegation was in the office before a public hearing of the Trustees, protesting against the use of that site, and alleging possible damage to the property values in Evanston.

The Trustees have indicated as yet no decision in the matter, but have been investigating very seriously the entire question since last October. The change in the Board in December re-aligned some of the committees. We expect a decision shortly, and orders to pro-
[fol. 384] ceed in one way or another on actual construction.

Q. As I understand the proposition they bring up is that they want to annex about 2,500 acres to Evanston, is that correct?

A. The reason for the objection is that Evanston has expressed a desire to annex 2,500 acres west of the Channel, extending out towards the north branch of the Chicago River north of Oakton Avenue; and the claim is made that the location of this plant will injure the desirability of that locality for the best class of residential buildings.

I would add this, however, that on this north side project we have already built five miles of sewer from Sheridan Road south to Oakton Avenue, so that the northwest line of the incercepting sewer is completed and ready to hook into the pumping station. And we have completed preliminary plans for the work from the south, and have already started on the plans for re-modeling Lawrence Avenue, so that the sewage that now passes to the river through the Lawrence Avenue conduit from the Lincoln Park region will be diverted to our interceptor.

Q. The program of the Evanstonian objectors is that you should
[fol. 385] move this plant out several miles, at a cost of something like $5,000,000 for sewer, is that right?

A. Yes, sir. The suggestions of Evanston are that we can move the plant five miles or more to the West, which would increase the sewer cost of the project at least a million and a quarter a mile for about four miles anyway, as a minimum. That is five million dollars and this would probably add to the operating expenses for pumping the sewage approximtely $100,000 a year.

Q. And the land, the 2,500 acres, is worth about $1,000 an acre.

A. I have been informed that that land is worth about $1,000 an acre. Our Board paid $1,500 an acre for the site of the treatment plant.

Q. You haven't finished your answer to the previous question?

A. No, sir. In our schedule, we further assume that the Corn Products plant could be started in 1925, and completed in 1927. I purposely allowed three years there for legal conditions, to arrive at an agreement with the Corn Products, because in our experience with the packers, after we had outlined the engineering plans for do-
[fol. 386] ing the work, that overcame the engineering objections,

we have been approximately four years negotiating as to the legal difficulties; and negotiating to arrive at an agreement under which the work could be prosecuted.

For the Stock Yards project, we allowed for a start in 1925, and assumed it would be completed in 1932. In making this allowance, we assumed that legal negotiations would take at least two years: that the design of the sewers and works would be done by 1924, and the construction of the sewers, pumping station, screens, and the first unit of aeration tanks completed in 1926. After operating for one year, a year is allowed for the design and contract plans for the entire plant, and a year for necessary legal negotiations. The plant is assumed to go under construction in 1929, and to be completed in 1932.

I would explain this arrangement was made, because when Mr. W. B. Richardson, representing the packers, and myself representing the District brought in a report outlining the engineering method of proceeding, in 1917, we made a recommendation that the work be done by gradual steps, first to construct the sewer, pumping stations and screens for the entire works. Mr. Richardson [fol. 386½] differed with me and said we ought to have the screens only for one unit, that is about one thirtieth of the entire flow, and then we both agreed that the activated sludge plant recommended by both of us as to process should be built gradually, in order to demonstrate to the packers on a working scale of at least a million and a half gallons per day, the entire feasibility of the process.

Since that time, I have taken the position that the size of the plant to start might be markedly larger, as we know more of the process to-day, and have been operating a plant at Maywood for over eight months.

Q. You have a little different situation as to the sewage at the Stock Yards from the one you have with the human sewage in Maywood, don't you?

A. The sewage is much stronger at the Stock Yards, expressed in biological oxygen demand. The sewage in the Stock Yards will run from 500 to 1,000 parts per million, as against 125 to 150, not over 200 in Maywood.

The amount of suspended matter in the Stock Yards will run from 3,000 to 4,000 pounds of dry matter to the million gallons, [fol. 387] whereas at Maywood we have 1,000 pounds. In other words, there is three to four times as much solid to be handled.

Further, with the screens at the Stock Yards, we estimate we can take out about 1,000 pounds of dry material to the million gallons, whereas at Maywood we are only taking out 200 pounds a day for 3,000 gallons. That is 60 pounds of wet material with 80 per cent moisture, or 16 pounds of dry material to the million gallons.

The Stock Yards sewage is one of the strongest sewages in the United States produced on such a scale, and is full of fresh organic matter, blood, particles of meat, hay, straw, and undigested contents of cattle paunches, hogs and other animals.

Q. Has any practical, satisfactory method been developed for the

reduction and disposition of the sludge coming from these activated sludge plants?

A. I feel that a reasonable program of handling has been devised, namely to de-water the sludge, which in its original form contains about 99 per cent of water; reduce that to 80 per cent or less by filter process, with the addition of either an acid or a coagulen like sulphate of alumina, and then take the solids with less than 80 per [fol. 388] cent of moisture and dry them in a rotary heat drier. They will then be in a form containing ten per cent of moisture, capable of passing through an eight mesh sieve, and suitable for sale in the market as fertilizer. We have been offered by at least two responsible firms the amount of five dollars and ten dollars per ton f. o. b. cars for Chicago for such material, to be used in mixing fertilizer for the Southern market, or for truck farms either in the East or the Ohio Valley.

Q. That has just been recently worked out?

A. That has been worked out in the last two years. In addition, the city of Houston has been selling similar material for eight dollars a ton for use in the Cotton Belt in the South, prepared in much the way that I have indicated.

The City of Milwaukee is installing a plant now to handle the sludge in exactly this fashion.

Q. What other project have you there that you have considered, and what is the time of construction?

A. In order to build up a sufficient treatment to meet the requirements of the Colonel Judson program, or a more elaborate program, we have had to plan the construction of the so-called West Side Project, including the sewers, and a plant which, for the purposes [fol. 389] of this estimate, we have assumed would be a settling plant to remove all the solids which may settle in the Channel. The construction of this plant has been assumed to begin in 1932 and to be completed in 1940.

Further, for the South West Side, we have laid out a similar program for treatment, including intercepting sewers and a settling plant, the construction to start in 1935 and to be completed in 1945.

Besides the new work which I have mentioned, viz: The North Side, West Side and South West Projects, the extension of existing projects will require attention in the life of the program.

The Desplaines River sewage treatment works, which has been in operation since August 1st, 1922, will need extensions in 1924 to take care of the increased population.

The Calumet treatment works, which has been in operation since October 1922, will need an extension of the tanks, and we have assumed an addition of sprinkling filters to produce a higher grade effluent than we were supplying, in the year 1930.

[fol. 390] We have further allowed for the extension of the North Side treatment works, assuming that they were completed in 1928, in the year 1931.

Q. What population does this program cover?

A. As originally outlined the program covers an equivalent population of 4,251,000, taking the Imhoff tank treatment as the equiv-

alent of one-third complete treatment. This is within five per cent of the figure set for 1945, as outlined by the Colonel Judson plan. This method of handling was assumed by settling the sewage which was not given complete treatment, in order to retain all the settling solids.

I would explain that the reason for presenting the material in this shape is, we have to construct certain intercepting sewers to take out the sewage and carry it to certain designated points for treatment. Having done so, those sewers serve for a certain population, and we have taken the tributary populations and added them together in order to supply a project that would come approximately to the population set by the plan. In order to bring it exactly to the plan, we would have to provide a little additional treatment, as I remember, because I think the figure of 4,251,000 is a little lower than the [fol. 391] amount called for, which would of course increase the expense of the construction.

I did not endeavor to bring it out exactly by taking the per capita figures and equating them by slide rule, but have left them in this shape to show exactly the projects that would be developed, and what they would accomplish.

Q. What change of construction program would be required if the contemplated diversion were cut to 4,167 c. f. s. by 1945?

A. If the flow were cut to 4,167 c. f. s., it would be necessary, we believe, by 1945 that the West Side plant, instead of being constructed with settling tanks would be equipped for complete treatment, probably by activated sludge. We would still leave the South West plant as a settling plant. Such a program would provide in the year 1945 for the population equivalent of 5,328,000, which comes within four per cent of the figures set.

The same explanation would apply here as made in the previous answer, namely that in order to come out exactly to the population set by the population computations, sufficient additional treatment would have to be provided on one plant by sprinkling filters or other [fol. 392] means, to bring up the total, which can be done, but would increase the amounts of the estimates.

The additional construction cost necessitated by the cut in diversion would exceed $16,800,000 if carried out by 1945. I have my doubts whether this could be done at the rate of progress that is necessitated by the methods of administration in our work and the financing, judging by past experience.

I have therefore estimated that in order to finance the work, cover the legal requirements and the like, somewhat more time would be required than on the previous work, which has been taken to be a period of ten years. In the interval from 1945 to 1955, in which the extent of that cut would be made, working on our assumptions, there would have to be expended not only the sum of $16,800,000 as noted, but a further sum roughly estimated at $16,710,000, making a total of $33,510,000, to cover the growth in population, which would have to be treated, as well as the difference required on account of the lowered diversion.

In addition to these figures, in accordance with a former answer, the filtration of the water supply of the City of Chicago would be [fol. 393] required, so that as of the year 1955, there would be added $106,500,000 to the program requiring financing.

Q. That is the sewage treatment program you have outlined?

A. To the sewage treatment program, yes.

Q. Is the true cost of handling the additional population of 993,000 shown by your computation?

A. The true cost of the additional population is not shown by our method of computation outlined, because the method of assembling by districts indicates a comparative cost for handling the sewage with a reduced diversion, which is lower than it really is, if you take the per capita costs and multiply by the population. That comes in the method of assembling the projects and calculating the cost of intercepting sewers in this treatment.

Q. What do you estimate the per capita cost to be?

A. I have estimated the cost of the activated sludge plants with intercepting sewers as $25 per capita, with an annual cost of around $2.25 to $2.75 according to the method of handling the sludge. I am therefore conservative in saying the cost in round figures on [fol. 394] account of this cut in diversion would add to the sewage treatment program approximately $25,000,000 based on the actual per capita charges for construction, and $2,250,000 for annual costs.

Q. Would there be any effect upon the cities other than Chicago?

A. If the diversion was cut to 4,167 cubic feet per second, I believe that there will be ultimately a heavy burden placed upon the cities and industries located on the Illinois River, particularly in the metropolitan area around Peoria and Pekin. While in 1920 the census population was only 88,207 for the two cities, there was in addition a starch works at Pekin grinding about 25,000 bushels of corn a day, equivalent to 158,000 people, besides other Corn Products industries about which little data could be obtained.

This equivalent population, through growth of industry as well as of population, I have estimated might exceed half a million in 1930. With the continued growth up to 1945, during low water, treatment may become necessary, making an additional burden upon the inhabitants of the State of Illinois. In 1920, the urban population on the banks of the Illinois River from Joliet to the mouth totaled 200,472.

Q. What expenditures have been made by the Sanitary District [fol. 395] for sewage treatment since 1909, for construction purposes?

A. I have assembled these expenditures in a table showing the amount spent year by year, which I hand you; these expenditures being taken from the books of the District and tabled.

Q. This table is entitled "Expenditures for Sewage Treatment since 1909, for Construction Purposes." You have assembled this, have you, from the records of the Sanitary District?

A. I have assembled this from the records of the Sanitary District and had them checked by our own clerical force, so that they are reasonably accurate.

Mr. Adcock: I offer that table in evidence as Pearse Exhibit 2 of this date.

(Table of expenditures for sewage treatment since 1909 for construction purposes, offered in evidence, was marked Pearse Exhibit 2, April 26, 1923, and is hereto attached.)

Q. Since January 1st, 1919, you have expended $16,382,944, is that correct?

A. Yes, sir.

Q. That has been spent under your direction?

[fol. 396] A. This money was spent under my general direction, under the orders of the Chief Engineer who is in charge of the entire engineering department, and was spent in accordance with the plans and specifications drawn by my division of the engineering department.

Q. You made up a table showing the expenditures for sites?

A. I made up a table showing the expenditures for sites, a copy of which I hand you as an exhibit.

Mr. Adcock: I offer that table in evidence as Pearse Exhibit 3 of this date.

(Table of expenditures for sites for sewage treatment works up to 1921, offered in evidence, was marked Pearse Exhibit 3, April 26, 1923, and is attached hereto.)

Q. You made that up in the same way as the others, from the records of the District?

A. This table was made in the same way, from the records of the District, checking the amounts against the vouchers paid, and the dates against the orders of the Board printed in our proceedings.

Q. What expenditures have been made by the Sanitary District since 1909, for testing stations and experimental work?

[fol. 397] A. Since 1909, up to the end of 1922, there has been expended under my direction by our engineering and laboratory forces the sum of $97,842, for construction and equipment on sewage testing work.

In addition to this sum, we have spent in the maintenance and operation of the works, including the operating of our laboratories and the other expenses chargeable to the investigations, the sum of $563,815. This makes a total expenditure on our books for construction, equipment, maintenance and operation of $661,657.

Q. Why was it necessary to do this?

A. When I first came with the District in 1909, the art of sewage treatment was less understood on a large scale than now. There was a transition period in the art; the old septic tank was in disfavor, as originally installed at Columbus. Experiments were found to be necessary, and were devised by men of the standing of Mr. Rudolph Hering, and others who studied the problems of the District, and had been connected with it since its inception in 1889.

We found the sewages we had to meet were so varied in strength and behavior that tests were needed to define the most efficient

method of treatment. Tests were needed in order to find how much [fol. 398] sewage could be treated with a given area of plant; for instance in sprinkling filters, how many hours were required for the settling of the sewage in settling tanks.

We saw very clearly that the problem ahead of the District in 1909, was a gigantic one, involving the largest sewage treatment works in the world, and involving the necessity of producing a high grade effluent for a large part of the sewage of the District.

In addition, we had to confront not only the human problem but the industrial waste problem of enormous extent, and at that time no solution was known for its treatment. Neither was the amount of the waste known. The period required for preliminary investigation was indefinite, but we knew that we had to study the sewage, not alone as to methods of treatment, but also to improve the methods of analysis.

The method I have explained of determining the oxygen consumption was one of our changes in method which has enabled us to express population equivalents. Short time tests we knew were of little value. Our experience had shown that at least a test running over the four seasons of the year was required, because the [fol. 399] operation of a sewage plant is different in the winter from the summer; and usually at the end of the year we had found improvements or changes in the studies that led us to continue.

Aside from the tests, surveys were required of the District. Preliminary plans had to be made; sites had to be secured, and then legal obstacles had to be overcome.

Our lawyers finally determined that the Act had to be amended, which was done in the last session of the Legislature, over two years ago now, whereby we were given the explicit right and command to build sewage treatment works, whereas prior to that time, I was informed that our right to establish complete works was in doubt and open to contest.

Q. That is they were built as incidental to the works of diversion, and supplementary to them, under the original theory, is that correct?

A. Yes, the opinions, I think during Mr. Adcock's incumbency as attorney, and prior to that time, were that whatever we did was merely an incident, and there might be a doubt if we had to condemn a site as to whether our powers would be seriously questioned, because we were acting more or less under implied powers, instead of actual, explicit powers.

[fol. 400] Q. How about your population figures there, with reference to the effect on loading of the Canal?

A. I regard the population figures as presented as very fair. They are calculated from census figures, which are as close as we can actually get them. We have had the advantage of the actual enumeration districts of the census. In representing the actual loadings on the Main Channel, we believe they may prove low rather than high, because of the fact we have made no allowance in the figures for the floating population in Chicago, and in particular for the Loop

District. In 1920, this was estimated at 250,000 people. Of these 250,000, some are commuters from within the boundary of the district, but many undoubtedly come from the outside, according to our figures.

The hotels and clubs we think may house 100,000 people. The increase in floating population we have determined to be approximately 50,000 for every decade, so that we believe by 1945 that there is an effect from the floating population which might be between 375,000 and 475,000, for which we have made no allowance in these estimates.

We have also made no allowance for any factor of safety, to take [fol. 401] care of the variations due to the variations in industry, or to extremely hot weather, which you may get in the summer time, that would upset our allowance of the effect of the water taken from the Lake, or for other contingencies.

Neither have we allowed for any extension of the boundaries of the district, which I believe will undobutedly occur, as shown by our past experience. All these factors would tend to increase the expenditures for sewage treatment.

Q. And your cost figures, are they conservative?

A. I think the estimates of cost of construction are conservative. We based them on unit prices slightly lower than have prevailed in the last two years. The office experience in the Sanitary District during the last two years, and in fact since the beginning of the war, has indicated that the contractors that we have to deal with want more for doing the work than we as engineers generally estimate. I think in our experience in the last two years, if I am not mistaken in my recollection, we have in general received figures that are higher than the estimates we have made as engineers, along the lines indicated in my evidence.

I have further assumed that the general conditions of labor, and [fol. 402] of the material market, will continue. I have not attemped to estimate the possible changes that may occur in the stretch of twenty-five years.

Q. You have handed me a table here entitled "The Sanitary District of Chicago, expenditures for construction of sewage treatment works 1910-1922, showing the expenditures by years. You have made these figures from the records of the district, have you?

A. Yes, sir, I have had this table, which may be identified as Exhibit 4, prepared to show item by item the expenditures made from 1910 to 1922, on the different projects of the district applicable to sewage treatment. That is for intercepting sewers, pumping stations and sewage treatment works.

Mr. Adcock: I offer this table in evidence as Pearse Exhibit 4.

(Table of expenditures for construction of sewage treatment works 1910-1922 offered in evidence was marked Pearse Exhibit 4, April 26, 1923, and is hereto attached.)

[fol. 403] HENRY M. CHRISTIE, a witness called on behalf of the defendant, was first duly sworn by the Commissioner, and testified as follows:

Direct examination.

By Mr. Adcock:

Q. What is your full name?
A. Henry M. Christie.
Q. Where do you reside?
A. 4336 West 22nd Street, Chicago.
Q. Are you employed by the Sanitary District?
A. Yes, sir.
Q. How long have you been so employed?
A. With the exception of an interval in 1901-1902, and another interval in 1909-1910, since April 1892.
Q. What are your present duties with the Sanitary District?
A. Emergency work.
Q. Have you had any experience in accounting work?
A. Yes, sir.
Q. In the case of Duffy vs. Sanitary District, you did quite a lot of work, did you not, as accountant?
A. In June, on June 9, 1906, what was known as Waterpower Development Sections 1, 2 and 3 at Lockport were taken from the J. J. Duffy Company, and I was delegated by the Chief Engineer [fol. 404] to go down and take charge of the business end of the work, which continued the remainder of 1906 and all of 1907.
Q. Have you made any estimate of the present and future resources of the district, by way of bond issues and probable tax income as based upon the statute providing for the taxation by the trustees of the district, for levying taxes by the trustees of the district?
A. Yes, sir.
Q. Just state what you have done?
A. In March 1922, working with Mr. Raney, the present Assistant Chief Engineer, we compiled a table showing annually our expectations in income, consolidated with certain estimates of the Sanitary District Engineers as to a construction program; and brought that table down from 1922 to 1945 inclusive.
Q. Have you got that table here?
A. Yes (producing same).
Q. Now, will you take this table that you have just handed me, entitled "The Sanitary District of Chicago, composite statement estimating resources and liabilities under 1945 construction program": there are various columns there, varous headings and figures, will you state what those different columns mean and how they were gotten up.
[fol. 405] A. Column No. 1 shows the years.

Column No. 2 shows the population increment as based on the rates of increase shown by the last decennial period.

Q. Shown by Mr. Pearse?
A. Shown by Mr. Pearse and taken from the same basis.

Column No. 3 shows the estimated valuation, assessed valuation as taken from information obtained from the Assessor's Office of Cook County, the increases being based on past experience.

Q. So that you start out with an assessed valuation of nearly two billion dollars in 1921, and you have an assessed valuation in 1945 of $3,300,000,000?
A. Yes, sir. Column No. 4 shows the assessed valuation per capita.

Column No. 5 shows the future tax rate as taken uniformly at .40 of 1 per cent, this being assumed as the limit which the Sanitary District is likely to realize under the present conditions.

Q. You show 1921 as .36.
A. $0.36, that is all we may obtain that year. The taxes for 1922 are spread on 40 cents.
Q. Actual.
A. Actual, spread at 40 cents.
[fol. 406] Q. The same as for 1923. That has not been determined.
A. That assume we can do as well as 40 cents.
Q. That has not been determined yet?
A. Column No. 6 shows the taxes for any one year based on the assessed valuation of the preceding year. That is the taxes spread for 1923 will not be collected until 1924, so we show in that column the actual collection of taxes in that year.
Q. And that is less a certain amount for loss, on account of delinquents and costs of collection?
A. Yes. I would like to explain, in that 40 cents we figure a loss of at least ten per cent. That was Mr. Ramey's and our judgment at that time. I read in the paper the other day about a much greater loss this year, and I verified that by calling up Mr. Jacob Lindheimer, the Assistant Treasurer of Cook County in charge of collections, to-day, and he informed me that the loss this year would be fully 12 per cent; that delinquents this year amounted to $18,000,000 in all the public bodies in this county, so that the ten per cent in our judgment was not excessive at that time.
I would like to state too, in clarifying this: This statement was made in March 1922, and we estimated that the assessed valuation [fol. 407] would be $1,870,000,000. When we got our returns, we found that there was a reduction of the actual valuation for the year 1922 to $1,784,391,952.
Q. Now, you have column 7, bond issues.
A. Column 7, future bond issues, started in the year 1922 to provide the revenue necessary for the heavy construction program.
Column No. 8 shows the total gross revenues, and is the sum of the figures in columns 6 and 7, being the combined sum of the revenues derived from taxes and from sale of bonds.

Column No. 9 shows the amounts required each year to liquidate the present outstanding bonds. These are for old bonds that have been issued for prior work.

Column No. 10 shows the amounts required each year to pay the interest on the present outstanding bonds.

Column No. 11 shows the amounts required each year to redeem future bond issues, except for one issue, $3,000,000, in 1921. The bonds are figured for redemption at the rate of 5 per cent per year.

[fol. 408] Column No. 12 shows the interest on outstanding bonds. The future issues are computed at the rate of 4½ per cent per annum.

Column No. 13, shows the estimated cost of administration, and the ordinary expenses of maintenance and operation of the work of the Sanitary District, based on the experience of recent years.

Q. And also, as you get along down further, you take into consideration the increase due to the additional works.

A. The cost of increase, to provide for the operation of the different plants, yes, sir; to take care of the Desplaines plant going into commission in 1923, the Calumet in 1923, the Southwest and so on.

Q. And Column 14 is the total?

A. Total expenditures.

Q. Column 15 is the net revenue?

A. The approximate net revenue available for new constructions.

Mr. Adcock: I offer this table in evidence as Christie Exhibit 1 of this date.

(Table entitled "Composite statement estimating resources and liabilities under 1945 construction program," offered in evidence, was marked Christie Exhibit 1, April 26, 1923, and is hereto attached).

[fol. 409] Q. Have you made up a table showing the movement of iron ore during the year 1920 in reference to harbors, and the net tons moved, and if you have, state how you made that table up?

A. I have. I have a table showing the movement of iron ore during 1920, compiled from Part 2 of Chief of Engineers U. S. Army Report for the Fiscal Year ending June 30, 1921.

Q. And that table is made up merely from figures you have taken from that report, is that correct?

A. Merely a compilation of the figures taken from that report.

Mr. Adcock: I offer this in evidence as Christie Exhibit 2 of this date.

(Table showing movement of iron ore during 1920 offered in evidence, was marked Christie Exhibit 2, April 26, 1923, and is attached hereto.)

Q. Have you made up a table showing comparison of depths in certain channels and harbors at sundry elevations of the waters of Lakes Michigan, Huron, Erie and Superior?

A. Yes.

Q. And also showing the project depths under acts of Congress?

[fol. 410] A. Yes, sir.

Q. How did you do that?

A. This is a comparison of depths in certain channels and harbors at sundry elevations of the waters of Lakes Michigan, Huron, Erie and Superior, compiled from Bulletin No. 31, "Survey of Northern and Northwestern Lakes" issued by the U. S. Lake Survey office, Detroit Michigan, April 1922, and water level records furnished by the same authority.

Mr. Adcock: I offer this table in evidence as Christie Exhibit 3.

(Table of Comparison of Depths in certain channels and harbors at sundry elevations, offered in evidence was marked Christie Exhibit 3, April 26, 1923, and is hereto attached.)

Q. Have you made up a table showing a summary of statement of resources and expenditures of the Sanitary District of Chicago under 1922-1945 construction program?

A. I have.

Q. And that is taken from the figures you have presented, and [fol. 411] also from figures Mr. Pearse has presented, is that correct?

A. Yes, sir.

Mr. Adcock: I offer this statement in evidence as Christie Exhibit 4.

(Table summary of statement of resources and expenditures of the Sanitary District of Chicago, under 1922-1945 construction program, offered in evidence, was marked Christie Exhibit 4, April 26, 1923, and is hereto attached.)

Adjourned subject to notice.

[fol. 412] PEARSE EXHIBIT 1

April 25/23

"An ordinance of the Board of Trustees of the Sanitary District of Chicago laying out and adopting a program for the construction and operation of works for the purification of or the removal of solids and organic and inorganic matter from sewage, trade waste, offall and other organic and inorganic matter so that within the period of the next twenty-five years not more than fifty per cent of the amount of said sewage and waste that is now passing into the Desplaines River from the main channel of the Sanitary District will at the end of such period find its way into said river. Such works are to supplement those constructed or in process of construction for the diversion of sewage and drainage arising within the limits of the Sanitary District of Chicago.

Whereas, the Sanitary District of Chicago was organized and now [fol. 413] exists under an Act of the General Assembly passed on

May 29, 1889, in force July 1, 1889, entitled, "An Act to Create Sanitary Districts and to Remove Obstructions in the Illinois and Desplaines Rivers," and Acts amendatory thereof or supplementary thereto; and,

Whereas, The said Act of the General Assembly provided for the construction and operation of the Main Channel of the Sanitary District, including adjuncts and additions thereto whereby the sewage and drainage of the City of Chicago and its environs should be diverted from Lake Michigan to the Desplaines river, together with a certain amount of water from Lake Michigan fixed acording to the population of the District as it might exist when such Main Channel should be constructed and as the population might thereafter increase, to-wit: Twenty thousand cubic feet of water per minute for each one hundred thousand of the population; and the Board of Trustees of The Sanitary District of Chicago is directed by said Act of the General Assembly to operate said works specified with such diversion of water; and,

Whereas, Said Act of the General Assembly was passed and the works provided therein to be constructed were built in order to re- [fol. 414] lieve the people of Chicago and environs of a serious menace to their health and lives arising by virtue of the pollution of Lake Michigan, the only water supply of Chicago by sewage passing into same by way of the Chicago and Calumet rivers and by way of sewers debauching directly into the lake at various points along Chicago's water front; and the said works were intended also to relieve the Desplaines and Illinois rivers of a serious condition of pollution due to a certain amount sewage and wastes of Chicago and environs passing into said river through the Illinois and Michigan Canal; and,

Whereas, The death rate per year from typhoid fever prior to the operation of the Main Channel of the Sanitary District at times equalled one hundred ninety per one hundred thousand of the population of Chicago, and its environs, which required the immediate construction and operation of works to relieve such condition; and,

Whereas, Immediately after the passage of said Act of the General Assembly of May 29, 1889, the Sanitary District was organized and thereafter commenced the construction of the Main Channel of [fol. 415] the Sanitary District, extending from Robey street and the West Fork of the South Branch of the Chicago river to the Desplaines river near Lockport, Illinois, a distance of thirty-two miles; and the work of constructing said Main Channel was carried forward with due speed until January 17, 1900, when the said Main Channel was placed in operation pursuant to the permit of the Governor of Illinois, in accordance with said Act, and the permit and consent of the Secretary of War of the United States; and the said Main Channel of the Sanitary District cost the people of Chicago and its environs many million dollars; and there was required for such construction the use of all the money that could be raised by the Sanitary District from taxation and by the issuance of bonds; and,

Whereas, The Sanitary District was compelled to construct and place in operation many adjuncts and addition to the Main Channel of the Sanitary District in order that the said Main Channel might accomplish the purpose for which it was constructed and there would thereby be constructed and placed in operation a complete and comprehensive system for a diversion of the sewage and drainage arising within the limits of the Sanitary District from Lake Michigan to the Desplaines river; and such works included the intercepting sewers and pumping stations on the North Shore and South [fol. 416] Shore of Chicago, the Calumet-Sag Channel, with its intercepting sewers, the enlargement of the flowage channel of the South Branch of the Chicago river and the West Fork of said South Branch, and the replacing of many old center-pier bridges with bascule bridges of modern type, and they included also many other works of similar character; and the construction of such works has largely engaged the resources of the Sanitary District, and

Whereas, the Works so constructed and placed in operation have caused a decrease in the death rate from typhoid fever per year in the City of Chicago and environs from an average rate of over seventy-five per one hundred thousand of the population for the ten years immediately preceding the opening of the drainage channel, so that now the death rate from typhoid fever is less than one-half of one per one hundred thousand of population; and,

Whereas, The Board of Trustees of the Sanitary District has recognized that by reason of various conditions existing, such as trade wastes and other materials passing into its channels and the inability to obtain at all points the necessary amount of water to dilute the sewage, thus causing local nuisances, that works should be constructed [fol. 417] and operated to remove a material portion of organic and inorganic matter from human sewage, and also to remove and eliminate a material portion of trade wastes and other materials so that the amount of organic and inorganic matter in sewage and the amount of trade wastes and other materials passing through the Main Channel of the Sanitary District into the Desplaines river would be materially diminished; and The Sanitary District of Chicago has for such purposes carried on experiments and investigations to ascertain the best method to accomplish such results; and it has constructed at Morton Grove, Illinois, an Imhoff tank for the removal of a certain portion of the solids from the sewage of the Town of Morton Grove, and is constructing in connection with such Imhoff tank a sprinkling filter to further purify the sewage of said town; and the Sanitary District is constructing an activated sludge plant with necessary intercepting sewers for the collection and purification of the sewage of the Towns of Riverside, Maywood, River Forest and others, the sewage of which towns is now passing into the Desplaines river; and the Sanitary District has authorized the condemnation of one hundred acres of land near the Calumet sewage [fol. 418] pumping station at 125th Street and Michigan avenue, Chicago upon which site there is to be constructed an artificial sewage disposal plant for the removal of organic and inorganic matter from human sewage and wastes that may pass into the Calumet in-

tercepting sewer; and the Sanitary District of Chicago has, in the Stock Yards District, to take care of the trade wastes of Packingtown, acquired a site for purification works to be constructed thereon to remove trade wastes and organic and inorganic matters from human sewage now finding their way from that locality to the Main Channel of the Sanitary District; and the South Park Improvement Project provides for the setting aside of sufficient land for the construction of purification works for the sewage and wastes collected at 39th Street and Lake Michigan by the intercepting sewers converging at that point, which intercepting sewers serve a population of approximately five hundred thousand people, and,

Whereas, The Chief Engineer of The Sanitary District of Chicago has made investigation of the amount of trade wastes and other wastes requiring pure water to oxidize same, now being discharged through the Main Channel of the Sanitary District into the Desplaines river, [fol. 419] and the Chief Engineer has found and the Board of Trustees of the Sanitary District believes that the amount of such wastes is approximately equal, if it does not exceed, the amount of human sewage now passing into said Main Channel and through same to the Desplaines river; and that there is required to oxidize said wastes and render same innocuous and nonputrescible, as much or more water from Lake Michigan than is required to oxidize and render innocuous and nonputrescible the human sewage of the present population within the territorial limits of The Sanitary District of Chicago; and by reason of such wastes passing into said channe land thereby into the Desplaines river, the works of the Sanitary District do not fully accomplish the purpose designed and nuisances are created at various places, which nuisances should be abated; and,

Whereas, It is the recommendation of the Chief Engineer of the Sanitary District that works should be constructed and operated to supplement the diversion works of the Sanitary District constructed or in process of construction whereby the amount of human sewage and the amount of trade wastes and other material should be continuously diminished from year to year so that at the end of a period [fol. 420] of twenty-five years at least only one-half of the amount of sewage, including all wastes that is now passing into the Desplaines river from the Main Channel of the Sanitary District shall enter same by way of said Main Channel; and the Board of Trustees of the Sanitary District believes that within the period of four years works of such character can be constructed and placed in operation to materially diminish the amount of such sewage and wastes passing into the said Desplaines river, as aforesaid; now, therefore be it ordained by the Board of Trustees of the Sanitary District of Chicago:

Section 1. To supplement the works of The Sanitary District of Chicago now constructed or in the process of construction for the diversion of sewage or drainage, and to aid said works in better accomplishing the purpose for which they were constructed, the Sanitary District does hereby lay out and adopt a program for the construction and operation of works for the purification of sewage or the

removal of organic or inorganic matter from human sewage and the removal of trade wastes and other wastes and for the carrying on of such work at such a rate as continuously after the lapse of four [fol. 421] years to diminish the amount of sewage including all wastes passing into the Desplaines river by way of the Main Channel of The Sanitary District of Chicago, so that within the period of twenty-five years such purification works shall be constructed and in operation, that the amount of such raw sewage and wastes so passing into said Desplaines River shall be at least fifty per cent less than that passing now.

Sec. 2. The Chief Engineer and the Attorney of the Sanitary District are hereby directed to take such steps as may be necessary to carry forward the foregoing program, and the Chief Engineer is directed to report to such officers of the United States and the State of Illinois as may be interested, the progress made from time to time in carrying out said program.

Sec. 3. The foregoing preamble to this ordinance is hereby adopted and made a part of same.

Sec. 4. This ordinance shall be in full force and effect from and after its passage and adoption.

[fol. 422] STATE OF ILLINOIS,
County of Cook,
The Sanitary District of Chicago, ss:

I, William W. Smyth, Clerk of the Sanitary District of Chicago and keeper of its official records and seal, do hereby certify that the attached and foregoing is a true and correct copy of an ordinance of The Sanitary District of Chicago, entitled: "An Ordinance of the Board of Trustees of The Sanitary District of Chicago Laying Out and Adopting a Program for the Construction and Operation of Works for the Purification of or the Removal of Solids and Organic and Inorganic Matter from Sewage, Trade Waste, Offall and Other Organic and Inorganic Matter so That within the Period of the Next Twenty-Five Years Not More Than Fifty Per Cent of the Amount of Said Sewage and Waste That Is Now Passing into the Desplaines River from the Main Channel of the Sanitary District will at the End of Such Period Find Its Way Into said River. Such Works are to Supplement Those Constructed or in Process of Con- [fol. 423] struction for the Diversion of Sewage and Drainage Arising Within the Limits of The Sanitary District of Chicago," which said ordinance was passed by the Board of Trustees of The Sanitary District of Chicago at a regular meeting held on Thursday, August 7, 1919, and is now in full force and effect.

In witness whereof, I have hereunto set my hand and affixed the seal of The Sanitary District of Chcago this 27th day of May, A. D. 1922.

(Signed) Wm. W. Smyth, Clerk of the Sanitary District of Chicago. (Seal.)

[fol. 424] PEARSE EXHIBIT 2

April 25/23

An Ordinance of the Board of Trustees of the Sanitary District of Chicago offering and agreeing to defray the expense of the construction of works in one or more of the outlets of the Great Lakes to compensate for any diminishing levels of the Great Lakes and connecting waters due to the diversion of 10,000 cubic feet of water per second from Lake Michigan by the Sanitary District of Chicago and authorizing the attorneys of the Sanitary District in the suits pertaining to said diversion now pending in the District Court of the United States for the Northern District of Illinois, Eastern Division, to make and present such offer and agreement in open court.

Whereas, There are now pending in the District Court of the United States, for the Northern District of Illinois, Eastern Division, two suits in equity instituted by the United States against the Sanitary District concerning the withdrawal of water from Lake Michigan by The Sanitary District of Chicago. The first suit was [fol. 425] instituted in the year 1908 and pertains particularly to the construction and operation and withdrawal of water from the operation of the Calumet Sag Channel, an adjunct of the main channel of The Sanitary District of Chicago. The second suit was instituted in the year 1913 and seeks to enjoin the Sanitary District from withdrawing from Lake Michigan, through its various channels, including the Calumet-Sag Channel, then and now under construction, more than 4,167 cubic feet of water per second. The said suits have been tried together and submitted together upon briefs; and,

Whereas, The Honorable Kenesaw M. Landis, one of the Judges of said District Court of the United States, for the Northern District of Illinois, Eastern Division, before whom said cases have been pending, did recently render an opinion or direction for the entry of a decree in said cases, in substance, to enjoin the Sanitary District of Chicago, defendant in said cases, from withdrawing from Lake Michigan more than 4,167 cubic feet of water per second; and,

Whereas, Various reports have been submitted pursuant to acts of The Congress of the United States by the Engineer Corps of the [fol. 426] U. S. A. finding that the claim of injury to navigation arising from the lowering of lake levels be-ause of the diversion from Lake Michigan of water at Chicago to the extent of 10,000 cubic feet of water per second, may be compensated for by the construction of fixed weirs or works of similar character, or by the construction and operation of movable dams in the St. Clair, Niagara and St. Lawrence Rivers, or one or all of them, and that the expense of constructing said fixed weirs in the St. Clair and Niagara Rivers would, at the time the report was made, not exceed $475,000; and it was recommended that if The Sanitary District of Chicago should defray the expense of constructing such works, then they should be

maintained by and at the expense of the United States; and, if such works were constructed and placed in operation, thereby the ground of the United States for securing the injunction herein would be removed; and,

Whereas, It is the opinion of the Board of Trustees that if the Sanitary District is enjoined from taking more than 4,167 cubic feet of water per second from Lake Michigan for sanitary purposes, it will be necessary to expend, in the construction of works to arti- [fol. 427] ficially purify sewage, supplement and aid the works diverting 4,167 cubic feet of water upwards of $150,000,000, and the operation and maintenance of the same will exceed upwards of $5,000,000 per annum; and it is, further, the belief of the Board of Trustees of The Sanitary District of Chicago that it is doubtful whether such works, with said limited withdrawal of 4,167 cubic second feet of water will provide for the people of The Sanitary District of Chicago which includes the population of Chicago and its environs, a safe drinking water supply, for the reason that it would be impossible, with said limited withdrawal, to keep the Chicago River at all times reversed so that it would not flow into Lake Michigan, carrying with it a large amount of sewage and drainage, and it is doubtful whether such purification works would accomplish practical results.

Now, therefore, be it ordained by the Board of Trustees of the Sanitary District of Chicago:

Section 1. The Sanitary District of Chicago does hereby offer and agree to defray the expense, and pay to the United States Government the cost of constructing and maintaining works to be installed [fol. 428] at the outlet or outlets of any of the Great Lakes to compensate for any diminishing levels of the Great Lakes and connecting waters, due to a diversion or withdrawal from Lake Michigan of 10,000 cubic feet of water per second by The Sanitary District of Chicago through its various channels and diversion works in the event The Sanitary District is not enjoined from diverting from Lake Michigan less than 10,000 cubic seconds feet of water.

Section 2. The said offer and agreement contained in Section 1 hereof is intended to embrace and cover not only the expense of constructing and maintaining fixed weirs or dams described in the report entitled "Final Report of Waterway from Lockport to the Mouth of the Illinois River," House of Representatives Document, No. 762, Sixty-third Congress, Second Session, but also any other works of similar character that may be planned or provided for by the Congress of the United States or by competent Governmental authority or works known as "regulating works," consisting of movable dams or dams that may be moved from time to time, that may be planned or provided for by the Congress or other competent authority, such works having for their purpose compensation for any diminishing levels of the Great Lakes or connecting waters due [fol. 429] to a diversion at Chicago of 10,000 cubic second feet of water, and the said The Sanitary District of Chicago offers and agrees

to pay to the United States the expense of constructing and maintaining such works whenever the United States shall provide for such construction and make request for the payment of the amount of money necessary to construct and maintain the same.

Section 3. The attorneys for The Sanitary District of Chicago, in said two suits above described, wherein the United States is complainant and The Sanitary District of Chicago is defendant, on behalf of The Sanitary District of Chicago, are hereby authorized, empowered and directed to present and make said offer in open court in said causes, or in any other manner that the said attorneys may deem proper.

Section 4. The preambles to this Ordinance are hereby made a part of same and this Ordinance shall take effect and be in force from and after its passage.

[fol. 430] STATE OF ILLINOIS,
County of Cook,
The Sanitary District of Chicago, ss:

I, William W. Smyth, Clerk of The Sanitary District of Chicago and keeper of its official records and seal, do hereby certify that the attached and foregoing is a true and correct copy of an ordinance of The Sanitary District of Chicago, entitled: "An Ordinance of the Board of Trustees of the Sanitary District of Chicago Offering and Agreeing to Defray the Expense of the Construction of Works in One or More of the Outlets of the Great Lakes to compensate for Any Diminishing Levels of the Great Lakes and Connecting Waters Due to the Diversion of 10,000 cubic feet of Water per Second from Lake Michigan by the Sanitary District of Chicago, and Authorizing the Attorneys of the Sanitary District in the Suits Pertaining to Said Diversion Now Pending in the District Court of the United States, for the Northern District of Illinois, Eastern Division, to Make and [fol. 431] Present Such Offer and Agreement in Open Court," which said ordinance was passed by the Board of Trustees of The Sanitary District of Chicago at a regular meeting held on Thursday, July 8, 1920, and was duly approved by the President of said Board of Trustees and is now in full force and effect.

In witness whereof, I have hereunto set my hand and affixed the seal of The Sanitary District of Chicago this 27th day of May, A. D. 1922.

(Signed) Wm. W. Smyth, Clerk of the Sanitary District of Chicago. (Seal.)

[fol. 432] PEARSE EXHIBIT 3

Chi. R., 140

May 24, 1921.

The Division Engineer; the Chief Engineers, U. S. Army, Washington, D. C.:

Cooperation with the Trustees of the Sanitary District of Chicago in Making a Study of Sewage Purification

1. Referring to the letter of the Chief of Engineers dated March 25, 1920 (E. D. 28918), instructing me to cooperate with the Trustees of the Sanitary District of Chicago in making a study of sewage purification, I desire to submit the following report of progress:

2. The history of the controversy between the United States and the Sanitary District may be briefly reviewed as follows:

Under a permit issued by the Secretary of War on December 5, 1901, the Sanitary District was authorized to divert through the drainage canal a maximum of 4,167 second feet of water from Lake Michigan for sanitary purposes. Since the permit was granted the Board of Trustees of the Sanitary District has made repeated applications for permission to increase the flow, which requests have [fol. 433] consistently been denied by the Secretary of War on the grounds that the permit already issued is of a temporary nature only and that congressional authority is necessary for any permanent diversion. In 1907 the Board of Trustees made application for authority to construct the Calumet-Sag Channel to connect the Calumet River with the main Drainage Canal, and to draw through it 4,000 second feet in addition to the 4,167 second feet previously authorized for the Chicago River. This application was denied, and the Board of Trustees thereupon declared its intention of proce-ding with the proposed work and withdrawing from Lake Michigan the additional 4,000 second feet without the sanction of the Secretary of War, unless prevented by injunction proceedings.

3. A suit was then instituted in March, 1908, by the Attorney General of the United States to restrain the Sanitary District from reversing the flow of the Calumet River and from withdrawing water from Lake Michigan in any other manner and in any greater quantity than that authorized by the Secretary of War.

4. Being thus stopped by court action from proceedings with its Calumet program, the Board of Trustees in 1910 applied for authority [fol. 434] to construct the Calumet-Sag Channel so as to carry the present flow through the two drainage canals instead of only one. In response to this application the Department on June 30, 1910, modified the existing authority so as to allow the previously authorized flow of 4,167 second feet to reach the main Drainage Canal through the Calumet-Sag Channel as well as through the Chicago River, provided, however, that the total amount withdrawn through

the two outlets should not exceed the 4,167 second feet already authorized to be withdrawn through the Chicago River alone.

5. However, the Board of Trustees was not satisfied with this limitation, and in 1912 made application for authority to withdraw through the two rivers, the Chicago and Calumet, a total of 10,000 second feet. After a public hearing this application was denied by the Secretary of War on January 8, 1913. As the Board refused to accept this decision, the attorney General filed another bill in October, 1913. This suit was combined with the one filed in 1908, but on account of the war and other reasons no decision was rendered by the court until June 19, 1920. On that date Judge Landis rendered an "oral opinion" in which he held that the 8,500 second [fol. 435] feet, more or less, which the Sanitary District was now diverting from Lake Michigan, had resulted in a lowering of the lake levels, and an impairment of the navigable capacity of all of the great lakes except Lake Superior; and that said diversion was not necessary "for the salvation of this community." He directed the attorneys for the two sides to get together and prepare for his signature an order sustaining the contentions of the plaintiff, to be effective 60 days after the meeting of the Supreme Court in October.

6. Instead of that, Judge Landis, in August, 1920, in the presence of the District Attorney and myself, heard the Sanitary District Attorney, Mr. Adcock, argue that the Judge should modify his oral opinion so as to allow a total flow of 10,000 second feet. As the arguments were not finished that day the hearing was adjourned to be concluded at his summer home at Trout Lake, Mich., on some day which was to be arranged later. On account of the sickness of the Judge's brother the adjourned meeting, which had been set for the latter part of August, was again postponed and has not been taken up since.

7. Ignoring all questions except that of the proper reduction and [fol. 436] disposal of Chicago sewage, by the existing method, it is apparent, from many considerations that an excessive amount of water from Lake Michigan is not being used. Contamination of the Illinois River is proceeding rapidly down stream toward Peoria; parts of the Chicago River and its branches show a state of contamination which is all too apparent to the eye and to the nose. It is easy to believe that if, under present conditions of sewage disposal, the amount of water from Lake Michigan is suddenly curtailed, the health of Chicago might be threatened. It is apparent therefore, that if the amount of water diverted from Lake Michigan is not to increase proportionately with the increase of population in Chicago and if health conditions in Chicago are to remain normal, there must be treatment of Chicago sewage. In 1919, with these facts in mind I took up with the Trustees of the Sanitary District the question of adopting an effective program for sewage disposal. As a result, a program was adopted on August 7, 1919, which contemplated that during the following four years there should be accomplished such work of land acquisition, planning, financing and actual con-

struction as would result in a continuous reduction thereafter of the raw sewage entering the drainage canal. The program further pro-
[fol. 437] vided that by the expiration of twenty-five years from the date of the program the work of purification shall have been so far advanced that the amount of raw sewage entering the Drainage Canal shall equal not more than one-half of that entering now, and this reduction must occur notwithstanding the fact that at the expiration of twenty-five years the amount of raw sewage produced in the district may be almost double that now originating there. Thus by the end of the twenty-five years period the Sanitary District might be required to treat some 50% more raw sewage than that now enters the Drainage Canal. The cost of carrying out this program was roughly estimated at $140,000,000.

8. The Sanitary District has had studies made by Mr. Francis C. Shenehon, a competent hydraulic engineer, for regulating and compensating works in the Niagara River and at the Galops Rapids in the St. Lawrence below the lower end of Lake Ontario. Mr. Shenehon has prepared preliminary plans and estimates for the works above mentioned. He estimates that regulating works in the Niagara River would cost approximately $1,224,000, and those at the Galops Rapids approximately $1,000,000. It is understood that the Sani-
[fol. 438] tary District, if the engineering propositions of Mr. Shenehon are approved by the United States, proposes to turn over to the latter the amount required for the construction of the works above described, the maintenance and operation of the same to be at the expense of the United States. These works, it may be said, contemplate a diversion of 10,000 cubic feet per second from Lake Michigan to the Drainage Canal. Digests of these two projects as prepared for me by Mr. Shenehon at my request are as follows:

Digest of Niagara Regulation Project

The Niagara River Regulation contemplates slack-water, vessel-draft betterments in Lake Erie, the Detroit River, Lake St. Clair and St. Clair River, Lakes Michigan and Huron and St. Mary's River to the locks at Sault Ste Marie.

The loss of draft due to a diversion of 10,000 second feet at Chicago is about 5½ inches. In a low water period such as the ten years 1893-1902, the regulation proposed will add over 14 inches to the depth of Lake Erie and Lower Detroit River; over 10 inches to Lake St. Clair, the Upper Detroit River and the Lower St. Clair
[fol. 439] River, with proportionate increase in St. Marys River. In a decade of more plentiful supply, the average betterment is less, because no increase in Lake stage is practicable at flood height. The regulation will compensate for lowerings due to all anticipated diversions at Chicago, in the Welland and Erie Canals and in the Niagara River for power purposes, and the regulation is accomplished without danger of riparian damage from flood stages.

The excess flow of May to August inclusive is saved to hol- up Lake Erie level during the season of navigation. The Niagara River

runs free from January to March inclusive, to avoid flood stages, to give unimpeded passage for ice and to add water for power purposes during the season of ice complications. Water power is the beneficiary of the larger winter flow, which averages 17,000 second feet in January and February, more than off-setting a diversion of 10,000 second feet at Chicago.

During the summer season about 30,000 second feet in addition to the controlled flow would be released during part of each day to furnish mill-pond water for power uses, so that the full natural river flow may pass over the cataracts to preserve scenic grandeur. Regu- [fol. 440] lation of the Niagara has been delayed by the fear of the people of Buffalo that regulating works would cause ice jams and hold up the vast ice fields which cover the east end of Lake Erie. This objection is met by placing removable vessel-type gates, which are removed in January and replaced in May.

The site chosen for works is at the head of the Niagara River, opposite the old water-works at Buffalo. The River is 1,800 feet wide here with bed limestone bottom. The river channel is divided into two sluice-ways by a submerged concrete wall, three-quarters of a mile long and parallel with the current. This carries a shutter dam to complete the partition and the shutters knock down during the winter. Four gates, each equipped with twelve large butterfly valves, close off the American Sluiceway. These gates rest and swing on massive concrete emplacements rising about two feet above the rock bottom. Special devices make the placing and removing of these gates easy. As each inch of added draft in Lake Erie is estimated as having a yearly value, of half a million dollars, the average increase of 13 inches is significant. The far reaching bene- [fol. 441] fits, from Buffalo to Sault Ste. Marie, without works or wiers in the Detroit or St. Clair Rivers, point this out as a project of great concern. The Niagara and St. Lawrence regulations work haul-in-hand.

Digest of St. Lawrence Regulation Project

The St. Laurence River Regulation contemplates higher surface levels for Lake Ontario in years when the lake is naturally low, and the avoidance of high stages which might cause riparian damage. This depends on the simple principles of slack-water betterment, utilizing movable regulating gates, which when open leave the full out-flow capacity of the lake undiminished as a safeguard against flood conditions. The aim of the project is not alone to restore the loss of navigable depth due to a diversion of 10,000 second feet at Chicago (5½ inches), but to maintain the lake at the highest practicable safe stage. By the manipulation of the outflow computations show 19½ inches gain for the record low water year 1895; over 21 inches gain for the ten-year period 1893-1902; and over 12 inches betterment for the normal supply period 1907-1916.

[fol. 442] The lower limit of slack-water betterment is at the Galops Rapids below Ogdensburg, New York, Navigation betterment below

these rapids is secured by impounding in Lake Ontario the excess supply of the flood months March, April, May and June, and holding this reservoired water for release in the fall months August to November, inclusive. It is found that, while Chicago takes away 10,000 second feet, this is replaced by 9,000 second feet of impounded water in September, 16,000 second feet in October and 20,000 second feet in November. The lower St. Lawrence is dependent for good volume of flow on Lake Ontario water only in these fall months. The Ottawa River entering the St. Lawrence at Montreal has a May flow of 150,000 second feet dwindling to perhaps 20,000 second feet in September, October and November.

Budgeting Lake Ontario water aids water-power by greater uniformity of flow. The attenuated January-February flow is diminished by 10,000 second feet for Chicago, and 17,000 second feet of impounded water more than restores the loss.

The two channels of the Galops Rapids are natural Sluiceways controlling the outflow of Lake Ontario. The Canadian Channel will remain unobstructed. The non-navigable American Channel, [fol. 443] carrying 43 per cent of the outflow, will be throttled by 1,020 feet in length of regulating works. The bottom is bed limestone, probably over-lain in part of glacial drift. The works are placed at the head of this channel. The gates consist of wickets, dropped from five 200-foot span steel bridge platforms. Some increase in outflow capacity of the American Channel is recommended.

9. The special Board of Waterway from Lockport, Ill., to the Mouth of the Illinois River, etc., reported that it would require $150,000 to build works in the Niagara River, and $325,000 for works in the St. Clair River to compensate in Lakes Michigan, Huron and Erie for a lowering of their levels due to the diversion of 10,000 second feet, with $15,000 annually for maintenance.

10. The Sanitary Trustees are very anxious to have a determination at this time of the amount of water the United States will permit to be diverted from the Lake. It seems to be admitted now by all concerned that this matter should be settled by Act of Congress. For example, see page 6, House Doc. 762, 63d Cong., 2d Session, from which the following is quoted:

"Further the Board believes that the total volume of water to be [fol. 444] diverted from the natural discharge channels of the Lakes should be definitely fixed by Congress; that a project with estimate of cost for works necessary to compensate for such diversion should be prepared to the satisfaction of the Chief of Engineers and the Secretary of War; that before any diversion is made beyond that at present existing, the State of Illinois, shall transfer to the Secretary of War the funds necessary for such works as given by the approved estimate of cost; that the works shall be built by the United States with the funds so provided; and that the control and maintenance of such works shall be in and at the cost of the United States."

11. The circumstances that the State of Illinois is now engaged in constructing a navigable link between the Sanitary District Canal

and the Illinois River at Utica makes it extremely desirable that an early determination be made of the amount of flow to be authorized permanently from Lake Michigan. Upon the amount of flow so au-
[fol. 445] thorized will depend to a large extent the character of the improvements which will be necessary to provide an 8 foot channel in the Illinois River should that depth be authorized by Congress.

12. In the letter from the Chief of Engineers dated March 25, 1920 (E. D. 28918) hereinbefore referred to, I was inforced that "at a conference with representatives of the Chicago Sewage Disposal Commission and the Sanitary District Trustee" (sic), it was agreed that the Trustees of the Drainage Canal and the Sanitary Officers of the State would make a study to ascertain what could be accomplished in regard to sewage purification before the sewage was allowed to enter the Drainage Canal or the Illinois River, and the results of such study communicated to the Chief of Engineers through the District Engineer at Chicago. In this same letter I was instructed to cooperate with the Trustees in their study of the case and to render such assistance as I was able, the study to be made "with the idea of withdrawing the least amount of water from Lake Michigan which would be necessary for the purpose."

13. In accordance with the instructions of the Chief of Engineers
[fol. 446] as contained in his letter of March 25, 1920 above referred to, I have held numerous conferences with the Officials of the Sanitary District with regard to their plane for sewage treatment. During the past year there has been considerable change in the official personnel of the Sanitary District, especially among those actively engaged in formulating plane for their sewage treatment system. Among those are the President Chief Engineer, General Counsel and a number of Trustees, considering these conditions the progress made has been very satisfactory.

14. In regard to the contention of the Sanitary District that it is necessary to divert more than 4,167 cubic feet per second in order to avoid contamination of the City water supply and consequent epidemics, I was empowered in a memorandum of the Secretary of War for the Chief Engineers dated July 21, 1920 to say "that if Judge Landis' decree is accepted as final, the War Department will issue no permit, since it is without legal power to do so, but will ask no further orders from the Court to enforce the limitation so long as the City of Chicago proceeds with dispatch to prepare plans and put them into process of execution for its sewage system. If the City of Chicago then prepares plans and consents to the War De-
[fol. 447] partment having current knowledge of its activity, either by reports to the courts or otherwise, the situation will be under the control of Judge Landis until the whole problem is disposed of. If however, the City of Chicago proposes to appeal the case and taken no steps pending the appeal to cure the trouble, Colonel Judson should be instructed to make no concessions or promises of any kind." This memorandum of the Secretary of War was obtained through the Chief of Engineers at my solicitation for use whenever Judge Landis decides to finish the hearing on Attorney Adcock's arguments for

allowing a total diversion of 10,000 second feet. In this connection Mr. Odcock was making the argument that the War Department would be arbitrary in acting on the findings of the court, and a statement was desired which would show that the Secretary of War would not be arbitrary in the matter.

15. On January 17, 1921, a formal conference was held between Mr. Chas. F. Clyne, United States Attorney, and myself representing the United States and the Trustees of the Sanitary District, their attorneys, Consulting Engineer and Chief Engineer. At this conference attention was invited o the Memorandum of the Secretary [fol. 448] of War for the Chief of Engineers dated July 21, 1920, above referred to, copies of which were furnished the Attorneys for the Sanitary District. The Trustees agreed to take under advisement the proposition of the Secretary of War as set forth in his memorandum and to submit an answer thereto at a later date. At this conference an agreement was reached with the Sanitary District authorities that I be furnished with an outline of their present plans for sewage treatment. A copy of the memorandum furnished in accordance with the above agreement giving an outline of the work already completed, that now under way and proposed, and indicating the probable future policy of the Trustees, is enclosed herewith.

16. A second conference was held on February 7, 1921, at which the United States Attorney was represented by his assistant Mr. J. B. Boddie. The proposal of the Secretary of War as embraced in the last paragraph of his memorandum of July 21, 1920 (E. D. 98093/657), was discussed and the Sanitary Trustees stated that they were unable to accept the proposition that Judge Landis' decree be accepted as final. On the other hand they stated that they would pro- [fol. 449] ceed diligently in the preparation and execution of plans for the treatment of sewage within the Sanitary District. They stated that since the conference of January 17, 1921, they had prepared their budget and in it had placed some $8,000,000 for sewage treatment operations, and that in subsequent budgets they would continue to provide for work upon a large scale to carry into effect plans already prepared or now being prepared for sewage treatment. They estimated that depending upon conditions in the labor and material market the entire cost of such treatment would be in excess of $100,000,000 and perhaps as much as $140,000,000 but stated that they were confident that they could provide this sum so that in somewhat less than 25 years they would be able to at least carry out the program adopted August 7, 1919, and perhaps do even better than was proposed in that program.

17. It was understood that the matter before Judge Landis would be proceeded with regardless of the more or less futile negotiations that have been in progress with reference to the proposition of the Secretary of War that the decree of Judge Landis be accepted as final. Mr. Boddie stated that he understood the situation and understood it to be the duty of the United States Attorney's office to proceed with [fol. 450] efforts on its part to secure the formulation and entering

of the formal decree by Judge Landis, opposing any efforts of the Sanitary District to procure a modification of the decree. It may of course be regarded as a fact that the Sanitary Trustees will appeal from the decree of Judge Landis if it is entered without modification, satisfactory to them.

18. The Chief Engineer of the Sanitary District, at the conference of February 7, 1921, informed me that it was the intention of a committee of Trustees and employes of the Sanitary District, including himself, to visit Fort Worth and Houston, Texas, and other localities, at an early date, to inspect activated sludge plants in course of construction or operation and suggested that I accompany them. This I subsequently undertook to do but my travels were interrupted by illness.

19. While the Sanitary District doubtless has authority under existing state laws to proceed with its sewage treatment program, in an excess of caution it has caused bills to be introduced in the State Legislature for explicit authority to construct the proposed sewage treatment works, in accordance with the accompanying memorandum, and the controlling works in the Niagara and St. Lawrence [fol. 451] Rivers as well, in accordance with the projects of Mr. Francis C. Shenehon, hereinbefore referred to. These bills are still pending with good prospects that they will be passed.

Opposing interests are also endeavoring to secure legislation to limit the bonding power of the Sanitary District, by requiring that each bond issue be subject to a referendum.

20. In the meantime the Sanitary Trustees are proceeding energetically with their plans for sewage treatment and disposal as outlined in enclosed memorandum. Since the date of their report they have acquired 180 acres of land located on the North Shore Channel as a site for their proposed North Side purification plant.

21. The progress made by the Sanitary District is well illustrated by Exhibits E and F constituting part of enclosure showing their budget appropriation for 1921 and their expenditures during the ten year period 1910-1920. During the last named period the expenditure for sewage treatment works has amounted to approximately $9,400,000. Their budget for 1921 provides $6,500,800 for the completion of old projects and $3,242,500 for new projects.

22. The program of the Sanitary District, if carried out, will [fol. 452] insure the practicability of keeping the volume of water diverted from Lake Michigan within limits which it is hoped all concerned will finally deem reasonable.

W. V. Judson, Colonel, Corps of Engineers, Divn. Engr., N. W. Divn. 1 encl.

[fol. 453] PEARSE EXHIBIT 4—Apr. 25/23

The Sanitary District of Chicago

Population and Area

Year	Population	Area	Date of census
1890	1,149,758	185.0	June 1
1900	1,775,832	185.0	June 1
1910	2,311,810	358.1	Apr. 15
1919	2,940,906*	388.14*	.....
1920	2,986,000	395.51	Jan. 1
1921	3,071,000	.....	.....
1922	3,142,000	437.39	.....

[fol. 454] PEARSE EXHIBIT 5—Apr. 25/23

The Sanitary District of Chicago

Population in Various Sewerage Districts

Locations	1920	1930	1940	1950	1960
North Side Treatment Plant	590,000	800,000	1,615,000	1,230,000	1,450,000
West Middle Plant Incl. Loop	1,300,000	1,420,000	1,550,000	1,680,000	1,800,000
S. W. Treatment	850,000	1,040,000	1,230,000	1,415,000	1,600,000
Calumet	160,000	225,000	290,000	350,000	415,000
Miscellaneous	100,000	215,000	340,000	465,000	595,000
S. D. C. Total	3,000,000	3,710,000	4,425,000	5,140,000	5,860,000

Dec. 31, 1921.

[fol. 455] PEARSE EXHIBIT 6—Apr. 25/23

The Sanitary District of Chicago

Population Estimates

Year	Human	Industrial equivalent	Total
1920	3,000,000†	1,500,000	4,500,000
1930	3,710,000	1,700,000	5,410,000
1940	4,425,000	1,900,000	6,325,000
1945	4,782,000	2,000,000	6,782,000
1950	5,140,000	2,100,000	7,240,000
1955	5,500,000	2,200,000	7,700,000
1960	5,860,000	2,300,000	8,160,000

*In June, prior to annexation of Salt Creek Villages.
†Based on 1920 Census.

[fol. 456] PEARSE EXHIBIT 7—Apr. 25/23

Year	Population	Mil. gal. per 24 hr.	Gal. per cap. per 24 hr.	Max. rate mil. gal. per 24 hr.
1920	2,700,190	715	265	945
1945	3,919,275	1,355	346	1,800
1955	4,406,909	1,610	365	2,130

[fol. 457] PEARSE EXHIBIT 1—Apr. 26/23

The Sanitary District of Chicago

Estimated Costs of Sewage Treatment Projects and Necessary Construction Work for Period 1922-1945

Work under contract and completed project	Contract liability	Date of completion
Calumet Treatment Plant	$2,200,000	1922
" Mach. & Adm. Bldg	520,000	1923
" Sewers—Contract #10	130,000	1922
" " " #11	2,300,000	1923
Desplaines Treatment Plant	300,000	1922
Oak Park Sewer	500,000	1922
39th St. Conduit Extension	2,000,000	1924
Calumet Sag Channel	200,000	1922
North Side Sewers—Contract #1	1,610,000	1923
Proposed work	**Estimated cost**	
Calumet Sewers—Contract #1	400,000	1923
Harbor Ave. Sewer	250,000	1924
Extension Blue Island Sewer	425,000	1928
Sewer to Riverdale & Dolton	200,000	1928
Sewer—Burnham, Hegewisch & W. Hammond	500,000	1928
95th St. Pumping Station	1,000,000	1924
Calumet Sag Channel	120,000	1923
Dredging Calumet River	1,000,000	1929
Glenview Treatment Plant	25,000	1922
La Grange Sewer & Treatment Plant	75,000	1923
Oak Forest Sewer	300,000	1923
Extension Desplaines Plant	100,000	1924
California Ave. Bridge	750,000	1924
Elmwood Park Sewer	250,000	1925
Stockyards Treat. Plant (Demonstration)	350,000	1926
" Sewers, Pump. Sta. & Screens	1,000,000	1926
Cicero Ave. Bridge	1,500,000	1926
Remodel Lawrence Ave. Pump. Sta	200,000	1926
Broadview Sewers	200,000	1926
Corn Products Treatment Plant	1,500,000	1927

Proposed work	Estimated cost	
Regulation Works—Niagara & St. Lawrence	2,500,000	1927
North Side Treatment Plant	13,500,000	1928
" " Sewers (exc. Cont. #1)	7,800,000	1928
Crawford Ave. Bridge	1,500,000	1928
Harlem Ave. Bridge	1,000,000	1929
Calumet Sp. Filters & Plant	2,000,000	1930
Extension Northside Plant	2,000,000	1931
Stockyards Treatment Plant	6,000,000	1932
Remodeling 39th St. & 73rd St. Pumping Sta.	900,000	1934
West Side Sewers	13,300,000	1940
" " Treat. Plant (Imhoff)	10,900,000	1940
South West Side Sewers	9,400,000	1945
" " " Treat. Plant (Imhoff)	7,200,000	1945
*Misc. Treat. Plants & Sewers	11,200,000	1927–1945

[fol. 458] PEARSE EXHIBIT 2—Apr. 26/23

Expenditures for Sewage Treatment Since 1909 for Construction Purposes

Year	Total
1910	$157,816
1	.....
2	55,269
3	19,683
4	490,468
5	280,348
6	700,648
7	1,533,260
8	1,543,227
9	1,803,064
1920	2,835,387
1	5,052,511
2	6,691,982
	$21,163,663

*To cover miscellaneous work which it is impossible to forsee and sewers for upper Desplaines River towns.

[fol. 459] PEARSE EXHIBIT 3—Apr. 26/23

The Sanitary District of Chicago

Expenditures for Sites for Sewage Treatment Works Up to 1921

Treatment plant	Amount paid for site	When acquired
Calumet Pumping Station	$12,423.40	May 27, 1015
Calumet Treatment Plant	159,636.00	Feb. 13, 1920
Desplaines Treatment Plant	25,194.00	Oct. 4, 1917
52nd Ave. Treatment Plant	39,505.88	Mar. 31, 1913
Evanston Pumping Station	11,341.60	April 20, 1916
North Side Treatment	269,995.00	April 21, 1921

(Here follow Pearse Exhibit 4 and Christie Exhibit 1, marked side folio pages 460 and 461.)

[fol. 462] CHRISTIE EX. 2—Apr. 26/23

TABLE I

Table Showing Movement of Iron Ore During 1920

Compiled from Part 2 of Chief of Engineers, U. S. Army Report, for Fiscal Year Ended June 30th, 1921

Page	Harbors	Shipment–Tons	
1001	Duluth, Minn	33,771,582	
1008	Ashland, Wis	9,162,554	
998	Agate Bay, Minn	10,391,879	
1017 / 1018	Marquette, Mich	3,824,921	
1030	Escanaba, Mich	7,361,069	
			64,512,005 Tons

[fol. 460]

W. 39th St. Conduit & Western Ave. Sewer	
52nd Ave. Sewer & Outlet	
52nd Ave. & W. 39th St. Sewer	
North Shore Interceptor, Contract 1	
North Shore Interceptor, Contract 2	
North Shore Interceptor, Contract 3	
Morton Grove Settling Plant	
Calumet Intercepting Sewer, Contract 2	
Calumet Intercepting Sewer, Contract 3	
Stockyards Intercepting Sewer	
Niles Center Sewer	
Evanston Intercepting Sewer	
Calumet Intercepting Sewer, Contract 4	
Calumet Intercepting Sewer, Contract 5	
Calumet Intercepting Sewer, Contract 6	
Calumet Intercepting Sewer, Contract 7	
Des Plaines River Intercepting Sewer	
Calumet Pumping Station	
Evanston Pumping Station	
Des Plaines Treatment Plant (All Divisions)	
Morton Grove Sprinkling Filter	
W. 39th St. Extension (Division A)	
Calumet Power Plant	
Calumet Treatment Works (Division A)	
Calumet Treatment Works (Division B)	
Calumet Treatment Works (Div. C. D. E. F. G & H)	
Calumet Intercepting Sewer, Contract 8	
Calumet Intercepting Sewer, Contract 9	
Calumet Intercepting Sewer, Contract 10	
Calumet Intercepting Sewer, Contract 11	
Oak Park Outfall	
W. 39th St. Extension (Division B)	
North Side Intercepting Sewer, Contract 1	
Total	

*Credit from Union Stockyards and Transit Co.

PEARSE EXHIBIT 4—Apr. 26/23

The Sanitary District of Chicago

Expenditures for Construction of Sewage Treatment Works, 1910-1922

1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
157,816	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	157,816
.....	.....	55,269	3,807	.....	.....	4,918	.....	.....	.....	.....	.....	.....	63,994
.....	.....	.....	15,876	140,771	28,155	.....	.....	16,360	.....	.....	.....	.....	201,162
.....	.....	.....	.....	197,710	52,113	30,409	.....	.....	.....	.....	.....	.....	280,232
.....	.....	.....	.....	86,383	14	.....	.....	.....	.....	.....	.....	.....	86,397
.....	.....	.....	.....	57,106	168,529	35,290	.....	.....	.....	.....	.....	.....	260,925
.....	.....	.....	.....	8,498	651	.....	.....	.....	.....	.....	.....	.....	9,149
.....	.....	.....	.....	.....	.....	94,911	88,272	1,505	.....	.....	.....	.....	184,688
.....	.....	.....	.....	.....	30,887	290,327	4,943	.....	.....	.....	.....	.....	326,157
.....	.....	.....	.....	.....	.....	96,587	*10,799	*673	.....	.....	.....	.....	85,115
.....	.....	.....	.....	.....	.....	1,442	22,695	299	.....	.....	.....	.....	24,436
.....	.....	.....	.....	.....	.....	7,571	479,901	467,731	119,570	262,982	14,016	.....	1,351,771
.....	.....	.....	.....	.....	.....	57,442	300,868	258,034	28,683	116,272	.....	.....	761,299
.....	.....	.....	.....	.....	.....	.....	.....	2,300	48,190	628,811	20,273	.....	699,574
.....	.....	.....	.....	.....	.....	95,764	198,737	226,833	65,141	231,302	.....	.....	817,777
.....	.....	.....	.....	.....	.....	25,987	448,649	446,681	.....	126,058	.....	.....	1,047,375
.....	.....	.....	.....	.....	.....	.....	.....	13,179	480,172	85,808	.....	4,071	583,230
.....	.....	.....	.....	.....	.....	.....	.....	110,978	636,847	560,790	55,021	369	1,364,005
.....	.....	.....	.....	.....	.....	.....	.....	.....	242,392	85,415	112,114	.....	439,921
.....	.....	.....	.....	.....	.....	.....	.....	.....	155,654	212,377	272,745	352,609	993,385
.....	.....	.....	.....	.....	.....	.....	.....	.....	26,415	12,465	.....	.....	38,880
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	173,915	277,155	.....	451,070
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	249,737	729,922	145,864	1,125,523
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7,197	1,547	.....	8,744
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	59,158	550,594	5,000	614,752
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	23,100	2,510,095	2,945,332	5,478,527
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	163,237	5,885	169,122
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	94,207	72,646	166,853
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	145,548	145,548
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	521,883	521,883
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	251,585	535,484	787,069
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	97,696	97,696
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1,902,700	1,902,700
157,816	.....	55,269	19,683	490,468	280,349	740,648	1,533,266	1,543,227	1,803,064	2,835,387	5,052,511	6,735,087	21,246,775

April 19, 1923.

[fol. 461]

CHRISTIE Ex. 1—Apr. 26/23

The Sanitary District of Chicago

Composite Statement Estimating Resources and Liabilities under 1940 Construction Progeam

Year	Population	Assessed valuation		Receipts				Expenditures						Net revenue available for new construction	Construction program
								Outstanding bonds		Future bond issues		Administration & maintenance & operation			
		Total	Per capita	Tax rate per $100 valuation	Tax receipts levy less 10% a/c costs and delinquencies	Bond issues	Total	Redemption	Interest	Redemption	Interest		Total		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1921	3,071,000	$1,824,157,564	$594	$0.36	.....	*$3,750,000	.....	.....	.....	.....	.....	.....	.....	.....	.....
1922	3,142,	1,870,	595	.40	$5,900,000	2,000,000	$11,650,000	$1,551,000	$944,440	.....	.....	$2,100,000	$4,595,440	$7,054,560	$6,400,000
1923	3,213,	1,915,	596	.40	6,650,000	6,000,	12,650,	2,146,	1,129,340	$1,000,000	$90,000	2,400,	5,865,340	6,784,660	7,000,
1924	3,284,	1,965,	598	.40	6,900,000	6,000,	12,900,	1,980,	1,035,960	400,	355,500	2,500,	6,271,460	6,628,540	7,000,
1925	3,355,	2,015,	600	.40	7,100,	7,000,	14,100,	1,880,	949,060	700,	607,500	2,600,	6,736,560	7,363,440	7,000,
1926	3,426,	2,065,	603	.40	7,250,	7,000,	14,250,	1,824,	866,160	1,050,	891,000	2,700,	7,331,160	6,918,840	7,000,
1927	3,497,	2,115,	605	.40	7,450,	8,000,	15,450,	2,124,	785,500	1,400,	1,158,750	2,800,	8,268,250	7,181,750	6,600,
1928	3,568,	2,170,	608	.40	7,600,	7,000,	14,600,	2,076,	685,340	1,800,	1,455,750	2,900,	8,917,090	5,682,910	6,100,
1929	3,639,	2,225,	611	.40	7,800,	9,000,	16,800,	2,076,	587,100	2,150,	1,689,750	3,900,	10,402,850	6,397,150	6,000,
1930	3,710,	2,280,	615	.40	8,000,	9,000,	17,000,	1,951,	488,860	2,600,	1,998,000	4,500,	11,537,860	5,462,140	5,500,
1931	3,782,	2,345,	620	.40	8,200,	8,000,	16,200,	1,373,	395,620	3,050,	2,286,000	4,500,	11,604,620	4,595,380	5,200,
1932	3,854,	2,400,	623	.40	8,450,	8,000,	16,450,	1,270,	330,500	3,450,	2,506,750	4,500,	12,057,250	4,392,750	4,200,
1933	3,926,	2,460,	627	.40	8,650,	8,000,	16,650,	770,	269,500	3,850,	2,713,500	4,500,	12,103,000	4,547,000	4,200,
1934	3,998,	2,520,	630	.40	8,850,	8,000,	16,850,	770,	233,500	4,250,	2,900,250	4,500,	12,653,750	4,196,250	4,200,
1935	4,070,	2,580,	634	.40	9,050,	8,000,	17,050,	770,	197,500	4,650,	3,069,000	4,500,	13,186,500	3,863,500	4,200,
1936	4,142,	2,645,	639	.40	9,300,	9,000,	18,300,	670,	161,500	5,050,	3,219,750	4,500,	13,601,250	4,698,750	4,200,
1937	4,214,	2,710,	643	.40	9,500,	9,000,	18,500,	670,	129,500	5,500,	3,397,500	4,500,	14,197,000	4,303,000	4,200,
1938	4,282,	2,780,	650	.40	9,750,	9,000,	18,750,	520,	97,500	5,950,	3,355,000	4,500,	14,622,500	4,127,500	4,200,
1939	4,354,	2,850,	654	.40	10,000,	9,000,	19,000,	520,	71,500	6,400,	3,692,250	4,500,	15,183,750	3,816,250	4,200,
1940	4,425,000	2,120,000,000	660	.40	10,250,000	11,000,000	21,250,000	520,000	45,500	6,850,000	3,809,250	6,000,000	17,224,750	4,025,250	4,200,000
1941	.....	.....	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Totals	.....	.....	....	....	$156,650,000	$151,750,000	$308,400,000	$25,461,000	$9,403,880	$59,200,000	$39,395,500	$72,900,000	$206,360,380	$102,039,620	$101,600,000

*$3,750,000 cash available February, 1922.

Compiled by H. M. Christie and H. P. Ramey.

CHRISTIE EX. 1—Apr. 26/23

The Sanitary District of Chicago

Composite Statement Estimating Resources and Liabilities under 1940 Construction Progeam

Assessed valuation		Receipts				Expenditures										
						Outstanding bonds		Future bond issues								
Total	Per capita	Tax rate per $100 valuation	Tax receipts levy less 10% a/c costs and delinquencies	Bond issues	Total	Redemption	Interest	Redemption	Interest	Administration & maintenance & operation	Total	Net revenue available for new construction	Construction program	Year	Bonds outstanding Jan. 2	Bonding capacity maximum
(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$1,824,157,564	$594	$0.36	.....	*$3,750,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	1921	.....	$54,723,000
1,870,	595	.40	$5,900,000	2,000,000	$11,650,000	$1,551,000	$944,440	.....	.....	$2,100,000	$4,595,440	$7,054,560	$6,400,000	1922	$25,851,000	56,100,
1,915,	596	.40	6,650,000	6,000,	12,650,	2,146,	1,129,340	$1,000,000	$90,000	2,400,	5,865,340	6,784,660	7,000,	1923	26,300,	57,450,
1,965,	598	.40	6,900,000	6,000,	12,900,	1,980,	1,035,960	400,	355,500	2,500,	6,271,460	6,628,540	7,000,	1924	30,054,	58,950,
2,015,	600	.40	7,100,	7,000,	14,100,	1,880,	949,060	700,	607,500	2,600,	6,736,560	7,363,440	7,000,	1925	33,674,	60,450,
2,065,	603	.40	7,250,	7,000,	14,250,	1,824,	866,160	1,050,	891,000	2,700,	7,331,160	6,918,840	7,000,	1926	38,094,	61,950,
2,115,	605	.40	7,450,	8,000,	15,450,	2,124,	785,500	1,400,	1,158,750	2,800,	8,268,250	7,181,750	6,600,	1927	42,220,	63,450,
2,170,	608	.40	7,600,	7,000,	14,600,	2,076,	685,340	1,800,	1,455,750	2,900,	8,917,090	5,682,910	6,100,	1928	46,696,	65,100,
2,225,	611	.40	7,800,	9,000,	16,800,	2,076,	587,100	2,150,	1,689,750	3,900,	10,402,850	6,397,150	6,000,	1929	49,820,	66,750,
2,280,	615	.40	8,000,	9,000,	17,000,	1,951,	488,860	2,600,	1,998,000	4,500,	11,537,860	5,462,140	5,500,	1930	54,594,	68,400,
2,345,	620	.40	8,200,	8,000,	16,200,	1,373,	395,620	3,050,	2,286,000	4,500,	11,604,620	4,595,380	5,200,	1931	59,043,	70,350,
2,400,	623	.40	8,450,	8,000,	16,450,	1,270,	330,500	3,450,	2,506,750	4,500,	12,057,250	4,392,750	4,200,	1932	62,620,	72,000,
2,460,	627	.40	8,650,	8,000,	16,650,	770,	269,500	3,850,	2,713,500	4,500,	12,103,000	4,547,000	4,200,	1933	65,900,	73,800,
2,520,	630	.40	8,850,	8,000,	16,850,	770,	233,500	4,250,	2,900,250	4,500,	12,653,750	4,196,250	4,200,	1934	69,280,	75,600,
2,580,	634	.40	9,050,	8,000,	17,050,	770,	197,500	4,650,	3,069,000	4,500,	13,186,500	3,863,500	4,200,	1935	72,260,	77,400,
2,645,	639	.40	9,300,	9,000,	18,300,	670,	161,500	5,050,	3,219,750	4,500,	13,601,250	4,698,750	4,200,	1936	74,840,	79,350,
2,710,	643	.40	9,500,	9,000,	18,500,	670,	129,500	5,500,	3,397,500	4,500,	14,197,000	4,303,000	4,200,	1937	78,120,	81,300,
2,780,	650	.40	9,750,	9,000,	18,750,	520,	97,500	5,950,	3,355,000	4,500,	14,622,500	4,127,500	4,200,	1938	80,950,	83,400,
2,850,	654	.40	10,000,	9,000,	19,000,	520,	71,500	6,400,	3,692,250	4,500,	15,183,750	3,816,250	4,200,	1939	83,480,	85,500,
2,120,000,000	660	.40	10,250,000	11,000,000	21,250,000	520,000	45,500	6,850,000	3,809,250	6,000,000	17,224,750	4,025,250	4,200,000	1940	85,560,000	87,600,000
.....	....	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	89,190,000	89,700,000
.....	....	....	$156,650,000	$151,750,000	$308,400,000	$25,461,000	$9,403,880	$59,200,000	$39,395,500	$72,900,000	$206,360,380	$102,039,620	$101,600,000	....	.....	.....

2.

H. P. Ramey.

Page	Harbors	Receipts–Tons	
1054	Milwaukee, Wis.	144,500	
1096	Calumet, Wis.	7,275,558	
1098	Indiana Harbor, Ind.	1,426,983	
1142	Rouge River, Mich.	910,987	
1143	Toledo, Ohio.	2,982,102	
1151	Huron, Ohio.	1,534,615	
1153	Lorain, Ohio.	4,508,600	
1155	Cleveland, "	8,957,165	
1158	Fairport, "	1,397,719	
1159	Ashtabula, "	12,351,940	
1161	Conneaut, "	6,708,534	
1164	Erie, Pa.	2,484,897	
1170	Buffalo, N. Y.	8,577,923	
1174	Tonowanda, N. Y.	602,695	
	Miscellaneous	3,368,048	
	Foreign Ports	1,279,739	
			64,512,005 Tons

Memoranda

	Lake Superior Shipments	57,150,936 Tons
1104	Passed 500—eastbound	56,780,498 "

Comparison of Depths in Certain Channels and Harbors at Sundry Elevations of the Waters of Lakes Michigan, Huron, Erie, and Superior, Compiled from Bulletin No. 31, "Survey of Northern and Northwestern Lakes," Issued by U. S. Lake Survey Office, Detroit, Mich., April, 1922, and Water Level Records Furnished by Same Authority.

Table II

Page of bulletin	Channels		Project depths of acts of Congress standard low water	Actual depths assuming water surfaces at mean for 62-yr. period, 1860-1921	Depths at 1921 annual mean	Depths at 1921 annual mean lowest	Depths at 1911 navigation season mean low	Depths for lowest month for 1911 navigation season, lowest monthly mean
			Feet	Feet	Feet	Feet	Feet	Feet
308	St. Clair Flats Canal		20.00	22.32	21.70	*20.73	*20.87	*20.39
319	Livingston Channel		21.00	23.52	23.31	22.33	22.47	21.99
	Harbors	Lake						
75	Duluth, Minn	Superior	20.00	21.79	21.63	21.00	21.28	20.43
68	Ashland, Wis	Superior	20.00	21.79	21.63	21.00	21.28	20.43
165	Milwaukee, Wis	Michigan	19.00	21.63	20.60	20.10	20.23	19.87
206	Calumet, Ill	Michigan	21.00	23.63	22.60	22.10	22.23	21.87
210	Indiana Harbor, Ind	Michigan	21.00	23.63	22.60	22.10	22.23	21.87
316	Rouge River, Mich	Detroit River	21.00	23.52	23.31	22.33	22.47	21.99
375	Toledo, Ohio	Erie	21.00	23.52	23.31	22.33	22.47	21.99
369	Huron, Ohio	Erie	19.00	21.52	21.31	20.33	20.47	19.99

365	Lorain, Ohio	Erie	20.00	22.52	22.31	21.33	21.47	20.99
357	Cleveland, Ohio	Erie	23.00	25.52	25.31	24.33	24.47	23.99
353	Fairport, Ohio	Erie	19.00	21.52	21.31	20.33	20.47	19.99
351	Ashtabula, Ohio	Erie	20.00	22.52	22.31	21.33	21.47	20.99
349	Conneaut, Ohio	Erie	20.00	22.52	22.31	21.33	21.47	20.99
345	Erie, Pa	Erie	20.00	22.52	22.31	21.33	21.47	20.99
326	Buffalo, N. Y.	Erie	21.00	23.52	23.31	22.33	22.47	21.99
		Elevations						
123	Lake Michigan		578.50	581.13	580.10	579.60	579.73	579.37
323	Lake Erie		570.00	572.52	572.31	*571.33	*571.47	*570.99
45	Lake Superior		600.50	602.29	602.13	601.50	601.78	600.95

NOTE.—Gages—Duluth—Milwaukee—Head of Detroit River—Cleveland.
1911—Lake Erie—Shenehan tables free flow less 10,000 C. S. F. Gage .14 foot higher.
1911—St. Clair Flats canal interpolated.

[fol. 464] CHRISTIE EX. 4—Apr. 26/23

Summary of Statement of Resources and Expenditures of the Sanitary District of Chicago under 1922-1945 Construction Program

Based Upon Plants Going Into Operation as Follows, viz:

Desplaines	1923
Calumet	1923
Corn Products	1927
North Side	1928
Stock Yards	1932
West Side	1940
South West Side	1945

Resources:		
Taxes—Net	$211,850,000	
Sale of bonds—Net	60,949,000	
		$272,799,000
Contra:		
New Construction	$106,300,000	
Ad. Maintenance & Operation	106,400,000	
Interest on Bonds	59,768,880	
Surplus	330,120	
		$272,799,000

NOTE.—Bonds outstanding Jan. 2, 1946	$84,050,000
Maximum bonding capacity Jan. 2, 1946	99,000,000

H. M. C. *G.

UNITED STATES OF AMERICA,
NORTHERN DISTRICT OF ILLINOIS,
EASTERN DIVISION. } ss.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,019 and Equity No. 114.

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CHICAGO

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NOTE 1.—Volume IV (pages 1813-2628) consists of extracts from testimony and historical data in the case of United States vs. Economy Light and Power Company, and historical data from Brown's Drainage Canal; the Report of the Illinois and Michigan Canal Commissioners for the year 1900; Andreas' History of Chicago and extracts from reports of United States Engineers and certain other public documents introduced by The Sanitary District of Chicago.

NOTE 2.—Pages 3601 to 3845, inclusive, of Volume VI, contain the following: Extracts from a public hearing on February 28, 1912, in connection with the application of the Sanitary District of Chicago, dated February 5, 1912, for permission to divert 10,000 cu. ft. per second of water through the Chicago and Calumet Rivers; extracts from a public hearing in connection with the same application on March 27, 1912, at which representatives of the Canadian Government and various Canadian cities and interests were heard; extracts from briefs and memoranda submitted; and also certain letters, telegrams, resolutions of protest and of approval from various states, cities, chambers of commerce, associations, and individuals located on the Great Lakes and in the Illinois River Valley.

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CORRECTIONS TO GARDNER S. WILLIAMS' TESTIMONY.

Page	Line	For	read
575	3, 7, 15	Couteau	Coteau
576	16	Millwright	Mill site
576	31	Case	Amount
578	8	Sewerage	Sewage
589	11	Increment	Increments
598	1	Lopesch	Aux Peche
598	24	Plan	Plane
602	38	Eough	Enough
609	4	Within average	Within an average
609	29	1909	1899
610	29	Gages	Gagings
612	9	Velocity	Discharge
616	29	Junior, Engineer	Junior Engineer
626	39	2.22	2.209
627	27	.79	.78
629	9, 11	Resistancies	Resistances
631	9	Represent	Represents
631	30	28872	28758
631	35	28872	28758
631	35	1617	1610
631	37	1617	1610
631	37	190681	190674
631	41	910	917
632	28	9.06	904
634	7	570.79	570.69
635	30, 31	Made 1896	Made in 1896
638	37	24436	24458
638	38	24436	24458
638	44	27861	28059
639	17	27861	28059
641	7	575,174	575,175
642	5	presented	presents
642	5	table 17 differences	Table 17, differences
642	22	581.56	581.57
642	25	8.71	8.72
643	18	raise	rise
643	44	27861	28059
645	39, 40	** of a foot. By Tables **	..... of a foot, by Tables
647	25	12995	13005
647	31	12995	13005
647	42	divide	divided
648	20	196908	196907
648	32	12995	13005
649	12	12995	13005
649	12	8664	8670
649	14	8664	8670
649	14	27523	27517
650	17	27523	27517
650	34	12995	13005
656	35	24620	24613
657	45	15820	16036
657	2	0.507	0.508
658	3	31203	31370
658	4	14608	14609
658	7	0.507	0.508
658	8	28872	28758
661	34	26	36

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Page	Line	For when	read whence
662	26	11389	11253
662	28	.268	.368
662	32	30948	30579
662	33	five	eight
662	33	10417	10281
663	29	.0368	0.368
663	33	28307	27938
663	34	575	820
663	35	28872	28758
663	45	28872	28758
664	8	40442	40328
664	13	40442	40328
664	18	191023	191614
664	38	197633	198002
664	40	248721	248908
670	4	197633	198002
670	15	98.8	99.0
670	16	0.988	0.99
670	20	0.85	0.855
670	20	29600	29780
670	21	29600	29780
670	31	29600	29780
670	33	27336	26155
672	16	28359	33142
672	37	32060	30460
672	38	240820	240818
680	42	196739	196729
681	4	196739	196729
681	11	199039	199029
681	12	199039	199029
681	14	41781	41791
681	14	41781	41791
681	33	4720	4730
681	35	35.78	35.76
681	38	35.78	35.76
681	43	4720	4730
682	6	14430	14420
682	6	196739	196729
682	14	196739	196729
682	17	10252	10242
682	23	199039	199029
682	24	10252	10242
682	38	9743	9753
682	39	9743	9753
682	7	35793	35803
683	10	correct	corrected
685	19	nearly	over
685	20	an excess	a deficit
689	18	35.06	35.32
689	19	34.13	34.90
689	19	0.93	0.42
689	20	28872	28758
689	40	0.366	0.368
689	42	28872	28758
690	2	30600	30483
690	2	30600	30483
690	3	197633	198002
690	3	11.6	15.4
690	9	34600	35000
690	22		

CORRECTIONS TO GARDNER S. WILLIAMS' TESTIMONY.

Page	Line			
690	25	For 34000		read 35000
690	25	.34		.33
690	30	34000		35000
690	30	17000		17850
690	32	30600		30480
690	33	13600		12630
692	15	30332		31918
692	18	0.33		0.31
692	19	0.33		0.31
692	19	0.61		0.63
692	20	0.61		0.63
692	21	30322		31918
692	21	18000		20000
694	26	28872		27938
694	30	28872		27938
694	30	45600		45900
705	23	Huran		Huron
707	2	Seven-eighths percent		Seven-eighths
707	27	197633		198002
707	31	197633		198002
707	31	172500		174000
707	38	25000		24000
707	40	10.4		10.0
708	1	25300		25200
710	27	is		observations
710	28	were		was
710	28	is, were		it was
712	33	28872		27938
712	34	32300		31300
724	13	LXIX-a		LIX-a
724	37	LXIX-c		LIX-c
724	42	LXIX-d		LIX-d
724	44	LXIX-e		LIX-e
725	1	LXIX-f		LIX-f
819	25	136		144.6
819	36	136		144.6
819	37	136		144.6
859	July 20th	1st Column for	0.23	read 0.26
		3rd Column	0.46	read 0.49
	July 25th	2nd Column	0.12	read 0.28
		3rd Column	0.47	read 0.63
860	Aug. 2nd	2nd Column	0.85	read 0.35
		3rd Column	1.17	read 0.67
	Aug. 11th	2nd Column	0.21	read 0.23
		3rd Column	0.44	read 0.45
	Aug. 26th	1st Column	0.58	read 0.60
		3rd Column	1.08	read 1.10
	Aug. 31	3rd Column	0.25	read 0.28
873	Line 40	gravity. The		gravity, the
888	Line 35	1898		1908
889	Line 22	571.96		571.94
889	Line 24	571.96		571.94
889	Line 24	573.26		573.24
898	Line 18	three		two
920	Line 35	1899		1889
963	Line 43	enough		through
968	Line 7	considered		to consider

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	725-27	Shenehon's Ex. B-D	Shenehon's Ex. B and D		
3142	733	Shenehon's Ex. E, F, G, H	Shenehon's Ex. E, F, G, H		
	725-27	Ex. B and D	Shenehon's Ex. B and D		
3147	53	Govts. Ex. No. 3	U. S. Ex. No. 3	10	
	763	Shenehon's Ex. T	Shenehon's Ex. T	1207	
3153	745	Shenehon's Ex. K, L, M, N	Shenehon's Ex. K, L, M, N	948	Three Curve Series
3155	589	Groat's paper	Freeman's Ex. 4	1183	Discharge by Sus. Bridge and Whirlpool Gages
3156	733	Shenehon's Ex. E, F, G, H	Shenehon's Ex. E, F, G, H	2806, 3066	
3157	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	St. Clair Curve
3157	759	Shenehon's Ex R	Shenehon's Ex. R	933	Red and blue
3174	721	Moore's Ex. 5	Moore's Ex. 5	2884	Printed in Record, page 2889
3184	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curve Curve
3184	49-55	"Ex. 1, 2, 3, 4"	U. S. Ex. 1, 2, 3, 4	7-10	

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3190	730	Shenehon's Ex. H	Shenehon's Ex. H	2809	Fluctuations Niagara
3191	733	Shenehon's Ex. E, F, G	Shenehon's Ex. E, F, G	2806-3086	Discharge Curves Niagara
3192	733	Shenehon's Ex. E	Shenehon's Ex. E	3086	
3199	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curve
3200	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curve
3215	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3216	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3217	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3221	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3240	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3240	725-29	Shenehon's Ex. B and D	Shenehon's Ex. B and D		
3254	51	U. S. Ex. No. 2	U. S. Ex. No. 2	10	St. Lawrence Curves Niagara Curves
3274	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3275	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3325	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	
3326	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	
3327	49	U. S. Ex. No. 1	U. S. Ex. No. 1	7	
3329	759	"The red and blue"	Shenehon's Ex. R	933	
3335	49	Ex. No. 1	U. S. Ex. No. 1	7	
3350	771	Shenehon's Ex. V	Shenehon's Ex. V, May 18, 1914	3350	Lake Erie and Chippawa
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3367	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3368	745	Three Curve Series	Shenehon's Ex. K, L, M, N	948	
3370	53	U. S. Ex. No. 3	U. S. Ex. No. 3	10	

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3464	792	Wisner's Ex. 14G	Wisner's Ex. 14F	3463	Chart 34A—Canal Tests
3467	792	"Chart 14C"	Wisner's Ex. 14F	3463	Chart 34A—Canal Tests
3469	792	"Chart 14C"	Wisner's Ex. 14F	3463	Chart 34A—Canal Tests

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PREFACE.

The record in this case contains a number of volumes, consisting of approximately 5,000 printed pages. It was considered advisable and proper, in connection with the presentation of this case, to prepare in condensed form a narrative statement of the pleadings and facts, to which reference could be made by both parties in preparing their respective briefs. Such of the facts as are contained in the record deemed to be material to either party to the suit are included in this statement. The facts bearing upon a particular subject have been drawn together in this statement and collected from different portions of the record, the record page where the matter may be found, being indicated. However, the submission of this statement shall not preclude reference to the record for any matter not contained herein.

IN THE

SUPREME COURT OF THE UNITED STATES.

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO, *Appellant,* *vs.* THE UNITED STATES OF AMERICA, *Appellee.*	Appeal from the District Court of the United States, for the Northern District of Illinois, Eastern Division.

APPELLANT'S NARRATIVE STATEMENT OF THE PLEADINGS, FACTS AND EVIDENCE.

There are two suits involved here. One bill of complaint was filed in the Circuit Court of the United States, for the Northern District of Illinois, Eastern Division, March 23, 1908, and involves the diversion of water from Lake Michigan through the Calumet River and the Calumet Sag Channel, an adjunct of the Main Channel of the Sanitary District, and will be called, for convenience, the Calumet Suit. In the second suit the complaint was filed October 6, 1913, in the District Court of the United States, for the Northern District of Illinois, Eastern Division, and involves the diversion of water through the Chicago River and the Main Channel of the Sanitary District, and all other diversion sources, including the Calumet River and Calumet Sag Channel.

PLEADINGS.

The bill of complaint in the Calumet suit, filed March 23, 1908, in the Circuit Court of the United States, for the Northern District of Illinois, alleged and set forth the following (Vol. VIII, pages 1 to 8, inclusive):

The complainant, The United States, was represented by Charles J. Bonaparte, attorney general, and Edwin W. Sims, District Attorney.

First. The Sanitary District is a municipal corporation, organized and existing under an act of the General Assembly of Illinois, approved May 29, 1889, in force July 1, 1889, and entitled: "An Act to create Sanitary Districts and to remove obstructions in the Desplaines and Illinois Rivers." Its principal office is Chicago, Illinois, and it is a citizen thereof.

Second. The Main Calumet River situated in, and flowing, in a northeasterly direction through, the County of Cook, in the said State of Illinois, and emptying into Lake Michigan at South Chicago, in said county, is a navigable river for its entire length from Lake Michigan to where it is formed by the Little and Grand Calumet Rivers. The United States has appropriated and expended large sums of money in improving the navigability of said river, and in improving the harbor at the mouth of the same, that is to say, it has appropriated and expended in such improvement of said river, including its tributaries in Indiana and Illinois, between the years 1884 and 1907, inclusive, the sum of $994,218.98, and in the improvement of said harbor since the year 1870, the sum of $1,567,230. At the present time the largest vessels on Lake Michigan can enter the said harbor and pass up said river for a distance of five miles, and small vessels can ascend the remaining three miles. The Little Calumet River, which, between the mouth of Stoney Creek and the mouth of said river, flows through the said County of Cook in an easterly direction, and in conjunction with the Grand Calumet River in said County, forms the said Calumet River, is also a navig-

able river from its month to the mouth of Stoney Creek in said County. For all of said distance it has a depth of about six feet and steamboats and sailing vessels engaged in interstate commerce use said river. The bridges across said river for said distance, are provided with draws for the accommodation of such craft, and such bridges are under the direct supervision of the Secretary of War of the said United States. The Grand Calumet River, an interstate stream rising in the State of Indiana and flowing in a northwesterly direction into and through the State of Illinois, to the said point of its conjunction with the Little Calumet River, is also a navigable river, and the United States has expended large sums of money in improving its navigability. Lake Michigan and its harbor and connecting rivers and channels, are navigable waters of the said United States. The United States has appropriated and expended large sums of money in improving the navigability of the rivers, channels and harbors connected with said Lake Michigan.

Third. On December 7, 1904, the Board of Trustees of the Sanitary District of Chicago, passed an ordinance, approved by its president, establishing and laying out a route for a channel and outlet of The Sanitary District of Chicago, to be known as the Calumet-Sag Channel. The said ordinance directed that said channel be constructed from a point on the main channel of The Sanitary District at or near Sag, Illinois, about eleven miles in a northerly direction up the said main channel from Lockport, to a point in said Little Calumet River at the mouth of Stoney Creek aforesaid, near the City of Blue Island, connecting the said Little Calumet River with the main channel of The Sanitary District. The said Calumet-Sag Channel was to be of such size, depth and slope that it would have a capacity of 4,000 cubic seconds feet of water, and thereby divert from Lake Michigan through it that amount of water, to the Desplaines, Illinois and Mississippi Rivers, and on to the Gulf of Mexico.

Fourth. On information and belief, it is stated that the diversion and abstraction of the waters of Lake Michigan

into the Mississippi River basin as aforesaid, will lower the level of the water in Lake Michigan, and thus diminish the navigable capacity and depth of the various rivers, channels and harbors connected therewith which have been deepened and improved at great expense under the authority of the Congress of the United States. The construction and maintenance of the Calumet-Sag Channel and the diversion and abstraction of the proposed amount of water from Lake Michigan will have a tendency to undo and annul the orders of Congress as expressed in the various river and harbor acts appropriating funds for improving the harbors and channels connecting with Lake Michigan. The construction and maintenance of said Calumet-Sag Channel as proposed, with its attendant diversion of waters of Lake Michigan, will alter and modify the condition and capacity of all the said harbors and of all the said channels (navigable waters of the United States), and will impede, injure and obstruct navigation in many of said harbors and channels, and will create an obstruction to the navigable capacity of the said mentioned waters of the said United States.

Fifth. For the diversion of said water and the creation of said obstruction to the navigable capacity of said navigable waters of the United States by the defendant, The Sanitary District of Chicago, has not been and is not affirmatively authorized by the Congress of the United States, and has not been and is not authorized in any way by said Congress.

Sixth. The construction and maintenance of the Calumet-Sag Channel as proposed, will lower the levels of the water in the Calumet, the Little Calumet and Grand Calumet Rivers, and will alter and modify the course, condition and capacity of those rivers, respectively.

Seventh. The proposed Calumet-Sag Channel with its attendant diversion, will lower the levels of the waters of Lake Michigan, and will injure and impede navigation in all the harbors and channels in said waters.

Eighth. Section 10 of the Rivers and Harbors Act of March 3, 1899, has remained in force and effect ever since its passage.

Ninth. About November 28, 1906, defendant applied to the Secretary of War for authority to construct and maintain said Calumet-Sag Channel, and to reverse the flow of the Calumet Rivers. Thereupon the Secretary of War requested the Chief of Engineers to make his recommendation concerning the said application. February 23, 1907, the Chief of Engineers reported that he was unwilling to recommend favorably. On March 14, 1907, the Secretary of War denied the application for the said work, and up to the present time the said work has not been recommended by the Chief of Engi neers and has not been authorized by the Secretary of War, and is otherwise without the authority, permission and approval of the said Secretary of War.

Tenth. Defendant, The Sanitary District of Chicago, has announced its intention to construct and maintain said Calumet-Sag Channel, reverse the flow of the Calumet Rivers, and divert water from Lake Michigan. The defendant's board of trustees, on September 18, 1907, adopted and passed an ordinance providing for the construction of said channel, and announcing defendant's intention to construct same, which is marked Exhibit A to the bill of complaint.

(All exhibits to pleadings and documents quoted therein were either offered in evidence or admitted by the pleadings.)

Eleventh. Defendant proposes to divert water from Lake Michigan through the said Calumet Rivers and Calumet-Sag Channel, for sanitary purposes, and for the development of water power. Congress has not fixed any amount of such water for such proposed diversion, and has not provided for same, nor has the Secretary of War, under congressional direction, fixed any amount of such water for such proposed diversion. On the contrary, the Secretary of War has refused to authorize same.

Twelth. Defendant cannot lawfully construct or maintain said Calumet-Sag Channel or reverse the flow of the Calumet Rivers or divert the water from Lake Michigan as proposed.

Thirteenth. October 16, 1907, defendant commenced the excavation of said Calumet-Sag Channel, and defendant intends to and will continue and complete the construction of said channel, reverse the flow of the Calumet River, divert waters from Lake Michigan as proposed, to the irreparable injury of complainant and its interstate navigation and commerce, unless restrained by injunction.

Prayer of bill.

Defendant be restrained and enjoined from beginning or attempting to construct or continuing the construction of, and from doing anything in, towards, or about, the construction of said proposed Calumet-Sag Channel, or diverting or abstracting any waters from Lake Michigan, or from doing or attempting anything in any way to connect the waters of the Calumet Rivers with the main channel of the Sanitary District, from doing or attempting anything in any way to reverse the flow of the Calumet Rivers, and from doing or attempting anything in any way to divert or abstract any waters from Lake Michigan in any channel other than the Chicago River as already authorized by the Secretary of War, unless prior to beginning any of said work or doing or attempting to do any of such things, the Chief of Engineers of the United States shall have recommended, and the Secretary of War of the United States shall have authorized, the doing of such work.

Exhibit A to the bill of complaint.—Ordinance passed by the Board of Trustees of the Sanitary District of Chicago on September 18, 1907.

Whereas, on December 7, 1904, by an ordinance passed by the board and approved by the president, the board established and laid out a route for a channel and outlet of The Sanitary District of Chicago, which channel was by said

ordinance to be constructed and maintained, together with the necessary additions thereto, within the limits of said route;

Whereas, by the terms of said ordinance, it is provided that a channel be constructed by The Sanitary District of Chicago, as described in the bill of complaint;

Whereas, the construction and maintenance of the channel provided for will result in diverting and reversing the flow of the Calumet River, a navigable stream now flowing into Lake Michigan;

Whereas, heretofore, to wit, on November 28, 1906, this board instructed its president to transmit to the Secretary of War an application for a permit to reverse the flow of said Calumet River and thereafter, to wit, on March 14, 1907, the Secretary of War communicated to the board his refusal to issue such permit;

Whereas, this board is advised that it has the right and that it is the duty under the laws of the State of Illinois, to construct said channel, nothwithstanding the refusal of the Secretary of War to issue a permit therefor, for the purpose of furnishing the proper sanitary method of disposing of the sewage of the territory and inhabitants contiguous to the said proposed channel and within the corporate limits of The Sanitary District of Chicago, and unless restrained by a court having jurisdiction of the subject matter at the instance of the United States Government; and

Whereas, the Board of Trustees of the Sanitary District of Chicago deemed the construction of such channel and the reversal of the flow of said Calumet River necessary for the preservation of the health of persons within the limits of the Sanitary District, and that it is in duty bound to proceed with the construction thereof, first giving notice of its intention so to do to the Secretary of War and to the Attorney General, that they may, if they see fit, take such steps as they think proper to protect the rights, if any, of the general government—

Ordered by the Board of Trustees of The Sanitary District of Chicago, as follows:

First. Finance committee to arrange for the purchase of right of way.

Second. Chief Engineer to prepare plans and specifications for the construction of said channel according to the terms of the ordinance adopted by the board December 7, 1904.

Third. The clerk of the district is directed to transmit a certified copy to the Secretary of War, Attorney General, Chief of Engineers, and District Engineer in charge at Chicago.

Answer of the Sanitary District of Chicago to the bill of complaint filed March 23, 1908, as follows: (Vol. VIII, pages 9 to 28.)

First. Admits it is a municipal corporation, as alleged in the bill of complaint. Map is attached as Exhibit A to the answer, showing the territorial limits of The Sanitary District of Chicago, comprising 358 square miles, located within which there are a number of cities, towns and villages, including Chicago.

Second. Admits the allegations of the bill of complaint as to the location of the Calumet River, but denies that it is a navigable river, and that it is traversed by vessels engaged in commerce; admits the allegations of Paragraph 2 of the bill of complaint as to the amount of moneys appropriated and expended by the Federal Government in the improvement of said river, but denies that the Calumet River, from its mouth to the conjunction with Stoney Creek, is a navigable river, and that it is traversed by the vessels engaged in interstate or intrastate commerce; that the Grand Calumet River from its origin in the State of Indiana to its confluence with the Little Calumet River, is a navigable river.

Third. Admits the passage of the ordinance of December 7, 1904, laying out the said Calumet-Sag Channel; a copy of said ordinance is attached, marked Exhibit G.

Avers that on January 22, 1908, the Board of Trustees of defendant passed another ordinance extending the right of way, laid out by ordinance of December 7, 1904, in an easterly direction to a point known as "Forks," as shown on Exhibit F attached; copy of said ordinance is attached as Exhibit H.

Denies that the construction of said channel as proposed will result in diverting and abstracting from Lake Michigan, 4,000 cubic feet of water per second.

Fourth. Denies that the diversion and abstraction of waters from Lake Michigan contemplated through the Calumet-Sag Channel, will lower the level of the water of the Great Lakes, and will diminish the navigable capacity of said waters or the harbors thereof.

Denies that interstate or any other commerce will be injured or interfered with by said diversion, or by the maintenance of said Calumet-Sag Channel; that the construction of said channel will have a tendancy to undo orders of Congress; that the construction of said channel will alter and modify the conditions of the rivers and harbors of the United States, or any of them, and substanially and seriously impede, injure and obstruct navigation of the Great Lakes. Avers that construction and maintenance of said waterway and channel, with its attendant diversions, will not in any wise affect the navigable capacity of the Great Lakes or the harbors and channels connected therewith, or the rivers flowing into same, and will not injure commerce; that the said channel and its operation and maintenance will be to the interest of interstate commerce.

Fifth. Denies the allegation to the effect that the said construction of the said Calumet-Sag Channel had not been affirmatively authorized by Congress. Avers that it has been expressly authorized.

Sixth. Denies that the construction and maintenance of said channel will lower the level of the Little Calumet River.

Seventh. Admits that the bodies of water mentioned in paragraph 7 of the bill of complaint, are each connected with the other, and are in a measure inter-dependent upon each other for the respective water levels. Denies that the said proposed channel would lower the levels of all of said waters, or any of them, or that it would injure or impede navigation in such harbors and channels.

Eighth. Admits Section 10 of the Rivers and Harbors Act of March 3, 1899, has been and is in full force and effect. Denies that said act has any binding force on the defendant, or prohibits the construction and maintenance of said channel, or that the same is a constitutional or valid enactment.

Ninth. Admits application November 28, 1906, to the Secretary of War for permit to reverse the flow of the Calumet River; denies that by making said application, it admitted the jurisdiction of the Secretary of War in such matters, that it required such permit. Avers that it made such application as a matter of comity and in order to promote and maintain the spirit of harmony which it believes should obtain between the Federal Government and the various state and local governments; all of which is shown by statement filed with the Secretary of War at the time of making said application—

> "That while insisting upon the right as a matter of right, we are entitled, nevertheless, to a permit from the Secretary of War; to evidence that there exists between the two governments that 'spirit of harmony and conciliation' which, in the words of Chief Justice Marshall, in *Gibbons* v. *Ogden* (9 Wheaton, 1), 'ought always to characterize the conduct of governments standing in the relation which that of the Union and those of the states bear to each other'; and to further evidence on the part of said governments that 'frank and candid cooperation for the general good' spoken of by Justice Johnson in the same case, ' which should always take place where there is a seeming blending of the power of the two governments and an apparent conflict'!"

Tenth. Admits that defendant has announced its intention to proceed to construct said Calumet-Sag Channel.

Eleventh. Admits Section 1 of Act of Congress approved June 29, 1906.

Twelfth. Denies the allegation of the bill of complaint to the effect that Congress has not provided for the diversion of any of the waters of Lake Michigan through said channel. Avers that the defendant and the State of Illinois are expressly authorized by congressional legislation to construct and maintain a waterway such as is proposed by the defendant and to divert the waters of Lake Michigan through the same into the Illinois River.

Thirteenth. Denies that defendant cannot lawfully construct and maintain said proposed channel. Avers that it is lawfully empowered to do so and that it is the duty under the laws of the United States and of Illinois.

Fourteenth. Admits that on October 16, 1907, it began work on said channel; that it proposes to construct the same in the manner and form and of the character, size and dimensions as hereinafter set forth. Denies that the construction and maintenance thereof would be to the manifest or irreparable injury of the United States or to interstate and foreign commerce. Avers that the waterway will benefit both state and interstate commerce.

Fifteenth. Avers that in 1822 and 1827 Congress enacted laws authorizing Illinois to construct a waterway suitable for navigation, connecting the waters of Lake Michigan with those of the Illinois River, and to thereafter maintain the same at all times in a condition suitable for navigation, as will more fully appear from the said acts, to which reference is made; that after the passage of said acts, the State accepted same and thereafter, by various acts duly passed by the General Assembly of Illinois, approved by the Governor, the State authorized the construction of and did construct and has ever since maintained, a waterway connecting the waters of Lake

Michigan with those of Illinois River over and through which waterway commerce has been carried on continuously since the date of the completion thereof in, to wit, 1848. Defendant refers to each and all of the several acts of Illinois legislature relating to said waterway. Avers that the waterway as originally constructed, connected the waters of Lake Michigan with those of the Illinois River by a channel terminating at or near the City of Peru, on the Illinois River, in the County of LaSalle, Illinois, and beginning at a point on the Chicago River which in turn connected with Lake Michigan, in the City of Chicago, and also by a branch terminating at or near the mouth of Stony Creek on the Calumet River, which said channel and which said branch connecting with said Calumet River, are represented and shown, by lines colored yellow, on the map or plat which is hereto attached, marked Exhibit E.

Sixteenth. Avers that the defendant, in compliance with and pursuant to the powers and duties resting upon it, constructed a channel of the character, size and dimensions provided for by the original act of its incorporation, extending from a point on the Chicago River in the City of Chicago near the original termination of the Illinois and Michigan Canal, parallel with said Illinois and Michigan Canal, to and through the City of Joliet, as shown upon Exhibit E to the answer; that the construction of said channel was begun in the year 1892; that said channel was completed from its said connection with the Chicago River to a point at or near Lockport, a distance of three or four miles northeasterly from the City of Joliet, in the year 1900, sufficiently to turn the waters therein for the purpose for which said canal had been constructed; that in the year 1900, pursuant to various laws of the State and of the United States, defendant did divert waters of said Chicago River and Lake Michigan to and into said waterway and discharged the same into the Desplaines and thence into the Illinois River; that since the turning in of said waters defendant has prosecuted the work of extending said canal through the City of Joliet, and has likewise

continued the work of deepening and widening the Chicago River with which it connects, for the purpose of making said waterway sufficient to accomplish the objects of its creation, both as an outlet for the sewage of The Sanitary District and for the purpose of commerce and navigation; that said waterway or channel has been substanially completed from the Chicago River to the City of Joliet, a distance of thirty-two miles; that at Lockport there is a lock 130 feet long and 22 feet wide and 12 feet over-mitre sills; that alongside this lock, there is a reservation for a lock of ample capacity to accommodate the largest lake-going vessels; that upon the construction of the large lock, the largest lake-going vessels will be able to pass through this channel from Lake Michigan to the City of Joliet; that defendant has expended in the construction and operation of said waterway to September 1, 1907, $54,500,000, which sum, added to that spent by the State of Illinois on the Illinois and Michigan Canal, equals $61,037,254.79.

Seventeenth. Avers that after the turning in of the water into said waterway already constructed by defendant, the City of Chicago, lying wholly within the confines of the territorial limits of the defendant, has so reconstructed and built its sewage system, by a system of intercepting sewers and trunk sewers, as to carry the sewage of that portion of said city north of Eighty-seventh street and south of Fullerton avenue into said channel, thus preventing the discharge thereof into Lake Michigan as it theretofore existed. That thereby the city has prevented the pollution of Lake Michigan and partially protected the water supply of said city procured from the lake through water tunnels and intakes. That the location of the intakes is indicated upon Exhibits A and D to the answer. That the territory of the City of Chicago discharging into the defendant's channel and waterway, is represented upon Exhibit B: That the City of Chicago has constructed a trunk sewer or conduit from a point near the intersection of the shore line of the lake with Thirty-ninth street westward to the south fork of the south branch through which

said trunk sewer or conduit water from Lake Michigan is pumped, and it has a maximum capacity of 120,000 cubic feet per minute.

Eighteenth. Avers that the sewage from that portion of defendant's territory lying south of Eighty-seventh street, still discharges into Lake Michigan either directly or through the Calumet River, and pollutes the waters of the lake, and is a constant menace to the people as it contaminates the water in proximity to and around and about the Hyde Park or Sixty-eighth street intake, through which a large portion of the water supply of the inhabitants of the city passes, and through which other muicipalities within the defendant's limits obtain their water. That the water mains of the City of Chicago are so interdependent that the water entering any of same may find its way into any and all portions of said city, and that the pollution of any one of the intakes of said city does or may pollute the water supply of said entire city and in this manner menaces and threatens the health and welfare of all of the people of said community; that there is being discharged into said Lake Michigan the sewage of substantially 200,000 people residing south of Eighty-seventh street.

Nineteenth. Avers that waterway and channel sought to be enjoined is for the purpose of protecting the water supply of inhabitants south of Eighty-seventh street, and in compliance with the duty prescribed by the several laws of Illinois; that when completed, it will be located as represented and shown on Exhibits B and C, substantially twenty-one miles in length from the eastern shore line of Lake Calumet to the connection thereof with the main channel at Sag, Illinois. That from Lake Calumet, the channel will extend along the little Calumet River to Blue Island; thence sixteen miles to Sag, Illinois. That the Calumet River will be dredged to a depth of twelve feet, with a bottom width of seventy-two feet and water line width of 160 feet; that the channel itself will have a width in the glacial section of seventy-two feet

and 162 feet at the water surface, with a depth of twenty-two feet; in the rock sections ninety-three feet with vertical sides and depth of twenty-two feet.

Twentieth. Avers that defendant proposes to flow westwardly through said channels, water sufficient to reverse the flow of the Calumet River in order to carry the sewage discharging therein away from Lake Michigan; that the quantity of water so diverted would only be sufficient to cause a reversal of said flow and to properly dilute the sewage so as to comply with the several laws under which the defendant is incorporated, not exceeding at any time 4,000 cubic feet per second; that the maximum amount of water that can be flowed through the main channel of the defendant westwardly from the confluence of the Calumet-Sag Channel with it, is 840,000 cubic feet per minute; that the amount of water the defendant will flow through said channel from time to time, will only be such amount as is required by law for the proper dilution of sewage of the district; that by the construction and maintenance of the proposed Calumet-Sag Channel, it is not proposed to flow any more water than sufficient to meet the requirements of law for sewage dilution, which amount it would be bound by law to flow through its main channel without the construction of the Calumet-Sag Channel complained of.

Twenty-first. Denies that the construction and maintenance of the proposed channel will in any wise affect the levels of the Great Lakes and their connecting waters, or that it will injure or be a detriment to commerce thereon, or that it will affect the navigable capacity of the Little Calumet or Grand Calumet Rivers. Avers that it will not in any wise affect, alter, modify or change the Little Calumet River other than as herein specifically set forth, which is to the benefit of said river and commerce thereon.

Twenty-second. Avers that Exhibit F attached, shows in detail the dimensions of the Calumet and Little Calumet Rivers from Lake Michigan to Stony Creek; that the Calumet River to the eastern terminus of defendant's Calumet-Sag Channel, has a depth twenty-two, twenty-one and seven-

teen feet; that from the easterly terminus of defendant's proposed channel along and in the Calumet River, the present depths of the river are from eight to four feet, and it is correspondingly narrow.

Twenty-third. Avers that upon the completion of the Calumet-Sag Channel as proposed, it will afford navigation for vessels of the Great Lakes through the Calumet River to its main channel, and from thence to the City of Joliet, and will be a sufficient and valuable route for commerce, and will be for the benefit of commerce on the Great Lakes, Desplaines, Illinois and Mississippi Rivers; that all the water proposed to be diverted through its main channel and the Calumet-Sag Channel, will be discharged into the Desplaines River, and from thence into the Illinois River, and will form, through and by said rivers, a navigable channel from Lake Michigan to the Mississippi River; that the construction and maintenance of said Calumet-Sag Channel and said main channel through and by the authority of the State, is in accordance with the declared and express public policy of the United States and the State of Illinois to forever maintain a waterway suitable for navigation connecting the waters of Lake Michigan with the waters of the Illinois and Mississippi Rivers.

Twenty-fourth. Avers that defendant is the only body or municipality clothed with authority to provide for the drainage and disposal of sewage in furnishing the outlets therefor within its corporate limits; that by reason of the laws of Illinois, it is proceeding to dispose of and provide a means for disposal of, by a channel and adjuncts thereto, of all the sewage arising within its corporate limits which would otherwise flow into Lake Michigan, polluting the water supply of the inhabitants of defendant; that there is no other lawful method provided of disposing of the sewage and drainage of said territory, than by the construction of channels and adjuncts thereto, and that said proposed Calumet-Sag Channel is part of the only plan provided for the disposal of sewage and the furnishing of outlets therefor.

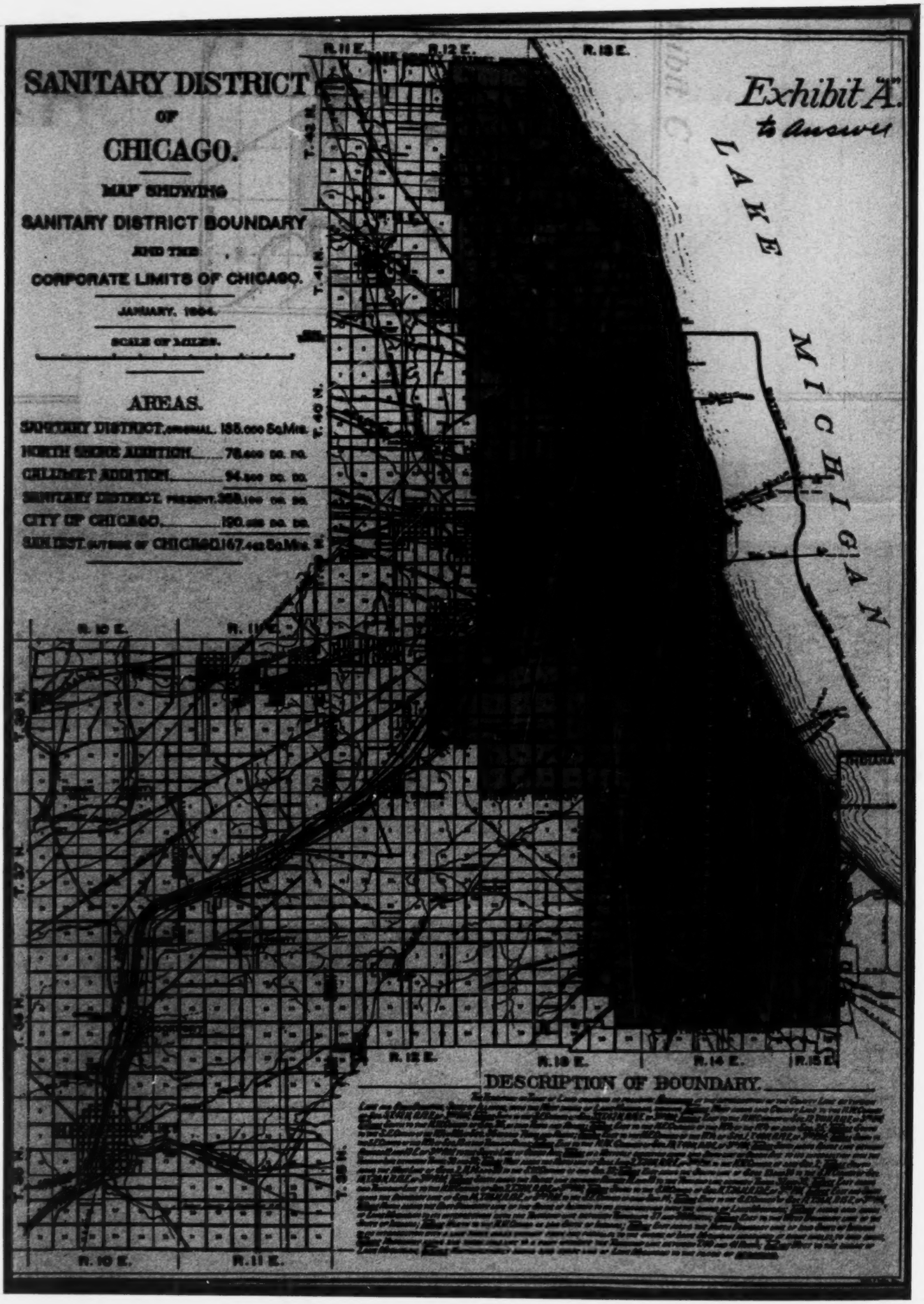
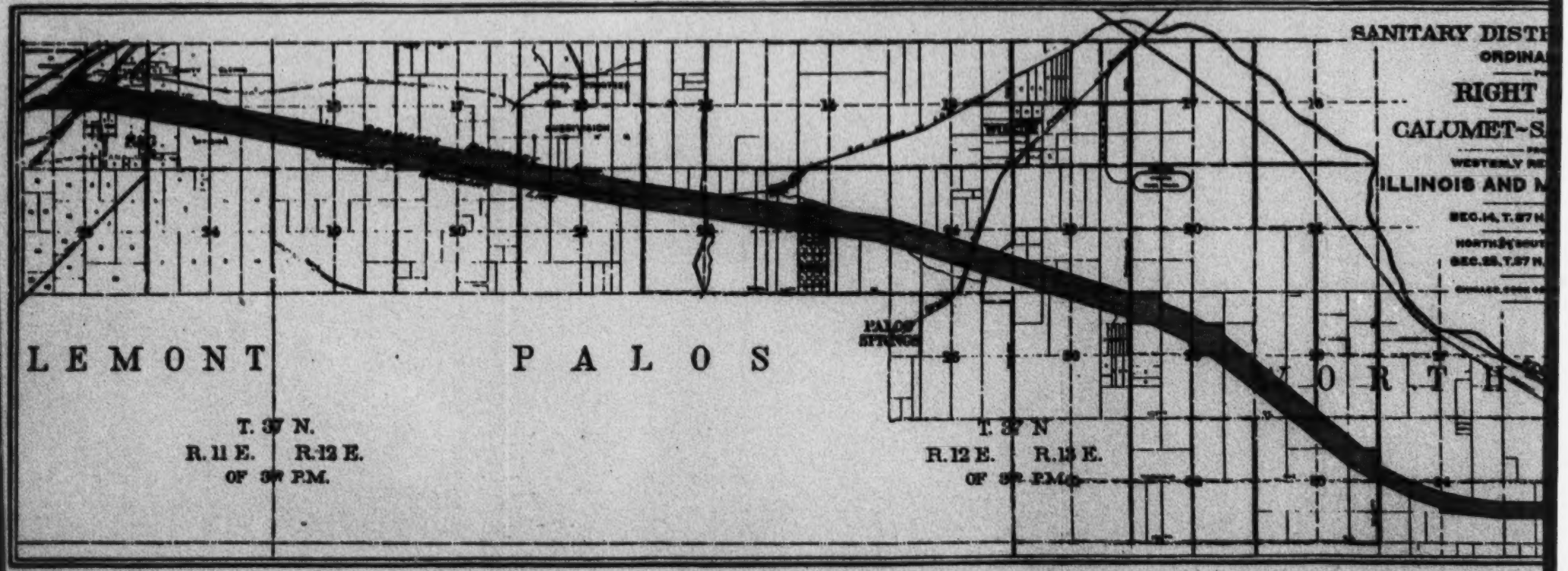

SANITARY DISTRICT
OF
CHICAGO.
MAP SHEWING
SANITARY DISTRICT BOUNDARY
AND THE
CORPORATE LIMITS OF CHICAGO.
JANUARY, 1904.
SCALE OF MILES.
AREAS.
SANITARY DISTRICT, original. 185.000 Sq.Mls.
NORTH SHORE ADDITION. 76.000 Sq. Mls.
CALUMET ADDITION. 94.000 Sq. Mls.
SANITARY DISTRICT, PRESENT. 355.100 Sq. Mls.
CITY OF CHICAGO. 190.000 Sq. Mls.
SANITARY DISTRICT OUTSIDE OF CHICAGO 167.442 Sq.Mls.
Exhibit A.
to Answer
LAKE MICHIGAN
R. 11 E.
R. 12 E.
R. 13 E.
R. 10 E.
R. 14 E.
R. 15 E.
T. 42 N.
T. 41 N.
T. 40 N.
T. 39 N.
T. 38 N.
INDIANA
DESCRIPTION OF BOUNDARY.

Exhibit B to Answer



B to Answer

Exhibit C

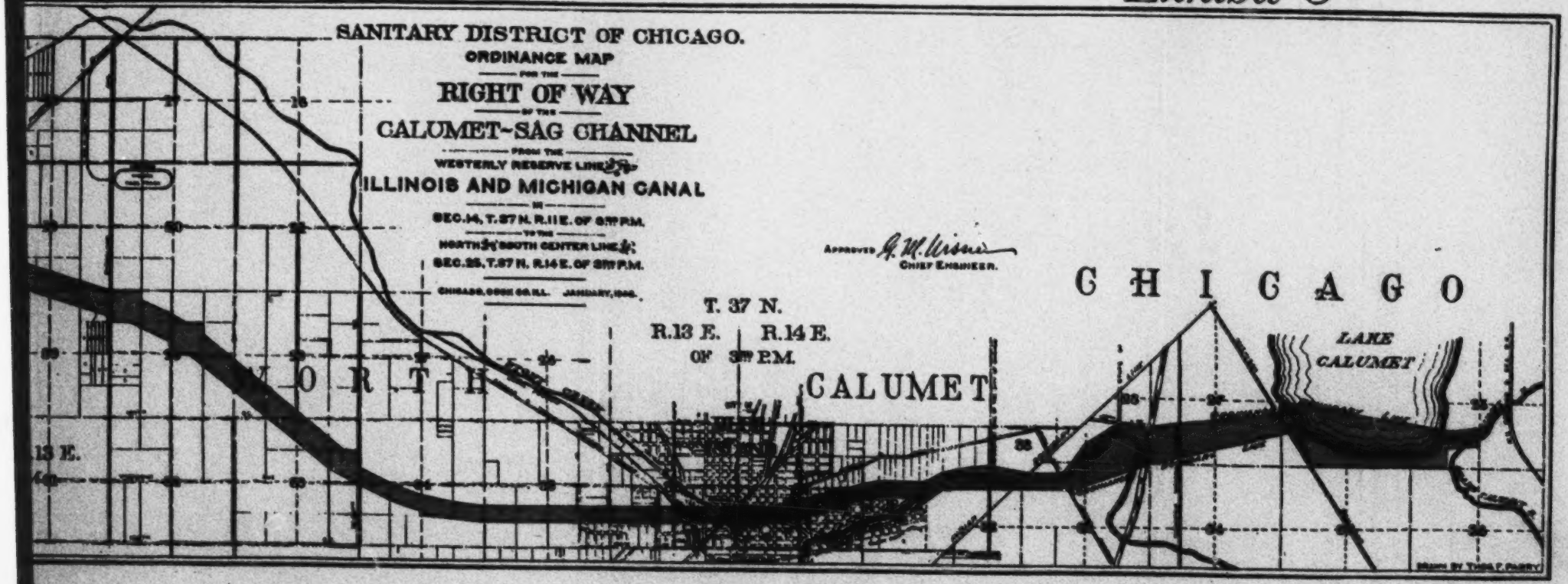
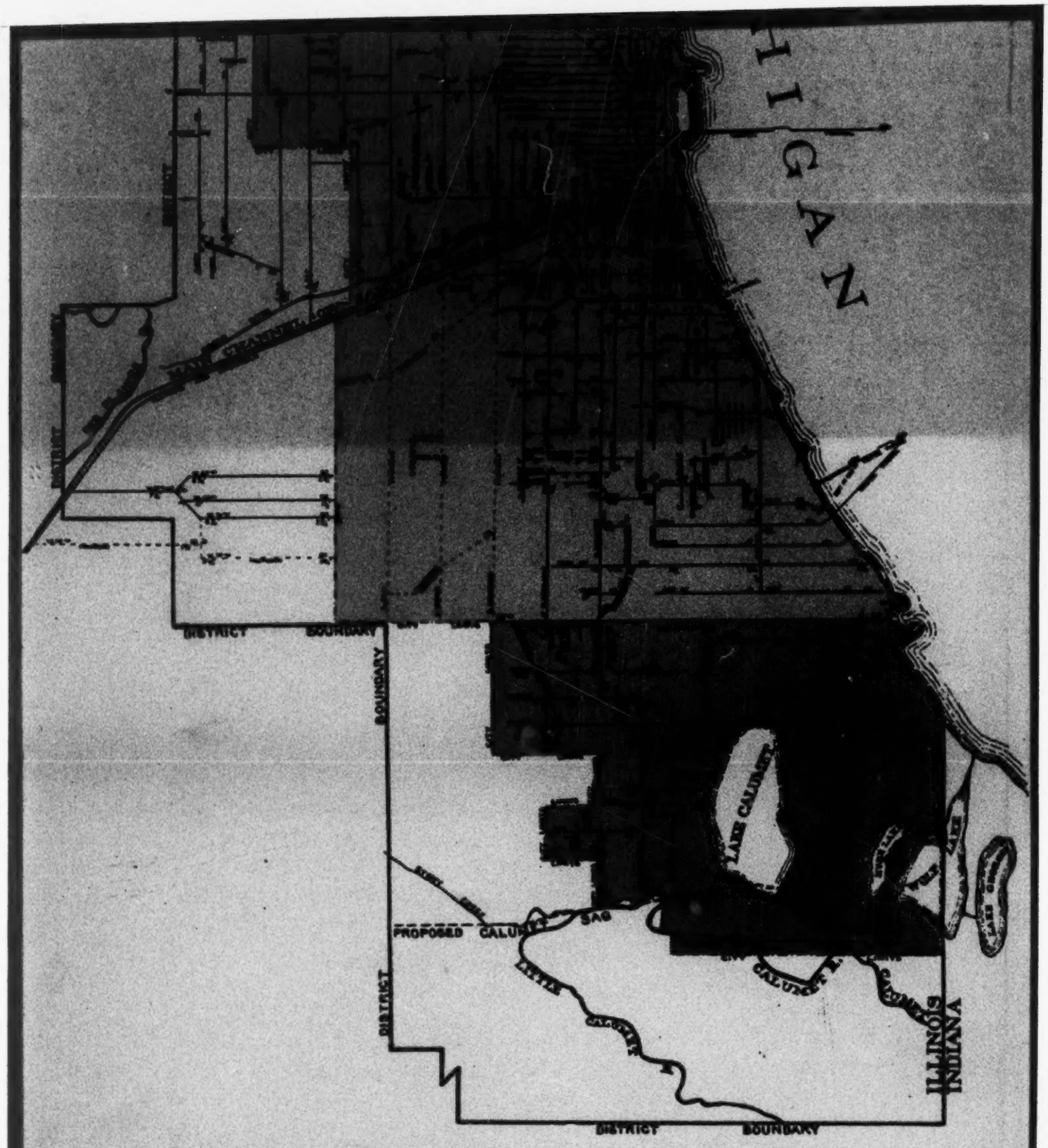


Exhibit "D"
To Answer
LAKE
MICHIGAN
CHANNEL
DISTRICT
BOUNDARY
DISTRICT
BOUNDARY
DISTRICT
BOUNDARY
LAKE
BRANCH
WEST BRANCH



SANITARY DISTRICT OF CHICAGO

MAP OF THE

CITY OF CHICAGO AND VICINITY

SHOWING

MAIN OUTFALL SEWERS.

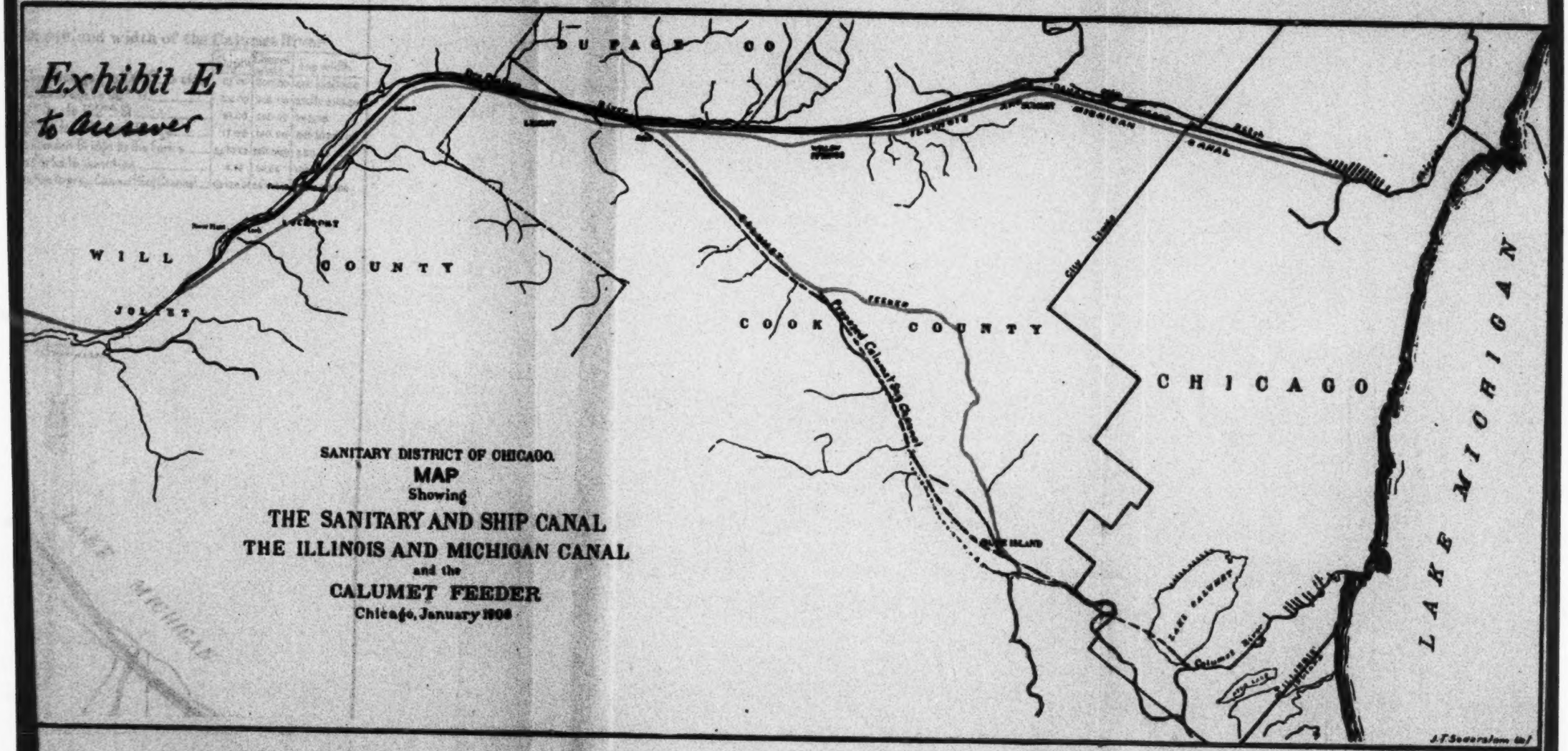
CHICAGO JAN. 23, 1908.

SCALE IN STATUTE MILES.

Territory draining into the Sanitary District Channel colored thus

Calumet River " "

Exhibit E
to Answer



SANITARY DISTRICT OF CHICAGO

MAP
CALUMET RIVER
from
LAKE MICHIGAN TO JUNCTION
with
PROPOSED CALUMET SAG CHANNEL

Scale ½ Mile = 1 Inch Chicago, Dec. 1907

EXHIBIT F.

to Answer

Depth and width of the Calumet River

	Depth	Channel width	Top width
from Lake Michigan to 106th St. Bridge	21.00	200.00	220 to 400
" 106th St. Bridge to 110th St.	20.00	200.00	220 to 400.00
" 110th St. to 122nd St.	21.00	200.00	400.00
" 122nd St. to Chiffendon Bridge	17.00	200.00	220 to 400
" Chiffendon Bridge to the Forks	21.00	21.00	200.00
" the Forks to Junction	9.00	21.00	100.00
" Junction to prop. Calumet Sag Channel	21 to 9	21 to 9	200 to 400

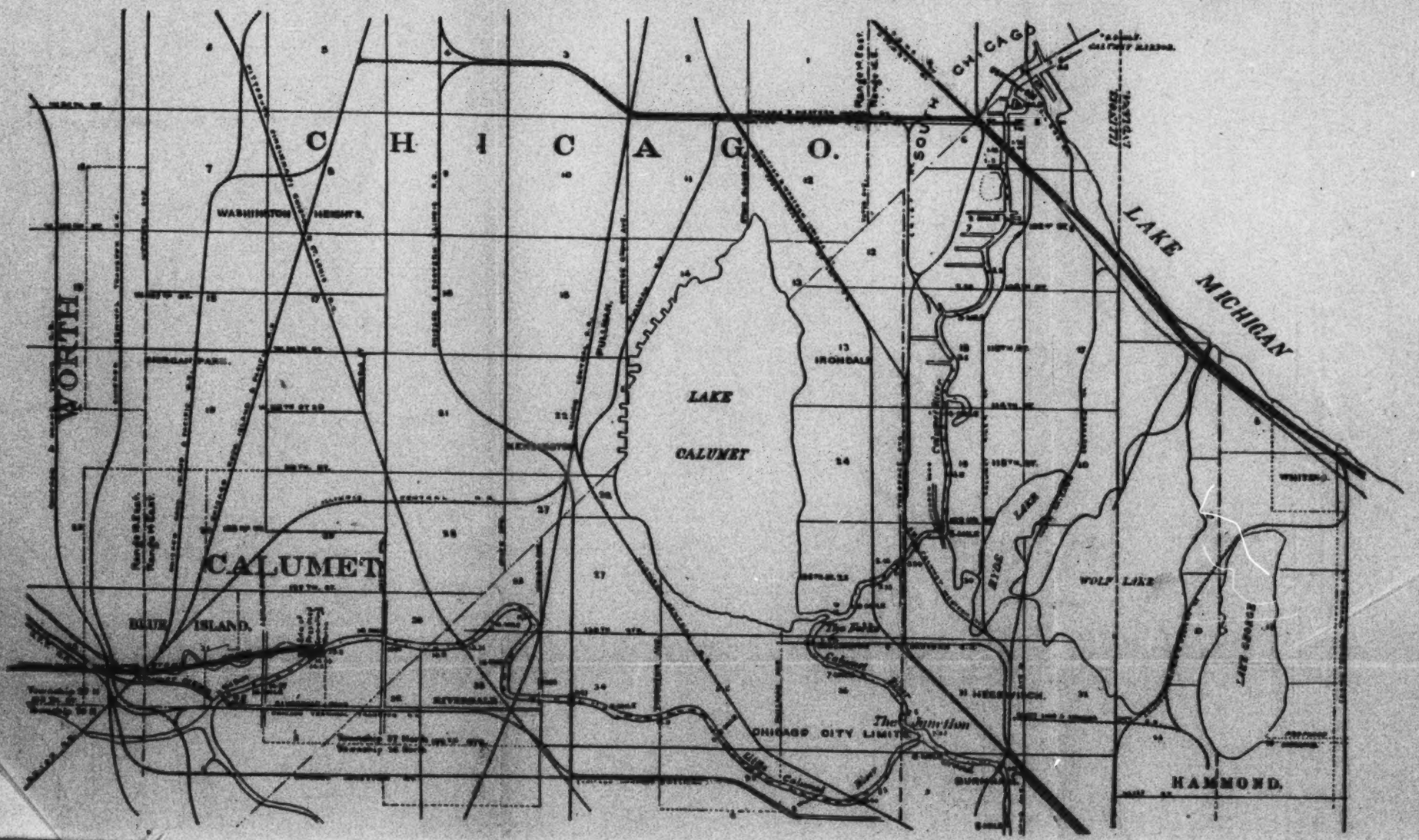


Exhibit G to answer, being an ordinance adopted December 7, 1904, by the Board of Trustees of the Sanitary District, laying out and adopting the project of the Calumet-Sag Channel. (Vol. VIII, Pages 19 to 26.)

The ordinance lays out the route of the Calumet-Sag Channel, describes by legal description the properties through and over which it passes, locates the center line as extending from the main channel of the Sanitary District near Sag, Illinois, easterly to a point at Stony Creek, near Blue Island, Illinois. (Exhibits A, C, D, E, F, page opposite.)

Exhibit H to answer, being ordinance passed January 22, 1908, supplementary to the ordinance of December 7, 1904, extending the right of way of the Calumet-Sag Channel easterly through Blue Island, to a point on the Little Calumet River. (Vol. VIII, Pages 26-28.)

Complaint in Main Channel suit, filed October 6, 1913. (Vol. VIII, pp. 39-58.)

The United States was represented by James G. McReynolds, Attorney General, and James H. Wilkerson, United States District Attorney for the Northern District of Illinois, against the Sanitary District of Chicago, and the complaint alleges the following:

First. Defendant, the Sanitary District of Chicago, is a municipal corporation, organized under an act of the General Assembly, approved May 29, 1889, in force July 1, 1889, and entitled: "An Act to create Sanitary Districts and to remove obstructions in the Desplaines and Illinois Rivers." Its principal place of business is Chicago, Illinois, and it is a citizen of said state.

Second. The Chicago River is situated in Cook County, Illinois, and consists of a main river, originally flowing in a generally easterly direction emptying into Lake Michigan. The said river was formed by two branches known as the

north and south branches, the south branch being divided into two forks, known as the west fork and the south fork.

Third. The Chicago River, including the north and south branches, west and south fork of the south branch, is a navigable water of the United States.

Fourth. The United States has appropriated and expended $4,216,066.36 in improving the said river and harbor at the mouth of the same.

Fifth. Section 10 of the act of Congress approved March 3, 1899, known as the Rivers and Harbors Act of that year has remained in full force and effect ever since its passage.

Sixth. Prior to May 8, 1899, the Sanitary District applied to the Secretary of War for permission to reverse the current and flow of the Chicago River and divert and abstract a quantity of water from Lake Michigan through said Chicago River and through a certain canal which was constructed by defendant. On May 8, 1899, the Secretary of War issued a permit to the defendant to reverse the current and flow of said river and to divert and abstract from Lake Michigan, not to exceed 300,000 cubic feet per minute, reserving the right to make changes as the Secretary of War should see fit in the interests of navigation and property rights. Copy of said permit is attached as "Exhibit A."

Seventh. April 9, 1901, the Secretary of War ordered defendant to reduce the flow through the Chicago River to 200,000 cubic feet per minute. Copy of the order is attached as "Exhibit B."

Eighth. Thereafter, the Secretary of War, pursuant to application of the Sanitary District of July 23, 1901, modified the preceding permit and order, and issued a permit to defendant to flow 300,000 cubic feet of water per minute, between the hours of 4:00 P. M. and 12:00 P. M. midnight, copy of which order or permit is attached as "Exhibit C."

Ninth. Subsequently, pursuant to application of the Sanitary District, on the 5th of December, 1901, the Secretary of War issued a permit to flow 250,000 cubic feet per minute throughout the twenty-four hours of the day, copy of which is attached as "Exhibit D."

Tenth. Thereafter, on the 17th day of January, 1903, a permit was issued to the Sanitary District to increase the flow to 350,000 cubic feet per minute until March 30, 1903, after which date the flow was to be reduced to 250,000 cubic feet per minute, as theretofore, copy of which is marked "Exhibit E" and attached.

Eleventh. On November 28, 1906, defendant made application to the Secretary of War for permission to construct a canal connecting the Calumet River with the main channel of the Sanitary District Canal at what is known as Sag, Illinois, and to reverse the flow of the Calumet River, which application was refused March 14, 1907, by the Secretary of War.

Twelfth. On the 11th of September, 1907, permit was granted pursuant to application of the Sanitary District to construct a canal connecting Lake Michigan at Wilmette, Illinois, with the north branch of the Chicago River, upon condition that the total diversion of water from Lake Michigan through the Chicago River should not exceed the amount already authorized by the War Department, to wit, 250,000 cubic feet per minute.

Thirteenth. Subsequently, pursuant to application of the Sanitary District of June 27, 1910, a permit was granted by the Secretary of War, authorizing defendant to construct a canal connecting the Calumet River with the main channel of the Drainage Canal at Sag, Illinois, and to divert and abstract water from Lake Michigan through said canal, providing, among other things, that the amount of water withdraw from Lake Michigan through the Chicago River should not exceed the total amount of 250,000 cubic feet per minute, the amount previously authorized to de withdrawn.

Fourteenth. February 5, 1912, defendant applied to the Secretary of War for permission to withdraw and divert from Lake Michigan, through the Chicago River and Calumet River, not to exceed 10,000 cubic feet of water per second. Copy of the application is attached as "Exhibit F."

Fifteenth. January 8, 1913, the Secretary of War refused the application of February 5, 1912, copy of which refusal is attached as "Exhibit G."

Sixteenth. Defendant has for a long period of time abstracted water from Lake Michigan, caused it to flow through the Chicago River, and is at present diverting through said river, from 400,000 to 600,000 cubic feet per minute, which amount is greatly in excess of the amount permitted by the Secretary of War, and is in violation of the permits of said Secretary of War, which limit the flow to 250,000 cubic feet per minute. Defendant intends and threatens to continue.

Seventeenth. Congress has not authorized the diversion through the Chicago River, and the Chief of Engineers has not recommended in excess of 250,000 cubic feet per minute.

Eighteenth. Diversion and abstraction of water in excess of 250,000 cubic feet per minute, has lowered and will continue to lower the level of the water of Lakes Michigan, Huron, St. Clair, Erie, Ontario, and the Rivers Sault Ste. Marie, St. Mary's, St. Clair, Detroit, Niagara, St. Lawrence, and all the harbors, canals, channels and rivers connected therewith, all being navigable waters of the United States, and will thus injure and diminish and create obstructions to the navigable capacity of all said waters.

Nineteenth. Said waters have been deepened and improved at great expense under congressional authority. The diversion and abstraction of waters from Lake Michigan in excess of the permits hereinabove set forth, will have a tendency to undo and annul the orders of Congress as expressed in the various Rivers and Harbors acts appropriating funds for im-

proving harbors and channels in the above named waters and channels connected therewith.

Twentieth. The diversion of waters of Lake Michigan through the Chicago River, in excess of the permits, will alter and modify the condition and capacity of the channel of the said Chicago River, which is a channel of a navigable water of the United States.

Twenty-first. The diversion of the waters of Lake Michigan through the Chicago River in excess of the permits, will alter and modify the condition and capacity of Lakes Michigan, Huron, St. Clair, Erie, Ontario, the Rivers Sault Ste. Marie, St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence, and the ports, roadsteads, havens, harbors, canals and harbors of refuge connected with the above named waters.

Twenty-second. Defendant cannot lawfully continue to divert and abstract water, in excess of the permits, as it is doing and threatens to do, without the recommendation of the Chief of Engineers and permission of the Secretary of War.

Prayer—That defendant be enjoined from diverting or abstracting any waters from Lake Michigan over, above and in excess of 250,000 cubic feet per minute, as already authorized by the Secretary of War.

Exhibit "A" to Bill of Complaint.

(Vol. VIII, Page 44.)

"Whereas, by Section 10 of an act of Congress approved March 3, 1899, entitled 'An act making appropriations for the construction repair and preservation of certain public works, on rivers and harbors, and for other purposes,' it is provided that it shall not be lawful to alter or modify the course, location, condition or capacity of the channel of any navigable water of the United States unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same:

And whereas, the Sanitary District of Chicago, a m
nicipal corporation, organized under the laws of the St
of Illinois, has constructed an artificial channel fr
Robey street, Chicago, to Lockport, and has been here
fore granted permission by the Secretary of War
make certain improvements in the Chicago river for
purpose of correcting and regulating the cross sectio
the river so as to secure a flowage capacity of 300,
cubic feet per minute with a velocity of one and one-qu
ter miles an hour, it being intended to connect the s
artificial channel with the west fork of the south bra
of Chicago river at Robey street in the City of Chic

And whereas, The said Sanitary District of Chic
has now applied to the Secretary of War for permis
to divert the waters of the said Chicago river and ca
them to flow into the said artificial channel at Ro
street as aforesaid;

And whereas, The said Sanitary District of Chic
represents that such movable dams and sluice gate
are necessary to, at all times, secure absolute and c
plete control of the volume and velocity of flow thro
the Chicago river have been constructed;

Now, therefore, The Chief of Engineers having
sented thereto, this is to certify that the Secretar
War hereby gives permission to the said Sanitary
trict of Chicago to open the channel constructed
cause the water of Chicago river to flow into the s
subject to the following conditions:

1. That it be distinctly understood that it is the in
tion of the Secretary of War to submit the questions
nected with the work of the Sanitary District of Chi
to Congress for consideration and final action, and
this permit shall be subject to such action as ma
taken by Congress.

2. That if, at any time, it becomes apparent that
current created by such drainage works in the south
main branches of Chicago river, be unreasonably
structive to navigation or injurious to property, the
retary of War reserves the right to close said disch
through said channel or to modify it to such exte
may be demanded by navigation and property inte
along said Chicago river and its south branch.

3. The the Sanitary District of Chicago must as
all responsibility for damages to property and na

tion interests by reason of the introduction of a current in Chicago river.

Witness my hand this 8th day of May, 1899.

R. A. Alger, Secretary of War. (Seal War Office.)
John M. Wilson, Brig. Genl. Chf. of Engrs.
U. S. A."

Exhibit "B" to Bill of Complaint.

"Whereas, under date of May 8th, 1899, the Secretary of War granted permission unto The Sanitary District of Chicago to open the artificial channel from Robey street, Chicago, to Lockport, and cause the waters of Chicago river to flow into the same, upon the following condition, *inter alia*:

(2) That if, at any time, it becomes apparent that the current created by such drainage works in the south and main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its south branch.

And whereas, It is alleged by various commercial and navigation interests that the present discharge from the river into the Drainage Canal sometimes exceeds three hundred thousand (300,000) cubic feet per minute, causing a velocity of nearly three (3) miles per hour, which greatly endangers navigation, in the present condition of the river.

Now, therefore, This is to certify that the Secretary of War, upon the recommendation of the Chief of Engineers, hereby directs said Sanitary District to regulate the discharge from the river into the Drainage Canal so that the maximum flow through the Chicago river and its south branch shall not exceed two hundred thousand (200,000) cubic feet per minute.

Witness my hand this ninth day of April, 1901.

Elihu Root, Secretary of War."

Exhibit "C" to Bill of Complaint.

"War Department, Washington

July 23, 1901.

SIR: Referring to War Department order of April 9th last, restricting the flow of water through the Chicago River under War Department permit of May 8, 1899 to 200,000 cubic feet per minute, and replying to your letter of the 15th instant, in which you request, for reasons stated, that the said order be amended to permit a flow of 300,000 cubic feet per minute between the hours of 4 P. M. and twelve o'clock midnight, I beg to inform you that I have this day approved the modification last referred to, which approval will be subject to revocation by the Department in case the increase shall prove to be dangerous to navigation.

Very respectfully, Elihu Root, Secretary of War.

Mr. Axelander J. Jones, President Sanitary District of Chicago, Chicago, Illinois."

Exhibit "D" to Bill of Complaint.

Whereas, Under date of May 8th, 1899, the Secretary of War granted permission unto the Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, upon the following condition, *inter alia*:

(2) That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch;"

And whereas, The Secretary of War subsequently directed said Sanitary District of Chicago, to regulate the discharge of water into the Chicago Drainage Canal so that the maximum flow through the Chicago River shall not exceed 200,000 cubic feet per minute from midnight to 4 p. m., nor 300,000 cubic feet per minute from 4 p. m. to midnight;

And whereas, Said Sanitary District of Chicago has applied to the Secretary of War for permission to increase the flow between midnight and 4 p. m., daily, to 250,000 cubic feet per minute; and the Chief of Engineers has recommended that the increase applied for be granted, but that the rate of flow from 4 p. m. to midnight be reduced to 250,000 cubic feet per minute, so that the flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day.

Now, therefore, This is to certify that, in acordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto the said Sanitary District of Chicago permission to regulate said discharge so that the maximum flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day, upon the following conditions:

(1). That this permission shall be in lieu of the present authorized rates of flow as stated above.

(2). That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

(3). That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

Witness my hand this 5th day of December, 1901.

W. Cary Sanger, Assistant Secretary of War."

Exhibit "E" to Bill of Complaint.

Whereas, under date of December 5, 1901, by an instrument supplementary to the original permission granted by the Secretary of War, May 8, 1899, to the Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of the Chicago River to flow into the same, the Secretary of War, pursuant to authority reserved in said permission of May 8, 1899, gave permission to the Sanitary District of Chicago to regulate said discharge so that the maximum flow per minute throughout the twenty-four hours of the day, upon the following conditions *inter alia*:

'That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require;'

And whereas, The said Sanitary District of Chicago has applied for permission to increase the flow through the Chicago River from 250,000 cubic feet per minute to 350,000 cubic feet per minute during the closed season of navigation, in order to carry off the accumulations of sewage deposit which line the shores along the city;

Now, therefore, This is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto said Sanitary District of Chicago permission to increase the flow through the Chicago River from 250,00 cubic feet per minute to 350,000 cubic feet per minute, until the 31st day of March, 1903, after which date it shall be reduced to 250,000 cubic feet per minute, as now authorized, upon the following conditions:

(1) That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

(2) That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized.

Witness my hand this seventeenth day of January, 1903.

W. Cary Sanger, Assistant Secretary of War."

Exhibit "F" to Bill of Complaint.

"The Sanitary District of Chicago

Chicago, February 5th, 1912.

SIR: On behalf of the Board of Trustees of The Sanitary District of Chicago, I have the honor to apply for enlargement of the terms of an instrument executed by The Secretary of War May 8, 1899, as modified by instruments similarly executed on December 5, 1901, and June 30, 1910, respectively, in the following particulars and in view of the facts hereinafter set forth, to wit:

The flow of water from Lake Michigan through the canal of The Sanitary District of Chicago is now limited by the said instruments to 4167 cubic feet per second.

The population of the Sanitary District, the sewage of which is to be disposed of through the channels constructed and to be constructed by the said District, exceeds 2,500,000 persons, and is rapidly increasing. The only method at present available for disposing of the sewage of this population is by diluting the same with water withdrawn from Lake Michigan and flowing through the Chicago Drainage Canal. The least amount of water necessary to render sewage innocuous by the dilution method has been estimated by well recognized sanitary experts as 1,000 feet per second for every 300,000 inhabitants; so that the amount permitted to be withdrawn by the instruments to which reference has been made is much below the amount at present needed by the District.

The Sanitary District has been for some time engaged in investigating methods and devising plans for the treatment of the sewage with a view to requiring less water for its safe dilution in the future. The methods of other states and countries for such treatment of sewage, are not as yet entirely satisfactory to all concerned, and any changes of methods for large cities must necessarily require several years.

Until these experiments are concluded and proper works installed, the use of additional water from Lake Michigan is essential to the health of the large population of the City of Chicago and of the Sanitary District and of those who live adjacent to the Des Plaines and Illinois rivers into which such waters are discharged.

Subject therefore to such restrictions as to you may seem proper for the protection of the public interest, and to such a method of supervision as you may suggest to promote the general welfare, and pending the completion of the investigations now being conducted to render the use of increasing quantities of water in the future necessary; I have the honor to apply for permission for The Sanitary District of Chicago to withdraw from Lake Michigan through the Chicago river and Calumet river—not to exceed ten thousand cubic feet of water per second; such permission to be revocable at any time by The Secretary of War, and subject to such action as the Congress of the United States may see fit to take in the premises.

Respectfully submitted, George M. Wisner, Chief Engineer. Hon. Henry L. Stimson, Secretary of War, Washington, D. C."

Exhibit "G" to Bill of Complaint.

"In the matter of the Application of THE TRUSTEES OF THE SANITARY DISTRICT OF CHICAGO for Permission to Divert from Lake Michigan 10,000 Cubic Feet of Water Per Second.

War Department

Washington, January 8, 1913.

The Sanitary District of Chicago applies to the War Department for permission to increase the amount of water it is authorized to withdraw from Lake Michigan from 4,167 cubic feet per second, the amount now authorized, to 10,000 cubic feet per second.

The Chicago Drainage Canal was opened in January, 1900. It reversed the flow of the Chicago River, which formerly emptied into Lake Michigan, and as a result a portion of the waters of that lake, instead of following their former course through Lakes Huron, Erie and Ontario into the St. Lawrence, are now carried across the watershed into the Illinois River, and through that to the Mississippi and the Gulf of Mexico. The canal thus serves as a system of drainage for the City of Chicago, carrying the sewage of that city southward to the Mississippi, and thus protects the water supply of that city, which is taken from Lake Michigan.

Permission to divert water from Lake Michigan was first granted by my predecessor, Secretary Alger, on May 8, 1899. He permitted a flowage of 5,000 cubic feet per second, but his permit contained the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it becomes apparent that the current created by such drainage works in the south and main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as

may be demanded by navigation and property interests along said Chicago River and its south branch.

Subsequently, during the administration of Secretary Root, the amount of the current permitted to be taken was modified or restricted until December 5, 1901, when it was fixed at the amount now permitted, and these permits contained the condition—

that the permission herein given shall be subject to such modifications as in the opinon of the Secretary of War the public interests may from time to time require.

On March 14, 1907, an application made for permission to divert an additional 4,000 cubic feet per second for the purpose of reversing the current of the Calumet River and flowing that river also through the canal to drain the southern portion of Chicago was denied by Secretary Taft in an opinion in which he referred once more to the desirability of submitting 'this question of capital and national importance to the Congress of the United States.'

It is clear that even under the conditions heretofore manifested on these applications, the proposition to divert the waters of Lake Michigan into another watershed has not been entertained without hesitation and careful restriction by my predecessors. The propriety of obtaining congressional sanction for the project has been pointed out from the beginning; and the form in which the permit has been granted, even for the moderate amount of diversion permitted, has been so phrased as to indicate that the permission was predicated upon the absence of any substantial injury to commerce.

The sanitary canal has never received the direct sanction of Congress. It was build solely under the authority of the State of Illinois, as given in its 1889 general act for creating sanitary districts. And although pursuant to the suggestion of my predecessors the question of the propriety of its diversion of water from Lake Michigan was presented urgently in the reports of the Chief of Engineers for the years 1899 and 1900 as transmitted to Congress, no action upon the question has ever been taken by that body. In the argument before me it was urged that the present canal represented the growth and development of a national policy expressed in two acts of Congress, 1822 and 1827, which authorized the construction of a canal 'to connect the Illinois River with Lake Michigan,' thus connecting the two watersheds. (Acts of March 30, 1822, and March 2, 1827.) But these statutes

authorized a canal for the purpose of navigation and not sanitation. (*Missouri* v. *Illinois*, 200 U. S. 526.) The Illinois and Michigan Canal, actually constructed under their authority, derived its water for navigation purposes from the Calumet, Des Plaines, and Chicago Rivers, and not from the Lakes. And although in the latter part of its existence it was used to a very slight extent to help purify the waters of the Chicago River and thus sanitate the City of Chicago, such a purpose could not have been dreamed of at the time its construction was authorized by Congress, 90 years ago. I can not see that its authorization and construction offer the slightest congressional sanction for the great canal now under discussion, which was not even contemplated until much more than half a century later. Even at the time when the present canal was constructed and opened it is very evident that its ultimate possible effect upon the navigation of the Great Lakes was not clearly realized by those interested in that navigation. The evidence before me indicates that the withdrawal of water from Lake Michigan at Chicago would require about five years to produce its full effect upon the levels of the Great Lakes (see report of International Waterways Commission on Chicago Drainage Canal, p. 7) and that this effect would be still further observed by periodic oscillations in the lake levels. These facts may easily explain any inaction on the part of the Nation and their representatives to this withdrawal of water and make it clear that any argument of implied acquiescence must be scrutinized with unusual care.

In this respect the situation is now very different. The present application was opposed by representatives of 23 cities and 6 States interested in harbors and commerce upon the Great Lakes, notably the Cities of Duluth, Milwaukee, Toledo, Cleveland and Buffalo. It was opposed by representatives of the navigation interests engaged on the Chicago River as well as on the Great Lakes, and by the official representatives of the Canadian Government as well as private Canadian interests engaged in the navigation of the Lakes and the St. Lawrence River, including representatives of the Cities of Kingston and Montreal.

A very careful consideration of the voluminous evidence and statements submitted, as well as a consideration of the reports of other commissons and boards of engineers who have investigated the subject, leaves no doubt in my mind that the withdrawal of 10,000 cubic feet

per second would substantially interfere with the navigable capacity of the Great Lakes and their connecting rivers. The Chief of Engineers, whose statutory authority in passing upon this application is concurrent with and independent of my own, and whose opinion upon such a question of scientific conclusion must be given especial weight, so states in his recommendation. His conclusions are corroborated by the authority of other boards of investigation, notably the report of the International Waterways Commission of January 4, 1907.

Careful observations and calculations conducted under the offices of the United States Lake Survey and reported through the Chief of Engineers, covering observations for the last 46 years, indicate that a withdrawal of 10,000 cubic feet per second would reduce levels at various places as follows:

	Inches
Lakes Huron and Michigan	6.9
Lake St. Clair	6.3
Lake Erie	5.4
Lake Ontario	4.5
St. Lawrence River at Rapide Plat	4.8 plus

The foregoing effects would be produced at mean lake levels; the lowering effects would be much greater at low-water periods—the precise time when any additional shortage would be most keenly felt. This reduction would create substantial injury in all of the American harbors of the Great Lakes and in the St. Marys', St. Clair and Detroit Rivers. It would produce equal injury in Canadian harbors on the Great Lakes, and a still greater injury on the lower St. Lawrence, the Canadian officials claiming a probable lowering effect of 12 inches at Montreal at low water.

The United States has improved about 106 harbors and rivers on the Great Lakes affected by this diversion and has spent on such improvements over ninety millions of dollars. The Canadian Government has improved over 50 harbors on Georgian Bay and Lakes Huron, St. Clair, Erie and Ontario. By treaty, American vessels are accorded equal rights of navivation with Canadian vessels in all these waters, including the St. Lawrence River. The reduction of the water in these harbors and channels would diminish to just that extent the amount of these improvements, and would nullify to just that extent the effects of the moneys which have been appropriated for that purpose by the respective Governments. Connecting

various portions of these waterways are the two canals at the Sault Ste. Marie, the Welland Canal, and a number of canals on the St. Lawrence River. The available depth of water over one or all sills of each of these canals would be affected, and in some cases reconstruction might even be made necessary.

The enormous lake traffic which uses these harbors and these rivers is increasing with great rapidity, both in gross volume and in the size and average drafts of the vessels employed therein. The Chief of Engineers reports that to lower the water surface 6 inches would reduce the permissible load of one of the large modern vessels by from 300 to 550 tons, with a consequent loss of from $3,600 to $7,500 in freights for such vessel per season. The International Waterways Commission reported that it would be a conservative estimate which would make the loss to the navigation interests resulting from a reduction of 6 inches in the depth of water as $1,500,000 per annum, or a sum which, capitalized at 4 per cent., would amount to a loss of $37,500,000 (see third progress report of International Waterways Commission of Dec. 1, 1907, p. 24). The lowest careful estimate of injury to American vessels alone is reported by the Chief of Engineers at $1,000,000 per year.

The argument was made before me that, owing to the well-known fact that the levels of the lake vary, owing to winds and change of barometic pressure, by amounts even greater than the reduction which would be caused by this canal, therefore the proposed reduction is of no consequence. This argument is well disposed of in the report of the International Waterways Commission of January 4, 1907, on page 8, as follows:

It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they cannot see it they will not know it and will not feel it. The argument is fallacious. It is true that they cannot see it immediately, but they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average

level is lowered unless the depth be restored by remedial works.

In a word, every drop of water taken out of Chicago necessarily tends to nullify costly improvements made under direct authority of Congress throughout the Great Lakes, and a withdrawal of the amount now applied for would nullify such expenditures to the amount of many millions of dollars, as well as inflict an even greater loss upon the navigation interests using such waters.

On the other hand, the demand for the diversion of this water at Chicago is based solely upon the needs of that city for sanitation. There is involved in this case no issue of conflicting claims of navigation. The Chief of Engineers reports that so far as the interests of navigation alone are concerned, even if we should eventually construct a deep waterway from the Great Lakes to the Mississippi over the route of the sanitary canal, the maximum amount of water to be diverted from Lake Michigan need actually be not over 1,000 feet per second, or less than a quarter of the amount already being used for sanitary purposes in the canal. This estimate is confirmed by the report of the special board of engineers on the deep waterway from Lockport, Ill., to the mouth of the Illinois River, dated January 23, 1911. It is also confirmed by the practical experience of the great Manchester Ship Canal in England. From the standpoint of navigation alone in such a waterway too great a diversion of water would be a distinct injury rather than a benefit. It would increase velocity of the current and increase the danger of overflow and damage to adjacent lands.

We have, therefore, presented in this case claims of entirely different characters and jurisdictions — the claim of sanitation on the one side and of navigation on the other; the vital interest of a single community on the one side and the broad interest of the commerce of the nation on the other. The discretion given to the Secretary of War under sections 9 and 10 of the act of 1899 is very broad, but I have very grave doubts as to whether it was intended to authorize him to grant a permit which would inflict a substantial injury upon commerce in order to benefit sanitation. The entire purpose and scope of that legislation was to make him the guardian of commercial interests of the nation represented in their waterways. And while he sometimes under that statute must decide that the interests of one class of transportation

are less important and must yield to the conflicting interests of another class. I have considerable doubt whether it was intended to give him authority to sacrifice substantial interests of navigation to entirely different claims over which he normally has no jurisdiction whatever.

But however that may be, and without resting my decision upon the question of my legal authority, I am quite clear as a matter of discretion that under the facts presented by this case no further diversion of water should be permitted at Chicago without the direct sanction of the Congress of the United States. I do not for one moment minimize the importance of preserving the health of the great City of Chicago; but when a method of doing this is proposed which will materially injure a most important class of the commerce of the nation and which will also seriously affect the interests of a foreign power, it should not be done without the deliberate consideration and authority of the representatives of the entire nation. The growth of Chicago is phenomenal and its representatives are quite unwilling to put any final limit to the demand which may be made upon the waters of Lake Michigan for its sanitation under the system now in use. I have before me the report of 1911 of the president of the sanitary district in which he says:

I am of the opinion that the presumption that our water supply is to be limited to 10,000 cubic feet per second, or 600,000 cubic feet per minute, is gratuitous and mischievous and should not be voiced by the officials of this district. I believe that we should have the volume requisite to our needs as they appear and are justified.

It is therefore quite conceivable that compliance with their sanitary needs according to this method of sanitation may eventually materially change this great natural watercourse now existing through the Lakes. The weighing of the sanitation and possibly the health of one locality over against the commerce of the rest of the Nation and the consideration of our relations and obligations to Canada in respect to a great international waterway are not matters of mere technical or scientific deduction. They are broad questions of national policy. They are quite different in character, for example, from the question of fixing the proper location of a pierhead line or the height or width of a drawbridge over a navigable stream—fair samples of the class of questions which come to the Secretary of War for decision under

the above-mentioned act of 1899. While the researches and opinions of experts in the respective fields are necessary and useful as an assistance toward reaching a fair and proper policy, the final determination of that policy should belong not to an administrative officer but rather to those bodies to whom we are accustomed to entrust the making of our laws and treaties.

In my view of the proper exercise of my discretion in this matter the foregoing considerations are sufficient for a decision of this case. Having reached the conclusion that the proposed diversion of the waters of Lake Michigan would substantially injure the interests of the navigation on the Great Lakes which it is my legal duty to protect, it would clearly follow that the present application should be denied.

I have carefully examined, however, the evidence which both sides have introduced bearing upon the sanitary needs of the City of Chicago, and my conclusion is in no way shaken. I am not persuaded that the amount of water applied for is necessary to a proper sanitation of the City of Chicago. The evidence indicates that at bottom the issue comes down to the question of cost. Other adequate systems of sewage disposal are possible and are in use throughout the world. The problem that confronts Chicago is not different in kind but simply larger and more pressing than that which confronts all of the other cities on the Great Lakes, in which nearly 3,000,000 people of this country are living. The urban population of those cities, like that of Chicago, is rapidly increasing, and a method of disposition of their sewage which will not injure the potable character of the water of the Lakes must sooner or later be found for them all. The evidence before me satisfies me that it would be possible in one of several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition. A recent report of the engineers of the sanitary commission (Oct. 12, 1911) proposes eventually to use some such method, but proposes to postpone its installation for a number of years to come, relying upon the present more wasteful method in the meanwhile. It is manifest that so long as the city is permitted to increase the amount of water which it may take from the Lakes, there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage. This is particularly true in

view of the fact that by so doing it may still further diminish its expenses by utilizing the water diverted from the Lakes for water power at Lockport. But it must be remembered that for every unit of horsepower realized by this water at Lockport four units of similar horsepower would be produced at Niagara, where the natural conditions are so much more favorable. Without, therefore, going more into detail in a discussion of this question, I feel clear that no such case of necessity has been presented by the evidence before me as would justify the proposed injury to the many varied interests in the great waterways of our lakes and their appurtenant rivers.

It remains only to consider certain special arguments that have been pressed upon me: It has been urged that the levels of the lakes, even if lowered, could be restored by compensating works. To a certain extent that is true. But the very nature of this consideration offers another illustration of the importance of having the whole question passed upon by Congress. Such compensating works can only be constructed by the authority of Congress and at very considerable cost. It is not a matter which is in the hands of the Secretary of War. Permission to divert water which will at one and the same time nullify the effect of past appropriations and make necessary similar expenditures in the future, should be granted only with the express consent of the body in whose hands the making of such appropriations and the authorization of such works rest.

Furthermore, in most cases such compensating works could only be constructed with the joint consent of our neighbor Canada. The United States Government alone would be unable, even if it were willing to spend its own funds, to compensate for the damage done through the lowering of these levels unless Canada were willing to join in constructing the portion of such works which would necessarily stand upon Canadian soil.

The question therefore becomes not merely national but international, and this leads me to the consideration of the arguments which were urged by both sides in reference to the treaty with Great Britain in respect to Canada of January 11, 1909. A careful consideration of that treaty fails to indicate to me that it is in any way controlling upon the questions now before me. It gives to the citizens of both countries certain mutual rights of navigation in the waters of the Great Lakes and their connect-

ing rivers; but beyond that the question of the right to this diversion at Chicago seems to me to have carefully excluded. The applicants for the permit have urged upon me that article 8 of the treaty gives a preference to the uses of water of the lakes for domestic and sanitary purposes over the uses of such water for navigation. Article 8, however, applies only to future cases brought before the International Joint Commission; and furthermore I am clearly of the opinion that the domestic and sanitary purposes referred to in that article were intended to be the "ordinary" uses of such waters for domestic and sanitary purposes referred to in article 3. It would be quite contrary to our own national policy to give such a preference to an extraordinary sanitary use of such a character as to create a substantial injury to navigation. The matter has been before our own Supreme Court in the case of the Unites States v. the Rio Grande Dam & Irrigation Co. (174 U. S., 690). In that case the Supreme Court held that a company which proposed to take the water of the Rio Grande river for the purpose, among others, "of supplying water to cities and towns for domestic and municipal purposes" could be prevented from so doing when the result would be a substantial injury to the navigability of the Rio Grande river farther down. In its opinion the court said:

The question always is one of fact, whether such appropriation substantially interferes with the navigable capacity within the limits where navigation is a recognized fact. In the course of the argument, this suggestion was made, and it seems to us not unworthy of note, as illustrating this thought. The Hudson river runs within the limits of the State of New York. It is a navigable stream and a part of the navigable waters of the United States, so far at least as from Albany southward. One of the streams which flows into it and contributes to the volume of its waters is the Croton river, a non-navigable stream. Its waters are taken by the State of New York for domestic uses in the City of New York. Unquestionably the State of New York has a right to appropriate its waters, and the United States may not question such appropriation, unless thereby the navigability of the Hudson be disturbed. On the other hand, if the State of New York should, even at a place above the limits of navigability, by appropriation for any domestic purposes, diminish the volume of waters, which, flowing into the Hudson, make it a navigable stream, to such an extent as to destroy its navigability,

undoubtedly the jurisdiction of the National Government would arise and its power to restrain such appropriation be unquestioned; and within the purview of this section (act of Sept. 19, 1890, ch. 907) it would become the right of the Attorney General to institute proceedings to restrain such appropriation.

The treaty, however, contains provisions in its article 10 by which "any questions or matters of difference arising between the high contracting parties involving the rights, obligations, or interests of the United States or of the Dominion of Canada, either in relation to each other or to their respective inhabitants, may be referred for decision" to an international joint commission established by the said treaty. The hearing before me brought forth the fact that the Government of Canada regards the proposal contained in this application as one which affects the material interests of that country. The establishment by formal treaty between the two countries of a tribunal with jurisdiction to decide just such questions seems to me to afford an additional reason against the assumption of jurisdiction to decide the question by an administrative officer of one of those countries.

In short, after a careful consideration of all the facts presented, I have reached the following conclusions:

First. That the diversion of 10,000 cubic feet per second from Lake Michigan, as applied for in this petition, would substantially interefere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.

Second. That that being so, it would not be appropriate for me, without express congressional sanction, to permit such a diversion, however clearly demanded by the local interests of the sanitation of Chicago.

Third. That on the facts here presented no such case of local permanent necessity is made evident.

Fourth. That the provisions of the Canadian treaty for a settlement by joint commission of "questions or matters of difference" between the United States and Canada offer a further reason why no administrative officer should authorize a further diversion of water, manifestly so injurious to Canada, against Canadian protest.

The prayer of the petition is therefore denied.

Henry L. Stimson, Secretary of War."

Answer of the Sanitary District of Chicago to complaint in the Main Channel suit—filed January 16, 1914, as follows (Vol. VIII, pp. 58-126, including exhibits):

(1) Admits it is municipal corporation, organized under the laws of Illinois, as charged in the bill of complaint; a copy of the original act under which the defendant was organized, passed May 29, 1889, is attached as Exhibit A.

(2) Admits the Chicago River is situated in Cook County, and originally flowed in a general easterly direction and is formed as described. Exhibit B, attached, shows the location of the river exactly.

(3) Admits the Chicago River and its branches are navigable waters of the United States.

(4) Admits the United States has expended the amount of money alleged in the bill of complaint, in improving the navigable capacity of said river and the harbor at its mouth.

Avers that $2,389,527.10 of said amount was expended in the improvement of the harbor at the mouth of said Chicago River; that down to the year 1896, the complainant had expended no money in the improvement of the Chicago River itself. That the balance of that original sum, namely, the sum of $1,626,539.20, was expended by complainant in and about the improvement of the Chicago River between the year 1896 and June 30, 1913; that the City of Chicago, beginning with the year 1861 and ending the first day of January, 1913, has expended in the improvement of the Chicago River, $6,272,574.52; that the defendant, the Sanitary District, has expended in the improvement of the Chicago River, in addition to the amounts expended by the City of Chicago, the sum of $10,640,739.52; that defendant made said expenditures for the purpose of enabling it to cause the flow of the several amounts of water provided for under the laws of Illinois, and the expenditures by the defendant did improve the capacity and navigability of said Chicago River and its several branches.

(5) Admits the passage of the Rivers and Harbors Act of March 3, 1899, and the continuance in force of Section 10 thereof.

(6) Denies that application was made by defendant for permission to divert any certain quantity of water from Lake Michigan through said Chicago River and its main channel. Avers that application was made to the Secretary of War for permission to open the channel constructed and cause the water of the Chicago River to flow into same, pursuant to and under the Act of May 29, 1889; that in the said permit the Secretary of War stated that he reserved the right to close said discharge or to modify it to such an extent as might be demanded by navigation and property interests along said Chicago River and its south branch.

(7) Admits the order of Secretary of War of April 9, 1901, concerning the limitation of flow to 200,000 cubic feet per minute.

(8) Admits the issuance of the order of July 23, 1901.

(9) Admits the issuance of the order of December 5, 1901.

(10) Admits the issuance of the order of the Secretary of War of January 17, 1903.

(11) Admits the application to the Secretary of War of November 28, 1906, for permission to construct a canal connecting the Calumet River with the main channel of defendant, and the refusal of the Secretary of War of March 14, 1907, to grant said permit. A copy of the statement of the Secretary of War is attached as Exhibit C.

(12) Admits the permit of September 11, 1907, to construct a canal connecting Lake Michigan at Wilmette, to the north branch of the Chicago River, a copy of which is attached as Exhibit D.

(13) Admits the issuance of the permit of June 30, 1910, with reference to the construction of the Calumet Sag Channel, a copy of which is attached as Exhibit E.

(14) Admits the making of the application of February 5, 1912, to divert 10,000 cubic feet of water per second through the Chicago and Calumet Rivers.

(15) Admits the refusal of the Secretary of War of January 8, 1913, to grant said application of February 5, 1912.

(16) Denies that defendant has, for a long period of time, diverted and abstracted from Lake Michigan, and is at present diverting 400,000 to 600,000 cubic feet of water per minute, as charged in the bill of complaint.

(17) Denies the diversion of water from Lake Michigan in excess of the amount of 250,000 cubic feet of water per minute has lowered or will lower the levels of Lakes Michigan, Huron, St. Clair, Erie, Ontario, the Rivers Sault Ste. Marie, St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence, or any of them, or any of the harbors, channels, canals or rivers connected therewith, or will injure or diminish or create an obstruction to the navigable capacity of said rivers, as charged.

(18) Neither denies nor affirms the allegation as to the amount of the expenditure by the United States in improving said harbors and channels. Denies that the diversion of waters from Lake Michgan in excess of the permits, has or will have a tendency to undo or annul the orders of Congress, as charged.

(19) Denies that the diversion from Lake Michigan in excess, or substantially in excess, of the amount provided by the permits of the Secretary of War, will modify the condition and capacity of the channel of the Chicago River, as charged.

(20) Denies that the diversion from Lake Michigan in excess of permits, will alter or modify the condition and capacity of Lakes Michigan, Huron, St. Clair, Erie, Ontario, the Rivers Sault Ste. Marie, St. Mary's, St. Clair, Detroit, Niagara and St. Lawrence, or any of them, and the ports, roadsteads, havens, harbors, canals and harbors of refuge

connected with the above named waters, or any of them. Denies that defendant cannot lawfully continue to divert and abstract waters from Lake Michigan as it now does, or that it cannot lawfully divert and abstract, without the permission of the Secretary of War, waters from Lake Michigan under the laws of Illinois, and by and through the channels and works it has already constructed; that complainant will be in any manner injured by the diversion through its works; that interstate navigation and commerce will in any manner be injured by the abstraction, pursuant to and under the laws of Illinois, and as contemplated by the channels and works of the defendant.

The remainder of the answer consists of affirmative allegations as follows:

(21) The Sanitary District is a municipal subdivision of the State. The area within its territorial limits is 386.2 square miles, located on the shore of Lake Michigan at its southwest end. The shore line is thirty-three miles long and the Sanitary District limits extend westward from the shore line a distance from six to fourteen miles. The drainage naturally is to Lake Michigan, for the most part through the Chicago and Calumet Rivers and their branches. The DesPlaines River rising in Wisconsin twelve miles from the Lake Michigan shore flows in a southerly direction at a distance of about ten miles from the lake paralleling it until the DesPlaines reaches a point fifteen miles southwest of the mouth of the Chicago River when it turns to the southwest a distance forty-five miles beyond, and empties into the Illinois River. Between Lake Michigan and the DesPlaines River, six miles from the shore line is an elevation of approximately eleven feet above the low water level of the lake. This is known as the Continental Divide, or the height of land on one side of which water flows into the Great Lakes thence into the Gulf of St. Lawrence, and on the other side of which water flows into the DesPlaines River, thence into the Illinois and Mississippi Rivers, then to the Gulf of Mex-

ico. By water trail from the mouth of the Chicago River, the lowest point in said Continental Divide is about eight miles. At this point there was located on the summit of said Divide a lake known as Portage Lake and later called Mud Lake. At times of high water, the DesPlaines River rose to the level of said lake and discharged itself over the divide and through the Chicago River into Lake Michigan. The land lying east of said divide is low, flat, level and swampy, and devoid of hills or elevations so that in times of high water large portions of said territory were inundated. The City of Chicago was established at the mouth of the Chicago River, located approximately in the center of the territorial limits of this defendant and, as it has expanded, has stretched out over the branches of the Chicago River. From the time when the site where the City of Chicago is now located, was settled, it has been menaced by floods and has had to contend with the natural disadvantages which it suffered by reason of the fact that the city was situated upon a flat, low, sandy soil and at the outlet or discharging point of a large drainage area. Prior to the organization of Chicago, from the time this part of the territory of North America was discovered, a trading post was located at the mouth of the Chicago River. In 1778 there was a fort, known as Fort Dearborn, which was destroyed in the massacre of 1812. Fort Dearborn was rebuilt by the United States in 1816. In 1837, the village of Chicago was organized with 709 lawful voters. By 1854, there were 40,000 people in Chicago. From the very beginning, because of the flat, low, marshy and sandy soil, and only a slight elevation above the level of Lake Michigan, the city was confronted with the necessity of constructing a sewer system. It raised the level of its streets. Between 1854 and 1889, sewers were so constructed that in the City of Chicago, north of the Chicago River, they drained into the Chicago River as far north as the boundaries of the City of Chicago. Territory lying to the west of the north and south branches of the Chicago river was drained by sewers into the river. Territory lying south of the Chicago

River and east of State street, drained directly into Lake Michigan, that is, sewers were constructed at 12th street, 22d street and 31st street, which emptied directly into the lake. The territory above described as being within the boundaries of the City of Chicago as it existed in 1889 was bounded on the north by Fullerton avenue, at a distance of two and one-half miles north of the Chicago River, on the west by Western avenue at a distance of between four and five miles west of Lake Michigan, and on the south by 39th street, a distance of approximately four and one-half miles south of the mouth of the Chicago River.

(22) South of 39th street and adjoining the City of Chicago was the Village of Hyde Park, with a population in 1889 of 41,000, the largest part of which had sewers emptying directly into Lake Michigan. West of Hyde Park was the Town of Lake, with a population of 58,661 in 1889, the sewage of which emptied into the South Fork of the South Branch of the Chicago River. Situated north of Fullerton avenue and adjoining the City of Chicago was the Town of Lake View with a population of 42,339, which had several sewers emptying into the North Branch of the Chicago River. And situated west of the Town of Lake View was the Town of Jefferson, with a population of 10,662, the sewers of which emptied into the North Branch of the Chicago River. The population of Chicago in 1889 was 802,651. The discharge of the sewage of Chicago and its adjoining suburbs either into Lake Michigan directly or indirectly by way of the Chicago River and its branches polluted the water supply of this great population. Conditions of pollution were such that it became necessary to create The Sanitary District of Chicago for the purpose of removing said pollution and providing the way, as hereinafter more fully shown, of disposing of the sewage of the City of Chicago and its adjacent towns and villages.

(23) When Chicago was first organized, the people of the village obtained their drinking water from shallow wells sunk into the sand, the water in said wells finding its way

by seepage from Lake Michigan and the Chicago River. As Chicago grew, the wells became polluted by sewage and by drainage that washed into said wells necessitating large numbers of people obtaining their water supply directly from Lake Michigan. This water was first obtained by means of wagons carting the water from the lake to individual users. Later wooden pipes were laid in the streets, which drew water from the lake. Still later, a tunnel was extended to Lake Michigan and the Chicago avenue crib was built to prevent the ends of the tunnels being injured or choked by ice in the winter time. Finally, the City of Chicago, or the towns and villages located near it and herein mentioned, built in Lake Michigan six intakes, cribs and tunnels connected therewith for the purpose of obtaining water from Lake Michigan, as follows:

The Lake View crib on the northern extremity of said city, at a distance of two miles from the shore of Lake Michigan; the Carter H. Harrison crib, situated at a distance of three miles from the shore; the Chicago avenue crib, situated at a distance of two miles from the shore; the Four Mile crib, situated approximately four miles from the shore and opposite the most densely populated portion of said City of Chicago, and the Hyde Park and Edward F. Dunne cribs, two miles off shore, situated near the southern extremity of said city. At points along the shore, pumping stations were erected by means of which water is pumped through said tunnels and distributed through pipes or water mains to the people of Chicago and adjoining towns. The distributing system is interconnected so that in case any one crib or tunnel should be incapacitated, the other tunnels would furnish water to the people. The City of Chicago has expended, in and about the construction of said cribs and tunnels, and in the construction of distributing pipes and distributing tunnels, large sums of money, in excess of $59,042,565. There is no other source of water supply for the inhabitants of Chicago and its adjoining towns than Lake Michigan.

(24) From the earliest discovery of this country, there has existed between Lake Michigan and the Mississippi River a water route used as a highway of trade and travel. This water route originally consisted of the Chicago River, its South Branch and the West Fork thereof, a ditch or canal in wet seasons and a portage in dry seasons from thence into a lake known as Mud Lake, and a ditch or canal in wet seasons and a portage in dry seasons from said Mud Lake into the DesPlaines River to the Illinois River and thence into the Mississippi River. The said route was used for the purpose of carrying on trade and for the purpose of travel for upwards of 160 years, and said use was prior to any improvements made by the United States or by the government then controlling the country now known as Canada. During said period, also, from the lower end of Lake Michigan through the Great Lakes and their connecting waters to the Atlantic Ocean, there were two water routes, one by way of a portage around Niagara Falls and from thence on the St. Lawrence River to the Atlantic Ocean; the other water route consisted of a route through Georgian Bay, Lake Nipissing and down the Ottawa River into the St. Lawrence River and thence to the Atlantic Ocean. The two water routes from the lower end of Lake Michigan to the Atlantic Ocean and the one to the Gulf of Mexico were used for the purpose of trade and travel up to approximately the year 1830. About the year 1822, there was a great demand for the improvement of these water routes and on March 30, 1822, the Congress of the United States passed an Act granting to the State certain public lands for the purpose of aiding the State in constructing a canal "connecting the Illinois River with the southern end of Lake Michigan." Said Act was entitled "An Act to Authorize the State of Illinois to Open a Canal Through the Public Lands to Connect the Illinois River with Lake Michigan." Section 1, among other things provided:

> "That the State of Illinois be, and is hereby authorized to survey and mark, through the public lands of the United States, the route of the canal connecting the Illinois River with the southern bend of Lake Michigan; and

ninety feet of land on each side of said canal shall be forever reserved from any sale to be made by the United States, except in the cases hereinafter provided for, and the use thereof forever shall be, and the same is hereby vested in the said State for a canal, and for no other purpose whatever; on condition, however, that if the said State does not survey and direct by law said canal to be opened, and return a complete map thereof to the treasury department, within three years from and after the passage of this act; * * * and grant hereby made shall be void and of none effect;"

The State of Illinois did not, within the time provided by the Act, cause a survey to be made and the grant in said Act lapsed. On January 28, 1826, the General Assembly of Illinois memorialized Congress setting forth the advantages of a canal to unite the waters of Lake Michigan with the Illinois River. The action of the government of Great Britain in refusing to the citizens of the United States free navigation of the St. Lawrence River also made it necessary for the United States to provide a free and unobstructed water route from the Great Lakes to the Atlantic Ocean by way of the Des Plaines River, Illinois and Mississippi Rivers, and the Gulf of Mexico. Thereupon, on March 2, 1827, the Congress of the United States passed an Act entitled "An Act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan." Section 1 of said Act is, in part, as follows:

"* * * That there be and hereby is granted to the State of Illinois, for the purpose of aiding the said State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each side of said canal, and reserving each alternate section to the United States, to be selected by the Commissioner of the Land Office, under the direction of the President of the United States, from one end of the said canal to the other; Provided, That the said canal when completed, shall be and forever remain a public highway for the use of the Government of the United States, free from any toll, or

other charge, whatever, for any property of the United States, or persons in their service passing through the same;"

On January 9, 1836, the General Assembly of Illinois passed an Act under which the said Illinois-Michigan canal was built to unite the waters of the Illinois River with those of Lake Michigan, entitled, "An Act for the Construction of the Illinois and Michigan Canal," Section 16 of which Act is as follows:

> "That said canal shall not be less than forty-five feet wide at the surface, thirty feet at the base, and of sufficient depth to insure navigation, to be supplied with water from Lake Michigan and such other sources as the Canal Commissioner may think proper, and to be constructed in the manner best calculated to promote the permanent interests of the country, reserving ninety feet on each side of said canal to enlarge its capacity whenever in the opinion of the Board of Canal Commissioners the public good shall require it."

The plan of said canal as contemplated under the said Act of January 9, 1836, provided for a flow of water from Lake Michigan by gravity into and through the canal and from thence into the Illinois River and was known as the "Deep-Cut" plan. On account of lack of funds, the State was unable to immediately construct the said canal on the deep cut plan and it was constructed on what was known as the shallow cut plan and completed in the year 1848. Water to partly operate the same was obtained from Lake Michigan by means of pumps. From the time the canal was opened until the construction of the main channel of the Sanitary District, it furnished a partial outlet for the sewage and drainage of Chicago. As the needs of the city required, said canal was enlarged so as to provide a better and more suitable outlet. About the year 1860, to meet the demands of increased population, larger pumps were installed to pump more water from Lake Michigan through the Chicago River into the Illinois and Michigan Canal. In the year 1865, to meet the further needs of Chicago, the General Assembly of Illinois passed an

Act entitled "An Act to Provide for the Completion of the Illinois and Michigan Canal upon the plan adopted by the State in 1836," which said Act is in part as follows:

> "Whereas, it has been represented that the City of Chicago, in order to purify or cleanse Chicago River, by drawing sufficient quantity of water from Lake Michigan, directly through it, and through the summit division of the Illinois and Michigan Canal, would advance a sufficient amount of funds to accomplish this desirable object; and,
>
> Whereas, the original plan of said canal was to cut down the summit so as to draw a supply of water for navigation directly from Lake Michigan, which plan was abandoned for the time being, after a large part of the work had been executed, only in consequence of the inability of the State to procure funds for its further prosecution; • • •
> now therefore, • • •
>
> Be it enacted by the People of the State of Illinois, represented in the General Assembly: That to secure the completion of the Illinois and Michigan Canal upon the original "deep cut" plan, with such modifications and changes of line, if necessary, as will most effectually secure the thorough cleansing or purification of the Chicago River, and facilitate the execution of the work, the City of Chicago, through its constituted authorities, may at once enter into an arrangenment with the board of trustees of said canal, with a view to the speedy accomplishment of the work."

The work of completing the said canal by the City of Chicago was completed about the year 1871. Thereafter, water of Lake Michigan was drawn through said canal by gravity and about the year 1884, pumps were installed at Bridgeport, the northern terminus of the canal, whereby a larger quantity of water was withdrawn from Lake Michigan through the Chicago River and said canal, all pursuant to a resolution of the General Assembly of Illinois passed in the year 1881, which resolution is in part as follows:

> "Whereas, The State of Illinois, in General Assembly, did, on the sixteenth day of February, 1865, grant and authorize the City of Chicago in the State of Illinois, to

deepen the Illinois and Michigan canal for the purpose of, and with the intent to better the system of sewage of the said City of Chicago by permitting a free flow of water from Lake Michigan through the Chicago River and said canal to the Desplaines and Illinois Rivers; and the City of Chicago did perfect said improvement in conformity with said permission; * * *

Whereas, the deepening of the canal as aforesaid has proved to be totally inadequate for the purposes intended, and the large amount of sewage of the City of Chicago, being far greater than the capacity of the canal and the water now passing through it to deodorize and render innocuous; and

Whereas, The foulness of the water annually causes the death of millions of fish in the Desplaines and Illinois Rivers, that float to the shores and decay; * * *

Whereas, The supplying of the canal from these sources will so dilute and weaken the sewage of the City of Chicago, as to greatly relieve it of its foulness and stench to the great delight, relief and health of the peoples near to and bordering upon the line of the canal, the Desplaines and Illinois Rivers; therefore be it Resolved"

The resolution then provided that the City of Chicago should cause pumps to be installed at the northern terminus of the canal whereby at least 60,000 cubic feet of water per minute should be pumped from the Chicago River into the canal.

(25) Lake Michigan was, is and will be the only adequate source from which drinking water for the metropolitan population of Chicago and its environs could or may be obtained, and the supply is adequate, sufficient and pure if unpolluted by sewage or drainage. The additional flow of water to the Illinois and Michigan Canal created by the pumping works installed in 1884 at Bridgeport did not serve to cleanse sufficiently the Chicago River of pollution. During a portion of each year, the Chicago River did flow into the lake thus carrying with its waters the sewage and drainage of Chicago and its environs, polluting the water of Lake Michigan. The population had increased so that the improvements made from time to time up to the year 1884 were insufficient and

inadequate to prevent the pollution of the lake, thus depriving the inhabitants of Chicago and its environs of a pure water supply for domestic purposes. Thus it became necessary that some further and better improvements be made by which the pollution of the drinking water of the inhabitants of Chicago would be prevented. The death rate from typhoid fever and other water-borne diseases had become very high and deaths from such causes were frequent through the City of Chicago and adjacent towns. The Chicago River and its branches were then a seething mass of septic sludge giving forth noxious and disagreeable odors which caused annoyance and danger to the people of Chicago and persons sojourning within its limits. Thereupon, the City of Chicago appointed a commission consisting of eminent sanitary experts for the purpose of making an investigation of the conditions, and a report as to the proper solution of the problem then confronting the people of Chicago and its environs who depended upon Lake Michigan for their water supply. The commission was appointed in the year 1886 and presented a report to the Mayor of the city recommending the construction of a channel and works connected therewith, substanially as provided for in the Act of May 29, 1889, under which The Sanitary District was organized. The said Act was passed, pursuant to the investigation and report of said commission and other investigations carried on at the same time by other persons. Said Act was passed for the purpose of providing for the organization of The Sanitary District of Chicago and the construction of channels and works by it, so that the pollution of the drinking water of Chicago and its environs would be relieved and a pure supply could be secured.

(26) By the Act of May 29, 1889, the Sanitary District was authorized to construct a channel of sufficient size to take care of not only the sewage and drainage of the City of Chicago and its environs, but also the sewage and drainage as the increase of population might require. The channel to be constructed was fixed by said Act with a capacity and size to produce a flow through the rock sections thereof,

not less than 600,000 cubic feet of water per minute and to produce and maintain a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of population in the Sanitary District. The Chicago River drainage area is approximately 420 square miles, the maximum run of which is approximately 10,000 cubic feet of water per second or 600,000 cubic feet per minute. In order to prevent the Chicago River from flowing into the lake and carrying the sewage into Lake Michigan, it was necessary that the channel so to be constructed should have a capacity of not less than 10,000 cubic feet of water per second, the maximum run-off of the Chicago River drainage area. In order to prevent the pollution of the waters of Lake Michigan by water of the Calumet River, it was necessary that a channel be constructed connecting the Calumet River with the main channel so that the Calumet River would be reversed. It was further provided by said Act under which the Sanitary District was organized that the channel when completed should be a navigable water of the United States and that the United States should have the authority to take over and operate said channel for navigation purposes, but not for sanitary or drainage purposes. The said channel to be constructed was intended to be an enlargement or replacement of the channel known as the Illinois and Michigan Canal.

(27) Pursuant to said Act of the General Assembly of May 29, 1889, the Sanitary District was organized by vote of the people on the 5th day of November, 1889, and the first trustees were elected December 12, 1889. On January 18, 1890, this board of trustees held a regularly organized meeting of the board to begin the actual work of constructing the Sanitary District channel provided for under said Act. The Sanitary District entered upon the construction of said main channel and other works long prior to September 19, 1890, and laid out plans for and entered upon the construction of its channel with a capacity of 840,000 cubic feet per minute or 14,000 cubic feet per second. Plans were at the same time made and considered for the construction of a channel to

connect the Calumet River with the said main channel; for the construction of intercepting sewers on the south side of the city converging at 39th street on the Lake Shore by which approximately 2,000 cubic feet of water per second should be pumped from Lake Michigan together with sewage accumulated at said point, through a conduit to be constructed into the South Fork of the South Branch of the Chicago River, and from thence into the said main channel. Said intercepting sewers so provided for on the south side of the city and converging at 39th street, were for the purpose of intercepting sewage then flowing directly into Lake Michigan, and thereby divert it into the main channel. The North Branch of the Chicago River was then a stagnant stream into which sewage from a large portion of the north side emptied. In order to create a current into said North Branch and thereby cleanse it and abate a public nuisance, plans were made for the construction of a conduit extending from the Lake Shore at Lawrance avenue in the City of Chicago to the said North Branch through which approximately 666 cubic feet of water per second from Lake Michigan should be caused to flow, and from thence into the main channel. It was contemplated that approximately 1,000 cubic feet per second of water from Lake Michigan should be caused to flow through said North Shore channel, together with said sewage and drainage from said district. Plans were then made for enlarging the cross section of the Chicago River, South Branch and West Fork to accommodate sufficient water so as to cause the course, current and flow of the Chicago River to be at all times reversed, in times of high water as well as in times of low water, and to provide for an ultimate flow through the Sanitary District main channel of sufficient water to dilute and purify the sewage of the City of Chicago and its environs flowing into the main channel, pursuant to the provisions of said Act of 1889. At that time the defendant, Sanitary District, entered upon the construction of said works. The complainant, the United States, had knowledge of said act and the improvements provided for under said Act.

(28) Pursuant to said Act of 1889, and said plans, the Sanitary District constructed a channel through what is known as the rock section of the route described, extending from the controlling works at Lockport north to Willow Springs, a distance of 14.93 miles, with a bottom width of 160 feet, a surface width of 162 feet, with a depth of at least twenty-four feet, and with a declivity of one foot in every 20,000 feet, having a capacity of flowing 840,000 cubic feet per minute or 14,000 cubic feet per second. From said Willow Springs to Robey street, a distance of 13.1 miles through what is known as the earth section, the defendant made plans for a channel with a bottom width of 202 feet and a surface width of 300 feet and a depth of not less than twenty-four feet, with a declivity of one foot in every 40,000 feet, Said defendant constructed said channel through said earth section as planned, except in this, that for a distance of 7.8 miles from Robey street to Summit the defendant left unexcavated a width of ninety two feet, inasmuch as said channel was not territory having a rocky stratum and was more easily capable of progressive development as the population of the District might increase. The capacity of said channel from Robey street to Summit, being a portion of the earth section was eighty percent of the flow of the rock sections, or 500,000 cubic feet of water per minute, or 8,000 cubic feet of water per second. Long prior to the filing of the bill of complaint, this defendant made and entered into a contract with the Great Lakes Dredge & Dock Company, under which the said main channel in the earth sections was to be enlarged by widening the same, so that through the said earth section, the said main channel would have a capacity of flowing in excess of 10,000 cubic feet of water per second. Before the filing of the said bill of complaint, the work provided for under said contract was substantially completed, so that the said main channel through the earth sections at the time of the filing of said bill of complaint herein, had a capacity of flowing in excess of 10,000 cubic feet of water per second.

(29) The said main channel from Robey street to the controlling works at Lockport, Illinois, was completed and ready for use on or about September 21, 1898, and about January 11, 1899, pursuant to said Act of 1889, section 27 thereof, such fact was reported to the Governor of Illinois. Whereupon, the governor appointed a commission to inspect and certify the completion of the channel as required by said Act. Pursuant to the report of said commission given the Governor of Illinois, he authorized and directed the opening of said channel.

(30) On January 17, 1900, said channel was opened and the flow of the Chicago River, South Branch and West Fork, as far as Robey street was reversed and water was caused to flow out of Lake Michigan, through the Chicago River, the South Branch and West Fork thereof, and down the Sanitary District channel from Robey street and discharged into the DesPlaines River at Lockport and from thence into the Illinois River to the Mississippi River, and continuing to the Gulf of Mexico.

(31) Contemporaneously with the construction of the main channel, defendant carried on certain construction work in the Chicago River, the South Branch thereof and its West Fork, to provide a larger cross section to enable the Chicago River and the South Branch and the West Fork to flow an increased quantity of water. July 3, 1896, the Sanitary District having made application, obtained a permit from the Secretary of War to enlarge the cross section of the Chicago River and its branches, copies of the application and the permit being attached as Exhibits H and I, respectively. July 11, 1900, the Secretary of War granted two permits to the defendant to make further changes, alterations and improvements in the South Branch of the Chicago River. The application for said two permits, the plans accompanying the same and the permits are attached and marked respectively, J, J-1, K-1, K-2, L and L-1. Pursuant to said permits of July 3, 1896, and July 11, 1900 and other permits granted by the Secretary of War at various times, defendant improved the

Chicago River, South Branch and West Fork so that the rivers have been enlarged sufficiently to accommodate a flow of water of at least 8,000 feet per second with a velocity not to exceed one and one quarter miles per hour. The volume of water above specified flowing through the said rivers and through the main channel of the Sanitary District, together with the 2,000 cubic feet emptying into the South Fork of the said Chicago River from the 39th Street Pumping Station will not create a current in any way injurious to navigation.

In the improvement of said Chicago River and its branches and the widening and deepening thereof and in the building of bridges, the Sanitary District has expended in excess of $10,000,000. A large part of said money was expended for the purpose of improving navigation in the said Chicago River, South Branch and West Fork. The Chicago River was thus deepened by the defendant to a depth of twenty-six feet from a depth of seventeen feet and widened to a width of 200 feet from a width of approximately one hundred feet.

The main channel or canal constructed by this defendant from Robey street to Lockport is twenty-four feet deep at all points and has a width of 162 feet. The Chicago River, South Branch and West Fork as improved by the Sanitary District and the main channel constructed by it are of sufficient capacity to enable the largest vessels, freight or passenger, traversing the Great Lakes, to pass through or into same. By virtue of the works of the defendant, the largest vessel traversing the Great Lakes can pass through said Chicago River and its branches to the city of Joilet. Since the completion of the Sanitary District main channel, the Illinois and Michigan Canal has been abandoned. The improvement of the Chicago River and its branches was in accordance with the plan of the complainant in connection with the improvement of navigation upon the said rivers.

(32) May 14, 1903, the General Assembly of Illinois passed an Act entitled "An Act in Relation to the Sanitary District

of Chicago to enlarge the corporate limits of said District and to construct dams, water wheels and other works necessary to develop and render available power arising from the water passing through its channels, and levying taxes therefor". Under this Act, the defendant extended its main channel to the City of Joilet and the work was completed about the year 1907. Certain works were also constructed and completed about the year 1907 for the development of water power at a cost of approximately $5,000,000. The amount of power being so developed is 30,000 H. P. and is worth approximately $30 per horse power per year net. The revenue obtained from said water power is used for the purpose of partially defraying the other expenses of the defendant. The operation of said hydro-electric plant and the development and sale of electrical energy does not in any way increase the amount of water caused to flow through said main channel and is incidental merely to the operation of the Sanitary District's diversion works. About the year 1910, the Sanitary District built what is known as the North Shore channel extending from Lake Michigan and Wilmette to the North Branch of the Chicago River, with a capacity of 1,000 cubic feet of water per second, which flows from Lake Michigan into and through said North Shore channel to the North Branch of the Chicago River.

(34) Under said Act of 1889, the defendant has constructed intercepting sewers and pumping stations at Lawrence avenue in the City of Chicago, and the Lake, and at 39th street, Chicago, and the Lake, by which all the sewage formerly flowing directly into Lake Michigan is diverted into the main channel aforesaid of this defendant.

In the year 1910, the defendant entered upon the construction of an adjunct or addition to its main channel at Sag, Illinois, known as the Calumet-Sag Channel, to a point on the main channel at Sag, Illinois, which channel is in course of construction, with a capacity of approximately 2,000 cubic feet of water per second. It is capable of enlargement so that it will accommodate a flow of 4,000 cubic feet of water

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per second. The Calumet Sag Channel is to drain what is called the Calumet District lying immediately south of the southern limits of Chicago and thus prevent the pollution of the drinking water supply by and through the Calumet River. The Calumet Sag Channel is also designed to furnish a certain amount of water by which to dilute sewage and drainage flowing through the main channel of the Sanitary District, and arizing in that portion of the Sanitary District tributary to the Chicago River and its branches and the main channel of this defendant.

(35) The works constructed or being constructed and the improvement made upon the Chicago River and its branches were made necessary by the Act of the General Assembly of Illinois of 1889 and Acts amendatory and supplementary thereto. They provide a complete and comprehensive system by which an outlet is provided for the territory comprised within the limits of the Sanitary District and for the drainage arising therein. Said works do and will prevent the pollution of the drinking water of the inhabitants and provide pure water for drinking and domestic purposes. Said Act of 1889 and acts amendatory and supplemental thereto were passed and adopted under the police power existing in the State for the purpose of protecting the health and lives of the people within said district and within the State of Illinois as well as persons sojourning or visiting within the limits of this defendant. Said works constructed and to be constructed provide the only method by which the sewage and drainage of the inhabitants of the Sanitary District could be diverted from Lake Michigan and a pure water supply for domestic purposes secured for such inhabitants. By virtue of the nearness of the Mississippi drainage area, and the insignificance of the so-called continental divide, it was possible to provide in the manner above set forth, an outlet for the sewage and drainage of the City of Chicago and its environs so that the water of Lake Michigan could be maintained pure and undefiled by any pollution from sewage or drainage arising within the City of Chicago, and other

cities and villages located upon the shore of Lake Michigan near the said City of Chicago. The Sanitary District and the City of Chicago have expended in and about the construction of the works and in making the improvements, the sum of $82,000,000. Of this said amount, the City of Chicago has expended approximately $6,500,000, in and about building intercepting sewers, pumping stations, etc.

(36) The said works constructed and the improvements made and the works being constructed are necessary to preserve the health and lives of the people within the Sanitary District. The Sanitary District comprises a large metropolitan district within Cook County. Attached is a map marked Exhibit M showing the territorial boundaries of the defendant within which there is located numerous cities.

(37) Congress has at various times appropriated money for improvement of navigation in the Illinois River, and for the making of surveys and investigations to determine the best method by which navigation on the Illinois and Des Plaines Rivers could be improved in connection with the main channel of the defendant heretofore constructed. The United States built in the lower Illinois River, certain dams at La Grange and Kampsville for the purpose of improving navigation in connection with and for the purpose of supplementing improvements made by the State of Illinois in constructing two dams, one at Henry, Illinois, and the other opposite Copperas Creek on said river. The dams constructed by the State and the United States were provided with locks by which vessels could pass from the level of the water created by the dam at the lock to the level below, or vice versa. During the period when the said main channel of defendant was under construction, prior thereto and since the opening of same, Congress has appropriated moneys for the purpose of making surveys and investigations for a deep waterway, extending from the terminus of the main channel of the defendant, at or near Lockport, Illinois, on the Des Plaines and Illinois Rivers to the Mississippi River and from thence to the Gulf of Mexico. All boards of engineers and

all engineer officers of the Corps of Engineers of the United States Army, who have made reports in regard to such deep waterway pursuant to congressional appropriations have recommended the improvement of the Des Plaines and Illinois Rivers to provide deep water navigation, and the plans and recommendations made by such engineers, contemplated the use of the said main channel of defendant as part of and as a link in such deep waterway, and the use of the water flowing through and contemplated to be passed through the main channel of the defendant in the Des Plaines and Illinois Rivers for the purpose of such navigation. The International Waterways Commission created by act of Congress and by an act of the Dominion of Canada by report made January 4, 1907, recommended that 10,000 cubic feet of water per second should be allowed to be diverted by the defendant from Lake Michigan. The Sanitary District constructed its main channel with a capacity of not less than 10,000 cubic feet of water per second, to comply with the plans and purposes of the United States. The United States approved said plans and purposes and the Congress of the United States cooperated with the defendant and invited the defendant to cooperate with the complainant, and joined in the improvement of the Chicago River, as has been more fully set out. The Attorney General of the United States, on December 14, 1909, caused a bill of complaint to be filed in the name of the United States against the Economy Light & Power Company, in the Circuit Court of the United States, Eastern Division, Northern District of Illinois, to enjoin the defendant, the Economy Light & Power Company, from constructing a dam in the Des Plaines River. In and by said bill of complaint, complainant further recognized the diversion and the right of defendant to divert the amount of water contemplated in and by its said works and in and by said act of May 29, 1889. Said bill of complaint in this respect, so far as it relates to said matters, is as follows:

"That in connection with the construction of said Sanitary District Canal, and in creating the system of waterways re-

sulting from the construction of said canal, said State of Illinois has caused the quantity of water flowing through said Des Plaines River below the point at which it connects with said canal to be largely increased, and that said portion of said river has been continuously since the opening of said canal, and is now, water navigable in fact and a part of the navigable waters of the United States and subject to the jurisdiction and control of the Federal Government. * * *

That in connection with and as a result of the construction of said Sanitary District Canal and the diversion of said water from Lake Michigan, said Sanitary District of Chicago, acting under authority of said State of Illinois, has largely increased the navigability of said Des Plaines River and that continuously since the opening of said canal there has been, and is, in said portion of said Des Plaines River below the point at which it connects with said canal, a body of water navigable in fact and which, by virtue of its connection with other navigable waters is to be deemed a part of the navigable waters of the United States and subject to the jurisdiction and control of said United States."

Complainant, in and by its bill of complaint in said cause, wherein the Economy Light & Power Company was defendant, based its right to an injunction enjoining the construction of the said dam upon the fact that the State of Illinois had, in and by and pursuant to the Act of May 29, 1889, created a navigable waterway in the DesPlaines River; that said navigable waterway thus created was connected with and was a part of the system of navigable waterways created by the Sanitary District of Chicago, which said waterways thus created were connected with and a part of other navigable waters of the United States.

(38) Complainant had knowledge of the passage of the Act of May 29, 1889, plans of the Sanitary District for the construction of the main channel, and the progress of construction. About the time of the opening of the Sanitary District's main channel the lake survey of the United States

under the direction of the corps of engineers of the United States Army, had determined the increments of the St. Clair, Niagara and St. Lawrence Rivers for the purpose of making estimates or calculations of the effect of the diversion of 10,000 cubic feet per second at Chicago. Said officers of the United States at said time, upon the determination of said increment, calculated the effect of said diversion to be about six inches upon the levels of the Great Lakes below Lake Superior. The United States about the same time, in providing for the improvement of the St. Mary's, St. Clair and Detroit Rivers and other channels connecting the Great Lakes with one another, fixed the reference plane for said improvements six inches lower because of the supposed effect of the said diversion upon the levels of the different lakes. The United States acquiesced in and agreed to said diversion.

If the diversion of water from Lake Michigan to the amount proposed by the Sanitary District, will have the effect of lowering the levels of the waters of the Great Lakes, except Superior, and their connecting channels, it is feasible and practicable to compensate or off set for such lowering by constructing works in the St. Clair, Detroit, Niagara and St. Lawrence Rivers, or in some or all of them. The International Waterways Commission, in its report on the regulation of Lake Erie, issued in the year 1910, recommended the building of regulating works to regulate the levels of Lake Erie and thereby raise such levels approximately one foot at low water times, the cost of which works was estimated by said commission at approximately $796,000. A more recent report of said commission on the regulation of said Lake Erie, estimates the cost of such works at approximately $3,000,000. Such regulating works would more than off-set for any alleged lowering of the levels of the Great Lakes and their connecting channels due to the Chicago diversion.

The levels of the waters of said Great Lakes and their connecting channels, have been lowered by works constructed

by the United States and by Canada, by private individuals and corporations, by and with the consent and acquiescence of the United States. The defendant is not responsible for any lowering of said levels.

(39) By consenting to the improvement of the Chicago River to accommodate the flow of water through the Sanitary District's main channel, as contemplated under the Act of 1889, by the appropriation of money for the purpose of determining the feasibility of improving waterways to connect with the navigable waterways created by this defendant, by acquiescing in and acknowledging the right to use said works and to abstract the water from Lake Michigan as proposed, solemnly asserted in the case of *United States* v. *The Economy Light & Power Company,* above referred to, by allowing this defendant to proceed with the construction of said works, with the knowledge of said complainant, without making any objection thereto, but, on the contrary, consenting to and agreeing to various improvements made necessary by virtue of the said system of works, complainant has estopped itself from making any objection to or attempting to prevent further use and continuance of said works for the purpose for which they were created. After the beginning of the construction of said works of the Sanitary District, the United States adopted the improvements contemplated and being then carried on in the Chicago River and its various branches and supplementing said improvements so being made by the defendant and inviting further improvements, itself expended approximately $1,000,000 in the improvement of the Chicago River from Rush street to the end of the West Fork.

(40) Defendant has never recognized the right of the United States in any manner to interfere with the construction, operation or use of its main channel, adjuncts or additions, or the right of the United States to determine or direct how the said main channel and its appurtenances should be operated or used, or the amount of water that should be abstracted from Lake Michigan through its various adjuncts

or channels, to carry out the purposes of said Act of May 29, 1889. Application for permits mentioned and described in the bill of complaint and in this answer, were made by reason of the close blending or association of the two governments, namely the Government of the State and of the United States. The defendant desired, if possible, to obtain the consent of the Secretary of War for the construction, operation and use of its works, but defendant never has admitted and does not admit, but on the contrary denies the right of the United States to determine the amount of water that should be caused to flow through said main channel or its adjuncts. The permit of May 8, 1899, granted to the Sanitary District the right to open the main channel and use the same for the purposes and to cause the amounts of water to flow therein as contemplated and provided for under the Act of May 29, 1889. The only condition of said permit as to limiting the amount of water to be allowed to flow through the said main channel, is the preservation of suitable conditions of navigation upon the Chicago River itself. Said condition was inserted in said permit by virtue of the fact that at that time the Chicago River had not been widened and deepened to the extent that it was proposed to be. The orders subsequently given by the Secretary of War to reduce the flow or to increase the flow of water through the Chicago River, were based entirely upon conditions of the Chicago River for the purpose of navigation. By said permit of May 8, 1899, and the subsequent orders and permits issued by the Secretary of War, the United States recognized the right of the Sanitary District to abstract water from Lake Michigan, and only limited the amount of such abstraction by the amount that the Chicago River could carry without injury to navigation thereon. Subsequently to the issuance of said permits and orders, the project for the widening and deepening of the Chicago River for a capacity of at least 8,000 cubic feet of water per second, was carried out with the consent of the Secretary of War. Before the filing of the bill of complaint herein, defendant had improved the Chicago River channel so that at least 8,000 cubic feet of water per

second could flow and was flowing into and through the said Chicago River and the South Branch and West Fork thereof, without creating a current of more than one and one quarter miles per hour and without creating a condition which would be or was injurious to navigation on said river. The condition created by the defendant in improving the Chicago River by widening and deepening it, greatly improved navigation in all respects upon said river.

(41) The water discharged into the DesPlaines River from the Sanitary District's works, flows through said Des Plaines River and empties into the Illinois River. As a result of this flow, the Illinois River has become navigable without the use of government or state dams heretofore constructed, so that the Illinois River may now be traversed by boats of a deeper draft than could have traversed the Illinois River by the use of the locks and dams constructed by the United States and by the State, namely, the Kampsville and LaGrange dams by the United States and the Henry and Copperas Creek dams by the State of Illinois. The Illinois River has become clear, which prior to the opening of the defendant's main channel was a sluggish, slow moving body of water badly polluted by sewage discharged by the City of Chicago and many towns and villages situated along it. Fish life in said river has increased rapidly and generally it has become more healthful to the people living thereon. If the flow of the Illinois River had not been increased by the waters caused to flow therein by defendant, or if the flow through the main channel of the defendant, were limited to 4,167 seconds feet, as charged that it should be, or to any amount materially less than required by said Act of May 29, 1889, it would be necessary for the cities and towns located on said Illinois and DesPlaines Rivers to expend vast sums of money in treating the sewage now discharged in the said Illinois River, in order to prevent a public nuisance.

(42) Since the opening of the defendant's main channel and the completion of the additions and adjuncts thereto, in-

cluding intercepting sewers, the health conditions in the City of Chicago and in other towns and villages located within the defendant's territorial limits have greatly improved and the death rate from water-borne diseases has greatly diminished. A pure water supply has been provided for said people. The City of Chicago is a great railroad and commercial center, and is a primal market. Many persons not residing within the limits of the Sanitary District, come each year from all parts of the United States and the world to Chicago, and remain there for various periods. Twenty-seven million people each year come into and leave the City of Chicago. In addition, there are forty-seven million persons residing without the City of Chicago, but in the suburban communities, who enter and leave Chicago each year.

(43) If the injunction prayed for is granted and defendant is obliged to limit the withdrawal of water to 4,167 seconds feet, a large portion of the moneys expended will have been lost, and the works constructed will be practically useless and of no substantial efficiency or value. The City of Chicago and other cities and towns and villages within the boundaries of the defendant, have constructed their waterways, water mains and other sewage disposal works and water supply works, upon the basis of the works of this defendant being permanant, to endure for all time, to be operated as provided by the Act of May 29, 1889, and acts amendatory and supplementary thereto. If the said flow of water through said main channel is reduced or limited to 4,167 cubic seconds feet, in order to prevent said sewage from becoming a public nuisance, it will be necessary to construct a plant or plants for the disposal of sewage by some other method or means. The construction of such plants would cost upwards of a hundred million dollars, and the annual operation of such system would cost over seven million dollars, which capitalized at five per cent, would mean a total investment or burden of two hundred and forty million. It will be necessary to construct, in connection with said disposal works, filtration works to filter all the drinking

water and water used for domestic purposes, at a cost of upwards of twenty-five million dollars, and an annual operation cost of two million dollars, making the total investment or burden, forty million dollars. The damage to the City of Chicago and other cities, towns and villages located within the boundaries of the Sanitary District, thus would amount to approximately three hundred million dollars, and the money expended for defendant's works already constructed at a cost of approximateyl eighty-two million dollars, would have been expended for no practical purpose, so far as taking care of sanitary conditions is concerned. The only method by which defendant can conveniently take care of and remove the sewage and drainage from its limits and protect the water supply of the inhabitants of Chicago and its environs, is the one laid out under the Act of May 29, 1889, and acts amendatory and supplementary thereto. The method or methods which it would be necessary for defendant to adopt if the flow of water through its main channel were limited to 4,167 seconds feet, would not accomplish the purpose now secured by defendant's works already constructed, nor would such works constructed under a plan made necessary by such limitation of flow, in any manner equal the efficiency of defendant's works.

(44) The State of Illinois under said Act of May 29, 1889, and acts amendatory and supplementary thereto, provided a comprehensive and effective method to dispose of the sewage within the boundaries of the defendant, and to provide pure drinking water for the inhabitants thereof and its floating population—to wit, the method of treating the sewage by dilution and diverting the same from Lake Michigan. Defendant is without power to provide any other method than the one set forth under the Act of May 29, 1889. If it were given power to dispose of the sewage by some other method and procure a pure water drinking supply in some other manner the constitutional limitation of the State of Illinois upon the creation of indebtedness by municipalities would prevent this defendant from providing the moneys

with which to build sewage disposal works and filtering plants to meet the conditions which would be created by said decrease of the flow of water. Defendant could not provide sufficient funds to build said works. Neither the City of Chicago nor the other cities, villages or towns within the limits of the Sanitary District, have the power to raise sufficient moneys by the sale of bonds or by taxation, to build sewage disposal works or water purification or filtration works which would be necessary to be constructed within the limits of the respective cities, towns and villages, if this defendant were compelled to limit the flow of water to 4,167 feet.

(45) If said injunction is granted and defendant is restrained as requested, it will be unable to keep the drainage water which will flow from said territory from reversing the Chicago River at various times during each year, so that the said drainage and sewage arising tributary to the Chicago River, will flow into Lake Michigan and thereby pollute the water supply of Chicago and other cities and towns within the Sanitary District's limits. At other times during the year, the river will become polluted, so that there would be thereby created an offensive condition and a public nuisance in the spread of water borne diseases, endangering the health and lives of the population of defendant and its floating population.

(46) The sewage disposal works and water filtration plants necessary to be constructed if such injunction were granted, would be, inadequate, ineffective and impracticable to provide for the disposition of the sewage aforesaid, and to provide pure drinking water for the inhabitants of said District. The purification of sewage artificially and the filtration of water polluted by sewage or an effluent arising from sewage purification work is a method for providing a water supply used only where the method provided for under the Act of 1889, to wit, the dilution method and diverting sewage and drainage from the water supply, is impossible.

Exhibit A to answer.—"An act to create sanitary districts and to remove obstructions in the DesPlaines and Illinois Rivers". Approved May 29, 1889, by the General Assembly of Illinois; in force July 1, 1889. (Vol. VIII; Rec. 92-107.)

Section 1. This section generally provides for the organization of the Sanitary District by vote of the people on petition of certain number of legal voters, which petition shall also describe the territorial limits of the Sanitary District.

Sections 2, 3, 4, 5 and 6 set forth how the trustees shall be elected, the number, salaries, proof of ordinances, orders and resolutions, and publication of appropriations.

Section 7 is as follows:

> "7. The board of trustees of any sanitary district organized under this act shall have power to provide for the drainage of such district by laying out, establishing, constructing and maintaining one or more main channels, drains, ditches, and outlets for carrying off and disposing of the drainage (including the sewage) of such district, together with such adjuncts and additions thereto as may be necessary or proper to cause such channels or outlets to accomplish the end for which they are designed in a satisfactory manner; also to make and establish docks adjacent to any navigable channel made under the provisions hereof for drainage purposes, and to lease, manage and control such docks, and also to control and dispose of any water power which may be incidentally created in the construction and use of said channels or outlets, but in no case shall said board have any power to control water after it passes beyond its channel, waterways, races or structures into a river or natural waterway or channel, or water-power or docks situated on such river or natural waterway or channel: Provided, however, nothing in this act shall be construed to abridge or prevent the State from hereafter requiring a portion of the funds derived from such water-power, dockage or wharfage to be paid into the State Treasury to be used for State purposes. Such channels or outlets may extend outside of the territory included within such sanitary district and the rights and powers of said board of trustees over the portion of such channel or outlet lying outside of such district shall be the same as those

vested in said board over that portion of such channels or outlets within the said district.

Sections 8, 9, 10 and 11 provide that the District may purchase real estate, borrow money, raise money by taxation, and let contracts for work in certain manner.

Section 12 is in part as follows:

"Provided, that no part of the taxes hereby authorized shall be used by such drainage district for the construction of permanent fixed, immovable bridges across any channel constructed under the provisions of this act; And provided further, that all bridges built across such channel shall not necessarily interfere with or obstruct the navigation of such channel, when the same becomes a navigable stream, as provided in section 24 of this act, but such bridges shall be so constructed that they can be raised, swung, or moved out of the way of vessels, tugs, boats, or other water craft navigating such channel; And provided further that nothing in this act shall be so construed as to compel said district to maintain or operate said bridges, as movable bridges, for a period of nine years from and after the time when the water has been turned into said channel pursuant to law, unless the needs of general navigation on the DesPlaines and Illinois rivers, when connected by said channel, sooner require it."

Sections 13, 14, 15 and 16 provide for special assessments, issuance of bonds and condemnation of property.

Section 17 is as follows:

"17. When it shall be necessary in making any improvements which any district is authorized by this act to make, to enter upon any public property or property held for public use, such district shall have the power so to do and may acquire the necessary right of way over such property held for public use in the same manner as is above provided for acquiring private property, and may enter upon, use, widen, deepen and improve any navigable or other waters, waterways, canal or lake: Provided, the public use thereof shall not be unnecessarily interrupted or interfered with, and that the same shall be restored to its former usefulness as soon as practicable: Provided, however, that no such district

shall occupy any portion of the Illinois and Michigan canal outside of the limits of the county in which such district is situated for the site of any such improvement, except to cross the same, and then only in such a way as not to impair the usefulness of said canal, or to the injury of the right of the State therein, and only under the direction and supervision of the canal commissioners: And, provided further, that no district shall be required to make any compensation for the use of so much of said canal as lies within the limits of the county in which said district is situated except for transportation purposes."

Sections 18, 19 and 19*a* provide certain limitations as to special assessments, and that the Sanitary District shall pay damages resulting to lands by the operation of its works including attorneys' fees of plaintiff to be assessed as part of the costs of suit.

Sections 20, 21, 22, 23, 24, 25 and 26, are as follows:

"20. Any channel or outlet constructed under the provisions of this act which shall cause the discharge of sewage into or through any river or stream beyond or without the limits of the district constructing the same shall be of sufficient size and capacity to produce a continuous flow of water of at least two hundred cubic feet per minute for each one thousand of the population of the district drained thereby, and the same shall be kept and maintained of such size and in such condition that the water thereof shall be neither offensive or injurious to the health of any of the people of this State; and before any sewage shall be discharged into such channel or outlet, all garbage, dead animals and parts thereof, and other solids shall be taken therefrom, and said district shall, at the time any sewage is turned into or through any such channel or channels, turn into said channel or channels not less than twenty thousand cubic feet of water per minute for every one hundred [fol. 181] thousand inhabitants of said district, and shall thereafter maintain the flow of such quantity of water.

"21. In case any sanitary district in this State formed under the provisions of this act shall introduce sewage into any river or stream of water, or natural or artificial water course, beyond or without the limits of such district, without conforming to the provisions of

this act, or having introduced such sewage into such water course, shall fail to comply with any of the provisions of this act, an action to enforce compliance shall be brought by the Attorney General of this State in the courts of any county wherein such water course is situated, or he may authorize the State's Attorney of any such county to commence and prosecute such action in any such county: Provided, that nothing in this section contained shall be construed to prevent the prosecution of any action or proceedings by individuals or bodies corporate or politic against such district: And, provided further, that if any individual or the authorities of any municipal corporation shall file with the Attorney General a verified statement, in writing, setting forth wherein said sanitary district has failed to comply with any of the provisions of this act, it shall be the duty of the Attorney General forthwith to file in the Supreme Court of this State a petition for mandamus, setting forth wherein said sanitary district has failed to comply with the provisions of this act, and said court shall thereupon hear and determine such cause and proceed to enforce compliance with the provisions of this act, as in other cases of mandamus.

And, in order to comply with the provisions of this act, such sanitary district is hereby authorized and empowered to levy and collect such tax, as an emergency tax, upon the taxable property of such sanitary district as may be necessary to carry into effect any order, judgment or decree of said court relating to the requisite flowage of water, capacity of the channel or outlet and the construction, maintenance and operation of movable bridges, as required by this act.

22. Nothing in this act contained shall be so construed as to constitute a contract or grant between the State of Illinois and any sanitary district formed under its provisions, or to prevent, debar or deprive the State of Illinois from, at any time in the future, altering, amending or repealing this act, or imposing any conditions, restrictions or requirements other, different or additional to any herein contained upon any sanitary district which may be formed hereunder.

23. If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Des Plaines or Illinois river such channel shall be constructed of sufficient size and capacity to produce and maintain

at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than fourteen feet, and a current not exceeding three miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan, of not less than eighteen feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than one hundred and sixty feet at the bottom capable of producing a depth of not less than eighteen feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000 such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than three miles per hour, and if at any time the general government shall improve the Des Plaines or Illinois rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter, enlarge the entire channel leading into said Des Plaines or Illinois rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom. In case a channel is constructed to the Desplaines river as contemplated in this section it shall be carried down the slope between Lockport and Joilet to the pool commonly known as the upper basin of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act, may correct, modify and remove obstructions in the Desplaines and Illinois rivers wherever it shall be necessary

so to do to prevent overflow or damage along said river, and shall remove the dams at Henry and Copperas Creek in the Illinois river, before any water shall be turned into the said channel. And the canal commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said canal commissioners to cause such dam or dams to be removed. This act shall not be construed to authorize the injury or destruction of existing water power rights.

24. When such channel shall be completed, and the water turned therein, to the amount of three hundred thousand cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the general government shall improve the Desplaines and Illinois rivers for navigation, to connect with this channel, said general government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary or drainage purposes.

25. Any district formed hereunder shall have the right to permit territory lying outside its limits and within the same county to drain into and use any channel or drain made by it, upon such payments, terms and conditions as may be mutually agreed upon, and any district formed hereunder is hereby given full power and authority to contract for the right to use any drain or channel which may be made by any other sanitary district, upon such terms as may be mutually agreed upon, and to raise the money called for by any such contract in the same way and to the same extent as such district is authorized to raise money for any other corporate purposes: Provided, that where the united flow of any sanitary districts thus co-operating shall pass into any channel constructed within the limits of the county wherein such districts are located, and which passes into the Desplaines or Illinois rivers, such united flow shall in no case and at no time be less than 20,000 cubic feet of water per minute for each one hundred thousand of the aggregate of the population of the districts co-operating: Provided, nothing in this act shall in any wise be so construed as to diminish, impair or remove any right or rights of any city, village, township or corporation, body politic or individual situated on

the Desplaines or Illinois rivers or their tributaries and within the valleys of the same to use the channel for drainage or otherwise not inconsistent with the rights of the district constructing the same as expressed in this act.

26. Whenever in any such sanitary district there shall be a city, incorported town or village, which owns a system of waterworks and supplies water from a lake or other source which will be saved and preserved from sewage pollution, by the construction of the main channel, drain, ditch or outlet herein provided for, and the turning of the sewage of such city and district therein, and there shall be in such sanitary district any territory bordering on any such city, incorporated town or village within the limits of another city, incorporated town or village, which does not own any system of waterworks, at the time of the creation of such sanitary district, then upon application by the corporate authorities of such latter named city, incorporated town or village the corporate authorities of such city, incorporated town or village having such system of waterworks shall furnish water at the boundary line between such municipalities by means of its waterworks to the corporate authorities asking for the same in such quantities as may be required to supply consumers within said territory, at no greater price or charge than it charges and collects of consumers, within its limits for water furnished through meters in like large quantities.

Section 27 provides for reporting the completion of the channel to the Governor of Illinois, the inspection of the works by a Commission to be appointed by him, and report showing that the Sanitary District had complied with the Act and thereupon the authorization by the Governor for the opening of the channel.

Here follows description of certain acts amendatory and supplementary to the original act. (Vol. VIII, pp. 107-112.)

May 13, 1901, the General Assembly passed an act, approved July 1, 1901, specifically authorizing the building of bridges over navigable streams and acquirement of right of way by condemnation for the purpose of widening and deepening any river or stream required.

May 14, 1903 the General Assembly passed an act in force July 1, 1903, Section 1 of which enlarged the District's territorial limits by adding the territory south of 87th street in the City of Chicago, known as the Calumet District, which is drained by the Calumet Sag Channel and other territory.

Sections 2, 3, 5, 6 and 8 being the pertinent sections of this Act, are as follows:

"2. The board of trustees of said sanitary District shall have the right to provide for the drainage of the additional territory added to said sanitary district by this act by laying out, establishing, constructing and maintaining one or more channels, drains, ditches and outlets for carrying off and deposing of the drainage (including the sewage) of such district, together with such adjuncts and additions thereto as may be necessary or proper to cause such channels or outlets to accomplish the end for which they are designed in a satisfactory manner and shall have the right to use what is known as the "Calumet feeder" of the Illinois and Michigan canal and lands adjacent to such feeder belonging to the State of Illinois for the site of any such channel, within the limits of the county in which such district is situated, in such manner as said district may elect, and shall also have the right to construct a channel across said Illinois and Michigan canal, without being required to restore said Illinois and Michigan canal or said feeder to its former usefulness. If by reason of said abandonment, a stagnant stream or pool of water shall remain upon the deposits of Chicago sewage, accumulated in said Illinois and Michigan Canal by reason of its years of usefulness by the city of Chicago as a sewage outlet, said sanitary district shall fill up said canal to a depth sufficient to remove said condition and prevent the spread of pestilence and disease throughout the territory in which said Illinois and Michigan Canal is abandoned; and the other powers and jurisdiction of said sanitary district of Chicago over and in connection with such added territory shall be the same as that vested in it over the territory included within the limits of said sanitary district as originally organized. Before said Calumet channel is connected with the present main sanitary channel, gates of suitable pattern for shutting off the flow of water into said Calumet channel shall be installed at or near the connection of said Calumet channel with the Calumet river and forever maintained for use in

case of an emergency, and for the protection of the property and lives of residents of the Illinois valley, and shall maintain the same proportion of dilution of sewage through such auxilliary channels as it may construct and join to its main channel as is now required by the act creating said sanitary district: Provided however, that before any such channel is constructed across said Illinois and Michigan Canal, or the navigation of said canal in any manner interfered with, said sanitary district of Chicago shall connect its present main channel from the controlling works at Lockport with the upper basin of the Illinois and Michigan Canal at Joilet by a channel of a depth of not less than ten (10) feet and a width of not less than one hundred and sixty (160) feet through its entire length, in which channel so to be constructed said sanitary district shall provide and construct a lock or locks of the size of at least twenty-two (22) feet in width by one hundred and thirty (130) feet in length between mitre sills, connecting upper and lower levels, and provide suitable protection for water craft in using said locks and channel. Said locks shall be constructed of the most approved pattern of their size, and be perfectly safe for use and be equipped with machinery to operate the same; and if only one lock is constructed it shall be provided with double gates to prevent accident, and said sanitary district shall forever maintain and operate the same. Provided, further, that said sanitary district shall furnish and provide at said lock a site of the dimensions of at least twenty by thirty feet upon which the State through the Canal Commissioners shall have the right to erect a suitable office building and keep an agent therein, and the Canal Commissioners shall have such authority in and about said lock as is necessary to enforce the rules and regulations prescribed by them pertaining to and governing navigation on the Illinois and Michigan Canal: Provided, further: That said sanitary district shall furnish, free of all expense, for the perpetual use of the Canal Commissioners, at some point in the township of Lockport to be agreed upon by the Canal Commissioners and the sanitary district trustees, a strip or parcel of land bordering upon said sanitary channel, eight hundred (800) feet in length and one hundred and thirty (130) feet in width, filling the same to a suitable depth to provide suitable roadways for approaches, whereon may be located, constructed and operated docks, shops, barns and other buildings controlled by the Canal Commissioners and used in connection with the operation of the Illinois and Michigan Canal.

3. Said sanitary district shall permit all water craft navigating or proposing to navigate said Illinois and Michigan Canal to navigate the water of all said channels of said sanitary district promptly, without delay and without payment of any tolls or lockage charges for so navigating in said channels. The rules of the United States government now in force, regulating navigation on the Chicago river shall govern navigation on the channels of said sanitary district of Chicago; Provided however, that the speed of all vessels while passing through the earth sections shall not exceed eight (8) miles per hour.

5. That the said sanitary district of Chicago is hereby authorized to construct all such dams, waterwheels and other works north of the upper basin of the Illinois and Michigan Canal as may be necessary or appropriate to develop and render available the power arising from the water passing through its main channel and any auxiliary channels now or hereafter constructed by said district.

6. That the power made available by the works constructed under the provisions of this act shall be converted into electrical energy and shall be transmitted to the various cities, villages and towns within said sanitary district or adjacent to the main channel of said sanitary district and may be used in the lighting of said cities, villages and towns, or parts thereof, or for the operation of pumping plants or machinery used for municipal purposes or for public service, or may be disposed of to any other person or corporation, upon such terms and conditions as may be agreed to by the said sanitary district; Provided, however, that it shall be the duty of said sanitary district to utilize so much of said power as may be required for that purpose to operate the pumping stations, bridges and other machinery of said sanitary district.

8. The said sanitary district shall at the expense of said district, in all respects comply with the provisions of the acts of Congress of March 22, 1822, and March 2, 1827, as construed by the courts of last resort of the State of Illinois and of the United States, in relation to the Illinois and Michigan Canal, so far as it affects that portion of the Illinois and Michigan Canal vacated or abandoned by the terms of this act.

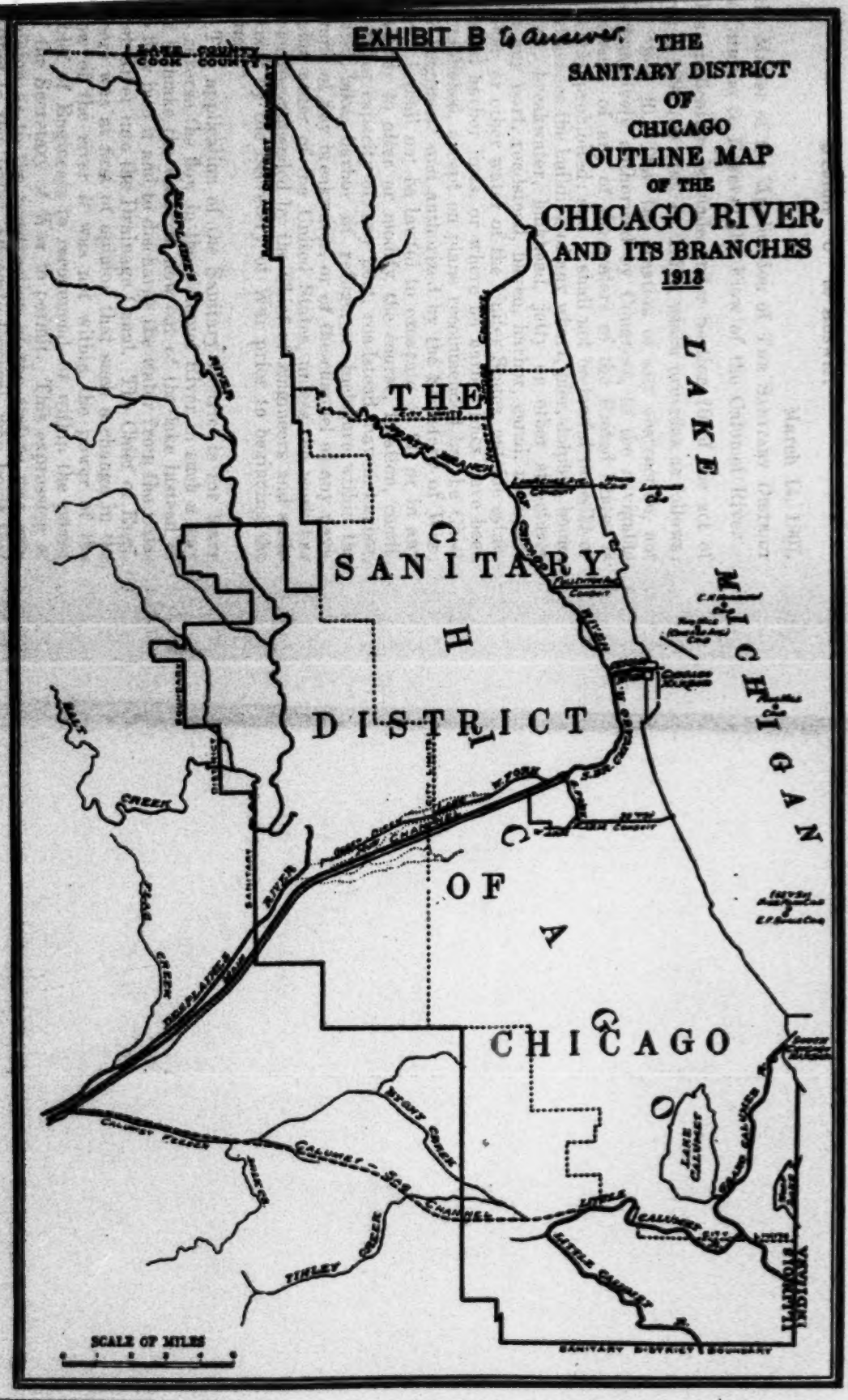


EXHIBIT B to answer
THE
SANITARY DISTRICT
OF
CHICAGO
OUTLINE MAP
OF THE
CHICAGO RIVER
AND ITS BRANCHES
1918
LAKE COUNTY
COOK COUNTY
THE
SANITARY
DISTRICT
OF
CHICAGO
LAKE
MICHIGAN
CHICAGO
SCALE OF MILES
SANITARY DISTRICT BOUNDARY

EXHIBIT B
SANITARY DISTRICT
OF
CHICAGO
OUTLINE MAP
SHOWING
CHICAGO RIVER
AND ITS BRANCHES
1913
LAKE
MICHIGAN
WISCONSIN
ILLINOIS
THE

Exhibit B page opposite.

Exhibit "C" to Answer.

March 14, 1907.

In the Matter of the Application of THE SANITARY DISTRICT OF CHICAGO to Reverse the Flow of the Calumet River

This application is made under Section 10 of the act of March 3, 1899 (30 Stat. L., 1151), which provides as follows:

> "Sec. 10. That the creation of any obstruction, not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the Unites States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same."

The application of the Sanitary District is for leave to reverse the flow in the Calumet River in such a way as to make the water to flow out of the lake instead of to flow into it and to discharge the water from the Calumet River into the Drainage Canal. The Chief of Engineers was at first of opinion that such a change in the flow of the river *it* was not within the power of the Chief of Engineers to recommend, or within the power of the Secretary of War to permit. This expression of opinion as to the construction of the statute was submitted to the Judge Advocate General, who holds that Section 10, as quoted above, applies to this case and and that it is one in which work could be allowed under the recommendation of the Chief of Engineers and the permission of the Secretary of War. Upon the con-

struction of the Judge Advocate General I requested the Chief of Engineers to make his recomendation, which he has done as follows:

February 23, 1907.

1. Respectfully returned to the Secretary of War.

2. The subject of the abstraction of water from Lake Michigan has been elaborately investigated by the Lake Survey Office at Detroit, and the results are published in the annual reports of the Chief of Engineers for the years 1900, 1902 and 1904. The international Waterways Commission has also given it careful consideration, and its conclusions are set forth in report of January 4, 1907, printed as War Department Document No. 293.

3. In my opinion, this abstraction will undoubtedly lower the levels of all the waters of the Great Lakes, except those of Lake Superior, and thus diminish the navigable capacity and depth of the various channels and harbors which have been deepened and improved under authority of Congress.

4. Leaving out Lake Superior, there are more than 100 works of river and harbor improvements on the Great Lakes and their connecting waters, for which appropriations aggregating more than $80,000,000 have been made. The application of this vast sum has resulted in securing and maintaining specified depths and widths of channel, which Congress has decided to be required for the accommodation of the traffic using those waters.

5. To diminish these depths even to a slight extent, would not only prove a serious injury to the traffic, but would practically undo the work which has been accomplished by Congressional direction, and necessitate the expenditure of further large sums of money for restoration. Any project that tends, in a measure, to annul or reverse the orders of Congress, as expressed in the various river and harbor acts appropriating funds for improving the harbors and channels connecting with the Great Lakes, should meet the disfavor of the Department, unless it has been sanctioned by that body. In my judgment, such a project is the one under consideration, and for this reason I am unwilling to recommend favorable action thereon, assuming that the Department is empowered to take such action, as is held by the Judge Advocate General.

A. Mackenzie, *Brig. Gen.*
Chief of Engineers, U. S. Army.

It is quite evident from the reading of the statute that the Congress intended in this statute, as in many others, to give the Chief of Engineers authority, independent of the Secretary of War, in reaching a conclusion as to the wisdom and propriety of granting a permit under the section, and that unless the Chief of Engineers shall recommend the granting of the permit, the Secretary of War is without power to give the requested authority. It follows, therefore, that the appliaction must be denied whatever my view of the case.

The decision of the Chief of Engineers and its final character has made it unnecessary for me to consider the merits of the question, but I may say this much, that the appliaction for a change in the Calumet River is to be made the basis for the withdrawal of a large amount of water from Lake Michigan and that all interested in the enormous lake traffic view the settlement of the question with grave apprehension. Added to this, is the international complication which is likely to arise in the threatened lowering of the lake level in the ports and harbors and canals of Canada. On the other hand, it is maintained with great emphasis and elaboration of detail that the change in the Calumet River, is essential to the healthful sanitation of Chicago, and that the threatened injury to navigation is so small as to be negligible.

Between two such great interests, the decision must be affected more or less by large public policy and expediency, and while I agree in the construction of the Judge Advocate General that the issue is left by statutes to the recommendation of the Chief of Engineers and the concurrent decision of the Secretary of War, it may be fortunate that circumstances now require submission of this question of capital and national importance to the Congress of the United States.

Wm. H. Taft, Secretary of War."

Exhibit "D" to Answer.

Permit.

"War Department,

Washington, September 11, 1907.

Sir: Referring to your letter of 2nd instant, in which you request approval of proposed drainage channel to connect Lake Michigan at Wilmette, Ill., with the North Branch of the Chicago River; also permission to con-

struct a pile crib in Lake Michigan at mouth of same, and to deposit filling within the limits of such crib, I beg to inform you that the War Department will interpose no objection to the project as set forth in your letter and indicated on drawing submitted, provided the following conditions are complied with:

1. That the pier constructions, the filling behind the same, and the excavation of the proposed channel shall be done subject to the supervision and approval of the local officer of the Corps of Engineers, U. S. Army, at Chicago, so far as to see that the work authorized is not exceeded;

2. That the total diversion of water from Lake Michigan through the Chicago River into the Illinois River shall be no greater than already authorized by past War Department permits;

3. That the work shall be commenced before December 31, 1908, and completed within five years thereafter.

Very respectfully, Robert Shaw Oliver, Acting Secretary of War. G. M. Wisner, Esq., Chief Engineer the Sanitary District of Chicago, American Trust Building, Chicago, Illinois."

Exhibit "E" to Answer.

"Permit

War Department,
Washington, June 30, 1910.

Sir: Referring to your application of the 27th instant on behalf of the Board of Trustees of The Sanitary District of Chicago to open a channel from the Calumet River to its existing Main Channel so as to substitute two routes instead of one between Lake Michigan and its canal, I have the honor to advise you to the following effect:

It appears from the records of the Department that by an instrument executed May 8, 1899, The Sanitary District of Chicago was given permission to connect its Drainage Canal with the South Branch of the Chicago River at Robey Street, in the City of Chicago, and to divert the waters of Lake Michigan through the Chicago River into said canal, subject to certain specified conditions designed to limit the amount of such diversion and in other ways to protect the public interest. The per-

mission so granted was subsequently modified at various times, and by an instrument executed December 5, 1901, the amount of flow was fixed at not exceeding 250,000 cubic feet per minute, equivalent to 4,167 cubic feet per second, which is the present rate allowed. At the time the original permit was given a connection with the Calumet River was not mentioned but if it had been it is probable that a connection with that river as well as with the Chicago River would have been allowed.

So long as the water-flow remains unchanged there seems to be no special objections to its extension to both rivers instead of confining it to a single one, especially since if the new (Calumet) route be developed later to a navigable state the double route will be advantageous to navigation interests. Accordingly, in view of the favorable recommendation of the Chief of Engineers and of the consent thereto by the Attorney General, under the conditions hereinafter prescribed, the Department hereby modifies the existing permission so as to allow the division of the already permitted water-flow in such manner as to reach the Sanitary District Canal by way of the Calumet River and a connecting channel, as well as by way of its present route through the Chicago River, subject to all pertinent conditions of the existing permissions and to other express conditions, as follows:

(a) That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of The Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

(b) That if at any time it became apparent that the current created by such drainage work in the Calumet, as well as Chicago rivers, be unreasonably obstructive to navigation, or injurious to property, the Secretary of War reserves the right to close the discharge through said channel or rivers, or to modify it to such an extent as may be demanded by navigation and property interests along said rivers.

(c) That The Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in the Calumet as well as Chicago River.

(d) That the amount of water withdrawn from Lake Michigan through the Chicago and Calumet rivers together, shall not exceed the total amount of 250,000 cubic

feet per minute (4,167 cubic feet per second) already authorized to be withdrawn through the Chicago River alone.

(e) That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

(f) That this permission shall in nowise affect or in any manner be used in the friendly suit now pending in the Circuit Court of the United States for the Northern District of Illinois brought by the United States of America against the Sanitary District of Chicago, to determine the right of the said Sanitary District to divert from Lake Michigan for sanitary purposes an amount of water in excess of that now being diverted, without having first obtained a permit from the Secretary of War.

(g) That the War Department shall have free access at all times to the waterflow records of The Sanitary District of Chicago and free access also to the regulating works and all other parts of its canals for the purpose of checking records or making water-flow measurements.

(h) That the plans for the proposed work shall be submitted to and approved by the Chief of Engineers and the Secretary of War.

(i) That the work shall be subject to the supervision and approval of the Engineers Officer of the United States Army in charge of the locality.

Very respectfully, Robert Shaw Oliver, Acting Secretary of War. Mr. George M. Wisner, Chief Engineer Sanitary District of Chicago, Chicago, Ill."

Exhibit "F" to Answer.

"Memorial to Congress on the Subject of the Illinois and Michigan Canal

(Laws Extra Session, 1826, p. 97)

To the Honorable the Senate and House of Representatives of the United States of America in Congress assembled:

The memorial of the General Assembly of the State of Illinois respectfully represents that the construction of a canal uniting the waters of Lake Michigan with the Illinois river, will form an important addition to the con-

necting links in the chain of internal navigation, which will effectually secure the indissoluble union of the confederate members of this great and powerful Republic. By the completion of this great and valuable work, the connection between the north and the south, the east and the west, would be strengthened by the ties of commercial intercourse and social neighborhood, and the union of the states might bid defiance to internal commotion, sectional jealousy and foreign invasion. All the states of the Union would then feel the most powerful motives to resist every attempt at dissolution. To effect so great and desirable an object, your memorialists believe to be of sufficient importance to engage the attention and awaken the munificent patronage of a government whose principle of action is the promotion of the general welfare. Your memorialists are sensibly alive to the spirit of improvement that manifests itself in almost every section of our extensive country, and would fain lend a helping hand in so great and good a cause; their situation, however, forbids their doing much, without the aid of the federal government; into whose treasury almost all the funds whether brought hither by emigrants or earned by the industry of their citizens, are paid for the purchase of the public lands. While this state of things shall continue and the money thus paid into the treasury of the Union is taken out of our State, our people will not be able to engage in the glorious work of improving our common country. Ought the people of this State to stand by with folded arms and behold the great work of internal improvement progress in other states without making an effort to improve their own conditions, and at the same time advance the interest of our beloved country? A condition thus paralyzed, is at war, not only with our interests, but with the best feelings of our hearts. Did this State possess the public domain lying within its bounds, as in the case with the older members of the confederacy, your memorialists would not appear before your honorable body to solicit aid in this important work. If, as your memorialists believe, the construction of this canal would be highly beneficial to the Union at large; if the receipts into the treasury of the United States would be augmented by the increased sales of public lands; and if the interest of this State would be also advanced thereby; is it unreasonable to apply to a paternal government for assistance in the promotion of such beneficial ends? It is unnecessary for your memorialists to enlarge on the great advantages of this canal to the

Union, in the facilities to be afforded in the event of a war with either the Indian tribes inhabiting our frontier, or the British nation. Your honorable body is aware that this State is situated on the borders of an Indian country, filled with numerous and powerful tribes of the sons of the forest. If our country should be again engaged in war, the saving of expense in the transportation of munitions of war, would alone defray the expense of the contemplated canal, and justify the United States in making a liberal appropriation for its construction. Your memorialists do not, however, ask your honorable body to appropriate money out of the treasury to aid them in this work; they only ask for a tract of land, through which the contemplated canal may pass, and which, for a series of years, will be wholly unproductive to the government unless the canal shall be commenced under auspices favorable to its completion; in which event all the land in the vicinity would immediately become available to the United States. Your memorialists sincerely believe that a liberal appropriation of land for this object, would, even in a pecuniary point of view be of immense importance to the treasury of the Union. The public lands in the vicinity would not only sell, but at a considerable advance upon the minimum price. Should this opinion be correct (and does not experience justify it?) the United States would be gainers by the proposed donation to the State. Your memorialists further state that at their last session, they passed an act of incorporation, upon very liberal terms, authorizing a company to construct the projected canal; but the remoteness of the country from the residence of capitalists, has prevented them from engaging in the work. At their present session, your memorialists have repealed the charter; and their only hope of soon beginning the work depends upon the liberality of your honorable body. Your memorialists have caused the route to be explored and estimates to be made of the probable expense of the work; from which it appears that the cost of constructing the canal will not be less than $600,000 and may possibly amount to $700,000. To the end, therefore, that your memorialists may be enabled to commence and complete this great and useful work, we pray your honorable body to grant to this State the respective townships of land through which the contemplated canal may pass; the avails of which to be appropriated exclusively, to the construction of said canal, upon such terms and conditions as to your honorable body may seem proper.

Exhibit "G" to Answer.

"An Ordinance for Cleansing the Chicago River and Appropriating the Proceeds of Two Hundred and Fifty Bonds Therefor.

Section 1. Be it ordained by the Common Council of the City of Chicago (June 5, 1865), That the plan of the board of public works for cleansing the Chicago River and its branches by cutting down the summit of the Illinois and Michigan Canal below the level of Lake Michigan so as to draw from it at a low stage of water in the lake not less than twenty-four thousand (24,000) cubic feet of water per minute, is hereby approved, and said board are hereby authorized to execute said work.

Section 2. That the board of public works are hereby authorized and empowered for the purpose of prosecuting the work described in the previous section, to make any contract necessary to carry into effect such purpose with the trustees of the Illinois and Michigan Canal, in conformity with and subject to the general provisions of the city charter.

Section 3. That as a temporary expedient for cleansing the South Branch of the Chicago River, the said board are hereby authorized and empowered to contract with the said trustees for the pumping from the river into the canal, by the hydraulic works at Bridgeport, and discharging through the canal of such amount of water as shall be found necessary and practical for such purpose.

Section 4. That for the purpose of carrying out the improvement specified in the foregoing sections, the board of public works be and they are hereby authorized to issue 250 bonds of the denomination of $1,000 each, to be dated July 1, 1865, and payable in New York, twenty-five years after the date thereof, with coupons for interest, at the rate of seven per centum per annum, payable semi-annually in New York; the said bonds to be issued in conformity with the provisions of an act of the General Assembly of the State of Illinois, approved February 15, 1865, and entitled 'An act to amend an act entitled an act to reduce the charter of the City of Chicago, and the several acts amendatory thereof, into one act, and to revise the same,' approved February 13, 1863."

Exhibit "H" to Answer.

Application of the Sanitary District for the Improvement of the Chicago River.

Chicago, June 16, 1896.

To the Honorable Daniel S. Lamont, Secretary of War, Washington, D. C.

Dear Sir: The work of The Sanitary District of Chicago has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport in Will County, twenty-eight miles distant.

Our connection with Lake Michigan must be through the Chicago river with the West Fork of the South Branch of which we make a junction at Robey Street. We send herewith a map showing in a general way our plans for improving the Chicago River by widening and deepening at the points indicated thereon by red hatchings and by figures which refer to explanation, given in the legend on the map. It is desired to so correct and regularize the cross section of the river as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles per hour. The cross section necessary to accomplish this can be obtained throughout the greater part of the distance between Monroe Street and Robey Street, by dredging the river to a depth of 20 ft. at mid stream, with 12 ft. at dock lines and a uniform slope away from docks of one foot in five, so that the full depth would be reached forty feet from the dock lines; but there are places so narrow that this cross section can only be obtained by widening the river; and again the depth to be obtained in the vicinity of Van Buren Street is limited by the height of the crown of the tunnel. To obviate this difficulty it is purposed to secure the requisite cross section by constructing a by-pass to the west of the bridges at Adams, Jackson and Van Buren Streets, as indicated. We ask your permission to proceed with the work upon the lines indicated and so far as is consistent with propriety the co-operation of the United States Engineering Department.

Awaiting your favorable reply, and holding ourselves ready to respond to any call from you for fuller information as to our plans, I am (map opposite, Exhibit H)

Yours respectfully, (Signed) B. A. Eckhart, President.

EXHIBIT H To Answer

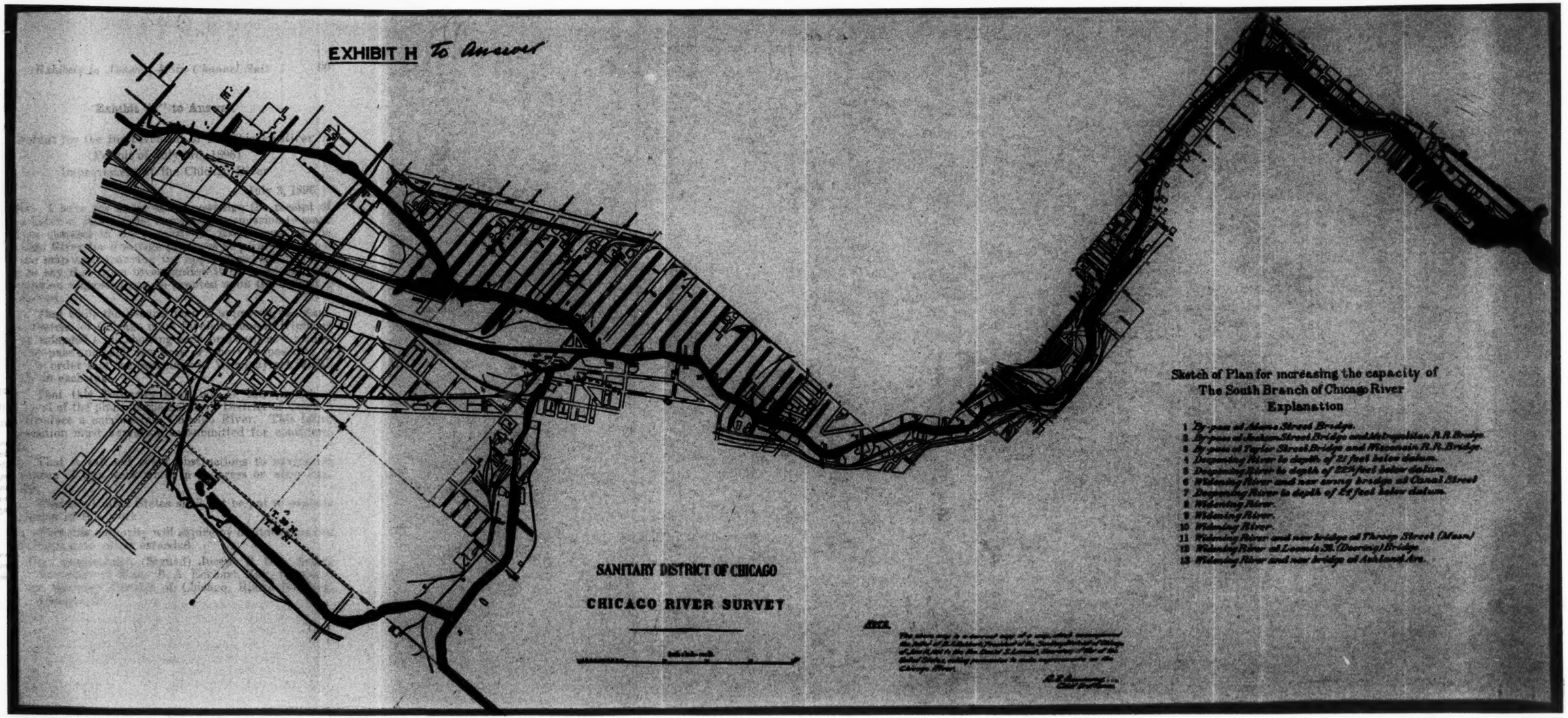


Exhibit "I" to Answer.

Permit for the Improvement of the Chicago River
(Permit of July 3rd, 1896)
Improvement of the Chicago River

July 3, 1896.

Sir: I have the honor to acknowledge the receipt of your letter of 16th ultimo, requesting permission to make certain changes in the capacity of the channel of the Chicago River for drainage purposes at points indicated on the map accompanying the application, and in reply beg to say that upon investigation it is found that the permission requested can be granted upon the following conditions:

1. That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each by-pass and each new dock or wharf proposed to be built, in order that the Secretary of War may act intelligently in each case.

2. That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submitted for consideration.

3. That it will not cover obstructions to navigation by reason of this work while in progress or when completed.

4. That the United States shall not be put to expense by reason of this work.

5. That this authority will expire by limitation in two years from date unless extended.

Very respectfully, (Signed) Joseph B. Doe, Acting Secretary of War. B. A. Eckhart, Esq., President the Sanitary District of Chicago, Rialto Building, Chicago, Ill.

Exhibit "J" to Answer.

Security Building
The Sanitary District of Chicago

Chicago, April 26, 1900.

To the Honorable the Secretary of War.

Sir: The Sanitary District of Chicago, a municipal corporation organized and existing under the laws of the State of Illinois, respectfully represents that, by the laws of the State of Illinois and the charter of this petitioner, it is authorized to enter upon, widen, deepen and otherwise improve any navigable stream, river or other waterway. That in pursuance of the power conferred upon it by the statutes of the State of Illinois, and in the performance of the duties enjoined upon it by the act of the Legislature authorizing its creation, and under which it is acting, it has been determined to improve the Chicago River by widening and deepening the same and to the end that such action on the part of your petitioner may be conformable to law and the statutes of the United States in that behalf, it hereby makes application for permission to make the changes, alterations and improvements in said Chicago River from or near Lake Street in the City of Chicago to or near Ashland Avenue in the City of Chicago, said work to conform to the plan and specifications as follows:

(a) A map herewith exhibits the existing boundaries of that part of the South Branch of the Chicago River which it purposes and desires to improve.

(b) The work to be done contemplates widening the river to a width of two hundred (200) feet between dock lines, except in so far as bridge abutments may project into the stream outside of the new dock lines; said widening in all cases to be made with a view of improving the navigability of the stream.

(c) The work to be so done as to ultimately permit excavation of the river bed to a depth of thirty (30) feet below water surface throughout the central portion of the stream.

(d) The widening of the river is to be so disposed that the effect will be to produce a straighter channel than now exists and, furthermore, to result in a continuous dock line having straighter alignment and being better

disposed for navigation than the docks which now exist.

(e) The work to be done is to be prosecuted progressively as to time. The rate of progress being limited by the rapidity with which right of way may be acquired and the resources for the execution of the work to be made available. The modification and alteration of said river as above indicated will greatly benefit navigation in said river. Your petitioner, therefore, respectfully requests that the plan of improvement as above outlined be approved by you.

Awaiting as early a reply as practicable under the circumstances, your petitioner has the honor, to be.

Very respectfully yours, The Sanitary District of Chicago, by William Boldenweck, President. Attest: Joseph H. Haas, Clerk.

Exhibit "J-1" to Answer.

Chicago, June 7, 1900.

To the Honorable, the Secretary of War.

Sir: Under date of April 26, 1900, the Sanitary District of Chicago had the honor to address a communication to you containing an outline of the proposed improvement of a portion of the South Branch of the Chicago River. Accompanying the letter was a map showing the location of the South Branch of the Chicago River, the bridges spanning said river and, also, the width of the stream along the entire course of the South Branch of the river. Since that date the Sanitary District of Chicago passed an ordinance for the improvement of the South Branch of the Chicago River from the south line of Twelfth Street to the east line of Ashland Avenue, so as to make said South Branch, between the lines aforesaid, of a uniform width of two hundred (200) feet; the work to be done so as to ultimately permit excavation of the river bed to a depth of thirty (30) feet below water surface throughout the central of said stream, in accordance with the plans adopted by the Board of Trustees of the Sanitary District of Chicago, a copy of which plans is hereto annexed. The ordinance refered to being marked Exhibit "A," with this letter; and the maps showing the plans of the proposed improvement being marked Exhibit "B." The maps are in two sections, known respectively as No. 2 and No. 3.

The Sanitary District of Chicago is a municipal corporation, organized and existing under the laws of the State of Illinois and by the laws of said State and the charter of said Sanitary District, it is authorized to enter upon, deepen, widen and otherwise improve any navigable stream, river, or other water-way; and that in pursuance of the power conferred upon it by the statutes of the State of Illinois and in performance of the duties enjoyed upon it by the act of the legislature authorizing its creation, and under which it is acting, it determined upon said plans outlined in the enclosed ordinance and further illustrated by the maps hereto annexed; and the said Sanitary District, in compliance with the Statutes of the United States, hereby makes application to you for permission to make the changes, alterations and improvements in said South Branch of the Chicago River, from the south line of Twelfth Street to the east line of Ashland Avenue.

Awaiting as early a reply as practicable under the circumstances, your petitioner has the honor to be,

Very respectfully yours, The Sanitary District of Chicago, by William Boldenweck, President. Attest: Joseph F. Haas, Clerk. (Exhibits K1, K2, page opposite.)

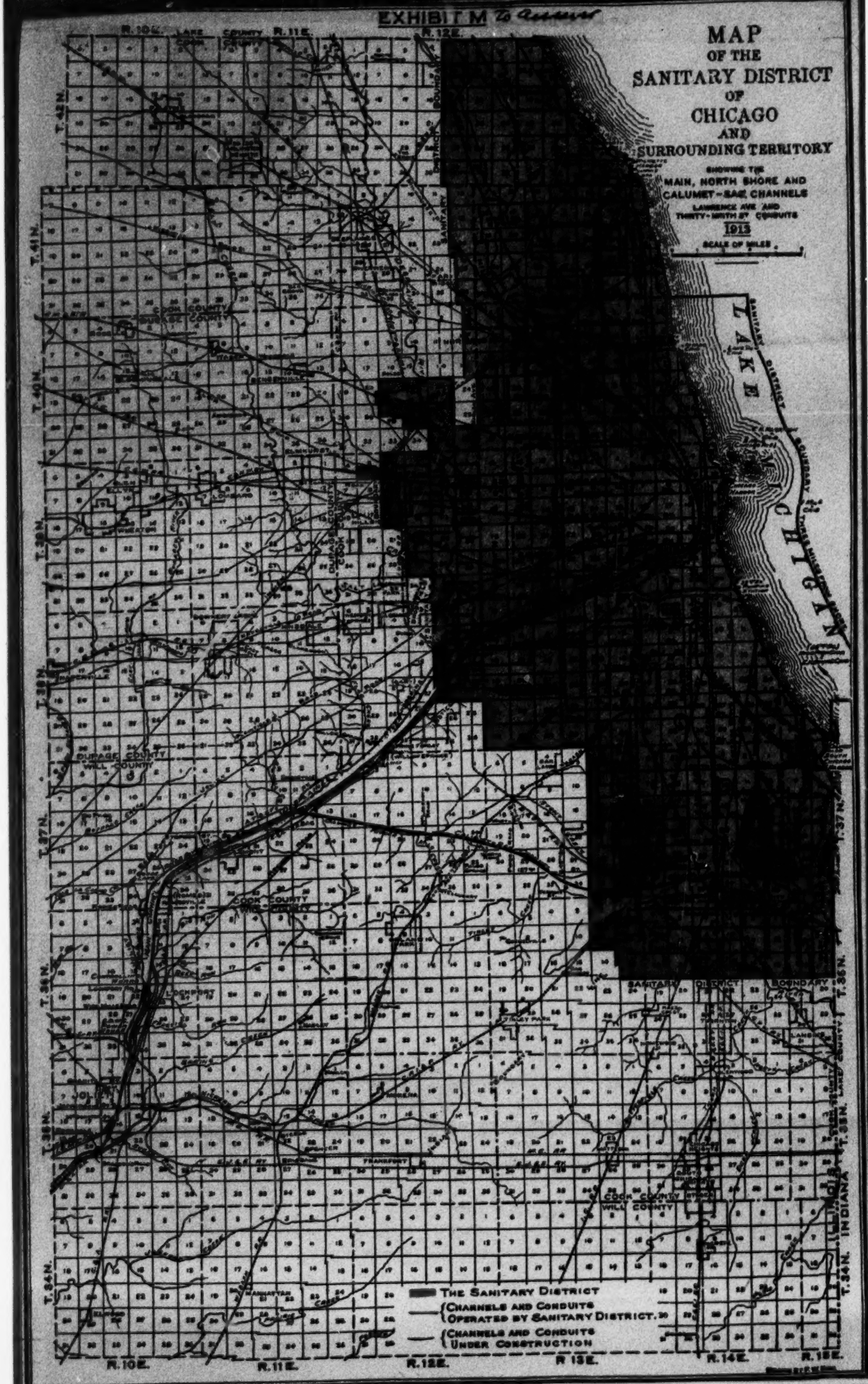
Exhibit "L" to Answer.

War Department,
Washington, July 11, 1900.

Sir: I have the honor to acknowledge the receipt of your letter of April 26th last, requesting, in behalf of the Sanitary District of Chicago, permission to change, alter and improve the Chicago River, from Lake Street to Ashland Avenue, in Chicago, as shown on maps which accompanied your said letter.

Replying thereto I beg to inform you that there is no objection on the part of the War Department to the prosecution of work of improvement of Chicago River, specified in the above mentioned letter and delineated on the maps which accompanied the same, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the general government in any way with the expense incident to the carrying out of the project, and does not in any way in-

EXHIBIT M to Answer



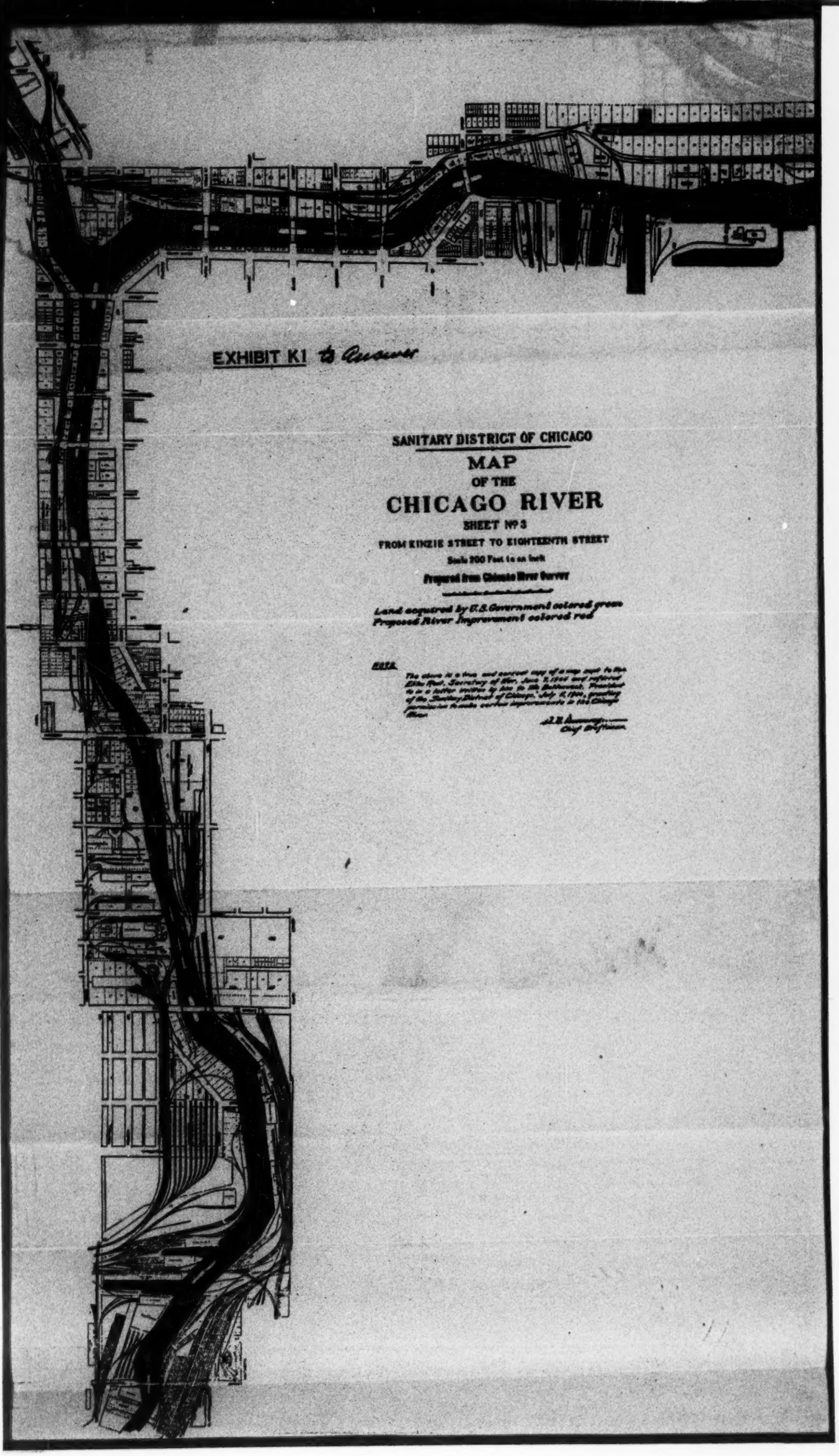


EXHIBIT K1 to Answer

SANITARY DISTRICT OF CHICAGO

MAP
OF THE
CHICAGO RIVER

SHEET № 3

FROM KINZIE STREET TO EIGHTEENTH STREET

Scale 200 Feet to an Inch

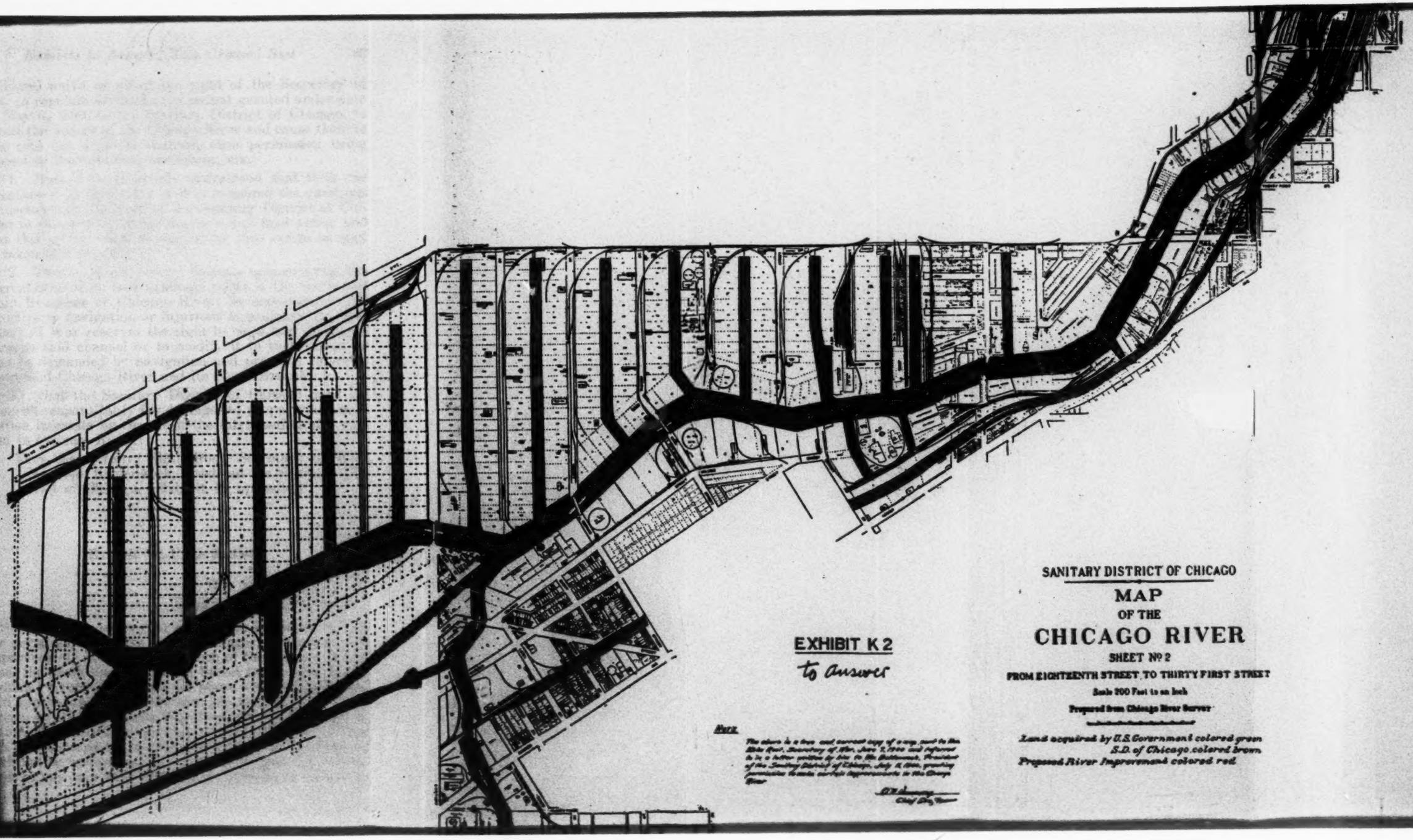
Prepared from Chicago River Survey

Land acquired by U.S. Government colored green
Proposed River Improvement colored red

[illegible]

The above is a true and correct copy of a map sent to the Hon. Secretary of War, June 7, 1911 and referred to in a letter written by him to the Metropolitan President of the Sanitary District of Chicago, July 8, 1911, granting permission to make certain improvements in the Chicago River.

[illegible]
Chief Engineer



SANITARY DISTRICT OF CHICAGO

MAP

OF THE

CHICAGO RIVER

SHEET No 2

FROM EIGHTEENTH STREET TO THIRTY FIRST STREET

Scale 200 Feet to an Inch

Prepared from Chicago River Survey

Land acquired by U.S. Government colored green
S.D. of Chicago colored brown
Proposed River Improvement colored red

EXHIBIT K 2

to answer

NOTE

The above is a true and correct copy of a map, sent to the State Dept. Secretary of War, June 2, 1910 and referred to in a letter written by Asst. Sec. Ellis Bothwick, President of the Sanitary District of Chicago, July 6, 1910, granting permission to make certain improvements in the Chicago River

[illegible]
Chief Eng. Officer

validate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago River and cause them to flow into the artificial channel, such permission being subject to the following conditions, viz:

"1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action and that this permit shall be subject to such action as may be taken by Congress.

"2. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

"3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River.

Very respectfully, Elihu Root, Secretary of War.
Mr. Wm. Boldenweck, President the Sanitary District of Chicago. (Exhibit M, opposite.)

Exhibit "L-1" to Answer

War Department,
Washington, July 11, 1900.

SIR: In response to your application of the 7th ultimo, for permission to make certain changes, alterations and improvements in the South Branch of the Chicago River, from the south line of Twelfth Street to the east line of Ashland Avenue, as shown on plans which accompanied said application, I beg to inform you that there is no objection on the part of the War Department to the prosecution of the work as specified, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the general government in any way with the expense incident to the carry-

ing out of the project, and does not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted, under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago River and cause them to flow into the artificial channel such permission being subject to the following conditions, viz:

"1. That it be distinctly understood that it is the intention of the Secretary of War to submit the question connected with the work of the Sanitary District of Chicago to Congress for consideration and final action and that this permit shall be subject to such action as may be taken by Congress.

"2. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main Branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

"3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interest by reason of the introduction of a current in Chicago River.

Very respectfully, Elihu Root, Secretary of War.
Mr. Wm. Boldenweck, President The Sanitary District of Chicago, Security Building, Chicago, Ill.

OPINIONS, ORDERS AND ASSIGNMENT OF ERRORS.

Between the filing of the Bill of Complaint in the Calumet suit, March 23, 1908, and December, 1914, and on April 25 and 26, 1923, evidence was offered by both parties before a Commissioner appointed by the Court upon the various issues involved in the pleadings. It was stipulated that evidence offered in either suit by either party, material or relevant to the issues in the other suit should be treated as if offered and presented in such suit. By agreement, the causes were submitted upon the evidence which was printed and upon printed briefs and arguments on behalf of

both parties to Honorable Kenesaw Mountain Landis, one of the Judges of the District Court of the United States for the Northern District of Illinois, Eastern Division, February 15, 1915. The evidence will be hereafter described and narrated. June 19, 1920, Judge Landis having called the attorneys for both parties together, delivered an oral opinion, announcement or direction for decree. A stenographic transcript of this opinion appears in the certificate of evidence filed June 29, 1923, after the order of injunction in said cases was entered. The oral opinion is as follows (Vol. VIII, pp. 149-152):

OPINION OF JUDGE LANDIS IN SANITARY DISTRICT CASES.

June 19, 1920.

"I have sent for you gentlemen to dispose of the Sanitary District cases. Before taking up these cases, just a word about time and delay. Six years was spent after these cases were filed in taking testimony, and about six years has passed since the cases were submitted to me on briefs. The six years that was taken up while taking testimony was all necessary. The delay that has occurred since the matters have been submitted to me have been the result of the exercise of my judgment. First, that during the war period, in view of the international questions possible, I thought it was better that this matter should continue just as it was, and secondly, since the war I have deferred entering this order with the understanding that there was a possibility of a composition of differences here that would enable the questions to be permanently adjusted along lines which I have been told were suggested by the Sanitary District to the War Department and the Canadian Government. I have held the matter, however, as long as I think proper on that theory and shall enter an order.

The bills were filed under legislation authorizing the United States to receive the injunctive power of the court as against obstruction of navigable waters and impairment of the navigable capacity of navigable waters. The averments, so far as I need to deal with the averments here now, are that the Sanitary District proposes to take an amount of water—is taking an amount of water—proposing to take more, the taking of which will result in such impairment and such obstruction. Specific-

ally, the impairment complained of most important in my view, is the impairment of the navigable capacity of the Great Lakes, excepting Lake Superior. The theory of the bills is—the charge is that such impairment by the district as is charged in the bills, without the consent of the Federal authorities at Washington, which consent is authorized and provided for by the Federal legislation, as I said before, entitles the government to an injunction. The defense of the Sanitary District is, first, that there is no impairment and no obstruction, and primarily, secondly, if there is an impairment or an obstruction, that it is necessary for the sanitation of this great populative territory. An examination of the proofs on the question of whether there is an impairment or not, an obstruction or not, that is to say, whether the taking of this water is felt or not, leads me to the conclusion that there is a lowering of the surface of this lake. In making that statement I have in mind the variation of the lake levels, traditional variation of the lake levels, known to all men that know anything about it. All that time finding that there is a lowering of the lake level, yes. That the taking of this vast volume of water each minute of each hour of each day of each month of each year continued unceasingly, no evidence in this case discrediting the fact, and has entirely resulted in the lowering of the level of the lake, and has resulted in changing the current of the Chicago River and reversing the current of the Chicago River. Now that the variation is only a matter of inches in the level of Lake Michigan, it is without doubt in my judgment, on the evidence in the matter, a matter of inches, and being a matter of inches, even though it be no more than three or four, having in mind the state of proof as to the depth of the harbors in the Great Lakes, it is directly an impairment of navigable capacity, and by leaving the bottom of the harbors that much closer, the water is the creation of an obstruction to the navigable waters of the United States; in other words, the question of fact—whether there is an impairment or obstruction here, are beyond controversy and beyond question, but the fact is clearly established that there is such a change in this lake level, in my judgment, so that in low lake level time the level is lower and in high lake level time it is less than it would be but for this diversion.

Q. How many cubic feet per minute now?

A. Just at present I think about 8,500 per second. 480,000 cubic feet per minute, that is approximately.

The diversion is 480,000 cubic feet per minute. The finding of the court is, on the evidence in this case, that that has resulted in the lowering of the lake level and the reversal of these currents, which latter fact is not controverted, and on the evidence in the case that the lowering is an impairment, as I said before, an impairment of navigable capacity, even though it amounts to no more than three or four inches, and as to the lowering to that extent there could be no controversy on the record, so on that fact the court's finding is against the contention of the defendant on the proposition that this is a necessary thing for the salvation of this community, that is, without this water this community will be at the mercy of diseases and germs from which it suffered before this diversion began and from which it has by this diversion been practically relieved of, as shown by statistics. The court has complied with the rule of law, that navigable rights are paramount, and even though the district is driven to the necessity of making some other provision, granting that the War Department and Congress should refuse to give that contention to this question of sanitation, it is entitled to the law which is in force in this room on me, which I must obey, that a navigable right is paramount, and that in the last analysis should Congress and the War Department in consideration of all these matters decline to permit the necessary diversion, the burden is on the District of providing some other method of relief; in other words, the defense that is necessary for the purposes of sanitation as against the rule that a navigable right and navigation right is a paramount right, is immaterial.

I had hoped, as I stated at the beginning, that there might be a composition of this thing. The Judge has no right to have personal feelings, but I live in this community, and it was my hope that there could be devised a program that would enable this district to have the benefit of this water, as much as it needs, that will give to the country this water in the solving of this problem of navigation.

There will be an order striking or sustaining the exceptions of the plaintiff, certain paragraphs of your answer setting up this sanitation defense. There will also be another sustaining the operation of this order which I am entering here this morning until 30 days after the Sanitary District has an opportunity to present to the Supreme Court of the United States an application for a supersedeas against high water, that is 30 days after

the date fixed for the meeting of the Supreme Court in October. The order will not go into effect, it will be suspended until 30 days after the Supreme Court meets in October. That is plenty of time, is it not? A. Yes, sir. I think that is plenty of time. I have considered that is enough. I wanted to make no mistake. You can form it in a way so that you will have a final order to appeal from. You have got to have that in mind. You may draw an order effective 30 days after the Supreme Court meets.

I omitted to mention one matter here which is not important, except the control of the Federal Government over this question has been recognized from the beginning by the Sanitary District itself before the diversion began and continuously down until what was that year when they attached that order, 1909? A. I think 1907 or 1908.

From the beginning, prior to the beginning of the diversion and down to 1907 or 1908, the constant attitude of the Sanitary District was a recognition of the control of the Federal Government over this whole question, everything that was done by the Sanitary District in the way of diversion being in a permit granted by the War Department on application of the Sanitary District to that end. The Sanitary District shall have an opportunity to apply for further relief to the War Department at Washington. Under no circumstances does this order go into effect now. Make that 60 days, and you may put in it, if it does not destroy the appealability of the order, you may put in a provision retaining me in control. The thing that the Government wants, at least the court wants, being a citizen of Chicago, the thing I want is water without microbes. That is why I have held your lawsuit."

July 12, 1920, subsequent to Judge Landis' delivering the opinion as aforesaid, the Sanitary District presented a motion entitled

"Motion for Reconsideration of Oral Opinion and Oral direction of the Court concerning the form of decree in said two causes, together with grounds of said motion." The Motion is in part, as follows (Vol. VIII, pp. 152-167):

"Now comes The Sanitary District of Chicago, defendant, in said two causes, by C. Arch Williams and

Edmund D. Adcock, its attorneys, and moves the court that it reconsider its oral opinion and oral direction heretofore announced concerning the form of decree to be entered in the said causes, and that the court direct that The Sanitary District of Chicago, defendant, be enjoined, only, from withdrawing or diverting from Lake Michigan, through its various works now constructed or under construction, more than ten thousand cubic feet of water per second from Lake Michigan on condition that if the Congress of the United States, or other competent governmental authority, provides for the construction of, in the St. Clair, Niagara or St. Lawrence Rivers, or in one or all of them, works to compensate for any diminishing levels of the Great Lakes and connecting waters, due to the diversion or withdrawal of ten thousand cubic feet of water per second from Lake Michigan by The Sanitary District of Chicago, then The Sanitary District of Chicago shall defray the expense and pay the cost of the construction and maintenance of any such works upon request therefor by the United States of America. In connection with said motion, and as a part thereof, the defendant hereby offers and agrees to defray the expense or pay to the United States upon demand the cost of the construction and maintenance of the works of the character above described in accordance with an ordinance of the Board of Trustees of The Sanitary District of Chicago passed and approved by said Board on the 8th day of July, A. D. 1920, a copy of which said ordinance is hereto attached and marked Exhibit "A," a certified copy of which is here ready to be produced in court. In support of said motion, and as grounds therefor, the defendant alleges and shows the following:"

As grounds for the said motion, the defendant recited the institution of the suits, the purpose of the complaint in the main channel suit filed October 6, 1913, and that the ground for the injunction sought was that the diversion of water would lower the levels of the Great Lakes and connecting waters, thereby injuring navigation and changing the navigable capacity of such navigable waters of the United States.

3. It is further set forth that it is an admitted and undisputed fact on the record in said causes that works may be installed in the St. Clair, Niagara and St. Lawrence Rivers,

which will compensate for the lowering of the lake levels due to diversion at Chicago of 10,000 cubic feet per second.

A portion of the River and Harbors Act of June 25, 1910, was set forth as follows:

> "The Secretary of War shall appoint a board of five members, to be composed of four engineer officers of the army and one civil engineer, taken from civil life. * * * Said Board shall report upon * * * such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, as far as practicable for the diminishing level in said lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway herein described, or diversion for any other purpose."

The motion further stated:

> "The Board of Engineers, provided for by said Act of Congress, so appointed, made an investigation and its report was submitted to the Board of Engineers for Rivers and Harbors on August 15, 1913. The Board of Engineers for Rivers and Harbors report, reviewing the report of the special board, is dated December 16, 1913. It is signed by General William M. Black, then senior member of the Board, who was later and for a number of years Chief of Engineers of the United States army. Concerning the Chicago diversion, the Board of Engineers for Rivers and Harbors, in its report stated:
>
> 'Further, the Board believes that the total volume of water to be diverted from the natural discharge channels of the lakes should be definitely fixed by Congress; that a project with estimate of cost for works necessary to compensate for such diversion should be prepared to the satisfaction of the Chief of Engineers, and the Secretary of War; that before any diversion is made beyond that at present existing, the State of Illinois shall transfer to the Secretary of War the funds necessary for such works as given by approved estimate of cost that the work shall be built by the United States with the funds so provided and that the control and maintenance of such works shall be in and at the cost of the United States.'
>
> The Special Board's report upon the subject of compensating for diminished or diminishing lake levels is as follows:

'To restore the diminished levels in the lakes by constructing contracting works in their outlets does not, however, present any serious difficulties. A careful discussion of the proper locations and dimensions of such works is also given in Appendix A.

At the foot of Lake Ontario the closure of the Gut channel of the Galops Rapids by the Canadian Government has had the effect of raising the level of Lake Ontario an amount nearly equal to the computed lowering of the lake by a diversion of 10,000 second feet at Chicago, and no compensation is at present deemed necessary to restore former conditions in this lake.

In Appendix A it is proposed to diminish the outflow of Lake Erie by the construction of three submerged weirs in Niagara River in the vicinity of Squaw Island, which would average about 4.2 feet in height and would contain about 15,000 cubic yards of masonry. The estimated cost is $150,000.

To raise the level of Lakes Michigan and Huron submerged weirs are proposed in St. Clair River, covering 3 miles of river below the mouth of Black River at Port Huron. The weirs as suggested in Appendix A have a height of from 5 to 6 feet above the river bed, contain about 65,000 cubic yards of material, and their estimated cost is $325,000. It is computed that these weirs will increase the velocity of the water flowing over them slightly (from a mean of 3.28 feet to 3.89 feet per second), but, on the other hand, above the mouth of Black River the river slopes and velocities which are now excessive will be diminished, and navigation on the whole will be considerably benefited.

The Chicago diversion has no effect on Lake Superior.

Compensation for the loss of elevation on Lakes Michigan, Huron and Erie, and their connecting waters, due to an assumed diversion from Lake Michigan of 10,000 second feet, will by the plan above outlined involve an expenditure of about $475,000, to which should be added an amount for the maintenance of the weirs, estimated at about $15,000 per year, the total cost being much less than the cost of restoration of depths by dredging. It is the opinion of the board that while other plans have been proposed compensation by fixed contraction works similar in general to those above described affords the cheapest and most satisfactory method of preserving the levels of the Great Lakes.'

Said report is signed by W. H. Bixby, Brigadier General, U. S. Army, retired, President of the Board; C. McD. Townsend, Colonel, Corps of Engineers, U. S. Army; C. Keller, Major, Corps of Engineers, U. S. Army; J. B. Cavanaugh, Major, Corps of Engineers, U. S. Army; and John Bogart, Civil Engineer.

* * *

4. On June 30, 1917, the Congress of the United States by joint resolution authorized and directed the Secretary of War to

"Make a comprehensive and thorough investigation, including all necessary surveys and maps, of the entire subject of water diversion from the Great Lakes and Niagara River, including navigation, sanitary and power purposes, and the preservation of the scenic beauty of Niagara Falls and the rapids of Niagara River, and to report to Congress thereon at the earliest practicable date."

Accordingly, the Chief of Engineers, by direction of the Secretary of War, authorized the Division Engineer, Lakes Division (Col. J. G. Warren, Corps of Engineers, U. S. Army), to make and prepare a report upon all the diversions of the Great Lakes. This report was recently submitted to the Board of Engineers on Rivers and Harbors, and, on June 3, 1920, * * * The said report found that there were many diversions of the waters of the Great Lakes which effected the lowering of lake levels, and particularly the level of Lake Erie—such as the diversions at Niagara for power purposes, the diversion of 4,500 cubic-seconds feet for power purposes through the Welland Canal and other diversions, including the Chicago diversion; that the Chicago diversion of 10,000 cubic feet per second would produce approximately 55 per cent of the entire lowering of Lake Erie. The report further finds that any diminished or diminishing levels of the lakes due to the Chicago diversion, or any other diversion, may be compensated for by the construction of works in the St. Clair and Niagara rivers of the character described in said report entitled "Final Report, Waterway from Lockport, Ill., to the Mouth of the Illinois River," or by the construction and operation of so-called "regulating works" in the Niagara River, which said works would consist of dams which may be moved at will to regulate the levels of Lake Erie. It was recommended that The Sanitary District be allowed and permitted to withdraw from Lake Michigan 10,000 cubic second-feet of water and that works to compensate for any diminished

or diminishing lake levels should be built at the expense of The Sanitary District.

5. The treaty between the United States and Great Britain of 1909, relating to Canadian boundary waters, provided that there may be diverted from the Niagara River above Niagara Falls, on the Canadian side, water to the extent of 36,000 cubic feet per second and on the American side, 20,000 cubic feet of water per second. The reason that the United States was only permitted to divert 20,000 cubic second-feet as compared with the Canadian right of 36,000 second-feet was because the United States was charged with the diversion of 10,000 second-feet at Chicago. Canada, therefore, can make no objection. The International Waterways Commission was organized and appointed pursuant to the joint action of the Congress of the United States and the Parliament of Canada. Canada and the United States each appointed three members thereof. The purpose of the organization of the International Waterways Commission was, among other things, to recommend the form of a treaty between the United States and Great Britain concerning the Canadian boundary waters. On April 25, 1906, the Canadian section of the International Waterways Commission made a report to the Commissioner of Public Works of Canada, as follows (proceedings I. W. C., page 333):

"At Chicago the Americans had built a drainage canal which, when in full operation will use about 10,000 cubic feet of water per second.

The quantity of water required for the purpose of a ship canal is comparatively small, but the character of this drainage canal at Chicago is such as to involve the continuous flow of water, which will have the effect of lowering Lake Michigan, by over 6 inches and Lake Erie by 4½ inches. The nature of this work may be judged when we state that the expenditure will be over $40,000,000 and that power works are in the course of construction on the canal which will generate some 30,000 H. P.

As the diversion from Lake Michigan to the Mississippi River is of a much more serious character than the temporary diversions from the Niagara River, it is felt that the amount of water taken on the American side of the Niagara River should be limited to 18,500 cubic feet per second. * * * It is exceedingly important in the interest of navigation, both to ourselves and the people of the United States, that the diversion by way of the Chicago drainage canal should be limited. * * * If our pro-

posal is carried out the diversions will be about as follows:

Diversions on the American Side

	Per Second Cubic feet
Niagara Falls	18,500
Chicago Drainage Canal	10,000
Total	28,500

Diversions on the Canadian Side

Niagara Falls and on the Niagara Peninsula	36,000

It is quite apparent that no further diversion can be made on the Niagara River without injury to the scenic effect of the Falls as a whole, and there should be no further diversion from Lake Erie or any other of the waters of the Great Lakes system, which will be injurious to navigation. Your Commission is, therefore, of opinion that the time has come when it is desirable to make a treaty limiting these diversions. * * * Therefore this Commission recommends that a treaty be had between the United States and Great Britain, in framing which, it should be recognized that * * *

Permanent or complete diversions of such waters are wrong in principal, and, therefore, should hereafter be absolutely prohibited. The diversions by the Chicago drainage canal should be limited to the use of not more than 10,000 cubic feet per second. * * * This would give an apparent advantage to Canadian interests, but as the diversion is not of serious injury to the Falls and does not materially affect the interests of navigation, it is more than counter-balanced by the complete diversion of 10,000 cubic feet by way of the Chicago drainage canal to the Mississippi River.

On May 3, 1906, the International Waterways Commission, by report signed by all members, made a report as follows (proceedings I. C. W., 339):

"The Commission has made a thorough investigation of conditions existing at Niagara Falls and the two sections have presented reports to their respective governments setting forth these conditions, to which attention is invited. The following views and recommendations are based upon a careful study of the facts and conditions set forth in these reports * * *

2. While the Commission are not fully agreed as to the effect of diversions of water from Niagara Falls, all are of the opinion that more than 36,000 cubic feet per second on the Canadian side of the Niagara River, or on the Niagara Peninsula, and 18,500 cubic feet per second on the American side of the Niagara River, including diversions for power purposes on the Erie Canal, cannot be diverted without injury to Niagara Falls as a whole.

3. The Commission, therefore, recommends that such diversions, inclusive of water required for domestic use or the service of locks in navigation canals, be limited on the Canadian side to 36,000 cubic feet per second, and on the United States side to 18,500 cubic feet per second (and in addition thereto, a diversion for sanitary purposes, not to exceed 10,000 cubic feet per second, be authorized for the Chicago drainage canal), and that a treaty or legislation be had limiting these diversions to the quantities mentioned.

The effect of the diversion of water by the Chicago drainage canal upon general navigation interests of the Great Lakes' system will be considered in a separate report. * * * The following principles are suggested * * *:

Permanent or complete diversions of navigable waters or their tributary streams should only be permitted for domestic purposes and for the use of locks in navigation canals."

On January 4, 1907, the International Waterways Commission made a special report, signed by all the members, entitled:

'The Chicago Drainage Canal—Joint Report of the International Waterways Commission.'

Among other things in said report, the said Commission stated:

'There appears to be a tacit general agreement that Chicago needs, or will need about 10,000 cubic feet of water per second for sanitary purposes and that the city should have it without further question. * * * We therefore recommend that the government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago drainage canal.' "

The Motion stated that the Secretary of War's permit of May 8, 1899, is limited only by the capacity of the channel to 10,000 cubic feet of water; that the limitation of flow thereafter made, was solely because of the then narrowness and

shallowness of the Chicago River and its South Branch and West Fork; that thereafter, with the consent of the Secretary of War and for the purpose of enlarging the cross section and channel of the Chicago River and its branches to provide a flow of 10,000 cubic seconds feet, the Sanitary District improved the river by deepening the channel from 17 to 26 feet, and widening it at all points to 200 feet so that its channel capacity was the amount of water desired to be withdrawn and required; that the cause for the limitation of the flow to 4,167 cubic seconds feet having been eliminated, the order of the Secretary of War so limiting it, should be considered of no force and effect.

The motion further set forth (Rec. Vol. VIII, p. 164):

"(7) The diversion of at least 10,000 cubic second-feet of water from Lake Michigan is essential for the sanitary needs and requirements of the population within the the limits of The Sanitary District, which includes that of the City of Chicago and its suburbs, comprising a population of approximately 3,000,000 people. The primary purpose of The Sanitary District is to construct and operate works to provide a pure drinking water supply for this population. The plans for the works of The Sanitary District were formulated and recommended by a commission of engineers, pursuant to an ordinance of the City of Chicago, known as "Drainage and Water Supply Commission." This commission studied the matter for two or three years and finally recommended the diversion of the drainage and sewage of Chicago and its environs to the Desplaines River, together with a sufficient amount of water from Lake Michigan (20,000 cubic feet per minute for each 100,000 population) to oxidize the sewage and waste. This Commission's report was made in 1887 and The Sanitary District Act was passed pursuant to the recommendations of that Commission at the next session of the Legislature, and the District has expended upwards of $100,000,000 in the construction of these works. They have accomplished practical results. There was not at the time the Commission made its report, and there has not been since that time, any other practical method that could have been adopted to accomplish the purpose of these works—namely, the protectection of the water supply. The record in this case shows that the art of artificially purifying sewage has been for years, and is now, in a state of uncertainty, and there is

no plan for artificially purifying sewage that engineers agree is feasible and practical, and will with any certainty serve for a considerable period of time in the future—and this is particularly true when dealing with great metropolitan populations.

The basis, therefore, of The Sanitary District's diversion works is the reversal at all times of the Chicago River, into which a large amount of sewage is emptied from sewers serving the people of Chicago and its suburbs. The maximum run-off of the Chicago River drainage area is 10,000 cubic second-feet. Obviously, if the capacity of the main channel of the District were less than 10,000 second-feet, the Chicago River would flow into Lake Michigan at certain flood times. The withdrawal of water from Lake Michigan must, therefore, be the same amount, because it would be impossible, if the flow were limited to 4,167 feet, or any amount materially below the 10,000 second-feet, to change the flow from the the limited amount to the maximum run-off of the drainage area in time to keep the water from going into Lake Michigan. This is demonstrated by testimony of witnesses in this case and it is recognized as a fact by the report of Col. Warren, Division Engineer of the Lakes Division, above mentioned. The limitation of the flow to 4,167 second-feet, or any amount materially less than 10,000 second-feet, would, therefore, require the absolute and complete purification of all sewage within the limits of the District, so that if any effluent found its way into Lake Michigan, it would not affect the water supply.

There was presented in this case estimates of the cost of constructing artificial purification works to completely purify the sewage and drainage. These estimates were made in the year 1913. The total cost of constructing these works, which would require a great number of years to complete, was from $75,000,000 to $100,000,000. The figures were made with reference to the cost of materials, labor, etc., as of the year 1913. Since that time the cost of labor and materials for similar works has increased approximately 100 per cent, so that to install the works which would be made necessary by reason of the limitation of the flow to 4,167 second-feet, would be from $150,000,000 to $200,000,000. The cost of operating and maintaining these works annually was also estimated, and the estimates were upwards of $5,000,000 per annum. The annual operating and maintenance cost would now, according to present prices of labor and materials, much exceed that amount.

It is also shown in the record in this case that it would be impossible for the District or this community to raise the money necessary to construct these works within any reasonable time, unless constitutional amendment should permit greater bonding power.

In addition to the amount which the District would be compelled to expend by virtue of the limitation of flow to 4,167 second-feet, it would lose the greater portion of the investment that it has already made in the present diversion works.

Furthermore, it is probable that any works which the District might install for the purification of sewage and drainage would, within a very short time, have to be discarded and thrown aside for some other works upon a different plan. Indicative of the changes in the art of artificially purifying sewage that have taken place we refer to the fact that it was only five years ago that most sanitary engineers believed that the best method to be used was the Imhoff Tank system. In these tanks a certain amount of sewage was allowed to settle and the effluent drawn off to run through what are called "sprinkling filters," by which the effluent from the Imhoff tank was, by means of a nozzle, sprayed over crushed rock of several feet in thickness. Lately, sanitary enginers have reached the conclusion that such method is not proper but that what is known as the "activated sludge" system should be used. This system contemplates the passing of the sewage and drainage at low velocities through tanks, which tanks are provided at the bottom with perforations so that a vast amount of air may be pumped through the sewage and thereby the sewage be purified.

If the District were limited now to the withdrawal of 4,167 second-feet, at many times during the year the Chicago River would flow into Lake Michigan, carrying with it a vast amount of sewage. At and prior to the time the Drainage Canal was opened and placed in operation, the death rate per year from typhoid fever was 75 per 100,000 population. Occasionally there would be epidemics, when the rate would be 190 per 100,000. Since the opening of the Drainage Canal there has been a steady reduction in the death rate per year from typhoid fever, with no epidemics, so that now the death rate from typhoid fever is less than 1 per annum per 100,000 of population. According to Hazen's theorem, where there is an increase of 1 per annum in death rate from typhoid fever, there is an increase of 3 from other kindred disease; and the same theorem applies conversely to a decrease. The

limitation to 4,167 second-feet would produce intolerable conditions in the Illinois River, because of the fact that the principal amount of the sewage of Chicago and its suburbs would be delivered to the Desplaines and Illinois Rivers without the necessary pure water for oxidization and purification purposes. All fish life would be destroyed throughout the entire course of said river and the fish industry along the Illinois River is one of the principal industries of the state. The conditions above mentioned that would result from the limitation of flow to 4,167 second-feet would continue until works were installed to practically purify a very large portion of the sewage and drainage arising within the limits of The Sanitary District, and it would continue to a certain extent until the works were installed to purify all sewage and drainage.

8. Since the drainage Canal was opened, January 17, 1900, all boats that were then navigating the Great Lakes and its connecting waters are not interfered with in any respect, by a less depth due to lowering of lake levels. All boats which the United States claims are affected—those owned by the Pittsburgh Steamship Co., a subsidiary of the United States Steel Corporation—were constructed since that time. All the critical points of navigation of the Great Lakes have been, since the opening of the Drainage Canal, deepened or improved, and the record in this case shows that the reference plane for the improvement of 1903, which included practically all the connecting channels, was made approximately 6 inches lower because of the diversion at Chicago—so that, the navigation interests have not been injured. They have the same depth of water that they would have had if the diversion had not existed.

9. The Sanitary District here and now offers and agrees to pay to the United States the amount of money necessary to construct, operate and maintain the compensating works which will off-set or compensate for any damage due to the diversion at Chicago. These works the Federal engineers have said may be installed and will accomplish the purpose named. If they were installed and placed in operation, the only ground of the Government for seeking the injunction here would be removed. The expense would be practically nothing as compared with the financial burden that would be placed upon the District if it is enjoined from withdrawing more than 4,167 second-feet of water, or any amount materially less than 10,000 second-feet. The only thing that the Government would have to do in order to accomplish the instal-

lation of the works would be to provide for their construction, operation and maintenance. The suggestion for modification of the opinion and direction of the Court with reference to the decree in these cases herein made points out the plain practical solution of this problem."

Exhibit "A" to Motion.

"An ordinance of the Board of Trustees of the Sanitary District of Chicago offering and agreeing to defray the expense of the construction of works in one or more of the outlets of the Great Lakes to compensate for any diminishing levels of the Great Lakes and connecting waters due to the diversion of 10,000 cubic feet of water per second from Lake Michigan by the Sanitary District of Chicago and authorizing the attorneys of the Sanitary District in the suits pertaining to said diversions now pending in the District Court of United States for the Northren District of Illinois, Eastern Division, to make and present such offer and agreement in open Court.

Whereas, there are now pending in the District Court of the United States, for the Northern District of Illinois, Eastern Division, two suits in equity instituted by the United States against The Sanitary District concerning the withdrawal of water from Lake Michigan by The Sanitary District of Chicago. The first suit was instituted in the year 1908 and pertains particularly to the construction and operation and withdrawal of water for the operation of the Calumet Sag Channel, an adjunct of the main channel of The Sanitary District of Chicago. The second suit was instituted in the year 1913 and seeks to enjoin The Sanitary District from withdrawing from Lake Michigan, through its various channels, including the Calumet Sag Channel then and now under construction, more than 4,167 cubic feet of water per second. The said suits have been tried together and submitted together upon briefs; and,

Whereas, the Honorable Kenesaw M. Landis, one of the Judges of said District Court of the United States, for the Northern District of Illinois, Eastern Division, before whom said cases have been pending, did recently render an opinion or direction for the entry of a decree in said cases, in substance, to enjoin The Sanitary District of Chicago, defendant in said cases, from withdrawing from Lake Michigan more than 4,167 cubic feet of water per second; and,

Whereas, various reports have been submitted pursuant to acts of The Congress of the United States by the Engineer Corps of the U. S. A., finding that the claim of injury to navigation arising from the lowering of lake levels because of the diversion from Lake Michigan of water at Chicago to the extent of 10,000 cubic feet of water per second, may be compensated for by the construction of fixed weirs or works of similar character, or by the construction and operation of movable dams in the St. Clair, Niagara and St. Lawrence Rivers, or one or all of them, and the expense of constructing said fixed weirs would, at the time the report was made, not exceed $475,000; and it was recommended that if The Sanitary District of Chicago should defray the expense of constructing such works, then they should be maintained by and at the expense of the United States; and, if such works were constructed and placed in operation, thereby the ground of the United States for securing the injunction herein would be removed; and,

Whereas, it is the opinion of the Board of Trustees that if The Sanitary District is enjoined from taking more than 4,167 cubic feet of water per second from Lake Michigan for sanitary purposes, it will be necessary to expend, in the construction of works to artificially purify sewage, supplement and aid the works diverting 4,167 cubic second feet of water upwards of $150,000,000, and the operation and maintenance of the same will exceed upwards of $5,000,000 per annum; and it is, further, the belief of the Board of Trustees of The Sanitary District of Chicago that it is doubtful whether such works, with said limited withdrawal of 4,167 cubic second feet of water will provide for the people of The Sanitary District of Chicago, which includes the population of Chicago and its environs, a safe drinking water supply, for the reason that it would be impossible, with said limited withdrawal, to keep the Chicago River at all times reversed so that it would not flow into Lake Michigan, carrying with it a large amount of sewage and drainage, and it is doubtful whether such purification works would accomplish practical results.

Now, therefore, be it ordained by the Board of Trustees of the Sanitary District of Chicago:

Section 1. The Sanitary District of Chicago does hereby offer and agree to defray the expense, and pay to the United States Government the cost, of constructing and maintaining works to be installed at the outlet or outlets of any of the Great Lakes to compensate for any diminishing levels of the Great Lakes and connecting

waters, due to a diversion or withdrawal from Lake Michigan of 10,000 cubic feet of water per second by The Sanitary District of Chicago through its various channels and diversion works in the event The Sanitary District is not enjoined from diverting from Lake Michigan less than 10,000 cubic seconds feet of water.

Section 2. The said offer and agreement contained in Section 1 hereof is intended to embrace and cover not only the expense of constructing and maintaining fixed weirs or dams described in the report entitled 'Final Report of Waterways from Lockport to the Mouth of the Illinois River.' House of Representative's Document No. 762, 63rd Congress, 2d Session, but also any other works of similar character that may be planned or provided for by the Congress of the United States or by competent Governmental authority, or works known as "regulating works," consisting of movable dams or dams that may be moved from time to time, that may be planned or provided for by The Congress or other competent authority—such works having for their purpose compensation for any diminishing levels of the Great Lakes or connecting waters due to a diversion at Chicago of 10,000 cubic second feet of water; and the said The Sanitary District of Chicago offers and agrees to pay to the United States the expense of constructing and maintaining such works whenever the United States shall provide for such construction and make request for the payment of the amount of money necessary to construct and maintain the same.

Section 3. The attorneys for The Sanitary District of Chicago in said two suits above described, wherein the United States is complainant and The Sanitary District of Chicago is defendant, on behalf of The Sanitary District of Chicago, are hereby authorized, empowered and directed to present and make said offer in open Court in said causes, or in any other manner that the said attorneys may deem proper.

Section 4. The preambles to this Ordinance are hereby made a part of same and this Ordinance shall take effect and be in force from and after its passage."

The said motion was partially heard by Judge Landis. When Judge Landis resigned and ceased to be one of the judges of the District Court of the United States for the Northern District of Illinois, Eastern Division, no order had been entered upon said motion, no decree had been entered

by him and no order or memorandum signed by him stating his findings and conclusions existed.

Order consolidating causes.

The case was thereafter submitted to the Honorable George A. Carpenter, one of the judges of said court, and after hearing argument of counsel on said motion, and in said case, on June 18, 1923, Judge Carpenter entered an order consolidating the cause known as the Calumet suit instituted March 23, 1908, with the Main Channel suit instituted October 6, 1913. At the same time Judge Carpenter rendered his decision in said cause and entered certain other orders hereafter mentioned.

Opinion of Judge Carpenter (Vol. VIII, pp. 127-130).

"CARPENTER, District Judge (orally): It is needless to say that this litigation is of vital interest to the people of the State of Illinois. It was started nearly fifteen years ago by bill filed in behalf of the United States of America against the Sanitary District of Chicago to restrain the defendant from diverting from the waters of Lake Michigan in excess of approximately 4,500 feet per second.

The parties used the better part of six years in putting in the proof. The matter was then presented with appropriate briefs to my distinguished colleague, Judge Landis, for final determination. Judge Landis kept the matter under advisement for another six years, moved undoubtedly by the thought that the State of Illinois was being benefitted all of the time by the withdrawal of 10,000 cubic feet a second by the defendant, and that the Government was not in any way actually harmed.

On June 19th, 1920, Judge Landis rendered an oral opinion, finding in effect that the withdrawal in excess of 4,167 cubic feet a second by the Sanitary District of Chicago was without authority of law; that the withdrawals then being made reduced the level of Lake Michigan, and other of the navigable waters of the United States, to such an extent as to be an interference with navigation; that the Secretary of War, acting under Congressional powers, had never given his consent to such excessive withdrawals; that the diversion by the Sanitary District was therefore unlawful, and an injunction should issue.

A motion was made thereafter not for a reconsideration of the findings of the Court, but for the purpose of settling the terms of the final decree.

Attorneys for the Sanitary District urged the evidence showed clearly that by the construction of weirs and other compensating works at a relatively small expense, the Government could restore the various water levels which had been reduced by the flow into the drainage canal. They also urged that the State of Illinois, by appropriate legislation, had authorized the Sanitary District to agree with the United States Government to stand the cost of such weirs and compensating works and their annual maintenance, and strenuously urged upon the Court that as a condition to the entry of any injunction, the plaintiff Government should agree to erect and maintain such works at the expense of the defendant.

Counsel for the Drainage District have also urged upon the Court at this time to reconsider entirely the case upon the evidence presented.

This Court is very much disinclined to interfere with the judgment of Judge Landis. At least it is entitled to the weight that would be given to the report of a Master in Chancery or Special Commissioner. In addition, this Court has gone over the entire record, and is able to say that it agrees with Judge Landis in every respect, although from a legal standpoint, with some reluctance.

It is not necessary to go into the duties of the Secretary of War with respect to navigable waters. It is not necessary to discuss the question of whether when the State of Illinois entered the Union in 1818 it joined with special reservations with respect to its own police powers. A reading of the Federal decisions from *Gibbons* v. *Ogden*, 9 Wheat, 1, down to the present date leaves no escape from the thought that the States in adopting the Constitution surrendered to the central government everything, without stint or reservation, so far as the terms of the Constitution are concerned. The right to regulate commerce was conferred with many other things, and that right imposed upon the central government to see to it that navigation was not interfered with, either by individuals, the several States, or any foreign power. It is very true that it is the duty of the State of Illinois, in the exercise of its police power, to provide for the safety and welfare of its own people. On the other hand, if that safety and welfare depends upon the operation of the things granted to the central government, the State of Illinois must look to Congress for eventual aid or relief.

The evidence shows, and Judge Landis found and I find that the waters of Lake Michigan and other navigable waters of the Great Lakes have been reduced in level by the amount of water in excess of 4,167 cubic feet per second withdrawn from Lake Michigan by the defendant. From the standpoint of the practical mariner the testimony may not be satisfactory. It was given by engineers more or less highly technical, but thoroughly equipped in their profession. In fact no Lake captain testified that by reason of the lowering of the level of Lake Michigan was navigation interfered with. I have grave doubts whether any boat has been stranded or delayed by reason of the action of the Sanitary District.

On the other hand, the water levels have been reduced, and the Secretary of War, in whom is reposed the sole authority in matters of this kind, has determined that there was an interference with navigation, and a permit to the Sanitary District to continue in its present withdrawals was refused.

The jurisdiction of the Court has not and could not be challenged, and an injunction must issue against the defendant.

The record shows that the Sanitary District of Chicago has expended in its work some hundreds of millions of dollars; and the evidence shows rather conclusively that no other system of disposing of the sewerage in the great district covered would work so well as that devised by the Sanitary District. The City of Chicago, since the Drainage District began to operate, has practcially doubled in population. The district served by the Sanitary District holds more people than over forty states in the Union. The rate of typhoid fever since the completion of the Drainage Canal has been reduced from seventy-five per hundred thousand to a negligible number.

The testimony of Government engineers shows that it would take from ten to twenty-five years for the Drainage District to erect sewerage treatment and disposal works to handle the sewerage within the Drainage District, if the flow of water was reduced from 10,000 to 4,167 cubic feet per second.

This matter is a subject which needs the consideration of thinking people, not only in the State of Illinois, but in the whole United States. The treaty with Canada entered into some years ago seemed to contemplate an acquiescence on the part of the Canadian Government to the withdrawal of 10,000 cubic feet a second by the Drainage District. However that may be, the Secretary of War

has not given his official consent. Whether the increased withdrawal should or should not be made is properly a political and not a legal question, in the absence of consent by the Secretary of War. The Legislature of the State of Illinois, the various civic bodies, the Association of Commerce, and senators and representatives should see to it that at the earliest possible moment the situation here is brought to the attention of Congress, so that by appropriate legislation the health and welfare of this great community may be safeguarded. I have no doubt that when the matter is properly presented it will be taken up by Congress and by the State Department, and some plan devised which will bring about adequate and desired results.

It goes without saying that this Court will not issue an injunction to be effective forthwith. It cannot impose the conditions so strenuously urged by the attorneys for the Sanitary District. It is doubtful whether the State of Illinois could authorize expenditures to be made in foreign states and foreign countries to restore the water levels.

On the testimony of the Government engineers the Court might in the exercise of a sound discretion, delay the affectiveness of its injunction for from fifteen to twenty-five years to enable the Sanitary District or the State of Illinois to arrange for other means of disposal of the sewerage now handled by the Sanitary District.

Believing as I do that it is a matter for the immediate action of Congress, a decree may be prepared finding the facts as stated in the Bill and enjoining the defendant from withdrawing from Lake Michigan in excess of 4,167 cubic feet a second; the decree, however, not to go into effect for six months.

The matter must necessarily go to the Supreme Court of the United States for final settlement, and no doubt, if need be, when the record is there filed, application may be made to that Court for a *supersedeas* or further stay.

Order refusing offer of sanitary district to construct certain works—entered June 18, 1923.

(Vol. VIII, p. 130)

This cause came on to be further heard at this term and was argued by counsel, and thereupon, upon consideration thereof, it was ordered, adjudged and decreed, as follows:

(1) The motion presented herein on the 12th day of July, 1920, by the defendant, asking that the defendant be not enjoined or restrained from withdrawing from Lake Michigan less than ten thousand (10,000) cubic seconds feet of water, and in connection with which said motion an offer was made to pay cost of constructing and maintaining such works as might be provided by complainant to off-set for the lowering of the surface elevations of Lakes Michigan, Huron, St. Claire, Erie and Ontario, due to a diversion of said amount by the defendant at Chicago, is hereby denied, and the said offer is refused.

Enter. CARPENTER, JUDGE, June 18, A. D. 1923.

Decree for injunctions.
(Vol. VIII, p. 131)

This cause came on to be further heard at this term, and was argued by counsel; and thereupon, upon consideration thereof, it was ordered, adjudged and decreed as follows, viz:

That the defendant, the Sanitary District of Chicago, its Board of Trustees, officers, agents, attorneys, representatives, employees and servants, and all other persons acting or claiming or assuming to act under its authority, be, and they hereby are, and each of them hereby is, enjoined from diverting or abstracting any waters from Lake Michigan over and above or in excess of 250,000 cubic feet per minute.

The operation of this injunction is hereby stayed for a period of six months to enable the defendant to present the record herein to the Supreme Court of the United States.

Enter:

Carpenter, Judge. June 18th, A. D. 1923.

Petition for appeal allowed and injunction suspended pending appeal.

June 29, 1923, petition for appeal to the Supreme Court of the United States was filed by the defendant, together with assignment of errors. On the same day, June 29, 1923, an order was entered allowing the appeal, suspending the opera-

tion of the injunction during the pendency of the appeal upon the defendant's filing injunction bond in the sum of $5,000 on said date filed and approved. An order was further entered on said day directing that the evidence as contained in the printed record be incorporated in the transcript of record on the appeal of said cause. On the said June 29, 1923, order was entered that the printed volumes of the record of the testimony and evidence presented before the Commissioner as identified by the signature of the clerk of the court on the initial page of each volume, should be substituted as part of the record showing the testimony and evidence in place of the typewritten transcript of said testimony and evidence filed by said Commissioner. An order was entered also extending the time in which to file transcript of the record in the Supreme Court until and including the 20th day of September, A. D. 1923.

Said orders entered on June 18 and 29, 1923, appear in the record, Vol. VIII, pp. 127, 130, 131, 145 and 147.

Assignment of errors filed June 29, 1923 (Vol. VIII, p. 132.)

(In stating here the assignment of errors, we have grouped various assignments as they appear in the record, as indicated.)

The Sanitary District of Chicago alleges that the injunction entered June 18, 1923, was erroneous because:

(*a*) Plaintiff is not entitled to the injunction granted, and plaintiff's bill should have been dismissed for want of equity. (Ass. 1.)

(*b*) Under the commerce clause of the Constitution, Article 1, Section 8, Clause 3, neither Congress nor any officer of the United States has power to regulate or limit the State of Illinois or The Sanitary District of Chicago in diverting water from Lake Michigan for public welfare in the exercise of the state's police power. (Ass. 2.)

(*c*) The Act of the General Assembly of Illinois of May 29, 1889, under which The Sanitary District was organized, expressly directs defendant to divert and abstract 20,000 cubic

feet of water per minute for each 100,000 population of the district, such population being approximately 3,000,000 people. (Ass. 3, 4, 5, 6, 7.)

(*d*) Said Act of May 29, 1889, of the General Assembly of Illinois, was passed for the sole and only purpose of preserving health and protecting life under the state's police power, and neither Congress nor any officer of the United States can interfere with the reasonable exercise of such police power. (Ass. 8.)

(*e*) The Act of May 29, 1889, of the General Assembly of Illinois and the construction and operation of the works provided to be built thereunder, cannot be interfered with by the United States, when the primary and sole purpose of such legislation and operation of said works is for public health and welfare of the people of the state and the impairment of navigation, if any, is only the indirect result of the operation of said Act of the General Assembly of Illinois and the works constructed thereunder. (Ass. 9.)

(*f*) The pure, wholesome, potable drinking water supply for the people of Chicago, its environs and those within the territorial limits of the defendant, the disposal of the sewage of said people, and the diversion of same from the water supply, can only be obtained through the operation and maintenance of defendant's diversion works constructed under said Act of the General Assembly of Illinois of May 29, 1889, requiring a diversion of 20,000 cubic feet of water per minute for each 100,000 of population (population now upwards of 3,000,000 people.) (Ass. 10, 11, 12, 13 and 14)

(*g*) With the diversion limited to 250,000 cubic feet of water per second, as required by said injunction, works to artificially dispose of sewage supplementary to said diversion and works to filter the water supply of the people, cannot be constructed within a period of less than twenty years, by reason of the inability of the Sanitary District, defendant, to raise funds therefor by taxation and by the issuance of bonds. (Ass. 15, 16, and 17)

(*h*) The Act of Congress of March 2, 1827, entitled "An Act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan", authorized the State of Illinois to build the main channel of the defendant, Sanitary District, supplementary to or in place of the old Illinois Michigan Canal constructed in 1848, and to divert from Lake Michigan for said main channel at least 600,000 cubic seconds feet of water per minute and in excess of 250,000 cubic feet per minute fixed by said injunctional order. (Ass. 18, 19, 20, 21 and 22)

(*i*) The United States had full and complete knowledge of the passage of the Act of May 29, 1889, providing for the construction of the main channel of the Sanitary District with its attendant diversion, the progress of construction, completion, and the purpose of such works and invited and acquiesced in said diversion provided by said Act of May 29, 1889, and is estopped to interfere with it. (Ass. 23)

(*j*) Congress has by various acts fixed the project depths of all harbors and connecting waters of Lake Superior, Michigan, Huron, Erie and Ontario, and the actual depths of water in such harbors and connecting waters has not been less than the project depths fixed, nothwithstanding defendant's diversion. (Ass. 24 and 25)

(*k*) The cost and financial burden resulting to the defendant by virtue of the said injunction and the limitation of said diversion is great, amounting to upwards of $250,000, and the damage to plaintiff by reason of the alleged injury to navigation is slight, and all claimed damage to navigation may be offset or compensated for by construction of compensating works, which cost would not exceed $475,000. (Ass. 26-28)

(*l*) The offer of defendant to pay the cost of constructing and maintaining compensating works to offset for the alleged lowering of the surface elevation of the Great Lakes system, on condition that the decree to be entered should

only enjoin defendant from diverting in excess of 10,000 cubic feet of water from Lake Michigan, should have been accepted by the court and a decree entered as requested by the defendant upon the condition that defendant comply with such offer. (Ass. 29-30)

(*m*) Congress has by various acts appropriated money for and required surveys and reports for a waterway from Chicago to the Gulf of Mexico, whereby the diversion of water by the defendant to the amount of 600,000 cubic feet per minute would be utilized and has by various acts also required surveys as to the means of offsetting or compensating for the lowering of the surface elevations of the Great Lakes system by said diversion, and has thereby indicated that it treated the said diversion by the defendant as existing, and did not intend to disturb it. (Ass. 31-32)

(*n*) Act of Congress of June 29, 1906, relating to the diversion of water from the Niagara River, known as the Act for the Preservation of Niagara Falls, expressly prohibits interference with diversions from the Great Lakes for sanitary or domestic purposes except as Congress might in the future provide. (Ass. 33)

(*o*) The works of the Sanitary District were commenced prior to the passage of the Rivers and Harbors Act of September 19, 1890, and such works are recognized by said act as authorized by law. (Ass. 34)

(*p*) Sections 9 and 10 of the Rivers and Harbors Act of March 3, 1899, do not authorize the Chief of Engineers or the Secretary of War in any manner to supervise or regulate or control the diversion of water by the defendant. (Ass. 35-36-37)

(*q*) Permit of May 8, 1899, authorized the Sanitary District to open its main channel and was without limitation as to amount except the capacity of the main channel of the Sanitary District as fixed by law. This permit was subject to a condition only as to limitation of flow—that if the cur-

rent should be unreasonably obstructive to navigation in the Chicago River, the Secretary of War might modify the discharge from Lake Michigan through the river. Thereafter, due to the then shallowness and narrowness of the Chicago River, its South Branch and West Fork, the Secretary of War ordered the flow limited to 250,000 cubic feet per minute. Because of such limitation for the purpose of providing for the greater flow of 10,000 cubic seconds feet, the Sanitary District, with the consent and approval of the Secretary of War, widened and deepened the channels of said rivers at a cost of approximately $13,000,000 so that there could be withdrawn through said river channels the amount of water required by said Act of May 29, 1889, without injury to navigation. Thereafter the Secretary of War or other officer of the United States was without authority to enforce the order limiting the withdrawal to 250,000 cubic feet per minute, made because of the then narrowness and shallowness of the channels of said rivers. (Ass. 38-39-40-41)

(*r*) The abstraction and withdrawal of water from Lake Michigan by defendant to the amount of 600,000 cubic feet of water per minute, or 10,000 per second, has not and will not impair the navigable capacity of any of the navigable waters of the United States, has not been observed by any lay witnesses, navigator or captain of any ship, or any one engaged in navigation. Such claim is only the result of the analyses of expert witnesses. (Ass. 41-42-43-44-45-46-47-48-49)

(*s*) Defendant cannot observe the injunctional decree without causing pollution of the water supply of upwards of three million people within defendant's limits, from which would result epidemics of typhoid fever and other water-born diseases. (Ass. 50-51.)

(*t*) Injunctional decree herein holds unconstitutional the Act of General Assembly of Illinois of May 29, 1889, under which the Sanitary District, the defendant, was organized. (Ass. 52)

(*u*) Treaty between the United States and Great Britain of January 11, 1909, concerning Canadian boundary waters, recognizes the diversion by the defendant to the amount of 10,000 cubic feet of water per second and precludes an injunction herein as to any diversion of 10,000 cubic feet seconds or less. (Ass. 53-54-55)

(*v*) It does not appear from the evidence that the diversion proposed by the defendant pursuant to said Act of May 29, 1889, under all the facts and circumstances, has obstructed or would unreasonably obstruct navigation. (Ass. 56-57 and 60)

(*w*) Decree herein enforces an arbitrary and unreasonable course pursued by the Secretary of War and the Attorney General. (Ass. 58)

(*x*) The Court should have balanced the equities and in so doing should have refused the injunction and dismissed the complainant's bill for want of equity. (Ass. 59)

(*y*) Congress will not be deemed to have acted concerning a matter of local regulation such as is embraced in the Act of the General Assembly of May 29, 1889, providing for defendant's diversion works, unless it has passed some special law with reference to the alleged obstruction. (Ass. 61)

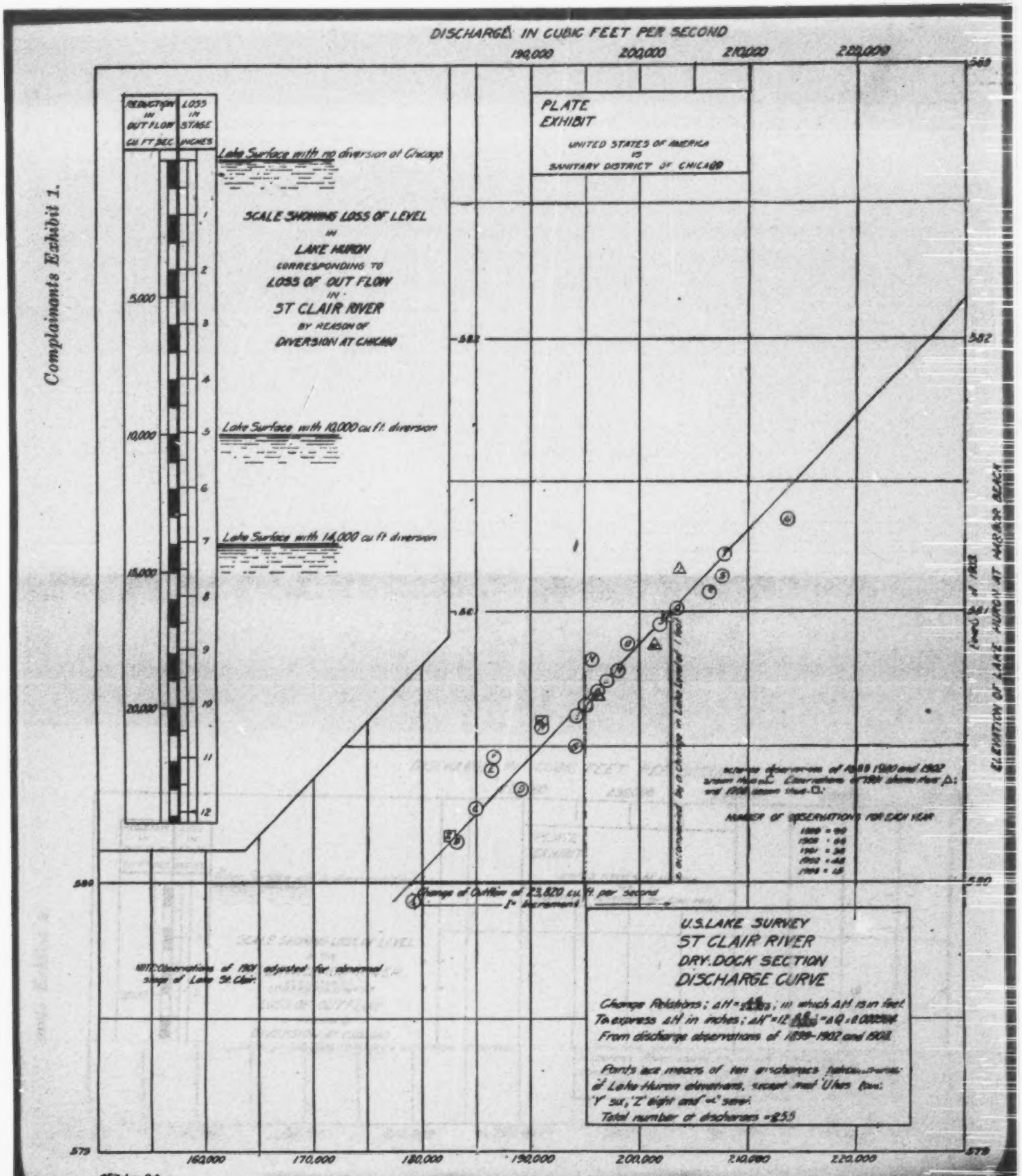
EVIDENCE.

The exhibits attached to and made a part of both the bill of complaint in the Calumet suit and the complaint in the main channel suit, and in the answers thereto by the defendant, and documents quoted in the pleadings, were either admitted by the pleadings or introduced in evidence.

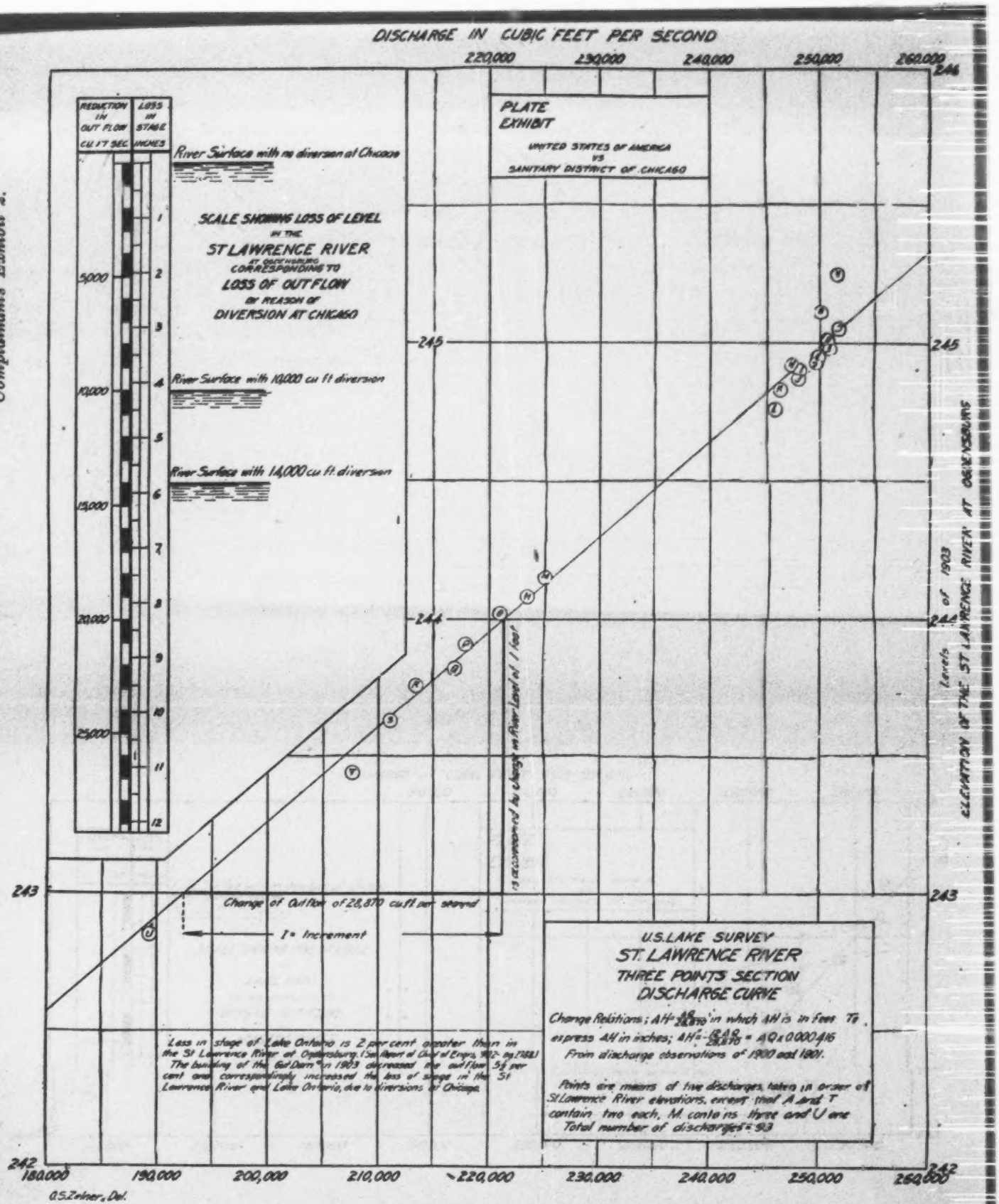
The United States will be hereinafter designated "Plaintiff."

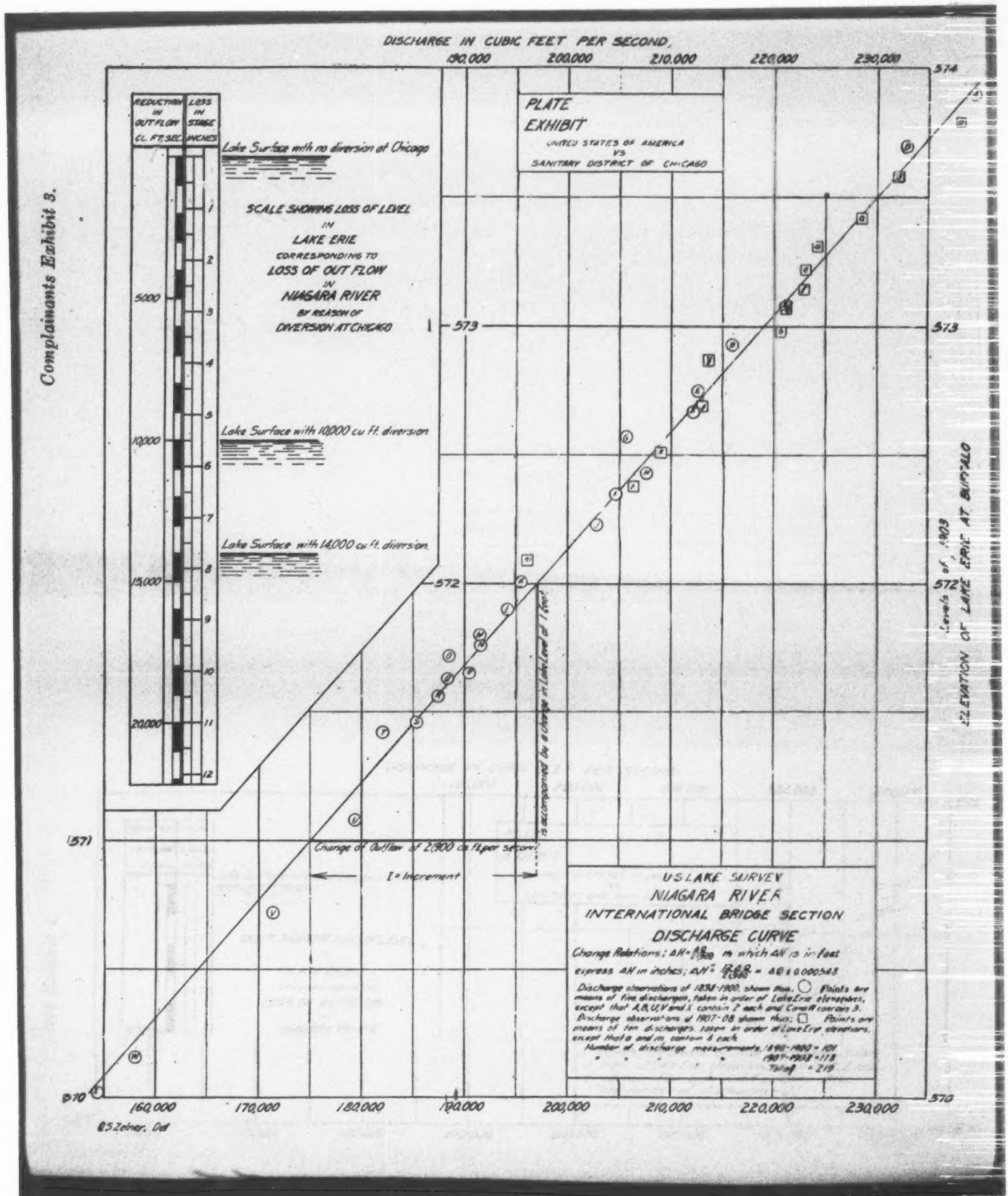
The evidence of plaintiff in chief related principally to establishing the increment of the Rivers St. Clair, Niagara and St. Lawrence by witnesses who were or had been connected with the United States Lake Survey. The increment of a river is the increase or decrease in its flow due to the rise or fall of one foot of the river's controlling lake. The Lake Survey had, running over a period of years beginning with the year 1898, made a great number of discharge measurements of these rivers. Hourly records had been kept of the stage of the various lakes during this period by automatic recording gages. The discharge measurements were then plotted on a piece of paper, each one placed according to the lake stage at the particular time the measurement was made. One side of such paper was measured showing discharge in cubic seconds feet. Another side of such paper vertical to the other was measured showing lake stage in feet above sea level. Thus a point could be ascertained on the paper which would indicate a particular discharge measurement and the elevation of the lake at the time the discharge was made. Having plotted all the discharge measurements in this way, a line was drawn through the plottings which represented the mean of such plottings. The line having been drawn, the discharge of the lake at any elevation within the range of the discharge measurements could be ascertained and thus the difference in the discharge measurement at elevation one foot above any

Complainants Exhibit 1.

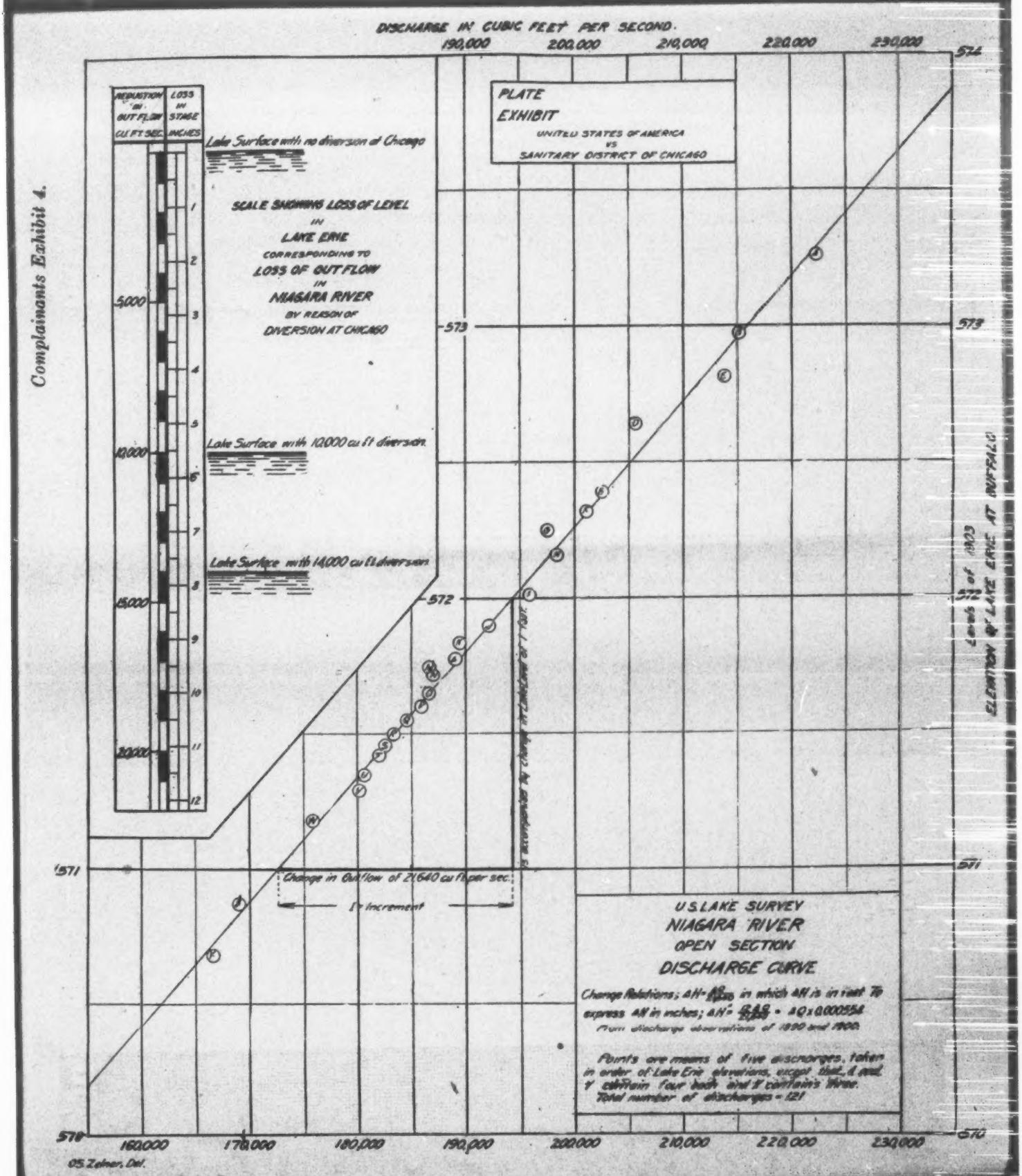


Complainants Exhibit 2.

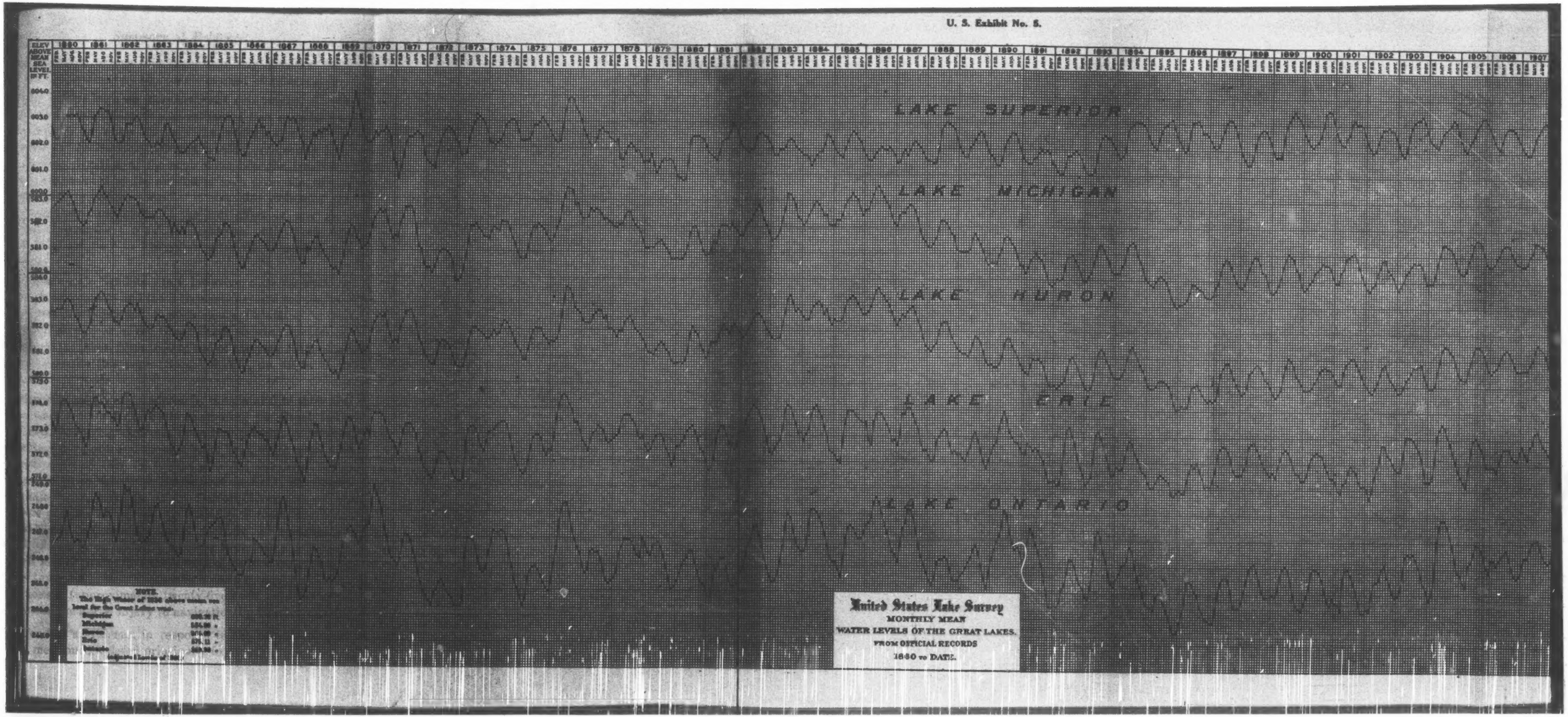



Complainants Exhibit 3.
DISCHARGE IN CUBIC FEET PER SECOND.
190,000
200,000
210,000
220,000
230,000
PLATE
EXHIBIT
UNITED STATES OF AMERICA
VS
SANITARY DISTRICT OF CHICAGO
REDUCTION IN OUT FLOW CU. FT. SEC.
LOSS IN STAGE INCHES
Lake Surface with no diversion at Chicago
SCALE SHOWING LOSS OF LEVEL
IN
LAKE ERIE
CORRESPONDING TO
LOSS OF OUT FLOW
IN
NIAGARA RIVER
BY REASON OF
DIVERSION AT CHICAGO
Lake Surface with 10,000 cu ft. diversion
Lake Surface with 14,000 cu ft. diversion
5000
10,000
15,000
20,000
1
2
3
4
5
6
7
8
9
10
11
12
574
573
572
571
570
Change of Outflow of 2,900 cu ft per second
I = Increment
is accompanied by a change in Lake level of 1 foot
ELEVATION OF LAKE ERIE AT BUFFALO
Levels of 1903
US LAKE SURVEY
NIAGARA RIVER
INTERNATIONAL BRIDGE SECTION
DISCHARGE CURVE
Change Relations; $\Delta H = \frac{\Delta Q}{2,900}$ in which ΔH is in feet
express ΔH in inches; $\Delta H = \frac{12 Q}{2,900} = \Delta Q \times 0.004138$
Discharge observations of 1858-1900, shown thus, ○ Points are means of five discharges, taken in order of Lake Erie elevations, except that A, B, U, V and X contain 2 each and Case B contain 3.
Discharge observations of 1907-08 shown thus; □ Points are means of ten discharges, taken in order of Lake Erie elevations, except that a and m contain 6 each.
Number of discharge measurements, 1858-1900 = 101
1907-1908 = 118
Total = 219
160,000
170,000
180,000
190,000
200,000
210,000
220,000
230,000
©S Zehner, Det

Complainants Exhibit 4.

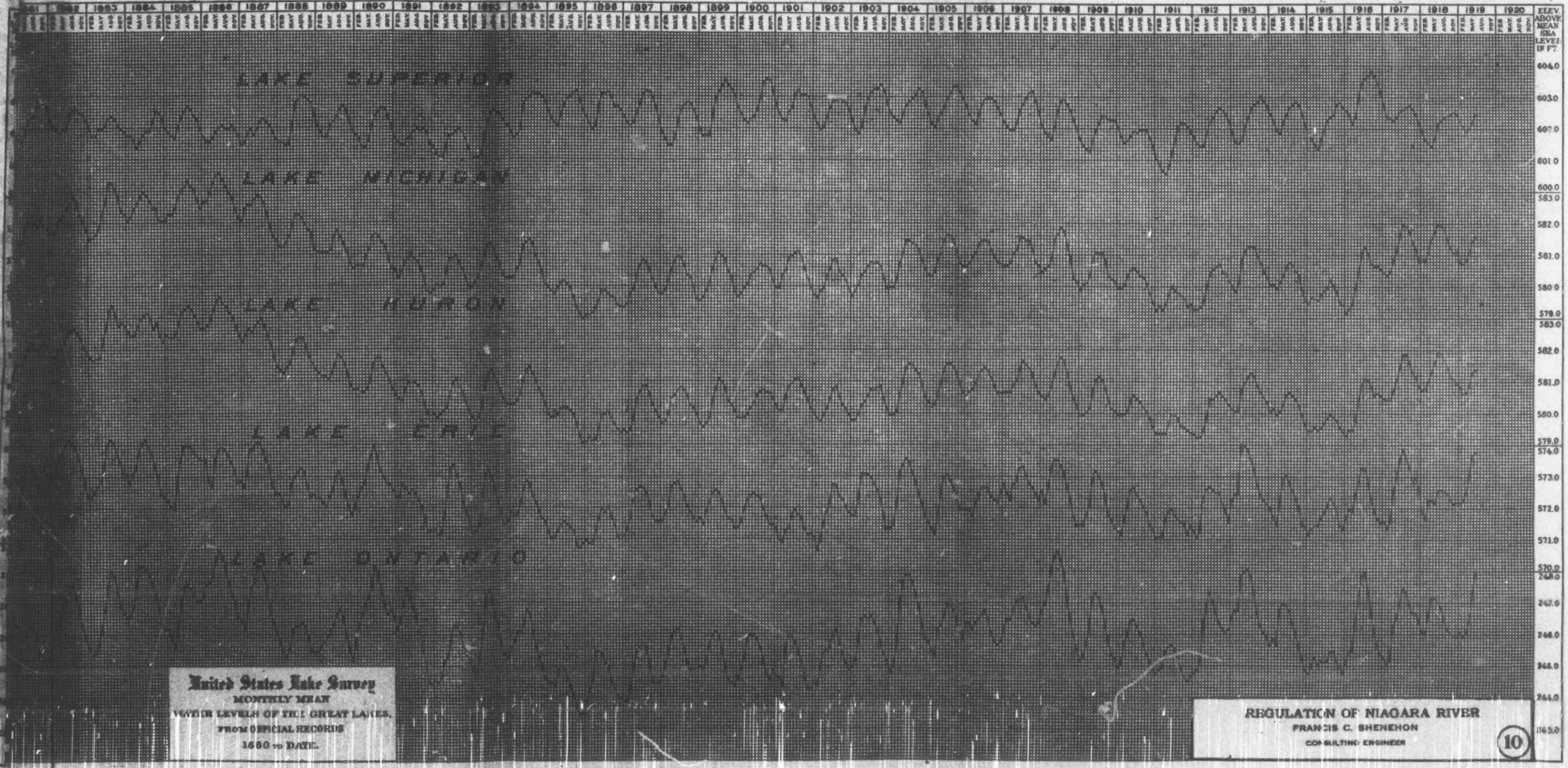


U. S. Exhibit No. 5.



U. S. Exhibit No. 5.

Complainants Exhibit 5.



elevation taken or one foot lower than any elevation taken, could be ascertained by the simple method of subtraction.

Thus, in this way, an increment was determined. Having obtained the increment, it was estimated that a withdrawal or diversion of water through the additional outlet constructed by the Sanitary District would permanently lower the surface elevation of the controlling lake the fraction of a foot, represented by the amount of such diversion, divided by the ascertained increment. It was also estimated that approximately nine-tenths of the full effect of any given amount of diversion through the additional outlet would take place in about four to five years after the diversion commenced.

Complainant's Exhibits 1 to 4, inclusive, show the plottings of the measurements and the increments derived for the various rivers involved, and Complainant's Exhibit 5 is Lake Survey Hydrograph of the Great Lakes showing surface elevations of the lakes, from 1860 to end of the year 1912. They appear opposite this page (Rec., Vol. VII, pp. 49 to 57, inclusive.)

Other witnesses were produced by the plaintiff to show that there were certain large boats navigating the Great Lakes and their connecting channels, operating principally between Lake Superior ports and those of Lake Erie, which could load to depths greater than the depths provided at critical points of navigation on the Great Lakes, such as Sault Ste. Marie, St. Clair River, Lake St. Clair, Detroit River and certain harbors of Lake Erie; that the inability to load these large boats to the full capacity, would decrease the amount that they could carry on each trip by from 90 to 100 tons for each inch of loss of draft; that there were a great number of such boats (over 100); that they make a certain number of trips each season (approximately twenty-five each), and therefore there was a material injury to navigation by this diversion.

Defendant's evidence, in response to the line of evidence above mentioned, related principally to showing:

First, that the discharge measurements of the different rivers were inaccurate, and the correct increment was not obtained, and therefore the effect upon the different controlling lakes was not as great as estimated by the plaintiff's witnesses by about two inches.

Second, that due to the hourly and daily continuous fluctuations and oscillations of the lake surfaces, boats could not load within such narrow limits, and therefore the loss of carrying capacity due to the few inches (five inches on Lake Michigan for 10,000 seconds feet diversion), claimed effect upon the lakes by the diversion, was negligible;

Third, that the cost of dredging the critical points of navigation to offset for the claimed effect upon navigation, would be small;

Fourth, that compensating or regulating works restricting the flowage capacity of the different rivers mentioned, could be, at small expense, installed, and their operation would entirely restore the lake levels to their natural condition without injury to navigation, and that such method had been recommended by various boards of engineers of the United States, made pursuant to Congressional acts.

Hydraulic Expert Evidence.

The evidence of the plaintiff and defendant upon the ascertainment of the correct increments of the different rivers involved and upon the effect of different amounts of diversion upon the levels of the different lakes will be stated briefly. Such evidence consists of the testimony of hydraulic engineering experts on both sides covering a large portion of the record. Only enough of the testimony of the experts on both sides will be stated to show the methods used and results reached.

The hydraulic engineering experts for the plaintiff in its evidence in chief, and their respective qualifications, are as follows:

ALFRED NOBLE (Vol. I, pp. 1-30):

Graduate civil engineering, University of Michigan; later honored with the degree of LL. D.; for twelve years at Sault Ste. Marie in the employ of the United States, and had local charge of the St. Mary's Falls Canal and River; a member of the Board of Engineers on Deep Waterways, which worked out projects for thirty foot channels connecting the Great Lakes with the Atlantic by way of the Hudson River; member of Nicaragua Canal Board and the Isthmian Canal Commission; president of the American Society of Civil Engineers; while member of the Board of Engineers on Deep Waterways, caused measurements of the discharge of the Niagara River to be made in 1897 and 1898.

EUGENE E. HASKELL (Vol. I, pp. 30-49):

Graduate of the College of Civil Engineering, Cornell University, and when he testified, he was dean or director of said college; was then a member of the International Waterways Commission; had been connected with river and stream hydraulics for approximately thirty years; studied ocean currents, including the Gulf Stream, under the Coast and Geodetic Survey; made stream measurements of the Mississippi River, and the discharge measurements of the rivers of the Great Lakes principally were under his direction as principal assistant engineer of the United States Lake Survey. Mr. Haskell designed a current meter known as the Haskel meter.

W. EDWARD WILSON (Vol. I, pp. 49-57):

Graduate College of Civil Engineering, Cornell University; had charge of the hydraulic measurements on the St. Mary's River in 1901 and 1902, and did some similar work on the Niagara River in 1903; while assistant professor of civil engineering in the University of Utah, for three years did some

hydraulic work in the Rocky Mountains. At the time he testified in 1909, he was secretary of the International Waterways Commission, and had been for two years and a half theretofore. He had to do with the hydraulic investigations of the Great Lakes involved in the discussion of the proposed regulation of Lake Erie, in the report of the International Waterways Commission.

GEN. O. H. ERNST (Vol. I, pp. 57-58):

Retired brigadier general of the Corps of Engineers, United States Army; graduate of West Point; from 1871 to 1878 was instructor of practical military engineering at West Point, and for eight years thereafter he was in charge at St. Louis of the River and Harbor District there, including the Mississippi River. For ten years he was a member of the Missouri River Commission, and for six years a member of the Mississippi River Commission, serving as its president from 1903 to 1906; at Galveston he was in charge of the rivers and harbors of the Texas coast; 1899 was a member of the Isthmian Canal Commission; 1901 to 1905 he was stationed at Chicago in charge of the rivers and harbors of that district, and was also engineer of the Northwest Division, which included the Great Lakes System as far east as Erie, Pennsylvania; was chairman of the Board of Engineers which made surveys and estimates for waterway from Chicago to St. Louis; in 1905 he was appointed on the International Waterways Commission as chairman of the American Section. The Commission made a special report on the Chicago Drainage Canal.

COL. CURTIS McDONALD TOWNSEND (Vol. I, pp. 71-72):

He was an officer of the Corps of Engineers; was stationed at Detroit; had charge of the District, including the Detroit and St. Clair Rivers, Lake St. Clair and certain harbors in

Lake Huron, and the St. Mary's River, including the ship locks at that place. At one time he was in charge of the Mississippi River District, the Grand Rapids District, including the rivers and harbors on the east shore of Lake Michigan, the Rock Island District, including the upper Mississippi River from St. Paul to St. Louis, and the Harbor of Manilla in the Philippines; the rivers and harbors of the Cleveland District, including the harbors of Lake Erie from Toledo to Conneaut.

EBEN S. WHEELER (Vol. I, pp. 87-155):

Graduate of civil engineering of the University of Michigan; was United States Assistant Civil Engineer in the office at Detroit; served under Colonel Townsend; engaged for a number of years on surveys of the Great Lakes made by the United States Lake Survey; assisted in some of the earlier stream measurements in the Detroit and St. Clair Rivers; was at Sault Ste. Marie, succeeding Alfred Noble there, in charge of the operation of the ship locks and in the improvements of the river channels; was chief engineer of the Nicaragua Commission of 1898 and 1899.

LOUIS C. SABIN (Vol. I, p. 156):

Graduate of the University of Michigan in civil engineering, and assistant on the improvements of the St. Mary's River from 1890 to 1897; made surveys and discharge measurements for the Lake Survey from 1898 to 1903; assisted on St. Mary's River improvements 1903 to 1905; 1905 and 1906 secretary of the American Section of the International Waterways Commission. At the time he testified, was in local charge of improvements on the St. Mary's River, and general superintendent of St. Mary's Falls Canal; 1898 to 1906 Mr. Sabin was in immediate charge of the hydraulic work on the St. Clair River, and in the reduction of the observations made.

MAJOR CHARLES KELLER (Vol. I, p. 224):

Graduate of West Point; since 1893 has been engaged in the work of river and harbor improvement; the United States Lake Survey which made the hydraulic measurements involved in this case, was under his charge from May, 1907, to the date he testified in 1909; had given special duty to lake levels as connected with the discharges of the connecting rivers.

SHERMAN MOORE (Vol. I, p, 252):

Graduate of the University of Wisconsin as a civil engineer; employed by the United States Lake Survey and has been engaged in such work since 1902 to the date he testified in 1909; for three years preceding 1909, he was almost exclusively employed on hydraulic measurements on the Niagara River on work connected with the investigation and preservation of Niagara Falls.

F. G. RAY (Vol. I, p. 273):

Graduate of the University of Iowa, 1902, and engaged in civil engineering work since that time; with the Mississippi River Commission until 1900; since then has been employed by the United States Lake Survey; charge of the field parties on triangulation, hydrography and topography during summer seasons and in winter in the reduction of the notes of water levels, hydraulics, etc.

F. C. SHENEHON (Vol. I, pp. 283-427).

Graduate of University of Minnesota; at the time of his direct testimony in 1909, he was principal civilian engineer of the United States Lake Survey; between 1886 and 1888

his engineering work consisted principally in the location and construction of railroads; from 1888 to 1891, in general practice as a civil engineer at Sault Ste. Marie, and then entered the service of the engineering department of the United States in the construction of the Poe Lock at Sault Ste. Marie; there until 1898; his work included channelizing the St. Mary's River, making discharge measurements of the St. Mary's River; in 1898 he was engineer for the Board of Engineers on Deep Waterways in charge of the Buffalo office. This work included slope measurements on rivers and the overseeing of discharge measurements at the International Bridge Section. He then took up work as an engineer for the United States Lake Survey, and between September, 1898, and August, 1900, made extensive measurements of the flow of the Niagara River and investigations of its hydraulics. In 1900 he took up the hydraulic measurements of the St. Lawrence River and was engaged in this work during the fall of 1900 and the spring of 1901. In the winter of 1901 additional measurements of the flow of the St. Lawrence was made through the ice; made report on preservation of Niagara Falls; succeeded E. E. Haskell as principal assistant engineer of the Lake Survey. In 1906 to 1909 he had jurisdiction over the hydraulic work done on the St. Clair and Niagara Rivers. In 1909 resigned and became Dean of the College of Engineering of the University of Minnesota.

Williams Exhibits 1 to 15, inclusive, are Lake Survey Charts or Maps, showing the five Great Lakes and their connecting channels, ~~and appear as appendices to this narrative.~~ (Rec., Vol. VII, pp. 59 to 87, inclusive.)

The witnesses for the plaintiff above mentioned in their direct testimony stated and concluded as follows:

(A.) That a diversion of 23,820 cubic feet per second from Lake Michigan would lower the level of the said Lake and Lake Huron, one foot. (Noble, Vol. I, p. 8; Sabin, Vol. I, p. 165; Keller, Vol. I, p. 228; Moore, Vol. I, p. 264; Shenehon, Vol. I, p. 296.)

That a diversion of 21,900 or 21,640 cubic feet per second from Lake Erie would lower the level of the lake one foot. (Noble, Vol. I, p. 13; Wheeler, Vol. I, p. 113; Moore, Vol. I, p. 265; Shenehon, Vol. I, p. 302).

That a diversion of 28,870 cubic feet per second from Lake Ontario would lower the level of that lake one foot. (Noble, Vol. I, p. 12; Wheeler, Vol. I, p. 113; Sabin, Vol. I, p. 172; Moore, Vol. I, p. 257.)

That any other amounts of diversion would lower the level of each lake in proportion to the respective amounts for one foot lowering. (Noble, Vol. I, p. 9; Haskell, Vol. I, p. 40; Wilson, Vol. I, p. 52; Ernst, Vol. I, p. 60; Wheeler, Vol. I, p. 99; Sabin, Vol. I, p. 172; Keller, Vol. I, p. 229; Moore, Vol. I, p. 266 and Shenehon Vol. I, p. 296.)

It was further developed that the determination of the above items were based upon measurements of the St. Clair, Detroit, Niagara and St. Lawrence Rivers by means of Haskell current meters. (Haskell, Vol. I, pp. 32, 36; Keller, Vol. I, p. 226; Moore, Vol. I, p. 260.) Also that the discharge so measured was assumed to be that due and corresponding to the elevation of the respective lakes at approximately the same time as the discharge measurements. (Shenehon, Vol. I, p. 300.)

(B) That the construction of the Gut Dam on the St. Lawrence River has decreased the flow of the St. Lawrence River about five and one-half per cent, (Moore, Vol. I, p. 256; Shenehon, Vol. I, p. 295), and has raised the level of Lake Ontario about five inches. (Shenehon, Vol. I, p. 308.)

That there have been no changes in the channels of the St. Clair and Detroit Rivers affecting the levels of the Lakes during the period of the government improvements therein. (Sabin, Vol. I, p. 175; Keller, Vol. I, p. 241; Shenehon, Vol. I, p. 317.)

As to the points mentioned, on cross examination, the witnesses testified:

As to "A"—That it had been assumed that the position of Lake St. Clair need not be considered in establishing the condition of lowering of Lakes Michigan-Huron from the experiments (Shenehon, Vol. I, p. 368), and that a series of measurements in 1901 had been excluded from the computation because Lake St. Clair was abnormally low. (Shenehon, Vol. I, p. 367.)

As to "B"—That the improvements in the St. Mary's River had certainly lowered the level of the water at the locks at Sault Ste. Marie (Shenehon, Vol. I, p. 327), and that it was possible that the improvements in the St. Clair and Detroit Rivers might have lowered the levels of Lakes Michigan and the St. Clair by small amounts. (Shenehon, Vol. I, p. 374.)

The lowerings in inches for 10,000 cubic seconds feet diversion at Chicago for the different lakes, as testified to by the plaintiff's different witnesses in chief, are shown by the following table:

Ref. No.	Witness	Michigan and Huron	Ref. Record	Erie	Ref. Record	Ontario	Ref. Record	
1	Keller			5.7	I-237-8			Quintus
2	Keller	5.	I-229	5.5	I-234	4.2	I-233	1893
3	Noble			4.8 5.8	I-13			From U. S. Exs. 1 to
4	Haskell	6.2	I-35-41	5.	I-40	4.2	I-40	4, Vol.
5	Wilson	6.2	I-51	5.	I-52	4.2	I-52	VII, 49-55.
6	Ernst	6.2	1-60	5.4	I-61	4.2	I-61	
7	Wheeler	4.8	1-99	5.5	I-103	4.3	I-106	
8	Sabin	5. 7.5 5.5	1-167 1-194	5.5	I-172	4.3	I-172	
9	Moore	5.7 5.5	1-265	5.5	I-254	4.3	I-257	
10	Ray	5.7 5.0	I-279					
11	Shenehon	6.2	I-296	5.5	I-304	4.3	I-295	

The hydraulic expert witnesses and their respective qualifications, testifying for the defendant in chief are as follows:

GARDNER S. WILLIAMS (Vol. II, pp. 566-990):

Ann Arbor, Michigan; member of the American Society of Civil Engineers, Detroit Engineering Society, American Water Works Association, New England Water Works Association and others; received the degree of Bachelor of Science in Civil Engineering University of Michigan, 1889; interested in and connected with the study of hydraulics and hydrography of the Great Lakes from the time he became civil engineer of the Board of Water Commissioners of Detroit in 1893; in 1898 became Prof. of experimental hydraulics and engineer in charge of the Hydraulic Laboratory, Cornell University; there until 1904, when he became Prof. of Civil, Hydraulic and Sanitary Engineering, at University of Michigan; in 1911 resigned to enter consulting practice; consulting engineer for the Michigan-Lake Superior Power Company on hydraulic installation at Sault Ste. Marie, and upon discharge measurements of the St. Mary's River before that. 1899-1900 consulting engineer for the Edison Sault Electric Company and the Chandler-Dunbar Water Power Company, and as such designed and supervised the construction of power plant in rapids at Sault Ste. Marie; consulting engineer for the Eastern Michigan Edison Company on water power developments on the Huron River; consulting engineer to Canadian Light & Power Company in connection with power development and incidental improvements to navigation on the Couteau and Cedar Rapids of the St. Lawrence River near Montreal.

FREDERICK P. STEARNS (Vol. II, pp. 990-1143):

Boston, Massachusetts; consulting civil engineer; been engaged in such work since 1869; from 1872 to 1880 was engaged upon the construction and operation of a new system

of water supply for Boston; 1887 measured the flow of the Sudbury River, using the current meter; made experiments upon the flow of water over weirs through channels and pipes and upon the current meter, the results of which were published in the transactions of the American Society of Civil Engineers; 1880-1886 engaged in the construction and later in the operation of the Boston Main Drainage Works and sewage disposal for the city; 1886-1895 chief engineer of the Massachusetts Board of Health. This work involved the discharge of sewage into streams and the care and control of streams used for water supply and the study of the condition of polluted rivers; 1895-1907 chief engineer of the Metropolitan Water Board and its successor, the Metropolitan Water & Sewer Board; was consulted in many cases, such as reporting upon the sewerage of the District of Columbia, consulting engineer of the First Rapid Transit Commission of Boston; consulting engineer to the Charles River Basin Commission of Boston; consulting engineer of the Board of Water Supply of the City of New York; 1905 to 1906 member of the International Board of Consulting Engineers for the Panama Canal; one of the advisory engineers to the Sewage Commission of the City of Baltimore; November and December, 1906, was a member of Board of Consulting Engineers to examine and report upon means for supplying water to the City of Los Angeles; 1905 received honorary degree of Master of Arts from Harvard University; 1906 Doctor of Science from the University of Michigan.

JOHN R. FREEMAN (Vol. III, pp. 1145-1195):

Providence, Rhode Island; civil engineer and engaged in such practice since 1876; graduated at that time in civil engineering, Massachusetts Institute of Technology; from 1876 to 1886 was principal assistant engineer of the Water Power Company controlling the Merrimac River at Lawrence, Massachusetts. A large part of his duties was measuring the quantity of water used by various factories and the flow of

the Merrimac River. At that time also was principal assistant to Hiram F. Mills in consulting engineering; measured the water used by factories at Manchester, New Hampshire; made investigations for water power development at Concord, New Hampshire, involving the flow of the river and making gagings of it; made exhaustive studies of the methods of accurate measurement of flowing water; the yield of water sheds of rivers and studies of evaporation. In 1895 member of Metropolitan Water Board of Massachusetts, which was to build waterworks to supply about fifteen different municipalities, Boston being one. For two years consulting engineer, New York State Water Supply Commission. For twelve years was consulting engineer to the City of New York in connection with the improvement and enlargement of its water supply, involving the estimation of the yield of many watersheds, etc.; consulting engineer to many cities in connection with water supply—namely, Nashua, New Hampshire, Los Angeles, California, Baltimore, San Francisco, Mexican Government on extension of water supply of the City of Mexico; consulting engineer of the Canadian Government on matters of water power development on various rivers in Western Canada; made studies of obstructions to flow of rivers caused by ice, such as the St. Lawrence River at Massena and at the Long Soo Water Power Development on said river; consulting engineer to Water Power Companies, Niagara Falls; consulting engineer to Mississippi Water Power Company with reference to the development of water on Mississippi River at Keokuk, Iowa; member of two boards of engineers appointed by President to investigate matters connected with the building of the Panama Canal; planned water power development of the Great Western Power Company upon the Feather River in California.

JOSEPH RIPLEY (Vol. III, pp. 1277-1353):

Resides Albany, New York; civil engineer; 1867 graduated civil engineering, University of Michigan; 1913 at the time he testified, he was consulting engineer to the state engineer on the Barge Canal Construction; member American Society of Civil Engineers; Western Society and others; 1877 employed by the Government on canal work at Sault Ste. Marie, Michigan; construction of the Weitzel Ship Lock, Alfred Noble being the civilian engineer in charge; was so connected with the work on the Great Lakes until 1906; first two years construction of the Weitzel Lock; next survey work of the St. Mary's River; 1879 dredging for deepening the channels of that river; 1897 became general superintendent in charge of the ship canal at Sault Ste. Marie and the St. Mary's River; was familiar also with the improvement of navigation on the Detroit River; was a member of the Board of Consulting Engineers in August, 1905, which studied and reported as to the type of canal to be built at Panama; was principal assistant engineer in charge of the plans for the construction of locks and regulating works in connection with the Panama Canal.

E. W. SCHROEDER (Vol. III, pp. 1533-1563):

Resides Ithaca, New York; graduate of University of Washington (Seattle), 1900; pursued post-graduate work at Cornell in engineering; at the time he testified, 1913, teacher and engineer at Cornell University and in charge of the hydraulic laboratory; has been connected with the university as such practically since 1900; made many experiments in hydraulics at the laboratory; made numerous experiments at the request of Gardner S. Williams in the hydraulic laboratory of Cornell University to ascertain the operation of the Haskell current meter in swift, turbulent and slow flowing waters. Such experiments were carried on in conjunction with Prof. K. B. Turner of the College of Civil Engineering, Cornell University.

KENNETH B. TURNER (Vol. III, pp. 1563-1592):

Resides at Ithaca, New York; teacher of civil engineering at Cornell University; at Cornell University for five years taking degrees of Civil Engineer and Master of Civil Engineer; with the United States Lake Survey for approximately two years, beginning with January, 1905. This was after the degree was obtained at Cornell. While with the Lake Survey worked in connection with river discharge measurements at Sault Ste. Marie and the St. Mary's River; also reduced the discharge measurements; used the Haskell current meter; carried on experiments with Professor Schroeder, Cornell University Hydraulic Laboratory, to ascertain the operation of the Haskell current meter in turbulent, swift and slow moving waters.

LYMAN E. COOLEY (Vol. III, pp. 1703-1810):

Resides at Evanston, Illinois; civil engineer; when testified (1914) consulting engineer to the Sanitary District of Chicago; received the degree of civil engineer at Rensselaer Polytechnic Institute, Troy, New York, in 1874, and has practiced the profession since. First eleven years, to 1885, connected with Northwestern University at Evanston, for three and one-half years of which was professor of Engineering and Mathematics; for six years during this period was assistant engineer to the war department on improvement of western rivers; from 1884 work consisted principally with the development of the Chicago Sanitary District Works; designed intercepting sewers for the lake front; 1905-1907 member International Deep Waterways Commission; engineer for the Union Water Company, Denver, Colorado; constructed the Cheseman Dam, 210 feet high; designed the Keokuk Water Power Works; reported on the Barge Canal; consulting engineer to the Gulf Deep Waterway Association; employed by the attorney general of Illinois in the case of the State of Illinois *vs.* Economy Light & Power Company, involving the

proposed dam of that company across the Desplaines River; was later employed by the United States in its suit against the Economy Light & Power Company, involving the same dam; 1886-1887 was engineer to the Drainage & Water Supply Commission, which recommended the construction of the works afterward built by the Sanitary District of Chicago to protect the water supply of Chicago.

The Great Lakes occupy six depressions in the earth surface, and receive the drainage or run-off from a large area of adjacent land partly in Canada and partly in the United States, which run-off reaches them in major part by flowing over the surface in rivers and creeks. (Rec., Vol. II, p. 584.)

The precipitation varies in amount from month to month and year to year. On the Huron-Michigan drainage area, it varied from 38.63 inches in 1883 to 27.17 inches in 1895, a variation of about 42% from the minimum. (Rec., Vol. VII, p. 202-208.) Evaporation takes place from the lake surfaces and from the ground and plant life.

These two agencies, precipitation and evaporation, are the principal ones affecting the annual and monthly elevation of the Great Lakes, and are responsible for the major part of their fluctuations. (Rec., Vol., II, p. 585.)

The levels of the Great Lakes were actually higher during the ten years immediately following than during the ten years immediately preceding the opening of the Chicago & Sanitary Ship Canal. (Rec., Vol. II, p. 727-739.)

The diversion from the Great Lakes at Chicago through the Sanitary & Ship Canal, varied progressively from 4,300 cubic feet per second in 1900, to approximately 7,600 cubic feet per second in 1910, and 1913. (Rec., Vol. III, p. 1618.)

The defendant's witnesses above mentioned testified and concluded as follows:

That it would take a much larger diversion of water from Lakes Michigan-Huron than the amount testified to by the

plaintiff to lower their surfaces one foot. (Williams, Vol. II, pp. 643, 649, 657, 658, 660, 662, 663, 664 and 740; Stearns, Vol. II, pp. 1032, 1036; Freeman, Vol. III, p. 1148); that it would take a larger diversion than that testified to by the plaintiff to lower the surface of Lake Erie one foot. (Williams, Vol. II, p. 668, 670, 671, 672, 674, 722 and 740; Stearns, Vol. II, pp. 1104, 1106); that it would take a larger diversion from Lake Ontario than that testified to by the plaintiff to lower its surface one foot. (Williams, Vol. II, pp. 666, 740; Freeman, Vol. III, p. 1148.)

That the assumptions by which the measurements of discharge were rated to the lake elevations producing them were incorrect. (Williams, Vol. II, pp. 651, 652, 654; Stearns, Vol. II, p. 1032, 1035; Freeman, Vol. III, pp. 1149, 1150; Cooley, Vol. III, pp. 1772, 1784.)

That the degree of precision of the discharge observations was much less than claimed by complainant. (Williams, Vol I, p. 737; Freeman, Vol. III, pp. 1178, 1187.)

That the accuracy of measurement was not sufficiently perfect to enable the detection of a variation of flow of 10,000 cubic feet per second. (Williams, Vol. II, p. 636; Freeman, Vol. III, pp. 1150, 1186-1189); that the exclusion of the 1901 observations in the St. Clair River was in error. (Williams, Vol. II, p. 643), and that including these the amount of diversion necessary to lower the lake one foot would be increased seventeen per cent. (Williams, Vol, II, p. 639), and that the influence of Lake St. Clair could not be ignored. (Williams, Vol. II, p. 639; Stearns, Vol. II, p. 1031; Freeman, Vol. III, p. 1149.)

That the Niagara discharge was inconsistent with those of the St. Lawrence, St. Clair and Detroit Rivers, and inconsistent with the physical characteristics of the several drainage areas. (Williams, Vol. II, pp. 671-737; Stearns, Vol. II, pp. 1014, 1020-1024, 1105; Freeman, Vol. III, pp. 1178-1180.)

That the improvements for navigation in the St. Clair and Detroit Rivers had lowered the level of Lakes Michigan-

Huron and St. Clair by greater amounts than the contemplated diversion at Chicago would do, thus indicating that keeping the lake surfaces at a high level was of secondary importance from a navigation standpoint. (Williams, Vol. II, p. 705; Stearns, Vol. II, pp. 1015, 1017; Freeman, Vol. III, pp. 1166, 1172; Cooley, Vol. III, p. 1783.)

That the improvements in the Niagara River had lowered the level of Lake Erie (Cooley, Vol. III, p. 1783), and that similar work in the St. Lawrence River had lowered the level of Lake Ontario. (Williams, Cross Examination, Vol. II, p. 823; Cooley, Vol. III, p. 1783.)

That the navigation improvements now substantially completed had been planned with a view to providing for the effects of a diversion of 10,000 c. f. s. (Ripley, Vol. III, pp. 1301, 1303); and that any lowering by such diversion could be compensated for by obstructions in the channels connecting the lakes without detriment to navigation. (Freeman, Vol. III, pp. 1172-1174; Ripley, Vol. III, pp. 1311-1313; Williams, Vol. II, pp. 742-743.)

Gardner S. Williams, the principal witness for defendant, on cross examination, testified (Vol. II, pp. 747-750) that a diversion of 10,000 cubic second feet at Chicago would not affect the levels of the different lakes more than the following:

Lakes Michigan-Huron	4.1 inches
Erie	3.5 inches
Ontario	4 inches

For a diversion of 14,000 cubic seconds feet, (Vol. II, p. 742)—

Lakes Michigan-Huron	5.7 inches
Erie	4.9 inches
Ontario	5.6 inches

AVERAGE DISCHARGES OF THE VARIOUS OUTLET RIVERS OF THE GREAT LAKES.

St. Mary's River	1900-1904	76, 060 cubic feet per second. (Williams, Rec., Vol. II, p. 683.)
St. Clair River	1900-1907	197,633 cubic feet per second. (Williams, Rec., Vol. II, p. 670.)
Niagara River	1900-1907	200,072 cubic feet per second. (Williams, Rec., Vol. II, p. 670.)
St. Lawrence River	1900-1907	247,762 cubic feet per second. (Williams, Rec., Vol. II, p. 674.)

Plaintiff's rebuttal evidence on hydraulics of the Great Lakes.

The plaintiff in rebuttal produced some of the witnesses that it had presented in its evidence in chief, and some other witnesses employed by the United States Lake Survey. These rebuttal witnesses testified and concluded:

That the methods of determining the amount of diversion to produce a lowering of one foot on the several lakes by the defendant were incorrect, particularly as applied to the Niagara River. (Ray, Vol. V, pp. 2797, 2798, 2799, 2802, 2804; Moore, Vol. V. p. 2877; Shenehon, Vol. V, pp. 3130-3149.)

That the several quantities of diversion required to produce a lowering of one foot on the several lakes as originally presented were incorrect for the St. Clair and St. Lawrence Rivers, which would be 21,500 and 21,125 cubic fee per second, respectively. (Ray, Vol. V. pp. 2793, 2795; Moore, Vol. V, pp. 2869, 2912; Richmond, Vol. V, p. 2946.)

That a new gaging section had been measured on the Niagara River and that the discharges observed there agreed closely with those at the previously measured locations. (Haskell, Vol. V, p. 2666; Ray, Vol. V, p. 2848; Richmond, Vol. V, pp. 2943, 3013; Shenehon, Vol. V, p. 3143.)

That the discharge of the several lakes at the several gaging stations were controlled by the elevations of the lakes a few minutes before the time of the discharge observation, to wit:

For Lake Huron, Section Dry Dock, sixteen minutes. (Richmond, Vol. V, p. 2948.)

For Lake Erie about eight minutes. (Shenehon, Vol. V, p. 3136); Moore, Vol. V, p. 2874; Ray, Vol. V, p. 2797.)

For Lake Ontario about two and one-fourth hours. (Ray, Vol. V, p. 2804; Shenehon, Vol. V, p. 3137.)

That its time limit is established by the "time interval for a crest of stage to advance" from the lake gage to the section. (Ray, Vol. V, p. 2798). That based upon observations of the "time interval for a crest of stage to advance" in the Sanitary and Ship Canal between Willow Springs and Lemont (Moore, Vol. V, pp. 2880, 2883), it would be possible by opening the gates at the controlling works to increase the flow from 4,167 to 10,000 cubic feet per second at Lake Michigan in two hours and twenty-five minutes, or certainly within three hours. (Ray, Vol. V, p. 2815; Moore, Vol. V, p. 2883.)

For 10,000 second feet diversion the witnesses for plaintiff who testified in rebuttal, found the lowering effect of the 10,000 second-feet diversion at Chicago on the different lakes to be as shown by the following table:

Ref. No.	Witness	Michigan and Huron	Ref. Record	Erie	Ref. Record	Ontario	Ref. Record	
12	Haskell	6.3	V-2663	5.5	V-2662	4.3	V-2727	
13	Ray	5.5 6.7	V-2810 V-2853	5.5	V-2810	5.1 5.6	V-2810	
14	Moore	5.5 7.0	V-2869	5.7 5.5	V-2867	5.2	V-2869	
15	Richmond	5.3	V-2946	5.6	V-2945	5.7	V-2946	
16	Hayford			5.5	V-3091		V-3358	
17	Shenehon	5.7 6.0	V-3142	5.5	VII-725	5.5	V-3159	By Stream Measurements
18	Shenehon	8.2	V-3140			6.4	V-3140	By Method of Fluctuations
19	Shenehon	6.6	II-669			6.4	II-670	By Method of Fluctuations*

* Using ratios derived by defendant's witness, Mr. Gardner S. Williams, but based on 5.5 inches for Erie.

Note—The greater lowerings indicated for Ontario are based on additional measurements made since the earlier testimony; and the same is true in part for Michigan-Huron.

Sur-rebuttal, hydraulic evidence of defendant.

Defendant's sur-rebuttal hydraulic expert witnesses testified and concluded as follows:

That the time required to establish a flow of 10,000 cubic feet per second through the Sanitary and Ship Canal, starting with a flow of 4,167 cubic feet per second was in excess of twenty hours, as demonstrated by experiment, (Wisner, Vol. VI, pp. 3415, 3419; Williams, Vol. VI, pp. 3536, 3537; Cooley, Vol. III, pp. 1788, 1801), and that the full effect of a change of flow was not coincident with the "crest of stage advance" but occurred many hours later, in the said canal, by actual observations. It therefore follows that the assumption upon which the discharges and lake stages had been connected by the plaintiff was erroneous, and the increments or effects of diversion so derived were very greatly in error. (Williams, Vol. VI, p. 3537; Cooley, Vol. III, p. 1773.)

Also, that the position of the meters in gaging the Niagara River at the International Bridge was not that computed by the complainant but further downstream in a larger cross section than that to which the meter registration was applied, and hence the discharge computed was materially too small. (Williams, Vol. VI, pp. 3521, 3531.)

Plaintiff's evidence on damage to commerce on Great Lakes due to the lowering of lake levels on account of the Chicago Diversion.

Plaintiff produced with reference to this subject, in addition to some of the witnesses who testified as to the amount of the lowering effect upon the lakes surfaces due to the Chicago diversion—Mr. Harry Coulby, president of the Pittsburgh Steamship Company (Vol. I, pp. 428-445); William Livingston, president Lake Carriers Association (Vol. I, pp. 200-209).

Plaintiff's witness Eben S. Wheeler (Vol. I, p. 91) states the theory upon which plaintiff's witnesses rely to deduce the damage claimed to commerce.

> "I have said in my notes that lowering means that a definite amount of diversion at Chicago will make the surfaces of Lakes Huron and Michigan a definite amount lower at all times and places than it would have been if the diversion had not taken place. Perhaps I have given too long an answer, the actual elevation of the surfaces of the lakes at any time is the algebraic sum of all the causes which tend to change the elevations. Some of the most important of these causes are rainfall, outflow, evaporation, etc. If two causes, producing opposite effects, are operating at the same time then the actual effect produced will be of the same kind as the larger one, and the amount will be the difference between the two causes. For example, a merchant deposits a thousand dollars each week, and checks out fifty dollars each day, his balance is lowered by the amount he takes out and raised by the amounts he deposits, and in this case the deposits are larger than the withdrawals, therefore his balance will be raised by the difference between the two. At the end of the week it will be raised $650, notwithstanding it was lowered $350 by his withdrawals. Similarly, if for the period, we will say, from 1900 to 1908, the rainfall was greater than the outflow, and evaporation, the lake would rise. This appears to have been the case, notwithstanding the outflow for the period was increased by the diversion at Chicago. A cause which tends to lower the lake itself actually does make the lake lower than it would have been without the cause. I do not know but my answers are a little too long."

Plaintiff's theory is further stated by F. C. Shenehon (Vol. I, p. 286):

> "Lowering is referred to the lake surface which would have prevailed in the absence of the diversion; that is, the lake may actually rise, while this lowering is going on at the same time, in just the same way that a man who is on a railroad train traveling East may reach the tail end of the car he is in by walking westward. It is a case of two movements going on at the same time. This lowering is going on, and it is independent of the other fluctuations that may prevail at the same time."

William Livingston, president of the Lake Carriers Association, stated (Rec. Vol. I, p. 201) that between Buffalo and points in Lake Superior, the depth to which a boat could load could be determined by the depth of water on Ballard's Reef in the lower Detroit River, the reason being that the water crossing Ballard's Reef is a little shoaler than the Lime Kiln Crossing and at Bar Point. If there was another harbor which was shoaler than Ballard's Reef, it would be necessary to take that into consideration, but witness did not know of any; that in loading in Lake Superior the depth at Poe Lock is also taken; that the engineer at Poe Lock keeps a constant gage of the water there; that it does not make any difference if you load to 100 feet outside—the shoalest spot is the one that governs; that the last eight years (Rec. Vol. I, p. 202) has worked a sort of revelation; (He was testifying in May, 1909) in the size of vessels built and operating on the Great Lakes; that approximately seven years ago the steamer A. B. Wolvin was built; that she was the largest vessel on the lake, carrying 3,500 tons more than the next largest vessel; that vessels which have been built since that time, except those built for some specific traffic, say for packing freight, have all been built of her type; that the smallest boat that is built now for business purposes will not run under 7,500 to 8,000 tons; that we have some boats that will carry 12,000 gross tons; that when a boat is loaded to 18 feet or more, the average per inch is 80 to 100 tons; that (Vol. I, p. 204) there are 600 boats that belong to Lake Carriers Association, which is the cream of the carrying capacity on the lakes; that not all of those boats would be affected by the lowering of the lake levels an inch; that about seventy per cent of these boats would be affected; that there are seventy-three ships in the Pittsburgh Steamship Company fleet carrying ore; that these load to nineteen feet, eighteen of them, however, may load to twenty-one feet; that the loss to the ships of the Lake Carriers Association (Vol. I, p. 205) would be over $85,000 per inch, or $500,000 per inch per year for the entire seventy per cent; that the total loss to commerce would be about one-eighth more;

that this would cover the boats not in our association; that larger vessels are being built right along (Vol. I, p. 207) and all the modern vessels could load considerably deeper if the shoalest spots would admit of it; (Vol. I, p. 210); that if the witness or any one else had predicted ten years ago boats would be built of the size of the Wolvin and the present line of boats being builded, that man would have been considered a fit candidate for a medical asylum.

Harry Coulby, president of the Pittsburgh Steamship Company testified (Vol. I, p. 428):

That Pittsburgh Steamship Company boats are engaged principally in carrying ore, coal and sometimes grain between Two Harbors, Duluth, Superior, Ashland, Marquette, Escanaba and the Lake Michigan ports, Milwaukee, South Chicago, Chicago, Gary and to all lower lake ports such as Cleveland, Buffalo, Erie, Conneaut, Ashtabula, Fairport, Lorraine, Huron, Sandusky and Toledo; that the company owns 106 vessels and employs or charters 100 more during the season; that there are 61 of these vessels that are capable of loading to twenty feet or more; that the depth to which boats going to Lake Superior may load is determined by the depth of water at the Poe Lock at Sault Ste. Marie; that as to those boats which are not going to Lake Superior, Ballard's Reef and the shallow waters across Lake St. Clair determine the depth; that the present depth at the time of testifying (July 8, 1909) was nineteen feet three inches at the Poe Lock and twenty feet Ballard's Reef, and the shoals of Lake St. Clair; that the large vessel makes about twenty-five trips a season; (Vol. I, p. 431); that every time you reduce the carrying capacity of a boat, you reduce the earnings that much without reducing the operating cost; (Vol I, p. 432); that all the harbors have been dredged out to take care of the ships that come over what the witness calls the "necks of the bottle"—that is, the Poe Lock and Ballard's Reef; that the harbors along the south shore of Lake Erie would be affected by lowering of the water surface; that each

inch of loss of depth on the sixty-one ships affected of the Pittsburgh Steamship Company's fleet, assuming twenty-five trips for each boat per season, and 100 tons for each inch loss of depth per boat per trip, causes a loss in total carrying capacity per inch of 152,000 tons per season; that 12 ships of the 61 may load to 25 feet. (Vol. I, p. 434.)

Cross Examination.

Pittsburgh Steamship Company corporation of West Virginia, and its stock is owned by the United States Steel Corporation; it carries ore for the United States Steel Corporation only.

The report of the Board of Engineers on Waterways from Lockport, Illinois, to the mouth of the Illinois River, dated August 15, 1913, (Rec. Vol. IV. p. 2587) signed by two of the plaintiff's witnesses, states the plaintiff's claims of damage to commerce:

> "The largest lake freighters recently built carry over 80 short tons of freight for each inch of loaded draft, and an uncompensated Chicago diversion of 10,000 second feet would cause a loss to each vessel of at least 446 tons in carrying capacity for each down trip through the channels connecting with Lakes Michigan and Huron. This, based upon 25 trips per season, with vessels returning light, means a loss of at least 11,150 tons per year, and at a freight rate of 55 cents per ton represents a monetary loss of at least $6,000 per large vessel per year. During the season of 1912 there passed through the locks at Sault Ste. Marie over 72,000,000 tons of freight, the greater part of which was carried in vessels of such size as to be affected by any loss of depth caused by a Chicago diversion. The tonnage of 1913 bids fair to exceed the tonnage of 1912. The lowest estimate of the loss to American vessels alone that has been brought to the attention of the Board is over $1,000,000 per annum, and the loss will increase with the increase in the number and size of vessels."

Defendant's evidence relating to damage to commerce, assuming a lowering of lakes surfaces due to the Chicago diversion.

Major Charles Keller, one of the witnesses for the plaintiff, made a study of this question, a report of which is contained in the report of the Board of Engineers entitled "Waterway from Lockport, Illinois, to the mouth of the Illinois River," dated August 13, 1913, and made pursuant to the Rivers and Harbors Act of June 25, 1910. The report of Major Keller contains the following (Rec. Vol. IV, p. 2608):

> "6. With the outlets free of ice at any instant the volume of water discharged from one of the lakes is a definite quantity fixed by the level of the lake. With a constant supply of water and constant evaporation there would then be no change in the elevation of the lake's surface, except such temporary changes as might be caused by winds and barometric disturbances. But the flow into each lake is, as has been explained, constantly varying, and while the discharge from the lakes is also ever changing, so as in the long run to tend to counterbalance changes in supply, yet these adjustments of supply and discharge are not simultaneous,and the surface levels of the lakes are therefore, constantly fluctuating, as is readily seen from the plates attached.
>
> 7. These regular but uncontrollable changes in lake level mask the effect produced by an artificial diversion."

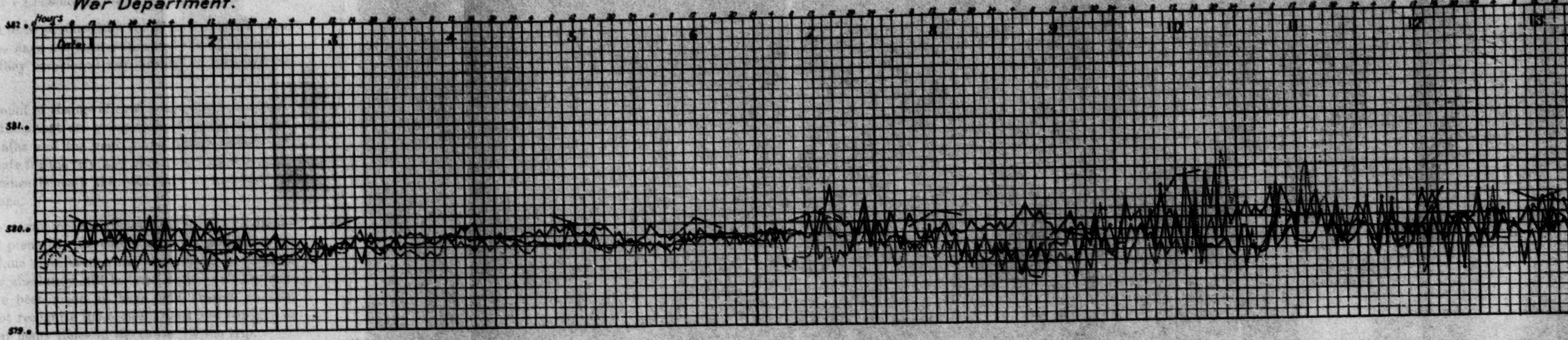
The plates referred to in the above quotation show hourly gage readings at different gaging stations, indicating the changes in surface elevations of Lakes Michigan and Huron for different months. Opposite is, as an example, one of these plates covering the month of August, 1911, (Rec. Vol. IV, p. 2653):

Lyman E. Cooley, whose qualifications as a witness for the defendant have been heretofore stated, testified (Rec. Vol. III, p. 1776):

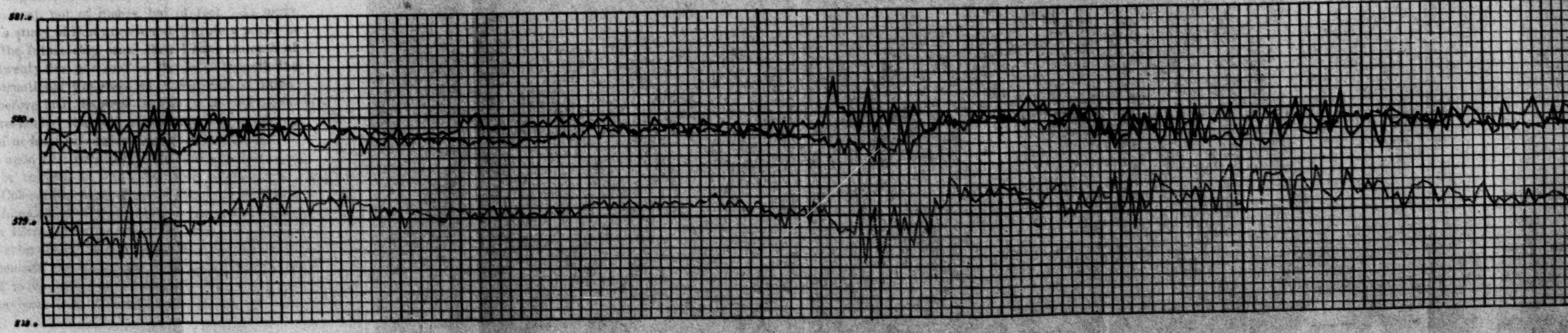
In my opinion lowering of the levels of Lakes Michigan and Huron five to six inches, Erie somewhat less, Ontario somewhat less than Erie, would cause no injury to navigation. The changes which have been made which influence the lakes' levels since the improvement of lakes' channels was undertaken, exceed in several instances all the changes pro-

War Department.

Automatic Gage Readings at C

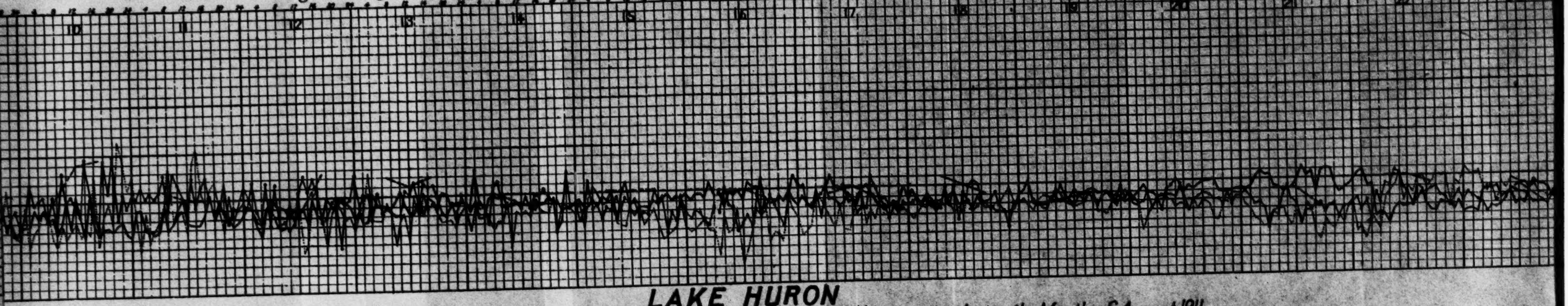


Automatic Gage Reading



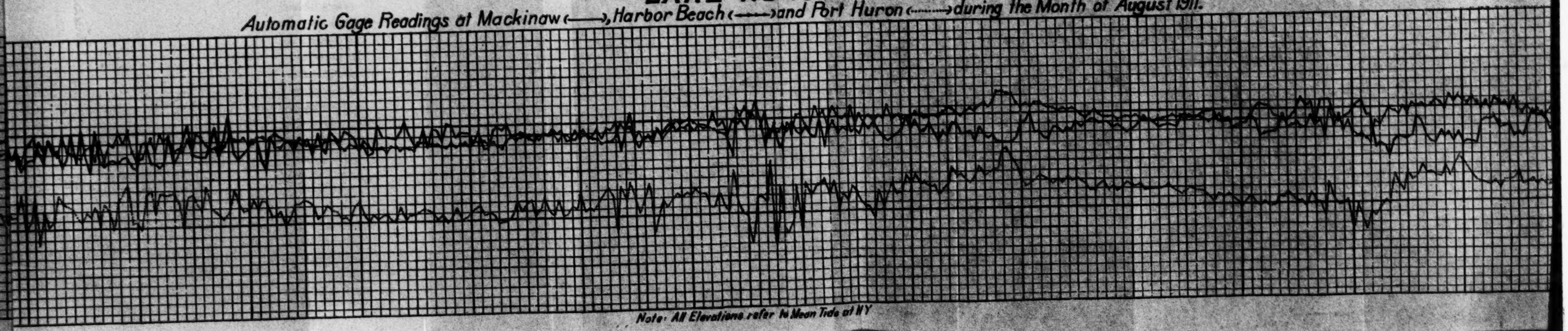
LAKE MICHIGAN

Automatic Gage Readings at Chicago (.....), Milwaukee (- - -), Grand Haven (- · -) and Mackinaw (——) during the Month of August 1911.

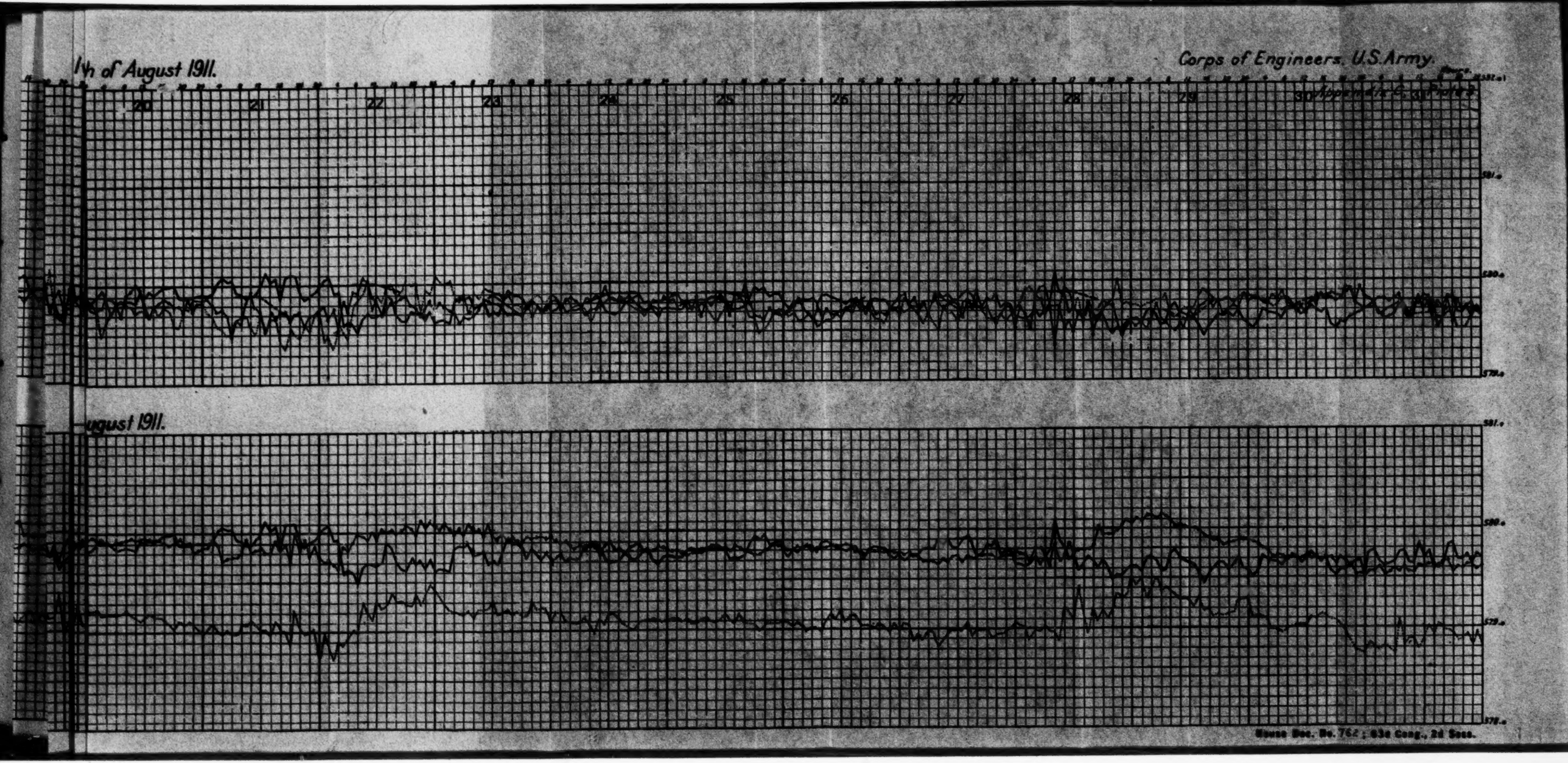


LAKE HURON

Automatic Gage Readings at Mackinaw (——), Harbor Beach (- - -) and Port Huron (.....) during the Month of August 1911.



Note: All Elevations refer to Mean Tide at NY


Corps of Engineers, U.S. Army.
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House Doc. No. 762, 63d Cong., 2d Sess.

duced or alleged to be produced by the diversion at Chicago, and such changes have not been considered worthy of attention, nor have they occasioned any protest or comment by lake carriers.

Again, the amount of change alleged is nominal in comparison with fluctuations that are going on by hour, by day, and through the months and the year. And vessel owners are obliged to load safe for the trip, and give a very much greater margin of clearance beneath the boat than is indicated by the alleged change.

Again, it is not competent to estimate the effects as a diminution in a fixed plane of reference, or as the difference between a fixed plane of reference and the bottom, as made in a canal or other absolutely still body of water; and the estimates that have been made up have been framed on that basis, and do not recognize these oscillations and changes in level which occur many times in the course of the trip.

Again, it is recognized as sound practice to provide a margin beneath the boat, not of inches, but of feet. As early as 1888 I made a study of that question and wrote a paper to the effect that the future ship canal should have a depth of not less than twenty-five per cent of its draft beneath the keel. The International Congress on Navigation at Philadelphia, year before last, declared as one of the principles which govern restricted channels and canals, that it should have a depth of at least one meter beneath the keel, depending, of course, upon the character of channel and the speed which was to be considered. And the same proposition is worked out by Colonel Black, an engineer officer of the United States Army (later Chief of Engineers) in his recent report on the Hudson River. Colonel Black lays down the proposition that the river should have a depth of two or three feet of clearance beneath the boat, and gives some remarkable data in regard to the effect of the Hudson River boats attempting to navigate with the restricted limit beneath the

boat, and also for the further reason that any item of cargo that would fall off the boat, like a barrel of cement, would roll the skin and frame out of the bottom of the boat if it happened to strike it. There should be enough clearance there for safety. I know from my own experience in navigation on western rivers, that a boat that would attempt to run within a foot or two of the bottom would be utterly uncontrollable in passing through the channelways of the lakes. So that a mere margin of a few inches would not be thought of by practical navigators; would not be accounted for and would not be known to exist, in the absence of a specific knowledge of a diversion of something of that kind existing at Chicago.

On the other hand, a lowering of the lakes by one foot, better by two feet, would be a profound advantage to every lake city about the Great Lakes, in giving a better freeboard for its sewer system and better elevation to its docks. All the cities about the lakes are built on low ground, margining some creek originally awash at high water of the lake, and the benefits of such a lowering to the sanitary welfare of the cities about the Great Lakes would be so great in proportion to the cost of producing two feet additional depth in all the harbors and channels of the lakes, that it would be a vanishing quantity. And, furthermore, I conceive that if there were not diverse jurisdictions in the matter, but were one jurisdiction that looked at public welfare as a whole, a proposition of that kind would be a proposition to at once elicit legislative attention.

Isham Randolph, a resident of Chicago, a civil engineer, a contemporary of Lyman E. Cooley, for a number of years Chief Engineer of the Sanitary District of Chicago, later its Consulting Engineer, and at one time a member of the Isthmian Canal Commission, testified as follows (Rec. Vol. VI, p. 3595):

In the report of the Board of Engineers on Deep Waterways from the Great Lakes to the Atlantic, 1901, p. 219, (Rec. Vol. IV, p. 2390), it is stated:

> "The speed attained by a ship in open sea will be reduced to a marked degree on entering shoal water, even of unlimited width."

On page 220 of the same report:

> "Retardation in shoal water. * * * Observations made recently on the freight steamship Angeline, in the deep water of Lake Huron and the shoal water of Lake St. Clair, indicate that the retardation is about 18 per cent. (Note, the Angeline is 414 feet long and 51 feet beam; was built in 1899.) The depth under the keel was about 2 feet 10 inches, no allowance being made for settlement of the ship in the water which always occurs when the water is shoal.
>
> The Senator (410 feet by 45 feet) is also cited with a loss of 16 per cent. in Lake St. Clair. This Commission provides for two feet of depth below the keel of vessels for which they designed a channel."

Kent's Engineers' Pocket Book, 1900 Edition, treats of this subject on page 1007. (Rec. Vol. VI, p. 3596, 3597.)

> "The Medusa, a third class cruiser, length 265 feet, beam 45, draft 16 feet 6 inches, displacement 2,880. Indicated horse-power for ten knots per hour, 700; for 14 knots per hour, 2,100; for 18 knots per hour, 6,400; for 20 knots per hour, 10,000.
>
> Atlantic passenger steamer 525 feet long, 63 feet beam, mean draft on trial 21.3, displacement 11,550 tons; indicated horse-power 10 knots per hour, 2,000; for 14 knots per hour, 4,600; for 18 knots per hour, 10,000; for 20 knots per hour, 14,500.
>
> The Medusa's figures for 20 knots are from the trial in Stokes Bay and show the retarding effect of shallow water. The figures for the other ships for 20 knots are estimated for deep water."

Here we have an example of two vessels, one having a displacement of about four times that of the other. The larger requiring in deep water only forty per cent more power to

give it twenty knots speed than was required to give the smaller vessel the same speed in shallow water.

On pages 34 and 35, Colonel Black says: It is believed that the minimum clearance allowable for safe navigation in the Hudson River is two feet. In Germany, the clearance adopted as safe is one meter (39 inches).

Captain Marshall states in the report of the Chief of Engineers for 1893, Appendix LL, pages 2798, 2799, in discussing the clearance over tunnels under the Chicago River (Rec. Vol. IV, p. 2370): "There should be at least two feet between the bottoms of vessels and the crowns of the tunnels to guard against chance obstructions of small extent lodging temporarily over the ridges crowns."

The witness further stated:

I am of the opinion that the amount of water that should be under the keel of a boat is a matter of feet rather than inches. If there were three feet under the keel and the depth was decreased so that there were six inches left, the effect upon navigation would be in loss of speed and increased consumption of coal on a trip from Lake Superior to Cleveland, considering the shallow places in the St. Clair and Detroit River. The increased consumption of coal under such conditions would be negligible and it must be borne in mind that through those channels the heavy loads are going with the current and they come light up-stream.

Joseph Ripley, for a great number of years in the employ of the United States Engineer Corps, and whose qualifications as a witness for the defendant have been heretofore stated, testified as follows, July 24, 1913, (Rec. Vol. III, pp. 1304, 1305):

The elevation of the floor of the Poe Lock is 562.37 above sea level. The lower mitre still is located opposite the gate recesses of the lower gate and the intermediate gates. The floor of those recesses is a foot and a half lower than the

general floor of the lock. The mitre sill is either four-
1305 teen or sixteen inches in height. Below the mitre sills for the intermediate gates and also for the lower lock gates, are platforms built of 12x12 timbers; the platforms being, as I remember it, some thirty feet along the axis of the lock. Below the lower guard gates, a platform was built which is .33 of a foot, or about four inches higher than the floor of the lock. The Poe Lock was opened for navigation in August, 1896; but the depth over the mitre sills was not available to navigation purposes until the spring of 1898 as the sill and platform for the movable dam located across the canal about 3,000 feet west of the Poe Lock was left in place until that time, and on that guard gate sill, the depth was only seventeen feet.

The opening of the West Neebish Channel in 1907 made the Poe Lock the critical place as to the depth of water for navigation purposes in the St. Mary's River, which has been the case since that time. The platform of the Poe Lock is the critical place, that is, the one I describe below the guard gates. The platform was placed for the purpose of protecting the lower mitre sill of the lock, but is really of no value because the platform directly below the sill could be utilized for that purpose, and that would not necessarily be any higher than the general floor of the lock. This platform could be removed at a cost of not exceeding $10,000 in the
1297 winter season without interfering with navigation.

In making improvements on the Great Lakes, a reference plane was fixed which was a certain elevation above sea level. This reference plane for an improvement is fixed by the engineer officer at Detroit upon recommendation of his assistants, and this reference plane becomes a matter of record in
1298 the Department. Prior to 1903 the improvements in the channels of the Great Lakes were referenced to a water surface assumed to be 584.37 above sea level at the foot of the St. Mary's locks and 581.47 at Mud Lake. This was the reference plane. In the 1903 project, however, the improvements were here referenced to an assumed water surface of 580.37

above sea level below the locks and 578.77 in Mud Lake, the variation between those points corresponding to the slope of the river. These were the reference planes for the
1299 improvements. When the channel improvements are made, it is provided that they shall have a depth of a certain number of feet below the reference plane. The reference plane for the 1903 project improvement in the St. Mary's River was fixed when the project was prepared. The depth of the improvement of course had to be
1300 stated so it would be incorporated in the Act of Congress authorizing the improvement, and as the prior improvements had been referenced to the mean stage of water as determined in 1870, and the water at times was below the mean stage, it would not provide navigation for the implied depth of the improvement. As the department had ruled that for appropriations made along the sea coast the depth should be referenced to low tide, I urged Major Bixby to reference the improvements in St. Mary's River to the lowest stage of water we had, or the probable lowest stage that we would have, and with his approval I prepared the grade plane as stated. This was in 1902. Major Bixby was at that time the engineer officer in charge at Detroit. I gave consideration to the probable lowering of the Lake Huron water surface due to the Chicago diversion, as indicated by the reports with reference to the gagings of the St. Clair River made by
1301 Louis C. Sabin, a witness for the plaintiff. The Chicago Canal had been opened at that time, and the gagings of the St. Clair River had been made and some discussion had been had with reference to the amount of the lowering which would be caused by the diversion by the Chicago Drainage Canal. I had discussed this matter with Mr. Eben S. Wheeler, Major Bixby and my assistant, Benno Rohnert. In fixing the plane, I intended that if we had an improvement for
1302 twenty-one feet that that twenty-one feet should be available for navigation on all occasions during the navigation season. The reference plane which I prepared was the one used for the 1903 project improvements in the St.

Mary's River and its lower channels. I fixed a different reference plane than I would have fixed had there been
1304 no diversion at Chicago. Under the 1903 navigation improvement project excavations and dredging were made in the channels of the St. Clair and Detroit River at different points. In 1901 some improvements were made for a twenty foot depth, reference plane being 571.5 above sea level. In 1904 improvements were made in the Detroit River for a twenty-one foot depth. The reference plane, however, for that was fixed at 571.0 feet above sea level.

Francis C. Shenehon, one of the plaintiff's hydraulic witnesses, stated that there are records of Lake Erie rising as much as eight feet in about eight hours (Rec. Vol. V, p. 3176); Lake Michigan as much as five feet in a very short time.

Herbert Charles Sadler, witness for the defendant, July 15, 1913, (Rec. Vol. III, p. 1240):

Residence Ann Arbor, Michigan; Professor of Naval Architecture and Marine Engineering, at University of Michigan, since 1900; educated at Dulwich College, England, and at Glasgow University, Scotland, latter degree of Bachelor of Science in Engineering in 1893; Doctor of Science from same U. in 1902; 1890-1896 engaged in practical shipbuilding on the Clyde; 1896-1900 Assistant Professor of Naval Architecture and Marine Engineering at Glasgow U., and during that time associated with Prof. Biles in consulting practice; 1901-1904 appraiser for the vessel properties in connection with the Michigan Railroad appraisal; appraised the vessels owned by the Duluth, South Shore & Atlantic in 1912; consulting naval architect for the City of New York in connection with municipal ferries; also for Great Lakes Engineering Works having one of the largest ship yards on the Great Lakes. Last two years acted as consulting engineer (testifying in July, 1913) for the Tow Boat Board of United States Army Engineers Corps, the Board consisting of Lt. Col. Lansing H. Beach, Major Charles Keller, and Col. Newcomber; con-

sulting naval architect for the White Star Line of Detroit; for the Detroit & Cleveland Navigation Company and for the Hudson River Day Line, New York.

1243 *He testified as follows*: The freight per year of all kinds on the Great Lakes, exclusive of package freight—that is Lake Superior, Huron, Michigan, Erie—freight that is carried through the St. Mary's Falls Ship Canal and the St. Clair and Detroit Rivers, as shown by the statistical report for 1912, is 72,472,676 tons, the ore tonnage being between forty and fifty millions; wheat 5,220,000 tons; coal 14,-
1244 900,000. The ships carrying this ore are 440x52x28 feet, 550x56x31 and 605x58x32 feet; first class 440 feet—there are 151 boats; 550 feet class, 93; 605 feet class, 73; 440 feet class are designed to be loaded to 19 feet; 550 feet class to 19 feet and the 600 feet class to 19 feet. It might be possible to load the two larger types to somewhat deeper draft.

The cost of constructing new boats to have the same carrying capacity with a less draft of one, two, three, four, five or six inches, has been estimated. 440 feet class, loss in
1245 capacity for 1 inch draft, 55 tons, would require an increase in length of about 2.1 feet for each inch; increased cost of vessel, $1,000; interest and depreciation, $100. For 3 inches less draft, increase in cost would be $3,000; interest and depreciation about $300. For 550 feet class, loss in capacity for 1 inch less draft, 70 tons; increase in length required to take care of this, would be 2.9 feet; increased cost of vessel $1,700; interest and depreciation, $170; for 3 inches loss the increased cost of vessel would be $5,100; interest and depreciation, $510; for the 605 feet class, loss in capacity for 1 inch would be 81 tons; increased length 3.1 feet; increased cost of vessel $1,800; interest and depreciation $180; for 3 inches loss in draft, increased cost of vessel $5,400; interest and depreciation $540. The three classes men-
1246 tioned carry about 70 per cent of the total of ore, coal and wheat; 48 per cent by the first class; 26 per cent by the second, and 26 per cent by the third. The cost of operating

the boat designed of the greater length to take care of the decrease in draft, would be no more than vessels con-
1247 structed in the present manner. All of the 500 and 600 feet class of boats have been built and put in service in the last 13 years; that is, since 1900. The 500 and 600 feet classes are the only boats that are designed to be loaded
1248 to more than 19 feet draft.

The cost of building the 93 vessels of the 500 feet class to take care of loss in draft of 3 inches, would be $1,404,300, and the 73 vessels of the 600 feet cost $1,197,200. These amounts represent the actual cost of construction and
1250 the capitalized interest and depreciation amount.

The cost of transporting tonnage carried by the vessels of the 500 and 600 feet classes for each inch of loss of draft is 0.116 cents per ton per inch. For the 73 vessels above
1251 mentioned for 3 inches of loss of draft, the loss would be per year, $42,480. for 15 trips, $56,700 for 20 trips and $70,950 for 25 trips; for the 93 vessels above mentioned, the loss would be for 15 trips, $49,950; for 20 trips, $66,390; for 25 trips, $82,860. Capitalizing these yearly amounts, the estimate of total loss, is 15 trips, $1,848,600; for 20 trips, $2,-461,800; for 25 trips, $3,076,200 loss. It is estimated that 37 million tons were carried by these two classes of vessels
1252 for the year 1912. The loss per year would be for 3 inches, $128,760. Capitalizing this at 5 per cent, equals $2,575,200 as the total loss.

Henry C. Adams (Rec. Vol. III, p. 1354; September 25, 1913), a witness for defendant:

Resides Ann Arbor, Michigan; Professor of Political Economy & Finance, University of Michigan, since 1887; prior to that time lectured Cornell U., Johns Hopkins and Michigan; in 1888 and until 1907 was statistician to the Interstate Commerce Commission; 1910 had charge of what is known as the determination of the intangible values of the Michigan Valuation of Railroads; was going to China shortly

as advisor to the Chinese Government as to standardization of Chinese Railway Accounts.

The witness testified as follows: I have examined the testimony of Mr. William Livingstone, witness for the plaintiff. He has computed the annual loss to commerce on the Great Lakes, assuming a depreciation of the normal lake level of 6 inches, to be $4,387,500. I think he is incorrect in this for he has multiplied the loss of load by the rate for carrying the ore, without taking into consideration the increased expense incident to that increased freight carried. Furthermore, this is incorrect in that the average number of
1372 trips for all vessels is 11.6, instead of 20 round trips, testified to by Mr. Livingstone, and 25 round trips, as testified to by Mr. Coulby. I agree with Mr. Livingstone, however, that the damage is confined to those boats
1376 carrying ore or to the ore traffic. I find that the average round trip for those boats loading to beyond 18.1 feet passing through the St. Mary's Falls Ship Canal, is 14.12 per year.

Joseph Ripley, witness for the defendant, whose qualifications have been heretofore stated, July 24, 1913, (Rec. Vol. III, p. 1306), testified as follows:

The cost of deepening the channels of the St. Mary's River, St. Clair, the channel in Lake St. Clair and those of the Detroit River, 4 inches or 8 inches, would be, for 4 inches, $163,990; 8 inches, $403,854. The cost for deepening in inches intermediate would be proportional. Including (p. 1307) the channels connecting the Great Lakes, the harbors of the United States and Canada, the cost of deepening 4 inches is $2,163,454; 8 inches is $4,405,008; capitalized maintenance for 4 inches, $728,510, and for 8 inches, $1,092,766 capitalized.

CHRISTIE EXHIBIT II, APRIL 26, 1923.

Table I.

Table Showing Movement of Iron Ore During 1920
Compiled from Part 2 of Chief of Engineers, U. S. Army Report, for Fiscal Year Ended June 30, 1921 (Rec. Vol. VIII, p. 220).

Page	Harbors	Shipment-Tons	
1001	Duluth, Minn.	33,771,582	
1008	Ashland, Wis.	9,162,554	
998	Agate Bay, Minn.	10,391,879	
1017 } 1018 }	Marquette, Mich.	3,824,921	
1030	Escanaba, Mich.	7,361,069	
			64,512,005 Tons

Page	Harbors	Receipts-Tons	
1054	Milwaukee, Wis.	144,500	
1096	Calumet, Wis.	7,275,558	
1098	Indiana Harbor, Ind	1,426,983	
1142	Rouge River, Mich	910,987	
1143	Toledo, Ohio	2,982,102	
1151	Huron, Ohio	1,534,615	
1153	Lorain, Ohio	4,508,600	
1155	Cleveland, "	8,957,165	
1158	Fairport, "	1,397,719	
1159	Ashtabula, "	12,351,940	
1161	Conneaut, "	6,708,534	
1164	Erie, Pa.	2,484,897	
1170	Buffalo, N. Y.	8,577,923	
1174	Tonawanda, N. Y.	602,695	
	Miscellaneous	3,368,048	
	Foreign Ports	1,279,739	
			64,512,005 Tons
	Memoranda		
	Lake Superior Shipments		57,150,936 Tons
1104	Passed 500—eastbound		56,780,498 "

Table II.

Comparison of Depths in Certain Channels and Harbors at Sundry Elevations of the Waters of Lakes Michigan, Huron, Erie and Superior, Compiled from Bulletin No. 31, "Survey of Northern and Northwestern Lakes," Issued by U. S. Lake Survey Office, Detroit, Michigan, April, 1922, and Water Level Records Furnished by same Authority. (Rec. Vol. VIII, p. 223.)

Page of bulletin	Channels		Project depths of acts of Congress standard low water	Actual depths assuming water surfaces at mean for 62-yr. period, 1860-1921	Depths at 1921 annual mean	Depths at 1921 annual mean lowest	Depths at 1911 navigation season mean low	Depths for lowest month for 1911 navigation season, lowest monthly mean
			Feet	Feet	Feet	Feet		Feet
308	St. Clair Flats Canal		20.00	22.32	21.70	*20.73	*20.87	*20.39
319	Livingston Channel		21.00	23.52	23.31	22.33	22.47	21.99
	Harbors	Lake						
75	Duluth, Minn.	Superior	20.00	21.79	21.63	21.00	21.28	20.43
68	Ashland, Wis.	Superior	20.00	21.79	21.63	21.00	21.28	20.43
165	Milwaukee, Wis.	Michigan	19.00	21.63	20.60	20.10	20.23	19.87
205	Calumet, Ill.	Michigan	21.00	23.63	22.60	22.10	22.23	21.87
210	Indiana Harbor, Ind.	Michigan	21.00	23.63	22.60	22.10	22.23	21.87
316	Rouge River, Mich.	Detroit River	21.00	23.52	23.31	22.33	22.47	21.99
375	Toledo, Ohio	Erie	21.00	23.52	23.31	22.33	22.47	21.99
369	Huron, Ohio	Erie	19.00	21.52	21.31	20.33	20.47	19.99
365	Lorain, Ohio	Erie	20.00	22.52	22.31	21.33	21.47	20.99
357	Cleveland, Ohio	Erie	23.00	25.52	25.31	24.33	24.47	23.99
353	Fairport, Ohio	Erie	19.00	21.52	21.31	20.33	20.47	19.99
351	Ashtabula, Ohio	Erie	20.00	22.52	22.31	21.33	21.47	20.99
349	Conneaut, Ohio	Erie	20.00	22.52	22.31	21.33	21.47	20.99
345	Erie, Pa.	Erie	20.00	22.52	22.31	21.33	21.47	20.99
326	Buffalo, N. Y.	Erie	21.00	23.52	23.31	22.33	22.47	21.99
	Elevations							
123	Lake Michigan		578.50	581.13	580.10	579.60	579.73	579.37
323	Lake Erie		570.00	572.52	572.31	*571.33	*571.47	*570.99
45	Lake Superior		600.50	602.29	602.13	601.50	601.78	600.95

NOTE.—Gages—Duluth—Milwaukee—Head of Detroit River—Cleveland.
1911—Lake Erie—Shenehan tables free flow less 10,000 C. S. F. Gage .14 foot higher.
1911—St. Clair Flats canal interpolated.

AFFIRMATIVE EVIDENCE ON BEHALF OF DEFENDANT, TO WHICH PLAINTIFF DID NOT INTRODUCE OR OFFER EVIDENCE IN REBUTTAL.

Compensating or regulating works to off-set for the lowering of lake levels and connecting channels of the Great Lakes.

July 12, 1920, the defendant filed a motion for a decree only enjoining it from diverting at Chicago in excess of 10,000 cubic seconds feet of water, on condition that it should defray the cost of building such compensating or regulating works as the United States or proper authorities might provide, to off-set for the lowering of the levels of the Great Lakes and their connecting channels, due to the Chicago diversion. As grounds of said motion, various facts were alleged. The motion was heard and denied by the Court upon the allegations of facts set forth in said motion, without the introduction of evidence in support of or in opposition to the issues raised. The motion and the facts alleged therein as grounds for said motion, have been heretofore set forth. See This Narrative, (p. 98).

Among other things, it was alleged in said motion that it was an undisputed fact in the record that it was feasible and practicable to construct compensating or regulating works to off-set for the lowering of the lake levels due to the diversion at Chicago, and **various portions of the record were referred to as sustaining this allegation, among others, the following:**

John R. Freeman, witness for defendant, civil engineer, whose qualifications have been heretofore set forth (Rec. Vol. III, p. 1173; This Narrative, p. 135), April 4, 1913, testified as follows:

Compensating works, called the Gut Dam, were built by Canada at the outlet of Lake Ontario. The probable effect of this dam was estimated by U. S. Engineers prior to the building and later found to be substantially correct. It raised

the level of Ontario greater than the estimated lowering that would result from greatest proposed diversion at Chicago. Also, at the outlet of Lake Superior, near the International Bridge, an obstruction was built. Its general effect was to raise the level of Lake Superior about six inches. At the outlet of Lake Erie compensation works were built near Black Rock and have had the effect of raising the level of the lake. A still more radical plan for raising the level of Lake Erie was presented in the Report of Engineers on Deep Waterways.

Properly designed compensating works constructed immediately below the outlet of Lake Huron, would cause the lessening of the high slope and injurious currents could be avoided by means of a series of wing dams, so that there would be no objectionable velocity, and compensating works for Lake Erie and Huron could be constructed for approximately a million dollars.

Joseph Ripley, witness for the Sanitary District, whose qualifications have been heretofore stated (This Narrative p. 137) testified as follows (Vol. III, p. 1310):

The distinction between compensating and regulating works is that the former consist of fixed weirs and the latter is a combination of fixed weirs and movable dams. The effect of such works would be to increase the depth of the lake and make certain a continuance of such depth. A dam could be constructed in the St. Clair River about 1,300 feet up stream at Bunce Creek. Another dam could be located in the Detroit River in the Stony Island section. Also a dam placed in the Niagara River either near the upper end or down below Tonawanda would provide for the regulation of Lake Erie. These works would cost anywhere from $1,400,000 to $3,950,000, depending upon type of dam and the extent of the regulating feature; the St. Lawrence River from $200,000 to $1,000,000. The level of the lakes would thereby be raised from four inches to one foot.

The regulating works in the St. Clair River would lessen the current at Fort Gratiot which is the place of the swiftest current in the St. Clair River, and would thereby benefit navigation.

Gardner S. Williams, consulting engineer; Ann Arbor, Michigan, witness for the defendant, whose qualifications have been heretofore stated (Rec. Vol. II, p. 743; This Narrative p. 134) testified:

The backing up of the Upper Detroit River by the Livingstone Channel works and the raising of Lake Ontario by the Gut Dam in the St. Lawrence, illustrate the ease with which it is possible to compensate for diversions from Lake Michigan. It would be entirely feasible to close the Stony Island Channel and thereby reduce the discharge of the lower Detroit River by about 11,000 cubic seconds feet, which would raise Lake St. Clair in the neighborhood of two inches. The capacity of the Trenton Channel, which was found to be about 36,000 cubic feet seconds, could be easily reduced to an extent equal to the reduction of the Stony Island Channel or even more by a judicious filling in of material, and thus the compensation of Lake St. Clair obtained for the diversion at Chicago. The cost of this filling based upon the prices paid for moving the material in the vicinity of the mouth of the Detroit River, would be about $250,000. The total discharge of several channels at the mouth of the St. Clair is 194,000 cubic feet seconds. This total might be restricted to the extent of 15,000 cubic feet seconds without detrimental effects, and this would compensate for lowering Lake Michigan—Huron by the contemplated Chicago diversion. The cost of this compensation would be about $500,000, which makes a total of about $750,000 to compensate for the lowering of Lakes Michigan—Huron, the St. Clair and the St. Mary's, St. Clair and upper Detroit Rivers. The construction of the Gut Dam in the St. Lawrence has already compensated for the abstraction of water from Lake Ontario; and the International Waterways Commission are submitting a report

upon works to regulate the level of Lake Erie, which, if constructed, would provide for a compensation for the diversion from Lake Erie and the lower Detroit River.

The Rivers and Harbors Act of June 25, 1910, provided for the creation of a special Board of Engineers to make a report upon a waterway from Utica to the mouth of the Illinois River "and upon such measures as may be required to properly preserve the levels of the Great Lakes, and to compensate, so far as practicable, for the diminished level in said lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway herein described, or diversion for any other purpose."

The Special Board made its report August 15, 1913, to the Chief of Engineers, U. S. A. The board consisted of William H. Bixby, Brigadier General of the United States Army, retired president of the board, C. McD. Townsend, one of the witnesses for the plaintiff here, Colonel Corps of Engineers, United States Army, C. Keller, also a witness for the plaintiff, Major, Corps of Engineers, United States Army, J. B. Cavanaugh, Major, Corps of Engineers, United States Army, and John Bogert, civil engineer.

The above mentioned report before it was sent to Congress, thereafter known as House Document 762, Sixty-third Congress, Second Session, was reviewed by the Board of Engineers for Rivers & Harbors, and report made thereon. That report, including the report of the Special Board, so far as they are material, are as follows (Rec. Vol. IV, p. 2576-2590):

Report of the Board of Engineers for Rivers and Harbors.

[Second Indorsement.]

BOARD OF ENGINEERS FOR RIVERS AND HARBORS.

December 16, 1913.

To the Chief of Engineers, United States Army:

1. The Board of Engineers for Rivers and Harbors has had under consideration the final report of the special board of engineers.

* * *

I. FEASIBILITY OF THE WATERWAY.

2578 3. In the valley of the Desplaines and Upper Illinois Rivers, excellent foundations for locks are available; the lower Illinois has a gentle slope, so that any reasonable depth can be obtained by dredging, and the present diversion of water from Lake Michigan through the Chicago Drainage Canal is more than sufficient for navigation purposes. It is therefore the opinion of the special board that the waterway from Lockport to the mouth of the Illinois River is feasible.

II. THE MOST ADVISABLE DEPTH AND DIMENSIONS FOR THE WATERWAY.

4. In determining the most advisable depth for the waterway, the special board gives consideration to the character, origin, and destination of the probable commerce, and the type and dimensions of the vessels best suited to handle the traffic. It states that if the waterway is to be used by vessels capable of navigating the ocean and the Great Lakes, it should be given a depth suitable for the economic carrier now used on those bodies of water, which would fix the depth at not less than 24 feet; but if it is to be constructed for vessels adapted to river traffic, navigation does not require its depth to exceed 9 feet. A depth of 14 feet, which has been frequently urged for this waterway, is greater than necessary for river navigation and entirely insufficient for either lake or ocean vessels. A uniform depth on the Mississippi and its leading tributaries will be far more beneficial to the navigation interests of the United States than a main channel of great depth with shallow feeders. As a channel of 8 feet depth is now maintained from Cairo to St. Louis, and can be extended from St. Louis to Utica, on the Illinois river, at relatively small cost, business caution dictates that a waterway of this depth be obtained and tested before entering upon enormously expensive projects of questionable utility.

5. The special board considers a bottom width of 160 feet in canal and 200 feet in the open river above the mouth of the Illinois sufficient for a channel of 8 or 9 feet
2579 available depth. For safety and ease of navigation, the channel should be excavated to 11 feet in rock cuts and canals, and the locks should be given 11 feet depth, 80 feet width, and 600 feet usable length. A waterway of these dimensions would have a capacity exceeding 100,000,000 tons per annum.

III. CO-OPERATION WITH THE STATE OF ILLINOIS.

6. A project has been presented by the State of Illinois which contemplates the development of water power at four sites between Lockport and Utica, and the improvement of navigation by the construction of five large locks, 80 by 900 feet in horizontal dimensions, with 24 feet depth on their miter sills. This project proposes the utilization for power purposes of the water which may flow through the Chicago Drainage Canal and contemplates an ultimate channel depth of 24 feet for navigation purposes, though the estimates, amounting to approximately $20,000,000, provided for 24 feet only to Brandon Bridge and for 14 feet below. The special board states that the waterway proposed is more that sufficient for any probable navigation. It believes that the General Government will fully cooperate with the State in a waterway from Lockport to the mouth of the Illinois river if it assumes charge of the State structures at Henry and Copperas Creek, and enlarges the existing channel in the Illinois river below Utica to suitable dimensions.

IV. CONDITIONS NECESSARY IN CONNECTION WITH COOPERATION TO FULLY PROTECT THE INTERESTS OF THE UNITED STATES.

7. The special board states that a primary condition of any cooperation between the United States and the State of Illinois should be the acceptance in perpetuity of full responsibility by the State of Illinois or its agencies for all damages by changes in lake levels, including cost of compensating works, and for all damages to riparian owners, and the State should transfer to the United States the locks and the control of the new waterway thus created so far as needed by navigation, and the locks and dams at Henry and Copperas Creek on the Illinois river. With such a transfer the obligations of the State of Illinois to the United States with reference to the maintenance of the Illinois and Michigan Canal may be considered as adequately fulfilled, and any
2580 equities of the United States in the rights of ways and other properties of this canal should be transferred by the State of Illinois. The special board believes that should the State of Illinois be unable to complete the locks suggested by the board or the bridges required by navigation, the United States might then properly undertake to complete these parts of the project.

VI. SUCH MEASURES AS MAY BE REQUIRED TO PROPERLY PRESERVE THE LEVELS OF THE GREAT LAKES, ETC.

2581 9. The investigations and studies of this special board show that the diversion of water from the Lakes lowers the levels progressively in proportion to the amount so diverted, the full effect not being observable for some time; and that for the 10,000 second-feet diverted through the Chicago Drainage Canal, at mean lake level, the water surface will be lowered in Lakes Huron and Michigan 0.465 foot; in Lake Erie, 0.448 foot; in Lake Ontario, 0.431 foot. Such lowering would materially affect the carrying capacity of the large freight vessels, estimated at 88 tons per inch of draft, and would cause a loss on American vessels alone at the lowest estimate of $1,000,000 per annum.

10. Three methods for compensating for such diversion have been considered by the special board: (1) By the construction of submerged weirs with arbitrarily controllable sluices at the lower ends of the Lakes; (2) by reducing the area of the natural outlets by the construction of fixed contraction works therein; (3) by dredging harbors and connecting channels. The investigations of the board show with certainty that the result of diversion of water through a new outlet is a lowering of Lake level. The effect of the great storage capacity of the lakes and of the natural fluctuations of level due to natural causes, such as the varying amount of rainfall and the varying amount and direction of wind pressures, is such that the absolute level at a given time at any given place can not be predicted, and human wisdom is inadequate to regulate a variation of discharge through the outlet in such a manner as to produce a definite desired result. Method No. 1 therefore must be classed as impracticable. Compensation by dredging is practicable, but on account of the extensive areas involved, this method would be unduly costly. Of the three methods, the second only is therefore favorably considered. The special board proposes to hold up the level of Lake Erie by the construction of three submerged wiers in Niagara River, at an estimated cost of $150,000, and that of Lakes Michigan and Huron by submerged weirs in St. Clair River, at an estimated cost of $325,000, the total for compensating works being $475,000, with $15,000 annually for maintenance.

* * *

CONCLUSIONS.

2582 14. After due consideration of the reports of the special board the Board of Engineers for Rivers and Harbors concurs in general with the views and conclusions expressed therein. With the information now available, it is not prepared to indorse certain details of the discussions in the appendixes and elsewhere pertaining to the regulation of the level of Lake Superior,
2583 the regulation of the day and night discharge at Niagara Falls, and the estimates of cost for the dams across the Mississippi River. But inasmuch as this difference of opinion on these points does not affect the final conclusions, the board believes that nothing would be gained at this time by pursuing its investigation further. The board concurs fully with the general conclusions expressed by the special board in its final report, but differs slightly from those given in its preceding report. In this connection attention is invited to the following statements made by the Board of Engineers for Rivers and Harbors in its report of January 30, 1911, printed in House Document No. 1374, Sixty-first Congress, third session:

> It does not concur with the view of the special board that the United States should assume that part, if any, of the cost that is in excess of $20,000,000 for constructing the portion of the waterway between Lockport and Utica. Moreover, it suggests that the amount of diversion to be permitted from Lake Michigan should be determined, if practicable, before the project is undertaken.
>
> * * *
>
> It is understood that the sanitary district of Chicago and the State expect to develop considerable water power on that portion of the waterway between Chicago and Utica. As it is proposed that the navigable channel between these points shall be built without cost to the United States, it is believed that the General Government should relinquish to these local agencies any rights that it may have in the power to be thus developed. It does not appear that there is any question of water power, flood control, or other matter that can be coordinated with that portion of the work to be done by the United States for the improvement of navigation, so as to lessen the cost and compensate the Government for its expenditures made in the interest of navigation.

In conclusion it is recommended that the work proposed by the special board for the United States in the Illinois River be not undertaken until the Secretary of War has received satisfactory assurance from the State of Illinois that the State will build that portion of the waterway from Lockport to Utica without cost to the United States, and in accordance with plans to be approved by him; and, further, until the interests of the United States
2584 have been satisfactorily safeguarded as indicated by the special board, viz., that the State of Illinois, or its agencies, shall assume entire responsibility in perpetuity for all damages by changes in lake levels incident to the work, including cost of compensating works, and for all damages to riparian owners along the proposed waterway from Lake Michigan to the mouth of the Illinois River, and that the State shall transfer to the United States the locks and the control of the new waterway thus created so far as needed for navigation, and the locks and dams at Henry and Copperas Creek on the Illinois River.

15. It is the distinct recommendation of the Board of Engineers for Rivers and Harbors that the term "control of the new waterway thus created so far as needed for navigation" shall be interpreted to include such control of the use of water for power purposes as shall be necessary to insure the conditions of flow required for navigation. Further, the board believes that the total volume of water to be diverted from the natural discharge channels of the Lakes should be definitely fixed by Congress; that a project, with estimate of cost, for works necessary to compensate for such diversion should be prepared to the satisfaction of the Chief of Engineers and the Secretary of War; that before any diversion is made beyond that at present existing, the State of Illinois shall transfer to the Secretary of War the funds necessary for such works as given by the approved estimate of cost; that the works shall be built by the United States with the funds so provided; and that the control and maintenance of such works shall be in and at the cost of the United States.

16. As indicated above, the work proposed by the special board involves an original outlay by the United States of $1,050,000 for the Illinois River and $3,710,000 for the Mississippi River, or a total of $4,760,000, and provides for a navigable channel depth of 8 feet from Utica to St. Louis. The act ordering the investigation

appropriated $1,000,000 "for the construction of a waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers to the mouth of said Illinois River," and provided that "until these plans and estimates have been submitted and a project adopted by Congress the appropriation of $1,000,000 herein made shall not be available for expenditure." If the project be adopted by Congress, this conditional appropriation should be
2585 made available for the improvement as a whole, and subsequent appropriations should be made with a view to completion of the work in four years. The Board of Engineers for Rivers and Harbors recommends the adoption of the project under the conditions stated above.

For the Board:

W. M. Black,
Colonel, Corps of Engineers,
Senior Member of the Board.

Final Report by a Special Board of Engineers on Waterway from Lockport, Ill., to Mouth of Illinois River.

New York City, August 15, 1913.

From: A Special Board of Engineers.

To: The Chief of Engineers, United States Army.

Subject: Report on waterway from Lockport, Ill., to the mouth of Illinois River, and on certain related subjects.

The Board of Engineers appointed by the Secretary of War September 8, 1910, in Special Orders, No. 43, Office of the Chief of Engineers, for the consideration of a waterway from Lockport, Ill., by way of the Des Plaines and Illinois Rivers, to the mouth of the said Illinois River, in its reports of November 1, 1910, and January 23, 1911, has discussed certain of the questions referred to it—namely: I, Feasibility of the waterway; II, the most advisable depths and dimensions for the waterway; III, cooperation with the State of Illinois; IV, conditions necessary in connection with cooperation to fully protect the interests of the United States, and V, plans and estimates of the cost of work recommended to be done by the United States. Since the submission of the above reports nothing has developed to require any changes in the statements and conclusions therein given. For convenience of reference these reports are attached hereto marked as Appendixes E and F.

The necessary additional investigations having been completed, the results of which are shown in Appendixes A, B, C, and D, the board now has the honor to submit the following report upon the remaining questions submitted to it for consideration:

> VI. Such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished level in said Lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway * * * or for any other purpose.

2586 This subject is specially discussed in Appendix A.

Since 1895 the United States Lake Survey, under the direction of the Chief of Engineers, has made a systematic series of measurements of discharges in the St. Mary's, St. Clair, Detroit, Niagara, and St. Lawrence Rivers, to determine the relation which exists between the volumes of water discharged by these rivers and the levels of the lake surfaces. These discharge measurements have been numerous and demonstrate conclusively that there is a direct connection between the height of each lake and the volume of water discharged at its outlet.

For a change of 1 foot from the mean of the stages covered by the observations on each lake the discharge will vary as stated in Table I, and conversely the changes of level in feet, due to diversions from the natural outlets of varying amounts, will be as shown in Table II.

TABLE I.

Lake	Mean stage.*	Discharge at mean stage.	Change in discharge due to 1 foot change in level close to mean stage.
	Feet	Second-feet.	Second-feet.
Superior	601.80	75,000	15,300 gauge at S. W. canal pier.
Michigan-Huron ..	580.38	192,300	21,500 Fort Gratiot gauge. Lake St. Clair normal.
Erie	571.96	195,500	22,300 Buffalo L. H. gauge.
Ontario	244.60	230,000	23,200 Ogdensburg gauge. Discharge adjusted for effect of closure of Gut Channel in Galops Rapids, estimated to reduce existing discharges 9,000 cubic feet per second below those formerly existing at the same stages.

* Mean of range during discharge measurements.

TABLE II.—CHANGES OF LEVEL, IN FEET, DUE TO DIRECT DIVERSION OF AMOUNTS VARYING BETWEEN 1,000 AND 14,000 CUBIC FEET PER SECOND.

1,000 cubic feet	Superior	Michigan and Huron	Erie	Ontario
	Foot	Foot	Foot	Foot
1	0.065	0.046	0.045	0.043
2	.131	.093	.090	.086
3	.196	.139	.134	.129
4	.261	.186	.179	.172
5	.327	.232	.224	.2165
6	.392	.279	.269	.260
7	.457	.325	.314	.303
8	.523	.373	.359	.346
9	.588	.419	.404	.399
10	.654	.465	.448	.431
11	.719	.511	.493	.474
12	.784	.558	.538	.517
13	.850	.602	.583	.560
14	.915	.659	.628	.603

2587 These changes are obscured by variations in the supply of water from rains, by evaporation, by the effects of winds, and by the obstruction of the outlets by ice, and due to the reservoir capacity of the different lakes the action will not be immediate. As shown in the report of the Lake Survey for 1904, page 4120, one-half of the ultimate fall of Lakes Michigan and Huron will occur in 1.46 years, and nine-tenths of the fall will be completed in 4.86 years. For Lake Erie 50 per cent of the ultimate lowering will occur in 2.5 months and 90 per cent in 8 months; for Lake Ontario, in 2.1 months and 7 months, respectively.

It is therefore evident that when the Lakes stand at mean lake level a diversion of 10,000 cubic feet per second from Lake Michigan through the Chicago Drainage Canal will ultimately produce a lowering of the water surface of Lakes Michigan and Huron and its connecting harbors and channels of 0.465 feet (5.58 inches), of Lake Erie of 0.448 feet (5.38 inches), and of Lake Ontario of 0.431 feet (5.16 inches); at lower stages the effect will be greater, due to the relatively smaller area of the cross section of the outlets.

The largest lake freighters recently built carry over 80 short tons of freight for each inch of loaded draft, and an uncompensated Chicago diversion of 10,000 second-feet would cause a loss to each vessel of at least 446

tons in carrying capacity for each down trip through the channels connecting with Lakes Michigan and Huron. This, based upon 25 trips per season, with vessels returning light, means a loss of at least 11,150 tons per year, and at a freight rate of 55 cents per ton represents a monetary loss of at least $6,000 per large vessel per year. During the season of 1912 there passed through the locks at Sault Ste. Marie over 72,000,000 tons of freight, the greater part of which was carried in vessels of such size as to be affected by any loss of depth caused by a Chicago diversion. The tonnage of 1913 bids fair to exceed the tonnage of 1912. The lowest estimate of the loss to American vessels alone that has been brought to the attention of the board is over $1,000,000 per annum, and the loss will increase with the increase in the number and size of vessels.

It is evident therefore that any diversion with consequent lowering of lake levels will cause a direct financial loss to vessel owners and such a loss can be prevented only by the adoption of remedial measures. For this purpose three methods have been proposed. First,
2588 to regulate the level of the Lakes between fixed limits by the construction of submerged weirs and adjustable sluices at the lower ends of the Lakes, and by this means not only to prevent the oscillations of lake levels which occur daily each season, but also to equalize the flow over a series of years. Second, to compensate for the diminished discharge by reducing the area of the natural outlets by construction of contraction works therein. Third, to restore the original depths of the harbors and connecting channels by dredging.

It is the opinion of the board that while it is feasible to raise the average surface of the Lakes to any desired elevation by means of weirs and sluices it will be exceedingly difficult and in many ways impracticable to regulate the oscillations of the Lakes to a greater extent than nature now does automatically. These oscillations arise from winds, from the relative amount of rainfall and evaporation, and from other natural causes, which man can neither control nor forsee. The effect of any attempted regulation will be local rather than general, and the local benefits will be offset by injuries elsewhere. The difficulties in regulating lake levels are fully discussed by the International Waterways Commission in House Document No. 779, Sixty-first Congress, second session, and a resume of the views expressed therein is given in Appendix A.

To restore the diminished levels in the Lakes by constructing contracting works in their outlets does not however present any serious difficulties. A careful discussion of the proper locations and dimensions of such works is also given in Appendix A.

At the foot of Lake Ontario the closure of the Gut channel of the Galops Rapids by the Canadian Government has had the effect of raising the level of Lake Ontario an amount nearly equal to the computed lowering of the lake by a diversion of 10,000 second-feet at Chicago, and no compensation is at present deemed necessary to restore former conditions in this lake.

In Appendix A it is proposed to diminish the outflow of Lake Erie by the construction of three *submerged weirs in Niagara River* in the vicinity of Squaw Island, which would average about 4.2 feet in height and would contain about 15,000 cubic yards of masonry. The estimated cost is $150,000.

To raise the level of Lakes Michigan and Huron *submerged weirs* are proposed *in St. Clair River,* covering 3 miles of river below the mouth of Black River at Port
2589 Huron. The weirs as suggested in Appendix A have a height of from 5 to 6 feet above the river bed, contain about 65,000 cubic yards of material, and their estimated cost is $325,000. It is computed that these weirs will increase the velocity of the water flowing over them slightly (from a mean of 3.28 feet to 3.89 feet per second), but, on the other hand, above the mouth of Black River the river slopes and velocities which are now excessive will be diminished, and navigation on the whole will be considerably benefited.

The Chicago diversion has no effect on Lake Superior.

Compensation for the loss of elevation on Lakes Michigan, Huron, and Erie, and their connecting waters, due to an assumed diversion from Lake Michigan of 10,000 second-feet, will by the plan above outlined involve an expenditure of about $475,000, to which should be added an amount for the maintenance of the weirs, estimated at about $15,000 per year, the total cost being much less than the cost of restoration of depths by dredging. It is the opinion of the board that while other plans have been proposed, compensation by fixed contraction works similar in general to those above described affords the cheapest and most satisfactory method of preserving the levels of the Great Lakes.

No estimates have been considered for compensating for the loss of depths in the St. Lawrence River, as such work is regarded as outside the scope of the duties of the board.

THE SANITARY DISTRICT DIVERSION WORKS COST AND THEIR OPERATION, EFFECTIVENESS, RESULTS, SEWER AND WATER SUPPLY SYSTEM OF CHICAGO AND COST.

George M. Wisner, a witness for the defendant (Rec., Vol. III, p. 1592-1703), January 20, 1914:

Resides at Chicago; civil engineer; graduate U. of Michigan, Academic Department, and also Degree of Civil Engineer, 1892; then Chief Engineer of the Sanitary District of Chicago; been Chief Engineer since 1907; started with Sanitary District in 1892 as a rod-man; then sub-instrument man; then sub-assistant engineer; then assistant engineer; then chief assistant engineer; chief engineer in 1907. As chief engineer, in charge of engineering department; designed all works carried on by the District and constructed and in process of construction; original research by experimental stations, particularly sewage disposal and water purification; duties for Sanitary District in beginning involved studying sewage disposal, sewage conditions, hydraulic problems; in connection with sewage disposal, visited plants at Columbus, Baltimore, Milwaukee, Washington and other American cities, Birmingham, Manchester, London, England; Paris, France and Berlin, Germany.

The witness further testified as follows:

1594 Familiar with all the works of the Sanitary District the sewerage and water supply system of Chicago.

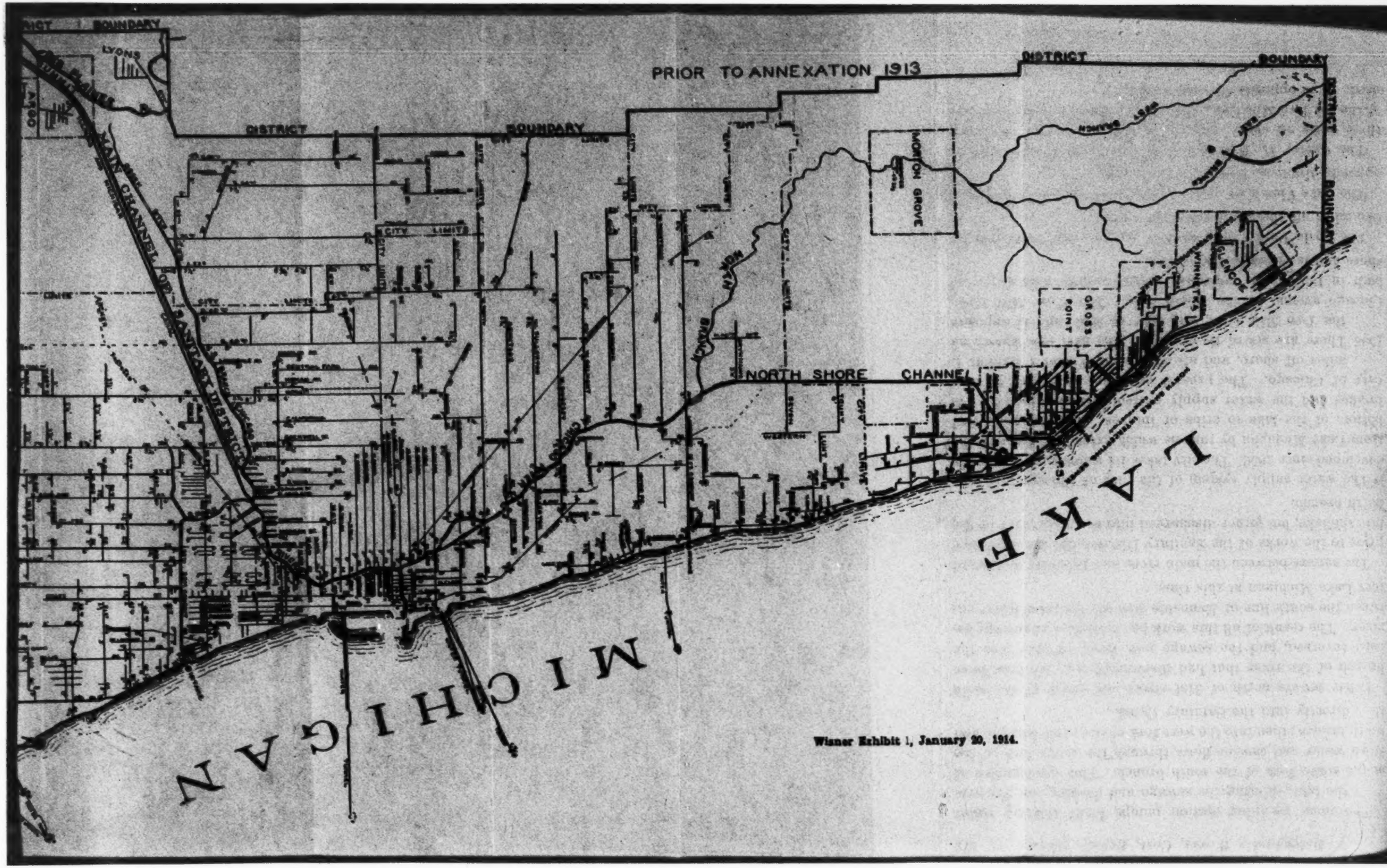
The sewerage system of the City of Chicago consists of sewers built for the collection of sewage; the first one being built in 1855, and they have been added to since, piece by

piece. They range in size from six inch tile up to brick sewers 20 feet in diameter. The more important sewers are those that are two feet in size and over, as shown on Wisner Exhibit 1 on page opposite.

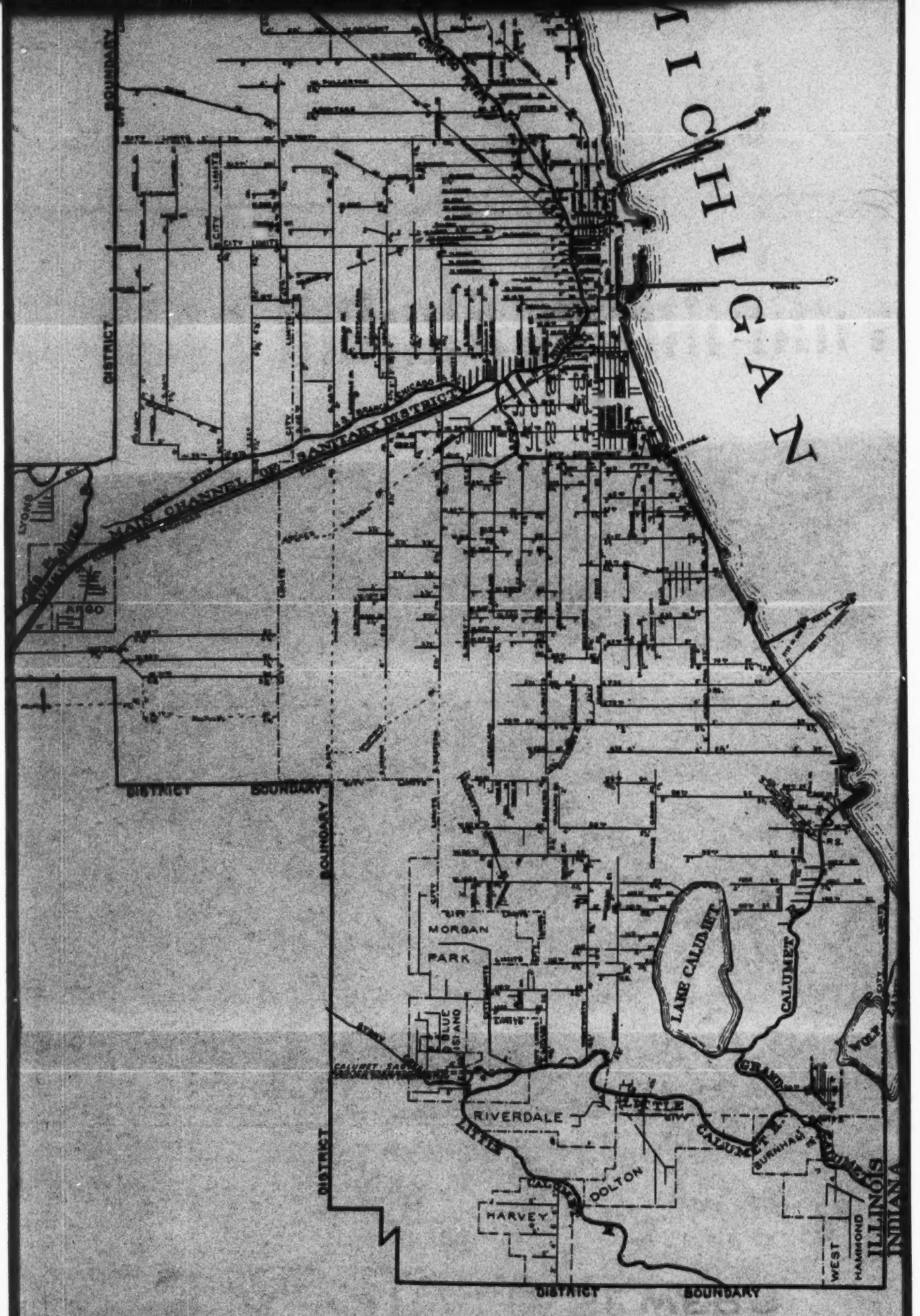
The sewers originally discharged into the Chicago River, and a part of them, on the north and south sides, directly into Lake Michigan. The sewers are all built on what is known as the combined system; that is they receive both the storm water and the sanitary sewage; all the sewage coming directly from the homes and buildings of the city. They also receive to a large extent the manufacturing wastes.

There have been completed recently two main intercepting sewer systems. These were built by the City of Chicago to prevent the sewers that had previously discharged directly into the Lake from discharging into it; in other words to keep the sewage out of the lake. One is on the North Side, and is shown on Wisner Exhibit 1, appearing on page opposite, starting on the north of Howard avenue and running south to Lawrence avenue, and a part of the same system starting on the south at Diversey boulevard and running north to Lawrence avenue, where the sewage is picked up by pumps and forced through a conduit 16 feet in diameter on Lawrence avenue to the west and into the north branch at that street. This pumping station also pumps diluting water
1595 from Lake Michigan, mixing it with the sewage water, and being utilized for dilution of the sewage and flushing the North Branch.

The other intercepting sewer system is on the South Side, as shown on Wisner Exhibit 1, and extends on the south from 87th street north to 39th street and the lake, and from 31st street south to 39th street, preventing the sewage which had flowed directly into the lake from flowing therein. At 39th street it is picked up by pumps and forced through a 20-foot conduit west to Halsted street, where it discharges into the east arm of the south fork of the south branch of the Chicago River. This is the arm of the river that is commonly known as Bubbly Creek. (Wisner Exhibit 1, inserted on page opposite.)



Wisner Exhibit 1, January 20, 1914.



SANITARY DISTRICT OF CHICAGO

MAP OF THE

CITY OF CHICAGO AND VICINITY

SHOWING

MAIN OUTFALL SEWERS.

CHICAGO JANUARY, 1914.

SCALE IN STATUTE MILES

The same pumping station pumps fresh diluting water from the lake, diluting the sewage and flushing out the arm of the south fork of the south branch. This combination of fresh water and sewage flows through the south fork to the south branch; then into the west fork of the south branch, and thence directly into the Sanitary Canal.

Other sewers north of 31st street and south of the main branch of the river that had discharged into the lake have been reversed, and the sewage now flows directly into the river. The result of all this work has been that no sewage between the south line of Evanston and the Calumet River enters Lake Michigan at this time.

The sewers between the main river and Diversey boulevard prior to the works of the Sanitary District, did not discharge into the lake, but either discharged into the main river or the north branch.

The water supply system of the City of Chicago has been developed since 1852. The city takes its water supply directly from Lake Michigan by tunnels which extend out beneath the bottom of the lake to cribs or intakes. These tunnels and intakes and the water supply system is maintained by the City of Chicago. The present cribs are from two to four miles off shore, and are shown on Wisner's Exhibit 1.
1596 There are six of these cribs. The first one, known as the Two Mile Crib, was built in 1867, and is opposite Chicago avenue on the North Side. The Four Mile Crib, built in 1892, is, as indicated, approximately four miles off shore and is opposite 14th street.

The Hyde Park Crib was built in 1894, and is practically two miles off shore opposite 68th street.

The Lake View Crib built in 1896, is two miles off shore and opposite Montrose avenue, or boulevard.

The Carter H. Harrison Crib was built in 1899, and is three miles off shore; practically amounts to the extending of the old Two Mile Crib, although I believe at times both are used. It is opposite Chicago avenue.

The Dunne Crib built in 1910, is two miles off shore and opposite 68th street. It is right alongside of what is known as the Hyde Park Crib. It was put in to give additional capacity for this particular part of Chicago that those two cribs serve.

This water, after passing through these tunnels under the lake is then carried by land tunnels to pumping stations located in different parts of the city, and forced through the mains to consumers.

The Sanitary District was organized in 1889, and the construction was started in 1892. The principal feature of its work has been the construction of what is known as the Main Channel. This channel begins at Robey street and the Chicago River, which is about 6 1/3 miles from the mouth of the river. It was originally 28.05 miles long and extended from Robey street the starting point to Lockport, Illinois. Practically the first 14 miles of it was through clay and glacial deposits, and the lower 14 miles was through limestone rock.

The Chicago end of the canal, for about 7 miles, was constructed to about half of the ultimate capacity. It was capable of progressive development as the needs for additional water became necessary to dilute the sewage. This extended to a place known as Summit.

1597 From Summit to Willow Springs, a distance of another 7 miles, the channel was constructed to its full capacity; and from Willow Springs to Lockport, through the rock, it was constructed to its full capacity.

The channel at the upper end was 110 feet wide on the bottom, and had side slopes of one vertical on two horizontals.

The second stretch through the glacial deposit to Willow Springs was 202 feet wide on the bottom, and with the same side slopes. From Willow Springs to Lockport, generally, the channel was 160 feet wide on the bottom, and 162 feet wide on the top, with sides that were practically vertical.

At the end of the channel were controlling works for regulating the amount of water flowed through the Chicago River and the Main Channel.

In 1903, the right was obtained from the Legislature to develop power which had been incidentally created in connection with this work, and the channel was extended to practically the City of Joliet. Prior to this, however, the Sanitary District had done considerable work improving the Des Plaines River below the end of the Main Channel and through the City of Joliet, removing several dams nd deepening the stream, building levees and walls. This power development involved the lengthening of the upper reach of the Main Channel for about two miles, at which point was located a power house, dams for regulating the flow and a lock for the passage of vessels from one level to the lower level. It developed an average head of about 34 feet, and the plant is capable of developing about 4,000 kilowatts for every 100,000 cubic feet of water flowed per minute; generally, in round numbers, that is true.

Below the power house, the channel is carried on the same depth, practically the same depth as above the power house, which I neglected to give, it being about 24 feet at normal stages of the lake, to a point near to the upper limits of Joliet, where it is from there through the City of Joliet ten feet or over in depth. This power extension was completed in the latter part of 1907.

This work involved the construction of transmission lines and distributing systems in the City of Chicago, most of the power being brought to Chicago for the lighting
1598 of streets and pumping of water for the municipality, the excess being sold for commercial purposes. This power was all developed incidental to the sewage disposal, and the District has never flowed more water on account of power developments than it would have flowed if there had been no development there. Prior to this construction this power was simply going to waste, and it simply amounted to the conservation of this wasted energy.

In connection with getting water through the Main Channel, it became necessary, on account of the restrictions placed

on the velocity of the current in the South Branch for the Sanitary District to improve the South Branch of the Chicago River by widening and deepening it and by the removal of certain bridges, whose center piers interfered with the free passage of the water through the river.

The Sanitary District has expended approximately $11,500,000, on the improvement of the Chicago River. This money was expended almost entirely under what is known as the 1900 Project. It generally was expended to widen the South Branch from its junction with the North Branch at Lake street to the beginning of the Drainage Canal at Robey street. The river has been widened to a width of at least 200 feet, and it has been deepened so that at the dock lines there is a depth of water of 16 feet, gradually deepening to a point 50 feet out from the docks where it is 26 feet deep for the middle 100 feet of the river. This depth of water is below what was known as the hydraulic grade of the river; that is the water in flowing from the Lake to the Drainage Canal has a slope which at times is two feet lower at Robey street than the Lake level.

This widening of the Chicago River involved the purchase of over 792,000 square feet of property along the Chicago River, and generally, I should say, the river had been widened on an average 50 feet. The widest piece taken off was 110 feet in width, and from that down to nothing.

This involved the excavation of over 5,500,000 cubic yards of material; the construction of over 19,000 lineal feet of dock, for wherever the Sanitary District widened the river it became necessary to build new docks.

In the improvement of the river, as already stated, the Sanitary District replaced many of the old center pier bridges with bridges of the modern type, known as bascule 1599 bridges. It has replaced or rebuilt the following bridges across the Chicago River: State street, Dearborn street, Randolph street (and is now engaged upon the construction of a new bridge at Jackson boulevard), Harrison street (Polk

street was built by the City of Chicago), Taylor street, Chicago Terminal Transfer Railroad Bridge, now owned and operated by the Baltimore & Ohio Railroad (it has agreed to pay half the cost of rebuilding the 12th street bridge, which has been ordered out by the Secretary of War), 18th street, Canal street, 22nd street, Main street, Throop street and Ashland avenue. One other bridge was removed and reconstructed by the City of Chicago. That is at Washington street.

Widening the river also involved the removal of many buildings, and paying damages to adjacent property owners.

The Sanitary District has also widened and deepened the North Branch of the Chicago River from Belmont avenue to Lawrence avenue, a distance of about two miles. This stream, prior to this straightening and deepening, was practically dry in the summer time, simply being a small creek. The Sanitary District made a stream having a depth of 12 feet and a width of 90; and has also deepened the South Fork of the South Branch to a depth of 20 feet; has done considerable work in the West Fork of the South Branch west of the beginning of the Main Channel, deepening it about three feet.

This, generally, covers the work done by the Sanitary District as far as its main channel and the Chicago River are concerned, with the possible exception of the North Shore Channel which was completed in the latter part of 1910 and early in 1911; and it extends from Wilmette and the Lake to the North Branch of the Chicago River at Lawrence avenue. This was a rather small canal, having about 13 feet of water. It is navigable and was built to take care of the sewage coming from what is known as the North Shore towns, that is the towns from Glencoe south to the Chicago Limit, including Evanston, Wilmette, Winnetka, Kenilworth and Glencoe. It is provided with a pumping plant at Wilmette, which pumps 1,000 cubic feet of water per second through this canal and down into the North Branch, and the water to be used for diluting the sewage and flushing out the North Branch, which otherwise would be stagnant, septic, and become a local nui-

sance. This water flows then directly into the South Branch and into the Drainage Canal.

The South Branch had been dredged by the United States Government to a depth of 17 feet, but it had shoaled up
1600 considerably, due to silt coming in from the lake and sediment coming from sewers, so that at the time the District started on the deepening of the South Branch, it did not have available probably over 16 feet.

At Joliet, the terminus of the Sanitary District Channel there was space left, and the work was so designed that a large lock could be installed when the deep waterway is constructed.

The Chicago River through the main river is 20 feet; through the South Branch and West Fork down to the main channel 26 feet. The main channel itself at ordinary stages is at least 24 feet as far as the power plant. Below the power plant it is 20 feet to the north limits of Joliet, and from there on at least 10 feet in depth down to Dam Number 1, which is near the center or heart of the city of Joliet. Below there the Des Plaines River is not navigable. The only means of navigation from there on at the present time to the Illinois River is by way of the old Illinois and Michigan Canal.

The United States has expended in the improvement of the harbor at the mouth of the Chicago River approximately $2,390,000. No part of that sum was expended in the improvement of the Chicago River. The Government did not expend any money in connection with the improvement of the Chicago River until 1896.

Since 1896 the United States expended, up to say June 30, 1913, in the improvement of the Chicago River itself approximately $1,626,000.

It was expended for dredging the North and the South Branches to a depth of 17 feet on the first project, and later the deepening of the North Branch as far north as Belmont avenue, I think, to a depth of 20 feet.

The Government also bought some land on both branches of the river for the purpose of constructing what is
1601 known as turning basins. These are basins that are large enough so that vessels can turn around and come back down the river bow first. The one on the North Branch is at Diversey boulevard, and the one on the South Branch is at the junction of the West Fork and the South Branch, just east of Ashland avenue. Part of this money on the original project was expended for widening the Chicago River at some of the narrowest and most dangerous places. Part of this money was expended deepening the main branch of the river to a depth of 20 feet from the mouth to the junction of the two branches. Generally this covers the money that was expended by the Government for the improvement of the river.

The City of Chicago has expended in the improvement of the Chicago River approximately $6,275,000.

From about 1861 to the present time, approximately to this time it was expended for dredging of the Chicago River, both the main river and on all its branches, building of bridges and docks, and general improvements.

These improvements in the Chicago River were done by the United States Government during the time that the Sanitary District was completing its works—particularly the South Branch. The deepening of the North Branch has been done in quite recent years; that is deepening the North Branch to 20 feet.

Since the 17 foot project of the United States Government it has done no work on the South Branch, although it has deepened the North Branch to 20 feet. The Sanitary District took up its work and did this dredging. When the Sanitary District started on this project, the Government had not quite completed the dredging to 17 feet. It was widening the river at certain places where it was narrow, that is the South Branch. Some of this work of the Government and the Sanitary District was carried on simultaneously. The widening

done by the Government however was at a few places, and did not amount to very much.

The Sanitary District commenced its work on the improvement of the Chicago River along about 1896.

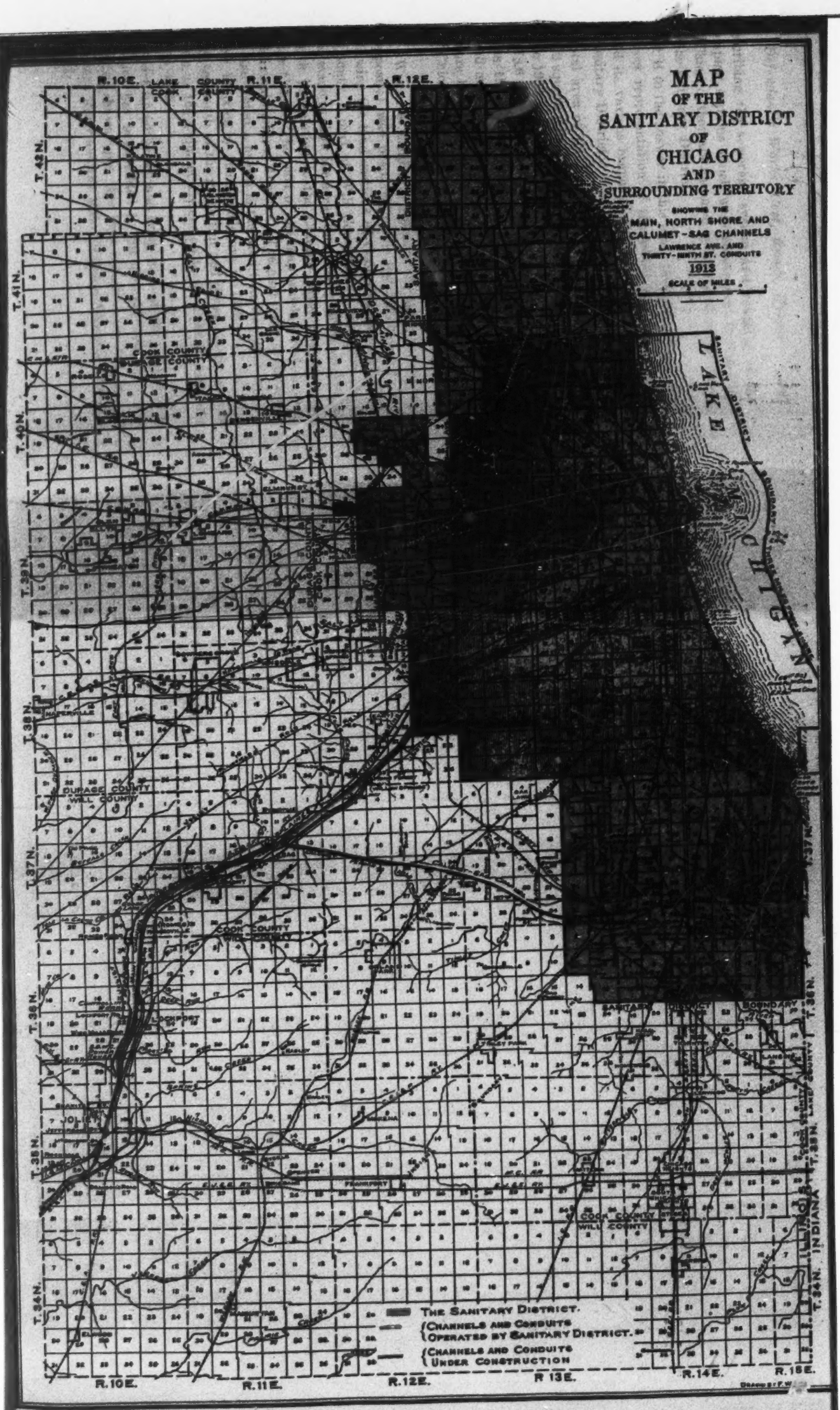
1602 Prior to the time the Sanitary District widened and deepened it, boats drawing over 16 feet of water could not have navigated the South Branch, even providing that the tunnels had been removed, for the reason that there was not any more available depth than that. Up to the time that the Sanitary District started its dredging a boat over 400 feet in length could not have navigated beyond 22nd street, for the reason that between 22nd and Halsted street the river was very narrow and tortuous, and a boat of that length could not make the turn. Boats having a beam greater than 48 feet would probably not have been able to pass through some of the bridge openings. These bridges have since been removed and replaced by modern bridges giving a wider opening.

As the result of the Sanitary District improvements in the Chicago River at this time a boat of probably 500 feet could navigate the river, and drawing 20 feet; the depth being controlled by the depth of the main branch of the river. If certain bridges, which are now either coming out or shortly to come out are removed, a boat of larger length could be taken down the river.

In the South Branch the critical point probably, the critical stretch, is from Lake street to the turning basin at Ashland avenue. This will safely take, in my opinion, 8,000 cubic feet a second. From there on to the Drainage Canal, the river is much wider, and with the same depth would take an additional flow of water without any injury to navigation.

The current would not exceed 1¼ miles an hour through that stretch anywhere.

The Sanitary District has done some work in improvement on the Illinois River, and some improvement in a sanitary way for some of the smaller towns within the limits of the Sanitary District.



ORIGINAL SANITARY DISTRICT SHOWN IN GREEN.

In describing the sewerage system and speaking of the pumping stations which were constructed by the City
1603 of Chicago, they are assumed to be a part of the works of the Sanitary District.

Exhibit B to the answer in this case (this narrative p. 79) is a correct representation of the position of the Chicago River and its various branches with reference to the limits of the Sanitary District.

The total area of the Sanitary District is at the present time 386.2 square miles. The original Sanitary District, that was up to 1903, was 185 square miles. The North Shore District of 78.6 miles was added at that time, as was what was known as the Calumet District amounting to 94.5 square miles, and under a recent act of the Legislature 28.1 square miles more have been added to it. This includes all of the City of Chicago, the area of which is a little over 191 square miles.

Map (Wisner's Exhibit 2, January 20, 1914, inserted on page opposite) was prepared under my direction. It is a map showing the land sections of Cook County, part of Du Page County, a part of Will County; and generally shows and was made to show the areas comprising the Sanitary District with its relation to the Chicago River and the main Drainage Canal. The part of the map which is tinted green is the original Sanitary District. The part lying to the north of this and tinted a brown is the area that was added to the Sanitary District by the Legislature in 1903; and the part lying to the south of the green tint and tinted brown is what is known as the Calumet Extension to the District, and was added in 1903.

The part tinted brown and lying west of the green tint is that which has been added to the District recently. The yellow tint shown upon this map indicates the branches of the Chicago River and the Main Drainage Channel extending to Joliet.

1604 The part tinted red, or red line, and marked Calumet-Sag Channel is the Calumet-Sag Channel which is now being constructed from the Little Calumet River, east of Blue Island to the present main drainage channel at the place marked Sag.

The Fullerton avenue conduit was built by the City of Chicago prior to the Sanitary District work, and is a conduit extending from Lake Michigan to Fullerton avenue and the North Branch; was installed for the purpose of flushing the North Branch.

The Calumet Sag Channel is a channel extending from the Little Calumet River just east of Blue Island to the Main Drainage Channel at the Sag, a distance of approximately 18 miles. It is a channel which is to have water 20 feet in depth, and through the rock sections is 60 feet in width, and through the earth sections generally 36 feet in width on the bottom, with side slopes varying from one vertical to two horizontal, to flatter slopes.

It is to have regulating and controlling works located at its eastern end, which will control the amount of water that can flow through it. Generally it is designed to carry 2,000 cubic feet per second at this time, but it is capable of progressive development so that it can ultimately be enlarged to carry at least 4,000 cubic feet per second. It was not done at this time for the reason that it figured cheaper to make this progressive development than to make a large initial investment, which would not be needed for some years to come.

At the present time, this work is under construction, there being nine contract sections awarded by contract averaging about a mile and a quarter long; there are about five more to be let within the next few months.

This canal will be navigable.

Cities, villages and towns located within the limits of the Sanitary District are Chicago, Evanston, Glencoe, Winnetka, Wilmette, Shermerville, Glen View, Morton Grove, Niles, Cicero, Stickney, Evergreen Park, Morgan Park, Blue

1605 Island, Riverdale, Oak Park, Berwyn, Forest Park, River Forest, Maywood, Riverside, Brookfield, Bellwood, Franklin Park, Melrose Park, River Grove, Dolton, Harvey, West Hammond, Worth, Bremen, Calumet, Kenilworth, Burnham.

The drainage area of the Chicago River basin is about 307 square miles. The run-off of the Chicago River basin in a dry season is practically the city water supply, and some little ground water, but at times of maximum floods it will reach as high as 10,000 cubic feet per second.

The inhabitants of the Sanitary District within the boundary of the Sanitary District have generally no available water supply other than Lake Michigan.

It would be impossible to supply the entire inhabitants of the Sanitary District with a good supply of water by any other means. There are a few wells in Chicago and the smaller places, which are used for that purpose; but it would be impossible to get sufficient water from a ground supply to supply the entire city.

Prior to the opening of the Drainage Channel to illustrate what the appearance of the Chicago River was, it is only necessary to say that practically the entire North and South branches were in the same condition as that part of the Chicago River known as Bubbly Creek is at the present time. It was a filthy, dirty sewage polluted water, in a septic condition, with gas bubbles rising; having large cakes of floating sewage mud. This mud was held at the surface by the gas being generated in it. A large percentage of the docks along the river were falling into the stream. The river was littered up with old worn out bridge protections which interfered with the passage of boats, and in fact often proved a menace to the boats, for the reason that the piles were rotted off below the surface of the water. Not only the appearance of the river was objectionable to the eye but the odors coming from it were objectionable to the nostrils; and at times of flood could be smelled for long distances. It was a disgrace to a civilized community at that time.

At times it flowed in different directions. The current was practically stagnant except in times of floods due
1606 to heavy rains, and the run-off of melting snows. Although the Bridgeport Pumping Works were operating, pumping between 40,000 and 50,000 cubic feet of water per minute out of the South Branch, this was so insufficient that it did not make any perceptible current; and often the current could be observed running towards the lake, due to the sudden drop of the lake level.

When the lake would rise, one might observe a current of water coming in from the lake, but generally the river was stagnant.

In times of heavy rains, this sewage polluted water was driven by the storm run-off into the lake, polluting the water supply. This was traced to several miles from shore, and went even beyond the present location of the Four Mile Crib.

On account of the lake rising and falling as stated above, large quantities of this sewage polluted water found its way into the lake and resulted in not only the river itself being objectionable to the eye and nose, but the lake at the mouth of the river was objectionable. It contained large quantities of sewage pollution for a considerable distance from the mouth of the river.

The opening of the Drainage Channel absolutely remedied this condition, so that at the present time there is no local nuisance in the Chicago River and the sewage does not get into the lake polluting the water supply at any place between the Calumet River and the south line of Evanston.

Up to December 31, 1912, $61,845,838 had been expended by the Sanitary District of Chicago and the City of Chicago for the construction of works now in operation. The works of the Sanitary District of Chicago include the Main Channel, North Shore Channel, and the various appurtenances necessitated, including bridges, the enlargement of the Chicago River, the diversion of the Des Plaines River, and the construction of flushing pumps. Those paid for by the City

1607 of Chicago include the intercepting sewers on the North and South Sides, the Lawrence avenue sewage pumping station, and also the sewage pumping station at Fullerton avenue and 39th street. The Sanitary District, as stated before, paid part of the construction of the 39th street station.

The 39th street pumping station and conduit, in taking water away from Lake Michigan has a capacity of 2,000 cubic feet per second, or 120,000 cubic feet per minute.

The Lawrence avenue pumping station has a capacity of 40,000 cubic feet per minute.

It is the intention to flow 8,000 cubic feet per second through the main river and the south branch to its junction with the South Fork of the South Branch, at which place will come an additional 2,000 feet from the 39th street pumping station, and from this junction of these two branches to the Main Channel, a flow of 10,000 cubic feet.

As stated before, this stretch of the river is wider than the river is east and north of Ashland avenue, and is fully capable of taking the 10,000 feet without creating a velocity of probably over a mile an hour.

The cost of the works built and paid for by the Sanitary District of Chicago and the City of Chicago, for the purposes of sanitation, with a rated capacity of 10,000 cubic feet per second through the Main Channel, and having a velocity in the Chicago River not to exceed a mile and a quarter per hour is $64,095,000.

This cost is made up of the amount expended by the Sanitary District on completed works, which has already been mentioned, and the expenditure by the City of Chicago for works already described, and for the work which has been practically finished during the last year, which is the widening of the eastern end of the present Main Channel, which have been spoken of before as being capable of progressive development; and also includes an estimate of the cost of completing the Chicago River widening to 200 feet. There yet remains four places where it is not quite com-

pleted; and certain other minor details, which go to bring this figure up to the amount stated.

1608 These costs have been taken from the books of the District and the City of Chicago. An allowance has been made for the actual interest on the bonds prior to the opening of the Main Channel in 1900, an estimated amount for interest during construction for works built by the District after 1900, and a proportion of the overhead charges of the District pro rated in accordance with the construction and maintenance expenditures. An allowance has also been made for the interest during construction on the city expenditures.

The following table gives in some detail the money that has been expended for different purposes and projects.

COST OF WORKS OF THE SANITARY DISTRICT OF CHICAGO AND THE CITY OF CHICAGO.

The Sanitary District of Chicago— To December 31, 1912.	
Right of Way,	$9,703,018.37
Construction of Main Channel and Controlling Works,	19,813,197.96
Bridges (Incl. Chicago R., North Branch and North Shore)	6,633,073.23
North Shore Channel and Wilmette P. Sta.	1,450,985.83
Rivers (Chicago River, River Diversion, and North Branch)	3,666,720.23
Flushing and sewers,	782,150.20
Joliet (Joliet Project, incl. bridges)	1,601,104.30
Administration, Engineering, Legal and Clerical Expenses (Excluding water power eng., and Calumet Sag and prorated M. & O. charge)	6,658,923.05

Miscellaneous (Illinois and Michigan Canal)	167,404.88	
Bond interest and Premium Acct. to Dec. 31, 1899, actual,	2,950,618.42	
Interest computed on construction carried on from Jan. 1, 1900, to Dec. 31, 1912, allowing equivalent one year at 4¼ per cent	737,697.42	
1609 Damages, Lands, Marine, personal	276,782.11	$54,441,676.00
Contract Work in 1913 and 1914.		
Estimated Overhead Expense	900,000.00	
Estimated Cost of Dredging	1,486,085.00	
Interest during construction 1 year at 4¼%	63,158.61	$ 2,249,243.61
	(Exhibit Cont.)	
	For	$56,690,919.61
The City of Chicago—		
Intercepting Sewers, Land, etc.	$5,312,024.74	
Fullerton Ave. Pumping Station	115,308.75	
Lawrence Ave. Pumping Station	452,635.65	
39th Street Pumping Station	944,143.98	
Estimated Interest during Construction — half period on four year basis	580,049.62	$ 7,404,162.74
		$64,095,082.35

The annual cost of the works for a diversion of 10,000 cubic feet per second is $508,832.09, including maintenance and operation, overhead charges and depreciation; and an allowance has been made for the receipts from rental.

This brings the total cost of a 10,000 cubic feet diversion project up to $76,067,582. This sum includes the annual cost

capitalized at 4¼ per cent and the original construction investment. The details are as follows:

M. & O. acct. 8,000 c. f. p. s.	$	210,036.99
1610 Estimated overhead		50,032.33
Depreciation:		
Main Channel, etc., as of 8,000 c. f. p. s.		265,030.68
Addit. investment ½ of 1% on $2,249,243.61		11,246.22
City Acct.		
½ of 1% on 6,414,440.88		32,072.20
5% on 409,672.24		20,483.61
	$	588,902.03
Less rentals		80,069.94
Annual		508,832.09
Capitalized at 4¼%		11,972,500.00
Investment		64,095,082.00
Corrected figures		$76,067,582.00

To December 31, 1913, about $2,080,000 has been expended on the Calumet-Sag Channel. This includes the construction of the channel, purchase of right of way, engineering, legal and real estate expenses; but no allowance for overhead or interest upon the money invested. The additional liability incurred on account of contracts that have been awarded is about $3,300,000. This brings the total amount of the liabilities up to about $5,380,000.

The estimated cost of the completed project is $14,290,000. This is made up of the items as given in the following table. This includes the construction of the channel for a capacity of 2,000 cubic feet per second, with controlling works, intercepting sewers to bring the sewage to the channel from the principal centers and for the sterilization of certain storm overflows, land, engineering and contingencies.

1611 CALUMET SAG CHANNEL

2000 C. F. P. S.

Canal Proper, incl. Eng. & Con.		$ 8,140,435.00
Contingencies 10%		814,043.00
Interest during Constr.—		
Allow for three years at 4¼% on	$8,954,478.00	1,141,695.00
Old Accounts—		
Main Channel Extension	458,082.50	
Bridges	179.08	
Engineering Expense	32,969.69	491,231.27
Interest on $491,231.27 1 year at 4¼%		20,877.33
		$10,608,282.53
Intercepting Sewer (1930) at 900 gals. P. Cap.	$1,468,045.00	
Pumping Stations (Bldgs. 1930 Eq. 1920	617,025.00	
Disinfection Plants	489,054.00	
Sewers account West Hammond, Harvey and Hegewisch	177,214.00	
Land	100,850.00	
	$2,852,188.00	
Eng. & Conting. 15%	427,828.00	
	$3,280,016.00	
Inter. during Constr.—		
Allow 3 years at 4¼%	401,802.00	3,681,818.00
Total cost		$14,290,100.53
Capitalized operating cost of Channel, etc		1,424,500.00
Capitalized operating cost sewers, etc., as of 1920		3,734,870.00
Total, Capitalized and Construction		$19,449,470.00

The capitalized operating cost of the channel is $1,424,500, and of the sewers that are to be constructed in connection with it $3,734,870, bringing the total capitalized cost and construction cost up to $19,450,000 in round numbers.

1612 The construction cost of the Calumet-Sag Project for a diversion of 4,000 cubic feet per second is estimated to bring the total construction cost of this channel when enlarged to 4,000 cubic feet per second up to $19,925,000. The capitalized operating cost would be, $6,229,000. The total capitalized cost and construction cost will be $25,729,000, in round numbers. The following is an estimate in detail, giving these figures:

CALUMET-SAG CHANNEL.

4000 C. F. P. S.

Cost of 2000 C. F. P. S. project,		$14,290,100.00
Additional to widen channel,		5,000,000.00
Interest during Constr., say 2 years at 4¼% ($200,000) (12,500)		425,000.00
Additional to bring equipment Pump Sta., etc., up to 1930.		
Pumping Sta.	$ 75,000.00	
Miscellaneous sewers, etc.	135,000.00	210,000.00
Total Construction Cost,		19,925,100.00
Capitalized Operating Cost (as of 1930)		
Total for sewer,		4,216,800.00
Total for channel,		2,012,740.00
Total Capitalized and Construction cost,		$25,729,640.00

The capacity of the Main Channel from the terminus of the Calumet-Sag Channel to the controlling works is 14,000 cubic feet per second.

The following is a table giving the costs for the different 1613 flows:

Flow Cu. Ft. Per Sec.	Investment of Construction cost	Annual Cost Operating Plus Depreciation	Capitalized Gross Cost
10,000	$64,095,082.00	$508,832.00	$76,067,600.00
+2,000	+14,290,100.00	+219,273.00	+19,449,470.00
12,000	78,385,182.00	728,105.00	95,517,070.00
+2,000	+5,635,000.00	+58,133.00	+7,002,840.00
14,000	84,020,182.00	786,238.00	102,519,910.00

The cost of the electrical development of the Sanitary District to December 31, 1912, was $5,349,241.57. This comprises the book account valuation of the electrical development of $5,047,625.57, plus an allowance made to have this cost comparable with the other costs for the purpose of our analysis, the allowance covering interest during construction, taken at 4¼% on the cost during construction for ½ the period during which these works were being built.

The following table gives the investment cost on the construction, the annual cost of operation and the gross capitalized and construction cost and the capitalized electrical credit; and this is subtracted in the last column from the gross capitalized cost. The allowance for the income coming from the electrical department is based on the value in the Chicago market for electric energy used for commercial purposes; and is based on what could be developed over that which could be developed with a flow of 4,167 cubic feet per second.

The present electrical plant and equipment is sufficient to generate the energy coming from the flow of 14,000 cubic feet per second, with the possible exception that one electrical water wheel unit would have to be installed, provision for which has been made.

1614 NET CAPITALIZED COST DILUTION SCHEME.

Flow Cu. Ft. per Sec.	Investment or Construction	Annual Cost Operating Plus Depreciation	Capitalized Gross Cost	Electrical Credit Capitalized	Net Capitalized
10,000	$64,095,082.00	$508,852.00	$76,067,600.00	$13,242,000	$62,825,600
12,000	78,385,182.00	728,105.00	95,517,070.00	17,790,000	77,720,970
14,000	84,020,182.00	786,238.00	102,519,910.00	22,306,000	80,213,900

Since the sewerage system was started to be installed in 1855, the City of Chicago has expended, up to December 31, 1912, $31,867,268.68. This is exclusive of any intercepting sewers. The sewer systems in the outlying villages and towns up to an average period of 1911, had cost $5,246,764.16.

The water supply system of the City of Chicago up to December 31, 1912, had cost $49,948,318.06. The water supply system of the outlying villages and towns within the Sanitary District, so far as the same can be obtained, has cost about $2,000,000 for five towns out of seventeen outside of Chicago, but inside the Sanitary District. No allowance is made for interest during construction in these figures. Adding the expenditures of the Sanitary District as given above, brings the total amount expended for water supply and sewage disposal up to the total sum of $150,908,189.64. If all charges could be obtained and the methods of work known, this figure would be materially increased.

The purpose of the works of the Sanitary District of Chicago is to provide for the proper and efficient sewage disposal, and to protect the water supply from pollution; and in so doing to so dilute the sewage that local nuisances will be prevented within the corporate limits of the Sanitary District; and to dilute this sewage with a minimum flow of 3⅓ cubic feet per second for every 1,000 people sewering into the channels of the District, so that nuisances will
1615 be prevented in the Des Plaines and Illinois Rivers below the end of the works of the Sanitary District.

For the disposal of the domestic sewage, 3⅓ cubic feet per second per thousand people draining into the channel is sufficient.

The effect of the flow through the Main Channel is to dilute the sewage coming from the Sanitary District to such an extent that it avoids all local nuisances in the Main Channel itself, and in the Des Plaines and Illinois Rivers. It flushes out the Chicago River, and the Des Plaines River from Joliet to the Illinois River is thoroughly flushed under summer conditions; whereas, formerly there was practically no flow in the Des Plaines River north of the junction of the Kankakee and the Des Plaines. This continued for many months in the year.

In the Illinois River, the effect has been to produce a constant flow, and it has improved the conditions of the water of the Illinois River all the way to the Mississippi River, over what it was under summer conditions.

The effect has also been to improve the navigation in the Des Plaines and the Illinois Rivers, by increasing the dry weather flow and giving greater depths. This also, as stated, has improved the sanitary conditions, by affording increased dilution for the cities and towns sewering into the river below Chicago.

The value of the water powers on the Illinois River has also been increased, by increasing the flow.

The value of the fish and mussel industry in the Illinois River has materially increased since the opening of the
1616 Main Channel. In my opinion this improvement is almost wholly due to the maintenance of a cleaner condition of the river, and the additional food furnished by the products of the self-purification of the stream for supporting fish life.

The fishing industry has gradually increased in value. The figures given in the special report of the United States census for 1908, on the Fisheries of the United States show that the fisheries in the Illinois River have grown as follows:

Year	Tons	Value
1894	3,000	$162,000
1899	7,000	382,000
1908	23,000	860,000

Besides the growth of the fishing industry, there has been a great increase in the mussel industry. The mussel shells are used for making buttons. This is shown by the following table, taken from the special report of the United States census, 1908:

Year	Tons	Value
1894	24	$ 700
1899	2,500	43,000
1908	20,000	184,000

And in that time there was also $170,000 worth of pearls taken from these mussels. From the investigations of the Sanitary District, it appears probable that the amount of fish now caught exceeds the figure given by the census of 1908.

The conditions in the Chicago River prior to the opening of the canal have been described. The Illinois River was a slow, sluggish stream in the summer time, having a very small discharge, and in times of run-off of melting snows and heavy rains, the discharge was quite voluminous. The condition of the river was that it was a polluted stream, particularly below Peoria where the sewage from Peoria and the wastes coming from the distilleries polluted the water to such an extent that it was practically a nuisance. From a navigation standpoint there was some little navigation maintained by dams, which produced slack water, and it was generally navigable from Utica to the Mississippi.

1617 Since 1909 regular examinations, both chemical and bacteriological of the waters of the Illinois River, showing the effects of the Drainage Canal upon the Des Plaines and the

Illinois Rivers have been made, and it shows that the waters are in good shape from the standpoint of the oxygen content below Marseilles. This has been carried on continuously for the last several years.

The same investigations have been made in the Main Channel, in regard to the condition of the combined sewage and fresh water, by having the water analyzed regularly. Up to the present time pretty nearly all of the manufacturing wastes from the city have been going into the sewage and channel without any preliminary treatment. There has been some slight treatment by means of removing part of the settling solids from certain industries. The result has been that there has been large accumulations of deposits in certain parts of the channel, where at times in the hot weather local nuisance is present; but the condition is now so much better than it was prior to the opening of the canal, which parallels the old Illinois and Michigan Canal, which prior to 1900 ran its capacity full of septic sewage, water and mud, so that the improvement down the Des Plaines Valley has been considerable, but at the same time there has not been sufficient water to take care of and properly oxidize both the domestic sewage and the manufacturing wastes, coming from the large industries in this city. There are large deposits of sewage mud in the Main Channel from the end of the narrow earth section that I have spoken of to Willow Springs where the rock section starts. There is practically no sludge deposits in the rock section until Lockport is reached, where the Main Channel was widened out for the purpose of making a basin at the controlling works, and in the stretch of the new channel built for the development of water power. In these stretches of the channel, there have been big deposits which in the summer time produce gas and are in a fair way to make a local nuisance. In the vicinity of the controlling works, odors are at times perceptible. This is where the deposits occur principally.

1618 The flow in the Main Channel in the last few years has been practically what is called for by the law, but prior

to that it was not up to what was called for by the State law, for the reason that the Chicago River had not been improved and the District was restrained by the Secretary of War from causing a current in the South Branch of the River to exceed a mile and a quarter an hour. For that reason, the flow in the early years of the canal was not what it should have been or what was called for by the state law; that is 20,000 cubic feet per minute for every 100,000 people draining into the channel.

The following tabulation shows the population within the limits from year to year between 1900 and 1913, and the average daily flow in cubic feet per second based on the population as provided by the state law.

Year	Population Based on U. S. Census		Average Daily Flow in Cu. Ft. per Second Population Basis	
	Within Limits S. D. C.	Actually Tributary M. C.	Total	Actual
Original Limits				
1900	1,638,656	1,294,312	5462	4314
1901	1,690,874	1,331,119	5636	4437
1902	1,740,129	1,364,961	5800	4569
1903	1,789,593	1,399,014	5965	4663
Territory Annexed				
1903	1,933,694	1,543,115	6445	5144
1904	1,987,205	1,581,376	6624	5271
1905	2,040,717	1,614,228	6802	5381
1906	2,094,228	1,887,605	6981	6292
1907	2,147,740	1,933,176	7159	6444
1908	2,201,250	1,978,744	7337	6596
1909	2,254,763	2,091,015	7516	6970
1910	2,308,276	2,139,787	7694	7132
1911	2,361,788	2,188,524	7872	7295
1912	2,415,300	2,237,330	8051	7458
1913	2,468,811	2,285,993	8229	7619
Territory Annexed				
1913	2,498,660	2,285,993	8329	7619

1619 In the early part of 1908, the water power plant was installed, and the only way of measuring the water that went through the canal was to use the water wheels as a meter. These wheels had been tested in a flume at Holyoke, by which in an approximate way we could get at their discharge under different gate openings.

Recently it has appeared that these discharges are somewhat small. This is based upon measurements made and some that have been submitted by the United States Government.

The amounts shown to have been discharged through the Main Channel of the Sanitary District in the last column, includes lake water, sewage and storm water and everything that passes through the end of the canal at Lockport.

The hygienic improvement in the Chicago water supply due to the opening and operation of the Main Channel and its appurtenances was very marked after all the sewage had been diverted from the lake. The intercepting sewers were not wholly completed until 1910, but were practically completed on the south side in 1906 and on the north side in 1908. Since that time, the reduction has been more marked in the typhoid fever death rate, so that today the water supply from the criterion of typhoid fever death rate compares very favorably with other large cities in the United States and in Europe. The typhoid fever death rate is lower than in many cities having filtered water supplies. In 1912, Chicago's typhoid fever death rate was 7.5 per hundred thousand. From 1909 to 1912, the typhoid fever death rate in Chicago was lower than that of Pittsburgh, Philadelphia,
Washington and New Orleans, all of which have filtered
1620 water supplies. The rate was also lower in Chicago than
in other cities having filters; namely, Albany, Atlanta, Birmingham, Columbus, Grand Rapids, Indianapolis, Louisville, New Haven, Oakland, Providence, Scranton and Toledo.

The following table shows the total population located in Chicago, the north shore towns and the Calumet district, which drains its sewage into the lake:

After the opening of the Main Channel, January 17, 1900.

POPULATION DISCHARGING INTO LAKE MICHIGAN INSIDE PRESENT SHORE LINES OF THE SANITARY DISTRICT.

Year	Total	Between 87th Street and South Boundary of Evanston
1900	344,344	223,625
1904	405,829	265,940
1905	426,489	281,708‡
1906	206,623	57,100
1907	214,564	60,300
1908	222,506	63,500†
1909	163,748	0
1910	168,489	0
1912	177,970	0

‡39th Street pumping station district diverted in 1905.

†Lawrence Avenue pumping station district diverted in 1908.

And this lesser number from year to year, as indicated upon this table, of population discharging into the lake and within the present shore lines is due to the fact that intercepting sewers were opened from time to time, and the sewage of the population discharged into the Main Channel where it is tributary to the Sanitary District.

The third column of the table shows the population between 87th street in Chicago on the south and Evanston on the north, that has drained into the lake since the opening of the channel.

The second column shows the total including Evanston and the Calumet District.

1621 And prior to 1900, all of the sewage substantially was drained into the lake, with the exception of what was pumped through the old Illinois and Michigan Canal.

The effect of the sewage from the towns in Lake County, Illinois, is practically nil on the water supply of Chicago. These towns include Highland Park, Lake Forest and Waukegan. There are no currents in Lake Michigan, other than

varying drifts produced by the wind. The sewage discharge in Lake County nearest the Lake View crib is over 16 miles away. The population is small, so that the protection to Chicago by dilution probably suffices for many years to come. The danger is to the water supply of the villages themselves more than to the City of Chicago proper.

The effect of the sewage from the towns in Lake County, Indiana, on the water supply of Chicago, as taken from the 68th Street or the Dunne Crib is largely influenced by the condition of the Calumet River, into which these towns discharge a part of their sewage. Flood discharges will heavily pollute the water of the lake around the crib. In drier weather, pollution may occur with sudden rains. The pollution has been traced eight to ten miles into the lake.

The district is taking steps now to reverse the Calumet River and to keep the sewage coming from the Sanitary District out of it, so that in times of flood the water in the river will not be polluted with sewage. It is also negotiating with the Indiana towns to get them to remove or purify their sewage before it enters the lake or the Calumet River, to such an extent that it will be non-putrescible.

The typhoid fever death rate shows that the quality of the Chicago water supply is excellent from a hygienic standpoint, and is far purer than most of the larger municipal supplies in the United States.

1622 The 68th Street and Dunne cribs on the south, and the Lake View crib on the north are, however, exposed to possible pollution and on the north on account of Evanston not having diverted its sewage as yet. The effect on the Chicago water of outside pollution from the north of the Cook County line is very remote. Pollution from the Calumet region in Indiana is very intermittent, but may be severe in its effect on the 68th Street and Dunne cribs.

The effect of pollution coming from passenger vessels and other vessels is being minimized by the action of the city in keeping the vessels away from the intakes, and to have the

closets locked, or tanks to store the sewage in while the vessels are passing in and out of the harbor. The shipping factor is particularly of moment in the summer months. This chiefly affects the cribs at the mouth of the Chicago River.

In the recent storms, this fall, the water supply of the city has been extremely turbid at times and in consequence the newspapers have quoted the Health Department as advising the boiling of the water. The condition of the water and the attitude of the Health Department was investigated by the Engineering Department. The records of the analysis made by the Health Department laboratory shows practically no difference in the hygienic quality of the water on account of the storms. The turbidity or aesthetic appearance of the water was, however, unsatisfactory. The Health Commissioner, Doctor Young, and his laboratory director, Doctor Tonney, both admitted advising the boiling of the water in an informal way to the newspaper men, but stated that this was a precautionary measure only, inasmuch as it is impossible to learn the quality of the water by immediate tests. The bacteriological tests employed do not give results until after 48 hours have elapsed. Their opinion was the same as ours, that only the appearance of the water had been injured by recent storms, and that the hygienic quality of the water was unimpaired, rendering boiling unnecessary.

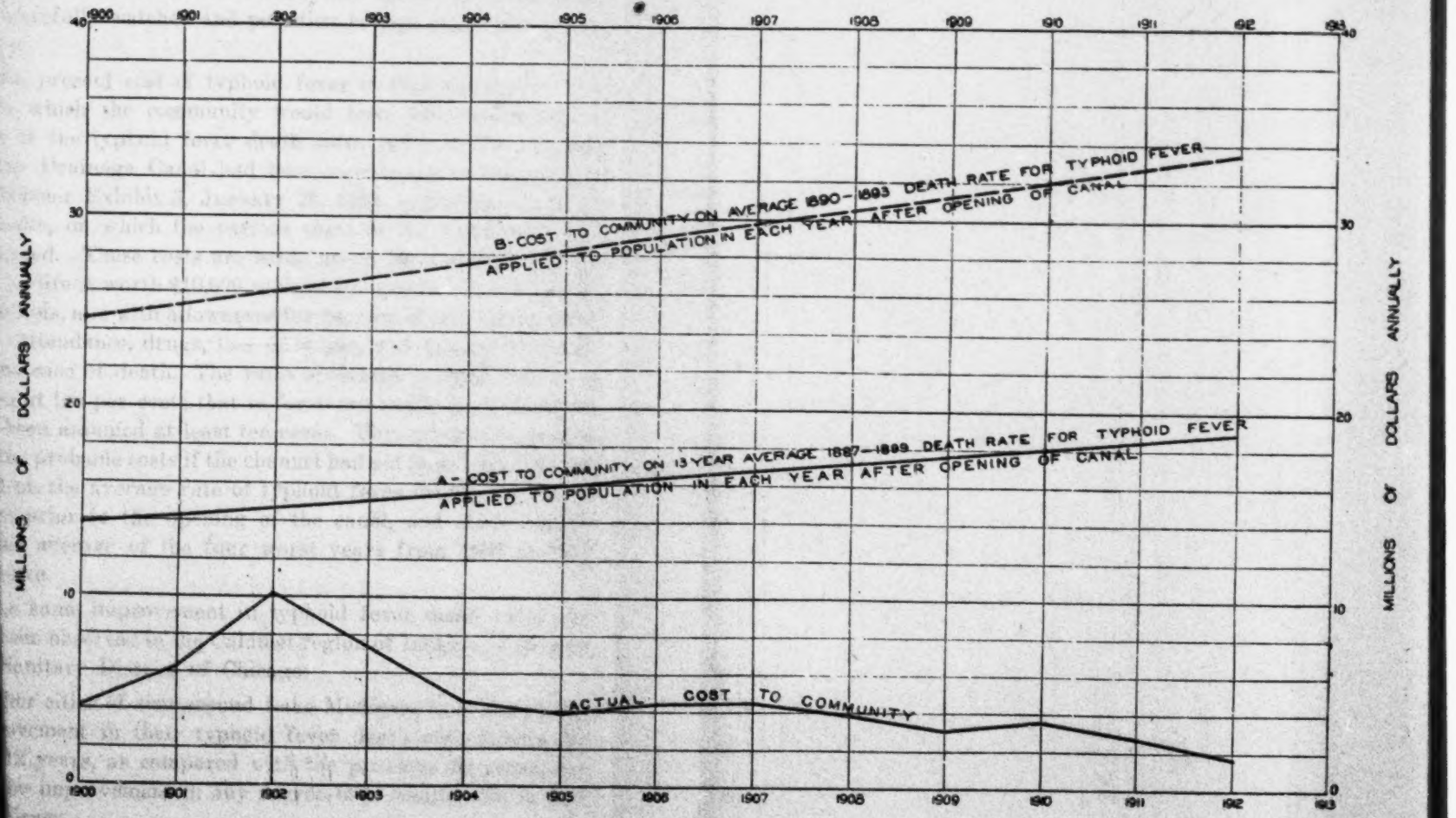
1623 For 13 years prior to the opening of the Drainage Canal, the average typhoid fever death rate was 52.6 per one hundred thousand. For the 13 years after the opening of the canal, the death rate was 19.9 per one hundred thousand. This reduction is about 68 per cent, and would have been more marked had the sewage been intercepted completely earlier in the last 13 years.

The average death rate for the diarrhoeal diseases for the period before the opening of the Drainage Canal was 418.2 per one hundred thousand. This was reduced to 187.2, a reduction of 55 per cent.

Wisner Exhibit 3, January 20, 1914.

THE SANITARY DISTRICT OF CHICAGO

CHART SHOWING SAVING TO COMMUNITY BY REDUCTION OF TYPHOID FEVER SINCE OPENING OF DRAINAGE CANAL JANUARY 2. 1900.



The typhoid fever death rate in Chicago has been reduced markedly, even compared with the reductions affected in cities where filtration plants have been installed. The rates for 1911 and 1912 were lower than the rates in the cities of Philadelphia, Washington, Pittsburgh, and New Orleans, where filtered water is supplied. They are as low as in Boston and lower than San Francisco where the water sheds are carefully watched and pollution is kept out of the reservoirs.

The present cost of typhoid fever to this community, the costs which the community would have been called on to bear if the typhoid fever death rates prior to the opening of the Drainage Canal had been maintained is best shown by Wisner Exhibit 3, January 20, 1914, appearing on page opposite, on which the various costs to the community are indicated. These costs are made up on the assumption that a life is worth $10,000 as fixed by certain statutes in Illi-
1624 nois, and with allowances for the cost of nursing, medical attendance, drugs, loss of wages, and funeral expenses in the case of death. The ratio of deaths to cases has been taken at ten per cent; that is for every death reported there has been assumed at least ten cases. Two curves are plotted for the probable costs if the channel had not been built, one figured on the average rate of typhoid fever deaths for the 13 years prior to the opening of the canal, and other figured on the average of the four worst years from 1890 to 1893 inclusive.

The same improvement in typhoid fever death rates has not been observed in the Calumet region of Indiana, adjoining the Sanitary District of Chicago.

Other cities of size around Lake Michigan have not shown improvement in their typhoid fever death rate during the last 12 years, as compared with the previous 20 years, nor has the improvement in any degree been comparable to that in Chicago.

In Milwaukee, for instance, the typhoid situation has been practically unchanged for over 30 years, the rate at times

being practically as high as 30 years ago. The improvement in Chicago has been very favorable. In Michigan City, a city of 19,000 people in 1910, the typhoid rate has been high, with violent fluctuations, extending over a range of from nothing to 112 deaths per one hundred thousand between 1882 and 1907.

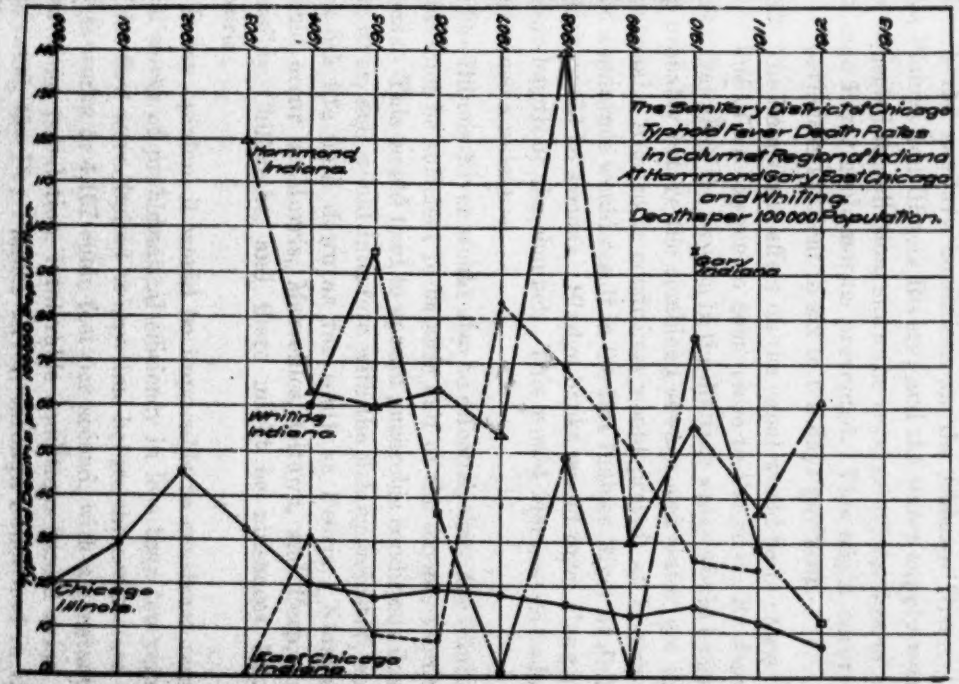
The same improvement in typhoid fever death rates in the towns in Indiana, adjoining Illinois, has not been ob-
1625 served. The current typhoid fever death rates are shown on Wisner Exhibit 4, January 20, 1914, appearing on page opposite.

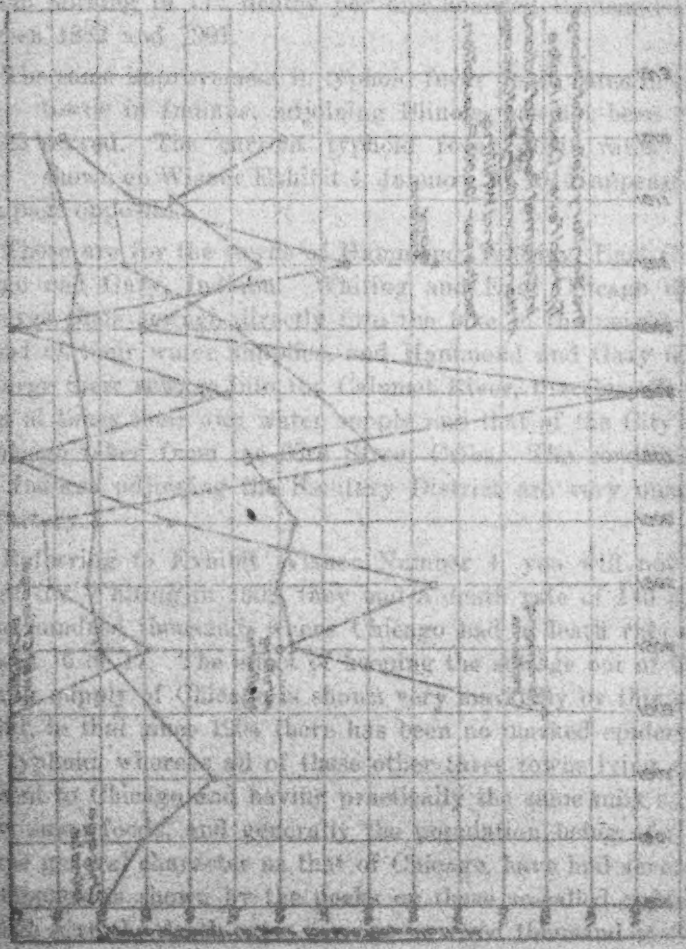
These are for the towns of Hammond, Whiting, East Chicago and Gary, Indiana. Whiting and East Chicago discharge their sewage directly into the lake in the neighborhood of their water supplies, and Hammond and Gary discharge their sewage into the Calumet River, thereby affecting at times their own water supply and that of the City of Chicago taken from the 68th Street Cribs. The conditions in Indiana adjoining the Sanitary District are very unsatisfactory.

Referring to Exhibit Wisner Number 4, you will notice that for Whiting in 1908, they had a death rate of 140 per one hundred thousand, where Chicago had a death rate of about 16 or 17. The effect of keeping the sewage out of the water supply of Chicago is shown very markedly by this exhibit, in that since 1904 there has been no marked epidemic of typhoid, whereas all of these other three towns lying adjacent to Chicago and having practically the same milk supply, same foods, and generally the population being of the same general character as that of Chicago, have had several epidemics as shown by the peaks on these so-called curves, which give the death rates per one hundred thousand of the people living in these towns.

Since 1902, Chicago has had nothing that represents an epidemic, and the line from 1904, the solid line on this exhibit, which represents the death rate from typhoid fever in

Wisner Exhibit 4.





Chicago, has been gradually going down, showing a decrease in the typhoid fever death rate.

The effect of a diversion of only 4,167 cubic feet per second would injure the quality of the water supply and seriously disturb the sanitary conditions in the Chicago River, the Des Plaines and Illinois Rivers; and the water supply would be subjected to pollution, since the reversal of the flow of the Chicago River could not be prevented. This might occur on periods equivalent to six to ten days per year.

1626 The immediate effect on the canal would be to cause the line of no oxygen to come close to the city. By that I mean that all of the oxygen in the diluting water would be used up probably before the combined sewage and water got into the canal. Anaerobic conditions would prevail at Lockport, and a nuisance would result in the Des Plaines River at Joliet which would be serious. Sludge banks would form along the whole length of the channel. This would increase the odors and cause a nuisance.

The Illinois River would also be affected, since the dilution would not be sufficient to balance half of the oxygen requirements. This would tend to spread anaerobic conditions down the river, and would interfere with the fishing industry, ending fish life until down as far south as Peoria. Nuisance would occur at Morris, Marseilles, Ottawa, and Peru, and possibly Chillicothe, and there might be nuisances below Peoria.

In my opinion, it would be impossible to construct remedial works of problematical efficiency in less than ten years. If the flow were limited at any time before the completion of these works to 4,167 cubic feet per second, with a constantly increasing population, intolerable conditions would arise in the canal, the Des Plaines River, through Joliet and in the Illinois. Conditions in large portions of the Chicago River proper would be a living nuisance. Sludge would accumulate in the Chicago River.

In times of high water when the river was reversed as just mentioned, this accumulation of sludge would probably be scoured into the lake, polluting the water supply with the sewage polluted water of the river itself.

Assuming that the flow were reduced at once to 4,167 cubic feet per second, there is no thoroughly satisfactory emergency treatment. If the flow were continued in accordance with the minimum ratio of 3 1/3 cubic feet per second, a double expense would be thrust upon the Sanitary District, as it would have to develop the canal to a capacity of 12,000 cubic feet per second before the other works could be put into service.
1627 The only suggestion would be the use of an excessive amount of chloride of lime. This would be unsatisfactory, as the sludge would still go into the river and create nuisance, and in addition would be very costly. Time would be required to install emergency works on such a large scale.

The daily floating population by 1920 in Chicago will be 300,000 people. There is today a transient population of 68,000,000 in the course of a year, including through and local travellers from outside the boundaries of the district, who may be assumed to come in contact with conditions in the City of Chicago.

The records obtainable from the different railroads coming into Chicago were obtained and these figures compiled from figures given to us; and also from steamship companies.

The people were counted coming into the stations for a certain length of time to get an estimate of the number of people where the railroad companies had no sufficient data at hand.

The probable population of the Sanitary District in the years 1920, 1930 and 1940 is based on the United States census reports, and upon the probable growth of the city in the future as based upon what it and other large communities have done in the past.

The amounts of water required for the population based upon the minimum legal flow for dilution and compilation with reference to future population are as follows:

Year	Population	Flow required in Cu. Ft. per. second
1910 Actual	2,308,276	7694
1920	3,110,036	10367
1930	3,866,023	12887
1940	4,466,000	14900

1628 The available methods for the sewage disposal of large cities comprise dilution, screening of the sewage, sedimentation, which is removal of the settling suspended matter by settling in various types of tanks, chemical precipitation, broad irrigation or land irrigation, intermittent filtration, contact beds and sprinkling filters. These methods may be used in combination, according to local circumstances or conditions. Sterilization by the use of chloride of lime, or liquid chlorine, may also be used on raw sewage and effluents of treatment works.

Screening is useful principally to remove coarse floating material. Sedimentation may remove most of the settling suspended matter, and improve the stability of the liquid from 15 to 25 per cent. Chemical precipitation will remove somewhat more of the settling suspended matter and some of the colloidal matter. In order to make a stable effluent after the suspended matter has been removed, treatment to oxidize the organic matter is required. This is frequently carried out in bacteria beds or biologic filters. Such processes include broad irrigation, intermittent filtration, contact beds and sprinkling filters. These methods, however, are not all equally practicable.

The methods of broad or land irrigation and intermittent filtration require very large areas of land. In the United States, broad irrigation is practically abandoned, save in the

arid regions, where it is of value principally for the water rather than for any other purpose. Intermittent filtration is not now installed for large cities, but is considered practicable for small towns under 10,000 population, where sand is cheap and land valuable. Sprinkling filters and contact beds are more practical for large cities as a larger population can be taken care of on smaller areas. Of these two, the sprinkling filter is most economical and efficient, as a rule.

The dilution method, by the use of the main channel and a supply of water from Lake Michigan, is the most economical and efficient, the surest and the most effective, in that it diverts all the sewage from the water supply, and 1629 works automatically; is not dependent upon any individual or individuals for its efficiency; and permits of self-purification of the sewage in the ordinary and natural way.

For handling the sewage of the Sanitary District in case the flow required by the legal ratio is restricted, settling would be the first step to bring about the removal of settling suspended matter. This could be followed by the use of sprinkling filters to produce a stable effluent, as required. Secondary settling basins would probably have to be used to remove the humus formed in the sprinkling filters. Sterilization by chloride of lime or liquid chlorine might be utilized on storm flows and sewage effluents as required by circumstances.

No allowance has been made for the industrial load, as it is recognized that whatever happens the industrial sewage would have to be cared for in any case. This means that the cost of handling the industrial sewage would be additional to all of the comparative estimates submitted. This has been recognized by the Board of Trustees, and special studies are now being conducted by the engineering department of the District to determine the methods of treatment for the industrial wastes, principally for those of Packingtown and the Stock Yards, and for the tanneries.

The dry weather sewage flows vary from 170 to 600 gallons per capita. An average flow of 300 gallons, about,

per capita, has been estimated from a study of the flows actually found on various typical areas by gagings made by the Sanitary District of Chicago. The storm flows vary considerably. Maximum storm flows have been found from 50 to 70 cubic feet per second per square mile on areas of some size, with a maximum of 128 cubic feet per second per square mile on small well built areas. Intercepting sewers planned for a flow equivalent to 900 gallons per capita daily are required to care for the first rush of storm flows, and the minor storms.

1630 Assuming that 4,167 cubic feet per second of water are available from Lake Michigan for dilution, the cost to the Sanitary District for handling population equivalent to diverted flows amounting to 10,000—12,000 and 14,000 cubic feet per second by means of these additional works are given in the following table:

COST OF CONSTRUCTION FOR SEWAGE TREATMENT ON ASSUMED DIVERSION OF 4167 C. F. P. S.

Items	Equivalent to Diversion of 10,000 c. f. p. s.	
Population Distribution Treatment		Net Load in Population.
Lawrence Ave,		997,000
West Side,		0
39th Street,		944,000
Calumet,		207,085
Dilution	1,562,500	
Less Floating,	300,000	
	1,262,000	
Less Factor Safety	362,000	
Net	900,000	900,000
		3,048,085

Costs	
Lawrence Ave.	$17,595,582.00
West Side,	7,170,045.00
39th Street,	17,549,206.00
Calumet,	5,106,957.00
Storm Water Disinfection,	1,545,988.00
Domestic Sewage Disinfection,	600,000.00
Aeration,	1,065,000.00
North Shore,	1,192,280.00
Public Utilities,	3,453,570.00
Paving,	365,843.00
	$55,644,471.00

1631 Forward,	$55,644,471.00
Interest during Construction, 21-1/4%	12,500,000.00
Legal and Administration, 10%	4,740,000.00
	$72,884,471.00

Population equivalent to a diversion of 12,000 c. f. p. s.,	3,600,000.
Population Equivalent to a diversion of 14,000 c. f. p. s.	4,200,000.

Cost Pro-rated from Cost for Equivalent to Diversion of 10,000 C. F. P. S.

Pro-rated for increase of population from 3,000,000 to 3,600,000 equivalent to a diversion of 12,000 c. f. p. s.	$87,200,000.00
Pro-rated for increase of population 3,600,000 to 4,200,000 equivalent to a diversion of 14,000 c. f. p. s.	101,900,000.00

No allowance has been made for the cost of the existing works in this table. The total costs of the projected works on the allowance of 4,167 cubic feet per second, added to the existing works, is given in the following table:

COST OF WORKS FOR SEWAGE DISPOSAL COMBINING COST OF NEW TREATMENT WITH EXISTING INVESTMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Construction Cost of New Works	Construction Cost Existing Works	Total Construction Cost
10,000	$72,884,471	$64,095,082	$136,979,553
12,000	87,200,000	64,095,082	151,295,082
14,000	101,900,000	64,095,082	165,995,082

The annual cost for sewage treatment is shown on the table as follows:

1632 ANNUAL COSTS FOR SEWAGE TREATMENT ON ASSUMED DIVERSION OF 4167 C. F. P. S.

Item	Basis 10,000 C. F. P. S.
1. General Expenses,	$30,000.00
2. Sewers,	23,000.00
3. Pumping Stations, 4910 W. H. P. at $350	1,820,000.00
4. Sedimentation at $0.15 per capita,	456,000.00
5. Sprinkling filters at 0.10 per capita,	214,800.00
6. Aeration at 0.08 per capita,	171,840.00
7. Disinfection,—	
Storm Sewage,	433,800.00
Domestic Sewage,	370,000.00
	3,519,440.00
8. Depreciation,	1,182,157.00
Total,	$4,701,597.00
9. Pro-rated for increase of population from 3,000,000 to 3,600,000 equivalent to a diversion of 12,000 c. f. p. s.	5,650,000.00
10. Pro-rated for increase of population from 3,600,000 to 4,200,000 equivalent to a diversion of 14,000 c. f. p. s.	6,590,000.00

This scheme contemplates the construction of intercepting sewers based on a dry weather flow of 300 gallons per capita per day, carrying flows up to 900 gallons per capita per day to Central points for treatment. Above this amount, the storm flows would be discharged into the Chicago River or Calumet River, with sterilization; special tanks being provided to give a contact of 10 minutes on flows based on the maximum peak discharges. Coarse screens and grit chambers are contemplated, with facilities for cleaning. Set-
1633 tling basins are also to be built of the double deck type for dry weather flow, with capacity up to 900 gallons per capita. Sprinkling filters are estimated for the excess population which cannot be cared for by the extended use of settling tanks. The estimates include the sterilization of all the sprinkling filter and settling tanks effluents before being discharged into the Chicago River or the Canal. The double deck tanks would be designed on a basis of two hours retention of 300 gallons per capita daily in the settling chamber, and six months retention of sludge. The sprinkling filters would be designed on a basis of 12,500 people to the acre, the filters being assumed to be 6 feet 4 inches in depth of filtering stone. Secondary settling tanks are to be used for the filters, nominally of half the size of the primary settling tanks.

The estimates given are based on the current cost of sewer construction in the City of Chicago, due allowance being made for the probable character of the work, the cost of labor and material, and the character of the excavation to be made. The cost of the pumping station is based on $500 per water horsepower, the amount being adjusted slightly to scale down for the larger installations. Such costs are based on the known cost of the existing pumping stations in the city of Chicago. The cost of the settling tanks and appurtenances is based on careful estimates made from detailed drawings for a unit plant designed to care for 40,000 people. The appurtenances include a Venturi Meter, grit chamber, sludge drying beds, office building, laboratory, walkways, roadway,

electric lighting, and the general appurtenances required. The cost of land has been estimated from actual cost of land purchased by the District for its right-of-way for channels, and current sales of real estate in the City of Chicago. In each case, an allowance has been made for the probable increase in future costs.

1634 The annual cost includes an allowance for labor, repairs and supplies for the operation of the grit chamber, settling basins, sprinkling filters, secondary settling basins, the cost of labor and supplies for the disinfecting plants; the cost of labor, fuel, supplies, and repairs for the pumping stations; depreciation on all structures; interest during construction at 4¼ per cent for the entire construction cost for one-half the period estimated for construction. The allowance however made on land is the interest on the cost for the entire period. In the making of the estimates for sterilization, chloride of lime has been used as a sterilizing agent for the effluent of settling basins and sprinkling filters, whereas liquid chlorine has been estimated for handling the storm flows, in order to have available a large potential supply of chlorine for immediate use on sudden storms.

The capitalized cost of the foregoing schemes, including in capitalization the construction cost, as well as the capitalized cost for maintenance, operation and depreciation are given in the following table:

CAPITALIZED COSTS OF SEWAGE TREATMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Construction Cost	Capitalized Operating and Depreciation Cost	Gross Capitalized Cost
10,000	$72,884,471	$110,625,800	$183,510,271
12,000	87,200,000	132,941,100	220,141,100
14,000	101,900,000	155,058,800	256,958,800

These costs are supplemental to the present expenditures made by the Sanitary District which have been given as construction and operating costs.

The combined total costs, covering construction and capitalized annual maintenance and depreciation, combining the existing investment of the District with the investment required to produce with a reduced flow of 4,167 cubic feet per second the equivalent of conditions of flow of 10,000—12,000 and 14,000 cubic feet per second are given in the following table:

1635 CAPITALIZED COST OF SEWAGE DISPOSAL COMBINING COST OF NEW TREATMENT WITH EXISTING INVESTMENT BASED ON DIVERSION OF 4167 C. F. P. S.

Treatment Equivalent to Diversion of Cu. Ft. per Sec.	Capitalized Cost New Works	Gross Capitalized Cost of Existing Works to Dec. 31, 1913	Total Gross Capitalized Cost
10,000	$183,510,271	$76,067,600	$259,577,871
12,000	220,141,100	76,067,600	296,208,700
14,000	256,958,800	76,067,600	333,026,400

Studies have been made of receipts from taxes in the past by the Sanitary District, and a study has been made of the probable increase in the taxable value of property within the Sanitary District, so as to estimate the amount of bonds that can probably be issued by the Sanitary District, and from these have estimated what the highest possible income could be up to 1925, by issuing all of the bonds it is possible to issue, and getting all of the money from general taxation that it is possible to get, and the amount available from 1914 to 1925 inclusive would be $54,729,000 approximately.

There has been compiled from the books of the District and from estimates the probable investments required in the next ten years to cover extraordinary repairs and to settle obligations on contracts, assuming that all existing contracts for construction are terminated on December 31, 1913. This includes the amounts necessary to complete the North Shore and Evanston intercepting sewers, to improve the Des Plaines River in the territory recently annexed, to adjust the conditions in the North Branch of the Chicago River, to build cer-

tain docks in the Main Channel, repair walls at Lockport and Joliet, and to carry a share of the expense of handling the industrial wastes. This amounts to $11,577,000. This
1636 would be deducted from the available resources given, thus reducing the net amount available for new works to $43,152,000 approximately.

It would not be possible to finance this plan with the net revenue available within ten years. Not only would the construction costs have to be met, but also certain operating costs, as parts of the works were finished and put into service.

1641 A diversion up to the full capacity of the rock section, viz.: 14,000 cubic feet per second is the most economical way of developing the resources of the Sanitary District for sewage disposal and is shown by the following table which shows the amounts which would have to be expended by the Sanitary District under the different alternative methods, first of dilution, and second of treatment, to produce approximately the same result in the treatment of the sewage. This scheme for treating the sewage with a diversion of 4,167 cubic
1642 feet per second, and the use of the supplemental works, is not as effective in protecting the water supply as the diversion of from ten to 14,000 cubic feet per second.

COMPARISON OF CAPITALIZED COST TO SANITARY DISTRICT FOR EQUIVALENT DIVERSIONS OF 10,000, 12,000 AND 14,000 CU. FT. PER SEC.

Existing Works plus Treatment on Basis of Diversion 4167 Cu. Ft. per Sec.	vs.	Extension Dilution from 10,000 to 14,000 Cu. Ft. per Sec.

Equivalent Diversion of Cu. Ft. per Sec.	Existing Works with 4167 C. F. P. S. Plus Treatment	Extension of Dilution, Gross	Extension of Dilution, Net*
10,000	$259,577,871	$76,067,600	$62,825,600
12,000	296,208,700	95,517,070	77,720,070
14,000	333,026,400	102,519,910	80,213,900

* This allows credit for Electric Dept. earnings.

As to the efficiency of the various methods of sewage treatment, the factors taken into consideration, in reaching the above conclusions are:

One factor is that of the known methods in 1887-1890, and even up to 1900. The present method of dilution is the only one available for handling the sewage of cities over 100,000 population, which has survived the test of time. We have definite knowledge of the workings of the Main Channel from 1900 to 1913, with the severe tests which actual continued use imposes. Of the alternate schemes, no one can show a continued use so long, nor an application on so large a scale.

Another factor has been the attitude of sanitary engineers and sanitarians in general. There is no sanitary engineer or expert qualified to speak authoritatively who does not say that the diversion method installed at Chicago is the best method for that locality. This opinion is found held not only by American but also by foreign experts.

For many years many engineers and others, particularly laymen, residing in and out of Chicago, had criticised the dilution method of sewage disposal, as exemplified in Chicago. In order to satisfy the Board of Trustees on this point, a testing station finally was authorized in 1909.

1643 This testing station has been running continuously ever since. The results obtained and the studies made on the canal and the Illinois River have only served to confirm my opinion that the method of diversion and dilution is the best, the safest, and the most economical for the local situation.

At this sewage experimental station at 39th street, and the second one at the Stock Yards, where the wastes of that industry are being tested at these places, we have tested out every known device that would be applicable to the treatment of sewage in this locality.

As an engineer, I have had serious doubts concerning the practicability of works for treating sewage on such a large scale. This does not come from fear or ignorance of the correct principles to follow, but is based on conservatism,

Wisner Exhibit 6, January 20, 1914.

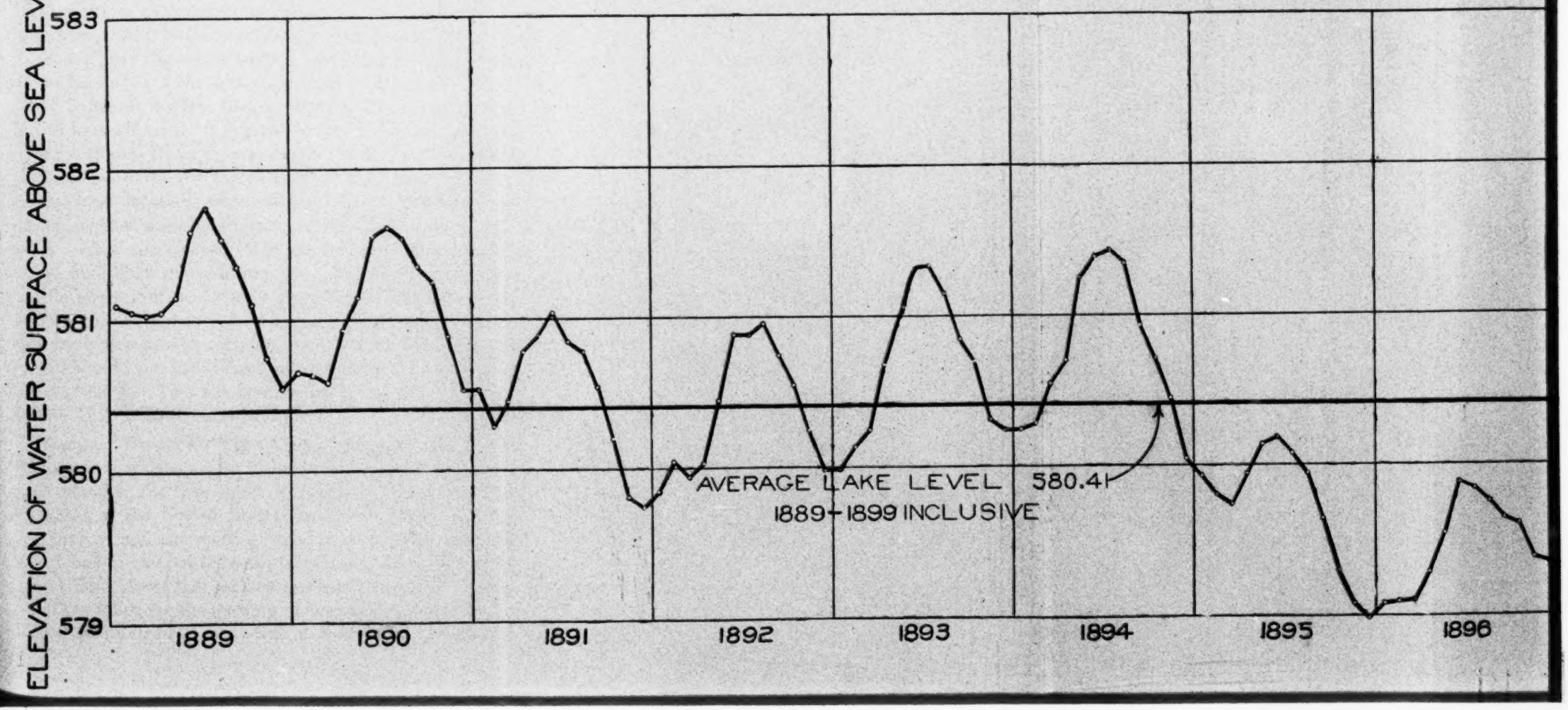


CHART SHOWING AVERAGE MONTHLY LEVEL OF LAKE MICHIGAN FROM 1889 TO DATE

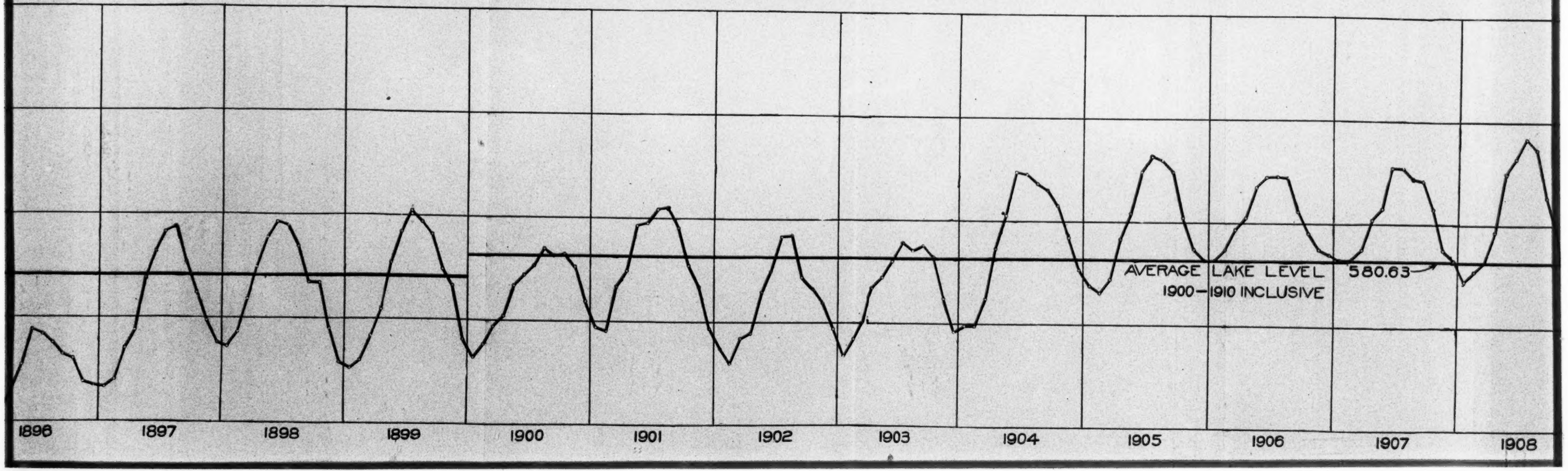
AND

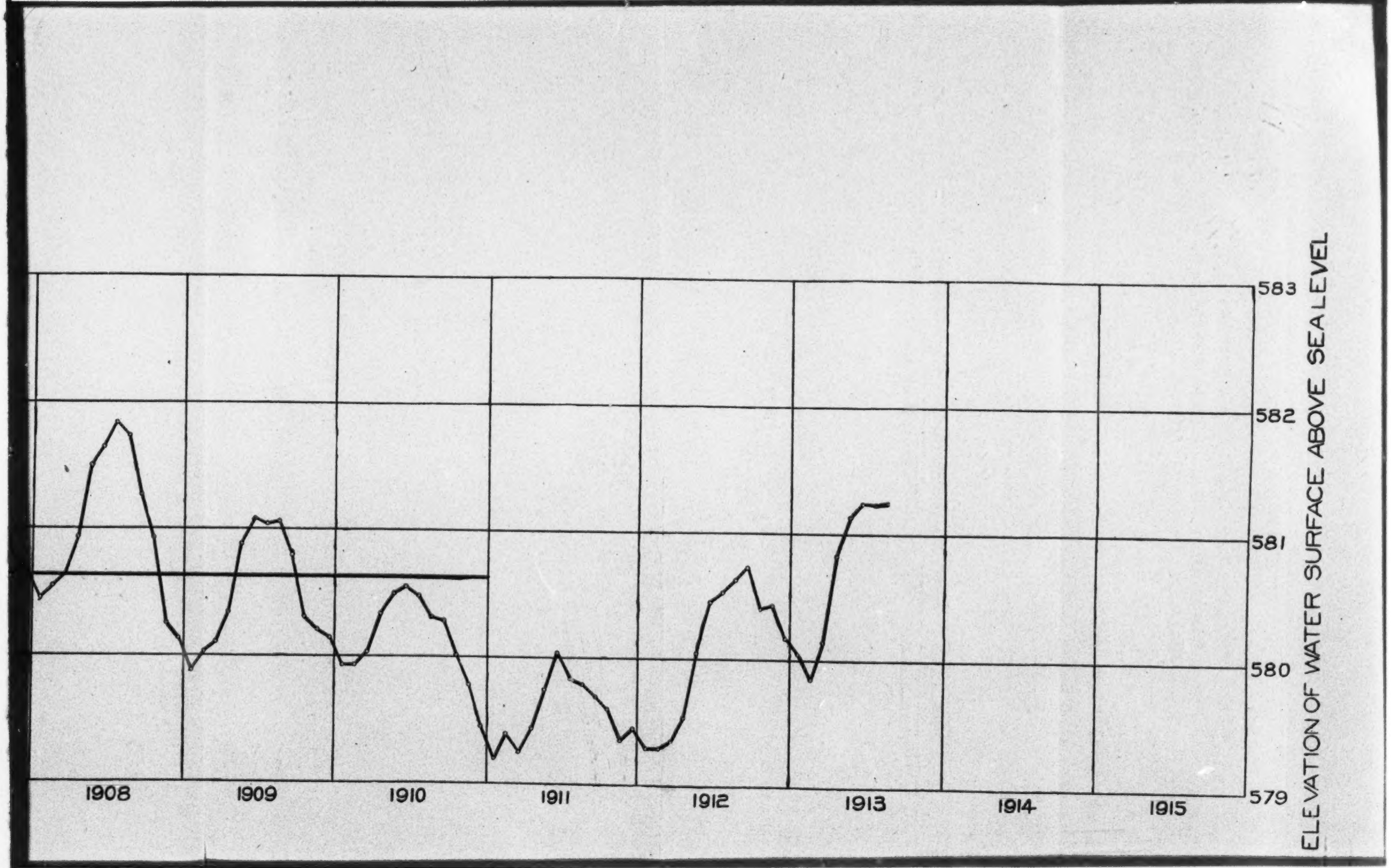
AVERAGE LAKE LEVEL 1889 TO 1899 INCLUSIVE

AVERAGE LAKE LEVEL 1900 TO 1910 INCLUSIVE

ENLARGED FROM UNITED STATES LAKE SURVEY CHART

AUGUST 1913

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ELEVATION OF WATER SURFACE ABOVE SEA LEVEL

induced by lack of precedent anywhere for the partial or complete treatment of sewage on such a large scale. There are many novel problems involved. One of the greatest difficulties in the way is the securing of suitable sites. Judging by the opposition developed in Chicago recently in the various wards to the location therein of garbage treatment plants, I would anticipate serious delay in obtaining the sites desired. Public sentiment, even though wrong, is slow to recognize the necessity of certain locations. Another condition that might work adversely to artificial sewage disposal is the climatic conditions of Chicago, where severe winter weather is encountered. Most of the plants that I have seen in operation do not have the severe winters that Chicago experiences.
1644 So far as the towns in the Illinois River Valley, exclusive of Joliet on the Des Plaines, are concerned, ample dilution has been afforded. It is possible that if only the natural flow of the Illinois River were available that the low flow would be insufficient today for the dilution of their sewage alone, provided local nuisances were avoided. Coarse screening and possibly sedimentation might have to be installed. The cost of this I have not studied, other than to note the probable need of additional expenditures over and above those now made for sewer systems. On the Des Plaines River, however, Joliet would have had an absolutely inadequate dilution, which would have necessitated complete treatment of the sewage at a probable cost, pro rated from our estimates for Chicago of about $1,000,000. This has been saved by the flow from the Sanitary District to the City of Joliet.

A diagram (Wisner Exhibit 6 shown on opposite page) has been prepared which has been brought up to date, month by month, showing the lake levels at Chicago, taken from the publication of the United States Engineer's Office, and the Lake Survey, and corrected to date in accordance with the monthly bulletin issued from the office of the Lake Survey at Detroit. This shows that the average lake level for the eleven years following the opening of the canal was 580.63 ele-
1645 vation referred to mean tide at New York, or 0.22 of a

foot higher than the average lake level for the eleven years prior to the opening of the canal, which was 580.41 elevation referred to mean tide at New York.

High lake levels will increase the cost somewhat of new sewers by reason of the ground water, but the principal influence is in retarding the efficient operation of the sewers by backing up the water in the sewers to a greater distance from the mouth, and probably permitting thereby the stranding of solid materials which is very undesirable. The engineer in constructing the sewerage system plans to put the sewers at a certain depth below the surface to permit discharges of liquids from cellars and to get grades which will produce safe velocities at low flows. With the flat topography of the City of Chicago and the back water produced by the lake, it is extremely important to produce the best working conditions on the intercepting sewer systems, which necessitates pumping and great increased cost.

Frederick P. Stearns, a witness for the defendant, his qualifications being heretofore given, (This Narrative p. 134) testified as follows, October 13, 1913, (Vol. II, pp. 1074, 1075):

The canal was built for 10,000 cubic feet a second, and I believe has a still larger capacity. And it was built to reverse the current in the Chicago River, so that that river which receives sewage should not be turned into the lake. And time is an important element in producing any change in sanitary conditions; and I do not believe that if the quantity were diminished to 4,167 cubic feet per second, that the city could catch up with those conditions, even. If the quantity had been fixed originally, they might possibly have purified the sewage to the extent so that they could get results from that quantity which were fairly satisfactory, except for the reversal of the river currents. There is a necessity for reversing, also, in ordinary times, the current of the Calumet River, in my judgment, so that the ordinary flow of the Calumet River should not be into the lake.

George W. Fuller, a witness for the defendant (Rec. Vol. III, p. 1409-1515) November 17, 1913:

Resides Summit, New Jersey; place of business New York City; hydraulic and sanitary engineer, making a specialty of matters of water supply, water purification, sewerage and sewage disposal; graduate of Mass. Inst. of Tech. in 1888; studied at Berlin Hygenic Institute, took special courses relating to the practical art of water filtration, 1888; 1890 in the office of Piefke, engineer of the Berlin Filters; 4½ years on Technical Staff of Mass. State Board of Health; at Law-
1410 rence from spring of 1891 until the autumn of 1895. The station at Lawrence was conducted by the Mass. State Board of Health with a view to ascertaining the best means of purifying water and sewage under local conditions in Mass.; succeeded Mr. Allen Hazen in March, 1893, as the man in charge; was 4 years at Louisville, Ky., and Cincinnati, Ohio, in ascertaining the best means in point of efficiency and economy of purifying the muddy polluted Ohio River water; since summer of 1899 has been in practice in New York City; 1901-1911 in partnership with Rudolph Hering in hydraulic and sanitary work; was connected with upwards of 100 different sewage disposal projects and an equal number of water supply and water purification projects; for 9 years was a member of the Board of Advisory Engineers at New Orleans, having to deal with the expenditure of some $20,000,000 on drainage, sewerage and water supply projects; connected with the Passaic Valley Trunk Sewer project in New Jersey, with regard to getting out the preliminary estimates of cost of that project to serve about 1,600,000 people; has been connected wtih the litigation before the U. S. Supreme Court in connection with the pollu-
tion of N. Y. Harbor waters by that sewer; connected
1411 with the design of the sewage treatment works at Columbus, Ohio, serving as consulting engineer during their construction similarly at Reading; was connected with sewage disposal designs in thirty or forty different instances, the more recent ones being Atlanta, Georgia, Schnectady, New York, Al-

toona, Pennsylvania, Norristown, Pennsylvania, and a group of cities in New Jersey in what is known as the Plainfield District. On water supplies, was a member of the committee appointed in 1901 by the U. S. Senate to consider water supply matters in point of purification of the City of Washington; consulting engineer for New York City, both as to Catskill project and the existing Croton water supply; also connected with water supply projects, including St. Louis, New Orleans, Louisville, Cincinnati, Columbus, Ohio, Minneapolis, Grand Rapids, Montreal, etc. Has followed the development of the art of sanitary engineering in Europe; made a number of visits to Europe for that purpose. During
1412 the World's Fair in 1893 at Chicago had spent a number of weeks and had charge for a time of the exhibit of the Mass. State Board of Health; took occasion then to look into the water supply and sewage disposal matters at Chicago; 1901 was called in as expert by the St. Louis Water Department with reference to the treatment of the then existing water supply of St. Louis; in 1903 was one of the experts in the Drainage Canal litigation, *Missouri* v. *State of Illinois*, with Mr. Rudolph Hering; made an investigation and report to the International Waterways Commission with reference to Chicago Sanitary District; 1909 had to do with testing a filter plant in the stock-yards district.

The witness testified further as follows:

1413 Was familiar with the conditions at Chicago in 1889 and prior thereto, and prior to the opening of the Drainage Canal in 1900.

Briefly stated, in 1889, the sewage of the residents of this community adjoining the lake front, and for some distance back from the lake front, discharged into the lake. The water supply was then taken from a number of cribs connected by a tunnel, and located in Lake Michigan at comparatively short distances from the shore. I speak of dis-

tances to emphasize the point that the tunnels were then not so far out into the lake as at present. The sewage from portions of this district removed from the lake shore discharged into the Chicago River and its various tributaries.

There was at Bridgeport an old pumping station of a capacity of something like 1,000 seconds feet; and the purpose of that station was to lift the sewage polluted waters of the Chicago River, and send them through the old Illinois and Michigan Canal down into the Valley of the Des Plaines River in the vicinity of Lockport. The water supply conditions in point of pollution with sewage were notoriously bad, as shown by the records of death rate from typhoid fever and other water borne diseases. The pollution of the lake water at the intake-cribs, where the water was drawn for the public supply of this district was brought about, with substantial regularity, by the flow of sewers discharging directly into the lake. The conditions at certain times were much worse than this, and then the accumulations of sludge in the Chicago River and its tributaries, at times of very heavy rainfall, were flushed out into the lake and unquestionably had a very deleterious influence upon the hygenic quality of the water supply at the intake cribs, and as sent to the water consumers of this general district.

That outlines the condition in 1889, so far as the main features are concerned.

1419 In 1889 as regards the protection of water supply, the larger cities having the foremost sanitary advisors, recognized the importance of keeping sewage out of water supplies. That was about the date when the early beginnings were made of separating sewage from water supply. In some instances, efforts were being made to locate new intakes for cities situated on rivers, so that the water would be taken from above the discharge of sewage. It was recognized that where this was not feasible, intercepting sewers should be built for river cities, so that the sewage would enter the stream below and not above the river intakes.

There was at that time nothing known at all about the sterilization of public water supplies. In this country, there were practically no water filters in towns of any considerable size. For 20 years the art of water purification had been dormant.

In the late sixties, Mr. Kirkwood, one of the leading American engineers, studied water filters as practiced in Europe, and had made an extensive report in the interests of the City of St. Louis. It was not thought wise, however, to build filters from information then available.

1420 There were one or two filters built in the Hudson River Valley at Poughkeepsie and Hudson, New York, but with that exception, there were no sand filters in existence in this country.

Mechanical filters, as now known, were practically unheard of and were then merely crude straining arrangements in use in mills and other industrial establishments, with a few scattered plants that were just beginning to be installed for some municipal supplies. In those days, the germ theory of disease, as I have already explained, was not generally recognized; and while there were sand filters in Europe, they were essentially clarifying devices, and the benefit to the hygienic quality of the water appeared to be a mere incident. In other words, there was practically nothing known in the art of filter filtration which had associated with it well defined laws which would allow hygienic accomplishments to be reliably secured. American engineers were afraid of water filters in those days, owing to the wide differences in climatic conditions as compared with European facts and conditions; and furthermore they had nothing to serve as a practical guide as to how they should build the filters to secure effective accomplishments at all times, under the wide range of local factors, climatic, and relating to the water itself.

I can best illustrate the negligible working art of water supply in 1889 by saying that I was at that time connected with the Massachusetts State Board of Health, and even a little later on their attitude was one of not knowing how to advise

the City of Lawrence to filter a grossly polluted water supply, at a time when severe epidemics of typhoid fever were raging.

In fact it was not until 1892 that experiments even were made at the Lawrence Experiment Station to work out what might be called the laws of filtration, which are the basis of water filtration of subsequent years.

1421 The hygienic improvement in the Chicago water supply due to the Drainage Canal is decidedly greater and better than could have been obtained by improving the water supply in other ways as known to the art of 1889. In other words, the diversion of the sewage from the lake and from the Chicago water supply was far better than to have attempted to try any other means for getting a pure water supply, as those means were known in those days.

At that time there were three methods that were studied for large cities. There was the dilution method, which was by far the most prevalent method, and there were available two other methods which had been tried somewhat in certain of the European countries where large centers of population had sprung up upon very small water sheds. Those methods other than the dilution method were known as chemical precipitation and land treatment. In explaining these last two terms, I will say that land treatment grew out of an effort to apply sewage to farm lands, in order to take advantage of the manurial properties of sewage.

It had been tried, for instance, here in the Chicago district, at Pullman, and it was found that the land was not suitable for such purposes.

In regard to chemical precipitation, that was a method of applying certain chemicals like lime, alum and iron sulphates to sewage, allowing the treated sewage to pass through tanks holding several hours' flow;and in the tanks there would be deposited the course sewage filth. Those chemical precipitation works in England that were then in existence, had their origin also in efforts made commercially to secure the manurial properties of the solid sewage substances. They were not

a success commercially, as to the securing of fertilizing properties at a cost which would be at all warranted on a large scale. They were essentially clarifying arrangements, and were then in considerable vogue, owing to the efforts
1422 made in London to clear up the lower Thames, which had very foul decomposing banks of sewage sludge in its lower reaches.

I might say that there were some little contrivances, called clarifying or straining arrangements, which were practiced at places like Atlantic City and Long Branch, in order to keep the sewage solids away from the more prominent sea shore bathing beaches, but they were very short lived and are not worthy of any serious consideration in a project such as then existed at Chicago.

Chemical precipitaton method did not produce a treated product so that you could safely discharge that treated sewage, clarified sewage into a stream or into a lake and have a safe water supply. It was a clarifying process and not one for removing completely disease germs. In fact it was applied, not with a view of protecting water supplies but solely to eliminate sewage sludge, prevent these foul decomposing masses of sludge, and that alone was its true function. It was not a means of protecting a source of water supply.

Sewage farming method in this country, has never been used with any success commercially. In fact, the method, even in our arid western states has had a very limited and merely nominal scope of usefulness. The reason of that is that it costs more to get the sewage to farm lands surrounding a large city than is the worth of that sewage for fertilizing purposes, or for irrigating purposes, or for the two combined. That is very well demonstarted by the experiences of Los Angeles, for instance.

Twenty years ago, the sewage from the outfall sewer at Los Angeles was used in sewage farming, but the resentment of the public to having garden truck come in from districts where it was known that sewage was used on the farm lands,

the odors which arose from the pooling of the sewage on the farms, and the interference with land development projects even miles away from sewage farms, all led that city, with a rainfall of only ten or twelve inches per year, to abandon sewage farming and build a new outfall sewer to the Pacific Ocean.

What I have said with regard to Los Angeles applies, to every other sizable city in our arid districts. It is not difficult to find references in official publications to
1423 some nominal use of sewage for sewage farming in the western states, but a careful examination such as I have given to these subjects, shows that the sewage has been used simply for its irrigating purposes, at times when it would be of benefit to the farmer, and that on other occasions it has been diverted to the nearest water courses.

In our eastern states, the matter stands in quite a different attitude, because the rainfall is generally sufficient for farming purposes, and when there is ample rainfall the farmers are in all cases, disposed to divert the sewage to some water course, or to allow it to build up on certain portions of the farm lands where it putrifies and produces nuisances.

Briefly stated, the attitude and experience in this country with regard to sewage farming, I would say that the method has never become well established, even for small cities, and it is entitled to no established footing or standing for the problems of large cities. That is true in the west, and still more so in our eastern states.

In 1889, I take it all sewage was disposed of by dilution. There are some instances where sizable towns have grown up on very small streams, where treatments works of some kind or another have come up for consideration, but today it is safe to say that somewhere from 93 to 96 per cent. of the sewage of all towns and cities is disposed of by dilution. Where it is not so disposed of, the dilution method is not a candidate for consideration, because of the small volume of water available for diluting purposes.

There are a few other exceptions along harbor towns, for instance, where shell fish pollution has been a factor.

Broadly speaking then the dilution method which was practically in universal use in 1889, has continued to be the prevailing one. In fact it is always applied to-day where the conditions allow of its being applied under reasonable conditions.

The sewage farming method that I have spoken of already is on the wane decidedly, in Europe. The largest sewage farm in England, at Birmingham, has been practically abandoned. In Paris, it is being gradually given up, and, beginning a couple of years ago, they are installing sprinkling filters to take the place of sewage farms now located in part in the growing suburbs of the district.

1424 In Berlin, the sewage farms are still used, where the conditions are very favorable as regards light, sandy, porous soil, on lands that were purchased many years ago at a very low price, and where the rainfall conditions allow the irrigating value of sewage to be taken advantage of, in a way that does not exist in our eastern or central states. The increment of land value alone at Berlin seems to justify a continuance of a method which is expensive at best.

The consumption of water percapita in Berlin, as compared with that in the cities of the United States, has quite a little to do with that problem. The amount of water consumed in Berlin is only about 30 gallons per capita as compared with 200 gallons and more found in many of our American cities. That has a good deal to do with the cost of intercepting sewers, pumping stations, and works for delivering the sewage to the farms. And it requires a much smaller area per capita in European cities than would be required in our American cities.

Chemical precipitation works in 1889, had been recommended for adoption in Providence, and those works were built after an interval of some 14 years, put in service in 1901, following the recommendation for adoption in 1887. Their

purpose was to eliminate sewage mud from the Providence Harbor, and to prevent the foul decomposing conditions there found.

That method of chemical precipitation at Providence, was continued until a year or two ago, when it was superseded by plain sedimentation and sterilization of the sewage, for the purpose of protecting the shell fish layings in the Providence River below the outfall from the treatment works in the deep water at Field's Point.

At Worcester, under orders of the court as the result of litigation on the part of the riparian owners in the lower Blackstone River, the City of Worcester about 1889 started to build chemical precipitation works, which were completed in 1891. Those works were enlarged a few years later, and are in service today to treat some of the sewage, which, for the most part however is now being treated in works of more modern, economical and efficient design. The few little chemical precipitation plants around Coney Island, and some of the beaches of greater New York, at Canton, Ohio, East Orange, New Jersey, and a little plant in the Mystic Valley just outsde of Boston, have all been abandoned.

1425 It is a fair general statement to say that the chemical precipitation method has no standing today in this country for disposing of sewage as regards elimination of sewage nuisances, except perhaps for some small problems where there are complicated trade wastes. Its day has come and gone, and I think that statement applies also to the large European cities generally speaking. It is certainly true of London, where this method of chemical precipitation received its great impetus in the late eighties.

Since the days of 1889, there has been quite a substantial advance made in treatment works for sewage, that has come in as the result of the pressing needs of some communities located on small streams, where the dilution method could not be satisfactorily applied in order to remove a nuisance in those streams.

Continuing the developments of the art since 1890, I will say that various methods have come up for the consideration of the solution of sewage treatment problems. From about 1895 to 1900, the so-called single story septic tanks were in vogue. Their purpose was to remove the solid sewage filth, and allow it to become septicised, and in early days it was assumed all solid sewage filth could be liquified, and gasified by bacteria. Practical developments have shown that this was not feasible.

More than that, the practice with large cities has shown that very severe complications in point of nuisance have been brought about, as the odors from septic tanks have arisen.

Recently, septic tanks of the single story type, built so frequently a dozen years ago or so, have been practically abandoned for all large municipal projects. Within the last year, there has been put in service at Atlanta a two story tank, a settling and septic tank, which has proved to be of much practical benefit, according to the data now available. This is the method of clarifying sewage that has superseded both the chemical precipitation of 20 years ago and the single story septic tanks of a dozen years ago.

In regard to methods of oxidizing those portions of sewage which are either in solution or will not settle in settling tanks, there has been a radical change in the art from 1889, when sewage farms were almost exclusively used.

First there was developed in Massachusetts the intermittent sand filter, where sewage was applied to large areas
1426 of porous sand found in place in sections where glacial drift formation was noted. In the central, western and southern states, that method had no footing because the porous sandy deposits did not exist in place, and the method was found to be too expensive when sand beds had to be built artificially.

Next, there came, about 1900, the so-called contact bed in which beds of stone were filled with sewage, and allowed to have the pores stand full of sewage, for a few hours when

the bed was drained and allowed to have its pores filled with air. That method was found to be prohibitively expensive for large projects, and its use today is confined to small communities in residential districts, where the effort is to minimize the odor question.

In places where water cannot be made available for oxidizing clarified sewage, so as to prevent sewage nuisances, it is found that the so-called sprinkling filters are the best means of making sewage stable or non-putrescible. By that I mean the treatment of sewage, so that it will no longer putrify after treatment, and after standing for an indefinite period. These devices are large beds of stone, perhaps one to three inches in diameter, and six feet or more deep, and on to which the sewage is thrown in the form of a spray from numerous spray jets, spaced perhaps ten feet apart, over the surface of the bed. The practice has shown that these devices will produce a non-putrescible effluent; but it has also been found, at Columbus and elsewhere, that unusual care must be taken for large projects, to keep the sewage in a fairly fresh condition, so that very serious odors will not arise in the neighborhood of the sprinkling filters. These odor factors have not been encountered in the smaller plants, and in a large scale, the art now shows means of guarding against the odors by keeping the sewage well aerated, and thus arresting putrefaction of the liquid before it meets the sprinkling filter beds.

In the general developments of the art of sewage treatment works, practice has shown that it is much more expensive to build and operate these works on a satisfactory basis than was anticipated a few years ago. In fact, the experiences of the past year or two indicate clearly that projects now in service involve considerably larger sums of money than the earlier estimates indicated.

One other factor I should mention in the art of sewage treatment works, and that is the sterilization of sewage to attempt to destroy disease germs.

Nothing was known of sewage sterilization on a practical scale until about 1906. It was then tried at Red Bank,
1427 New Jersey, to apply hypochlorite of lime in settling tanks to sewage with a view to reducing the number of disease germs in the liquids that were sent out in tide water, in the vicinity of shell fish layings. There have been a number of projects recommended for the sterilization of sewage, but so far as I know there is no instance where large cities have made public any records as to experiences in the systematic sterilization of sewage. The nearest approach to it is at Providence, that I have already spoken of, and where they have abandoned chemical precipitation and started out on a tentative scheme of using their tanks to settle the sewage and to apply sterilizing processes in the interests of shell fish layings in Narragansett Bay.

I have been told also that recently the City of Toronto is attempting to sterilize its settled sewage before discharging it into Lake Ontario.

With regard to the dilution method, the greater attention given to sanitary matters in various parts of the country has shown that it was applied in earlier years with many shortcomings. By that I mean that sewer outlets were built into water courses to a very unsatisfactory degree. There are many American rivers and lakes where sewers reach only to within 100 feet or so of the water's edge, and show a pollution which has given rise to offensive conditions that do not exist or would not exist if the sewage had been well mixed with available water for dilution.

It is also found in some places that sewage has built up sewage banks or sludge deposits, which could be remedied with a little care.

So in brief, the dilution method in my opinion, as the result of careful study of the various engineers, now applying it on a more rational basis than in earlier years, is now on a firmer basis than ever before.

It is true however that it is suffering, in the public mind at least, from the poor reputation it got in earlier years, when it was applied in a very inadequate and haphazard fashion in a great many cities, with attending nuisances as to odor. Today I believe it is entitled to far more consideration than ever before, and I think that engineers in approaching these problems will give it in many cases more careful consideration than they would have done a short time ago, when it was not so clearly appreciated as to what the conditions were, under which it could be used, and take advantage of its economy and allow local nuisances not only to be eliminated, but to allow them to be eliminated in a way that they would not be transferred to other neighborhoods.

1428 The ratio of dilution, that is to say 3.33 cubic feet per second per thousand population, that is prescribed by the act under which the Sanitary District of Chicago is organized, in my opinion is as low a ratio as it is feasible to employ, when consideration is given to the domestic sewage of a community.

If I were to consider any change in this ratio, I should be disposed to increase it. That ratio makes no provision for trade wastes; and if trade wastes were to be considered as well as the domestic sewage, I believe this ratio should be increased.

I have looked into this matter with considerable care; have been down the length of the Drainage Canal, studied the records on may occasions. I am making this statement now with respect to conditions as applied to the Chicago Drainage Canal.

I take trade wastes to mean those products which arise in large industrial establishments, for instance tanneries, packing houses and slaughter houses, where the wastes are removed by water carriage, are substantial in quantity, and are entirely different from what you would get in sewers, which drain the ordinary residential community, with the wastes that would come from business blocks, commercial en-

terprises and small manufacturing establishments where the wastes that went into the sewers were merely nominal in amount. As applied here particularly to the Chicago problem, it relates essentially to the waste coming from the Stockyards district and to the tanneries and to the other establishments along the North branch.

Now, in this problem, I have given no consideration to the trade wastes item. The reason for that position is that the disposal of trade wastes is a matter which applies with equal force, whether on the one hand you are considering the dilution method for the local problem, or whether there are considered treatment devices for disposing of the sewage other than by dilution methods.

In other words, it is an item which appears on both sides of the equation in these dilution projects which I have studied; and being the same item on each side of the equation, it properly drops out of consideration.

1429 I might further say that it is my understanding that the Drainage Canal here was projected on the basis that trade wastes were not to be a factor ultimately in dilution ratios, or in other aspects as regards sewage disposal. It is a fact, however, that trade wastes have gone down the Drainage Canal, as an incident to the period during which the volume of domestic wastes has not required the amount of diluting water equaling the capacity of the channel.

I understand further that in the Department of Engineering of the District, there has been established a division, the purpose of which is to study various methods for treating trade wastes, without, however, any consideration, so far as I know, of the financial arrangements under which such treatment methods would be applied.

In my opinion, the protection of the Chicago water supply is secured in a more simple, effective, economical and therefore better way, than could be secured by any other means of treating the sewage than by the present method; and that applies to the art of 1889, and also to the art as known to-

day, in the matter of sewage diversion and sewage treatment.

A reduction to 4,167 cubic feet per second in the flow of lake water through the main channel and its adjuncts would create a profound and unfavorable disturbance in the fundamental principles upon which this project was designed and built. They would relate to several factors, which I will speak of in turn.

First, a flow of water from the lake of 4,167 seconds feet would defeat the main purpose of the channel, which is to secure at all times a reversal of flow of the Chicago River, in order to protect the water at the intake cribs of the Chicago water supply.

In other words, at times of very heavy rainfall, there would be a reversal of flow of the Chicago River carrying the
1430 river water and considerable sewage out into the lake, such as was the condition of affairs prior to 1900. That reversal would occur on a good many days in the course of a year; at least ten in the ordinary year, and a much greater number than that during years of abnormally high rainfall, or having periods of unusually high rainfall.

I wish to point out that even on the assumption that at times of heavy rainfall the flow down the channel would not be limited to 4,167 seconds feet, that, in a practical working way, this does not modify my statement above as to inability to secure a reversal of flow of the Chicago River such as is necessary in order to protect the Chicago water supply. The reason for that is that it takes a good many hours, half a day or so, in order to change the regulating works at Lockport so as to increase the volume of flow in the vicinity of the Chicago River down into the main channel and into the Des Plaines River. It is this lag of half a day or so, which in my opinion would prevent the practical operation of the Drainage Canal in times of storm flows, so as to secure the protection that now comes from the present method of operation with respect to preventing sewage getting to the intake cribs.

A third aspect of the proposition, assuming 4,167 seconds feet diversion from Lake Michigan water through the main channel and its adjuncts, would force to consideration other means of treating the sewage, which now is disposed of by the dilution method. That flow corresponds to the legal minimum ratio of dilution for about 1,250,000 people. Obviously the domestic sewage from a population in excess of that figure would require treatment works, or other means of eliminating sewage. This last proposition involves two aspects: One is the feature of the dilution of sewage, so as to prevent putrefication of the flowing sewage; and in the second place, with this assumed reduction in the flow of Lake Michigan water, the velocities in the waterways of the 1431 channels, main channel, Chicago River and the various appurtenances would be reduced so that the solid sewage matters would become stranded to an extent where sewage mud banks would arise, putrefy and produce seriously offensive odors.

To my thought, it means that with this reduced flow of lake water it would be necessary to settle all of the sewage so as to keep the sludge out of the waterways, as well as to provide means of protecting the water supply through the sterilization of all sewage. And it would further mean the use of sprinkling filters, or other devices, for rendering stable and non-putrefactive the flow of sewage in excess of that which could be properly diluted with this 4,167 seconds feet of lake water.

In the event that the flow of lake water were reduced, or limited to 4,167 cubic feet per second there are two styles of procedure, or two projects which could be adopted for protecting the water supply of Chicago and eliminating sewage nuisances.

The first of these (which I will call A) would involve the collection of the dry weather sewage flow and the first flushings of storm flows, after they pass through settling tanks and apply them to sprinkling filters, so as to render the sewage non-putrescible.

The sprinkling filters should be built to take care of the sewage flow from such portion of the population as could not allow its settled sewage to be adequately diluted by the 4,167 seconds feet of lake water. It would be necessary in protecting the water supply to sterilize this flow of sewage after its treatment by settling or sprinkling filters, or both; and it also would be necessary to sterilize the storm overflows at times of very heavy rainfall. The reason for this sterilization would be that if it were not sterilized some of this treated sewage or storm overflow, or both, being present in the Chicago River and its tributaries at the beginning of heavy downpours, would be sent out into the lake at times. Therefore, to be on the safe side and reasonably to protect the water supply, it would be not only necessary to settle or filter the sewage to guard against nuisance day by day, but it would also be necessary to sterilize these liquids to protect the water of the lake at the intake cribs.

1432 There is a second method of procedure (which I will call B) which would be a project involving, in the first place a system of separate sewers throughout the district for collecting the household wastes. That would mean a new set of sewers on all the streets where sewers now exist. It would mean that the rain water falling on the streets and roofs and various areas, yards, vacant land and parks, would reach the water courses through the present system of sewers; and that all house connections for all the properties of this district would be disconnected from the present system of combined sewers and shifted over to the proposed system of separate or sanitary sewers. The flow of such a proposed system of separate or sanitary sewers would then be treated by sedimentation and filtration to secure a product which would not produce putrefactive conditions in the channel, and this flow would also be sterilized.

Under this arrangement, the storm water which would reach the water courses through the existing system of sewers would go there without any treatment of any kind.

As these two projects have been developed, it is necessary, first, to state how the sewage would be brought to various places for treatment.

I will speak first of project A, in which the flow of sanitary sewers would be through the existing present combined sewers. Speaking generally, there would be intercepting sewers, which would run along the margin of the Chicago River, and at some other points, picking up the sewage from the lake front. These intercepting sewers would receive the settled sewage which would flow from the sewers as they exist to-day. By that I mean that the sewage flow would be led into settling tanks before it discharges into the water courses. This ordinary dry weather flow and the first flushings of storm water would then pass from the tanks to intercepting sewers. These intercepting sewers would lead to sprinkling filter sites in most cases, where the sewage, with some intermediate pumping, would all be lifted at the end of the intercepting sewers on to sprinkling filters, where it would be applied to beds of stone through various spray jets.

Speaking generally now of locations—I am looking at the map marked Fuller Exhibit 1, November 17, 1913—I will call attention to the fact that along the north branch, for instance, intercepting sewers would be built from Kinzie street on either side of the north branch to a point above Fullerton avenue, where the conditions would allow sedimentation tanks to be built. There are some sixteen sedimentation tanks
1433 which would be required along the north branch north of Fullerton avenue. The flow of sewage from these settling tanks would be into interceptors, which would lead on either side of the river to about Lawrence avenue. Thence they would unite in a single interceptor built, leading to a proposed sprinkling filter area, just north of the city limits between Devon street on the south and Touhy avenue on the north. This area lies immediately west of the present north shore channel.

These intercepting sewers would be built of a capacity of about 900 gallons per capita, with a population estimated

SANITARY DISTRICT OF CHICAGO.

MAP SHOWING

SANITARY DISTRICT BOUNDARY

AND THE

CORPORATE LIMITS OF CHICAGO.

JANUARY. 1904

SCALE OF MILES.

AREAS.

SANITARY DISTRICT, ORIGINAL	185.000 Sq.Mls.
NORTH SHORE ADDITION	76.600 DO DO
CALUMET ADDITION	94.800 DO DO
SANITARY DISTRICT, PRESENT	356.180 DO DO
CITY OF CHICAGO	190.638 DO DO
SAN. DIST. OUTSIDE OF CHICAGO	167.442 Sq.Mls.
Des Plaines River Addition	28.1 Sq.Mi.

SEWAGE DISPOSAL PROJECTS
OCT. 1913
Scale ½ in. = 1 mi.

Intercepting Sewer.
Sewage Pumping Stations.
Sedimentation and Disinfection Plants.
Sprinkling Filters.

LAKE MICHIGAN

INDIANA

R. 11 E. R. 12 E. R. 13 E. R. 14 E. R. 15 E.

T. 42 N. T. 41 N. T. 40 N. T. 39 N. T. 38 N. T. 37 N. T. 36 N. T. 35 N.

R. 10 E. R. 11 E.

DESCRIPTION OF BOUNDARY.

as of 1930 for the various areas tributary to these respective sewers.

There are, besides this so-called Lawrence avenue project, for treating the sewage north of the Chicago River, three other projects. The second one, spoken of as the West Side project, would involve the collection of sewage from the Loop District, and an intercepting sewer which would run along the west bank, or near the west bank of the Chicago River, to the vicinity of Western avenue. There the settled sewage, which at various outlet sewers would pass through settling tanks and into this interceptor would be lifted from the interceptor to settling tanks located between Western avenue and Kinzie avenue beyond the Bridewell; and thence the sewage from the western portion of the city in the sewers now existing and located north of the main channel would likewise return to this main settling tank.

Sprinkling filters, so far as required, would treat the settled sewage from this main west side plant at an area located north of the main channel, south of 39th street, and between South 64th and South Harlem avenues. These sprinkling filter sites in all instances are colored brown on this map.

The third main project, spoken of here as the 39th Street Project, would receive the sewage from the various sewers tributary to the present 39th Street Pumping Station. There on the lake front, settling tanks would be located, the flow of which would be pumped through a conduit which should receive also settled sewage from various main sewers in this area lying south of the Chicago River, excepting the Loop District, and south of the main channel. This settled sewage would be delivered for treatment in sprinkling filters to an area immediately south of that which I have previously
1434 described, that is south of the main channel, and lying between South 64th avenue and Harlem avenue.

There would be needed in this instance several pumping stations and settling tanks for the Stock Yards District and for the various sewer outlets now discharging into the river

or channel, and not tributary to the main pumping station at 39th street.

The fourth project, spoken of here as the Calumet Project, would involve an intercepting sewer starting in the vicinity of the 95th Street Pumping Station, taking the flow from the various centers of population in the Calumet District and leading to sprinkling filters lying just north of the Calumet River, south of 130th street, and lying immediately west of Cottage Grove avenue extended south. On this system of intercepting sewers, there would be settling tanks at the outlets of the various sewers and a number of pumping stations, all of which will be detailed in the estimates which I will consider later on.

On this map, the intercepting sewers are marked in red showing their location, and also with an arrow indicating the direction of flow.

The sewage pumping stations, at points where it is necessary to lift the sewage flow along the line of the interceptors, are shown with black circles, and the same black circles are used to indicate the pumping stations needed for lifting the sewage at each of the respective sprinkling filter sites. The sedimentation and disinfecting plants are shown in yellow with a heavy black margin around the area, and as I have already stated, the sprinkling filter areas are shown in brown.

I should explain that at all of these settling tanks, the flow of the sewers in excess of 900 gallons per capita for the 1930 population would have disinfection or sterilization plants where such excess storm flow would be thoroughly disinfected.

1435 Now, proceeding to what I have called the other project, Project B, the various treatment works would be located at the same areas as I have just described for Project A. The intercepting sewers, however, would be smaller because they would deal only with the domestic wastes and not receive storm flows. They would be, roughly, half of the capacity of the interceptors of Project A. The pumping stations would

also be smaller in size, on account of having no storm water to deal with.

I have assumed that the settling tanks, sprinkling filters and the interceptors, in point of location, would all be located precisely as in Project A.

By Project B, there would drop out of consideration, however, the disinfecting plants as regards storm water flows; but the treated sewage would in all cases be subjected to sterilization.

One further word about the sterilization should be added, and that is that where the sewage is subjected to treatment in sprinkling filters, the sterilization plant would deal with the filtered sewage after it had been subjected to a secondary sedimentation.

In those cases where the sewage is not passed through sprinkling filters, the disinfection would take place at the primary settling tanks, and adjoin the works for sterilizing storm overflows in Project A.

This map marked Fuller Exhibit 1, on page opposite, shows also a small project marked here the "North Shore Project," wherein is shown a system of intercepting sewers beginning in Glencoe near the northern district boundary line, coming through Winnetka, Kenilworth, down to Wilmette; there showing a pumping station and small treatment works for a population of 55,000 people estimated as of 1920.

In regard to the collection of the sewage flow from the present sewers discharging into the various water courses, I should state that in these intercepting sewers and appurtenances arrangement is made for areating the sewage. The purpose of that aeration is to prevent putrification taking place such as is found in a great many outfall sewers of large cities, owing to the age of the sewage. Now, to prevent and offset the putrification, which is due to bacterial processes taking place as the liquid flows in the sewer, provision is

made in these projects for pumping in air so as to keep the decomposition on an oxidizing and not on a putrifying basis.

With respect to the population, it will perhaps be more explicit to repeat a word or two, and say that these intercepting sewers for delivering the sewage flow to settling basins, 1436 sprinklers and treatment works, the design has been based on the assumed populations of 1930, namely 3,500,000 people. With respect to the treatment works, this is including the filters, settling basins and sterilizing arrangements, the population has been assumed as of the date 1920. On that date, the estimates of population show for the city a population of 2,900,000. In fitting these different projects to a population basis, there has been some little latitude used and there has been included the population of the Calumet District on the south and the North Shore district on the north.

The population provided for in my estimates is: Within the city, 2,900,000 population; outside of the city limits, in District 14 on the west side, 133,000; 21,000 outside the city limits in the Calumet District, and in the North Shore District 55,950. The latter figure includes Evanston.

Now, the summation of all of these different populations assumed to be provided for in the respective treatment works amounts to roughly 3,000,000. I have assumed in my estimate that that would be equivalent to what would be served by 10,000 seconds feet flow in the main drainage canal, equal to 3,000,000 people.

I am aware that in making estimates of future growths of population in different districts there are bound to be some discrepancies, and these aggregate figures are rather more liberal than should be made for the respective individual treatment plants.

I think next I will outline briefly the particular devices which it is proposed here to use in settling and filtering the sewage, and in sterilizing it; and refer roughly to what in practice elsewhere these particular devices have accomplished in the nature of improving the hygienic character of the

sewage, and with regard to the bearing which the works would have upon the elimination of sewage nuisances.

The settling tanks would be built of the two-story Imhoff type. By that I mean that there would be large settling tanks built with their flow line roughly corresponding to the flow line in the existing sewers. They would have a depth of some 25 feet, say, and be in two stories. In the upper compartment, the sewage would flow through the tanks for a period on an average of two hours. The increase in the cross-section of that settling compartment with respect to the size of the sewer so checks the velocity down to half an inch per second or so, with the result that there are deposited the coarse matters in the sewage.

In the bottom of this compartment is a slot or opening, through which the solid matters would pass to a large
1437 chamber beneath. This lower chamber is called a digestion chamber, and in it the solid matters would be allowed to accumulate for perhaps six months or so. During this interval bacterial decomposition would intentionally be directed and encouraged, so that it would gasify, putrify and allow the bacteria to eat up all of the unstable organic matters. Much of this solid matter would be changed to liquid and gaseous substances. The result of this is that the sewage sludge would become septicised or eaten over by the bacterial life, so that it would be taken out in a substantially inodorous condition.

This wet sludge from the lower compartment would be removed at intervals through a pipe, and applied to little thin beds of sand and gravel; and it so happens that the sludge as removed contains much gas. This is of importance, because when it is removed and applied to these straining beds or sludge beds, the gas seems to lift the solid matter to the surface, and it allows the liquid from the bottom to pass down through the sand and gravel of the bed to which it is applied. In the course of a week or so this septicised sludge has been so freed of water that it is spadeable, and can be

shoveled into containers for its removal to any convenient place to be used for filling, or to be stored in a spoil bank.

At these settling tanks along the various sewer outlets going into the water courses, arrangements would be made whereby the sewage flow passing through the tanks would be limited to three times the dry weather flow, or to 900 gallons per capita daily. The storm flow in excess of that quantity would not pass through the regular settling tanks, but would be subject to sterilization. By sterilization, I mean that there would be added to the storm flows liquid chlorine sufficient to kill the disease germs in the liquid and upon the exterior of particles of suspended matter. Sterilization is, of course, not effective in killing the germs in the interior of particles of suspended matter.

These tanks for purposes of sedimentation would allow the removal of some 90 per cent or so of the particles which are capable of settling. They do not of course affect at all those soluble matters in the sewage, such as urine, nor the fine particles of fecal matter, or substances of other origin which are so fine that they will not subside. That is, the non-settling solids and the soluble matters in the sewage pass through the settling tank and on into the intercepting sewers.

In the course of six or eight hours or so, sewage will become, under ordinary conditions in large cities, putrifying, and productive of foul odors to an objectionable degree.
1438 These intercepting sewers are supposed to carry sewage which has its content of oxygen not depleted; and the oxygen supply is assumed to be replenished by pumping air at intervals into the flowing liquid in the intercepting sewers. The quantity is, in accordance with various tests at New York, roughly, one-tenth of a cubic foot of air to one gallon of sewage.

In those cases where the settled sewage must be filtered, that is for all projects other than the West Side Project, the settled sewage will flow in these intercepting sewers and be pumped at the respective filter sites onto the sprinkling filters. I should say that for the West Side, I have assumed that

the settled sewage from the central west side area, from the Loop District and the floating population in the Loop District of some 300,000 people, that that settled sewage could be adequately diluted by 4,167 seconds feet flow of lake water, so that it would not be necessary to filter it.

The removal of organic matter by sedimentation is taken to be roughly 25 per cent on an average, as compared with the organic matter in the raw material. To reduce the organic matter of the settled sewage to a point where it will not putrify in the water courses, it is estimated that there would be required one acre of sprinkling filters for 12,500 population.

These sprinkling filters, as I have already stated, would be large beds of stone, of a size ranging from one to three inches in diameter, about six feet deep. To these filters, the settled sewage would be applied from a series of sprinkler nozzles, spaced roughly ten feet apart. The sewage would then be thrown as a form of spray such as from a lawn sprinkler over the surface of the bed of stone. These sprinkler filters operated at this rate will produce an effluent which will not putrify after there has been removed from it some suspended matters which are released from the bed in an irregular way.

To clarify this filtered sewage, these projects provide for secondary settling tanks holding about one hour's flow, and of about the same size structure as the primary settling tanks, but of one-half size for a given sewage volume.

This sewage sludge would be similarly strained on sludge beds to remove the water, so as to get it in a spadeable condition for removal to a sludge bank, or any other convenient way of disposal. The sludge has somewhat limited value for fertilizing purposes, and in some cases in Europe it is taken away free of charge by the farmers of the neighborhood.

I have assumed that it would cost some 50 cents a yard
1439 to get rid of this sludge, and that it would not be feasible to dispose of it to farmers.

Wherever the dry weather flow of sewage is subjected to filtration the sterilization process would be applied to the effluent after it leaves the filters, and not to the settled sewage before it reaches the filters. In the West Side Project where filters would not be needed with the present assumed volume of lake flow, the sterilization process would be applied of course to the flow from the primary settling tanks.

In the matter of efficiency of sprinklers, I would say that they will reduce the organic matter in the sewage some 70 per cent or more, and in connection with the oxygen present in the filtered sewage, they will produce a stable liquid which will not putrify upon exposure to sunlight and the air, for a long term. There are times when these beds unload their solid matter, when perhaps that would not be literally true; but generally speaking these beds, in practice at the rate here indicated would produce a liquid which would not give trouble from putrifaction.

The removal of bacteria by the sprinkling filters would probably range from 80 to 90 per cent. The liquid would be substantially free of suspended matter. The sterilization of the filtered sewage would have for its purpose, of course, the destruction of disease germs to the extent of the 10 or 20 per cent remaining in the filtered sewage as compared with that appearing in the raw sewage.

As to storm water flows, the liquid coming from the streets contains a good deal of organic matter, and would probably call for as much as 70 pounds of liquid chlorine to the million gallons. For the ordinary settled sewage coming from the primary tanks, I assume it would take some 50 pounds of liquid chlorine to a million gallons. For the filtered and settled sewage I have assumed that about 10 pounds per million gallons would be sufficient.

As to what sterilization will accomplish in point of removal of disease germs, I should say that the removal would amount to 95 to 99 per cent, depending upon the success with which the applied quantity of liquid chlorine was adjusted to

the particular organic content of the liquids flowing, and recognizing the variation in such flow, and in their strength from time to time.

In the matter of pumping stations, these projects for the
1440 treatment of the sewage would involve the operation of the present pumping stations for sewage flows at 39th street, Lawrence avenue, 95th street and elsewhere. They would also require some intermediate pumping along the line of the interceptors, at settling basins and at each of the respective filter plants it would be necessary to lift all the flow, in order to produce a head sufficient to distribute the sewage to these various sprinklers scattered over the surface of the filter bed. There would have to be a head at the nozzle of some six to eight feet, as well as to lift the sewage up to the elevation of the nozzle itself.

In regard to the question of odors and nuisances, I have already spoken of the great importance of preventing such conditions as have arisen at Columbus and Baltimore, where the sewage has become highly putrefactive before it reached the treatment works. That would be accomplished by the aeration that I have described.

In regard to the sprinkling filter sites, I have outlined certain locations which have been used as the basis of these studies. It is not necessary to treat them precisely at the areas indicated on this map marked Fuller Exhibit 1, but those approximate areas, however, are convenient and suitable; and in these instances are entirely reliable for the purposes at hand. These different filtering site areas cannot be limited to the immediate ground which would be occupied by the structures. It is found that in these beds there will grow flies and various forms of animal life, and it is necessary for that reason to purchase land which would keep other property owners from living immediately adjacent to the beds.

There is also the item of odor, which is not very serious if the sewage is kept in this fresh condition that I have spoken about with respect to aeration.

For instance at Reading, Pennsylvania, where the sewage is fresh, it is a mountainous town and high velocities obtained in all cases, the odors are rarely if ever noticed more than 300 feet away. Most sprinkling filters, however, are apt to develop an odor, in the case of large plants for a quarter of a mile; occasionally in some plants it is extended much further than this.

In these estimates made in developing this project, allowance is made for the purchase of land one-quarter of a mile in extent around the entire outer periphery or building line of the proposed works.

In regard to the question of odor around the settling basins, I do not believe that there would be anything serious encountered there, nor would the flow of storm water
1441 treated with liquid chlorine be objectionable in the water courses. It is conceivable, however, that lack of care might produce an excessive application that might not be present except for a very short time.

That, I believe, covers in outline the main features of the best methods now available for building treatment works to clarify sewage, to eliminate the stranding of sewage solids, and putrefaction of mud banks, to take the sewage after settlement and where there would not be water available for oxidizing it by dilution, then subjecting it to the oxidization in sprinkling filters and finally in sterilizing all of these flows so as to destroy objectionable bacteria to the extent of say 95 to 99 per cent of those contained in the original sewage.

This residual small percentage, as I have already explained, cannot be reached by sterilization or any other process, on account of some of those germs being located within the interior of tiny little particles of fecal matter, where the chemicals will not have access. These treatment works are the best that can be applied to problems of this kind, as the art of sewage treatment is known today, both in point of theory and practice.

In regard to the pumping stations, I might add a word and say that they are all assumed to be centrifugal pumps, steam driven, and are assumed in the estimates to be strictly in line with the installations of sewage pumping machinery in the district here in Chicago, and in other large cities. The equipment, as I have said, provides for handling the sewage at a number of points along these interceptors, and in pumping all of the sewage going onto the sprinklers.

That approximate figure of population in 1920, has shaped itself in these estimates by virtue of the fact that the population then existing in the city and in the outlying areas within the Sanitary District would roughly equal the diluting capacity of a 10,000 seconds feet flow of lake water down the main channel. It also represents the best judgment of those familiar with the details, according to my information, of the past growth and the increments in growth leading to proper and reasonable conclusions as to what the 1920 population may be.

My own purpose was largely in getting at a figure as to scope of project which would allow a comparison to be made of the treatment works for a 3,000,000 population which has come into this project, and my reflections in connection
1442 with the 10,000 seconds feet flow, when treating the population at the legal minimum dilution ratio of 3.33 seconds feet per thousand.

I have estimated that it would cost for construction purposes to build Project A, $71,365,866. The annual operating expense and depreciation I estimated at $5,116,057. I have capitalized this annual charge for operation, maintenance and depreciation at 4.25 per cent, and have added it to the investment cost. This makes a sum of $191,742,866. That is the sum which it would cost this district to take care of the sewage by Project A, for the population estimated to exist in 1920, roughly 3,000,000 of people.

For Project B, the investment cost I place at $131,229,707. The annual cost of operation, maintenance and depreciation,

I place at $4,524,952. Capitalizing the latter sum at 4.25 per cent, and adding it to the investment cost, there is obtained $226,970,647, as representing the cost to the district of treatment works for 3,000,000 people by Project B.

Under Project A, to provide treatment works corresponding to a population which would be taken care of by a lake
1443 flow of 12,000 seconds feet, the investment cost would be $85,000,000. The annual operating maintenance and depreciation cost would be $6,102,000. Capitalizing the annual cost and adding it to the investment, there would be obtained $230,000,000. The corresponding figures for treatment works of a capacity equal to that which would be taken care of by 14,000 seconds feet flow of lake water would mean, by Project A, an investment cost of $100,000,000, an annual operation, maintenance and depreciation item of $7,260,000. The sum of the investment and capitalized operating expense would be $268,000,000.

I should state that these figures which I am reading are round figures, obtained with a slide rule. They are not figured to individual dollars and cents.

By Project B, the investment cost of treatment works, with separate sewers to provide for a population equal to that which would be taken care of by 12,000 seconds feet flow of lake water would be $157,000,000. The annual cost would be $5,40,0000. Capitalizing the operating expense and adding it to investment, the total cost becomes $270,000,000.

The corresponding figures by Project B, for treatment works equivalent in population served to that for 14,000 seconds feet flow of lake water becomes for investment cost $183,000,000; the annual cost would be $6,300,000. The sum of the investment plus capitalized annual charges would become $316,000,000.

I should perhaps state with regard to Project B, one or two points that I think I briefly touched upon in my preceding answer; and that is this Project B deals with no storm water sewage at all, no street wash, but assumes a complete

new system of sanitary sewers which would deliver to settling basins the sanitary wastes of the community. That settled sewage would pass through interceptors with areating arrangements onto sprinkling filters, all in substantially the same way as in connection with Project A. The intercepting sewers, however, would be of about half size. The pumping stations would be somewhat smaller. There would be no
1444 sterilization of storm flows; it would go directly into the river without treatment through the existing sewers. The settled sewage, filtered sewage, would be sterilized.

I should say that eight years would be a fair estimate for the period of active construction. I have placed the time at ten years, assuming that conditions would be favorable in all respects with regard to securing funds with which to build these works, and to get the necessary legislation, enabling acts, and condemnations of lands and rights of way.

I could point out for instance that at Providence it was determined in 1887, to build chemical precipitation works, but they were not put in service until 1901. That period
1445 in the interim was required for financing and building the necessary intercepting sewers and treatment works and in adjusting delivery of sewage to those new structures.

In Boston, the original main drainage works were recommended in 1875 for collecting the sewage of the old city of Boston and delivering it to Moon Island for discharge on the outgoing tide. Those works went into service in about 1884.

The Washington works for intercepting the sewage of Washington City and pumping it after some screening into the Potomac River below Washington were recommended by the Commission appointed by President Harrison in 1889. Those recommendations by the Commission were made in the early part of 1890. I think it was 1908 before those works were completed and put in service.

In the Passaic Valley Project, in New Jersey, opposite New York City, the first recommendations there were made in 1897. The matter was reviewed by a State Sewage Commission again in 1901. There was an enabling act passed in 1903. It was in litigation in point of constitutionality until 1907, and the project in its present form was outlined by Hering & Fuller, in 1908, and the construction work was started in 1912, about a year ago, and it is still subject to injunction suits and various vicissitudes of litigation, and including an injunction suit brought in the United States Supreme Court by the State of New York with respect to discharging this sewage into the upper New York Bay.

The Charles River Dam project in Boston was active in my days there in 1891. That relates to building a dam across the Charles River near the old Cragie bridge, and preventing the exposure of the tidal flats on the Boston and Cambridge sides of the river, and in building intercepting sewers along the water front on each side to send the sewage down to points beyond or outside of Boston Harbor.

Those works were the subject of many legislative investigations, particularly a very exhaustive one made by Mr. John R. Freeman in 1903. The works have been in service I should say about three or four years, so that I think experience very abundantly shows that actual periods required for getting legislation and in getting financial programs adjusted, getting works that will not be made the subject of too many legislative inquiries and investigations by Citizens' Committees, I think all of those things taken into account make the period very much longer than the actual designing and construction calls for.

I doubt whether any of them exceeds $15,000,000 in in-
1446 vestment as compared with $70,000,000 here for Project A, and $130,000,000 for Project B.

Project A would involve tearing up streets along the lines shown here in red ink on this map marked Fuller Exhibit 1. It would cover a good many miles of streets in the

vicinity of the water courses of the north branch, the
1447 main Chicago River from 39th street over beyond the Stock Yards district, to a point where 39th street meets the Drainage Canal; also down through the Calumet District as shown in this plan.

In Project B, there would be involved the tearing up of every street throughout the district, in order to build the sanitary sewers in it to parallel the existing sewers. It would not only mean tearing up every street that is now paved, but it would also mean lateral house branches from the street sewer out to the curb line under the sidewalk to the property to the building line.

It would encounter, of course, a good many underground obstructions, in the nature of interference by existing utilities, water mains, gas mains, electric light conduits and telephone conduits, etc.; also make a decided impression on street pavements; involve considerable care in maintaining trolley lines in service during construction periods.

(Mr. Fuller corroborated the testimony of Mr. Wisner as to the conditions at Chicago and with reference to the effect of the Sanitary District diversion works.)

Asa E. Phillips, a witness for the defendant, (Rec. Vol. III, pp. 1516-1533; December 12, 1913):

Resides at Washington, D. C.; civil engineer; graduated from civil engineering, Lehigh University, 1893; had charge of the preparation of the plans for construction and operation of the sewage disposal system of the District of Columbia, covering a period of more than fourteen years; for the last seven years superintendent of the sewer department of the District of Columbia; made special studies of modern development of sewage treatment; connected in an advisory way with the Passaic Valley work.

The witness further testified:

City of Washington uses the dilution method; sewage is collected at certain points, then pumped from the low level to a higher level sewer by means of which it is discharged into the Potomac River mid channel below the city. The Washington city sewage disposal was planned and recommended by commission of engineers appointed by President Harrison in 1889, consisting of Messrs. Rudolph Hering, Frederic P. Stearns and Samuel M. Gray. Total cost of the work was $5,000,000. They were not completed until 1907. A modern filter plant has been installed for the water supply.

In a broad sense, artificial sewage treatment plants are not used. In something like eighteen cities having a population of over 300,000 people, the disposal of sewage is entirely by dilution, with the one exception of Baltimore, which has recently completed a plant but has only partly operated same to date. In fourteen cities having a population of over 150,000 and less than 300,000, there are treatment works at Providence, Rhode Island, Columbus, Ohio, and Worcester, Massachusetts. The purpose of these treatment plants is generally to prevent a nuisance in streams into which they discharge. One of the older works of Providence, Rhode Island, was put in with a view of preventing the oyster beds in the Providence River below the point of discharge from being polluted. The same is true as to the works at Baltimore.

Looked at from the point of view of practical results up to date, none of these works have accomplished what would reasonably be supposed to be their complete function. In every case, they discharge either an effluent that does not have a degree of purification such as to prevent the streams from actual and dangerous pollution, or they operate intermittently, and intermittently throw a load of sewage directly into the streams, or discharge the sludge from the treatment works at times into the streams.

In the comparison between what is accomplished at these works and what is accomplished at other works using the method of dilution where reasonably uniform and con-
1522 stant results are obtained, practically unchangeable except due to the variation of season and of temperature, these artificial treatment works have not been successful. Some qualification ought to be made as to this, in the case of the new works at Baltimore which, while completely constructed, handle only a very small portion of the sewage, and with regard to these works they have developed just as the works at Providence developed, very serious local nuisances, which are involving lawsuits. And at Baltimore, a very great reliance, even by the engineers in planning the works, has been placed in the effectiveness of the purification by dilution, that would be accomplished in the travel through the arm of the Bay in which they discharge.

In the case of the other works, having only in view the prevention of the gross pollution of small streams, such as the new works at Atlanta, there is no very serious problem such as the protection of the water supply, involved.

The works at Providence, chemical precipitation works, designed to protect the oyster beds from pollution, have been substantially abandoned, and the works there today, with the exception of some sedimentation and some attempt to disinfect the sewage, are substantially, pure and simple, works of dilution.

The abandonment of older processes, though comparatively new themselves, and the fact that the present appliances that have been introduced in the design of artificial treatment works are extraordinarily new, and might fairly be considered experimental, it is a reasonable conclusion that with the changes that have been going on in a short space of a little more than fifteen years, and most of it in the space of a little more than five years, possibly within ten years, there will be new lines in the treatment of sewage, and new processes that will revolutionize as completely the methods of today as

those methods were revolutionized only a very few years ago.

1523 The very first consideration in weighing various possible plans in any case would be the protection of the water supply. The absolute necessity of this exists where a water supply is in reasonable proximity to the works. That is in the discharge, for example, of the effluent of artificial works or of sewage for dilution within a certain range of distance subjects the water supply to pollution and to serious injury. At greater distances, further removed, of course, that becomes less important. In any case, the method should be such and the design of the works such as to absolutely prevent at any time the pollution of the water supply if that is within the range of possibility; that is even the contingency of pollution should be prevented.

It involves both the raw sewage and the effluent because there is no, absolutely no certainty that with the most modern works, most carefully devised and designed, that there will not be periods when raw sewage may be discharged.

And then, on the other hand, is the question of the efficiency of the works themselves in obtaining, if it is possible to obtain such a thing, an effluent that is entirely, at all times, free from dangerous pollution.

I give great weight to the danger which may result from the operation, that is, the inefficient operation of these plants, disposal plants, or the efficient operation of filter plants to filter water supply, owing to the absolute uncertainty of continuous, efficient operation in both cases.

The greatest difficulty is involved in the impracticability of handling the sewage otherwise than on a system of units, owing to the enormous volume of sewage, to the great areas covered, and the long period of time involved for the transit of the sewage to the treatment works. It involves the necessity of the construction of such works substantially within the city close to dwellings; that is in fairly close proximity to dwellings; and all experience on the treatment of sewage

today, so far as the location of treatment works is concerned, is in favor of their remote removal.

Baltimore, for example, one of the newest, and the larg-
1524 est city in America to put in treatment works, located the works something like seven or eight miles from the city, selecting a location remote from any dwellings. In addition to that, they felt compelled to buy large tracts of ground to create a neutral zone around their works, and yet, with a very short period of operation, and very low load on their works, only having part of the sewage to handle, they have been confronted with damage suits for the creation of a nuisance, by the owners of property along their holdings. The certainty in a very large community of the sewage reaching the works stale, its creating local nuisances along the line of travel in the interceptors, even with the entire area broken up into districts, is a great problem and a source of danger in a very large community.

The difficulty of handling the resulting materials accumulated, the sludge particularly, from the treatment works, its removal, its necessary storage in preparation for its removal, appears to me to be a most serious problem in considering any treatment works for very large communities.

In the years 1910, 1911 and 1912, the death rate from typhoid in Washington was 24, 22 and 22, respectively; per 100,000 population.

LYMAN E. COOLEY, witness for the defendant, whose qualifications have heretofore been stated (This narrative, p. 138; Rec. Vol. III, p. 1705), testified as follows:

The State Board of Health undertook to cooperate in the investigations that we were making at Chicago between 1885 and the passage of the Sanitary District Act in 1889, and
1706 made a very comprehensive series of analyses of samples through one summer and one winter, taken at various points between Lake Michigan and the City of St. Louis, in or-

der to determine the question of the self-purification of sewage introduced by the Illinois & Michigan Canal from the City of Chicago.

I made a study of the possibility of utilizing this great natural reservoir in passing waters by way of the Des Plaines and Illinois Rivers to the Mississippi River; and gave the matter general consideration at that time.

Later, I took up the matter as part of my duty as chief assistant to the Drainage and Water Supply Commission in 1886 and 1887. I followed the matter up, prepared a paper upon the subject matter in 1888, and brought the whole subject matter into final form in a series of papers before the Western Society of Engineers in 1888; printed early in 1889.

I later gave it further consideration, while a member of the International Waterways Commission. The instructions of Congress to that Commission were that we consider in full the water supply in connection with the development of ocean navigation into the lakes from the Atlantic Seaboard.

I have had occasion to make a study and examination of
1707 the necessities of the navigation interests and the improvement of navigation at Chicago and through the Illinois and Des Plaines Rivers.

That proposition was in view from the inception of the drainage enterprise, and in fact you might say from the time that the Chicago divide was discovered, in 1673; and it was a part of the policy of this State from the beginning to procure the construction of a waterway through the State. And when the Chicago sanitary question came up, and it was determined that the solution would require a large canal across the Chicago divide, the State, through its General Assembly, took the view that it should be constructed so as to lend itself to the development of a deep waterway through the State. And so from the beginning, the effect of this water which was needed for the sanitation of Chicago upon the regimen of the Illinois River and of the Mississippi River; and how it could be utilized in producing a waterway, was a prominent

factor and an important factor also in determining the policy of the State in granting the privilege to the City of Chicago of sewage disposal in the manner proposed.

I am familiar with the history of the State prior to the time when this matter was taken up. I acted as consulting engineer to a special joint committee of the General Assembly, which framed the Sanitary District law and was familiar with
1708 all the considerations that influenced that law, in Chicago and in the valley.

I was at Springfield during the entire consideration of the matter, and had general charge in the latter part of the session of the bill for the City of Chicago, for the City Council of Chicago and for the several civic organizations of Chicago, and I believe that I know as much about what the policy of the State was at that time, as anybody can know.

I drew some supplemental measures known as the Little Waterway Bill and the joint resolutions of 1889 and also of 1897, which were passed by the General Assembly, declaring the policy of the State.

I had at that time been over all the documentary evidence in relation to the subject matter, reports of various kinds, going back to that of Major Long in 1816; Phillips and Graham, in 1819, and to the report of General Gratiot, in 1834, in which the United States proposed at that time to construct a channel 10 feet deep and 100 feet wide; the land grant to the State of Illinois to aid in the construction of the Illinois and Michigan Canal; the report of the survey and examinations of John B. Preston, 1857 and '58.

John B. Preston, was a civil engineer in the State of Illinois, who made a project for steamboat navigation between Lake Michigan and the Mississippi River, in which the low water navigation of the Illinois River was to be made by aid of a water supply from Lake Michigan.

That proposition was followed up by joint resolution of the General Assembly in 1861, which called upon the canal trustees to examine the subject matter.

In 1862, there was a bill in Congress providing for such a waterway. The Honorable Thad Stevens made a speech, in which he denounced the proposition as a measure to drain Lake Michigan and convert it into a cornfield. So the objection on this lake diversion proposition goes back a long ways.

1866, General Wilson was charged with the duty of making a survey, and based his report of 1866 and '67 on the notes and data collected by John B. Preston in 1857-'58.

In 1867, General Wilson by the aid of a special appropriation from Congress made a survey of his own, which was
1709 reported upon in December of that year, and there was also a report on the Upper Illinois River by Colonel McComb, 1874 and by Major Benyaurd in 1883, and also upon the enlargement of the Illinois & Michigan Canal in connection with the Hennepin Canal in 1882-4, and by the Comstock Board in 1886 and '87.

All these documents gave a very complete idea of the physical conditions of the Illinois River and its possibilities of development, and were available prior to the passage of the Sanitary District Act.

Howard Stansbury, United States Engineer, made an examination of the Illinois River in 1838, and General Joe Johnson, later of Confederate fame, was upon the river engaged in improving the same in 1852 and '54. We had all that material.

I was the first chief engineer from January 1890 to December of that year; and a year later, December, 1891, I became a trustee of the Sanitary District and the chairman of its engineering committee until the close of my term in 1895.

1710 The Chicago River basin, as it originally existed in nature, consisted of the North Branch and its drainage basin, together with the South Branch, an area of about 240 square miles (now about 300 square miles). West of the Chicago River basin, was the Des Plaines River basin, drained by the

Des Plaines River which ran parallel to the lake from the headwaters in Wisconsin down to a point about ten miles from Lake Michigan at Lyons; and then leading southwesterly to a junction with the Illinois River, or to the junction with the Kankakee River, which formed the Illinois.

This Des Plaines River, in the vicinity of Lyons, had a low water elevation of about eight feet, and a drainage area of 633 square miles.

The divide between the Des Plaines River and the Chicago River was in the vicinity of the Bridewell, just west of Kedzie avenue, and had an original elevation of about 10½ feet above Lake Michigan, and whenever the Des Plaines River rose from two or three feet above low water, or exceeded a volume of about 1,000 second feet, the flow of the river divided, part of it coming through the South Branch of the Chicago River to Lake Michigan, and in great floods 60 to 70 per cent of the entire flow of the Des Plaines River came to Chicago.

This condition existed up to about 1854, after the Illinois and Michigan Canal had been opened in 1848, when the Drainage Commissioners cut out the original divide at Kedzie avenue and drained out the Mud Lake region as it was known in Voyageur's days, and on the original land maps as "Portage Lake, Portage Swamp, and Portage Slough."

For a number of years thereafter, the entire flow of the Des Plaines River came in the direction of Chicago except at such times as in the fall and winter when the ice interests of the Des Plaines River Valley made a temporary dam in order to fill the ponds on the 12-mile level between Summit and Lemont, for ice-making purposes.

Finally the flow from this source became such a nuisance to the City of Chicago that after 1870 they constructed the Ogden-Wentworth Dam. That crossed the old Portage Slough at the range line at Summit, at an elevation of something over 11 feet above Chicago datum. And this was overflowed also, whenever the river rose above a volume of about

1,000 feet per second; and the waters continued to come this way in flood times when the volume exceeded that amount until 1893, when the Sanitary District executed its river diversion and created a spill-way above Summit, which restricted the flow down the river until the volume reached between 3,000 and 4,000 feet per second. And in about 1909, 1711 this was finally closed, so that no waters from that source have come through the Chicago River to Lake Michigan since.

The effects of this overflow have been most pronounced and is noted from time to time in the narratives relating to Chicago and its portage. For a portion of each year boats in the fur trade made the trip from the Chicago River to the Des Plaines River and down the Illinois to the Mississippi River without any portage at all. For a portion of each year, a portage of two miles was required; for another portion seven miles, and in very dry seasons the portage was 51 miles to the junction of the Des Plaines and Kankakee Rivers at Dresden. Those conditions were availed of in trade and travel, from the time of the Discovery down to the time of the removal of the Indians from the State of Illinois in 1836.

The first white settler of Chicago, or the first white man to domicile here was Marquette, in 1674-5, and he was driven from his cabin on the West Fork of the South Branch near Robey street by a flood that came over the divide; and the next day he resumed his journey down the Des Plaines and Illinois Rivers without making a portage.

In 1832, the United States made an appropriation for opening the mouth of the Chicago River, and projected two piers from the vicinity of the present site of Rush street bridge, across the sand spit into the lake; and made a single dredge cut across the bar. This bar was washed out in 1834 by one of these floods that came across the divide.

A schooner entered the port of Chicago for the first time after this flood.

In 1849, a great flood came over the divide and cleaned out all the bridges in the Chicago River, wrecked all the shipping, producing a great disaster for its day.

The same thing was repeated in 1858.

In 1881, the water came over the divide for probably six weeks or eight weeks continuously, in large volumes.

In 1887, I measured a flow coming across the Chicago Divide of 7,000 feet per second, the flood of that year.

In 1892, this flood condition was very critically examined from the Chicago River to Lake Joliet, and a steamboat drawing three feet of water could at that time have gone from
1712 the Chicago River down to the Illinois River, and returned, in the absence of bridges. Aside from these conditions respecting the flood waters, the site of Chicago itself was substantially a morass, similar to what exists adjacent to the Calumet River up to a recent time, and still exists in some sections, awash in high waters of Lake Michigan, and overflowed in all these flood times. It was of much less extent than the Calumet marsh region; and along the lake shore there were the remnants of a sand spit, and wind blown sands rising from 10 to 20 feet above the lake; but generally behind that and out to the slopes beyond, the low lands bordering the Chicago River, the banks were only three to five feet high at low water, and consisted of ooze and muck and alluvial clay, interstratified with layers of sand.

The City of Chicago, or Village of Chicago was organized on August 10, 1833, 28 electors voting; population estimated at 350, from which I presume that none except those that were running for office voted.

At that time it was a mere frontier camp, and the usual well 6 to 12 feet deep in the front yard; slops thrown in the back yard; a privy vault on the back end of the lot. The soil conditions very soon made this intolerable, and the floods occurring annually diffused the deposits on these lots, without regard to sanitary discrimination.

As early as 1836, the conditions had so developed that the people were taking their water in pails from the 1713 river and from the Lake Shore; and the first water system of the City of Chicago consisted of barrels mounted on two wheel carts, that were backed down into the lake and peddled on routes, much like the milk routes today.

As early as 1836, a franchise was granted for a water company to supply the citizens with water, but owing to the panic of 1837 and the financial stress of that period, this company did not get its works installed until 1840; and these works consisted of a 250 barrel tank mounted on blocks at the foot of Lake street, with a 25 horse power engine, a short pipe intake into Lake Michigan and two miles of log pipe, bored out by hand; laid in the streets as a distribution system.

The people of even that day were adverse to monopolies, and did not patronize this water company to the extent of making it a financial success; still preferring the institution of a barrel on two wheels. So in 1851, a charter was granted to a water company, a new water company. The city had been organized in 1837 with a population of about 4,400 to 5,000 in 1840. In 1851, the population had reached about 35,000 and a new water company had been chartered; but the city finally took over the whole proposition in 1854 and established the works at the present site at Chicago avenue on the North Side.

There was some discussion at that time in regard to whether the site should be on the north side of the river or the south side of the river, but the general opinion prevailed that there was a lake current tending southerly along this shore, and it would be safer from pollution to put it on the North Side.

There was another event happening about this time, the opening of the Illinois and Michigan Canal in 1848. The first shovel had been thrown on this Canal at Bridgeport within the present city limits July 4, 1836; and that had contributed greatly to the growth of Chicago during its construction.

The first railroad out of Chicago was opened out to Elgin, also in 1848. The Michigan Southern Road came to Chicago in 1852.

There was a sickly period in Chicago between 1849 and 1854, in which the death rate rose to 48 to 50 in a thousand; three times what is now normal to well sanitated cities.

All these events, what was happening to the water supply, the death rate which had grown so enormously, the feeling that Chicago had ceased to become a mere camp and had
1714 a future before it, led the citizens to make an extraordinary effort to better the conditions here, in order that she might realize destiny. And so in 1855, or 1854, Mr. E. S. Chesbrough, of Boston, was employed as the Sanitary Engineer of the city; particularly at that time to devise a sewer system. Mr. Chesbrough went abroad and studied the conditions at Hamburg and at London and other foreign cities in 1856-7, but had submitted plans for his sewer system late in 1855.

In that connection I desire to say that this was the first comprehensive sewer system in the United States, and that we had at that time about 75,000 to 80,000 of population; and that other cities in the United States like New Orleans have only had a sewer system within the last ten years. Baltimore has not yet completed a sewer system.

I will say further that it was the second comprehensive sewer system built in the world. Hamburg had built a sewer system after its great fire, about 12 or 14 years before. London had started a sewer system, but its plans were not yet complete, and were not completed for three or four years later for a comprehensive system.

The state of the art up to that time had been that all human wastes were excluded from sewers by law. That was the law in England. And it was not until the report of the cities and towns commission in 1844 in England that that law was changed. At that time there had received general acceptance the filth theory of disease, and England and the Continent went on a general clean-up, you might say.

Berlin did not have a sewer system until 1860. All human wastes were excluded from the sewers of Paris up to 1880, so Chicago was a generation or so ahead of the world, and led the United States in regard to its sanitary provision in 1855.

Mr. Chesbrough planned his sewers so as to give a seven foot basement under the buildings, and as a result the grades of Chicago were established at 10 to 12 feet above city datum.

Street grades; and in many places the sewers were built on mounds entirely above the level of the ground, the natural ground, or on embankments; and walls were built on the curb line; and that is the reason for the general conditions that you notice in Chicago, that the basements all go out to the curb line so as to save the filling required to cover the sewers; and the sidewalk space beneath, which does not exist to the same extent in any other city.

1715 After the Great Fire, the grade was again re-established to the present level of 14 feet above the city datum. I was here in 1872, after the Great Fire in 1871, and remember distinctly the condition, that the sidewalk of the city was going up and down at every street crossing, on account of the new grades.

The sewer system then planned by Mr. Chesbrough discharged for the most part to the river. No sewers entered the lake on the north side, on account of the water supply. And the early main sewers came to the main river, so as to be within the influence of any circulation that might be established by way of the Illinois and Michigan Canal. The only sewers that were planned toward the lake was the one east of State street on 12th street and at 22nd street; and later when the city was extended down to 39th street, the 35th street sewer was added, also discharging into the lake. These plans were followed out substantially with the raising of the general grade of the city; and the conditions on the unimproved low lands continued as observed by me in 1872 and 1874 to 1878. Meantime the condition in the river itself was becoming intolerable.

On account of the great cost of raising the city to the grades required to produce a sewer system, the trunk sewers were laid on extremely low grades, 2½ to 4 feet per mile, which constituted them sewers of deposit in low water, under conditions of dry weather flow. And it was recognized from the beginning that catch basins and sewers would have to be cleansed from time to time, and it was only in storm time when the sewers were running substantially full that the sewers were self scouring, that is the trunk sewers.

The conditions in the river early became intolerable with the growing population. We had reached 125,000 by 1860. Chicago early became a packing center, and winter slaughtering was practiced at that time, before they had the refrigerator methods which permitted of all the year around slaughtering. And there had not been introduced at that time the saving in the by-products, bloods and other matter (this has since become a feature of Chicago slaughtering institutions), and everything went to the river, and so the river, particularly in winter time, became very bad.

Under some arrangement, the pumps were operated during the later fifties in the interest of a better river.

1716 The Illinois and Michigan Canal, as it was finally completed under the canal trustees, had a summit level of 8 feet above Lake Michigan, and it was fed in ordinary seasons from the Des Plaines River and by a feeder through the Sag Valley and the Calumet River at Blue Island.

That was known as the Shallow Cut Plan.

A dam was built across the Calumet River at an elevation of 11 feet above Chicago datum. This was insufficient in the dry seasons, and a Dutch Wheel or Lift Wheel was erected at Bridgeport, at the forks of the Chicago River and at the head of the canal for the purpose of supplementing the feed water of the canal, and in such seasons that was sufficient in cleansing the Chicago River and these were operated for that purpose in the later fifties.

But in 1863, after Chicago had established a Board of Public Works, the Chicago River became very offensive. An erysipelas epidemic occurred, which was co-terminus with the South Branch and was attributed to the blood and other matters from the slaughtering houses, and it was depicted on the spot maps as the "Valley of Death."

The Board of Public Works at that time made an arrangement with the Canal Trustees by which the Bridgeport Pumping Station should be operated and the city would contribute to the cost of doing so for the purpose of cleasing the Chicago River; and that arrangement continued up to the time that the canal deepening was completed in July, 1871.

Meantime the effluent from the river was contaminating the water supply, and Mr. Chesbrough projected the first lake tunnel in 1862. It was authorized in 1863. It was to be five feet in diameter, and extended out to the crib two miles from shore, and it was thought that this would give immunity for a long time in the future. It was believed that the effluent from the river for the most part would stay near the shore line, and would not reach out that distance into the lake.

Nevertheless, in designing that tunnel, he made his plans in such a manner as to invite an extension in the future without disturbing the existing conditions, providing an
1717 extension out from the crib in a separate shaft, so it could be shut off and extended at a future time.

This work was severely criticized by all the wise men of Chicago at that time, and Mr. Chesbrough's life was made a burden to him, but in 1867 it was opened, and attracted the attention of the world and made the reputation of Mr. Chesbrough as an international engineer. It has since been followed in all lake cities and followed in all water works practice, to the extent that tunnels can be made available.

He immediately followed this tunnel with a seven foot tunnel parallel to the five foot tunnel, leading from the same crib by way of the Chicago Avenue Station southwesterly across

the city some four miles from Chicago avenue to 22nd street and Ashland avenue. That station was opened in 1874.

The Chicago River at this time was in a deplorable condition. I was in Chicago nearly every day, or several times a week, from 1874 to 1878, and made a study of the conditions here, and was personally very well acquainted with Mr. Chesbrough. The North Branch, as I used to ride by it, between Evanston and the city, in the heated term of summer, exhaled an effluvia that compelled the passengers on the Northwestern Road to shut down the windows in order to keep themselves from being nauseated. No words can describe the potency of that smell.

This condition led Mr. Chesbrough to project the Fullerton Avenue Conduit, started in 1874 for the purpose of circulating the waters of the North Branch. It was put in operation in 1878, and as operated it changed the waters of the North Branch about once in three days, which greatly mitigated the badness of the smell. But it was still far from a satisfactory exhibit.

The South Fork conditions were even more serious than the North Branch; the smell from that source reaching out to the lake shore in the then best part of the city, down in the vicinity of the Douglas monument and above. This was noticed particularly in the night time and on foggy days. The sun seems to have some resolving powers in dissipating these smells.

Mr. Chesbrough projected a similar conduit to the South Fork, but his enterprise in behalf of the welfare of the city by that time had reached such a magnitude that he was unable to carry out that enterprise, and we retained the
1718 conditions of the South Fork with us until the Sanitary District finally changed the same along about 1908, I think.

Meantime, a Commission had proposed the deepening of the Illinois and Michigan Canal on the original plan; and in 1865 an enabling act was procured from the General Assembly

which authorized the City of Chicago to deepen this canal on the original plan for sanitary purposes; and the city of Chicago did so, and expended thereon about Three Millions in cash and opened the same in July, 1871.

That was gravity flow.

The General Assembly was called in special session after the Great Fire of October, 1871, and repaid this money to the city of Chicago, and it was all the funds that it had until the city was in shape to again realize taxation.

This canal as originally projected and worked on from 1836 to 1841, when the state went broke, had a declivity of a tenth of a foot per mile or 2.9 feet between Bridgeport and Lockport. But when work was resumed under the trustees for the bondholders in 1843, they adopted the expedient of a temporary level 8 feet above Chicago datum for 26½ miles, which I have already described.

The original divide at Kedzie avenue was about 10½ feet above Chicago datum called the "Continental Divide."

But this was a mere alluvial deposit. The real divide was the rock floor at Lemont which was between 7and 8 feet above Chicago datum, and about 2 or 3 feet above the high water of 1838, which was the highest water on record. The original divide was only 5 to 6 feet above high water of 1838.

This was the only relief that the city had until the canal was reinforced by pumping works in 1883. The canal when opened to gravity is estimated to have carried out 40,000 cubic feet of water per minute. But the lake was then high, and in later years as the lake fell, the capacity shrunk to 15,000 or 20,000 feet per minute, which was scarcely more than the dry weather flow and the water supply of the city, so it was ineffective in preventing the sewage from flowing towards the lake. And the condition of the canal became so bad that at the instance of the State Board of Health, first in 1878, when it was organized, I think, in 1877, the Munn 1719 Resolution was passed by the Legislature in 1881, calling upon the City of Chicago to erect pumping works there of a capacity of not less than 60,000 feet per minute.

These pumping works were installed in 1883, but were not actually accepted from the contractors and taken over by the city until 1886, although they were operated meantime.

These pumping works were authorized by the Legislature in response to the representations of the State Board of Health, which had taken a position supported by the report of Superintendent Thomas that the canal could be made to carry 100,000 cubic feet of water per minute, and that such a volume of water would dilute the sewage substantially beyond offense. But they did not get the recommendations carried out except with the minimum limit of 60,000 cubic feet. It was for the purpose of relieving the nuisance at Joliet, and in the Valley further down; and also for the purpose of purifying the Chicago River that these pumps were installed, or called for by the Legislature.

Mr. Chesbrough was uncertain in his own mind in 1878 as to what the future solution of the sanitary question was to be. He had planned along the line of the State Policy, which had contemplated from the beginning the flow of water in the direction of the Illinois Valley, and which comes up from time to time in all the actions of the state. But the city was unable to finance a proposition of that kind. Conventions had been had, reports had been made; there was a
1720 Great Waterway Convention in 1847 and again one in 1863, in which 14 states were represented, urging this project; the Board of Public Works had considered it in 1860, so the matter was a familiar one to the people of Chicago, the idea that eventually sewage disposal was to be down the Des Plaines and Illinois Valley.

The only incident that occurred of particular moment between 1878 and 1885, was the Great Flood in the Des Plaines River. This flood reached a magnitude of 13,000 second feet; continued at a uniform elevation for about four days; gradually shrunk, but exceeded 10,000 feet per second for 21 days, at Riverside. There was probably from 5,000 to 8,000 cubic feet per second coming across the Chicago Divide during that time; and a lesser amount probably for two or three times as

long a period. In addition there was probably a maximum flood from the Chicago basin of not less than seven to 8,000 feet. These conditions swept the Chicago River clean and led the people of Chicago to renewed earnestness in the consideration of their sanitary problems. Between that time and 1885 various projects were mooted, one of which was to shift the water supply to Grosse Point, the north limits of the City of Evanston; another to shift it to Highland Park in Lake County, and let the water come down by gravity. Another was a deep cut proposition which was worked up by Mr. Matthiesen at Joliet, by which a narrow and deep channel with high velocity was to be constructed from the Chicago River and located between the Illinois and Michigan Canal to the Des Plaines River; and discharging in the upper basin at Joliet.

The Citizens' Association of Chicago had taken particular charge of this matter and had worked up this latter proposition of Mr. Matthiesen's and made a report thereon.

1721 On August 2, 1885, occurred a rainfall of over 6 inches in 24 hours, the greatest precipitation that has occurred during Chicago rainfall record, beginning in 1843. The effect of this rainfall was to sweep out the contents of the Chicago River; to scour out all the sewers and catch basins and to wash the streets. The entire effluent went into the lake and filled the lake with a black filthy mass extending several miles north and south along the shore, and out beyond the crib. And its effect was visible in the water supply for a long time afterwards.

The Standing Committee of the Citizens' Association appointed a sub-committee consisting of Mr. Ossian Guthrie, who had operated the Bridgeport Pumping Station, since its installation in 1848 up to the time it was abandoned in 1871 by the deepening of the canal. He had ice interests in the Des Plaines River, and was thoroughly familiar with all the flood conditions at Chicago. They selected also Doctor Frank Reiley, who was then the Assistant Secretary of the State Board of Health of Illinois, and they selected me as engineer.

We made a general examination of the situation, visited the Des Plaines River and all the points of interest in connection with the phenomena, and wrote a report which I drew; and this report substantially unchanged was adopted by the General Committee of the Citizens' Association, and printed in all the Chicago papers on August 27, 1885. A rainfall not quite so large occurring a week or two later, also producing a large flood, came in to re-enforce the findings of the report and give them general credence and acceptance among the people.

This report contemplated or recommended that all storm waters including all sewage be permannently excluded from Lake Michigan; that a channel large enough to accomplish this be built through the Des Plaines Valley to an outlet near Joliet; and that in order that this channel should not be unnecessarily large, the headwaters of the Des Plaines and North Branch should be diverted to Lake Michigan. Of course it involved taking out all the sewers and reversing them, or intercepting those that emptied into the lake; and also providing a circulation in those parts of the river which had no circulation; parts of the harbor.

This proposition was followed by an ordinance of the Council which I drew, and which was promptly vetoed by Carter Harrison, Senior, on the ground that the city had no means of financing the undertaking; and it was vicious to discuss these propositions, and unpatriotic under those circum-
1722 stances.

Later Mr. Harvey B. Hurd, went to Mr. Harrison and pointed out to him a constitutional method of raising money through the creation of a blanket corporation, such as we have precedent for in the Park Boards, with its own power of taxation and bonding. Mr. Harrison later sent a message to the Council recommending the appointment of an expert Commission, and this was adopted.

In April, 1886, Mr. Rudolph Hering of Philadelphia was selected as Chairman of the Commission, and later Mr. Samuel

B. Artingstall, who had been assistant engineer to Mr. Chesbrough and was then city engineer, was made a member; and also Mr. Benezette Williams, who had been an assistant engineer to Mr. Chesbrough, and who had recently completed the Disposal Works at Pullman, which were looked upon as model works at that time, and an augury of the future disposal of sewage, by scientific and rational methods. I became chief assistant in general charge, in the absence of Mr. Hering, of all the work, and in special charge of those parts of the investigation which we are particuary concerned with in this inquiry.

I had the subject of streams examination through all the water sheds that affected the Chicago condition, the lake currents, lake levels, the ship canal surveys, borings, calculations of the capacity of channel; the Illinois River problems; its effect on the Illinois River of the proposed flow of water from Lake Michigan; the examination of the Chicago River and its contents and of the special filth producing industries; an examination of the conditions of the Illinois and Michigan Canal; an examination of the conditions produced in the Illinois River by the sewage which had been sent down the canal. Mr. Swan of Boston had particular charge of the investigations relating to land disposal, sewage treatment and lake disposal. Mr. Swan was a man who had been connected with the Massachusetts Board of Health, which had made perhaps the most extensive researches up to that time respecting the pollution of streams; and he had also made a number of trips abroad.

1723 I had included in the report of the Sub-Committee to the Drainage Committee of the Citizens' Association a statistical statement to show that Chicago would reach one million inhabitants in the year 1890, and would be able to finance the undertaking. I was asked to strike out that matter as it would discredit the report, as nobody in Chicago believed that this city would reach a million inhabitants in the year 1890. There was no member of the committee who believed it; and so I struck it out, as it had no material bearing upon

the project itself. There were on that Committee such citizens still living as J. J. Glessner and J. Harley Bradley.

1724 I also made a critical examination of the Chicago River and its contents, and dredged up every acre of its bottom within the city to ascertain the nature of the deposits there occasioned by sewage. The Chicago Harbor has an area of about 450 acres, which was actually used for shipping purposes. This river, as I have already stated, was swept clean in August, 1885.

In the Fall of 1886, it had a sludge deposit in the North Branch from a foot and a half to 6 feet in depth; and in the South Branch about 4 feet in depth. This sludge was not what is ordinarily termed sludge in the nomenclature of sewage disposal. It was a black, jelly-like mass full of cavities like Swiss cheese, indicating a secondary decomposition, and emitting gases on its own account; and from all the studies and examinations and knowledge which I could acquire in regard to the same, it appeared to be largely hydro carbon, bacterial gases that are thrown down through the decomposition. I estimated that the South Fork would have filled up in four years from these deposits, except for the progressive decomposition that was going on.

I repeated this examination after the spring flood of 1887, and found that the river had been swept clean of these deposits.

1725 Those went out into the lake.

They were of that constitution, so cellular in composition that when they are once broken up by a propeller or other disturbing forces, they would float readily in the water.

I also made an examination of the Illinois and Michigan Canal to ascertain its condition respecting these sludge deposits and what current must be maintained to keep the same from settling on the bottom. I found practically no deposits similar to those which I have described in the Illinois and Michigan Canal. There were deposits in wide water, which consisted very largely of earthy matters; and it seemed

to be that a velocity of ½ to ¾ of a mile would maintain all these substances in suspension.

I also made an examination of the conditions in the Illinois Valley since the sewage had been down there through the canal, and made an extended trip from Joliet to La Salle, interviewing all the people and fishermen who were familiar with the condition of the river, respecting that subject.

We had a breakup flood in 1887, occurring the latter part of February, which reached 10,000 second feet at Riverside, but was of extremely short duration, as a freezeup set in the next day, after the flood got fairly under way. I measured that flood in the North Branch and in the West Fork of the Chicago River, where I ascertained that 7,000 second feet was coming across the divide. I also had a party at Riverside. Mr. Hering was in personal charge of a party at the mouth of the Chicago River, and as I recall measured 12,000 feet of water going out into the lake in that flood, which was by no means an extraordinary flood.

A preliminary report of the Commission was made January 30, 1887, and in that report they considered three methods of sewage disposal for Chicago.

One of these methods was to gather up the sewage by intercepting sewers and conduits, and pump the same to the sand ridges and dunes of Indiana, east of Hammond, and between the Little Calumet River and Lake Michigan; and there dispose of the sewage on land by broad irrigation and intermittent filteration. This scheme was regarded as impracticable by reason of divers political jurisdiction, and by reason of cost. And it still left problems to be solved in the circulation of rivers and the care of floods. It was known even at that time, and more fully developed later, that the condi-

tions of flood waters and especially the conditions of the
1726 water in the Chicago River when this city was taking a

bath, the sewers were being scoured out and the streets washed, were worse than at any other time. And no such scheme could care for these food conditions; and the condi-

tions for the maintenance of proper sanitary conditions in the river itself.

The second scheme worked out was like the first, so far as gathering up the sewage was concerned, and a conduit was to be driven out into the lake opposite Jackson Park and the sewage there forced out through this conduit and diffused in the lake. The water supply was to be shifted north to Grosse Point at the northern city limits of Evanston. This proposition was estimated, and it was also regarded as prohibitive. It was strongly objected to on the score of possible contamination of the water supply even at that distance, as the lake currents showed that to be possible: and also for sentimental and other reasons. The effect would be to pollute the bottom of the lake here over a very large area to be stirred up in storms and result in a bad condition of the water in this end of Lake Michigan. It also failed, like the first scheme, to take care of flood water conditions, and the circulation of the river.

The third proposition, which was affirmatively recommended, was the ship canal solution, substantially as outlined by the report of the Citizens' Association of August, 1885, and the capacity of the channel which it was then determined it would be necessary to take care of the flood conditions was fixed at not less than 10,000 second feet.

This would also take care of the Chicago River and produce proper circulation in its branches by means of adjuncts. The population estimated in all these schemes was two million and a half people, and on that basis the dilution was inferred at four cubic feet per second for each thousand of population; although this matter as to what population such dilution would take care of or such volume of water would take care of was not specifically passed on at that time.

It had other collateral merits which were mentioned. It would lend itself to the development of an inner harbor here in Chicago and would provide the water supply required to produce a deep waterway to the Gulf and would contribute to the extent of the cost of the main channel of such deep wa-

terway, without expense to the State or to the United States, all of which were motives which left no doubt as to the proper scheme to select.

1727 Following this report, a bill was introduced in the General Assembly known as the Hurd Bill, the same being drawn by Harvey B. Hurd, an eminent constitutional lawyer of Chicago, which provided not only for the construction of this work, but also for taking over the sewer system and eventually the water system of the city, so as to combine under one jurisdiction all elements of the sanitary problem in Chicago.

Extensive hearings were had, which were printed at the time, before a Joint Committee of the General Assembly, which went into the merits of the whole question as then understood. The General Assembly considered the subject matter unripe for action and postponed the Hurd Bill, and passed a subordinate bill known as the Roach-Winston Bill, which gave authority to divert the head waters of the Des Plaines River and North Branch to Lake Michigan and enter upon other expedients of temporary relief pending the development of the major project.

The General Assembly also authorized a Joint Committee to sit *ad interim* to investigate the whole subject matter and report back to the next General Assembly; and constituted the Mayor of Chicago *ex officio* chairman of this committee.

The Drainage and Water Supply Commission reported on the schemes covered by the Roach-Winston Bill, in July, 1887, and did project various measures of temporary relief such as extending the water tunnels, enlarging the canal out to Summit, or the Ogden Ditch, and putting in pumping works there to pump 120,000 cubic feet of water per minute, but none of these measures were actually carried out.

The investigation of the Drainage and Water Supply Commission continued after this report until November, 1887, and then the Commission was disbanded, without ever having made a final report or completed all the topics which it had

undertaken to consider. Following the disbandment of the Commission, I entered into the service of the State Board of Health of Illinois, as its consulting engineer.

The State Board of Health, in cooperation with the City of Chicago, had in 1885 and again in 1886, made an extended series of chemical analyses of samples from a number of points between Chicago and Peoria for the purpose of determining the effect of sewage in the Illinois River and the purification of the same. They presented a very sanguine report in 1886, in regard to the progressive oxidation of the sewage downstream, which was challenged and much criticized by the sanitary world as a misinterpretation of the facts; that the real cause of the purification shown was sedimentation and dilution, and not purification.

1728 The sanitary world at that time had been much impressed and still entertained the dogma which had been pronounced by the Royal Rivers Pollution Commission of Great Britain, which had issued a dictum much quoted even to this day, that there was not a river in Great Britain long enough to purify itself.

My work with the State Board of Health consisted of various examinations and consultations here at Chicago, special examination of the Illinois River, in which I twice examined the conditions produced by the distilleries and the cattle pens of the Corn Products factories at Peoria and Pekin, which were producing a condition in the Illinois River at that time for 20 to 25 miles below Peoria only less offensive than that which existed in the Chicago River.

In 1888, they undertook a very comprehensive series of stream examination of the Illinois River and its tributaries, and the entire route from Lake Michigan to St. Louis, and continued these observations into the winter months of 1889. And I undertook to work up the physical facts connected with the flow of the river in that connection. These results were published in a preliminary report in 1889, along with my own contribution respecting the Illinois River System, and were before the Legislature in the session of 1889.

In the spring of 1888, the special joint committee of which Mayor Roach of Chicago was Chairman, got busy and employed Mr. John P. Wilson as legal adviser and he called in consultation eight of the most eminent constitutional lawyers that were then in Chicago and the State, to determine the legal basis of a proposed Sanitary District Act. I was employed as consulting engineer to this committee; and in the subsequent months hearings were had in Chicago and in the Illinois Valley in relation to all matters in controversy.

I was called upon particularly to pass upon and determine the capacity of the channel, and adopted the prior determinations that it should have a capacity of not less than 600,000 cubic feet of water per minute, but that in order that Chicago would be better able to finance it, only the rock cuts were required to have this capacity at the outset; the earth cuts permitting progressive development with the growth of population; and it was so entered in the law, or in the bill then prepared.

The other question that I was called upon most particularly to consider was the subject of proper ratio of dilution.
1729 There was a difference of opinion in the Commission itself and in the hearings, ranging from 14,000 cubic feet of water per minute for each 100,000 of population up to 30,000 cubic feet of water per minute, and the subject matter was finally referred to the consulting engineer to make an exhaustive investigation as possible, and that whatever findings he made in the premises would be satisfactory to all parties.

At that time we had not only our own investigations here in Chicago and in the Illinois Valley, which perhaps were more comprehensive than had ever been undertaken upon a similar subject and upon a much larger scale.

And we had also the very excellent reports of the Massachusetts Board of Health, and some from other New England States going back for 15 years or more, dealing particularly with the subject of river pollution. We had also all the reports that had been made by Royal Commissions in Great

Britain; the reports in regard to Paris and Berlin, and other foreign data.

In addition to this, I made a special compilation of the population of American cities in relation to the low water supplies of streams into which they discharged their sewage. So I felt then, and feel now, that we had all the data which was available for such a consideration. We had on the one hand a city so situated and conditioned that all the sewage that was produced by its population was practically tributary to the sewer system, perhaps more completely so than in any other city of the world . We had also at that time the established leadership in the preparation of food products of vegetable and animal origin, and the waste from those sources in themselves amounted to the equivalent of a very large city. But in respect to this matter, it was reasoned that there had been a very great development in by-products from these industries in the past, and that probably by the time the capacity of the channel approached exhaustion these wastes would be all converted into useful commercial products, so that there would remain substantially only the domestic sewage in the eventual windup.

On the other hand most of the data existing here and abroad were cases of actual pollution of streams, of natural streams which were all highly charged, in some cases to their practical limit in digesting the organic remains from the land. That matter had come up for very careful and full consideration in the studies by the State Board of Health, or under the direction of the State Board of Health, and we had made estimates of the organic product from the Illinois water-
1730 shed, a very rich watershed, in its vegetal cover which showed that the organic wastes coming to the stream from this source were manifold.

These facts had led to very high estimates in different localities and in different countries in regard to the ratio of dilution that was tolerable in streams; whereas we had at Chicago a lake water charged to its limit with oxygen, in fact surcharged much of the time, so that it was not a case of

river pollution in fact, but a case of contributing a new stream to the Illinois carrying its own standard of purity.

After going over all these matters which I have outlined, I determined the ratio at 20,000 cubic feet of water per minute for each 100,000 inhabitants, as a minimum. The bill as drawn was submitted by the committee to the General Assembly as its report, February 1, 1889, and was passed in May of that year without any amendments whatever as affecting the sanitary provisions of the bill.

I was instructed to remain in Springfield by the Mayor of Chicago, and was eventually left in charge of the measure after the preliminary hearing. I am able to say that every feature of the bill that affected the Illinois Valley was canvassed at great length. In my work for the commission, I had the assistance of a party of men, among others Mr. John Erickson, now City Engineer of Chicago; and we were called upon and did compile everything relating to conditions in the Illinois Valley, and made the best estimates that it was possible to make at that time regarding the effect of this volume of water in the Illinois Valley. And those matters were fully explained.

In order to further safeguard the interests of the Valley, provisions were put into the bill to remove certain dams belonging to the State. A supplemental bill was drawn. I myself drew it at the request of the Valley interests providing for a cession of these dams to the United States, on condition that they should remove the same and change its policy to a deep water policy in conjunction with the water supply from Lake Michigan. In the event of the United States not accepting the same, the canal commissioners were directed to remove the dams whenever the water turned down from Chicago should give an equivalent depth for navigation.

1731 A joint resolution was passed by the General Assembly, which I prepared by request stating the policy of the State, which was to produce a channel not less than 22 feet deep across the Chicago Divide to Lake Joliet, and not less than 14 feet deep thence to Utica, so fashioned as to permit fa-

ture increase in depth, and requesting the United States to stop work on the dams at La Grange and Kampsville and enter upon a policy of deepening the Illinois River by dredging, in conjunction with this water supply from Lake Michigan, and produce such depth as might be feasible by such method. This resolution was repeated in 1897, which I also drew by request, and there the proposition is mentioned of 14 feet through the Valley, which is the origin I think of that phrase.

Our examination of the Illinois Valley had determined that 14 feet could be produced by the aid of this water supply; and that by producing such depth of water, this channel would be self-sustaining and not subject to depreciation and would make a better drain for the Valley, and assist in the reclamation of the lands. All these matters were prime factors, as well as another matter which was uppermost in the minds of the State Board of Health and in the minds of the General Assembly, and that was that the solution that served Chicago would likewise serve all the populations that could exist between Chicago and the Mississippi River, by reason of the progressive purification of the sewage, through which it could take on an additional burden from point to point.

After the passage of this bill, the subject matter of a petition for the organization of the Sanitary District was taken up by the Citizens' Association, and I acted as consulting engineer to the petitioners and prepared a number of exhibits which were submitted to a committee of Judges of the Circuit Court, which was provided for by law, who held hearings and entertained objections in respect to the proposed boundaries of the District, and to finally determine the same. These hearings were continued over a number of days, and all interests subject to taxation within and without the proposed district appeared. And it became necessary to develop before this Commission a complete project, to determine you might say a complete project by which the Commission could judge that every part of the territory which it was proposed to tax would be benefited and could be served.

They finally determined the boundaries of the district on the North by the north line of Lake View and Jefferson; on the West, the west line of Cicero, and along the range line through the township of Lyons, including outside thereof some eight square miles along the Des Plaines River below Riverside; thence easterly along the south line of the
1732 Town of Lake and across Hyde Park at 87th street; the same including 185 square miles.

At the time of the passage of the Sanitary District Act, this area was divided up into a number of municipalities. The city of Chicago itself covered 37 square miles and had a population in 1888 of 802,651; the town of Lake View 42,339; Jefferson, 10,622; town of Lake 56,661; Hyde Park north of 87th street 41,000.

All these areas above scheduled were consolidated with the City of Chicago at the general election in 1889 by authority of an act of the General Assembly. There was in addition the town of Cicero, with a population of 13,926 and a part of the township of Lyons with a population of 1,293, and these together aggregated nearly 1,000,000 (988,329). The proposition was voted upon at the general election in November, and the Sanitary District Act was adopted by vote of 70,000 to 200, in round numbers.

In the December immediately following, a special election was held for trustees; and the Board finally organized as a Board of Trustees of the Sanitary District in January, 1890, and elected its officers. I was elected Chief Engineer for the Sanitary District, and entered upon my duties at once. These consisted in bringing together all the data and exhibits that had been prepared during the prior investigations until the Supreme Court decision affirming the validity of the act was handed down on June 12, 1890.

Immediately thereafter an engineering force was organized on a large scale and proceeded with the definitive surveys which preceded construction, and the actual carrying out of the work itself.

At that time, our particular studies and surveys were directed towards locating the main channel and the river diversion from the Chicago River to Joliet, and making all land surveys required in connection with acquiring the right of way; and of course with a view to putting that work under construction as soon as possible.

Later, and in the course of my first term as engineer and trustee of the Sanitary District we completed compre-
1733 hensive surveys extending over the entire area of the District and outside of the same for the purpose of taking up the border definitions on the collateral projects.

The plans except as to details and except as to specific definition had all been practically determined before the law was passed, and were exhibited with all needful detail before the Committee that determined the boundary of the District.

The plans of that period not only exhibited an auxiliary channel from the main channel to connect with the little Calumet River, but also the Evanston Channel. In fact the Calumet proposition was worked up by the preliminary report of the Hering Commission in 1887 and was always regarded as one of the integral parts of the comprehensive plan.

It was further developed or reported upon in 1896-7 by the Intercepting Sewer Commission of the City of Chicago; and also considered at length by the Committee on a comprehensive plan in 1901. I was a member of the Intercepting Sewer Commission and also the Committee on Comprehensive Plan.

Plans with reference to intercepting sewers for the city of Chicago were considered from the beginning, and plans were actually made in connection with the disposal schemes in Indiana and in the lake for intercepting the lake shore sewage, and this matter was taken up in final preparation for work by the Intercepting Sewer Commission or what was known as the Pure Water Commission of the City of Chicago in 1896, and definite plans prepared which have since been car-

ried out with some amendments covering the entire city front from 87th street on the south to the northern city limits. There were two of the sewers that discharged into the lake under the old Chesbrough plan, the one at 12th street and the one at 22nd street, and they were actually reversed on or about this time.

The Sanitary District was instituted for the specific purpose of carrying out the projects which were outlined prior to its organization, and had proceeded by September, 1890, in the definitive surveys in relation to the main channel from the Chicago River to Joliet. They had also instituted sur-
1734 veys on the Chicago River with a view to the definitive surveys for its enlargement.

When I became chief engineer in January, 1890, I proceeded immediately to further work upon those plans for the Sanitary District.

There was nothing left to do except to define the things on the ground, practically. The genius of the whole proposition from the outset, held in mind unvaryingly, was to keep the flow of sewage away from Lake Michigan as far around the rim of the lake as was practicable.

After December, 1890, when I ceased to be the chief engineer I again resumed my connection with the State Board of Health as consulting engineer, with a view of completing the report which had been made in preliminary form in 1889, and putting the whole subject matter of our knowledge of the conditions in the Illinois Valley in proper form for printing and record.

1735 No water supply has ever been entertained for the City of Chicago except Lake Michigan. and no other source of water for the city is really feasible, except Lake Michigan. The water supply from all the Great Lakes has been regarded perhaps as superior to any source of water supply elsewhere existing in this country, by reason of the age of its waters, through which all the biologic processes of nature have worked

themselves out, those that are in any way detrimental to human kind.

The average flow over Niagara Falls would take one hundred and fifty years to drain out the contents of these lakes, if they were not replenished and in the absence of evaporation. The Chicago Sanitary Canal, if operated at 15,000 second feet, would be supplied for 2,000 years, so the average age of the water of the lakes is 150 years.

There is no possible substitution for these waters, which could equal them in value or efficiency. There is no possible treatment of water which is the equivalent of these aged waters. The matter of age in waters has been given in
1736 the last few years a very great deal of consideration.

Mr. Frederic P. Stearns of Boston in the Metropolitan Boston Supply projected a reservoir there and places considerable stress by reason of the fact that the average age of those waters will be six to eight years, and they will have time to whiten and bleach, and work out their biologic cycle.

The same proposition I had up in connection with the Denver water supply where I was instrumental in constructing a reservoir that would carry three years' supply for the City of Denver, and secure the same object.

There is very little land water going into the south end of Lake Michigan; the nearest point of any tributary of considerable size being the mouth of the St. Joe River, more than 60 miles away.

The sanitary project contemplates and has contemplated from the outset extending this divorce between land waters and lake waters as far around the rim of the lake as possible; north to Lake Bluff at least, on the north and east across Lake County in the State of Indiana; and when the proposition is entirely worked out there will be some 60 and 70 miles of the lake shore entirely free from the intrusion of any land water or sewage whatever. And this puts Chicago in a better position in relation to its water supply, and secures for it a better water supply than is provided for perhaps

in any city in the world; one that is automatically free from contamination or possibility of contamination.

After 1883, the Illinois and Michigan Canal was operated up to a limit of 60,000 feet of water per minute or a thousand feet per second, which was little in excess of the ordinary flow of the sewers coming from the water supply and the ground waters; and the result was that any rain of any considerable amount that produced any run-off at all in the sewers or in the watersheds outside of the sewerage area
1737 produced a flow towards Lake Michigan, which entered the lake water and contaminated the same.

There were also conditions where lake fluctuations produced a similar result. This bobbing of the lake up and down, which I have observed through a range of eighteen inches every twenty minutes, had the effect of sending the current up the river, and then set it back again, amounted to a species of milking process, by which the content of the Chicago River was gradually milked out into the lake.

Again, there were other changes; sometimes the lake would be up an extra foot, and all the bad waters would be sent up the slips and the South Fork and North Branch, and fish would attempt to make a trip through the blue waters of the river and the lake would fall as quickly, and all the bad waters would set out into the channel, and we would have large numbers of dead fish in the river and in the canal.

The South Fork was without circulation during this period, and in a malignant condition.

The North Branch had only the nominal circulation created by the Fullerton avenue conduit, which was changed once in about three days and was in a bad condition. Of course in flood time, when there was any considerable amount of water, the contents of the river went out in a most affirmative way into the lake.

I will say, further, that the duration of this positive flow into the lake was variable. Under the conditions of the flood of 1881, it probably was not less than 100 to 120 days; prob-

ably in the minimum years not less than twenty-five or thirty days, but that is an estimate and not a positive determination.

The smells were affirmative in the North Branch along the main river, and beyond any power to describe the same in the South Fork. In the examination which I made in 1887—1886 rather, I was on the river in a tug for several days dredging every acre of its content to ascertain the character of the deposits on the bottom. These were brought up and spread over a broad table on the fantail of the boat and examined carefully by working them over with a paddle and examining them with a glass, and samples of them taken from time to time for more critical examination. And in my trips up the river, and especially up the South Fork, men were
1738 so nauseated that they were unable to take their meals, and some of them did not recover for a week.

At times there would be a scum, sometimes extending clear across the South Fork, which appeared to be six or eight inches thick, and over which the fowls, geese and duck of that region, proceeded without difficulty. I have heard of that scum having been afire; and the vessels that went up into those forks lost their white paint very quickly.

There was noticed, however, in the death charts which I prepared in regard to zymotic diseases in Chicago, covering the years 1890, 1891 and 1892, that the deaths from miasmatic or air-breathing diseases seemed to be more prevalent in the region where these bad gases were most intense. And in the inquiries which I made at that time among physicians, it was generally recognized that throat troubles and other air-breathing maladies were more malignant where these emanations were breathed.

This pollution of the Lake Michigan water had an effect upon the death rate from typhoid fever and other water-borne diseases.

I investigated a typhoid fever epidemic in Lake View in 1889 for the State Board of Health, and later followed the

matter up in 1891. The epidemic that started in Lake View continued with ups and downs through 1890, 1891 and 1892, and then gradually subsided.

In 1891, the death rate in Chicago was 480, I believe, in May of that year, and for the entire year the number of deaths from typhoid as then diagnosed was something over 1,700.

Estimating the population at 1,000,000 within the city proper, it would be 170 per 100,000.

1739 I sent men to the health records, or to the records at the City Hall and we went through the entire list of deaths of the year. At that time they were not classifying and printing a classified statement of deaths. We made a card for each name for each location, and then proceeded to spot it out on the map. In that way we made up the charts for the years 1890, 1891 and 1892, for the particular purpose of disclosing that epidemic, and also the relation of other zymotics.

I was elected as trustee, and took office as a trustee in December, 1891, and continued in that position until December, 1895, and during that period we executed the Des Plaines River diversion, a collateral work of the main channel, by which the river was given a course by itself on the west side of the Des Plaines Valley, so as to leave an intermediate strip between the river and the canal, on which we located and built the Drainage Canal.

At the end of 1895, excavation on the Main Channel was about three-fourths actually made or completed. The right of way had all been procured at that time; the contracts for the Main Channel were also arranged before the close of my term as to be completed in November, 1897.

I was consulting engineer of the District in 1897, and we were overtaken at that time with a financial stringency, which seriously embarrassed the progress of the work of the District. The work was proceeding faster than the District could get the funds to pay for it, and so the real work on the channel, the Main Channel, which was scheduled to be completed

in November, 1897, was not actually completed until about November, 1898, when it was substantially completed, and the District then notified the Governor of that fact and asked for the appointment of a commission. The first action by the Board on that matter was in November, 1898, and the petition actually was transmitted to the Governor in January, 1899, as I recall it.

1740 There was a delay at that time in view of the fact that the state had made no appropriation for the maintenance of this Commission, and the Sanitary District deposited the necessary funds with the State Treasurer, and the Commission proceeded later to perform its functions, and the Sanitary Canal was finally opened on the recommendation of the Commission to the Governor, January 17, 1900.

The channel was then opened and the water flowed through the Main Channel into the Des Plaines River, and has been flowing continuously ever since.

Very elaborate surveys were made of the Chicago River for the purpose of defining the property questions at the place of the enlargement while I was a trustee of the District prior to 1895; and the work of actual enlargement of the river began in 1896.

The United States took jurisdiction of the Chicago River and exercised authority over it for the first time under the clause in the Rivers and Harbors Bill of 1896, and a permit was then issued to the Sanitary District for the improvement of the stream, by the Secretary of War. The stream was prepared for a flow of 300,000 feet of water, the preliminary requirement of the Sanitary District law, some time prior to the opening of the channel.

After the flow of water had been established, in 1900, the Sanitary District then matured plans for enlarging the river for the purpose of getting the larger quantity of water required by the Sanitary District Act, and actually entered upon that proposition in 1900; and the whole subject matter was before the Commission on a comprehensive plan of 1901, of

which I was a member, and the trustees went to the Legislature and got an enlargement of their bonding power for the purpose of expediting the work in 1901.

The improvement made prior to the opening of the channel was simply preliminary improvement. It was recognized that in order to obtain this flow in the quickest possible time
1741 and at the lowest possible expense, it was recognized that there would have to be a wholesale improvement from the beginning, such as was undertaken in 1900.

I refer to a resolution passed by the Board of Trustees of the Sanitary District of Chicago on April 21, 1891, appearing in the printed proceedings of the Board as follows:

> "Resolved, That this Board hereby ordains that the Sanitary District of Chicago do forthwith enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the South Branch thereof, and also the South Branch thereof, together with the South and West Forks thereof, so as to make the same a proper and sufficient supply channel for the Main Channel heretofore surveyed from the Chicago River to Joliet;
>
> And further, that the acting Chief Engineer be and he is hereby directed immediately to investigate and report upon the capacity of said river and its said South Branch and Forks for that purpose; and also as to any changes that should be made therein. And that a copy of this resolution, certified by the Clerk, be forthwith transmitted to the Mayor and Common Council of the City of Chicago and the Secretary of War of the United States."

The Chief Engineer of the District went ahead and made an exhaustive survey of the Chicago River from Robey street to the lake, defining all property rights and cross sections of the stream, with a view to definitive plans for the improvement of the river. And these surveys were completed prior to 1895. They were followed by definite plans for the improvement of the river, which were inaugurated in 1896, in cooperation with the United States, which made an appropriation for the improvement of the river in that year; and the river was improved to a depth of twenty feet by dredging the stream. And the bad angles in the stream were cut off,

and in some places the river was widened, and in the vicinity of Adams street and Jackson street, by-passes were con-
1742 structed at the constricted parts of the river, in that vicinity, for the purpose of giving the preliminary flow required by the Sanitary District law of 300,000 cubic feet at the velocity of one and one-fourth miles per hour.

These surveys were also used as the basis of the larger improvement which was immediately defined and inaugurated after the opening of the channel in 1900, for a capacity of 10,000 feet per second.

That plan consisted in bascule bridges in the stream of a uniform width of 200 feet, and a central depth of twenty-six feet; and has also been carried uot in part with the cooperation of the United States.

The capacity of the Main Channel at the Rock Section was actually 840,000 cubic feet per minute.

The occasion for making further improvement in the Chicago River and its branches after 1900, by the Sanitary District, was to get the increased capacity which was required with the growth of population, after the initial capacity of 300,000 feet had been established, and to accommodate
1743 600,000 feet by way of the Chicago River, and later that was supplemented by the flow by way of the 39th street conduit.

That new improvment or the improvement after 1900 was known as the Chicago River Improvement Project of 1900.

If the flow through the Sanitary District Canal had been limited to 5,000 cubic feet per second after 1900, it would not have been necessary for the Sanitary District to have made the changes and alterations in the Chicago River that it subsequently did make after 1900.

1746 Amounts expended on Chicago River improvement:

Total expenditure up to and including 1899	$ 727,441.02
Expended in 1900,	837,165.39
Total expenditures up to and including 1900,	1,564,606.41
" " five-year period, 1901-1905,	6,727,708.34
" " up to and including 1905,	8,292,314.75
" " five-year period, 1906-1910,	2,082,229.92
" " up to and including 1910,	10,374,544.67
" " two-year period, 1911-1912,	266,194.85
" " up to and including 1912,	$10,640,739.52

The building of the Main Channel and the improvement of the Chicago River which is a part thereof has extended lake navigation to a depth of twenty-four feet, thirty-six miles from Lake Michigan and within a mile or two of the City of Joliet. Lake navigation has not yet developed on a scale of twenty-four feet, but is predicated for that depth by the new lock now under construction at Sault Ste. Marie.

Below the water power station at Lockport, navigation is extended by a lock constructed by the Sanitary District suitable for small boats down to Dam Number 1, at Joliet, two and six-tenths miles; and this channel is twenty feet or more in depth for most of the distance, and a limited depth of ten feet after it reaches the Des Plaines River and the upper basin at Joliet. Navigation by small craft can extend to Dam Number 1 at Joliet.

1747 The Sag Channel is of smaller dimensions than the Main Channel, and is available for barge navigation of any draft of barge which can pass under the bridges, such as has been repeatedly recommended by federal engineers, in connection with the route between here and the Mississippi.

At the end of the Main Channel near the power station, thirty-six miles from Lake Michigan, a location has been reserved for a lock of any dimensions that may be necessary or desired, by which the depths and capacity of the Main Channel can be extended down the Des Plaines River by future improvements thereof.

The jurisdiction of the Sanitary District, so far as producing channels for navigation is concerned, stops at the upper basin at Joliet. The state has projected from the end of the Sanitary Canal at Lockport at the waterpower station, under the report of the Internal Improvement Commission in 1907, and by virtue of the constitutional amendment adopted in 1908, a project by which the navigable depth available in the Drainage Canal can be extended to Utica over the rock-bound section and the high declivities of the upper Illinois River by means of five locks and four dams and the development of the pools between these dams. This project proceeds on the basis of twenty-four feet to the second lock at the head of Lake Joliet through the City of Joliet, where it is largely in rock cut. But from that point, the head of Lake Joliet to Utica, it proceeds on the basis of a preliminary depth of fourteen feet, to be deepened progressively as the needs of navigation shall require.

Further than that, there has been no actual legislative provision as far as the state is concerned. The state has expressed its policy in a number of resolutions and statutes, and the United States has been asked to cooperate to the extent of building the locks in that part of the river, under the constitutional amendment, between the water power station at Lockport and Utica, at a cost of about eight millions of dollars, and to make the improvement by dredging in an open channel in the Illinois River between Utica and the mouth of the Illinois River, a distance of 230 miles; and there provide a channel of a preliminary depth of fourteen feet, at a cost of about $8,000,000.

In other words, the proposition as it now stands is this: That the State of Illinois, by the Act of 1889, makes the Main Channel of the Sanitary District to the upper basin a 1748 navigable stream and gives the United States control of it whenever the river shall be improved below, and the Sanitary District has expended upon that and collateral works something like $80,000,000, and the State of Illinois has put itself in position, by act of the Assembly, to spend an additional $20,000,000 in extending, a total of about $100,000,000. And the United States has been asked to cooperate to the extent of providing $16,000,000; the effect of it all being to produce a waterway from Lake Michigan, 327 miles long, to the Mississippi River at Grafton, with all structures, and rock cuts in the same channel for a depth of twenty-four feet and a preliminary depth of fourteen feet in the river below the head of Lake Joliet.

Perhaps I may add in that connection that in the later consideration of the matter by the State after 1907, it is based on a flow of 14,000 second feet; and that the Deep Water Project is not practicable without the aid of the large water supply from Lake Michigan, which has been authorized by the State law.

Outside of that, we would be limited to eight or nine feet as the best that could be done.

These depths of fourteen feet were predicated by the original act and collateral legislation in 1889, and in all subsequent legislation, were based on a flow of 10,000 feet and the report of 1907 used that depth of fourteen feet as a preliminary depth, but states that with the aid of the 14,000 feet, it will be possible to continue twenty-four feet to the City of Peoria and twenty feet more or less from thence to the mouth of the river.

And I assume from the fact that the constitutional amendment was based on that report, that is the project. It is the one that has been advocated by the Lakes to the Gulf Deep Waterways Association, and the one that was presented to

Congress in the hearings of 1910, before the House Committee and before the Senate Committee, and Congress made conditional appropriation of a million dollars for the beginning of work, whenever an understanding should be reached with the State of Illinois regarding a plan of cooperation.

The Chicago River prior to this improvement was little more than an adaptation of the Chicago Creek, which 1749 was known before Chicago was here; and its capacity for carrying a flow of water was limited. It is difficult to make a comparison where the stream was so little adapted to the present purpose, and where the change has been so radical.

Originally the Chicago Creek carried twelve feet up to the Forks, and its original improvement, the first improvement, was based on a depth of thirteen feet, which was subsequently increased to sixteen, and the tunnels built under the river limited the use of the Chicago River to sixteen feet, until they were removed within a comparatively recent period. They were removed by the city at a very considerable cost, which should be added to the expenditure of the Sanitary District and the United States, in getting at the true cost of the improvement of the Chicago River.

When the Sanitary District entered upon the improvement of the Chicago River, it was approximately sixteen feet in depth.

The depth has been increased to approximately twenty-six feet, and that is the depth carried through the main channel, to the power house.

There were portions of the river that would run up to 200 feet and even 300 feet in width, and again other portions that were less than 100. The narrow portions have been widened, or are being widened, except a very limited area near the Pennsylvania Central Station, which has been greatly delayed.

It has been widened to a large extent throughout its entire length, the Chicago River and the South Branch, so much so that it could almost be considered a new river.

There were center pier bridges with openings varying all the way from sixty feet up, depending on the width of the river; and the openings have now all been made uniformly 140 feet or more, so that vessels can go down the center of the stream without interfering with vessels that are moored at the docks, whereas formerly with the old type of bridge, they had to crowd the dock line, making it unavailable, in order to pass through.

This increase of depth and width of the river and the changing of the bridges has been of very great benefit to navigation. Under former conditions the river in many places was so constricted and tortuous that boats of the model prevailing along in 1900, 476 feet in length or thereabouts, were unable to pass through the river.

Since then, we have had boats up to 617 feet in length which could pass through. The alignment has been corrected and the channel deepened to a limit of twenty-six feet for a width of 140 feet in the center and the bridges have been put in with that central opening, so that the river is now available for a type of vessels which could not be considered in the early history of the stream and up to 1900.

There has been a very substantial and material increase in the depths in the Des Plaines and Illinois Rivers. The lock and dam system built by the State between LaSalle and Havana provided for a depth of six feet on the mitre sills at low water of the Illinois River, and this low water has shrunk at times down to limits of 400 and 500 feet per second within the division that I am speaking of. The present flow of the Sanitary District would give six feet throughout all that reach above the plans of the old low water, to which you could add twenty inches for the depth existing under original low water. In other words you would have seven and a half feet under the natural conditions in the river between those points without the dams.

The Board of Engineers known as the Ernst Board, which reported in 1905, stated that with a flow of 4,200 second feet

it would be possible to obtain in the Illinois River a navigation considerably in excess of seven feet, without the aid of any dams whatever, and that there should be no objection to the removal of these dams.

It was examinations of these questions which led to the
1757 project of the State for an open river improvement in these parts without the aid of the dams.

The estimates which were made at that time, made largely by me and my assistants have proven to be conservative, and that we can obtain better navigation without the dams at Henry and Copperas Creeks, and the Federal dams at LaGrange and Kampsville, than we had supposed when the State fixed its policy in that matter; and that we can obtain the fourteen feet more readily than supposed, and obtain the twenty-four feet and the twenty feet which I mentioned above and below Peoria more readily than supposed.

The State dam at Henry was opened in 1871. The State dam at Copperas Creek was opened in 1877.

The Federal dam at LaGrange was opened in 1889 and the Federal dam at Kampsville was opened in 1893. They were all part of a project that goes back to 1866 and 1867.

Before the Sanitary District flow was established through there, at low water and at ordinary stages of the river, boats used the locks. At high water they passed over the dams without obstructions.

Not to be compelled to use dams of that kind, or locks, is a very great benefit on account of delays; on account of tolls charged at the State dam, though there is no charge at the Federal dam, and by reason of the fact that the capacity of the locks is limited and boats and barges and fleets have to be accommodated to the size of the locks. Boats without the dams today would come to LaSalle, and barge fleets would be made up there. They would not pass through the locks if the dams were absent.

1752 The Sanitary District has an estate between Robey street and Lake Joliet of between seven and eight thou-

sand acres; and under the law is permitted to develop dockage and utilize this property.

This property that the Sanitary District owns is adjacent to the channel and along the channel its entire length on both sides and was obtained for the purpose of facilitating the construction of the channel and the river diversion.

Taking the channel at thirty miles from Robey street, it really adds to the capacity of the Chicago Harbor and its potential value about sixty miles of dockage; and if the estate is developed further by slips, why the amount of dockage that can be thus developed is unlimited.

So that it would be possible to establish practically an inner harbor.

That is one of the propositions that has been held in view from the beginning, and was outlined in a report which I prepared in 1890, printed in 1891, that the Drainage Canal on its waterway site would be developed as an auxiliary to the Chicago Harbor, and that future industrial development would largely take place, by a natural evolution as the city expanded, alongside and down this channel into the state; and that view of the proposition was in harmony with sound public policy, as these growing industries with their wastes would thus be automatically cared for in the simplest and cheapest manner. So it had a double reason, both commercial and sanitary, for the development of a harbor and its appurtenances in that direction.

That was one of the reasons why the item was put in the bill permitting the district to develop that as incidental to its other purposes: In fact it was the view held in constructing these works that all collateral advantages should be utilized; all by-products that were possible should be cre-
1753 ated, with a view of mitigating the heavy tax burdens of the community. And I think that the Chicago Project in its entirety, involving the waterways and dockage and waterpowers and other things that it does is really the first example that we have in this country of a well considered,

scientific project of conservation, for all the collateral utilities are to be developed and utilized.

The Chicago & Western Indiana, which is the main Belt Road, crosses the channel near the city limits, between Robey street and Summit. And the Calumet Terminal, which is also a Belt Road crosses the channel a mile below Summit. And furthermore the E. J. & E., which is the Outer Belt Line, crosses our channel between the water power station and Joliet; and makes the channel accessible to the entire railway system. And in that connection, it may be remarked that the report of the Federal Officer at this point recommends the development of a certain amount of harbor facilities adjacent to the channel, in the vicinity of Summit.

These Belt Roads mentioned make it possible to bring all kinds of freight down to the Main Channel.

And makes it possible, if the channel is developed as I have indicated, to have arrangements for the interchange of lake and rail freight.

In my judgment the location of the Sanitary Canal is really the only practical and economical location for such an interchange about Chicago, the logical place for it to occur. It is centrally located with reference to our commercial facilities by rail. It is accessible directly by a number of the trunk lines, and this number is so large that it practically would do away with the switching charge for all the other lines and we would be rid of $5 to $8 per car on all reshipment business done at Chicago as at present.

On the other hand such facilities transferred more remotely to the South or North would subject the commerce of Chicago to that extra burden.

The Calumet-Sag Channel runs from the Main Channel 1754 at Sag, Illinois, to the Little Calumet River at Blue Island and is something over sixteen miles long from the mouth of Stoney Creek, at its junction with the Calumet River to Sag Station; about 17 miles from the beginning of the San-

itary Canal at Robey street, and about 13 miles above the power station at Lockport.

It runs through a natural depression or valley called the Sag Valley, which is only less adapted to the development of a channel than the territory along the main channel of the District. This route has always been regarded as a favorite route in official reports of the United States, and has been frequently recommended for development for purposes of navigation.

The United States has taken steps towards the improvement of the Little Calumet River for navigation up to the point where the Sag Channel will connect with the Little Calumet.

The Calumet River is already improved for a width of 200 feet and a depth of 20 feet up to what is called the forks or outlet of the Calumet Lake; and in the last Rivers and Harbors Bill, there was an item calling for a project for the improvement of the river up to Blue Island.

And that is the point at Blue Island where the Sanitary District Channel connects with the Little Calumet.

Under the plans laid out by the District, there will be free navigation into the Sag Channel from the Little Calumet River.

And free navigation from the Sag Channel into the Main Channel of the District.

Any boats that would pass through would be able to pass through the Sag Channel, where it has a depth of 20 feet the same as the improvement of the Calumet River. Mean-
1755 while, craft can all pass up this route to Blue Island. It only requires deepening to adapt it to deeper navigation. There will be no limitation on the capacity of boats passing through except the bridges.

Navigation by the construction of this Calumet-Sag Channel, under the plans which the Sanitary District has adopted, and under which it is now being constructed well be greatly aided.

The flow of water has been and will be of enormous benefit to the Illinois Valley for two reasons; the first of which relates to sanitary conditions and the other of which relates to the physical conditions attending upon the river itself, and the overflow lands.

In a condition of nature, the Illinois River had in dry seasons an extremely small volume, which was measured in 1867 as low as 633 second feet. The reclamation of the swamps, which constituted 1/3 to ½ of the drainage in some watersheds and the tillage of the uplands has greatly reduced the low water supply and greatly increased the load of detritus which the stream has to carry.

The Illinois watershed is also one of the richest watersheds of the United States in proportion to its area, and produces thereby an enormous vegetable growth which quite consumes the water supply that falls in the growing season, leaving practically nothing to run into the streams. It happens by reason of these conditions that the stream is incapable of taking on any considerable load of sewage from the cities and towns located along its banks.

Further the stream bed is rapidly depreciating on account of the detritus from the uplands. These conditions at times under an ice cover when the organic matters in the water depleted the oxygen supply resulted in the decimation of the fish crop. Nevertheless, even prior to the opening of the Drainage Canal, by reason of the use of the river as an outfall for Chicago sewage and the very considerable increase in the low water volume which was doubled by the canal, even the old Illinois and Michigan Canal in low water seasons in
the upper half of the river, this fish crop had grown to
1756 large proportions, reaching from six to eleven and even
14,000,000 pounds; and was the best fresh water fishery in the United States, but was not a reliable industry.

The introduction of the water from the Sanitary District in comparatively large volume multiplying the low water supply at LaSalle by ten times, the low water supply in the

lower river by six or seven times, the fish crop became a reliable industry and has reached a magnitude under the census of 1908 of about 46,000,000 of pounds, of all kinds. And the value to the fishermen had reached over $800,000, and double that to the consumers. This crop represented $10 per acre on all the water space of the Illinois River Valley, or has been otherwise expressed, that the annual output was equal to 50 cents a lineal foot for the river.

Some idea of the magnitude and importance of this industry may be gathered from the fact that the output of this single stream represents ten per cent of all the fresh water fisheries of the United States, 30 per cent of all the fisheries of the Mississippi Valley, and is equal to 25 per cent of the entire fish output of the Great Lakes.

I think it is a fair assumption, and is so regarded by our Fish Commission, and by the Natural History Survey of Illinois, that this fish crop is largely due to the use of the stream for sewage disposal. The plankton in the Illinois River at Havanna, which is the basis of fish food, have been under examination by the Natural History Survey of this state since 1894; and since the introduction of the water in 1900, they recognize that the plankton have increased about from two to three times per cubic foot of water. And in view of the fact that the average flow of the stream has or will be doubled at Peoria when the channel is operated to a capacity of 10,000 second feet, the plankton content of the Valley will be increased from four to six times, and the fish crop stimulated proportionately, so that it is likely to grow to far larger proportions than even the present output.

This matter of the fertilization of waters is a new thought to people who have not considered the matter, but has been practiced from time immemorial in the fish culture in China, and is a recognized method of producing fish products as much as fertilization of land in the older countries, in the oriental countries.

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On the other side of the question, in regard to the physical conditions in the Illinois River, we have below Utica a stream

230 miles long with only 28 feet fall, or less than an inch and a half to the mile. The upper half of the stream, down to Havanna, has less than an inch per mile. There are conditions in the Mississippi River when if the Illinois River were low, flood waters would set back clear to Utica, and the stream would be level. There are other conditions in which the Illinois River might be assumed to be in flood and the Mississippi River low, in which the slopes would be doubled.

These conditions make the reclamation of the bottom lands extremely difficult and the maintenance of the river itself as a drain under the increasing load of detritus also extremely difficult. The only salvation, and that has been recognized from the beginning of this project, for the lower Illinois Valley is to introduce into that stream a large supply of water, to remove the dams and deepen the stream by dredging so as to maintain a channel of a good depth with a positive current that will be self scouring.

That condition cannot be produced in nature because the heavy flows in the Illinois correspond more or less closely with the heavy flows in the Mississippi, and with a large supply of water introduced into the Illinois River when the Mississippi is low, we can maintain a scouring channel; and the presence of the dams in that river is not consistent with maintaining such a channel.

Some recent examinations which I have made respecting conditions in the Illinois River show that since the state dams were erected at Henry and at Copperas Creek, there has been a depreciation on the upper half of the river of 2½ feet in the depth of the water below the original low water line of 1867, as it was defined in that survey. In other words, the river bed below low water has shrunk already, between the surveys of 1867 and the Ernst Board surveys of 1903, by 30 per cent; and the bank-full capacity of the stream has diminished by 15 to 20 per cent.

Further examination of the stream lower down shows that the Federal dams have been instrumental in contributing to the depreciation of that portion of the stream, and the only

remedy is to make a better drain of the Illinois by deepening it, without the dams, and introducing therein a positive and a large flow of water.

1758 This is important, not only from the standpoint of maintaining navigation automatically, as it were, without maintenance from year to year; but is of absolute necessity from the standpoint of conservation in the reclamation of the bottom lands themselves, of which there are some 40,000 acres between Utica and the Mississippi River. So from this standpoint, not only the interests of sanitation, the interests of the salubriety of the Valley itself, which will become a morass if present conditions continue or if the natural conditions continue, but also in the interest of reclamation of the bottom lands, a deep channel with a sufficient supply of water to maintain a scouring current therein is an absolute necessity.

On the sanitary side, as respects the disposal of sewage in this stream, such disposal was intolerable under natural conditions of flow, practically impossible by reason of the fact already stated, that the waters are already highly charged with organic matter from the very rich watershed, and particularly in flood times more than in low water.

I have seen, when I was examining the river for the State Board of Health, the output at Peoria alone, and at Pekin, from the wastes of the population and the wastes of the industries at those points, produce a black water through which fish could not pass, all the way down to the Copperas Creek Dam, a distance of 25 miles, when the river resumed its normal appearance.

This was significant, not only as to the ease with which the industries and the limited population polluted the stream in its natural condition, but was also very significant in regard to the progressive purification of the stream, even with that limited volume of water.

It was a material consideration in the Legislation of 1889, not only from the standpoint of the State Board of Health but also from the standpoint of all the Valley cities that this water

which served Chicago would through its progressive purification be able to serve also all the future population that might exist in the Illinois Valley in urban communities; and that in making a provision here as we did actually make for a population of over 4,000,000, we could assume at least that that would care for an additional future population in the Valley of 1,000,000. So that the Sanitary problem, from the state's point of view and the forces that prayed in the legislation of 1889 was a mutual problem, not only for Chicago but also for the Illinois Valley; the two representing over 70 per cent of the urban population of the entire state. To deprive them of this water would force all the towns in the
1759 Valley adjacent to the Des Plaines and Illinois Rivers to resort to artificial treatment, at very large cost, whereas their problems are now cared for automatically and without cost to themselves.

The problem presented of the disposal of sewage of a large metropolitan population like Chicago and its environs, which is included within the limits of the Sanitary District of Chicago, is materially different from the problem presented in the disposition of the sewage of a small city.

In small cities, they are not endowed usually with the industries of the great towns nor are their sewage wastes disposed of to the same extent by the sewer system as is necessitated in the large cities.

Again, in large cities, dimensions and magnitudes increase with the distances that have to be covered, so that the cost of any solution increases faster than the growth of population; or is out of proportion, you might say, to the growth of population, as compared to the small town or to the average small city, rather.

Removing sewage so that neither an effluent nor the raw sewage nor the rain drainage from streets, etc., would reach the water supply of the city is the very purpose to be attained with the greatest degree that it is practicable to do so. Fortunately, here, we can reach an ideal limit in that respect.

Any proposition that does not absolutely exclude sewage and land waters from the water supply is unsafe, by reason of the fact that no process of artificial treatment as now advocated, or of filtration of water supplies, gives immunity from any pathogenic germs that may be in the water; and by reason of the fact that any laxity in management or care is liable to bring about contaminations of the water supplies upon which the people may be relying as entirely safe.

I do not regard any proposition in connection with a water supply as safe, that is not automatic, and that depends upon human agencies and solicitude, under the civil service conditions that prevail in American cities.

1760 The Chicago water supply, on the other hand, can be made absolutely automatic and absolutely free from contamination, and the disposal of sewage can be put on the same basis, so that we can go away and forget about it; have no fear as to the consequences.

It depends upon the action of no person; does not depend upon the whims of an appropriation bill, or anybody's action as to whether they are exercising more care and vigilance than is necessary, or any of those things,—human frailties, it is free from. And experience has abundantly demonstrated that whereas in the early stages of these artificial methods much was expected of them in the way of absolutely arresting germ life that was deleterious to health; on the contrary none of them are quite safe. Filters and bacterial beds may get seeded down with the wrong kind of germs, so that the water supplies have to be watched with extreme care.

I think the best illustration of that is the recent report on the Milwaukee conditions by a Board of Engineers that is partial to artificial treatment, where they gather up the supply at the southern limits of the city, and after treatment pump it out into the lake as far south from the water supply as practicable. Then after doing this, they have to provide artificial methods for circulating the waters in the rivers in order that they shall not become offensive; and after going to

all this cost, they find that it is necessary to filter the water supply. And then they proceed to say that filteration methods, and slow sand filteration is so uncertain that it will be necessary to watch the results very carefully, and to be prepared at all times to doctor the water with chlorine or some other preparation to kill any germ life that may ecape the filters.

I think that probably is as severe a comment as could be made respecting conditions as they have been worked out for other cities not so fortunately situated as Chicago.

Chicago is the only city situated about the Great Lakes in which sewage disposal can be made through the back lots, and in which even storm waters for long distances along the lake shore may be absolutely excluded from the lake itself, 1761 the source of water supply. The pass that we have to cut down to divert our waters to the southwestward is only 7 to 8 feet as measured by the rock floor at Lemont above the low water of 1847; and only 2 to 3 feet above the high water of 1838, so that a channel can be cut in that direction at a minimum cost.

On the other hand, the lowest divide to the east between the waters of the lakes and the Ohio River is the Wabash-Maumée Divide at Ft. Wayne, which is about 190 feet above Lake Erie. And on the north is the Fox-Wisconsin Divide at Portage, Wisconsin, between the Fox River that empties into Green Bay and the Wisconsin River which empties into the Mississippi River, and this divide is 210 feet above the lake. So it is not possible at any other point about the Great Lakes to make a solution at all similar to that which has been provided at Chicago.

It is one of the endowments of our site, and it is the reason we are here, and it is the reason that the city is here; and from my point of view we are entitled to avail ourselves of it like any other bounty of nature, and to utilize the lakes in that connection.

From a conservation standpoint we utilize the lakes in that connection for all the utilities that can be worked out of it. It

is perhaps the highest conservation to which waters have ever been put in the world.

The investigations of the Sanitary District and of the
1762 State Board of Health in 1885 to 1890 considered a number of propositions of sewage disposal which were then seriously advocated as alternatives, and which are now regarded as obsolete.

The matter of land disposal, which is the most effective of all these methods is usually regarded as prohibitive on account of the cost, and because it can only be resorted to in favorable localities; and it is now recognized that if the effluents are to be disposed of in streams where water is used for water supply, that even in this case they must be sterilized. That was one of the principal methods advocated in 1886 and 1887 as an alternative.

The other plan of sewage disposal in the lake would not now be considered, even with sterilization, as a proper solution under conditions where it was humanly possible to do anything else. The objections are that sterilizing methods are subject to all the human limitations involved in the management of other methods, and are liable to be inefficient; sterilizing fluids are not considered as particularly conducive to public health and that even after sterilization the decompositions go on; there would be a tremendous pollution of the lake bottom, which would be a nidus in which deleterious germs might reproduce at a later period. And in a condition of stirring up of the lake bottom by wings, would make a very unwholesome looking water, if it was not actually dangerous to the health.

As applied at Milwaukee, as I have already remarked, they do not consider it, even with chemical treatment, to be a tolerable treatment without also at the same time filtering the water supply, and even after that sterilizing the water supply, after it had been filtered, when dangerous conditions appear in such filtration effluents.

It is recognized that disease germs will pass through even filters that are used for the purification of waters that are not contaminated with sewage. Unhappily, they get seeded down at times with the wrong kinds of germs.

The third method which was considered but not reported upon, but however was much advocated at that time and appeared in bills before the General Assembly for consideration as alternatives were the methods of chemical treatment. The principal one of these was the scheme of Gordon H. Knott, which was endorsed by very influential men, including some engineers from Chicago, which contemplated a tunnel 20 feet in diameter to extend down to Joliet and there the sewage was to be treated and released to the Des Plaines River. The tunnel which was then projected would carry something like 1,000 feet of water per second, barely more than the present water supply of this city. It would not solve any of the other problems associated with the good health of the city; and
1763 the treatment of the sewage proposed by chemical means only removes from 30 to 40 or 50 per cent depending upon the character of the putrescible matter; so that the effluent somewhat stabilized would still go to the Des Plaines and Illinois Rivers, and in the known high condition of the organic matters contributed from the land would produce an intolerable condition and be an impossible solution.

The fourth method which has found advocates and was mentioned as an alternative in the St. Louis case is the method by septic tanks, which was developed however after our consideration here at Chicago. Abroad, it was known as the Cameron Tank Proposition, and originally contemplated decompositions without a supply of oxygen, or aeration, known as anaerobic, to be alternated with aerobic decomposition, or the presence of oxygen.

This is in effect the cesspool method, which through various appliances, or in the use of euphonious names is called a septic tank proposition. Everbody is familiar with the cesspool proposition as it existed before we had any method of sewage treatment, or any sanitary science, or where in the country

sanitary provisions have not been adopted according to the modern method. But it seemed to have taken on a highly scientific value when proposed by wholesale, in the minds of its advocates.

That was, to my mind, effectually disposed of at Chicago, so effectively that it ought never to have been advocated by anyone, because we had a septic tank on the largest scale possible in this world in the 64 acres of the South Fork; and we had it in the North Branch in an area of more than 100 acres, and the conditions produced were so totally intolerable and inadmissible that it always seemed to me an impossible method of solution for any considerable body of people.

There have been a number of works even in this state and in Indiana constructed on that plan, ten or twelve I think. I believe today there are only two of them in actual operation. So that method may be considered as having passed into disuse or having become obsolete, and it should never have been considered, in my opinion, in view of the conditions that were patent here at Chicago.

The later methods were an evolution from the experiments at Lawrence, in a large degree, and consisted of bacteria beds; first, what was known as the contact beds, consisting of a bed of stone in a tank from six to nine feet deep, which was charged with sewage a number of times each day, and it was in fact a bacteriological stock farm on a concentrated scale.

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The anaerobic decomposition was supposed to occur while the bed was filled with sewage, and then the water was allowed to drain out and was supposed to give place to the aerobic decomposition, and this was much practiced up to a recent time, but is now considered obsolete, or not exactly obsolete but is discarded for a method considered to be superior, which is the percolating beds, so called sprinkling filters, which also consist of a bed of stone or other material; it is also a bacteriological stock farm, and in which the decompositions are entirely aerobic, except that it is usually

recommended that some sedimentation be given in advance and a slight septic condition produced by ten to twelve hours in the tank before it goes on to the bed. That is the last remnant of the septic tank proposition.

This method is the only alternative, a survival of all the experimental methods that have been tried out in the last forty years, and it may be said that no alternative that has ever been suggested for Chicago up to this time has proven up in practice, even for a moderate sized city, much less a city of this magnitude.

The method of nature in the percolating filter proposition, in fact in all methods that are practiced is the oxidation method, precisely the reactions which occur by dilution except in the dilution method the gases are absorbed and the operation is without offense; and the danger from the passage of pathogenic forms is probably much less.

All these methods in early times and up to a very recent time were presumed to dispose of the pathogenic germs, but it is now recognized that even the percolating filter does not do that, and that it must be followed by sterilization if the effluent is to be put into any possible source of water supply.

In regard to the chemical treatment, that is practiced still to a limited extent in the outfalls at Manchester and at London, for the purpose of getting rid quickly of a certain unstable element in the sewage, which they throw down as sludge. In the case of London, this sludge is put into tank boats and 7,200 tons a day are taken out and dumped into the sea.

In the case at Manchester, they carry on their purification by bacteria beds and chemical means; mostly by bacteria beds, and remove the sludge to the sea, in order to save the conditions in the Manchester Ship Canal as far as possible from becoming a nuisance. And they even go so far as to purify the storm water and run that through beds also. I went over the Manchester Canal in the autumn of 1909, 1765 when the temperatures were moderate and rode from

Salford down to Liverpool on a sludge boat that was taking out a cargo of sludge to sea, and the Manchester Canal, with all the efforts made in the communities about the Manchester Ship Canal, to purify the sewage outflow before it was put into the canal, was not what I would call in a tolerable condition at all. So that what they consider a measure of success over there in regard to the purification of sewage, I do not think would be looked upon here as a tolerable condition.

I will say that in regard to the subject of efficiency, there is no method at the present time available that can compare in efficiency with the method which we have adopted here at Chicago; and there is no alternative which could be adopted which would give us a water supply of any character approaching that which we may enjoy in connection with the dilution method.

I would say further that all these artificial methods are very costly in operation and maintenance, whereas the method here is automatic in action.

I will say further that with the possible exception of Berlin none of these methods make any returns against operating expenses, and even in the case of Berlin it is contributory rather than in any sense a profitable investment, whereas in our case I look upon the conduct of the sewage effluent and its purification on its way to the Illinois Valley as having produced the most successful and profitable sewage farm that has been produced in the world, to the fish product in the Illinois Valley; and that we have really here the only tried out and completely successful proposition in the world.

At the time that we proposed the Chicago proposition, it was looked upon by a large part of the sanitary and scientific world, who admitted their own superior achievements and attainments, as a barbarous one. I think the sentiment in that respect throughout the world has radically changed, and that dilution methods are now regarded as the best and the proper method wherever water supplies are adequate for such a purpose.

I wish to add to that, as a tribute to our own foresight and sagacity, that we are far ahead today of the other parts of the United States and the rest of the world in regard to this subject of sanitary treatment as we were when Mr. Chesbrough projected the sewer system in 1855. And I believe if we had been able—this I consider very unfortunate for Chicago—to have worked out all the results and made a rec-
1766 ord such as should have been made of the investigation that preceded and accompanied this work that it would have been regarded as a monumental achievement and revolutionary of the whole thought of sanitary engineering at the time; and would have changed the public thought, scientific thought in the matter as completely as it was changed along in the forties when the filth theory of disease originated.

I refer to Mr. John D. Watson's report (of Birmingham, England) to the Metropolitan Sewage Commission of New York dated January 31, 1913, wherein in discussing the various methods of sewage disposal for the city of New York, he says (page 30 of book entitled "Preliminary Reports on the Disposal of New York's Sewage, Number VII"): "What influences me most in favor of scheme 4, is the conviction that where it is possible to remove the bulk of the sewage of New York entirely away from its source to the ocean, it should be so removed, although the cost may be somewhat higher than it would be under a project like Scheme 3."

The Metropolitan Sewage Commission of New York was constituted a number of years ago for the purpose of studying the conditions and remedies therefor around New York Harbor and Bay; and it has projected four principal schemes or alternative methods for the treatment of the conditions at New York, which are discussed by Mr. John D. Watson, engineer for the Borough of Birmingham, England, and also by Doctor Fowler, who is in the same position in relation to Manchester, England, which are usually regarded as the highest development of artificial methods of treatment.

The 4th method, which is the one endorsed by both Mr. Watson and Mr. Fowler, is estimated to cost about $100,000,000, and is substantially a dilution method so far as the same can be applied to the New York conditions. It consists of interceptors for the purpose of gathering up the sewage; conduits for conducting the same to a common outlet, and pumping works. And an artificial island is to be created in the sea opposite Jamaica Bay and out beyond the entrance of New York Harbor; and the sewage conducted to this point and released on the outgoing tide, with only such treatment and screening as are necessary to operate the pumps and the system as a whole.

1770 There are no currents in the lake except those induced by the winds, and they change with the changes in wind direction.

With the Calumet River reversed as it will be when the Calumet Sag Channel is completed and in operation, and the Main Channel of the District and other works in op-
1771 eration, as is provided by the Statute of 1889, and the project as now operated, I do not consider that there will be any pollution of Chicago's water supply from cities like Waukegan or other cities near or around the City of Chicago.

I cannot conceive of conditions which would bring currents of waters from that distance to opposite the mouth of the Chicago River, for instance. The probability would be so extremely remote as to be a vanishing quantity.

All our intakes are substantially this side of the Evanston line on the north and opposite 67th street on the south, and under such conditions, there would be no sewage effluent going to the lake nearer than Michigan City or nearer than Waukegan. There is just the possibility that under contingencies that might occur in an occasional year we might get a little pollution from as far as Waukegan; but I assume that the conditions at Waukegan will be remedied as they already have the authority to organize a sanitary district on their own account at that point. Certainly with

that done, I see no possibility of sewage pollution as affecting the water supply now taken at Chicago.

I think that after the beams are all out of our eye, we are bound to go after the moats that come from that source, and there should be some regulation that will prohibit steamers from dumping their wastes into the lake within a reasonable distance of Chicago.

Frederic P. Stearns, a witness for the defendant, whose qualifications have been heretofore stated (This Narrative p. 134), testified, July 26, 1913 (Vol. II, p. 1044):

The situation is extremely unfavorable for any other system of sewage disposal than that which the City of Chicago now uses. It is impracticable to obtain a water supply for the city from any other source than Lake Michigan, and in no other way can the water supply taken from the lake be as well protected from contamination as by the present general method of sewage disposal, which not only keeps the sewage from entering the lake but creates a constant tendency to draw from the lake any water that may become contaminated along its shores, and it keeps from the lake the necessarily contaminated water of its rivers.

1049 It is therefore in my judgment impossible for the Sanitary district of Chicago to reproduce by any other method of sewage disposal than that now used with the right to take from Lake Michigan the quantity of water, commensurate with the needs of the District from time to time.

1058 I believe the method in use is by far the best method; and I think it is also the only practicable method, practicable and efficient method of taking care of the sewage and protecting the water supply; but there may be some combinations of purification, or there may be some partial purification of the sewage which could be used in connection with the present method. But I do not see how the present method

could be abandoned, or greatly restricted in the quantity of water, and obtain results that should be obtained.

1077 I do not favor the discharge of the sewage of a great population into a lake from which a water supply is to be taken, in any case, without purification of the water supply; and even then I would place the intakes of water supply far from the place where the sewage is turned into the lake,

1078 if it were necessary. But it is very much better from a sanitary standpoint that neither the sewage nor the effluent should go into the lake.

Henry C. Adams, a witness for the defendant, whose qualifications have been heretofore shown (This Narrative p. 159; September 25, 1913), testified as follows (Rec. Vol. III, p. 1355):

I have made examinations of the records of the City of Chicago as to death rates from various diseases in the last twenty-six years.

Adams Exhibit 1 shows this computation, as follows:

1360

2—CHICAGO.

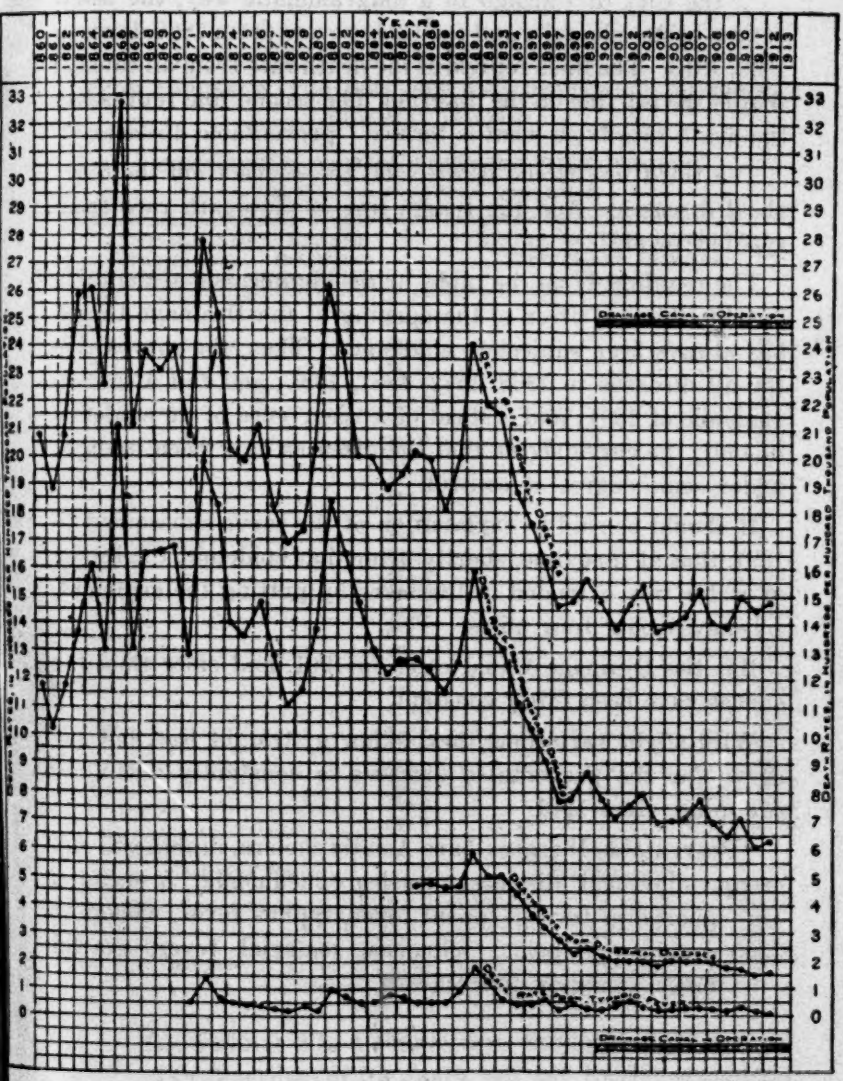
Death rates per 100,000 of population.

Years.	All Causes.	Typhoid Fever.	Diarrhœal Diseases.	Tuberculosis.	Pneumonia.	Bronchitis.	Influenza.	Diphtheria and Croup.	Scarlet Fever.	Tuberculosis of the Lungs.	Measles.	Whooping Cough.	Small-pox.	Bright's Disease.	Heart Disease.	Cancer.	Violence.	Tuberculosis other than Pulmonary.	Children under 5 years.
1887	2027	50.3	477.6	202.6	132.6	99.2	....	184.9	25.0	180.7	44.9	13.9	.3	42.1	72.2	39.6	126.8	22.0	996
1888	1965	46.7	457.2	201.3	137.7	102.5	....	161.6	22.6	182.1	13.8	22.8	....	41.1	77.1	45.0	110.5	19.2	939
1889	1812	48.4	465.6	181.0	126.0	87.3	0.1	161.4	19.6	164.9	21.8	10.3	.2	39.9	71.0	40.3	104.4	16.0	878
1890	1987	91.6	471.5	201.9	188.5	108.1	10.2	114.7	17.5	182.8	6.1	13.8	....	46.3	74.2	41.6	120.4	19.2	890
1891	2416	173.8	585.3	208.9	251.8	120.1	1.7	113.2	43.2	184.5	23.1	16.9	....	51.7	80.8	47.4	128.8	24.4	1097
1892	2185	124.1	606.3	198.6	199.8	108.6	3.6	129.0	31.8	182.3	15.4	13.7	.2	50.8	88.2	44.6	133.4	19.2	972
1893	2161	53.5	512.6	211.2	196.1	111.4	7.0	117.1	26.3	188.5	18.7	16.8	1.8	60.1	88.3	48.6	151.4	22.2	986
1894	1826	37.5	445.5	191.0	116.1	80.5	3.6	108.4	14.5	167.4	13.6	16.0	78.9	52.0	72.3	48.6	118.4	22.2	843
1895	1772	37.9	372.7	180.2	172.6	82.3	12.4	120.1	5.6	159.1	11.4	8.3	11.5	51.3	80.3	49.6	108.3	21.1	765
1896	1629	52.6	337.2	186.3	150.0	81.6	1.2	76.2	3.8	162.4	5.1	13.1	.1	57.3	88.3	51.4	103.7	24.5	680
1897	1463	29.3	278.3	172.6	144.3	68.3	1.0	51.6	4.8	146.4	9.3	10.7	....	62.3	91.6	49.3	98.1	25.5	574
1898	1464	40.8	241.5	181.7	159.1	68.3	18.0	43.7	4.8	155.2	3.5	13.4	....	67.5	89.3	50.6	97.5	25.5	525
1899	1568	27.2	253.5	178.9	211.4	62.3	19.1	58.4	32.8	154.7	10.3	4.7	1	72.6	91.7	54.7	97.5	24.4	546
1900	1468	19.8	216.2	173.9	190.5	65.1	9.4	49.5	13.3	153.0	11.4	16.8	.1	65.7	111.4	56.2	97.8	20.8	457
1901	1397	29.1	211.3	164.0	178.5	49.3	11.5	28.4	9.4	142.4	9.0	14.8	.2	67.3	111.1	57.2	98.9	21.5	428
1902	1473	44.5	201.0	165.4	190.6	54.3	6.6	24.8	24.7	141.9	6.8	14.6	....	69.3	116.5	59.6	104.4	23.5	445
1903	1562	31.8	194.6	182.5	290.1	54.3	9.6	24.4	16.0	155.0	14.6	14.6	2.5	61.3	113.0	57.4	130.3	23.1	447
1904	1410	19.6	177.7	186.5	217.3	45.5	7.6	21.5	7.5	164.8	11.5	5.4	2.1	62.3	107.5	58.2	108.3	24.1	371
1905	1413	16.5	192.5	188.8	184.1	43.5	4.1	22.7	24.7	161.3	6.4	18.4	....	106.5	108.3	61.1	108.3	24.1	438
1906	1453	18.5	197.0	192.0	202.5	38.3	6.6	27.7	35.1	171.5	12.8	8.4	.05	106.5	109.8	66.5	111.6	20.7	440
1907	1572	18.2	196.4	197.2	232.1	38.4	11.6	26.5	19.6	163.0	8.1	12.0	....	121.4	113.2	75.1	121.4	23.7	493
1908	1440	15.8	202.3	186.7	167.4	37.6	15.4	26.5	17.2	155.9	7.7	6.5	.05	102.0	128.1	74.9	118.1	22.1	458
1909	1458	12.6	171.1	181.0	219.6	6.8	8.1	21.7	18.4	153.3	8.7	7.9	.05	105.9	147.4	76.7	126.5	26.1	436
1910	1514	13.7	177.2	178.0	240.8	7.8	6.6	37.4	....	....	....	....	....	113.9	151.4	82.3	116.2	24.7	461
1911	1455	10.9	147.0	166.0	219.6	4.0	5.2	....	....	....	....	....	....	....	....	....	....	....	408
1912	1482	7.5	140.7	163.5	220.4	4.7	2.8	....	....	....	....	....	....	....	....	....	....	....	436

1361 The water-borne diseases are the typhiod fever and the diarrheal diseases, intestinal diseases in general. The impure air diseases are tuberculosis, pneumonia, bronchitis, influenza, grippe, and things of that kind.

1362 The decrease in the water-borne diseases is 56.9 per cent and the decrease in the air-borne diseases, computed in the same way, is 6.1 per cent.

1363



ADAM'S EXHIBIT 2.

1364 This table, Adam's Exhibit 2, presents the death rate in the City of Chicago in a diagrammatic way, the usual curves being adopted; and the table covers from 1860 down to 1912, 1913. The lines represent the death rate from all causes; that is the top line on the diagram. The second line represents the death rate from what is termed "preventable diseases."

The third line is the death rate, the curve from the diarrheal diseases. And the fourth line is the death rate from typhoid fever.

The readings from the table, or the significance of the table is that Chicago, prior to the opening of the Drainage Canal, has always been subject to epidemics. Thus, the curves rise for all diseases to 1866, 1872, 1881, 1891; and fall after the epidemic of 1891; and instead of a recurrence of an epidemic in 1901, the curve shows that the diseases have been brought under some degree of control.

It should be said in explanation of the curve subsequent to 1891, that at that time, shortly after that epidemic, the intake of water was extended in the lakes by putting the cribs out, I believe about four miles.

But the Drainage Canal came in 1901, and since then the curves have been fairly constant.

With slight variations they follow a straight line, but the curve for the preventable diseases is constantly declining, dropping, since 1901.

"Preventable Diseases" are Asiatic cholera, diphtheria and croup, diarrheal disease, measles, pneumonia, bronchitis, puerperal fever, typhoid fever, typhus fever, whooping
1365 cough, erysipelas, influenza, malarial fever, scarlet fever, smallpox, tuberculosis.

ADAMS' EXHIBIT 3.

6.

COURSE OF THE DEATH RATES

FROM IMPURE WATER DISEASES AND IMPURE AIR DISEASES

CHICAGO, 1887-1912.

COMPARISON OF TWO THIRTEEN-YEAR PERIODS.

Death-Rates per 100,000 Population.

Year	IMPURE AIR DISEASES (Tuberculosis. Influenza.) (Pneumonia. Bronchitis.) Total	IMPURE WATER DISEASES. Typhoid and Diarrheal Diseases.
1887	434.5	527.6
1888	441.5	533.9
1889	393.4	514.0
1890	508.7	563.1
1891	593.1	758.1
1892	515.6	623.7
1893	525.7	566.1
1894	401.5	483.0
1895	447.8	410.6
1896	419.6	389.8
1897	386.8	307.5
1898	422.7	282.3
1899	471.8	280.7
1900	447.8	236.0
1901	403.4	240.4
1902	416.8	245.5
1903	495.9	226.4
1904	454.3	197.3
1905	424.3	209.4
1906	436.8	215.5
1907	479.4	213.6
1908	407.6	218.1
1909	416.1	183.7
1910	433.2	190.9
1911	394.8	157.9
1912	391.4	157.2
	Average Rate.	Average Rate.
1887-1899	458.7	480.7
1900-1912	430.9	207.1
Decrease	27.8	237.6
Per Cent Decrease	6.1%	56.9%

This Exhibit 3 is a comparison for the two periods al-
1366 ready described of the death rate per 100,000 population from impure air diseases and the impure water diseases. The percentage result of that comparison has already been given.

The average decrease in the death rate for impure air diseases is but 27.8 per 100,000 population, whereas, for the impure water diseases, the decrease on a comparison of the average for the two periods, is 237.6, showing a decrease of 6.1 per cent in the impure air diseases and 56.9 per cent in the impure water diseases.

It is a well established fact, as shown by the statistics of cities before and after the introduction of the improvement of water supply, that the decrease in the death rate of the particular diseases held in mind, and usually this is typhoid fever, is accompanied by a corresponding decrease in the death rate of other diseases. And typhoid fever is commonly accepted as the basis from which to measure the general effects of the improvement of the water supply.

This relationship is what is known as Hazen's Theorem or Hazen's Law. It is universally conceded that the improvement that is reflected in typhoid conditions must be multiplied by some figure in order to get the general improvement in the health conditions of the community.

Here is a statement of Hazen's Theorem as given by himself, he says: "Where one death from typhoid fever has been avoided by the use of pure water, a certain number of deaths, probably two or three, from other causes have been avoided."

All my information on this point is taken from an article by W. T. Sedgwick, who is Professor of Biology at the Massachusetts Institute of Technology, and J. Scott McNutt, Health Officer, New Orange, New Jersey, published in the Journal of Infectious Diseases, 1910.

Professor Sedgwick is a recognized authority upon this
1367 matter in the United States. It was for the purpose of testing the accuracy of Hazen's Law that Sedgwick and McNutt undertook this investigation in American cities.

ADAMS' EXHIBIT 4.

Distribution of Deaths from Typhoid Fever, by sex and age. Chicago, 1912.

Age	Males	Per Cent of all Deaths of Males	Females	Per Cent of all Deaths of Females	Both Males and Females	Per Cent of all Deaths
1- 5	5	4.27%	4	6.8	9	5.1
5-10	5	4.27	7	11.9	12	6.8
10-20	18	15.4	13	22.0	31	17.6
20-30	42	35.9	20	33.9	62	35.2
30-40	22	18.8	10	16.9	32	18.2
40-50	18	15.4	2	3.4	20	11.4
50-60	5	4.27	1	1.7	6	3.4
60-70	2	1.7	1	1.7	3	1.7
70-80			1	1.7	1	.6
All ages	117	100.0	59	100.0	176	100.0

Males constitute 66.5% of all deaths, females 33.5%.
(Data taken from the records of the Chicago Department of Health.)

This exhibit shows the distribution of deaths from typhoid fever by sex and by age. The sex classes are under 5,
1368 from 5 to 10, from 10 to 20, from 20 to 30, from 30 to 40, from 40 to 50, from 50 to 60, from 60 to 70, from 70 to 80.

The third column of the exhibit shows the percentage of the total diseases borne by males at the various ages named. The significance, or the bearing of the table upon the question of the loss that might be suffered by a city in the absence of proper preventive causes for typhoid fever is that a larger percentage of diseases from typhoid fever is suffered by males than females; and that the age when typhoid fever is likely to result fatally for males is between the age, as shown here, between the age of 10 and of 60. Closer figures will show that between the age of 17 and 18 and 55 66-5/10 per cent of all deaths are male and 33.5 female. The figures here are taken from the records of the Chicago Department of Health.

I would add that the figures in this exhibit influenced me in choosing the multiplier in the application of Hazen's Law.

ADAMS' EXHIBIT 5.

II.

DECREASE IN VARIOUS DEATH-RATES SINCE THE DRAINAGE CANAL WENT INTO OPERATION.

Comparison of Two Thirteen Year Periods: (1887-1899) and (1900-1912)
Death-rates per 100,000 Population.

CAUSE	Decrease in Death-rate (1887-1899) (1900-1912)	Per Cent Decrease (1887-1899) (1900-1912)	Number of Deaths Prevented from cause named for every death Prevented from Typhoid
All Causes	398	21.3	9.3
Preventable Disease	418	36.9	9.8
Impure Water Diseases (as recognized by Chicago Dept. of Health)	274	56.9	6.4
Impure Water Diseases (as recognized by Sedgwick MacNutt)	*290	31.8	6.8
Diarrheal Diseases	231	55.2	5.4
Typhoid Fever	42.7	68.2	....

*1887-1899 compared with 1900-1912.

This exhibit is one designed to show the decrease in the
1369 various death rates since the Drainage Canal went into operation; first, from all causes; second, from the Preventable Diseases, and third, from the impure water diseases, as recognized by the Chicago Department of Health. Fourth, from the impure water diseases as recognized in the work of Sedgwick and MacNutt. Fifth, the diarrheal diseases. Sixth, the typhoid fever.

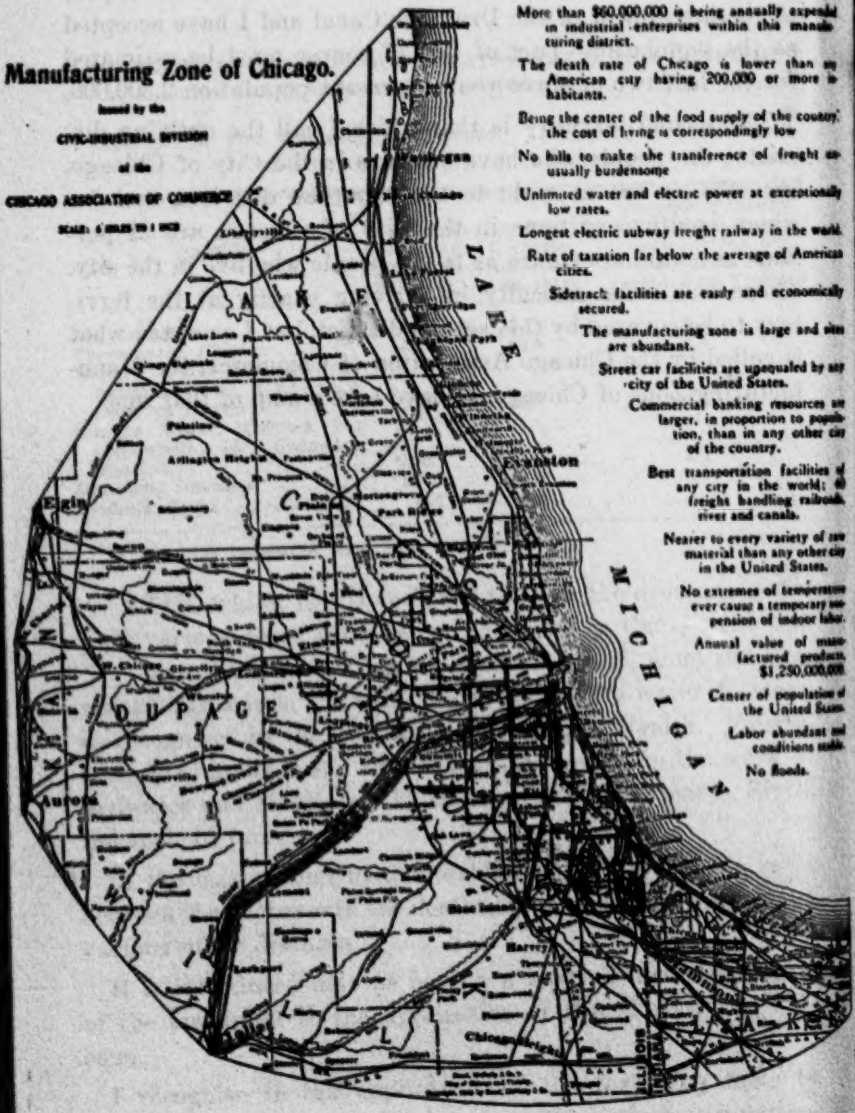
In the last column in that exhibit will be found the ratio between the decrease in the deaths from typhoid fever and the various other diseases.

It is introduced also as having a bearing upon the choice of the multiplier in the application of Hazen's Law to Chicago.

I recognize in the application of the foregoing facts to Chicago at least three territories with distinct population. The first is the municipality of the City of Chicago. This is

the narrowest possible conception of Chicago as a center of population. This is the unit that has bonded itself for part of the investment of the Drainage Canal and I have accepted as the population—part of this of course must be estimated for the last two or three years—present population 2,300,000.

The second territory is that which I call the outlying districts; the people who have business in the City of Chicago, but who go out at night to the suburban districts, and for whom health conditions in the City of Chicago are of perhaps as vital importance as to the people who live in the city. There was some difficulty in arriving exactly at the territory to be covered by this second district, but I accepted what is called by the Chicago Association of Commerce, the Manufacturing Zone of Chicago. I have here a map of that zone.


Manufacturing Zone of Chicago.
Issued by the
CIVIC-INDUSTRIAL DIVISION
of the
CHICAGO ASSOCIATION OF COMMERCE
SCALE: 4 MILES TO 1 INCH
More than $60,000,000 is being annually expended in industrial enterprises within this manufacturing district.
The death rate of Chicago is lower than any American city having 200,000 or more inhabitants.
Being the center of the food supply of the country, the cost of living is correspondingly low
No hills to make the transference of freight unusually burdensome
Unlimited water and electric power at exceptionally low rates.
Longest electric subway freight railway in the world.
Rate of taxation far below the average of American cities.
Sidetrack facilities are easily and economically secured.
The manufacturing zone is large and sites are abundant.
Street car facilities are unequaled by any city of the United States.
Commercial banking resources are larger, in proportion to population, than in any other city of the country.
Best transportation facilities of any city in the world; all freight handling railroads, river and canals.
Nearer to every variety of raw material than any other city in the United States.
No extremes of temperature ever cause a temporary suspension of indoor labor.
Annual value of manufactured products, $1,250,000,000
Center of population of the United States.
Labor abundant and conditions stable.
No floods.
LAKE MICHIGAN
DUPAGE
Elgin
Aurora
Evanston
Chicago
ILLINOIS
INDIANA

The factors employed in computing the community loss
1399 on account of premature death as working citizens are,
first: the number of working years annihilated by premature death. For any given person this is measured by the difference between the age at which death occurs and the normal expectation of life for that age. For the community, the average at which death occurs is the point from which the measurement is taken.

The second factor is the worth or value to be imputed to a working year. By the first, it is evident that we learn the
number of working years for each year annihilated by a
1400 premature death. If now we know the value to the com-
munity of a working year, the multiplication of the one into the other gives the desired result.

That is well established by actuarial methods. And in the case of typhoid fever, which is made the basis of this computation, the loss, the average age of those who died of typhoid fever is 29 and a fraction years. Now, the average expectation of life for that age, 29, is 66 years. If now we take 65 as the limit of working years, there is by a death of typhoid fever annihilated the difference. At that age there is an expectation of 36 working years for each person that dies. Therefore, the deaths multiplied by 36 years gives the loss to the community in years.

Now, the other element the value of a year is one that the actuaries have always dodged. They have made assumptions, but have never given the matter, in my judgment at least, sufficient analysis, industrial or economic analysis.

I have for the purpose of this case endeavored to analyze the community's interest in premature deaths. And by the community's interest I mean the interest of the community as though the community were a unit, an organization, an industrial corporation, you may say, of perpetual life. And starting from that point, the burden that must be placed upon current industry is the burden first of maintaining the current social asset, the important asset being in the number of

workers in existence, so that notwithstanding deaths there will be births, raising children, education of workers, who will come to supply the place of the worker so that what you may call the labor asset of the community will be maintained.

Every time there is a premature death, the community loses in this respect; that is, the fund for the maintenance of its industrial or social aspects is impaired.

It is also a burden or a duty imposed upon current industry to provide for the normal development of industry, the normal growth of society, increase in numbers and increase in grade, quality of labor, greater education; and that I call as distinguished from maintenance of development, the additions and betterments that come to this society, considered as an industrial organization. Those are the two elements that are attempted to be measured; and each of them is impaired by a premature death.

Then, third, there is a dissipation of assets, a dissipation of energy, dissipation of well being, dissipation of work,
1401 dissipation of time, on account of sickness and death, and the cost of the sickness being a burden upon the community, a burden eliminated if there were no sickness, and this class is recognized as the third element of loss. Those are the three elements on that side of the equation.

ADAMS' EXHIBIT 13.

19

Loss that would be sustained by the City of Chicago and dependent populations were the present facilities for obtaining an adequate supply of pure water impared or destroyed, based upon a comparative study of health statistics of the city for 13 years before and 13 years after the opening of the Chicago Drainage Canal.

Per Annum.

Per 100,000 of the Population.

Kinds of Loss	From Increase in Typhoid Fever	From Increase in Other Diseases
I. By Loss of Contribution to Maintenance:		
a. Through premature death of workers, 83% of 28.39x36x300..	$254,488	$636,220
b. Through sickness, 83% of (484x10) + (28.39x2) + 52x300	23,400	23,400
II. By Decrease in Capital Building:		
a. Through premature death, 42.7x36x40	28,256	70,640
b. Through sickness (726x10) + 52x40	5,581	5,581
III. By Unnecessary Dissipation of Resources:		
483x58.41	42,405	42,405
	$354,130	$778,246

$354,130x23=$ 8,144,900.

$778,246x23=$17,899,658, which is the annual loss to the City of Chicago.

In the same way and for the same reason that a corporation 1402 sustains a loss, a railway corporation sustains a loss in case its locomotive is wrecked ten years before its life has expired. It also must use its resources to supply the place of that locomotive. But the resources used to supply the place of the locomotive that is prematurely retired cannot be used in any other way. I think the analogy between a corporation maintaining its property and improving its property and a community maintaining its labor force and extending its labor force is very close.

Under the first item mentioned in the table, namely, "By loss of contributions to maintenance," there are two subitems, *a*: "Through premature death of male workers" and

b: "Through sickness." The formula for computing the loss through premature death of male workers is as follows: 83 per cent of 28.39 multiplied by 36 multiplied by 300. The 83 per cent of what will be the result of the computation 1403 following that figure in the formula is arrived at in this way: this computation rests upon the loss incident to the premature death of active workers, and it would therefore be improper to include all of the deaths as the computation should confine itself to the deaths from typhoid fever that occur during the working period.

Now, about 83 per cent of the deaths from typhoid fever occur within the working years, and for that reason only 83 per cent of the 100 per cent of computed loss is permitted to enter into the present computation.

The table upon which that percentage rests has already been submitted as Exhibit 4.

The figure 28.39 is derived as follows: as already explained, the decrease in the number of deaths from typhoid fever per 100,000 population since the introduction of the Chicago Drainage Canal is 42.7; this decrease being arrived at by a comparison of the average number of deaths per 100,000 population for the 13 years prior to the opening of the Drainage Canal with the corresponding figure for the 13 years subsequent to that event.

Now, the table of distribution of deaths from typhoid fever shows that males constitute 66.5 per cent of all deaths. The decrease in the number of males dying from typhoid fever, therefore, is 28.39 per 100,000 of population. That means in effect that the deaths of females are thrown out in this computation, although there are some reasons why females should be included in the productive population, as well as males. But here, as everywhere throughout the computation, I have taken the lowest of the figures that can be used.

The figure 36 is the computed expectation of working life at the average age of death from typhoid fever. This average age for the City of Chicago including all deaths at all

ages, is 29.04 years. The average expectation of life for that age is 37 years. If now 65 years be accepted as the average limit of the normal working period, it follows that the number of years lost to a community, of working years, resulting from a death caused by typhoid fever is the difference between 29 and 65 or 36 years.

That next item in the formula is 300. This figure covers that portion of current earnings, the expectancy of which is for a communal or community purpose described in the foregoing analysis. That rests upon the assumption that the general average income representing the productive ca-
1404 pacity of workers is some $700 a year. We are concerned here not simply with workers, men who get wages, men on payrolls of factories, but it is all members of the community, and really you should take into account men who earn from a dollar a day up to men of very high income, all of whom are subject to death from typhoid fever.

The amount that is required for the support of the worker, what you may call the personal expenditure of the worker is deducted from what is called the average productive capacity of individual citizens, and the remainder is accepted as the community loss on account of premature death. That is, the remainder measures the amount that is contributed from the income of the worker to the maintenance of the working fund, and the expense, the personal expense, the demand for or the occasion of that expense dies with the man, but to the extent that while a man is living he contributes to what is the community need, namely, the maintenance of the number of workers, the education and rearing of working men so that they can take the place of workers when retired on account of age, that is the community contribution of the individual, and that community contribution of the individual is what is destroyed by a premature death.

I have put it here at the low figure of $300, on the basis of a $700 income. There has been a great deal of analysis and work by economists in arriving at those figures. I do not

care to go any further into that unless it is desired that I should do so.

1405 On the particular question, namely the estimate of productive ability, perhaps the best authority is Dilfredo Tatreto. He has made a study of the distribution of incomes, and has established what some regard as law of the distribution of incomes, so that if it is known, according to his law, if it is known what the daily unskilled wage is, he can arrive at the average of the incomes from $300 up to $30,000.

1406 Men like Hoffman usually take $600 as the earning capacity and merely say that the earning capacity is equal to the productive ability of the worker; but that includes only the day workers, the unskilled and the low paid workers. And that rests upon the statistics of wages which are very voluminous and very carefully worked out. This law arrives at an income, not only for day workers, wage workers, but for others who create their own wages, pay themselves their own wages, and there the average would be according to this law for a dollar a day something like $700 or $800. I took the lower figure and estimated the amount of personal expenditure, and the difference is recognized as the loss suffered by the community on the occasion of the premature death of any citizen.

The second formula presents the loss on account of cases of typhoid fever which did not result fatally. The 83 per cent is arrived at in the same way as in the first formula described. The figure 483 represents the number of male cases of typhoid fever which occur annually in the City of Chicago, but which do not result fatally. It is arrived at by the multiplication of the number of deaths, 28.39 by the figure 17, which is the figure accepted as representing the number of cases of typhoid fever for every death from typhoid fever. My authority for that figure is the Pittsburgh Survey, and Whipple on Typhoid Fever.

The figure 10 is the number of weeks that each case that recovers is out of work. That assumes that the sickness and convalescence in every case covers at least 10 weeks; I mean that is the average of the cases.

The 28.39 in this formula has already been explained, this being the number of deaths, and the 2 is the number of weeks on the average prior to the time that the death occurs, which is a burden for the community in the same way that the weeks of sickness of those that do recover. This is divided by 52 to reduce it to years and multiplied by 300, which is the figure in the formula already described.

The second kind of loss is expressed in the table as a loss by decrease in capital building. That is, every worker, every member of an industrial community, during his active life, not only contributes to his own maintenance but contributes something to the fund of which he is a part and to take his place when he dies; he not only does that but he contributes something toward the increase of the working fund and towards the higher education, which is equivalent to the raising of the quality of labor. This is the same thing as additions and betterments in the case of an industrial corporation.

This also is submitted under two heads: *a*, loss through
1407 premature death, and *b*, loss through sickness. 42.7 in the first formula has already been explained. I ought to say before explaining these figures that in this case it is population as such that is taken into consideration, because we only know the increase in wealth and capital on the per capita basis, and therefore it is not the deaths of workers, the working age, but the total deaths from typhoid fever that must be considered.

Now the 42.7 in the equation under A is the average decrease in the death rate from typhoid fever during the 13 years subsequent to the introduction of the Drainage Canal as compared with the 13 years prior thereto. This is multiplied by 36, because this loss continues for 36 years. And the loss per year is computed at $40 on the authority of the United States Census that the increase in capital or valuation from year to year is about $40.

There is also added here a loss because of the decrease in capital building through sickness, which is 726 multiplied by

10 divided by 52 multiplied by 40, all of which figures explain themselves.

The third point in the formula is losses by unnecessary dissipation of resources. That is what is commonly called the sick loss. And I have taken 483 cases of typhoid fever that do not result fatally, and I have taken the result of the Pittsburgh Survey, giving 58.41 per case. That seems to me to be unusually low, and so far as I know it is the lowest figure that has ever been arrived at, and I think is too low, for the reason that this Survey in Pittsburgh had to do with the poorer people in the poorer districts, whereas, the question we are now interested in covers all citizens of Chicago, of all classes.

The figure 90 has been suggested but the figure 58.41 is the one that is used in this computation.

I think that explains everything in the table, except the question of multipliers. The character and need of Hazen's Law has already been explained, and this table accepts 2½ as the multiplier; that is, it accepts the Hazen Law, as originally stated, and not as modified in figures by Sedgwick and McNutt and others, who place a higher figure.

Isham Randolph, a witness for defendant, whose qualifications have been heretofore stated, testified as follows:

February 23, 1898, the Committee on Rivers and Harbors of the House of Representatives, U. S. Congress, inspected the Sanitary District works.

May 5, 1898, Russel A. Alger, Secretary of War, and Gen. John M. Wilson, Chief of Engineers, in company with the Governor of Illinois and the Board of Trustees of the Sanitary District, inspected the works and the main channel then constructed. (Rec., Vol. VI, p. 3591-92.)

As Chief Engineer of the Sanitary District, I determined the volume of flow of water through the channel, and laid out the improvement of the Chicago river, South branch and West Fork, in 1900, that is, for a flow of 8,000

cubic feet per second through the South Branch of the Chicago river, and 10,000 cubic feet through the West Fork from its junction with the South Fork of the South Branch to the northern terminus of the Drainage channel. (Vol. VI, p. 3593.)

The improvement of the channels of the South Branch and the West Fork was laid out so that the current would not be more than 1¼ miles per hour, except at bridge openings, where there was some contraction. Until 1902, as Chief Engineer, I conformed fairly well to the limitations placed upon the permit of May 8, 1899. In 1902 considerable improvements were made in Chicago river, South Branch and West Fork, to create a greater cross-section. (Vol VI, p. 3594.)

Further and later evidence relating to the works of the Sanitary District, introduced April 25 and 26, 1923, and in connection with motion of defendant filed July 12, 1920. (Rec. Vol. VIII, pp. 175-223; This Narrative, p. 339-383.)

An ordinance of the Board of Trustees of the Sanitary District of Chicago, passed and approved August 7, 1919,
201 Pearse Exhibit 1, April 25, 1923, as follows:

"An ordinance of the Board of Trustees of the Sanitary District of Chicago laying out and adopting a program for the construction and operation of works for the purification of or the removal of solids and organic and inorganic matter from sewage, trade waste, offal and other organic and inorganic matter so that within the period of the next twenty-five years not more than fifty per cent of the amount of said sewage and waste that is now passing into the Des Plaines River from the main channel of the Sanitary District will at the end of such period find its way into said river. Such works are to supplement those constructed or in process of construction for the diversion of sewage and drainage arising within the limits of the Sanitary District of Chicago.

Whereas, the Sanitary District of Chicago was organized and now exists under an Act of the General Assem-
202 bly passed on May 29, 1889, in force July 1, 1889, entitled, "An Act to Create Sanitary Districts and to Remove Obstructions in the Illinois and Des Plaines Rivers," and Acts amendatory thereof or supplementary thereto; and,

Whereas, The said Act of the General Assembly provided for the construction and operation of the Main

Channel of the Sanitary District, including adjuncts and additions thereto whereby the sewage and drainage of the City of Chicago and its environs should be diverted from Lake Michigan to the Des Plaines river, together with a certain amount of water from Lake Michigan fixed according to the population of the District as it might exist when such Main Channel should be constructed and as the population might thereafter increase, to-wit: Twenty thousand cubic feet of water per minute for each one hundred thousand of the population; and the Board of Trustees of The Sanitary District of Chicago is directed by said Act of the General Assembly to operate said works specified with such diversion of water; and,

Whereas, Said Act of the General Assembly was passed and the works provided therein to be constructed were built in order to relieve the people of Chicago and environs of a serious menace to their health and lives arising by virtue of the pollution of Lake Michigan, the only water supply of Chicago by sewage passing into same by way of the Chicago and Calumet rivers and by way of sewers debauching directly into the lake at various points along Chicago's water front; and the said works were intended also to relieve the Des Plaines and Illinois rivers of a serious condition of pollution due to a certain amount sewage and wastes of Chicago and environs passing into said river through the Illinois and Michigan Canal; and,

Whereas, The death rate per year from typhoid fever prior to the operation of the Main Channel of the Sanitary District at times equalled one hundred nintey per one hundred thousand of the population of Chicago, and its environs, which required the immediate construction and operation of works to relieve such condition; and,

Whereas, Immediately after the passage of said Act of the General Assembly of May 29, 1889, the Sanitary District was organized and thereafter commenced the construction of the Main Channel of the Sanitary District, extending from Robey street and the West Fork of the South Branch of the Chicago river to the Des Plaines river near Lockport, Illinois, a distance of thirty-two miles; and the work of constructing said Main Channel was carried forward with due speed until January 17, 1900, when the said Main Channel was placed in operation pursuant to the permit of the Governor of Illinois, in accordance with said Act, and the permit and consent of the Secretary of War of the United States; and the said

Main Channel of the Sanitary District cost the people of Chicago and its environs many million dollars; and there was required for such construction the use of all the money that could be raised by the Sanitary District for taxation and by the issuance of bonds; and,

Whereas, The Sanitary District was compelled to con-
203 struct and place in operation many adjuncts and addition to the Main Channel of the Sanitary District in order that the said Main Channel might accomplish the purpose for which it was constructed and there would thereby be constructed and placed in operation a complete and comprehensive system for a diversion of the sewage and drainage arising within the limits of the Sanitary District from Lake Michigan to the Des Plaines river; and such works included the intercepting sewers and pumping stations on the North Shore and South Shore of Chicago, the Calumet-Sag Channel, with its intercepting sewers, the enlargement of the flowage channel of the South Branch of the Chicago river and the West Fork of said South Branch, and the replacing of many old center-pier bridges with bascule bridges of modern type, and they included also many other works of similar character; and the construction of such works has largely engaged the resources of the Sanitary District, and

Whereas, the Works so constructed and placed in operation have caused a decrease in the death rate from typhoid fever per year in the City of Chicago and environs from an average rate of over seventy-five per one hundred thousand of the population for the ten years immediately preceding the opening of the drainage channel, so that now the death rate from typhoid fever is less than one-half of one per one hundred thousand of population; and,

Whereas, The Board of Trustees of the Sanitary District has recognized that by reason of various conditions existing, such as trade wastes and other materials passing into its channels and the inability to obtain at all points the necessary amount of water to dilute the sewage, thus causing local nuisances, that works should be constructed and operated to remove a material portion of organic and inorganic matter from human sewage, and also to remove and eliminate a material portion of trade wastes and other materials so that the amount of organic and inorganic matter in sewage and the amount of trade wastes and other materials passing through the Main Channel of the Sanitary District into the Des

Plaines river would be materially diminished; and The Sanitary District of Chicago has for such purposes carried on experiments and investigations to ascertain the best method to accomplish such results; and it has constructed at Morton Grove, Illinois, an Imhoff tank for the removal of a certain portion of the solids from the sewage of the Town of Morton Grove, and is constructing in connection with such Imhoff tank a sprinkling filter to further purify the sewage of said town; and the Sanitary District is constructing an activated sludge plant with necessary intercepting sewers for the collection and purification of the sewage of the Towns of Riverside, Maywood, River Forest and others, the sewage of which towns is now passing into the Des Plaines river; and the Sanitary District has authorized the condemnation of one hundred acres of land near the Calumet sewage pumping station at 125th Street and Michigan avenue, Chicago upon which site there is to be constructed an artificial sewage disposal plant for the removal of organic and inorganic matter from human sewage and wastes that
204 may pass into the Calumet intercepting sewer; and the Sanitary District of Chicago has, in the Stock Yards District, to take care of the trade wastes of Packingtown, acquired a site for purification works to be constructed thereon to remove trade wastes and organic and inorganic matters from human sewage now finding their way from that locality to the Main Channel of the Sanitary District; and the South Park Improvement Project provides for the setting aside of sufficient land for the construction of purification works for the sewage and wastes collected at 39th Street and Lake Michigan by the intercepting sewers converging at that point, which intercepting sewers serve a population of approximately five hundred thousand people, and,

Whereas, The Chief Engineer of The Sanitary District of Chicago has made investigation of the amount of trade wastes and other wastes requiring pure water to oxidize same, now being discharged through the Main Channel of the Sanitary District into the Des Plaines river, and the Chief Engineer has found and the Board of Trustees of the Sanitary District believes that the amount of such wastes is approximately equal, if it does not exceed, the amount of human sewage now passing into said Main Channel and through same to the Des Plaines river; and that there is required to oxidize said wastes and render same innocuous and nonputrescible, as much or more water from Lake Michigan than is required to oxidize and

render innocuous and nonputrescible the human sewage of the present population within the territorial limits of The Sanitary District of Chicago; and by reason of such wastes passing into said channel and thereby into the Des Plaines river, the works of the Sanitary District do not fully accomplish the purpose designed and nuisances are created at various places, which nuisances should be abated; and,

Whereas, It is the recommendation of the Chief Engineer of the Sanitary District that works should be constructed and operated to supplement the diversion works of the Sanitary District constructed or in process of construction whereby the amount of human sewage and the amount of trade wastes and other material should be continuously diminished from year to year so that at the end of a period of twenty-five years at least only one-half of the amount of sewage, including all wastes that is now passing into the Des Plaines river from the Main Channel of the Sanitary District shall enter same by way of said Main Channel; and the Board of Trustees of the Sanitary District believes that within the period of four years works of such character can be constructed and placed in operation to materially diminish the amount of such sewage and wastes passing into the said Des Plaines river, as aforesaid; now, therefore be it ordained by the Board of Trustees of the Sanitary District of Chicago:

Section 1. To supplement the works of The Sanitary District of Chicago now constructed or in the process of construction for the diversion of sewage or drainage, and to aid said works in better accomplishing the purpose for which they were constructed, the Sanitary District does hereby lay out and adopt a program for the
205 construction and operation of works for the purification of sewage or the removal of organic or inorganic matter from human sewage and the removal of trade wastes and other wastes and for the carrying on of such work at such a rate as continuously after the lapse of four years to diminish the amount of sewage including all wastes passing into the Des Plaines river by way of the Main Channel of The Sanitary District of Chicago, so that within the period of twenty-five years such purification works shall be constructed and in operation, that the amount of such raw sewage and wastes so passing into said Des Plaines River shall be at least fifty per cent less than that passing now.

Sec. 2. The Chief Engineer and the Attorney of the Sanitary District are hereby directed to take such steps

as may be necessary to carry forward the foregoing program, and the Chief Engineer is directed to report to such officers of the United States and the State of Illinois as may be interested, the progress made from time to time in carrying out said program.

Sec. 3. The foregoing preamble to this ordinance is hereby adopted and made a part of same.

Sec. 4. This ordinance shall be in full force and effect
206 from and after its passage and adoption.

An ordinance of the Board of Trustees of the Sanitary District of Chicago, passed and approved July 8, 1920, Pearse Exhibit 2, April 25, 1923, appearing as Exhibit to motion, (This Narrative P. 111).

Letter of the Division Engineer at Chicago, U. S. Army, to the Chief of Engineers, dated May 24, 1921, Pearse Exhibit 3, April 25, 1923, as follows:

"PEARSE EXHIBIT 3

May 24, 1921.

209 The Division Engineer; the Chief Engineers, U. S. Army, Washington, D. C.:

Cooperation with the Trustees of the Sanitary District of Chicago in Making a Study of Sewage Purification:

1. Referring to the letter of the Chief of Engineers dated March 25, 1920 (E. D. 28918), instructing me to cooperate with the Trustees of the Sanitary District of Chicago in making a study of sewage purification, I desire to submit the following report of progress:

2. The history of the controversy between the United States and the Sanitary District may be briefly reviewed as follows:

Under a permit issued by the Secretary of War on December 5, 1901, the Sanitary District was authorized to divert through the drainage canal a maximum of 4,167 second feet of water from Lake Michigan for sanitary purposes. Since the permit was granted the Board of Trustees of the Sanitary District has made repeated applications for permission to increase the flow, which requests have consistently been denied by the Secretary of

War on the grounds that the permit already issued is of a temporary nature only and that congressional authority is necessary for any permanent diversion. In 1907 the Board of Trustees made application for authority to construct the Calumet-Sag Channel to connect the Calumet River with the main Drainage Canal, and to draw through it 4,000 second feet in addition to the 4,167 second feet previously authorized for the Chicago River. This application was denied, and the Board of Trustees thereupon declared its intention of proceeding with the proposed work and withdrawing from Lake Michigan the additional 4,000 second feet without the sanction of the Secretary of War, unless prevented by injunction proceedings.

3. A suit was then instituted in March 1908, by the Attorney General of the United States to restrain the Sanitary District from reversing the flow of the Calumet River and from withdrawing water from Lake Michigan in any other manner and in any greater quantity than that authorized by the Secretary of War.

4. Being thus stopped by court action from proceedings with its Calumet program, the Board of Trustees in 1910 applied for authority to construct the Calumet-Sag Channel so as to carry the present flow through the two drainage canals instead of only one. In response to this application the Department on June 30, 1910, modified the existing authority so as to allow the previously
210 authorized flow of 4,167 second feet to reach the main Drainage Canal through the Calumet-Sag Channel as well as through the Chicago River, provided, however, that the total amount withdrawn through the two outlets, should not exceed the 4,167 second feet already authorized to be withdrawn through the Chicago River alone.

5. However, the Board of Trustees was not satisfied with this limitation, and in 1912 made application for authority to withdraw through the two rivers, the Chicago and Calumet, a total of 10,000 second feet. After a public hearing this application was denied by the Secretary of War on January 8, 1913. As the Board refused to accept this decision, the Attorney General filed another bill in October, 1913. This suit was combined with the one filed in 1908, but on account of the war and other reasons no decision was rendered by the court until June 19, 1920. On that date Judge Landis rendered an 'oral opinion' in which he held that the 8,500 second feet, more

or less, which the Sanitary District was now diverting from Lake Michigan, had resulted in a lowering of the lake levels, and an impairment of the navigable capacity of all of the Great Lakes except Lake Superior; and that said diversion was not necessary 'for the salvation of this community,' He directed the attorneys for the two sides to get together and prepare for his signature an order sustaining the contentions of the plaintiff, to be effective 60 days after the meeting of the Supreme Court in October.

6. Instead of that, Judge Landis, in August, 1920, in the presence of the District Attorney and myself, heard the Sanitary District Attorney, Mr. Adcock, argue that the Judge should modify his oral opinion so as to allow a total flow of 10,000 second feet. As the arguments were not finished that day the hearing was adjourned to be concluded at his summer home at Trout Lake, Mich., on some day which was to be arranged later. On account of the sickness of the Judge's brother the adjourned meeting, which had been set for the latter part of August was again postponed and has not been taken up since.

7. Ignoring all questions except that of the proper reduction and disposal of Chicago sewage, by the existing method, it is apparent, from many considerations that an excessive amount of water from Lake Michigan is not being used. Contamination of the Illinois River is proceeding rapidly down stream toward Peoria; parts of the Chicago River and its branches show a state of contamination which is all too apparent to the eye and to the nose. It is easy to believe that if, under present conditions of sewage disposal, the amount of water from Lake Michigan is suddenly curtailed, the health of Chicago might be threatened. It is apparent therefore, that if the amount of water diverted from Lake Michigan is not to increase proportionately with the increase of population in Chicago and if health conditions in Chicago are to remain normal, there must be treatment of Chicago sewage. In 1919, with these facts in mind I took up with the Trustees of the Sanitary District the question of adopting an effective program for sewage disposal. As a result, a program was adopted on August 7, 1919, which contemplated that during the following four years
211 there should be accomplished such work of land acquisition, planning, financing and actual construction as would result in a continuous reduction thereafter of the raw sewage entering the drainage canal. The program

further provided that by the expiration of twenty-five years from the date of the program the work of purification shall have been so far advanced that the amount of raw sewage entering the Drainage Canal shall equal not more than one-half of that entering now, and this reduction must occur notwithstanding the fact that at the expiration of twenty-five years the amount of raw sewage produced in the district may be almost double that now originating there. Thus by the end of the twenty-five years period the Sanitary District might be required to treat some fifty per cent more raw sewage than that now enters the Drainage Canal. The cost of carrying out this program was roughly estimated at $140,000,000.

8. The Sanitary District has had studies made by Mr. Francis C. Shenehon, a competent hydraulic engineer, for regulating and compensating works in the Niagara River and at the Galops Rapids in the St. Lawrence below the lower end of Lake Ontario. Mr. Shenehon has prepared preliminary plans and estimates for the works above mentioned. He estimates that regulating works in the Niagara River would cost approximately $1,224,000, and those at the Galops Rapids approximately $1,000,000. It is understood that the Sanitary District, if the engineering propositions of Mr. Shenehon are approved by the United States, proposes to turn over to the latter the amount required for the construction of the works above described, the maintenance and operation of the same to be at the expense of the United States. These works, it may be said, contemplate a diversion of 10,000 cubic feet per second from Lake Michigan to the Drainage Canal. Digests of these two projects as prepared for me by Mr. Shenehon at my request are as follows:

Digest of Niagara Regulation Project

The Niagara River Regulation contemplates slackwater, vessel-draft betterments in Lake Erie, the Detroit River, Lake St. Clair and St. Clair River, Lakes Michigan and Huron and St. Mary's River to the locks at Sault Ste. Marie.

The loss of draft due to a diversion of 10,000 second feet at Chicago is about 5½ inches. In a low water period such as the ten years 1893-1902, the regulation proposed will add over 14 inches to the depth of Lake Erie and Lower Detroit River; over 10 inches to Lake St. Clair,

the Upper Detroit River and the Lower St. Clair River, with proportionate increase in St. Mary's River. In a decade of more plentiful supply, the average betterment is less, because no increase in Lake stage is practicable at flood height. The regulation will compensate for lowerings due to all anticipated diversions at Chicago in the Welland and Erie Canals and in the Niagara River for power purposes, and the regulation is accomplished without danger of riparian damage from flood stages.

The excess flow of May to August inclusive is saved
212 to hold up Lake Erie level during the season of navigation. The Niagara River runs free from January to March inclusive, to avoid flood stages, to give unimpeded passage for ice and to add water for power purposes during the season of ice complications. Water power is the beneficiary of the larger winter flow, which averages 17,000 second feet in January and February, more than off-setting a diversion of 10,000 second feet at Chicago.

During the summer season about 30,000 second feet in addition to the controlled flow would be released during part of each day to furnish mill-pond water for power uses, so that the full natural river flow may pass over the cataracts to preserve scenic grandeur. Regulation of the Niagara has been delayed by the fear of the people of Buffalo that regulating works would cause ice jams and hold up the vast ice fields which cover the east end of Lake Erie. This objection is met by placing removable vessel-type gates, which are removed in January and replaced in May.

The site chosen for works is at the head of the Niagara River, opposite the old water-works at Buffalo. The River is 1,800 feet wide here with bed limestone bottom. The river channel is divided into two sluice-ways by a submerged concrete wall, three-quarters of a mile long and parallel with the current. This carries a shutter dam to complete the partition and the shutters knock down during the winter. Four gates each equipped with twelve large butterfly valves, close off the American Sluiceway. These gates rest and swing on massive concrete emplacements rising about two feet above the rock bottom. Special devices make the placing and removing of these gates easy. As each inch of added draft in Lake Erie is estimated as having a yearly value, of half a million dollars, the average increase of 13 inches is significant. The far reaching benefits, from Buffalo to Sault Ste. Marie, without works or weirs in the Detroit or St.

Clair Rivers, point this out as a project of great concern. The Niagara and St. Lawrence regulations work hand-in-hand.

Digest of St. Lawrence Regulation Project

The St. Lawrence River Regulation contemplates higher surface levels for Lake Ontario in years when the lake is naturally low, and the avoidance of high stages which might cause riparian damage. This depends on the simple principles of slack-water betterment, utilizing movable regulating gates, which when open leave the full out-flow capacity of the lake undiminished as a safeguard against flood conditions. The aim of the project is not alone to restore the loss of navigable depth due to a diversion of 10,000 second feet at Chicago (5½ inches), but to maintain the lake at the highest practicable safe stage. By the manipulation of the outflow computations show 19½ inches gain for the record low water year 1895; over 21 inches gain for the ten-year period 1893-1902; and over 12 inches betterment for the normal supply period 1907-1916.

The lower limit of slack-water betterment is at the
213 Galops Rapids below Ogdensburg, New York. Navigation betterment below these rapids is secured by impounding in Lake Ontario the excess supply of the flood months March, April, May and June, and holding this reservoired water for release in the fall months August to November, inclusive. It is found that, while Chicago takes away 10,000 second feet, this is replaced by 9,000 second feet of impounded water in September, 16,000 second feet in October and 20,000 second feet in November. The lower St. Lawrence is dependent for good volume of flow on Lake Ontario water only in these fall months. The Ottawa River entering the St. Lawrence at Montreal has a May flow of 150,000 second feet dwindling to perhaps 20,000 second feet in September, October and November.

Budgeting Lake Ontario water aids water-power by greater uniformity of flow. The attenuated January-February flow is diminished by 10,000 second feet for Chicago, and 17,000 second feet of impounded water more than restores the loss.

The two channels of the Galops Rapids are natural Sluiceways controlling the outflow of Lake Ontario. The Canadian Channel will remain unobstructed. The non-navigable American Channel, carrying 43 per cent of the

outflow, will be throttled by 1,020 feet in length of regulating works. The bottom is bed limestone, probably overlain in part of glacial drift. The works are placed at the head of this channel. The gates consist of wickets, dropped from five 200-foot span steel bridge platforms. Some increase in outflow capacity of the American Channel is recommended.

9. The special Board of Waterway from Lockport, Ill., to the Mouth of the Illinois River, etc., reported that it would require $150,000 to build works in the Niagara River and $325,000 for works in the St. Clair River to compensate in Lakes Michigan, Huron and Erie for a lowering of their levels due to the diversion of 10,000 second feet, with $15,000 annually for maintenance.

10. The Sanitary Trustees are very anxious to have a determination at this time of the amount of water the United States will permit to be diverted from the Lake. It seems to be admitted now by all concerned that this matter should be settled by Act of Congress. For example, see page 6, House Doc. 762, 63d Cong., 2d Session, from which the following is quoted:

'Further the Board believes that the total volume of water to be diverted from the natural discharge channels of the Lakes should be definitely fixed by Congress; that a project with estimate of cost for works necessary to compensate for such diversion should be prepared to the satisfaction of the Chief of Engineers and the Secretary of War; that before any diversion is made beyond that at present existing, the State of Illinois, shall transfer to the Secretary of War the funds necessary for such works as given by the approved estimate of cost; that the works shall be built by the United States with the funds so provided; and that the control and maintenance of such works shall be in and at the cost of the United States.'

11. The circumstances that the State of Illinois is now engaged in constructing a navigable link between the
214 Sanitary District Canal and the Illinois River at Utica makes it extremely desirable that an early determination be made of the amount of flow to be authorized permanently from Lake Michigan. Upon the amount of flow so authorized will depend to a large extent the character of the improvements which will be necessary to provide an 8 foot channel in the Illinois River should that depth be authorized by Congress.

12. In the letter from the Chief of Engineers dated March 25, 1920 (E. D. 28918) hereinbefore referred to, I was informed that 'at a conference with representatives of the Chicago Sewage Disposal Commission and the Sanitary District Trustee' (sic), it was agreed that the Trustees of the Drainage Canal and the Sanitary Officers of the State would make a study to ascertain what could be accomplished in regard to sewage purification before the sewage was allowed to enter the Drainage Canal or the Illinois River, and the results of such study communicated to the Chief of Engineers through the District Engineer at Chicago. In this same letter I was instructed to cooperate with the Trustees in their study of the case and to render such assistance as I was able, the study to be made 'with the idea of withdrawing the least amount of water from Lake Michigan which would be necessary for the purpose.'

13. In accordance with the instructions of the Chief of Engineers as contained in his letter of March 25, 1920 above referred to, I have held numerous conferences with the Officials of the Sanitary District with regard to their plans for sewage treatment. During the past year there has been considerable change in the official personnel of the Sanitary District, especially among those actively engaged in formulating plans for their sewage treatment system. Among those are the President Chief Engineer, General Counsel and a number of Trustees, considering these conditions the progress made has been very satisfactory.

14. In regard to the contention of the Sanitary District that it is necessary to divert more than 4,167 cubic feet per second in order to avoid contamination of the City water supply and consequent epidemics, I was empowered in a memorandum of the Secretary of War for the Chief Engineers dated July 21, 1920 to say 'that if Judge Landis' decree is accepted as final, the War Department will issue no permit, since it is without legal power to do so, but will ask no further orders from the Court to enforce the limitation so long as the City of Chicago proceeds with dispatch to prepare plans and put them into process of execution for its sewage system. If the City of Chicago then prepares plans and consents to the War Department having current knowledge of its activity, either by reports to the courts or otherwise, the situation will be under the control of Judge Landis until the whole problem is disposed of. If however, the City

of Chicago proposes to appeal the case and takes no steps pending the appeal to cure the trouble, Colonel Judson should be instructed to make no concessions or promises of any kind.' This memorandum of the Secretary of War was obtained through the Chief of Engineers at my solicitation for use whenever Judge Landis
215 decides to finish the hearing on Attorney Adcock's arguments for allowing a total diversion of 10,000 second feet. In this connection Mr. Adcock was making the argument that the War Department would be arbitrary in acting on the findings of the court, and a statement was desired which would show that the Secretary of War would not be arbitrary in the matter.

15. On January 17, 1921, a formal conference was held betwen Mr. Chas. F. Clyne, United States Attorney, and myself representing the United States and the Trustees of the Sanitary District, their attorneys, Consulting Engineer and Chief Engineer. At this conference attention was invited to the Memorandum of the Secretary of War for the Chief of Engineers dated July 21, 1920, above referred to, copies of which were furnished the Attornevs for the Sanitary District. The Trustees agreed to take under advisement the proposition of the Secretary of War as set forth in his memorandum and to submit an answer thereto at a later date. At this conference an agreement was reached with the Sanitary District authorities that I be furnished with an outline of their present plans for sewage treatment. A copy of the memorandum furnished in accordance with the above agreement giving an outline of the work already completed, that now under way and proposed, and indicating the probable future policy of the Trustees, is enclosed herewith.

16. A second conference was held on February 7, 1921, at which the United States Attorney was represented by his assistant Mr. J. B. Boddie. The proposal of the Secretary of War as embraced in the last paragraph of his memorandum of July 21, 1920 (E. D. 98093/657), was discussed and the Sanitary Trustees stated that they were unable to accept the proposition that Judge Landis' decree be accepted as final. On the other hand they stated that they would proceed diligently in the preparation and execution of plans for the treatment of sewage within the Sanitary District. They stated that since the conference of January 17, 1921, they had prepared their budget and in it had placed some $8,000,000 for sewage treatment operations, and that in subsequent budgets

they would continue to provide for work upon a large scale to carry into effect plans already prepared or now being prepared for sewage treatment. They estimated that depending upon conditions in the labor and material market the entire cost of such treatment would be in excess of $100,000,000 and perhaps as much as $140,000,000 but stated that they were confident that they could provide this sum so that in somewhat less than 25 years they would be able to at least carry out the program adopted August 7, 1919, and perhaps do even better than was proposed in that program.

17. It was understood that the matter before Judge Landis would be proceeded with regardless of the more or less futile negotiations that have been in progress with reference to the proposition of the Secretary of War that the decree of Judge Landis be accepted as final. Mr. Boddie stated that he understood the situation and understood it to be the duty of the United States Attorney's office to proceed with efforts on its part to secure
216 the formulation and entering of the formal decree by Judge Landis, opposing any efforts of the Sanitary District to procure a modification of the decree. It may of course be regarded as a fact that the Sanitary Trustees will appeal from the decree of Judge Landis if it is entered without modification, satisfactory to them.

18. The Chief Engineer of the Sanitary District, at the conference of February 7, 1921, informed me that it was the intention of a committee of Trustees and employes ofthe Sanitary District, including himself, to visit Fort Worth and Houston, Texas, and other localities, at an early date, to inspect activated sludge plants in course of construction or operation and suggested that I accompany them. This I subsequently undertook to do but my travels were interrupted by illness.

19. While the Sanitary District doubtless has authority under existing state laws to proceed with its sewage treatment program, in an excess of caution it has caused bills to be introduced in the State Legislature for explicit authority to construct the proposed sewage treatment works, in accordance with the accompanying memorandum, and the controlling works in the Niagara and St. Lawrence Rivers as well, in accordance with the projects of Mr. Francis C. Shenehon, hereinbefore referred to. These bills are still pending with good prospects that they will be passed.

Opposing interests are also endeavoring to secure legislation to limit the bonding power of the Sanitary District, by requiring that each bond issue be subject to a referendum.

20. In the meantime the Sanitary Trustees are proceeding energetically with their plans for sewage treatment and disposal as outlined in enclosed memorandum. Since the date of their report they have acquired 180 acres of land located on the North Shore Channel as a site for their proposed North Side purification plant.

21. The progress made by the Sanitary District is well illustrated by Exhibits E and F constituting part of enclosure showing their budget appropriation for 1921 and their expenditures during the ten year period 1910-1920. During the last named period the expenditure for sewage treatment works has amounted to approximately $9,400,000. Their budget for 1921 provides $6,500,800 for the completion of old projects and $3,242,500 for new projects.

22. The program of the Sanitary District, if carried out, will insure the practicability of keeping the volume of water diverted from Lake Michigan within limits which it is hoped all concerned will finally deem reasonable.

W. V. Judson, Colonel, Corps of Engineers, Divn. Engr., N. W. Divn. 1 encl."

Langdon Pearse, a witness for the defendant, testified as follows (April 25 and 26, 1923; Rec. Vol. VIII, pp. 176-197): 177 Resides Winnetka, Illinois.

Been employed with The Sanitary District of Chicago in various capacities since March 1st, 1909; at present in the position of Sanitary Engineer, in charge of the sanitary engineering work of the District.

Graduate of Harvard College with the degree of A. B. 1899; and from the Massachusetts Institute of Technology, with a degree of Bachelor of Science in Civil Engineering; also Master of Science in Civil Engineering, of date 1902.

In the period between 1901 and 1909, at which time became connected with the Sanitary District, was successively Level-

man for the Massachusetts Harbor and Land Commission, on the Brockton Ship Canal; Assistant Engineer to the Charles River Dam Commission, under John R. Freeman; Assistant Engineer for the Commission on Additional Water Supply in New York City, known as the Herring-Burr-Freeman Commission; also as Personal Assistant to George C. Whipple in work for the Augusta Water District, Me., Cleveland and Jersey City; and also in connection with the suit of *Missouri* v. *Illinois*.

From there, was Assistant Engineer for the Improved Water and Sewage Works at Columbus, Ohio, involving the construction of a water filtration and softening plant; also sewage treatment; and also Assistant Engineer on the Greater Water Supply for the People's Water Company of Oakland, California, a water filtration project.

From 1909 to date, have been successively assistant engineer, division engineer, and since 1917, sanitary engineer with the Sanitary District of Chicago, in charge of all sanitary work, involving the laboratory work covering chemistry and bacteriology, in connection with our testing stations, studies of the Canal and River, as well as industrial wastes; the construction and operation of four Testing stations, respectively on domestic sewage at 39th Street and the Lake, packinghouse waste, tannery sewage and Corn Products sewage; the design and construction of intercepting sewers in size from six inches to twenty-two feet in diameter, including the North Shore Intercepting Sewer, the Stockyards Intercepting Sewer, the Calumet Intercepting Sewer, and the 52d Avenue Sewer Outlet; the design of sewage pumping stations, known as the Evanston, Des Plaines, Calumet, 95th street stations, and also the remodeling of Lawrence Avenue and 39th Street; the design of sewage treatment works and other construction at Morton Grove, the so-called Calumet works at 125th Street and Cottage Grove Avenue, the Des Plaines River Treatment Works, near the Subway Hospital in Broadview; Glenview Sewage Treatment Works, and the designs for the North Side Sewage Treatment Works.

Have further been in charge of the general operation of the Sewage Treatment Works, of which we now have three in operation, one at Morton Grove, one at Calumet, and one known as the Des Plaines River.

178 In addition to these technical duties, have also been in charge of preparing special reports and data for the use of the Chief Engineer and others in different suits.

In addition to duties with The Sanitary District, have further served as a Consultant for the U. S. Public Health Service on stream pollution for the last three years; and in that connection served for the Sanitary District on a joint survey with the U. S. Public Health Service of the Illinois River, extending over a period of one year.

In private capacity as a Consulting Engineer, have executed the following works, in special partnership with George W. Fuller; designed and built the Evanston Water Filtration plant. As a member of the firm of Pearse, Greeley & Hansen, we designed and built the Decatur, Illinois Dam & Sewage Treatment Works; the Whiting, Indiana Water Filtration plant, and the Winnetka, Illinois, Water Filtration plant.

And further, as engineer, have made reports for, designed and built works forthe Sanitary District of Decatur, the North Shore Sanitary District, the Downers Grove Sanitary District, the Sanitary District of Champaign and Urbana; and in addition have made miscellaneous reports on industrial wastes for the Holland-St. Louis Sugar Company, the Standard Oil Company of Indiana and others.

Am a member of the American Society of Civil Engineers, and the American Institute of Consulting Engineers.

Witness further testified:

I was first employed in 1909, with the intent of making a complete and thorough investigation of the sewage treatment problem of The Sanitary District. I have been at that ever since.

I first went into the engineering details in the so-called 1911 report of Mr. Wisner, who was then Chief Engineer; and later in 1912 and 1914, I went into the matter again in connection with this particular lawsuit for Mr. Wisner. And further in 1919 and 1920, in connection with the report of the so-called Expert Commission composed of Eddy, Fuller and Hatton.

It was early evident that to unravel the sewage treatment problem, a close study was required, not only of the sewage from the human sources, but also of the wastes of industrial origin.

The study of the domestic sewage was begun by a testing station at 39th Street and the Lake, operating on sewage coming from an area of over twenty-two square miles, and from a population of 270,000 and up. This was very free from industrial wastes. In this Station were tried all the practical methods of sewage treatment then known, including septic tanks, Imhoff tanks, biolytic tanks, sprinkling filters, etc.

The difference between the different tanks mentioned is essentially one of construction as well as operation. By
179 septic tanks, I mean the single story tank in which the solids deposited from the sewage are allowed to accumulate, with cleaning at infrequent intervals.

By the Imhoff tank, I mean a double deck type of tank in which the upper chamber serves as a settling chamber, the solids passing through a trap into the lower chamber where they digest at leisure, the gases passing off through a separate vent, in order not to contaminate the sewage flowing through, which is settling.

The sludge from this tank may be drawn at intervals of two weeks, in the warm weather; the storage capacity provided being from four to six months, according to the design.

The biolytic tank is a special device, in which all the sewage entering the tank comes in at the bottom and passes through the sludge deposit. This tank has been used only experi-

mentally, and while it gave a remarkable reduction of sludge, it produced offensive odors and was therefore discontinued.

The sprinkling filters mentioned are beds of crushed stone, in the experimental work ranging from five to ten feet in depth, but usually in active work around six feet and a half, the stone being composed of one and a half to two inches in size. These beds are placed upon prepared underdrains to permit free drainage of the liquid trickling down through. The liquid is sprinkled upon the surface by nozzles spaced up 13½ feet on centers, operating intermittently and dosing the beds at a rate of from two to five million gallons per acre per twenty-four hours.

The 39th Street Testing Station was operated from October, 1909, to January, 1915. The results that were obtained there indicated that with the more dilute sewage found in Chicago, liberal provision for treatment, loadings, was required.

The value of the Imhoff tanks and sprinkling filters was clearly demonstrated.

Following the study of the domestic sewage, we entered upon an extended study of the Packingtown situation in January, 1911. The preliminary investigation showed the lack of knowledge for handling such waste. Consequently a Testing Station was established in 1912, and operated until September, 1918. These studies showed that the activated sludge process was the most promising of success on Packinghouse waste.

I might explain that the activated sludge process is a process in which the solids settling from the sewage are held back and conditioned by the blowing of air, so that in a period of about two weeks it has acquired the property of changing from the organic matter coming in the sewage to a more mineral form. It is essentially a biological process, involving the same principles as in the sprinkling filter, except that the films which are active and doing the work are held in suspension by air blown in at the bottom of the tanks, in

stead of the films being around the periphery of the stones in a bed above ground. The sludge is retained by settling tanks, returned to the incoming sewage and then held in contact and in thorough mixture by the air blown in 180 at the bottom of the tanks.

From day to day a certain amount of sludge can be removed from the system, about one thousand pounds per million gallons of domestic sewage, and in the case of Packingtown about between three and four thousand pounds of dry solids per million gallons.

This sludge is higher in nitrogen than the usual sludge from Imhoff tanks or other processes.

In connection with our packinghouse investigation, a thorough inspection was made of every packinghouse in the Sanitary District, the flow from each being gaged and analyzed before entering the sewer.

In 1911, all the packinghouses were examined. In 1917, the work was repeated, the flow of thirty-one houses being measured and analyzed in a period of about three months.

The study of the tannery situation was begun in 1912. A recent investigation showed twenty houses all located on the north branch of the Chicago River. After a number of inspections, a tannery testing station was established in December, 1919, and operated up to December 31, 1922. In this the various processes applicable to handling tannery wastes were tried, including sprinkling filters and activated sludge. A survey of the industry was also made, house by house.

The Corn Products Refining Company plant at Argo was early recognized as an outstanding source of organic pollution. After some preliminary work, a testing station was established in 1921, by which the experiments have been conducted to date, using activated sludge and also a sprinkling filter. The flow of the plant has been measured, analyzed and correlated to the grind. This plant manufactures primarily starch and glucose, and is the largest of its kind in

the world, grinding upwards of 75,000 bushels of corn every twenty-four hours.

There are other sources of pollution, which we have investigated in a cursory way, which add to the load, but are not so important as those listed. Among these may be mentioned the Pope Beet Sugar factory, miscellaneous butterine factories, paint and glue works, gas works, paper mills and wire mills.

The study I have made in the last fourteen years has led me to divide the Sanitary District into five main geographical projects, namely:

The Calumet, south of 87th street.

The Southwest, south of the canal and the river and north of 87th street.

The West, north of the canal and river, and south of Ful-
181 lerton avenue in general, and the

North Side Project, north of Fullerton avenue.

In addition, there is the Des Plaines River Project.

Besides these five main projects, there are the Packingtown, Corn Products and Tannery Industrial Projects. The first two require separate treatment plants distinct from the human sewage plants, whereas the tannery situation is to be combined with the North and West Side Projects.

Besides the major projects outlined, there are and will be for many years small treatment units, plants for isolated villages such as Morton Grove, Glenview, Shermerville and the like, where the population is small and the distances are too great to warrant the construction of an intercepting sewer at present.

I have made a careful study of the population in the Sanitary District from the United States census figures from the component parts of the census of 1890, 1900, 1910 and 1920. From the figures an estimate has been made of the future population of the District up to 1960. The growth of the various sewage treatment project areas has also been worked out in detail.

We have plotted the populations as they have existed, with the correction for the date, on paper, and then projected a curve on that.

We have further tested the ten-year increment by the actual differences, taking into account the growth of the territory of the Sanitary District, and have arrived at the figures given in the table.

This method has been used and is one that is usual among engineers.

Pearse Exhibit 4 as follows:

The Sanitary District of Chicago

217 Population and Area

Year	Population	Area	Date of census
1890	1,149,758	185.0	June 1
1900	1,775,882	185.0	June 1
1910	2,311,810	358.1	Apr. 15
1919	2,940,906*	388.14*	.....
1920	2,986,000	395.51	Jan. 1
1921	3,071,000	.....	.....
1922	3,142,000	437.39	.....

* In June, prior to annexation of Salt Creek Villages.

181 Table for the years 1920, 1930, 1940, 1945, 1950, 1955 and 1960, as Pearse Exhibit 5, April 25, 1923, is as follows:

The Sanitary District of Chicago

217 Population in Various Sewerage Districts

Locations	1920	1930	1940	1950	1960
North Side Treatment Plant	590,000	800,000	1,615,000	1,230,000	1,450,000
West Middle Plant Incl. Loop	1,300,000	1,420,000	1,550,000	1,680,000	1,800,000
S. W. Treatment	850,000	1,040,000	1,230,000	1,415,000	1,600,000
Calumet	160,000	225,000	290,000	350,000	415,000
Miscellaneous	100,000	215,000	340,000	465,000	595,000
S. D. C. Total	3,000,000	3,710,000	4,425,000	5,140,000	5,860,000

Dec. 31, 1921.

182 These loads are shown in the table which I have prepared based on the census populations nad the projected population for the human load, and based upon our surveys for the industrial load expressed in equivalent population.

Table shown as Pearse Exhibit 6 as follows:

The Sanitary District of Chicago

217 Population Estimates

Year	Human	Industrial equivalent	Total
1920	3,000,000†	1,500,000	4,500,000
1930	3,710,000	1,700,000	5,410,000
1940	4,425,000	1,900,000	6,325,000
1945	4,782,000	2,000,000	6,782,000
1950	5,140,000	2,100,000	7,240,000
1955	5,500,000	2,200,000	7,700,000
1960	5,860,000	2,300,000	8,160,000

† Based on 1920 Census.

182 The estimates for the years following 1930, and up are given in the Exhibit 6, following the figures given for 1920, for the totals there expressed.

The method by which I have arrived at the population equivalent of the industrial wastes is based on the dissolved oxygen required to oxidize the putrescible matter in sewage. Continued research over many years in the laboratory of the Sanitary District has shown this to be a reliable and accurate measure of the strength of sewage, inasmuch as it utilizes exactly the same biological activities which are effective in the stream. By stream I mean the Canal, Des Plaines and Illinois Rivers.

Essentially, the test depends on mixing with the sample sufficient standard water saturated with dissolved oxygen to supply enough dissolved oxygen to oxidize the organic or putrescible material, in five, ten or twenty days, as the case may be, and leave a small amount of oxygen over at the end of a period.

The amount of dissolved oxygen required is expressed in parts per million. For purposes of comparison, a ten-day period has been chosen in our work, inasmuch as 90 per cent of the oxidation of the putrescible material is generally completed in sewage within that period. Such a test is called the Biochemical oxygen demand, and has been widely used by the U. S. Public Health Service, the Sanitary District and other research workers, as being more delicate and expressive than the old line chemical determinations. In some instances we have used nitrate of soda, added in known amounts, in place of dissolved oxygen.

The first step in the study of our sewage was to determine the amount of dissolved oxygen required per capita to oxidize the putrescible matter in human sewage. Prior to the work of the Sanitary District this figure had never been determined. Experiments were made on the sewage at 39th 183 Street Pumping Station during the year 1914. This sewage was chosen because a thorough inspection of the area tributary showed no industrial wastes likely to upset the tests.

On 179 days, hourly portions were collected during the twenty-four hours and daily composites were made. These were analyzed. The flow of the sewage was measured. The population tributary was estimated. From the data the average figure was determined that 100 grams of oxygen are required per capita to properly oxidize the human sewage, or 0.22 pounds. Subsequently other research chemists confirmed this figure to me personally.

The next step was to determine the amount of putrescible material requiring oxidation from the different industries. This was done from time to time as follows:

The Packingtown and Union Stock Yards situation was investigated in the summer of 1917 between July 9 and October 6. At that time thirty firms were actively engaged in the packing and allied industries, in addition to the Stockyards. All of these houses were examined, and the flow gaged

and analyzed from forty-one outlets, besides the public sewers, and certain outlets from the Stockyards. In all cases (except three of the smaller houses where the examination lasted two days) the sampling and gaging continued a week, night as well as day.

The flow was read as frequently as every ten minutes in most cases. For analysis, individual portions were taken every ten minutes and combined into hourly composites, which in turn were combined into day or night composites, weighted according to the flow. I mentioned the fact we made day and night composites, bacause there was a marked difference in the flow, in the strength day and night, as well as in the quantity.

From the determination of the biological oxygen demand and the flow, the total oxygen requirement was calculated. Based on the 0.22 pound per capita, the effect of the Stockyards and Packingtown was found to be practically 1,000,000 people. This investigation alone cost $5,661.97, an amount which was reimbursed to the Sanitary District by the packers.

For the Tannery industry, the investigations made between 1911 and 1919, gave a rough indication of the equivalent. However, the most detailed survey was made in the summer of 1921, when twenty tanning houses were inspected. For each house, the flow was gaged and analyzed, the work being done substantially in the same manner as for the Packing-house survey. The determination of the biological oxygen demand and the flow from the houses showed a total oxygen requirement equivalent to 70,000 people, on a normal hides capacity rating. In addition, seven wool pulleries and three wool scouring houses were examined.

For the Corn Products Refining Company, the investigations were made in December, 1921, and January and February, 1922, in connection with the testing station then operated on the Corn Products wastes. The flow was gaged and sampled throughout the twenty-four hours, analyses being made on twenty-four composites. The resulting oxygen

demand showed that the population equivalent was 411,000 people, at that time when a grind of 64,500 bushels was being made. Since that time the grind has increased.

The Sanitary District Channel in the main section was designed upon the assumption that the runoff of the Chicago River would not exceed 10,000 cubic feet per second, and could therefore be diverted from the lake by a channel having that hydraulic capacity.

If the diversion from the lake is limited to 4,167 cubic feet per second, the likelihood of overflow into the lake is very much increased, with a result that pollution of the water supply is likely to occur, which will be severe. This is due to the fact that the intercepting sewers as designed cannot be made large enough to carry more than twice the dry flow in 1950; hence overflows will come into service, at times of storm, spilling sewage into the branches of the Chicago River. Consequently, with any reversal of the flow, storm water and sewage mixed will fill the river and be swept into the lake.

It does not seem safe to me to rely entirely upon chlorination of the water supply for protection, where water would be exposed to sudden and so-called explosive pollution. In my experience, the only adequate and certain protection would be filtration, accompanied by chlorination, as a finishing process.

I have prepared an estimate of the use of water at the present time in the City of Chicago, that is as of 1920; and also for 1945 and 1955. These estimates have been checked with those of the Water Bureau of the City of Chicago, and are in substantial agreement. That is practically the pumping. That has nothing to do with the diversion from the lake by the Sanitary District.

Table of water consumption for 1920, 1945 and 1955,
218 Pearse Exhibit 7, April 25, 1923, is as follows:

Year	Population	Mil. gal. per 24 hr.	Gal. per cap. per 24 hr.	Max. Rate mil. gal. per 24 hr.
1920	2,700,190	715	265	945
1945	3,919,275	1,355	346	1,800
1955	4,406,909	1,610	365	2,130

185 I have made a rough estimate of the cost of filtration, basing the capacity of the plant on the maximum daily rate, and including in round figures the low lift pumping stations.

In 1945, the cost would be for construction approximately $90,000,000, or by 1955, a cost of $106,500,000. These costs are in round figures and undoubtedly would require some additional expansions to increase the figures in a detailed survey, because of the necessity of the connections to the intake tunnels and other incidental work, which at present it is difficult to estimate. I present them as an indication of figures based on the cost of works in the past and present, to show the magnitude of the filtration expenditure.

The estimate may be within fifteen or twenty per cent, based on round figures, calculated per million gallons for plants of like nature. They are figures that perhaps are not accurate enough to predicate a bond issue upon for a public vote, but are accurate enough to indicate the magnitude of the expenditure for handling the filtration of a city of the size of Chicago. Such a plant would be the largest filtration plant of its kind in the world, and would necessitate special designs and lay-out, so that the figures necessarily at the present moment are not contractors' estimates of what the work could actually be built for, but they are what we call preliminary estimates which may be accurate within fifteen or twenty per cent, thereabouts.

I believe that in 1945, the cost of maintaining and operating such filter plants for the city would exceed three million

dollars, and that by 1955, the cost would have probably reached $3,526,000, the additional cost being due to the additional service required for the population, and increased pumpage.

To these figures necessarily should be added interest charges and depreciation, to give the total annual costs. These costs cover labor, chemicals, supplies and general repairs necessary and incidental to the operation of such filtration plants.

I have made a calculation based on the plan outlined by the ordinance of August 7, 1919, the so-called "Colonel Judson plan." This was designed to outline the program for the Sanitary District for the twenty-five years following 1920, to construct works which would reduce the load on the channel to one-half that existing in 1920. The figures are 186 presented as follows:

For Conditions in 1920.

By census, S. D. C. in 1920	2,986,000
Estimated Industrial Wastes	1,500,000
Total	4,486,000
One-half	2,243,000

Equivalent population expressed in the equivalent sewage from human beings. That is, that represents, according to such estimates, half the waste passing from the southern terminus of the Main Channel of the Desplaines River. The figure of 2,243,000 is in round figures to the nearest thousand.

The equivalent population, under the Colonel Judson plan that would be required to reduce the sewage pollution to in 1945, outlined in 1945, the conditions are as follows:

For Conditions in 1945.

Estimated S. D. C. in 1945	4,782,000
Estimated Industrial Wastes	2,000,000
Total	6,872,000
Deduct residual one-half	2,243,000
Requiring treatment by	4,539,000

Four million five hundred thirty-nine thousand is the population which I understand would have to be provided for by treatment works, under this so-called Colonel Judson plan.

That is, during the period from 1920 to 1945. I have based the figures on the minimum legal dilution expressed in the Act of the Sanitary District, namely 3⅓ cubic feet per second per thousand population, and on that base I find the population of 2,243,000 requires 7,500 cubic feet per second, in round figures for dilution. From the sewers there may come a flow which we have assumed to be 346 gallons per capita per twenty-four hours for a population of 4,782,000 in 1945, which would give a flow of 2,482 cubic feet per second, making a total flow through the channel of diversion from the lake, and of water supply coming through the sewers of practically 10,000 second feet; a difference of only a few unit second feet, so that it rounds out to the 10,000 second feet.

187 On the assumed basis of the minimum legal dilution 4,617 cubic feet per second, at 3½ cubic feet per second per thousand population, is equivalent to 1,250,000 people. In 1945, the total population equivalent, both human and industrial is estimated at 6,782,000. The difference, or 5,532,000 people would require treatment. In 1945, this means 993,000 more people than would be required under the Colonel Judson plan.

188 It would take, probably, to build these additional works for the 993,000 people not over ten years. The human population would amount to 5,500,000 in 1955 and the industrial wastes 2,200,000, making a total of 7,700,000. The figures given previously may be developed as follows: The total population in 1955 we have estimated at 7,700,000; the total population in 1945, at 6,782,000, making a difference of 918,000 population, as the growth in the ten years.

If you take the total in 1955, namely 7,700,000 and from this deduct the population equivalent to the 4,167 cubic feet per second, namely 1,250,000, you have as a difference as of 1955 a population of 6,450,000.

Under the Colonel Judson plan as mentioned before, the population requiring treatment in 1955 would be 5,457,000, the difference then between the two being 993,000 people.

We have made an estimate of the cost. The sewage treatment program based on this plan (August 7, 1919 ordinance) was estimated in 1920, to require directly an expenditure for sewage treatment of $104,335,000, out of a total program of over $106,000,000. I say over $106,000,000 because in addition to the $104,000,000 would be the other items such as regulating works, bridges over the Main Channel, and dredging of the Calumet River, which amount to $7,250,000. Of the 189 total as estimated, over $9,490,000 has been spent or put under contract to date, thus leaving a total of about $94,845,000 still to be expended. The amount of approximately $9,000,000 has been either expended or contracted for since 1920.

Estimated cost of sewage treatment projects and necessary construction work 1922-1945, as Pearse Exhibit 1, April 26. 1923, is as follows:

The Sanitary District of Chicago

Estimated Costs of Sewage Treatment Projects and Necessary Construction Work for Period 1922-1945

Work under contract and completed project	Contract liability	Date of completion
Calumet Treatment Plant	$2,200,000	1922
218 " Mach. & Adm. Bldg.	520,000	1923
" Sewers—Contract #10	130,000	1922
" " " #11	2,300,000	1923
Desplaines Treatment Plant	300,000	1922
Oak Park Sewer	500,000	1922
39th St. Conduit Extension	2,000,000	1924
Calumet-Sag Channel	200,000	1922
North Side Sewers—Contract #1	1,610,000	1923

Proposed wokr	Estimated cost	
Calumet Sewers—Contract#1	400,000	1923
Harbor Ave. Sewer	250,000	1924
Extension Blue Island Sewer	425,000	1928
Sewer to Riverdale & Dolton	200,000	1928
Sewer—Burnham, Hegewisch & W. Hammond	500,000	1928
95th St. Pumping Station	1,000,000	1924
Calumet Sag Channel	120,000	1923
Dredging Calumet River	1,000,000	1929
Glenview Treatment Plant	25,000	1922
La Grange Sewer & Treatment Plant	75,000	1923
Oak Forest Sewer	300,000	1923
Extension Desplaines Plant	100,000	1924
California Ave. Bridge	750,000	1924
Elmwood Park Sewer	250,000	1925
Stockyards Treat. Plant (Demonstration)	350,000	1926
" Sewers, Pump. Sta. & Screens	1,000,000	1926
Cicero Ave. Bridge	1,500,000	1926
Remodel Lawrence Ave. Pump Sta.	200,000	1926
219 Broadview Sewers	200,000	1926
Corn Products Treatment Plant..	1,500,000	1927
Regulation Works—Niagara & St. Lawrence	2,500,000	1927
North Side Treatment Plant	13,500,000	1928
" " Sewers (exc. Cont. #1)..	7,800,000	1928
Crawford Ave. Bridge	1,500,000	1928
Harlem Ave. Bridge	1,000,000	1929
Calumet Sp. Filters & Plant	2,000,000	1930
Extention North Side Plant	2,000,000	1931
Stockyards Treatment Plant	6,000,000	1932
Remodeling 39th St. & 73rd St. Pumping Sta.	900,000	1934
West Side Sewers	13,300,000	1940
" " Treat. Plant (Imhoff)	10,900,000	1940
South West Side Sewers	9,400,000	1945
" " " Treat. Plant (Imhoff)	7,200,000	1945
*Misc. Treat. Plants & Sewers	11,200,000	1927-1945

We based this schedule on the following assumptions as to the progress that might be made. I would make this explan a-

tion, however, that this general program was worked up in 1922, that is not 1923, and we estimated then that the North Side work would be started in 1922. The plans were practically ready last fall for the first contract of that plant, but owing to the discussion with Evanston over the location of
the site, the work has not actually been put under con-
190 tract, but the program is outlined to start on the North
side plant in 1922, and completed by 1928.

The District has acquired approximately 200 acres at Oakton avenue and the North Shore Channel for the purpose of a site. This site was acquired about two years ago. Last year, when it was announced that we were prepared to start work on the plant, objections were raised by various Evanstonians, and only to-day a large delegation was in the office before a public hearing of the Trustees, protesting against the use of that site, and alleging possible damage to the property values in Evanston.

The Trustees have indicated as yet no decision in the matter, but have been investigating very seriously the entire question since last October. The change in the board in December re-aligned some of the committees. We expect a decision shortly, and orders to proceed in one way or another on actual construction. The reason for the objection is that Evanston has expressed a desire to annex 2,500 acres west of the Channel, extending out towards the north branch of the Chicago River north of Oakton avenue; and the claim is made that the location of this plant will injure the desirability of that locality for the best class of residential buildings.

I would add this, however, that on this north side project we have already built five miles of sewer from Sheridan Road south to Oakton avenue, so that the northwest line of the intercepting sewer is completed and ready to hook into the pumping station. And we have completed preliminary plans for the work from the south, and have already started on the plans for re-modeling Lawrence avenue, so that the sewage that now passes to the river through the Lawrence avenue

conduit from the Lincoln Park region will be diverted to our interceptor.

The suggestions of Evanston are that we can move the plant five miles or more to the West, which would increase the sewer cost of the project at least a million and a quarter a mile for about four miles anyway, as a minimum. That is five million dollars and this would probably add to the operating expenses approximately $100,000 a year. I have been informed that that land is worth about $1,000 an acre. Our board paid $1,500 an acre for the site of the treatment plant.

In our schedule, we further assume that the Corn Products plant could be started in 1925, and completed in 1927. I purposely allowed three years there for legal conditions, to arrive at an agreement with the Corn Products, because in our experience with the packers, after we had outlined the engineering plans for doing the work, that overcame the engineering objections, we have been approximately four years negotiating as to the legal difficulties; and negotiating to arrive at an agreement under which the work could be prosecuted.

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For the Stock Yards project, we allowed for a start in 1925, and assumed it would be completed in 1932. In making this allowance, we assumed that legal negotiations would take at least two years; that the design of the sewers and works would be done by 1924, and the construction of the sewers, pumping station, screens, and the first unit of aeration tanks completed in 1926. A year is allowed for the design and contract plans for the entire plant, and a year for necessary legal negotiations. The plant is assumed to go under construction in 1929, and to be completed in 1932.

I would explain this arrangement was made, because when Mr. W. B. Richardson, representing the packers, and myself representing the District brought in a report outlining the engineering method of proceeding, in 1917, we made a recommendation that the work be done by gradual steps, first to construct the sewer, pumping stations and screens for the entire

works. Mr. Richardson differed with me and said we ought to have the screens only for one unit, that is about one thirtieth of the entire flow, and then we both agreed that the activated sludge plant recommended by both of us as to process should be built gradually, in order to demonstrate to the packers on a working scale of at least a million and a half gallons per day, the entire feasibility of the process.

Since that time, I have taken the position that the size of the plant to start might be markedly larger, as we know more of the process to-day, and have been operating a plant at Maywood for over eight months.

The sewage is much stronger at the Stock Yarks, expressed in biological oxygen demand. The sewage in the Stock Yards will run from 500 to 1,000 parts per million, as against 125 to 150, not over 200 in Maywood.

The amount of suspended matter in the Stock Yards will run from 3,000 to 4,000 pounds of dry matter to the million gallons, whereas at Maywood we have 1,000 pounds. In other words, there is three to four times as much solid to be handled.

Further, with the screens at the Stock Yards, we estimate we can take out about 1,000 pounds of dry material to the million gallons, whereas at Maywood we are only taking out 200 pounds a day for 3,000 gallons. That is sixty pounds of wet material with eighty per cent moisture, or sixteen pounds of dry material to the million gallons.

The Stock Yards sewage is one of the strongest sewages in the United States produced on such a scale, and is full of fresh organic mattter, blood, particles of meat, hay straw, and undigested contents of cattle paunches, hogs and other animals.

192 I feel that a reasonable program for handling has been devised, namely to de-water the sludge, which in its original form contains about ninety-nine per cent of water; reduce that to eighty per cent or less by filter process, with the addition of either an acid or a coagulen like sulphate of alumina

and then take the solids with less than eighty per cent of moisture and dry them in a rotary heat drier. They will then be in a form containing ten per cent of moisture, capable of passing through an eight mesh sieve, and suitable for sale in the market as fertilizer. We have been offered by at least two responsible firms the amount of five dollars and ten dollars per ton f. o. b. cars for Chicago for such material, to be used in mixing fertilizer for the Southern market, or for truck farm either in the East or the Ohio Valley.

That has been worked out in the last two years. In addition, the City of Houston has been selling similar material for eight dollars a ton for use in the cotton belt in the South, prepared in much the way that I have indicated. The City of Milwaukee is installing a plant now to handle the sludge in exactly this fashion.

In order to build up a sufficient treatment to meet the requirements of the Colonel Judson program, or a more elaborate program, we have had to plan the construction of the so-called West Side Project, including the sewers, and a plant which, for the purposes of this estimate, we have assumed would be a settling plant to remove all the solids which may settle in the Channel. The construction of this plant has been assumed to begin in 1932 and to be completed in 1940.

Further, for the South West Side, we have laid out a similar program for treatment, including intercepting sewers and a settling plant, the construction to start in 1935 and to be completed in 1945.

Besides the new work which I have mentioned, viz: the North Side, West side and South West Projects, the extension of existing projects will require attention in the life of the program.

The Desplaines River sewage treatment works, which has been in operation since August 1, 1922, will need extensions in 1924, to take care of the increased population.

The Calument treatment works, which has been in operation since October, 1922, will need an extension of the tanks, and

we have assumed an addition of sprinkling filters to produce a higher grade effluent than we were supplying, in the year 1930. We have further allowed for the extension of the North Side treatment works, assuming that they were completed in 1928, in the year 1931.

As originally outlined the program covers an equivalent population of 4,251,000 taking the Imhoff tank treatment
193 as the equivalent of one-third complete treatment. This is within five per cent of the figure set for 1945, as outlined by the Colonel Judson plan. This method of handling was assumed by settling the sewage which was not given complete treatment, in order to retain all the settling solids.

I would explain that the reason for presentmg the material in this shape is, we have to construct certain intercepting sewers to take out the sewage and carry it to certain designated points for treatment. Having done so, those sewers serve for a certain population, and we have taken the tributary populations and added them together in order to supply a project that would come approximately to the population set by the plan. In order to bring it exactly to the plan, we would have to provide a little additional treatment, as I remember, because I think the figure of 4,251,000 is a little lower than the amount called for, which would of course increase the expense of the construction.

I did not endeavor to bring it out exactly by taking the per capita figures and equating them by slide rule, but have left them in this shape to show exactly the projects that would be developed, and what they would accomplish.

If the flow were cut to 4,167 c. f. s., it would be necessary, we believe, by 1945, that the West Side plant, instead of being constructed with settling tanks would be equipped for complete treatment, probably by activated sludge. We would still leave the South West plant as a settling plant. Such a program would provide in the year 1945, for the population equivalent of 5,328,000, which comes within four per cent of the figures set.

The same explanation would apply here as made, namely that in order to come out exactly to the population set by the population computations, sufficient additional treatment would have to be provided on one plant by sprinkling filters or other means, to bring up the total, which can be done, but would increase the amounts of the estimates.

The additional construction cost necessitated by the cut in diversion would exceed $16,800,000 if carried out by 1945. I have my doubts whether this could be done at the rate of progress that is necessitated by the methods of administration in our work and the financing, judging by past experience.

I have therefore estimated that in order to finance the work, cover the legal requirements and the like, somewhat more time would be required than on the previous work, which has been taken to be a period of ten years. In the interval from 1945 to 1955, in which the extent of that cut would be made, working on our assumptions, there would have to be expended not only the sum of $16,800,000 as noted, but a further sum roughly estimated at $16,710,000, making a total of $33,510,000, to cover the growth in population, which would have to be treated, as well as the difference required on account of the lowered diversion.

194 In addition to these figures, the filtration of the water supply of the City of Chicago would be required, so that as of the year 1955, there would be added $106,500,000 to the program requiring financing.

The true cost of the additional population is not shown by our method of computation outlined, because the method of assembling by districts indicates a comparative cost for handling the sewage with a reduced diversion, which is lower than it really is, if you take the per capita costs and multiply by the population. That comes in the method of assembling the projects and calculating the cost of intercepting sewers in this treatment.

I have estimated the cost of the activated sludge plants with intercepting sewers as $25 per capita, with an annual cost of around $2.25 to $2.75 according to the method of handling the sludge. I am therefore conservative in saying the cost in round figures on account of this cut in diversion would add to the sewage treatment program approximately $25,000,000 based on the actual per capita charges for construction, and $2,250,000 for annual costs.

If the diversion was cut to 4,167 cubic feet per second, I believe that there will be ultimately a heavy burden placed upon the cities and industries located on the Illinois River, particularly in the metropolitan area around Peoria and Pekin. While in 1920, the census population was only 88,207 for the two cities, there was in addition a starch works at Pekin grinding about 25,000 bushels of corn a day, equivalent to 158,000 people, besides other Corn Products industries about which little data could be obtained.

This equivalent population, through growth of industry as well as of population, I have estimated might exceed half a million in 1930. With the continued growth up to 1945, during low water, treatment may become necessary, making an additional burden upon the inhabitants of the State of Illinois. In 1920, the urban population on the banks of the
195 Illinois River from Joliet to the mouth totaled 200,472.

Table of expenditures for sewage treatment since 1909 for construction purposes, Pearse Exhibit 2, April 26, 1923, is as follows:

Expenditures for Sewage Treatment since 1909 for Construction Purposes

219

Year	Total
1910	$ 157,816
1	.....
2	55,269
3	19,683
4	490,468
5	280,348
6	700,648
7	1,533,260
8	1,543,227
9	1,803,064
1920	2,835,387
1	5,052,511
2	6,691,982
	$21,163,663

195 Table of expenditures for sites for sewage treatment works up to 1921, Pearse Exhibit 3, April 26, 1923, is as follows:

PEARSE EXHIBIT 3—Apr. 26/23

The Sanitary District of Chicago

Expenditures for Sites for Sewage Treatment Works Up to 1921

219

Treatment plant	Amount paid for site	When acquired
Calumet Pumping Station	$ 12,423.40	May 27, 1915
Calumet Treatment Plant	159,636.00	Feb. 13, 1920
Desplaines Treatment Plant	25,194.00	Oct. 4, 1917
52nd Ave. Treatment Plant	39,505.88	Mar. 31, 1913
Evanston Pumping Station	11,341.60	April 20, 1916
North Side Treatment	269,995.00	April 21, 1921

195 This table was made in the same way, from the records of the District, checking the amounts against the vouchers paid, and the dates against the orders of the Board printed in our proceedings.

Since 1909, up to the end of 1922, there has been expended under my direction by our engineering and laboratory forces the sum of $97,842, for construction and equipment on sewage testing work.

In addition to this sum, we have spent in the maintenance and operation of the works, including the operating of our laboratories and the other expenses chargeable to the investigations, the sum of $563,815. This makes a total expenditure on our books for construction, equipment, maintenance and operation of $661,657.

When I first came with the District in 1909, the art of sewage treatment was less understood on a large scale than now. There was a transition period in the art; the old septic tank was in disfavor, as originally installed at Columbus. Experiments were found to be necessary, and were devised by men of the standing of Mr. Rudolph Hering, and others who studied the problems of the District, and had been connected with it since its inception in 1889.

We found the sewages we had to meet were so varied in strength and behavior that tests were needed to define the 196 most efficient method of treatment. Tests were needed in order to find how much sewage could be treated with a given area of plant; for instance in sprinkling filters, how many hours were required for the settling of the sewage in settling tanks.

We saw very clearly that the problem ahead of the District in 1909, was a gigantic one, involving the largest sewage treatment works in the world, and involving the necessity of producing a high grade effluent for a large part of the sewage of the District.

In addition, we had to confront not only the human problem but the industrial waste problem of enormous extent, and at

that time no solution was known for its treatment. Neither was the amount of the waste known. The period required for preliminary investigation was indefinite, but we knew that we had to study the sewage, not alone as to methods of treatment, but also to improve the methods of analysis.

The method I have explained of determining the oxygen consumption was one of our changes in method which has enabled us to express population equivalents. Short time tests we knew were of little value. Our experience had shown that at least a test running over the four seasons of the year was required, because the operation of a sewage plant is different in the winter from the summer; and usually at the end of the year we had found improvements or changes in the studies that led us to continue.

Aside from the tests, surveys were required of the District. Preliminary plans had to be made; sites had to be secured, and then legal obstacles had to be overcome.

Our lawyers finally determined that the Act had to be amended, which was done in the last session of the Legislature, over two years ago now, whereby we were given the explicit right and command to build sewage treatment works, whereas prior to that time, I was informed that our right to establish complete works was in doubt and open to contest.

The opinions, I think during Mr. Adcock's incumbency as attorney, and prior to that time, were that whatever we did was merely an incident, and there might be a doubt if we had to condemn a site as to whether our powers would be seriously questioned, because we were acting more or less under implied powers, instead of actual, explicit powers.

I regard the population figures as presented as very fair. They are calculated from census figures, which are as close as we can auctually get them. We have had the advantage of the actual enumeration districts of the census. In representing the actual loadings on the Main Channel, we believe they may prove low rather than high, because of the fact we
197 have made no allowance in the figures for the floating population in Chicago, and in particular for the Loop Dis-

trict. In 1920, this was estimated at 250,000 people. Of these 250,000, some are commuters from within the boundary of the district, but many undoubtedly come from the outside, according to our figures.

The hotels and clubs we think may house 100,000 people The increase in floating population we have determined to be approximately 50,000 for every decade, so that we believe by 1945, that there is an effect from the floating population which might be between 375,000 and 475,000, for which we have made no allowance in these estimates.

We have also made no allowance for any factor of safety, to take care of the variations due to the variations in industry, or to extremely hot weather, which you may get in the summer time, that would upset our allowance of the effect of the water taken from the Lake, or for other contingencies.

Neither have we allowed for any extension of the boundaries of the district, which I believe will undoubtedly occur, as shown by our past experience. All these factors would tend to increase the expenditures for sewage treatment.

I think the estimates of costs of construction are conservative. We based them on unit prices slightly lower than have prevailed in the last two years. The office experience in the Sanitary District during the last two years, and in fact since the beginning of the war, has indicated that the contractors that we have to deal with want more for doing the work than we as engineers generally estimate. I think in our experience in the last two years, if I am not mistaken in my recollection, we have in general received figures that are higher than the estimates we have made as engineers, along the lines indicated in my evidence.

I have further assumed that the general conditions of labor, and of the material market, will continue. I have not attempted to estimate the possible changes that may occur in the stretch of twenty-five years.

Table of expenditures for construction of sewage treatment works 1910-1922, as Pearse Exhibt 4, April 26, 1923, page opposite.

Henry M. Christie, witness for the defendant, testified as
198 **follows** (April 26, 1923; Rec. Vol. VIII, pp. 198-201):

Resides at Chicago; employ of Sanitary District since 1892, except during the years 1901-1902 and 1909 to 1910; familiar with the accounts; compiled a table showing present and future resources of the District by way of bond issue, tax income showing annual expectations in income from those sources, consolidated with certain estimates of the Sanitary District Engineers as to construction program; table covers years 1922 to 1945, inclusive. The table known as Christie Exhibit 1, April 26, 1923, page opposite.

Column 1 shows the years; column 2 shows the population increment as based on rates of increase shown by the last
199 decennial period; column 3 shows estimated valuation, assessed valuation as taken from information obtained from the Assessor's Office of Cook County, the increases being based on past experience; column 4 shows the assessed valuation per capita; column 5 shows future tax rate as taken uniformly at 0.40 of 1 per cent, this being assumed as the limit which the Sanitary District is likely to realize under the present conditions; column 6 shows the taxes for any one year, based on the assessed valuation of the preceding year; column 7 shows future bond issues to provide revenue; column 8 shows total gross revenue and is the sum of the figures
201 in columns 6 and 7; column 9 shows the amounts required each year to liquidate the present outstanding bonds; these are for old bonds that have been issued for prior work; column 10 shows the amounts required each year to pay the interest on the present outstanding bonds; column 11 shows the amount required each year to redeem future bond issues. The bonds are figured for redemption at the rate of five per

CHRISTIE EXHIBIT 4, April 26, 1923.

Summary of Statement of Resources and Expenditures of the Sanitary District of Chicago under 1922-1945 Construction Program.

Based Upon Plants Going into Operation as follows, viz:

Desplaines	1923
Calumet	1923
Corn Products	1927
North Side	1928
Stock Yards	1932
West Side	1940
South West Side	1945

Resources:		
Taxes—Net	$211,850,000	
Sale of Bonds—Net	60,949,000	
		$272,799,000
Contra:		
New Construction	$106,300,000	
Ad. Maintenance & Operation	106,400,000	
Interest on Bonds	59,768,880	
Surplus	330,120	
		$272,799,000

Note—Bonds outstanding Jan. 2, 1946 ..... $84,050,000
Maximum bonding capacity Jan. 2, 1946 99,000,000

The Sanitary District of Chicago

Expenditures for Construction of Sewage Treatment Works 1910-1922

	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	Total
W. 39th St. Conduit & Western Ave. Sewer	157,816													157,816
52nd Ave. Sewer & Outlet			55,269	3,807			4,918							63,994
52nd Ave. & W. 39th St. Sewer				15,876	140,771	28,155			16,360					201,162
North Shore Interceptor, Contract 1					197,710	52,113	30,409							280,232
North Shore Interceptor, Contract 2					86,383	14								86,397
North Shore Interceptor, Contract 3					57,106	168,529	35,290							260,925
Morton Grove Settling Plant					8,498	651								9,149
Calumet Intercepting Sewer, Contract 2							94,911	88,272	1,505					184,688
Calumet Intercepting Sewer, Contract 3						30,887	290,327	4,943						326,157
Stockyards Intercepting Sewer							96,587	*10,799	*673					85,115
Niles Center Sewer							1,442	22,695	299					24,436
Evanston Intercepting Sewer							7,571	479,901	467,731	119,570	262,982	14,016		1,351,771
Calumet Intercepting Sewer, Contract 4							57,442	300,868	258,034	28,683	116,272			761,299
Calumet Intercepting Sewer, Contract 5									2,300	48,190	628,811	20,273		699,574
Calumet Intercepting Sewer, Contract 6							95,764	198,737	226,833	65,141	231,302			817,777
Calumet Intercepting Sewer, Contract 7							25,987	448,649	446,681		126,058			1,047,375
Des Plaines River Intercepting Sewer									13,179	480,172	85,808		4,071	583,230
Calumet Pumping Station									110,978	636,847	560,790	55,021	369	1,364,005
Evanston Pumping Station										242,392	85,415	112,114		439,921
Des Plaines Treatment Plant (All Divisions)										155,654	212,377	272,745	352,609	993,385
Morton Grove Sprinkling Filter										26,415	12,465			38,880
W. 39th St. Extension (Division A)											173,915	277,155		451,070
Calumet Power Plant											249,737	729,922	145,864	1,125,523
Calumet Treatment Works (Division A)											7,197	1,547		8,744
Calumet Treatment Works (Division B)											59,158	550,594	5,000	614,752
Calumet Treatment Works (Div. C. D. E. F. G & H)											23,100	2,510,095	2,945,332	5,478,527
Calumet Intercepting Sewer, Contract 8												163,237	5,885	169,122
Calumet Intercepting Sewer, Contract 9												94,207	72,646	166,853
Calumet Intercepting Sewer, Contract 10													145,548	145,548
Calumet Intercepting Sewer, Contract 11													521,883	521,883
Oak Park Outfall												251,585	535,484	787,069
W. 39th St. Extension (Division B)													97,696	97,696
North Side Intercepting Sewer, Contract 1													1,902,700	1,902,700
Total	157,816		55,269	19,683	490,468	280,349	740,648	1,533,266	1,543,227	1,803,064	2,835,387	5,052,511	6,735,087	21,246,775

*Credit from Union Stockyards and Transit Co.

April 19, 1923.

Christie Exhibit 1—April 26, 1923.
Composite statement, estimated resources and liabilities under 1940 construction program of Sanitary District.

Year	Population	Assessed valuation		Receipts				Expenditures							
								Outstanding bonds.		Future bond issues					
		Total	Per capita	Tax rate per $100 valuation	Tax receipts levy less 10% a/c costs and delinquencies	Bond issues	Total	Redemption	Interest	Redemption	Interest	Administration & maintenance & operation	Total	Net revenue available for new-construction	C
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	
1921	3,071,000	$1,824,157,564	$594	$0.36		*$3,750,000									
1922	3,142,	1,870,	595	.40	$5,900,000	2,000,000	$11,650,000	$1,551,000	$ 944,440			$2,100,000	$4,595,440	$7,054,560	$6
1923	3,213,	1,915,	596	.40	6,650,000	6,000,	12,650,	2,146,	1,129,340	$1,000,000	$90,000	2,400,	5,865,340	6,784,660	7
1924	3,284,	1,965,	598	.40	6,900,000	6,000,	12,900,	1,980,	1,035,960	400,	355,500	2,500,	6,271,460	6,628,540	7
1925	3,355,	2,015,	600	.40	7,100,	7,000,	14,100,	1,880,	949,060	700,	607,500	2,600,	6,736,560	7,363,440	7
1926	3,426,	2,065,	603	.40	7,250,	7,000,	14,250,	1,824,	866,160	1,050,	891,000	2,700,	7,331,160	6,918,840	7
1927	3,497,	2,115,	605	.40	7,450,	8,000,	15,450,	2,124,	785,500	1,400,	1,158,750	2,800,	8,268,250	7,181,750	6
1928	3,568,	2,170,	608	.40	7,600,	7,000,	14,600,	2,076,	685,340	1,800,	1,455,750	2,900,	8,917,090	5,682,910	6
1929	3,639,	2,225,	611	.40	7,800,	9,000,	16,800,	2,076,	587,100	2,150,	1,689,750	3,900,	10,402,850	6,397,150	6
1930	3,710,	2,280,	615	.40	8,000,	9,000,	17,000,	1,951,	488,860	2,600,	1,998,000	4,500,	11,537,860	5,462,140	5
1931	3,782,	2,345,	620	.40	8,200,	8,000,	16,200,	1,373,	395,620	3,050,	2,286,000	4,500,	11,604,620	4,595,380	5
1932	3,854,	2,400,	623	.40	8,450,	8,000,	16,450,	1,270,	330,500	3,450,	2,506,750	4,500,	12,057,250	4,392,750	4
1933	3,926,	2,460,	627	.40	8,650,	8,000,	16,650,	770,	269,500	3,850,	2,713,500	4,500,	12,103,000	4,547,000	4
1934	3,998,	2,520,	630	.40	8,850,	8,000,	16,850,	770,	233,500	4,250,	2,900,250	4,500,	12,653,750	4,196,250	4
1935	4,070,	2,580,	634	.40	9,050,	8,000,	17,050,	770,	197,500	4,650,	3,069,000	4,500,	13,186,500	3,863,500	4
1936	4,142,	2,645,	639	.40	9,300,	9,000,	18,300,	670,	161,500	5,050,	3,219,750	4,500,	13,601,250	4,698,750	4
1937	4,214,	2,710,	643	.40	9,500,	9,000,	18,500,	670,	129,500	5,500,	3,397,500	4,500,	14,197,000	4,303,000	4
1938	4,282,	2,780,	650	.40	9,750,	9,000,	18,750,	520	97,500	5,950,	3,355,000	4,500,	14,622,500	4,127,500	4
1939	4,354,	2,850,	654	.40	10,000,	9,000,	19,000,	520,	71,500	6,400,	3,692,250	4,500,	15,183,750	3,816,250	4
1940	4,425,000	2,120,000,000	660	.40	10,250,000	11,000,000	21,250,000	520,000	45,500	6,850,000	3,809,250	6,000,000	17,224,750	4,025,250	4
1941															
Totals					$156,650,000	$151,750,000	$308,400,000	$25,461,000	$9,403,880	$59,200,000	$39,395,500	$72,900,000	$206,360,380	$102,039,620	$101

*$3,750,000 cash available February, 1922

Compiled by H. M. Christie and H. P. Ramey.

Christie Exhibit 1—April 26, 1923.
Composite statement, estimated resources and liabilities under 1940 construction program of Sanitary District.

Valuation		Receipts			Expenditures										
					Outstanding bonds,		Future bond issues								
Per capita	Tax rate per $100 valuation	Tax receipts levy less 10% a/c costs and delinquencies	Bond issues	Total	Redemption	Interest	Redemption	Interest	Administration & maintenance & operation	Total	Net revenue available for new-construction	Construction program	Year	Bonds outstanding Jan. 1	Bonding capacity maximum
(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
$594	$0.36	.....	*$3,750,000	.....	.....	.....	.....	.....	.....	.....	.....	.....	1921	.....	$54,723,000
595	.40	$5,900,000	2,000,000	$11,650,000	$1,551,000	$ 944,440	.....	.....	$2,100,000	$4,595,440	$7,054,560	$6,400,000	1922	$25,851,000	56,100,
596	.40	6,650,000	6,000,	12,650,	2,146,	1,129,340	$1,000,000	$90,000	2,400,	5,865,340	6,784,660	7,000,	1923	26,300,	57,450,
598	.40	6,900,000	6,000,	12,900,	1,980,	1,035,960	400,	355,500	2,500,	6,271,460	6,628,540	7,000,	1924	30,054,	58,950,
600	.40	7,100,	7,000,	14,100,	1,880,	949,060	700,	607,500	2,600,	6,736,560	7,363,440	7,000,	1925	33,674,	60,450,
603	.40	7,250,	7,000,	14,250,	1,824,	866,160	1,050,	891,000	2,700,	7,331,160	6,918,840	7,000,	1926	38,094,	61,950,
605	.40	7,450,	8,000,	15,450,	2,124,	785,500	1,400,	1,158,750	2,800,	8,268,250	7,181,750	6,600,	1927	42,220,	63,450,
608	.40	7,600,	7,000,	14,600,	2,076,	685,340	1,800,	1,455,750	2,900,	8,917,090	5,682,910	6,100,	1928	46,696,	65,100,
611	.40	7,800,	9,000,	16,800,	2,076,	587,100	2,150,	1,689,750	3,900,	10,402,850	6,397,150	6,000,	1929	49,820,	66,750,
615	.40	8,000,	9,000,	17,000,	1,951,	488,860	2,600,	1,998,000	4,500,	11,537,860	5,462,140	5,500,	1930	54,594,	68,400,
620	.40	8,200,	8,000,	16,200,	1,373,	395,620	3,050,	2,286,000	4,500,	11,604,620	4,595,380	5,200,	1931	59,043,	70,350,
623	.40	8,450,	8,000,	16,450,	1,270,	330,500	3,450,	2,506,750	4,500,	12,057,250	4,392,750	4,200,	1932	62,620,	72,000,
627	.40	8,650,	8,000,	16,650,	770,	269,500	3,850,	2,713,500	4,500,	12,103,000	4,547,000	4,200,	1933	65,900,	73,800,
630	.40	8,850,	8,000,	16,850,	770,	233,500	4,250,	2,900,250	4,500,	12,653,750	4,196,250	4,200,	1934	69,280,	75,600,
634	.40	9,050,	8,000,	17,050,	770,	197,500	4,650,	3,069,000	4,500,	13,186,500	3,863,500	4,200,	1935	72,260,	77,400,
639	.40	9,300,	9,000,	18,300,	670,	161,500	5,050,	3,219,750	4,500,	13,601,250	4,698,750	4,200,	1936	74,840,	79,350,
643	.40	9,500,	9,000,	18,500,	670,	129,500	5,500,	3,397,500	4,500,	14,197,000	4,303,000	4,200,	1937	78,120,	81,300,
650	.40	9,750,	9,000,	18,750,	520	97,500	5,950,	3,355,000	4,500,	14,622,500	4,127,500	4,200,	1938	80,950,	83,400,
654	.40	10,000,	9,000,	19,000,	520,	71,500	6,400,	3,692,250	4,500,	15,183,750	3,816,250	4,200,	1939	83,480,	85,500,
660	.40	10,250,000	11,000,000	21,250,000	520,000	45,500	6,850,000	3,809,250	6,000,000	17,224,750	4,025,250	4,200,000	1940	85,560,000	87,600,000
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	89,190,000	89,700,000
.....	.....	$156,650,000	$151,750,000	$308,400,000	$25,461,000	$9,403,880	$59,200,000	$39,395,500	$72,900,000	$206,360,380	$102,039,620	$101,600,000	.....	.....	.....

cent per annum; column 12 shows the interest on outstanding bonds; column 13 shows the estimated cost of administration and running expenses of maintenance and operation of the works of the Sanitary District, based on the experience of recent years; column 14 is the total; column 15 is the net revenue. Christie Exhibit 4, opposite.

Tests made by the Sanitary District to determine length of time required to change flow in channel from 4,167 seconds feet to 10,000 seconds feet.

George M. Wisner, witness for defendant, his qualifications being heretofore shown (This Narrative, p. 177; April 15, 1914, Rec. Vol. VI, pp. 3404-3405), testifying in sur-rebuttal said:

Since testifying previously, I have had two different tests made, one on February 22 and the other on March 8, 1914, to determine how much the discharge in the main channel and the Chicago River would change when the discharge at the Controlling Works was increased from approximately 4,000 cubic feet per second to 10,000 cubic feet per second.

3405 For the 12 hours preceding the time at which the flow was changed from approximately 4,000 cubic feet to 10,000 cubic feet per second, we tried to adjust the flow of the canal so as to have as near as possible a uniform flow of 4,000 cubic feet through the channel.

3406 On February 22, and 23, from six P. M. until about 5:30 A. M., we flowed as near as it was possible 10,000 cubic feet through the Controlling Works and measured the water, as I stated, at the other places by means of current meters. The gaged were also read.

The flow was increased at about 5:53 to about 6:10; took that long to increase the flow, manipulate the works; that is P. M. on February 22. Generally, I would say throughout

that time the flow according to the power house measurements probably averaged 200 cubic feet over 10,000.

The computations were worked up of the discharge at Lemont and at Summit and Dearborn Street.

The section at Summit was about four or five miles above Willow Springs. The discharge measurement at Lemont was taken by means of a Haskell Current Meter; at Summit we used the Price Meter; and at Dearborn Street a Haskell Meter. We only had those three meters available at that time.

I would have run this test longer but it was absolutely impossible to do it without absolutely breaking a lot of contracts that we had for the furnishing of power, and I could not run it at that time any longer than the 12 hours approximately, as testified to.

The largest flow that we were able to get at Lemont was 9300 cubic feet per second, within the whole time between six o'clock P. M. of February 22, and 5:30 of the next morning.

There is a peculiar thing that seems to happen when this flow is turned on: There will be an indication of a large flow at Lemont about an hour and a half to an hour and 50 minutes after the flow was increased at Lockport.

It is eight miles from the old Controlling Works in round figures, and ten miles from the power house. That flow
3407 only keeps up for a very short time, and it drops off as though there were possibly an influence, an impulse set up in the water; and the water only being measured at one particular point, I am of the opinion you get a false indication of the discharge at that time, because the flow then did not go up again until about 3:30 the next morning.

That was an hour and a half afterwards. Then it dropped off to about 8200 cubic feet per second.

It reached that at ten o'clock at night, when it raised gradually to 9300 and some odd cubic feet per second at 3:30 the following morning. That is we had 9300 flow twice, about 7:30. About an hour and a half after we started to turn it

on at about 5:50. Then it went down to about 8,000 cubic feet per second between 9:30 and 10 o'clock that night. Then gradually rose to 9300 feet at about 3:30 the following morning.

At Summit, the first indication of the increase in the discharge came at seven o'clock, and it gradually rose so that at eight o'clock there was a flow of 7,000 cubic feet. There was a gradual rise of the discharge at Summit then until
3408 about one thirty, when the flow reached 8200 cubic feet. From then until the end of the test, at about six o'clock the next morning, the flow ran practically 8,000 cubic feet. It is about four or five miles above Willow Springs; that is about 12 or 13 miles above Lemont. 22 miles from the power house.

The measurements at Dearborn Street were carried on, as I stated, by a Haskell Meter and the flow had an increase, starting in about 8:30 that night, began to slowly increase and raised gradually to about 2:30 in the morning when there was a flow of about 5800 cubic feet per second.

It then gradually decreased to five o'clock in the morning when there was an indicated flow of 5500 cubic feet per second; and from five o'clock in the morning until six in the morning it increased, so that at that time there was approximately 6200 cubic feet per second passing Dearborn Street.

I would say in this connection that Dearborn Street being so close to the lake, it is influenced by the rise and fall of the lake.

The height of Lake Michigan generally varied during February 22d and 23d, at the time of the tests, from plus .5 up to plus .9, in round numbers; but the elevation of the lake
3409 varied two or three-tenths within half an hour, at times.

We made another measurement on March 8, as stated before. I did this to have a check upon the first one; and tried to make it under a little better conditions; used more current meters, more discharge sections. It was a more complete

test, and ran over a longer period. The weather conditions were better.

Prior to increasing the flow, we tried to get as near uniform flow at about 4,000 cubic feet per second as was possible. We started in on that day early in the morning of March 8 flowing 4,000 cubic feet per second.

That was changed so that we seemed to have a fairly even flow there for some distance above the Controlling
3410 Works; and the flow was increased at 12 o'clock noon to 10,000 cubic feet per second. We maintained the flow at 4,000 cubic feet per second from about three or four in the morning until twelve noon of March 8. Of course it took some time to get the rest of the channel flowing that amount. For instance, around the different gaging stations the flow seemed to vary between four and five thousand cubic feet per second, at the different sections, at twelve noon, when we changed the flow.

The flow was put on at about 11:50 in the morning and at 12:00 noon, or shortly after that, there was 10,000 going through the Controlling Works and power house at Lockport; and the flow as indicated there got up as high as 10,500; but it ran at 10,000 or above until one A. M. of the following day.

There were discharge sections at Dearborn Street, Loomis Street, Robey Street, Willow Spring, Lemont and at Lockport; the Lockport discharge section being about a half a mile this side, or towards Chicago, from the old Controlling Works in the Rock Section.

From Lockport up—first was the Controlling Works and then the Lockport discharge section; Lemont, Willow Springs, Robey Street, which is the junction of the Chicago River and the Canal; Loomis Street, Dearborn Street.

3411 From the Power House to Lockport, 2.46 miles; to Lemont from the the same place (I will give the distances every time from the Power House) 9.51 miles; Willow Springs, 16.93 miles; Summit 22.30 miles; Robey street, 29.90

miles; Loomis street, 31.0 miles; Dearborn Street, 35.2 miles: Lake Michigan, 36.3.

The flow at the Controlling Works averaged 10,000 cubic feet per second from 12:00 o'clock noon until 2:45 the next morning, a time interval of 14 hours and 45 minutes.

The flow at the Lockport discharge section was approximately 4,000 cubic feet per second when we started, and the indicated flow was 8,000 at about half past twelve, or half an hour later. At 1:50 to 2:00 o'clock, the flow at this station reached a little over 8900 cubic feet per second, and it ran approximately at that flow until 5:30 P. M. of March 8. It then increased to 10,000, which it reached at 7:00 P. M. of March 8.

The flow at this discharge section then varied from 10,000 to 10,400, and down to 9500 at 3:30 A. M. of March 9. That is the Lockport discharge.

They were run continuously from about 10:00 A. M. of March 8, until 9:30 to 10:00 A. M. the next day, with the exception of the Dearborn Street Section, which was dis-
3412 continued at 12:00 o'clock midnight on account of an accident to the meter; and also at Lemont. At those two places we had no record from 12:00 o'clock midnight, or 12 hours after the test started.

The next station is Lemont; and the flow at Lemont at about 12:00 o'clock varied between 4500 cubic feet per second and 5,000.

That is 12:00 o'clock noon of March 8. It gradually rose, so that at one o'clock, or one hour after the flow was increased, there was a flow of approximately 8500 cubic feet per second.

It increased uniformly from one o'clock to approximately two o'clock. In connection with the Lemont station, it did not start to increase until 12:20. At 2:00 o'clock it reached 9100 cubic feet, when it seemed to vary from a little above 9,000 to a little below 9,000, from 2:00 P. M. until 6:00 P. M. when there was a fairly uniform increase to 8:00 P. M., when the flow was 9600 cubic feet. It ran fairly uniform at this

same discharge until about 9:30, and from 9:30 it increased uniformly to 10:00, when there was an indicated discharge at Lemont of 10,000 cubic feet per second. And it continued at approximately that discharge until 12:00 o'clock, when the meter, as I said, was damaged; got out of order.

It was ten hours after the water was increased from 4,000 to 10,000, before we got a discharge of 10,000 cubic feet at Lemont.

At Willow Springs, the flow started to increase at about 12:45 P. M. From that time, it uniformly increased until 1:10 or 1:15 when the flow was 7,000 cubic feet per second. From this time until 4:00 P. M. the flow uniformly increased so that the discharge at Willow Springs was 7800 cubic feet per second. It ran practically at the same discharge until 6:10 P. M. when there was a discharge, of 8,000 cubic feet per second. From 6:10 it increased uniformly until 9:30 P. M. when the discharge was 9,000 cubic feet per second. From 9:30, the increase was uniform to 3:50, when the highest discharge was reached, amounting to 9300 cubic feet per second. That is 3:50 the morning of March 9. From then on the water dropped slightly until 6:10 or 6:20, when there was a flow of 9,000 cubic feet per second. After that the discharge commenced to decrease as the water had been lessened at Lockport.

3413

The next station where a discharge measurement was made was Robey street. The flow started to increase at 1:35 or 1:40, and at that time the indicated flow at Robey street was about 4,600 cubic feet per second. That was at 1:35 when it started to increase, and it increased uniformly to 2:20 when the flow was 5,900. From that time to 4:40 P. M., the flow as indicated was practically constant. There was a uniform increase from 4:40 to 5:40, the flow increasing to 6,500. From this time, that is, from 5:40 P. M. to 12:00 o'clock midnight, the flow increased fairly uniformly and the discharge was 7,800 cubic feet. It ran fairly constant from this time to 4:00 A. M., the discharge varying between 7,800

and 7,900 cubic feet. Beginning at 4:00 A. M. the flow gradually increased so that at 6:40 to 6:50 it ran a maximum of 8,400 cubic feet per second. From that point the discharge decreased. The change had been made at Lockport before that.

The next gaging was at Loomis street. At the beginning of the test, the flow at Loomis street as indicated by the meter was about 3,800 cubic feet. The first indication of an increase of flow, that was at all marked, was at 2:00 P. M. From 2:00 P. M. until 3:20, there was a uniform increase and the flow was 5,100. From this time to 12:30 A .M. of March 9, the flow increased fairly uniformly and there was a discharge of 7,000 cubic feet per second.

From 1:20 until 4:00 o'clock in the morning, the meter was out of service and was being repaired, and the record on that section was incomplete during that stretch; but at 4:20 the flow was 7,000 cubic feet per second and increased gradually to a maximum of 7,200 cubic feet per second at 8:30 A. M., when the flow started to decrease.

In regard to Dearborn street, I wish it understood that this section and the discharge is affected by the lake which is only a mile away from it. The discharge at the beginning of the test, as indicated by the discharge measurement at this place was about 4,200 cubic feet per second. The

3414 first marked indication of a change in the discharge started at 4:00 o'clock P. M. of March 8, when it uniformly increased, or practically uniformly increased, to the end of the test at 12:00 o'clock midnight, when the discharge amounted to 7,300 cubic feet per second.

As stated before, the meter became damaged at that time, or out of order, and no further measurements were made at that section. The flow at 4:00 P. M. at Dearborn street was 4,350 cubic feet per second.

3415 I doubt if you could get more than 9/10ths of the total change in less than from twenty-two to twenty-four hours at Robey street when the channel flow at Lockport has been increased from 4,100 to 10,000.

We made a study as to how long it would take storm water coming from the Chicago River basin to concentrate in the Chicago River in cases of storm, by the gaging of several of the large sewerage districts, in which the sewage has been measured, and we have made a study of the time after the rain starts until the maximum discharge was reached. This study has been very careful and has been carried on in the 39th Street District, and Robey Street District and the Diversey avenue sewerage district. These are three separate and distinct areas about Chicago; one of them being on the South side, another on the West side and another on the North side.

3417 These measurements were authorized by the Board of Trustees upon my recommendation, and have been carried on under my direction, and the results have been worked up under my direction. That is the Chief Engineer was directed by a resolution or ordinance of the Board of Trustees to make these measurements to install weirs and measure certain discharges from certain well defined sewerage districts.

3418 From these studies as near as we can determine, the time of concentration of the storm run-off on the large sewerage areas upon the urban drainage area of the City of Chicago will be from three to three and one-half hours. The suburban district along the North Branch North of Lawrence avenue would take in the neighborhood of twenty-four hours to reach the maximum. The discharge of 10,000 cubic feet per second will occur, in heavy storm, in the neighborhood of three to four hours. I mean there would be that amount of water coming into the Chicago River South of Lawrence avenue.

It would not be possible to so manipulate the Controlling Works at Lockport as to change the flow from 4167 to 10,000 cubic feet per second so as to prevent any of the storm water or sewage of the City of Chicago going into Lake Michigan.

3419 The engineer or executive in charge of this work of changing the flow from 4,167 cubic feet per second to

10,000 cubic feet would have to anticipate every storm by at least from twenty to twenty-one hours in order to prevent the Chicago River from discharging partly into the lake. This means that every time there was the slightest indication that there might be a rainstorm, the flow would have to be increased so that if a heavy storm did occur, the Chicago River would not be reversed and discharged into Lake Michigan.

Another point is that it would be impossible to maintain a channel from Lake Michigan to Lockport that would ordinarily flow 4,167 cubic feet per second and still be capable of flowing 10,000 cubic feet per second when needed.

For the reason that with such slow velocity as would obtain with a flow of only 4,167 cubic feet per second the channel would fill with sediment coming either from the solids of sewage and street washings or from the sediment in the lake water itself. The result would be that during the slow flow the channel would be gradually filling up with sediment so that at the time you needed a larger flow there would not be a sufficient cross sectional area to permit the flow of
3421 10,000 cubic feet per second through the canal.

COST OF NAVIGATION FEATURES OF THE MAIN CHANNEL OF APPELLANT.

John R. Freeman, testified as follows (Rec. Vol. III, 1176):

It is certain beyond all doubt or serious question that a channel over substantially the same route could have been built of sufficient capacity to carry 10,000 second feet or 14,000 second feet, which is the utmost that it is proposed to ever divert through this canal, for only a fraction of the cost that was necessitated in building a channel of the present dimensions, in order to fit it for navigation. Had the channel been built solely for sanitary purposes, that is, solely so as to give it a capacity to convey from 5,000 to 10,000 or 14,000
1177 second feet of water at the lowest levels to Lake Michi-

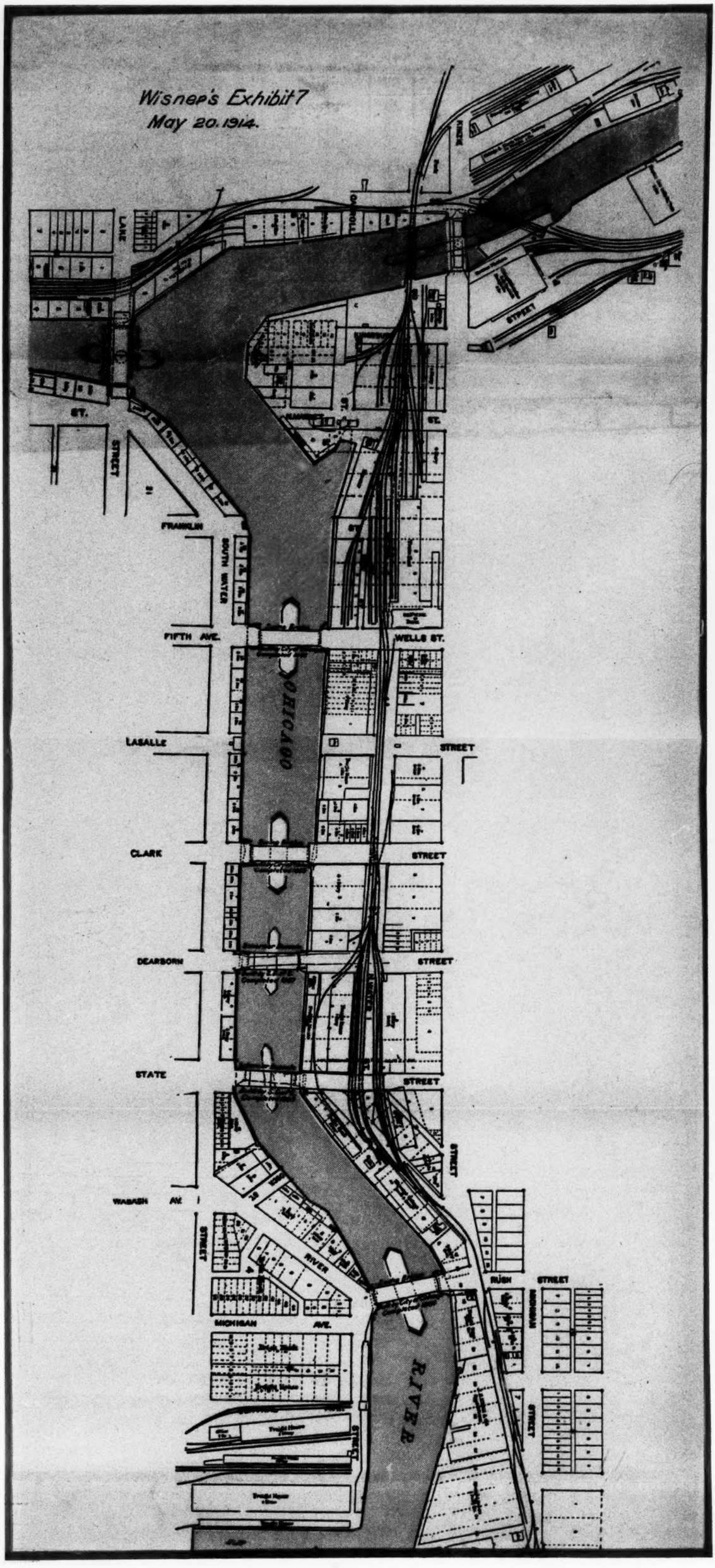
gan, a cut probably less than ¼ part of the width of the present cut would have served every purpose, for carrying 5,000 second feet considering that the slope of this channel from the Chicago River to Lockport could have been made at the steep rate of more than 1 foot per mile, and thus give a high velocity to the current.

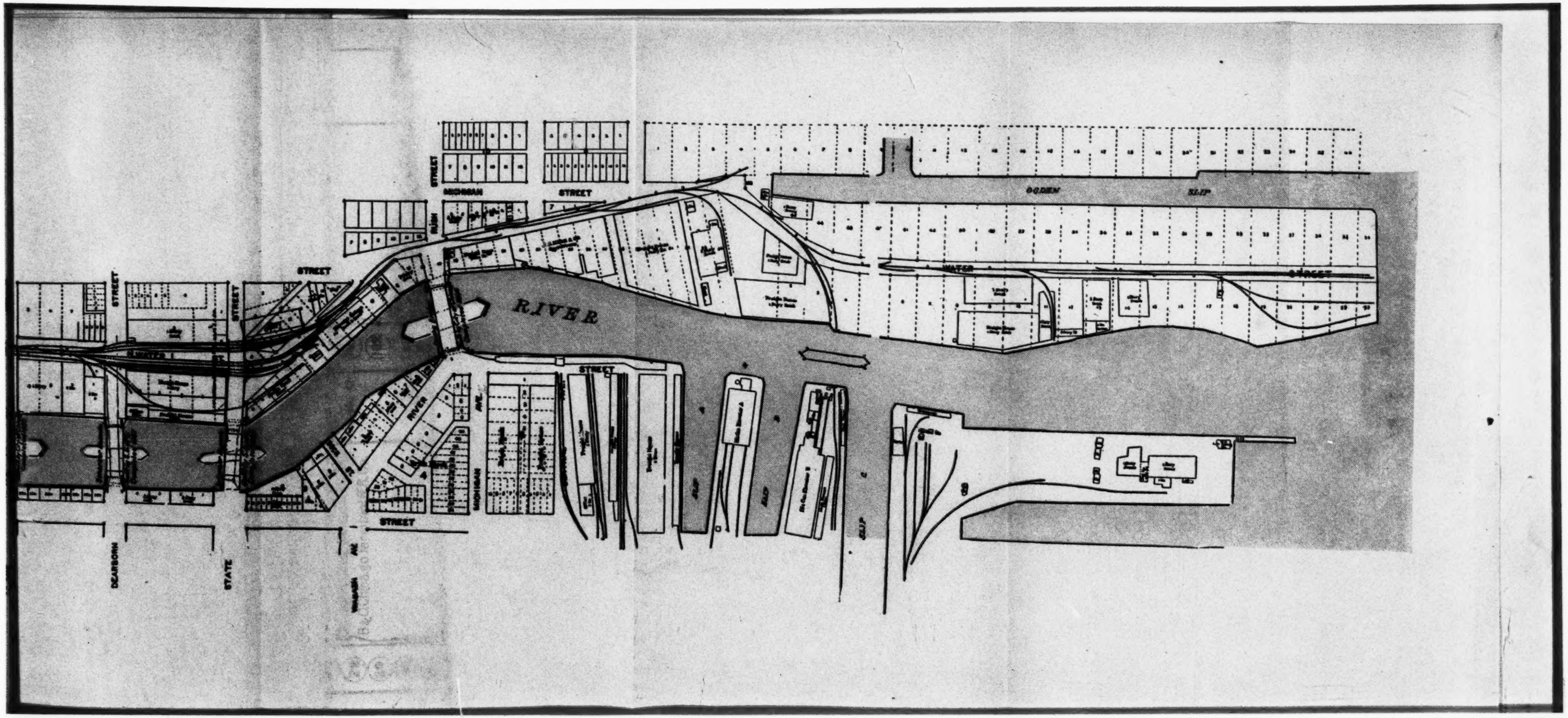
It is certain that a much narrower channel than the present would have easily carried from 10,000 to 14,000 cubic feet of water per second, and that the amount of excavation would have been correspondingly reduced.

Although I have not had time to design such a channel, and compute its cost, it is my belief from general experience in the construction of large aqueducts and canals, that careful estimates would show that more than fifteen million dollars of the expenditure actually made upon the Chicago Sanitary and Ship Canal was distinctly for the benefit of navigation at some future time. And it is my belief that at some future time, whenever the contemplated works are completed through to the Mississippi River, this extra width and capacity obtained as a result of this expenditure will far outweigh any possible injury to navigation arising upon the Great Lakes or through connecting channels, from the lowering of their levels to the extent which has been estimated.

Appellee offered in evidence a memorandum from Major Ferguson to the Secretary of War, dated November 4, 1913, concerning the intervention of the United States in a certain suit pending in the Illinois courts. This memorandum reviewed the history of The Illinois & Michigan Canal and among other things states, Rec. Vol. IV 3888, 3891, as follows:

The object, authority, and responsibility of the United States is to secure a suitable waterway from Lake Michigan to the Mississippi River. By direct appropriations such a waterway has been or is being provided for portions of the route. For the section of the route from the Illinois River


Wisner's Exhibit 7
May 20. 1914.
LAKE
STREET
FRANKLIN
SOUTH WATER
FIFTH AVE.
WELLS ST.
LASALLE
CLARK
DEARBORN
STATE
WABASH AV.
MICHIGAN AVE.
RIVER
RUSH
OHIO


RIVER
STREET
MICHIGAN
STREET
RUSH
STREET
STREET
STREET
STREET
STREET
WATER
STREET
RIVER
AVE.
MICHIGAN
STREET
DEARBORN
STATE
WABASH AVE
OGDEN
SLIP
WATER
STREET
SLIP
SLIP
SLIP

SANITARY DISTRICT OF CHICAGO

MAP

Showing

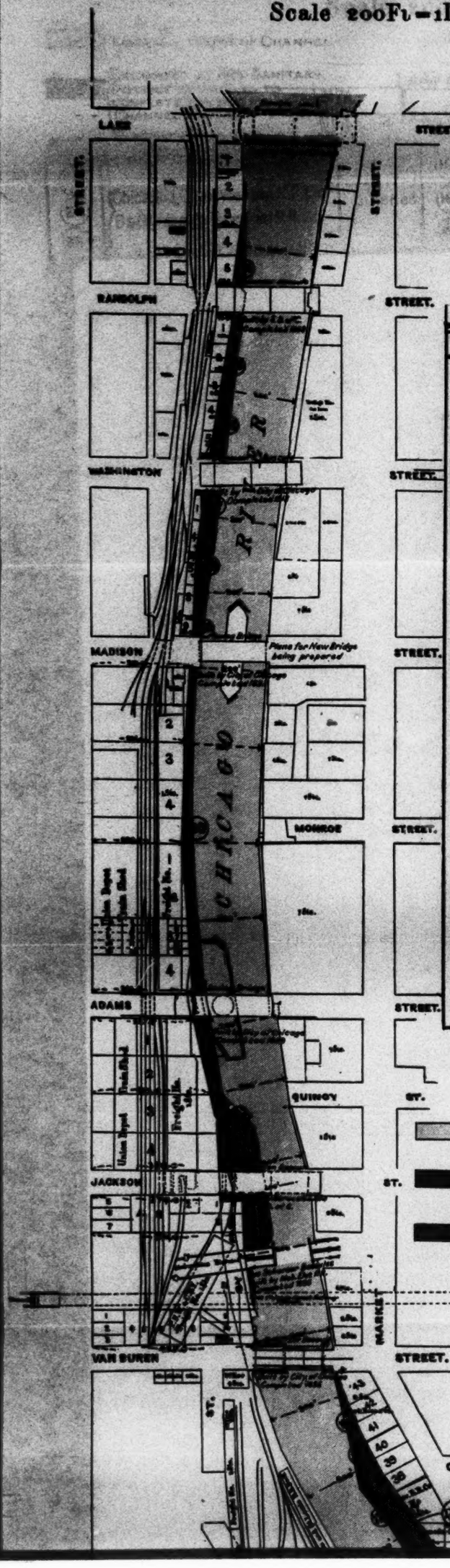
CHICAGO RIVER IMPROVEMENT

From

LAKE STREET TO 12TH STREET

Scale 200 Ft = 1 Inch

Wisner's Exhibit 8
May 20. 1914



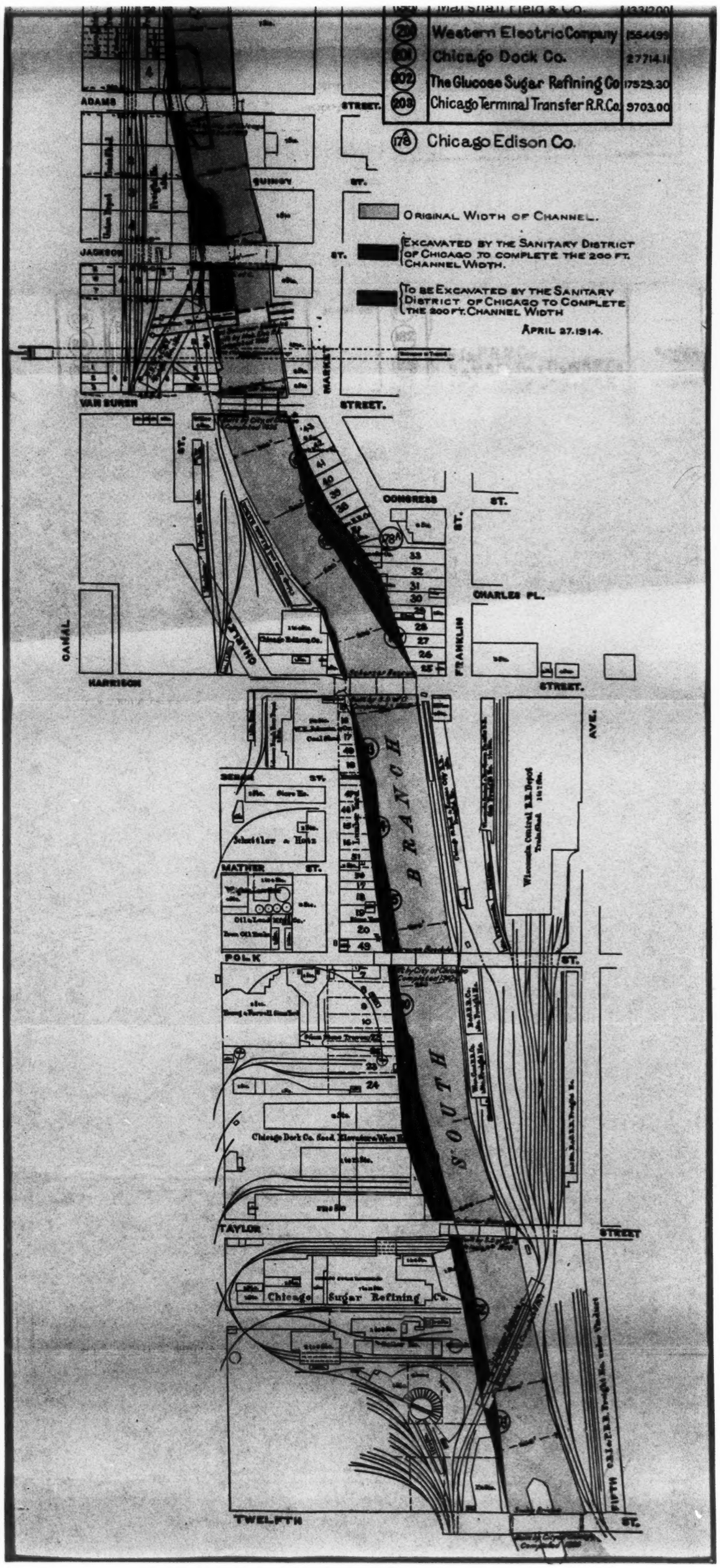
TRACT №	NAME OF OWNER	AREA SQ FT.
177	James B. Clow & Sons	4685.42
178	Charles C. Chappiret. al	1557864
179		
180	Richard L. De Zeng	3555.80
181	Clara R. Bacon & Husband	3288. 6
182	Cornelia R. Green & Husband	2593. 0
183	William C. Seipp & Wife	5075 .0
184	Joy Morton & Wife	3286.94
185	Star & Crescent Milling Co.	15825.24
186	Hugh T. Dickney Est. & Creamery Packing Mfg. Co	10213.78
187	Louisa Healy & John Cook	5456.56
188	Adelle L. Shreve Ballard Thomas T. Shreve	14046.18
189	Norton Milling Company	5123.78
190	Pittsburgh Fort Wayne	
191	and Chicago Railway	58443.13
192	City of Chicago Company et. al.	10053.00
193	Lehigh Valley Coal Co.	5103.23
194	Chicago & Alton R.R. Co.	10905.79
195	Marshall Field & Co.	13312.00
200	Western Electric Company	1554.99
201	Chicago Dock Co.	27714.11
202	The Glucose Sugar Refining Co	17529.30
203	Chicago Terminal Transfer R.R. Co.	9703.00
178A	Chicago Edison Co.	

ORIGINAL WIDTH OF CHANNEL.

EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

TO BE EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH

APRIL 27. 1914.


Marshall Field & Co. 1332200
200 Western Electric Company 1554499
201 Chicago Dock Co. 27714.11
202 The Glucose Sugar Refining Co 17529.30
203 Chicago Terminal Transfer R.R.Co. 9703.00
178 Chicago Edison Co.
ORIGINAL WIDTH OF CHANNEL.
EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.
TO BE EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH
APRIL 27. 1914.
ADAMS STREET.
QUINCY ST.
JACKSON ST.
VAN BUREN STREET.
MARKET
CONGRESS ST.
CHARLES PL.
CANAL
HARRISON STREET.
FRANKLIN
SOUTH BRANCH
MATHER ST.
POLK ST.
TAYLOR STREET
Chicago Sugar Refining Co.
TWELFTH ST.
AVE.

SANITARY DISTRICT OF CHICAGO

MAP

Showing

CHICAGO RIVER IMPROVEMENT

From

12TH STREET TO 18TH STREET

Scale 200 Ft = 1 Inch *Wisners Exhibit 9*

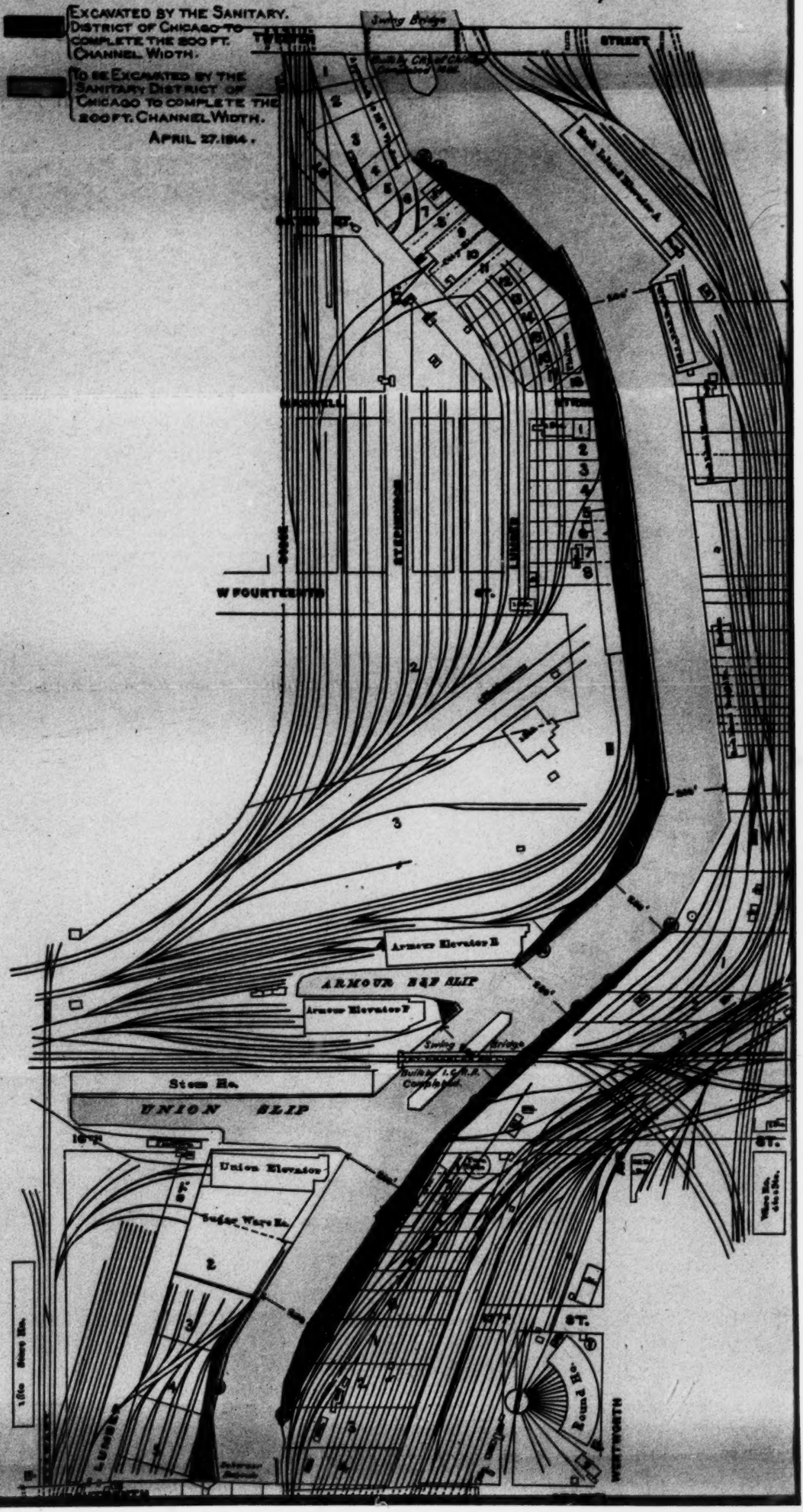
May 20 1914

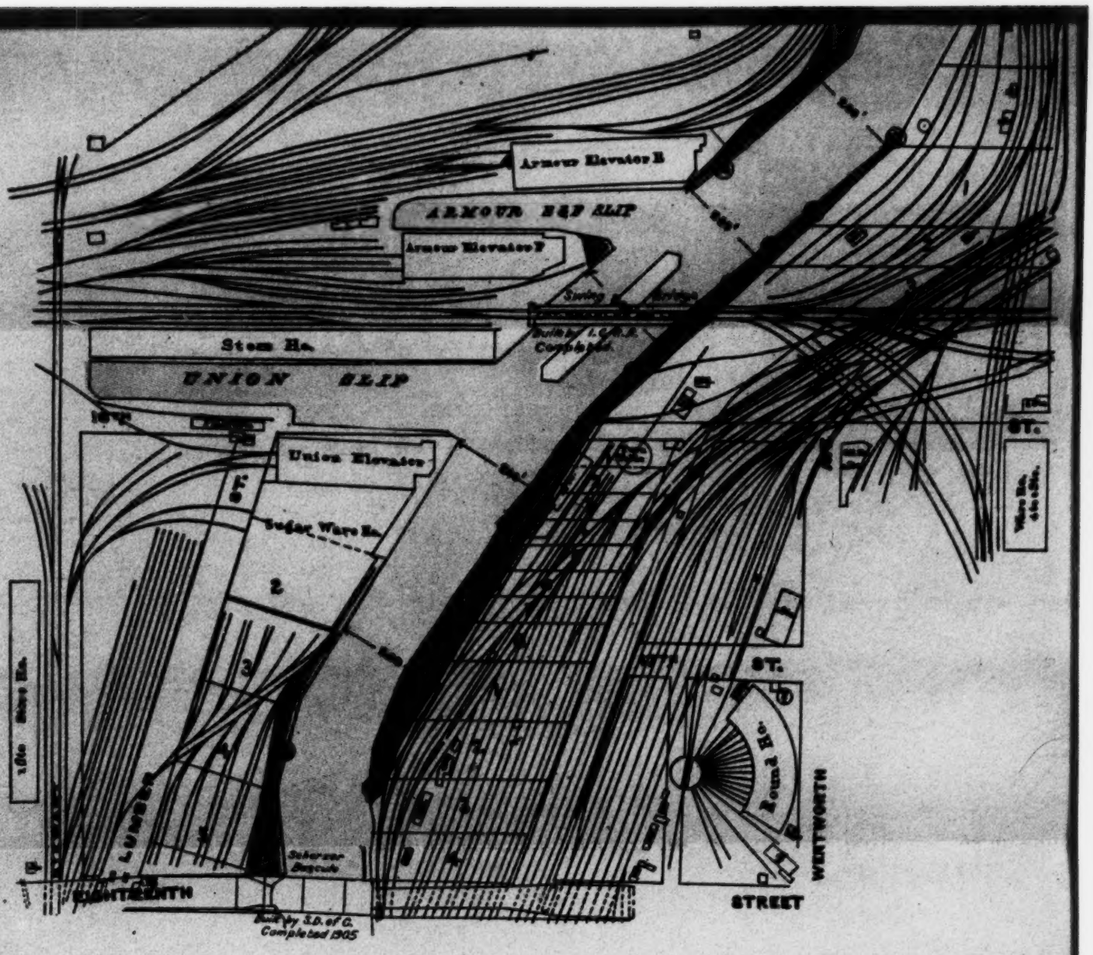
ORIGINAL WIDTH OF CHANNEL.

EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

TO BE EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

APRIL 27. 1914.





TRACT No.	NAME OF OWNER	AREA SQ. FT.	TRACT No.	NAME OF OWNER	AREA SQ. FT.
15	Chicago Terminal Transfer R.R. Co.	6,305.95	35	See Tracts 33 & 34 for Owners and Area	
16			36		
17			37A		
18			37	Chicago & North Western Ry. Co	37,772.2
18A	George M. Eckles Edith O. Eckles (City Elevator Property)	11,583.66	38		1,727.20
19			152		
20			153		
21			154		
21A			155		
22	Chicago Terminal Transfer R.R. Co	1292.63	156		
23			157	Chicago & Western Indiana R.R. Co. et. al	42,805.80
24			158		
25 S.R.			159		
26			160		
27	Chicago & Great Westen R.R. Co. B & O. Chicago Terminal R.R. Co.	31,491.65	161		
28			162		
29			163	C.R.I. & P.R.R. Co. L.S. & M.S.Ry. Co. & C. & W.R.R. Co	6,410.02 16,03
30			163A	M.C.R.R - I.C.R.R. - C.B. & Q.R.R.	1,768.80
31			164	C.R.I. & P.R.R. Co. L.S. & M.S.Ry. Co. C. & W.R.R. Co.	8,960.37
32			165		
33	George M. Eckles Edith O. Eckles (Iowa Elevator Property)	24,604.56	166		
34			167	L.S. & M.S.R.R. Co.	60 78
			82	Wm. A. Havemeyer & Rosa R. Havemeyer	5686.00

SANITARY DISTRICT OF CHICAGO

MAP

Showing

CHICAGO RIVER IMPROVEMENT

From

18TH STREET TO HALSTED STREET

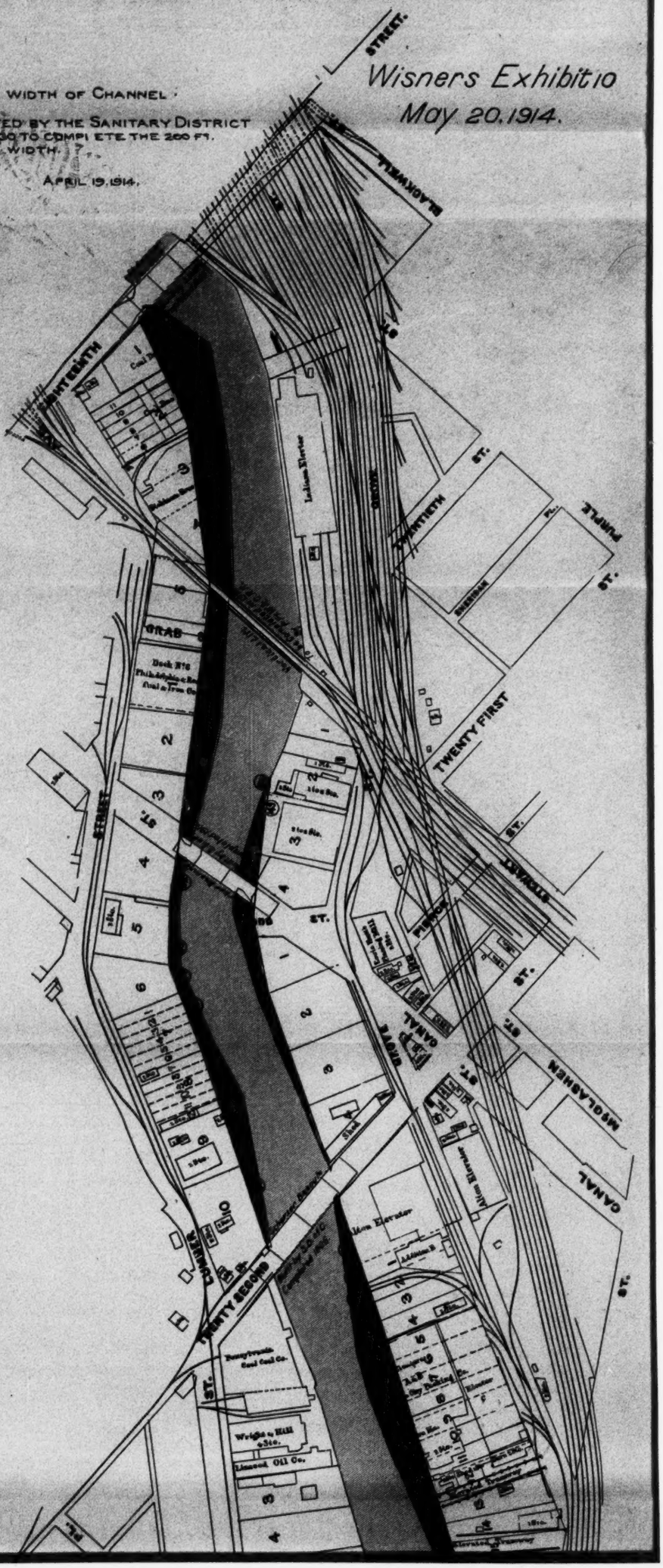
Scale 200 Ft = 1 Inch

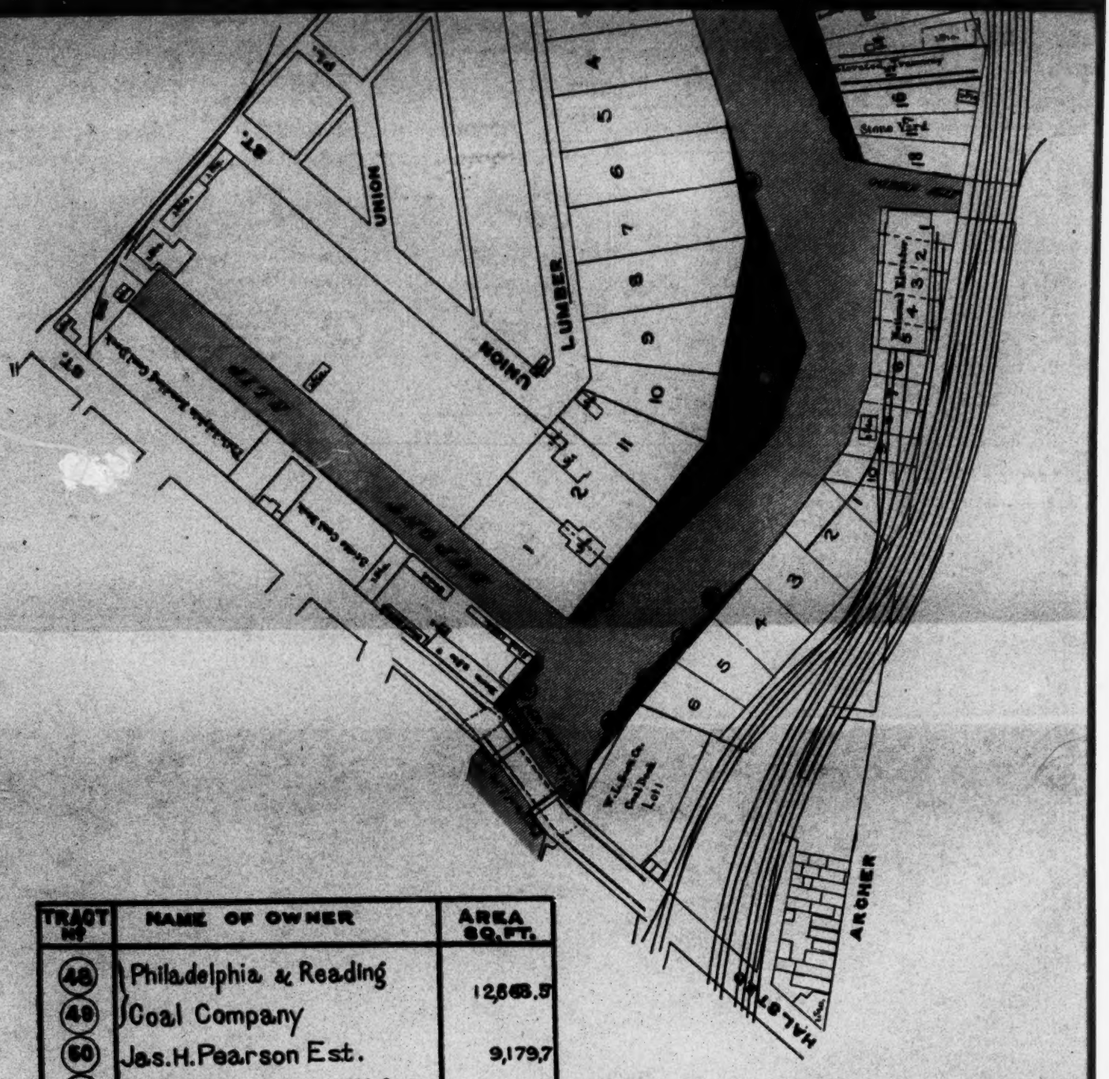
ORIGINAL WIDTH OF CHANNEL.

EXCAVATED BY THE SANITARY DISTRICT OF CHICAGO TO COMPLETE THE 200 FT. CHANNEL WIDTH.

APRIL 19, 1914.

Wisners Exhibit 10
May 20, 1914.





TRACT Nº	NAME OF OWNER	AREA SQ. FT.
48, 49	Philadelphia & Reading Coal Company	12,568.5
50	Jas. H. Pearson Est.	9,179,7
51	C.W. Tegtmeyer & Wife	5406.0
52	H.D. Gibson	2,148,5
53	Mary C. Lilly & Husband	2,905,0
54, 55	E. A. Lord et. al.	5,176,0
56	Clarence E Carr et. al.	6,239.0
57	W. Sherriffs	7,397.0
58	Illinois Stone Co.	4,480.0
65	B.F. McConnell	3,506.72
66, 67, 68	Mrs A. Babcock & Husband	25,570,02
69, 70, 71, 71A	Henry A. Du Pont	18,168.23
122, 123, 124	W.L. Scott & Co.	10,228,12

TRACT Nº	NAME OF OWNER	AREA SQ. FT.
125	C. & A. R.R. Co.	729,20
127 to 133 incl	Wm. B. Ogden Est. Western Stone Co.	15,593,47
134 to 140 incl	Nebraska City Packing Co.	27,596,86
141 to 145 incl	Seaverns Elevator Co.	14,836,19
149	Cosmopolitan Elec. Co.	1,812,65
150	General Chemical Co	616.41
41, 42	Delaware Lackawanna R.R. et al	17,041.00
41A	Robt. W. Hall & Wife	534.93
43	Thos. H. Hoyne et al.	7,631.03
44, 45, 46, 47	Jose B. King et. al.	23,133,92
146	Louis Hutt & Wife	7,101.9
147, 147A	Wm. R. Mamine & Wife	5,564.3

SANITARY DISTRICT OF CHICAGO

MAP

Showing

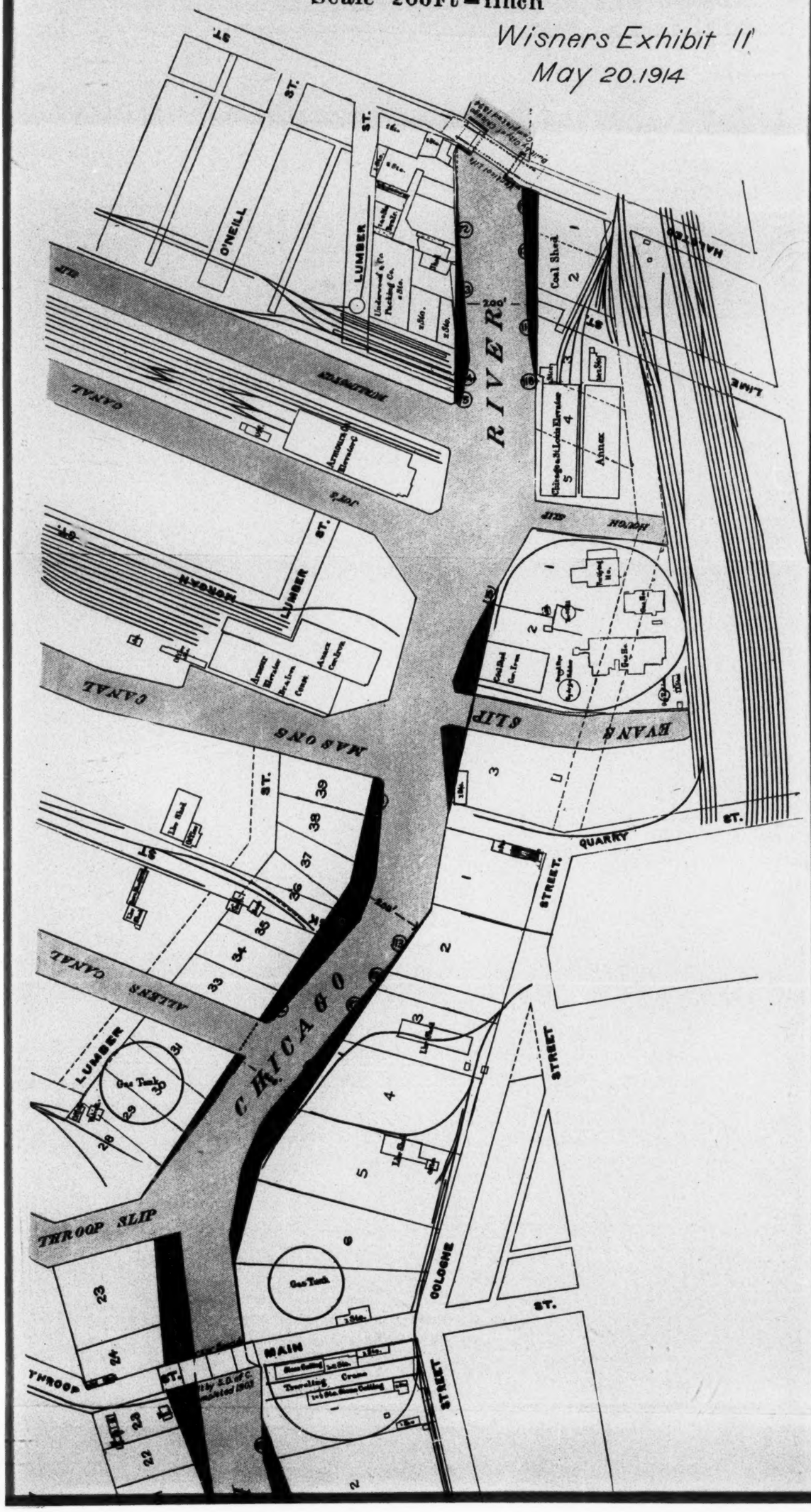
CHICAGO RIVER IMPROVEMENT

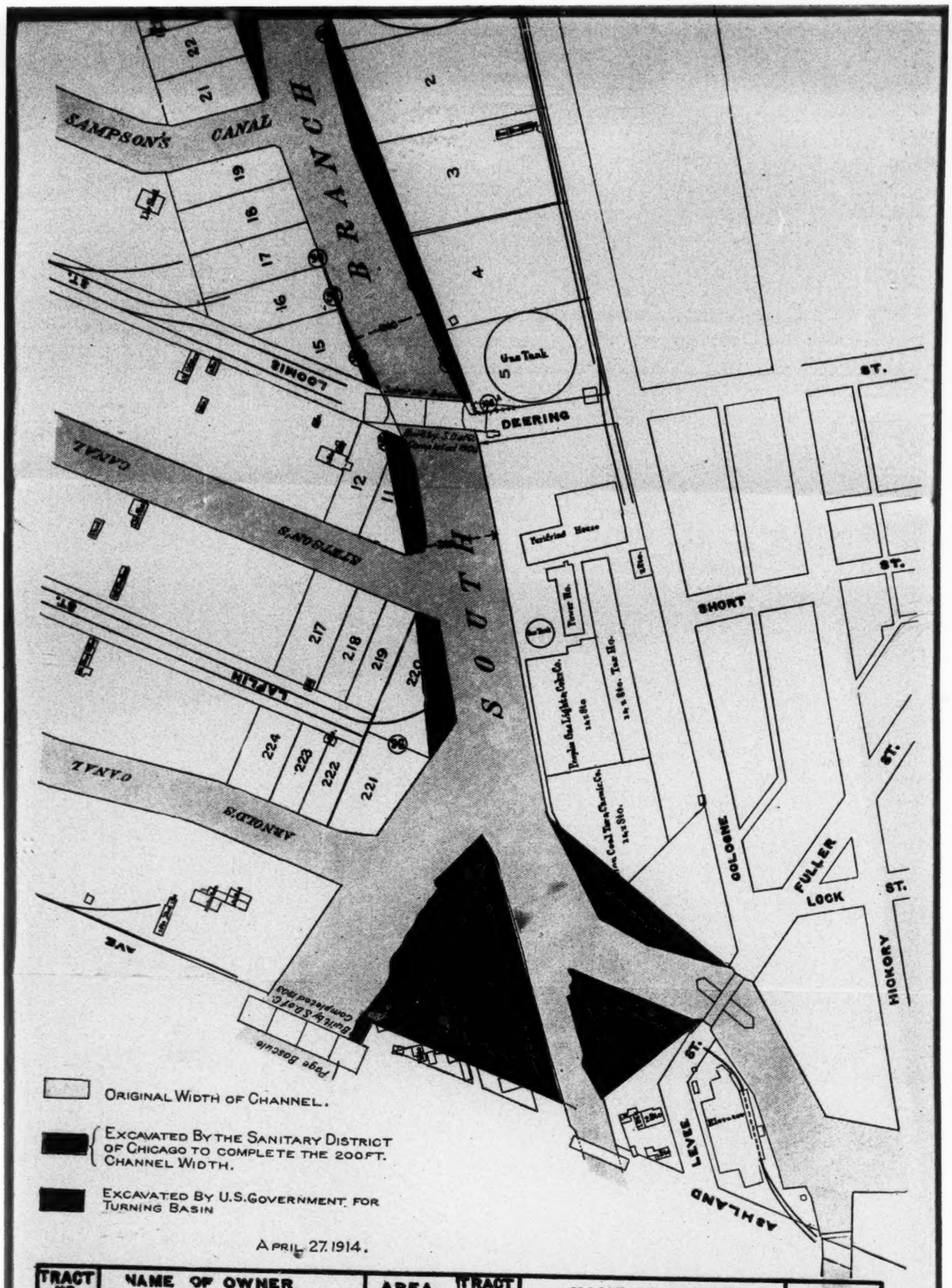
From

HALSTED STREET TO ASHLAND AVE

Scale 200Ft = 1Inch

Wisners Exhibit 11
May 20.1914





April 27. 1914.

Tract No.	Name of Owner	Area Sq. Ft.	Tract No.	Name of Owner	Area Sq. Ft.
72		1,393,47	105	Peoples Gas Light & Coke Co.	4,372,30
73	Omaha Packing Company	5,346,87	106	J.J. Mitchell et al	8,531,66
74	C.B & Q.R.R.	3,207,33	107	Francis S. Peabody Delia S. Gallup	11,255,55
75			108	Eliz Boyer	10,015,27
76 to 82 inc	Commonwealth Electric Co.	20,927,85	109	E. Heldmaier & Wife	
			111	Estate of Benj. S. Rotch	9,580,68
90	L.W. Fargo	529,44	112 & 122	Commonwealth Electric Co.	5,065,70
91			113	Drexel Estate	1,173,42
92	Wm. G. Roelker	404,80	114	North Western University	6,741,62
93			115	The Peoples Gas Light & Coke Co.	10,422,77
94			116	Peoples Gas Light & Coke Co	312,97
96	Maxwell Bro's.	2 Lots 63,953,50	118 to 121 inc	Estate of Edson Keith	11,598,86
83 to 86 inc	The Peoples Gas Light & Coke Co.	4,529,00	110	Peoples Gas Light & Coke Co	5,110,00
87 to 89 inc	Henrietta A Boel & Husband	8 674,20	105A	Peoples Gas Light & Coke Co	1,431,00

to Lake Michigan, U. S. Congress attempted to reserve the right of way in 1822. By default of Illinois this attempt became void. In 1827 Congress provided for this section by the indirect means of land grant to Illinois.

* * *

It is therefore assumed that the effect of the United States appearing in this case will be to establish (1st) the contention that there is a contract between Illinois and the United States, and (2d) the nature of this contract, whether it is (a) a narrow contract requiring specific fulfillment by enlarging this canal, or (b) a broad contract to provide a suitable waterway from Lake Michigan to the Illinois River. If the ruling be that the contract is a narrow one (a), it is believed that any attempt to enforce it will be, in fact, futile. The required dimensions of the canal are nowhere specified and it would seem that these dimensions must hereafter be determined, as they have been heretofore by Illinois. If the ruling be that a broad contract exists, the obligation resting on Illinois will not be lessened, but may be met by (1) specific fulfillment—enlarging old canal—or (2) otherwise providing a waterway, and such a ruling by her Supreme Court should have the effect of causing Illinois to decide promptly how this acknowledged obligation would be met. Illinois' self-inflicted paralysis in this case is perhaps more technical than it is intentional. She has the undoubted right to maintain this canal or not, according to her judgment on costs and benefits, but in case she refuses to maintain it, its forfeiture should be considered.

Conditions of Chicago River (April 15, 1914) compared with time prior to Sanitary District improvements.

Mr. Wisner further testified and Exhibits 7, 8, 9, 10 and 11, here shown, were offered. (Opposite this page.)

The depth of the South Branch of the Chicago River before the Sanitary District started work was approximately sixteen to seventeen feet. It is now twenty-six feet except at

a few bridge openings; that is the South Branch of the Chicago River.

3422 The central 100 feet of the stream is twenty-six feet in depth with a depth of sixteen feet at the Dock lines.

Exhibits 7, 8, 9, 10 and 11 above shown are maps of the Chicago River from Lake Michigan through the main branch of the river, and South and West on the South Branch of the Chicago River to Ashland avenue, which is about half a mile east of the beginning of the canal. The maps are drawn accurately to a scale of 200 feet to the inch and indicate the dock lines of the river, the bridges, and indicate the condition both before and after the improvement.

3423 With the exception that it does not show the location of the old bridge piers and center pier protections of the bridges that were removed and changed from the swing type of bridge to the center pier—to the bascule type of bridges. It does indicate the type of bridge, and when it is completed, as stated on the map, for instance State Street Bridge, which was built by the Sanitary District is a Scherzer bascule, as indicated, "built by the S. D. of C." meaning Sanitary District of Chicago, completed 1903. So by looking at these maps at the different bridges, you can learn by whom they were built and when completed.

The lake is on the right hand side of the map, Wisners Exhibit 7. When I say on the right hand side of the map, I mean to have it so placed that the words "Chicago River" in the part tinted blue reads right side up; that being to the East, and Lake Street being to the West.

The streets like 5th Avenue, LaSalle, Clark, State, run practically north and south, and streets like Kinzie and Lake run east and west. This first sheet shows the junction of the south and the north branches of the river.

On Exhibit 7, which is as I stated the main branch of the river, the improvements made by the Sanitary District consisted of the removal of the State and the Dearborn Street bridges, which bridges were of the center pier swing type such

as now exists at Fifth Avenue and Michigan avenue. These were replaced by the bascule type of bridge giving a wide center opening and doing away with the center pier and the center pier protection, which clogged up the river and interfered with navigation. The Sanitary District also dredged the river in the vicinity of these bridges to a depth of twenty-one feet.

On the main river, in addition to what was done by the Sanitary District, the City of Chicago removed the LaSalle Street tunnel, deepening the river at that place. The tunnel at LaSalle street interfered with navigation; the boats at times being stuck on it and blocking the river.

Wisner's Exhibit 8 of this date consists of a map of the same scale extending south from Lake street to 12th street showing the docks on the river before and after improvements made by the Sanitary District. This stretch of the river has been widened practically throughout its entire length, the widening being indicated by the dark blue tint. By applying a scale to this dark blue tinted area, the amount of the widening can be determined at any place. Generally, it varies in width from nothing to approximately ninety feet. The 3424 part tinted green of which there are two places indicated on this sheet are stretches along the river which have not as yet been widened for the reason that the property has not been acquired by the Sanitary District, but is included in the general project, and it is expected will be obtained and widened within the next year.

There are condemnation suits pending against both of these pieces of property, referring to the parts tinted green, one being on the east side of the river between Van Buren street and Harrison street and labeled "Union Elevated R. R. Co. Power House."

That is called the Union Loop Power House. The other is indicated by "Tract Number 201," the 201 being in a circle and being just north of Taylor street.

The Sanitary District has widened and excavated the river throughout this stretch to twenty-six feet in depth; has re-

moved all of that part tinted a dark blue thus widening the river, and has rebuilt all the docks where the river was widened.

The width where completed is at least 200 feet.

All except those two that have not yet been excavated. The District has removed a center pier bridge and built a bascule bridge at Randolph street, which was completed in 1903.

The Washington Street Bridge and the tunnel thereunder were removed by the City of Chicago and a new bridge completed in 1913 at this street.

The Madison Street bridge, the one that now exists, is of the center pier swing type, and is to be removed by the city of Chicago.

It has been ordered out and plans and specifications are being prepared and it will be rebuilt within the very near future.

The Jackson Boulevard Bridge is now being removed by the Sanitary District, and is to be replaced by a bridge
3425 of the bascule type, having a wide opening.

The opening of the Jackson Boulevard Bridge will be 167 feet in width; the one at Madison street, as I recall, is to be 180 feet, somewhere in that neighborhood.

The bridge openings there are only about fifty-five to sixty feet in width at the present time. At Jackson Boulevard, the opening is a little wider, I believe about ninety feet.

The next bridge to the south is the Metropolitan Elevated Railroad Company Bridge. This was ordered out by the Secretary of War.

It is part of the contemplated plan of the Sanitary District to remove and replace the Van Buren Street Bridge with a bridge having a 200-foot opening.

The Harrison Street Bridge, which was of the center pier type has been removed and rebuilt by the Sanitary District, being completed in 1905.

Polk Street Bridge which was of a similar character has been removed and was rebuilt by the City of Chicago, being completed in 1910.

Taylor Street Bridge which was of the center pier type was removed by the Sanitary District and rebuilt in 1900.

The railroad bridge just south of that and indicated as "B. & O. C. T. R. R." was of the center pier type and was built by the Sanitary District, being completed in 1901.

Twelfth Street Bridge has been ordered out by the Secretary of War and is to be rebuilt jointly by the City of Chicago and the Sanitary District, with an opening of 200 feet instead of the present opening of about fifty-five to sixty feet.

Wisner Exhibit No. 9, is the third sheet of this set, being of the same scale, and is a map of the south branch from 12th street to 18th street inclusive. The part tinted a dark blue represents the river widening performed by the Sanitary District, and the part tinted green is a piece of property not yet obtained, but which is under condemnation; and in my opinion will be obtained within the next few months, when this whole stretch of the river will have been completed; so that from Lake street to the beginning of the
3426 Drainage Canal, with the exception of the three pieces mentioned and the stretch of the river at the Metropolitan Elevated, the entire river has been widened to at least 200 feet and even to twenty-six feet or more, with the exception of the bridge openings of the old center pier bridges.

The widening on this stretch of the river varies from zero to eighty feet in width. The river was redocked and deepened as stated.

The bridge marked "St. Charles Air Line" which is practically on 16th street, is to be rebuilt by the railroad companies. Plans are now being prepared, and this bridge is to be taken out and replaced with a 200-foot opening bridge.

The 18th Street Bridge which was of center pier type was rebuilt and replaced with a bascule type bridge completed in 1905 by the Sanitary District.

Wisner's Exhibit 10 of this date is a continuation of this map and gives the Chicago River on the same scale, 200 feet to the inch from 18th street to Halsted street. The same general tinting indicates what has been done by the Sanitary District. The widening varies from nothing to nearly 140 feet in width at Collision Bend.

It got its name on account of there being so many collisions at this place before this widening was made; I mean collisions between vessels.

The original width at the Bend was a little over 100 feet. There was a narrow point on the river immediately south, or west of 18th street, and at that place the Sanitary District widened it about 120 feet at the widest point. The old 18th Street Bridge, on account of the narrow river and bend in it, the vessels were unable to use but one bridge opening, that one being on the east side of the river. By that I mean vessels of any size.

The bridge marked "P. Ft. W. & C. R. R." is a bridge owned by the Pennsylvania Railroad Company, and is now in the process of being removed; a new bridge having been built at this place with I think a 200-foot opening.

The Canal Street Birdge was built by the Sanitary District and completed in 1903. That was not of the center pier type, but was of a narrow opening type, known as a jackknife. It stood askew and was a very difficult place for navigation.

The 26th Street Bridge was of the center pier type and was removed; rebuilt by the Sanitary District; completed in 1906.

The next sheet shows in the same way the improvements made by the Sanitary District from Halsted street to Ashland avenue. The part near Ashland avenue tinted brown is a turning basin that was built by the United States Gov-

ernment to facilitate the turning around of vessels after
3427 going up the river. Generally, this river was widened throughout this stretch, throughout the entire length, to give a channel which is now at least 200 feet wide and twenty-six feet deep.

The Sanitary District removed a center pier bridge and rebuilt with a bascule bridge at Main or Throop street, completing it in 1903. And one at Loomis or Deering street, completing that in 1904; and one at Ashland avenue, completing that in 1903.

The river from Ashland avenue down the West Fork to the beginning of the Canal was over 200 feet in width, and was simply deepened by the Sanitary District to twenty-six feet in depth.

At the lower end of this last sheet the water as indicated on the left hand side of the sheet is the West Fork of the South Branch, from which the Canal starts at Robey street.

The indicated water to the right of the map is the South Fork of the South Branch, the far end of which is known as Bubbly Creek, being located near the Stock Yards, and having been mentioned in this case several times.

The middle water stretch is the entrance to the old Illinois and Michigan Canal.

On Wisner's Exhibit No. 8, I neglected to mention that the City of Chicago had removed and rebuilt a tunnel under the Chicago River immediately North of Van Buren street and indicated on this map as "West Chicago Street Railway tunnel." This prevented the deeping of the river for some time, as the top of the tunnel was about, as I remember, twenty feet below the surface, twenty or twenty-one feet below datum.

3435 The Sanitary District lowered the Kampsville Dam two feet and we attempted to lower the other one, but with the restrictions placed upon us by the Government we did not succeed in getting it down.

It was 1905 or 1906. And that was done pursuant to a permit from the Secretary of War.

HISTORY OF ROUTE OF NAVIGATION FROM LAKE MICHIGAN TO MISSISSIPPI, ACTS OF STATE AND FEDERAL GOVERNMENT CONCERNING ITS MAINTENANCE AND IMPROVEMENT, AND CONNECTION OF SANITARY DISTRICT'S DIVERSION WORKS WITH SUCH ROUTE.

History of the route.

By stipulation (Rec., Vol IV, p. 1813) the testimony of Professor Clarence W. Alvord, professor of history of the University of Illinois, Professor A. C. McLaughlin, professor of history of the University of Chicago and Dr. Reuben Golde Thwaites, secretary of the Wisconsin Historical Society, witnesses for the United States in the case of *United States* v. *Economy Light & Power Company* (involving the navigability of, and the jurisdiction of, the Secretary of War over the Des Plaines River) as given in that case, was introduced on behalf of the defendant Sanitary District of Chicago (Rec., Vol. IV, pp. 1814-1977).

The testimony of these witnesses established that the route now occupied by the main channel of the Sanitary District of Chicago between the Chicago River and the Des Plaines River was used from time immemorial as a route for trade and travel by water; that at a point now known as Riverside, which is approximately 39th street, Chicago, extended, where the Des Plaines River turned to the southwest, there was a small stream which in a state of nature before any improvements were made, flowed into the Des Plaines River from Mud Lake, a large stretch of water, which was from 300 feet to half a mile wide and from a mile to three or four miles in length, depending upon the wetness or dryness of the season; that in wet seasons from the easterly extremity of this marsh or Mud or Portage Lake, as it was called by the early settlers, was a stream flowing easterly, which was known as the West Fork of the South Branch of the Chicago River, so that in wet seasons

it was possible to pass in a boat from the Des Plaines River to Lake Michigan or from Lake Michigan to the Des Plaines River and in drier seasons it was at times necessary to make one or more portages in going to and fro between the Chicago River and the Des Plaines River; that this route through Mud Lake was the route (Rec., Vol. IV, p. 1814, *et seq.*) of the early explorers and the traders, trappers, and travelers who had reason to make a journey either way between the Great Lakes and the Illinois River. The exerpts set out in Volume IV show actual trips, maps, accounts of travelers, statements in public documents, contemporaneous histories, gazeteers, guide books, and the statements of individuals living on the route that the route was used as a highway for trade and travel.

Father Marquette stated that on his first voyage he came up, over this route using the Illinois River and Chicago portage to the Chicago River in 1673. (Rec. Vol. IV, p. 1816.)

Tonti, who was a lieutenant of the Cavalier de LaSalle, made use of this route in the winter of 1681. (Rec. Vol. IV, p. 1819.) The Cavalier de LaSalle himself came over the route on ice leaving the junction of the Des Plaines and Kankakee on the sixth of January, 1681, and again on the fourth of January, 1682. (Rec. Vol. IV, p. 1821.) Upon the death of de LaSalle, Father Membre and Abbe Cavalier, the brother of LaSalle, came up over this route in 1688. (Rec. Vol. IV, p. 1822.)

Father St. Cosme, in 1698, used this route from Chicago to the Des Plaines River and down the Des Plaines River to the Illinois River. (Rec. Vol. IV, p. 1826.)

Father Gravier writes that he used the route in September, 1700. (Rec. Vol. IV, p. 1829.)

John Baptiste Perrault made a trip from Chicago over to and down the Des Plaines River to Cahokia and returned over the same route in 1783. (Rec. Vol. IV, p. 1851.)

Hugh Heward, a Canadian, associated with the British fur trading houses, on May 9, 1790, describes in a diary kept by him, such a trip from Chicago across to the Des Plaines and down the Des Plaines River. (Rec. Vol. IV, p. 1852.)

Professor of History Clarence W. Alvord, of the University of Illinois, after having examined the various historical data, stated his conclusion to be that from the latter part of the 17th century through the first third of the 19th century, men engaged in the fur trade passed up and down the Chicago and Des Plaines Rivers in canoes and flatboats very regularly; that the fur trade was pursued by the French as long as they held possession of this country; was developed more fully by the English and later by the Americans; that the most active trade carried on the two rivers falls between the period of 1783 and 1825, or thereabouts; that the traders found a very easy passageway by means of these rivers in the early spring. That during the time of drought such as occurred in the summer or fall, the passage was hard, but even then they forced their boats through the waterway, often being obliged, however, to carry their packages around the shoals and rapids. (Rec. Vol. IV, p. 1929, 1930.)

Professor of History A. C. McLaughlin, of the University of Chicago, says:

> "Referring now to the period from the time of Charlevoix to the year 1825, and basing my answer upon the sources of historical information to which my attention has been specifically directed, assuming that as a historical writer I was preparing a history of Illinois, concerning the use of the Desplaines River, I should say that the Desplaines River was used with apparently considerable frequency as a route of trade and com-

merce; that at certain seasons of the year it seemed to have presented some difficulties, other seasons of the year it was used with considerable ease, and that it was a well known means of communication between the lake region and the lower Illinois and Mississippi." (Rec. Vol. IV, p. 1936)

Dr. Reuben Gold Thwaites, secretary of the Wisconsin Historical Society, states his conclusion on the same evidence as follows:

"Giving due weight to all the sources of information that I have examined my opinion is that from the latter part of the 17th century through the first third of the 19th century, men engaged in the fur trade with the western Indians actually and quite regularly passed up and down the Chicago and Desplaines Rivers in canoes and bateaux, Mackinaw boats and other boats propelled by oars, or poles, laden with merchandise and furs; that these traders and travelers found a comparatively easy passageway by means of these rivers in the early spring, and sometimes at other seasons; that during times of drought such as often occurred in the summer and fall on most of the western portage routes between the Great Lakes and the Mississippi (as, for instance, on the well-known and much used Fox-Wisconsin portage route) the passage was sometimes difficult; but even then these fur traders appear to have succeeded in forcing their boats over the Chicago-Desplaines waterway although perhaps, they were obliged here and there to make some carriage at that time of year, the length of the carriage varying greatly from season to season, and from year to year, according to the stage of water." (Rec. Vol IV. pp. 1947):

The Session of Virginia of 1783 of the Northwest Territory provided that the Northwest Territory shall

"be laid out and formed into states containing a suitable extent of territory not less than 100 nor more than 150 miles square, or as near thereto as circumstances will admit, and that the states so formed shall be distinct republican states and admitted members of the Federal Union, having the same rights of sovereignty, freedom and independence as the other states."

The Report of March 24, 1786, on the division of the Northwest Territory, adopted by Congress, among other things provided (Journals of Congress, Vol. IV, p. 663):

"Whereas it appears * * * that the laying it out and forming it into states of the extent mentioned in the resolution of Congress of the tenth of October, 1780, and in one of the conditions contained in the cession of Virginia, will be productive of many and great inconveniences; that by such a division of the country, some of the new states will be dperived of the advantages of navigation, some will be improperly intersected by lakes, rivers, and mountains, and some will contain too great a proportion of barren, unimproved land, and of consequence will not for many years if ever have sufficient number of inhabitants to form a respectable government, and entitled them to a seat and voice in the federal council: And whereas in fixing the limits and dimensions of the new states, due attention ought to be paid to natural boudaries and a variety of circumstances which will be pointed out by a more perfect knowledge of the country, so as to provide for the future growth and prosperity of each state, as well as for the accommodation and security of the first adventurers."

Article 5 of the ordinance of 1787 provided (p. 962):

"There shall be formed in the said territory not less than three nor more than five States; and the boundaries of the States, as soon as Virginia shall alter her act of cession and consent to the same, shall become fixed and established as follows, towit: The Western State, in the said terrritory, shall be bounded by the Mississippi, the Ohio and the Wabash Rivers; a direct line drawn from the Wabash and Post Vincents, due north, to the territorial line between the United States and Canada; and by the said territorial line to the Lake of the Woods and Mississippi. The middle State shall be bounded by the said direct line, the Wabash from Post Vincents to the Ohio, by the Ohio, by a direct line drawn due north from the mouth of the Great Miami to the said territorial line, and by the said territorial line. The eastern State shall be bounded by the last-mentioned direct line, the Ohio, Pennsylvania, and the said territorial line."

The following from 32 Annals of Congress, 15th Congress, 1st Session, April 3, 1818:

(P. 1677)

"STATE OF ILLINOIS.

The House resolved itself into a Committee of the Whole on the bill to enable the people of Illinois Territory to form a constitution and State government, and for the admission of such State into the Union on a footing with the original States.

Mr. Pope moved to amend the bill by striking out the lines defining the boundaries of the new States, and to insert the following:

> 'Beginning at the mouth of the Wabash river; thence up the same, and with the line of Indiana to the northwest corner of said State; thence east with the line of the same Sate to the middle of Lake Michigan; thence north along the middle of said lake to north latitude 42 deg. 30 minutes; thence west to the middle of the Mississippi river; and thence down along the middle of that river to its confluence with the Ohio river; and thence up the latter river along its northwestern shore to the beginning.'

The object of this amendment, Mr. P. said, was to gain, for the proposed State a coast on Lake Michigan. This would afford additional security to the perpetuity of the Union, inasmuch as the State would thereby be connected with the States of Indiana, Ohio, Pennsylvania and New York, through the Lakes. The facility of opening a canal between Lake Michigan and the Illinois river, said Mr. P., is acknowledged by every one who has visited the place. Giving to the proposed State the port of Chicago, (embraced in the proposed limits,) will draw its attention to the opening of the communication between the Illinois river and that place, and the improvement of that harbor. It was believed, he said, upon good authority, that the line of separation between Indiana and Illinois would strike Lake Michigan south of Chciago, and not pass west of it, as had been supposed by some geographers who had favored us with maps of that country; and, Mr. P. added, that all the country north of the proposed State, and bounded by Lakes Michigan, Huron, Superior and of the Woods, and the Mississippi river, must form but one State, Congress being restricted, by

the ordinance of 1787, from erecting more than five States in the Northwestern Territory.

This motion was agreed to without a division.

* * *

The Committe rose and reported the bill to the House, and it was ordered to be engrossed, as amended, and read a third ime, *nemine contradictente.*"

In an official report transmitted on December 28, 1819, to the House of Representatives by the then Secretary of War John C. Calhoun, is a report to the Secretary of War by Major Stephen H. Long, in which Major Long, said. (Rec. Vol. IV, pp. 1881, 1882):

"The river Desplaines is a small stream rising in the lowlands, bordering upon the west side of Lake Michigan and has its general course in a southwesterly direction. The Valley of this river has an average width of about one mile and is terminated on both sides by regular banks nearly parallel to each other, extending along the river about thirty miles from the head of the Illinois. In ascending this river, also the banks and bluffs gradually decrease in height being as before mentioned about one hundred feet high at the mouth and only 100 or 125 at the distance of thirty miles higher up the river, where, instead of maintaining their parallel direction, they form nearly right angles with the course of the river, that on the right taking an easterly, and that on left a northwesterly course; but, being gradually inflected from these courses, they form extensive curves encircling a large tract of flat prairie, in no part elevated more than twelve or fourteen feet above the common level of the water in this vicinity. The river, throughout the above mentioned distance has four or five short rapids or ripples that make their appearance only in times of low water. In every other part it has the appearance of being a chain of stagnant pools and small lakes, affording a sufficient depth of water for boats of moderate draught.

In the flat prairie, above mentioned, is a small lake, about five miles in length and from six to thirty or forty yards in width, communicating both with the river Desplaines and Chicago river by means of a kind of canal which has been made partly by the current of water, and

partly by the French and Indians for the purpose of getting their boats across in that direction, in time of
1882 high water. The distance from the river Desplaines to Chicago river by this water course is about nine miles through the greater part of which there is more or less water, so that the portage is seldom more than three miles in the driest season, but in the wet season boats pass and repass with facility between the two rivers."

REPORT OF R. GRAHAM, ASSISTANT SECRETARY OF WAR, AND
1884 JOSEPH PHILIPS, CHIEF JUSTICE OF ILLINOIS.

The next report attached to this same document is the report of R. Graham and Joseph Philips. Philips was one who accompanied this expedition of Major Long and made a report likewise on the subject. He was the first Chief Justice.

The said report of Graham and Philips of April 4, 1819, in part is as follows:

1885 "It was, however, determined, from certain data, that the level of the river was two feet, or thereabouts, above the level of the lake. From this view it would seem that the cutting of a canal in this place between the Plein and the Lake would be a work of neither skill, difficulty or expense. Small, however, as the labor would be under this view it is still diminished upon a close examination, and by finding that an arm of the lake called Chicago puts out in the direction of the Plein and that an arm of the Plein, also called Chicago, puts out in the direction of the lake. They approach within two miles of each other; so that, in common water, there is only dry ground to that extent between them. The character of these two arms is essentially different; that of the lake being about sixty feet wide, and from ten to forty feet deep; that of the river, being in high water, from four to six feet deep, and in, places a mile wide, and, in low water, either dry or reduced to a gutter. Between the heads of these two arms is also a gutter, which is dry in the dry seasons of summer and fall, and full of water in the spring, and, when thus filled with water, the boats, of six or eight tons, engaged in the Mackinaw and Mississippi trade, run through, backwards and forwards, so as to make no portage between Mackinaw and

the Mississippi. This gutter, judging from the appearance of others now forming, was, at first, a path worn out by the feet of those who carried things across the
1886 portage, and afterwards deepened by the attrition of the waters until formed into a little canal. The wind, alone, gives the water a current in this little canal, and its direction depends upon the course of the wind. Objects have been seen to float out of it from the same point to the river and to the lake.

It is incontestably true, that an east wind will drive the water of the lake through this gutter into the Plein, and that water from Lake Michigan has been discharged by this outlet into the Mississippi, and thence into the Gulf of Mexico. It is equally incontestable, that the waters of the Plein have been driven, by the same channel, into the lake; and these phenomena may now be witnessed, at any time, when the waters are high and the wind blows hard. It follows, therefore, that to finish the canal began by nature, in this place, would require, as we have already said, but little of skill, time or expense."

In 1795, Anthony Wayne, Major General of the United States, made a treaty of peace, known as the Treaty of Greenville, with the several Indian tribes then living in the Northwest Territory (Illinois, Indiana, Ohio, Michigan and Wisconsin) which provided for a free passage by water over this water route between the Chicago River and the Des Plaines River. (Rec. Vol. IV, p. 1861, 1862):

In 1816 the United States made a treaty of peace with the Ottawa Indians whereby the land in which the Sanitary District Canal is now located was ceded to the United States. (Rec. Vol. IV, p. 1874):

Right of Navigating St. Lawrence by citizens of the United States denied by Great Britain.

By acts of Parliament in 1822 and 1824 the British Government denied the citizens of the United States the free navigation of the St. Lawrence between the Great Lakes and the Sea.

In a communication between Minister Rush and Mr. Adams, Mr. Rush, says (Rec. Vol. IV, p. 2276):

Extracts from Message of the President of Jan. 7, 1828, State Papers 1st Session 20 Congress, Vol. 2, Doc. 43, Page 8, entitled "Extract of a Dispatch from Mr. Rush to Mr. Adams, Dated London, August 12, 1824."

"The act of parliament of August 5, 1822, having immediate relation to the commercial intercourse between the United States and the British continental possessions in their neighborhood, I naturally regarded it as your instructions to me had done in connection with the act of June 24, 1822. This brought under consideration our claim to the navigation of the St. Lawrence. Between this question and the questions of commercial intercourse under the act of June, 1822, the British plenipotentiaries were constantly unwilling to acknowledge any connection. Nevertheless, looking to your instructions, and as well to the reason of them as to their authority, I treated the two questions as belonging to one and the same general subject. They asked whether, taking the two acts of parliament together, the United States did not already enjoy the navigation of this river? I said that they did; by the act of June 24, 1822, they enjoyed it from the ocean to Quebec; and by that of August 5, 1822, from any part of the territories of the United States to Quebec. But from the fact of the colonial government in Canada being invested with a discretionary power to withdraw the latter of these concessions by excepting any of the Canadian ports from those to which our vessels were made admissible, it followed that our enjoyment of the navigation of this river was rendered contingent upon British permission."

The negotiations began by Mr. Rush were concluded by Mr. Gallatin and resulted in the refusal of the British to permit longer the free navigation of the St. Lawrence River. Mr. Gallatin say (Rec. Vol. IV, p. 2294):

EXTRACT OF LETTER FROM MR. GALLATIN TO MR. CLAY, DECEMBER 21, 1827.

"The British plenipotentiary will not entertain any proposition respecting the navigation of the St. Lawrence founded on the right claimed by the United States to navigate that river at the sea."

EXTRACT OF LETTER FROM MR. GALLATIN TO MR. CLAY, OCTOBER 1, 1827.

"The British plenipotentiary reply that however well disposed Great Britain might be to treat with the United States respecting the free navigation of the St. Lawrence as a question of mutual convenience, yet the views of the British government, being the same now as they were in 1824, and they being prohibited by express instructions from entering into any discussion respecting the free navigation of the river, if claimed as heretofore by the United States on the ground of right, they could not entertain any proposition to that effect if now made by me. * * *"

Acts of Federal Government and Illinois concerning establishment, maintenance and improvement of Illinois Michigan Canal.

On March 30, 1822, the Congress of the United States passed an act authorizing the State of Illinois to open a canal to connect the Illinois River with Lake Michigan, which act provided among other things, as follows (Rec. Vol. VIII, p. 67):

"Act of March 30, 1822

(3 U. S. Stat. at Large, p. 659)

An Act to Authorize the State of Illinois to Open a Canal Through the Public Lands to Connect the Illinois River with Lake Michigan. (Approved and in force March 30, 1822.)

Section 1. Be it enacted by the Senate and the House of Representatives of the United States of America, in Congress Assembled: That the State of Illinois be, and is hereby authorized to survey and mark, through the public lands of the United States, the route of the canal connecting the Illinois River with the southern bend of Lake Michigan; and ninety feet of land on each side of said canal shall be forever reserved from any sale to be made by the United States, except in the cases hereinafter provided for, and the use thereof forever shall be, and the same is hereby vested in the said State for a canal, and for no other purpose whatever; on condi-

tion, however, that if the said State does not survey and direct by law said canal to be opened, and return a complete map thereof to the treasury department, within three years from and after the passage of this act; or, if the said canal be not completed, suitable for navigation within twelve years thereafter; or, if said ground shall ever cease to be occupied by, and used for, a canal suitable for navigation; the reservation and grant hereby shall be void and of none effect; Provided, always, and it is hereby enacted and declared, that nothing in this act contained, or that shall be done in pursuance thereof, shall be deemed or construed to imply any obligation on the part of the United States to appropriate any money to defray the expenses of surveying or opening said canal; **Provided, also, and it is hereby further enacted and declared, that the said canal, when completed, shall be and forever remain a public highway for the use of the Government of the United States, free from any toll or other charge whatever, for any property of the United States, or persons in their service passing through the same."**

In 1826 the legislature of Illinois petitioned the Congress of the United States for an additional act for the construction of a canal. The other act of 1822 had ceased to have any force or effect because of the failure of the state to act within the time required. (Rec. Vol. IV, p. 2017.)

MEMORIAL OF ILLINOIS.

"The memorial of the General Assembly of the State of Illinois respectfully represents: That the construction of a canal, uniting the waters of Lake Michigan with the Illinois river, will form an important addition to the great connecting links in the chain of internal navigation, which will effectually secure the indissoluble union of the confederate members of this great and powerful Republic."

In 1827 the Congress of the United States passed an additional act authorizing the opening of the canal and the granting of public land to the State of Illinois in aid of such a project. The act is as follows (Rec. Vol. VIII, pp. 68, 69):

ACT OF MARCH 2, 1827.

"(4 U. S. Stat. at Large, p. 234)

An act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan. (Approved and in force March 2, 1827.)

Section 1. Be it enacted by the Senate and House of Representatives of the United States of America, in Congress Assembled, That there be and hereby is granted to the State of Illinois, for the purpose of aiding the said State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each side of said canal, and reserving each alternate section to the United States, to be selected by the Commissioner of the Land Office, under the direction of the president of the United States, from one end of the said canal to the other; and the said land shall be subject to the disposal of the Legislature of the said State, for the purpose aforesaid, and no other; Provided, *That the said canal when completed, shall be and forever remain a public highway for the use of the Government of the United States, free from any toll, or other charge, whatever, for any property of the United States, or persons in their service passing through the same;* Provided, That said canal shall be commenced within five years and completed in twenty years, or the State shall be bound to pay to the United States the amount of any lands previously sold, and that the title to purchasers under the State shall be valid.

(Duty of the Governor of the State when the canal is located, etc.)"

On January 9, 1836, the State Legislature of Illinois passed an act for the construction of the Illinois and Michigan Canal. Record Vol. IV, pp. 2295-2304. Section 16 of said act provided as follows (Rec. Vol. IV, p. 2298):

"SEC. 16. (DESCRIPTION—PROVISO.) The said canal shall not be less than forty-five feet wide at the surface, thirty feet at the base and of sufficient depth to insure a navigation of at least four feet, to be suitable for ordinary canal boat navigation, to be supplied with water

from Lake Michigan and such other sources as the canal commissioners may think proper, and to be constructed in the manner best calculated to promote the permanent interest of the country; reserving ninety feet on each side of said canal, to enlarge its capacity, whenever in the opinion of the board of canal commissioners, the public good shall require it; *provided,* that all persons who have purchased, or shall hereafter purchase lands fronting the said canal shall be permitted to lease from the said board the said reserved ground on each side of said canal, from year to year, or until the said ground shall be wanted to enlarge the capacity of said canal, for the best price that can be obtained to be paid into the canal fund."

Physical and health conditions at Chicago.

The physical conditions prior to the projection of the Sanitary District works are stated in the testimony of Lyman E. Cooley (Rec. Vol. III, pp. 1710, 1711) as follows:

The Chicago River basin, as it originally existed in nature, consisted of the North Branch and its drainage basin, together with the South Branch, an area of about 240 square miles (now about 300 square miles). West of the Chicago River basin, was the Des Plaines River basin, drained by the Des Plaines River which ran parallel to the lake from the headwaters in Wisconsin down to a point about ten miles from Lake Michigan at Lyons; and then leading southwesterly to a junction with the Illinois River, or to the junction with the Kankakee River, which formed the Illinois.

This Des Plaines River, in the vicinity of Lyons, had a low water elevation of about eight feet, and a drainage area of 633 square miles.

The divide between the Des Plaines River and the Chicago River was in the vicinity of the Bridewell, just west of Kedzie avenue, and had an original elevation of about 10½ feet above Lake Michigan, and whenever the Des Plaines River rose from two or three feet above low water, or exceeded a volume of about 1,000 second feet, the flow of the

river divided, part of it coming through the South Branch of the Chicago River to Lake Michigan, and in great floods sixty to seventy per cent of the entire flow of the Des Plaines River came to Chicago.

This condition existed up to about 1854, after the Illinois and Michigan Canal had been opened in 1848, when the Drainage Commissioners cut out the original divide at Kedzie avenue and drained out the Mud Lake region as it was known in Voyageur's days, and on the original land maps as "Portage Lake, Portage Swamp, and Portage Slough."

For a number of years thereafter, the entire flow of the Des Plaines River came in the direction of Chicago except at such times as in the fall and winter when the ice interests of the Des Plaines River Valley made a temporary dam in order to fill the ponds on the twelve-mile level between Summit and Lemont, for ice-making purposes.

Finally the flow from this source became such a nuisance to the City of Chicago that after 1870 they constructed the Ogden-Wentworth Dam. That crossed the old Portage Slough at the range line at Summit, at an elevation of something over eleven feet above Chicago datum. And this was overflowed also, whenever the river rose above a volume of about 1,000 feet per second; and the waters continued to come this way in flood times when the volume exceeded that amount until 1893 when the Sanitary District executed its river 1711 diversion and created a spill-way above Summit, which restricted the flow down the river until the volume reached between 3,000 and 4,000 feet per second. And in about 1909, this was finally closed, so that no waters from that source have come through the Chicago River to Lake Michigan since.

The effects of this overflow have been most pronounced and is noted from time to time in the narratives relating to Chicago and its portage.

The Illinois and Michigan Canal was constructed and opened in 1848. Lyman E. Cooley (Rec. Vol. III, p. 1713) testified as follows:

There was another event happening about this time, the opening of the Illinois and Michigan Canal in 1848. The first shovel had been thrown on this canal at Bridgeport within the present city limits July 4, 1836; and that had contributed greatly to the growth of Chicago during its construction."

In 1861 the Illinois Senate and House of Representatives passed a joint resolution with reference to a survey of the Illinois, Des Plaines and Chicago Rivers for the purpose of improving navigation from Chicago to the mouth of the Illinois River. (See Laws of Illinois, 1861-63, p. 277.)

"RESOLVED BY THE SENATE, THE HOUSE OF REPRESENTATIVES CONCURRING HEREIN, That the board of trustees of the Illinois and Michigan Canal be and are hereby authorized and instructed to cause prompt and thorough surveys, examination and estimates to be made of the Illinois River, and of the Illinois and Michigan Canal, and also of portions of the Desplaines and Chicago rivers, and of the portage between said rivers, for the purpose of accurately ascertaining the comparative value, cost, efficiency, benefits, and advantages, direct, prospective and incidental, of the different methods proposed or desirable for improving the navigation of the Illinois River, by dredging or excavation of the channel and wing dams, *or by supplying water from Lake Michigan, through the enlargement and deepening of the Illinois and Michigan Canal, or otherwise, or by opening a channel from Lake Michigan, by way of the south branch of the Chicago river and Mud Lake to the Desplaines river, and down said canal to a point that will secure a free, flowing, ample and never failing supply of water, sufficient for the navigation of the Illinois river at all seasons and times,* when not obstructed by ice.

* * *

and to include also an estimate for the channel hereinbefore mentioned, of sufficient size to admit of full and free steamboat navigation from the Illinois river to Chicago and Lake Michigan, *as well as a size sufficient for supplying water for all the deficiencies of navigation in the Illinois river, at all seasons.* * * *"

The Illinois and Michigan Canal originally was built upon the shallow cut plan and did not take water from Lake Michigan by gravity flow at first. Mr. Cooley testified (Rec. Vol. III, p. 1716) as follows:

The Illinois and Michigan Canal, as it was finally completed under the canal trustees, had a summit level eight feet above Lake Michigan, and it was fed in ordinary seasons from the Des Plaines River and by a feeder through the Sag Valley and the Calumet River at Blue Island.

That was known as the Shallow Cut Plan.

A dam was built across the Calumet River at an elevation of eleven feet above Chicago datum. This was insufficient in the dry seasons, and a Dutch wheel or lift wheel was erected at Bridgeport, at the forks of the Chicago River and at the head of the canal for the purpose of supplementing the feed water of the canal, and in such seasons that was sufficient in cleansing the Chicago River and as I have stated, these were operated for that purpose in the later fifties.

But in 1863, after Chicago had established a Board of Public Works, the Chicago River became very offensive. An erysipelas epidemic occurred, which was co-terminus with the South Branch and was attributed to the blood and other matters from the slaughtering houses, and it was depicted on the spot maps as the "Valley of Death."

The Board of Public Works at that time made an arrangement with the Canal Trustees by which the Bridgeport Pumping Station should be operated and the city would contribute to the cost of doing so for the purpose of cleansing the Chicago River; and that arrangement continued up to the time that the canal deepening was completed in July, 1871.

That was completed then on the Deep Cut Plan.

On April 16, 1865, the State of Illinois passed an act to provide for the completion of the Illinois and Michigan Canal upon the plan adopted by the state in 1836 which authorized the City of Chicago to deepen the Illinois and Michigan Canal

in order to purify and cleanse the Chicago River by withdrawing a greater quantity of water from Lake Michigan. Said act is as follows (Rec. Vol. VIII, pp. 70, 71):

"An Act to Provide for the Completion of the Illinois and Michigan Canal upon the Plan Adopted by the State in 1836. (Approved February 16, 1865, in Force April 16, 1865.)

(Preamble.)—Whereas, it has been represented that the City of Chicago, in order to purify or cleanse Chicago River, by drawing sufficient quantity of water from Lake Michigan, directly through it, and through the summit division of the Illinois and Michigan Canal, would advance a sufficient amount of funds to accomplish this desirable object; and,

Whereas, the original plan of the said canal was to cut down the summit so as to draw a supply of water for navigation directly from Lake Michigan, which plan was abandoned for the time being, after a large part of the work had been executed, only in consequence of the inability of the State to procure funds for its further prosecution; and,

Whereas, under the law creating the trust the plan of the summit division of the canal was changed, the level being raised so as to require the principal supply of water to be obtained through the Calumet feeder, subject to serious contingencies, and by pumping on to the summit with the hydraulic works at Bridgeport; now, therefore,

(Summit Division to Be Completed.)—Section 1. Be it enacted by the People of the State of Illinois, represented in the General Assembly: That to secure the completion of the summit division of the Illinois and Michigan Canal, upon the original 'deep cut' plan, with such modifications and changes of line, if necessary, as will most effectually secure the thorough cleansing or purification of the Chicago River, and facilitate the execution of the work, the City of Chicago, through its constituted authorities, may at once enter into an arrangement with the board of trustees of said canal, with a view to the speedy accomplishment of the work.

(Opening and Closing of Canal.)—2. The canal shall not be constructed of a less capacity than the plan adopted by the canal commissioners in 1836, nor shall the work of deepening it be prosecuted so as to materially interfere with the navigation. By consent of the board

of trustees, however, the navigation may be opened later and closed earlier than usual in former years, but it shall never be diminished to a less time than six months.

(Right of Way.)—3. It shall be lawful for the City of Chicago to enter upon and use any lands which may be necessary for the right of way for said canal, if the route should in any part vary from the present line of canal, and to take and use any materials of any description, necessary for the prosecution of the work contemplated, along the line thereof; the value of the same to be determined in the mode provided by the general laws of this State."

February 12, 1867, in an official report made to the Chief of Engineers of the War Department of the United States by Major Gen. J. H. Wilson, United States Engineer, who had been instructed to make a survey of the Illinois River, pursuant to the Act of Congress, June 23, 1866, Major Gen. Wilson said (Rec. Vol. IV, p. 2242):

"The Illinois River seems to have been specially designed by nature as the line by which the waters of Lake Michigan are to be connected with those of the Mississippi. Its two principal tributaries, the Des Plaines and the Kankakee, rising the one in Wisconsin and the other in Indiana, run for many miles almost parallel with the western and southern lake shore, and are separated from the lake basin by a ridge of insignificant height and width. A moment's consideration will show that at no remote period the waters of the lake must have been carried off by these streams as well as by the St. Lawrence. It has been already shown that the highest point of this ridge on the line of the Illinois and Michigan Canal is only 14 feet above the ordinary level of the water in the Chicago River at Bridgeport, and it is by no means certain that a lower line may not be found by a careful survey. In fact, it is the opinion of many old contractors who are well acquainted with the entire region, that a much more favorable location for a steamboat canal can be obtained from Bridgeport to Section 46 of the present canal, by following the line through Mud Lake. But let this result be as it may, the data herein contained, together with the existence of a canal of limited capacity already in operation, demonstrate beyond a doubt that the waters of the lake may be carried into the Illinois River through a navigable

channel of any required dimensions, and at a cost which cannot be regarded as excessive when the objects to be obtained are duly considered.

As all the lockage will be descending from the lake, it is apparent that the only limit to the capacity of the canal will be that which depends upon the velocity with which the locks can be filled and emptied. The summit will be inexhaustible, and this cannot be said of any other practicable line of water communication between Lake Michigan and the Mississippi."

The Deep Cut plan for the Illinois and Michigan Canal was carried out and completed in 1871 by the City of Chicago, to take more water from Lake Michigan by gravity as stated by Mr. Cooley (Rec. Vol. III, pp. 1718, 1719) as follows:

Meantime, a Commission had proposed the deepening of the Illinois and Michigan Canal on the original deep cut plan; and in 1865 an enabling act was procured from the General Assembly which authorized the City of Chicago to deepen this canal on the original plan for sanitary purposes; and the City of Chicago did so, and expended thereon about $3,000,000 in cash and opened the same in July, 1871.

Pursuant to the River and Harbor Act of 1875, Col. J. N. Macomb, made a report to the Chief of Engineers and by him transmitted to Congress, in which he said (Rec. Vol. IV, pp. 2243, 2244, 4748-4750):

"Report of Colonel J. N. Macomb, Corps of Engineers.

Rock Island, Ill., January 25, 1875.

General: I have the honor to present herewith the report of Mr. F. C. Doran, assistant engineer, who was charged by me with the duty of making the surveys and estimates for the Hennepin Canal Route, and particularly for the extension to Chicago.

In considering the Hennepin Canal as a part of the water-communication desired for connecting some point of the Mississippi River near Rock Island, with Lake Michigan, at Chicago, it appears that the basin at Hennepin is about 100 feet below the level of the Mississippi River in the vicinity of Rock Island, and nearly 140 feet below the level of Lake Michigan.

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The improvement of the eastern portion of the Illinois and Michigan Canal involves the further cutting down of the summit level and enlarging the waterway so as to afford an unfailing supply of water from Lake Michigan for the improved Illinois River.

Report of Mr. F. C. Doran, Assistant Engineer.

Rock Island, Ill., January 9, 1875.

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Colonel: I have the honor to submit the following report upon the examination and survey of a route for a canal between Lake Michigan and the Mississippi River, together with the survey of a portion of the Illinois River. * * *

2247 Page 97.

Prior to the year 1872, the summit-level of the Illinois and Michigan Canal was some 8 feet above the standard-level of Lake Michigan, and the quantity of water requisite to maintain navigation on the summit-level of the canal was supplied from Lake Calumet by a feeder and from the Chicago River by expensive pumping-machinery.

Sometime during the year 1866, the Board of Public Works of the City of Chicago entered into a contract with the State to cut down and reduce the summit-level of the canal to the elevation of the lake.

The object of this work on the part of the city authorities was to obtain an outlet for the south branch of the Chicago River; that being a receptacle for the sewerage of a large part of the city.

This contract was satisfied, the work completed, and navigation on the canal resumed July 18, 1872. The exertions and labors of the city to rid itself of a nuisance were not in vain; the residents of the city were relieved of a truly great evil, and the problem of securing a permanent and ample supply of water for the canal was practically solved.

Happy as such results were, the work, from its con-
2248 tracted dimensions afforded only partial relief; and recent drainage improvements in the vicinity of the city have proved quite detrimental to and interfered very seriously with the city's purposes and interests in respect to this work.

In view of the many benefits that would accrue to the city in case of a further enlargement of this canal, as contemplated, the question is believed to be pertinent, will the city assume her portion of the cost of such enlargment?

One of the important duties of this survey was to determine accurately the volume of water to be drawn from the lake to maintain a depth of water in the river after it should be improved.

Experience on the summit-level of the canal, since it has been supplied from the lake, proves conclusively that the varying stages of water in the lake very materially affect navigation on this part of the canal. This fact is more noticeable during periods when the direction of the wind is parallel with the axis of the canal; the fluctuations in the elevation of the surface of the water being directly traceable to this cause."

In an extract from U. S. Chief of Engineer's Report, 1880, made pursuant to Rivers & Harbors Act of March 3, 1879, Appendix EE, Page 1995, survey of Illinois River, Major G. J. Lydecker said (Rec. Vol. IV, p. 2248):

"United States Engineer Office.

Chicago, Ill., May 10, 1880.

General: I have the honor to submit the following report on a survey of the Illinois River, executed in pursuance of the act of Congress making appropriations for the improvement of certain rivers and harbors, approved March 3, 1879.

The question of a through line of water communication from the Mississippi to Lake Michigan, via the Illinois River, has been before Congress since an early date. In 1822, the State of Illinois was authorized to make through the public lands of the United States a route for a navigable canal connecting the Illinois River with Lake Michigan, and between that date and 1854, Congress had granted to the State 321,760 acres of land to assist in its construction. The canal was first opened to navigation in 1848, its cost up to that time being $6,409,509.95; since then the state has spent a great deal towards its enlargement and maintenance. In the meantime several surveys, having in view the improvement of the Illinois River, have been made, the first in 1838 by Capt. Howard

Stansbury, Topographical Engineers; the next of any considerable importance was made under the direction of General J. H. Wilson, in 1866, the object of which was 'to obtain such specific and accurate information in
2249 regard to obstructions to navigation in that river as will enable you to submit estimates for its improvement, so that the largest boats navigating the Illinois and Michigan Canal, and steamboats drawing four feet of water, will be enabled to pass through the river to St. Louis during the season of extreme low water without breaking cargo.'

His report on this survey led Congress to direct a more complete survey in 1867 (act approved March 2), the object of which was to prepare plans and estimates 'for a system of navigation by way of the Illinois River, between the Mississippi and Lake Michigan, adapted to *military, naval,* and *commercial* purposes.' This duty was committed to a Board of Engineers composed of General J. H. Wilson and Mr. William Gooding, Civil Engineer, the latter having been for a long time the Chief Engineer of the 'Illinois and Michigan Canal.' The report of this Board was submitted to the Chief of Engineers under date of December 17, 1867, and is published in his annual report for 1868, pages 438 to 468. It recommended that the Illinois River be improved by the construction of five locks and dams, creating thereby a slack water system with a navigable depth of 7 feet at the lowest stage, from the mouth of the river at Grafton to Utica, 227 miles above; the lock chambers were to be 350 feet long, 75 feet wide, and the estimated cost of the entire work was $1,953,600. To complete the through line to Lake Michigan, an enlargement of the canal was recommended, the estimated cost of this enlargement being, in round numbers, $16,250,000.

No appropriations were made by Congress to carry out the plan of improvement above indicated, but the State of Illinois, in substantial conformity with that plan, has constructed *two* of the proposed locks and dams (viz, at Henry and Copperas Creek), at a cost of $747,747, while the annual appropriations by Congress for improving the Illinois River (aggregating to date $589,150) have been applied mainly to ameliorating its navigable condition by dredging channels through the worst bars, and constructing dikes and wing-dams for contracting the waterway. For a more detailed description of these operations I would respectfully refer to my report dated

August 30, 1878 (which was published as House Ex. Doc. No. 81, 45th Congress, 3rd Session), a copy of which is transmitted herewith.

The several surveys and reports above referred to
2250 gives so complete a description of the physical characteristics of the route, and present the arguments in favor of its improvement so forcibly, that it seems unnecessary to extend this report by repeating what has been so fully set forth before; accordingly it is limited to a brief outline of operations on the last survey, and a statement of what is necessary to complete the improvement of the river.

A substantial improvement having been effected from its point of connection with the canal down to Copperas Creek Lock, it was decided to apply the $5,000 allotted for our survey to the remainder of the river, viz, from Copperas Creek to Grafton, where the Illinois empties into the Mississippi.

* * *

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The laws of Congress require that reports of surveys of rivers and harbors shall contain 'statements of all existing facts tending to show to what extent the general commerce of the country will be promoted by the several works of improvements contemplated by such examinations and surveys.' In fulfillment of this requirement, it seems only necessary to note that the improvement of the Illinois River, supplemented by the enlargement of the Illinois and Michigan Canal as heretofore proposed, will furnish a reliable and commodious channel of water communication from the Mississippi River to the Northwestern lakes; by this time the vast Mississippi Valley, and all the country tributary thereto, is brought into direct water communication with Lake Michigan, at the great City of Chicago, with its flood of commerce eastward and westward; the route exists as a practicable one of considerable importance today, and the question is simply one of enhancing its value by increasing its capacity to a degree commensurate with the important interests involved.

Other routes have been examined and studied with care but neither of them occupies so central a position, can be built so soon, and with such certain results, maintained so economically, nor utilized through so great a part of the year.

Considering this simple statement, the facts so fully set forth in previous elaborate reports, and noting the wonderfully rapid development of the entire western country, it would seem that nothing further is necessary to indicate 'to what extent the general commerce of the country will be promoted' by the contemplated improvement, nor to show how desirable it is that the work should be accomplished with the least delay practicable."

In 1881 the State of Illinois passed a resolution authorizing City of Chicago to furnish the canal with 60,000 cubic feet of water per minute by means of pumps. (Rec. Vol. VIII, pp. 72, 73; this Narrative, p. 49.)

January 30, 1887, the Drainage and Water-Supply Commission rendered a report, in which the resolution of the City of Chicago City Council authorizing the Commission and the appointment by the mayor are set out as well as the findings of the Commission.

Said report is as follows (Rec. Vol. I, pp. 496-522):

"Chicago, January 30, 1887.

To the Honorable Mayor and City Council of the City of Chicago:

Gentlemen: On January 27, 1886, your honorable body passed a resolution authorizing the creation of a drainage water-supply commission. After being amended, February 23, it read as follows:

Whereas pure water and scientific drainage are necessities of this community, and the people demand a system of water supply and drainage adequate to meet the requirements not only of the present, but of years to come, nor will any temporary expedient or makeshift satisfy them; and

Whereas a thorough and permanent system of supplying pure water to our citizens and caring for the drainage of the municipality can not be paid for out of current taxation, therefor it is desired that a plan shall be devised and perfected before the next meeting of the legislature to the end that necessary legislation may be had.

For the purpose of carrying into effect the objects sought, there is recommended the appointment by the Mayor of a commission to consist of one expert engineer, whose reputation is so high that his opinion and report will command the respect of the community, and with him one or two consulting engineers of like experience in engineering and sanitary matters. The duty of this drainage and water supply commission, made up as above set forth, should be to consider all plans relating to drainage and water supply which may be brought to its attention; to make such examinations and investigations and surveys as may be deemed necessary; to collect all information bearing on this problem; to consider all recent developments in the matter of sewage disposal, and their
497 application to our present and future needs; to consider and meet necessity of increasing our water supply and of protecting the same from contamination; to remedy our present inadequate methods of drainage and sewage disposal; to consider the relations of any system proposed to adjacent districts, and whether there may not be a union between the city and its suburbs to solve the great problem; to determine the great question as to the interest which the State and the United States may have in the disposal of sewage by way of the Illinois River, and to devise plans to meet any objections thereto, if such a system shall be thought best; and in general to consider and report upon any and all things which relate to the matter of water supply and drainage of the City of Chicago.

The commission should report on the whole matter committed to it in the most full and comprehensive manner, with maps, plans, and diagrams complete, and accompany the report with estimates of the first cost and annual requirements for the maintenance of the system proposed.

The report of the commission should be made as early as practicable, and not later than the convening of the next session of the Illinois legislature, in January, 1887.

In consideration of the foregoing, be it,

Resolved, That the Mayor be, and is hereby, authorized and directed to employ on behalf of the city one expert engineer of reputation and experience in engineering and sanitary matters, at a salary not to exceed $10,000 per annum, and also to employ such consulting engineers, not exceeding two in number, as may seem necessary, and such assistant engineers as may be re-

quired, all to be paid according to services rendered, for the purpose of carrying out the objects set forth in the preamble hereto. For the fees of said assistant engineers and for all expenses connected with said work there shall be allowed not to exceed the sum of $20,000. All fees, salaries, and expenses connected with said work shall not exceed in the aggregate the sum of $30,000, and the same shall be paid from the water fund of the city upon vouchers audited by the Mayor and city comptroller.

In accordance with the terms expressed herein his honor, Carter H. Harrison appointed Rudolph Hering as chief engineer, Benezette Williams and S. G. Artingstall
498 as consulting engineers, who together should constitute a commission. Mr. Hering entered upon duty March 28, Mr. Williams September 17, and Mr. Artingstall December 21, 1886.

The investigation designated by the resolution was a formidable one, composing no less a task than the consideration of the entire subject of the future water supply and drainage of Chicago. It appeared doubtful from the beginning that a report such as was demanded could be furnished within the specified time, for the simple reason, if for no other, that observations of the lake phenomena and of the flow of certain rivers should be extended over at least one year, covering four consecutive seasons, in order to draw satisfactory deductions.

But the large amount of work alone that was asked for made it impracticable to present a complete report in so short a time. It was expected, however, that results could be reached sufficient to indicate the character of legislation required to carry out any project that might be determined upon, and that therefore a preliminary report having this end in view could be made at the stated time, leaving to a later date the presentation of a report outlining the detailed features of the scheme recommended and embracing the minor results of the entire inquiry.

The present communication is to cover the ground indicated for the preliminary report, and besides containing the conclusions reached regarding the main features of the proposed project, it contains also a brief review of the work done during the past year and of what still remains to be done.

The month of April was devoted to a general examination of the subject of the territory to be investigated, and

of the various suggestions that had been made toward effecting a solution of the problem.

The examination disclosed the fact that the city is sometimes greatly suffering from the offensive condition of parts of the Chicago River and its branches, caused by the discharge of sewage into the same, and from the occasional contamination of its water supply, brought about by the discharge of the polluted contents of the river into the lake. It also disclosed the fact that almost every conceivable way of dealing with these questions had been suggested and in some forms applied during the past thirty years.

[The problem therefore demands the attainment of two
499 ends—the protection of the water supply and the removal of the river nuisance. As the water must be taken from the lake, it is evident that both its pollution and the objectionable condition of the rivers should be prevented by a better disposition of the sewage. It is, therefore the latter question which constitutes the main object of this investigation.

Among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy of an extended consideration, namely: A discharge into Lake Michigan, a disposal upon land, and a discharge into the Des Plaines River. The preliminary work has, therefore, been confined to these three projects, and was classed as topographic, hydrographic, and miscellaneous.]

At the time when the present commission began its labors the topographical work had already received some attention. Surveys were being made of the Des Plaines River from Bridgeport westward under the direction of Mr. Artingstall, city engineer. These surveys were continued, and have now been completed as far as Joliet. They include contours of the entire valley and borings to rock between Bridgeport and Lemont. In order to understand the hydrography of the Des Plaines Valley above the point where the Chicago sewage could be discharged into it, and also to ascertain the probable magnitude and effect of floods in the river, a survey was made of its bed as far north as Northfield township. To determine the area of the basin its entire divide was located. To ascertain the practicability of diverting the flood waters from the upper portion of the Des Plaines and North Branch water sheds directly into the lake, and thus avoiding the difficulties which would arise from their passing

through the Chicago River, all feasible lines were surveyed. Finally, a few levels were taken of the area adjoining the city wherever no connected levels existed to show the general topographical features of the territory over which the future city will spread out and from which the drainage will require artificial removal.

[The hydrographic work consisted in ascertaining the flow of the Des Plaines River, the rainfall upon its area, its flood discharges, the character of its bed, and the probable effect of discharging the Chicago sewage into it when diluted by a large and constant stream of water from the lake. It consisted, further, in examining the
500 nature of the currents in the lake and in studying the rise and fall of its level, and in ascertaining the amount and character both of the sewage discharged into it and of the deposits in the river and lake in front of the city to determine the effects of the present sewage disposal.

Inquiry and surveys were made to show the feasibility of purifying the Chicago sewage by filtration on land.] Land damages were carefully estimated for the different schemes; existing records were searched concerning borings and excavations made in and about the city, so that the practicability of certain lines of tunnels could be discovered; the probable growth of the city and its suburbs, as well as the probable distribution of the future population, received a careful attention, and, finally, a large number of data were compiled which pertain to the existing works of water supply and sewerage in Chicago and the adjoining towns.

In reporting the result thus far gained we will present them in the order most convenient for discussion, but before doing so will briefly describe the present manner and effect of the sewage disposal, as shown by this investigation.

Present Sewage Disposal.

The sewage works of Chicago and suburbs have been planned on what is called the combined system, in which the sewers serve for the removal both of sewage and rain water. In the town of Evanston they empty into the lake. In the town of Lake View they partly discharge into the lake and partly into the North Branch. From the north and west divisions and part of the south division of Chicago, the drainage enters the Chicago River and its branches, and from the remaining part of the

south division it flows into the lake at three outlets, situated respectively, at Twelfth, Twenty-second, and Thirty-fifth streets. The sewers of Hyde Park discharge into the lake excepting those of Pullman, where the sewage is disposed of on land. The town of Lake, including the Stock Yards district, drains into the South Fork of the Chicago River.

When the sewage works of this city were designed, in 1856, by Mr. E. S. Chesbrough, it was apprehended that ultimately some means would have to be found to change the water in the river from time to time or to keep the sewage entirely out of it. The first step toward improv-
501 ing the condition of the river was taken by deepening the Illinois and Michigan Canal, so as to cause a current from the lake to the Des Plaines River at Lockport. The next step was the building of the Fullerton avenue conduit in order to produce a circulation in the North Branch; and the last step was the erection of the canal pumping works to increase the flow in the river, which had become greatly polluted.

The influence of these works is confined to the main river and its north and south branches. But the south fork of the latter, receiving a large amount of sewage from Chicago and the town of Lake, and charged with the waste from the Union Stock Yards and packing houses, has no artificial means for a circulation of its water, and as a consequence is in a condition of great filthiness.

The accompanying diagram (a) has been prepared to show the present pollution of the Chicago River and its branches during the time when all of their water is discharged into the canal by the Bridgeport pumps. On the left are shown the main river and the north branch, one above the other, their combined waters forming the south branch, and reaching Bridgeport on the right, where they are lifted into the canal.

At the latter point the south fork is shown as joining it. The shaded portions indicate the amount of sewage entering and passing the respective points, and the blank portions the lake water diluting it. The degree of dilution is shown by the relative areas. It diminishes in the north branch from Fullerton avenue to the south branch, and becomes still less toward Bridgeport, and finally receives the foul waters of the south fork.

The depth and character of sewage deposits in the river and harbor, as might be expected, vary consider-

ably. They are not great in the track of the vessels, but increase toward the docks and quieter portions of the slips, where they reach a depth of from one to four feet. While the deposits in the channel are of a heavier kind, such as cinders, those in the docks are mostly a foul mass of decomposing organic matter. No form of life is found to exist above Clark street bridge as far north as Clybourn place and as far south as Ashland
502 avenue. The effect of this condition of the river is to endanger the purity of the water supply whenever the river, with its accumulated deposits, flows into the lake, which occurs when the rain water that finds its way into the river exceeds the amount pumped into the canal. If this excess is great, as in the spring and occasionally in the summer months, the contamination of the lake is considerable, and must constantly increase.

From the foregoing it is seen that the present method of disposal of the sewage from Chicago and its suburbs is partly by discharging it into Lake Michigan, but mainly, except during floods, by discharging it into the Des Plaines River.

Future population.

The first question which requires an answer, and upon which many of the subsequent inquiries depended, was the population which it is economical and advisable to consider at present, and the extent of territory upon which such a population will be located.

The growth of Chicago has been frequently quoted as phenomenal. Estimates made thereof for various purposes have turned out to be rather under than over the actual result.

It is taken for granted that Chicago and its suburban towns will have to dispose of their sewage so that the water supply for the entire community residing near the lake from the south line of Hyde Park to the north line of Evanston will be guarded against pollution by the sewage from any one of its separate communities. For this purpose the whole populated area within the above limits is considered as forming one city with a common interest.

The growth of this metropolis was obtained partly from the United States census and partly from the school census of Cook County, which gave a record up to the summer of 1886. In order to forecast the probable ratio of the future increase it was desirable to compare this

growth with that of other cities. By considering the ratio in increase elsewhere, and including the natural suburbs
503 of each city, a fair and instructive basis of comparison was obtained; and by realizing the respective natural advantages for growth in each of the communities the probable ratio for Chicago was determined with a satisfactory degree of exactness.

The accompanying diagram shows the results of this comparison. It represents by curves the population of the largest cities in the country since 1790, not as usually quoted from the census, giving the inhabitants on certain arbitrary areas fixed by law, but as virtually making up the population of the respective municipalities, by including adjacent towns and natural suburbs, the only method which enables the true growth of the great cities to be recognized. For instance, the New York center naturally includes Brooklyn, Jersey City, Hoboken, Newark and other suburbs, and Chicago the entire territory from Hyde Park to Evanston.

The diagram indicates that the character of growth of the different cities permits them to be divided into two distinct classes. Philadelphia, Boston, St. Louis and Cincinnati show very much the same character of increase, and represent by comparison the more conservative communities. New York and Chicago, on the other hand, while showing a remarkable resemblance to each other, form quite a contrast to the rest of the cities, and might be called the more progressive communities. The diagram finally indicates the time when the Chicago curve, which was the lowest one prior to 1864, intersected in turn those of St. Louis, Cincinnati, Boston, and there is a high degree of probablity of its intersecting the Philadelphia curve in or before 1891—*i. e.*, in four years from now—after which Chicago will be the second largest center of population in America.

As it is not practicable in so young a city as Chicago to forecast a definite line of growth, it is preferred to give the probable maximum and the probable minimum between which the true line will most likely be contained. The minimum line represents a growth resembling that of New York and the maximum line assumes the ratio of increase per decade to be consistent instead of gradually decreasing as in most other cities. The result indicates that the population of Chicago and suburbs will be 2,500,000 between the years 1905 and 1915, or about three times the present population is 18 to 28 years.

In providing public works for large communities it
504 must be borne in mind that it is economical to invest only such sums as will bring a return within a certain number of years, leaving expenditures for benefits that will be realized only at a later time to a later generation. This fact, together with the probable growth of Chicago, shows it to be economical and judicious at present to plan works sufficiently extensive to dispose of the sewage of not less than 2,500,000 inhabitants.

In addition to the population the area that will be occupied by it has to be determined. While this is a far more difficult task, owing to the many accidental causes influencing the distribution of the population, it is possible nevertheless to outline the area sufficiently close for the present purposes.

The future metropolis, with a population three times as great, will be distributed along the lake from South Chicago to Evanston, and will reach inland to the Blue Island Ridge on the south to the Des Plaines River in the center, and to the higher parts of Niles Township in the north. Outside of these general limits, a more or less dense population will extend for some distance along the lines of railroad.*

As inferred above, it is proper to consider at this time the wants of the population that will reside upon this entire territory.

Discharge of the Sewage into Lake Michigan.

To discharge the sewage from cities into comparatively large bodies of water is not only the usual, but often the best method for its disposal. Dilution and dispersion thoroughly expose it to the action of the oxygen contained in both the water and the superincumbent air; it is thereby gradually oxidized. Where the body of water is a large river with a strong current, the best conditions for such purification are found. Where it is a lake in which the circulation is slight and irregular, the efficacy of the method is less and depends for its success on the character of the currents and the relative amount of sewage to be discharged into it.

The hydrographic surveys of the lake made during
505 the past season were therefore partly for the purpose of

*Here occurs a diagram showing the "growth of several population centers in the United States," not here reproduced.

ascertaining, if possible, the laws governing the currents, so that we would know their effect in dispersing the sewage discharged into the lake. The trend of the shore currents was actually ascertained by daily recording the direction of spar buoys placed at the Chicago waterworks crib, at Michigan City and at St. Joseph. A large number of bottle floats were thrown into the lake at different points and different times for the same purpose. They were partly single surface floats and partly double, the lower one being placed at varying depths, according to the depth of the water. More than half of them have been picked up and returned, with place and date noted. The currents were also observed by means of large can buoys from an anchored tugboat at different points in the lake, extending from Hyde Park to Evanston, about six miles from the shore. Two general lake trips were undertaken, one to St. Joseph and back to Grosse Point, and another one parallel with the shore around the head of the lake.

When the observations are completed and compiled in detail, some valuable information will be available for the question of water supply. Light will be thrown on the movement of the water under different winds and the sudden changes of temperature of the water at the crib and on the turbidness of the same.

The following results have a bearing on the question of sewage disposal: Where not affected by local conditions, the currents practically go with the winds in water of moderate depth and quickly respond to any change. In deep water also the surface currents run with the wind, but at the bottom and even at mid-depth the direction is usually different. The prevailing current along the shore of Cook County during the past summer has been observed to be toward the north, but it is possible that this result may be different during the winter months. In the open lake wave action seems to be effective in preventing the permanent deposits down to a depth of about 60 feet; inside of the breakwater sewage deposits are found on the bottom.

The general deduction from these results is clear that, as no constant current exists which would carry the sewage away in one direction, it should be discharged into the lake at one end of the future city, while the water supply should be obtained as far away from it as prac-
506 ticable towards the other end, a conclusion which is being acted upon in the other large lake cities. The proper place from which to bring the water would be opposite

Grosse Point, and the sewage discharge should be east of Hyde Park. While it might be practicable to allow the sewage in its crude form to enter the lake under such conditions for many years, the necessity would arise later for clarifying it at least partially previous to its discharge. It could not be allowed to run into the river as at present, but the dry weather flow and a considerable amount of storm water would have to be intercepted and carried to the outfall through many miles of special conduits. This entire quantity would have to be raised by pumping in order to get sufficient head to empty into the lake, while the diluted sewage during storms, in excess of the capacity of the intercepting sewers, would be allowed to discharge directly into the river.

The water supply would have to be brought from Grosse Point in large conduits to the several pumping stations scattered over the city and its present suburbs. The circulation of the water in the Chicago River and branches would have to be maintained practically as it is at present, because the removal merely of the dry weather flow of sewage would not altogether prevent is pollution.

Disposal on land.

We shall not at this time enter into a general discussion of the principles underlying land purification of sewage, or make historical references showing the success or ill success of the method as practiced elsewhere. We will simply state that with good management under ordinarily favorable conditions a disposal on land proves satisfactory, so far as the purification of the sewage is concerned, and that with proper conditions in the way of good markets and a favorable soil and climate sewage farms can be operated on a large scale after the sewage is delivered upon the same without financial loss.

In speaking of a sewage farm of the magnitude required for the metropolitan area of Chicago, it is not understood as being land devoted primarily to the raising of crops, using the sewage only when and where it
507 would most promote the growth of vegetation. The primary object would be the purification of the sewage on an area of land as small as could serve the purpose. Technically speaking, the sewage disposal would be by means of intermittent filtration rather than irrigation. To carry out such a scheme for Chicago involves the following:

(1) The acquirement of sufficient land suitable for the purpose.

(2) A comprehensive system of intercepting and collecting sewers carrying the sewage to the farm.

(3) Pumping works of a capacity to handle all the dry weather flow of sewage and a certain proportion of storm water.

(4) A thorough underdrainage, leveling and preparing of beds for the filtration areas.

(5) A system of underground conduits and surface carriers for distributing the sewage over the ground and a system of open ditches for removing the purified water to the nearest water courses.

(6) Buildings, roads, and a complete farming outfit.

(7) An organization for properly distributing the sewage, for carrying on the farming operations, for conducting the business of disposing of the crops in the best market.

In making estimates for the size of intercepting sewers, conduits, pumps and area of land required, we have used as a basis a population of 2,500,000 people, with an average dry weather sewage discharge of 150 gallons, or 20 cubic feet, per head daily, and made provision for storm water equivalent to one-fifth of an inch in 24 hours over all portions of the district now drained or likely to be drained by a combined system of sewers, allowing surplus water to escape in the rivers and lakes.

The dry weather flow of sewage would therefore be 50,000,000 cubic feet per day, and the maximum flow of storm water 65,000,000 cubic feet per day, making a total maximum discharge of 115,000,000 cubic feet.

From an examination of rainfall tables we conclude that the annual amount of storm water that would be carried off by such an intercepting system would range from 9 to 12 inches, an average of which in round numbers may be taken at 40,000 cubic feet per acre per annum over the area drained by a combined system of sewers. It is practicable, however, to exclude the storm water from the sewers over a large portion of the future
508 city by adopting the separate system of sewerage. The area north of the town of Jefferson and of the middle of Lake View may be treated to advantage in this way,

and also a large portion of Hyde Park, Lake Calumet and other adjacent towns.

Assuming that the area which does not allow the storm water to be entirely excluded is 140 square miles, the average daily amount becomes 10,000,000 cubic feet, which gives, when added to the sewage, 60,000,000 cubic feet, or 24 cubic feet per head of population per day to be provided for on the farm.

As the amount of land required to purify sewage can only be determined by experience, and as this has been very limited in our own country, we are forced to rely mainly upon that of Europe. Without going into details at present, we will simply state that a fair consensus of this experience justifies us in the conclusion that from 10,000 to 15,000 acres of land would be required to dispose of the sewage from the entire metropolitan area.

The only available territory for sewage filtration in the neighborhood of Chicago consists of two sandy ridges in the Town of Thornton, extending across the state line into Indiana, and in a sandy ridge crossing the Town of Niles. The soil is quite favorable, but the character of the surface is such that the necessary preparation to make it suitable for filtration beds would be comparatively expensive. An enormous cost is, however, represented by the fact that the sewage would have to be collected by large intercepting sewers, lifted altogether some 90 feet, and carried about 20 miles before reaching the farms. We therefore consider such a project entirely impracticable.

The land treatment can only be seriously thought of in connection with the sewage disposal from the smaller areas mentioned above and comprising the extreme northern and southern parts of the future metropolis. The drainage of parts of Evanston, Lake View and Niles might be taken to the sandy ground in the latter town, and that of the Calumet region to the sandy ridges in Thornton, should this method be found most advantageous when compared with others.

The preliminary investigation made for this purpose consisted in an examination of the grounds in the projection of a farm, and in an estimate of the cost of preparing the same and delivering the sewage to it by intercepting sewers and conduits.

Discharge of the Sewage into the Des Plaines River.

509 [A third solution of the drainage problem is rendered practicable by the fact that the divide between Lake Michigan and the Mississippi Valley lies about 10 miles west of Chicago, with so slight an elevation that it is not a difficult matter to carry the sewage from the city westward into the Des Plaines River, and thence into the Mississippi River.] The method of disposal, as previously explained, is in fact mainly the present one, most of the sewage now being carried across the divide by the Illinois and Michigan Canal.

There are two low depressions between the future metropolis and the Des Plaines River—the Mud Lake Valley, with the present canal, and the Sag Valley west of Lake Calumet. Neither is more than 10 feet above the lake, nor do they present any engineering difficulties for canal construction. It is therefore quite feasible to carry all the drainage from the territory ultimately to be occupied by the metropolis, extending from Lake Calumet to Evanston, into the Mississippi Valley through these depressions, avoiding thereby all possible lake pollution and permitting the supply of water to be drawn from any number of convenient points in front of the city.

The possibility of this solution was recognized as early as 1856 by Mr. E. S. Chesbrough, and the first step towards its adoption was taken, as already mentioned, by turning the sewage into the Illinois and Michigan Canal. Not until quite recently, however, has it become practicable to consider the construction of a special waterway for sewage removal, because when the population was smaller the expense of the undertaking was too great.

The sanitary requirements demand a flow of water large enough to dilute sewage sufficiently to make it inoffensive along the river at all times. Beyond this, any increase in the size of the channel to provide for the storm water which naturally enters it should be kept at a minimum. A glance at the map and an examination of the ground show the possibility of diverting the greater part of the storm water from the metropolitan district without serious difficulty. Both branches of the Calumet River can be diverted west of the Indiana state line into Wolf Lake, and thence into Lake Michigan. The Des
510 Plaines River can have its flood water diverted into the North Branch near the north line of the Town of Jefferson, and the combined waters can be led from Bowmanville directly into the lake. Salt Creek, a branch of the

Des Plaines River, can readily be turned southwardly near Western Springs, through a water course known as Flag Creek, at one time evidently its old bed, discharging into the Des Plaines opposite Sag, and thus reducing the necessary storm water capacity in the new channel between Sag and Summit.

In order to determine the probable quantity of flood water which can thus be excluded, it was necessary to ascertain the maximum flood discharges from all the watersheds in question. This requirement called for a gauging of Des Plaines, North Branch and Calumet Rivers; a gauging of the rainfall, which is a measure of the stream flow; a survey of the watersheds and an examination of the river channels. It was also necessary to make a reconnoissance of all possible lines for diverting the Des Plaines, the North Branch, the Calumet River and Salt Creek, and a survey of those which were most important.

The results indicate that each one of these diversions is both practical and economical. By adopting the "separate system" of sewerage for the territory lying north of the proposed Bowmanville channel, the surface drainage from this territory can be safely turned into the lake.

A second branch of the investigation extends to the elements governing the proper size of the waterway from which a large proportion of the storm water has been excluded. The area still draining into it will consist largely of paved streets and roofs, allowing of no absorption and shedding the water rapidly. It requires a careful consideration to determine the maximum quantity of water that may enter the proposed channel, and for which an ample allowance must be made to prevent a back flow of the polluted water to the lake.

The proper degree of sewage pollution in the new channel demanded a careful investigation. When sewage is mingled with a sufficiently large quantity of water it not only becomes inoffensive, but readily finds the oxygen which gradually purifies it. When the surface is covered with ice a greater dilution is necessary for this purpose than at other times when there is a constant
511 replenishment of oxygen from the air. The proposed waterway should, of course, provide immunity from offense at all times.

The information upon which definitely to decide this question will be given in the final report, as the data have not yet been all collected, owing to the necessity of

making actual tests of the oxidation of the canal water under the ice, which is being done for the use of the commission by Dr. J. H. Rauch, secretary of the State Board of Health. The summer conditions are presented in his late report on the water supply and sewage disposal of Chicago. The result of these analyses will be compared with those of other streams that are also polluted with sewage in order to show the rate of oxidation with varying degrees of dilution and aeration.

For the purpose of estimating the cost of the water channel we have assumed 3,600 square feet for the cross section and a velocity of the water 3 feet per second, or 2 miles per hour. This gives a discharge of 600,000 cubic feet of water per minute, or 24,000 cubic feet for each 100,000 persons, which we believe equal to the maximum requirements of a population of 2,500,000 people.

A third branch of the inquiry covers the selection of routes for the proposed canals.

Between Chicago and Summit three lines are practicable—one following the west fork and Ogden ditch, and another extending from the southwestern end of the south fork in a westerly direction to the Ogden ditch, and thence to Summit, and a third being an enlargement of the present canal. We are of the opinion that eventually both the first and second of these lines should be adopted, but that the second one should be built first in order to secure circulation in the south fork. From Summit westward the bed of the river and the present canal were the only lines to be considered. The best location has not yet been finally determined.

For the drainage of the Calumet region a simple inspection shows that a canal should start from the river at the southern point of Blue Island, and extend almost directly westward to the Des Plaines Valley at Sag.

A fourth branch of the inquiry relates to the study of such data as have reference to securing a proper circulation for the waterways within the city.

To throw light upon this point the variations of the lake level have been recorded since last spring by means
512 of an automatic gauge indicating an almost continual fluctuation, averaging several inches, and recurring at periods of about 20 minutes. During a low pressure of the atmosphere the amplitude of these oscillations increases, and not unfrequently reaches several feet. The accompanying diagram shows the level of the lake on

August 16, 1886, at a time when an area of low barometer passed over it. From 6:40 a. m. to 6:55 a. m.—that is, in 15 minutes—the water fell 2 feet 10 inches.

A rising level causes an inflow to the river and drives the water of the latter into the slips, where it deposits a portion of its suspended sewage matter and becomes foul. A falling level reverses the flow, and the slips empty their foul water into the river and lake. During heavy fluctuations of the latter, such as the one referred to above, it has been traced more than a mile in the direction of the crib.

As the proposed canal from Bowmanville to the lake will lower the water of the North Branch at this point to the lake level, provision must be made for its circulation. The size of the Fullerton avenue conduit is not sufficient to furnish the water required for a current in both directions, nor would such an arrangement be satisfactory or economical. It will be necessary to establish a flow towards the South Branch from the lake opposite Bowmanville in order to prevent a future lake pollution by the proposed channel. This can be accomplished by placing a lock in the North Branch at any point that may be found most desirable and raising the water at the same time about one foot. If such a lock is placed at Fullerton avenue the present pumping works, with slight modifications, can be utilized.

Finally, it must be mentioned that circulation can be secured in the proposed waterways of the Calumet region, into which the sewage is discharged, by a gravity flow from Lake Michigan into the Des Plaines Valley through Lake Calumet and the Sag. The detailed features of this project have not yet been wholly matured, the estimates of cost being based on a channel having a capacity of 1,000 cubic feet per second.

Comparison of projects.

513 In the foregoing we have outlined the main features of the only three feasible methods of disposing of the metropolitan sewage, and have given the results of the investigation reached to date. A general conclusion as to the preferable method may be given at present, and also an approximate estimate of cost. But we are not able as yet to give either conclusions or detailed statements of the probable expense regarding all parts of the

proposed work, and must defer them until the final report.

In comparing the projects we will first mention their probable cost and then their relative advantages.

The discharge of the sewage into the lake from a population of 2,500,000 in the manner described above, including the extra expense, otherwise not necessary, of taking the water supply of Grosse Point, would cost at least $37,000,000, with an annual expense for interest and operation of at least $2,400,000. It would require an immediate investment of about $20,000,000.

To dispose of the entire metropolitan sewage by filtration on land would require an investment of about $58,000,000, with an annual expense of over $3,000,000 for interest, pumping, and maintenance, after deducting the profit from the sale of crops. It would be necessary to invest at once about $34,000,000. Land disposal for the sewage, from the Calumet region alone, with a future population of 300,000, would require an investment of about $4,000,000 and an annual expense of at least $250,000.

Finally, the cost of the Des Plaines project is approximately estimated as follows:

1. A channel from the South Fork to Joliet of the capacity heretofore given will cost between $17,000,000 and $21,000,000.

2. A diversion of the flood waters of the Des Plaines, the North Branch, and Salt Creek will cost between $2,500,000 and $2,800,000.

3. Pumping works and locks for the North Branch will cost about $150,000.

Omitted; printed in House Ex. Doc. No. 264, 51st Cong., 1st sess.

514 4. A separate system of sewers to collect the sewage now discharged directly into the lake and to carry it into the river will cost about $600,000.

5. A channel from Lake Calumet to Sag will cost between $2,500,000 and $3,000,000.

6. A diversion of the flood waters of the Calumet River will cost between $350,000 and $400,000.

The total cost of the Des Plaines drainage project would therefore be, for the main district, between $20,250,000 and $24,550,000; for theCalumet district, between $2,850,000 and $3,400,000. The annual cost, including interest, etc., is estimated at about $1,300,000 per annum.

The pollution of the lake can be decreased and the present condition of the Chicago River, and particularly of the South Fork, can be improved by the immediate construction of the following works, which, with the exception of the pumping works at the South Fork discharging into the Illinois and Michigan Canal, are all a part of the final plan.

1. Channels diverting the flood waters of the Des Plaines, North Branch, and Salt Creek, as described above.

2. A modification of the Fullerton avenue pumping station and the construction of locks for the purpose of getting circulation in the North Branch.

3. A separate system of sewers to collect the sewage now flowing into the lake from the south division and to discharge it into the South Fork.

4. A waterway extending from the western end of the South Fork to the Illinois and Michigan Canal, with a new pumping station to promote circulation.

5. By raising the banks of the canal and by removing deposits this capacity can be increased 40 per cent. at a small cost, and thus provide for a greater flow of water in the same.

The cost of the works comprised under these five items is estimated to be between $5,000,000 and $5,500,000. They could be finished in three years, and would greatly lessen the liability of polluting the water supply, while the sewage would be disposed of in the best practicable maner until the final completion of the Des Plaines project.

It therefore appears that this project is decidedly the least expensive one for the present as well as for the future.

Besides the economical advantages of the Des Plaines scheme, its superiority is still further emphasized by advantages of another kind. The proposed canal will, from
515 its necessary dimensions and its regular discharge, produce a magnificent waterway between Chicago and the

Mississippi River, suitable for navigation of boats having as much as 2,000 tons burden. It will establish an available water power between Lockport and Marseilles fully twice as large as that of the Mississippi River at Minneapolis, which will be of great commercial value to the state. The Calumet region will be much enhanced in value by having a direct navigable channel to the Des Plaines River and by a lowering of the flood heights of Calumet Lake and River. Within the city the water of the Chicago River and its South Branch will get a much better circulation if it flows by gravity than if it has to be pumped, the necessity for which would remain even if the sewage should be discharged through intercepting sewers, either into the lake or upon land. Upon either of the latter conditions an occasional overflow from the sewers into the river during heavy rains would be more objectionable than a constant discharge of sewage into a more rapidly flowing stream. Flood waters entering the lake by way of the Chicago River would carry into it much filthy matter, either suspended or deposited, notwithstanding the existence of intercepting sewers, but the proposed diversion of such waters before reaching the populated districts will for all time obviate this undesirable occurrence. Lowering the level of the North Branch at Bowmanville by its diversion to the lake will be equivalent to raising the low prairie extending towards Evanston and Niles and greatly benefit parts of these towns.

The water supply.

In reaching the conclusion that the sewage of the city should be discharged into the Mississippi Valley the question of water supply is materially simplified, because the lake will then at all times furnish good water wherever intakes are desired for an extension of the works."

The Illinois General Assembly in 1887 did not pass the Sanitary District Act known as the Hurd Bill but authorized a joint committee to sit *ad interim* and report to the next session of General Assembly in 1889. See testimony of Cooley (Rec. Vol. III, p. 1727. This narrative p. 280.)

In a report by Major W. H. H. Benyaurd, under the Rivers and Harbors Act of August 2, 1882, (Rec. Vol. IV, p. 2251), he said:

"EXTRACT FROM THE CHIEF OF ENGINEER'S REPORT 1884, APPENDIX HH, P. 1957, ENTITLED 'PRELIMINARY EXAMINATION OF ILLINOIS AND DES PLAINES RIVERS BETWEEN LA SALLE AND JOLIET, ILLINOIS.'

UNITED STATES ENGINEER OFFICE,

CHICAGO, ILL., September 2, 1882.

General: I have the honor to present the following report in regard to the proposed survey of the Illinois and Des Plaines Rivers from Joilet to La Salle, Ill., as provided for in the river and harbor act of August 2, and assigned to my charge by letter of August 11.

Several surveys have been made of the route by the State and by the General Government, and I have not deemed it necessary therefore to make a personal examination of the stretch of river in question, in order to report upon the necessity of an instrumental survey. I have examined the maps and consulted the reports and other sources of information, and deem it necessary to make survey, estimates for which are presented herewith.

The necessity of the improvement derives its importance from several considerations. The State has improved the river for ship navigation from La Salle to Copperas Creek, and the Government is now engaged in
2252 continuing the improvement thence to the mouth. I am directed to report upon the cost of enlarging the Illinois and Michigan Canal, which extends from Lake Michigan to La Salle. This work, if ever carried on, will give through navigation for large vessels from the lake to the Mississippi. The canal runs in close proximity to the river the entire distance from Joilet to La Salle, and in making up the estimates for the enlargement of the canal it will be necessary to discuss whether or not it will be more economical to enlarge the canal between those two points, or to improve the river and abandon the other.

Very respectfully, your obedient servant,

W. H. H. BENYAURD.
Major of Engineers.

Brig. Gen. H. G. Wright,
Chief of Engineers, U. S. A."

March 5, 1884, Major Benyaurd made a further report pursuant to said Act of August 2, 1882, in which it was stated:

> "That with the improvement of the River now in question carried on, navigation will be brought to within thirty-three miles of the Lake, and this stretch can be opened by improving the DesPlaines higher up and by enlarging the present Illinois and Michigan Canal."

Section 4 of the Rivers and Harbors Act of August 5, 1886, is as follows:

> "Sec. 4. The Secretary of War shall prescribe such rules and regulations as may be necessary to secure a judicious and economical expenditure of the money herein appropriated, and shall cause to be made and submitted to Congress annual reports, together with maps and plans, including the report of the Mississippi River Commission, on or before December first, giving detailed statements of the work done, contracts made, the expenditures thereunder or otherwise, and balances of money on hand up to November first, and the effect of such work, together with such recommendations as he may deem proper. He shall at the same time report to Congress all cases in which piers, breakwaters, locks and dams, or other structures or works built or made by the United States in aid of commerce or navigation are used, occupied, or injured by a corporation or an individual, and the extent and mode of such use, occupation or injury. He shall report, at the same time, whether any bridges, causeways or structures now erected or in process of erection do or will interfere with free and safe navigation."

In a report by Major Handbury, 1887, under the Rivers and Harbors Act of August 5, 1886, (Rec. Vol. IV, p. 2257) he said:

> "Extract from a Report of Major Handbury, Chief of Engineer Reports 1887, Appendix II, p. 2119, Entitled 'Improvement of Illinois River, Illinois.'
>
> The project now in the course of execution for the reach of the Illinois River lying between the state lock at Copperats Creek and the mouth, a distance of 135 miles, contemplates the construction of two locks and dams and the dredging of a channelway where neces-

sary, so as to insure a continuous depth throughout of not less than 7 feet at low water.

The sites selected for the locks and dams are one at Kampsville, about 30 miles above the mouth of the river: the other at LaGrange, 45 miles above Kampsville. These locks are 350 feet long and 75 feet wide, with 7 feet over miter-sills at low water.

The ultimate object of this improvement is to provide a channelway from the lower end of Lake Michigan to the Mississippi River of sufficient capacity to accommodate large sized Mississippi River boats, so that the products of the country may be carried from the Lake to the Gulf without breaking bulk; also to enable vessels of war of considerable capacity to pass freely from the Gulf of Mexico into the defenseless waters of our northern lakes, should the exigencies of our foreign relations ever require this to be done.

Page 2121.

When this work is completed it will then be practicable for the large steamers belonging to the Upper and Lower Mississippi, the Ohio, and Missouri Rivers to come with their unbroken cargoes to within 100 miles of Lake Mich-
2258 igan. All this can be brought about by an expenditure on the part of the government of less than $600,000.

The Illinois River, from the western terminus of the Illinois and Michigan Canal at LaSalle to Copperas Creek, about 80 miles below, has been improved by the State of Illinois by means of two locks and dams similar to those in process of construction by the United States on the river below. From LaSalle to Joliet the Illinois and Des Plaines Rivers have been carefully surveyed, and plans and estimates of cost for their improvement to the same navigable capacity as the river below have been made and submitted to Congress. The report on this project submitted by Maj. W. H. H. Benyuard, Corps of Engineers, U. S. Army, may be found in the Chief of Engineer's Report for 1884, page 1958. The estimated cost of improving this reach of the river is $3,433,562. The distance is 64 miles and the fall 100 feet. Congress has now before it the engineering data showing the feasibility and cost of a water communication between the Mississippi River and a point 30 miles distant from navigable water leading into Lake Michigan sufficiently commodious for the commercial and military exigencies of

the country, and from this point to the lake perfectly practical routes over which the line can be constructed are known to exist. It only remains for Congress to provide the means for making the necessary surveys and estimates of cost for continuing this work from Joliet to Lake Michigan, when it will have the engineering features of the whole subject before it in a shape necessary for intelligent legislation. I estimate that about $10,000 will be sufficient to defray the expenses of the necessary surveys and examinations and preparation of the plans and estimates of costs of the work.

The United States and the State of Illinois have long been committed to the project of opening a water communication between the Mississippi River and the north-
2258 ern lakes of capacity sufficient for the wants of commerce and for the exigencies of our national defense, should these ever arise. The amount expended by the United States to the end of the present fiscal year in carrying out this project is $680,633.42, exclusive of $62,359.80 expended on the foundation of the Copperas Creek Lock, which was afterwards turned over to the State. The cost of the locks and dams built by the State of Illinois at Copperas Creek and Henry was $747,747.

The distance by this route from the Gulf of Mexico to the southern end of Lake Michigan is about 1,620 miles. When the projected improvement of the Illinois
2259 River below Copperas Creek, on which we are now working, has been finished, more than 1,520 miles of this distance will be available for the water transportation of commerce in bulk between these points. Pushing this improvement through to the lake, the connecting line will be formed which will join the northern lakes with the vast net-work of navigable rivers whose waters flow into the Gulf of Mexico on a scale to a certain degree commensurate with the importance of the commerce that will be affected by it. The mere fact that such a route is available will serve as a wholesome regulator to the rates that would be exacted by other methods of transportation were this one not in existence. Besides the immense commercial advantages that may be expected from the completion of the project, there are military and naval exigencies that might easily arise where it would figure as a prominent factor in the problem of our national defenses. From whatever point we look at the subject there is nothing local or sectional in it. It is true that all the work to be done happens to be in

the State of Illinois. The benefits to be derived belong to the nation at large. It is fortunate, too, that at this time the subject is unencumbered by any phase of a political character. The problem of connecting Lake Michigan with the Mississippi River by a commodious waterway, that could be used for commercial, military and naval purposes, has received attention from our most thoughtful statesmen from the day of Albert Gallatin to the present."

On May 28, 1889, the legislature of the State of Illinois passed a resolution stating the deep waterway policy of the state asking the cooperation of the Federal Government for the construction of the Sanitary District Channel. The Resolution is as follows (Rec. Vol. IV. pp. 2329-30):

"Joint Resolution

Whereas the present addition to the low-water volume of the Illinois River through the summit level of the Illinois and Michigan Canal from Lake Michigan more than doubles the volume of water used in the estimate of 1868 for the channel below Peru, and adds 50 per cent to the volume used in the estimate of 1880 for the channel below Copperas Creek and said contribution from Lake Michigan will be increased in the immediate future, thus enabling the depth now projected for navigation below Peru to be obtained by channel improvement at moderate cost, and with decided advantage to material interests and to healthfulness along the valley.

Whereas it is contemplated to increase the volume from Lake Michigan to 300,000 cubic feet per minute within a few years, and ultimately to add 600,000 cubic feet or more, thus enabling a large depth for navigation to be obtained by an improved channel, and that said channel will be self-sustaining and self-improving and will discharge flood waters more readily, thus benefiting the bordering lands and increasing the healthfulness of the valleys.

Whereas works now projected by the City of Chicago will form part of a waterway of large proportions from Lake Michigan via the Des Plaines and Illinois rivers to the Mississippi River, of which the dams and locks upon the alluvial section of the Illinois River, can form no part, and which, if allowed to remain, will increase,

overflow and be detrimental to the welfare of the Illinois Valley and the interests of the State: Therefore be it Resolved,

By the Senate of the House of Representatives concurring herein (1) That it is the policy of the State of Illinois to procure the construction of a waterway of the greatest practicable depth and usefulness for navigation from Lake Michigan via the Des Plaines and Illinois rivers to the Mississippi River and to encourage the construction of feeders thereto of like proportions and usefulness. (2) That the United States is hereby requested to stop work upon the locks and dams at La Grange and at Kampsville, and to apply all funds available and future appropriations to the improvement of the channel from La Salle to the mouth with a view to such a depth as will be of present utility and in such manner as to develop progressively all the depth practicable by the aid of a large water supply from Lake Michigan at Chicago. (3) That the United States is requested to aid in the construction of a channel not less than 160 feet wide and 22 feet deep with such a grade as to give
2230 a velocity of 3 miles per hour from Lake Michigan at Chicago to Lake Joliet, a pool of the Des Plaines river, immediately below Joliet, and to project a channel of similar capacity and not less than 14 feet deep from Lake Joliet to La Salle all to be designed in such manner as to permit future development to a greater capacity.

On May 29, 1889, the Legislature of the State of Illinois passed an act providing for the creation of the Sanitary District of Chicago, which act became in force, July 1, 1889. (Rec. Vol. VIII, p. 92.) Said Act provides for the size of channel to be constructed in Section 23. (Rec. Vol. VIII. pp. 103-104.) Other sections of the Act are set forth in this narrative statement page 69.

"23. If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Des Plaines or Illinois river such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than fourteen feet, and a current not exceeding three miles per hour, and if any portion of any

such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan, of not less than eighteen feet, such portion of said channel shall have double the flowing capacity above provided for and a width of not less than one hundred and sixty feet at the bottom capable of producing a depth of not less than eighteen feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000 such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than three miles per hour, and if at any time the general government shall improve the Des Plaines or Illinois rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter, enlarge the entire channel leading into said Des Plaines or Illinois rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom. In case a channel is constructed in the Des Plaines river as contemplated in this section it shall be carried down the slope between Lockport and Joliet to the pool commonly known as the upper basin of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act, may correct, modify and remove obstructions in the Des Plaines and Illinois rivers wherever it shall be necessary so to do to prevent overflow or damage, along said river, and shall remove the dams at Henry and Copperas Creek in the Illinois river, before any water shall be turned into the said channel. And the canal commissioners, if they shall find at any time that an additional

supply of water has been added to either of said rivers, by any drainage district or districts, to maintain a depth of not less than six feet from any dam owned by the State, to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dam, at low water, then it shall be the duty of said canal commissioners to cause such dam or dams to be removed."

In the report of Captain Marshall, United States Engineer at Chicago of February 28, 1890, Captain Marshall (Rec. Vol. IV, pp. 2156-58) said: Chief of Engineers Reports 1890 Appendix J. J. 2419.

Survey of Waterway from Lake Michigan to the Illinois River at La Salle, Illinois.

"United States Engineer Office.

Chicago, Ill., February 28, 1890.

General: I have the honor to submit the following report upon a survey of a waterway from Lake Michigan to the Illinois River at La Salle, Ill., forming part of a through route of transportation from Lake Michigan to the Mississippi River, required by Act of Congress of August 11, 1888.

2157 The Act in question is entitled 'An Act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors, and for other purposes,' and the items directing the survey, plans and estimates, and relating thereto, are as follows:

'Improving Illinois River, Illinois: Continuing improvement Two Hundred Thousand Dollars. And for the purpose of securing a continuous navigable waterway between Lake Michigan and the Mississippi River, having capacity and facilities adequate for the passage of the largest Mississippi River steamboats, and of naval vessels suitable for defense in time of war, the Secretary of War is authorized and directed to cause to be made the proper surveys, plans, and estimates for a channel improvement and locks and dams in the beds of the Illinois and Des Plaines Rivers from La Salle to Lockport, so as to provide a navigable waterway, not less than one hundred and sixty feet wide, and not less than fourteen feet deep, and to have surveyed and located a channel

from Lockport to Lake Michigan, at or near the City of Chicago, such channel to be suitable for the purposes aforesaid; the necessary expenses of such surveys, estimates, plans and location to be paid for out of the sum herein appropriated for the improvement of the Illinois River.'

In compliance with the orders of the Chief of Engineers a project for this survey was submitted September 21, 1888, which was approved September 25, 1888. The expenses of the survey to be paid from an allotment of $25,000 from the appropriation for the improvement of the Illinois River.

A letter of instructions was received from the chief of engineers, dated August 27, 1888, a copy of which is herewith, directing that whatever line might be found most advantageous and economical to the United States, and best suited to subserve the ends in view, that plans and estimates in any event should be submitted for a route terminating within the (then) limits of the City of Chicago sufficiently distinct and in detail to enable the Chief of Engineers to form a definite and conclusive
2158 opinion as to its merits regarded from the standpoint of the commercial and sanitary interests of Chicago.

The most practicable routes across the Chicago Divide, and which have been long known and recognized, are two, each of which admits choice of location, the valleys being quite wide.

(1) By way of the Chicago River and its South Branch and the present location of the Illinois and Michigan Canal, or Mud Lake and the Ogden Ditch, to the Des Plaines, near Summit, about 12 miles from the City Hall of Chicago and about 8 miles from Bridgeport; thence via the Des Plaines River Valley, uniting at Sag Bridge with route."

* * * *

Referring to the drainage and water supply commission report of 1887 and the Sanitary District Act of 1889, the United States Engineer reports to the Chief Engineer as follows: (Rec. Vol. IV, 2161, 2162, 2167.) (Chief of Engineers Report 1890 Appendix J. J. 2436.)

2161 "Page 2436.

Attached to this report will be found the full preliminary report of the special commission or board of experts employed by the City of Chicago to examine into the question of drainage and water supply, made in 1887; also the laws and joint resolutions of the Legislature of the State of Illinois relating to the same matter, and authorizing the establishment of 'Sanitary Districts, etc.,' which will give a clear explanation of the requirements of the case and the proposed remedies.

Without going into the subject in detail, which is better treated in the report mentioned than it could be by me, it is sufficient to state that after examination by capable experts the conclusion has been arrived at that it is necessary, for sanitary reasons, to construct a channel or channels from the lake to the Des Plaines valley, beyond the Chicago Divide, capable of carrying to the Illinois River from 300,000 to 600,000 cubic feet of water per minute, to carry off and dilute to inoffensiveness the sewage of
2162 this great city, to prevent contamination of its water-supply *necessarily taken from Lake Michigan;* and that the necessary legislation to enable the city to undertake the work has been obtained from the State Legislature.

2167 Commercial Advantages.

This route has invited attention as a practicable locus for a waterway between the Great Lakes and Mississippi River for many years, and its advantages have been so often reported to Congress that anything herein said would be more repetition. It is sufficient to say that the minimum channel herein estimated upon will open a channel of commerce with a maximum annual capacity of 30,000,000 tons (foot note: Or 7,500,000 tons easily attainable capacity in practice.—W. L. M.) between the Great Lakes, with its terminus at their greatest port, and a system of navigable rivers penetrating one-half of the states and territories of the Union, with a total navigable length equal to more than half the circumference of the globe."

On April 21, 1891, the Sanitary District of Chicago passed a resolution for improving the Chicago River, which resolution is as follows (Rec. Vol. IV, pp. 2274, 2275):

"Resolution of April 21, 1891, of the Board of Trustees of the Sanitary District of Chicago.

Resolved, That this Board hereby ordains that The Sanitary District of Chicago do forthwith enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the South Branch thereof, and also the South Branch thereof, together with the South and West Forks thereof so as to make the same a proper and sufficient supply channel for the main channel heretofore surveyed from the Chicago River to Joliet; and further, that the Acting Chief Engineer be, and he is hereby, directed immediately to investigate and report upon the capacity of said River and its said South Branch and Forks for that purpose, and also as to any changes that should be made therein, and that a copy of this resolution, certified by the clerk, be forthwith transmitted to the Mayor and Common Council of the City of Chicago, and the Secretary of War of the United States."

In 1892 the United States Engineer at Chicago, Captain Marshall in a report to the Chief of Engineers, United States Army, reported the progress of the work of the Sanitary District as follows, Chief of Engineers Report 1892, Appendix J. J., page 2255 (Rec. Vol. IV, pp. 2180-2182):

"Page 2258.

The completion of the La Grange Lock and Dam has been followed by a material increase in the tonnage passing La Grange. The completion of the Kampsville Lock
2181 and the dredging the channel below it by extending the period of navigation there will have a more marked effect still in increasing the size and tonnage of vessels navigating the Illinois River and the value of this stream as a means of transportation.

Doubtless the slow improvement of this river has resulted from a difference of opinion as to the method of improvement that should be applied: On the one hand, the necessities of the city of Chicago for better drain-

age has demanded a large discharge into the Illinois River for sanitary purposes, which discharge would make an open river improvement practicable below La-Salle; on the other hand is the fact that the most economical and effective system, as far as navigation is concerned, is that by slackwater, modified, perhaps, by movable dams in the alluvial valley of the Illinois, Lake Michigan being the summit level, the channels being comparatively shallow but of greater width than proposed for sanitary purposes. Additional friction and consequent injury to both the scheme for a navigable channel and to the local drainage measure, delaying both, has been due to the demand by advocates of the latter that the United States shall construct the navigable channel of the dimensions necessary for the drainage scheme, without regard to the most economical channel and speedy method of meeting the absolute requirements of commerce by water over the connecting link between 14,000 miles of interior navigation existing upon the Mississippi River and its tributaries, and the Great Lakes.

These dissensions are now apparently quieted, and without friction the question of the extension of the navigation existing on the Western rivers to the Great Lakes, the best dimensions and location of channel from Joliet to La Salle, and the advisability and conditions of joint use by the United States for navigation and the city of Chicago for drainage of the channel that must be cut for both purposes across the rock in place, from near Willow Springs to near Lockport, can be now examined.

Upon this subject the reports of the Chief of Engineers for 1889, page 2121, *et seq.;* for 1890, page 2419, *et seq.;* and 1891, page 2611, *et seq.,* are referred to.

The authorities of the sanitary district of Chicago have progressed so far with their work as to have definitely located for the third time a part of the drainage channel, and have taken an additional step in advance by soliciting and receiving proposals for the construction of their channel for drainage across the rock between
2182 Willow Springs and Lockport. The prices secured are very favorable; the contract has not yet been awarded, but the proposals are under advisement by the trustees."

On August 9, 1893, Captain Marshall, United States Engineer at Chicago made a report to the Chief of Engineers which was by him transmitted to Congress with the annual re-

port of the Chief of Engineer, informing the United States that the work of constructing the Sanitary District Channel had begun. Captain Marshall said (Rec. Vol. IV, 2366, 2367, 2371), Chief of Engineers Reports, 1893, Part 4, Appendix L.L. p. 2794:

"With reference to the feeling of disgust entertained by the populace towards this stream, it must be said that from the earliest settlement of Chicago the most obvious disposal of their sewage and refuse, *i. e.*, into the lake and river, has been followed. As the city grew, the old sewers were enlarged and additional ones built. The Illinois and Michigan Canal was constructed, and the contents of the river loaded with sewage was to a then sufficient degree pumped into it; later, this proved insufficient, and the canal was cut deeper to allow a flow by gravity towards the Mississippi River; this also proved in time inadequate, and it was required by the Illinois Legislature that sixty thousand cubic feet of water per minute should be pumped into the Illinois and Michigan Canal from the Chicago River to purify that stream. This requirement has never been attained. As far as ascertained, the discharge has never for any length of time for the past four years exceeded forty-five thousand
2367 cubic feet per minute, and it is not believed to have averaged much, if any, above one-half the legal requirements, or thirty thousand cubic feet per minute. To purify the North Branch, pumping works and a tunnel from Lake Michigan to the North Branch at Fullerton avenue have been for years in use. Lake water is pumped through this tunnel and creates a feeble current towards the main river. This supply forms part of the thirty thousand to forty-five thousand cubic feet per minute pumped into the Illinois and Michigan Canal at Bridgeport.

The insufficient discharge of the pumps into the canal results, in rainless weather in a very feeble current from the lake towards the pumps at Bridgeport, and in an indescribable state of putridity and offensiveness in Chicago River, due to domestic sewage and a discharge from manufacturing establishments through the sewers into the river. At ordinary rains, upon freshets in the Desplaines or Chicago rivers draining areas, great volumes of putrescent matter are disgorged into the lake through the mouth of Chicago river threatening the water supply of the city, which in the main is taken through tunnels under the bed of the lake from two inlet cribs, situate, one north of and the other south of, and a few miles distant from the mouth of the river.

To remedy the, at times, insupportable and disgusting condition of the river and its branches; to purify the river and to preserve the city water, relief is now sought under state laws by constructing a drainage canal from the south branch of Chicago river to the Desplaines river above Joliet, capable of discharging into the Illinois River Valley from three hundred thousand to six hundred thousand cubic feet of water per minute.

It is a remarkable fact that this city, while seemingly unable or unwilling to provide funds for purifying Chicago river by pumping sixty thousand cubic feet per minute is ready to embark in, and has commenced the execution of a canal for discharging ten times that amount by gravity at a comparatively enormous expense.

This channel has been located from the south branch of the Chicago River to Lockport, and is under construction, but no provision has yet been made for channels of supply from Lake Michigan. Whatever the outcome or plans of the local officials having this work in charge may be, it can be said that the Chicago River and its branches cannot in their present condition, supply materially more
2368 than from one-third to one-half of the minimum requirements of the law, without producing currents that will be prohibitory to navigation at some of the bridges and obstructions now existing.

It is certainly evident, granting the proposition that effective channels for the purpose will be constructed, that if this method of solving the drainage problem is to be carried to conclusion, there must be a complete remodeling of Chicago River throughout both its branches, and there must be also artificial channels of large capacity to furnish even approximately effective outfalls to the sewerage systems of a great city founded on low lands extending some twenty-two miles long, and for miles back from the lake, as well as other large feeders connecting the lake with such channels.

Without criticizing in any way the local measures taken for local relief, it may be said that the state laws, if effectively executed for the purposes specified, seemingly require changes in the capacity of Chicago River and its branches that may increase, may diminish, or may even entirely destroy their value for commercial purposes. In any case under existing laws, no alteration in the capacity of Chicago River can be made without the consent of the Secretary of War, or without full examination by agencies established by Congress, and the

execution of the state laws are therefore limited by superior authority.

As before said, the navigable channel of Chicago River is now maintained by the City of Chicago by dredging out the solid matter cast into it through sewers, and dumped into it, especially in winter, by its street cleaning department. The city also maintains bridge tenders, harbor master, and vessel dispatchers, patrols the stream with fire boats; pumps inefficiently the sewage from the river into the Illinois and Michigan Canal; constructs and maintains all bridges except such as are necessary for corporate public carriers.

Riparian owners have constructed the docks and wharves, of which there are none for public use, and dredge for landings alongside.

It is estimated that the total annual expenditure of the City of Chicago on the Chicago River is $350,000, of which about $120,000 is for dredging. This latter work is the only work that can be said to be in the interest of navigation.

The expenses for pumping of sewage, for bridges, for lighting and fire service, and other expenditures, are the necessary costs of encroachments upon this public highway to be paid by the profiting parties.

The dredging also is to remove solids and filth passed by the city into this navigable stream, contrary to the
2369 laws of the United States. It is necessary that either the law be enforced and the sewers sealed, or else awaiting a change of system which is not at all contemplated to require that solid matter necessarily placed in the river by the citizens of Chicago shall be removed by them before accumulating to such an extent as to obstruct navigation.

General Remarks.

Chicago River is the most important navigable stream of its length on the globe. In the number of arrivals and departures of vessels annually it leads all harbors of the United States in tonnage it is second only to New York. In these elements it is the head of the great commerce of the lakes, but in capacity, depth, and width of navigation it is but a third-class port. Improvements are in progress along the chain of Great Lakes contemplating 20 to 21 feet depth of water at low water. Several harbors have 18 feet or more depth of channel.

Chicago Harbor has 16 feet at entrance to the river, is obstructed by three tunnels with from 16 to 18 feet of water over their crowns, and can carry through but a comparatively small part of its navigable channel exceeding 15 feet. The entire inner harbor can be regarded as only a long private slip; there are no public wharves or docks, throughout its length, including branches; it is an offensive though navigable open sewer, obstructed by an average of four bridges to the mile, and lined for a greater part of its course by wooden docks in great part built up to the waters' edge by heavy buildings, elevators, etc., that will not admit a channel against them exceeding 16 to 18 feet without damage. The docks are generally of cheap construction of piles and sheet piles reaching but a few feet below the bottom of the channel existing when they were constructed but anchored back into the bank to other piles by iron tie rods about 1 and ½ to twice the channel depth in length. The docks are backed with earth. In many cases, as stated, over these cheap docks, but on foundations of additional tiles are constructed warehouses, etc., that may be more or less damaged by dredging close to the dock line to deepen the channel.

The river at numerous points, notably near Adams and Van Buren streets, has been contracted by filling within the meandered lines to less than one-half its original width. At other places in rebuilding docks, new docks have been constructed outside the first dock line. Abutments of bridges also project into the river, and piles or
2370 rip rap stone have been placed in the stream to buttress insufficient bulkheads or docks. Bends in the river now rigidly fixed by docks, of curvature with chords of sufficient length to allow the free passage of vessels of dimensions of twenty years ago, taken in connection with obstructive bridges prohibit passage by the largest modern vessels.

At the same time the increasing value of lands for other purposes near the mouth of the river is causing grain elevators, coal yards, lumber yards and manufacturing establishments, dependent upon marine transportation either to recede farther and farther from the mouth of the river, or to go elsewhere. Some establishments have moved to South Chicago, and Waukegan and Milwaukee have also profited at the expense of Chicago.

Consequent upon this recession, vessels must pass an ever-increasing number of obstacles in reaching places of transfer of cargoes. Tugs, often two of them to a vessel,

must be employed in all movements of vessels in the river above the junction of the two branches, and it is averred by prominent vessel owners that the cost of moving one of the larger vessels from the lake to the elevators above Twenty-second street and returning it to the lake is one-half the cost of transferring the cargo from Chicago to Buffalo.

This excessive cost, due entirely to the obstructions in Chicago River, is shown by differential freights on coal and other heavy commodities to other harbors on the Great Lakes, comparing mileage and rates, against Chicago.

In the present condition of Chicago River no material widening or deepening of the channel can be effected without great expense. A large proportion of the docks or bulkheads must be constructed, and in some cases precautions are necessary to prevent damage to buildings if the water is materially deepened against their foundations.

There should always be at least 2 feet of water between the bottoms of vessels and the crowns of tunnels to guard against damages to vessels by chance obstructions of small extent lodging temporarily over the rigid crowns. To secure 18 feet available water the three tunnels under the river should be lowered until there will be from 20 to 21 feet of water over their crowns. If the improvement be made on the basis of 18 feet and the use of Chicago River and its branches be conceded by the United States to the State of Illinois as a drainage channel, of the capacity indicated by the State law,
2371 the modifications therein must be radical and costly whether the expense thereof be borne by the United States or the City of Chicago.

Heretofore, under recent river and harbor acts, the United States Government has exercised a limited control over Chicago River. It has been simply a conservative control, the United States intervening only where encroachments prejudicial to the rights of the public in the navigation of Chicago River were in question. Plans for bridges across Chicago River have been acted upon by the Secretary of War, and at least one bridge, *i. e.*, that bridge originally constructed at Canal street, has been condemned as an obstruction to navigation by the War Department and has been altered or changed by the City of Chicago upon the mandate of the Secretary of War, but not in exact accordance with that mandate

either as to plan or time. The Secretary of War has not exercised his authority under the law to stop the deposit of filth in the river, nor interfered in any way with the regulations of the city with reference to the movement of vessels and bridges in or over the stream or with local police regulations relating to this stream.

In the opinion of the engineer officer in charge of this district, for the present awaiting developments of local plans under State authority, no improvement in Chicago River should be made by the General Government; nor any public funds be expended thereon so long as the City of Chicago uses it as a dumping ground for its filth and refuse of all kinds. The City should be required to remove all deposits made therein that tend to diminish its present navigable capacity, or to cease depositing its sewage therein.

This disposition of its sewage and deposit is now a necessity to this city and it is not in accord with public policy to prevent it as long as the city continues to remove the solid residue. The United States should continue its control so far as to preserve the navigation of the river from injury.

It will soon be necessary for Congress to provide for the extension to Lake Michigan of the navigation established on the Illinois River below La Salle, and to determine to what extent, if at all, it will utilize for navigation the great channel now being cut by local authorities in the rock divide, separating Lake Michigan from the Mississippi Valley. The question is at hand and must be determined at some date not far in the future, whether the national highway will utilize this cut and Chicago River as part of this communication, or the Calumet River route in connection with this local channel, or other-
2372 wise. There are no other practicable routes. If Chicago River be adopted (which is not, in the opinion of the officer in charge, in view of the rapid extension in territorial area as well as in population of this city, advantageous to either the local population for drainage purposes or for the United States for navigation), material improvements in the Chicago River channel will be required, but as before stated, even if Chicago River be utilized, the most direct channel for navigation is not the channel demanded by the necessities for drainage by the City of Chicago. If navigable channel must be arranged to best subserve local purposes, it is evident that material modifications will be required in Chicago

River that may properly demand other navigable inlets than the one already provided at the mouth of Chicago River.

It seems, therefore, that before making appropriations for the improvement of Chicago River, the question of the future uses of this stream should be settled, whether it shall continue to be as now simply a long slip or succession of private slips, docks and wharves, utilized indeed for interstate and foreign commerce, but mainly for private and corporate gain, and for the main sewer of a great urban community, or whether it shall constitute a connecting link under federal control between the navigation of the Great Lakes and that of the Mississippi River and tributaries.

This opinion is given as required by the law of July 13, 1892, but for the information of Congress the following is respectfully submitted:

To reasonably accommodate existing commerce without extensive changes in Chicago River and without reference to future developments, the following work would be in the interest of commerce and navigation:

First. That the Chicago River from its mouth to the stock yards on the south branch and to Belmont avenue on the north branch as far as may be permitted by existing docks and wharves be dredged to admit passage by vessels drawing 16 feet of water.

Second. All encroachments on the stream by docks within the original meandered lines of the streams obstructive to navigation, as it exists today, should be removed at the expense of the encroaching parties, and obstructive bridges be required altered or changed.

To admit the passage of the largest lake vessels drawing not exceeding 16 feet of water at load draft, with no changes in the dock lines beyond the obstructive abutments of bridges and projecting obstructive angles
2373 of docks, will require 1,200,000 cubic yards of dredging, approximately, and 8,000 linear feet of docking, at an expense of about $700,000, first cost, with an annual charge for dredging of from $80,000 to $120,000 to maintain the channel.

The cost of maintenance, for reasons stated above, should evidently be borne by the City of Chicago as long as sewage is emptied into the river and the United States should be released from all damages to property by reason of the improvement in Chicago River, as required on the Calumet River.

Should a discharge of 250,000 cubic feet per minute be required through the south branch and main river, wholesale modification of bridges, tunnels and docks, and a widening of the river at many points will be required, and deepening to at least 18 feet of water below Chicago city datum with a slope necessary for this discharge, will be required at an estimated cost of $6,000,000, primarily, not including consequential damages, and an annual expenditure for maintenance of from $60,000 to $75,000.

In 1895, the United States Engineer, Captain Marshall again reported to the Chief of Engineers War Department (Chief of Engineers Reports, 1895, Appendix J. J., p. 2715, Rec. Vol. IV, 2373):

"Extract from the Chief of Engineers Reports 1895, Part 4, Appendix J J, p. 2715, being report of Capt. W. L. Marshall, United States Engineer at Chicago in charge of Chicago River and Illinois River referring to the improvement of the Illinois River. Captain Marshall said:

The City of Chicago expects to turn into the channel of the Illinois at some future time 5,000 cubic feet of Lake Michigan water per second; at some more remote period there may be 10,000 cubic feet per second, but not probably within a generation. By law it is now required to pump 1,000 cubic feet per second into that channel, so that we may expect 4,000 cubic feet per second additional discharge given to the Illinois River at low water. Discharge measurements on the Illinois show conclusively that this amount of water, or even the maximum discharge, will not produce a channel without dredging or without locks and dams equal in depth to that easily attained now at very small expense by completing the dredging required. Under any probable condition an equal or nearly equal amount of dredging will be required to give an equivalent channel in the Illinois River.
2374 The proposed discharge (5,000 cubic feet) will increase the depth of water over the crest of the Kampsville dam at low water about 8 inches, and the depth over Six Mile Bar near the mouth of the Illinois but little if any more. A low-water channel 7 feet deep will exceed in depth very materially the low-water capacity of the Mississippi River, and there can be no rational demand for one of greater capacity.

In 1895, the Board of Engineers appointed by the Secretary of War to investigate the effect of the Sanitary District Channel then being constructed addressed a letter to the Sanitary District which communication was as follows (Rec. Vol. IV, p. 2380):

"Hon. Frank Wenter, President of Board of Trustees, Sanitary District of Chicago, Chicago, Ill.:

Sir—The Board of Engineers appointed by direction of the Secretary of War to consider and report upon 'the probable effect of the operation of the Chicago Drainage Canal upon the lake and harbor levels and upon the navigation of the Great Lakes and their connecting water ways' would be pleased to receive from your Honorable Board of Trustees any information or data bearing upon the subject submitted to us, and especially the following:

First—The conclusions arrived at from investigations made by your attorney or by others as to the effects upon the levels of the great lakes by the operation of your Canal, including any mathematical analyses and discussions of the question from which these conclusions have been arrived at.

Any references to printed discussions by titles, etc., will be very much appreciated if copies cannot be furnished.

2381 *Second*—Description of the Canal, including dimensions of wetted perimeter, slopes, and character of material through which excavated.

Third—Whether any part of the inner harbor of Chicago, which includes Chicago River and its branches, will be utilized as part of the proposed Canal, and if so what amount of water you propose to take through these river channels.

Fourth—If Chicago River be utilized, what changes you propose to make in the navigable channels of the river, in dimensions, slopes and structures to adapt them to your purposes; and what additional channels of supply other than the main branch of the Chicago River; which is now the only evident connection between Lake Michigan and the proposed canal, your Board proposes to make.

In making these inquiries, the Board of Engineers consider that your Honorable Body is much interested in the solution of the questions submitted to us, and therefore desirous to aid as far as practicable in arriving at correct conclusions.

Any communications you may desire to make should be addressed to me at Detroit, Michigan,

Very respectfully,
Your obedient servant,
(Signed) O. M. Poe,
Colonel, Corps of Engineers."

On August 16, 1895, The Board of Engineers of the War Department made a report on the effect of the opening of the Sanitary District channel, which report was as follows (Rec. Vol. VI., p. 3931, 3940):

3932 Chicago, Illinois, August 16, 1895.

Brig. Gen. William P. Craighill,
Chief of Engineers, U. S. A.,
Washington, D. C.

General:

The Board of Engineers appointed by virtue of S. O. No. 14, C. S. Corps of Engineers to consider and report upon 'the probable effect of the operation of the Chicago Drainage Canal upon the lake and harbor levels and upon the navigation of the Great Lakes and their connecting waterways' submits the following report:

The Board met in Chicago, August 12, 1895, and on the 13th and 14th accompanied the officers of the Drainage Canal over the line under construction. Every facility and courtesy possible has been extended by the trustees and engineers of the canal for a full investigation of the subject matter. A brief description of the canal is extracted from the printed report furnished the Board by these gentlemen.

The Main Drainage channel of the Sanitary District of Chicago is now under contract from its confluence with the South Branch of the Chicago River, at Robey street, in the City of Chicago, to its southern terminus, in Will County, Illinois. At the southern end of the channel the

controlling works will be located. Beyond these works, the construction contemplated by the District will be the work necessary for conducting the flow from the channel in conjunction with the waters of the Des Plaines River down the declivity to and through the City of Joliet, and making such changes in the Illinois and Michigan Canal as the new conditions developed will make necessary.

The first work put under contract extended southwesterly from the Willow Springs road, and these sections were numbered consecutively Nos. 1 to 14. Average length of sections, 1 mile. Easterly from Willow Springs road, the sections are lettered from A to O, omitting J. The lettered sections are, except for a short distance near Summit, entirely in glacial drift, defined in the specifications thus: 'Glacial drift shall comprise the top soil,
3933 earth, muck, sand, gravel, clay, hard pan, boulders, fragmentary rock displaced from its original bed, and any other material that overlies the bed rock.'

The sections from 1 to 14 were put under contract in July, 1892; from A to F were put under contract late in 1892, and early in 1893; and G to M, inclusive, were contracted for in December, 1893. Sections N and O were put under contract May 2nd, and section 15, August 27th, 1894.

Earth was first broken on 'Shovel Day,' September 3rd, 1892, on the Rock Cut below Lemont.

The Des Plaines valley is traversed by the river from which it takes its name—a stream of wide fluctuations with no constant and reliable fountain supply. During some seasons its whole discharge would pass through a six-inch pipe, and at others its volume reaches 800,000 cubic feet per minute. Then it rolls majestically along, flooding the whole valley. Such being the situation, control of this stream was a condition precedent to the successful prosecution of the work upon the main Channel. This control has been secured by the outlay of nearly $1,000,000 in constructing what is known as the River Diversion Channel.

About 13 miles of new river channel had to be excavated with the location of the Main Drainage Channel, and about nineteen miles of levee built to divorce the waters of the Des Plaines watershed from the channel which is to receive the waters of Lake Michigan and pass them on to the Mississippi River, via the lower Des Plaines and the Illinois Rivers. The width of the River Diver-

sion Channel on the bottom is 200 feet, side slopes 1½ to 1, grade generally 12-100 per 1,000 feet.

At the head of this River Diversion it was necessary to provide a safety valve in the form of a spillway, to allow surplus water to flow towards Chicago, because arrangements have not as yet been perfected for carrying the entire flood waters of the Des Plaines through Joliet.

This spillway is a concrete dam capped with cut stone, and its wings faced with stone masonry; it is 397 feet long and its crest is 16.25 feet above Chicago datum (this datum is referred to the low water of Lake Michigan of 1847, and is 579.61 above sea level at Sandy Hook). No water flows over this spillway until the volume passing the water gage above it reaches 300,000 cubic feet per minute.

The cross-section of the earth sections from A to E inclusive is 202 feet on the bottom, side slopes two to one.
3934 This section extends for about 500 feet into the west end of F and then reduces to 110 feet on the bottom, preserving the same side slopes. The explanation for this change of cross-section is as follows: Throughout the rock sections, and those sections in which there is a preponderance of hard material, or where rock may appear, the section adopted is designed according to law for a flow of 600,000 cubic feet of water per minute, which means provision for a population of 3,000,000 people. The narrow channel provides for a flow of 300,000 cubic feet per minute, or for about the present population of Chicago. The enlargement of the narrow channel can be made by the easier method of excavation, such as dredging; whenever the needs of the city require it. The grade throughout the lettered sections is one foot in 40,000 (.025 per 1,000 feet) and the bottom of the channel at Robey Street is 24.448 feet below datum. The numbered sections from No. 1 to No. 6 inclusive are underlaid with solid rock. The width of the bottom in rock, is 160 feet, and walls of masonry laid in cement will be built upon the rock surface to a height of five feet above datum. Section 7 to 14, inclusive, are in solid rock; width at bottom 160 feet, sides vertical, prism taken out in three stopes with offset of six inches on each side for each cut, making top width of 162 feet; grade in rock 1 foot in 20,000 (.05 per 1,000).

Section No. 15 is also in rock and its cross sections is enlarged at its south end so as to form a 'windage basin' in which large vessels may be turned around. The controlling works are located on this section. These works

will consist of gates or movable dams by which the flow of water from the Main Channel into the tail race, which is to deliver the outflow into the Des Plaines River, can be controlled.

This river below Lockport follows the trough of the valley down a steep declivity to the canal basin in Joliet. The fluctuations in Lake Michigan, by varying slope of water surface, will be felt at the controlling works, and provisions must be made to meet these fluctuations within a range of five feet above datum and eight feet below, or an extreme oscillation of 13 feet. The fall from datum at the controlling works to the level of the upper basin will be about 42 feet, in a distance of about 4⅓ miles. As the plans for controlling works have not been finally adopted by the Board of Trustees they cannot now be discussed.

The total amount of excavation involved in the construction of the Main Channel is 26,077,765 cubic yards of
3935 glacial drifts and 12,071,668 cubic yards of solid road, or an aggregate of 38,149,433 cubic yards, to which must be added the material excavated from the River Diversion; glacial drift, 1,564,403 cubic yards; solid rock, 258,926 cubic yards; total River Diversion, 1,823,329; grand total Main Channel and River Diversion, 39,972,762 cubic yards. All of this work is now under contract and in addition thereto 384,958 cubic yards of retaining wall.

In response to the request of the Senior Member of the Board the Board of Trustees of the Sanitary District of Chicago has furnished a report on Lake Level effects on account of the main channel of the Sanitary District of Chicago containing briefs by Trustee L. E. Cooley, C. E., and by Thos. T. Johnston, Assistant Chief Engineer, accompanied by numerous blue prints.

These papers present a full discussion of the subject as viewed by the canal officials, and will be found in the Appendix marked A.

What Is the Outflow of the Lower Lakes?

In November, 1891, the Chief of Engineers U. S. A., at the request of the Secretary of the American Society of Civil Engineers (who had been asked by the Chief Engineer of the Montreal Harbor Commission of Canada, to suggest the subject), ordered a set of observations made to determine the amount of water flowing down the Niagara River. The time was especially propitious as the water was then very low.

The results of these measurements were somewhat unexpected, and they were repeated in May, 1892. The second set corroborated the first, and the whole formed the subject of a report to the Chief of Engineers, which appeared in his annual report of 1893, page 4364, and following. But, as the subject was important, the 'Engineeering News' anticipated the appearance of the official report by publishing in its issue of March 8, 1893, this report, with the permission of the Chief of Engineers. This publication was the first ever made in which as a result of careful measurements a relation between the level of the lakes, and their outflow, or discharge, had been established and given to the public. Prior determination of this discharge had not attempted to detect this relation, and nothing more than a general determination of a season's work had been published.

In all plans for the Chicago Drainage Canal the early measurements had been taken, and those studying the subject chose such isolated figures as suited them best.

3936 The report of 1892, being so late in appearance, long after the Drainage Canal was put under construction, escaped the notice of many who are interested in navigation, for two reasons. Some were too busy to see anything, unless specially brought to their notice. Others thought the whole matter already fully canvassed, and settled. It is true there is nothing showing that the consent of Congress had been asked, for this enterprise. Certain that the subject had not been treated as an Interstate affair; to say nothing of its being an International affair. The United States has always been slow to move; with its many sleeping rights it has for many years been loath to exercise them. Not till 1888 did it begin to exercise positive legislation over its navigable waters in order to preserve them for all its citizens. Each River and Harbor bill since then is found to have sections strengthening the hands of those who wish to keep the waterways open, and in good order for all classes of navigators. Not till 1890 had any prohibitive clauses been enacted into laws forbidding, for example, the destruction of channels by improper dumpings. Saw mills went their own unchecked way every year clogging up the streams. Railroads bridged all smaller streams, in the states, without interference from the United States. Many other features can be quoted. But it is sufficient to say that all that is now changed. The adopted policy is to defend, as well as improve all water courses, now navigable, or probably navigable in the reasonably close future. Wa-

terways are under the charge of the United States, and there is no likelihood of their being abandoned for some time to come.

With this an established fact it is impossible to think that U. S. supervision shall not be extended to the Chicago Drainage Canal in due time. Under whatever law built, and for whatever purpose constructed, just so soon as it is shown that that canal affects, or becomes a part of the system of navigable waterways of the United States some supervision or control of it must follow. When boats use it for harbor purposes; when its waters add to the Illinois River, or take from the lakes, they alter natural conditions and the matter rises for consideration under national authority.

The water levels of the Great Lakes are very delicate. Storms, barometric changes, rainfall, even tidal changes are felt. Records show at Buffalo no less than 13 feet as a total possible change, between the lowest and the highest gage readings. Each lake is a basin. The water is constantly pouring in from not only one, but several
3937 inlets. The overflow, however, is now always out of the one outlet provided for that purpose; the second one formerly at Chicago, has been plugged up.

As in our basins when the water rises enough to take two, three, or more of the small holes to carry it off, it is always to be noted that those holes are always carrying that surplus off. They do not wait until the water has time to pass from one end to the other. In the same channel the head alone governs the rate of outflow, and that head is measured by the gage reading at the outlet. The supply of water in the lake: The net supply, allowing for evaporation, is the sole cause of the outflow. That supply depends solely upon rainfall, but the lake when it receives more than it has been receiving must discharge more. When it has less there is less to run out. If the outlet be dug down, or new ones made the water runs off faster than it ran off before.

The outflow is instantly affected by a changed inflow; Provided there is enough such to increase or reduce the head. If we have a rainfall of one inch over the lake area (and such are not uncommon events), there is a head of one inch to run off. But if there are two outlets to run out of, instead of one this inch must run off sooner than through the one.

If the new outlet should reduce the levels of Lake Michigan and Huron about 6 inches this effect will be

produced in full in about two years; it is not then a question of many years as some suppose.

We may feel very sure, therefore, that in this question two points are certain.

1st. The drainage canal is not solely a State affair; but a national one.

2nd. The tapping the lakes must affect their levels. But it is said, first, that the changes in levels does not concern shippers, and then that at most the affects will be trifling.

If one watched carefully the course pursued by shippers one would see that as a rule each vessel carries all that it can take, and get out of its port, or into that it intends to reach. Vessel owners, and managers are very shrewd, watchful men. They know what they can safely carry allowing for storms, and short detentions arising from passing causes. They average pretty well the practicable depths, and carry all the channels will stand. They are as conversant as are theorists about the effects of storms, but they keep good watch on ruling depths. Now should it be certain that these average depths were reduced three
3938 inches, or six inches, they must load accordingly. And not only the large boats, but also the small ones using the small harbors that the large ones cannot go into. All must lose the three, or six inches, as it may be; and not for one, or more trips, but for all trips, and for all time; a diminution of capacity is not a single tax, but a continuous one. A vessel that when light draws six feet, and loaded twelve feet, must lose three inches out of 72, say four per cent in capacity each loading; a vessel drawing 12 feet light and 20 feet loaded, would lose somewhat over three per cent in capacity at each end every loading.

Should the loss of levels be six inches instead of three, then these figures become doubled. Will the loss be six inches or will it be three? This is an important question and we have only the Niagara River discharge observations from which to answer it. These cover a range of about 1 foot and eight-tenths. There were scattering observations outside these limits, but the mass of results was secured between gage readings, mean lake level, the highest, and—1. '85. The 'smooth curve' as published enables us to note the fall of 0′ .53 on the gage per 10,000 cubic feet per second for the first foot of fall and 0′ .44 for the whole.

These observations, especially at the lower readings are erratic and indicate a need for more measurements, especially at these levels. This lower portion of the gage should be studied and additional observations made, and the Board is a unit in suggesting the importance of a series of gaging of the St. Clair River at the present time for this purpose, and to furnish additional knowledge of the relation between gage readings, and discharge. The subject is of such general bearing upon the navigation of the lakes, that it demands careful treatment, and full data. The Niagara data do not show how much Lakes Huron and Michigan would be lowered, even if 0'53 were the net loss to Lake Erie. The opinion expressed by Mr. Johnson that the effect on the two upper lakes would be some 15 per cent greater than upon Erie would seem to point to a probable loss of say 0'61. This possible loss of seven inches certainly is important enough to justify careful measurements of the discharge through the St. Clair. It is true that the law as it stands, and the intention of the Trustees contemplates the abstraction of only 300,000 cubic feet under present conditions, but after the canal is opened measurements would not be so instructive, and we must assume that ultimately the entire 600,000 cubic feet per minute will be drawn from Lake Michigan as required by the State Law.

3939 The abstraction of 10,000 cubic feet of water per second from Lake Michigan will lower the levels of all the Lakes of the system except Lake Superior and reduce the navigable capacities of all harbors and shallows throughout the system to an extent that may be determined, if at all, by actual measurements only. Under the laws of the United States these changes in capacity cannot be made without Federal authority, and to enable the executive officers of the United States to act advisedly in the matter it is necessary in the opinion of the Board not only that these measurements be taken but that the money cost of restoring the navigable depths in channels and harbors be carefully estimated.

In this connection the Board submits without expression of opinion an estimate prepared by Mr. Charles H. Keep, Secretary of the Lake Carriers Association, of the commercial losses in carrying capacity of the Lake fleet of one, three or six inches.

(Appendix Marked B.)

The Board notices that the same peculiarity exhibited by the Niagara discharge curve, is pointed out by Mr.

Johnston as existing in the Morris, Ill., and South Branch Chicago River curves. (See page 25 Appendix A 1.)

The Board also notes Mr. Johnston's conclusions on page 23, Appendix A-1, that 'applying the reasoning to the St. Clair and Detroit Rivers, then the value of Q'—Q may be taken from the diagrams illustrating the tables before described, the only uncertainty being as to the value of 'd.' Suppose 'd' to be unity, and the mean depth 20 feet. Then Q'—Q will equal something greater than 20,000 cubic feet per second," which practically corresponds with the deductions made from Niagara River observations.

So many uncertainties arise in the application of hydraulic formulae that the only way to ascertain the approximate discharge of these streams is to measure them for periods long enough to eliminate accidental fluctuations and to cover all stages.

While the navigable capacity of all harbors and channels on the Great Lakes below St. Marys Falls will be injuriously affected by a diminution in depth, the navigability of the inner harbor of Chicago will be diminished also by the introduction of a current therein, which in the present condition of the river even with the minimum
3940 flow of 5,000 cubic feet per second or 300,000 cubic feet per minute is entirely inadmissible. The estimates of the effect of the Drainage Canal upon this harbor should also consider this element.

The Board of Trustees have not yet determined upon a plan of treatment of this navigable channel, and their plans may be such as may improve, impair or destroy its utility as a navigable river.

All of which is respectfully submitted.

O. M. Poe,
Col. Corps of Engineers,
Br. Brig. Genl. U. S. Army.

E. H. Ruffner,
Major of Engineers, U. S. Army.

W. L. Marshall,
Major Corps of Engineers."

On June 16, 1896, the Sanitary District of Chicago applied to the Secretary of War for a permit to improve the Chicago River in order to secure the necessary water through the Chicago River to make available the artificial channel

then under construction, a map accompanied the request showing just what work the Sanitary District proposed to do in the Chicago River, said letter is attached to the answer, as Exhibit H. (Rec. Vol. VIII, pp. 120, 121; This Narrative p. 88.) Under date of July 3, 1896, Joseph P. Doe, Acting Secretary of War, approved the plan submitted. (Rec. Vol. VIII, p. 121.)

"July 3, 1896.

Sir: I have the honor to acknowledge the receipt of your letter of 16th ultimo, requesting permission to make certain changes in the capacity of the channel of the Chicago River for drainage purposes at points indicated on the map accompanying the application, and in reply beg to say that upon investigation it is found that the permission requested can be granted upon the following conditions:

1. That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each by-pass and each new dock or wharf proposed to be built, in order that the Secretary of War may act intelligently in each case.

2. That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submitted for consideration."

November 16, 1897, pursuant to request of the Sanitary District, the Secretary of War issued a permit to widen the Chicago River between Quincy and Harrison streets in certain respects. The request and permit are as follows (Rec. Vol. VI, pp. 3575, 3576):

"B. A. Eckhart, Esq.,
President The Sanitary District of Chicago,
Rialto Building,
Chicago, Ill.

The Sanitary District of Chicago.

Chicago, October 28, 1897.

To the Hon. Russell A. Alger,
Secretary of War,
Washington, D. C.

Sir:

I have the honor of transmitting to you through Maj. W. L. Marshall, Corps U. S. Engineers, plats showing the proposed widening of the Chicago River between Quincy and Harrison streets, to conform to the plans of this District for securing an adequate flow of water through the said stream. Our general plans have been heretofore submitted to the War Department and in the communication under date of July 3, 1896, signed by the then acting Secretary of War, Joseph B. Doe, have received a qualified approval subject to the general requirement that plans for each separate division of the work shall be submitted for specific approval. We respectfully ask your approval of the plans now transmitted.

Very respectfully,

Thomas Kelly,
President.

1st Indorsement,

U. S. Engineer Office,

Chicago, Ills., October 29, 1897.

Respectfully forwarded to the Chief of Engineers U. S. A.

The works indicated are by-passes and docks indicated on the general plans conditionally approved by the Acting Secretary of War, July 3, 1896. (E. D. File No. 15715/5).

As these works make possible a material improvement in the capacity of Chicago River for navigation in the vicinity of Adams and Van Buren streets, I respectfully recommend that the necessary authority to do the work be granted by the Secretary of War, subject to all the conditions attached to the original authority dated July 3, 1896.

W. L. Marshall,
Maj. Corps Engrs.

3576 Form No. 5.

Whereas, by Section 3 of the Act of Congress, approved July 13, 1892, entitled 'An Act making appropriations for the construction, repair, and preservation of certain public works on rivers and harbors and for other purposes,' it is provided that, without the permission of the Secretary of War, it shall not be lawful to build any wharf, pier, dolphin, boom, dam, weir, breakwater, bulkhead, jetty or structure of any kind outside established harbor lines or where no harbor lines are or may be established in any port, homestead, haven, harbor, navigable river, or other waters of the United States, in such manner as shall obstruct or impair navigation, commerce, or anchorage of said waters; or to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of any port, roadstead, haven, harbor of refuge, or inclosure within the limits of any breakwater of the channel of any navigable water of the United States, unless approved and authorized by the Secretary of War;

And whereas, the Sanitary District of Chicago has submitted to the Secretary of War for his approval the attached plans for the widening of the Chicago River between Quincy and Harrison streets of said city, by the construction of by-passes and docks;

Now, Therefore, This is to certify that the Secretary of War hereby approves and authorizes the work shown on said plans upon the following conditions:

1. That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale showing each proposed new bridge, each by-pass, and each new dock or wharf, proposed to be built, in order that the Secretary of War may act intelligently in each case.

2. That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.

3. That it will not cover obstructions to navigation, by reason of this work while in progress, or when completed.

4. That the United States shall not be put to expense by reason of this work.

5. That this authority shall expire by limitation in two years from date unless extended.

Witness my hand this 16th day of November, 1897.
R. A. Alger, Secretary of War.
(War office Seal.)"

November 30, 1898, the Secretary of War granted a permit pursuant to the request of the Sanitary District to construct a coffer dam around the east side of the center pier of the Adams Street Bridge, in connection with the improvement of the Chicago River. (Rec. Vol. VI, p. 3578.)

January 13, 1899, pursuant to the request of the Sanitary District, the Secretary of War granted a permit to remove Taylor Street Bridge across the Chicago River. (Rec. Vol. VI, p. 3580.)

March 10, 1899, permit was granted by the Secretary of War for the erection of a bridge at Taylor street in connection with the river improvement. (Rec. Vol. VI, p. 3585.)

May 12, 1899, pursuant to the river improvement plan, permit was granted by the Secretary of War to construct a coffer dam along the west side of the Chicago River at certain place. (Rec. Vol. VI, p. 3582.)

On February 9, 1898, the Sanitary District of Chicago invited the Committee on Rivers and Harbors of the House of Representatives to make an inspection of the Chicago

River and the main channel of the Sanitary District then nearing completion. (Rec. Vol. IV, p. 2381.)

On February 23, 1898, the Committee made the investigation. (Vol. IV, p. 2382.)

On April 24, 1899, Major Marshall, of the Corps of Engineers of the United States Army, acting as United States Engineer at Chicago, wrote to the Chief of Engineers recommending that a permit to open the main channel of Sanitary District be issued by the Secretary of War and Chief of Engineers. His report is as follows (Rec. Vol. VI, pp. 3586-3588):

"United States Engineers Office,
#1637 Indiana Ave., Chicago, Ill.

April 24, 1899.

Brig. Gen. John M. Wilson,
Chief of Engineers, U. S. A.,
Washington, D. C

General:

I have the honor to report as follows on the application of the trustees of the Sanitary District of Chicago for authority to open their drainage canal. It is a strange fact that this city has expended, or will expend, over $30,000,000 with the intention of diverting an apparently unlimited amount of water from the Great Lakes to the Mississippi drainage area for sanitary purposes without finding out whether such diversion would be allowed by the great interests of the United States and the Colonies of Great Britain along the chain of Great Lakes in the navigation of the rivers and harbors of the Great Lakes. Now, they ask the authority of an executive officer of the United States to open a channel that will to some unknown extent, lower the levels of all the Great Lakes below Lake Superior and of their outlets, introduce a current also unknown and not to be ascertained otherwise than by actual experiment, in Chicago River, the most important navigable river of its length on the Globe, but which is already obstructed by bridges, masses of masonry and bends, and of difficult navigation at best.

The possible effects of this diversion are not known further than that to some unknown degree they will be injurious. Whether the amount of this injury will be so small as to be accepted by the interests affected, in view of the manifest advantages to and apparent necessities of their neighbors, cannot be determined by other than the interests themselves.

It is clear to me that I am not competent to make a recommendation as to what should ultimately and definitely be done.

3587 The matter of what effect the opening of this channel would have on the levels of the Great Lakes has been heretofore submitted to a Board of Engineers. The Board reported that the Great Lakes would be lowered, but that there was not sufficient data to determine the exact effects of the proposed discharge, and recommend extended investigations, which it is believed are being carried on now by the Deep Waterways Commission or Board. They have not reported. In my opinion the abstraction of from 300,000 to 600,000 cubic feet per minute will permanently lower Michigan, Huron and Erie from three to eight inches; not more than eight nor less than three, corresponding to an extreme reduction of from 160 to 466 tons in carrying capacity of the large vessels of the lakes, and that it will take from three to four years for this full effect to be obtained. But the state law is unlimited in its requirements. 20,000 cubic feet per minute must be taken from Lake Michigan for each 100,000 population of the District; already nearly 400,000 cubic feet must be taken, and at the same ratio of increase for a few decades, in a very short time there must be taken 1,000,000 c. ft. per minute under this indefinite law. The amount should be limited and the injurious effect stopped somewhere.

The mean current to be introduced in Chicago River upon the opening of the canal is estimated by the Engineers of the Drainage Board at 1¼ miles per hour, or 110 feet per minute. This is simply an assumption that with such velocity in an unobstructed river, the amount of 300,000 cubic feet per minute can be discharged through Chicago River,—but I have seen this river so jammed with vessels, drawing all the water that is in it, —that by leaping from deck to deck I could cross the river. What the velocity would be in such conditions, with Lake Michigan on one side and a great fall on the other side of such vessels, no one knows. But it is a

simple mathematical problem to determine the effect on steel-plate vessels of from 2,000 to 4,000 tons mass drifting upon or striking stone piers with a velocity of near 2 feet a second. They will go to the bottom.

Individually I have to say that I am in entire sym-
3588 pathy with the people in their effort to purify their water supply. I have lost my only son from typhoid fever, produced, I believe from drinking water polluted by defective drainage at Chicago, which this channel will correct. In every proper way I have aided the officers of the Drainage District. I would like further to aid them, but I believe this question to be entirely out of my sphere, and too great and important for me even to venture an opinion or make a recommendation about. Yet I may venture to suggest that the entire subject be referred to Congress for final solution, and that a conditional permit or authority be granted to the authorities of the Chicago Sanitary District by the War Department, awaiting action by Congress, to open their channel, and under the following conditions:

1st. That if, at any time, it becomes apparent that the current created by such drainage works in the South and Main branches of Chicago River, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South Branch.

2nd. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River. With 300,000 cubic feet per minute discharge, it will take one year to lower the level of Lakes Michigan and Huron 1/10 of a foot, and several years to reach the maximum permanent effect of this discharge, which will not probably much exceed three inches, so that the main injury to navigation, if any that can be expected before action by Congress, will be in Chicago River, and that can be at once abated.

All the changes made by the Sanitary District of Chicago, taken by themselves, have been such as to increase the navigable capacity of Chicago River. Taken in connection with the current to be introduced I am not able to say that the river will be as navigable as it was before these changes were made. The changes materially lessen

the probable injury to navigation of this current, at the points where the changes have been or will be made.

I believe their channel will be entirely under control and that if the discharge be injurious it can be at once and at any time shut off, and it is evident that the War Department should preserve the right to control the current and discharge through the Controlling Works of this channel.

Very respectfully,
Your obedient servant,
W. L. Marshall,
Maj. Corps of Engineers, U. S. A."

On May 8, 1899, pursuant to the recommendations of Major Marshall and the Chief of Engineers, the Secretary of War issued a permit for the opening of the Sanitary District Channel. (Rec. Vol. VIII, pp. 44, 45; Narrative p. 21.)

Whereas, by Section 10 of an act of Congress approved March 3, 1899, entitled 'An Act making appropriations for the construction, repair and preservation of certain public works, on rivers and harbors, and for other purposes,' it is provided that it shall not be lawful to alter or modify the course, location, condition or capacity of the channel of any navigable water of the United States unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same:

And whereas, the Sanitary District of Chicago, a municipal corporation, organized under the laws of the State of Illinois, has constructed an artificial channel from Robey street, Chicago, to Lockport, and has been heretofore granted permission by the Secretary of War to make certain improvements in the Chicago river for the purpose of correcting and regulating the cross section of the river so as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles an hour, it being intended to connect the said artificial channel with the west fork of the south branch of Chicago river at Robey street in the said City of Chicago.

And whereas, The said Sanitary District of Chicago has now applied to the Secretary of War for permission to divert the waters of the said Chicago river and cause

them to flow into the said artificial channel at Robey street as aforesaid;

And whereas, The said Sanitary District of Chicago represents that such movable dams and sluice gates as are necessary to, at all times, secure absolute and complete control of the volume and velocity of flow through the Chicago river have been constructed;

Now therefore, The Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the waters of Chicago river to flow into the same, subject to the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it become apparent that the current created by such drainage works in the south and main branches of the Chicago river, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago river and its South Branch.

3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago river.

Witness my hand this 8th day of May, 1899.

R. A. Alger, *Secretary of War.* (Seal War office.)
John M. Wilson, *Brig. Genl. Chf. of Engrs. U. S. A.*"

On January 17, 1900, the Sanitary District Channel was opened, and water has flowed out of Lake Michigan through the Chicago River down the Sanitary District Channel continuously since that day. (Cooley Rec. Vol. III, p. 174; Narrative p. 293.)

On June 20, 1900, Major Willard, United States Engineer at Chicago, made a full report upon the operation of the Sanitary District Channel and its effect upon navigation in the Chicago River. In this report Major Willard said: (Rec. Vol. IV, pp. 2385, 2386):

"There is no doubt that the reversed current in Chicago River has increased the difficulty of navigating it with the large boats now demanded by commerce, but it is a noteworthy and gratifying fact, not unexpected by me at least, that the pilots have been quick to adapt themselves to the new conditions and I have little doubt but that they could handle their boats safely even in greater currents than now obtain.

If I have not overestimated pilots' skill, and considering the immense benefit of the Drainage Canal to the City of Chicago since its opening only a few months
2386 ago, I recommend that no restrictions be placed upon the legal requirements of flow into the Sanitary Canal, unless it should be found absolutely necessary to do so.

The Engineer Department, the City of Chicago, and the Sanitary District are of one mind as to the need of improving Chicago River, and are co-operating heartily to that end, and large sums are appropriated and being expended judiciously by each for the objects in view. The interests of navigation are not only being protected, but are being advanced practically sooner than could be hoped for in the usual course."

On April 26, 1900, the Sanitary District submitted plans for the improvement of the south branch of the Chicago River from Lake street to Ashland avenue and asked the Secretary of War to issue a permit for such improvement. (Rec. Vol. VIII, p. 122; Narrative p. 90.)

On June 7, 1900, the Sanitary District again submitted plans for the widening of the south branch of the Chicago river between 12th street and Ashland avenue to a uniform width of 200 feet. (Rec. Vol. VIII, p. 123; Narrative p. 91.)

On July 11, 1900, the Secretary of War approved the plans and issued the permit as requested on April 26, 1900. (Rec. Vol. VIII, p. 124; Narrative p. 92.)

On July 11, 1900, the Secretary of War also approved the plans and issued the permit as requested in the application of June 7, 1900. (Rec. Vol. VIII, p. 125; Narrative p. 93.)

On April 9, 1901, the Secretary of War issued an order directing the Sanitary District to reduce the flow through the Chicago River to 200,000 cubic feet per minute instead of the withdrawal of over 300,000 cubic feet because of the velocity of nearly three miles per hour in the Chicago River, which was dangerous to navigation in its then condition. (Rec. Vol. VIII, p. 45; Narrative p. 23.)

On July 23, 1901, the Secretary of War amended the order of April 9th, permit the Sanitary District to flow 300,000 cubic feet per minute between the hours of 4 P. M. and Midnight. (Rec. Vol. VIII, p. 46; Narrative p. 24.)

On December 5, 1901, upon application of the Sanitary District the Secretary of War issued a permit authorizing a flow of 250,000 cubic feet per minute throughout the twenty-four hours of the day. (Rec. Vol. VIII, p. 47; Narrative p. 24.)

On January 17, 1903, the Secretary of War issued a permit authorizing the Sanitary District to increase its flow to 350,000 cubic feet per minute until the 31st day of March, 1903 after which date it was to reduce it to 250,000 cubic feet per minute. (Rec. Vol. VIII, p. 48; Narrative p. 25.)

On September 11, 1907, the Secretary of War issued an order approving the plans for the proposed drainage channel to connect Lake Michigan at Wilmette, Illinois, with the north branch of the Chicago River with the provision that the total diversion of water from Lake Michigan should be no greater than already authorized by the War Department. (Rec. Vol. VIII, p. 115; Narrative p. 81.)

On June 30, 1910, the Secretary of War authorized the Sanitary District of Chicago to open the channel from the Calu-

met River to its main channel with the provision that the total amount of water withdrawn from Lake Michigan should not exceed the War Department permit. (Rec. Vol. VIII, p. 116; Narrative p. 82.)

On January 27, 1897, Major Marshall made a preliminary examination of the Upper Illinois River and the Lower Des Plaines River with a view of the extension of navigation from the Illinois River to Lake Michigan at Chicago in compliance with the requirements of the Rivers and Harbors Act of June 3, 1896, which report was transmitted to the Congress of the United States as House Document 353, 54th Congress, 2nd Session. (Rec. Vol. IV., p. 2202.) This letter of Major Marshall is the basis of survey provided by the Rivers and Harbors Act of March 3, 1899.

"54th Congress, 2d Session. House of Representatives.
Document No. 333.

PRELIMINARY EXAMINATION OF THE UPPER ILLINOIS RIVER AND LOWER DES PLAINES RIVER, ILLINOIS.

Letter from the Secretary of War, Transmitting, with a Letter from the Chief of Engineers, a Report of a Preliminary Examination of the Upper Illinois River and Lower Des Plaines River, Illinois.

March 2, 1897.—Referred to the Committee on Rivers and Harbors, ordered to be printed.

War Department,

Washington, D. C., March 3, 1897.

Sir: I have the honor to enclose herewith a letter from the Chief of Engineers dated March 2, 1897, together with a copy of a report from Maj. W. L. Marshall, Corps of Engineers, dated January 27, 1897, of a preliminary examination made by him in compliance with the provisions of the river and harbor act of June 3, 1896, of the upper Illinois River and lower Des Plaines River, Illinois.

Very respectfully,
DANIEL S. LAMONT,
Secretary of War."

2203 "Washington, D. C., March 2, 1897.

Sir: I have the honor to submit the accompanying report of January 27, 1897, by Maj. W. L. Marshall, Corps of Engineers, of the results of a preliminary examination of the upper Illinois River and lower Des Plaines River, Illinois, with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago, made in compliance with requirements of the river and harbor act of June 3, 1896.

Major Marshall states that the locality embraces an important commercial route between the Great Lakes and the Mississippi River system, and its utility and worthiness have long been recognized by Congress.

The division engineer, Col. Henry M. Robert, Corps of Engineers, is of the opinion that the upper Illinois and the lower Des Plaines rivers are worthy of improvement, and I concur in his views.

It is estimated that the cost of the necessary survey and preparation of detailed plans of improvement will be $75,000.

Very respectfully, your obedient servant,

JOHN M. WILSON,
Brig. Gen., Chief of Engineers, U. S. Army.

Hon. DANIEL S. LAMONT,
Secretary of War."

"PRELIMINARY EXAMINATION OF UPPER ILLINOIS RIVER AND LOWER DES PLAINES RIVER, ILLINOIS, WITH A VIEW TO EXTENSION OF NAVIGATION FROM ILLINOIS RIVER TO LAKE MICHIGAN AT OR NEAR CHICAGO.

United States Engineer Office,

Chicago, Ill., January 27, 1897.

General: In accordance with your letter dated August 11, 1896, I have the honor to submit the following report upon a preliminary examination of 'the upper Illinois River and lower Des Plaines River, with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago,' directed by the river and harbor act of June 3, 1896.

* * *

The sanitary district of Chicago has nearly completed
2204 a canal for drainage purposes from Chicago River at Robey street to near Lockport from 18 to 22 feet in depth below the proposed water surface, and varying in width from 160 feet in rock to more than 200 feet in earth, a length of 28 miles, which may be made available as part of any enlarged waterway over the route in question, and is of much greater dimensions than required by any commercial canal adapted for the conditions and requirements of present or prospective traffic by water between Lake Michigan and the region along the water courses of the Mississippi Valley. To comply with the law of the State of Illinois under which this drainage canal is constructed — it has been constructed of a capacity to discharge 600,000 cubic feet per minute through the section excavated in rock and 300,000 cubic feet per minute throughout the earth section— the law requires a discharge of 20,000 cubic feet per minute for each 100,000 inhabitants of the drainage district, which at present requires more than 300,000 cubic feet and in a few years will require the full 600,000 cubic feet discharge through the canal. The taking of water from Lake Michigan, however, for drainage purposes (or rather for dilution of sewage) has not yet been authorized by Congress. This deep channel abruptly terminates at Lockport, and it is proposed to discharge the water through controlling gates into a non-navigable tail race down the slope to and through the City of Joliet into the lower Des Plaines and Illinois rivers. Any navigable channel, therefore, constructed in continuation of the drainage canal must connect with this canal at Lockport and terminate at or above LaSalle, about 66 miles distant, but the lockage after the opening of the drainage canal will be reduced by at least the amount that the increased discharge will raise the water surface of the Illinois River at LaSalle, increased by the slope in the drainage canal from Lake Michigan to Lockport, or, say, at least 12 feet when the drainage canal is actually discharging. This will result in reducing the number of locks required in any
2205 of the proposed schemes by one, but will substitute an obstruction due to the current in the canal and river, repeated in each pool of the river, if the natural channel be improved.

* * *

The trustees of the Chicago sanitary district are constructing their canal with fixed bridges with 22 feet clear

headroom over the canal. This is ample headroom for a commercial barge canal of the largest capacity, and the difference in cost between fixed and drawbridges crossing the canal between Chicago and Lake Joliet, with a reasonable allowance for difference in cost of operation, is probably sufficient to construct the canal from the present terminus of the drainage canal to Lake Joliet of from 8 to 10 feet depth, with locks suitable for the passage of the largest Mississippi River barges. Mississippi River towboats could then carry their tows to Lake Joliet, then transfer them to more handy tugs for passage through the more obstructive canal portion of the route. For an 8-foot channel from Lockport to Lake Joliet the estimated cost in 1890, exclusive of bridges, was $3,900,000. Swing bridges from Chicago to Lake Joliet were estimated at $3,653,000. The cost of operating the swing bridges would far exceed the cost of operating the locks without any corresponding advantages for a commercial canal, other than sentimental, over the part of the route where towing on the Mississippi River style cannot be applied.

Conclusion.

1. In my opinion the surveys already made are in sufficient detail for preliminary estimates of the cost of any suitable extension of the navigation of the Illinois River to Lake Michigan that does not involve enlargement of the Illinois and Michigan Canal from Joliet to LaSalle.

2. That prior to embarking in any such improvement it is advisable to secure from the State of Illinois the State works along the Illinois River and such parts of the Illinois and Michigan Canal as may be utilized; also to thoroughly complete the lower Illinois River improvement which has slowly progressed for thirty years, resulting in diversion of water traffic to rail.

3. That the dimensions and route of the proposed extension should be examined into and decided by a competent board of engineers, with means and authority to make such additional surveys as their proper enlightenment demands. The expenses and costs of such a board of the surveys are estimated at $30,000; if detailed plans, etc., are to be made, at $75,000.

2206 The locality embraces an important commercial route between the Great Lakes and the Mississippi River system, and its utility and worthiness has long been recognized by Congress.

Preliminary estimates of cost on various plans have been heretofore made, and reports containing them are referred to hereinbefore.

Very respectfully, your obedient servant,

W. L. MARSHALL,
Major, Corps of Engineers.

Brig. Gen. W. P. CRAIGHILL,
Chief of Engineers, U. S. A.

(Through the Division Engineer.)
(First indorsement.)
U. S. Engineer Office,
Northwest Division,

New York, February 20, 1897.

Respectfully forwarded to the Chief of Engineers, United States Army.

I am of the opinion that the upper Illinois and lower Des Plaines rivers are worthy of improvement with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago.

HENRY M. ROBERT,
Colonel, Corps of Engineers, Division Engineer."

On March 17, 1900, a Board of three Engineers appointed by the Secretary of War, under the Rivers & Harbors Act of March 3, 1899, made a report, which report is in part as follows. Chief of Engineers Report of 1900, Appendix MM., p. 3858. (Rec. Vol. IV, p. 2183.)

"*Extract from a Report of Board of Engineers March 17, 1900.*

Appendix MM of Report of Chief of Engineers 1900.
Page 3858.

Having considered the available facts bearing upon the questions presented, the Board has the honor to submit the following preliminary report, in compliance with Department letter of February 13, 1900.

2184 The instructions of the Board are found in the act of Congress approved March 3, 1899, as follows:

> 'The Secretary of War is directed to appoint a board of three engineers, which board shall make a survey and estimates of cost for the improvement of the Upper Illinois River and Lower Des Plaines River, in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago; said board of engineers shall report the estimates of cost for a channel seven feet deep, and also for a channel eight feet deep, throughout said proposed route; said survey and estimates of cost shall be made in pursuance of and according to the recommendations in report of January twenty-seventh, eighteen hundred and ninety-seven, and there is hereby appropriated for the expenses of said board and such survey the sum of thirty thousand dollars, or so much thereof as may be necessary.'

The report of January 27, 1897, is a 'Preliminary examination of Upper Illinois River and Lower Des Plaines River, Illinois, with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago,' made by Maj. W. L. Marshall, Corps of Engineers, U. S. A., and published in the report of Chief of Engineers, 1897, pages 2882-2887.

Detailed reports and surveys have also been submitted to Congress by the following officers:

Gen. J. H. Wilson, 1867, report published in House Ex. Doc. No. 16, Fortieth Congress, first session.

Col. J. N. Macomb, Corps of Engineers, Report of Chief of Engineers, 1875, Vol. II, page 525.

Maj. W. H. H. Benyaurd, Corps of Engineers, Report Chief of Engineers, 1884, page 1958.

Board of Engineers on Hennepin Canal and Illinois and Michigan Canal, Report of Chief of Engineers, 1887, page 2125.

Capt. W. L. Marshall, Corps of Engineers, Report of Chief of Engineers, 1890, page 2419.

The last report covers most thoroughly the entire subject, as far as it had then been developed, considers the various routes, shows the character and location of the works required on each, with detailed estimates of cost, and the 8-foot channel of those estimates is a water-way of so nearly the same dimensions as the 7 and 8-foot chan-

nels now called for that the work of the Board might be confined to the presentation of revised plans and estimates derived from this report, if it were not for the
2185 change in conditions which has resulted from the construction by the Sanitary District of Chicago of a drainage canal through the divide between Chicago and Lockport. This channel opens a waterway over this part of the route which more than meets the requirements of the one called for or of any other likely to be called for by those interested in navigation.

If the route by the Chicago River and drainage canal be adopted, there remains but little more than half of the work involved in the 8-foot project of 1890 for the Government now to take in hand in order to complete the improvement, since the estimated cost of this portion of the channel (about 28 miles) was nearly $14,000,000. By the Calumet and Sag route only about 10½ miles of the drainage canal can be utilized.

But while the drainage canal covers about half of the work involved in the project by way of Chicago River, it at the same time has turned an additional flow into the Des Plaines River, materially changing its low-water regimen. The requirement of this flow at present are 5,000 cubic feet per second, while the limit of 10,000 is probably more nearly the flow that will have to be dealt with, at least not long after the completion of the present project. As nearly as can now be estimated, this flow gives a water line indicated on the accompanying profile, and the contrast is shown with the low-water conditions hitherto existing. The steep slope shown on the profile indicates that with so large a volume of discharge the velocity of the current would be too great for up-stream navigation in an open river. This might be overcome to a great extent by canalizing the river by high dams, entailing great expenditures for the necessary works, as well as for the purchase of lands overflowed, the cost of which cannot even be approximated from present information."

November 17, 1900, the Board of Engineers made a report pursuant to the Rivers and Harbors Act of March 3, 1899, H. R., Document No. 112, 56th Congress, 2nd Session, Vol. 4, p. 2190. The report is in part as follows:

"The Board finds the most economic route for waterways of 7 feet and 8 feet depth to be from Utica to Marseilles in the bed of the river, 11.4 miles; thence around

the Marseilles rapids by canal, 7.4 miles; thence in the bed of the river to near the mouth of Kankakee River, 21.2 miles; thence by enlarging the Illinois and Michigan Canal to the Joliet basin, 18.3 miles; thence by canal through Joliet Basin and along the east bank of the Des Plaines River, 4½ miles, connecting with the Sanitary Canal at Lockport and thence through the Sanitary Canal
2191 and the Chicago River to Lake Michigan, thus complying with the terms of the Act of March 3rd, 1899. • • • •

2192 As in the preliminary report, the Board invites attention to the fact that the estimates are based upon the assumption that the State of Illinois and the sanitary
2193 trustees of the City of Chicago will cede the necessary parts of their respective franchises free of cost to the United States, both for construction and use.

The Sag Route

Since the Board's report of March 17, 1900, the trustees of the sanitary district have undertaken to cooperate with the United States in deepening the South Branch of Chicago river to 21 feet and widening it to at least 200 feet. They have already planned to substitute 7 bascule bridges for the center-pier bridges now obstructing the river. It is expected that this project will be extended, and that the City of Chicago will undertake a part of the bridge reconstruction and lower, or cause to be lowered, the three tunnels now limiting the navigable depth of the river to 17 feet. The fears entertained with respect to the dangers of navigating the South Branch of the river under the new conditions of reversed flow have been allayed to a great degree by the practical experience of the past season. For this reason, and because the plans for both the 7-foot and 8-foot waterways comply with the requirements of the act contained in the words "with a view to the extension of navigation from the Illinois river to Lake Michigan at or near Chicago" in connection with the Sanitary Canal, the Board is of the opinion that the additional cost will not justify the construction at the present time of an auxiliary canal from the Sanitary Canal to Lake Michigan by way of the Sag and Calumet Route, and is also of the opinion that such a route would not become a necessity until commerce of either 7-foot or 8-foot route should develop to a degree not expected for years."

Pursuant to the Rivers & Harbors Act of June 6, 1900, the Board of Engineers appointed under said Act, made a report dated November 18, 1900, in part as follows: (Vol. 4, p. 2197.)

"The project for the Lower Illinois river provides for locks 75 feet wide and 350 feet between miter sills with 7 feet on the miter sills at low water. The discharge
2198 of the Chicago Drainage Canal should increase the navigable depth to over 8 feet, and if the project be extended to Lake Michigan by the 8 foot project on which estimates have been submitted by the Board, there will be afforded a connecting link between the Great Lakes and the rivers of the Mississippi valley, not only ample for river navigation as it now exists, but also for any improvement therein that has been authorized by Congress.

But it is held by not a few that the United States should take the initiative and construct a great waterway of which the Illinois Valley line should be a link, extending lake navigation to the interior of the country, and that a commerce which does not now exist will then develop to such a magnitude as will more than justify the expenditures. For such a project a depth of 14 feet or greater will be required, and further surveys and estimates for a waterway of less depth than 14 feet cannot be considered by the terms of Section 22, under which the Board is instructed to act.

The engineering questions presented in a project for a deep waterway to connect Lake Michigan with the Illinois river, although attended with considerable difficulty, are by no means insuperable. The proposed line would embrace, first, the Chicago river, consisting of the main river and a portion of the South Branch for a distance of about 5 miles. This section is now under improvement by the United States in cooperation with the trustees of the Sanitary District of Chicago, and will, when the many changes in bridges and tunnels have been made, and the widening and deepening of the channel completed, afford a navigable depth of 21 feet and an available width of 200 feet.

Connecting with this section the sanitary canal affords a magnificent waterway, 28 miles in length, of sufficient depth and width for any possible requirement of navigation.

From the west end of this canal the waters of Lake Michigan, in a steady flow amounting to from 5,000 to 10,000 cubic feet per second, are discharged into the bed of the Des Plaines river, and are carried thence down through the Illinois to the Mississippi.

The velocity of current along the Des Plaines river, which would have resulted from confining this discharge to a channel of 8 feet depth for barge navigation, will be sufficiently reduced in a ship canal of 14 feet depth *or over to make up-stream navigation feasible.* On the lower Illinois river the prevailing slope of less than 0.15 foot
2199 per mile will insure so gentle a current that the depth required can be secured simply by enlarging the existing waterway by dredging in an alluvial deposit, at a cost which will be small when compared with the work which has been done by the City of Chicago in cutting through the divide between the Lake Basin and the Illinois Valley watershed,, so eloquently described in the memoir of the Board of Trustees of the Sanitary District of Chicago.

But such a channel to be of commercial value should either form a through line of communication between the lakes and the Gulf of Mexico or extend to some large center of population, as St. Louis. A waterway stopping at the Village of Grafton would have little commercial importance, except locally over one to the present terminus of the Drainage Canal at Lockport. The terminal arbitrary described by Mr. Cooley in his paper submitted will be as applicable in the one case as in the other.

The commercial possibilities of navigation by lake vessels to St. Louis and the Gulf of Mexico have been ably discussed in the papers accompanying this report, but all of these projects are based upon the assumption that the Mississippi river can be rendered navigable for such vessels. The feasibility of the development of the navigation of the Mississippi river is the essential element, which must first be determined before any project for extending lake navigation inland can be considered advisable."

Major Willard, U. S. Engineer at Chicago in 1901, pursuant to the Rivers and Harbors Act of July 3, 1896, made a report to the Chief of Engineers, which is found in the Chief of Engineers' Report 1901, p. 3006. (Rec. Vol. IV, p. 2187).

"The State laws authorizing the construction of the
2188 Sanitary Canal require removal of the state dams, when the flow required by the state law of 20,000 cubic feet per minute for each 100,000 inhabitants of the Sanitary District shall have become permanent, the expectation being that the increased discharge would furnish an open navigation equivalent to that pooled by the dams. The discharge of the sanitary canal, however, is regulated by the Secretary of War *insofar as it affects the interests of navigation in the Chicago River,* and has been reduced by his order to 200,000 cubic feet per minute until the South Branch shall have been widened and deepened sufficiently to permit the full flow required by the State law, or so much thereof as may be found safe."

In 1902 Col. O. H. Ernst, United States Engineer at Chicago, made a report to the Chief of Engineers, Report of Chief Engineers, 1902. App. K. K., p. 2097. (Rec. Vol. IV, p. 2200.)

"Since the flow of the Chicago River has been reversed through the South Branch by the discharge into the sanitary canal the slope has also been reversed from the lake upstream and the depth correspondently reduced. This loss in navigable depth will be more than restored in the main stream and in the South Branch by the excavations of the sanitary district, which, in order to facilitate the flow of the large volume of water required for the dilution of the sewage discharged into the drainage canal, has undertaken to enlarge these portions of the Chicago River to a width of 200 feet and central depth of 26 feet. These dimensions have no relation to the draft of vessels using the river, and if maintained as they should be for drainage purposes will furnish a navigable depth in excess of the requirements. The south fork of of the South Branch, and the North Fork, however, do not share in these benefits. In the South Fork particularly the dimensions of channel obtained by the operations of the Government were seriously impaired by the change of slope. The sanitary district has undertaken to restore these dimensions, and will no doubt do so, though it has been prevented from fully accomplishing the work by some difficult rock excavation. But it has not undertaken as yet to maintain them.

The Chicago River is the main sewer of Chicago, and as such is subject to deteriorating influences as a navigable channel from which there is no escape. The city ordinances against dumping solid matter into it are ample, and, I think, generally well observed. But a very large amount of solid matter must of necessity go into it with a perfectly legitimate use of it as a sewer. Periodical dredging will be necessary to maintain it as a navigable channel and, eventually, to maintain it even as a sewer. That work would seem to be as much the duty of the city as the maintenance of any other part of its sewer system. So far as the South Branch is concerned, the question has been solved by the necessities of the drainage canal, as already mentioned, but the sanitary district has not accepted responsibility for maintaining the other branches. Whether that organization or some other representing the people of Chicago should do the work is for them to decide, but it seems to me clear that the United States should not be called upon to do it. Accordingly, no estimate for maintaining the channel excavated under the project of 1896 is submitted."

In the Rivers and Harbors Act of June 13, 1902, an appropriation was made of $200,000 by Congress for the survey of a waterway 14 feet in depth from the terminus of the Sanitary District canal to St. Louis, Mo. The report of the commission was transmitted December 18, 1905, by Wm. Howard Taft, Secretary of War, said Document is known as H. R. Document 263, 59th Congress, 1st Session. (Rec. Vol. IV, pp. 2261-2269.)

In a letter from the Chief of Engineers to the Secretary of War, the Chief of Engineers said (Rec. Vol. IV, p. 2262):

"Washington, December 12, 1905.

Sir: The river and harbor act approved June 13, 1902, contained an item as follows:

The sum of two hundred thousand dollars, or so much thereof as may be necessary, is hereby appropriated for making such surveys, examinations, and investigations as may be required to determine the feasibility of, and to prepare and report plans and estimates of cost, of a navigable waterway fourteen feet in depth from Lockport, Illinois, by way of the Des Plaines and Illinois rivers to

the mouth of said Illinois River, and from the mouth of the Illinois River, by way of the Mississippi River, to Saint Louis, Missouri: *Provided*, That twenty-five thousaid dollars of said sum, or so much thereof as may be necessary, may be expended by the Mississippi River Commission in making surveys, examinations, and investigations herein required from the mouth of the Illinois River to Saint Louis *provided further* that the Secretary of War shall appoint a board of three engineers to make the surveys, examinations and investigations hereinbefore required from Lockport, Illinois, through the Des Plaines River and Illinois River, to the mouth of said Illinois River, and that all such surveys, examinations, and investigations shall be made to determine the feasibility of, and to prepare and report plans and estimates of cost of, a navigable waterway fourteen feet in depth from
2264 Lockport, Illinois, to Saint Louis, Missouri.

* * *

The Board estimates the cost of the channel from Lockport to Grafton at $23,543,582. This estimate is based on concrete locks 600 feet long, 80 feet wide, and 14 feet deep over the miter sills. The Board remarks that this depth while corresponding to the channel mentioned in the act, will not provide for any future increase, which may be made possible by argumenting the flow through the Chicago Drainage Canal above 10,000 cubic feet per second. The Board states that, to take full advantage of such possible increase in navigable depth, the locks would have to be entirely rebuilt, or would have to have increased depths given to them at the present time. To increase the depth over the miter sills 6 feet now would add about $1,376,000 to the cost of the project. The plan proposed is based upon the assumption that the abstraction of 10,000 cubic feet of water per second from Lake Michigan, a quantity contemplated in the State legislation affecting the drainage canal, will eventually be permitted by competent Federal authority.

In this connection the Board states that it does not condemn the present plan of taking 10,000 cubic feet per second, believing as it does that some such amount will be needed to protect the lives and health of the people of a great city and of a populous valley; but it invites attention to the fact that if a much larger amount be taken it will be necessary to construct remedial works elsewhere, and that these are, or should be, of an international character. It is led to make this remark by the attitude of the Illinois legislature and of the other principal advocates

of this enterprise, which is that the 14-foot waterway is only a beginning, and that a much deeper channel ulti-
2265 mately should be constructed, which means that a much larger volume of water must be taken from Lake Michigan. It is the opinion of the Board that the sanitary reasons for the abstraction of water so far exceed and overshadow the commercial reasons that the amount should be strictly limited by the sanitary necessities of the case. It is impossible to fix a limit to the future growth of Chicago. In a future not remote larger amounts of water may be needed for sanitary purposes, and channels deeper than 14 feet will then become practicable in the open alluvial portion of the Illinois River.

* * *

Very respectfully,

A. MACKENZIE,

Brig. Gen., Chief of Engineers, U. S. Army.

Hon. WM H. TAFT,

Secretary of War."

In the report of the Commission itself, it is stated, (Rec. Vol. IV, p. 2265):

"Extract from the Report of the Board, Page 9, Entitled Chicago Drainage Canal.

Besides being a highway of commerce, the Illinois and Michigan Canal has from the beginning served to carry off the sewage of Chicago. The Chicago River has always been the main receptacle of the sewage of the city, and as the volume of sewage has increased with the growth of the city additional facilities for discharging it into the canal have become necessary. When the canal was opened in 1848, a pumping plant was established at Bridgeport, where it joins the Chicago River. In 1860 the capacity of this plant was nearly doubled, being increased to about 400 cubic feet per second. Later on the summit level of the canal was cut down so as to provide a continuous gravity flow from the Chicago River and Lake Michigan. That work was completed in 1871 and the pumping plant abandoned. In 1883 a new pumping plant was brought into use, having a nominal capacity of 750 cubic feet per second, but it soon became evident that the discharging capacity of the old canal was quite inadequate to carrying the volume of water required to dilute

the sewage and that a new and greatly enlarged channel
2266 must be provided. The Chicago Drainage Canal was then constructed and was brought into use in January, 1900. It has not yet been completed to its full capacity as designed. When fully completed it will have a capacity of about 10,000 cubic feet per second, flowing at a low velocity. As now constructed, it has a depth of about 22 feet and a bottom width in different parts 110 feet, 160 feet and 202 feet, respectively. It constitutes a navigable channel able to accommodate the largest vessels now navigating the Great Lakes. It extends from the Chicago River to Lockport, where it discharges into the Des Plaines River and is now being extended 2 miles farther to a new power house. With the six miles of the Chicago River and the two miles extension just mentioned it provides a wide and deep channel for a distance of 36 miles from Lake Michigan. At present it has no navigable connection with the streams below, but under State legislation a connection is to be made. It creates an important water power.

Although the primary object of the Chicago Drainage Canal was the discharge of Chicago sewage, its function as a channel, for navigation, was kept in view from the beginning. All of the bridges over it are draw bridges with ample openings. The original act of the Illinois legislature providing for its construction dated May 29, 1889, contained the following item, viz:

> 24. When such channel shall be completed, and the water turned therein, to the amount of three hundred thousand cubic feet of water per minute, the same is hereby declared a navigable stream, and whenever the General Government shall improve the Des Plaines and Illinois Rivers for navigation, to connect with this channel, said General Government shall have full control over the same for navigation purposes, but not to interfere with its control for sanitary or drainage purposes.

As its utility for sanitary or drainage purposes is dependent upon the supply of water which it may obtain from Lake Michigan, a matter wholly at the discretion of the Federal Government, the degree of control which the State offers to the United States in this act, although limited, is probably sufficient. It is conditioned, however, upon the improvement by the Federal Government of the Illinois and Des Plaines Rivers, and the degree

of improvement is described in Section 23 of the above mentioned State law, which contains the following language:

2267 If at any time the General Government shall improve the Des Plaines or Illinois Rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute, from such channel may cause to private property, so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter enlarge the entire channel leading into said Des Plaines or Illinois Rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet per minute, with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom.

The taking of large quantities of water from Lake Michigan for drainage purposes has not been authorized by Congress. It has been the policy of the War Department thus far to regulate the quantity of water which is admitted to the canal by the necessities of navigation in the Chicago River. The capacity of that stream at present is such that not more than about 4,200 cubic feet per second can pass without creating velocities which will unreasonably obstruct navigation. The quantity of water admitted to the canal is, for the present, limited to that amount, or, as expressed in the permit of the Secretary of War, to 250,000 cubic feet per minute. This is less than is required by the State law. It will no doubt be increased as the obstructions in the Chicago River are removed, and its discharging capacity increased, a work upon which the Sanitary District is now engaged. In repairing its estimates the Board has assumed that the full discharge of 10,000 cubic feet per second contemplated in the plans of the Sanitary District will eventually be permitted by the Secretary of War.

2268 VESTED RIGHTS.

The effect upon the level of Lake Michigan of withdrawing 10,000 cubic feet per second for an indefinite period has been the subject of an elaborate investigation under the office of the Lake Survey in Detroit, and the conclusion reached is that the final effect will be to lower the level about 6 inches. (See Annual Report of Chief of Engineers for 1900, p. 5401, and for 1902, p. 2779 and p. 2825; also for 1904, p. 4120.) Oscillations of more than 6 inches in the level of the lake's surface are very common, often occurring hourly for many hours in succession, while oscillations of 2 or 3 feet within an hour are not uncommon. Still greater oscillations within a year or series of years occur, all from natural causes. Moreover, during a severe winter the discharge of St. Clair River is reduced by ice less than one-third its normal discharge, the remaining two-thirds being stored up in Lakes Huron-Michigan and raising their levels; and the difference between the total discharge during a severe winter and the discharge during a mild winter will probably equal, or nearly equal, the discharge of the Chicago Drainage Canal for a year. A permanent average lowering of 6 inches in the lake's level, therefore, is not easily observed and will probably not be noticed by navigators. Nevertheless the effect is real and important. Evidently there is a limit to the amount of water which can be taken from the southern end of Lake Michigan without compensating works at the outlet of Lake Huron. The Board does not condemn the present plan of taking 10,000 cubic feet per second, believing as it does that some such amount will be needed to protect the lives and health of the people of a great city and of a populous valley; but it invites attention to the fact that if a much larger amount be taken it will be necessary to construct remedial works elsewhere, and that these are, or should be, of an international character. It is led to make this remark by the attitude of the Illinois legislature and of the other principal advocates of this enterprise, which is that the 14 foot waterway is only a beginning, and that a much deeper channel ultimately should be constructed, which means that a much larger volume of water must be taken from Lake Michigan. It is the opinion of the Board that the
2269 sanitary reasons for the abstraction of water so far exceed and overshadow the commercial reasons that the amount should be strictly limited by the sanitary necessities of the case. It is impossible to fix a limit to the fu-

ture growth of Chicago. In a future not remote larger amounts of water may be needed for sanitary purposes, and channels deeper than 14 feet will then become practicable in the open alluvial portion of the Illinois River."

On May 22, 1906, Lieut. Col. Bixby, Division Engineer at Chicago, made a report on the effect of the withdrawal of water from Lake Michigan by the Sanitary District at Chicago which report was transmitted to Congress as House Document 6, 56th Congress, 1st Session. (Rec. Vol. IV, p. 2397A.)

"Extract From a Special Report by Lt. Col. W. H. Bixby, U. S. Engineer, at Chicago, Entitled 'Effect of Withdrawal of Water from Lake Michigan by the Sanitary District of Chicago,' Dated May 22, 1906.

(H. R. Doc. 6, 59th Cong., 1st Sess.)

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Furthermore, by reason of winds and barometric effects, oscillations of 6 inches several times in a single day are frequent, and 2 to 4 feet within an hour are occasionally experienced. Consequently, individual exceptional levels are misleading, and the general effects of water diversions must be measured by annual average rather than by monthly or daily.

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In the few cases where past troubles from currents have been real, they have been due to the contracted channel ways at bridges, tunnels, and other special points,
2397B where full dimensions of water flow have already been secured or are being secured by the drainage district improvements, or will soon be provided by tunnel owners.

These troubles in the past have been quite freely and fully commented upon or reported upon by the boat interests and by this office, the most important of such reports being those of the hearing before the honorable Secretary of War, May 16, 1900 (E. D. 35242/7), that of Major Willard, February 16, 1901 (with third indorsement on E. D. 35242/26), that of Major Willard, June 20, 1900 (E. D. 35242/(?)), that of Major Willard, March 29, 1901 (with third indorsement on E. D. 35242/40), and that of Colonel Ernst, November 5, 1901 (which led to permit E. D. 35242/74, quoted above). These reports show that the greatest velocity heretofore actually observed at

any single point of the worst old bridge draw opening (that of Canal street, now greatly improved), was 2.24 miles per hour (3.29 feet per second), while the average for a whole cross section at this draw was only about 1.8 miles per hour (2.6 feet per second), and the average for a full 200-foot width of river just above and below the bridge would not have been over 1.2 miles per hour (1.8 feet per second); and that even a large part of this was probably due to sudden changes of lake levels for which the drainage district was not responsible. These currents, although much complained of at the time, are not greater than are constantly encountered in many tidal rivers on the Atlantic coast, where no complaints are made, because all boat captains and pilots are accustomed to such currents and make their arrangements accordingly.

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17. In the capacity of sewer to properly carry off all the diluted sewage which the sanitary district must dispose of in the future, the South Branch and West Fork of Chicago River and the district drainage canal will need the use of the full cross section now being given to them at their typical points of constriction, viz., 4,700 square feet in South Branch, Chicago River, where a future 8,000 cubic feet per second is now asked for; 5,200 square feet in West Fork, South Branch, Chicago River, 5,412 square feet in the earth sections and 3,542 square feet in the rock sections of the drainage canal, for all of which 10,000 cubic feet per second is now asked for; and 5,412 square feet in the lower (south) end of the drainage canal, where 14,000 cubic feet per second is now being asked for. I assume that after this volume of water reaches the
2397C Des Plaines and Illinois rivers it can be taken care of more easily than in the Chicago River and that the 2,800 square feet cross section of the proposed 14-foot waterway, now under consideration by Congress, will be supplemented sufficiently by the rest of the natural river on each side of the improved boat channel. The above cross-sections, so long as no boats lie at wharves or pass up and down the river, will allow the passage of the 8,000 cubic feet per second through the South Branch, with average velocities of not exceeding about 1.2 miles per hour (1.7 linear feet per second); 10,000 cubic feet through the West Fork, with average velocities of not exceeding about 1.3 miles per hour (1.9 linear feet per second), and the same flow through the earth sections of canal at not ex-

ceeding 1.2 miles per hour (1.8 linear feet per second), and through the rock section of canal at not exceeding 1.9 miles per hour (2.8 linear feet per second); and 14,000 cubic feet through the lower end of canal at not exceeding 1.8 miles per hour (2.6 linear feet per second).

Wherever the full free cross section of the river is obstructed by bridge abutments or by boats, either at docks or passing, the average 8,000 to 10,000 cubic feet per second water flow must pass through the reduced cross section at increased speed. The full development of this increase, while not instantaneous, will require only a few moments. In this manner, at bridges, the velocities will be increased for a short length by about 30 per cent; at places where two boats of 40 to 50 feet beam and 800 square feet wetted cross section are abreast the increase of velocity will be about 50 per cent; at places where three such boats are abreast the increase will be about 100 per cent; and in case four such boats should be abreast (one tied at the wharf on each side of the stream and two others trying to pass in mid-river), the increase will be about 200 per cent. The drainage currents in the South Fork, South Branch, due to the 2,000 cubic feet per second coming from the Thirty-ninth street pumping station, and in the North Branch, due to a similar pumpage probably soon to be established at some street near Evanston, in the north end of Chicago, will be only about one-half of those in the South Branch, and their effects will probably be so small as not to be complained of by navigation interests. The drainage currents in the canal prop-
2397D er between the West Fork and Lockport will be about the same as in the South Branch; but as this part of the canal was not originally a public waterway and has not yet been accepted as such by the Federal Government, it is doubtful whether the United States can object to any current which its owners may establish or desire to establish therein. It is therefore evident that so long as the Chicago River serves merely as a sewer and is not to be used by boats the drainage district currents will not be objectionable, but soon as it is also used as a harbor or as a canal or water route the currents begin to be seriously questionable.

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25. Summing up the above it may be briefly stated, therefore that 10,000 cubic feet per second diversion of water from Lake Michigan into the drainage canal will be, probably, not unreasonably obstructive to navigation and

injuries to property if divided up into 6,000 cubic feet per second through the main river and south branch, increased by 2,000 cubic feet per second more through the Thirty-ninth street sewer and 2,000 cubic feet per second more through Calumet River (10,000 cubic feet per second in all), but that an increase in these amounts to 8,000, 2,000, and 4,000 cubic feet, respectively (14,000 cubic feet per second in all), will probably prove to be unreasonably obstructive and injurious. Also that the 10,000 cubic feet per second will eventually and permanently lower the levels of Lakes Michigan and Huron by about 0.5 foot and Lake Erie by about 0.4 foot, and 14,000 cubic foot per second will make these depths 0.7 and 0.6 foot, respectively, which will be quite costly in future results."

On the fourth day of January, 1907, the International Waterways Commission made a report to the United States and to Canada which is as follows:

Senate Doc. 959, 62nd Congress, 3rd Session, p. 21. (Rec. Vol. IV, pp. 2409-2433.)

"Extract Entitled Appendix I Attached to the International Waterways Commission Progress Report Above Mentioned.
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Report Upon the Chicago Drainage Canal by the Commission, January 4, 1907.

International Waterways Commission,
Toronto, Ontario, January 4, 1907.

The Honorable Secretary of War of the United States and the Honorable Minister of Public Works of Canada:

The International Waterways Commission has the honor to submit the following report upon the Chicago Drainage Canal:

1. The headwaters of the Illinois River, an important tributary of the Mississippi, approach within 10 miles of Lake Michigan near its southerly end, where stands Chicago. The river, called here the Des Plaines, is separated from the lake by a low and narrow divide running nearly north and south. In the divide are two depressions, about 8 miles apart, in which the height is only about 10

feet above the surface of the lake. The area eastward of the divide is drained by two streams, the Chicago and the Calumet Rivers, which empty into Lake Michigan.

The City of Chicago was originally built on the Chicago River, and, although it is now spreading into the Calumet region, it was for many years drained exclusively by the Chicago River, and its principal parts are now so drained. This river constitutes the main sewer of Chicago. The lake furnishes the city's water supply. To prevent the pollution of the water supply by sewage has always been the most important municipal problem with which Chicago has had to deal. Its solution has from a very early day been found in diverting a part of the river's flow into the valley of the Des Plaines through the most northerly of the two depressions mentioned above. The Illinois and Michigan canal, which was
2410 opened to navigation in 1848, was at once utilized for this purpose, and all subsequent improvements consisted in efforts to force more sewage through that canal until, in 1889, it was decided to build a new and greatly enlarged channel which should completely divert the Chicago River from Lake Michigan and draw from that lake a body of pure water large enough to make the sewage inoffensive to the communities by whose doors it must pass.

2. Before embarking upon this work the city in 1886 appointed a commission of three engineers 'to consider and report on any and all things which relate to the matter of water supply and drainage of the City of Chicago.' In January, 1887, the commission submitted a report to the mayor and city council of Chicago (copy appended marked 1), which it styled a preliminary report. It intended to submit an additional or final report in which the data upon which its conclusions were based should be given in greater detail, but such additional report was never submitted. After remarking that 'almost every conceivable way of dealing with these questions had been suggested and in some form applied during the past thirty years,' the commission stated that 'among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy of consideration, namely, a discharge into Lake Michigan, a disposal upon land, and a discharge into the main river.' It considered the first method too expensive, involving as it does a wide separation between the outlets of the sewers and the intakes of the water supply. It pronounced the second inapplicable to the metropolitan district as a whole, under the topographical conditions ex-

isting, but thought that it might be employed for the extreme northern and southern parts, the latter including the Calumet region. It recommended the third method. It was uncertain as to the quantity of water required to dilute the sewage so as to make it inoffensive, but in order to prepare an estimate of cost it was compelled to assume some approximate size of channel, and it did assume a size large enough to discharge 600,000 cubic feet per minute, that being the estimated amount of water falling upon the area tributary to the Canal during storms and not otherwise disposed of. It includes the drainage basis of the upper Des Plaines and of the Chicago rivers, but not that of the Calumet River. With a channel of less dimensions in times of storms and floods the Chicago
2411 River would not be fully diverted into the Des Plaines, but would back up into Lake Michigan. The result was a supply of 24,000 cubic feet per minute for each 100,000 people in a population of 2,500,000, the population which the commission thought it desirable to provide for, and the opinion was expressed that this would equal the maximum requirements.

3. Following this report the Illinois Legislature passed an act approved May 29, 1889, 'to create a sanitary district and to remove obstructions in the Des Plaines and Illinois Rivers,' of which the twenty-third and twenty-fourth paragraphs read as follows, viz:

'Paragraph 23. If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the Des Plaines or Illinois Rivers, such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than 14 feet, and a current not exceeding 3 miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rock stratum is above a grade sufficient to produce a depth of water from Lake Michigan of not less than 18 feet, such portion of said channel shall have double the flowing capacity above provided for, and a width of not less than 160 feet at the bottom capable of producing a depth of not less than 18 feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000, such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per min-

ute for each 100,000 of the population of such district, at a current of not more than 3 miles per hour, and if at any time the General Government shall improve the Des Plaines or Illinois Rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall, within one year thereafter, enlarge the entire channel leading into said Des
2412 Plaines or Illinois Rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute, with a current of not more than 3 miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water of not less than 18 feet throughout said channel, and shall have a width of not less than 160 feet at the bottom. In case a channel is constructed in the Des Plaines River, as contemplated in this section, it shall be carried down the slope between Lockport and Joliet to the pool, commonly known as the upper basin, of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act may correct, modify and remove obstructions in the Des Plaines and Illinois Rivers wherever it shall be necessary so to do to prevent overflow or damage along said rivers, and shall remove the dams at Henry and Copperas Creek, in the Illinois River, before any water shall be turned into the said channel. And the canal commissioners, if they shall find at any time that an additional supply of water has been added to either of said rivers by any drainage district or districts, to maintain a depth of not less than 6 feet from any dam owned by the State to and into the first lock of the Illinois and Michigan Canal at La Salle, without the aid of any such dams, at low water, then it shall be the duty of said canal commissioners to cause such dam or dams to be removed. This act shall not be construed to authorize the injury or destruction of existing water-power rights.

'Paragraph 24. When such channel shall be completed and the water turned therein, to the amount of 300,000 cubic feet of water per minute, the same is hereby de-

clared a navigable stream, and whenever the General Government shall improve the Des Plaines and Illinois Rivers for navigation, to connect with this channel, said General Government shall have full control over the same for navigation purposes but not to interfere with its control for sanitary or drainage purposes.'

2413 By this act a flow of not less than 20,000 cubic feet per minute is required for each 100,000 inhabitants and provision is made for a population of 3,000,000. The evidence before the legislative committee which framed the bill as to the quantity required was contradictory. The amount fixed for dilution of the sewage was a minimum. (See Appendix I.)

4. Under this act the Sanitary District of Chicago was organized, embracing all of the city north of Eighty-seventh street and some 43 square miles of Cook County outside of the city limits. The total area of the district was 185 square miles and did not include the Calumet region nor the north shore. The trustees held their first meeting January 18, 1890. The Chicago Drainage Canal was then constructed, water being turned into it for the first time in January, 1900. It was not then, and has not since been, completed to its full capacity as designed. In some places where the excavation was in rock the full dimensions of the prism were taken out, but in earth a considerable volume was left to be removed by the easy method of dredging hereafter. When fully completed it was designed to have a capacity of 600,000 cubic feet per minute, or 10,000 cubic feet per second, flowing at a velocity of 1.25 miles per hour in earth and 1.9 miles per hours in rock.

5. The canal is 28.05 miles in length. For a distance of 7.8 miles from its junction with the Chicago River at Robey street its dimensions are 110 feet width at bottom, side slopes 1 on 2, depth of water 22 feet at low stage of Lake Michigan, with a grade of 1 in 40,000, the material being earth. This section is eventually to have a width of 200 feet at bottom.

6. For a farther distance of 5.3 miles, although the material is principally earth, the dimensions are 202 feet width at bottom, side slopes 1 on 2, minimum depth of water 22 feet, with a grade of 1 in 40,000. This section is completed.

7. For the remaining 15.95 miles the canal is excavated wholly or partially in rock. Where the natural rock does

not come to the surface walls of masonry have been built upon the rock surface, thus artificially carrying it to a height 5 feet above datum. The dimensions here are 160 feet width at bottom, 162 feet width at top, minimum depth of water 22 feet, with a grade of 1 in 20,000. This
2414 section also is completed.

8. The controlling works are situated near the town of Lockport at the western end of the canal. They consist of a bear-trap dam 160 feet wide, with a vertical play of 17 feet, and of seven sluice gates of the Stoney type, each 30 feet wide and having a vertical play of 20 feet. These works provide a very efficient means of controlling the flow of water through the canal.

9. The project of the sanitary district for the disposal of sewage by the canal when completed is briefly as follows: All sewers will discharge into the Chicago River, either directly or through intercepting sewers. From the mouth in Lake Michigan to the point where the North and South Branches unite the river will flow 8,000 cubic feet per second, less such quantity as may be pumped into the upper portion of the North Branch, which under the original project was 200 cubic feet per second admitted through a conduit at Fullerton avenue. From this point the combined flow will be 8,000 cubic feet to the point where the South Fork enters the South Branch, where it will be increased to 10,000 cubic feet by the water pumped from Lake Michigan at Thirty-ninth street and flowing through a large conduit in Thirty-ninth street to the South Fork. The volume which will finally enter the canal under this project will be 10,000 cubic feet per second.

10. The channel of the Chicago River is not large enough to transmit that volume from the lake to the canal except at velocities which are an obstruction to navigation. The amount which the Secretary of War has thus far permitted the sanitary district to pass through the river is 4,167 cubic feet per second. In order to obtain authority for a larger amount the trustees have undertaken to enlarge the channel of the river and have accomplished a large amount of work in that direction.

11. By act of the Illinois Legislature in 1903 the sanitary district was enlarged by annexing thereto the north shore district, containing 78.6 square miles, and the Calumet district, containing 94.48 square miles. The total area of the sanitary district is therefore now 358.08 square miles. The same legislature authorized the development of the water power created by the diversion.

12. The plans for the north shore region involve two additional conduits from the lake to the North Branch of the Chicago River, one at Lawrence avenue, into which 583 cubic feet per second, and one at Wilmette, into which 1,000 cubic feet per second, are to be pumped. As this water is to form a part of the 10,000 cubic feet originally to be taken out through that river, it does not add to the amount of water to be taken from Lake Michigan.

2415 13. The plans for the Calumet region involve a treatment of the Calumet River similar to that of the Chicago River. The river is to be diverted into the Des Plaines Valley. For this purpose a new channel is to be cut through the southerly depression in the divide, and to join the present drainage canal at Sag, about 11 miles from the controlling works at Lockport. From Sag to Lockport the drainage canal must carry the flow from the Calumet River in addition to that from the Chicago River. It was designed to accomodate the latter river alone, or 10,000 cubic feet per second, but improved methods of excavation, particularly channeling in rock, gave it a greater capacity than was computed; and the hydraulic formulae with which its dimensions were figured, being adapted to smaller streams, gave results which proved to be too large. It is found that the portion completed in rock, which includes the reach from Sag to Lockport, will carry an amount stated by the chief engineer to be 14,000 cubic feet per second. The difference, 4,000 cubic feet per second, is the amount which it is proposed to divert from the Calumet River. For this purpose it is proposed to excavate a channel having in earth a bottom width of 72 feet, with side slopes 3 on 5, and in rock a bottom width of 90 feet with vertical sides, the depth in both cases to be 25 feet.

14. Work in the territory annexed in 1903 has been limited to surveys, and the preparation of plans, and the expenditures in that territory have been small. The amount expended upon the drainge canal and accessory works, including the above, to December 31, 1905, is $40,873,629.71; in addition to which $1,556,226.56 has been expended for the development of water power and $7,290,101.27 has been paid out for interest. For a financial statement more in detail, see Appendix I.

15. Although the primary object of the Chicago Drainage Canal was the discharge of Chicago sewage, its function as a channel for navigation was kept in view from the beginning. All of the bridges over it are draw-

bridges with ample openings. A provision of this kind, as well as the care exercised to make the sewage inoffensive by liberal dilution, was necessary to conciliate the interests in the valley of the Des Plaines and Illinois River,
2416 which would otherwise be adversely affected. It can hardly be doubted that the canal will eventually form a part of an improved waterway between the Great Lakes and the Mississippi River, though its full depth will probably not be required for that purpose. Congress has not adopted any scheme for this improvement, but by its direction a survey was made, and plans with estimates for a waterway 14 feet deep were submitted, by a board of engineers in a report dated August 26, 1905. The board found that for a distance of about 100 miles from Chicago the improvement must be with locks and dams, and as the quantity of water required would be merely that needed for the service of locks and other incidentals, the extent of the improvement of depth which could be obtained in that part of the route was without limit so far as it depended upon the amount of water available. For the remaining distance, about 223 miles, the improvement would be an enlargement of the open channel and the degree to which it was practicable was entirely dependent upon the quantity of water flowing. The board assumed that the Chicago Drainage Canal would eventually be permitted to take 10,000 cubic feet per second from Lake Michigan ,and it expressed the opinion that with that volume added to the natural low-water discharge of the Illinois River a depth of 14 feet in the open channel could be maintained; also that if a much greater depth was to be secured a much larger volume of water must be taken from Lake Michigan.

16. In the neighborhood of Lockport the natural level of the ground falls away rapidly and excellent facilities are found for the development of water power. Under the state legislation of 1903 the sanitary district is now engaged in utilizing this incidental advantage of the drainage canal. The plans provide for an extension of the canal 10,700 feet between concrete walls and earth and rock embankments to the site selected for the power house and for the excavation of a tail race 6,800 feet long, 160 feet wide, and 22 feet deep. If the maximum quantity of water which the sanitary district now claims to be necessary for sanitary purposes—14,000 feet per second—be utilized it will be possible to develop about 40,000 electrical horsepower under a head of 34 feet. With 10,000 cubic feet per second about 28,000 horsepower can be

developed. A power house is being erected which will accomodate 8 turbines, each capable of generating 5,000 horsepower.

17. The sanitary district has acquired land on both sides of the canal throughout its length, the width of the strips varying from 200 to 800 feet. This land is offered to manufacturers at moderate prices, and it seems probable that they will in the course of time be attracted thereto, particularly after arrangements for furnishing them with cheap power from Lockport are completed.

18. The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congres. The plans of the sanitary district, except those for the enlargement of the Chicago River, have not been submitted to any Federal authority for approval. It was only after the opening of the canal that application was made to the Secretary of War for permission to divert the quantity of water required by The State law. The secretary granted permission for such quantity as would pass through Chicago River without detriment to navigation, a quantity considerably less than that required by the State law. After experimenting with various amounts it was fixed at 250,000 cubic feet per minute, or 4,167 cubic feet per second, and that is the amount now authorized. It is 'subject to such modification as, in the opinion of the Secretary of War, the public interests may from time to time require.' Copies of all the permits granted by the Secretary of War in this connection will be found in Appendix I.

19. In the expenditure of $40,000,000 for the drainage canal the people of Chicago, with its population of 2,000,000 incurred a burden equivalent to that due to an expenditure of $1,600,000,000 by the United States, with its population of 80,000,000—that is, enough to build eight or more Panama canals. It was a very serious effort and has commanded the admiration and sympathy of all observers. The diversion of 10,000 cubic feet per second from Lake Michigan affects other interests adversely, but these interests have withheld their opposition, seeming to believe that some such amount was necessary, and apparently willing to contribute their share to protect the lives and health of the people of a great city. The plans calling for that amount have been under public discussion for some years. Although withholding formal approval, the Federal authorities have taken no steps to prevent their execution. Congress has called for a

plan and estimates for an improvement of the waterways connecting with it, the scope of which is fixed by that amount. There appears to be a tacit general agreement that Chicago needs or will need about 10,000 cubic feet of water per second for sanitary purposes and that the city should have it without further question.

20. It was not generally known until after the publication in March last of the report of the American section of this commission upon Niagara Falls that an amount greater than 10,00 cubic feet per second would be asked for. In that report, subsequently concurred in by the Canadian section, it was recommended that the diversion of 10,000 cubic feet be allowed. The preservation of Niagara Falls alone was considered, and that in the light of the tacit agreement above described. It was supposed at the time that this was all that Chicago needed, but the recommendation gave offense to the officials of the sanitary district, and the further demand then came out in the form of appeals to the committees of Congress and to the Secretary of State. It is necessary now to take up the question anew, and, after considering it in all its bearings, to reach some conclusion as to whether there should be a limit to the amount of water to be diverted at Chicago, and, if so, as to what that limit is.

21. That the abstraction of water from Lake Michigan has a tendency to lower the level of that lake and of all the waters to which it is tributary is self-evident; but the exact effect of abstracting a given amount can be ascertained only from prolonged observation of the natural outlets under the varying conditions to which they are subjected during a series of years. An elaborate investigation of this subject was made under the office of the United States Lake Survey in Detroit, the results of which were published in the annual reports of the Chief of Engineers for 1900, page 5401; for 1902, pages 2779 and 2825; and for 1904, page 4120. Further observations are needed to be made when the difference of the level between Lake Erie and Lake Huron is greater or less than when the existing observations were made, but the results obtained from the latter are believed to be reliable within one-tenth of a foot. The amounts by which the
2419 mean level, as derived from observations of the last 46 years of the various waters will be lowered by a discharge of 10,000 and also by 14,000 cubic feet per second are given in the following table:

Location	Water level lowered by diversion at Chicago of—	
	10,000 cubic feet per second. Foot.	14,000 cubic feet per second. Foot.
Lakes Huron and Michigan	0.52	0.70
Lake St. Clair	.45	.64
Lake Erie	.45	.64
Lake Ontario	.35	.49
St. Lawrence River at Rapids Plat	.40	.56

From this table it appears that all the waters, including Lakes Michigan and Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, besides the important connecting channels, the Detroit and St. Clair Rivers, will be lowered by amounts varying from 4¼ to 6¼ inches for 10,000 cubic feet and from 6 to 8½ inches for 14,000 cubic feet per second. The length of time required to produce this effect is about five years; about half of it will be produced at the end of 18 months. The above figures give the effect at average level; they are much more considerable during low-water periods.

22. Variations in the level of the lakes' surface, due to winds and to change of barometric pressure, are frequent and irregular and at times violent. Variations of more than 6 inches are very common, often occurring hourly for many hours in succession, while variations of 2 or 3 feet within an hour are not uncommon. Besides these irregular variations there is a regular annual variation due to the difference in rainfall, evaporation, and run-off, the water level being highest in midsummer and lowest in midwinter. The levels are affected also by the greater or less severity of the winter and the consequent greater or less decreases in the discharging capacity of the outlets by ice. In order to study the annual oscillatons it is necessary to eliminate the irregular oscillations, and
2420 that is accomplished by using the average levels for a month. Using the monthly mean levels it is found that the regular fluctuation in Lake Huron-Michigan usually does not exceed 2 feet in any one year, but in a long series of years there is a great difference in the height

to which high water will rise. The highest high water (monthly mean) recorded for that lake was in June, 1886, and the lowest high water in June, 1896, the difference between the two being over 3½ feet. The first is what navigators of the Great Lakes call a high-water year and the second a low-water year.

23. It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they can not see it they will not know it and will not feel it. The argument is fallacious. It is true that they cannot see it immediately, they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works.

24. The most important lake traffic is now carried on in large freight carriers which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the lakes. With the depth now available they are usually loaded to a draft of about 19 feet, but careful watch is kept on the stage of the waterways and advantage is taken of any temporary increase of stage to load the vessels deeper. In the modern vessel each inch of increased draft adds about 50 tons to the carrying capacity. To lower the water surface 6 inches is to reduce the capacity of the vessel about 300 tons. If the freight rate on iron ore be taken at 55 cents per ton, exclusive of the cost of loading and unloading, and the number of trips during the season at 22, there appears a loss of over $3,600 for the season for each vessel. The number of vessels navigating the Great Lakes which draw 19 feet or more is 417, and their tonnage is 1,541,414 tons, which is about three-quarters of the total tonnage of the
2421 Great Lakes. It is a conservative estimate that the loss to the navigation interests resulting from a reduction of 6 inches in the depth of the water is $1,500,000 per annum, which capitalized at 4 per cent, amounts to a loss of $37,500,000. With a greater reduction of depth the resulting loss would be proportionately greater. The number of deep draft vessels and the share of lake traffic which

they carry is increasing each year, while the lake traffic itself is increasing with mavelous rapidity. The total number of tons of freight which passed through Detroit River in 1905 was about 58,000,000, valued at about $615,000,000. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit River in 1908 exceeded 65,000,000, valued at $690,000,000. The loss will be even greater in the future than it is now. It is quite certain that the loss will not pass unnoticed, and that the Governments will be compelled to restore the depth either by additional excavations or by regulating works.

25. Careful estimates have been made of the cost of deepening the channels between the lakes 1 foot. To deepen the Detroit River is estimated to cost $4,115,430. In Lake St. Clair the full depth of the lake is now utilized, and any lowering of its surface involves the excavation of an artificial channel entirely across the lake, a distance of 18 miles, of which it has been necessary heretofore to artificially deepen only one-third. To deepen the channel here and at certain shoal places in St. Clair River and at the foot of Lake Huron is estimated to cost $1,080,720. It results in replacing open lake navigation by canal navigation for a distance of 12 miles in Lake St. Clair, a decided disadvantage.

26. The data are not at hand for an accurate estimate of the cost of restoring the depths in the harbors of the Great Lakes, but an approximation may be reached from a consideration of the cost of improvement heretofore made. The depth to be gained being small, the cost will not vary largely, whether that gain be a few inches more or less. The United States has improved 35 harbors on Lake Michigan, Huron, Erie, and has expended thereon about $20,000,000, of which about one-quarter was for maintenance. The average increase of depth is 10 feet
2422 and the cost per foot of increase was therefore about $1,500,000, but as the cost of a small increase would be much greater per foot than an increase of 10 feet, and as several harbors on Lake Ontario are to be added, the cost per foot in this case would probably not be less than $2,000,000 for harbors in the United States. The Canadian Government has improved over 50 harbors on Georgian Bay, Lake Huron, St. Clair, Erie and Ontario. A large amount, say $3,000,000, must be added for increasing the depth of these harbors.

27. The depth in the Welland Canal and in the six canals employed to overcome rapids in the St. Lawrence River is now 14 feet, of which every inch is needed. At the head of the Cornwall Canal in the St. Lawrence River the abstraction of 14,000 cubic feet of water per second at Chicago will lower the surface about 6¾ inches at mean level and much more at low water. To restore the depth in these canals involves the reconstruction of all the end locks and deepening the approaches thereto, and is estimated to cost $2,500,000.

28. The total cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is therefore roughly $10,000,000, and of restoring it in the Welland and St. Lawrence Canals is $2,500,000 additional, or $12,500,000 in all.

29. The shores of the Great Lakes are very far from being fully developed, and it is highly probable that many harbors not now in existence remain to be created, or if in existence remain to be improved. The lowering of the lakes' surface increase the difficulty and cost of such improvements. This consideration is of importance, although no money value can now be given it.

30. The expenditure of the sums mentioned above will restore the depths now existing, but it will not prevent very serious annoyance to the navigation interests during the execution of the work. The time required will be several years, and in the meantime the vast commerce of the Great Lakes will be hampered, not only by deficient depth, but also by the occupation of the channels, already crowded with commerce, by the excavating machines.

31. It is evident from the foregoing that large bodies of water cannot be diverted by the Chicago Drainage
2423 Canal without very serious detriment to the navigation interests of the Great Lakes and of the St. Lawrence Valley. The greater the amount of water diverted the greater the injury. Chicago being one of the principal lake ports. there will be very few communities which will feel this detriment more than she will.

32. In the presence of these interests, the effect upon Niagara Falls may be simply mentioned with a reference to our former reports on that subject. The volume of Niagara Falls will be reduced by the full amount diverted at Chicago.

33. The City of Chicago was organized as a city in 1837 with a population of about 4,000. Its population in 1840 was 4,479; in 1850, 28,269; in 1860, 112,172; in1870, 298,977; in 1880, 503,185; in 1890, 1,099,850; and in 1900 it was 1,698, 575. It is estimated now to be about 2,000, 000. Should the rate of growth continue which prevailed between 1880 and 1900, the population will be 3,000,000 in the year 1922, and 4,000,000 in the year 1939. It is impossible to foretell its future growth, but there is no reason to doubt that it will in time greatly exceed the largest of these numbers. The city is the commercial center of an empire still in its infancy. It is entirely reasonable to expect a population of five or six millions or more. It will cover territory not now covered. Methods of sewerage disposal appropriate to one portion of it may not be appropriate to other portions. If the diversion of 20,000 cubic feet per minute (or 333⅓ cubic feet per second) for each 100,000 of population, as required by the State law, is accepted as the standard, then from 17,000 to 20,000 cubic feet per second will be required, and the 14,000 cubic feet now contemplated will not be sufficient. Even more than 20,000 cubic feet will be required for a population greater than 6,000,000. The diversion of 20,000 cubic feet per second would lower Lakes Michigan and Huron about 13 inches and Lake Erie about 11 inches. Plans which lead to this result should be carefully scrutinized.

34. One of the reasons given in 1889 for adopting this method of disposing of Chicago sewage was that it offered the advantage of furnishing a navigable waterway from Chicago to the Mississippi River. The navigable depth or capacity of such a waterway has never been authoratively fixed. Congress has considered a depth of 14 feet to the extent of ordering a survey and estimates of cost for that depth, but the Illinois legislature has declared its policy to be to secure the construction of a deeper channel, not limiting its proposed capacity in
2424 terms, but defining it to be 'of the greatest practicable depth and usefulness for navigation.' See joint resolution adopted May 27, 1889, copy omitting preamble hereto appended, marked 'I_5.' A fair interpretation of this language gives a proposed depth of 20 feet, that being the depth required to accomodate the most important vessels now navigating the Great Lakes. It will require a volume of water greater than the 10,000 cubic feet per second originally contemplated.

35. The amount which it is proposed to divert from the Calumet River 4,000 cubic feet per second, is fixed by accident rather than by design, being the excess which the Chicago Drainage Canal is found capable of carrying after providing for the 10,000 cubic feet from the Chicago River, for which it was originally constructed. It is certain that no greater amount than 4,000 cubic feet can be diverted from the Calumet without checking the flow from the Chicago River, and thus giving relief to a suburban portion of the city at the expense of the richest and most populous centers.

36. It is equally certain that the diversion of 4,000 cubic feet or less will not at all times afford the desired relief to the Calumet. In the first place it provides for a population of only 1,200,000, a number which will in all probability be greatly exceeded at a day not remote. At present the population is estimated at about 200,000, but for the present necessities it is not a question of population, but of drainage area and rainfall. A flood discharge of the Calumet has been measured at Riverdale, about 10 miles from its mouth, of about 13,300 cubic feet per second from a drainage area of about 700 square miles, and even that amount may at times be exceeded. The total drainage area of the Calumet region, including the Sag Valley, is about 825 square miles, and assuming the discharge to increase in proportion to the area, the flood discharge to be provided for is over 15,700 cubic feet per second. The diversion of only 4,000 cubic feet will not prevent a heavy discharge into Lake Michigan in time of flood. To overcome this difficulty it is proposed, if suitable legislation can be secured, to divert the upper Calumet into Lake Michigan through an artificial channel to be excavated in Indiana about 17½ miles east of the
2425 State line. Indiana has not authorized such diversion, but supposing it to be accomplished, there will still be times when the discharge from the drainage area remaining to be cared for by the canal, 238 square miles, will exceed 4,000 cubic feet per second. The excess must enter Lake Michigan through the mouth of the Calumet, and at such times the system will fail. Of course it makes no provision for the future occupation of the upper Calumet region and the pollution of the lake from that source. It thus appears that the diversion of the Calumet River as now proposed by the Sanitary District will not be complete even for the present, and will not make adequate provision for the future.

37. The diversion of 4,000 cubic feet per second provides for a population of 1,200,000 by the standard fixed by the State law. The population of the Calumet region is now about 200,000, and until it reaches 1,200,000 only a part of the flow will be needed for sanitary purposes during a large part of the year; but the channel must be there, available for the full flow, if this method of sewage disposal is to be useful to any population, however small. Likewise the channel from the Chicago River must be, as it is, large enough to provide for a population of 3,000,000, whether that number of people are ever to become tributary to the Chicago River or not. The channels having once been constructed, any reduction of flow below their fullest capacity is a dead loss to the water power dependent upon them. It has been said that it would be absurd to develop water power at the cost per horsepower which this water power costs if the drainage canal be included, and that is true. But being given the channels, it would not be absurd to use them to their fullest capacity. The Chicago Drainage Canal having been constructed, with a capacity, as it turn out, of 14,000 cubic feet per second, full power development will call for the whole of that amount, and in fact power works are now under construction at Lockport to utilize it. Inasmuch as the sanitary requirements by the standard fixed in the State law are only 6,667 cubic feet per second for the present population of 2,000,000, it is evident that power development incidental though it be, does lead to demands for water not required for sanitary purposes.

38. It remains to be seen whether any diversion, complete or otherwise, is necessary to preserve the health of Chicago. Upon this point the commission sought the advice of two eminent sanitary engineers—Messrs. Rudolph Hering and George W. Fuller—whom it instructed as fol-
2426 lows, viz.: 'To examine the sanitary situation at Chicago, so far as it is affected by sewage disposal, and to report whether it is or is not necessary to the health of the city to extend to outlying territory the system which was adopted in 1889 for the main city. * * * The commission desires an emphatic opinion from authoritative sources as to whether the system of diverting the water of Lake Michigan in large quantities into the Illinois Valley is the only way to preserve the lives and health of the people of Chicago. It does not desire an investigation of the effect upon the navigation interests

of the Great Lakes. It has satisfied itself upon that point. Nor does it wish to reopen the case of the Chicago Drainage Canal as designed and built. It accepts that as a fixed fact, with its attendant diversion of 10,000 cubic feet per second through the Chicago River. The extension of the system to the Calumet River alone is in question, and the question is, Are there not other methods of sewage disposal which can be applied here at a cost not exceeding much, if at all, the cost of the method proposed, and which will be equally effective in preventing the pollution of the lake? It desires a report upon the various systems which may be found available for application here, with a statement of their relative efficiency. It also desires a statement of their relative cost, so far as that can be given without the preparation of detailed plans. The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive should be given.' These gentlemen visited Chicago, and after a thorough examination of the situation submitted a report, of which a copy is hereto appended, marked 'I.' The entire report should be carefully studied. Its conclusions only are here quoted. They are as follows, viz.:

'The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive are that a dilution of 3½ cubic feet per second for each 1,000 persons connected with the sewers, as provided for in the enactment of the Illinois legislature in 1889, is as low a figure as it is now possible to state. We believe that with the elimination of objectionable trade wastes and the occasional dredging of the river this amount of dilution will be sufficient to prevent offensiveness.

The extension of the dilution method to the outlying territory is not the only way to preserve the lives and
2427 health of the people of Chicago. The application of the method, with flow of 10,000 and 14,000 cubic feet per second, respectively, for the area tributary to the present drainage canal, will serve populations not exceeding 3,000,000 and 4,200,000, respectively. For greater populations other methods of sewage disposal will be required.

For the Calumet area, as well as other districts, there are several methods for the disposal of sewage as effective as the present method of dilution in preventing the pollution of the lake waters.

All these methods involve intersecting sewers and pumping stations to collect and deliver the sewage at suitable sites. Septic tanks are used for partially clarifying the sewage, which may then be applied to any one of three methods, of filters, viz.: intermittent sand filters, contact filters and sprinkling filters.

All of these filters if well built and well managed remove the suspended and organic matters so that the effluents are practically clear and non-putrescible. The removal of bacteria by these three types of filters average at least 98, 80 and 90 per cent., respectively. Such effluents may be discharged into any of the water courses of the Calumet region.

The approximate total costs, liberally estimated, without the preparation of detailed plans, for a population of 1,200,000 are as follows:

A—Intermittent Sand Filters.

Construction	$11,063,000
Annual cost of operation, $866,000, capitalized at 5%	17,320,000
	28,383,000

B—Contact Filters.

Construction	$11,787,500
Annual cost of operation, $551,000, capitalized at 5%	11,020,000
	22,807,500

C—Sprinkling Filters.

Construction	$ 9,257,500
Annual cost of operations, $419,000, capitalized at 5%	8,380,000
	17,637,500

2428 The present population on the Calumet area of the sanitary district being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expended at the outset.

Of the available methods of disposing of the sewage of the Calumet area other than by dilution, the sprinkling

filter method, being the cheapest both in cost of construction and of operation and accomplishing an adequate degree of purification, is clearly the most advantageous one.'

These engineers stand in the front rank of their profession as sanitary experts. One of them, Mr. Hering, was chairman of the commission of 1887, whose report to the mayor and city council of Chicago was the foundation of the subsequent legislation and led to the construction of the drainage canal. The conclusions reached are those of friends of Chicago and not of her enemies or rivals.

39. A method of sewage disposal for the Calumet region is proposed which for a population of 1,200,000 is estimated to cost $17,637,500. For the present population of about 200,000 only a part of the expense need be incurred, and the works can be developed as the population increases. It can, when the necessity arises, be applied with a population much exceeding 1,200,000. The cost of diverting the Calumet River into the Chicago Drainage Canal is estimated at $12,000,000. The greater efficiency at present and in the future of the method now proposed would justify a considerable increase of cost, but in view of the fact that the entire expense of the diversion must be incurred at the outset, while by the new method the expenditures will be regulated by the growth of population, the difference in cost may be considered unimportant.

Summary.

40. The following is a summary of the more important facts recited in this report:

(a) Chicago obtains its water supply from Lake Michigan, and to avoid polluting it must either dispose of its sewage otherwise than in the lake or place its intakes for water at a great distance from the city.

(b) The topography of the country favors the discharge of the sewage into the Des Plaines River, a tributary of the Mississippi, through two depressions in the divide which separate that river from Lake Michigan.

(c) The slope on the lake side of the divide is drained
2429 by two streams—the Chicago River and the Calumet River—into which the sewers of the city empty. By a cut through the northerly depression the flow of the Chi-

cago River has been reversed and diverted into the Des Plaines River instead of into Lake Michigan, and by a cut through the southerly depression the same process can be applied to the Calumet River.

(d) To make this reversal effective the channels must be large enough to take all the water which falls upon the respective drainage areas during the most violent rainstorms. This amount is estimated at 10,000 cubic feet per second for the Chicago River and 15,700 cubic feet per second for the Calumet River.

(e) The City of Chicago was originally built upon tha Chicago River, and that stream now drains the richest and most populous part of the city. It is now spreading over the Calumet region.

(f) In 1889 the plan of diverting the Chicago River into the valley of the Des Plaines was definitely adopted, and the Chicago Drainage Canal was undertaken. It was designed to carry 10,000 cubic feet per second. Though not entirely completed, it has been in use since January, 1900. The amount expended upon the canal and accessory work is about $41,000,000.

(g) The Illinois law which authorized the canal required a flow of 333 cubic feet per second for each 100,000 of population in order to render the sewage inoffensive. This amount of dilution is probably not excessive. It is reasonable to expect a population in a future not remote of five or six millions or more, involving the diversion by this standard of some 20,000 cubic feet per second. The Chicago River with its 10,000 cubic feet provides for a population of 3,000,000. The present population of the city is about 2,000,000.

(h) It is now proposed to apply to the Calumet River a treatment similar to that applied to the Chicago River, viz.: to reverse its flow, so that instead of discharging into Lake Michigan it shall discharge into the Des Plaines, but for a part of the new route it must follow the drainage canal already excavated for the Chicago River.

(i) Although the Chicago Drainage Canal was designed to carry 10,000 cubic feet per second, it is found to have, in its completed rock portion, an actual capac-
2430 ity of 14,000 cubic feet. This additional capacity fixes the amount which it is proposed to divert from the Calumet at 4,000 cubic feet per second. Any greater amount

from the Calumet will overtax the drainage canal at the expense of the richest part of Chicago and for the benefit of a suburban part.

(k) The diversion of only 4,000 cubic feet will not be effective at all times, since a much greater amount must be diverted from the Calumet during heavy rainstorms if the lake is to be protected. Moreover, it provides for a population not exceeding 1,200,000, which number will probably be exceeded at a date not far distant.

(l) The large channels necessary to provide for the contingencies of rainstorms are capable of discharging a volume of water largely in excess of sanitary requirements during the greater part of the year, but the development of water power creates the demand that they be employed to their full capacity throughout the year.

(m) The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress, but there appears to be a tacit general agreement that no objection will be made to the diversion of 10,000 cubic feet per second, as originally planned.

(n) The diversion of 10,000 cubic feet per second will lower the levels of Lake Michigan-Huron, Lake St. Clair, Lake Erie, Lake Ontario, and the St. Lawrence River, besides the important connecting channels, the Detroit and St. Clair Rivers, by amounts varying from 4¼ to 6¼ inches for the different waters, and the diversion of 14,000 cubic feet will lower them from 6 to 8½ inches. The diversion of 20,000 cubic feet will lower Lake Michigan-Huron about 13 inches and Lake Erie about 11 inches.

(o) The lake traffic which passed through the Detroit River in 1905 was about 58,000,000 tons, valued at about $615,000,000. It is increasing annually with marvelous rapidity. The records for the year 1906, so far as they are made up, indicate that the number of tons which passed through the Detroit River in 1906 exceeded 65,000,000, valued at $690,000,000. The lowering of the water surface has a very injurious effect upon this traffic and upon that of the Welland and St. Lawrence Canals. Chicago being one of the principal lake ports, there will be very few communities which will feel the injury more than she will.

2431 (p) The cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is estimated at $10,000,000, and of restoring it in the Welland and St. Lawrence Canals at $2,500,000. This expenditure would not prevent very serious annoyance to the navigation interests during the execution of the remedial works, which would occupy several years. In Lake St. Clair navigation of the open lake would be replaced by that of an artificial channel or canal with submerged banks.

(q) The extension to the Calumet region of the method of sewage disposal already applied to the Chicago River is not necessary to preserve the health of Chicago, there being other and better methods available for the Calumet region. The final cost of these methods is somewhat greater than that of the one proposed, but the works can be developed as the population increases, and only a part of their cost need be incurred at present, while their greater efficiency justifies the increase of final cost.

(r) The diversion of 10,000 cubic feet of water per second at Chicago will render practicable a waterway to the Mississippi River 14 feet deep. Any greater depth must be obtained by the abstraction of more water from Lake Michigan and at the expense of the navigation interests of the Great Lakes and of the St. Lawrence Valley.

(s) The effect upon Niagara Falls of diverting water at Chicago is of secondary importance when considering the health of a great city and the navigation interests of the Great Lakes and of the St. Lawrence Valley, but it is proper to note that the volume of the falls will be diminished by the full amount diverted at Chicago.

Recommendations.

41. The waters of Lake Michigan in the United States, the waters of Georgian Bay in Canada, and the waters of Lake Superior partly in the United States and partly in Canada all form sources of supply of the Great Lakes system, finding their way by St. Lawrence to the sea. All are interdependent and there can be no diversion from any of them without injury to the whole system. By Article XXVI of the treaty of 1871 it is provided that

2432 'navigation of the river St. Lawrence, ascending and descending from the forty-fifth parallel of north latitude, where it creases to form the boundary between the two countries, from, to, and into the sea, shall forever remain free and open for the purposes of commerce to the citizens of the United States, subject to any laws and regulations of Great Britain, or of the Dominion of Canada, not inconsistent with such privileges of free navigation.' It is desirable that in any treaty arrangement the waters of Lake Michigan, Georgian Bay, and all other waters forming part of the Great Lakes system should be declared to be 'forever free and open for the purposes of commerce' to the citizens of the United States and the subjects of His Britannic Majesty, subject to any laws and regulations of either country not inconsistent with such privilege of free navigation.

42. The preservation of the levels of the Great Lakes is imperative. The interest of navigation in these waters is paramount, subject only to the right of use for domestic purposes, in which term is included necessary sanitary purposes. In our report of November 15, 1906, upon the application of the Minnesota Canal & Power Co. to divert certain waters in Minnesota, we recommended, among other things 'that any treaty which may be entered into should define the uses to which international waters may be put by either country without the necessity of adjustment in each instance, and would respectfully suggest that such uses should be declared to be (a) uses for necessary domestic and sanitary purposes; (b) service of locks for navigation purposes; (c) the right to navigate.' It is our opinion that so far as international action is concerned a treaty provision of that kind is all that is required in this case. We accordingly renew our recommendation of November 15, 1906, just quoted.

43. A careful consideration of all the circumstances leads us to the conclusion that the diversion of 10,000 cubic feet per second through the Chicago River will, with proper treatment of the sewage from areas now sparsely occupied, provide for all the population which will ever be tributary to that river, and that the amount named will therefore suffice for the sanitary purposes of the city for all time. Incidentally it will provide for the largest navigable waterway from Lake Michigan to the Mississippi River which has been considered by Congress.

We therefore recommend that the Government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal.

All of which is respectfully submitted.

O. H. Ernst,
Brigadier General, U. S. Army, Retired,
Chairman American Section.

George Clinton,
E. E. Haskell,
Members American Section.

Geo. C. Gibbons,
Chairman Canadian Section.

W. F. King,
Louis Coste,
Members Canadian Section.

Attest:

W. Edward Wilson,
Secretary American Section.

Thomas Cote,
Secretary Canadian Section.

International Waterways Commission progress report, Senate Doc. 959, 62d Congress, 3d Session, pages 67-77."

April 25, 1906, the Canadian Section of the International Waterways Commission made report recommending the division of waters of the Niagara River at Niagara Falls, in which there was allotted to the Chicago Drainage Canal 10,000 second feet. (Rec. Vol. VIII, p. 159; This Narrative p. 104.)

May 3, 1906, the International Waterways Commission, signed by both the American and Canadian members, made a report with similar recommendations. (Vol. VIII, p. 160, this Narrative p. 104.)

On January 11, 1909, the United States made a treaty with Great Britain regarding the use of Canadian boundary waters, which is as follows (Rec. Vol. IV, p. 2561-2572):

"Treaty between the United Kingdom and the United States of America relating to Boundary Waters and

Questions arising along the Boundary between Canada and the United States, signed at Washington, January 11, 1909.*

Treaty relating to Boundary Waters and Questions arising along the Boundary between Canada and the United States, signed at Washington, January 11, 1909.

His Majesty the King of the United Kingdom of Great Britain and Ireland and of the British Dominions beyond the Seas, Emperor of India, and the United States of America, being equally desirous to prevent disputes re-
2562 garding the use of boundary waters and to settle all questions which are now pending between the United States and the Dominion of Canada involving the rights, obligations or interests of either in relation to the other or to the inhabitants of the other, along their common frontier, and to make provision for the adjustment and settlement of all such questions as may hereafter arise, have resolved to conclude a Treaty in furtherance of these ends, and for that purpose have appointed as their respective Plenipotentiaries:

His Britannic Majesty, the Right Honourable James Bryce, O. M., his Ambassador Extraordinary and Plenipotentiary at Washington; and

The President of the United States of America, Elihu Root, Secretary of State of the United States;

Who, after having communicated to one another their full powers, found in good and due form, have agreed upon the following Articles:

Preliminary Article

For the purposes of this Treaty boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms, and inlets thereof, but

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* Ratifications advised by the Senate ..... March 3, 1909
Ratified by the President ..... April 1, 1910
Ratified by Great Britain ..... March 31, 1910
Ratifications exchanged at Washington ..... May 5, 1910
Proclaimed ..... May 13, 1910

not including tributary waters which in their natural channels would flow into such lakes, rivers, and waterways, or waters flowing from such lakes, rivers, and waterways, or the waters of rivers flowing across the boundary.

ARTICLE 1

The High Contracting Parties agree that the navigation of all navigable boundary waters shall forever continue free and open for the purposes of commerce to the inhabitants and to the ships, vessels, and boats of both countries equally, subject, however, to any laws and regulations of either country, within its own territory, not inconsistent with such privilege of free navigation, and applying equally and without discrimination to the inhabitants, ships, vessels, and boats of both countries.

It is further agreed that so long as this Treaty shall remain in force this same right of navigation shall extend
2563 to the waters of Lake Michigan, and to all canals connecting boundary waters and now existing or which may hereafter be constructed on either side of line. Either of the High Contracting Parties may adopt rules and regulations governing the use of such canals within its own territory, and may charge tolls for the use thereof; but all such rules and regulations and all tolls charged shall apply alike to the subjects or citizens of the High Contracting Parties and the ships, vessels, and boats of both of the High Contracting Parties, and they shall be placed on terms of equality in the use thereof.

ARTICLE 2

Each of the High Contracting Parties reserves to itself, or to the several State Governments on the one side and the Dominion or Provincial Governments on the other, as the case may be, subject to any Treaty provisions now existing with respect thereto, the exclusive jurisdiction and control over the use and diversion, whether temporary or permanent, of all waters on its own side of the line which in their natural channels would flow across the boundary or into boundary waters; but it is agreed that any interference with or diversion from their natural channel of such waters on either side of the boundary resulting in any injury on the other side of

the boundary, shall give rise to the same rights and entitle the injured parties to the same legal remedies as if such injury took place in the country where such diversion or interference occurs; but this provision shall not apply to cases already existing or to cases expressly covered by special agreement between the parties hereto.

It is understood, however, that neither of the High Contracting Parties intends by the foregoing provision to surrender any right which it may have to object to any interference with or diversions of waters on the other side of the boundary the effect of which would be productive of material injury to the navigation interests on its own side of the boundary.

ARTICLE 3

It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter provided for by special agreement between the Parties
2564 hereto, no further or other uses or obstructions or diversions, whether temporary or permament, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line, shall be made except by authority of the United States or the Dominion of Canada within their respective jurisdiction and with the approval, as hereinafter provided, of a Joint Commission, to be known as the International Joint Commission.

The foregoing provisions are not intended to limit or interfere with the existing rights of the Government of the United States on the one side and the Government of the Dominion of Canada on the other, to undertake and carry on governmental works in boundary waters for the deepening of channels, the construction of breakwaters, the improvement of harbours, and other governmental works for the benefit of commerce and navigation, provided that such works are wholly on its own side of the line and do not materially affect the level or flow of the boundary waters on the other, nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes.

ARTICLE 4

The High Contracting Parties agree that, except in cases provided for by special agreement between them,

they will not permit the construction or maintenance on their respective sides of the boundary of any remedial or protective works or any dams or other obstructions in waters flowing from boundary waters or in waters at a lower level than the boundary in rivers flowing across the boundary, the effect of which is to raise the natural level of waters on the other side of the boundary unless the construction or maintenance thereof is approved by the aforesaid International Joint Commission.

It is further agreed that the waters herein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other.

ARTICLE 5

The High Contracting Parties agree that it is expedient to limit the diversion of waters from the Niagara River so that the level of lake Erie and the flow of the stream shall not be appreciably affected. It is the desire of both
2565 Parties to accomplish this object with the least possible injury to investments which have already been made in the construction of power plants on the United States' side of the river under grants of authority from the State of New York, and on the Canadian side of the river under licenses authorized by the Dominion of Canada and the Province of Ontario.

So long as this Treaty shall remain in force, no diversion of the waters of the Niagara River above the Falls from the natural course and stream thereof shall be permitted except for the purpose and to the extent hereinafter provided.

The United States may authorize and permit the diversion within the State of New York of the waters of the said river above the Falls of Niagara, for power purposes, not exceeding in the aggregate a daily diversion at the rate of 20,000 cubic feet of water per second.

The United Kingdom, by the Dominion of Canada, or the Province of Ontario, may authorize and permit the diversion within the Province of Ontario of the waters of said river above the Falls of Niagara for power purposes, not exceeding in the aggregate a daily diversion at the rate of 36,000 cubic feet of water per second.

The prohibitions of this Article shall not apply to the diversion of water for sanitary or domestic purposes, or for the service of canals for the purposes of navigation.

ARTICLE 6

The High Contracting Parties agree that the St. Mary and Milk Rivers and their Tributaries (in the State of Montana and the Provinces of Alberta and Saskatchewan) are to be treated as one stream for the purposes of irrigation and power, and the waters thereof shall be apportioned equally between the two countries, but in making such equal apportionment more than half may be taken from one river and less than half from the other by either country so as to afford a more beneficial use to each. It is further agreed that in the division of such waters during the irrigation season, between the 1st of April and 31st of October, inclusive, annually, the United States is entitled to a prior appropriation of 500 cubic feet per second of the waters of the Milk River, or so much of such amount as constitutes three-fourths of its natural flow, and that Canada is entitled to a prior appropriation of 500 cubic feet per second of the flow of St. Mary River, or so much of such amount as constitutes three-fourths of its natural flow.

The channel of the Milk River may in Canada be used
2566 at the convenience of the United States for the conveyance, while passing through Canadian territory, of waters diverted from the St. Mary River. The provisions of Article 2 of this Treaty shall apply to any injury resulting to property in Canada from the conveyance of such waters through the Milk River.

The measurement and apportionment of the water to be used by each country shall from time to time be made jointly by the properly constituted reclamation officers of the United States and the properly constituted irrigation officers of His Majesty under the direction of the International Joint Commission.

ARTICLE 7

The High Contracting Parties agree to establish and maintain an International Joint Commission of the United States and Canada composed of six Commissioners, three on the part of the United States appointed by the President thereof, and three on the part of the United Kingdom appointed by His Majesty on the recommendation of the Governor in Council of the Dominion of Canada.

ARTICLE 8

The International Joint Commission shall have jurisdiction over and shall pass upon all cases involving the use or obstruction or diversion of the waters with respect to which under Articles 3 and 4 of this Treaty the approval of this Commission is required, and in passing upon such cases the Commission shall be governed by the following rules and principles which are adopted by the High Contracting Parties for this purpose:—

The High Contracting Parties shall have, each on its own side of the boundary, equal and similar rights in the use of the waters hereinbefore defined as boundary waters.

The following order of precedence shall be observed among the various uses enumerated hereinafter for these waters, and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of precedence—

1. Uses for domestic and sanitary purposes;

2567 2. Uses for navigation, including the service of canals for the purposes of navigation:

3. Uses for power and for irrigation purposes.

The foregoing provisions shall not apply to or disturb any existing uses of boundary waters on either side of the boundary.

The requirement for an equal division may in the discretion of the Commission be suspended in cases of temporary diversions along boundary waters at points where such equal division can not be made advantageously on account of local conditions, and where such diversion does not diminish elsewhere the amount available for use on the other side.

The Commission in its discretion may make its approval in any case conditional upon the construction of remedial or protective works to compensate so far as possible for the particular use or diversion proposed, and in such cases may require that suitable and adequate provision, approved by the Commission, be made for the protection and indemnity against injury of any interests on either side of the boundary.

In cases involving the elevation of the natural level of waters on either side of the line as a result of the con-

struction or maintenance on the other side of remedial or protective works or dams or other obstructions in boundary waters or in waters flowing therefrom or in waters below the boundary in rivers flowing across the boundary, the Commission shall require, as a condition of its approval thereof, that suitable and adequate provision, approved by it, be made for the protection and indemnity of all interests on the other side of the line which may be injured thereby.

The majority of the Commissioners shall have power to render a decision. In case the Commission is evenly divided upon any question or matter presented to it for decision, separate reports shall be made by the Commissioners on each side to their own Government. The High Contracting Parties shall thereupon endeavor to agree upon an adjustment of the question or matter of difference, and if an agreement is reached between them, it shall be reduced to writing in the form of a Protocol, and shall be communicated to the Commissioners, who shall take such further proceedings as may be necessary to carry out such agreement.

Article 9

The High Contracting Parties further agree that any other questions or matters of difference arising between them involving the rights, obligations, or interests of
2568 either in relation to the other or to the inhabitants of the other, along the common frontier between the United States and the Dominion of Canada, shall be referred from time to time to the International Joint Commission for examination and report whenever either the Government of the United States or the Government of the Dominion of Canada shall request that such questions or matters of difference be so referred.

The International Joint Commission is authorized in each case so referred to examine into and report upon the facts and circumstances of the particular questions and matters referred, together with such conclusions and recommendations as may be appropriate, subject, however, to any restrictions or exceptions which may be imposed with respect thereto by the terms of the reference.

Such reports of the Commission shall not be regarded as decisions of the questions or matters so submitted either on the facts or the law and shall in no way have the character of an arbitral award.

The Commission shall make a joint report to both Governments in all cases in which all or a majority of the Commissioners agree, and in case of disagreement the minority may make a joint report to both Governments, or separate reports to their respective Governments.

In case the Commission is evenly divided upon any question or matter referred to it for report, separate reports shall be made by the Commissioners on each side to their own Government.

Article 10

Any questions or matters of difference arising between the High Contracting Parties involving the rights, obligations or interests of the United States or of the Dominion of Canada either in relation to each other or to their respective inhabitants, may be referred for decision to the International Joint Commission by the consent of the two Parties, it being understood that on the part of the United States any such action will be by and with the advice and consent of the Senate, and on the part of His Majesty's Government with the consent of the Governor-General in Council. In each case so referred, the said Commission is authorized to examine into and report upon the facts and circumstances of the particular questions and matters referred, together with such conclusions and recommendations as may be appropriate, subject, however, to any restrictions or exceptions which may be imposed with respect thereto by the terms of the reference.

A majority of the said Commissioners shall have power
2569 to render a decision or finding upon any of the questions or matters so referred.

If the said Commission is equally divided, or otherwise unable to render a decision or finding as to any questions or matters so referred, it shall be the duty of the Commissioners to make a joint report to both Governments, or separate reports to their respective Governments, showing the different conclusions arrived at with regard to the matters or questions so referred, which questions or matters shall thereupon be referred for decision by the High Contracting Parties to an Umpire chosen in accordance with the procedure prescribed in the fourth, fifth and sixth paragraphs of article 45 of The Hague Convention for the pacific settlement of international disputes, dated October 18, 1907. Such Um-

pire shall have power to render a final decision with respect to those matters and questions so referred on which the Commission failed to agree.

ARTICLE 11.

A duplicate original of all decisions rendered and joint reports made by the Commission shall be transmitted to and filed with the Secretary of State of the United States and the Governor-General of the Dominion of Canada, and to them shall be addressed all communications of the Commission.

ARTICLE 12.

The International Joint Commission shall meet and organize at Washington promptly after the members thereof are appointed and when organized the Commission may fix such times and places for its meetings as may be necessary, subject at all times to special call or direction by the two Governments. Each Commissioner, upon the first joint meeting of the Commission after his appointment, shall, before proceeding with the work of the Commission, make and subscribe a solemn declaration in writing that he will faithfully and impartially perform the duties imposed upon him under this Treaty, and such declaration shall be entered on the records of the proceedings of the Commission.

The United States and Canadian sections of the Com-
2570 mission may each appoint a Secretary, and these shall act as joint Secretaries of the Commission at its joint sessions, and the Commission may employ engineers and clerical assistants from time to time as it may deem advisable. The salaries and personal expenses of the Commission and of the Secretaries shall be paid by their respective Governments, and all reasonable and necessary joint expenses of the Commission, incurred by it, shall be paid in equal moieties by the High Contracting Parties.

The Commission shall have power to administer oaths to witnesses, and to take evidence on oath whenever deemed necessary in any proceeding, or inquiry, or matter within its jurisdiction under this Treaty, and all parties interested therein shall be given convenient opportunity to be heard, and the High Contracting Parties agree to adopt such legislation as may be appropriate and necessary to give the Commission the powers above

mentioned on each side of the boundary, and to provide for the issue of subpoenas and for compelling the attendance of witnesses in proceedings before the Commission. The Commission may adopt such rules of procedure as shall be in accordance with justice and equity, and may make such examination in person and through agents or employes as may be deemed advisable.

ARTICLE 13.

In all cases where special agreements between the High Contracting Parties hereto are referred to in the foregoing Articles, such agreements are understood and intended to include not only direct agreements between the High Contracting Parties, but also any mutual arrangement between the United States and the Dominion of Canada expressed by concurrent or reciprocal legislation on the part of Congress and the Parliament of the Dominion.

ARTICLE 14.

The present Treaty shall be ratified by His Britannic Majesty and by the President of the United States of America, by and with the advice and consent of the Senate thereof. The ratifications shall be exchanged at Washington as soon as possible, and the Treaty shall take effect on the date of the exchange of its ratifications. It shall remain in force for five years, dating from the day
2571 of exchange of ratifications, and thereafter until terminated by twelve months' written notice given by either High Contracting Party to the other.

In faith whereof the respective Plenipotentiaries have signed this Treaty in duplicate and have hereunto affixed their seals.

Done at Washington, the 11th day of January in the year of our Lord one thousand nine hundred and nine.

(L. S.) James Bryce
(L. S.) Elihu Root

The above Treaty was approved by the United States Senate on the 3rd March, 1909, with the following Resolutions:—

Resolved,—That the Senate advise and consent to the ratification of the Treaty between the United States and

Great Britain, providing for the settlement of international difference between the United States and Canada, signed on the 11th day of January, 1909.

Resolved further (*as a part of this ratification*),—That the United States approves this Treaty with the understanding that nothing in this Treaty shall be construed as affecting, or changing, any existing territorial, or riparian rights in the water, or rights of the owners of lands under water, on either side of the International Boundary at the rapids of the St. Mary's River at Sault Ste. Marie, in the use of the waters flowing over such lands, subject to the requirements of navigation in boundary waters and of navigation canals, and without prejudice to the existing right of the United States and Canada, each to use the waters of the St. Mary's River, within its own territory; and further, that nothing in this Treaty shall be construed to interfere with the drainage of wet, swamp, and overflowed lands into streams flowing into boundary waters, and that this interpretation will be mentioned in the ratification of this Treaty as conveying the true meaning of the Treaty, and will, in effect, form part of the Treaty.

Protocol of Exchange.

On proceeding to the exchange of the ratifications of the treaty signed at Washington on January 11, 1909, between Great Britain and the United States, relating to boundary waters and questions arising along the boundary between the United States and the Dominion of
2572 Canada, the undersigned plenipotentiaries, duly authorized thereto by their respective Governments, hereby declare that nothing in this treaty shall be construed as affecting, or changing, any existing territorial, or riparian rights in the water, or rights of the owners of lands under water, on either side of the international boundary at the rapids of the St. Mary's river at Sault Ste. Marie, in the use of the waters flowing over such lands, subject to the requirements of navigation in boundary waters and of navigation canals, and without prejudice to the existing right of the United States and Canada, each to use the waters of the St. Mary's river, within its own territory; and further, that nothing in this treaty shall be construed to interfere with the drainage of wet, swamp, and overflowed lands into streams flowing into boundary waters, and also that this declaration shall be deemed to

have equal force and effect as the treaty itself and to form an integral part thereof.

The exchange of ratifications then took place in the usual form.

In witness whereof they have signed the present Protocol of Exchange and have affixed their seals thereto.

Done at Washington this 5th day of May, one thousand nine hundred and ten.

James Bryce (SEAL)
Philander C. Knox (SEAL)

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*The British ratification of this further Instrument was deposited with the United States Government July 23, 1910."

Respectfully submitted,

Clyde L. Day
Wm. F. Barrett
Edmund D. Adcock

Attorneys for Appellant.

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No. 161

IN THE

Supreme Court of the United States

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO,
Appellant,

vs.

THE UNITED STATES OF AMERICA,
Appellee.

Appeal from the District Court of the United States, for the Northern District of Illinois, Eastern Division.

BRIEF AND ARGUMENT FOR APPELLANT

MR. CLYDE L. DAY,
MR. GEORGE F. BARRETT,
MR. LOUIS J. BEHAN,
MR. EDMUND D. ADCOCK,
ATTORNEYS FOR APPELLANT.

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IN THE

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO, *Appellant*, vs. THE UNITED STATES OF AMERICA, *Appellee.*	Appeal from the District Court of the United States, for the Northern District of Illinois, Eastern Division.

BRIEF AND ARGUMENT FOR APPELLANT.

STATEMENT OF THE CASE.

MAY IT PLEASE THE COURT:*

Appellant, The Sanitary District of Chicago, is here on appeal from a decree of the District Court, enjoining appellant from abstracting any waters from Lake Michigan across the Continental Divide to the DesPlaines, Illinois and Mississippi Rivers, in excess of 4,167 cubic feet per second, or 250,000 cubic feet per minute. (Appellant's Narrative, p. 117.) The decree was entered on June 18, 1923, appeal was allowed and the injunction suspended pending the appeal, and

* Owing to the length of the record, upwards of five thousand pages, appellant has filed, (as an appendix hereto), a condensation wherein is stated narratively the pleadings and evidence conceived by appellant's counsel to be material to either party, and it is entitled "Appellant's Narrative Statement of Pleadings, Facts and Evidence". For amplification of the facts stated herein, we will refer to this condensation as "Appellant's Narrative". Beginning with July 1, 1924, appellant furnished appellee's counsel with galley proofs of said narrative statement as it was being prepared, the final proofs being delivered about August 23d last, with request that any inaccuracies in the narrative occurring to appellee's counsel, should be indicated. At the time of filing this brief, no objections have been made to appellant by appellee.

the record was filed herein within the required time. The decree holds unconstitutional Section 20 of the Act of May 29, 1889, in force July 1, 1889, of the State of Illinois under which the appellant was organized and exists (Appellant's Narrative, p. 71), in that it limits the withdrawal of water from Lake Michigan for sanitary purposes to less than half what is prescribed by Section 20 of said Act, namely 20,000 cubic feet per minute for each 100,000 of the population within the territorial limits of the Sanitary District—upwards of 3,000,000 people. Thus, when the decree was entered, appellant was required by the Illinois Act to abstract from Lake Michigan 600,000 cubic feet of water per minute or 10,000 per second.

The decree also held it within the power of the Secretary of War, under Section 10 (this Brief, p. 108) of the Rivers and Harbors Act of March 3, 1899, to regulate the action of the State of Illinois taken pursuant to its police power, and thus the interpretation of the commerce clause of the Constitution is involved in this appeal.

There were two suits—a bill of complaint filed on March 23, 1908, and a complaint filed October 6, 1913. The first action was consolidated with the second one. (Appellant's Narrative, p. 113.)

The suit instituted March 23, 1908, involved the abstraction or diversion of water through an adjunct to the main diversion canal (called the Sanitary and Ship Canal or Main Channel). This adjunct is called the Calumet Sag Channel, and at the time the suit was instituted construction work had just been commenced. It was laid out to extend from the Little Calumet River westerly to appellant's main channel. It was designed to reverse the Calumet River and furnish an outlet for the drainage and sewage of the extreme southern area of appellant, namely that portion of Chicago lying south of 87th street and other territory lying south of the limits of the City of Chicago. It involved no other of ap-

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NOTE: The volume of water mentioned as per minute or per second indicates the amount flowing past a given point each second or each minute.

pellant's diversion works. However, the complaint filed October 6, 1913, not only involved all diversions of the Sanitary District, including that through its Main Channel and the Chicago River, but also the diversion by means of the Calumet Sag Channel covered by the first suit instituted, so that it is unnecessary to further consider the bill of complaint filed March 23, 1908.

The complaint in the second suit merely set up the organization of appellant in 1889 under an Act of the Illinois General Assembly passed May 29, 1889; the fact that it was diverting more water from Lake Michigan than appellee claimed was authorized by the Secretary of War, that the diversion would lower the levels of all the Great Lakes (except Lake Superior) and their connecting waters, and would thereby prevent boats carrying the cargo that they might have carried without the diversion; that such diversion was therefore a material injury to navigation. The complaint prayed that the appellant be enjoined from abstracting from Lake Michigan by means of its various diversion works, any waters in excess of 4,167 cubic seconds feet, the amount which appellee alleged the Secretary of War, had limited the abstraction under Section 10 of the Rivers and Harbors Act of March 3, 1899. (Appellant's Narrative, p. 21.)

The complaint was filed by the authority of the Attorney General, under Section 12 of the Rivers and Harbors Act of March 3, 1899, providing that *structures erected* in violation of Sections 9 and 10 *might be removed* by injunction instituted by the Attorney General (this Brief p. 108). It will be noted that this suit does not seek the removal of a *structure*.

Appellant's answer denied any injury to commerce or to navigation, and that there was any limitation of withdrawal made by the Secretary of War. It set up that there was an overruling necessity for such diversion, and various affirmative facts of defense—among others, that Congress had authorized the diversion across the Continental Divide by the Act of March 2, 1827, providing for the construction of the Illi-

nois and Michigan Canal from the southern end of Lake Michigan to the Illinois River; and that appellee had invited and acquiesced in appellant's course and it was thus estopped to deny appellant's right. (Appellant's Narrative, p. 39, *et seq.*)

It is unnecessary to further describe the pleadings, as there is no question of pleading involved, and the various issues of fact will appear in the succeeding portion of the statement of the case.

NOTE: There is no dispute as to any facts in the record except concerning the theoretical effect of appellant's diversion upon the surfaces of the Great Lakes, except Lake Superior, and appellee's claimed damage to commerce upon the Great Lakes. On other subjects appellee offered no evidence.

DESCRIPTION OF APPELLANT'S SANITARY & SHIP CANAL AND OTHER SUPPLEMENTARY DIVERSION WORKS.

Appearing in appellant's narrative (opposite p. 187) is a map entitled "Sanitary District of Chicago Map, showing right of way in Cook, Du Page and Will Counties". The map shows the territorial limits of the Sanitary District, the location of its various works completed in the beginning of the year 1914 and others, then, in process of construction. The completed channels, intercepting sewers, etc., are shown by yellow lines; the works in process of construction by red lines; the portion of the map appearing in dark red represents the original territorial limits of the Sanitary District as it was organized and laid out in the year 1889. The portions of the map colored yellow show the additional territory annexed by later acts. The entire territory of appellant contained 386.2 square miles, with a population at the time the decree was entered in this case, of approximately 3,300,000 people.

Lake Michigan is the only water supply for Chicago and its environs.

The underlying feature of appellant's works, from a sanitary standpoint, is the diversion at all times from Lake Michigan, of all sewage and drainage, so that this water supply will not at any time be or become polluted by the filth of this great metropolitan drainage area. This necessitated principally the construction of a canal and adjuncts of such size as to at all times keep reversed and flowing away from Lake Michigan, the Chicago River, its south branch and west fork. This principal canal, known as the Sanitary & Ship Canal, extends from the West Fork of the South Branch of the Chicago River at or near Robey street, upwards of twenty-eight miles, to a point just north of Joliet, where it empties into the DesPlaines River. Movable dams are located at its southern terminus by which the flow through it and appellant's

other diversion works may be at all times controlled. Its constructed capacity in the rock section, which is the southern portion of the Canal, is 14,000 cubic seconds feet of water. (Appellant's Narrative, p. 295.) Section 23 of the Sanitary District Act, provided that it should have a capacity in the rock section of not less than 10,000 cubic seconds feet of water. (Appellant's Narrative, p. 72.) This was and is the maximum or flood run-off of the Chicago River Drainage Area. (Appellant's Narrative, pp. 278, 279, 189.) If the capacity of the Main Channel were less than 10,000 cubic seconds feet, the Chicago River would at times flow into Lake Michigan, polluting the water supply.

Section 23 of the Act further provided that the Canal should be not less than 18 feet in depth and that it should not have a current greater than three miles per hour, all in order to provide proper navigation facilities thereon. The Channel is in the rock section 160 feet wide and in the earth section upwards of 200 feet, with a depth of 26 feet at all points. (Appellant's Narrative, p. 180.) Construction of the Channel was begun in 1890 by the making of surveys, and in 1893 by actual excavation. It was completed in 1898 and opened January 17, 1900, and since that time has been continuously operated. (Appellant's Narrative, pp. 288, 293.)

The Chicago River proper is very short, and extends from Lake Michigan approximately one mile, to the junction of the North and South branches of the Chicago River. The South Branch extends for some miles in a south and southwesterly direction, to the junction of the West Fork and South Fork of the South Branch. It is some distance on the West Fork southwesterly to the junction with it of the northern terminus of the Sanitary & Ship Canal just described.

At the time the Sanitary & Ship Canal was constructed, the South Branch and its West Fork were narrow, shallow and tortuous, so that it was necessary for the appellant to enter upon, use, widen and deepen, under Section 17 of the Sanitary District Act (Appellant's Narrative, p. 394) the

channels of these rivers, in order that they should become a supply channel by which the waters of Lake Michigan could be withdrawn through them to the Sanitary & Ship Canal. (Appellant's Narrative, p. 294.)

Consequently, beginning with the year 1896, the Sanitary District deepened, widened and straightened the channels of the South Branch and West Fork so that they have a capacity of withdrawing through them from Lake Michigan, water to the extent of 10,000 cubic seconds feet without creating a current injurious to navigation. The appellant deepened the channels of these rivers from 17 feet to 26 feet throughout, and widened them at all points to 200 feet; replaced old center pier bridges with modern bascules, so that at the bridge sites a current injurious to navigation would not exist with the added water, and the bridge openings would be large enough to permit the easy passage of boats. (Appellant's Narrative, p. 394.) The work of deepening and widening the channels of these rivers and the construction of the bridges, was all done with the consent of the Secretary of War under the various Rivers and Harbors Acts existing at the time the work was done, and at a cost to appellant of upwards of $10,500,000. (Appellant's Narrative, p. 296.)

This river improvement work may be properly divided into two periods—the work done prior to the opening of the Sanitary & Ship Canal on January 17, 1900, and the work done after that date. In the first period it was only necessary to improve the channels of the rivers, the West Fork and South Branch, to provide for the initial operation of the Sanitary and Ship Canal, which would then require a flow through it of waters from Lake Michigan of only 300,000 cubic feet per minute, as the population of the Sanitary District then was only approximately one and a half million people, all as is provided by Section 20 of the Act under which appellant exists. (Appellant's Narrative, p. 294.)

The authority of the Secretary of War for the work of excavating, etc., in improving the channels of the West Fork and the South Branch of the Chicago River during the first

period, 1896 to January 17, 1900, was represented by various permits then issued for specific work done from time to time. His consent for the improvement of the channels of these rivers, made after 1900, is represented by two permits issued on July 11, 1900, describing the proposed comprehensive improvement in these channels in order to provide for the withdrawal of at least 10,000 seconds feet of water from Lake Michigan through these channels to the Sanitary & Ship Canal. The work described by these permits and in the applications therefor made by the Sanitary District, provide for the deepening of the channels of these rivers from 17 to 26 feet, and widening at all points to 200 feet, including the work of reconstructing bridges to suit this improvement. (Appellant's Narrative, p. 90, 91.) The channel of the Chicago River itself was deepened by the United States, as the deepening and widening of the channels of the West Fork and South Branch of the Chicago River progressed, as above described. (Appellant's Narrative, p. 185.)

May 8, 1899, the Secretary of War issued a permit authorizing appellant to open its Sanitary and Ship Canal. The amount of water to be withdrawn through it was limited only by two conditions material here: (1) if Congress should act and specifically legislate, then the permit was to be null and void; (2) the Secretary of War might limit the flow through the Chicago River in the event a current was created therein unreasonably obstructive to navigation on the Chicago River, the Chicago River being then only 17 feet deep and narrow, and having obstructive bridges across it. (Appellant's Narrative, p. 21.)

Prior to the deepening and widening of the channels of the Chicago River, its South Branch and the West Fork of the South Branch, under the permits of July 11, 1900, (Appellant's Narrative, p. 92) the Secretary of War issued orders to limit, solely because of the current in the channels of those rivers, the diversion from Lake Michigan, (finally, on December 5, 1901), to 4,167 seconds feet. (Appellant's Narrative, p. 24.) Thereafter the river was deepened to 26

feet at all points and widened to 200 feet, pursuant to said permits of July 11, 1900, and bridges necessary for the improved channels were constructed. The Secretary of War has since refused to remove this limitation, notwithstanding the completion of the improvements of the channels of the Chicago River, its South Branch and the West Fork of the South Branch, and it is upon the limitation of the Secretary of War of December 5, 1901, that this litigation is founded. (Appellant's Narrative, p. 28.)

The sewer system of Chicago was constructed so that most of the sewers emptied into the Chicago River, its North and South Branches, the West Fork and South Fork of the South Branch. Some, however, debouched their sewage directly into Lake Michigan. (Appellant's Narrative, p. 178.) Consequently, large intercepting sewers were constructed along the shore of Lake Michigan to pick up the sewers emptying directly into Lake Michigan and by large conduits to divert this sewage to the DesPlaines River by means of the Sanitary & Ship Canal. On the south side of the city, as is shown by the map above described (Appellant's Narrative opposite p. 187), the interceptors converged at 39th Street and the sewage is there pumped, together with a certain amount of lake water, through the 39th Street Conduit into the East Arm of the South Fork of the South Branch of the Chicago River, whereupon it finds its way through the South Fork to the West Fork, and thence into the Sanitary & Ship Canal. The maximum capacity of the 39th Street Conduit, including sewage, is 2,000 cubic feet per second. The intercepting sewers on the North Side converge at Lawrence Avenue Pumping Station, and the sewage is pumped, together with a certain amount of water from Lake Michigan for dilution purposes, to the North Branch of the Chicago River, whereupon it finds its way through the North Branch to the South Branch of the Chicago River, and thence by its West Fork to the Main Channel. The maximum capacity of the Lawrence Avenue Conduit and Pumping Station is 40,000 cubic feet of water per minute, including sewage. (Appellant's Narrative, p.

191.) The North and South Side Intercepting Sewer Systems with pumping stations described, were completed about the year 1907 and thereby with the operation of the Sanitary & Ship Canal practically all the sewage and drainage arising in the original limits of appellant, was diverted from the water supply through the Sanitary & Ship Canal to the DesPlaines and Illinois Rivers. (Appellant's Narrative, p. 203.)

To further complete this drainage system and thereby protect the water supply of the inhabitants of Chicago and its environs, on May 14, 1903, an Act was passed by the General Assembly of Illinois (Appellant's Narrative, p. 76) providing for the annexation of territory north of the City of Chicago covering what may be called the North Shore Suburbs, including Evanston, Wilmette, Kenilworth, Winnetka, Glencoe, Hubbard Woods and others. The Act also provided for the annexation of territory to the south of the southern limits of the Sanitary District, or 87th Street of the City of Chicago, which includes what is known as the Calumet District, extending east to the Indiana State line. Under this Act, appellant was authorized to construct adjuncts, canals and other works necessary to furnish an outlet for the drainage of the added territory, cut through and destroy that portion of the Illinois & Michigan Canal, which parallels the Sanitary & Ship Canal to the DesPlaines River at or near Joliet. What is known as the North Shore Channel, extending from the North Branch of the Chicago River at or near Lawrence Avenue in the City of Chicago north to the shore of Lake Michigan at Wilmette, just north of Evanston, was constructed and placed in operation in the year 1910. The capacity of this channel is 1,000 cubic feet per second, and water is taken through it from Lake Michigan to dilute the sewage of the North Shore Suburbs as well as to furnish additional dilution water for the sewage entering the North Branch at various points. (Appellant's Narrative, p. 183.)

In connection with the North Shore Channel, intercepting sewers were constructed to divert the sewage of the North Shore Suburbs. The North Branch of the Chicago River

was straightened, widened and deepened to carry the additional water, and also to provide a navigable waterway all the way from the North Branch's junction with the Chicago River and its South Branch North to Wilmette, where a lock is provided for boats to pass from the North Shore Channel to Lake Michigan. This improvement was all done with the consent of the Secretary of War. (Appellant's Narrative, p. 183.)

To provide an outlet for the sewage and drainage of the Calumet District, immediately after the passage of said Act of May 14, 1903, the appellant laid out a right of way for and entered upon the construction of the Calumet Sag Channel (Appellant's Narrative, p. 6.) When the first bill of complainant was filed, namely, March 23, 1908, work on this canal was stopped and was not resumed until after June 30, 1910, when The Sanitary District obtained, from the Secretary of War, a permit to reverse the flow of the Calumet and Little Calumet Rivers. The permit was subject to the condition that there should not be diverted from Lake Michigan, by means of said channel, water in addition to what the appellant had the right to divert through its main channel, the Chicago River and its branches. (Appellant's Narrative, p. 82.) This channel extends from the Little Calumet River at or near Blue Island, westerly to a point at or near Sag, Illinois, on the Sanitary and Ship Canal. The capacity of this channel as it is now constructed, is approximately 2,000 cubic feet per second. There have been constructed intercepting sewers converging at or near the easterly terminus of said channel to divert all the sewage of the Calumet District so that no sewage will flow into the Calumet River or its branches within the State of Illinois. This channel, completed in the year 1922, reverses at practically all times the flow of the Calumet and Little Calumet Rivers. (Appellant's Narrative, p. 188.)

The Calumet Sag Channel is upward of 18 feet deep and over 60 feet wide, and at certain points is wider to provide for boats meeting or passing one another. It is designed for

further widening to provide a maximum capacity of 4,000 cubic seconds feet. (Appellant's Narrative, p. 188.)

The Sanitary & Ship Canal is wide enough and deep enough and the current therein is proper to permit the largest boats navigating the Great Lakes to pass through it to its southern terminus. All bridges over this channel have been so constructed that they may be moved, raised or lifted to leave the channel entirely unobstructed for navigation. This includes highway as well as railroad bridges. The Calumet Sag Channel, the North Shore Channel and all other improvements in rivers made by appellant, have been constructed or made so that all boats navigating the Illinois & Michigan Canal may pass through such canals or rivers without hindrance. (Appellant's Narrative, p. 188.) All this is pursuant to and under the express direction of the statute under which appellant exists, and to carry out the second great purpose of appellant's diversion works.

The cost of constructing the Sanitary and Ship Canal to provide navigation facilities over what it would have cost had it been built merely for the diversion of drainage and sewage with the statutory amount of water from Lake Michigan for dilution purposes is many millions of dollars. (Appellant's Narrative, 392.)

Section 7 of the Act under which the Sanitary District exists (Appellant's Narrative, p. 69) provides for appellant's owning dock property and leasing same along its right of way, in order that manufacturing or other establishments might locate there on water transportation. There was also constructed by appellant at the southern terminus of its main channel, for navigation purposes, a lock of sufficient size to permit the passage of boats to and from the Sanitary & Ship Canal into the DesPlaines River. The DesPlaines River was deepened and widened to connect navigation on the Sanitary & Ship Canal with the upper basin of the Illinois & Michigan Canal. (Appellant's Narrative, p. 181.) The Illinois & Michigan Canal between its Upper Basin at Joliet and Chicago, has not been used for years and navigation from Joliet to

Chicago has been carried on over the Sanitary & Ship Canal. (Appellant's Narrative, p. 296.) At the southern terminus of the Sanitary & Ship Canal, sufficient property has been reserved and set aside by appellant as a site for a lock upon which one may be built large enough to permit the passage of any boats capable of navigating the Sanitary & Ship Canal from it to the DesPlaines River below. (Appellant's Narrative, p. 297.)

At the southern terminus of the Sanitary & Ship Canal, at or near Joliet, there is a drop between the surface elevation of water in the Canal and the surface elevation of the water in the DesPlaines River just below, of approximately 34 feet. In order to utilize the potential water power existing, the original act of May 29, 1889, under which the Sanitary District was organized and now exists, authorized, and the Act of May 14, 1903, more expressly authorized, appellant to install such machinery as was necessary to convert the water power energy there into electricity. It was also empowered to use such of it as was necessary for its various pumping works and to sell the same primarily to municipalities, parks and districts within appellant's limits. (Appellant's Narrative, p. 78.) Consequently, in the latter part of the year 1907, this hydro-electric plant was completed and placed in operation. No water, however, has ever been diverted from Lake Michigan for the development of water power, and only the water that has been diverted for sanitary and navigation purposes has been so used. (Appellant's Narrative, p. 181.)

The diversion works and drainage and sewage outlets above described of the appellant thus provide for the diversion of a total of 12,000 cubic feet per second from Lake Michigan, and when the Calumet Sag Channel is fully completed, an additional 2,000 cubic seconds feet may be diverted through it, making a total of 14,000 cubic seconds feet, the original constructed capacity of the rock section of the Sanitary & Ship Canal. This diversion is accomplished as follows: Six thousand two hundred fifty seconds feet is drawn from Lake

Michigan through the Chicago River proper, to the junction of its North and South Branches. It is there augmented by 1,750 seconds feet, 750 from the Lawrence Avenue Conduit and Pumping Station, and 1,000 from Lake Michigan by means of the North Shore Channel; 8,000 cubic seconds feet thus flows through the South Branch of the Chicago River, to its junction with the West Fork and South Fork. This amount is augmented there by the 2,000 seconds feet coming from the 39th Street Pumping Station and Conduit to the West Arm of the South Fork of the South Branch. From the junction of the South Fork of the South Branch and the West Fork of the South Branch, there flows through the West Fork to the Northern Terminus of the Sanitary & Ship Canal at Robey Street and the West Fork, and thence through the Sanitary & Ship Canal to Sag, Illinois, 10,000 cubic seconds feet. At this point the Calumet Sag Channel enters with its flow of 2,000 cubic seconds feet of water, to be increased later by an equal amount. Thence the water flows or will flow in the amounts mentioned to the Southern Terminus of the Canal at or near Joliet, where it enters the DesPlaines River, and proceeds on its way to the Gulf of Mexico. (Appellant's Narrative, p. 191.)

The total cost of all these diversion works is approximately $75,000,000, and in addition there was expended $5,000,000 in the hydro-electric development at the southern terminus of the Sanitary & Ship Canal. (Appellant's Narrative, p. 194.)

ACTION OF THE STATE AND FEDERAL GOVERNMENTS CONCERNING THE DIVERSION OF WATER FROM LAKE MICHIGAN AT CHICAGO.

Waterway from Lake Michigan to the Gulf of Mexico.

The diversion of water across the Continental Divide or that small elevation of land which within a few miles of Chicago represents the division between the Great Lakes Basin, and the Mississippi River Basin, has been the subject of action of the State and Federal Governments substantially since Illinois became a member of the Union in the year 1818. Since the very earliest discovery by Joliet and Marquette of the Illinois River Basin in 1673, and thereafter, a water route has existed from the lower end of Lake Michigan through the Chicago River, its South Branch and the West Fork of the South Branch, and from there through Mud Lake to the DesPlaines River and thence to the Illinois. (Appellant's Narrative, p. 400.) This water route was used by the early explorers. adventurers and fur traders until about the year 1830. (Appellant's Narrative, p. 400.)

The DesPlaines River, rising in the State of Wisconsin, flows south to within ten miles of Lake Michigan at Chicago, near the source of the West Fork of the South Branch, then it veers southwesterly to a point where it forms a junction with the Kankakee River, creating the Illinois River. (Appellant's Narrative, p. 407.)

In times of high water, and during a large portion of the year, water flowed across the Continental Divide from the DesPlaines to the West Fork of the South Branch of the Chicago River. Likewise water flowed from the West Fork of the South Branch of the Chicago River to the DesPlaines River. Boats in these high water times could pass from the West Fork of the South Branch to the DesPlaines River, and vice versa. (Appellant's Narrative, p. 408.) In times of low water, there existed a portage whereby boats passed to and fro along this water route.(Appellant's Narrative, p. 407.)

The water route was described in the early reports made by Secretary of War John C. Calhoun to Congress. (Appellant's Narrative, p. 407.) The Enabling Act to permit the Illinois Territory to organize as a state, was amended in 1818 to include a coast on Lake Michigan, being the port of Chicago and extending to the present boundary between Illinois and Wisconsin. This water route and its probable improvement and enlargement, was stated to be, by Mr. Pope, in submitting the amendment, the reason for the addition of the coast of Lake Michigan to the Illinois territory. (Appellant's Narrative, p. 405.) The water route was recognized in the Treaty of Peace made by Major General Anthony Wayne in 1795, known as the Treaty of Greenville, and in the Treaty of 1816 with the Ottawas. (Appellant's Narrative, p. 408.)

The necessity of enlarging and improving the waterway was emphasized by reason of the refusal of the Government of Great Britain to permit the citizens of the United States free navigation on the St. Lawrence River. This refusal first took form in Acts of Parliament of 1822 and 1824. It was the subject of diplomatic exchanges in those years, also in the year 1827. These negotiations continued, until the year 1854, when a Treaty was made with Great Britain which gave to the citizens merely the privilege, but not the right of free navigation on the St. Lawrence River. (Appellant's Narrative, p. 409.)

March 30, 1822, Congress passed an act entitled "An Act to authorize the State of Illinois to open a canal through the public lands to connect the Illinois River with Lake Michigan." A portion of said Act is as follows:

> "That the State of Illinois be, and is hereby authorized to survey and mark through the public lands of the United States, the route of the Canal connecting the Illinois River with the southern bend of Lake Michigan; and ninety feet of land on each side of said canal shall be forever reserved from any sale to be made by the United States." (3 U. S. Stat. at large 659. Appellant's Narrative, p. 410.)

By reason of the failure of the State within three years from its passage to perform certain conditions, the Act ceased to have force or effect. Thereafter the General Assembly of Illinois memorialized Congress, setting forth the necessity of the passage of another act looking to the establishment of a canal from Lake Michigan to the Illinois River. Among other things, the Memorial stated:

> "That the construction of a canal uniting the waters of Lake Michigan with the Illinois River, will form an important addition to the Great Connecting Links in the chain of internal navigation which will effectually secure the indissoluble union of the confederate members of this great and powerful Republic." (Appellant's Narrative, p. 411.)

On March 2, 1827, Congress passed another act which has remained in force from and after its passage, and it still exists unrepealed, entitled "An Act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan." Said Act, among other things, provided:

> "That there be and hereby is granted to the State of Illinois, for the purpose of aiding the said State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each side of said canal, and reserving each alternate section to the United States, to be selected by the Commissioner of the Land Office, under the direction of the President of the United States, from one end of the said canal to the other; and the said land shall be subject to the disposal of the Legislature of the said State, for the purpose aforesaid, and no other; provided, that the said canal when completed shall be and forever remain a public highway for the use of the Government of the United States, free from any toll, or other charge, whatever, for any property of the United States, or persons in their service passing through same; * * *" (4 U. S. Stat. at large 234. Appellant's Narrative, p. 412.)

January 9, 1836, the General Assembly of Illinois passed an act under which the Illinois and Michigan Canal was con-

structed. Section 16 of this Act prescribed the initial width to be not less than 45 feet, and fixed its depth, and

> "to be supplied with water from Lake Michigan and such other sources as the Canal Commissioners may think proper".

The Act reserved 90 feet on each side of the canal to enlarge its capacity whenever the public good should require. (Appellant's Narrative, p. 412.)

The original plan of the canal provided for its construction from Chicago to Joliet in such way that water should be taken through it from the West Fork of the South Branch of the Chicago River and from Lake Michigan by gravity. However, lack of funds prevented its completion on this plan, known as the Deep Cut Plan, and it was completed in 1848 upon the Shallow Cut Plan, whereby water was obtained for its operation from the West Fork of the South Branch of the Chicago River by means of pumps at its Northern Terminus, and by a feeder extending from the canal at Sag, Illinois, to the Little Calumet River, substantially on the site of the present Calumet Sag Channel of appellant above described. (Appellant's Narrative, p. 413.)

For the purpose of further enlarging the Canal and to provide greater depths of water in the Illinois River below the Canal's Southern Terminus, the General Assembly of Illinois in 1861 directed that a survey be made of the Illinois River and Illinois and Michigan Canal, portions of the Des Plaines and Chicago Rivers

> "of the different methods proposed or desirable for improving the navigation of the Illinois River, by dredging or excavation of the channel and wing dams, or by supplying water from Lake Michigan, through the enlargement and deepening of the Illinois and Michigan Canal, or otherwise, or by opening a channel from Lake Michigan by way of the South Branch of the Chicago River and Mud Lake to the DesPlaines River and down said Canal to a point that would secure a free, flowing, ample and never failing supply of water, sufficient for navigation of the Illinois River at all seasons and times, * * * and to include also an estimate for the channel herein-

before mentioned, of sufficient size to admit of full and free steam-boat navigation from the Illinois River to Chicago and Lake Michigan, as well as a size sufficient for supplying water for all the deficiencies of navigation in the Illinois River, at all seasons. * * *" (Appellant's Narrative, p. 415.)

February 12, 1867, pursuant to the Act of Congress of June 23, 1866, Major General Wilson reported to the Chief of Engineers upon a survey for the improvement of this waterway along the lines of the resolution of the General Assembly of Illinois of 1861, above mentioned. Among other things, the report stated:

"The Illinois River seems to have been especially designed by nature as the link by which the waters of Lake Michigan are to be connected with those of the Mississippi. * * * the data herein contained, together with the existence of a canal of limited capacity already in operation, demonstrate beyond a doubt that the waters of the Lake may be carried into the Illinois River through a navigable channel of any required dimensions, and at a cost which cannot be regarded as excessive when the objects to be obtained are duly considered. * * * The summit will be inexhaustible, and this cannot be said of any other practicable line of water communication between Lake Michigan and the Mississippi River." (Appellant's Narrative, p. 418.)

January 9, 1875, Major F. C. Doran reported upon a survey of this waterway to the Chief of Engineers, U. S. Army, in which, among other things, it was stated:

"The improvement of the eastern portion of the Illinois and Michigan Canal involves the further cutting down of the summit level and enlarging the waterway so as to afford an unfailing supply of water from Lake Michigan for the improved Illinois River." (Appellant's Narrative, p. 419.)

This canal (summit level) had just then been (1871) deepened to conform to the deep cut plan.

Under the Rivers and Harbors Act of March 3, 1879, Major Lydecker made a report to the Chief of Engineers, which was transmitted to Congress, concerning a survey for the

improvement of this waterway. The report made May 18, 1880, reviewed the history of the development of this waterway, and reports heretofore mentioned as to improvements, and further stated:

> "* * * It seems only necessary to note that the improvement of the Illinois River, supplemented by the enlargement of the Illinois and Michigan Canal, as heretofore proposed, will furnish a reliable and commodious channel of water communication from the Mississippi River to the Northwestern Lakes; by this means the vast Mississippi Valley, and all the country tributary thereto, is brought into direct water communication with Lake Michigan, at the Great City of Chicago, with its flood of commerce eastward and westward. The route exists as a practicable one of considerable importance today, and the question is simply one of enhancing its value by increasing its capacity to a degree commensurate with the important interests involved. * * * Considering this simple statement, the facts so fully set forth in previous elaborate reports, and knowing the wonderfully rapid development of the entire western country, it would seem that nothing further is necessary to indicate 'to what extent the general commerce of the country will be promoted' by the contemplated improvement, nor to show how desirable it is that the work should be accomplished with the least delay practicable." (Appellant's Narrative, p. 421.)

Pursuant to the Rivers and Harbors Act of August 2, 1882, Major W. H. H. Benyaurd made two reports, one dated September 2, 1882, and the other March 5, 1884. In the latter report, it was stated:

> "that with the improvement of the River now in question carried on, navigation will be brought to within thirty-three miles of the Lake, and this stretch can be opened by improving the DesPlaines higher up and by enlarging the present Illinois and Michigan Canal".

(Appellant's Narrative, p. 444.)

By the Rivers and Harbors Act of August 5, 1886, Congress provided for a survey of this water route and the improvement thereof which was made by Major Handbury in 1887, and the report of said survey among other things stated:

> "The United States and the State of Illinois have long been committed to the project of opening a water com-

munication between the Mississippi River and the Northern Lakes of capacity sufficient for the wants of commerce and for the exigencies of our national defense, should these ever arise. * * * Besides the immense commercial advantages that may be expected from the completion of the project, there are military and naval exigencies that might easily arise where it would figure as a prominent factor in the problem of our national defenses. From whatever point we look at the subject, there is nothing local or sectional in it. It is true that all the work to be done happens to be in the State of Illinois. The benefits to be derived belong to the nation at large. It is fortunate, too, that at this time the subject is unencumbered by any phase of a political character. The problem of connecting Lake Michigan with the Mississippi River by a commodious waterway that could be used for commercial, military and naval purposes, has received attention from our most thoughtful statesmen from the day of Albert Gallatin to the present." (Appellant's Narrative, p. 445.)

On May 28, 1889, the General Assembly of Illinois adopted a resolution expressing the waterway policy of the State, and asking cooperation of the Federal Government:

"Whereas, it is contemplated to increase the volume from Lake Michigan to 300,000 cubic feet per minute within a few years, and ultimately to add 600,000 cubic feet or more, thus enabling a large depth for navigation to be obtained by an improved channel, and that said channel will be self-sustaining and self-improving, and will discharge flood waters more readily, thus benefitting the bordering lands and increasing the healthfulness of the valleys;

"Whereas, works now projected by the City of Chicago will form part of a waterway of large proportions from Lake Michigan via the DesPlaines and Illinois Rivers to the Mississippi River; * * *

"Therefore, be it resolved * * *

(1) That it is the policy of the State of Illinois to procure the construction of a waterway of the greatest practicable depth and usefulness for navigation from Lake Michigan via the DesPlaines and Illinois Rivers to the Mississippi River, and to encourage the construction of feeders thereto of like proportions and usefulness. * * *

* * *

(3) That the United States is requested to aid in the construction of a channel not less than 160 feet wide and 22 feet deep, with such a grade as to give a velocity of three miles per hour from Lake Michigan at Chicago to Lake Joliet, a pool of the DesPlaines River, immediately below Joliet, and to project a channel of similar capacity and not less than fourteen feet deep from Lake Joliet to LaSalle, all to be designed in such manner as to permit future development to a greater capacity". (Appellant's Narrative, p. 448.)

The above resolution was adopted the day before the act, under which appellant was organized and exists, was passed by the General Assembly of Illinois. This act provided for three uses of the diversion: (1) Sanitary—to prevent the water supply of Chicago and its environs from being polluted by sewage or drainage; (2) Navigation—the diversion channels and canals to be constructed of such size and depth as to provide easy transportation for boats engaged in commerce, state and interstate, greater depths in the DesPlaines and Illinois Rivers for navigation, removal of all dams in the Illinois River to provide a free passage for boats; (3) Incidental to the two principal uses, development of water power and use of right of way along diversion channels or canals for docks, thus providing an inner harbor for navigation.

We will now trace and describe the things done by Illinois and the City of Chicago to the date of the passage of the act under which appellant was organized and now exists—May 29, 1889—in the diversion of waters of Lake Michigan through the Illinois and Michigan Canal for sanitary purposes.

In 1863 an erysipelas epidemic broke out in Chicago, along the South Branch of the Chicago River. Thereupon, in cooperation with the trustees of the Illinois and Michigan Canal, the City of Chicago provided for the operation of the Bridgeport Pumping Station at the northern terminus of the Illinois and Michigan Canal, to pump more water through the Illinois and Michigan Canal from the West Fork of the South Branch of the Chicago River, the South Branch of the Chi-

cago River, the Chicago River itself, and from Lake Michigan, to cleanse those rivers. (Appellant's Narrative, p. 270.)

April 16, 1865, the General Assembly of Illinois authorized the City of Chicago, at its expense, to complete the Illinois and Michigan Canal from Chicago to Joliet upon the original Deep Cut Plan, whereby more water would be withdrawn from Lake Michigan through the Chicago River and its branches by gravity, one of the preambles to said act being as follows:

> "Whereas, it has been represented that the City of Chicago, in order to purify or cleanse Chicago River, by drawing sufficient quantity of water from Lake Michigan, directly through it, and through the summit division of the Illinois and Michigan Canal, would advance a sufficient amount of funds to accomplish this desirable object." (Appellant's Narrative, p. 417.)

Pursuant to this act, the Illinois and Michigan Canal was completed in 1871 on the Deep Cut Plan at an expense of upwards of $3,000,000, and thereafter more water was drawn through it from Lake Michigan—upwards of 40,000 cubic feet per minute. (Appellants' Narrative, p. 419.)

In 1881 the City of Chicago having greatly increased in population, the Chicago River having become badly polluted, contaminating the Lake Michigan water supply, the General Assembly of Illinois by resolution authorized the City of Chicago to install pumps at the northern terminus of the Illinois and Michigan Canal to withdraw from Lake Michigan through it, not less than 60,000 cubic feet of water per minute. (Appellant's Narrative, p. 49.)

These pumps were installed in 1884. The installation of the pumps, however, did not relieve pollution of the Chicago River and the water supply. A great flood in 1885 caused great quantities of filth to be carried out into Lake Michigan, further polluting the water supply. (Appellant's Narrative, p. 274.)

As a result, typhoid fever epidemics existed. The people of Chicago and vicinity became aroused concerning the danger

to health (Appellant's Narrative, p. 274.) Whereupon, January 27, 1886, a resolution passed the City Council of Chicago, authorizing the appointment by the Mayor of a Commission of Engineers, to be known as the **Drainage and Water Supply Commission.** The resolution stated the duties of this Commission to be—

> "to consider all plans relating to drainage and water supply which may be brought to its attention; to make such examinations and investigations and surveys as may be deemed necessary; to collect all information bearing on this problem; to consider all recent developments in the matter of sewage disposal and their application to our present and future needs; to consider and meet necessity of increasing our water supply and of protecting the same from contamination; to remedy our present inadequate methods of drainage and sewage disposal; to consider the relation of any system proposed to adjacent districts and whether there may not be a union between the city and its suburbs to solve the great problem; to determine the great question as to the interest which the State and the United States may have in the disposal of sewage by way of the Illinois River, and to devise plans to meet any objections thereto, if such a system shall be thought best; and in general to consider and report upon any and all things which relate to the matter of water supply and drainage of the City of Chicago." (Appellant's Narrative 424.)

The Commission was further instructed by the resolution to report in a comprehensive manner upon all phases of the question and *"not later than the convening of the next session of the Illinois Legislature in January,* 1887."

Accordingly, pursuant to the resolution of the City Council of Chicago, the Mayor appointed three eminent engineers of national standing—Rudolph Hering, as Chief Engineer, Benzette Williams and S. G. Artingsall as consulting engineers. The report of the Drainage and Water Supply Commission was made January 30, 1887, to the Mayor and City Council of Chicago, and a copy of the resolution under which the Commission was appointed, appears in said report.

The Commission made an examination and investigation of the entire subject, and among other things stated, reported and concluded as follows (Appellant's Narrative, p. 427):

"The examination disclosed the fact that the city is sometimes greatly suffering from the offensive condition of parts of the Chicago river and its branches, caused by the discharge of sewage into the same, and from the occasional contamination of its water supply, brought about by the discharge of the polluted contents of the river into the lake. It also disclosed the fact that almost every conceivable way of dealing with these questions had been suggested, and in some forms applied during the past thirty years.

"The problem therefore demands the attainment of two ends—the protection of the water supply and the removal of the river nuisance. As the water must be taken from the lake, it is evident that both its pollution and the objectionable condition of the rivers should be prevented by a better disposition of the sewage. It is, therefore the latter question which constitutes the main objection of this investigation.

"Among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy of an extended consideration, namely: A discharge into Lake Michigan, a disposal upon land, and a discharge into the DesPlaines River. The preliminary work has, therefore, been confined to these three projects, and was classed as topographic, hydrographic, and miscellaneous."

* * *

"The hydrographic work consisted in ascertaining the flow of the DesPlaines River, the rainfall upon its area, its flood discharges, the character of its bed, and the probable effect of discharging the Chicago sewage into it when diluted by a large and constant stream of water from the lake. It consisted, further, in examining the nature of the currents in the lake and in studying the rise and fall of its level, and in ascertaining the amount and character both of the sewage discharged into it and of the deposits in the river and lake in front of the city to determine the effects of the present sewage disposal.

"Inquiry and surveys were made to show the feasibility of purifying the Chicago sewage by filtration on land."

* * *

"When the sewage works of this city were designed, in 1856, by Mr. E. S. Chesbrough, it was apprehended that ultimately some means would have to be found to change the water in the river from time to time or to keep the sewage entirely out of it. The first steps toward improving the condition of the river was taken by deepening the Illinois and Michigan Canal, so as to cause a current from the lake to the DesPlaines River at Lockport. The next step was the building of the Fullerton avenue conduit in order to produce a circulation in the North Branch; and the last step was the erection of the canal pumping works to increase the flow in the river, which had become greatly polluted."

* * *

"The depth and character of sewage deposits in the river and harbor, as might be expected, vary considerably. They are not great in the track of the vessels, but increase toward the docks and quieter portions of the slips, where they reach a depth of from one to four feet. While the deposits in the channel are of a heavier kind, such as cinders, those in the docks are mostly a foul mass of decomposing organic matter. No form of life is found to exist above Clark street bridge as far north as Clybourn place and as far south as Ashland avenue. The effect of this condition of the river is to endanger the purity of the water supply whenever the river, with its accumulated deposits, flows into the lake, which occurs when the rain water that finds its way into the river exceeds the amount pumped into the canal. If this excess is great, as in the spring and occasionally in the summer months, the contamination of the lake is considerable, and must constantly increase.

"From the foregoing it is seen that the present method of disposal of the sewage from Chicago and its suburbs is partly by discharging it into Lake Michigan, but mainly, except during floods, by discharging it into the DesPlaines River."

* * *

"The growth of Chicago has been frequently quoted as phenomenal."

* * *

"This fact, together with the probable growth of Chicago, shows it to be economical and judicious at present to plan works sufficiently extensive to dispose of the sewage of not less than 2,500,000 inhabitants."

* * *

"A third solution of the drainage problem is rendered practicable by the fact that the divide between Lake Michigan and the Mississippi Valley lies about 10 miles west of Chicago, with so slight an elevation that it is not a difficult matter to carry the sewage from the city westward into the DesPlaines River, and thence into the Mississippi River."

* * *

"The possibility of this solution was recognized as early as 1856 by Mr. E. S. Chesbrough, and the first step towards its adoption was taken, as already mentioned, by turning the sewage into the Illinois and Michigan Canal. Not until quite recently, however, has it become practicable to consider the construction of a special waterway for sewage removal, because when the population was smaller the expense of the undertaking was too great."

* * *

"A second branch of the investigation extends to the elements governing the proper size of the waterway from which a large proportion of the storm water has been excluded. The area still draining into it will consist largely of paved streets and roofs, allowing of no absorption and shedding the water rapidly. It requires a careful consideration to determine the maximum quantity of water that may enter the proposed channel, and for which an ample allowance must be made to prevent a back flow of the polluted water to the lake."

* * *

"The proposed waterway should, of course, provide immunity from offense at all times."

* * *

"A third branch of the inquiry covers the selection of routes for the proposed canals.

"Between Chicago and Summit three lines are practicable—one following the west fork and Ogden ditch, and another extending from the southwestern end of the south fork in a westerly direction to the Ogden ditch, and thence to Summit, and a third being an enlargement of the present canal."

* * *

"For the drainage of the Calumet region a simple inspection shows that a canal should start from the river at the southern point of Blue Island, and extend almost directly westward to the DesPlaines Valley at Sag."

* * *

"In the foregoing we have outlined the main features of the only three feasible methods of disposing of the metropolitan sewage, and have given the results of the investigation reached to date."

* * *

"Besides the economical advantages of the DesPlaines scheme, its superiority is still further emphasized by advantages of another kind. The proposed canal will, from its necessary dimensions and its regular discharge, produce a magnificent waterway between Chicago and the Mississippi River, suitable for navigation of boats having as much as 2,000 tons burden. It will establish an available water power between Lockport and Marseilles fully twice as large as that of the Mississippi River at Minneapolis, which will be of great commercial value to the state. The Calumet region will be much enhanced in value by having a direct navigable channel to the DesPlaines River and by a lowering of the flood heights of Calumet Lake and River. Within the city the water of the Chicago River and its South Branch will get a much better circulation if it flows by gravity than if it has to be pumped, the necessity for which would remain even if the sewage should be discharged through intercepting sewers, either into the lake or upon land. Upon either of the latter conditions an occasional overflow from the sewers into the river during heavy rains would be more objectionable than a constant discharge of sewage into a more rapidly flowing stream. Flood waters entering the lake by way of the Chicago River would carry into it much filthy matter, either suspended or deposited, notwithstanding the existence of intercepting sewers, but the proposed diversion of such waters before reaching the populated districts will for all time obviate this undesirable occurrence."

* * *

"In reaching the conclusion that the sewage of the city should be discharged into the Mississippi Valley the question of water supply is materially simplified, because the lake will then at all times furnish good water wherever intakes are desired for an extension of the works."

The report of the Drainage & Water Supply Commission, above mentioned, was made, as required by the resolution of the City Council of Chicago under which the Commission was established, in time for the session of the General Assembly of Illinois of 1887. While the subject was

considered at this session of the General Assembly and a bill was introduced, it was not passed, and there was constituted a joint committee of the House and Senate to sit *ad interim* to consider the subject matter and future legislation. (Appellant's Narrative, p. 280.) The joint committee was empowered to and did obtain the advice of counsel, and John P. Wilson, late of the Chicago Bar, was one of its legal advisors. (Appellant's Narrative, p. 282.) This committee, reported to the next session of the General Assembly, after making a thorough investigation of various questions involved, and finally, on May 29, 1889, the bill was passed under which appellant was organized and now exists. This act became in force on July 1, 1889.

The Act, hereinafter, for convenience, called "The Sanitary District Act", was a culmination of the efforts of the State and Federal Government to comprehensively improve and enlarge the old waterway existing from time immemorial between Lake Michigan, the Illinois and Mississippi River and the Gulf of Mexico, and also the efforts of the State and the City of Chicago, beginning practically at the time Chicago became a city, to protect the Lake Michigan water supply and dispose of the drainage and sewage of the city.

THE SANITARY DISTRICT ACT DESCRIBED.

(Appellant's Narrative, p. 69.)

While the Act was in terms general and applied to any territory that might come within its specifications, yet it was generally understood that there was no similar situation in Illinois, and the Act may be considered as a special act to meet the conditions then confronting Chicago and its environs.

Pursuant to Section 1 of the act, appellant was organized and given its name by a proper petition filed as provided, and by an election held on November 5, 1889. The trustees, being the corporate authorities of the municipality thus organized, were elected in December following, and the trustees took office and organized as a Board immediately.

Express powers were given under the act to (Section 7)

> "provide for the drainage of such district by laying out, establishing, constructing and maintaining, one or more main channels, drains, ditches and outlets for carrying off and disposing of the drainage, including the sewage of such district, together with such adjuncts and additions thereto as may be necessary or proper to cause such channels or outlets to accomplish the end for which they are designed, in a satisfactory manner; also to make and establish docks adjacent to any navigable channel made under the provisions hereof for drainage purposes, and to lease, manage and control such docks, and also to control and dispose of any water power which may be incidentally created in the construction and use of said channels, or outlets, but in no case shall said Board have any power to control water after it passes beyond its channels, waterways, races or structures into a river or natural waterway or channel or water power or dock situated on such river, natural waterway or channel:" (Appellant's Narrative, p. 28.)

To carry out these express powers, appellant was authorized to levy taxes, borrow money, purchase real estate, and let contracts.

NOTE: The Illinois Supreme Court held the act constitutional on June 12, 1890.

Section 12 prohibited appellant from building over or across its Sanitary & Ship Canal, immovable bridges. It was expressly provided that all bridges built should not interfere with or obstruct navigation, and should be so constructed that they could be raised, swung or moved out of the way of vessels, tugs or boats.

In order to permit and empower the District to improve the Chicago River and its various branches, enlarge the Illinois and Michigan Canal if found to be a suitable site for the Sanitary & Ship Canal, and to reverse the Calumet River, Section 17 provided:

> "When it shall be necessary in making any improvements which any district is authorized by this act to make, * * * such district shall have the power to * * * and may enter upon, use, widen, deepen and improve any navigable or other waters, waterways, canal or lake:" (Appellant's Narrative, p. 69.)

Section 20 expressly directed appellant to turn into the channel or channels constructed as outlets for the sewage and drainage within its limits,

> "not less than 20,000 cubic feet of water per minute for every 100,000 inhabitants of said district, and shall thereafter maintain the flow of such quantity of water." (Appellant's Narrative, p. 71.)

Section 21 authorized the Attorney General to compel compliance with the above mentioned provision of Section 20.

Section 23 specified the dimensions and capacity of the Sanitary and Ship Canal.

> "23. If any channel is constructed under the provisions hereof by means of which any of the waters of Lake Michigan shall be caused to pass into the DesPlaines or Illinois river such channel shall be constructed of sufficient size and capacity to produce and maintain at all times a continuous flow of not less than 300,000 cubic feet of water per minute, and to be of a depth of not less than fourteen feet, and a current not exceeding three miles per hour, and if any portion of any such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan, of not less than eighteen feet, such portion of said channel shall have double the flowing capacity above provided for, and

a width of not less than one hundred and sixty feet at the bottom capable of producing a depth of not less than eighteen feet of water. If the population of the district draining into such channel shall at any time exceed 1,500,000 such channel shall be made and kept of such size and in such condition that it will produce and maintain at all times a continuous flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of such district, at a current of not more than three miles per hour, and if at any time the general government shall improve the DesPlaines or Illinois Rivers, so that the same shall be capable of receiving a flow of 600,000 cubic feet of water per minute, or more, from said channel, and shall provide for the payment of all damages which any extra flow above 300,000 cubic feet of water per minute from such channel may cause to private property so as to save harmless the said district from all liability therefrom, then such sanitary district shall within one year thereafter, enlarge the entire channel leading into said DesPlaines or Illinois rivers from said district to a sufficient size and capacity to produce and maintain a continuous flow throughout the same of not less than 600,000 cubic feet of water per minute with a current of not more than three miles per hour, and such channel shall be constructed upon such grade as to be capable of producing a depth of water not less than eighteen feet throughout said channel, and shall have a width of not less than one hundred and sixty feet at the bottom. In case a channel is constructed to the Desplaines river as contemplated in this section it shall be carried down the slope between Lockport and Joliet to the pool commonly known as the upper basin of sufficient width and depth to carry off the water the channel shall bring down from above. The district constructing a channel to carry water from Lake Michigan of any amount authorized by this act, may correct, modify and remove obstructions in the Desplaines and Illinois rivers wherever it shall be necessary so to do to prevent overflow or damage along said river, and shall remove the dams at Henry and Cooperas Creek in the Illinois river, before any water shall be turned into the said channel. * * *" (Appellant's Narrative, p. 72.)

Note: If appellant exercised the power to build outlets for the sewage and drainage within its territorial limits, it was compelled to construct it through a rocky stratum and through the Des Plaines River to Lockport and Joliet. Appellant waived the condition stated in the act that the General Government should improve the DesPlaines and Illinois Rivers, and built its main channel, or the Sanitary and Ship Canal, of a capacity throughout of not less than 600,000 cubic feet per minute, or 10,000 per second.

Section 24 provided that the Sanitary & Ship Canal should be a navigable water of the United States, under the control of the Government for navigation purposes, but not for sanitary or drainage purposes.

Section 26 gave the right to any municipality contiguous to the City of Chicago and within the territorial limits of appellant, to receive water obtained by Chicago from Lake Michigan for drinking and domestic purposes. (Appellant's Narrative, p. 75.)

Section 27 provided for the appointment of a commission by the Governor to inspect the Sanitary & Ship Canal and report as to whether the appellant had complied in the construction of it with the provision of the Sanitary District Act.

The appellant immediately entered upon the construction of the canal, by making the surveys provided for by the Drainage & Water Supply Commission report above mentioned, which formed the basis of the Sanitary District Act, and pursuant to the act itself. (Appellant's Narrative, p. 286.)

UNITED STATES ENGINEERS' ACTS CONCERNING THE SANITARY AND SHIP CANAL.

Captain Marshall, U. S. Engineer stationed at Chicago, immediately reported to the Chief of Engineers the action of the Drainage & Water Supply Commission and the passage of the Act of May 29, 1889, *verbatim* copies of the Commission's report and of the Act being transmitted therewith. The report of Capt. Marshall is contained in the Chief of Engineers Reports to Congress for the year 1890. (Appellant's Narrative, p. 451.)

April 21, 1891, the Board of Trustees of the appellant, by resolution provided that the appellant should forthwith

> "enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the South Branch thereof, and also the South Branch thereof, together with the South and West Forks thereof, so as to make the same a proper and sufficient supply channel for the Main Channel heretofore surveyed from the Chicago River to Joliet;"

The resolution also provided that a copy of same should be, and it was, sent to the Secretary of War of the United States. (Appellant's Narrative, p. 454.)

The Chief of Engineers Reports to Congress for the year 1892, contained a report by Capt. Marshall, U. S. Engineer at Chicago, of the progress of the work of the appellant. (Appellant's Narrative, p. 454.)

August 9, 1893, Capt. Marshall reported to the Chief of Engineers, U. S. Army, that actual excavation of the Sanitary & Ship Canal had been commenced. This report was contained in the Chief of Engineers Reports to Congress for the year 1893. (Appellant's Narrative, p. 455.) Among other things, Capt. Marshall stated:

> "Without criticising in any way the local measures taken for local relief, it may be said that the state laws, if effectively executed for the purposes specified, seemingly require changes in the capacity of Chicago River

and its branches that may increase, may diminish, or may even entirely destroy their value for commercial purposes. In any case under existing laws, no alteration in the capacity of Chicago River can be made without the consent of the Secretary of War, or without full examination by agencies established by Congress, and the execution of the state laws are therefore limited by superior authority."

Further, Capt. Marshall's report stated:

"It will soon be necessary for Congress to provide for the extension to Lake Michigan of the navigation established on the Illinois River below LaSalle, and to determine to what extent, if at all, it will utilize for navigation the great channel now being cut by local authorities in the rock divide, separating Lake Michigan from the Mississippi Valley. The question is at hand and must be determined at some date not far in the future, whether the national highway will utilize this cut and Chicago River as part of this communication, or the Calumet River route in connection with this local channel, or otherwise. There are no other practicable routes."

* * *

"Should a discharge of 250,000 cubic feet per minute be required through the south branch and main river, wholesale modification of bridges, tunnels and docks, and a widening of the river at many points will be required, and deepening to at least 18 feet of water below Chicago city datum with a slope necessary for this discharge, will be required * * *"

The Chief of Engineers' Reports for the year 1895, contained a further report of Capt. Marshall to the Chief of Engineers of that year, and the report stated:

"The City of Chicago expects to turn into the channel of the Illinois at some future time 5,000 cubic feet of Lake Michigan water per second; at some more remote period there may be 10,000 cubic feet per second, but not probably within a generation." (Appellant's Narrative, p. 463.)

The Secretary of War appointed a Board of Engineers, consisting of Gen. O. M. Poe, Brig. Gen. E. H. Ruffner and Maj. W. L. Marshall, to consider and report upon

"the probable effect of the operation of the Chicago Drainage Canal upon the lake and harbor levels and

upon the navigation of the Great Lakes and their connecting waterways." (Appellant's Narrative, p. 464.)

This Board of Engineers reported, on August 16, 1895, to the Chief of Engineers, and among other things stated (Appellant's Narrative, p. 465.)

> "The Board met in Chicago August 12, 1895, and on the 13th and 14th accompanied the officers of the Drainage Canal over the line under construction. Every facility and courtesy possible has been extended by the Trustees and Engineers of the Canal for a full investigation of the subject matter".

The report of this Board of Engineers described the works under construction, the purpose of withdrawing approximately 10,000 cubic seconds feet of water from Lake Michigan through the Sanitary & Ship Canal. It was estimated that this would lower the levels of Lakes Michigan and Huron approximately six inches, and the other Great Lakes, except Lake Superior, in varying amounts, including their connecting channels.

June 16, 1896, appellant requested the Secretary of War for a permit to improve the South Branch and the West Fork of the Chicago River, to increase its capacity for the initial operation of the Sanitary & Ship Canal at its opening. The population of the District was then estimated to be approximately a million and a half people, requiring a diversion of 5,000 cubic seconds feet of water, in accordance with the statutory ratio of dilution. Among other things, the request for the permit stated (Appellant's Narrative, p. 88):

> "The work of the Sanitary District has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport in Will County, twenty-eight miles distant.
>
> Our connection with Lake Michigan must be through the Chicago River, with the West Fork and the South Branch of which we make a junction at Robey Street."

Attached to the request, was a plan showing the improvements to be made on a certain section of the river. On June 24, 1896, Maj. Marshall reported to the Chief of Engineers, recommending the granting of a permit as requested, and in so doing, among other things stated:

> "As far as the work itself is concerned, there can be no objection to it, as in every case the navigation channel of the Chicago River will be improved." (Rec. Vol. VI, p. 3473.)

On July 3, 1896, in every respect following the recommendations of Maj. Marshall and those of the Chief of Engineers, the Secretary of War issued a permit for the improvement, requiring as a condition, however, that each by-pass, new dock and new bridge, be authorized by special permit.

Condition 2 provided (Appellant's Narrative, p. 474):

> "That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into the Chicago River. This latter proposition must be hereafter submitted for consideration."

On October 28, 1897, a request for permit for the improvement of certain other sections of the South Branch and West Fork of the Chicago River, was sent to the Secretary of War, the purpose of which was stated in the request to be

> "to conform to the plans of this District for securing an adequate flow of water through said stream. Our general plans have been heretofore submitted to the War Department. * * *" (Appellant's Narrative, p. 475.)

On November 16, 1897, pursuant to the recommendations of Maj. Marshall, U. S. Engineer at Chicago, a permit was granted by the Secretary of War, subject to the same conditions as were contained in the July 3, 1896, permit. (Appellant's Narrative, p. 475.)

November 30, 1898, January 13, 1899, March 10, 1899, and May 12, 1899, permits were granted by the Secretary of War to appellant to do various work in connection with the river

improvement, such as construction of bridges, building by-passes, coffer dams, etc. (Appellant's Narrative, p. 477.)

On February 23, 1898, pursuant to the invitation of appellant, the Rivers & Harbors Committee of the House of Representatives inspected the Sanitary & Ship Canal which was then substantially completed. (Appellant's Narrative, p. 184.)

On May 8, 1899, the Secretary of War issued a permit for the opening of the Sanitary & Ship Canal. There were certain preambles to the permit stating the purposes of the appellant's works and the request of the appellant for a permit. The permit, not including said preambles, is as follows:

> "Now therefore, The Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the waters of Chicago river to flow into the same, subject to the following conditions:
>
> 1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.
>
> 2. That if, at any time, it become apparent that the current created by such drainage works in the south and main branches of the Chicago river, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago river and its South Branch.
>
> 3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago river." (Appellant's Narrative, p. 481.)

Prior to the issuance of the said permit, complete investigation of the subject matter was made by Maj. Marshall, U. S. Engineer at Chicago, the result of which is embodied

in his report to the Chief of Engineers dated April 24, 1899, portions of which are as follows:

> "* * * In my opinion the abstraction of from 300,000 to 600,000 cubic feet per minute will permanently lower Michigan, Huron and Erie from three to eight inches; not more than eight nor less than three, corresponding to an extreme reduction of from 160 to 466 tons in carrying capacity of the large vessels of the lakes, and that it will take from three to four years for this full effect to be obtained."
>
> "* * * Individually I have to say that I am in entire sympathy with the people in their effort to purify their water supply. I have lost my only son from typhoid fever, produced, I believe from drinking water polluted by defective drainage at Chicago, which this channel will correct. In every proper way I have aided the officers of the Drainage District. I would like further to aid them, but I believe this question to be entirely out of my sphere, and too great and important for me even to venture an opinion or make a recommendation about. Yet I may venture to suggest that the entire subject be referred to Congress for final solution, and that a conditional permit or authority be granted to the authorities of the Chicago Sanitary District by the War Department, awaiting action by Congress, to open their channel * * *." (Appellant's Narrative, p. 478.)

Prior to the issuance of the permit of May 8, 1899, General Alger, the Secretary of War, who issued the permit and Gen. John M. Wilson, the Chief of Engineeers, who recommended its issuance, personally inspected the appellant's works. (Appellant's Narrative, p. 338.)

The Commission appointed by the Governor of Illinois under Section 27 of the Sanitary District Act, certified that the Sanitary & Ship Canal had been completed in all respects in accordance with the provisions of Section 23 of said Act. Thereupon, on January 17, 1900, the Sanitary & Ship Canal was opened, placed in operation, and has been continuously operated. Improvements had been made as heretofore stated, in the Chicago River, the South Branch and the West Fork thereof, to provide for a flow from Lake Michigan through the channels of said rivers to the Sanitary & Ship Canal, of

approximately 300,000 cubic feet per second, without creating a current unduly obstructive to navigation in the Chicago River, the population of appellant being then approximately a million and a half of inhabitants.

The channels of the Chicago River, the South Branch and the West Fork thereof, were then, however, narrow, shallow and tortuous, being only 17 feet deep and at places only 90 feet in width, with many obstructive center pier bridges. To provide immediately for the increase in population, and to prevent these rivers from flowing into Lake Michigan, carrying pollution to the water supply, when the run-off of the Chicago River drainage area exceeded 300,000 cubic feet per minute, a plan for the comprehensive improvement of the Chicago River and its branches to the northern terminus of the Sanitary & Ship Canal was adopted by appellant. This plan provided for the deepening of the channels of these rivers at all points to 26 feet, and widening them to 200 feet, replacement and reconstruction of obstructive bridges with new bridges of the bascule type and the wideming of bridge openings.

Two requests for permits to carry out these plans were made to the Secretary of War, dated April 26th and June 7th, 1900, respectively. The two requests covered the entire stretch off the channels of the South Branch and the West Fork to the northern terminus of the Sanitary & Ship Canal. They stated the purpose of appellant in improving the said river channels, and described the width and depth of the river channels as they would be when the plan was carried out, and that

> "the work to be done is to be prosecuted progressively as to time, the rate of progress being limited by the rapidity with which the right of way may be acquired and the resources for the execution of the work to be made available." (Appellant's Narrative, p. 90.)

Thereupon, on July 11, 1900, the Secretary of War issued two permits, as requested by the application of April 26th

and June 7th, 1900, respectively, above mentioned. The two permits, after referring to the application, each stated:

> "I beg to inform you that there is no objection on the part of the War Department to the prosecution of work of improvement of Chicago River, specified in the above mentioned letter, and delineated on the maps which accompany the same, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the General Government in any way with the expense incident to the carrying out of the project, and does not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted under date of May 8, 1899, to the Sanitary District of Chicago to divert the waters of the Chicago River and cause them to flow into the artificial channel, such permission being subject to the following conditions, viz." (Appellant's Narrative, p. 91.)

The conditions were precisely the same as contained in the May 8, 1899, permit for the opening of the channel. (this Brief p. 38.)

Orders of Secretary of War claimed by appellee to modify the May 8, 1899 permit.

The first modification of the permit of May 8, 1899, was made by the Secretary of War on the 9th of April, 1901, solely because of the current in the Chicago River. This modification was contained in a document signed by the Secretary of War which, after reciting the issuance of the permit of May 8, 1899, to open the Sanitary & Ship Canal, and Condition 2 thereof—namely that the Secretary of War might modify and restrict the flow if it should prove unreasonably obstructive to navigation on the Chicago River, provided:

> "And whereas it is alleged by various commercial and navigation interests that the present discharge from the river into the drainage canal sometimes exceeds 300,000 cubic feet per minute, causing a velocity of nearly 3 miles per hour, which greatly endangers navigation in the present condition of the river.

> "Now, therefore, this is to certify, that the Secretary of War, upon the recommendation of the Chief of Engineers, hereby directs said Sanitary District to regulate the discharge from the river into the drainage channel, so that the maximum flow through the Chicago river and its South Branch, shall not exceed 200,000 cubic feet per minute." (Appellant's Narrative, p. 23.)

On July 23, 1901, on the application of the Sanitary District, the Secretary of War amended the direction of April 9, 1901, providing that the flow through the river to the Sanitary & Ship Canal might be increased to 300,000 cubic feet per minute between the hours of 4:00 P. M. and 12:00 o'clock midnight. (Appellant's Narrative, p. 24.)

On December 5, 1901, the Secretary of War directed the appellant to limit the flow through the Chicago River, the South Branch and West Fork thereof, to 250,000 cubic feet per minute throughout the 24 hours of the day. The document so directing appellant, recited the issuance of the permit of May 8, 1899, for the opening of the Sanitary & Ship Canal, and Condition 2 thereof with reference to navigation on the Chicago River and the various directions of the Secretary of War thereafter made. (Appellant's Narrative, p. 24.)

On January 17, 1903, the Secretary of War, after reciting the issuance of the original permit of May 8, 1899, and the directions made thereunder, consented to appellant's increasing the flow until the 31st day of March, 1903, to 350,000 cubic feet per minute, and directed that thereafter it should be reduced to 250,000 cubic feet per minute throughout the 24 hours of the day, as prescribed by the direction of December 5, 1901. It is therefore upon this direction or so-called permit of December 5, 1901, that this litigation is based, as the Secretary of War did not thereafter issue any other permits or give any further directions with reference to the flow through the Chicago River, the South Branch and the West Fork thereof, to the northern terminus of the Sanitary & Ship Canal. (Appellant's Narrative, p. 25.)

Chicago River improvement under appellant's project of 1900, made pursuant to the permits of the Secretary of War of July 11, 1900.

Almost immediately upon the opening of the Main Channel, January, 1900, and after the permits of the Secretary of War above mentioned were issued, the appellant commenced the improvement of the South Branch and West Fork thereof, by acquiring many pieces of right of way for the river widening, (792,000 square feet). The channels were deepened from 17 feet to 26 feet throughout, and widened at all points to 200 feet, an average of 50 feet being taken off of the river channels at various points. The most at any one place was 110 feet. It involved the excavation of 5,500,000 cubic yards of material, and the construction of over 19,000 lineal feet of dock. This improvement also required the replacement of old center pier bridges with modern bascules. The bridges being built were State Street, Dearborn Street, Randolph Street, Jackson Boulevard, Harrison Street, Taylor Street, Chicago Terminal Transfer Railroad Bridge, 18th Street, 22nd Street, Main Street, Throop Street, Ashland Avenue, Washington Street. (Appellant's Narrative, p. 182.)

This work was practically completed prior to February 5, 1912, when the Sanitary District asked that the limitation of 4,167 seconds feet be removed, and that it be specifically authorized to divert 10,000 cubic seconds feet by means of its various diversion sources. (Appellant's Narrative, p. 395.)

Appellant also deepened the North Branch of the Chicago River, making it 12 feet deep, 90 feet wide and navigable. The South Fork of the South Branch was also deepened to 20 feet. (Appellant's Narrative, p. 183.)

The Chicago River proper was deepened by the United States to 20 feet at all points.

The Chicago River improvement described enabled appellant to draw through the Chicago River, the South Branch and the West Fork, and divert to and through the Sanitary & Ship Canal, 10,000 cubic seconds feet of water, so that

the current in the river channels would not be over one and one-quarter miles per hour and therefore not injurious to navigation on said river. A mile and a quarter an hour was the velocity the Secretary indicated to be acceptable. (Appellant's Narrative, p. 182.)

Acts amendatory and supplementary to the original Sanitary District Act of May 29, 1889.

In connection with the Chicago River improvement, the General Assembly passed an act approved May 13, 1901, in force July 1, 1901, expressly authorizing appellant to construct bridges over any river made necessary

> "by reason of widening, deepening or improving of such river." (Appellant's Narrative, p. 30.)

May 14, 1903, the General Assembly of Illinois passed an act, in force July 1, 1903, authorizing the annexation to the appellant's corporate limits of certain territory south of 87th Street of the City of Chicago, known as the Calumet Region, and certain territory north of the City of Chicago, to embrace what is called the North Shore Suburbs. The act authorized appellant to construct and maintain channels, drains, ditches and outlets for this additional territory, substantially the same as authorized for the original Sanitary & Ship Canal under the Act of May 29, 1889: To cut through the Illinois & Michigan Canal and thus destroy it between Joliet and Chicago, on condition, however, that it build a proper lock at its southern terminus to connect with the Des Plaines River, and a channel not less than 10 feet deep and 100 feet wide to connect with the upper basin of the Illinois & Michigan Canal at Joliet, thus making proper connection with the Illinois & Michigan Canal at Joliet, permitting boats to pass from Joliet over the Sanitary & Ship Canal to Chicago and Lake Michigan. Another condition was that there should be reserved and provided by the appellant at its southern terminus, a site for a lock 800 feet in length and 130 feet

in width, to be used in case of enlargement of the waterway.

Section 3 of this act provided:

> "Said Sanitary District shall permit all water-craft navigating or purposing to navigate said Illinois & Michigan Canal, to navigate all of said channels of said Sanitary District promptly, without delay, and without payment of any tolls or lockage charges for so navigating in said channel."

Sections 5 and 6 of this act expressly authorized the District to make available the water power at the southern terminus of its main channel to be used in the operation of its own pumping plants and machinery, and to be sold for public purposes to cities, villages and towns within the limits of the District.

Section 8 of the act provided:

> "The said Sanitary District shall, at the expense of said District, in all respects comply with the provisions of the acts of Congress of March 30, 1822, and March 2, 1827, as construed by the courts of last resort of the State of Illinois and of the United States in relation to the Illinois & Michigan Canal so far as it affects that portion of the Illinois & Michigan Canal vacated or abandoned by the terms of this act." (Appellant's Narrative, p. 32.)

Pursuant to the Act of May 14, 1903, the Calumet Sag Channel was constructed and completed in the year 1922, extending from the Little Calumet River to the Sanitary & Ship Canal at Sag, Illinois, and likewise the North Shore Channel was constructed and completed in the year 1910, extending from the North Branch of the Chicago River to the Lake Shore at Wilmette, Illinois. (Appellant's Narrative, p. 137.)

JANUARY 8, 1913, SECRETARY OF WAR STIMSON REFUSED TO REMOVE THE ALLEGED LIMITATION ON THE WITHDRAWAL OF WATER THROUGH THE CHICAGO RIVER, SOUTH BRANCH AND WEST FORK, AND TO FIX IT AT 10,000 SECONDS FEET, AS REQUESTED BY APPELLANT.

The Chicago River Improvement Project of 1900 having been substantially completed, so that a current would not exist injurious to navigation on the Chicago River and its branches, on February 5, 1912, the appellant asked the Secretary of War to remove the alleged limitation of December 5, 1901, made, at that time, because of the current in the Chicago River, the South Branch and the West Fork thereof. This amount, 10,000 cubic seconds feet, was necessary in order to keep the said rivers at all times reversed and flowing away from Lake Michigan, (Appellant's Narrative, p. 12) thus protecting the water supply. The Secretary of War, however, refused by memorandum dated January 8, 1913. (Appellant's Narrative p. 12.) The memorandum of Secretary of War Stimson concluded as follows:

> "1. That the diversion of 10,000 cubic feet per second from Lake Michigan as applied for in this petition, would substantially interfere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.
>
> "2. That being so, it would not be appropriate for me, without express Congressional sanction, to permit such a diversion, however clearly demanded by the local interests of the sanitation of Chicago.
>
> "3. That on the facts here presented, no such case of local permanent necessity is made evident.
>
> "4. That the provisions of the Canadian Treaty for a settlement by a Joint Commission of 'questions or matters of difference' between the United States and Canada, offer a further reason why no administrative offi-

cer should authorize a further diversion of water manifestly so injurious to Canada, against Canadian protest." (Appellant's Narrative, p. 16.)

Thereupon the principal branch of this litigation was instituted by the complaint filed October 6, 1913, heretofore described.

NOTE: Appellant contends that the memorandum of the Secretary of War is immaterial. His only power was to grant or refuse the permit.

ACTS OF CONGRESS AND REPORTS AND RECOMMENDATIONS OF BOARDS OF ENGINEERS AND COMMISSIONS, PURSUANT TO SUCH ACTS, PASSED AND MADE SUBSEQUENT TO THE PASSAGE OF THE SANITARY DISTRICT ACT OF MAY 29, 1889, RELATING TO THE PRESERVATION AND COMPLETE UTILIZATION TO THE FULL AMOUNT OF APPELLANT'S DIVERSION.

Under the Rivers and Harbors Act of June 3, 1896, (Laws Improvement of Rivers & Harbors, Vol. 1, p. 793, U. S. Stat. at large Vol. 29, p. 202), the following item appeared for survey and examination:

> "The Upper Illinois River and Lower DesPlaines River, with a view to extension of navigation from Illinois River to Lake Michigan at or near Chicago."

Pursuant to this act, Gen. W. L. Marshall made a report, dated January 27, 1897, which was transmitted to Congress March 3, 1897, as H. R. Document No. 33, 54th Congress, 2d Session. Among other things, this report stated:

> "The Sanitary District of Chicago has nearly completed a canal for drainage purposes from Chicago River at Robey street to near Lockport from 18 to 22 feet in depth below the proposed water surface, and varying in width from 160 feet in rock to more than 200 feet in earth, a length of 28 miles, which may be made available as part of any enlarged waterway over the route in question, and is of much greater dimensions than required by any commercial canal adapted for the conditions and requirements of present or prospective traffic by water between Lake Michigan and the region along the water courses of the Mississippi Valley. To comply with the law of the State of Illinois under which this drainage canal is constructed—*it has been constructed of a capacity to discharge* 600,000 *cubic feet per minute through the section excavated in rock and* 300,000 *cubic feet per minute*

Note: In referring to the Rivers and Harbors Acts of Congress for convenience we use "Laws of the United States relating to the Improvement of Rivers and Harbors, from August 11, 1790, to March 4, 1913," H. R. Document No. 1491, 62nd Congress, 3rd Session, copies of which for each member of the court are provided.

throughout the earth section—the law requires a discharge of 20,000 *cubic feet per minute for each* 100,000 *inhabitants of the drainage district which at present requires more than* 300,000 *cubic feet and in a few years will require the full* 600,000 *cubic feet discharge through the canal. The taking of water from Lake Michigan, however, for drainage purposes (or rather for dilution of sewage) has not yet been authorized by Congress."* (Appellant's Narrative, p. 487.)

This report is referred to in the following item of the Rivers & Harbors Act of March 3, 1899, which contained Sections 9 and 10 under which the Secretary of War seeks to regulate the Chicago diversion (This Brief, p. ....)

"Illinois River and DesPlaines River, Illinois: The Secretary of War is directed to appoint a board of three engineers, which board shall make a survey and estimates of cost for the improvement of the Upper Illinois River and Lower DesPlaines River, in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago; said board of engineers shall report the estimates of cost for a channel seven feet deep, and also for a channel eight feet deep, throughout said proposed route; said survey and estimates of cost shall be made in pursuance of and according to the recommendations in report of January twenty-seventh, eighteen hundred and ninety-seven."

Act of Congress of June 6, 1900, further carrying out the purpose of said Act of March 3, 1899, provided (Laws Improvement of Rivers and Harbors, Vol. 2, 914; U. S. Stat. at large, Vol. 31, p. 578.)

"That the board of three engineers, appointed by the Secretary of War, in pursuance of a paragraph in the river and harbor act approved March third, eighteen hundred and ninety-nine, to make a survey and estimates of cost of the improvement of the Upper Illinois River and the lower DesPlaines River in Illinois, with a view to the extension of navigation from the Illinois River to Lake Michigan at or near the City of Chicago, is hereby authorized to report the estimates of cost for a channel ten feet deep, and for a channel twelve feet deep, and for a channel fourteen feet deep through said proposed route, and that the said estimates cover and include a proper *connection at Lockport with the sanitary and*

ship canal which has been constructed by the sanitary district of Chicago. The said board of engineers is also further authorized to make a survey and estimates of cost for the improvement of the Lower Illinois River from the end of said proposed route to the mouth of said river, for channels ten, twelve and fourteen feet deep, respectively, and to report the estimates of cost thereof:"

Act of Congress of June 13, 1902, provided (Laws Improvement of Rivers and Harbors, Vol. 2, 995; U. S. Stat. at large, Vol. 32, p. 573):

"The sum of two hundred thousand dollars, or so much thereof as may be necessary, is hereby appropriated for making such surveys, examinations, and investigations as may be required to determine the feasibility of, and to prepare and report plans and estimates of cost of, a navigable waterway fourteen feet in depth from *Lockport,* Illinois, by way of the DesPlaines and Illinois rivers, to the mouth of said Illinois River, and from the mouth of the Illinois River, by way of the Mississippi River, to Saint Louis, Missouri."

Section 4 of the same act provided for the establishment of the International Waterways Commission, to make among other things a study and report to Congress upon the regulation of diversions of water. The members of the International Waterways Commission appointed under said Act, were to act in conjunction and cooperation with members of said Commission to be appointed by the Government of Canada. Said section is in part as follows (Laws Improvement of Rivers and Harbors, Vol. 2, 1007):

"That the President of the United States is hereby requested to invite the Government of Great Britain to join in the formation of an international commission, to be composed of three members from the United States and three who shall represent the interests of the Dominion of Canada, whose duty it shall be to *investigate and report upon the conditions and uses of the waters adjacent to the boundary lines between the United States and Canada, including all of the waters of the lakes and rivers* whose natural outlet is by the River Saint Lawrence to the Atlantic Ocean; *also upon the maintenance and regulation of suitable levels; and also upon the ef-*

fect upon the shores of these waters and the structures thereon, and upon the interests of navigation, by reason of the diversion of these waters from or change in their natural flow; and further, to report *upon the necessary measures to regulate such diversion,* and to make such recommendations for improvements and *regulations as shall best subserve the interests of navigation in said waters.* The said Commissioners shall report upon the advisability of locating a dam at the outlet of Lake Erie, with a view to determining whether such dam will benefit navigation, and if such structure is deemed advisable, shall make recommendations to their respective Governments looking to an agreement or treaty which shall provide for the construction of the same, and they shall make an estimate of the probable cost thereof."

Resolution of April 21, 1904, specifically with reference to the crests of the dams at Kampsville and La Grange is as follows (Laws of United States relating to Improvement of Rivers and Harbors, Vol. 2, 1049; U. S. Stat. at large, Vol. 33, p. 589):

"*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled,* That the Secretary of War is hereby authorized, in his discretion, with the concurrence of the Chief of Engineers, to permit the Sanitary District of Chicago, at the expense of said corporation, to lower the height of the Government dams in the Illinois River at Kampsville and LaGrange, Illinois, in accordance with such plans as he may prescribe and subject to such stipulation and conditions as, in his judgment, may be necessary to protect the interests of the United States."

The appellant, by permit and authorization of the Secretary of War, partially removed the crests of said dams. (Appellant's Narrative, p. 399.)

Section 1 of an Act of Congress of June 29, 1906, provided (Laws Improvement of Rivers and Harbors, Vol. 2, 1192; U. S. Stat. at large, Vol. 34, p. 626):

"That the diversion of water from Niagara River or its tributaries, in the State of New York, is hereby prohibited, except with the consent of the Secretary of War as hereinafter authorized in section two of this Act: *Provided, that this prohibition shall not be interpreted as*

forbidding the diversion of the waters of the Great Lakes or of Niagara River for sanitary or domestic purposes, or for navigation, the amount of which may be fixed from time to time by the Congress of the United States or by the Secretary of War of the United States under its direction."

Section 2 of this Act for the Preservation of Niagara Falls, authorized the Secretary of War to grant permits for the diversion of the Niagara River in New York for power purposes, with certain limitations as to gross amount, the principal object being to enable the operation of existing power plants.

Section 3 provided a penalty upon persons diverting water contrary to the provisions of the act.

Section 4 requested the President of the United States to open negotiations with the Government of Great Britain, looking towards the making of a treaty for regulation and control of the waters of the Naigara River and its tributaries.

Section 5 provided that the act should remain in force for three years.

Section 6 appropriated $50,000 to carry out the provisions of the act.

Section 7 reserved the right to alter, amend or repeal the act.

The history of the passage of this act is important. April 11, 1906, the bill was introduced in the House and referred to the Committee on Rivers and Harbors. It was reported back with amendments and passed the House. In the Senate it was ultimately referred to the Committee on Foreign Relations, of which Senator Lodge was Chairman. Among other amendments made in the Senate, was the one offered by Senator Albert J. Hopkins of Illinois, (numbered 6),

"provided, however, that nothing contained herein shall be construed to hold or concede that the waters of Lake Michigan or other lakes or rivers wholly within the territory of the United States, are the subject of international negotiation".

The House nonconcurred in the Senate amendments, and asked for a conference. The conference was thereupon held, and the report of the conferees recommended that the Senate recede from the amendment offered by Senator Hopkins, on the ground that this amendment would embarrass the President in the negotiations with Great Britain suggested by Section 4 of the bill relating to the making of a treaty to fix the diversion of the Niagara River and its tributaries. (Congressional Record, Vol. 40, p. 9097.)

Senator Hopkins opposed the adoption of the conference report, for the reason that his amendment was rejected. In answer to Senator Hopkins, Senator Lodge, the chairman of the committee, and one of the conferees, stated:

> "*Mr. Lodge.* Mr. President, I had supposed that the Senator from Illinois (Mr. Hopkins) realizes that the report of this bill in its present condition would not in any way endanger the rights of Chicago to have water from the lake. Certainly I should have adhered to the amendment if I had thought that the drainage canal of Chicago would have been in any way endangered by the Commission. The House would not accept this amendment. It is attached to a clause which requests the President to enter upon negotiations. It, of course, is merely advisory. Congress cannot possibly restrict the powers of the Executive in making a treaty. The result of putting on this clause beforehand would have been to have made any negotiations impossible. No country would enter into negotiations with a limitation on the other side like that.
>
> The first section of the bill protects the rights of Chicago. No treaty would be made by our Commissioners which would impair or infringe those rights.
>
> Moreover, Mr. President, the fact that it must be a matter of treaty, while it is a protection also, I think, warrants me in saying that what Canada desires is not to limit in any way the outflow of water at Chicago, but to be able to have a corresponding amount credited to her when they come to an agreement as to how much water each country may divert from the stream.
>
> I think, Mr. President, it would be a very great misfortune if the report should be rejected. Every right is safeguarded. The conferees were as anxious as the Senator from Illinois could possibly be to protect the

drainage canal at Chicago, but they did not feel warranted in allowing the whole legislation for such an important object to fall."

The Rivers and Harbors Act of March 2, 1907, provided for the appointment of a board to make a survey and examination of a channel 14 feet deep from St. Louis to the mouth of the Mississippi River;

"and the said Board may consider in connection with the examination herein provided for, the survey of a proposed waterway from Chicago to St. Louis, heretofore reported. * * * What increase of depth will be obtained over the natural flow of water in such regulated channel by an added volume of ten thousand cubic feet per second; also fourteen thousand cubic feet per second." (Laws Improvement of Rivers & Harbors, Vol. 2, p. 1261; U. S. Stat. at large, Vol. 34, p. 1073.)

The Rivers and Harbors Act of June 25, 1910, appropriated a million dollars for the construction of a waterway from Lockport, the southern terminus of the Sanitary & Ship Canal, by way of the DesPlaines and Illinois River, to the mouth of the Illinois, and also provided that the Secretary of War should appoint a Board of five members, four of whom should be engineer officers of the army, and one an engineer from civil life. The duties of the Board were stated in the act as follows:

"Said Board shall report upon the feasibility of such waterway and the most advisable depth and dimensions therefor in case the same is recommended; also upon such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished level in said lakes and the connecting waters thereof by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway herein described, or diversion for any other purpose. And further, also, upon the influence on volume and height of water in the Mississippi River below Cairo". (Laws, Improvement of Rivers & Harbors, Vol. 2, p. 1420; U. S. Stat. at large, Vol. 36, p. 630.)

On June 30, 1917, a joint resolution was adopted by Congress, as follows:

> *"Resolved by the Senate and House of Representatives of the United States of America in Congress assembled,* That public resolution numbered forty-five of the Sixty-fourth Congress, approved January 19, 1917, entitled 'Joint Resolution authorizing the Secretary of War to issue permits for additional diversion of water from the Niagara River,' is continued in full force and effect, and under the same conditions, restrictions and limitations, until July 1, 1918; *Provided,* That the Secretary of War is hereby authorized and directed to make a comprehensive and thorough investigation, including all necessary surveys and maps, *of the entire subject of water diversion from the Great Lakes and the Niagara River, including navigation, sanitary and power purposes,* and the preservation of the scenic beauty of Niagara Falls and the rapids of Niagara River, and to report to Congress thereon at the earliest practicable date. To carry out the provisions of this proviso there is hereby appropriated, out of any money in the Treasury not otherwise appropriated, the sum of $25,000." (U. S. Stat. at large, Vol. 40, p. 241.)

The reports of Boards of Engineers and Engineer Officers made pursuant to said Acts of Congress requiring same, assumed a diversion of 10,000 seconds feet at Chicago through appellant's works to be an existing fact, and recommended the location of a deep waterway along the Sanitary & Ship Canal, and the utilization of the said diversion through said Canal in connection with the improvement of the waterway below its southern terminus along the DesPlaines and Illinois Rivers to St. Louis.

The reports of the engineers as to the diversions of water from the Great Lakes, including the Board of Engineers for Rivers & Harbors, recommended the construction of compensating or regulating works in the St. Clair and Niagara Rivers to off-set for the diversions through the Sanitary & Ship Canal and at other places. No curtailment of diversions either for power and navigation purposes at Niagara Falls or through the Welland Canal or through appellant's canal for navigation and sanitary purposes, affecting lake surfaces, was recommended. Extracts from these reports will be found in Appellant's Narrative (p. 163).

REPORTS OF INTERNATIONAL WATERWAYS COMMISSION AND TREATY MADE PURSUANT TO RECOMMENDATIONS OF SAID COMMISSION, BETWEEN GREAT BRITAIN AND THE UNITED STATES SIGNED JANUARY 11, 1909, PROCLAIMED MAY 13, 1910, RELATING TO CANADIAN BOUNDARY WATERS.

The International Waterways Commission consisted of three members representing the United States, and three representing Canada. The Commission's duties and organization sprang from Section 4 of the Rivers and Harbors Act of June 13, 1902, above mentioned, and reciprocal legislation of the Canadian Government. Its duties generally involved the investigation of and reporting on all matters relating to the conditions and uses of boundary waters and waters adjacent thereto, and making recommendations as to a proposed treaty concerning such waters.

The International Waterways Commission made investigation of and reports upon the diversion of waters at Niagara Falls for water power purposes, and the division of such diversions between the United States and Canada. On May 3, 1906, report was made, signed by all the members of the Commission, the American as well as the Canadian members, recommending approximately 36,000 seconds feet diversion on the Candian side at Niagara Falls, and approximately 18,500 cubic seconds feet on the American side for power purposes. In reaching the amounts named and the division between the United States and Canada, the United States was charged with 10,000 cubic seconds feet diversion at Chicago by appellant, in addition to the 18,500 seconds feet at Niagara Falls. (Appellant's Narrative, p. 104.)

On January 4, 1907, the International Waterways Commission made a special report relating to appellant's diversion, entitled, "Report upon the Chicago Drainage Canal". This report reviewed the entire history of the construction

and operation of appellant's works, the proposed diversion of 4,000 cubic seconds feet through the Calumet Sag Channel and the Calumet River, in addition to that through the Sanitary & Ship Canal and the Chicago River. The Commission treated as an existing fact the diversion of 10,000 seconds feet, and considered that the only controversy which existed with reference to the amount of diversion by appellant, was that contemplated through the Calumet Sag Channel, namely the 4,000 cubic seconds feet maximum capacity. In referring to this matter, the report stated (Appellant's Narrative, p. 495):

> "Nor does it wish to re-open the case of the Chicago Drainage Canal as designed and built. It accepts that as a fixed fact with its attendant diversion of 10,000 cubic feet per second through the Chicago River. The extension of the system to the Calumet River alone is in question. * * * "

The Commission concluded:

> "The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress, but there appears to be a tacit general agreement that no objection will be made to the diversion of 10,000 cubic feet per second, as originally planned.
>
> * * *
>
> "The diversion of 10,000 cubic feet of water per second at Chicago will render practicable a waterway to the Mississippi River 14 feet deep. Any greater depth must be obtained by the abstraction of more water from Lake Michigan and at the expense of the navigation interests of the Great Lakes and of the St. Lawrence Valley."
>
> * * *

The Commission recommended:

> "* * * A careful consideration of all the circumstances leads us to the conclusion that the diversion of 10,000 cubic feet per second through the Chicago River will, with proper treatment of the sewage from areas now sparsely occupied, provide for all the population which will ever be tributary to that river, and that the amount named will therefore suffice for the sanitary purposes of

the city for all time. Incidentally it will provide for the largest navigable waterway from Lake Michigan to the Mississippi River which has been considered by Congress.

We therefore recommend that the Government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal."

* * *

Thereupon, a treaty was made and entered into between the United States and Great Britain, covering and following the subject matter of the recommendations of the International Waterways Commission. It was signed January 11, 1909, proclaimed May 13, 1910. (Appellant's Narrative, p. 529.)

The Treaty provided in the preliminary article that it was the intention

"to settle all questions which are now pending"

relating to the subject matter. Boundary waters were defined to be those

"from main shore to main shore of the lakes and rivers and the connecting waterways or the portions thereof, along which the international boundary * * * passes * * * but not including tributary waters which in their natural channels would flow into such lakes, rivers and waterways * * *"

Article 2 reserved to each of the parties

"or to the several State governments on the one side and the Dominion or Provincial Governments on the other, * * * the exclusive jurisdiction and control over the use and diversion * * * of all waters on its own side of the line which in their natural channels would flow across the boundary or into boundary waters."

Article 5 provided for diversion of 20,000 cubic feet of water per second at Niagara Falls on the American side for power purposes, and 36,000 cubic feet per second on the Canadian side.

Article 8 fixed the order of precedence of the uses of boundary waters to be.

"1. Uses for domestic and sanitary purposes.

2. Uses for navigation, including service of canals for the purposes of navigation.

3. Uses for power and for irrigation purposes." (Appellant's Narrative, p. 206.)

RESULTS AND EFFECT FROM HEALTH AND SANITARY STANDPOINT OF APPELLANT'S DIVERSION WORKS WITH THE ATTENDANT ABSTRACTION OF 10,000 CUBIC SECONDS FEET OF WATER FROM LAKE MICHIGAN.

The method of diverting sufficient water from Lake Michigan through the Chicago River, its branches, and the Sanitary & Ship Canal, to keep the Chicago River and its branches reversed (10,000 cubic seconds feet) was at the time the works were laid out and constructed, and is now, the only available method for the protection of the water supply.

The maximum run-off of the Chicago River drainage area is 10,000 cubic feet per second. In order to keep the Chicago River from flowing into Lake Michigan, carrying with it pollution to the water supply, it is necessary to divert from Lake Michigan an amount of water equal to this maximum run-off: (Appellant's Narrative: Fuller, p. 237; Phillips, p. 258; Stearns, p. 222; Wisner, p. 190; Cooley, p. 279.)

If the flow through the Sanitary & Ship Canal were reduced to 4,167 seconds feet, many times during each year in times of heavy rains, the Chicago River would flow into Lake Michigan. On account of the vast paved and sewered area, the water is delivered quickly to the Chicago River and its branches in from two to three hours. (Appellant's Narrative: Wisner, p. 390.) Tests were made on the drainage channel to ascertain how long it would take to change the flow from 4,167 second feet to 10,000 second feet. These tests showed that it would require approximately twenty-four hours to make such change, so that it would be impossible to so operate the Sanitary & Ship Canal and its controlling works at its southern terminus to anticipate the effect of heavy rains upon the water supply with the diversion reduced to 4,167 seconds feet, or any amount materially less than 10,000 seconds feet. (Appellant's Narrative: Wisner, p. 390.)

The cardinal principle, underlying proper protection of the water supply, is so arranging the works for the disposal of sewage and drainage that no sewage or drainage or effluent from artificial purification works may enter or come in contact with the water supply. (Appellant's Narrative: Cooley, p. 309; Wisner, p. 190; Phillips, p. 258; Stearns, p. 222.)

The Chicago River and its branches, before the Sanitary & Ship Canal was placed in operation, were filthy, dirty, sewage polluted waters, in septic condition, with gas bubbles rising, having large cakes of floating sewage mud. (Appellant's Narrative: Wisner, p. 189; Cooley, p. 291.)

The operation of the Sanitary & Ship Canal has absolutely remedied this condition so at the present time there is no local nuisance in the Chicago River, and the sewage does not get into the lake, polluting the water supply. (Appellant's Narrative: Wisner, p. 190; Cooley, p. 288.)

Prior to the opening of the Sanitary & Ship Canal, there were great epidemics of typhoid fever due to the polluted water supply, the death rate in such epidemics being as high as 170 per 100,000 people. (Appellant's Narrative: Cooley, p. 291.) For the 13 years prior to the opening of the Sanitary & Ship Canal, the annual death rate from typhoid fever was 52.6 per 100,000 population. For the 13 years after the opening of the canal, the annual death rate from typhoid fever was 19.9 per 100,000, a reduction of 68%. The reduction was greater in the latter period of 13 years than in any other American city, even where filtration plants had been installed. The rate for 1911 and 1912 was lower than the cities of Philadelphia, Washington, Pittsburg and New Orleans, where filtered water is supplied. The rate for those years is as low as in Boston, lower than San Francisco, where the water is obtained from carefully watched water sheds to prevent pollution. In the 13 years following the opening of the Sanitary & Ship Canal, diarrheal diseases were reduced 55%. (Appellant's Narrative: Wisner, p. 206.)

At page 323 of Appellant's Narrative, there is a chart showing death rate from typhoid fever in Chicago. There were no marked epidemics of typhoid fever at Chicago after the Sanitary & Ship Canal was opened. (Appellant's Narrative, p. 323.) The death rate from typhoid fever is a test of the health conditions of a city. Where one death from typhoid fever has been avoided by the use of pure water, a certain number of deaths, probably 2 or 3, from other causes have been avoided. This is known as Hazen's Law. (Appellant's Narrative: Adams, p. 326.) These facts are undisputed and no evidence was offered by appellee to the contrary.

HYDRAULIC EVIDENCE CONCERNING THE GREAT LAKES AND CLAIMED DAMAGE TO COMMERCE.

To what extent, if any, has or will the diversion of water from Lake Michigan at Chicago lower the levels of the Great Lakes and their outlets?

The Great Lakes occupy six depressions in the earth surface, and receive the drainage or run-off from a large area of adjacent land partly in Canada and partly in the United States, which run-off reaches them in major part by flowing over the surface in rivers and creeks. (Appellant's Narrative, p. 139.)

The precipitation varies in amount from month to month and year to year. On the Huron-Michigan drainage area, it varied from 38.63 inches in 1883 to 27.17 inches in 1895, a variation of about 42% from the minimum. (Appellant's Narrative, p. 139.) Evaporation takes place from the lake surfaces and from the ground and plant life. These two agencies, precipitation and evaporation, are the principal ones affecting the annual and monthly elevation of the Great Lakes, and are responsible for the major part of their fluctuations. (Appellant's Narrative, p. 139.)

The levels of the Great Lakes were actually higher during the ten years immediately following than during the ten years immediately preceding the opening of the Sanitary & Ship Canal. (Appellant's Narrative, p. 139.)

The diversion from the Great Lakes at Chicago through the Sanitary & Ship Canal, varied progressively from 4,300 cubic feet per second in 1900, to approximately 7,600 cubic feet per second in 1910. (Appellant's Narrative, p. 139.)

The waters involved are those of the entire lake system except Lake Superior and its tributaries, and except so much of the St. Mary's River as is above the foot of the Rapids at St. Ste. Marie.

The evidence of appellee as to the effect of the Chicago diversion upon the levels of the Great Lakes and their connecting waters, consisted entirely of the testimony of expert witnesses. (Appellant's Narrative, p. 127.) It related to the establishment of the increment of the St. Clair, Niagara and St. Lawrence Rivers. The increment of a river is the increase or decrease in its flow due to the rise or fall of one foot of the river's controlling lake.

Beginning with the year 1898, the United States Lake Survey had attempted to measure on numerous occasions the outflow of the discharge of the various outlet rivers. At the time when the determinations were made, hourly records had been kept of the stage of the different controlling lakes by automatic recording gauges. From these determinations, the discharge of the river at the time the velocity was obtained, could be calculated. The stage of the controlling lake at the time the discharge measurement was made, was then taken from the records of the recording gauge. The discharge measurements were plotted upon a paper according to the amount of the discharge and elevation of the lake at the time the discharge measurement was made. (Appellant's Narrative, p. 125.) As shown on Complainant's Exhibits 1 to 4, inclusive, a line is drawn through representing the mean of the measurements. (Appellant's Narrative, p. 125.) The difference between the discharge at a certain elevation and that at an elevation one foot higher, or one foot lower, was claimed to represent the increment. Thus, to determine the increment, it was necessary to do three things; *first*, to correctly measure the discharges of the rivers at the times made; *second*, to correctly determine what discharges are due to or correspond to the selected elevations; *third*, to correctly measure the difference in discharge between at least two elevations of the lake surface.

Having determined the increment, it was assumed that the lake was lowered by a diversion at Chicago equal to that fraction of a foot resulting from dividing the amount of the diversion by the increment of the outlet river as thus deter-

mined. (Appellant's Narrative, p. 127.) The greater the number of discharge measurements of the river whose increment it was sought to ascertain, and the greater the range of stage of the elevation of the controlling lake when the various discharge measurements were made, the more accurately would the increment of the outlet river be determined. (Appellant's Narrative, p. 145.) Thus errors in the discharge measurements of these great rivers and errors in the gauging of the surface elevations and in tying each discharge measurement to the proper elevation, would the more likely be eliminated. From a hydraulic standpoint, Michigan-Huron is treated as one lake, as their elevations are the same.

The witnesses for appellee concluded by means of these processes that the diversion through the Sanitary & Ship Canal of 10,000 to 14,000 cubic feet per second, was as follows:

Michigan-Huron 5. to approximately 6¾ inches.

Lake Erie, from 4 to 6 inches.

Lake Ontario, from 4 1/6 to 6 inches.

Lake Superior would not be affected. (Appellant's Narrative, p. 133.)

Appellant's expert testimony showed that the accuracy in determining the necessary data to ascertain the increment of the different outlet rivers, as above described, was not sufficiently perfect to enable the detection of a variation of flow of 10,000 cubic seconds feet, and thus the theoretical effect of the diversion through the Sanitary & Ship Canal could not be detected. (Appellant's Narrative, p. 140.)

The gauging sections of the different outlet rivers used in the measurements of the discharge to determine the increment, were several miles down the river from the respective controlling lakes. A discharge measurement was made at a certain time. It was then assumed that the stage of the lake at an estimated number of minutes before the time the discharge measurement was made, was the stage that con-

trolled the particular discharge at the time the measurement was made. (Appellant's Narrative, p. 145) The time interval estimate in tying the discharge measurement to the stage of the lake, or vice versa, was based upon certain assumptions made by some of appellee's witnesses, that the flow in the Sanitary & Ship Canal would be changed throughout from 4,167 seconds feet to 10,000 seconds feet in two to three hours from the time such change in flow was made at its southern terminus by lowering of the dams located there. This was found by actual tests to be entirely inaccurate, as it would take to accomplish this result not two to three hours, but at least twenty-four hours. (Appellant's Narrative, p. 390.)

Claimed damage to commerce.

It was not claimed by appellee that all vessels navigating the Great Lakes were or would be affected in their carrying capacity due to a lowering of the lakes surfaces, or that such lowering would affect any vessel at all places. It was claimed however, that there were certain critical points of navigation at which the depth of the water determined the depth to which large ore carrying vessels of the Pittsburg Steam Company could load; that these vessels, all built since the Sanitary & Ship Canal was opened, plied principally between points on Lake Superior and points on Lake Erie, thus passing through the locks at Sault Ste. Marie, St. Clair River, Lake St. Clair and the Detroit River. The locks at Sault Ste. Marie and places in the stretch of rivers and lake from Huron to Erie, were claimed to be critical points of navigation for these vessels. (Appellant's Narrative, p. 148.)

It was also claimed that these ore vessels carried about 81 to 100 tons for each inch of loaded draft; that based upon 25 trips per season, the vessels returning light, there would be loss of 11,150 tons per year; that assuming a freight rate of 55 cents per ton, a monetary loss would therefore exist of $6,000 per large vessel; that 72,000,000 tons of freight passed through the locks at Sault Ste. Marie during the year

1912, the greater part of which was carried in vessels of such size as to be affected by any loss of depth caused by the Chicago diversion. That therefore the loss to American vessels due to the diversion of 10,000 seconds feet, would be a million dollars per annum. (Appellant's Narrative, p. 149.)

Appellant claimed that the lowering of the lake surfaces of the small amount testified to by appellee's witnesses would not materially affect navigation; that these ore carrying boats could not load within such narrow limits; that the flow into each lake is constantly varying as is the discharge, affecting their levels; that there are also daily and hourly changes due to winds and barometric disturbances of from 6 inches to a number of feet (Appellant's Narrative, p. 150) and as is shown on plates attached to the report of the Board of Engineers, entitled "Waterway from Lockport, Illinois, to the mouth of the Illinois River," dated August 13, 1913, and made pursuant to the Rivers & Harbors Act of June 25, 1910, an extract from said report and a typical plate being shown in Appellant's Narrative (p. 150).

The unimportance of a few inches is shown by the failure of the appellee to remove a platform over the floor of the Poe Lock, which reduced the available depth of the Poe Lock approximately 0.33 of a foot, or about 4 inches. This condition existed from the time it was available for navigation in 1898 to 1913 when Mr. Ripley testified as to such condition. (Appellant's Narrative, p. 154.)

All boats claimed to be affected by the Chicago diversion, were built after the diversion began. (Appellant's Narrative, p. 159.)

The reference plane for the navigation improvement project of 1903, of the critical points of navigation between Lake Superior and Erie ports provided for by Congress, was fixed by the Engineer Corps six inches lower because of the diversion of 10,000 seconds feet at Chicago. (Appellant's Narrative, p. 155.) In other words, these critical points of navigation were dredged and deepened six inches lower than they

would have been had the Chicago diversion not existed, and navigation was thus protected from the claimed effects of the Chicago diversion.

Taking all the boats that could possibly be affected, namely 93 vessels of the 500 foot class, and 73 vessels of the 600 foot class, it was estimated that they could have been built longer without affecting their handling or cost of operation to carry an additional amount equal to the claimed loss of tonnage due to the smaller draft. The estimate for 3 inches less draft for all these boats in cost of constructing them in that manner, 93 of the 500 foot class and 73 of the 600 foot class, is $1,404,300 and $1,197,200, respectively. (Appellant's Narrative, p. 159.)

It is inaccurate to take the supposed loss or tonnage per inch and multiply it by the freight rate per ton to determine the monetary loss due to one inch less depth. There is only so much tonnage to carry by boats of the classes affected, and the loss is therefore represented by the extra cost of transporting the tonnage with the boats affected carrying the smaller cargo. (Appellant's Narrative, p. 159.)

Taking all these things into consideration, it is determined that the cost of transporting tonnage carried by the vessels of the 500 and 600 foot class for each inch loss of draft is 0.116 cents per ton. Calculating the number of trips for each vessel of the total affected—166—and the decrease in tonnage carried per year, the total capitalized loss which represents the entire loss for 3 inches loss in draft, is for 15 trips $1,848,600; for 20 trips $2,461,800; for 25 trips $3,076,200. The 166 vessels mentioned carried 37,000,000 tons of freight during the year 1912. On this basis, the loss per year for 3 inches loss in draft would be $128,760. Capitalizing this sum at 5%, is $2,575,200 as the total loss. (Appellant's Narrative, p. 159.)

The average number of trips of vessels loading beyond 18.1 feet passing through the locks of the Sault, is 14.12 per year, and this represents the 166 vessels mentioned. (Appellant's Narrative, p. 159.)

The cost of deepening the channels of the St. Mary's River, St. Clair River, channel in Lake St. Clair and those of the

Detroit River for 4 inches, is $163,990; 8 inches $403,854. The cost of deepening the harbors, including, also, the said channels, is 4 inches—$2,163,454; 8 inches—$4,405,008. The capitalized maintenance for 4 inches is $728,510; for 8 inches $1,092,766. (Appellant's Narrative, p. 160.)

A table was prepared showing the ports from and to which ore was carried and the amount for each port, during the fiscal year ending June 30, 1921; also a table was prepared showing the project depths as fixed by Congress up to the year 1922 for these various ports, including the critical points of navigation above mentioned—the St. Clair River and Livingston Channel in the Detroit River; also the table showed the actual depths of water for the low water years since the drainage channel was opened. This table shows that at no time was the actual depths of water at these ports and critical points of navigation, lower than the project depths as fixed by Congress. (Appellant's Narrative, pp. 161, 162.)

WORKS MAY BE CONSTRUCTED AT LITTLE COST TO OFFSET OR COMPENSATE FOR THE CLAIMED LOWERING OF THE ELEVATIONS OF THE LAKES, KNOWN AS COMPENSATING OR REGULATING WORKS.

It has long been established that submerged weirs or dams may be constructed and so placed in the outlet rivers such as St. Clair, Niagara and St. Lawrence Rivers, that the flowage capacity of these rivers will be contracted to an amount equal to the Chicago diversion of 10,000 or 14,000 cubic seconds feet. Thus the levels of the lakes would be restored and navigation would not be injured. (Appellant's Narrative, p. 164.)

These are called compensating works. Another kind of works effects the same purpose in a different way and are known as regulating works. They consist of movable dams placed in the outlet rivers so that at times the river may be more contracted than at others. These works are operated to maintain the levels of the controlling lake at an even stage; that is, the lake will not at the time of small supply reach the low stage that it would in natural conditions, nor will it reach as high a stage. The operation of the works would entirely off-set and take care of the diversion and give better navigation facilities. (Appellant's Narrative, p. 166.) For years works of this kind have been maintained and operated in the St. Mary's River and the stage of Superior has been controlled and the flow of the St. Mary's River regulated. (Appellant's Narrative, p. 176.) The International Waterways Commission and other Boards of Engineers have recommended the installation of such works. The Board of Engineers on Rivers & Harbors reporting under the above mentioned resolution of June 30, 1917, with reference to all diversions from the Great Lakes, recommended that regulating works be installed not only to take care of the effect of all diversions from the Great Lakes affecting the levels, including that of appellant, but also for the purpose of providing

better navigation facilities than would have existed under natural conditions. (Appellant's Narrative, p. 102.)

The Special Board of Engineers appointed under the Rivers & Harbors Act of June 25, 1910, made its report on August 15, 1913. This report was reviewed by the Board of Engineers for Rivers and Harbors in a report dated December 16, 1913, all of which was transmitted to Congress in the year 1914 (Appellant's Narrative, p. 176) known as H. R. 762, 63rd Congress, 2nd Session. The Special Board reporting, as stated, under date of August 15, 1913, found that

> "To restore the diminished levels in the lakes by constructing contracting works in their outlets, does not, however, present any serious difficulties";

also that

> "At the foot of Lake Ontario the closure of the Gut channel of the Galops Rapids by the Canadian Government has had the effect of raising the level of Lake Ontario an amount nearly equal to the computed lowering of the lake by a diversion of 10,000 second-feet at Chicago, and no compensation is at present deemed necessary to restore former conditions in this lake. (Appellant's Narrative, p. 176.)

Submerged weirs were recommended by the Board to be constructed in the Niagara River, also in the St. Clair River, to raise the levels of Erie and Michigan-Huron. (Appellant's Narrative, p. 176.)

In speaking of the works proposed to be constructed in the St. Clair River, the report stated:

> "It is computed that these weirs will increase the velocity of the water flowing over them slightly (from a mean of 3.28 feet to 3.89 feet per second) but, on the other hand, above the mouth of the Black River the river slopes, and velocities which are now excessive will be diminished *and navigation on the whole will be benefitted*".

The Board of Engineers for Rivers and Harbors, in reviewing the report of the Special Board above mentioned,

by its report of December 16, 1913, recommended (Appellant's Narrative, p. 171)

> "that the total volume of water to be diverted from the natural discharge channels of the lakes should be definitely fixed by Congress; that a project, with estimate of cost, for works necessary to compensation for such diversion, be prepared to the satisfaction of the Chief of Engineers and the Secretary of War; that before any diversion is made beyond that at present existing, the State of Illinois shall transfer to the Secretary of War the funds necessary for such works as given by the approved estimate of cost; that the works shall be built by the United States with the funds so provided, and that the control and maintenance of such works shall be in and at the cost of the United States".

The estimate of the cost of constructing the compensating works in the St. Clair and Niagara Rivers, as reported by the Special Board, was $475,000, and the annual cost of maintenance was $15,000. (Appellant's Narrative, p. 176.)

IF DIVERSION LIMITED TO 4,167 SECONDS FEET, ILL EFFECTS CANNOT BE OVERCOME.

In 1914 appellant made an estimate of the cost of constructing works that would be necessary if the diversion were limited to 4,167 seconds feet, and it was not permitted to divert the amount fixed according to the capacity of the Sanitary & Ship Canal, and the results of this investigation were produced in evidence that year. The sewer system of Chicago is what is called the combined system, that is, the sewers carry the sewage coming from the houses, buildings and factories and other places, as well as the storm and drainage water from the streets and ground surface. (Appellant's Narrative, p. 178.) These sewers principally and must necessarily discharge into the Chicago River or its branches (Appellant's Narrative, p. 179.) If the diversion is limited to 4,167 seconds feet, it would be necessary to artificially purify all sewage and let the effluent from these works discharge into the Chicago River, its branches and the Drainage Canal. The art of artificially purifying sewage has been in a state of change or flux—that is, one method would no sooner be adopted by engineers as the proper method to purify sewage, than it would be discarded for some other or newer method, which in turn would receive like treatment. (Appellant's Narrative, p. 257.) In the next place, it is impossible by artificial sewage purification works to completely produce an effluent from them that would not pollute the water supply if allowed to reach it. (Appellant's Narrative, p. 258.) With the diversion limited to 4,167 seconds feet, there would be many times during each year when the water of the Chicago River and its branches would flow into Lake Michigan, polluting the water supply. (Appellant's Narrative, p. 209.) No works could be constructed to purify the sewage arising in appellant's territorial limits, to take the place of the diversion required in excess of 4,167 second feet, without not only endangering the water supply, but also actually polluting it.

(Appellant's Narrative, p. 220.) It would take years to construct such works, even if the funds could be provided. As before stated, appellant made investigations of the cost of constructing works to supplement the diversion of 4,167 seconds feet and partially take the place of the additional diversion required. It is unnecessary to here state the details of such plans as they appear in the record and in appellant's narrative (p. 217). We will merely give the estimate of cost.

The estimated cost for the installation of such works, in 1914, including capitalized cost of operation, if the flow were limited to 4,167 seconds feet, was $183,000,000, assuming maximum 10,000 seconds feet; $220,000,000 assuming maximum 12,000 seconds feet, the present capacity of appellant's diversion works, and $257,000,000, assuming maximum 14,000 seconds feet, the total capacity of the Sanitary and Ship Canal in the rock section. The above estimates are based upon the assumption that there will be in a short time a population large enough to require the 12,000 and 14,000 cubic seconds feet to oxidize the sewage of this additional population. (Appellant's Narrative, 217.)

After the above mentioned facts and estimates were presented in the record, appellant submitted (April 25th and 26th, 1923), evidence showing that works to supplement the diversion of 10,000 cubic seconds feet, that is, to artificially purify the sewage and other wastes in excess of the population equivalent of three million people, would cost upwards of one hundred million dollars, and they could not be installed prior to the year 1945. (This Brief p. 79.)

OPINIONS OF THE DISTRICT COURT.

The case was submitted on the 15th of February, 1915, to District Judge Kenesaw Mountain Landis, upon printed record and printed briefs and argument, a brief of facts and a brief on the law being tendered by each party. All of the evidence mentioned hertofore, except the tables showing the carriage of ore for the year 1921 and the table showing the project depths in comparison with actual depths at low water times since the opening of the Drainage Channel and the reference to the report made under the resolution of June 30, 1917, as to the regulating works to off-set for diversions, was presented during the period beginning with the year 1908 and ending January, 1915. Certain other evidence was presented on the 25th and 26th of April, 1923, in connection with the motion made on July 12, 1920, about to be mentioned.

OPINION OF JUDGE LANDIS.

Judge Landis, having had the case under advisement from February 15, 1915, on June 20, 1920, rendered an oral opinion or direction for the preparation of a decree. This opinion was taken down in shorthand and transcribed, but never was signed by the Judge, and no other written memorandum signed by Judge Landis of his opinion exists. (Appellant's Narrative, p. 95.) In substance the Court found the issues with the appellee, and directed that a decree be prepared enjoining the appellant from abstracting water from Lake Michigan in excess of 4,167 seconds feet, as prayed by the complaint of October 6, 1913.

MOTION OF APPELLANT, FOLLOWING OPINION OF JUDGE LANDIS.

On July 12, 1920, appellant presented a motion that the Court

> "reconsider its oral opinion and oral direction heretofore announced concerning the form of decree to be entered in the said causes, and that the court direct that The Sanitary District of Chicago, defendant, be enjoined, only, from withdrawing or diverting from Lake Michigan, through its various works now constructed or under construction, more than ten thousand cubic feet of water per second from Lake Michigan on condition that if the Congress of the United States, or other competent governmental authority, provides for the construction of, in St. Clair, Niagara or St. Lawrence rivers, or in one or all of them, works to compensate for any diminishing levels of the Great Lakes and connecting waters, due to the diversion or withdrawal of ten thousand cubic feet of water per second from Lake Michigan by The Sanitary District of Chicago, then The Sanitary District of Chicago shall defray the expense and pay the cost of the construction and maintenance of any such works upon request therefor by the United States of America. In connection with said motion, and as a part thereof, the defendant hereby offers and agrees to defray the expense or pay to the United States upon demand the cost of the construction and maintenance of the works of the character above described in accordance with an ordinance of the Board of Trustees of The Sanitary District of Chicago passed and approved by said Board on the 8th day of July, A. D. 1920, a copy of which said ordinance is hereto attached and marked Exhibit 'A', a certified copy of which is here ready to be produced in court. In support of said motion, and as grounds therefor, the defendant alleges and shows the following:" (Appellant's Narrative, p. 98.)

Appellant also by said motion set up the various proceedings in the case and the issues, and alleged principally that it was an undisputed fact in the record that compensating works could be constructed to off-set for the supposed lowering of the lake surfaces and their connecting channels. The ordinance of the Board of Trustees of appellant offering to

defray the expense of constructing these compensating works was set forth by attaching a copy thereof as an exhibit to the motion. There were other facts set forth in the motion that are not here pertinent to be mentioned. The motion was partially heard by the Court on the 12th of July, 1920, and further hearing was postponed. Finally, on March 1, 1922, Judge Landis ceased to be a Judge of the District Court by reason of his resignation. Thereafter the motion was heard before Judge George A. Carpenter of said District Court.

Appellant desired and asked that Judge Carpenter, the successor judge, hear all questions involved in the case, as well as said motion, in view of the fact that there was no memorandum signed by Judge Landis showing his conclusions. There was nothing upon which the successor judge could act except the pleadings and evidence in the record. However, Judge Carpenter refused to go into the merits and heard only argument upon the motion, and thereafter, on July 18, 1923, entered a decree enjoining the appellant, according to the prayer of the bill. At the same time he rendered an opinion orally, which was thereafter signed by him. (Appellant's Narrative, p. 113.)

In connection with said motion, prior to the entry of the decree and prior to Judge Carpenter's rendering his opinion as aforesaid, appellant offered evidence showing that on August 7, 1919, in cooperation with the United States Engineer at Chicago, Colonel Judson, its Board of Trustees, by ordinance, adopted a program for the construction of artificial sewage disposal works to supplement a diversion of 10,000 cubic seconds feet of water from Lake Michigan whereby over a period of twenty-five years appellant should construct and place in operation progressively works, so that at the end of said period of twenty-five years, the sewage of the increase of population and trade wastes, would be taken care of by these supplementary works. (Appellant's Narrative, p. 110.)

It also appeared from this evidence that the trade wastes, including the stockyards and tanneries entering the San-

tary & Ship Canal from the sewers of Chicago, would require as much water to dilute it as would be necessary to take care of the sewage of a million and a half of people. The population of the Sanitary District within the territorial limits of appellant was then approximately 3 million people. Thus the human sewage and wastes had a population equivalent for dilution equal to that of almost 5 million people. The increase in waste and human sewage would give an equivalent by 1945 of approximately 7 million people. (Appellant's Narrative, p. 362.) The total cost of these works would be upwards of a hundred million dollars (Appellant's Narrative, p. 366.)

Using all the financial resources of the District from taxation and issuance of bonds, funds could not be provided to install the works to take care of the sewage and wastes undisposed of by 10,000 seconds feet diversion, so that the works could be completed prior to 1945. At that time there would still be required 10,000 seconds feet diversion to take care of the sewage and wastes not treated. (Appellant's Narrative, p. 368.)

Before the diversion could be reduced below 10,000 seconds feet, it would be necessary to install filtration plants to filter the water supply, because with the diversion limited to 4,167 second feet or any amount materially lower than 10,000 seconds feet, the water supply would at times be polluted by the Chicago River flowing into Lake Michigan, carrying with it sewage and wastes. Under no circumstances could danger of such condition taking place be permitted without the entire water supply being filtered. (Appellant's Narrative, p. 365.) Therefore, in the year 1945, when the artificial sewage disposal works are constructed to supplement the 10,000 seconds feet diversion, taking care of the increase and the overloading of the Sanitary & Ship Canal, it would be necessary to begin the construction of filter plants at a cost of approximately 200 million dollars. (Appellant's Narrative, p. 366.)

Appellant is not authorized to actually take water out of the lake and disseminate it by means of mains and other devices

to the consumer. This duty rests upon the cities and towns within its limits. The cost of filtration plants is estimated at about $100,000,000 and the annual operating cost is about $3,500,000. Whether these cities and towns can ever,—or, if able, when they can—build these filtration plants, does not appear. They were not before the court as defendants or otherwise. (Appellant's Narrative, pp. 366, 367.)

It appeared that if the diversion were immediately limited to 4,167 seconds feet, the Chicago River would immediately become a polluted stream and a public nuisance (Appellant's Narrative, p. 208.) At times of storm many times during each year it would flow into Lake Michigan, polluting the water supply, causing epidemics of typhoid fever and other water born diseases, creating a condition as bad as that which existed prior to the opening of the Sanitary & Ship Canal. In addition,the Drainage Canal itself would become a public nuisance, the DesPlaines and Illinois Rivers would likewise be a public menace, all fish life there would be destroyed by reason of the sewage exhausting the oxygen content of the water, and generally an intolerable condition would result. (Appellant's Narrative, p. 209.)

Opinion of Judge Carpenter.

On June 18, 1923, Judge Carpenter rendered an opinion on which various decrees and orders were entered.(Appellant's Narrative, p. 113.) The opinion stated that it overruled the motion made by appellant, July 12, 1920, for reconsideration of Judge Landis' direction for a decree. The opinion further stated:

> "The record shows that the Sanitary District of Chicago has expended in its work some hundreds of millions of dollars; and the evidence shows rather conclusively that no other system of disposing of the sewerage in the great district covered would work so well as that devised by the Sanitary District. The City of Chicago, since the Drainage District began to operate, has practically doubled in population. The district served by the Sanitary District holds more people than over forty states in

the Union. The rate of typhoid fever since the completion of the Drainage Canal has been reduced from seventy-five per hundred thousand to a negligible number.

The testimony of Government engineers shows that it would take from ten to twenty-five years for the Drainage District to erect sewerage treatment and disposal works to handle the sewerage within the Drainage District, if the flow of water was reduced from 10,000 to 4,167 cubic feet per second.

This matter is a subject which needs the consideration of thinking people, not only in the State of Illinois, but in the whole United States. The Treaty with Canada entered into some years ago seemed to contemplate an acquiescence on the part of the Canadian Government to the withdrawal of 10,000 cubic feet a second by the Drainage District. However that may be, the Secretary of War has not given his official consent. Whether the increased withdrawal should or should not be made is properly a political and not a legal question, in the absence of consent by the Secretary of War. The Legislature of the State of Illinois, the various civic bodies, the Association of Commerce, and senators and representatives should see to it that at the earliest possible moment the situation here is brought to the attention of Congress, so that by appropriate legislation the health and welfare of this great community may be safeguarded. I have no doubt that when the matter is properly presented it will be taken up by Congress and by the State Department, and some plan devised which will bring about adequate and the desired results.

It goes without saying that this Court will not issue an injunction to be effective forthwith. It cannot impose the conditions so strenuously urged by the attorneys for the Sanitary District. It is doubtful whethere the State of Illinois could authorize expenditures to be made in foreign states and foreign countries to restore the water levels.

On the testimony of the Government engineers the Court might, in the exercise of a sound discretion, delay the effectiveness of its injunction for from fifteen to twenty-five years to enable the Sanitary District or the State of Illinois to arrange for other means of disposing of the sewerage now handled by the Sanitary District.

Believing as I do that it is a matter for the immediate action of Congress, a decree may be prepared finding the facts as stated in the Bill and enjoining the defendant

from withdrawing from Lake Michigan in excess of 4,167 cubic feet a second; the decree, however, not to go into effect for six months."

Orders and Decree for Injunction.

On the same day, the opinion was rendered by Judge Carpenter June 18, 1923, an order was entered denying the said motion made by appellant on the 12th day of July, 1920, requesting that it be not enjoined or restrained from withdrawing from Lake Michigan less than 10,000 cubic seconds feet of water. (Appellant's Narrative, page 116.)

At the same time the following decree for injunction was entered:

"This cause came on to be further heard at this term, and was argued by counsel; and thereupon, upon consideration thereof, it was ordered, adjudged and decreed as follows, viz:

That the defendant, the Sanitary District of Chicago, its Board of Trustees, officers, agents, attorneys, representatives, employees and servants, and all other persons acting or claiming or assuming to act under its authority, be, and they hereby are, and each of them hereby is, enjoined from diverting or abstracting any waters from Lake Michigan over and above or in excess of 250,000 cubic feet per minute.

The operation of this injunction is hereby stayed for a period of six months to enable the defendant to present the record herein to the Supreme Court of the United States." (Appellant's Narrative, page 117.)

Thereafter, on June 29, 1923, the appeal was allowed, assignment of errors was filed and an order was entered staying the injunction during the pendency of the appeal. (Appellant's Narrative, page 117.)

ERRORS UPON WHICH APPELLANT RELIES.

The injunctional decree was erroneous because (Appellant's Narrative, p. 118.)

(*a*) Plaintiff is not entitled to the injunction granted, and plaintiff's bill should have been dismissed. (Ass. 1.)

(*b*) Under the commerce clause of the Constitution, Article 1, Section 8, Clause 3, neither Congress nor any officer of the United States has power to regulate or limit the State of Illinois or The Sanitary District of Chicago in diverting water from Lake Michigan for public welfare in the exercise of the state's police power. (Ass. 2.)

(*c*) The Act of the General Assembly of Illinois of May 29, 1889, under which The Sanitary District was organized, expressly directs defendant to divert and abstract 20,000 cubic feet of water per minute for each 100,000 population of the district, such population being approximately 3,000,000 people. (Ass. 3, 4, 5, 6, 7)

(*d*) Said Act of May 29, 1889, of the General Assembly of Illinois, was passed for the sole and only purpose of preserving health and protecting life under the state's police power, and neither Congress nor any officer of the United States can interfere with the reasonable exercise of such police power. (Ass. 8.)

(*e*) The Act of May 29, 1889, of the General Assembly of Illinois and the construction and operation of the works provided to be built thereunder, cannot be interfered with by the United States, when the primary and sole purpose of such legislation and operation of said works is for public health and welfare of the people of the state and the impairment of navigation, if any, is only the indirect result of the operation of said Act of the General Assembly of Illinois and the works constructed thereunder. (Ass. 9.)

NOTE: We will not here state the assignment of errors with particularity or detail, but will set forth merely the substance.

(*f*) The pure, wholesome, potable drinking water supply for the people of Chicago, its environs and those within the territorial limits of the defendant, the disposal of the sewage of said people, and the diversion of same from the water supply, can only be obtained through the operation and maintenance of defendant's diversion works constructed under said Act of the General Assembly of Illinois of May 29, 1889, requiring a diversion of 20,000 cubic feet of water per minute for each 100,000 of population (population now upwards of 3,000,000 people.) (Ass. 10, 11, 12, 13 and 14.)

(*g*) With the diversion limited to 250,000 cubic feet of water per minute, as required by said injunction, works to artificially dispose of sewage supplementary to said diversion and works to filter the water supply of the people, cannot be constructed within a period of less than twenty years, by reason of the inability of the Sanitary District, defendant, to raise funds therefor by taxation and by the issuance of bonds. (Ass. 15, 16, and 17)

(*h*) The Act of Congress of March 2, 1827, entitled "An Act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan", authorized the State of Illinois to build the main channel of the defendant, Sanitary District, supplementary to or in place of the old Illinois Michigan Canal constructed in 1848, and to divert from Lake Michigan for said main channel at least 600,000 cubic seconds feet of water per minute and in excess of 250,000 cubic feet per minute fixed by said injunctional order. (Ass. 18, 19, 20, 21 and 22)

(*i*) The United States had full and complete knowledge of the passage of the Act of May 29, 1889, providing for the construction of the main channel of the Sanitary District with its attendant diversion, the progress of construction, completion, and the purpose of such works and invited and acquiesced in said diversion provided by said Act of May 29, 1889, and is estopped to interfere with it. (Ass. 23)

(*j*) Congress has by various acts fixed the project depths of all harbors and connecting waters of Lake Superior, Michigan, Huron, Erie and Ontario, and the actual depths of water in such harbors and connecting waters has not been less than the project depths fixed, notwithstanding defendant's diversion. (Ass. 24 and 25)

(*k*) The cost and financial burden resulting to the defendant by virtue of the said injunction and the limitation of said diversion is great, amounting to upwards of $250,000,000 and the damage to plaintiff by reason of the alleged injury to navigation is slight, and all claimed damages to navigation may be offset or compensated for by construction of compensating works, which cost would not exceed $475,000. (Ass. 26-28)

(*l*) The offer of defendant to pay the cost of constructing and maintaining compensating works to offset for the alleged lowering of the surface elevation of the Great Lakes system, on condition that the decree to be entered should only enjoin defendant from diverting in excess of 10,000 cubic feet of water from Lake Michigan, should have been accepted by the Court and a decree entered as requested by the defendant upon the condition that defendant comply with such offer. (Ass. 29-30)

(*m*) Congress has by various acts appropriated money for and required surveys and reports for a waterway from Chicago to the Gulf of Mexico, whereby the diversion of water by the defendant to the amount of 600,000 cubic feet per minute would be utilized and has by various acts also required surveys as to the means of offsetting or compensating for the lowering of the surface elevations of the Great Lakes system by said diversion, and has thereby indicated that it treated the said diversion by the defendant as existing, and did not intend to disturb it. (Ass. 31-32)

(*n*) Act of Congress of June 29, 1906, relating to the diversion of water from the Niagara River, known as the Act for the Preservation of Niagara Falls, expressly prohibits

interference with diversions from the Great Lakes for sanitary or domestic purposes except as Congress might in the future provide. (Ass. 33)

(*o*) The works of the Sanitary District were commenced prior to the passage of the Rivers and Harbors Act of September 19, 1890, and such works are recognized by said act as authorized by law. (Ass. 34)

(*p*) Sections 9 and 10 of the Rivers and Harbors Act of March 3, 1899, do not authorize the Chief of Engineers or the Secretary of War in any manner to supervise or regulate or control the diversion of water by the defendant. (Ass. 35-36-37)

(*q*) Permit of May 8, 1899, authorized the Sanitary District to open its main channel and was without limitation as to amount except the capacity of the main channel of the Sanitary District as fixed by law. This permit was subject to a condition only as to limitation of flow—that if the current should be unreasonably obstructive to navigation in the Chicago River, the Secretary of War might modify the discharge from Lake Michigan through the river. Thereafter, due to the then shallowness and narrowness of the Chicago River, its South Branch and West Fork, the Secretary of War ordered the flow limited to 250,000 cubic feet per minute. Because of such limitation for the purpose of providing for the greater flow of 10,000 cubic seconds feet, the Sanitary District, with the consent and approval of the Secretary of War, widened and deepened the channels of said rivers at a cost of approximately $13,000,000 so that there could be withdrawn through said river channels the amount of water required by said Act of May 29, 1889, without injury to navigation. Thereafter the Secretary of War or other officer of the United States was without authority to enforce the order limiting the withdrawal to 250,000 cubic feet per minute, made because of the then narrowness and shallowness of the channels of said rivers. (Ass. 38-39-40-41)

(*r*) The abstraction and withdrawal of water from Lake Michigan by defendant to the amount of 600,000 cubic feet of water per minute, or 10,000 per second, has not and will not impair the navigable capacity of any of the navigable waters of the United States, such impairment has not been observed by any lay witnesses, navigator or captain of any ship, or any one engaged in navigation. Such claim is only the result of the analyses of expert witnesses. (Ass. 41-42-43-44-45-46-47-48-49.)

(*s*) Defendant cannot observe the injunctional decree without causing pollution of the water supply of upwards of three million people within defendant's limits, from which would result epidemics of typhoid fever and other water-born diseases. (Ass. 50-51)

(*t*) Injunctional decree herein holds unconstitutional the Act of General Assembly of Illinois of May 29, 1889, under which the Sanitary District, the defendant, was organized. (Ass. 52)

(*u*) Treaty between the United States and Great Britain of January 11, 1909, concerning Canadian boundary waters, recognizes the diversion by the defendant to the amount of 10,000 cubic feet of water per second and precludes an injunction herein as to any diversion of 10,000 cubic feet seconds or less. (Ass. 53-54-55)

(*v*) It does not appear from the evidence that the diversion proposed by the defendant pursuant to said Act of May 29, 1889, under all the facts and circumstances, has obstructed or would unreasonably obstruct navigation. (Ass. 56-57 and 60)

(*w*) Decree herein enforces an arbitrary and unreasonable course pursued by the Secretary of War and the Attorney General. (Ass. 58)

(*x*) The Court should have balanced the equities and in so doing should have refused the injunction and dismissed the complainant's bill for want of equity. (Ass. 59)

(*y*) Congress will not be deemed to have acted concerning a matter of local regulation such as is embraced in the Act of the General Assembly of May 29, 1889, providing for defendant's diversion works, unless it has passed some special law with reference to the alleged obstruction. (Ass. 61)

BRIEF.

Appellant's Narrative 17, 21.

Sections 7 and 10, Rivers and Harbors Act, September 19, 1890.

Laws Improvement of Rivers and Harbors, Vol I, p. 582. U. S. Stat. at Large, Vol. 26, p. 426.

Sections 9, 10 and 12, Rivers and Harbors Act of March 3, 1899.

Laws Improvement of Rivers and Harbors, Vol. 2, p. 886.* U. S. Stat. at Large, Vol. 30, p. 1121.

I.

The diversion by appellant to the amount provided for under the Act of Illinois of May 29, 1889, under which appellant was organized and exists, has been "affirmatively authorized by law" (River and Harbors Act of September 19, 1890). Likewise, it has been "affirmatively authorized by Congress" (Rivers and Harbors Act of March 3, 1899).

(a) Appellant was organized under an Act of the General Assembly of Illinois passed in the exercise of the state's police power. This Act fixed appellant's powers and duties, and specified the required diversion of water from Lake Michigan.

Wilson v. *Board of Trustees,* 133 Ill. 443, 465.
People v. *Nelson,* 133 Ill. 565, 580, 582, 592, 594.
Beidler v. *The Sanitary District of Chicago,* 211 Ill. 628, 638.

*For convenience in referring to Rivers and Harbors Acts, we cite Document Number 1491, 62nd Congress, 3rd Session, entitled "Laws of the United States Relating to Improvement o.. Rivers and Harbors, August 11, 1790 to March 4, 1913." Sufficient copies have been furnished the Clerk.

Pittsburg, Fort Wayne & Chicago Railway Company v. *The Sanitary District of Chicago*, 218 Ill. 286, 287, 295.

Appellant's Narrative, p. 92.

United States v. *Bellingham Bay Boom Co.*, 176 U. S. 211.

(*b*) The diversion of water from Lake Michigan to operate the Sanitary & Ship Canal of appellant has been authorized by the Act of Congress of March 2, 1827. (Appellant's Narrative, p. 412.)

Appellant's Narrative, pp. 404, 405, 406, 410, 411, 408, 412.

Missouri v. *Illinois*, 200 U. S. 496, 519, 526.

Mortell v. *Clark*, 272 Ill. 201, 213.

Appellant's Narrative, p. 415.

Vol. 5, Messages and Papers of the Presidents, p. 3334.

Statement, p. 19.

Appellant's Narrative, pp. 448, 447.

Rec., Vol. IV, 2172.

(*c*) Appellee, through its engineer officers and the Secretary of War, observed the action of the State of Illinois and appellant pursuant to its authority in planning and constructing the diversion works. The Secretary of War consented to the work necessary to accomplish the diversion and authorized the opening of the main channel of the district. The Secretary of War construed the Congressional Act of March 2, 1827, and the laws of Illinois, as affirmatively authorizing the diversion.

Appellant's Narrative, pp. 451, 453, 464.

Statement, p. 48.

Appellant's Narrative, pp. 487, 454, 88, 474, 475, 23, 92, 90, 91.

(*d*) The Secretary of War, charged with the duty of enforcing the Rivers and Harbors Acts of September 19, 1890,

and March 3, 1899, has thus construed a diversion to the capacity of appellant's Sanitary and Ship Canal, to have been "affirmatively authorized by law" and "affirmatively authorized by Congress." These acts of the Secretary of War should have the force of judicial interpretation.

Hastings & Dakota Railroad Company v. *Whitney*, 132 U. S. 357, 366.

U. S. v. *Moore*, 95 U. S. 760, 763.

Shells Executors v. *Fauche*, 138 U. S. 562, 572.

Heath v. *Wallace*, 138 U. S. 573, 582.

II.

The permits of the Secretary of War of July 11, 1900, authorizing the work of deepening and widening the channels of the Chicago River to provide for the diversion or abstraction from Lake Michigan through them of the amount of water required by the state law according to the population of appellant, constituted all the authority required by appellant from appellee, to divert said waters.

Appellant's Narrative, p. 28.

Maine Water Company v. *Knickerbocker Steam Towage Company*, 99 Maine 473.

Sections 7 and 10, Rivers and Harbors Act of September 19, 1890. (Argument p. 106.)

Sections 9, 10 and 12, Rivers and Harbors Act of March 3, 1899. (Argument, p. 116.)

Maine Water Company v. *Knickerbocker Steam Towage Company, supra*, p. 477.

The altering or modifying of the navigable capacity of the waters, not only of the Chicago River and its branches, but of Lakes Huron, Michigan, Erie, Ontario, their connecting waters, and other navigable waters of the United States, by the diversion of water provided for through appellant's works, was thus authorized and is lawful.

Cummings v. *Chicago*, 188 U. S. 410.

Hubbard v. *Fort*, 188 Fed. 987.

Maine Water Company v. *Knickerbocker Steam Towage Company, supra.*

Hudson County Water Company v. *McCarter*, 209 U. S. 349.

III.

In any event, the Secretary of War has authorized the opening of appellant's Sanitary & Ship Canal, its operation and attendant diversion of water from Lake Michigan by the permit of May 8, 1899, every condition of which has been fulfilled, assuming such conditions to be valid. The Secretary of War was only authorized to grant or refuse a permit. He had no power to regulate the diversion of water at Chicago. The Attorney General had no authority to institute the suit for injunction.

(*a*) The effect of the May 8, 1899 permit and attempted limitation thereon.

Appellant's Narrative, pp. 90, 91, 23, 26, 202, 194, 2, 12, 526.

Statement, p. 51.

Monongahela Bridge Co. v. *U. S.*, 216 U. S. 177, 195.

Philadelphia Company v. *Stimson*, 223 U. S. 605.

Kwock Jan Fat v. *Edward White, as Commissioner of Immigration*, 253 U. S. 454, 464.

(*b*) The Attorney General under the Act of March 3, 1899, is only authorized to institute suits in equity for the removal of structures. The District Court was without jurisdiction to entertain this suit or enter the decree.

Appellant's Narrative, p. 21.

Laws, Improvement of Rivers and Harbors, Vol. 2, p. 887. (Argument p. 106.)

Laws, Improvement of Rivers and Harbors, Vol. 1, p. 583. (Argument p. 106.)

Section 12, Act of March 3, 1899. (Argument p. 106.)

Ogden City v. *Boreman*, 20 Utah 98; 57 Pac. 843.

Endlich on Interpretation of Statutes, Sec. 51.

Sutherland Statutory Construction, Sec. 140.

U. S. v. *Rio Grande Dam & Irrigation Company*, 174 U. S. 690.

(*c*) The Secretary of War is only authorized to grant or refuse a permit. He has no power to regulate the diversion.

IV.

Regardless of the effect of the Act of Congress of March 2, 1827, providing for the construction of the Illinois and Michigan Canal across the continental divide, and the interpretation of Section 10 of the Act of March 3, 1899, as heretofore stated, nevertheless, the Illinois Act of May 29, 1889, under which appellant has built and is operating its diversion works, is valid and enforceable, pursuant to the police power reserved to the states under the Constitution. The diversion by appellant to the amount necessary for the operation of its works is lawful without express consent of the Secretary of War. Any other construction of the Act of March 3, 1899, would tend to nullify appellant's acts in the interest of public health. This result cannot obtain unless such congressional intention is expressed in plain and unmistakable terms.

(*a*) The Illinois Act of May 29, 1889, under which appellant was organized and exists, was sufficient legislative authority for the construction of appellant's various diversion works and for the diversion of water from Lake Michigan as required by such works.

Cummings v. *Chicago*, 188 U. S. 410, 427, 428, 430.

Montgomery v. *Portland*, 190 U. S. 89, 107.

Corrigan Transit Company v. *The Sanitary District of Chicago*, 137 Fed. 851, 856 (C. C. A. 7th Circuit.)

Canada Atlantic Transit Company v. *Chicago*, 210 Fed. 7, 10, 11, (C. C. A. 7th Circuit).

Laurel Hill Cemetery v. *San Francisco*, 216 U. S. 358.

Escanaba L. M. Transportation Company v. *Chicago*, 107 U. S. 678.

Lake Shore & Michigan Southern Railroad Company v. *Ohio*, 165 U. S. 365.

Cardwell v. *American River Bridge Company*, 113 U. S. 205.

Huse v. *Glover*, 119 U. S. 543.

Willamette Iron Bridge Company v. *Hatch*, 125 U. S. 1.

The creation of appellant's Sanitary & Ship Canal and its other diversion works, was "authorized by law" under the Rivers and Harbors Act of September 19, 1890.

United States v. *Bellingham Bay Boom Co.*, 176 U. S. 211.

(*b*) The diversion by appellant to the amount necessary for the operation of its works, is lawful without the express consent of the Secretary of War. Any other construction of the Act of March 3, 1899, would tend to nullify appellant's acts in the interest of public health. This result cannot obtain unless such congressional intention is expressed in plain and unmistakable terms.

Columbus v. *Mercantile Trust Co.*, 218 U. S. 645, 658.

Missouri v. *Kansas Natural Gas Co.*, 68 L. Ed. Advance Sheets p. 585, June 16, 1924.

Public Utilities Commission v. *Landon*, 249 U. S. 236.

Pennsylvania Gas Co. v. *Public Service Commission*, 252 U. S. 23.

Missouri v. *Kansas Natural Gas Co.*, *supra*, p. 587.

Texas v. *White*, 7 Wall. 700, 725.

New York v. *Miln*, 11 Peters 102, 139.

Minnesota Rate Cases, 230 U. S. 352, 402.

Lake Shore & Michigan Southern v. *Ohio*, 173 U. S. 285.

Hennington v. *Georgia*, 163 U. S. 299, 317.

Crossman v. *Lurman*, 192 U. S. 189.

Plumley v. *Massachusetts*, 155 U. S. 461.

In re Rahrer, 140 U. S. 545, 554.

Mutual Loan Co. v. *Martell*, 222 U. S. 225, 233.

Cummings v. *Chicago*, 188 U. S. 410, 430.

Savage v. *Jones*, 225 U. S. 501.

Missouri, Kansas & Texas Ry. Co. v. *Haber*, 169 U. S. 613, 623.
Reid v. *Colorado*, 187 U. S. 137, 148.
Sinnott v. *Davenport*, 22 How. 227, 243.
Missouri Pacific R. R. Co. v. *Larabee Flour Mills Co.*, 211 U. S. 612, 623.
Missouri, Kansas & Texas R. R. Co. v. *Harris*, 234 U. S. 412, 418.
Carey v. *State of South Dakota*, 250 U. S. 118, 122.
Houston, East & West Texas Ry. Co. v. *U. S.*, 234 U. S. 342.
Illinois Central R. R. Co. v. *Public Utilities Commission*, 245 U. S. 493, 510.
Sligh v. *Kirkwood*, 237 U. S. 52, 60.
Hammer v. *Dagenhart*, 247 U. S. 251, 273, 275, 276.
Bailey v. *Drexel Furniture Co.*, 259 U. S. 20, 37.

(*c*) Congress has otherwise by legislation indicated that it was not its intention to prohibit the operation of appellant's diversion works, or that any act of any of its officers should have that effect.

Statement, pp. 48, 49, 49.
United States v. *Chandler-Dunbar W. P. Co.*, 229 U. S. 51.
Statement, pp. 49, 50, 50.
Appellant's Narrative, p. 505.
Statement, pp. 51, 51, 53, 55, 71.
Appellant's Narrative, p. 102.
International Bridge Company v. *People of State of New York*, 254 U. S. 126, 131.
West Chicago Street Railroad v. *People of Illinois*, 201 U. S. 505, 527.

V.

Appellee has invited and acquiesced in the construction by appellant of its Sanitary & Ship Canal to divert water from Lake Michigan to the amount represented by the capacity of said canal. It is estopped now to deny the right.

Statement, pp. 19, 34.

Missouri v. *Illinois*, 200 U. S. 496, 526.

United States v. *Pensylvania & Lake Erie Dock Company*, 272 Fed. 839, 848 (C. C. A. 6th Circuit).

United States v. *Board of Commissioners of Osage County*, 254 Fed. 570, 573.

United States v. *Debell*, 227 Fed. 775, 779 (C. C. A., 8th Circuit).

United States v. *Midway Northern Oil Company*, 232 Fed. 619, 631.

United States v. *Chandler-Dunbar W. P. Co.*, 152 Fed. 41, 81.

Monongahela Navigation Company v. *United States*, 148 U. S. 312, 334.

Hemmer v. *United States*, 204 Fed. 898, 901 (8th C. C. A.)

State of Iowa v. *Carr*, 191 Fed. 257, 266 (8th C. C. A.)

Appellant's Narrative, pp. 155, 162.

The force and effect of the treaty between the United States and Great Britain of January 11, 1909, relating to Canadian boundary waters and the reports of the International Waterways Commission recommending its terms.

Appellant's Narative, pp. 104, 505, 531, 532, 535, 522.

Schooner Exchange v. *McFaddon*, 7 Cranch, 116, 136.

See also opinion of Judson Harmon on right of United States in Rio Grande, 21 Opin. Atty. Gen. 274, 280.

VI.

The decree of the lower court is based solely upon the testimony of expert witnesses. No witness was produced by appellee to testify that the lowering of the lake surfaces or damage to commerce, was ever actually observed. Appellee's case depends entirely upon an inference of the unseen and the subtle analyses of expert witnesses, which cannot form the basis of an injunctional decree.

(*a*) Expert evidence in injunction cases.

Statement, p. 64.

Appellant's Narrative, pp. 125, 150.

Missouri v. *Illinois*, 200 U. S. 496, 523.

Joyce on Nuisances, 1906 Ed., Sec. 299, Sec. 420.

Salvin v. *North Brancepeth Coal Company*, L. R. 9, Chanc. Appeals, 705, 709.

North Dakota v. *Minnesota*, 68 Law Ed. 159 (Advance sheets, January 1, 1924).

(*b*) Disregarding all questions heretofore presented as to the right of appellant to operate its works with the diversion required, nevertheless the injunction decree should not have been entered unless the injury and damage to commerce was material and the obstruction to navigation was unreasonable.

United States v. *Rio Grande Irrigation Company*, 174 U. S. 690, 709.

Corrigan Transit Company v. *Sanitary District*, 137 Fed. 851, 857. (C. C. A. 7th Circuit.)

Lake Shore & Michigan Southern Railway Company v. *Ohio*, 173 U. S. 285, 294.

Cummings v. *Chicago*, 188 U. S. 410, 428.

Union Bridge Company v. *U. S.*, 204 U. S. 364, 365, 385, 400.

(*c*) It must appear in a case of this character, considering the parties involved, that an unreasonable obstruction and damage to commerce clearly exist.

New York v. *State of New Jersey & Passaic Valley Sewage Commissioners*, 256 U. S. 296, 309.

Kansas v. *Colorado*, 206 U. S. 46, 117.

Attorney General v. *Mayor, Alderman and Corporation of Kingston-on-Thames*, 13th Weekly Reporter, 1863-1865, 888.

Mississippi & Missouri R. R. Co. v. *Ward*, 2 Black 485, 495.

2 Story, Com. on Eq., 203, 204.

VII.

A court of equity in determining whether or not it will grant an injunction looks not only to the naked legal rights of the complainant and the advantages to be by it gained, but also to the inconveniences and injuries to be sustained by the defendant. And if it appears that the granting of the injunction would cause comparatively greater injury to the defendant than it would cause benefit to the complainant, a court of equity will not hesitate to deny the relief.

Appellant's Narrative, p. 217.

Vol. 1, Joyce on Injunctions, Sec. 20, p. 41, Sec. 25, p. 50.

Kansas v. *Colorado*, 206 U. S. 46, 117.

Georgia v. *Tennessee Copper Co.*, 206 U. S. 230, 237.

Dun v. *Lumbermen's Credit Assn.*, 209 U. S. 20.

McCarthy v. *Bunker Hill, Sullivan Mining & Concentrating Co.*, 164 Fed. 927, 940 (C. C. A. 9th Circuit).

City of New York v. *Pine*, 185 U. S. 93, 97.

VIII.

The statement made by the Secretary of War (January 8, 1913) in refusing to remove the alleged limitation by the order of December 5, 1901 (4,167 seconds feet withdrawal) and denying express authority of appellant to divert 10,000 cubic seconds feet, is immaterial. The statute does not authorize any findings or conclusions by the Secretary of War. If it did, the conclusions would be subject to review. In any event, the conclusions of fact and of law stated, are erroneous, as appears by the record of this case.

(*a*) The statute does not authorize the Secretary to make any findings or conclusions. If it did, such would be subject to review.

Philadelphia Company v. *Stimson*, 223 U. S. 605, 620.

Hardin v. *Jordan*, 140 U. S. 371.

Rosenberger v. *Harris*, 136 Fed. 1001, 1002.

United States v. *United Verde Copper Company*, 196 U. S. 207, 215.

School of Magnetic Healing v. *McAnnulty*, 187 U. S. 94, 110.

(*b*) In any event, Secretary of War Stimson's findings and conclusions were erroneous.

Appellant's Narrative, p. 28.

Corrigan Transit Company v. *Sanitary District*, 137 Fed. 851, 855, (C. C. A. 7th Circuit).

Appellant's Narrative, p. 29.

Mortell v. *Clark*, 272 Ill. 201.

This Brief, p. 120.

Appellant's Narrative, p. 176.

United States v. *Rio Grande Irrigation Company*, 174 U. S. 690.

IX.

The lower court should have granted the motion of July 12, 1920, by appellant, following the opinion of Judge Landis and his direction as to the drafting of a decree, that the appellant be only enjoined from taking in excess of 10,000 cubic seconds feet of water from Lake Michigan on condition that appellant pay the cost of constructing such compensating or regulating works as the United States should provide to be built to offset for the claimed lowering of the lake surfaces and their connecting channels due to 10,000 seconds feet diversion at Chicago. Admitting, for the sake of argument, only, all contentions of appellee to be true, appellant cannot be enjoined from taking an amount of water materially less than 10,000 cubic seconds feet from Lake Michigan, until appellant and cities and towns within its limits can, if at all, readjust their works of sewage disposal and of purification of water supply to suit the changed conditions.

(*a*) By granting the motion of appellant above mentioned, July 12, 1920, the lower court would have done equity. The construction of compensating or regulating works was entirely feasible, as the undisputed facts of the record show.

Appellant's Narrative, p. 111.
Statement, pp. 77, 71.
This Brief, p. 78.
Rec., Vol. IV, 2387.
Appellant's Narrative, p. 102.
Appellant's Narrative, pp. 100, 101, 111, 532.
Myers v. *Block*, 120 U. S. 206, 214.
Russell v. *Farley*, 105 U. S. 433, 438, 445.
Marine Ins. Company v. *Hodgson*, 7 Cranch, 332, 337.
Veazie v. *Williams*, 8 Howard 134, 161.
Walden v. *Bodley*, 14 Peters 156, 164.
Newton v. *Consolidated Gas Co.*, 258 U. S. 165, 177.

Northern Pacific Railway Company v. *U. S.*, 104 Fed. 691, 695 (C. C. A., 8th Circuit).

Sanitary District of Chicago v. *Martin*, 227 Ill. 260, 268.

Cushman v. *Bonfield*, 139 Ill. 219.

Phillips v. *Thomson*, 1 Johnson Chan. 133.

2 Sutherland on Damages, 590.

Story's Equity Jurisprudence, 798.

(*b*) Assuming that appellee is legally entitled at some time to an injunction, a decree, providing for the reduction of the diversion below to 10,000 cubic seconds feet before appellant and the cities, villages and towns within its limits can readjust their works of sewage disposal or of purifying the water supply, is contrary to equitable principles.

Appellant's Narrative, pp. 339, 362, 382, 366, 368.

Pomeroy's Equity Jurisprudence, (Vol. 5, Sec. 1948, p. 4429).

United States v. *Luce*, 141 Fed. 385, 422.

Peck v. *Newberg Light, Heat & Power Company*, (Supreme Court, App. Div., 2d Dept.) 116 N. Y. Supp. 433, 436.

Sammons v. *City of Gloversville*, 67 N. E. 622; 175 N. Y. 346.

Appellant's Narrative, p. 97.

Appellant's Narrative, p. 115.

(*c*) The decree of injunction in the court below absolutely enjoined appellant from withdrawing from Lake Michigan in excess of 4,167 seconds feet without any condition. The Secretary of War would be powerless under this decree to permit or authorize any further diversion. This condition should have been observed.

Appellant's Narrative, pp. 339, 344.

Transportation Act of 1920, 41 Statutes at Large, 456.

(*d*) This matter should be settled by Congress.

New York v. *New Jersey and Passaic Valley Sewage Commissioners*, 256 U. S. 296, 313.
Virginia v. *West Virginia*, 246 U. S. 565.
Amer. Bar Assn. Journal, February, 1922.
Rec., Vol. VIII, pp. 77-82.

CONCLUSION.

ARGUMENT.

The complaint upon which the relief was sought here and upon which the decree was entered, was filed October 6, 1913. (Appellant's Narrative, p. 17.) The relief was asked under Section 10 of the Rivers and Harbors Act of March 3, 1899. (This Brief, p. 106.) The complaint alleges the issuance of the permit of May 8, 1899, by the Secretary of War for the opening of the channel, subject to the conditions:

(1) If Congress should act, the permit should be of no force or effect;

(2) If the current should prove unreasonably obstructive to navigation in the Chicago River, the Secretary of War might cut off the discharge or modify it.

(3) Appellant should be responsible for damages. (Appellant's Narrative, p. 21.)

The complaint also alleges various orders of the Secretary of War, beginning April 9, 1901, purporting to modify the discharge through the Chicago River because of objections of navigation interests to the current in that river. One of said orders is the one of the Secretary of War of the 5th of December, 1901, seeking to limit the discharge through the channel from Lake Michigan to 250,000 cubic feet per minute, or 4,167 per second; and it is alleged that the Secretary of War had never authorized an increase of withdrawal from Lake Michigan over that amount; that appellant has been and is withdrawing, and proposes further to withdraw from Lake Michigan much in excess of that amount, and, in fact, the amount fixed by its organic act—20,000 cubic feet per minute for each 100,000 of its population; that the withdrawal of this water injures the navigable capacity of Lakes Michigan, Huron, St. Clair, Erie, Ontario and their connecting

channels, navigable waters of the United States, and thereby commerce on the Great Lakes is damaged. The complaint asks an injunction against appellant's diverting more than 250,000 cubic feet per minute, the alleged limitation of the order of the Secretary of War of December 5, 1901.

Appellee's position, therefore, is based upon the validity of the action of the Secretary of War in fixing the limitation mentioned—4,167 cubic seconds feet of withdrawal.

As shown by the statement of facts, these works were constructed under the Act of May 29, 1889, of the General Assembly of Illinois, and were commenced immediately thereafter and before the Rivers and Harbors Act of September 19, 1890, was passed. The Sanitary & Ship Canal, the main diversion channel of appellant, was completed in 1898, and prior to the passage of said Rivers and Harbors Act of March 3, 1899. It was not, however, placed in operation until afterwards.

Sections 7 and 10 of the Rivers and Harbors Act of September 19, 1890, and Sections 9, 10 and 12 of the Rivers and Harbors Act of March 3, 1899, in most respects, are similar. As it will be necessary to construe the effect of these various sections, we will here, at the outset, set forth the above mentioned sections in juxtaposition.

Sections 7 and 10, Rivers and Harbors Act of September 19, 1890 (Laws, Improvement of Rivers & Harbors, Vol. I, p. 582)—

"*Sec.* 7. That it shall not be lawful to build any wharf, pier, dolphin, boom, dam, weir, breakwater, bulkhead, jetty, or structure of any kind outside established harbor-lines, or in any navigable waters of the United States where no harbor-lines are or may be established, without the permission of the Secretary

Sections 9, 10 and 12, Rivers and Harbors Act of March 3, 1899 (Laws, Improvement of Rivers & Harbors, Vol. 2, p. 886)—

"*Sec.* 9. That it shall not be lawful to construct or commence the construction of any bridge, dam, dike, or causeway over or in any port, roadstead, haven, harbor, canal, navigable river, or other navigable water of the United States until the consent of Congress to the building of such structures shall have been ob-

of War, in any port, roadstead, haven, harbor, navigable river, or other waters of the United States, in such manner as shall obstruct or impair navigation, commerce, or anchorage of said waters, and it shall not be lawful hereafter to commence the construction of any bridge, bridgedraw, bridge piers and abutments, causeway or other works over or in any port, road, roadstead, haven, harbor, navigable river, or navigable waters of the United States, under any act of the legislative assembly of any State, until the location and plan of such bridge or other works have been submitted to and approved by the Secretary of War, or to excavate or fill, or in any manner to alter or modify the course, location, condition or capacity of the channel of said navigable water of the United States, unless approved and authorized by the Secretary of War; *Provided*, that this section shall not apply to any bridge, bridge-draw, bridge piers and abutments and construction of which has been heretofore duly authorized by law, or be so construed as to authorize the construction of any bridge, draw bridge, bridge piers and abutments, or other works, under an act of the legislature of any State, over or in any stream, port, roadstead, tained and until the plans for the same shall have been submitted to and approved by the Chief of Engineers and by the Secretry of War: *Provided*, That such structures may be built under authority of the legislature of a State across rivers and other waterways the navigable portions of which lie wholly within the limits of a single State provided the location and plans thereof are submitted to and approved by the Chief of Engineers and by the Secretary of War before construction is commenced. *And provided further*, that when plans for any bridge or other structure have been approved by the Chief of Engineers and by the Secretary of War, it shall not be lawful to deviate from such plans either before or after completion of the structure unless the modification of said plans has previously been submitted to and received the approval of the Chief of Engineers and of the Secretary of War."

haven or harbor, or other navigable water not wholly within the limits of such State."

"*Sec.* 10. That the creation of any obstruction, not affirmatively authorized by law, to the navigable capacity of any waters, in respect of which the United States has jurisdiction, is hereby prohibited. The continuance of any such obstruction, except bridges, piers, docks and wharves, and similar structures erected for business purposes, whether heretofore or hereafter created, shall constitute an offense and each week's continuance of any such obstruction shall be deemed a separate offense.

"*Sec.* 10. That the creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same."

Every person and every corporation which shall be

"*Sec.* 12. That every person and every corpora-

guilty of creating or continuing any such unlawful obstruction in this act mentioned, or who shall violate the provisions of the last four preceding sections of this act, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding five thousand dollars, or by imprisonment (in the case of a natural person) not exceeding one year, or by both such punishments, in the discretion of the court, the creating or continuing of any unlawful obstruction in this act mentioned may be prevented and such obstruction may be caused to be removed by the injunction of any circuit court exercising jurisdiction in any district in which such obstruction may be threatened or may exist; and proper proceedings in equity to this end may be instituted under the direction of the Attorney-General of the United States."

tion that shall violate any of the provisions of sections nine, ten, and eleven of this Act, or any rule or regulation made by the Secretary of War in pursuance of the provisions of the said section fourteen, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine of not exceeding twenty-five hundred dollars nor less than five hundred dollars, or by imprisonment (in the case of a natural person) not exceeding one year, or by both such punishments, in the discretion of the court. And further, the *removal* of any *structures* or parts of structures erected in violation of the provisions of the said sections may be enforced by the injunction of any circuit court exercising jurisdiction in any district in which such structures may exist, and proper proceedings to this end may be instituted under the direction of the Attorney-General of the United States."

Sections 9, 10 and 12 of the 1899 Act, and certain other sections thereof, were enacted as a result of the following procedure: The Rivers and Harbors Act of June 3, 1896 (Laws of U. S. for Rivers & Harbors, Vol. 1, p. 743; U. S. Statutes at Large, Vol. 29, p. 202) directed the Secretary of War

"to cause to be prepared a compilation of all general laws that have been enacted from time to time by Congress for the maintenance, protection, and preservation of the navigable waters of the United States which are now in force, and to submit the same to Congress to-

gether with such recommendation as to revision, emendation, or enlargement of the said laws as, in his judgment, will be advantageous to the public interest."

Accordingly, the Secretary of War, on February 13, 1897, submitted to Congress a letter of the Chief of Engineers dated February 10, 1897, which letter was accompanied by the compilation aforesaid, and a draft of Sections 9, 10 and 12 of the 1899 Act mentioned. The letters of the Secretary of War and Chief of Engineers are contained in House Document No. 293, 54th Congress, 2d Session. The draft as submitted by the Chief of Engineers and the Secretary of War, and as contained in the House Document mentioned, contains therein sections numbered 1, 2 and 4, which are identical with Sections 9, 10 and 12 of the March 3, 1899 Act.

We will now discuss the legal obstacles to this Court's sustaining the decree of the District Court, enjoining appellant from abstracting from Lake Michigan in excess of 4,167 cubic seconds feet of water.

I.

THE DIVERSION BY APPELLANT TO THE AMOUNT PROVIDED FOR UNDER THE ACT OF ILLINOIS OF MAY 29, 1889, UNDER WHICH APPELLANT WAS ORGANIZED AND EXISTS, HAS BEEN "AFFIRMATIVELY AUTHORIZED BY LAW" (RIVERS AND HARBORS ACT OF SEPTEMBER 19, 1890) LIKEWISE, IT HAS BEEN "AFFIRMATIVELY AUTHORIZED BY CONGRESS" (RIVERS AND HARBORS ACT OF MARCH 3, 1899).

(a) Appellant was organized under an Act of the General Assembly of Illinois, passed in the exercise of the state's police power. This Act fixed appellant's powers and duties and specified the required diversion of water from Lake Michigan.

Appellant, as has heretofore been pointed out in the statement, (p. 30), was organized under the Act of the General Assembly of Illinois passed May 29, 1889, in force July 1, 1889. There were three purposes of this legislation.

1. To provide for the organization of appellant.

2. To construct a canal with necessary adjuncts and appurtenances across the Continental Divide, from Chicago to Joliet, the minimum capacity of which should be not less than 10,000 cubic feet of water per second, which water, together with the drainage and sewage from Chicago and its environs, appellant was required to divert from Lake Michigan to the DesPlaines River for the purpose of protecting from pollution Chicago's only water supply.

3. To provide, by this Sanitary & Ship Canal and attendant diversion, from Lake Michigan to its southern terminus and on the Illinois River, a deep waterway, to take care of the demands of navigation.

Appellant was organized pursuant to its Organic Act by vote of the people. The Board of Trustees was elected. This Board immediately entered upon its duties to provide an outlet for the sewage and drainage of Chicago, as prescribed by the Organic Act. An ordinance was passed by the Board for the issue and sale of bonds for the purpose of raising money to carry out its objects. A taxpayer filed a bill to enjoin the operation of this ordinance on the ground that the Act under which appellant was organized, was repugnant to the constitution of Illinois. This suit was decided on appeal by the Supreme Court of the state on June 12, 1890.

Wilson v. *Board of Trustees*, 133 Ill. 443.

In another case,

People v. *Nelson*, 133 Ill. 565,

decided the same day, the Court again held the Act constitutional. The Court said (p. 580):

> "Of course it must be conceded both as a historical fact and as a fact abundantly shown by the terms of the act itself, that this scheme was formulated mainly, if not exclusively, with reference to the sanitary condition and needs of the City of Chicago and its environs, and we cannot give proper construction of the act without taking into account the peculiar situation of the territory which the proposed Sanitary District of Chicago is intended to embrace. * * * The object of the system of drainage proposed by said act, is to prevent the drainage and sewage of the City of Chicago and its environs being carried into Lake Michigan, thereby contaminating the waters of the lake. This result is to be reached by cutting a channel which will give an outlet for the drainage and sewage of the city in the direction of the Desplaines and Illinois Rivers, and which will also cause a large flow of water from the lake through the proposed artificial channel into those rivers, for the purpose of diluting the sewage and rendering it innocuous to the people living along the course of those streams."

In speaking of the amount of diversion, the Court said (p. 582):

> "The act contemplated a minimum flow of 300,000 and a maximum flow of 600,000 cubic feet of water per minute

through the proposed artificial channel into said rivers." (Desplaines and Illinois rivers.)

Further, in speaking of the removal of obstructions in the DesPlaines and Illinois Rivers, it was further said (p. 582):

> "Among these are the dams heretofore constructed by the state for the purpose of improving the navigation of the Illinois River, and the act specifically confers upon the district the power to make such removal."

In speaking of the waterway features of the Act, the Court said (p. 592):

> "The provisions of the act conferring upon the district powers and imposing upon it duties in relation to the waterways beyond the terminus of its own channel, were inserted for this purpose and are therefore a part, and a necessary part, of the general system of drainage for sanitary purposes embraced within the subject expressed in the title."

Again, the Court said (p. 594):

> "Section 24, however, recognizes the obvious fact that the contemplated channel when completed in such a way as to accomplish in a satisfactory manner the purposes for which it is designed, will constitute a waterway capable of being utilized for purposes of navigation, and therefore declares what, in the absence of such declaration, would be the fact, viz., that when so completed it shall be a navigable stream."

In

Pittsburg, Fort Wayne & Chicago Railway Company v. *The Santiary District of Chicago,* 218 Ill. 286,

a petition to condemn the lands of the railroad company along the south branch of the Chicago River, was filed (shortly after June 19, 1901) (p. 287):

> "to enable it (appellant) to deepen, widen and improve said river from Lake to Robey Streets and thereby increase the flow of water from Lake Michigan through said river into its main artificial channel, which connects with the said south branch at Robey Street and extends to Lockport—Illinois—increasing the said current in said

river to a greater velocity than that provided for by the Secretary of War in the permit issued to said Sanitary District by him permitting it to divert a portion of the waters of Lake Michigan to the said south branch into its main channel, * * * in order that it might comply with the statute of the State of Illinois and obtain a minimum flow through its channel of 300,000 cubic feet of water per minute and such additional quantities of water as from time to time the population of the Sanitary District might require."

The question was raised as to whether the Sanitary District had the power under its act to condemn this railroad property. The Court said (p. 295):

"The statute requires the Sanitary District to provide a minimum flow of 300,000 cubic feet of water per minute and the velocity of the flow was limited to 3 miles per hour, which was afterwards limited by the Secretary of War to 1¼ miles per hour. No water could be obtained except from Lake Michigan through the river with its narrow, winding and obstructed channel, which was lined with docks, railroads and other improvements, and when the statute authorized the Sanitary District to enter upon, use, widen, deepen and improve the Chicago River, * * * it manifestly intended to and did confer upon said Sanitary District the power to condemn any and all property * * * which was necessary for it to possess and control in order that it might successfully widen, deepen and improve said river, which clearly includes the property of appellants."

The acquisition of the property mentioned in the foregoing case, was required in order to carry out the comprehensive improvement of the Chicago River and its branches, by widening and deepening their channels, to provide for the withdrawal of at least 10,000 cubic seconds feet of water through these channels and the Sanitary & Ship Canal. The Secretary of War had by the two permits of July 11, 1900, authorized this "work" or improvement. (Appellant's Narrative, p. 92.)

So far as the authority of Illinois for the diversion was required it was full and complete. The works with their at-

tendant diversion were thus "authorized by law" under the Rivers and Harbors Act of September 19, 1890.

United States v. *Bellingham Bay Boom Co.*, 176 U. S. 211.

(b) The diversion of water from Lake Michigan to operate the Sanitary & Ship Canal of appellant has been authorized by the Act of Congress of March 2, 1827. (Appellant's Narrative, p. 412.)

The Act in question was entitled

> "An Act to Grant a Quantity of Land to the State of Illinois for the Purpose of Aiding in Opening a Canal to Connect the Waters of the Illinois River with those of Lake Michigan".

The first section of said Act provided

> "that there be, and hereby is, granted to the State of Illinois, for the purpose of aiding the State in opening a canal to *unite the waters of the Illinois River with those of Lake Michigan*, a quantity of land. * * * That the said canal, when completed, shall be, and forever remain, a public highway."

In order that the force and effect of this Act, and the intention of Congress thereunder, may be best understood, we will call attention to some of the attendant facts which undoubtedly were the cause of this legislation. At this time, and prior, the country was sparsely settled. The possibility of its development was generally recognized. Statesmen appreciated the value of water routes extending throughout the country then practically the only means of transportation. The necessity of developing these water routes was recognized as furnishing the only means by which the commercial activity of the country could be extended and the different parts bound together and made a homogeneous whole. It was necessary that the interests of the people located in different localities be made dependent one upon the other, by trade and travel. The Act of Cession of the Northwest Territory, by Virginia, passed in 1783, made it a condition of the grant that

it should be divided into states, not less than one hundred square miles nor more than one hundred and fifty square miles in extent. Under this plan, it was proposed to divide the Northwest Territory into fourteen or sixteen states. James Monroe shortly thereafter visited the country and reached the conclusion that there should be fewer states, and thereupon reported to Congress, and his report was adopted on July 7, 1786. The report, in referring to the division, stated (Appellant's Narrative, p. 404):

> "Some of the new states will be deprived of the advantages of navigation, some will be improperly intersected by lakes, rivers and mountains * * * Due attention ought to be paid to natural boundaries."

Thereupon the Ordinance of 1787 was passed, Article V thereof providing that the Northwest Territory should be divided into *not less than three states nor more than five states.* The division between the Western and Middle and Eastern states was provided to be substantially the present boundary between Illinois and Indiana and that between Ohio and Indiana. The Northern boundary of the three states was Canada. It was further provided that North of a line drawn through the Southern end of Lake Michigan that territory might be made into one or two states. The Illinois Enabling Act of Congress of 1818 was amended, at the time of its passage to include in Illinois the port of Chicago and a considerable portion of the shore of Lake Michigan to the present Northern boundary of Illinois. When this Enabling Act was amended, Mr. Pope, territorial delegate from Illinois stated, in proposing the amendment:

> "The object of this amendment was to gain for the proposed state a coast on Lake Michigan. This would afford additional security to the perpetuity of the Union inasmuch as the state would thereby be connected with the states of Indiana, Ohio, Pennsylvania and New York through the lakes. *The facility of opening a canal between Lake Michigan and the Illinois River * * * is acknowledged by everyone who has visited the place. Giving to the proposed state the port of Chicago, embraced in the proposed limits, will draw its attention to*

> *the opening of communication between the Illinois River and the improvement of that harbor.*" (Appellant's Narrative, p. 405.)

The water route from Lake Michigan through the Chicago River, its South branch and West fork, to the DesPlaines and Illinois Rivers had been used from time immemorial by explorers, adventurers and fur traders. In 1819, official reports were made by engineers and officers of the United States as to this route, and the feasibility of improving and enlarging it for navigation (Appellant's Narrative, p. 406.)

On March 30, 1822, Congress passed an Act entitled substantially the same as the March 2, 1827 Act, providing

> "That the State of Illinois be, and is hereby, authorized to survey and mark through the public lands of the United States the route of the canal *connecting the Illinois River with the Southern bend of Lake Michigan, and ninety feet of land on each side of the canal shall be forever reserved from any sale to be made by the United States.*" (Appellant's Narrative, p. 410.)

The failure of Illinois to act upon the grant within the time required caused it to be of no further force or effect.

Thereupon the General Assembly of Illinois memoralized Congress in 1826, calling attention to the importance of constructing a canal to unite the waters of Lake Michigan with the Illinois River, which

> "will form an important addition to the great connecting links in the chain of internal navigation, which will effectually secure the indissoluble federal union of this great and powerful republic." (Appellant's Narrative, p. 411.)

It was obviously important to the statesmen of that day that there should be an outlet to the sea from Lake Michigan. Undoubtedly the position of Great Britain, denying to the people of the United States the free navigation of the St. Lawrence River, also had an important bearing upon the purpose of Congress in providing for a canal and for the use of the waters of Lake Michigan to operate it (Appellant's Nar-

rative, p. 408). Great Britain maintained this position as to the St. Lawrence until the treaty of 1854, which granted merely the privilege to the people of the United States to pass along the St. Lawrence.

On January 9, 1836, the General Assembly of Illinois passed the Act under which the Illinois and Michigan Canal was constructed. Section 16 of this Act provided for the width of the canal and also that ninety feet on each side should be reserved for its future enlargement. This followed exactly the expressed will of Congress as to such reservation. The canal, as provided by said Section 16, was

> "to be supplied with water from Lake Michigan and such other sources as the Canal Commissioners may think proper." (Appellant's Narrative, p. 412.)

The Act of March 2, 1827, is still in force, and whatever rights were granted to, and whatever obligations were imposed upon, the State of Illinois under that Act, now exist. The Act authorized the construction of a canal across and through the public domain and granted lands to the state to aid in constructing it

> "to unite the waters of the Illinois River with those of Lake Michigan."

Lake Michigan was the highest point. It must necessarily have been the start of the canal. The only water supply for the operation of the canal was Lake Michigan. Illinois was empowered to construct a canal of any size that it considered reasonable to accomplish the objects desired,—in other words, to build such a canal as it considered would suit the demands of commerce. It was authorized not only then to construct the canal, but it was empowered further to improve, enlarge or supplant the canal and maintain one, at all times, in such manner as it considered the interests of navigation required. The State was empowered then to divert such quantity of water as in its judgment was necessary

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NOTE: The Sanitary and Ship Canal is approximately the width of the old Illinois and Michigan Canal plus the ninety feet on each side reserved for enlargement.

to operate the canal, and also to divert any other or greater quantity necessary to operate an enlarged canal to accomplish the purpose of the Act of Congress of March 2, 1827. There was no limitation on the amount of the diversion from Lake Michigan. Complete authority—all the authority that was required for this purpose—the State had under the Act of March 2, 1827.

In

Missouri v. *Illinois*, 200 U. S. 496,

Missouri instituted a suit to enjoin the Sanitary District from diverting water from Lake Michigan and turning its sewage and drainage into the DesPlaines and Illinois Rivers, claiming that it polluted the Mississippi River and the water supply of St. Louis. This Court said (p. 519):

> "In the case at bar, whether Congress could act or not, there is no suggestion that it has forbidden the action of Illinois."

The Court further said (p. 526):

> "Some stress was laid on the proposition that Chicago is not on the natural watershed of the Mississippi, because of a rise of a few feet between the Desplaines and the Chicago rivers. We perceive no reason for distinction on this ground. The natural features relied upon are of the smallest. And if, under any circumstances, they could affect the case, it is enough to say that Illinois brought Chicago into the Mississippi watershed in pursuance, not only of its own statutes, but also of the acts of Congress of March 30, 1822 (chap. 14, 3 Stat. at L. 659), and March 2, 1827 (chap. 51, 4 Stat. at L. 234), the validity of which is not disputed."

The effect of the Act of Congress of March 2, 1827, was interpreted by the Supreme Court of Illinois in

Mortell v. *Clark*, 272 Ill. 201.

In that case a taxpayer sought to enjoin the action of appellant in constructing the Calumet Sag Channel, an adjunct of the Sanitary and Ship Canal, extending from the Little Calumet River to the main canal at Sag, Illinois, and designed to reverse the flow of the Calumet River and furnish an out-

let for the sewage and drainage of the territory South of 87th Street in Chicago. It was claimed that there was no authority from the Federal Government to construct this canal. The Court said (p. 213):

> "Said act of 1903 permits the crossing of the Illinois and Michigan canal near Sag bridge and provides for the abandoning of certain portions of said canal. Counsel for appellant argue that this is in violation of the Federal grant of 1822, under which the Illinois and Michigan canal was constructed, which provides, among other things: 'If said ground shall ever cease to be occupied by and used for a canal suitable for navigation, the reservation and grant hereby made shall be void and of none effect.' (Hurd's Stat. 1913, p. LXXXVIII.) The canal was built under the authority of the act of Congress of March 2, 1827, the act of 1822 having been mutually abandoned by the State and Federal governments. (*Werling* v. *Ingersoll*, 181 U. S. 131; *Wells* v. *Wells*, 262 Ill. 320.) This Federal act did not provide just where the canal should enter Lake Michigan, simply stating that the land was granted for the purpose of opening 'a canal to unite the waters of the Illinois river with those of Lake Michigan,' etc. (Hurd's Stat. 1913, p. LXXXVIII.) *The sanitary district's main channel as now constructed practically complies with this act and furnishes a canal more suitable for navigation than the Illinois and Michigan canal. Furthermore, the Sag channel or cut-off is required to be navigable* by said act of 1903, and the proof shows that the Calumet river is navigable to the point where it is intersected by the Sag channel. *This cut-off would therefore also practically comply with both of said Federal acts as to furnishing part of the canal for connection of the Illinois river with Lake Michigan.*"

The Illinois-Michigan Canal was placed in operation in 1848. No sooner had it been completed than the necessity of its enlargement was recognized. The General Assembly of Illinois in 1861 provided for a survey to be made for the enlargement and improvement of this water course and the diversion of waters from Lake Michigan

> "to secure a free-flowing, ample and never failing supply of water sufficient for navigation of the Illinois River at all season and times." (Appellant's Narrative, p. 415.)

President Lincoln in his message to Congress of December 1, 1862 (Vol. 5, Messages and Papers of the Presidents, p. 3334) stated:

> "The military and commercial importance of enlarging the Illinois-Michigan Canal and improving the Illinois River is presented in the report of Colonel Webster to the Secretary of War and now transmitted to Congress. I respectfully ask attention to it."

Congress provided for a survey for the improvement of this water course on June 23, 1866, and the next year, February 12, 1867, General Wilson made recommendations as to its improvement. The summit level of the canal was cut down at the expense of the City of Chicago in 1871 to provide for the taking of a greater amount of water from Lake Michigan to operate the canal. Pursuant to Acts of Congress, in 1875, 1880, 1882 and 1887, further reports were made as to the enlargement of the waterway by constructing a deep waterway with a large diversion from Lake Michigan to the DesPlaines and Illinois Rivers. (Statement, p. 19.)

The day before the Act under which appellant was organized was passed, May 28, 1889, the General Assembly of Illinois passed a resolution stating its waterway policy—namely

> "That it is the policy of the State of Illinois to procure the construction of a waterway of the greatest practical depth and usefulness for navigation from Lake Michigan via the Desplaines and Illinois Rivers to the Mississippi River, and to encourage the construction of feeders therto of like proportions and usefulness." (Appellant's Narrative, p. 448.)

Only two years before appellant's Organic Act was passed, Major Handbury made a report under the Rivers and Harbors Act of August 5, 1886, which report was published in the Chief of Engineers' report for the year 1887, in which he stated (Appellant's Narrative, p. 447):

> *"The United States and the State of Illinois have long been committed to the project of opening a water communication between the Mississippi River and the northern lakes of capacity sufficient for the wants of commerce*

> *and for the exigencies of our national defense, should these ever arise.* * * * Pushing this improvement through to the Lake, the connecting link will be formed which will join the northern lakes with the vast network of navigable rivers whose waters flows into the Gulf of Mexico *on a scale to a certain degree commensurate with the importance of the commerce and will be affected by it.*"

The State of Illinois, in providing for the construction of the Sanitary & Ship Canal of the size capable of diverting at least 10,000 cubic feet of water from Lake Michigan for sanitary and navigation purposes, proceeded with deliberation and care. It's acts, in this respect, were consonant with the interpretation of the March 2, 1827 Act by Congress and by appellee's officers extending over half a century.

The basic principle of the plan, as stated, was the reversal of the Chicago River at all times so that it would not ever flow into Lake Michigan, carrying with it its sewage and drainage pollution. The maximum flood run-off of the Chicago River drainage area or flow of the Chicago River being 10,000 seconds feet, it is obvious that the capacity of the Sanitary & Ship Canal could not be less. To provide a "never-failing" supply of water for navigation of the Illinois River at all times, it was likewise necessary to have a volume of water from Lake Michigan for navigation purposes of that amount. (Statement, p. 18.) The improvement of navigation by the construction of the Sanitary & Ship Canal, and its diversion of water, required the amount necessary to protect the Chicago water supply.

Major Marshall, the U. S. Engineer at Chicago, on May 1, 1889, pursuant to the Rivers and Harbors Act of August 11, 1888, made a report which is published in the Chief Engineers' Reports, concerning the improvement of this waterway. This report was made while the bill to authorize the construction of these works was pending in the General Assembly of Illinois. He reported the purpose of the diversion in the same

way, as appears from the following statement of his report (Rec. Vol. IV, 2172):

> "Whenever the large channel contemplated by the City of Chicago for drainage is actually determined upon, *in view of the fact that a channel for navigation and the channel for drainage across the Chicago divide must necessarily occupy the same field, it is evident that to avoid duplication of expense, the channel, at least in the expensive rock section, should be constructed best to meet the requirements of navigation in slope, velocity of current, and dimensions of section, while at the same time of sufficient flowing capacity to carry off the drainage of the Sanitary District.*"

Illinois fixed the amount of the diversion by appellant's organic act which action was also pursuant to the Act of Congress of March 2, 1827. The diversion has, thus, not only been "affirmatively authorized by law," but also "affirmatively authorized by Congress," complying with both the Rivers and Harbors Acts of September 19, 1890, and of March 3, 1899.

(c) Appellee, through its engineer officers and the Secretary of War, observed the action of the State of Illinois and of appellant pursuant to its authority in planning and constructing the diversion works. The Secretary of War consented to the work necessary to accomplish the diversion and authorized the opening of the main channel of the district. The Secretary of War construed the Congressional act of March 2, 1827, and the laws of Illinois, as affirmatively authorizing the diversion.

The Chief of Engineers, immediately upon the passage of the appellant's Organic Act of May 29, 1889, reported to Congress the fact of its passage, and the report contained a copy of the Act. It contained also a copy of the report of the Drainage and Water Supply Commission of January 30, 1887. It is published in the Chief of Engineers Reports for

1890 (Appellant's Narrative, p. 451). In this report Major Marshall stated (Appellant's Narrative, p. 453):

> "This route has invited attention as a practicable locus for a waterway between the Great Lakes and Mississippi River for many years, and its advantages, have been so often reported to Congress, that anything herein said would be mere repetition."

Each year the Chief of Engineer's reports contained statements of the progress of the work on the construction of the Sanitary & Ship Canal.

August 16, 1895, the Board of Engineers, of which General Poe was Chairman, reported to the Secretary of War as to the effect of the diversion of 10,000 cubic seconds feet of water from Lake Michigan upon the surface elevations of the Great Lakes. (Appellant's Narrative, p. 464.)

Even Congress took cognizance of the report of Major Marshall of January 27, 1897, by specifically mentioning the report in the Rivers and Harbors Act of March 3, 1899. (Statement, p. 48.) Major Marshall's report was made pursuant to a prior act of Congress. In this report thus specifically mentioned by said Rivers and Harbors Act, it is stated that the Sanitary & Ship Canal had approximately been completed, with a depth of from 18 to 22 feet, and with a width in the rock section of 160 feet to more than 200 feet in earth

> *"which may be made available as part of any enlarged waterway over the route in question."*

It is further stated

> "To comply with the law of the State of Illinois under which this drainage canal is constructed—it has been constructed of a capacity to discharge 600,000 cubic feet per minute through the section excavated in rock, and 300,000 cubic feet per minute throughout the earth section—the law requires a discharge of 20,000 cubic feet per minute for each 100,000 inhabitants of the Drainage District, which at present requires more than 300,000 cubic feet, and in a few years will require the full 600,000 cubic feet discharge through the canal." (Appellant's Narrative, p. 487.)

Early in the construction work, April 21, 1891, the Board of Trustees of appellant laid out a project to enter upon, use, widen, deepen and improve the Chicago River and the South Branch from Lake Michigan to the West Fork

> *"so as to make the same a proper and sufficient supply channel for the main channel heretofore surveyed from the Chicago River to Joliet."* (Appellant's Narrative, p. 454.)

A copy of this ordinance was sent to the Secretary of War.

The Sanitary & Ship Canal was constructed and excavated entirely in lands within the State of Illinois and not upon any lands or in any navigable waters of the United States. However, to accomplish the taking of the water from Lake Michigan through the Chicago River and its branches to the Sanitary & Ship Canal, it was necessary to greatly deepen and widen their channels. Otherwise the water could not be drawn through in the quantities required by appellant's diversion works. This was the occasion for the ordinance of April 21, 1891, above mentioned.

June 16, 1896, to carry out this object, the Sanitary District made request to the Secretary of War for a permit to improve the Chicago River and certain of its branches in certain particulars. In this request, appellant stated:

> **"The work of the Sanitary District of Chicago has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport, in Will County, 28 miles distant. Our connection with Lake Michigan must be through the Chicago River, the West Fork of the South Branch, of which we make a junction at Robey Street. (Appellant's Narrative, p. 38.)**

The Secretary of War, July 3, 1896, granted the request for

> **"permission to make certain changes in the capacity of the channel of the Chicago River * * * at points indicated on the map accompanying the application"**

on condition—

> "(1) That while the general plan is approved, the Sanitary District of Chicago must furnish plans in triplicate on an enlarged scale, showing each proposed new bridge, each by-pass and each new dock or wharf proposed to be built in order that the Secretary of War may act intelligently in each case.
>
> (2) That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration." (Appellant's Narrative, p. 474.)

Was there anything in this transaction that indicated that the Secretary of War did not consider appellant to be authorized by law to divert the water provided by appellant's Organic Act, 20,000 cubic feet per minute for each 100,000 of the population?

Following this permit, there were many others issued on request of the Sanitary District, consenting to the work of deepening and widening the Chicago River, its South Branch and West Fork, and prior to the opening of the canal on January 17, 1900. (Appellant's Narrative, p. 475.)

The work of the improvement of the Chicago River prior to the opening of the Sanitary & Ship Canal, looked only to so enlarging the cross section of its channels as to allow the withdrawal through it of the water required at that time, the population of appellant being approximately a million and a half. So when the Sanitary & Ship Canal was constructed, appellant requested a permit for the opening of same (May 8, 1899 permit). Among other recitals, it was stated that *permission has heretofore been granted to make certain improvements in the Chicago River for the purpose of correcting and regulating the cross section of the river so as to secure a flowage capacity of* 300,000 *cubic feet per minute, with a velocity of* 1¼ *miles an hour,*

> "it being intended to connect the said original channel with the West Fork of the South Branch of the Chicago River at Robey Street, in the said City of Chicago." (Appellant's Narrative, p. 22.)

Then permission is granted to open the channel constructed and cause the water of the Chicago River to flow into the same, subject to the following conditions only:

(1) Congressional action.

(2) Current in the Chicago River.

(3) Sanitary District to be responsible for damage to property.

Here there was affirmative evidence of the Secretary of War's understanding that the diversion was authorized by law, and it was his only duty to approve the plans for the work of securing a proper channel from Lake Michigan through these rivers to the Sanitary and Ship Canal, by which the necessary water could be diverted for sanitary and navigation purposes.

The work of improving the channels of the Chicago River and its branches, authorized by the two permits of July 11, 1900, (Appellant's Narrative, p. 92) was done for the avowed purpose of making those channels of such width and depth that they could properly carry through them 10,000 cubic seconds feet of water from Lake Michigan to the Sanitary and Ship Canal. (Requests for Permits, Appellant's Narrative, pp. 90, 91.) The depth under these permits, as will be recalled, was 26 feet and the width at all points of 200 feet. The work has been done according to these plans so approved at a cost of upwards of $10,000,000.

(d) The Secretary of War, charged with the duty of enforcing the Rivers and Harbors Acts of September 19, 1890, and March 3, 1899, has thus construed a diversion to the capacity of appellant's Sanitary and Ship Canal, to have been "affirmatively authorized by law" and "affirmatively authorized by Congress." These acts of the Secretary of War should have the force of judicial interpretation.

In

Hastings & Dakota Railroad Company v. *Whitney*, 132 U. S. 357, 366,

suit was instituted to recover certain lands which the defendant claimed it owned under a United States patent. A question arose as to the construction of the Soldiers' Homestead Law. This Court said:

> "It is true that the decisions of the Land Department on matters of law are not binding upon this court in any sense, but on questions similar to the one involved in this case, they are entitled to great respect in the hands of any court."

> "In *U. S.* v. *Moore*, 95 U. S. 760, 763, this Court said: 'The construction given to a statute by those charged with the duty of executing it, is always entitled to the most respectful consideration, and ought not to be overruled without cogent reasons. * * * The officers concerned are usually able men and masters of the subject; not infrequently they are the draftsmen of the laws they are afterwards called upon to interpret.'"

See, also,

Shells Executors v. *Fauche*, 138 U. S. 562, 572.
Heath v. *Wallace*, 138 U. S. 573, 582.

The Act of Congress of March 2, 1827, providing for the construction of a canal from Lake Michigan to the Illinois River, thus expressly authorized the State of Illinois to divert such quantity of water as it should deem reasonably necessary for navigation purposes, not only for the operation of the canal, but for the purpose, also, of providing deeper channels at low water times in the Illinois River, so that naviga-

tion thereon would be assured—navigators would feel secure in having the proper depths. At no time during the history of the construction and installation of the works of appellant, did any officer or agent of appellee suggest that this authority did not exist. It was recognized from the beginning. When the State of Illinois provided for the construction of appellant's works to divert at least 10,000 cubic seconds feet of water through the Sanitary & Ship Canal, the officers of the United States carefully observed the activities of appellant in making plans for these works and in doing the construction work. These facts were reported to Congress. When it became necessary to excavate or fill in the channels of the Chicago River and its branches, there was no hesitancy indicated in granting the permission in order that appellant's Sanitary & Ship Canal when completed might be made effective for the purpose of diverting the required water from Lake Michigan for sanitary and navigation purposes. When the canal was ready to be opened, like consent was given without limitation, except concerning current in the Chicago River unreasonably obstructive to navigation thereon. The future action of Congress was, of course, made, also, a condition which would exist in any event without its being named as a condition in the permit. The Secretary of War thus authorized the work of reversing the current and flow of the Chicago River which would be accomplished by opening the Sanitary & Ship Canal.

When the canal was opened, the channels of the Chicago River and its branches had been improved to provide for the withdrawal then necessary for the then population of appellant, approximately 1½ millions of people. To provide for the increase in population, it was necessary to comprehensively enlarge and improve these channels in order to take the additional volume of water from Lake Michigan through them to appellant's Sanitary & Ship Canal.

Appellant's requests for permits to do this work, were made on April 26 and June 7, 1900. Almost immediately thereafter the Secretary of War consented to the doing of the work,

approved the plans for the work, (July 11, 1900), and the work was done. *"The work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same."* (Sec. 10, Rivers and Harbors Act of March 3, 1899, *ante*, p. 106.)

The Secretary of War, in authorizing the opening of the Sanitary and Ship Canal, and in authorizing the excavation in the channels of the Chicago River and its branches to provide for the diversion through them to the Sanitary and Ship Canal of the amount of water required by appellant, must be deemed to have construed and interpreted the March 2, 1827 Act and the Illinois Act of May 29, 1889, as authorizing appellant's diversion.

II.

THE PERMITS OF THE SECRETARY OF WAR OF JULY 11, 1900, AUTHORIZING THE WORK OF DEEPENING AND WIDENING THE CHANNELS OF THE CHICAGO RIVER TO PROVIDE FOR THE DIVERSION OR ABSTRACTION FROM LAKE MICHIGAN THROUGH THEM OF THE AMOUNT OF WATER REQUIRED BY THE STATE LAW ACCORDING TO THE POPULATION OF APPELLANT, CONSTITUTED ALL THE AUTHORITY REQUIRED BY APPELLANT FROM APPELLEE, TO DIVERT SAID WATERS.

We will consider, now, the force and effect of Section 10 of the Rivers and Harbors Act of March 3, 1899, without regard to the Act of March 2, 1827, providing for the construction of the Illinois and Michigan Canal across the Chicago or Continental Divide.

In this connection it must be remembered that the Act of May 29, 1889, of the Illinois General Assembly specifically directs and empowers appellant to build and operate its diversion works to abstract from Lake Michigan 20,000 cubic feet of water per minute for each 100,000 population of appellant. The population of appellant at the time the decree was entered herein, exceeded three million inhabitants, thus requiring 600,000 cubic feet of water per minute, or 10,000 cubic feet per second. This authority, of course, is fundamental, and is the foundation of appellant's acts in this respect. Was there any further authority required than that the work should be

> "recommended by the Chief of Engineers and authorized by the Secretary of War prior to the beginning of same"? (Sec. 10, Rivers and Harbors Act, March 3, 1899.)

Excavating and filling in the channels of the Chicago River and its branches, was the only work appellant was required to do in navigable waters of the United States to accomplish

and bring about the diversion. The reversal of the current and flow of the Chicago River and its branches was a necessary result. Anyway, this was consented to specifically by the permit of May 8, 1899, for the opening of the canal. The work of improving these channels was done for the purpose only of providing for the abstraction of the water through them in a proper manner. The only requirement of Congress was that appellant should not excavate or fill or in any manner alter or modify the course, location, condition or capacity of any port, road-stead, haven, harbor, canal, lake, harbor of refuge or enclosure within the limits of any breakwater or of the channel of any navigable water of the United States, unless *the work was recommended by the Chief of Engineers and authorized by the Secretary of War prior to the beginning of same.* The waters were entirely within the confines of the State of Illinois. Appellant having unquestioned state authority, having obtained the authorization of the Secretary of War before commencing *the work* of *excavating,* etc., leading to the alteration or modifying of the course, location, condition or capacity of navigable waters and having done *the work,* the operation of its Sanitary & Ship Canal and other diversion works was and is lawful. That includes, of course, the diversion of water to the amount required by state authority. (10,000 cubic feet per second.)

It has never been suggested that the work of deepening and widening the channels of the Chicago River and its branches under the two permits of July 11, 1900, was not properly performed. While the statement of Secretary of War Stimson of January 8, 1913, in refusing to remove the limitation fixed by the Secretary of War of December 5, 1901, (4,167 cubic seconds feet of water) and to expressly authorize the diversion of 10,000 seconds feet, is perhaps not material here as the statute does not require any findings to be made in such cases, yet there is nothing in such statement as to any failure of appellant to perform the work under said permits. In fact, there is nothing in said statement suggesting any difficulties in navigating the Chicago River and its

branches. (Appellant's Narrative, p. 28.) On the other hand, it is plain that the improvement of the Chicago River made by appellant and all its works have been great aids to navigation. The river was deepened and widened, old bridges were replaced with new bascules, creating vastly deeper, wider and freer channels.

The construction of Sections 9 and 10 of the Rivers and Harbors Act of March 3, 1899, was thoroughly considered in

> *Maine Water Company* v. *Knickerbocker Steam Towage Company*, 99 Maine 473 (decided Feb. 17, 1905).

The Water Company brought suit against the Towage Company for damages sustained to the Water Company's pipe line across the Kennebeck River at Bath, a tidal, navigable river, wholly within the state. The placing of the pipe line in the river was properly authorized by the state. The Secretary of War issued a permit as recommended by the Chief of Engineers, for the work of placing the pipe line in said river. It was claimed by the defendant that the pipe line unlawfully occupied the river, inasmuch as there was no Act of Congress expressly authorizing the plaintiff to place its pipe line in said river. The Court compared Sections 7 and 10 of the Rivers and Harbors Act of September 19, 1890, and Sections 9 and 10 of the Rivers and Harbors Act of March 3, 1899.

Before further discussing the Court's opinion in the Maine case, we will, for the convenience of this Court, set forth in juxtaposition similar clauses of the sections of the two Acts mentioned. Words and clauses not common to both Acts are in italics and, for convenience in future reference, the separate clauses in the 1890 Act will be designated (*a*), (*b*), etc., and those in the 1899 Act (*aa*), (*bb*), etc., respectively.

1890.		1899.	
Sec. 7.	*a*	*Sec.* 10.	*aa*
It shall not be lawful to build any wharf, pier, dol-		It shall not be lawful to build *or commence the*	

phin, boom, *dam*, weir, breakwater, bulkhead, jetty, or structure *of any kind*, outside established harbor-lines, or in any navigable waters of the United States where no harbor-lines are or may be established, *without the permission* of the Secretary of War, in any port, roadstead, haven, harbor, navigable river, or other waters of the United States, *in such manner as shall obstruct or impair navigation.*

Sec. 7. b

It shall not be lawful hereafter to commence the construction of any bridge, *bridge-draw, bridge piers* and abutments, causeway or other works *over or in any port, road, roadstead, haven, harbor, navigable river* or *navigable waters of the United States*, under *any act of the legislative assembly* of *any* state, until the location and plan of such bridge or other works *have been* submitted to and approved by the Secretary of War.

Sec. 7. c

That *this section* shall not * * * be so construed as *to authorize* the construction of any bridge, *draw-bridge, bridge piers and* abutments, *or other* works, *under an act of the legislature of any state*, over or in any *stream*, port,

building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty or *other* structures in any port, roadstead, haven, harbor, canal, navigable river or other water of the United States, outside established harbor lines or where no harbor lines have been established, *except on plans recommended by the Chief of Engineers and authorized* by the Secretary of War.

Sec. 9 bb

Such structures (any bridge, *dam*, dike or causeway) *may* be built *under authority* of the *legislature* of *a* state *across* rivers and *other waterways, the navigable portions of which lie wholly within the limits of a single state*, provided the location and plans *thereof are* submitted to and approved *by the Chief of Engineers* and by the Secretary of War, *before construction is commenced.*

Sec. 9. cc

That it shall not be lawful to *construct or commence* the construction of any bridge, dam, dike or causeway over or in any port, roadstead, haven, harbor, *canal, navigable river*, or other navigable water of the United States, until the

roadstead, haven or harbor, or other navigable water not wholly within the limits of such state.

Sec. 7. *d*

It shall not be lawful * * * to excavate or fill, or in any manner to alter or modify the course, location, condition or capacity of the channel of said navigable water of the United States, unless *approved* and authorized by the Secretary of War.

Sec. 7. ***d1.***

That this section shall not apply to any bridge, bridge-draw, bridge piers and abutments, the construction of which has been heretofore duly authorized by law.

Sec. 10. *e*

That the creation of any obstruction, not affirmatively authorized by *law,* to the navigable capacity of any waters, *in respect of which the United States has jurisdiction,* is hereby prohibited.

consent of Congress to the building of such structures shall have been obtained and until the plans for the same shall have been submitted to and approved by the Chief of Engineers and by the Secretary of War.

Sec. 10. *dd*

It shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition or capacity of *any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or* of the channel of *any* navigable water of the United States, unless *the work has been recommended by the Chief of Engineers* and authorized by the Secretary of War *prior to the beginning of same.*

Sec. 10. *ee*

That the creation of any obstruction, not affirmatively authorized by *Congress,* to the navigable capacity of any *of the* waters of the United States is hereby prohibited.

Sec. 10. *f*

The creating or continuing of any unlawful obstruction in this act mentioned may be prevented and such obstruction may be *caused to be removed* by the injunction of any circuit court exercising jurisdiction in any district in which such *obstruction may be threatened or* may exist; and proper proceedings in equity to this end may be instituted under the direction of the Attorney-General of the United States.

Sec. 12. *ff*

The *removal* of any *structures or parts of structures erected in violation of the provisions of the said sections* may be *enforced* by the injunction of any circuit court exercising jurisdiction in any district in which such *structures* may exist, and proper proceedings to this end may be instituted under the direction of the Attorney-General of the United States.

The Court

(*Maine Water Company* v. *Knickerbocker Steam Towage Company, supra*)

said:

(477) "We cannot help remarking, in passing, that if the defendant's interpretation of the Act of 1899 is the correct one, it leads to a rather surprising condition. It would seem that not a wharf or pier, outside established harbor lines, or where no harbor lines have been established, can now be built, in the navigable waters of the United States, not a dolphin can be anchored for mooring vessels, not a boom can be stretched, nor a weir erected for any purpose, until hereafter authorized by Act of Congress. We think it cannot be assumed that Congress intended any such result unless the Act in question is so expressed as not to admit of any other reasonable interpretation."

The effect of the first sentence of Section 10 of the 1899 Act containing the prohibition against obstructions "not affirmatively authorized by Congress", was particularly important. The Court with reference to this, further said:

(481) "The general prohibition in section 10 is brought with only one substantial change from section 10 of the Act of 1890. The Act of 1890 said 'not affirmatively authorized by law,' which was held in *U. S.* v. *Bellingham*

Bay Boom Co., 176 U. S. 211, to mean not only by a law of Congress, but even by a law of the state in which the river is situated. The Act of 1899 says 'not affirmatively authorized by Congress.' Following this general prohibition, and immediately connected with it, is the remainder of section 7 of the Act of 1890, which relates to wharves and other structures, which would include this pipe line. The only important change is this. The Act of 1890 made unlawful the erection of such structures without the permission of the Secretary of War, in the waters of the United States, outside established harbor lines, or where no harbor lines have been established, in such manner as shall obstruct or impair navigation. The Act of 1899 makes unlawful such erections, except they are built on plans recommended by the Chief of Engineers and authorized by the Secretary of War.

Although in the arrangement of parts, the general prohibition now is found at the beginning of a section which also relates to the specific regulation of the building of wharves and so forth, instead of being in a section by itself as before, we are not persuaded that Congress, by changing its position, intended to change its effect. It is still general as before. And though general in terms before, we think, as we have stated, that structures impliedly authorized by Congress in the preceding sections were not prohibited. And in its new position we think that the general prohibition is likewise qualified by the sentences which follow. It cannot make any substantial difference whether the general prohibition is at the beginning of a section, or at the end, or in a section by itself, if it clearly appears from the language used and from the context, all taken together, that the legislative intention was that the general prohibition was to be regarded as subject to specified qualifications. * * *

* * * the implication seems clear to us that such structures, if built according to plans recommended and authorized as provided in the section, are authorized by Congress—that they are affirmatively authorized,—though the affirmative authority arises by implication,—and that they are lawful without any further action by Congress."

Structures actually named in the 1899 Act are wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, bridge, dam, dike or causeway. The words "or other structures" follow the naming of each class. The bridges rebuilt were the only

structures built by appellant in connection with the deepening and widening of the Chicago River and its branches actually named in the Act. As to such structures, the *plans* were required to be approved by the Chief of Engineers and Secretary of War, and there is no question about these bridge structures. The work of excavating for the widening and deepening, and the work of construction of docks, was covered by the general clause with reference to excavating and filling. (*dd* above p. 135.) As to this (excavating for widening and deepening and thereby to alter and modify, etc.) the *work* (of such deepening and widening) should be

> *"recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same."*

The *work* was so *recommended* and *authorized*. The *work* was done. Thus the altering or modifying the course, location, condition or capacity of the navigable waters of the United States flowing from the work so *recommended* and *authorized*, was lawful. It was immaterial, therefore, *where the navigable waters of the United States were located* that were thus altered and modified as the result of the work so *recommended* and *authorized*.

The altering or modifying of the navigable capacity of the waters, not only of the Chicago River and its branches, but of Lakes Huron, Michigan, Erie, Ontario, their connecting waters, and other navigable waters of the United States, by the diversion of water provided for through appellant's works, was thus authorized and is lawful.

Cummings v. *Chicago*, 188 U. S. 410.

The case of

Hubbard v. *Fort*, 188 Fed. 987 (Circuit Court, opinion by District Judge Rellstab)

is contrary to the opinion of the Supreme Court of Maine in the *Water Company case, supra*. But in that case, the receivers of the Hudson County Water Company who filed the bill to enjoin officers of the State of New Jersey from interfering with the construction of their conduits in the Kill von Koll,

were acting contrary to an Act of New Jersey expressly forbidding the diversion of the waters of New Jersey into the State of New York. The New Jersey Act was held constitutional and valid in

Hudson County Water Company v. *McCarter*, 209 U. S. 349.

In

Southern Pacific Co. v. *Olympian Dredging Co.*, 260 U. S. 205, 210,

this court, in construing the Rivers and Harbors Acts here in question, cited with approval

Maine Water Co. v. *Knickerbocker Steam Towage Co.*, 99 Me. 473, *supra.*

III.

IN ANY EVENT, THE SECRETARY OF WAR HAS AUTHORIZED THE OPENING OF APPELLANT'S SANITARY & SHIP CANAL, ITS OPERATION AND ATTENDANT DIVERSION OF WATER FROM LAKE MICHIGAN BY THE PERMIT OF MAY 8, 1899, EVERY CONDITION OF WHICH HAS BEEN FULFILLED, ASSUMING SUCH CONDITIONS TO BE VALID. THE SECRETARY OF WAR WAS ONLY AUTHORIZED TO GRANT OR REFUSE A PERMIT. HE HAD NO POWER TO REGULATE THE DIVERSION OF WATER AT CHICAGO. THE ATTORNEY GENERAL HAD NO AUTHORITY TO INSTITUTE THE SUIT FOR INJUNCTION.

(a) The effect of the May 8, 1899 permit and attempted limitation thereon.

The Sanitary & Ship Canal was completed during the year 1898 of capacity and size sufficient to take through it the maximum diversion, 14,000 cubic seconds feet of water, when the population of the appellant reached an amount requiring such diversion according to the ratio of dilution fixed by the state law—20,000 cubic feet per minute for each 100,000 of population. The population of the Sanitary District was then only about a million and a half. In order that the amount of water necessary to dilute the sewage of this population might be taken through the channels of the Chicago River and its branches, these channels were partially improved under various permits and authority of the Secretary of War, beginning with July 3, 1896. Notwithstanding the improvements of these channels that had been made, they were still shallow, narrow and tortuous, at some places being only 100 feet wide. With this condition in mind, when the appellant sought to obtain the consent of the Secretary of War to the opening of the Main Channel, the Secretary granted the

permit to open the Sanitary & Ship Canal without any limitation as to the amount of water, except that the current created by the withdrawal should not be unreasonably obstructive to navigation on the Chicago River. This condition was inserted with the view that the channels of the Chicago River and its branches would be later vastly deepened and widened, to provide for the future increase in population and the efficient operation of the canal to divert all of the sewage and drainage of Chicago and its environs. The channel was opened pursuant to this permit on January 17, 1900. Immediately thereafter, appellant made application to the Secretary of War, May 26th and June 7th, 1900, (Appellant's Narrative, pp. 90, 91) to comprehensively improve these rivers. The purpose of such improvement was stated—namely, to provide the means by which the necessary waters of Lake Michigan and the drainage and sewage could be carried to the Sanitary & Ship Canal. The permits of July 11, 1900, for this work were granted in order to carry out this express purpose.

There was no occasion for appellant to thus deepen the Chicago River from 17 to 26 feet and widen it at all points to 200 feet, rebuild bridges at an expense of ten and one-half millions of dollars, if its diversion from Lake Michigan would be limited to 4,167 seconds feet, the amount fixed by the decree of the District Court herein.

With the channels of the Chicago River in this restricted condition, the Secretary of War, on December 5, 1901, directed that the maximum flow through the Chicago River and its South Branch should not exceed 250,000 cubic feet per minute. The orders so limiting the flow, expressly recited the condition of the May 8, 1899 permit as to current in the Chicago River, and that commercial and navigation interests thereon had made objections. (Appellant's Narrative, pp. 23-26.)

The permits of July 11, 1900, for the work of comprehensively deepening and widening the channels, were in existence, had not been revoked, and appellant was proceeding to act under them.

It did do the work thus *authorized* and *recommended*, with the knowledge of the Secretary of War and the Chief of Engineers, without objection. There was no indication or suggestion that the December 5, 1901, order would be sought to be enforced when the work recommended and authorized under the July 11, 1900, permits, was done. In fact, as these river channels were improved, and the population of the district increased, water was diverted in amounts vastly greater than the limitation of 250,000 cubic seconds feet, (the order of December 5, 1901.) (Appellant's Narrative, p. 202.) In addition to the river improvement, appellant otherwise completed its diversion works by constructing the intercepting sewers, North Shore and Sag Channels, with their adjuncts, pumping stations, etc., at a total cost for all works of upwards of $75,000,000.00 and all this was done pursuant to authority of the Secretary of War. (Appellant's Narrative, p. 194.)

After Secretary of War Taft had on March 14, 1907, refused a permit for the diversion of 4,000 cubic feet per second through the Calumet River and the then proposed Calumet Sag Channel, which amount was additional to the diversion of 10,000 cubic feet per second then being provided for through the Chicago River and its branches, the Attorney General of the United States instituted suit, March 23, 1908, to enjoin its construction. (Appellant's Narrative, p. 2.) This suit only involved a diversion by way of the Calumet River and the Calumet Sag Channel *in addition to that through the Chicago River.*

The bill of complaint in the Calumet Sag suit, after reciting the ordinance of the Board of Trustees of appellant providing for the construction of the Calumet Sag Channel, alleges that the construction of said channel,

> "will result in diverting and abstracting from Lake Michigan a large quantity of water, towit, 4,000 cubic feet of water per second, and causing said water to flow through said Calumet Rivers into said Calumet Sag

Channel, through that channel into the Main Channel of said Sanitary District, and thence to the DesPlaines and Mississippi Rivers, and on to the Gulf of Mexico."

Paragraphs 16 and 17 of the answer in said Calumet suit, filed March 23, 1908, describe appellant's Sanitary & Ship Canal and the various other works constructed as adjuncts thereto, for the diversion of 10,000 cubic seconds feet through the channels of the Chicago River and its branches (Appellant's Narrative, p. 12). Yet no legal action or protest was made concerning the actual diversion through the channels of the Chicago River and its branches, of water in excess of the limitation of December 5, 1901, or concerning the diversion that would necessarily take place to the maximum capacity of the Sanitary & Ship Canal as the improvement of the channels of the Chicago River was completed, and as the population of appellant increased.

When the improvement of the channels of the Chicago River was completed, the cause and the reason for the limitation by the order of the Secretary of War of December 5, 1901,—250,000 cubic minutes feet withdrawal from Lake Michigan—was removed. Necessarily it followed that such limitation should then have no further force or effect. It had been so treated, not only by the Secretary of War, but also by the Attorney General in failing, March 23, 1908, or afterwards to take any action thereon.

In the meantime, the International Waterways Commission constituted under authority of the Rivers and Harbors Act of Congress of 1902 (Appellant's Narrative, p. 526) had specially reported finding that there was a tacit general agreement that the diversion of at least 10,000 cubic seconds feet of water would exist at Chicago. The Treaty of 1909 between Great Britain and appellee as to Canadian Boundary Waters, had been made upon the recommendations as to terms made by the International Waterways Commission. Furthermore, the Treaty itself recognized diversions of water from the Great Lakes System for sanitary purposes as paramount and taking precedence over all others.

The Act for the preservation of Niagara Falls had been passed June 29, 1906. Section 1 contained a proviso that under no circumstances should it permit the Secretary of War to limit the diversions for sanitary and domestic purposes except as Congress might in the future direct. (Statement, p. 51.)

Consequently, on February 5, 1912, the channels of the Chicago River and its branches having been deepened and widened pursuant to the permits of July 11, 1900, appellant sought the removal of the limitation of diversion contained in the order of December 5, 1901, and an express authorization for the diversion of at least 10,000 cubic seconds feet by means of all of its diversion works. Appellant undoubtedly assumed, as it had the right to, that the limitation of December 5, 1901, was merely a technical or paper limitation. It desired to have a cloud removed upon its otherwise perfect title. However, May 8, 1913, the Secretary of War refused this application, (Appellant's Narrative, p. 28), and the complaint here in controversy was filed October 6th, 1913.

The action of the executive officers of the Government in seeking to enjoin the operation of appellant's works as required by state law and under all the circumstances, is arbitrary and unreasonable. Equity cannot grant the relief asked and equity would undoubtedly enjoin any overt acts taken by such officers to enforce the said limitation of December 5, 1901.

In

Monongahela Bridge Co. v. *U. S.*, 216 U. S. 177, 195,

it was claimed by the respondent that the action of the Secretary of War was arbitrary and unreasonable in connection with the direction for the alteration of a certain bridge. The Court said:

> "Learned counsel for the defendant suggests some extreme cases, showing how reckless and arbitrary might be the action of executive officers proceeding under an act of Congress, the enforcement of which effects the enjoyment or value of private property. It will be time

enough to deal with such cases as and when they arise. *Suffice it to say that the courts have rarely, if ever, felt themselves so restrained by technical rules that they could not find some remedy, consistent with the law, for acts, whether done by government or by individual persons, that violated natural justice or were hostile to the fundamental principles devised for the protection of the essential rights of property."*

In

Philadelphia Company v. *Stimson*, 223 U. S. 605,

the Court recognized the right of an aggrieved person in equity to enjoin the arbitrary and unreasonable action of the Secretary of War.

In

Kwock Jan Fat v. *Edward White*, as Commissioner of Immigration, 253 U. S. 454, 464,

this Court, in speaking of the power of the Commissioner of Immigration, said:

"It is a power to be administered, not arbitrarily and secretly, but fairly and openly."

The limitation of 4,167 seconds feet, diversion, does not now exist under any condition of the May 8, 1899, permit.

(b) The Attorney General under the Act of March 3, 1899, is only authorized to institute suits in equity for the removal of structures. The District Court was without jurisdiction to entertain this suit or enter the decree.

The suit here is that appellant be enjoined

"from diverting or abstracting any waters from Lake Michigan over and above and in excess of 250,000 cubic feet per minute, as already authorized by said Secretary of War. * * *" (Appellant's Narrative, p. 21.)

Section 12 of the Act of March 3, 1899, authorizing suits in equity, only related to

"the removal of any structures or parts of structures erected in violation of said sections (9-10 and 11)". 'Laws, Improvement Rivers and Harbors, Vol. 2, p. 887, *ff* above p. ....)

Obviously, this suit does not seek the removal of any structure. It was not the purpose of Congress that the Attorney-General should have any other powers than that to cause the removal, by injunction, of structures built contrary to the provisions of the Act. It was not intended that these executive officers could by injunction interfere with the operation of works built under state authority for the protection of public health even though they might have the effect of incidentally obstructing navigation. Congress intended to deal with such cases individually and separately.

That this construction of the effect of Section 12, viz., that it is limited to the institution by the Attorney General of suits only to remove unlawful structures, is borne out by a reference to the provisions of the Act of September 19, 1890, as to such injunction suits. The only clause relating to such suits, is contained in the latter part of Section 10, (Laws Improvement of Rivers and Harbors, Vol. I, p. 583, *f* above p. 136.)

> "the creating or continuing of any unlawful obstruction in this act mentioned, may be prevented and such obstruction may be caused to be removed by the injunction of any Circuit Court exercising jurisdiction in any district in which such obstruction may be threatened or may exist; and proper proceedings in equity to this end may be instituted under the direction of the Attorney General of the United States."

The elimination of the words

> "the creating or continuing of any unlawful obstruction in this act mentioned may be prevented"

contained in the 1890 Act, from the 1899 Act upon a similar subject, and the failure to substitute any words even remotely alike, leads to the inevitable conclusion that it was the intention of Congress that the Attorney General's activity should be confined solely and only to suits to enjoin *the removal* of unlawful *structures.*

Webster's New International Dictionary defines "structure" to be—

> "Something constructed or built, as a building, a dam, a bridge, esp. a building of some size; an edifice."

The clause of the 1899 act refers to "*structures erected*" in violation, etc. Those words cannot possibly cover the excavation in the Chicago River and its branches, such as deepening and widening, which was the work done for the diversion in excess of the 4,167 seconds feet specified by the order of the Secretary of War of December 5, 1901. It cannot refer to appellant's Sanitary and Ship Canal. The words "*structures erected*" certainly would not include a canal built or excavated. These words convey the impression of something placed in a navigable water, which things by their very form or by reason of the very location, would obstruct navigation. The word "structure" is a much narrower term than "obstruction." The word "obstruction" may include a "structure," but the word "structure" certainly cannot cover every "obstruction."

An examination of Sections 9 and 10, furnishes the definition of the word "structures" as used in Section 12. In Section 9, the things mentioned are "bridge, dam, dike or causeway." These are referred to in two places in said section as "such structures," once as "other structure," and once as "the structure."

In Section 10, particular things are also described as "wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty." Immediately following the naming of them, are the words "or other structures." Certainly appellant's works for the diversion of this water to the amount required, can not possibly be of the character of the things mentioned as structures. In the first sentence of Section 10, the word "obstruction" is used, and in the last sentence of Section 10 "excavating or filling" is referred to as "work." Had the clause with reference to the Attorney General's instituting suit for injunction in the 1890 Act, been included in the 1899 Act, the Attorney General could have proceeded with reference to obstructions to enjoin their creation or continuance, and also to enjoin the beginning of the work of excavating or filling, or the continuance of the enjoyment of the benefits derived from excavating or filling contrary to the provisions of the Act.

It is important also to consider that in the first part of Section 12, any violations of Sections 9 and 10 "shall be punished by fine or by imprisonment." That portion of Section 12 is as follows:

> "That every person and every corporation that shall violate any of the provisions of sections nine, ten and eleven of this Act, or any rule or regulation made by the Secretary of War in pursuance of the provisions of the said section fourteen, shall be deemed guilty of a misdemeanor, and on conviction thereof shall be punished by a fine not exceeding twenty-five hundred dollars nor less than five hundred dollars, or by imprisonment (in the case of a natural person) not exceeding one year, or by both such punishments, in the discretion of the court." (Above p. 109.)

It is plain that the above quoted provision covers the doing of anything contrary to the provisions of Sections 9 and 10, excavating or filling or the creating of an obstruction or the constructing or commencing the construction of any of the *structures* mentioned. It must be presumed that Congress believed that the exaction of the penalty and imprisonment was a sufficient remedy to prevent the creation of obstructions or the excavating or filling contrary to the provisions of the Act. It may be further presumed that Congress did not intend to give to the Attorney General, or any other officer of the United States, the broad power by injunction to prevent the doing of the things by a state or municipality which would only indirectly obstruct navigation; that is, where it was an incidental result of the state's or municipality's action, such as exists in this case. If the power were granted the courts would perhaps feel themselves compelled to enforce it, notwithstanding the dire results that might follow. Thus, by the mere fiat of an executive officer, could the whole course and plan of a state for the protection of the health of its people, be set at naught. The executive officer could thus prevent the carrying out of a most important waterway policy of the state, affecting not only the people of the state, but the people of the entire nation.

In

Ogden City v. *Boreman*, 20 Utah 98, 57 Pac. 843,

the question arose as to whether the City of Utah by ordinance could provide for a license fee to be paid for practicing law in Ogden. It was held that the Statutes of Utah did not empower cities to make such requirement. The laws of Utah as codified in 1888, expressly provided for the licensing of lawyers. There was also a general clause in the 1888 laws authorizing cities to license all trades and businesses. When the laws were re-codified in 1898, the provision with reference to lawyers was not included. It was argued that the general clause covered and embraced the right to license lawyers. The court cited

Endlich on Interpretation of Statutes, Sec. 51.

Sutherland Statutory Construction, Sec. 140.

and held that the City of Ogden had no power to impose a license fee on lawyers. The court said:

> (142) "In Suth. St. Const. Sec. 140, it is said: 'An affimative enactment of a new rule implies a negative of whatever is not included or is different; and if, by the language used, a thing is limited to be done in a particular form or manner, it includes a negative that it shall not be done otherwise. An intention will not be ascribed to the law making power to establish conflicting and hostile systems upon the same subject, or to leave in force provisions of law by which the later will of the legislature may be thwarted and overthrown.' By repealing the clause providing for licensing and taxing lawyers, and enacting the general clause referred to, leaving lawyers and the professions generally out of such re-enactment, impels the conclusion that the legislature intended to deprive the cities of the power to impose a license fee or tax upon lawyers that they had formerly possessed. There must have been an object and purpose in this deliberate repeal in one section and omitting to insert its provision in the act as reenacted, having special reference to licensing and taxing in cities."

The Attorney General and the United States District Attorney who instituted this suit, cannot rely upon the general power to

> "prosecute * * * all civil actions in which the United States are concerned."

The statute with reference to the control of navigable waters by the United States, provides a remedy in certain instances. It necessarily follows that the remedies in instances not named are denied. This is particularly convincing when authority as to certain situations, such as filing a bill to enjoin the creation or continuance of an obstruction, is eliminated from the 1899 Act.

The case of

U. S. v. *Rio Grande Dam & Irrigation Company*, 174 U. S. 690,

is not an authority in support of the Attorney General's power to enjoin the operation of an obstruction under the March 3, 1899, Act. In that case, the bill was filed under the Act of September 19, 1890, which expressly authorized such injunctive relief. Furthermore, the authority of the Rio Grande Dam & Irrigation Company arose by virtue of the Act of the Territory of New Mexico. There was no reserved power of the state exercised as there is here.

The injunctive relief is not available for the United States in the event of the failure of a person, firm or corporation owning a bridge to alter it, as directed by the Secretary of War under Section 18 of the Rivers and Harbors Act of March 3, 1899. The only remedy is the enforcement of the penalty expressly provided by said section.

The Attorney General not being authorized to institute a suit for injunction in the instance described in this proceeding, the District Court was, therefore, without jurisdiction. It could not enter the decree enjoining the continuance of the acts of appellant, for there is no statute providing for either the institution of the suit or its entertainment by the Court.

(c) The Secretary of War is only authorized to grant or refuse a permit. He has no power to regulate the diversion.

An examination of Sections 9 and 10 clearly discloses that there is not delegated to the Secretary of War, the power to supervise or regulate the operation of works placed in navigable waters of the United States. No such discretionary power is given. He has not the power to act as a supervising or construction engineer. He is merely to authorize the construction of certain specific works on plans recommended or approved by the Chief of Engineers.

With reference to the structures before the Court, as heretofore pointed out, he is merely to authorize the work that has been recommended by the Chief of Engineers. So, when the Secretary of War authorized the opening of the Sanitary & Ship Canal by removing the earth between the West Fork of the South Branch of the Chicago River and the excavated channel of the Sanitary & Ship Canal at its Northern Terminus, he had performed his duty; likewise his jurisdiction over the subject ended, and he could not thereafter regulate the operation of the Sanitary & Ship Canal.

The Secretary of War, by the order of December 5, 1901, boldly, by the use of the very words, assumes "to regulate" the diversion. (Appellant's Narrative, p. 24, 25.) The decree of the lower court seeks to enforce that order. Both the decree and the order of the Secretary of War attempt to regulate the diversion, a power clearly not existing in either the Secretary of War or the Court under said Rivers and Harbors Act of March 3, 1899.

IV.

REGARDLESS OF THE EFFECT OF THE ACT OF CONGRESS OF MARCH 2, 1827, PROVIDING FOR THE CONSTRUCTION OF THE ILLINOIS AND MICHIGAN CANAL ACROSS THE CONTINENTAL DIVIDE, AND THE INTERPRETATION OF SECTION 10 OF THE ACT OF MARCH 3, 1899, AS HERETOFORE STATED, NEVERTHELESS, THE ILLINOIS ACT OF MAY 29, 1889, UNDER WHICH APPELLANT HAS BUILT AND IS OPERATING ITS DIVERSION WORKS, IS VALID AND ENFORCEABLE, PURSUANT TO THE POLICE POWER RESERVED TO THE STATES UNDER THE CONSTITUTION. THE DIVERSION BY APPELLANT TO THE AMOUNT NECESSARY FOR THE OPERATION OF ITS WORKS IS LAWFUL WITHOUT EXPRESS CONSENT OF THE SECRETARY OF WAR. ANY OTHER CONSTRUCTION OF THE ACT OF MARCH 3, 1899, WOULD TEND TO NULLIFY APPELLANT'S ACTS IN THE INTEREST OF PUBLIC HEALTH. THIS RESULT CANNOT OBTAIN UNLESS SUCH CONGRESSIONAL INTENTION IS EXPRESSED IN PLAIN AND UNMISTAKABLE TERMS.

The proper consideration of the questions involved in this case, necessarily leads one to investigation and determination of the extent of the police powers expressly reserved to the States by the Tenth Amendment to the Constitution. It involves necessarily the construction of the Commerce clause of the Constitution and the various congressional acts in exercise of this power. We are not here concerned with any question as to whether Congress may not occupy the entire field concerning the regulation of navigable waters of the United States, whether wholly within or partly within and partly without the limits of a state, thereby intentionally excluding entirely state control over those waters within its limits. Obviously, Congress has not, under the Rivers and Harbors Act

of March 3, 1899, or any other act, attempted to enact legislation to exclusively control and regulate these navigable waters.

The question necessarily first arises as to whether the State's Act of May 29, 1889, authorizing the diversion of water by means of appellant's works, is inoperative so far as the diversion is concerned without express congressional authority; that is, without some act of Congress expressly and in unmistakable terms, authorizing this particular diversion and its amount. Was it intended by Congress to exclude the exercise by the state of its police power to protect the health of its people? The query is also presented whether the failure of the Secretary of War to give his consent to the abstraction of the water to the amount claimed by appellant that it requires, *ipso facto*, prevents said abstraction or withdrawal. The state being authorized to take such water from Lake Michigan as is reasonably required to protect the water supply of appellant's population, the Secretary of War cannot frustrate the state's efforts for this worthy purpose, by merely refusing his consent.

The situation would not be different had Congress plainly and unmistakably, by special act, authorized the State of Illinois to divert from Lake Michigan, 10,000 cubic seconds feet of water through its various diversion works, subject to the Secretary of War's authorizing, by permit, the work of deepening and widening the channels of the Chicago River and its branches to take through them this amount of water, without creating any current injuriously affecting navigation on said river channels. Appellant presents its plans for such work. Secretary of War approves them and authorizes the work. The Secretary of War then fails to remove a limitation fixed as to the amount of withdrawal made because of the then condition of the river channels as to shallowness and narrowness. The work is done. There is no objection or suggestion, by the Secretary of War in refusing to remove the limitation, that there are difficulties of navigation on the Chicago River by reason of

current resulting from appellant's abstraction. He arbitrarily refuses to remove the limitation, saying that he does not believe that the necessities of the occasion require it, or for any other reason, outside of the ones which he was authorized by the Congressional Act to consider. Such action obviously would entirely destroy the carrying out of the will of Congress under this supposed special act authorizing a definite amount of withdrawal. This very situation exists here for three reasons;

(1) The March 2, 1827 Act authorized the State of Illinois to build a canal and divert water for its uses, the amount of withdrawal to be determined by the State for the canal's purposes. The state has fixed that amount by the Act of May 29, 1889. Thus we have express congressional action for that amount of withdrawal.

(2) The Secretary of War has authorized *the work* as *recommended* by the Chief of Engineers, which work would result in the withdrawal of the water, to the extent of at least 10,000 cubic feet, and the altering or modifying of the navigable capacity of the navigable waters of the United States.

(3) The State likewise has reserved to it the police power to take the amount of water reasonably required for the purposes designed—namely the protection of the water supply of Chicago and its environs. Of course the amount must be determined by the State and Congress has not occupied the field to such an extent as to deny to the state that power.

In either one of the three instances above mentioned, the Secretary's refusal to remove the limitation of December 5, 1901, arbitrarily deprives the State of Illinois of enjoying that to which it is entitled under any one of these situations.

The cases which we desire to cite under this Point of our brief, are applicable to the various propositions suggested under this heading (Point IV), now to be discussed. Where a

case cited on one proposition applies to the others mentioned under this heading, we assume that they will be so considered, thus avoiding repetition.

(a) The Illinois Act of May 29, 1889, under which appellant was organized and exists, was sufficient legislative authority for the construction of appellant's various diversion works and for the diversion of water from Lake Michigan as required by such works.

This Act of May 29, 1889, of the Illinois General Assembly, rests upon the police power of Illinois reserved to it by the Constitution and never delegated to the Federal Government.

It had two objects: *first*, the protection of public health; *second*, the improvement of the state's waterways. There is no question raised in this record that the work provided for under this act and the diversion of water from Lake Michigan in the amount required by said act was not reasonably necessary to accomplish the objects and purposes of the legislation. The action of the state in this respect was taken deliberately, after thorough investigation and consideration. The necessity for the diversion and construction of the various diversion works, the Sanitary and Ship Canal and its adjuncts, for waterway purposes, has never been questioned. In fact, from the very time the old Illinois and Michigan Canal was built, its enlargement either by excavation in the canal itself or by the construction of the new canal paralleling it, and the diversion of large quantities of water for its operation and for the benefit of navigation on the Illinois River, was recommended continuously by government engineers. Contemplating the history of the development of this project, we find a unanimity of purposes for the development of this waterway.

In connection with the purpose sought—protection of the public health—the state likewise pursued the only course open to it. The old Illinois and Michigan Canal had been used as a partial outlet for the drainage and sewage finding its way

into the Chicago River, its South Branch and West Fork, to cleanse the river and to some extent keep pollution from the water supply. In the year 1871 it was enlarged at the expense of the City of Chicago to withdraw the water by gravity. In 1884, additional devices were provided, pumps at the northern terminus of the canal, to divert a greater quantity of water. The Continental Divide being insignificant at Chicago, made possible the passage of the drainage and sewage polluting water from Lake Michigan across it. It enabled Chicago to adopt the very best method to provide a pure and unpolluted water supply for its people. The alarming prevalence of typhoid fever epidemics aroused the people of Chicago to an appreciation of the dangers confronting the community. Chicago set about to solve this problem in a wise manner. She created in 1886 the Drainage and Water Supply Commission, which deliberately and carefully studied from health and waterway standpoints the entire problem, and recommended the construction of the works built by the Sanitary District—the Sanitary and Ship Canal and its adjuncts, and the diversion of water from Lake Michigan to operate them, as provided by statute.

The effect upon the Great Lakes System, navigable waters of the United States, if any, is entirely incidental to the carrying out of the purpose of the operation of appellant's works. The improvement of the channels of the Chicago River and its branches, the building of the Sanitary and Ship Canal and its various adjuncts, has admittedly improved and benefitted waterways within the State of Illinois. The channels of the Chicago River and its branches have been made deeper and wider and freed of all obstructions. The old Illinois and Michigan Canal between Chicago and Joliet, has been replaced or supplanted by the Sanitary and Ship Canal, of a size sufficient to meet all possible demands of commerce, and in keeping with the State and Federal intention, as to the canal's enlargement,—even the express congressional purpose under the Act of March 30, 1822.

Section 10 of the Rivers and Harbors Act of March 3, 1899, has been definitely construed by this Court in

Cummings v. *Chicago*, 188 U. S. 410,
Montgomery v. *Portland*, 190 U. S. 89.

In

Cummings v. *Chicago*, 188 U. S. 410,

Cummings proceeded to reconstruct a dock along the Calumet River, a river entirely within the state's limits. The dock was located within the City of Chicago. Cummings had obtained the consent of the Secretary of War to the doing of the work as recommended by the Chief of Engineers, but had failed to obtain the approval of the proper officer of the City of Chicago, as required by an ordinance of said city. It appeared, also, that Congress had provided for the improvement of this river by deepening and widening it, and it was claimed that thereby and in addition to the intention expressed by Secton 10 of the Rivers and Harbors Act of March 3, 1899, the United States had assumed exclusive jurisdiction over this river. The Secretary of War, in issuing his permit for the dock's reconstruction, recited the provisions of Section 10 of the 1899 Act and issued the permit thereunder. The Chicago authorities threatened to stop Cummings in his construction work, and the bill was filed to enjoin such threatened action on the ground that Cummings, by obtaining the Secretary of War's authority, was completely and fully authorised. It will be observed that a dock is not specifically mentioned in either Sections 9 or 10, but is likely the character of a structure mentioned in Section 10, such as pier, wharf, etc. At any rate, to build the dock it was necessary to excavate or fill in the Calumet River, a navigable water of the United States. This Court held that to fully empower Cummings to reconstruct the dock, it was necessary to have the approval of the City of Chicago, required under said ordinance, in addition to that of the Secretary of War; that when those two approvals were obtained, then the acts of Cummings would be entirely lawful; that under Section 10, the Secretary of War had the authority without any further

or other act of Congress specifically consenting to the reconstruction of this particular dock.

This Court, in passing upon this question, said:

(427) "Calumet river, it must be remembered, is entirely within the limits of Illinois, and the authority of the state over it is plenary, subject only to such action as Congress may take in execution of its power under the Constitution to regulate commerce among the several states. That authority has been exercised by the state ever since it was admitted into the Union upon an equal footing with the original states."

The Court further said (428):

"Did Congress, in the execution of its power under the Constitution to regulate interstate commerce, intend by the legislation in question to supersede, for every purpose, the authority of Illinois over the erection of structures in navigable waters wholly within its limits? Did it intend to declare that the wishes of Illinois in respect of structures to be erected in such waters need not be regarded, and that the assent of the Secretary of War, proceeding under the above acts of Congress, was alone sufficient to authorize such structures?"

Again, it is stated (430):

"If it had intended by the act of 1899 to assert the power to take under national control, for every purpose, and to the fullest possible extent, the erection of structures in the navigable waters of the United States that were wholly within the limits of the respective states, and to supersede entirely the authority which the states, in the absence of any action by Congress, have in such matters, such a radical departure from the previous policy of the government would have been manifested by clear and explicit language. In the absence of such language it should not be assumed that any such departure was intended."

* * *

"Whether Congress may, against or without the expressed will of a state, give affirmative authority to private parties to erect structures in such waters, it is not necessary in this case to decide. It is only necessary to say that the Act of 1899 does not manifest the purpose of Congress to go to that extent under the power to regulate foreign and interstate commerce and thereby to supersede the original authority of the states. *The effect*

of that act, reasonably interpreted, is to make the erection of a structure in a navigable river, within the limits of a state, depend upon the concurrent or joint assent of both the national government and the state government. The Secretary of War, acting under the authority conferred by Congress, may assent to the erection by private parties of such a structure. Without such assent the structure cannot be erected by them. But under existing legislation they must, before proceeding under such an authority, obtain also the assent of the state acting by its constituted agencies."

In

Montgomery v. *Portland*, 190 U. S. 89,

the Secretary of War had established, under the Congressional Act, harbor lines in the Willamette River. Likewise, harbor lines were established under state authority, which coincided with the harbor lines fixed by the Secretary of War, beyond which piers, wharfs, etc., could not be built. Montgomery obtained a changing of the harbor line by the Secretary of War, whereby the harbor line was extended further out into the stream, and the Secretary of War consented to his building his wharf there and beyond the harbor line fixed by state authority. He proceeded to build his wharf on the line last fixed by the Secretary of War, and the City of Portland filed its bill in the State Court to enjoin construction, and the case reached this Court by writ of error to the Supreme Court of Oregon. The Court reiterated its holding in the *Cummings case*, and held that to permit Montgomery to construct his wharf on the new line fixed by the Secretary of War, it was necessary also to obtain the state's consent. It then said (p. 107):

> "It is sufficient now to say that the legislation upon which the defendant relies to justify the construction of the works in question does not, when reasonably interpreted, indicate any purpose upon the part of Congress to assume such complete and absolute control of the navigable waters of the United States as will make of no avail the action of the states in respect of the erection by private parties of structures in waters wholly within their respective limits."

Ths Court, in the *Cummings* and *Montgomery cases, supra*, held that the state's authority was concurrent with that of the Federal Government under the Rivers and Harbors Act of March 3, 1899, and that the state's direct regulation of navigable waters within its limits had not been denied or superseded by the legislation mentioned. How much stronger is the case where the state's action is in the interest of public health, as here, and where the principal effect of appellants works upon navigation is in aid thereof and the claimed injury, if any, to commerce is only indirect and incidental.

In

Corrigan Transit Company v. *The Sanitary District of Chicago*, 137 Fed. 851, (C. C. A. 7th Circuit),

the permit of May 8, 1899, authorizing the opening of appellant's Sanitary and Ship Canal, was directly under consideration. The suit was filed by the Corrigan Transit Company to recover damages to a boat which damage it was claimed resulted from the current in the Chicago River created by appellant's diversion. The Court held that the recitals or preambles of the permit of May 8, 1899, did not limit the granting clause—namely, to open the channel; that therefore the permit was unlimited. In other words, there was express authority from the Secretary of War to operate the Sanitary and Ship Canal to its full capacity.

In speaking of the effect of Section 10 of the Rivers and Harbors Act of March 3, 1899, the Court of Appeals, speaking through Mr. Justice Baker, said (p. 856):

> "Congress, acting under the commerce clause, said to Illinois, which would otherwise be sovereign, 'You are not to change the course of the river unless you first obtain the secretary's approval of your plan.' The sentence in its entirety—the subjunctive clause as well as the indicative—expressed the will of Congress. The expressed intention was, not to exclude Illinois utterly from exercising her police powers over the river for the welfare of her citizens (and that suggests a nice and delicate question), but to permit the continuation of the exercise upon condition. Now, if the conditional clause is to be deleted, it is not for the courts to construct a new

congressional policy out of the fragment. Compare *Montgomery* v. *Portland*, 190 U. S. 105, 23 Sup. Ct. 735, 47 L. Ed. 965.

(4) If section 10 stands, libelants' attack fails, because defendant obtained the permit and complied with its conditions. If section 10 falls, what is the result? If a matter affecting commerce is of national scope and susceptible of uniform regulation, the failure of Congress to speak to the subject is deemed equivalent to a declaration that the states shall let the matter alone; but if the matter is local, and concerns the public policy of a state, though it may incidentally affect interstate and foreign commerce, congressional inaction is a recognition that the subject is fitted for local regulation, and is an invitation that the state continue in the unimpeded exercise of its police powers, on the understanding, however, that Congress may thereafter intervene to the extent, at least, of destroying and forbidding whatever unnecessarily embarrasses commerce. *Covington Bridge Co.* v. *Kentucky*, 154 U. S. 204, 14 Sup. Ct. 1087, 38 L. Ed. 962; *Lake Shore, etc., Ry. Co.* v. *Ohio*, 173 U. S. 285, 19 Sup. Ct. 465, 43 L. Ed. 702, and cases therein cited. The bridging, dredging, purification of a navigable waterway wholly within a state are matters of the latter class. *Escanaba Transp. Co.* v. *Chicago*, 107 U. S. 678, 2 Sup. Ct. 185, 27 L. Ed. 442; *Lake Shore, etc., Ry. Co.* v. *Ohio*, 165 U. S. 365, 17 Sup. Ct. 357, 41 L. Ed. 747. With the commerce clause in abeyance, Illinois, as to every being in the world except future Congresses, was absolute sovereign in the premises. The absolute sovereign may change the grade of highways or may vacate them, may alter the courses and currents of rivers or may dam or fill them up, and neither alien nor subject traveler and navigator may complain. No one can claim a vested right to have the United States interfere with Illinois, nor can a cause of action arise from want of interference."

The work of excavating to provide for the diversion has been authorized by the Secretary of War and recommended by the Chief of Engineers. The reversal of the course and current of the river, has likewise been authorized. The connection of the Sanitary and Ship Canal with the West Fork of the South Branch of the Chicago River, was approved. Everything for the lawful diversion to the full capacity of the Sanitary and Ship Canal has been obtained.

In

Canada Atlantic Transit Company v. *Chicago*, 210 Fed. 7, (C. C. A. 7th Circuit),

the court had before it an ordinance of the City of Chicago requiring that vessels navigating the Chicago River when passing any bridge, shall move at a rate of speed not less than two miles per hour, and that steam vessels of 1,200 gross tons burden, or more, while navigating certain portions of the river, shall have the assistance of a tug or tugs. The court held the ordinance valid, and that it was within the province of the state, acting through the City of Chicago, to make such regulation. It also held that the reasonableness of the ordinance was not to be questioned, saying, through Judge Seaman:

(10) "All the contentions on behalf of the appellants in derogation of such power inherent in the state, must be overruled".

With reference to the inherent power of the state the court said:

(11) "Neither preponderance of evidence nor proof which convinces the court of want of justifiable cause for the requirements, can serve to authorize judicial interference with legislative action upon a subject within the power of the state or municipal legislation."

The Court cited upon this proposition the strong statement of Mr. Justice Holmes in *Laurel Hill Cemetery* v. *San Francisco*, 216 U. S. 358.

We apprehend that the capacity of the navigable water of the United States may be altered or modified in the way provided by said ordinance mentioned in Canada Atlantic Transit Co., *supra*, just as completely, so far as the effect upon commerce is concerned, as they may be altered by excavation or filling in such navigable waters.

We refer the Court to the following cases:

Escanaba L. M. Transportation Company v. *Chicago*, 107 U. S. 678.

Lake Shore & Michigan Southern Railroad Company v. *Ohio*, 165 U. S. 365.

Cardwell v. *American River Bridge Company*, 113 U. S. 205.

Huse v. *Glover*, 119 U. S. 543.

Willamette Iron Bridge Company v. *Hatch*, 125 U. S. 1.

The creation of the appellant's Sanitary and Ship Canal and its other diversion works, was "authorized by law" under the Rivers and Harbors Act of September 19, 1890.

United States v. *Bellingham Bay Boom Co.*, 176 U. S. 211.

The Act of March 3, 1899, declaring that obstructions "not authorized by Congress" were prohibited (Section 10), did not intend to make unlawful those things lawfully provided for under the 1890 Act.

(b) The diversion by appellant to the amount necessary for the operation of its works, is lawful without the express consent of the Secretary of War. Any other construction of the Act of March 3, 1899, would tend to nullify appellant's acts in the interest of public health. This result cannot obtain unless such congressional intention is expressed in plain and unmistakable terms.

The position boldly taken by appellee is that Congress has provided that nothing shall be done affecting navigable waters of the United States unless the consent of the Secretary of War has been obtained, and that the diversion beyond 4,167 seconds feet is unlawful unless the Secretary of War has directly and in terms consented to it. It is immaterial, says appellee, for what reason the Secretary of War has failed to expressly authorize the excess diversion. We have shown that the work of excavating in the channels of the Chicago River for the purpose of withdrawing water to the full capacity of appellant's Sanitary and Ship Canal was authorized

by the Secretary of War; that he had directed and authorized the opening of this canal and its connection with the river; that the permit of May 8, 1899, so authorizing, was unlimited except by the maximum capacity in the Sanitary and Ship Canal; and that the Secretary of War had limited the withdrawal by his order of December 5, 1901, before the work of excavating, pursuant to the Secretary of War's authority of July 11, 1900, had been commenced or completed. We have then, under the July 11, 1900 permits, direct authority to alter or modify the navigable capacity of the navigable waters of the United States, wherever situated, necessary or resultant from the work of excavating which had been done. We have, on the other hand, a supposed limitation of the amount of withdrawal, never removed, which is in conflict with the permits of July 11, 1900. There is also the refusal of the Secretary of War to remove the limitation—not because of any condition expressed in the May 8, 1899 permit, but because of the claimed injury or obstruction to navigable waters other than the Chicago River—namely, the Great Lakes and their connecting channels. However, the Great Lakes and their connecting channels were waters, if the appellee's contention is correct as to the effect of the diversion thereon, which would be altered or modified by the doing of the work of excavating authorized by the Secretary of War under the July 11, 1900 permits.

We lay aside, for the moment, all these circumstances relating to the unreasonableness of the Secretary of War's action in failing to remove the limitation of December 5, 1901, and our contention that the diversion is lawful for the reason that the work necessary to accomplish the diversion of 10,000 cubic seconds feet of water through the channels of the Chicago River and its branches to the Sanitary and Ship Canal has been fully authorized.

The acts of appellant, taken pursuant to the state's police power, in diverting the amount of water required for sanitary purposes and the protection of the water supply, must stand as lawful, without the express consent of the Secretary

of War. These acts, under the undoubted reserve power of the state, must prevail over the acts of or failure to act by the Secretary of War, unless it is clear that Congress intended otherwise. There is no such intention expressed in any Congressional act. It has always been recognized by this Court that the protection of public health by the states is paramount. Congressional acts or authority apparently in conflict with such acts taken by the state must be so reconciled that the state may be left unfettered in the exercise of such police power. Of course, it is assumed that in such instances the state's acts are reasonably necessary to accomplish the purpose desired.

In

Columbus v. *Mercantile Trust Co.*, 218 U. S. 645,

this court said, (658):

> "No higher police duty rests upon the municipal authority than that of furnishing an ample supply of pure and wholesome water for public and domestic uses."

In

Missouri v. *Kansas Natural Gas Co.*, 68 L. Ed. Advance Sheets p. 585, June 16, 1924,

this court held that the State of Kansas was without power to fix rates of gas sold by a supply company transporting the gas in mains from outside the state. In no instance did the supply company sell the gas directly to consumers but merely sold it to distributing companies, who thereupon transmitted and sold it to individual concerns. This followed the holding in the case of

Public Utilities Commission v. *Landon*, 249 U. S. 236.

However,

Pennsylvania Gas Co. v. *Public Service Commission*, 252 U. S. 23,

was a case where the gas was transmitted from Pennsylvania directly to the consumers of the gas in Jamestown, New York. The acts taken under the authority of the State of

New York in fixing the price of gas to the consumers was held valid by this court. In distinguishing that case, this court said, in

Missouri v. *Kansas Natural Gas Co., supra,* (p. 587)

"The service to the consumers, which was the thing for which the regulated charge was made, was essentially local, and the decision rests upon this feature."

In

Texas v. *White,* 7 Wall. 700, 725,

it is stated:

"But the perpetuity and indissolubility of the Union by no means implies the loss of distinct and individual existence, or of the right of self-government by the states. * * * The Constitution, in all its provisions, looks to an indestructible Union, composed of indestructible states."

In

New York v. *Miln,* 11 Peters 102, 139,

a penalty was provided by the state for the failure of a ship's master to, within twenty-four hours, report the names, age and last settlement of persons on board the vessel arriving at port. This court said:

"It is not only the right, but the bounden and solemn duty of a state to advance the safety, happiness and prosperity of its people, and to provide for its general welfare by any and every act of legislation which it may deem to be conducive to these ends."

The delimitation between the state's police powers and the powers exercised under the Commerce Clause of the Constitution of Congress was so thoroughly discussed by this court in

Minnesota Rate Cases, 230 U. S. 352,

that is seems unnecessary and useless to attempt to add any thing to the opinion in that case. In that case this court said (402):

"Further, it is competent for a state to govern its internal commerce, to provide local improvements, to cre-

ate and regulate local facilities, to adopt protective measures of a reasonable character in the interest of the health, safety, morals and welfare of its people, although interstate commerce may incidentally or indirectly be involved."

In

Lake Shore & Michigan Southern v. *Ohio*, 173 U. S. 285,

a state law providing for stops of trains at certain stations was upheld, even though it operated upon interstate trains.

In

Hennington v. *Georgia*, 163 U. S. 299,

a state law providing against the operation of all trains on Sunday, state or interstate, was upheld. This court said (317):

> *"Legislative enactments of the states passed under their admitted police powers, and having a real relation to the domestic peace, order, health and safety of their people, but which, by their necessary operation, affect, to some extent, or for a limited time, the conduct of commerce among the states are yet not invalid by force alone of the grant of power to Congress to regulate such commerce."*

It is the rule, many times repeated, that the power of Congress under the Commerce Clause of the Constitution is a dormant one and remains in the states until Congress occupies the field or assumes the power; yet it is also the established rule that without the exercise of specific power interstate commerce must be free. Any law of the state directly obstructing such commerce is invalid. So the cases upholding state laws, passed in the interest of public health, safety or morals, which operate indirectly in obstructing interstate commerce, are in point in determining the validity of similar acts of the state which indirectly affect or burden some regulation of such commerce expressly provided by Congress. In such situation, unless the congressional act clearly and plainly shows that Congress intended to cut the state off from any exercise of authority on the subject, the state act

will prevail. Here we have the acts of appellant, taken in the exercise of the highest order of police power by the state, requiring the withdrawal of water from Lake Michigan to the amount of at least 10,000 cubic seconds feet, indirectly affecting, as it is claimed by appellee, interstate commerce by reason of the lowering of the surface elevations of the Great Lakes and their connecting channels. There is no claim that this obstruction of navigation—lowering the lake surfaces—absolutely stops interstate commerce, but merely inconveniences it or makes it slightly more expensive.

In

Hennington v. *Georgia, supra,*

the state's statute against the operation of any and all trains on Sunday absolutely stopped interstate commerce by railroad through the state one-seventh of the time. But, as the court said, this was not intended to be a direct burden upon interstate commerce, but was merely intended to express the will of the people of Georgia on the question of whether the Sabbath day should be observed in a certain manner, *and only incidentally affected interstate commerce.*

In

Crossman v. *Lurman*, 192 U. S. 189,

the constitutionality of the State Pure Food Law was upheld. There was also a federal act involving the same subject.

In

Plumley v. *Massachusetts*, 155 U. S. 461,

the oleomargine law was held constitutional, even though it operated indirectly as a burden upon interstate commerce.

Also see

In re Rahrer, 140 U. S. 545, 554.

In

Mutual Loan Co. v. *Martell*, 222 U. S. 225,

a state statute declaring invalid assignments of wages unless accepted by the employer and filed and recorded in a certain manner, was upheld, this court saying (p. 233):

> "Legislation cannot be judged by theoretical standards. It must be tested by the concrete conditions which induced it."

The repugnance of the Congressional Act must be direct and positive in order that the state's acts may be held invalid.

In

Cummings v. *Chicago*, 188 U. S. 410, 430,

the court, in speaking of this very question, said:

> "In the absence of such language, it should not be assumed that any such departure was intended"—
>
> *Savage* v. *Jones*, 225 U. S. 501.

In

Missouri, Kansas & Texas Ry. Co. v. *Haber*, 169 U. S. 613,

the state act with reference to the importation into the state of diseased cattle was upheld, although there was a federal statute pertaining to the same subject matter. This court said, (623):

> "May not these statutory provisions stand without obstructing or embarrassing the execution of the Act of Congress? * * * *A statute* enacted in the execution of a reserved power of the state is not to be regarded as inconsistent with an Act of Congress passed in the execution of a clear power under the Constitution, unless the repugnance or conflict is so direct and positive that the two acts cannot be reconciled or stand together."

In

Reid v. *Colorado*, 187 U. S. 137, 148,

the state cattle inspection law was upheld. This court said:

> "It should never be held that Congress intends to supersede, or by its legislation suspend the exercise of the

police powers of the states, even when it may do so, unless its purpose to effect that result is clearly manifested."

In

Sinnott v. *Davenport*, 22 How. 227,

the state's ship registration law was upheld. This court said, (243):

"* * * in the application of this principle of supremacy of an Act of Congress in a case where the state law is but an exercise of a reserve power, the repugnance or conflict should be direct and positive, so that the two acts could not be reconciled or consistently stand together; * * *"

In

Missouri Pacific R. R. Co. v. *Larabee Flour Mills Co.*, 211 U. S. 612,

this court said, (623):

"Running through the entire argument of counsel for the Missouri Pacific is the thought that the control of Congress over interstate commere, and a delegation of that control to a commission, necessarily withdraws from the state all power in respect to regulations of a local character. This proposition cannot be sustained. Until specific action by Congress or the Commission, the control of the state over these incidental matters remains undisturbed."

In

Missouri, Kansas & Texas R. R. Co. v. *Harris*, 234 U. S. 412, 418,

the court, in speaking of the powers of the Interstate Commerce Commission, as affecting state regulations, said:

"These cases recognize the established rule that a state law enacted under any of the reserved powers—especially if under the police power—is not to be set aside as inconsistent with an Act of Congress, unless there is actual repugnancy, or unless Congress has, at least, manifested a purpose to exercise its paramount authority over the subject. *The rule rests upon fundamental grounds that should not be disregarded.*"

In

Carey v. *State of South Dakota*, 250 U. S. 118,

a state statute relating to the shipment out of the state of migratory birds was upheld. This court said, (122):

> "It is, however, urged that Congress has manifested its intention to assume exclusive jurisdiction of the subject; and that the failure to make any provision in the Federal act concerning shipping evidences the purpose of Congress that the shipping of game birds shall not be prohibited. This argument rests upon the clause which declared that the migratory birds 'shall hereafter be deemed to be within the custody and protection of the government of the United States.' But that clause may not be read without its context; and the words immediately following show that the custody and protection is limited to prohibiting their being 'destroyed or taken contrary to regulations' which are to fix the closed seasons in the several zones. If, reading the Federal act as a whole, there were room for doubt, two established rules of construction would lead us to resolve the doubt in favor of sustaining the validity of the state law. *First*: The intent to supersede the exercise by a state of its police powers is not to be implied unless the act of Congress, fairly interpreted, is in actual conflict with the law of the State. *Savage* v. *Jones*, 225 U. S. 501, 533, 56 L. ed. 1182, 1194, 32 Sup. Ct. Rep. 715; *Missouri, K. T. & R. Co.* v. *Haber*, 169 U. S. 613, 623, 42 L. ed. 878, 881, 18 Sup. Ct. Rep. 488. *Second*: Where a statute is reasonably susceptible of two interpretations, by one of which it would be clearly constitutional and by the other of which its constitutionality would be doubtful, the former construction should be adopted."

In

Houston, East & West Texas Ry. Co. v. *U. S.* 234 U. S. 342,

(the *Shreveport cases*), the order of the Interstate Commerce Commission was upheld because it was clear and plain in such order that it was the intention to hold certain intrastate rates to be discriminatory against certain interstate rates, and the removal of this discrimination was unmistakably directed. However, in

Illinois Central R. R. Co. v. *Public Utilities Commission*, 245 U. S. 493,

this court did not permit the order of the Interstate Commerce Commission to override that of the Public Utilities Commission of Illinois for the reason that the order of the Interstate Commerce Commission was uncertain and indefinite, and did not clearly express an intention so to do.

The court said, (510):

"In construing Federal statutes enacted under the power conferred by the commerce clause of the Constitution the rule is that *it should never be held that Congress intends to supersede or suspend the exercise of the reserved powers of a state, even where that may be done, unless, and except so far as,* its purpose to do so is *clearly manifested.* * * * (Citing numerous cases.) This being true of an act of Congress, it is obvious that an order of a subordinate agency, such as the Commission should not be given precedence over a state rate statute otherwise valid, unless, and except so far as, it conforms to a high standard of certainty.

"We conclude that the uncertainty in this order is such as to render it inoperative and of no effect as to the intrastate rates established and maintained under a law of the state, and therefore that the suits by the carriers were rightly dismissed on the merits."

In

Sligh v. *Kirkwood,* 237 U. S. 52,

held the statute of Florida against offering for sale or shipment decayed fruits, valid. This court said:

(60) "Nor does it make any difference that such regulations incidentally affect interstate commerce, when the object of the regulation is not to that end, but is a legitimate attempt to protect the people of the state."

* * *

"and whether such regulation is necessary in the public interest is primarily within the determination of the legislature, assuming the subject to be a proper matter of state regulation."

In

Hammer v. *Dagenhart,* 247 U. S. 251,

which case involved the validity of the Child Labor Law, this court said:

(p. 273)

"The grant of power to Congress over the subject of interstate commerce was to enable it to regulate such

commerce, and not to give it authority to control the states in their exercise of the police power over local trade and manufacture.

"The grant of authority over a purely Federal matter was not intended to destroy the local power always existing and carefully reserved to the states in the 10th Amendment to the Constitution.

"Police regulations relating to the internal trade and affairs of the states have been uniformly recognized as within such control."

* * *

(p. 275)

"* * * The maintenance of the authority of the states over matters purely local is as essential to the preservation of our institutions as is the conservation of the supremacy of the Federal power in all matters intrusted to the nation by the Federal Constitution."

(p. 276)

* * *

"* * * This court has no more important function than that which devolves upon it the obligation to preserve inviolate the constitutional limitations upon the exercise of authority, Federal and state, to the end that each may continue to discharge, harmoniously with the other, the duties intrusted to it by the Constitution."

* * *

(p. 276)

"* * * Thus the act in a twofold sense is repugnant to the Constitution. It not only transcends the authority delegated to Congress over commerce, but also exerts a power as to a purely local matter to which the Federal authority does not extend."

With the language of the above case in mind, consider the situation of the people residing within appellant's territorial limits, and the geographical location of Chicago, with its ever-increasing activity in trade and commerce, situated, as it is, at the lower end of Lake Michigan. We have, on the one side, the immense transportation facilities of the Great Lakes connecting, through the St. Lawrence River and the Erie Canal with the Atlantic Ocean. Chicago is the gateway also to the great transportation system of the Mississippi River and its tributaries. This transportation system reaches ap-

proximately fourteen of the richest states of the Union— not only in the fertility of soil but in the production of minerals and manufactures. Chicago is one of the termini of practically all of the great railroad systems of the country. Almost forty years ago her population reached approximately 1,000,000 people—greater than is now the population of either Cleveland, Detroit, Buffalo or other great cities on the Lakes. Her only water supply was Lake Michigan. Unless her sewage and drainage could be diverted from Lake Michigan to the Illinois River, it was necessary that it be discharged either through the Chicago River or by means of sewers or otherwise into Lake Michigan. The only way that a pure water supply for this vastly increasing population could be obtained was by diverting the sewage and drainage from the Lake. The people of Chicago would have been derelict in their duty to the nation, to themselves and to posterity if they had not availed themselves of the only opportunity they had to provide a pure water supply. There are no cities of any size in the United States, except those cities located upon the shores of the Great Lakes, that are compelled to obtain a water supply from a source (the Lake) which also is the place into which the city is naturally drained. Chicago is the only one of these cities that had the opportunity to do what other cities of the United States of size do—namely, to obtain water from an unpolluted source and discharge sewage into streams that do not constitute a water supply for any considerable population. The Desplaines and Illinois Rivers have not been and are not a water supply for human beings.

Other large cities located on the shores of the Great Lakes are only, now, at this late date confronted with the problem that Chicago had forty years ago. The people of Chicago and environs proceeded to cause the construction by appellant of the works necessary for and provided for themselves a pure water supply at an expense of approximately a hundred million of dollars. The only objections that have ever been made to this plan have just recently arisen from navigation inter-

ests which operate ore-carrying vessels, and from the water power interests on the Niagara and St. Lawrence. This geographical situation of Chicago invited and required the protection of the water supply of the people of Chicago by diverting the sewage and drainage from Lake Michigan, with the necessary abstraction of water to accomplish that purpose. This whole problem is one of local concern. It can be best handled by local authorities whose interests are the securing of the proper results, and whose acts should be unquestioned. The effect upon navigable waters whether wholly within the state or outside is purely incidental, and, in fact, more helpful than harmful.

These facts lend further force to the proposition that the Act of Congress of March 3, 1899 and the action of the Secretary of War thereunder, shall not be deemed repugnant to the state acts unless the intention of Congress so to do is expressed in the very clearest language.

In the Child Labor Tax case,

Bailey v. *Drexel Furniture Co.*, 259 U. S. 20,

this court, in speaking of the principles here contended for, and so admirably stated in the numerous cases above cited, pointing out the necessity of adherence to them, said, (37):

> **"In the maintenance of local self-government, on the one hand, and the national power, on the other, our country has been able to endure and prosper for nearly a century and a half."**

It is thus apparent that Section 10 of the Rivers and Harbors Act of March 3, 1899, and the acts of the Secretary of War thereunder, cannot be construed as repugnant to the Illinois Act of May 29, 1889, and to the operation of the works of appellant built thereunder.

Charles Warren, in his work entitled

"The Supreme Court in United States" (1922), Vol. 3, page 464,

in speaking of this Court's attitude in cases involving the police power of the states, said:

> "It may fairly be said that the support which the court has thus given to the police power of the states has been

one of the most remarkable features of its career. Certainly a litigant who hopes to overturn the deliberate judgment of a State Legislature, as expressed in this form of legislation, has a very scanty hope of assistance from the court."

Again the author states (466):

"The doctrine which the court has finally worked out in deciding these constitutional cases may be summed up briefly as the recognition of 'the paramount right of public necessity.'"

(c) Congress has otherwise by legislation indicated that it was not its intention to prohibit the operation of appellant's diversion works, or that any act of any of its officers should have that effect.

We have in the statement of this case (p. 48) set forth various acts of Congress indicating that it was the Congressional intention that appellant's diversion should proceed as required by state law, unhindered; that no executive officer was empowered to limit it, and that if any regulation was to be made of this diversion, it would be done by Congress in the future.

In the very Rivers and Harbors Act of March 3, 1899 (Statement 49), containing Section 10, upon which appellee relies for the Secretary of War's authority, there is an item providing for a survey for the improvement of the Illinois and Des Plaines River *"with a view to the extension of navigation from the Illinois River to Lake Michigan at or near Chicago * * * in pursuance of and according to the recommendations in the report of January 27, 1897."* The report referred to was the one made by Major Marshall pursuant to a previous act of Congress. This report described in detail appellant's Sanitary and Ship Canal, its size and the purpose of diverting at least 600,000 cubic feet of water from Lake Michigan through it—that is, its capacity (Statement, p. 48).

Certainly it cannot be conceived, in view of the attitude of Congress as to the powers of the states over local matters,

particularly those matters affecting public health, that Congress intended by inference merely under Section 10 to delegate the regulation of appellant's works to an executive officer. These works had been constructed over a period of ten years, and the purpose of the construction was well known. The progress of the work had been reported to Congress almost yearly by means of the Chief of Engineers' reports. The purpose of Congress in requiring these reports was to obtain each year specific information with reference to the condition of navigable waters, in order to determine whether there were encroachments which might not be in accordance with the will of Congress. If it found that there were works being built that would operate as undesirable obstructions to navigation, it could and would have specially legislated. Some specific langauage would have been used indicating the clear intention of Congress that the Secretary of War should regulate this diversion, if that were the Congressional intention.

Congress followed this procedure with reference to the encroachments of the Chandler-Dunbar Water Power Co. in the St. Mary's River. It, in that case, specially legislated with reference to these various obstructions, canceling all permits and licenses in existence and directing the Secretary of War to take proceedings to remove these obstructions.

United States v. *Chandler-Dunbar W. P. Co.*, 229 U. S. 51.

The Rivers and Harbors Act of June 6, 1900, contained a provision for the continuing of the survey provided for by the Act of 1899 (specially mentioning appellant's Sanitary and Ship Canal)

> "for a channel 14 feet deep through said proposed route, and that said estimates cover and include a proper connection *at Lockport with the Sanitary and Ship Canal, which has been constructed by the Sanitary District of Chicago.*" (Statement p. .)

In the Rivers and Harbors Act of June 13, 1902, further survey was provided for

> "from Lockport, Illinois, by way of the DesPlaines and Illinois Rivers, to the mouth of the said Illinois River,

and from the mouth of the Illinois River by way of the Mississippi River to St. Louis". (Statement, p. 49.)

Section 4 of the same act provided for the establishment of the International Waterways Commission. This commission was to make a study of the conditions of all boundary waters upon which a treaty might be framed, and also

"upon the effect upon the shores of these waters and the structures thereon, and upon the interests of navigation by reason of the diversion of these waters from or change in their natural flow, and further to report upon the necessary measures to regulate such diversion and to make such recommendations for improvements and regulations as shall best serve the interests of navigation in said waters". (Statement, 50.)

The above quotation from the Rivers and Harbors Act, referred directly to the Chicago diversion. The International Waterways Commission understood that the clause referred to the Chicago diversion, for it made several reports regarding it, including the special report upon the Sanitary and Ship Canal and its operation of January 4, 1907. (Appellant's Narrative, 505.) This Commission found the diversion of 10,000 seconds feet to be an existing fact, and that in dividing the water of the Niagara River between the United States and Canada for electric power purposes, the United States should be charged with the 10,000 seconds feet diversion, and that the State of Illinois and appellant were entitled to that diversion. The treaty itself followed the recommmendations of the International Waterways Commission in practically every respect. It preserved to the State of Illinois this diversion.

On April 21, 1904, Congress passed a resolution authorizing the Secretary of War to permit appellant to cut down the crests of the government dams in the Illinois River. (Statement 51.) The only purpose of this was to remove an obstruction to the flow in the Illinois River, and to arrange the river so that it would better carry appellant's additional diversion;—that is, the diversion that was or would be made

possible by the work of excavating in the channels of the Chicago River and its branches under the permits of the Secretary of War of July 11, 1900.

The Act of Congress of June 29, 1906, for the preservation of Niagara Falls (Statement 51) provided in Section 1:

> "That the diversion of water from Niagara River or its tributaries, in the State of New York, is hereby prohibited, except with the consent of the Secretary of War as hereinafter authorized in section two of this Act; *Provided, That this prohibition shall not be interpreted as forbidding the diversion of the waters of the Great Lakes or of Niagara River for sanitary or domestic purposes, or for navigation, the amount of which may be fixed from time to time by the Congress of the United States or by the Secretary of War of the United States under its direction.*"

The foregoing Act related to the preservation of Niagara Falls, which was being injured primarily by the use of the waters of the Niagara River for the development of water power. If the Rivers and Harbors Act of March 3, 1899, authorized the Secretary of War to regulate diversions of water, there would have been no occasion for the passage of this Act, for the Secretary of War could have regulated or limited diversions of water from the Niagara River for water power purposes under the 1899 Act as well as under the Act just quoted. Congress carefully by the proviso mentioned, indicates its intention that, under no circumstances, not even for the preservation of the scenic beauty of the Falls, shall the diversion at Chicago for domestic and sanitary purposes be affected, except as Congress may thereafter fix the amount. The words

> "or by the Secretary of War of the United States under its direction,"

mean that the Secretary of War may be *thereafter* directed how to fix that diversion. These words absolutely negative the idea that the Secretary of War was *then* authorized under any Act of Congress to fix the amount of the diversion. *No*

Act has been passed since authorizing the Secretary of War to limit or in any way affect the diversion for sanitary purposes.

Senator Lodge's statement in the United States Senate upon the report of the conferees concerning Senator Hopkins' amendment, leaves no doubt as to the intention of Congress as expressed by the proviso in Section 1 of said act for the preservation of Niagara Falls. It will be recalled that Senator Lodge said, as to his understanding of the meaning of the proviso and that of the conferees of the House and Senate—

> "The first section of the bill protects the right of Chicago." (Statement 53.)

The Rivers and Harbors Act of Congress of June 25, 1910, provided for a survey for the improvement of the waterway

> "from Lockport, Illinois, by way of the DesPlaines and Illinois Rivers to the mouth of said Illinois River",

and appropriated one million dollars for its construction. The Board of Engineers to be established, was to report

> "upon such measures as may be required to properly preserve the levels of the Great Lakes and to compensate, so far as practicable, for the diminished levels in said lakes and the connecting waters thereof, by reason of any diversion of water from Lake Michigan for the maintenance of the proposed waterway herein described, or diversion for any other purpose."

Here was a direct reference to the Chicago diversion. It speaks of a diversion for waterway purposes

> "or for any other purpose"

from Lake Michigan. There was and is no other diversion from Lake Michigan than the Chicago diversion. The Board of Engineers which was appointed under that act, made a report to Congress upon the diversion at Chicago and the means by which the surface elevations of the lakes could be restored. (Statement 71.) Certainly it is plain that it was not the intention of Congress that this abstraction of water from Lake Michigan for health purposes, should be limited or regulated. It is further clear that Congress did not under-

stand that by any previous act an executive officer had been empowered to frustrate the acts of the State of Illinois in the interest of the health of its people.

June 30, 1917, by resolution of Congress, the Secretary of War was authorized to cause a report to be made upon

> "the entire subject of water diversions from the Great Lakes and from the Niagara River, including nagivation, sanitary and power purposes". (Statement 55.)

The report was made. (Appellant's Narrative, p. 102.)

In

> *International Bridge Company* v. *People of State of New York*, 254 U. S. 126,

suit was instituted by the State of New York against the Bridge Company to collect certain penalties arising under a statute of New York of 1915 amending the charter of the International Bridge Company by directing that the bridge company construct a foot path across the bridge. The bridge was constructed under an act of the State of New York passed prior to 1870, and an act of Congress of 1870, authorizing the bridge company to construct a bridge across the International Stream, subject to plans being approved by the Secretary of War. Another act of Congress was passed later which found the bridge to be a lawful structure. There were reciprocal acts of Canada.

Was the Act of New York of 1915 providing for the foot path for the International Bridge valid? The court said:

> (131) "The only argument that impresses us, and the one that was most pressed, is that this is an international bridge, and that Congress has assumed such control of it as to exclude any intermeddling by the state. It is said that the bridge as constructed was and is devoted wholly to international commerce, and that when Congress authorized it in that form in 1874, that authority must be regarded as the charter under which it was maintained. Without repeating the considerations urged in support of this conclusion we will state the reasons that prevail with us. The part of the structure with which

we are concerned is within the territorial jurisdiction of the state of New York.

* * *

"Not only the existence of the company but its right to build upon New York land, came from New York, * * *.

* * *

"From an early date the state has been recognized as the source of authority, in the absence of action by Congress. * * * And this court has been slow to interpret such action as intended to exclude the source of rights from all power in the premises."

In

West Chicago Street R. R. Co. v. *People of Illinois*, 201 U. S. 505, 527,

this Court held that the approval of the Secretary of War was not necessary for the lowering of tunnels under the Chicago River as directed by an ordinance of the City of Chicago; and that Congress intended, by the Rivers and Harbors Act of March 3, 1899, that the work of "lowering tunnels," etc., to provide a twenty-one-foot depth in the Chicago River, should be done by Chicago,

"to give the assent of the United States to any work done by the City towards accomplishing the end which the Government had in view."

The lowering of the tunnels was part of the river enlargement work, under the July 11, 1900 permits, for appellant's 10,000 c. s. f. diversion through the Chicago River to the Sanitary & Ship Canal.

V.

APPELLEE HAS INVITED AND ACQUIESCED IN THE CONSTRUCTION BY APPELLANT OF ITS SANITARY AND SHIP CANAL TO DIVERT WATER FROM LAKE MICHIGAN TO THE AMOUNT REPRESENTED BY THE CAPACITY OF SAID CANAL. IT IS ESTOPPED NOW TO DENY THE RIGHT.

The Illinois and Michigan Canal as originally built was only a make-shift. It did not meet the ideas of the state and federal government for the creation of a waterway from Lake Michigan to the Illinois and Mississippi Rivers. As will be recalled from the statement of the case herein, hardly had the old Illinois and Michigan Canal been opened, than a demand immediately arose for its enlargement and for the diversion of water from Lake Michigan not only to operate the enlarged canal, but to furnish better navigable facilities on the Illinois River. The resolution of Illinois General Assembly of 1861, the Congressional Act for the survey of waterway of 1866, the provision for the other surveys following, are all important. The surveys made prior to the passage of the Act of May 28, 1889, all recommended that the waterway be improved by the building of an enlarged canal with the diversion of water to operate it. (Statement, p. 19.)

After the Act of May 29, 1889, was passed, the surveys and reports, as well as the congressional acts requiring them, looked to the utilization of appellant's Sanitary and Ship Canal, its adjuncts and the attendant diversion for a waterway, and also to the making of provisions for the restoration of lake levels by compensating works. (Statement, p. 34.)

The appellant expended upwards of seventy-five millions of dollars on the faith of the acquiescence in and the invitation extended for the building of the Sanitary and Ship Canal and its various adjuncts.

In

United States v. *Pennsylvania & Lake Erie Dock Company*, 272 Fed. 839, (C. C. A. Sixth Circuit), action of ejectment was brought by the United States to recover possession of a strip of land used as a pier by the defendant company. The Court found as facts: (*a*) That the government in the exercise of its paramount power over navigation had, in 1827, constructed a pier on part of the territory now in controversy; (*b*) That up to 1838, the government did expend money upon the maintenance of the pier; (*c*) That after 1838, the government did not expend any money upon the maintenance and repair of the south portion of the pier; (*d*) That the defendant company made application to the War Department for permission to encroach on the harbor line at the points indicated on a map submitted with the application; (*e*) That no objection and no claim was at that time made by the government to the submerged land; (*f*) That the defendant company made large expenditures for the concrete dock.

THE COURT HELD: That the evidence sustained the findings of the lower court; that the government had abandoned by failure and neglect, its right to the property in controversy saying:

> (848) "Regardless of whether the change in harbor lines was to be north or south of Second Street, the application and accompanying map fully informed the plaintiff of the purpose of the defendant to construct this concrete dock 15 feet wide upon this particular location. If the government then made any claim whatever to this property, it should then have asserted that claim, instead of delaying until after this defendant had expended large sums of money in the construction of this concrete dock; but it did nothing of the kind. On the contrary, it not merely passively, but by granting this permission for a change of harbor line, it actually, consented to the construction of this dock. It not only made no claims to this property at that time, but by its action induced the defendant to believe that it had no such claim, and that it had abandoned the exercise of its dominant power to construct and maintain a pier at this location.

The War Department was, by the Act of June 13, 1902, clothed with full authority to determine whether it would or would not maintain a pier along this portion of the water front, and it would seem that by this act alone, if by no other, the government must be held to have abandoned this particular site, or at least to have estopped itself from now claiming that it had not done so.

* * *

"In the case of *United States* v. *Stinson*, 197 U. S. 200-204, 25 Sup. Ct. 426, 49 L. Ed. 724, the Supreme Court held that, 'while laches or limitations do not of themselves constitute a distinct defense as against an action by the United States to assert a right in property,' nevertheless it affirmed the judgment of the lower court in that case, which judgment was based upon the declaration that 'the substantial consideration underlying the doctrine of estoppel applies to the government as well as to individuals.' Applying this doctrine to the facts of this case, in connection with the presumption that the United States government intended to act fairly in its dealings with its citizens, the finding of the trial court that the plaintiff had abandoned this part of the east pier and the location upon which it rested is sustained by competent evidence."

United States v. *Board of Commissioners of Osage County*, 254 Fed. 570, 573.

United States v. *Debell*, 227 Fed. 775, 779 (C. C. A., 8th Circuit).

United States v. *Midway Northern Oil Company*, 232 Fed. 619, 631.

The above cited cases enunciated the principle that

"It derogates from the dignity and character of the government to suppose that, formed as it is to secure impartial justice between individuals, it may nevertheless, in the conduct of its own affairs, without regard to the principles it represents, perpetrate upon its citizens wrongs which it would promptly condemn if practiced by one of them upon another."

United States v. *Chandler-Dunbar W. P. Co.*, 152 Fed. 41, 81.

In

Monongahela Navigation Company v. *United States*, 148 U. S. 312,

which was a proceeding by the government to condemn certain lands, the Court said (p. 334):

"* * * in this case there was not only the full authority of the State of Pennsylvania, but also so far as respects this particular lock and dam they were constructed at the instance and *implied invitation of Congress.* The Act of March 3rd, 1881, making appropriations for the improvement of the river in terms provided that no such improvement should be made until the * * * company had in good faith started upon the building of this lock and dam. * * * This is something more than the mere recognition of an existing fact; it *is an invitation to the company to do the work; and when in pursuance of that* invitation, and under authority given by the State of Pennsylvania, the company has constructed the lock and dam, it does not lie in the power of the state or *the United States to say that such lock and dam are an obstruction and wrongfully there,* * * *."*

In

Hemmer v. *United States*, 204 Fed. 898 (8th C. C. A.),

a suit was instituted by the United States for the purpose of setting aside certain conveyances which had been made under the Indian Homestead Law on the ground that a statute passed subsequently to the one under which the original homesteader had acquired his land had prolonged the restriction of alienation to twenty-five years, though it had been but five years before the passage of the Act. At page 901 the Court said:

"This is a suit in equity. In such a suit the claims of the government appeal to the conscience of the chancellor with no greater or less force than those of a private individual under similar circumstances. (Citing cases.)"

In

State of Iowa v. *Carr*, 191 Fed. 257 (8th C. C. A.),

there was an appeal by defendants in a suit to quiet title to a certain piece of land which had formed in a river. The

facts showed that complainant had occupied the land for a long period of time and had made improvements and paid taxes thereon without objection from either the state or the other complainants. At page 266 the Court said:

> "The equitable claims of a state or of the United States appeal to the conscience of a Chancellor with the same, but with no greater or less force than would those of an individual under the circumstances. (Citing cases.)"

The improvement of the critical points of navigation in the Great Lakes was fixed six inches lower by reason of the Chicago diversion. This improvement is known as the "1903 project" (Appellant's Narrative, p. 155). The table (Appellant's Narrative, p. 162) shows the project depths of the various improvements in the channels and harbors, where sail the large ore-carrying boats which claim to have been affected in their carrying capacities. This table also shows the actual depths of water which obtained up to the year 1922, at low water times. An examination of this table demonstrates that at no time was the depth of water less than the project depths. In fixing the reference plane lower for these various improvements because of the Chicago diversion, the Government accepted it as an existing fact, and Congress thereby not only acquiesced, but actually consented to the diversion and whatever effect it might have upon the lakes. It will be remembered that on August 16, 1895, the Board of Engineers reported to the Secretary of War on the subject of the effect of the diversion of 10,000 seconds feet, and in 1898 to 1900 deductions were made by the Lake Survey of the United States as to the effect of this lowering. The report of 1895, and the deductions made by the United States Lake Survey indicated that the effect on Michigan and Huron would be approximately six inches.

Appellant excavated the channels of the Chicago River and its branches to provide for a diversion of 10,000 seconds feet through them to its Sanitary and Ship Canal. If it were not going to abstract more than 4,167 seconds feet, all this work

was unnecessary. It also built, on the faith of the permits of July 11, 1900, for the excavation in said channels, intercepting sewers, North Shore and Calumet Sag Channels, pumping stations and other works. On the principle of the cases cited, appellee cannot now be heard to say that appellant has not the right. No intimation was given to appellant that the right was denied until after the work was done. The purpose of this expenditure was well known to appellee.

The force and effect of the treaty between the United States and Great Britain of January 11, 1909, relating to Canadian boundary waters and the reports of the International Waterways Commission recommending its terms.

As before stated, the International Waterways Commission, in its reports of May 3, 1906 (Appellant's Narrative, p. 104), and January 4, 1907 (Appellant's Narrative, p. 505), found and recommended that there should be allowed at Chicago a diversion from the Great Lakes system, at least 10,000 cubic seconds feet of water. In dividing the water for diversion at Niagara Falls for power purposes between the United States and Canada, the United States was charged with the 10,000 seconds feet Chicago diversion. In other words, it was agreed that Canada might, under the treaty, divert some 16,000 seconds feet at Niagara Falls more than the United States, because of this Chicago diversion. When the treaty was made, the right to divert this water by appellant and the State of Illinois was recognized. That right was not in any respect curbed. The treaty expressly eliminates from its terms by the preliminary article, Lake Michigan, as follows:

> "For the purposes of this Treaty boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms, and inlets thereof, but not including *tributary waters which in their natural channels would flow into such lakes, rivers, and*

waterways, or waters flowing from such lakes, rivers and waterways, or the waters of rivers flowing across the boundary."

Obviously, Lake Michigan is not a boundary water, as defined by the Treaty.

Article II of the Treaty reserves to each of the parties, or to the state governments, or provincial governments, as the case may be, all rights over these nonboundary waters, as follows:

> "Each of the High Contracting Parties reserves to itself, or to the several State Governments, on the one side, and the Dominion or Provincial Governments on the other, as the case may be, subject to any Treaty provisions now existing with respect thereto, the exclusive jurisdiction and control over the use and diversion, whether temporary or permanent, of all waters on its own side of the line which in their natural channels would flow across boundary or into boundary waters; but it is agreed that any interference with or diversion from their natural channels of such waters, on either side of the boundary resulting in any injury on the other side of the boundary, shall give rise to the same rights and entitle the injured parties to the same legal remedies as if such injury took place in the country where such diversion or interference occurs; but this provision shall not apply to cases already existing, or to cases expressly covered by special agreement between the parties hereto.
>
> It is understood, however, that neither of the High Contracting Parties intends by the foregoing provision to surrender any right which it may have to object to any interference with or diversions of waters on the other side of the boundary, the effect of which would be productive of material injury to the navigation interests on its own side of the boundary." (Appellant's Narrative, p. 531.)

And again in Article III it is stated:

> "* * * nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes." (Appellant's Narrative, p. 532.)

Article VIII expressly provides that the uses for domestic and sanitary purposes shall be paramount. (Appellant's Narrative, p. 535.)

The Treaty thus completely protects the diversion at Chicago. There was no dispute between the United States and the Dominion of Canada as to the right to divert 10,000 cubic seconds feet of water from Lake Michigan at Chicago. The International Waterways Commission, which was composed of representatives of the two governments, settled that. The two reports mentioned, those of May 3, 1906, and January 4, 1907, were signed by all the members of the Commission—three from the United States and three from Canada. As to the diversion at Chicago, the only question remaining unsettled was whether there should be diverted by the State of Illinois and appellant, at Chicago, more than 10,000 cubic seconds feet of water. The purpose is stated, in the treaty itself, to be—

> "* * * *to settle all questions which are now pending* between the United States and the Dominion of Canada involving the rights, obligations or interests of either in relation to the other or to the inhabitants of the other along their common frontier, * * *"

Article II thus left unhampered the power of the sovereign over the waters that were not boundary waters within the sovereign's territory, subject only—

(1) to the right of the citizens of one country to sue in the courts of the other country for damages as to any caused by a diversion not then existing;

(2) to the right merely of either party to object to further diversions than those which existed, the effect of which diversions would injure navigation.

The Chicago diversion to the amount of 10,000 seconds feet was found by International Waterways Commission to be an existing diversion, as follows:

> "It (the Commission) does not desire an investigation of the effect upon the navigation interests of the Great Lakes. It has satisfied itself upon that point. Nor does it wish to reopen the case of the Chicago Drainage Canal as designed in the bill. It accepts that as a fixed fact, with its attendant diversion of 10,000 cubic feet per second through the Chicago River." (Appellant's Narrative, p. 522.)

The right to the sovereign having jurisdiction over Lake Michigan, a non-boundary water, subject to the conditions mentioned, was thus reserved. As to those waters, the sovereign could do anything with them it chose.

In

The Schooner Exchange v. *McFaddon*, 7 Cranch 116,

Chief Justice Marshall stated the rule to be (p. 136):

> "The jurisdiction of the nation within its own territory is necessarily exclusive and absolute. It is susceptible of no limination not imposed by itself. Any restriction upon it, deriving validity from an external source, would imply a diminution of its sovereignty to the extent of the restriction, and an investment of that sovereignty to the same extent in that power which could impose such restriction.
>
> All exceptions, therefore, to the full and complete power of a nation within its own territories, must be traced up to the consent of the nation itself. They can flow from no other legitimate source."

See also opinion of Judson Harmon on right of United States in Rio Grande, 21 Opin. Atty. Gen. 274, 280.

This we understand is the accepted rule of international law and is recognized by the treaty.

The waters which are diverted from Lake Michigan at Chicago are wholly within the limits of the State of Illinois. The boundary line of the State extends due north into Lake Michigan from the intersection of the shore of the Lake with the boundary between Indiana and Illinois to a point where it is met by the boudary line between Wisconsin and Illinois extended due East.

The treaty between the United States and Great Britain, of 1909, ratified by the Senate is the law of the land, and may properly be said to have been made, so far as the Chicago diversion is concerned, for the benefit of the State of Illinois and the appellant. Such being the case, the State or appellant may compel the recognition of such contract right. The Treaty reserved the right of the sovereign—and the state is

a complete sovereign except as to those things delegated to the Federal Government—over these waters. Article II begins—

> "Each of the high contracting parties reserves to itself, or to the several State Governments—"

the right of the sovereign over the nonboundary waters. There was thus recognized the right of the state government as a sovereign to divert or use non-boundary waters. This construction is borne out by the provisions of Article V of the Treaty relating to the diversions at Niagara Falls, wherein it is provided:

> "The United States may authorize and permit the diversion within the State of New York of the waters of the said river above the Falls of Niagara, for power purposes, not exceeding in the aggregate a daily diversion at the rate of 20,000 cubic feet of water per second."

The Niagara River at this point is an international stream and a boundary water, and the makers of the Treaty took this fact into consideration and made it a condition of the diversions at Niagara Falls that the *United States itself* should *first* "authorize and permit" them.

At least the United States, by making the Treaty, must be construed to have acquiesced and consented to the conditions of the diversions as they existed at the time it was made, unless some definite action were taken by Congress indicating a different intention. Not only has Congress not indicated any such contrary desire, but, on the other hand, has taken action June 25, 1910, and June 30, 1917 looking towards making provision for the maintenance of the surface elevations of the lakes, as they would be if the diversions did not exist. This includes not only the Chicago diversion for sanitary purposes, but all other diversions, even for navigation and power purposes. Of course, Canada is not in a position to even object to the diversion to the amount of 10,000 seconds feet at Chicago.

VI.

THE DECREE OF THE LOWER COURT IS BASED SOLELY UPON THE TESTIMONY OF EXPERT WITNESSES. NO WITNESS WAS PRODUCED BY APPELLEE TO TESTIFY THAT THE LOWERING OF THE LAKE SURFACES OR DAMAGE TO COMMERCE, WAS EVER ACTUALLY OBSERVED. APPELLEE'S CASE DEPENDS ENTIRELY UPON AN INFERENCE OF THE UNSEEN AND THE SUBTLE ANALYSES OF EXPERT WITNESSES, WHICH CANNOT FORM THE BASIS OF AN INJUNCTIONAL DECREE.

(a) Expert evidence in injunction cases.

In the statement (p. 64) we have set forth the method by which appellee's expert witnesses sought to establish the basis for this injunction. Measurements were made of the discharge at different times of the outlet rivers of the different lakes, such as Huron, Erie and Ontario. The discharge measurements were plotted and by means of these plottings an increment, that is the increase or decrease of the flow of the outlet river due to one foot of change of the surface elevation of the controlling lake, was sought to be deduced. It was then assumed that the Chicago diversion would have a lowering effect upon the lake surface due to the fraction of a foot resultant from dividing the amount of the diversion by the increment. But the determination of this increment depended upon the accuracy of many things done and upon the correctness of the premises upon which the conclusion was based. In these plottings a discharge measurement made at a certain time in an outlet river many miles below the lake's outlet, depended upon whether the particular discharge was referred to the correct elevation of the lake. A time interval was assumed so that if, say, a particular discharge measurement was made at 11:00 o'clock upon a certain day, it was assumed that 10, 15, 20 or 25 minutes prior to that time, the surface elevation of the lake as appeared by the

recording gauge influenced that particular discharge measurement. The fixing of the time interval was based upon conjecture. It was found that the government witnesses as to the time necessary to create a change of flow throughout the Drainage Canal, were entirely wrong, as the tests showed. The result of these tests was never questioned. Also, it appears that the surface elevation of the lakes is constantly changing as much as six inches to several feet in a few minutes or hours. But no one testified to observing any lowering effect. On the contrary, it appeared that the mean elevation of the different lakes involved for the ten years immediately subsequent to the opening of the Drainage Channel, was higher than the mean for the ten years immediately preceding.

The next steps in appellee's program for the determination and showing of injury to navigation and commerce, was to assume that the lake surfaces would be thus lowered by 5 to 6 inches for Huron and Michigan for 10,000 seconds feet diversion, and in smaller amounts for Erie and Ontario, and that certain boats navigating the Great Lakes would be deprived of that number of inches of draft. Of course, on appellee's own theory the total number of inches of lowering the surface elevation of Lake Michigan, here involved, cannot be over three inches. They admit appellant has the right to divert 4,167 seconds feet. So the effect upon the lake surface of the difference between that amount and 10,000 seconds feet is the one to be considered here. It was estimated that for each inch of lowering, there would be a loss of 80 to 100 tons in the amount a vessel affected would carry each trip. But there were a number of difficulties in reaching this result, even if the first assumption were correct as to the reduction in surface elevations of the lakes. No one testified to observing a loss in the amount the boats actually carried. The expert witnesses concluded that they would be deprived for each trip of the amount mentioned. But it appeared that boats could not load within such narrow limits as the few inches involved. The lakes were changing, as

stated, constantly. Lake Erie would change sometimes as much as 8 feet in a few hours. Lake Michigan and Huron almost as much. A perusal of the hydrograph of the Great Lakes (Appellant's Narrative, p. 125) shows continuous yearly fluctuations of a foot or more. The hourly readings, as shown by the plat attached to the report of the Board of Engineers on Waterway from Utica to the Mouth of the Illinois River (Appellant's Narrative, p. 150), shows these oscillations due to barometric pressure or seiches. Further, the evidence showed that the channels traversed by boats should be of a depth so that there would be at least two feet of water beneath them. (Appellant's Narrative, p. 150.) A few inches, such as involved here, is of no importance.

So we find that appellee's evidence starts with the conclusion of expert witnesses and goes no further and ends with the request that, upon such conclusions and an inference of the unseen, the injunctive relief should be ganted.

In

Missouri v. *Illinois*, 200 U. S. 496, 523,

this Court recognised the principle that injunctive relief would not be granted upon this sort of evidence. The question involved there was whether the sewage discharged by appellant into the Illinois River, carried disease to the Mississippi River, the water supply of St. Louis. Plaintiff's witnesses in that case were experts, and it was upon their conclusions that the injunction was sought. This Court, in stating the reliance to be placed upon this kind of evidence, said:

> "There is nothing which can be deducted by the unassisted senses,—no visible increase of filth, no new smell. * * * The plaintiff's case depends upon an inference of the unseen. * * * The experts differ as to the time and distance within which a stream would purify itself. No case of an epidemic caused by an infection at so remote a source, is brought forward, and the cases which are produced are controverted."

This case was cited and the opinion quoted in full in

Joyce on Nuisances, 1906 Ed., Sec. 299.

The same author, at Section 420, states the rule—

"The nuisance must be actual and existing and not future, however strongly the apprehension of injury may be supported by scientific evidence."

In

Salvin v. *North Brancepeth Coal Company*, L. R. 9, Chanc. Appeals, 705,

a bill was filed to prevent the Colliery Company from erecting or using any coke ovens or other ovens to the nuisance of the plaintiff, the nuisance alleged being from smoke and deleterious vapors. Sir William M. James, in rendering his opinion, said:

(709) "When the Masters of the Rolls said that the damage must be visible, it appears to me that he was quite right; and, as I understand the proposition, it amounts to this, that, although when you once establish the fact of actual substantial damage it is quite right and legitimate to have recourse to scientific evidence as to the causes of that damage, still if you are obliged to start with scientific evidence, such as the microscope of the naturalist, or the tests of the chemist, for the purposes of establishing the damage itself, that evidence will not suffice. The damage must be such as can be shown by a plain witness to a plain common juryman.

The damage must also be substantial, and it must be, in my view, actual; that is to say, the Court has, in dealing with questions of this kind, no right to take into account contingent, prospective, or remote damage. I would illustrate this by analogy. The law does not take notice of the imperceptible accretions to a river bank or to the seashore, although after the lapse of years they become perfectly measurable and ascertainable; and if, in the course of nature, the thing itself is so imperceptible, so slow, and so gradual as to rquire a great lapse of time before the results are made palpable to the ordinary senses of mankind, the law disregards that kind of imperceptible operation. So, if it were made out that every minute a millionth of a grain of poison were absorbed by a tree, or a millionth of a grain of dust deposited upon a tree, that would not afford a ground for interfering, although after the lapse of a million minutes the grains of poison or the grains of dust could be easily detected."

See also

North Dakota v. *Minnesota,* 68 Law. Ed. 159 (Advance sheets Jan. 1, 1924).

Commerce upon the Great Lakes has gone on apparently unimpeded, and each year has shown an increase in the amount of tonnage carried by boats. In fact, all the great ore carrying vessels claimed to be damaged, have been built since the Drainage Canal was opened.

(b) Disregarding all questions heretofore presented as to the right of appellant to operate its works with the diversion required, nevertheless the injunction decree should not have been entered unless the injury and damage to commerce was material and the obstruction to navigation was unreasonable.

In

United States v. *Rio Grande Irrigation Company,* 174 U. S. 690,

a bill was filed to restrain the construction of a dam across the Rio Grande River in that portion of the river in New Mexico which was not navigable. It was claimed that this dam would impound the waters in such manner that it would affect the navigable capacity of the Rio Grande River lower down in its navigable portions. The Court refused the injunction. This Court held that it was necessary for the Government to show a substantial interference with navigation, and said (709):

> "• • • it becomes a question of fact whether the act sought to be enjoined is one which fairly and directly tends to obstruct (that is, interfere with or diminish the navigable capacity of a stream) • • • The question always is one of fact, whether such appropriation substantially interferes with the navigable capacity within the limits where navigation is a recognized fact."

This Court ordered:

> "• • • an inquiry into the question whether the intended acts of the defendants in the construction of a dam and

in appropriating the water of the Rio Grande will substantially diminish the navigability of that stream within the limits of present navigability, * * *"

Corrigan Transit Company v. *Sanitary District*, 137 Fed. 851, 857.

Lake Shore & Michigan Southern Railway Company v. *Ohio*, 173 U. S. 285, 294.

Cummings v. *Chicago*, 188 U. S. 410, 428.

Union Bridge Company v. *U. S.*, 204 U. S. 364, 365, 385, 400.

The above cases show that the only things with which the courts are concerned, in protecting navigable waterways of the United States, are unreasonable obstructions.

(c) It must appear in a case of this character, considering the parties involved, that an unreasonable obstruction and damage to commerce clearly exist before an injunction will issue.

In the recent case of

New York v. *State of New Jersey & Passaic Valley Sewage Commissioners*, 256 U. S. 296,

where New York instituted suit to enjoin the defendants from discharging sewage into New York Bay, injuring navigation thereon, this Court said (p. 309):

"With the record in this state we come to consider the evidence introduced, but subject to the rule that the burden upon the State of New York of sustaining the allegations of its bill is much greater than that imposed upon a complainant in an ordinary suit between private parties."

In

Kansas v. *Colorado*, 206 U. S. 46,

Kansas brought sought to enjoin Colorado from diverting the waters of the Arkansas River for irrigation purposes. It was claimed that this diversion seriously injured the people

of Kansas, and that Colorado had no right to such diversion. This Court, in summing up its conclusions, stated (p. 117):

> "* * * that the result of that appropriation has been the reclamation of large areas in Colorado, transforming thousands of acres into fertile fields, and rendering possible their occupation and cultivation when otherwise they would have continued barren and unoccupied; that while the influence of such diminution has been of perceptible injury to portions of the Arkansas Valley in Kansas, particularly those portions closest to the Colorado line, yet, to the great body of the valley it has worked little, if any, detriment, and regarding the interests of both States, and the right of each to receive benefit through irrigation and in any other manner from the waters of this stream, we are not satisfied that Kansas has made out a case entitling it to a decree."

See also

Attorney General v. *Mayor, Alderman and Corporation of Kingston-on-Thames,* 13th Weekly Reporter, 1863-1865, 888.

In

Mississippi & Missouri R. R. Co. v. *Ward,* 2 Black 485,

Ward charged the railroad with having created a nuisance by erecting a bridge across the Mississippi River at Rock Island, and prayed that it be abated as a nuisance (p. 495):

> "Then again, the obstruction to navigation must be plainly a nuisance within this rule before it can be removed by decree. If the proceeding was by indictment, and the jury doubted whether the obstruction was a nuisance or not, they would be instructed to acquit the defendant; and so, if this case was referred to a jury to try the fact and they doubted, they would be bound to acquit. And the same rule applies in a court of chancery where the Court ascertains the fact of nuisance. 2 Story, Com. on Eq., 203, 204."

VII.

A COURT OF EQUITY IN DETERMINING WHETHER OR NOT IT WILL GRANT AN INJUNCTION LOOKS NOT ONLY TO THE NAKED LEGAL RIGHTS OF THE COMPLAINANT AND THE ADVANTAGES TO BE BY IT GAINED, BUT ALSO TO THE INCONVENIENCES AND INJURIES TO BE SUSTAINED BY THE DEFENDANT. AND IF IT APPEARS THAT THE GRANTING OF THE INJUNCTION WOULD CAUSE COMPARATIVELY GREATER INJURY TO THE DEFENDANT THAN IT WOULD CAUSE BENEFIT TO THE COMPLAINANT, A COURT OF EQUITY WILL NOT HESITATE TO DENY THE RELIEF.

The above proposition is the rule in suits for injunctions between private persons. Where the parties are public bodies and represent the interests of the public, the Court should be meticulous in observing the rule and especially where the great question of the protection of the public health is involved. Here, as is shown by the undisputed facts, the injunction can have but one result—the immediate pollution of the only water supply for Chicago. If all the artificial purification and filtration works that could be installed, at a time in the future impossible now to determine were now in existence, still with the limitation of withdrawal to 4,167 cubic seconds feet, or materially less than 10,000 seconds feet, the Lake Michigan water supply would be polluted. There is no means by which, with such purification works in existence, an effluent from them can be prevented from finding its way at numerous times during the year into Lake Michigan. This effluent would carry disease germs. This results from the fact that the Chicago River and its branches cannot be kept reversed at all times unless there is allowed a continuous flow through them of at least 10,000 cubic seconds feet of water. This flow of water cannot be obtained except from Lake Michigan. In 1914, when the tests were made, it

was found that the volume of flow through the drainage channel and the Chicago River and its branches to the lake could not be increased from 4,167 seconds feet to 10,000 seconds feet, the maximum drainage run-off, within a period of less than twenty-four hours. This would be too late. The water would pile up in the channels of the river in from three to four hours in case of storm on this area and would flow into the lake carrying the sewage pollution. (Appellant's Narrative, p. 390.) The frequency of such occurrences increases and the danger to the water supply is more imminent as the paved and sewered area of the Chicago River basin is extended. That would be the condition even if Chicago and its environs had now installed these vast sewage and water purification works. How much more aggravated would the condition be with practically none of the sewage purified. The result of this decree would be the immediate cutting down of the flow from 10,000 cubic seconds feet, which now exists, to the limited flow of 4,167 seconds feet. The condition of nuisance in the Chicago, DesPlaines and Illinois Rivers would be intolerable. Lake Michigan would be polluted. Typhoid fever would exist and ever increasing epidemics would follow.

10,000 cubic seconds feet diversion from Lake Michigan will dilute the sewage of 3,000,000 people; 12,000 cubic seconds feet 3,600,000 people; and 14,000 cubic seconds feet 4,200,000 people. The cost of artificially treating the sewage of the difference between that population which would be oxidized by 4,167 cubic seconds feet of diversion and that population that would be oxidized by 10,000 cubic seconds feet is $183,510,507.00. The cost of artificially treating the sewage of the difference between that population which would be oxidized by 4,167 cubic seconds feet of diversion and that population which would be oxidized by 12,000 cubic seconds feet in $220,141,100.00. And the cost of artificially treating the sewage of the difference between that population which would be oxidized by 4,167 cubic seconds feet of diversion and that by 14,000 cubic seconds feet would be $256,958,800.00. (Appellant's Narrative, p. 217.) This would leave still untreated the

sewage that would be oxidized by 4,167 cubic seconds feet, which sewage would have to be treated if the diversion were limited to that amount, so that no raw sewage would go into Lake Michigan. The cost of sewage purification works to take care of this amount must also be added, which would be approximately $75,000,000.00. First, however, the wastes and the sewage from the increase of population in the period ending with the year 1945 must be treated. The resources of appellant will not permit this before the year 1945. The cost is upwards of one hundred million dollars. A like sum would have to be expended for water filtration plants, also, by the cities and towns furnishing water to the consumer. (Statement, p. 79.) And we would not then have a situation as to the water supply, approaching the conditions that prevail today, with all the sewage and drainage kept away from Lake Michigan. In such instance an effluent from these purification works would be discharged, at times, into the lake. Instead of Chicago having an unpolluted water supply, it would then have a polluted one, with constant danger of epidemics of typhoid fever and other water-borne diseases.

On the other hand, the benefit of this injunction to the appellee or to commerce on the Great Lakes, as has been heretofore stated, is problematical. Granting all that appellee claims, it is slight compared with the inconvenience, money expenditure, damage, danger to health and creation of nuisances that would result to appellant upon the enforcement of the injunction in any form.

In

Volume 1, Joyce on Injunctions, Sec. 20, p. 41,

it is said:

> "And an injunction will not be granted when the injury complained of is slight compared to the inconvenience to the defendant and the public that would result from granting the injunction."

Again at Sec. 25, p. 50:

> "Where the rights of the parties are at all doubtful the court applied to for an injunction should look at the

balance of convenience, and act upon the consideration of the comparative inconvenience which may arise from granting or withholding the injunction."

In

Kansas v. *Colorado*, 206 U. S. 46, 117,

this Court recognized the principle stated.

In

Georgia v. *Tennessee Copper Co.*, 206 U. S. 230,

a suit was instituted by the State of Georgia against a corporation, a citizen of the State of Tennessee, to enjoin the discharge of noxious gasses from their works in Tennessee over large tracts of territory in Georgia. The Court recognized the principle for which we contend, and, in speaking of the character of the action of the State in seeking the injunction, said (p. 237):

"It has the last word as to whether its mountains shall be stripped of their forests and its inhabitants shall breathe pure air."

The Court, in granting the injunction, did so reluctantly, because it would have the effect of very seriously injuring the defendant's works. It was recognized that where the public health of the people of the State of Georgia was so directly involved, the different equities of the defendant would not be so carefully weighed. The converse, of course, of that must follow. Here the protection of the health of the people residing within appellant's limits is concerned—almost half of the population of the State of Illinois. On the other side, there is only the question of possible, remote or, at most, indirect damage to commerce.

This rule was recognized also in

Dun v. *Lumbermen's Credit Assn.*, 209 U. S. 20.

In

McCarthy v. *Bunker Hill & Sullivan Mining & Concentrating Co.*, (C. C. A. 9th Circuit), 164 Fed. 927,

a suit was instituted to enjoin the mining company from discharging its tailings into a stream. It appeared that the

benefit to the plaintiff would be slight, and that the damage to the defendants and its employees would be great. The Court said (940):

> "To an injunction, however, even on final hearing, no one has an absolute and unqualified right. Such an application appeals to the conscience of the chancellor, to the exercise of a wise and sound discretion, and should be granted or withheld according to the equities of the case as made to appear by the record. Each case must be considered and made to depend upon its own particular facts and circumstances, in the consideration and determination of which the general rules governing courts of equity are to be borne in mind and applied."

In

City of New York v. *Pine*, 185 U. S. 93,

suit was instituted to enjoin the City of New York from maintaining a dam on the West branch of the Byram River and diverting the waters from their natural flow through the plaintiff's farms. This Court assumed, as was found by the lower court, that the plaintiffs would suffer substantial damage and, besides, that they have the legal right to the natural flow. It was held that the decree enjoining the City of New York should not be sustained because of the damage that would result thereby to that city, and considered the greater equities in the City of New York (p. 97):

> "* * * *a municipality undertaking a large work with a view of supplying many of its citizens with one of the necessities of life.*"—

namely, a pure water supply.

VIII.

THE STATEMENT MADE BY THE SECRETARY OF WAR (JANUARY 8, 1913) IN REFUSING TO REMOVE THE ALLEGED LIMITATION BY THE ORDER OF DECEMBER 5, 1901 (4167 SECONDS FEET WITHDRAWAL) AND DENYING EXPRESS AUTHORITY TO APPELLANT TO DIVERT 10,000 CUBIC SECONDS FEET, IS IMMATERIAL. THE STATUTE DOES NOT AUTHORIZE ANY FINDINGS OR CONCLUSIONS BY THE SECRETARY OF WAR. IF IT DID, THE CONCLUSIONS WOULD BE SUBJECT TO REVIEW. IN ANY EVENT, THE CONCLUSIONS OF FACT AND OF LAW STATED, ARE ERRONEOUS, AS APPEARS BY THE RECORD OF THE CASE.

(a) The statute does not authorize the Secretary to make any findings or conclusions. If it did, such would be subject to review.

It will be recalled that on February 5, 1912, appellant asked that the limitation of the December 5, 1901 order be removed. At that time appellant had completed the work of excavating, expressly authorized by the Secretary of War and recommended by the Chief of Engineers under the July 11, 1900 permits, whereby the channels of the Chicago River and its branches had been deepened and widened, so that they would properly permit a flow of water through them equal to 10,000 cubic seconds feet. Appellant then had complete authority for the diversion to that amount, as we have showed. A limitation placed upon the withdrawal at a time before appellant had completed the excavation in the channels of these rivers had no force or effect. However, as the limitation remained unchanged, notwithstanding the work thereafter done, it was the desire, of course, of appellant to have this apparent conflict removed. It thus made its application for the removal of the limitation on the assurance, justified, that the Secretary of War would remove it as a matter of course. No

other course in keeping with fair dealing could follow, after appellant had, in good faith, deepened and widened the channels of the Chicago River and its branches, at an expense of upwards of $10,000,000, to accomplish this purpose. And it must be well considered that it was unnecessary for appellant to do this work, except for the withdrawal of more than 4,167 seconds feet and up to 10,000 seconds feets. It had fruther constructed adjuncts and other works in reliance upon its right to take from Lake Michigan for sanitary purposes, the larger quantity.

Neither Section 9 nor Section 10 of the March 3, 1899 Act, under which the Secretary of War sought to act, authorizes that official to make findings or conclusions in refusing or granting a permit or authorizing work to be done. Neither is there any provision for findings and conclusions of the Chief of Engineers in refusing to recommend or in recommending as to those things by said sections provided.

Section 18 of the Act of March 3, 1899, with a reference to the altering of bridges, expressly provides for a hearing and findings to be made by the Secreary of War. *Inclusio unius, exclusio alterius.* If Congress had intended conclusions and findings to be made, it would have so stated with reference to the subjects for the Secretary of War to act upon, mentioned in Sections 9 and 10.

If it may be construed that the Secretary of War had authority to make findings and conclusions, they are subject to review.

In

Philadelphia Company v. *Stimson*, 223 U. S. 605,

suit was brought to set aside certain harbor lines, and to restrain the Secretary of War from causing criminal proceedings to be instituted against the company because of the reclamation and occupation of land outside the prescribed limits. This Court said (p. 620):

> "In case of an injury threatened by his illegal action, the officer cannot claim immunity from injunction proc-

ess. The principle has frequently been applied with respect to state officers seeking to enforce unconstitutional enactments.

* * *

And it is equally applicable to a federal officer acting in excess of his authority or under a power not validly conferred."

See also

Hardin v. *Jordan*, 140 U. S. 371.

Rosenberger v. *Harris*, 136 Fed. 1001, 1002.

United States v. *United Verde Copper Company*, 196 U. S. 207, 215.

School of Magnetic Healing v. *McAnnulty*, 187 U. S. 94.

In the latter case, the Court had under consideration the act of the Postmaster General in regard to the delivery of the mails, in which a decision by him was made. This Court said (p. 110):

"Yet such decision, being a legal error, does not bind the courts."

(b) In any event, Secretary of War Stimson's findings and conclusions were erroneous.

In speaking of Secretary of War Alger's permit of May 8, 1899, Secretary of War Stimson said:

"He permitted a flowage of 5,000 cubic feet per second." (Appellant's Narrative, p. 28.)

The fact is, as clearly shown, the capacity of the Sanitary and Ship Canal as built prior to the May 8, 1899 permit, and as fixed by law, was not less than 10,000 cubic seconds feet. Many officers of appellee had so found, and there is no dispute about this. However, the permit recited that the channels of the Chicago River and its branches had been widened and deepened so that 5,000 cubic second feet of water could be taken through them without creating a current greater than one and one-fourth miles per hour. This was merely a recital.

The granting clause of the permit authorized, as recommended by the Chief of Engineers, the opening and operation of the channel to its full capacity subject to only the two principal conditions mentioned, namely (1), Congressional action; (2), if a current in the Chicago River should be obstructive to navigation thereon, the Secretary of War might modify the amount of the discharge.

In

Corrigan Transit Company v. *Sanitary District*, 137 Fed. 851,

the Circuit Court of Appeals of the Seventh Circuit construed the effect of this very permit of May 8, 1899, and held that the preambles did not limit the granting clause, as the granting clause was unambiguous. In that case, it was claimed that the rate of flow of one and one-fourth miles per hour, was a condition or a limitation upon the amount of the withdrawal. The Court said (p. 855):

> "In the grant of permission no reference to rate is found. The only reference is in the second clause of the preamble to the grant. But a preamble cannot be resorted to except to help solve an ambiguity in the body of the grant or enactment. The grant here is unambiguous."

Again, the Secretary states, in his January 8, 1913 statement, that

> "the amount of the current permitted to be taken was modified or restricted until December 5, 1901, when it was fixed at the amount now permited, and these permits contained the condition—that the permission herein given shall be subject to such modification as in the opinion of the Secretary of War public interest may from time to time require."

The so-called permit of December 5, 1901, was an order of the Secretary of War to limit the flow under Condition 2 of the May 8, 1399 permit, with reference to an unreasonably obstructive current in the Chicago River. This December 5, 1901 order recites this Condition 2 and refers to other orders made under it. The words, "subject to such modification as

the public interest may from time to time require," cannot be construed to enlarge conditions of the May 8, 1899 permit.

The Secretary, by this January 8, 1913 statement, construed the March 2, 1827 Act as not authorizing the construction of the Sanitary and Ship Canal, or the diversion of water required for its operation. It stated that the Illinois and Michigan Canal,

> "derived its water for navigation purposes from the Calumet, Des Plaines and Chicago Rivers, and not from the Lakes",

and that the authorization and construction of the Illinois and Michigan Canal did not

> "offer the slightest congressional sanction for the great canal now under discussion which was not even contemplated until much more than a half century later." (Appellant's Narrative, p. 29.)

The holding of the Supreme Court of Illinois in *Mortell* v. *Clark*, 272 Ill. 201,

heretofore cited (this brief, p. 120) is absolutely contrary to the conclusion that the Sanitary and Ship Canal was not authorized under the congressional act mentioned.

The Act of January 9, 1836, of the Illinois General Assembly, under which the Illinois and Michigan Canal was constructed, provides for its being supplied with water from Lake Michigan, and for the reservation of ninety feet on each side for its enlargement. The width of the present Sanitary and Ship Canal is approximately the 180 feet thus reserved plus the then provided width of the Illinois and Michigan Canal, 45 feet, a total of 225 feet. This certainly gives some weight to the proposition that the parties intended (that is, Congress and Illinois) at that early day, in providing for this waterway, that at some time it should be of the size of the present Sanitary and Ship Canal, with the authority in Illinois to take such water from Lake Michigan as it considered necessary for the operation of such enlarged canal. The fallacy of the Secretary's statement is further heretofore demonstrated by us. (This Argument, p. 118.)

Secretary Stimson also found that Lakes Michigan and Huron's surfaces would be lowered by this diversion 6.9 inches. The evidence here of appellee places the lowering of Michigan and Huron at 5 inches. The Secretary also found correspondingly larger amounts for the effect of 10,000 seconds feet diversion upon Lake St. Clair, Lake Erie, Ontario and the St. Lawrence River and at Rapide Plat. He did not, however, make the statement that the possible lowering effect upon Lake Ontario was taken care of by the construction of the Gut Dam by the Canadian Government in 1903, as found by the Boad of Engineers on Waterway from Utica to the mouth of the Illinois River, appointed pursuant to the Act of Congress of June 25, 1910. (Appellant's Narrative, p. 176.)

The Secretary, in ascertaining the damage to commerce, followed the procedure of calculating a certain number of trips each season of the ore carrying vessels claimed to be affected and multiplied this by the amount per inch of claimed loss in cargo for each trip (100 tons per inch). He then multiplied the freight rate by the total claimed loss, and reached the result of many millions of dollars per year loss to commerce on the Great Lakes. The mere statement of the proposition shows its fallacy. This could not possibly be the loss, because there was only so much freight to carry by water on these boats so claimed to be affected. The loss necessarily could not be greater than the actual loss of carrying the volume of freight by these boats with the smaller tonnage.

The Secretary also concluded that it would be possible for appellant to get along with less than 10,000 seconds feet. In this, he absolutely overlooked the basic principle of the diversion for sanitary purposes—the reversal of the flow of the Chicago River at all times. 10,000 seconds feet is its minimum flowage. Without that continuous flow, the river would many times each year flow into Lake Michigan, carrying its pollution. There is no dispute upon this point.

The Secretary also concluded that objections of Canada to the 10,000 seconds feet diversion, was an obstacle in the way of the Secretary's acting upon the request of appellant. The treaty cannot be so construed.

The Secretary's construction of the force and effect of the case of

United States v. *Rio Grande Irrigation Company*, 174 U. S. 690,

was also error, as that case arose under a territorial act of New Mexico which is entirely different from the authority which appellant has under a reserve power of a *state*.

IX.

THE LOWER COURT SHOULD HAVE GRANTED THE MOTION OF JULY 12, 1920, BY APPELLANT, MADE FOLLOWING THE OPINION OF JUDGE LANDIS AND HIS DIRECTION AS TO THE DRAFTING OF A DECREE, THAT THE APPELLANT BE ONLY ENJOINED FROM TAKING IN EXCESS OF 10,000 CUBIC SECONDS FEET OF WATER FROM LAKE MICHIGAN ON CONDITION THAT APPELLANT PAY THE COST OF CONSTRUCTING SUCH COMPENSATING OR REGULATING WORKS AS THE UNITED STATES SHOULD PROVIDE TO BE BUILT TO OFF-SET FOR THE CLAIMED LOWERING OF THE LAKE SURFACES AND THEIR CONNECTING CHANNELS DUE TO 10,000 SECONDS FEET DIVERSION AT CHICAGO. ADMITTING, FOR THE SAKE OF ARGUMENT ONLY, ALL CONTENTIONS OF APPELLEE TO BE TRUE, APPELLANT CAN NOT BE ENJOINED FROM TAKING AN AMOUNT OF WATER MATERIALLY LESS THAN 10,000 CUBIC SECONDS FEET FROM LAKE MICHIGAN, UNTIL APPELLANT AND CITIES AND TOWNS WITHIN ITS LIMITS CAN, IF AT ALL, READJUST THEIR WORKS OF SEWAGE DISPOSAL AND OF PURIFICATION OF WATER SUPPLY TO SUIT THE CHANGED CONDITIONS.

(a) By granting the motion of appellant above mentioned, July 12, 1920, the lower court would have done equity. The construction of compensating or regulating works was entirely feasible, as the undisputed facts of the record show.

As grounds of the motion, it was alleged principally that the Board of Trustees of appellant had by ordinance on July 8, 1920, offered to pay the expense of constructing such regulating and compensating works as the United States might

determine to build to off-set for the claimed lowering of the surfaces of the Great Lakes and connecting channels, due to a diversion of 10,000 cubic seconds feet. The ordinance also authorized the attorneys for appellant to make such offer in this case. (Appellant's Narrative, p. 111.)

The motion alleged that the undisputed facts of the record, as has heretofore been pointed out in the statement (p. 77) and in Appellant's Narrative Statement showed that compensating or regulating works were feasible and would accomplish the end proposed. It will be recalled that the Board of Engineers on Waterway from Utica to the mouth of the Illinois River, recomended that contracting works be constructed in the St. Clair and Niagara Rivers, and found that Ontario did not require any such works to be constructed in the St. Lawrence, as the closure of the Gut Channel in the St. Lawrence had already off-set for any claimed lowering due to the 10,000 seconds feet diversion at Chicago. (Statement, p. 71.) It was alleged also that various witnesses and boards of engineers had likewise testified and found as to the feasibility of such compensating, contracting or regulating works, and that these facts were not disputed by appellee in this record. It was further pointed out in this motion that the Treaty of 1909 as to Canadian Boundary Waters, heretofore discussed (this brief, p. 78) contemplated that the United States might construct such contracting works. The estimate of the cost of these contracting works, according to the Board of Engineers on Waterway from Utica to the mouth of the Illinois River, as made in 1913, would not exceed $475,000 (Appellant's Narrative, p. 100) and they would entirely off-set for any claimed injury to commerce on the Great Lakes. (Appellant's Narrative, p. 101) And this amount, or any other that such works might cost, appellant offered to pay. (Appellant's Narrative, p. 111.)

Article 3 of the treaty is significant, as follows:

"ARTICLE 3.

It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter pro-

vided for by special agreement between the Parties
2564 hereto, no further or other uses or obstructions or diversions, whether temporary or permanent, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line, shall be made except by authority of the United States or the Dominion of Canada within their respective jurisdiction and with the approval, as hereinafter provided, of a Joint Commission, to be known as the International Joint Commission.

The foregoing provisions are not intended to limit or interfere with the existing rights of the Government of the United States on the one side and the Government of the Dominion of Canada on the other, to undertake and carry on governmental works in boundary waters for the deepening of channels, the construction of breakwaters, the improvement of harbours, and other governmental works for the benefit of commerce and navigation, provided that such works are wholly on its own side of the line and do not materially affect the level or flow of the boundary waters on the other, nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes."

(Appellant's Narrative, p. 532.)

It is apparent by this article that the contracting works of the character described were contemplated and in the minds of the high contracting parties; that is, that the United States might desire, in order to off-set for the claimed lowering of the levels of the lakes due to the Chicago diversion and other diversions, to build the contracting works recommended by the Board of Engineers on Waterway from Utica to the mouth of the Illinois River. Plans for works of this kind had been in contemplation for many years prior to the making of the Treaty. The Board of Engineers on Deep Waterways, in its report to the 56th Congress, 2nd Session, appointed pursuant to the Act of March 3, 1899, concerning the control of lake levels by building works of the character mentioned, recommended the construction of such works. (Rec. Vol. IV, p. 2387.) The International Waterways Commission likewise recommended the installation of such works. The Board of Engineers for Rivers and Harbors, in 1920,

reporting under the above mentioned resolution of June 30, 1917, with reference to all diversions from the Great Lakes, so recomended. (Appelant's Narrative, p. 102.)

The Court would have done complete equity between the parties, had it granted the motion and entered a decree accordingly. At comparatively small expense, the appellant could have been assured of the diversion from Lake Michigan of 10,000 seconds feet, absolutely required for the protection of the health of the people within its limits. On the other hand, the appellee would have, with the diversion to this amount existing, by the installation of these compensating or regulating works, had as good or better navigation facilities than would exist without the diversion.

It is fundamental, as stated in numerous cases, that it is within the power of a court of equity, in its discretion, to so enter a decree that neither party will be injured. The mere fact that this principle is sought to be applied to a novel situation, such as exists here, is no argument against its use. The fundamental principles of equity must be adjusted to every situation.

In

Myers v. *Block*, 120 U. S. 206, 214,

this Court said:

> "As to the power of a court of equity to impose any terms in its discretion, as a condition of granting or continuing an injunction, there can be no question."

In

Russell v. *Farley*, 105 U. S. 433, 438.

the question arose as to whether the Circuit Court had power to enter a decree on the subject of damages arising from an injunction where an injunction bond had been required. The Court discussed fully the powers of courts of equity to prescribe terms and conditions upon the parties at whose instance it proposed to act. The Court said:

> "The power to impose such conditions is founded upon and arises from the discretion which the court has in such cases, to grant or not to grant the injunction applied for."

Again it is stated, (p. 445)

> "The imposition of terms and conditions upon the parties before the court, is an incident to its jurisdiction over the case; and having possession of the principal case, it is fitting that it should have power to dispose of the incidents arising therein, and thus do complete justice and put an end to further litigation."

In

Marine Ins. Company v. *Hodgson*, 7 Cranch, 332,

the Court, by Chief Justice Marshall, said (337):

> "Being capable of imposing its own terms on the party to whom it grants relief, there may be cases in which its relief ought to be extended to a person who might have defended, but has omitted to defend himself at law."

See, also,

Veazie v. *Williams*, 8 Howard 134, 161.
Walden v. *Bodley*, 14 Peters 156, 164.

In

Newton v. *Consolidated Gas Co.*, 258 U. S. 165,

the District Court held an eighty-cent gas rate confiscatory, and entered a decree enjoining the enforcement of this rate, subject, however, to the condition that the company should not charge more than $1.20, and upheld the decree of the lower court in this respect. This Court said (177):

> "It was within the court's discretion to grant the injunction upon terms * * *."

In

Northern Pacific Railway Company v. *U. S.*, 104 Fed. 691, (C. C. A. 8th Circuit),

opposite the City of Grand Forks, NorthDakota, the railway company's tracks had been placed parallel with the bank of the Red River on the north and about 320 feet therefrom. The embankment of the railroad, by reason of its resting upon a sandy, clay stratum which extended to the river bed, caused a bar to be formed in the river, the railroad's embankment consequently settling. The railroad company was about to increase the height of the embankment to take care

of this settlement, when the United States brought suit in equity to enjoin it from so doing, under Section 10 of the Rivers and Harbors Act of September 19, 1890. A decree was entered accordingly. The Court of Appeals, however, found from the facts in the record that if the embankment were raised as proposed by the railroad company, ultimately this embankment would settle, so that it would extend through the clay, sandy stratum and rest upon a hard foundation, at which time there would be no further forming of the bar in the river; and it also found that, by dredging, the bar could be removed, and navigation would thus be unimpeded. The Court accordingly directed that the decree below be amended, as follows (p. 695):

> "The injunction hereby awarded shall not be so construed as to prevent the defendant company from proceeding with the work of raising its tracks between Cheyenne and Hill avenues to the proper level, if by dredging or otherwise, as the work progresses, it shall, at its own cost and expense, prevent the formation of any such bar in the channel of the Red River of the North as will at any time lessen or impair its navigability."

In many instances, the court of equity refuses relief to which the complainant may be, upon technical legal rights, entitled, where the granting of this relief would unjustly operate upon the defendant. In such case, if the payment of money damages will do justice to the complainant, the Court will impose that condition upon the defendant and deny the relief to the complainant.

In

Sanitary District of Chicago v. *Martin*, 227 Ill. 260,

the Sanitary District had acquired from Martin, in 1902, certain lands for right of way purposes. The deed contained a covenant that the Sanitary District should build a levee to protect certain other lands of Martin. This the District refused to do, on the ground that it did not have the right of way to build the levee and also because the cost of constructing the levee would be in the neighborhood of $60,000, whereas

the value of Martin's land and the damage to it was a very small amount compared with the cost of the levee. A bill for specific performance was filed. The Court refused Martin's relief and assessed the damages for the failure to build the levee. This was sustained by the Illinois Supreme Court. It said (268):

> "Appellant claims in its answer that the cost of the levee and ditch would be so much in excess of the benefit that it would be unjust and inequitable to require specific performance. The court accepted this view of the case, as it had a right to do, and sought to ascertain the damage in dollars and cents."

See, also,

Cushman v. *Bonfield*, 139 Ill. 219.
Phillips v. *Thomson*, 1 Johnson Chan. 133.
2 Sutherland on Damages, 590.
Story's Equity Jurisprudence, 798.

(b) Assuming that appellee is legally entitled at some time to an injunction, a decree, providing for the reduction of the diversion below 10,000 cubic seconds feet before appellant and the cities, villages and towns within its limits can readjust their works of sewage disposal or of purifying the water supply, is contrary to equitable principles.

After the motion of July 12, 1920, relating to the settlement of the decree in the lower court, and in support of the allegations of said motion, it was proved by evidence offered, about which there is no dispute, that appellant had on August 7, 1919 (Appellant's Narrative, p. 339), by ordinance laid out a program or project for the construction of artificial sewage purification works to take care of the human sewage and trade wastes not to be disposed of by the 10,000 cubic seconds feet diversion. These works were completely described and it was shown that the program of construction covered a period of approximately twenty-five years—namely to the year 1945. There was described in detail the location of the works and the method of construction. These works

so to be constructed in said period, were designed to dispose of and purify the sewage of the population of appellants, which exceeded in that period 3,000,000 people, and also the trade waste, which was equal to the sewage of a population of a million and a half or two million people. (Appellant's Narrative, p. 362.) The cost of all these works was estimated to be upwards of a hundred million dollars. It was shown that the total amount that the appellant could raise by taxation and the issuance of bonds in that period would barely take care of this construction cost. (Appellant's Narrative, p. 382.)

The cities, towns and villages within appellant's limits take or obtain water from Lake Michigan for domestic use and disseminate it by mains and other devices to the consumer. With this function of municipal government, appellant has nothing to do. The water supply of the people within appellant's limits, is not now filtered, and under no circumstances can sewage or an effluent from artificial sewage purification works be permitted to come in contact with the water supply unless that water supply is filtered before being delivered to the consumer. (Appellant's Narrative, p. 365.) The cost of filtering the water supply is the enormous sum of one hundred million dollars, and the annual cost of operating the filtration plants is three and a half million dollars. (Appellant's Narrative, pp. 366, 367.) The cities, villages and towns within appellant's limits were not made parties to this suit by appellee. No evidence as to whether the municipalities actually delivering domestic water to the consumer can build such works, is before the court. When, if ever, such works may be built by such municipalities, so that the water supply to the consumer will be filtered, is not shown. Even with all the sewage purified, as best it can be, by artificial means, and the entire water supply filtered, there would still be obviously not only danger of, but actual, pollution to the water supply. That does not exist today. It would be a change from a perfect system in operation today to a makeshift. To accomplish this end, it would be necessary for the

appellant first to complete its project of 1945, whereby the sewage and waste equivalent of the population exceeding three million people is purified at a cost of upwards 100 millions of dollars; second, after 1945, to install works to completely purify the sewage of a population equivalent of three million people now taken care of by the 10,000 cubic seconds feet diversion, at a cost of approximately an additional two hundred thirty-eight million dollars. (Statement, p. 79.) In addition, it would be necessary for the cities, villages and towns within appellant's limits furnishing the water to the consumer, to install water filtration plants and operate same, at installation cost, as stated, of one hundred million dollars and annual operating cost of three and a half million. When this gigantic task, a make-shift, could be accomplished, is beyond the power of human beings to determine. These cities and towns furnishing the water to the consumer during all these years have relied upon having the ideal water supply produced by the diversion of sewage and drainage therefrom. They have, of course, made no plans for any other pure water supply.

A Court, in applying principles of equity between private persons, will refuse to impose upon the defendant a decree which would cause even great financial loss, to take effect immediately, but will so make its decree, that the defendant may re-adjust itself and thus avoid unreasonable loss. Here we have a defendant before the Court representing the public, which has installed works to protect the health and a decree which would absolutely, as the undisputed evidence shows, destroy the effectiveness of those works and cause the raging of diseases due to an impure water supply, including nuisances in rivers and canals flowing through populous sections. And these diversion works of appellant have been in operation for almost a quarter of a century, performing efficiently their functions of providing a pure water supply for the people of Chicago and its environs, preserving lives and protecting health. It has been practically a third of a century since the construction work of appellant was commenced.

The work of appellant was projected and carried out, not in the night time, but openly, within full view of every one, observed by appellee's engineer officers, under the eye of Congress as reported to it by the Secretary of War in the Chief of Engineers Reports. Congressional acts sought to utilize appellant's works and diversion for navigation purposes. The operation of these works received international consideration by the International Waterways Commission, and were recognized as proper by the Treaty of 1909. In fact, every Board of Engineers or Commission that reported upon the subject of the use made by appellant of the water from Lake Michigan to operate these works, has sanctioned it. But, strange to relate, we have the Attorney General, by the suit instituted October 6, 1913, attempting to enforce, by an injunction immediately an order made by the Secretary of War December 5, 1901, because of current in the Chicago River due to the then restricted channels of it and its branches. That current was removed. The order ceased to have any force or effect. Appellee is proceeding upon an alleged paper right without substance or reason beneath it.

Under Section 18 of the Rivers and Harbors Act of March 3, 1899, the Secretary of War may, after hearing and findings, cause the alteration of a bridge. We apprehend that an order of the Secretary, with reference to such a bridge, must provide a certain reasonable time within which the obstruction to navigation may be eliminated, thus giving the railroad company an opportunity to re-adjust itself. An order providing an unreasonably short time, would be held invalid, and a court of equity would grant relief.

Pomeroy's Equity Jurisprudence, states (Vol. 5, Sec. 1948, p. 4429):

> "Whenever necessary to prevent a hardship, a reasonable amount of time in which the defendant may conform to the injunction, may be allowed."

In

United States v. *Luce*, 141 Fed. 385, 422,

(Circuit Court of Delaware. Opinion of Judge Bradford) a bill was filed by the United States to enjoin the defend-

ants from further prosecuting their business of manufacturing oil and fertilizer from fish, or alternatively, from so prosecuting their business there, as to allow offensive odors from their factory premises to reach the quarantine station of the United States, in Delaware Bay, near Lewes. The Court found the operation of the defendant's plant to be a nuisance. With reference to the entering of the decree, the Court said:

> "* * * the defendants should be accorded a fair opportunity of suppressing the nuisance caused or contributed to by them, if they can."

In

Peck v. *Newberg Light, Heat & Power Company,* (Supreme Court, App. Div., 2nd Dept.) 116 N. Y. Supp. 433,

(Opinion by Judge Jenks), the Court found that a nuisance created by the vibration of the engines could be prevented by changing the foundations, and concluded (p. 436) that

> "* * * the defendant should have an opportunity for such correction, * * *."

Sammons v. *City of Gloversville,* 67 N. E. 622; 175 N. Y. 346.

(The Court of Appeals of New York, Opinion by Judge Gray). Plaintiff instituted the suit to restain the City of Gloversville from continuing to empty the contents of its sewers and drains into Cuyadutta Creek. The judgment of the lower court

> "* * * suspended the operation of the injunction for the period of one year, with the privilege to apply to the court for other suspensions of the decree in order that the defendant might obtain 'appropriate legislation,' or change its system of sewage."

This judgment was unanimously affirmed by the Appellate Division and by the Court of Appeals.

Both Judge Landis and Judge Carpenter in this case recognized that time should be allowed for re-adjustment, but both apparently felt that the case was one to be ultimately presented to this Court or to Congress, and that proper re-

lief, in any event, and in this respect, would be granted. Judge Landis said:

> "I had hoped, as I stated at the beginning, that there might be a composition of this thing. The judge has no right to have personal feelings, but I live in this community, and it was my hope that there could be devised a program that would enable this district to have the benefit of this water, as much as it needs, that will give to the country this water in the solving of this problem of navigation (sanitation)."

The Judge directed a decree to be drawn, enjoining the defendant from abstracting more than 4,167 seconds feet of water from Lake Michigan, and said:

> 'The order will not go into effect, it will be suspended until thirty days after the Supreme Court meets in October. That is plenty of time, is it not? * * * Under no circumstances does this order go into effect now. Make that sixty days, and you may put in it, if it does not destroy the appealability of the order, you may put in a provision retaining me in control. The thing that the government wants, at least the court wants, being a citizen of Chicago, the thing I want is water without microbes. That is why I have held your law-suit." (Appellant's Narrative, p. 97.)

Judge Carpenter said, in his opinion (Appellant's Narrative, p. 115.)

> "This matter is a subject which needs the consideration of thinking people, not only in the State of Illinois, but in the whole United States. The Treaty with Canada entered into some years ago seemed to contemplate an acquiescence on the part of the Canadian Government to the withdrawal of 10,000 cubic feet a second by the Drainage District. However, that may be, the Secretary of War has not given his official consent. Whether the increased withdrawal should or should not be made is properly a political and not a legal question, in the absence of consent by the Secretary of War. The Legislature of the State of Illinois, the various civic bodies, the Association of Commerce, and senators and representatives should see to it that at the earliest possible moment the situation here is brought to the attention of Congress, so that by appropriate legislation the health and welfare of this great community may be safeguarded.

I have no doubt that when the matter is properly presented it will be taken up by Congress and by the State Department, and some plan devised which will bring about adequate and the desired results.

It goes without saying that this Court will not issue an injunction to be effective forthwith.

* * *

On the testimony of the Government engineers the Court might in the exercise of a sound discretion, delay the effectiveness of its injunction for from fifteen to twenty-five years to enable the Sanitary District or the State of Illinois to arrange for other means of disposal of the sewerage now handled by the Sanitary District.

Believing as I do that it is a matter for the immediate action of Congress, a decree may be prepared finding the facts as stated in the Bill and enjoining the defendant from withdrawing from Lake Michigan in excess of 4,167 cubic feet a second; the decree, however, not to go into effect for six months.

The matter must necessarily go to the Supreme Court of the United States for final settlement, and no doubt, if need be, when the record is there filed, application may be made to that Court for a supersedeas or further stay."

Afterwards, Judge Carpenter (June 29, 1923), in granting the appeal to this Court, suspended the injunction during its pendency.

(c) The decree of injunction in the court below absolutely enjoined appellant from withdrawing from Lake Michigan in excess of 4,167 seconds feet without any condition. The Secretary of War would be powerless, under this decree, to permit or authorize any further diversion. This condition should have been observed.

On appellee's theory the Secretary of War has the authority to authorize the diversion, otherwise he would have no right to limit. The injunction suit is based upon the limitation made by the Secretary of War December 5, 1901. Obviously, the decree should have provided that it should be subject to any further action that the Secretary of War

might take in authorizing or consenting to a diversion in excess of the limitation of December 5, 1901 (4,167 cubic seconds feet).

Furthermore, as it appeared from the record, many things had transpired since the limitation of December 5, 1901. Over ten years had elapsed between the refusal of the Secretary of War on January 8, 1913, to remove the limitation and the date of the entry of the decree, June 18, 1823.

This was a suit instituted by the Attorney General under Section 12 of the Rivers and Harbors Act of March 3, 1899. In view of the lapse of time, the lower court should have directed that the matter be presented again to the Secretary of War before a decree was entered at such late date enforcing an order of the Secretary of War made twenty-two years prior thereto.

This is particularly true in view of the many things that had transpired—among others, negotiations between the War Department and appellant, as represented by appellant's ordinance of August 7, 1919, (Appellant's Narrative, p. 339), and as shown by the letter of the Division Engineer at Chicago to the Chief of Engineers of May 24, 1921. (Appellant's Narrative, p. 344.)

The Transportation Act of 1920 (41 Statutes at Large, 456), Section 500 thereof, particularly, directs the Secretary of War to develop water transportation by inland waterways, co-operate with municipal governments and "to investigate any other matter that may tend to promote and encourage inland water transportation." (41 Statutes at Large, 499.) The existence of this act is a further reason why this whole matter should have been further considered by the Secretary of War, before the limitation made twenty-two years ago as to the withdrawal from Lake Michigan, should be enforced. Under the Transportation Act mentioned, the Secretary's duties were much broader than under any previous legislation. In investigating the matter of diversion, it would be necessary for him to take into consideration the

question of the use of appellant's diversion for navigation and to have given force and effect to the various reports made pursuant to acts of Congress that any damage to the Great Lakes by the diversion, could be entirely compensated for by building contracting or regulating works. Compensation or regulating works would thus take care of any damage to commerce on the Great Lakes by reason of the diversion, and the diversion would at the same time make available a deep waterway from Chicago direct to the Gulf of Mexico through the Sanitary and Ship Canal, the Desplaines, Illinois and Mississippi Rivers. This broad question might well be considered by him under said Transportation Act.

(d) This matter should be settled by Congress.

In February, 1924, appellee asked that this case be set for an early hearing. Appellant objected, on the ground that bills had been and were pending in Congress looking to direct authorization of this diversion. Since that time hearings have been had on a number of bills pending before the House of Representatives by the Rivers and Harbors Committee. The hearings on these bills were not concluded, when the last session of this Congress ended, and the Committee adjourned to take up the matter at the next session of this Congress. The said bills are still pending, undisposed of by said committee on River and Harbors of the House, no action has been taken thereon, and they have not yet been reported. We believe that this matter, in any event, is one which should be disposed of by co-operative study.

New York v. *New Jersey and Passaic Valley Sewage Commissioners*, 256 U. S. 296, 313:

"We cannot withhold the suggestion, inspired by the consideration of this case, that the grave problem of sewage disposal presented by the large and growing populations living on the shores of New York Bay is one more likely to be wisely solved by co-operative study and by conference and mutual concession on the part of representatives of the States so vitally interested in it than by proceedings in any court, however constituted."

In

Virginia v. *West Virginia*, 246 U. S. 565,

this Court, while giving an opinion upon certain of the points involved, reserved further action to enable the parties to reach an adjustment of their differences impelled by consideration of "the character of the parties."

Hon. John W. Davis, in an address before the New York State Bar Association, January 20, 1922, in discussing the above case, *Virginia* v. *West Virginia*, said (Amer. Bar Assn. Journal, February, 1922, Vol. VIII, pp. 77-82):

> "* * * after suggesting the possibility of Congress coming to the aid of the Court and hinting at the power of the Court itself to decide the amount and method of taxation to be put into effect, the Court with a call for further argument postponed its decision and threw itself back once more upon the sense of duty and the suggestions of self-interest of the contending parties. It is gratifying to reflect that this last appeal was not made in vain, and that an amicable adjustment by the States themselves proved one more the moral power of the Court, and vindicated its confident reliance upon 'a decent respect to the opinions of mankind' as the ultimate sanction of its judgments."

The Secretary of War in the May 8, 1899 permit for the opening of the Sanitary and Ship Canal, and in almost every permit issued in connection with this matter, stated:

> "1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress."

CONCLUSION.

The history of the establishment of the Chicago diversion to the capacity of appellant's works as fixed by the Illinois Statutes and the connection of appellee with it, discloses a well settled policy of appellee to co-operate with the State of Illinois, extending over a period of almost a century. The people of Chicago and environs, relying upon this policy, expended millions to also utilize the resultant waterway for the protection of their water supply; and they have so used it for upwards of sixty years. Until the refusal of Secretary Stimson to specifically authorize the diversion to the amount of 10,000 seconds feet and the further act of the Attorney General in filing the bill for injunction on October 6, 1913, there was no digression. This former policy of co-operation by the Government is in every respect in keeping with appellant's position here. Appellee by such action not only recognized the specific authority for the diversion, under the Act of Congress of March 2, 1827, for the construction of the Illinois and Michigan Canal, but also the authority of Illinois under its police power as expressed by the Act of May 29, 1889, under which the Sanitary District was organized. Not only acts of engineer officers and the Secretary of War, but also acts of Congress, are evidence of appellee's recognition of appellant's right in the premises.

Appellant's Sanitary & Ship Canal was under construction for years, to be used in diverting from Lake Michigan a definite quantity of water. To use the canal as it was constructed, it was necessary to effectively connect its northern terminus with Lake Michigan. The capacity of the channels of the Chicago River and its branches was originally not sufficient. Excavating to widen and deepen these channels was necessary. The preliminary work of excavation to provide for the initial operation of the channel was authorized.

To open the Sanitary and Ship Canal after it was completed, it was necessary to do certain work. This was authorized by the principal permit of May 8, 1899, without limitation as to amount of flow, except as to a current in the Chicago River becoming unreasonably obstructive to navigation. It was understood that further work of excavating in the Chicago River and its branches was necessary to provide for the water for the increase in population. In due course this further work of excavating in the channels of these rivers to make them large enough for the maximum diversion was authorized. The work was done, performed and carried out in accordance with the plans for such work, as authorized by the Secretary of War.

The work of excavating the channels of the Chicago River and its branches ~~having not~~ has been performed as authorized. If further excavation were necessary to enlarge them so that a current would not be obstructive to navigation thereon, then a decree should have been entered allowing appellant its full diversion, but containing a condition that appellant further improve those channels.

The Secretary of War recognized that the problem, making necessary appellant's diversion works, was one of great public importance, which might be submitted to Congress. The Secretary reported everything to Congress. Congress not only did not act in any manner indicating an intention to limit the operation of the works, but, on the contrary, acted in such manner as to show its purpose to utilize the works and the attendant diversion for navigation. It also evinced the intention to build works in connecting channels of the Great Lakes to offset for any diversion. So the facts show appellant was acting with the co-operation of the Federal Government in the solution of this problem. It had the right to believe that its exercise of the police power of the state in this reasonable manner was lawful.

Appellant is not attempting to divert from Lake Michigan an unlimited amount of water. Its purpose now, and the rec-

ord discloses no other, is to withdraw only a reasonable amount for the protection of the water supply, for navigation and to prevent nuisances. That amount was deliberately fixed a third of a century ago when its Sanitary and Ship Canal was laid out. It then appropriated the quantity of water necessary, as fixed. No one questioned its right.

Appellant's offer (July 12, 1920,) to defray the expense of building works in the Great Lakes outlets to offset for any claimed injury to commerce on the Great Lakes was more than equity required. It should have been accepted by the court. A decree should have been entered allowing appellant to divert the 10,000 cubic seconds feet of water from Lake Michigan on condition that it comply with its offer. Appellee would thereby have been protected in the only interest it has in this suit —navigation upon the Great Lakes system. That was the least the court could have done for appellant.

Appellant is now confronted with a decree which will compel appellant to change its plan for a deep waterway and its whole policy of protecting public health, the works to accomplish which were determined upon after deliberate and careful investigation, to throw aside the works thus constructed at a cost of many millions of dollars, and to enter upon another and different method of protecting the water supply, the execution of which will cost a gigantic sum, which method in effectiveness will be, at best, a mere shadow of that already in use.

The decree of the District Court should be reversed.

Respectfully submitted,

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No. 161

IN THE

Supreme Court of the United States

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO,
Appellant,

vs.

THE UNITED STATES OF AMERICA,
Appellee.

Appeal from the District Court of the United States, for the Northern District of Illinois, Eastern Division.

REPLY BRIEF AND ARGUMENT FOR APPELLANT

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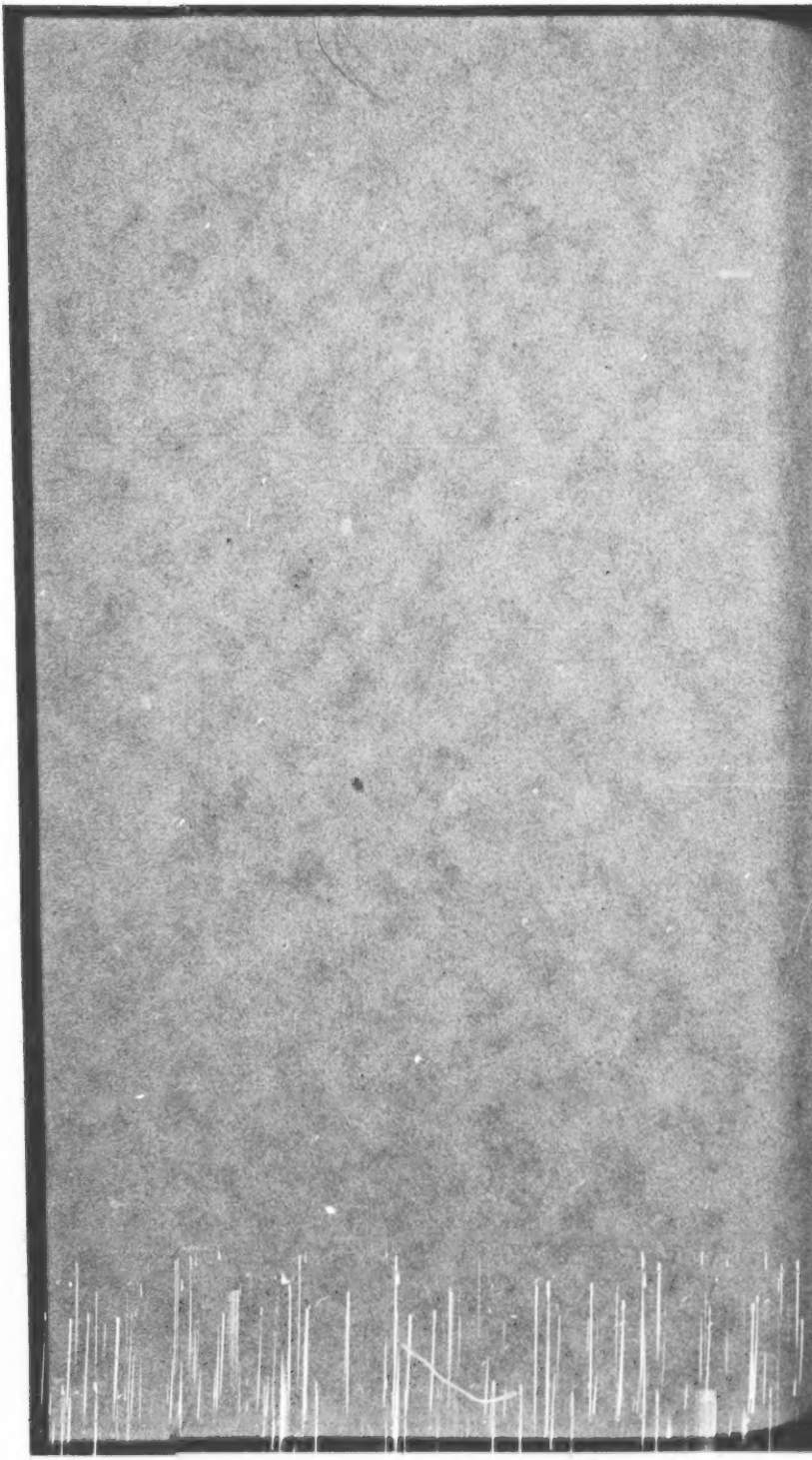

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IN THE

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO, *Appellant*, vs. THE UNITED STATES OF AMERICA, *Appellee*.	Appeal from the District Court of the United States for the Northern District of Illinois Eastern Division.

REPLY BRIEF AND ARGUMENT FOR APPELLANT.

MAY IT PLEASE THE COURT:

Appellee's brief is voluminous. There are many inaccurate statements of fact, the incorrectness of which in every instance we will show by quotations from or reference to the record. Several hundred authorities are cited. The limited time at our disposal does not permit an analyzation of each case. We are compelled to confine ourselves to a consideration in this brief of only the cases from which quotations have been made by appellee, or upon which it particularly relies. The seemingly harsh criticisms of our statements of fact and points and arguments, appearing at so many places in appellee's long brief, will not be answered by us in kind. We will, however, take up *seriatim* the various incorrect statements of fact and points and arguments contained in appellee's brief.

The briefs filed by *amici curiae* in support of appellee's position, being States of Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, Wisconsin and Lake Carriers' Association, as *amici curiae,* are discussed in the briefs filed supporting appellant's position, by *amici curiae,* being States of Illinois, Missouri, Tennessee, Louisiana, Chamber of Commerce of St. Louis, Memphis Chamber of Commerce, New Orleans Board of Trade, New Orleans Association of Commerce, the Mississippi Valley Association, the Chicago Association of Commerce.

APPELLEE'S ARGUMENT ON THE FACTS.

(Its Brief, p. 1.)

Appellee's so-called argument on the facts should properly be disregarded in the consideration of the issues here, as it is largely repetition. Most of the facts stated by appellee are restated in its argument on the law in the places where appellee's counsel have attempted to apply authorities to the facts. Many facts appearing in our statement are merely restated by appellee. In that portion of this reply Brief where we discuss appellee's points and authorities, we have, in *extenso,* by reference to or quotations from the record or appellant's narrative, demonstrated the incorrectness of various statements of fact which do not agree with those stated by us in our original brief. Therefore, in discussing appellee's Argument on the facts, we will only refer to some of the most glaring inaccuracies.

To avoid repetition, we will carry in the margin of the discussion of appellee's argument on the facts, a reference to the page of its argument where may be found the matter considered by us to be incorrect. We may also refer by page to portions of our reply brief where, in discussing appellee's legal points, we have shown the inaccuracy of appellee's statements of fact.

Page of Appellee's Brief.

2 The appellant does not propose to divert 20,000 cubic feet per minute for each one hundred thousand of the population in 1960. The Sanitary and Ship Canal was only authorized to be built for a capacity of approximately 10,000 cubic feet per second. The capacity in the rock section is 14,000 cubic seconds feet. (Cooley, Appellant's Narrative, p. 295.)

There is no evidence in the record that the City of Chicago has profited by cheap water supply in comparison with other cities on the Great Lakes. The record does not disclose whether the water supply of such other cities is cheap or expensive. It does disclose, however, that the water supply of the people of Chicago as produced by appellant's works, is much better than the other cities, the death rate from typhoid fever for Chicago being very much below that of other cities. (Appellant's Narrative, p. 203.)

5 The record does not disclose any motion made by appellee to strike portions of appellant's answer in the Main Channel suit. No order was ever entered concerning any such motion. There was only a notice given by appellee that it would make such a motion on February 28, 1914. (Rec., Vol. III, p. 126.)

What Judge Landis said he might do, is unimportant. It was a mere oral opinion. It was not signed by him. Judge Carpenter entered the final orders and decrees. He rendered an opinion. (Appellant's Narrative, 113.) There is no mention in his opinion of any motion to strike or that he would enter any order concerning it, or as to any agreement or understanding such as counsel refers to, concerning their presenting evidence in opposition to that offered by appellant in support of the portions of its answer of which appellee complains.

Furthermore, appellee filed exceptions on June 25, 1908, among others, to the three principal affirmative defenses set forth in appellant's answer to the complaint in the Calumet River suit. The exceptions were overruled on June 26, 1908. (Appellee's Brief, p. 11.) The three principal affirmative defenses set up in this answer were the same affirmative defenses alleged in the answer in the Main Channel suit. The exceptions filed to the answer in the Calumet River suit raised the issue as to rele-

vancy and materiality that it is claimed was raised by appellee's alleged motion to strike certain portions of appellant's answer to the Main Channel suit. Thus it was apparent that the motion to strike portions of appellant's answer in the Main Channel suit, was in effect passed upon when the court overruled the exceptions to the answer in the Calumet River suit. Appellee cannot here claim that it did not have an opportunity to meet various affirmative defenses of appellant, as they were direct issues in the case. They were kept in the case by order of the court. The case was tried on the issues raised by the bills and answers as filed.

18 Appellee's counsel suggest that the delay in the final disposition of this case in the District Court, was due to appellant. The record does not disclose any such facts. They refer to Vol. VI pp. 3878-80, which is merely a memorandum for the Secretary of War by the Chief of Engineers, dated December 18, 1911, not quite three years after the first suit was instituted, and approximately three years before the second suit, the Main Channel suit, was commenced. Furthermore, some suggestion has been made that all of appellee's evidence was submitted, and appellant delayed putting in its evidence. The record discloses that the evidence of appellee as to current in the Chicago River was not presented until April, 1914. (Rec., Vol. V, pp. 1320-30, witnesses Emerson, Minskey, Green, Hamilton and Simmons.)

This was after appellant had submitted all its evidence in chief, and when appellee was presenting its rebuttal.

Counsel say: "Judge Landis in effect found." There was no decree entered by Judge Landis. There was no memorandum signed by him; there was a mere oral opinion in the nature of a direction for preparation of a decree. And he never reached a position where he performed or was about to perform, any formal act of en-

tering an order or even signing a memorandum stating his conclusions.

23 We take issue with counsel's construction of Section 23 of appellant's Organic Act. This section expressly provided that the canal should be of capacity of not less than 300,000 cubic feet of water per minute, to be of a depth of not less than 14 feet, with current not exceeding three miles per hour, "*and if any portion of such channel shall be cut through a territory with a rocky stratum where such rocky stratum is above a grade sufficient to produce a depth of water from Lake Michigan, of not less than* 18 *feet, such portion of said channel shall have double the flowing capacity above provided for.*" (Appellant's Narrative, p. 73.) The channel was so constructed across the rocky stratum, as it was intended it should be at the time the Act of May 29, 1889, was passed.

26 The date of the commencement of work is prior to September 19, 1890, as set forth elsewhere. (*Infra*, p. 27.)

27 The subject matter of Major Marshall's letter of August 24, 1892, was the item in the Rivers and Harbors bill of July 13, 1892, asking that the engineer at Chicago submit a report as to improvement in the Chicago River, and related to cooperation by the Federal Government with appellant in appellant's plans for deepening and widening the Chicago River and its branches, to make it the supply channel by which the waters of Lake Michigan could be carried to the Sanitary and Ship Canal, as stated in the resolution of appellant's board of trustees of April 21, 1891. (Appellant's Narrative, p. 454.) The cooperation mentioned was given appellant by Congress in many acts following the one under which Capt. Marshall was to make his report, mentioned in said letter of August 24, 1892, which are set forth elsewhere herein. (*Infra*, pp. 104 to 110.)

The president of appellant's board, in replying to said letter of Capt. Marshall, August 25, 1892, said (Rec., Vol. IV, p. 2377):

> "I am personally very glad to note in your communication your good will towards the enterprise in which we are engaged, and I trust that the good feeling which exists will tend towards a proper solution of the question of a waterway from the Lakes to the Mississippi."

The letter of Capt. Marshall, May 23, 1893, part of which is quoted by appellee, also stated (Rec., Vol. IV, p. 2378):

> "I have to say for the information of your Honorable Body, that however I may differ from the local authorities as to the methods adopted by them for the amelioration or care of their defective sewerage, and water supply, that *I recognize their right and the authority and capacity of the commonwealth of Illinois and the municipality of Chicago to deal with their local matters in their own way*, and that having declared their choice, *United States officers shall place full faith and credence in their acts*. This office then, as far as not called by law to express opinions, etc., shall work in accord with local laws to further rather than obstruct, their ends and objects, as expressed clearly by the laws of the locality.
>
> • • •
>
> I have to say that I desire the backing and cooperation of the Trustees of the Sanitary District of Chicago to prevent any encroachments whatever upon the present channel of Chicago River, and to express to the Trustees of the Sanitary District my disinclination to recommend to the Secretary of War any restriction by bridges, filling or otherwise upon the capacity of the Chicago River, except where imperatively demanded by the people of Chicago in crossing the river by bridges.
>
> An examination of the locality in question will be made at the earliest practicable date, and if it be found that it comes within the purview of the in-

structions issued to the United States District Attorney to stop by injunction from an United States Court such encroachment this action will undoubtedly be taken on my application, by the District Attorney."

It will be observed from the above quotations that the engineer officer at Chicago recognized the full authority of appellant to proceed in the manner it was doing, and that it construed appellant's program as lawful and properly sanctioned. (Point I-D of our original brief, p. 128.)

Furthermore, it is apparent Capt. Marshall recognized that appellant would have to enlarge the channels of these rivers and he proposed to prevent encroachments, which would be in the way of appellant's work there.

28 Capt. Marshall's report of August 9, 1893, is analyzed herein. (*Infra*, p. 105.)

The letter of Col. Poe of March 22, 1895, asked for information from appellant. Apparently Col. Poe and his Board received all they desired, for in the second paragraph of the Board's report, it is stated (Appellant's Narrative, p. 465):

"The Board met in Chicago August 12, 1895, and on the 13th and 14th accompanied the officers of the Drainage Canal over the line under construction. Every facility and courtesy possible has been extended by the trustees and engineers of the canal for a full investigation of the subject matter."

Counsel quote certain portions of the report of the Board of Engineers, of which General Poe was chairman, dated August 16, 1895, and state that by that report the United States "*asserted its paramount control with respect to the creation of obstructions to navigable waters.*" This is entirely refuted by the following sentence in said report (Appellant's Narrative, p. 470):

"With this an established fact it is impossible to think that U. S. supervision shall not be extended to the Chicago Drainage Canal in due time."

There was not only no question of authority, but an express statement by this board of engineers of which the United States engineer at Chicago was a member (Major Marshall) but on the contrary an express statement that Congress had not then exercised control over the use and diversions of United States navigable waters for domestic and sanitary purposes. The report is in keeping with the attitude of the same United States engineer at Chicago, as shown by his other reports on this subject, and with our contentions.

31 The United States officers observed appellant's work, made careful study and investigation of its purpose and the effect of the operation of the works, and reported the same to Congress. The United States itself did not assert any control. Congress never acted at any time in opposition to appellant and is not acting.

35 The argument as to the effect of Section 10 of the Act of March 3, 1899, has no place in the Argument on the facts, and has been fully considered by us in our original brief, (Points I and II, pp. 111-140) and also herein (Infra, p. 50.)

37 The only possible condition of the full diversion under the permits mentioned and according to the conditions thereof to be taken up, was the question of current in the Chicago River. The only thing that appellee's officers were concerned about, and considered they had authority to determine, was the question of the reversal of the Chicago River and current therein.

41 The contentions of appellee as to the effect of the July 11, 1900 permits are elsewhere discussed herein. (*Infra*, p. 89.)

48 The statement of the Secretary of War of January 8, 1913, refusing to remove the limitation of the order of December 5, 1901, and to specifically grant authority for

10,000 seconds feet diversion, is discussed under Point VIII of our original brief, (p. 205).

51 The Wilmette permit, September 11, 1907, is referred to us herein. (*Infra*, p. 64.)

53 The effect of counsel's position as to the Calumet permit, June 30, 1910, is discussed by us elsewhere herein. *Infra*, p. 65.)

against appellant or its officers under Section 12 of said

57 There was no admission by appellant of the correctness of the allegations as to the lowering of the levels of the Lakes in the hearing before Secretary of War Stimson, except for the purpose of that argument. (*Infra*, p. 58.)

58 As to the so-called decision of Secretary of War Stimson of January 8, 1913, see our original brief. (Point VIII, p. 205.)

64 What purpose counsel have in referring to the letters of February 24, 1913, and March 15, 1913, from the Engineer Department of the United States, in which they threaten state officers performing their duties under mandatory provisions of state law in the interest of public health, with penal action, is impossible for us to even guess. It is not likely that any United States attorney at Chicago would have considered seriously a suggestion by the War Department that criminal action be taken Act of March 3, 1899. It would seem only proper that appellee's counsel should quote the portions of the letters of Mr. Adcock to the War Department referred to

66 which show the true import of said letter. The correctness of the statement in that letter to the effect that the International Waterways Commission by its report of January 4, 1907, had recommended a diversion of 10,000 cubic seconds feet of water at Chicago, is considered elsewhere herein. (*Infra*, p. 82.) Just before ap-

pellee's last quotation from said letter of March 22, 1913, the following appears (Rec., Vol. VI, p. 3972):

> " 'Until the decision of the Honorable Secretary of War of January 8, 1913, it was the general belief that the Secretary of War would without question formally consent under present existing conditions to the taking of water up to at least 10,000 cubic feet per second from Lake Michigan through the channels of the Sanitary District.
>
> The Act under which the Sanitary District is organized and under which it is now operating makes it mandatory upon the Trustees of the Sanitary District to cause not less than 20,000 cubic feet of water per minute for each 100,000 of the population of the District to flow from Lake Michigan through its channels. The population of the District is such that to comply with its organic law, it is necessary that the Board of Trustees cause more than 4,167 cubic feet of water per second to flow through the channels of the Sanitary District. That condition has existed for a number of years past and the Sanitary District has been flowing through its channels sufficient water to dilute the sewage pursuant to its Organic Act (20,000 cubic feet per minute for each 100,000 of population). The Sanitary District cannot either under the law of its creation or if it intends to preserve the health of the inhabitants of the District reduce that flow.
>
> I have at some length pointed out to you the facts with most of which no doubt you are familiar so that the situation in which the Sanitary District is now placed may be fully considered by you.' "

It concludes as follows (Rec. Vol. VI, p. 3973):

> " 'I respectfully request that before any definite conclusion is reached by the Government with reference to these suggestions that a conference be arranged between the representatives of the Sanitary District and the Government at such time and place as may be convenient to the Government representatives.' "

So it is apparent that the letter is merely a suggestion for future conference. Furthermore, it set forth the

utter futility and childishness of the War Department suggestion for any penal proceedings.

67 Appellee has failed to give consideration to the ordinance of the Board of Trustees of appellant of August 7, 1919, under which a project was laid out for the construction of artificial sewage purification works by appellant during the period ending with 1945, whereby the sewage and waste of the population over 3,000,000 would be taken care of without additional diversion from Lake Michigan. This program was explained in detail by the witness Langdon Pearse, to which there is no evidence to the contrary. (Appellant's Narrative 345-361.) This ordinance of August 7, 1919, was passed by appellant's board of trustees in cooperation with the United States Engineer officer at Chicago, Col. William V. Judson, as is shown by his letter of May 24, 1921, to the Chief of Engineers, U. S. A. (Appellant's Narrative 344.) After describing the project for artificial sewage disposal laid out by appellant under the ordinance of August 7, 1919, Colonel Judson in his letter concludes (Appellant's Narrative 354):

> "'20. In the meantime the Sanitary Trustees are proceeding energetically with their plans for sewage treatment and disposal as outlined in enclosed memorandum. Since the date of their report, they have acquired 180 acres of land located on the North Shore Channel as a site for their proposed North Side purification plant.
>
> 21. The progress made by the Sanitary District is well illustrated by Exhibits E and F constituting part of enclosure showing their budget appropriation for 1921 and their expenditures during the ten year period 1910-1920. During the last named period the expenditure for sewage treatment works has amounted to approximately $9,400,000. Their budget for 1921 provides $6,500,800 for the completion of old projects and $3,242,500 for new projects.
>
> 22. The program of the Sanitary District, if carried out, will insure the practicability of keeping the

volume of water diverted from Lake Michigan within limits which it is hoped all concerned will finally deem reasonable.' "

The above quotation from Col. Judson's letter of May 24, 1921, to the Chief of Engineers, must be read, of course, in connection with his letter to the Chief of Engineers dated March 23, 1921 (H. R. Doc. No. 2, 67th Congress, 1st Session), wherein he speaks of the amount of diversion required for a deep waterway from the lakes to the Gulf, and concludes as follows (*Infra*, p. 75.):

> "Then should Congress place the limit of the amount of water to be withdrawn from lake Michigan at 10,000 seconds feet, which I deem probable and under proper conditions advisable, that increment would of itself increase the depth to 9 feet."

So, when Col. Judson in the last paragraph of the quotation from his May 24, 1921, letter stated that the program of appellant would keep the flow *"within limits which it is hoped all concerned will finally deem reasonable,"* he had in mind the 10,000 cubic seconds feet of water mentioned in his letter of March 23, 1921, when he spoke of the limit of the water to be withdrawn as 10,000 seconds feet *"probable and under proper conditions advisable."*

69 The table shows the yearly average withdrawal from 1900 to 1913 inclusive. It was not until the end of the period shown (1913) that the appellant's diversion works were entirely completed. It was a physical impossibility until the channels of the Chicago River were substantially deepened and widened, as authorized under the permits of the Secretary of War of July 11, 1900, to withdraw through these channels the full 10,000 cubic seconds feet. All this was shown by Mr. Randolph. (*Infra*, p. 43.) Furthermore, the necessity for the full 10,000 seconds feet diversion in order to keep the Chicago River at all

times flowing away from Lake Michigan, became more marked as the sewered and paved area of Chicago and its environs increased, because of which the floods would be more quickly delivered to the river.

78-114 Appellee has devoted many pages to a discussion of the evidence concerning the Great Lakes and claimed damage to commerce; that is, the theoretical effect of appellant's diversion at Chicago upon the levels of the Great Lakes and their connecting channels, including the theoretical damage to commerce. We believe that in our original brief (Statement of the case, pp. 63 to 69) this evidence is fully set forth and in such manner that it can be understood. Only one conclusion can be drawn from a perusal of appellant's discussion of the hydraulic evidence and the evidence relating to commerce; and that conclusion is that the whole basis of appellee's case is theory of experts. The results depend upon an inference of the unseen. No lay witness has testified as to the actual lowering of the levels of the lakes or their connecting channels, or that damage to commerce has been observed, notwithstanding the diversion has existed for almost a quarter of a century.

We will, however, briefly refer to certain pertinent facts appearing in the record relating to the character of appellee's conclusions as to the Chicago diversion's effect upon the levels of the lakes. Obviously the ascertainment of the correct increment of the different outlet rivers, was important. We have pointed out the ingenious process by which appellant's experts sought to obtain an increment. (Appellant's Statement, Original Brief, p. 64.) In the first place, a great number of discharge measurements were required to be made and tied or related to the level of the controlling lake which produced or was responsible for the amount of discharge at the time the measurement was made. The measurement

of the discharge was a complicated matter, and required the exact determination of the cross sections of these great rivers at the place called the discharge measurement section. It required, also, the correct establishment of the rate of flow at a given instant. A current meter was used, called the Haskell meter. There were two kinds of meters, and there were numbers of methods for determining rate of current. Various witnesses differed as to what instrument should be used. However, the discharge measurements were made by the United States Lake Survey and they used a Haskell current meter. Some of the sources of error occurring appear in the record.

The correctness of such measurements of discharge depend first upon the *rating of the meter,* that is, the relation of the revolutions of the meter wheel in a given time to the velocity of the water passing it. Due to changes in lubrication resulting from the displacement of the oil by water, the revolutions for a given velocity decrease as the time of immersion increases. (Haskell, Vol. V, pp. 2737, 2738; Shenehon, Vol. V, pp. 3374, 3380.) Variations of as much as 2 per cent in a day have been noticed. (Shenehon, Vol. I, pp. 352, 366.) In rating meters by the methods used by the lake survey in the field it is not possible to subject them to as rigorous conditions as those they encounter in actual gaging, on account of the limits of human endurance. (Williams, Vol. II, p. 908.) It follows then that when a meter has been used in a gaging for two hours the lubricant has been materially more reduced than by two hours of rating, where during a considerable portion of the time the meter wheel would not be rotating, while in the stream it is in motion continuously. The erroneous indication resulting from applying the average results of a rating to obtain the average results of a gaging are

in one direction and produce an indication of velocity less than the true one. (Williams, Vol. II, pp. 913, 963.)

The effect of *turbulence* and *pulsations* upon meter indications has been presented by Williams, Schoder and Turner, and by experiment was found to reduce the meter indication practically 10 per cent. (Williams, Vol. II, pp. 734, 958; Schoder, Vol. III, p. 1549; Turner, Vol. III, p. 1575.) Pulsations are present at all the gaging stations to some extent and decided turbulence is encountered especially at the bridge and open sections of the Niagara. (Freeman, Vol. III, pp. 1165, 1186; Williams, Vol. II, p. 733.)

The next source of inaccuracy in a meter measurement of flow is in the determination of the *area of the cross section.* For this work the Engineers of the Lake Survey have developed processes of considerable refinement, involving corrections of observed depths from a theoretically computed table designed to provide for the drift of the sounding weight due to the current. (Moore, Vol. I, p. 255; Moore, Vol. V, p. 2908.) No experimental evidence of the accuracy of these corrections has been submitted in this case and the question still remains unsettled as to whether the corrections applied may have been too little or too great.

Necessarily it is not possible to sound every point of the bottom and soundings were taken at intervals usually of from 10 to 20 feet. (Moore, Vol. V, pp. 2897, 2902; Shenehon, Vol. I, p. 299.) What the elevation of the bottom may have been between soundings is unknown, but is assumed to be uniformly varying from one to the other. The area of the cross-section changes as the lake rises and falls and sometimes the surface rises more at one end of the section than at the other. (Rec., Vol. I, p. 191.) The witnesses for appellee have claimed an

accuracy of from 1 to ½ of 1 per cent for the determination of area. (Shenehon, Vol. I, p. 311; Moore, Vol. V, p. 2870; Richmond, Vol. V, p. 2942; Ray, Vol. V, p. 2801; Haskell, Vol. V, p. 2662.) In water averaging 25 ft. depth an error of 3 inches would represent 1 per cent and, with the possibility of an unmeasured variation of 1 inch at the surface, the soundings must be made within ½ inch to maintain the accuracy of ½ of 1 per cent that is claimed by the appellee's witnesses. The probability of this is left to the judgment of the court.

However, the sounding of a section is one thing and keeping the meter on it in a swiftly flowing stream is quite another. As shown by the testimony of Williams, uncontradicted by appellee, at the Niagara bridge section the meter was several feet away from the section sounded and in an area considerably larger, the apparent discharge being thus reduced by an error of about 3 to 6 per cent. (Williams, Vol. VI, p. 3531.)

The next source of error is that due to the fact that the *velocity in only a part of the section* is *observed* by the meter. (Haskell, Vol. V, p. 2739; Shenehon, Vol. I, p. 341.) In a so-called discharge measurement at the Bridge Section of the Niagara River as shown by Plate No. 5, Rec., Vol. IV, p. 2475, the velocity was observed at 21 index points. (Shenehon, Vol. I, p. 299.) As shown by the Report of F. C. Shenehon (Rec., Vol. IV, p. 2466), and Shenehon's Testimony (Rec., Vol. I, p. 352), when the meters were within 5 feet of each other their indications failed to agree within one or two per cent. The area of a meter wheel is considerably less than half a foot (Haskell, Vol. V, p. 2739), and if for the sake of argument it be granted that its revolutions correctly represent the velocity in an area two feet square with the meter at the center, the area of stream actually measured would be 4 x 21—84 square feet out of an area of over 41,000 square feet, or by observing the velocity in 2/10 of 1

per cent of the stream it is assumed by the appellee's witnesses that they know of the velocity in the remaining 99.8 per cent within ½ of 1 per cent. (Moore, Vol. V, p. 2870; Haskell, Vol. V, p. 2714.)

If the observations taken in the so-called co-efficient work be included there are by Shenehon's Report about 90 x 11—990 positions occupied by the meter (Rec., Vol. IV, p. 2469), and granting each position to cover four square feet there are about 4,000 square feet of current measured out of a total of 41,000, so that on a most liberal estimate, the velocity in 90 per cent of the stream is unmeasured and only guessed at, yet it is claimed that the discharge is known within ½ of 1 per cent.

Lack of Evidence of Accuracy. In spite of these claims of accuracy there is no evidence to support them and they must be regarded as mere expressions of opinion of more or less qualified experts. The appellee has submitted no evidence that in the disturbed water of the Niagara River the meter registers within ten or any other per cent of correctness, while appellant has shown that under similar conditions it under-registers anywhere from five to ten per cent. (Schoder, Vol. III, p. 1548.) The only basis for a claim to accuracy in the work of the complainant is in the correspondence of the discharges at different and the same sections (Haskell, Vol. V, p. 2662; Shenehon, Vol. V, p. 3170), and this is no evidence of accuracy, as each may be and probably is, in error several per cent in the same direction due to effects of turbulence, incomplete investigation of the cross section of the stream, and variations of rating of meters due to changing conditions of lubrication.

In speaking of the determination of the increment of the St. Lawrence, Mr. Shenehon, the principal witness for appellee, said (Rec., Vol. V, p. 3182):

> "We had, I believe, only 93 observations. Those were in two groups, the lower ones being in one sea-

son and the upper ones in the second season. It appears at the present time that an error did enter there. This is still in the melting pot, and we don't know our increment as accurately, or we did not know our increment as accurately on the St. Lawrence as indicated by my original testimony; that is, that is the indication from the present investigations.

* * *

I believe the error in the St. Lawrence increment as originally derived and as finally derived, is somewhere in the neighborhood, that is the difference is somewhere in the neighborhood of 10 or 15 per cent."

Major Keller, one of appellee's witnesses, stated (Rec., Vol. I, p. 229):

"A. I think that in all probability the results that I have just given are accurate within approximately 5 per cent.

Q. Can you, without going through any long mathematical process, state why you put that at 5 per cent? What is the reasoning in your mind that leads you to say 5 per cent?

A. Well, as a general rule, we have found out in our discharge measurements that the line which most nearly expresses the law of discharge will be so drawn upon a diagram that the extreme measurements, those which diverge furthest from the line, will contain an error not to exceed about 2 per cent. That in itself is probably an error that does not altogether measure the total error which appears in the measurement. It shows the internal or relative consistency of the measurements, but it does not exhibit the fact that it is possible that in addition to small errors due to the use of the meter itself, there may appear small errors due to the impossibility of measuring the cross section with absolute accuracy. And the final result will also show a very small error due to the slight errors of gage readings that may appear in the result. And while I have said 5 per cent, it is merely my opinion that the final result may show an error as large as 5 per cent. I do not believe it will show anything larger. I think all causes combined would probably aggregate at the very utmost 5 per cent."

In speaking of the error that may enter into the determination of an increment from the ice effects in these various outlet rivers, Major Keller stated (Vol. I, p. 240):

> "My conclusion, independently of that of this office, my personal conclusion is that the ice effect is a large but unknown factor in the determination of the levels of the Great Lakes; and that up to the present time the Lake Survey has not made sufficient measurements to enable any one to form a justifiable conclusion as to the measure of the ice effect, either in the St. Clair River, or in any of the other rivers; the Niagara or the St. Lawrence."

Prof. Eugene E. Haskell, one of the principal witnesses for appellee, in discussing an increment determined by the Lake Survey for the St. Clair River, said (Rec., Vol. V, p. 2735):

> "Q. The discharges would be in error 4% and the increment 40%?
>
> A. Yes."

Mr. Haskell invented the so-called Haskell current meter which was used in these determinations by the Lake Survey.

The witness F. G. Ray, who was when he testified the head of the United States Lake Survey, in speaking of the increment development for the St. Clair River, said (Vol. V, p. 2793):

> "I believe that increment may be in error from 10 to 15 per cent."

The witness Moore, in testifying as to the latest increments determined by the Lake Survey and in the employ of the Lake Survey, said (Rec., Vol. V, p. 2866, 2867):

> "I took up each of the rivers connecting the Great Lakes; examined all of the observations for possibilities of error, and made some changes and altera-

tions in gages and meter readings, which seemed indicated by the observations and by our further knowledge of the subject, and wherever necessary I derived new equations expressing the law of flow in terms of the controlling gage".

In speaking of the latest increment determined for the St. Clair River by the Lake Survey, Mr. Moore further said (Rec., Vol. V, pp. 2868, 2869):

> "The latest reduction by the Lake Survey shows an increment at mean stage of about 21,000 cubic feet per second. That, in my opinion, may possibly be in error by as much as 20 per cent."

Concerning the increment derived by the Lake Survey in 1909, Mr. Moore stated that the error was

"Not to exceed 25% maximum possible error."

Appellee has taken the position that the Secretary of War would have the authority to authorize a diversion from Lake Michigan of 4,167 seconds feet through the Chicago River, but would not have the authority to authorize 10,000 cubic seconds feet, or a diversion materially larger than the amount first mentioned, because in the first instance there would be no obstruction to navigation, but in the second instance there would be. When the conditions assumed for the second were apparent to the Secretary of War, his authority under Section 10 of the Act of 1899 ceased and would not cover an authorization of the larger diversion which would amount to, as they say, an obstruction. The Government's determination of the effect of 10,000 seconds feet diversion from Lake Michigan, is based upon an increment of approximately 23,800 cubic seconds feet. Dividing the diversion by the increment, to determine the effect, produces the result of 5 inches (approximately), which is the amount testified to and shown by Appellee's Exhibit 1. (Appellant's Narrative, opposite page 124.) If

there is 40% error in the increment, there may be 40% error in the determination of the effect—5 inches,—so that the 5 inches should be reduced by 40%, which would give a possible result of 3 inches as the effect of diversion of 10,000 cubic seconds feet at Chicago. This is a little over half an inch more than the effect of 4,167 second feet which appellee says does not create an obstruction to navigation, ascertained according to their determination of an increment of 23,820 cubic seconds feet.

Finally, appellant submits that for the determination of the magnitude of the effect of the Chicago diversion, the actual facts, *if established*, in the language of Mr. Justice Holmes, (*Missouri* v. *Illinois*, 200 U. S. 518, *et seq.*)

> "have required for their establishment the most ingenious experiments and for their interpretation the most subtle speculations of modern science. * * * There is nothing which can be detected by the unassisted senses. * * *"

The comments as to the qualifications of appellant's witness Gardner S. Williams, have been considered by us elsewhere. (*Infra*, p. 60.)

Appellee complains, (Its Brief 93), about our reference to the testimony of Mr. Ripley as to the platform of the Poe Lock being some four inches above the mitre sill. The Poe Lock being constructed about the year 1898, Mr. Ripley testified that the platform remained thus restricting the drafts of vessels from the time it was built until he testified in the year 1913. Appellee's particular complaint is that appellee's witness DeYoung was not mentioned in appellant's narrative statement, or in the index of the record appearing as Volume A. This index was prepared for the District Court, and was merely rebound for the use of this court. The DeYoung testimony was offered by appellee, on December 19, 1914,

after the record was printed and the index had been prepared. The following statement appears in the record at the time the DeYoung testimony was taken (Vol. VI, p. 3976):

> "Mr. Adcock: No; everything is in the printed record now."

The DeYoung evidence and some other evidence offered at that time, (December 19, 1914), was merely added to Vol. VI of the record. The index was not reprinted simply to include the additional material. So counsel's severe criticism in this respect is entirely unfounded. Furthermore, the DeYoung testimony was absolutely of no value. Ripley testified as to how the lock was built. DeYoung testified as to some soundings that were made, at which he was not present, as appears in his testimony, as follows (Rec., Vol. VI, p. 3979):

> "Q. Do you know the elevation of the top of this platform that you speak of as compared with the elevation of the top of the lower mitre sill of the Poe Lock.
>
> A. I don't think I do. I think, however, it is the same elevation.
>
> Q. That is only an opinion that you have?
>
> A. Yes.
>
> Q. You don't know anything about it?
>
> A. No, sir."

114 It was not until after both appellee and appellant had presented their evidence in chief, that appellee offered any evidence as to current in the Chicago River. In April, 1914, it produced certain persons who operated boats at times upon the Chicago River. (Rec., Vol. V, p. 3020.) These witnesses had never measured the current, nor had they made any calculations as to what the current would be from the cross sections and slope of the river produced by appellant's enlargement under the July 11, 1900, permits, with a flow of 10,000 cubic seconds feet.

They only testified as to what they thought they saw at certain places, at bridge draws and other parts of the river, when there were two or more boats abreast in the stream. The mile and a quarter per hour current, which was unobstructive to navigation, with the withdrawal of 10,000 cubic seconds feet through these river channels, was ascertained by competent engineers, (Randolph, *Infra*, p. 43, and Wisner, *Infra*, p. 62). Appellee's own division engineer at Chicago, in his report (1906) found that the current with this amount of diversion would not exceed a mile and a quarter an hour (*Infra*, p. 61.) No engineer of appellee appeared to testify that the channels of the Chicago River and its branches had not been completely so enlarged that the 10,000 cubic seconds feet of water could be taken through them without producing a current obstructive to navigation.

The Secretary of War, Stimson, in his statement of January 8, 1913, took up almost every question that could possibly be presented in support of his refusal to remove the limitation of December 5, 1901. He did not mention an obstructive current in the Chicago River that was or would be produced by the 10,000 cubic seconds feet diversion. He did not therein suggest that this diversion through those river channels had caused or would would cause any injury to navigation on that river. **If a current did or would exist in the improved channels of the Chicago River and its branches, the Secretary undoubtedly would have so stated in his January 8, 1913, statement.** In any event if there were any question as to whether a current is considered unreasonably obstructive to navigation, the river channels could be easily deepened to take care of this condition. The court, without difficulty, could properly, by its decree, take care of that situation.

We will now discuss the various points of appellee's argument.

APPELLEE'S POINT I.

(Its Brief, p. 123.)

It is true that these waters of the Great Lakes and their connecting channels, are navigable waters of the United States. The International Boundary passes through some of these lakes and along some of the connecting rivers. The waters on one side of the boundary are in Canada, and those on the other are in the United States. What counsel's purpose is in calling them "high seas", we are unable to discern.

The cases referred to by counsel, turned upon the proposition that they were navigable waters of the United States, and therefore admiralty courts had jurisdiction.

In referring to *The Genessee Chief* v. *Fitzhugh*, 12 Howard 443, this Court, *in U. S.* v. *Rogers*, 150 U. S. 247, 258, said:

> "The court, perceiving that the reason for the exercise of the jurisdiction did not in fact depend upon the tidal character of the waters, but upon their practicable navigability for the purposes of commerce, disregarded the test of tide water prevailing in England as inapplicable to our country with its vast extent of inland waters."

At page 259, the Court further said:

> "We may as appropriately designate the open, unenclosed waters of the lakes as the high seas of the lakes, as to designate similar waters of the ocean as the high seas of the ocean, or similar waters of the Mediterranean as the high seas of the Mediterranean."

The Boundary Waters Treaty of January 11, 1909, very clearly defines the character of these waters. Article I referred to by counsel, merely gives the same right of navigation to the citizens of Canada on Lake Michigan, that the United States has, "subject, however, to any laws and regulations of their country within its own territory."

The word "free" has a double meaning—one, "without toll", *second*, "equal" rights.

The preliminary article defines boundary waters. Lake Michigan is not a boundary water and therefore is not subject to the treaty; in fact, the treaty expressly recognizes and reserves to the State of Illinois and the United States, the free and unlimited power to deal with Lake Michigan as the United States and the State of Illinois may consider proper for the public interest. By the treaty, therefore, Lake Michigan may be treated as if it had no connection whatever with the other Great Lakes.

APPELLEE'S POINT II

(Its Brief, p. 128.)

In some mysterious way, not disclosed, appellee seeks to gain some advantage or comfort from calling the waters of the Great Lakes "international". Since the Treaty of January 11, 1909, with reference to Canadian boundary waters, the character of and the rights of the states and the nation in the waters of the Great Lakes, whether boundary or non-boundary waters, are not open to debate or question. Suffice it to say that the rights in Lake Michigan are recognized to exist in the state and nation. They may be diverted as the state or nation may provide, subject, only, to the right of Canadian citizens to sue for injuries, or the right of Canada to object in case navigation is affected as to any diversion not settled by the treaty. As we pointed out in our original brief, p. 188) the treaty left open the question *only* of a diversion at Chicago from Lake Michigan of that amount which would be in excess of 10,000 cubic seconds feet.

Counsel make two misstatements of fact in this connection—*first*, that the work on the canal and on the Sanitary District's diversion works, was not commenced prior to the passage of the Act of September 19, 1890, and, *second*, that the canal was not completed until after the passage of the March 3, 1889, Act. On this subject we refer the Court to the testimony of Mr. Lyman E. Cooley, who was the first chief engineer of appellant, and also was closely and intimately connected with appellant's projects from their inception (Appellant's Narrative, p. 288):

> "The Sanitary District was instituted for the specific purpose of carrying out the projects which were outlined prior to its organization, and had proceeded by September, 1890, in the definitive surveys from the Chicago River to Joliet. They had also instituted surveys on the

Chicago River with a view to the definitive surveys for its enlargement. When I became chief engineer in January, 1890, I proceeded immediately to further work upon those plans for the Sanitary District. There was nothing left to do except to define the things on the ground, practically. The genius of the whole proposition from the outset, held in mind unvaryingly, was to keep the flow of sewage away from Lake Michigan as far around the rim of the lake as was practicable."

Again, Mr. Cooley states, as to the date of the completion of the canal (Appellant's Narrative, p. 292):

"The work was proceeding faster than the District could get the funds to pay for it and so the real work on the channel, the Main Channel, which was scheduled to be completed in November, 1897, was not actually completed until about November, 1898, when it was substantially completed, and the District then notified the Governor of that fact and asked for the appointment of a commission. The first action by the Board (of Trustees of Appellant) on that matter was in November, 1898, and the petition actually was transmitted to the Governor in January, 1899, as I recall it."

Mr. Cooley is the only witness who testified to these facts. There was no controversy.

We construe the Act of September 19, 1890, as treating to be lawful appellant's structures erected under its May 29, 1889, Act, as held in

United States v. *Bellingham Bay Boom Co.*, 176 U. S. 211, 44 Law Edition, 437.

This case was construed in

Maine Water Company v. *Knickerbocker Steam Towage Company*, 99 Maine, 473,

as so holding, and the *Maine Water Company case* was cited with approval by this Court in

Southern Pacific Company v. *Olympian Dredging Company*, 260 U. S. 205, 210.

A distinction is sought to be drawn by appellee, because the waters affected by appellant's works built in exercise of Illinois' police power, affect other waters than those wholly within the limits of the state. Counsel fail to recognize the distinction between an act passed in the exercise of a well-known police power reserved to the state, as here, which act has a reasonable relation to the purpose sought, from an act of the state passed directly to regulate interstate commerce. In the first instance, the effect upon interstate commerce is *incidental,* and in the latter instance, it is *direct.* In the latter instance, the whole subject is delegated to Congress, and the states have no authority. In the first instance, the state's authority exists, and if the act is reasonable, then it must be reconciled with the congressional power or exercise thereunder. In the present instance, the state's acts operate upon navigable waters outside of the state, as claimed by appellee, and through that medium affect, incidentally, interstate commerce. In the ultimate analysis interstate commerce is the particular matter involved. The case is no different from a bridge constructed over the Chicago River, or some other river wholly within the state, which would have the result of affecting boats plying between some point further within the state, than the bridge erected, and ports of other states. It is similar to a regulation such as was before this Court in

Escanaba v. *Chicago,* 107 U. S. 678.

Interstate commerce outside of the state and generally is often incidentally affected through action under the state's police power. A good example is the discriminatory effect upon interstate commerce outside the State of Minnesota before this Court in the *Minnesota Rate Cases,* 230 U. S. 352.

The case of

Chandler-Dunbar Water Power Company v. *U. S.,* 229 U. S. 51.

does not support appellee's contention, for in that case the power plants were constructed in the St. Mary's River, and

produced the effect, as counsel claim, of lowering the levels of the lakes. They were lawful structures and so considered by appellee and every one until the Act of Congress was passed specifically declaring them to be unlawful, and directing the Secretary of War and Attorney General to remove them.

Kansas City Street Railway Co. v. *Kaw Valley Drainage Dist.*, 233 U. S. 75,

is not in point, for there the Court directed the *absolute* removal of a bridge over the stream in question, which bridge carried railroad tracks, an instrument of interstate commerce. This Court in that case based its decision upon the character of the decree directing complete removal. If there had been a proper order of the Court providing for *reasonable* alteration of the bridge, as required, to prevent overflow and damage to lands, then this Court's decision would have been different.

Appellee's Point II-A.

(Its Brief, p. 132.)

Appellee here again fails to recognize the distinction between acts of the state directly operating upon interstate commerce, from those acts which only incidentally affect it and passed in the exercise of a reserved police power. Counsel quote extensively from *Minnesota Rate Cases*, 230 U. S. 352, and lay much stress upon the language contained in that opinion

> "There is no room in our scheme of government for the assertion of state power in hostility to the authorized exercise of federal power."

In the case at bar, there is no exercise of state power in *hostility* to the federal power. The state proceeded in the best way possible regarding those things over which, under our scheme of government, it has jurisdiction. It has not sought to set up any power to regulate interstate commerce, and

this distinction is plain from the very language of the opinion quoted by appellee:

> "The grant in the Constitution of its own force, that is, without action by Congress, established the essential immunity of interstate commercial intercourse from the *direct control* of the states with respect to those subjects embraced within the grant * * *."

This Court, after using the language quoted by counsel, makes its position clear beyond question. Note the following language in the *Minnesota Rate cases*, which bears out our contention:

> (P. 402) "Our system of government is a practical adjustment by which the national authority as conferred by the Constitution is maintained in its full scope without unnecessary loss of local efficiency. Where the subject is peculiarly one of local concern, and from its nature belongs to the class with which the state appropriately deals in making reasonable provision for local needs, it cannot be regarded as left to the unrestrained will of individuals because Congress has not acted, although it may have such a relation to interstate commerce as to be within the reach of the Federal power. **In such case, Congress must be the judge of the necessity of Federal action.** Its paramount authority always enables it to intervene at its discretion for the complete and effective government of that which has been committed to its care, and, for this purpose and to this extent, in response to a conviction of national need, to displace local laws by substituting laws of its own. The successful working of our constitutional system has thus been made possible.
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> * * *
>
> But this exercise of the important power to provide local improvements has not been regarded as constituting such a **direct burden** upon intercourse or interchange of traffic as to be repugnant to the Federal authority in its dormant state."

In speaking of quarantine regulations, this Court further said:

> (P. 406) "In view of the need of conforming such measures to local conditions, Congress from the begin-

ning has been content to leave the matter for the most part, notwithstanding its vast importance, to the states, and has repeatedly acquiesced in the enforcement of state laws."

This Court clearly recognizes that Congress should be deemed to have consented to the state's action in the exercise of a reserved police power, even though it indirectly affects interstate commerce, until Congress acts in the premises. So it did in the situation presented by the case of

Chandler-Dunbar Water Power Company v. *U. S.*, 229 U. S. 51.

A similar situation existed with reference to the diversions of water at Niagara Falls for water power purposes. These diversions existed without any congressional authority and without permits of the Secretary of War. The authority for such diversions existed solely under the laws of New York, until the passage of the Act for the preservation of Niagara Falls of June 29, 1906, at which time Congress exercised its paramount authority upon the particular subject. Counsel's quotation (Appellee's Brief, p. 221) from the committee report concerning the bill introduced, bears this statement out conclusively.

In

Covington & Cincinnati Bridge Co. v. *Kentucky*, 154 U. S. 204,

there was an attempt under state authority to fix rates of charge for passage over the bridge, a direct regulation of interstate commerce, and, of course, the case is not in point on the situation presented here.

This Court applied the same principle in

Missouri v. *Kansas Natural Gas Company*, 68 Law Edition, Advance Sheets, p. 585, June 16, 1924,

and in

Public Utilities Commission v. *Landon*, 249 U. S. 236.

In the former case, the Court held that the state was without power to fix the price of gas transmitted from one state to another, where the gas was delivered to a distributing company or companies, who thereupon delivered it to the individual consumer. In the *Missouri case,* this Court distinguished *Pennsylvania Gas Company* v. *Public Service Commission,* 252 U. S. 23, solely because the gas was transmitted from Pennsylvania by the Pennsylvania Gas Company to the individual consumer. In the *Pennsylvania Gas Company case,* the price fixed for gas under the authority of the State of New York, was the price to the individual consumer, and was peculiarly a local or state matter, and therefore it was held that the state's action should be reconciled and held valid. And in the *Missouri case,* this Court, making the distinction between the facts in that case and those in *Pennsylvania Gas Company* v. *Public Service Commission, supra,* said (587):

> "In such case the *local interest* is *paramount* and the interference with interstate commerce, if any, *indirect* and of minor importance."

Appellee's Point II-B.

(Appellee's Brief, p. 135.)

The cases cited under this subheading do not support the proposition presented, for the state's actions were upheld. The distinction attempted to be made by appellee does not exist. The situations presented by those cases were instances of the state's exercise of the reserved power, which indirectly affected interstate commerce. They are authorities in support of our position.

Appellee's Point II-C.

(Appellee's Brief, p. 136.)

It is unnecessary to consider the numerous cases cited by appellee as they support our contention. We will, however,

analyze the *Wheeling Bridge case,* 13 Howard 553, for the reason that counsel lay so much stress upon it as an authority in their favor. It is cited and the opinion is quoted at length under Point II-C of their argument (page 139), and also it is cited in almost twenty other places in appellee's brief. As we understand it, for that case, counsel contend the following: (1) it disposes of the contentions of appellant as to the invitation and acquiescence of appellee in the construction, operation and attendant diversion of appellant's works; (2) it disposes also of the contention of appellant that its works interfere, if at all, but slightly with interstate commerce; and (3) appellee further makes the claim that the Ordinance of 1787 as to the Northwest Territory has the same force and effect as the compact between Virginia and Kentucky as to the free navigation of the Ohio River, sanctioned by Congress, under consideration in this *Wheeling Bridge case.*

In order that these contentions of appellee may be shown to be fallacious, we will refer to the facts in the *Wheeling case,* which are entirely unlike the facts in the case at bar. The *Wheeling Bridge case* was instituted in this court by the State of Pennsylvania against the bridge company to enjoin the construction of a bridge across the Ohio River, which river at this point was entirely within the State of Virginia. The river, however, rose in Pennsylvania and extended through the State of Virginia, and thereupon formed the boundary between Ohio and Virginia and farther down between Kentucky and Ohio. This river in Virginia was entirely different from the Chicago River and its branches as they are wholly within the limits of the State of Illinois. The Chicago River and its branches do not stand to Illinois as the Ohio River at Wheeling did to the State of Virginia. However, as they connect with navigable waters outside the state, and navigation may be carried on continuously, the Chicago River and its branches are navigable waters of the United States and the facts are similar to those presented in *Willamette Iron Bridge Co.* v. *Hatch,* 125 U. S. 1. The Willamette River forms

with the Columbia River, a highway of interstate commerce. It is navigable water of the United States. It appeared that the purpose of building the bridge as proposed was to make Wheeling the head of navigation of the Ohio River, and thus cut off Pennsylvania towns.

Whether Congress would authorize the construction of the bridge across the Ohio River of the height and length of span, as it was being constructed, was before Congress on several occasions. Pennsylvania objected. Congress refused to pass any act authorizing the structure. Mr. Stanton, in his argument, summing up the effect of these applications to Congress, said (p. 528):

> "It is manifest, therefore, that the only constitutional power that could in any event authorize this bridge had been invoked, and that by its negative action, potentially as by express enactment, this structure was prohibited."

In the case at bar, the converse was true, for from the very beginning of the discussion of the project by the people of Chicago and Illinois, and from the time the Act of May 29, 1889, was passed, the entire matter had been brought to the attention of Congress by its own officers, and its inaction must necessarily be construed to be consent and acquiescence in Illinois' program for the protection of the public health of Chicago.

Pennsylvania instituted its suit immediately upon the initiation of the construction of the bridge. Notwithstanding the pendency of the suit, the bridge company proceeded to complete the structure in a manner to obstruct navigation. How much different are the facts before this court! Congress, long before the works of appellant were commenced to be built, provided for numerous surveys for a deep waterway. These acts covered a period of a quarter of a century prior to the passage of appellant's organic act. Surveys were made recommending the building of a deep waterway and the diversion of water from Lake Michigan for that purpose. After appel-

lant's works were placed under construction, and during the period of construction and afterwards Congress passed acts looking to the utilization of its canals and the water diversion for this deep waterway. At no time did Congress refuse to authorize their operation as required by the Illinois Act.

All of appellant's diversion works were constructed prior to the institution of any suit questioning the validity of its diversion; in fact, in the very suit to which appellee refers—the Calumet River suit, started on March 23, 1908,—as we pointed out in our original brief, appellee sought only to question the right to divert water through the Calumet River and the Calumet Sag Channel, a mere adjunct of the main diversion canal, the Sanitary and Ship Canal. The principal diversion provided for was through the Chicago River and its various branches to the northern terminus of the main canal. This Calumet River suit did not in any way question the right of appellant as to the Chicago River diversion, but assumed that to be a lawful diversion, as required by state law; otherwise appellee would have at that time included this diversion within the Calumet River suit.

This Court in the *Wheeling Bridge case* also based its decision upon the compact between Virginia and Kentucky, sanctioned by Congress—

> "That the use and navigation of the River Ohio, so far as the territory of the proposed state (Kentucky), or the territory that shall remain within the limits of this Commonwealth lies thereon, shall be free and common to the citizens of the United States."

This is entirely different from the provisions of the Ordinance of 1787 for the government of the Northwest Territory—

> "The navigable waters leading into the Mississippi and St. Lawrence, and the carrying places between the same, shall be common highways, and forever free, as well to the inhabitants of said territory as to the citizens of the United States, and those of any other states that may be admitted into the confederacy, without any tax, impost, or duty therefor."

In

Willamette Iron Bridge Co. v. *Hatch, supra,*

with reference to the effect of this provision of said ordinance, this Court said (page 2):

> "This court has held that when any new State was admitted into the Union from the Northwest Territory, the ordinance in question ceased to have any operative force in limiting its powers of legislation as compared with those possessed by the original States. On the admission of any such new State, it at once becomes entitled to and possessed all the rights of dominion and sovereignty which belong to them."

Again the Court said (page 12):

> "What the people of the old States wished to secure was the free use of the streams and carrying places in the Northwest Territory, as fully as it might be enjoyed by the inhabitants of that territory themselves, without any impost or discriminating burden."

Again this Court, in the *Willamette case* in speaking of the *Wheeling Bridge case*, said (page 15):

> "But in that case (*Wheeling Bridge case*) this court had original jurisdiction in consequence of a State being a party; and the complainant (the State of Pennsylvania) was entitled to invoke, and the court had power to apply, any law applicable to the case, whether state law, federal law or international law. * * * But Virginia, in consenting to the erection of Kentucky into a State, had entered into a compact with regard to the free navigation of the Ohio, confirmed by the Act of Congress admitting Kentucky into the Union, which the court held to be violated by authorizing the bridge to be constructed in the manner it was; and the bridge, so constructed, injuriously affected a supra-riparian State (Pennsylvania) bordering on the river, contrary to international law."

See also

Huse v. *Glover*, 119 U. S. 543.

In the late case of *Economy Light & Power Co.* v. *United States*, 256 U. S. 113, this Court, in referring to *Escanaba* v.

Chicago, 107 U. S. 678, 688, 689, and *Willamette Iron Bridge Co.* v. *Hatch*, 125 U. S. 1, and other cases, said (page 121):

> "Those cases simply hold, in effect, that a state formed out of a part of the Northwest Territory has the same power to regulate navigable waters within its borders that is possessed by other states of the Union; that is to say, until Congress intervenes, the power of the state, locally exerted, is plenary; nevertheless, where the navigation serves commerce among the states or with foreign nations, Congress has the supreme power when it chooses to act, and is not prevented, by anything the states may have done, from assuming entire control in the matter. In short, that the rule laid down in *Willson* v. *Black Bird Creek Marsh Co.*, 2 Pet. 245, 252, 7 L. Ed. 412, 414, and *Gilman* v. *Philadelphia*, 3 Wall. 713, 731, 18 L. Ed. 96, 101, applies to states formed out of the Northwest Territory as well as to others. This is not questioned."

As to the effect upon the commerce that would result by the construction of the Wheeling bridge, it appeared that the facts as to this question had been referred to a Master and found against the bridge company. Furthermore, the bridge was almost entirely constructed after Pennsylvania instituted the suit, so there were no equities in favor of the bridge company. Notwithstanding this fact, however, this Court suspended the operation of the decree giving the bridge company the opportunity to change its bridge as directed by this Court so that it would not unnecessarily obstruct navigation. This Court, in speaking of its action in the *Wheeling Bridge case*, said (*Willamette Iron Bridge Co.* v. *Hatch*, *supra*, page 16):

> "But to mitigate the apparent hardship of such decree, if executed unconditionally, the court, in the exercise of a merciful discretion, granted a stay of execution on condition that the bridge should be raised to a certain height, or have a draw put in it which would permit boats to pass at all stages of the navigation."

In

Miller v. *State of New York*, 109 U. S. 385,

it does not appear that the Act of Congress approving the plans of the bridge, was necessary, but this Court intimated

that without the congressional Act, its decision would have been the same, as the bridge was constructed under the authority of the State of New York at a time when Congress had not assumed any jurisdiction of such structures. And this Court cited

Gilman v. *Philadelphia*, 3 Wallace 713,

in which case a bridge over the Schuylkill River, Chestnut street, in the City of Philadelphia, connecting two parts of said city, was held to be a lawful structure, having only the legislative sanction of the State of Pennsylvania.

Appellee's Point II-D.

(Appellee's Brief, p. 151.)

Appellee cites

Economy Light & Power Company v. *United States*, 256 U. S. 113,

and seeks to argue that the Ordinance of 1787 of the Government of Northwest Territory, limits the action of Illinois the same way this Court held Virginia to be limited by the compact between Kentucky and Virginia, considered in that case. We have heretofore pointed out the distinction fully, and have shown that the Ordinance of 1787 was in no respect similar to the compact between Virginia and Kentucky mentioned.

Appellee's Point II-E.

(Its Brief, p. 154.)

Here counsel seek again to give some undisclosed effect to calling the waters of the Great Lakes "international." We will later discuss this subject more fully, where we deal completely with appellant's argument as to the force of the treaty (*Infra*, p. 85), as we believe the treaty fully disposes of all appellee's contentions.

APPELLEE'S POINT III.

(Its Brief, p. 159.)

At the outset, appellee's counsel seem to have forgotten the circumstances under which the Chicago River and its branches were enlarged. In construing Section 10 of the 1899 Act, it must be borne in mind that the Secretary of War was authorized only to do certain things. In the case of structures mentioned in said Act, he was empowered to approve the plans recommended by the Chief of Engineers. In the case of excavating or filling or altering or modifying the course or location, it was not to be done *"unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same,"* that is, the **work** of excavating or filling, or the **work** of altering or modifying. There was no authority for the Secretary of War to act, except under those conditions. We have pointed out that the work of excavating and filling and connecting the Sanitary and Ship Canal with the West Fork of the South Branch of the Chicago River, was authorized under the permits for the improvement of the Chicago River —the improvement beginning with July 3, 1896, permits, the more comprehensive improvement under the permits of July 11, 1900, and the permit of May 8, 1899, providing for the opening of the channel. As early as April 21, 1891, the Secretary of War was advised by being delivered a copy of the ordinance of that date adopted by the board of trustees of appellant, expressly stating its purpose *"to make"* the Chicago River and its branches *"a proper and sufficient supply channel for the Main Channel heretofore surveyed from the Chicago River to Joliet."* (Appellant's Narrative, p. 454.) In the application for the permit of July 3, 1896, which was the initial one for the improvement of the Chicago River, it was stated that appellant's work had prog-

ressed so far that it was necessary to enter upon that which should be done to make the Sanitary and Ship Canal available. The purpose of the work was disclosed. The same was true of the applications for the permits of July 11, 1900, under which the Chicago River was finally improved for the increased diversion—10,000 cubic seconds feet.

Appellee's counsel are in error when they state in substance that there was nothing done prior to March 3, 1899, by appellant "affecting in the slightest any navigable waters of the United States, except the accomplishing of certain improvements in the Chicago River." (Appellee's Brief, p. 160.) The excavations in the channels of the Chicago River were not mere boyish pranks of appellant. They were serious acts in the interest of the public health. The purpose was well known to the government officers, for they had been definitely advised. Mr. Lyman E. Cooley testified with reference to these improvements in the Chicago River and its branches (Appellant's Narrative, p. 294):

> "The improvement made prior to the opening of the channel was simply preliminary improvement. It was recognized that in order to obtain this flow in the quickest possible time and at the lowest possible expense, that there would have to be a wholesale improvement, such as was undertaken in 1900.
>
> * * *
>
> The Chief Engineer of the District went ahead and made an exhaustive survey of the Chicago River from Robey street to the lake, defining all property rights and cross sections of the stream, with a view to definitive plans for the improvement of the river. And these surveys were completed prior to 1895. They were followed by definite plans for the improvement of the river, which were inaugurated in 1896, in co-operation with the United States, which made an appropriation for the improvement of the river in that year; and the river was improved to a depth of twenty feet by dredging the stream. And the bad angles in the stream were cut off, and in some places the river was widened, and in the vicinity of Adams street and Jackson street, by-passes were con-

structed at the constricted parts of the river, in that vicinity, for the purpose of giving the preliminary flow required by the Sanitary District law of 300,000 cubic feet at the velocity of one and one-fourth miles per hour.

These surveys were also used as the basis of the larger improvement which was immediately defined and inaugurated after the opening of the channel in 1900, for a capacity of 10,000 feet per second.

That plan consisted in bascule bridges in the stream of a uniform width of 200 feet, and a central depth of twenty-six feet; and has also been carried out in part with the co-operation of the United States.

The capacity of the Main Channel at the Rock Section was actually 840,000 cubic feet per minute.

The occasion for making further improvement in the Chicago River and its branches after 1900, by the Sanitary District, was to get the increased capacity which was required with the growth of population, after the initial capacity of 300,000 feet had been established, and to accommodate 600,000 feet by way of the Chicago River, and later that was supplemented by the flow by way of the 39th Street conduit.

That new improvement or the improvement after 1900 was known as the Chicago River Improvement Project of 1900.

If the flow through the Sanitary District Canal had been limited to 5,000 cubic feet per second after 1900, it would not have been necessary for the Sanitary District to have made the changes and alterations in the Chicago River that it subsequently did make after 1900."

Again, speaking of the improvement of the Chicago River and its branches, Mr. Cooley stated (Appellant's Narrative, p. 299):

"The Chicago River prior to this improvement was little more than an adaptation of the Chicago Creek, which was known before Chicago was here; and its capacity for carrying a flow of water was limited. It is difficult to make a comparison where the stream was so little adapted to the present purpose, and where the change has been so radical.

Originally the Chicago Creek carried twelve feet up to the Forks, and its original improvement, the first im-

provement, was based on a depth of thirteen feet, which was subsequently increased to sixteen, and the tunnels built under the river limited the use of the Chicago River to sixteen feet, until they were removed within a comparatively recent period. They were removed by the city at a very considerable cost, which should be added to the expenditure of the Sanitary District and the United States, in getting at the true cost of the improvement of the Chicago River.

When the Sanitary District entered upon the improvement of the Chicago River, it was approximately sixteen feet in depth.

The depth has been increased to approximately twenty-six feet, and that is the depth carried through the main channel, to the power house.

There were portions of the river that would run up to 200 feet and even 300 feet in width, and again other portions that were less than 100. The narrow portions have been widened, or are being widened, except a very limited area near the Pennsylvania Central Station, which has been greatly delayed.

It has been widened to a large extent throughout its entire length, the Chicago River and the South Branch, so much so that it could almost be considered a new river."

Mr. Isham Randolph, who was Chief Engineer of appellant at the time the comprehensive improvement of the Chicago River for the larger diversion was laid out and, also, during a considerable period of the channel enlargement, stated (Rec. Vol. VI, p. 3593, *et seq*):

"Q. Did you have anything to do with the so-called project of 1900, for the improvement of the Chicago River, and with the preparation of the plans for that project?

A. It was my project, and the plans were prepared under my direction.

Q. Were those plans submitted to the Secretary of War and Chief of Engineers, and approved by him?

A. Yes, sir.

Q. What did you take into consideration in determining the plans for that improvement?

A. I took into consideration that we wanted to pass through the main river, through the South Branch of the Chicago River as far as the Stock Yards Branch 480,000 cubic feet a minute.

Q. That would be about 8,000 cubic feet per second?

A. 8,000 cubic feet per second. We wanted to take in through the 39th street conduit 2,000 cubic feet per second, 120,000 a minute, making a total of 10,000 cubic feet from the junction of the Stock Yards Branch with the main river.

Q. Did you take into consideration what the mean current would be through the Chicago River and the South Branch and West Fork?

A. I figured it on the basis of a shade under a mile and a quarter an hour, except in bridge openings where it was slightly contracted.

Q. That was the current which the Secretary of War considered proper for navigation purposes, was it, at that time?

A. Yes, sir.

Q. Now there were some modifications of the May 8th, 1899, permit, whereby the flow of water was limited. After about 1902, did you as Chief Engineer attempt to keep the flow within the limits of the permit as stated by the Secretary of War?

A. Up to June, 1902. I conformed fairly well to those figures. After that we exceeded them, and paid very little attention to that from that time on.

Q. That is in 1902, improvements were made in the Chicago River so as to create a greater cross section for the flow of water?

A. In that year we excavated 600,000 cubic yards of earth from the river and we built 4,700 feet of new dock. The narrowest place in the river was beyond 22nd street. It was only 115 feet wide, and we enlarged that to 200 feet; 26 foot, mid-channel depth.

Q. In other words those improvements were such that a current would not be created of more than a mile and a quarter an hour with a flow exceeding the limitations which had been indicated by the Secretary of War?

A. That was true, wherever our channel was completed. There were some few narrow spots where the current still exceeded that.

Q. There were not very many of those places?
A. And not very serious.
Q. Rather immaterial, were they?
A. Yes, sir."

Wisner's Exhibits 7, 8, 9, 10 and 11 (Appellant's Narrative, opposite page 393) show the extent of these improvements in the Chicago River under the so-called 1900 project to accommodate the greater diversion. In speaking of the tunnels under the Chicago River, removed by direction of Congress in connection with this river widening and at the suit of the City of Chicago, Mr. Wisner stated (Appellant's Narrative, p. 399):

> "This prevented the deepening of the river for some time, as the top of the channel was about, as I remember, 20 feet below the surface, 20 or 21 feet below datum."

The same was true of the channel at LaSalle Street, under the main river.

As stated by the witnesses, it is obvious that it was necessary to deepen and widen the channels of these rivers, so that the necessary volume of water could be drawn through them to the Sanitary and Ship Canal. Appellee's counsel attempt to belittle this statement. It is plainly evident, according to the laws of gravity. Anyway, there is no dispute about it in this record, as there is no evidence contrary to appellant's witnesses.

In

West Chicago Street Railway Company v. *Chicago*,
201 U. S. 505,

cooperation of the Federal Government appears by the records of this Court. The Chicago River proper was deepened at the expense of the United States to conform to the deepening of the South Branch and West Fork by the appellant. The government's work was thus done in cooperation with appellant and the City of Chicago. The City of

Chicago, to remove the tunnels in order to provide this depth, by ordinance found the tunnels to be obstructions to navigation, and directed their removal. The Rivers and Harbors Act of March 3, 1899, the very act under which appellant is seeking to limit the diversion, contained the following item:

> "Improving Chicago river in Illinois: Survey and estimate of cost for a channel twenty-one feet deep from its mouth to the stock yards on the south branch, and to Belmont avenue, on the north branch, so far as may be permitted by existing docks and wharves, exclusive of cost of removing or constructing bridges or piers or lowering tunnels; and the aforesaid depth of twenty-one feet is hereby adopted as the project depth for the improvement in lieu of that fixed by the act of June third, eighteen hundred and ninety-six (29 Stat. at L. 202, chap. 314): *Provided,* That all the work of removing and reconstructing bridges and piers and lowering tunnels necessary to permit a practicable channel with said depth to be obtained shall be done, or caused to be done, by the city of Chicago, without expense to the United States."
>
> 30 Stat. at L. 1156, Chap. 425,
> *West Chicago Street Railway Company* v. *Chicago, supra,* 516.

Other acts of Congress and facts bearing upon this matter are set forth herein. (*Infra,* pp. 104-110.)

So it is apparent that even before the appellant's Sanitary and Ship Canal was opened, Congress had been advised of the project for comprehensively deepening and widening the Chicago River to make it of depth for the withdrawal of water through it as required by the state law and for navigation purposes, and that Congress sought to cooperate in this improvement. And this Court, in

West Chicago Street Railway Company, supra,

held that it was unnecessary to obtain the permit of the Secretary of War, as the Congressional Act, above quoted

(p. 527), "*meant to give the assent of the United States to any work done by the city towards accomplishing the end which the government had in view.*" If a permit of the Secretary of War were unnecessary in that instance, it was equally unnecessary so far as the Sanitary District's improvement of the Chicago River was concerned, and the use thereof resulting from such deepening and widening. **Congress itself had expressly approved these works.**

Appellee's counsel state (Appellee's Brief, p. 161):

> "The mere excavation of a ditch in the interior of a city, is of no concern to the Federal Government."

They are speaking of the Sanitary and Ship Canal, completed the latter part of the year 1898. The same position, however, was not taken as to the Calumet Sag Channel. As soon as construction on that channel was started, the Calumet River suit was commenced, March 23, 1908.

Appellee's Point III-A.

(Appellee's Brief, p. 163.)

It is difficult to tell at what counsel are driving. We do not disagree with counsel, so far as this record is concerned, that when Congress seeks to act in making complete and full regulation of all subjects whereby navigable waters may be affected, it may do so. Whether an act of Congress in effect excluding the state's exercise of police power on this subject would be constitutional, is not now before this Court. We say that Congress has not by any act, in those plain and unmistakable terms necessary to express its will, intended to delegate to the Secretary of War power to regulate diversions from Lake Michigan by appellant for sanitary purposes.

Appellee's Point III-B.

(Appellee's Brief, p. 164.)

Counsel here quote at length from
United States v. *Rio Grande Dam & Irrigation Co.*,
174 U. S. 690.

There was no consent of the Secretary of War for the diversion of the head waters of the Rio Grande River for irrigation purposes. The diversion contemplated by this dam would accomplish the taking of substantially all the waters of the river at the point where the dam was to be constructed. The Court said (p. 709):

> "It does not follow that the courts would be justified in sustaining any proceeding by the attorney general to restrain any appropriation of the upper waters of a navigable stream. The question always is one of fact, whether such appropriation substantially interferes with the navigable capacity within the limits where navigation is a recognized fact."

There is no allegation in the bill in the main channel suit that the diversion of water in excess of 4,167 seconds feet substantially or materially interferes with the navigable capacity of any of the waters of the United States; nor is there any allegation that there is or will be a material injury to interstate commerce by said diversion. The case is not an authority to the effect that appellant required more for the building of its Sanitary and Ship Canal than the authorization by the State of Illinois, for the Act of Illinois amounted to an authorization by law of any obstruction to navigable waters of the United States resulting from carrying out the provisions of said Act. This Court said, in the *Rio Grande Dam & Irrigation Co. case* (p. 703):

> "The power of the State to thus legislate for the interests of its own citizens is conceded, and until in some way Congress asserts its superior power, and the

necessity of preserving the general interests of the people of all the states, it is assumed that state action, although involving temporarily an obstruction to the free navigability of a stream, is not subject to challenge."

The Act of March 3, 1899, does not help counsel. That Act was prospective in its operation, for it refers to things thereafter to be done. Appellant's canal was then built. This reasoning is supported by the language in Section 18 of the March 3, 1899, Act, where it gives the Secretary of War jurisdiction to cause the alteration of a bridge *"now constructed or which may hereafter be constructed."* If it had been the intention of Congress that Section 10 should apply to structures theretofore constructed, Congress would obviously have clearly stated its intention, as it did in Section 18 in relation to bridges.

In *Economy Light & Power Co.* v. *United States*, 256 U. S. 113 (Appellee's Brief, p. 167), the dam across the Desplaines River, under construction when the suit was instituted, had neither state nor federal sanction. The Secretary of War had not given his assent and the State of Illinois had in no way authorized it. The only question involved was whether the Desplaines River was a navigable water of the United States. If it were found to be such, as the Court did conclude, then obviously the authority did not exist in the Economy Company to build the dam. *Cummings* v. *Chicago*, 188 U. S. 410.

Southern Pacific Co. v. *Olympian Dredging Co.*, 260 U. S. 205 (Appellee's Brief, p. 168) related to the construction of a bridge over the Sacramento River. The structure was specifically mentioned in the 1899 Act. The same is true of the dam mentioned in the *Economy case*. This Court stated that the Congressional legislation of 1899 committed to the Secretary of War *"administrative power in so far as administration was necessary."* There is no suggestion that such act committed to the Secretary of War power to

regulate the state's action, such as, the diversion of water from Lake Michigan under the state's police power and in the interest of the public health, or in connection with the improvement and maintenance of its waterways. These broad questions were left to the states to solve according to the judgment of their legislative bodies—always with the understanding that Congress might exercise its dormant power in case the state's action was not in keeping with its plans and purposes.

Appellee's Point III-C.

(Appellee's Brief, p. 168.)

Counsel say (Appellee's Brief 169):

> "That the words 'affirmatively authorized by law' did not cover the obstruction caused within the state but affecting the navigable capacity of waters outside the state is clear from the opinion of this Court in *United States* v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 698."

This is obviously a misstatement of the holding in that case. In the first place, New Mexico was a territory, and in the second place there was no authorization for the construction of the dam by the Secretary of War under the 1890 Act. Had the latter existed, as the Court held, the dam would have been considered to be a lawful structure. The fact that navigable waters outside the state would be affected did not enter into the decision of that case, so far as legislative and administrative authority was concerned. A *non sequitur* follows when counsel state (Appellee's Brief, p. 169).

> "There is, therefore, no doubt as to the meaning and intent of the words 'affirmatively authorized by Congress' as they appear in Section 10 of the Act of 1899."

Cummings v. *Chicago*, 188 U. S. 410, and *Montgomery* v. *Portland*, 190 U. S. 89, cited by appellee (Appellee's Brief,

pp. 203, 204) merely hold that as to the particular structures named in Section 10 of the 1899 Act, state action was necessary to authorize their construction. Also, these cases hold that when the Secretary of War authorized same, pursuant to the recommendation of the Chief of Engineers, they were lawful structures. We argue from those cases that the only legislative action required under either the 1890 Act or the 1899 Act was appellant's organic act of the General Assembly of Illinois, May 29, 1889. No legislative authority by Congress was required. The work of excavating and filling, and the work of altering or modifying the navigable waters of the Chicago River and its branches, which would result, as appellee claims, in the altering or modifying of other navigable waters of the United States, was authorized by the Secretary of War under the various permits mentioned. Even Congress had assented to it by the Act of March 3, 1899, mentioned in the case of

West Chicago Street R. R. Co. v. *Chicago*, 201 U. S. 505.

See also other acts of Congress mentioned herein. (*Infra*, pp. 104-110.)

So in

United States v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 690,

had the Secretary of War authorized the construction of the dam or approved the plans therefor, as recommended by the Chief of Engineers, this Court would have refused to reverse the case and would have held the dam, when constructed, to be a lawful structure.

We are sorry that counsel were unable to see the application of *International Bridge* v. *New York*, 254 U. S. 126, (Appellant's Original Brief, p. 181, Appellee's Brief, p. 172) for it was claimed that because it was an international bridge, Congress had

> "assumed such control of it as to exclude any intermeddling by the state."

International commerce was carried on over this bridge. Even that fact did not move this Court to exclude the state from the exercise of those powers reserved to it, though this did affect the operation and maintenance of the international bridge.

Appellee's Point III-D.

(Appellee's Brief, p. 174.)

Counsel again fail to give any consideration to the purpose and effect of the permits for the enlargement of the channels of the Chicago River and its branches. There never was any question as to why the river channels were to be widened and deepened. The Act expressly provided how much water should be diverted from Lake Michigan. The ordinance of appellant and requests for permits stated the purpose of deepening and widening the Chicago River to make it a supply channel connecting Lake Michigan with the northern terminus of the Sanitary and Ship Canal, through which the necessary amount of water could be withdrawn. By some process of reasoning, appellee here claims that an authorization by the Secretary of War upon the recommendation of the Chief of Engineers for the work of excavating and filling to accomplish the withdrawal from Lake Michigan of 10,000 seconds feet would be invalid, and beyond the power of the Secretary of War. At the same time, counsel maintain that the so-called authorized diversion of 4,167 cubic seconds feet is lawful. In other words, while the Secretary of War is delegated the authority of determining what work he will authorize on the recommendation of the Chief of Engineers, yet if he should err in his judgment, to the extent that such work would cause an obstruction to navigation, then his authorization would be invalid. We presume that counsel are endeavoring here to meet our proposition that the July 11, 1900, permits, in authorizing the

work of excavating and filling in the Chicago River and its branches, approved the diversion resulting therefrom. Counsel further, in their reasoning, assume that the diversions resulting from this work so authorized under the July 11, 1900, permits, have obstructed navigation. Therefore, as they say, the Attorney General, acting under the supposed authority of Section 12, would have the power, if he believed, or somebody told him, or in some other way he came to the conclusion, that the diversion was an obstruction, to proceed by injunction to restrain its continuance. According to counsel's contention, when the Secretary of War reaches the conclusion that a proposed structure, or proposed work of excavating or filling, will amount to an obstruction, his power ceases. An authorization approving the plans of such structure, or authorizing the work, would be of no force. This is certainly not the correct construction of Section 10. The Secretary of War, by authorizing the work of excavating or filling, found, so far as the United States is concerned, that such work, and the results thereof, are not obstructions to navigation.

Congress has authorized the Secretary of War to approve plans of bridges, and to authorize work of excavating, etc., as recommended by the Chief of Engineers, and when such plans have been approved, and a bridge is constructed thereunder, and excavation is done, according to the plans, the bridge is a lawful structure, and the work and the results thereof are lawful, even though navigation is obstructed. The Secretary of War is the arm of Congress in this respect, and the situation is not unlike that presented in the second *Wheeling Bridge Case*, 18 Howard 421.

Congress declared that bridge a lawful structure, which this Court had theretofore found to be an obstruction to navigation. This Court held the Congressional Act valid.

Counsel again (their brief, p. 178), indicate that they consider the acts of appellant in deepening and widening the

Chicago River, rebuilding bridges at an expense of upwards of $10,000,000, as merely the cavortings of a child. For what purpose did appellant make this vast improvement, all of which was authorized by the Secretary of War? As stated by Mr. Cooley (*Infra*, p. 42), there was no occasion for deepening the Chicago River from seventeen to twenty-six feet, and widening it at all points to 200 feet, if appellant were to be confined to the 4,167 seconds feet diversion. True, it would have been possible for appellant to have closed the bear trap dam at the southern terminus of the Sanitary and Ship Canal and operated it after the channels of the Chicago River and its branches were excavated for the larger diversion, if it by law could have done so. The situation is just the same as if there were no controlling works at the southern terminus of the Sanitary and Ship Canal, for appellant was mandatorially directed by the state law to build a canal of not less than 10,000 cubic seconds feet in capacity, and to maintain a flow through it to the amount of 20,000 cubic feet per minute for each 100,000 of population. (Sections 23 and 20, Act May 29, 1889, Appellant's Narrative, pp. 71-72.) So when the excavation in the channels of the Chicago River and its branches was made, it was compelled by law to so operate its channel and its controlling works, that that amount of water would be withdrawn.

Furthermore, under Section 21 of its organic act, (Appellant's Narrative, p. 71) appellant could have been forced by action of the Attorney General of Illinois or the State's Attorney of any county along the Desplaines and Illinois Rivers, to so operate its canal by withdrawing from Lake Michigan the larger diversion, as contemplated by the work authorized under the permits of July 11, 1900.

Counsel quote at length from

Hubbard v. *Fort*, 188 Fed. 987,

and rely upon it in support of their construction of Section 10 of the 1899 Act. As we stated in our original brief, (p.

138) *Hubbard* v. *Fort, supra,* is contrary to the case upon which we rely, *Maine Water Company* v. *Knickerbocker Steam Towage Company,* 99 Me. 473. The latter case was cited, as before stated, with approval by this Court. (Our original brief, p. 139.) So far as we are able to ascertain, *Hubbard* v. *Fort* has never been even cited by any Federal Court. In addition, the *Maine Water Company* v. *Knickerbocker Steam Towage Company case, supra,* has been cited with approval in

Garrison v. *Greenleaf Johnson Lumber Co.,* 215 Fed. 576, 580 (C. C. A. 4th).

Counsel fail to understand the dissections of the 1899 and 1890 Acts made by us (our original brief, pp. 133-136.) We assumed that counsel would find this dissection convenient, in elaborating the analysis made by the Court in the *Maine Water Company case.*

Appellee's Point III-E.

(Its Brief, p. 181.)

Many cases are cited, among others, *United States* v. *Chandler-Dunbar Water Company,* 229 U. S. 51. We are not here concerned with the question whether Congress may exercise paramount control over the Chicago diversion. It has not done so. Until it acts, the diversion is lawful. This the Court held to be the law in the *Chandler-Dunbar case, supra.*

Appellee's Point III-F.

(Its Brief, p. 184.)

At the outset, counsel say (their brief, p. 184):

"It will be recalled at the very outset, in granting the permit of May 8, 1899, the Secretary of War entertained grave doubt as to his power to authorize the diversion

of water by appellant. This was the reason for the incorporation of the first condition in that permit, namely, that it should 'be subject to such action as may be taken by Congress.'"

How counsel can reach this conclusion from the facts and circumstances of this case, is difficult to even guess. The Secretary of War undoubtedly advised by the Judge Advocate General, concluded that the Illinois Act of May 29, 1889, was sufficient legislative authority that the exercise by the state of its reserved police power, was lawful until Congress acted. In order that there might be no question, the Secretary of War inserted the condition 1 referred to, as to Congress's future action, which was and is the law anyway.

In refusing to issue the permit for the reversal of the flow of the Calumet River, Honorable William Howard Taft, then Secretary of War, issued a memorandum which contained the following statement (Appellant's Narrative, p. 79):

"The application of the Sanitary District is for leave to reverse the flow in the Calumet River in such a way as to make the water to flow out of the lake instead of to flow into it and to discharge the water from the Calumet River into the Drainage Canal. The Chief of Engineers was at first of opinion that such a change in the flow of the river *it* was not within the power of the Chief of Engineers to recommend, or within the power of the Secretary of War to permit. This expression of opinion as to the construction of the statute was submitted to the Judge Advocate General, who holds that Section 10, as quoted above, applies to this case and that it is one in which work could be allowed under the recommendation of the Chief of Engineers and the permission of the Secretary of War. Upon the construction of the Judge Advocate General I requested the Chief of Engineers to make his recommendation. * * * Between two such great interests, the decision must be affected more or less by large public policy and expediency, and while I agree in the construction of the Judge Advocate General that the issue is left by statutes to the recommendation of the Chief of Engineers and the concurrent deci-

sion of the Secretary of War, it may be fortunate that circumstances now require submission of this question of capital and national importance to the Congress of the United States."

The effect of the so-called decision of Secretary of War, Stimson, of May 8, 1913, has been fully discussed in our original brief (pp. 205, 206). Counsel have made no new points, and it is unnecessary to reiterate our argument there made.

APPELLEE'S POINT IV.

(Its Brief, p. 189.)

Appelle's counsel here, in their preliminary argument under Point IV, assume, which is not a fact, that appellant in diverting the waters of Lake Michigan to the amount of 10,000 cubic seconds feet, is violating Section 10 of the Act of 1899. They assume that Section 10 of that Act covers the Chicago diversion, and that the Secretary of War has not authorized the work necessary to accomplish the diversion, and has not, therefore, authorized the diversion itself. They say (Appellee's Brief, p. 190) that the amount as compared with the flow of other streams and with the flow of the outlet rivers, necessarily shows that an obstruction to navigation exists. Some mention is made (Appellee's Brief, p. 190) that

> "appellant made no effort to rebut the testimony of appellee's witnesses on this subject, all men of experience and standing",

in the Calumet River suit. The fact is that the Calumet River suit was consolidated with the Main Channel suit instituted on October 6, 1913, and all testimony taken in the first suit was treated as if taken in the second suit, so far as such evidence was material. Many witnesses were produced by appellant who testified as to the inaccuracy of appellee's deductions. The statements of the Chief of Engineers, of the Officers of the United States Lake Survey and of the International Waterways Commission as to the amount of the lowering of the levels of the Great Lakes due to a diversion at Chicago, were the conclusions reached in the same way that similar conclusions were testified to by appellee's experts in this case.

Appellee's counsel mention the statement of appellant's Chief Engineer before the Secretary of War,—that he did not desire

> "to question the accuracy of the figures or the fairness of the calculations—* * *"

This statement was made for the purpose of the hearing before the Secretary of War upon the application of appellant that the Secretary of War remove the limitation of December 5, 1901, due to the fact that the Chicago River had been then improved under the Secretary of War's permits of July 11, 1900. (Rec. Vol. VI, p. 3701.) The above statement of the Chief Engineer of appellant immediately succeeded the following sentence:

> "If all the theories can be relied upon, the observations are accurate, and calculations fairly made, it is probable that such a diversion would be theoretically determined as affecting the level of Lake Michigan to the extent of about five inches."

Obviously, the statement of appellant's Chief Engineer referred to by appellee's counsel, was intended to be made only for the purpose of the proceeding before the Secretary of War. That is, he did not wish to go into a complicated analyzation of the conclusions of appellee's officers on this subject. Previously, the Chief Engineer in his statement (Rec., Vol. VI, p. 3696), in referring to the calculations made, said:

> "To indicate the different results obtained, attention may be called to the estimates given in the report upon the Chicago Drainage Canal by the International Waterways Commission (1907), page 7, wherein the effect of the withdrawal of 10,000 cubic feet from Lake Michigan at Chicago upon the St. Lawrence River at Rapide Plat is stated as four-tenths of a foot. This is approximately 4¾ inches.
>
> The brief submitted by the Dominion of Canada, to which is affixed the signature of the engineers who prepared the data therein contained, gives the effect at the same point, of the same diversion, as 6.8 inches. This is a difference of nearly 50 per cent. and is a fair indication of the lack of accuracy with which compilations can be made as to the effect of a diversion from a given body of water. Generally no two engineers figuring upon this effect arrive at the same result. This is to be expected by reason of the unknown quantities entering into the computation, and also because in making the computation

the data obtained by the Lake Survey cannot all be used, and the results must vary according to the data that may be utilized."

Counsel refer to appellant's principal hydraulic witness, we presume Mr. Gardner S. Williams. Mr. Williams thoroughly analyzed appellee's witnesses' statements as to the effect upon the lakes. He was competent to do so. His qualifications were of the highest, having been for many years engaged in work where calculation of the flow of water was required. He was for a considerable time Professor of Engineering at Cornell University. Later, for a number of years, he was Professor of Engineering at the University of Michigan, and had been engaged also in private consulting engineering practice of great magnitude. (Appellant's Narrative, p. 134.)

Appellant's other witnesses, on the hydraulics of the Great Lakes, corroborated Mr. Williams' calculations. They reached the conclusion, as stated in the statement of the case (our original brief, p. 63) that the observations made by appellee's witnesses as to the discharge of the different outlet rivers of the lakes were not sufficiently accurate to entitle any definite conclusions to be reached as to the effect of a diversion of 10,000 cubic seconds feet at Chicago; that there were many elements entering into the processes by which appellee's witnesses reached the conclusions as to the lowering effect, which would necessarily cause inaccurate results.

Mr. Williams merely stated on cross examination, (Appellant's Narrative, p. 141) that from his study of the conclusions of appellee's witnesses, that the lowering could not be over 4.1 inches for Lakes Michigan-Huron, assuming 10,000 cubic seconds feet diversion.

We have pointed out the inaccuracy of appellee's conclusions as to the evidence concerning injury and damage to commerce on the subject of appellee's statement of the case (Appellant's Brief, p. 65.)

Finally, appellee refers to a current in the Chicago River, as follows (Appellee's Brief, p. 192):

> "We do not believe that appellant will gain-say that it has created and is maintaining a current of a greater rapidity."

The inaccuracy of this statement is clearly refuted by the report of May 22, 1906, of Col. William H. Bixby, U. S. Engineer at Chicago, later Chief of Engineers, entitled:

> "Effect of withdrawal of water from Lake Michigan by the Sanitary District of Chicago".

As to the rate of flow in the Chicago River that would exist after the work of deepening and widening the river under the July 11, 1900, permits, was completed, he stated (Rec., Vol. IV, p. 2397b):

> "17. In the capacity of sewer to properly carry off all the diluted sewage which the sanitary district must dispose of in the future, the South Branch and West Fork of Chicago River and the district drainage canal will need the use of the full cross section now being given to them at their typical points of construction, viz., 4,700 square feet in South Branch, Chicago River, where a future 8,000 cubic feet per second is now asked for; 5,200 square feet in West Fork, South Branch, Chicago River, 5,412 square feet in the earth sections and 3,542 square feet in the rock sections of the drainage canal, for all of which 10,000 cubic feet per second is now asked for; and 5,412 square feet in the lower (south) end of the drainage canal, where 14,000 cubic feet per second is now being asked for. I assume that after this volume of water reaches the Des Plaines and Illinois rivers it can be taken care of more easily than in the Chicago River and that the 2,800 square feet cross section of the proposed 14-foot waterway, now under consideration by Congress, will be supplemented sufficiently by the rest of the natural river on each side of the improved boat channel. The above cross-sections, so long as no boats lie at wharves or pass up and down the river, will allow the passage of the 8,000 cubic feet per second through the South Branch, with average velocities of not exceeding about 1.2 miles per hour (1.7 linear feet per second); 10,000 cubic feet through the West Fork, with average velocities of not exceeding about

1.3 miles per hour (1.9 linear feet per second), and the same flow through the earth sections of canal at not exceeding 1.2 miles per hour (1.8 linear feet per second), and through the rock section of canal at not exceeding 1.9 miles per hour (2.8 linear feet per second); and 14,000 cubic feet through the lower end of canal at not exceeding 1.8 miles per hour (2.6 linear feet per second.)"

In conclusion, Colonel Bixby stated in this report (Rec., Vol. IV, p. 2397d), as follows:

"25. Summing up the above it may be briefly stated, therefore, that 10,000 cubic feet per second diversion of water from Lake Michigan into the drainage canal will be, probably, not unreasonably obstructive to navigation and injurious to property if divided up into 6,000 cubic feet per second through the main river and south branch, increased by 2,000 cubic feet per second more through the Thirty-ninth street sewer and 2,000 cubic feet per second more through Calumet River (10,000 cubic feet per second in all), but that an increase in these amounts to 8,000, 2,000, and 4,000 cubic feet, respectively (14,000 cubic feet per second in all), will probably prove to be unreasonably obstructive and injurious."

Appellant's witness, George M. Wisner, testified as to the current in the Chicago River with a diversion of 10,000 seconds feet and with the Chicago River deepened and widened under the permits of the Secretary of War of July 11, 1900, as follows (Appellant's Narrative, page 186):

"In the South Branch the critical point probably, the critical stretch, is from Lake street to the turning basin at Ashland avenue. This will safely take, in my opinion, 8,000 cubic feet a second. From there on to the Drainage Canal, the river is much wider, and with the same depth would take an additional flow of water without any injury to navigation.

The current would not exceed 1¼ miles an hour through that stretch anywhere."

Mr. Isham Randolph, who laid out the project for the enlargement of the channels of the Chicago River and its branches for the diversion of 10,000 cubic seconds feet

through them to the Sanitary & Ship Canal, stated that with the river so improved, under the July 11, 1900, permits, the current would be less than a mile and a quarter per hour (*infra*, p. 43). There was some controversy as to this in the hearings before Secretary of War Stimson, so much mentioned. The Secretary in his statement made January 8, 1913 (Appellant's Narrative, p. 28), did not find that a current in the Chicago River exceeding a mile and a quarter per hour, would be created by the 10,000 cubic seconds feet diversion through it, or that such diversion would be in any way obstructive or injurious to navigation thereon.

Appellee's Point IV-A.

(Its Brief, p. 192.)

We have heretofore pointed out that,

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does not support appellee's contention that the July 11, 1900, permits would not authorize any effect upon the navigable capacity of other waters than the Chicago River. In that case the Secretary of War had not granted a permit for the diversion of the waters of the Rio Grande River. The Court held that, had there been such a permit, the Irrigation Company's works would have been treated as lawful structures.

We have heretofore pointed out that the channels of the Chicago River and its branches were enlarged under the July 11, 1900, permits (*infra*, pp. 42 to 45) so that the diversion of 10,000 seconds feet could be withdrawn through them; that under the Illinois statute the amount of water required as the population of appellant increased, should be diverted from Lake Michigan just as surely as if there were no gates at Lockport by which the diversion could be controlled. This follows, because the Act of May 29, 1889, is mandatory as to

the amount of the diversion, and the trustees of appellant could be forced under that Act to comply with it. (*Infra*, p. 54.)

Counsel refer to the September 11, 1907, and July 30, 1910, permits for the construction of the North Shore Channel and the Calumet Sag Channel, respectively, as granting a privilege to appellant, with a condition that the diversion should not exceed 250,000 cubic feet per minute. The September 11, 1907, permit on this subject, contains the following provision as a condition to the diversion of water through the North Shore Channel at Wilmette and the Lake Shore (Appellant's Narrative, p. 82):

> "2. That the total diversion of water from Lake Michigan through the Chicago River into the Illinois River, shall be no greater than already authorized by past War Department permits."

The July 11, 1900, permits were at that time valid and subsisting. Appellant had been for a number of years previously and was then actually performing the work of deepening and widening the channels of the Chicago River and its branches, as authorized by those permits. Such deepening and widening would permit the withdrawal of the amount of water required by appellant's organic act according to the population of appellant. Necessarily, appellant assumed that the condition of the September 11, 1907, permit for the diversion from Lake Michigan at Wilmette, Illinois, through the North Shore Channel, referred to those permits and not to the December 5, 1901, order, the latter one being made purely because of the then restricted channels of the Chicago River and its branches. At that time no objection had ever been made to the proposed withdrawal of water through the Chicago River as required by appellant's works. It could not be assumed by appellant that the War Department or the Attorney General would seek to enforce the order of December 5, 1901, which had become a mere paper limitation because of the removal of the reason for its issuance.

Counsel also refer to the condition of the permit of June 30, 1910, as follows (Appellant's Narrative, p. 83):

> "(d) That the amount of water withdrawn from Lake Michigan through the Chicago and Calumet rivers together, shall not exceed the total amount of 250,000 cubic feet per minute (4,167 cubic feet per second) already authorized to be withdrawn through the Chicago River alone."

Appellant had then completed its North Shore Channel. The suit of March 23, 1908, had been instituted by the Attorney General (Calumet River suit), questioning *only* the diversion through the Calumet River and Calumet Sag Channel proposed by this adjunct to the Main Sanitary & Ship Canal and the diversion through the Chicago River. The work of deepening and widening the channels of the Chicago River and its branches, had not then been completed. Under the permits of July 11, 1900, appellant had been diverting (admittedly), for a number of years, water in excess of the limitation of 4,167 seconds feet as it was required by its organic act. It was necessarily assumed that it was the desire of the Secretary of War to maintain this paper limitation *only* until the deepening and widening of the channels of the Chicago River and its branches had been *entirely* completed under the July 11, 1900, permits, and that, of course, such limitation would be removed when the work was done. Furthermore, condition (f) of said June 30, 1910, permit (Appellant's Narrative, p. 84) expressly provided that it should not be used in litigation

> "to determine the right of the said Sanitary District to divert from Lake Michigan for sanitary purposes an amount of water in excess of that now being diverted, without having first obtained a permit from the Secretary of War."

We have not used this permit and are not basing any right upon it. The only purpose of referring to it, was to show that any facts and controversies with reference to the diver-

sion through the Calumet River and the Calumet Sag Channel, are not material in this litigation. We are willing to assume that it was the intention of this permit that the privilege granted should be conditioned upon appellant's being limited to a diversion from Lake Michigan from all sources equal to that which it was under the facts, circumstances and the law, entitled to withdraw through the channels of the Chicago River and its branches to the Sanitary & Ship Canal; and that it should not make any claim for a diversion by way of the Calumet River and the Calumet Sag Channel in addition to that which it is entitled to take through the Chicago River. We do not believe that our attitude on these important matters can be characterized as

> "the untenable position taken by appellant throughout its brief." (Appellee's brief, p. 194.)

Appellee's Point IV-B.

(Its Brief, p. 195.)

The very language of the case cited by appellee

(*United States* v. *Rio Grande Dam & Irrigation Company*, 174 U. S. 690.)

shows that this court would not uphold an injunction unless the works of the irrigation company would

> "*substantially diminish the navigability,*"

of the Rio Grande River. We are amused at the attempt of appellee's counsel to make the word "substantially" mean "appreciably." Webster's New International Dictionary, defines the adjective *substantial*—

> "1. Consisting of, pertaining to, of the nature of, or being, substance; material; as, *substantial* life.
>
> 2. Not seeming or imaginary; not illusive; real; true.
>
> 6. Considerable in amount, value, or the like; large, as, a *substantial* gain.
>
> 8. That is of moment; important; essential; material."

The same dictionary defines the adjective *appreciable*—

> "Capable of being appreciated or estimated; large or material enough to be estimated; perceptible; as, an *appreciable* quantity."

We have distinguished elsewhere in this brief

Economy Light & Power v. *U. S.*, 256 U. S. 113, (*infra* 49),

U. S. v. *Chandler-Dunbar Co.*, 229 U. S. 53, (*infra* 29), and the

Wheeling Bridge case, 13 Howard 553, (*infra* 54).

We apprehend that the conflicting interests of health, on one side, and commerce, on the other, as here, is just as important to be considered as the "conflicting interests of commerce over the bridge and under the bridge" (Appellee's Brief, p. 198).

In

Henning v. *Georgia*, 163 U. S. 299, 317,

this court gave such consideration to the conflicting interests of the state's public morals with interstate commerce, that it upheld a state statute against operating trains intrastate as well as interstate on Sunday. See also the many other cases cited by us, Point 4 (b). (Appellant's Brief, p. 165, *et seq.*)

Union Bridge Co. v. *United States*, 204 U. S. 364.

The cases of

New York v. *State of New Jersey*, 256 U. S. 296,

and

Kansas v. *Colorado*, 206 U. S. 46

were cited by us in support of the position which we believe to be correct—that appellee here must establish its right to an injunction more clearly than would be required of one of the states of the Union in a suit against another.

Appelee's Point IV–C.

(Its Brief, p. 201.)

In the

Wheeling Bridge case, 13 Howard 553,

cited by appellee, the question of finding whether the bridge there considered was an obstruction to navigation was determined by ascertaining the height of the smoke-stacks or other projections of boats navigating the Ohio River which would come in contact with the span of the bridge. The number of feet that the smoke-stack extended above the water level could be ascertained by measurement with an ordinary tape. The distance from the surface elevation of the water in the Ohio River under the Wheeling bridge to the span of the bridge could likewise be determined by the use of a tape. Then it was a mere question of taking the two measurements and comparing them to see whether a boat could pass under the bridge. Here, as we have pointed out in our original statement of the case (our Original brief, p. 63), there was a complicated process used by appellee's experts to reach conclusions as to a supposed lowering effect and damage to commerce upon the Great Lakes.

APPELLEE'S POINT V.

(Its Brief, p. 202.)

We are pleased to note that appellee does not "laugh off" our argument that appellant's diversion is authorized under the Act of Congress of March 2, 1827, by the remark that it is "childish" or "puerile." The *amici curiae* brief in support of appellee's position characterizes our argument as to the effect of this Act of Congress as follows (*Amici Curiae* Indiana, *et al.*, Brief, p. 30):

> "Appellant, by a most interesting, *if not convincing*, argument, attempts to connect its right to the abstraction of water from Lake Michigan with the provisions of the Act of March 2, 1827."
>
> (Italics ours.)

Counsel call a mere guess the statement of Mr. Wisner (Rec. Vol. VI, p. 3433), as to the minimum run-off of the Chicago River drainage area being less than the amount of water drawn from the West fork of the South branch of the Chicago River through the old Illinois-Michigan Canal, after the pumps were installed at its Northern terminus, in the year 1883, thus causing the reversal of the flow of said river and the taking of water directly from Lake Michigan. It appeared that Mr. Wisner had for twenty-five years prior to the time he testified been connected with the appellant in the Engineering Department. During a large portion of the time he was its Chief Engineer and was thoroughly familiar with the various things necessary to know in order to reach the conclusion stated (Rec. Vol. VI., p. 3433). We apprehend that the taking of water from the Chicago River through the Illinois-Michigan Canal to the Desplaines and Illinois Rivers is not logically different from the direct taking from Lake Michigan, because the natural flow of the Chicago River was into Lake Michigan. The taking of the water before it reached the lake

—which water would naturally go there—is, we believe, the same as taking it from the lake itself.

The findings of Secretary of War Stimson of January 8, 1913, are fully discussed in our original brief (p. 205).

Appellee's Point V-A.

(Its Brief, p. 203.)

The Act of Illinois (January 9, 1836), under which the old Illinois-Michigan Canal was built, specifically provided that the canal should be at least 45 feet wide, and there should be reserved 90 feet on each side for the purpose of enlargement (Appellant's Statement, Original Brief, p. 18). Appellee makes the statement (its brief p. 209)—

> "It is not claimed that appellant's canal is within this 90-foot zone. It could not be, for the new canal is 160 to 200 feet wide."

The fallacy of appellee's statement is shown by merely adding the 90 feet on each side—which makes a total of 180 feet—to the original width of the canal, 45 feet, which gives an area of 225 feet for the enlarged canal. *This is substantially the width of the present Sanitary and Ship Canal in the earth section and is greater than the width of the Sanitary and Ship Canal in the rock section.*

The Act of Congress of March 30, 1822, expressly provided that ninety feet should be reserved on each side of the canal to be built. (Appellant's Brief, p. 16.)

Appellee states (its brief, p. 210):

> "The Act of Congress authorized a canal, not two canals or a dozen."

It was incumbent upon the state to build a canal suitable for navigation in consideration of the grant of land. The state did not exhaust its power or discharge its obligation by building a canal which in 1848 suited the then requirements of navi-

gation. To say that it could not and was not required to thereafter—when commerce demanded a larger canal—either enlarge the old canal or abandon it and build another in its place, is not in keeping with the purpose sought to be accomplished by the legislation in question. The requirement by the January 9, 1836, Act of Illinois that 90 feet on each side of the canal should be reserved for enlargement, and the same requirement of the March 30, 1822 Act of which the March 2, 1827, Act was a mere reenactment, beyond question shows congressional as well as state intent that the canal to be then built should be enlarged as the public interest might require.

Counsel refer to Section 3 of an Act of the General Assembly of the State of Illinois of July 1, 1919, (Appellee's Brief, p. 210). It is obvious that the *only* purpose of this legislation was to preserve this canal for use as a "terminal and harbor" in connection with the Sanitary and Ship Canal. It was not designed to maintain it for the purpose of providing means whereby boats could pass from the West fork of the South branch of the Chicago River to Joliet. Another construction is not in keeping with the physical conditions as they existed at the time the 1919 Act of the General Assembly of Illinois was passed, for then there existed the Sanitary and Ship Canal connecting the West fork of the South branch of the Chicago River with the Illinois and Michigan Canal at Joliet, which was much deeper and wider than the old canal and was designed by the state for the increasing demands of commerce on this water route.

There is no question but that the General Assembly of Illinois, under the Act of May 29, 1889, granted full authority to appellant to build the Sanitary and Ship Canal as a link in the waterway to the Gulf of Mexico. As we have pointed out in our original brief (p. 31)), Section 17 of the said Act expressly gave authority to enter upon, use, widen and deepen any waterway, canal or lake belonging to the state. The joint

resolution of May 28, 1889, adopted by the General Assembly, (Our Original Brief, p. 21) expressly stated the waterway policy and the purpose to build through Illinois a deep waterway, using the Chicago diversion.

Appellee states that there was no express authority to discharge sewage under the Act of March 2, 1827, into the canal or other waterways. (Appellee's Brief, p. 212.) This was very thoroughly considered in

Missouri v. *Illinois*, 200 U. S. 496.

The waterway was constructed. Necessarily, the people of Chicago could use it for the discharge of sewage and wastes, the same as all the other waterways of the United States have been used. Congress had not occupied the field. It was just as lawful to use the waterway in this way as were any other acts of the states under their sovereign powers.

Concerning the amount of water diverted or to be diverted by appellant, appellee puts the following query (Appellee's Brief, p. 213.)

> "Does that mean that eventually appellant will be forced to take 25,000 c. f. s. under the Act of 1827?"

Such consideration is wholly aside from any facts presented here. Appellant is acting under the Illinois Act of May 29, 1889. This Act authorized it to lay out and construct a canal across the Continental Divide not less than 10,000 cubic seconds feet in capacity, for the purpose of reversing at all times the Chicago River and diverting from the water supply the drainage and sewage. Under this act, it laid out a canal in the rock section of capacity of 14,000 seconds feet, and has built its diversion works now for a diversion of 12,000 seconds feet. It is probable that it is limited by the condition of the June 30, 1910, permit for the reversal of the Calumet River and Sag Channel to 10,000 seconds feet, or the amount it is under the facts and the law entitled to divert through the channels of the Chicago River and its branches to the Sanitary and Ship Canal.

Appellant has planned so that it will not be necessary to protect the water supply to divert the full maximum run-off of the Calumet Drainage Area approximately 15,000 seconds feet, by so arranging its Calumet Sag Channel and the intercepting sewer system, that the sewage and wastes may be carried to a point on the Sag Channel so that they will not ever be carried back into Lake Michigan. This is accomplished by placing the necessary controlling works at the Northern terminus of the Sag Channel. The Calumet Drainage Area population is comparatively sparse, and the problem there is entirely different from the one which exists to provide an outlet for the drainage and sewage emptying into the channels of the Chicago River and its branches. Why this question should be raised, is beyond our comprehension. There is no suggestion made in the pleadings or in the brief that the State of Illinois abused its discretion in authorizing the Sanitary and Ship Canal to be constructed with its attendant diversion, as provided by the Act of May 29, 1889. In fact, we apprehend under the authorities cited in our original brief (p. 162), that any such contention would receive no consideration by this court.

Counsel (Appellee's Brief, p. 213), in referring to statement (our Original Brief, p. 122) that it was necessary to have 10,000 cubic seconds feet diversion from Lake Michigan for navigation purposes, as well as for the protection of the water supply, characterize our statement to be

"without foundation in the record or in fact."

The fallacy of appellee's said statement is demonstrated by the report of the International Waterways Commission on the Chicago Drainage Canal, January 4, 1907, (Appellant's Narrative, p. 511), as follows:

"15. Although the primary object of the Chicago Drainage Canal was the discharge of Chicago sewage, *its function as a channel for navigation was kept in view from the beginning.* All of the bridges over it are draw

bridges with ample openings. A provision of this kind, as well as the care exercised to make the sewage inoffensive by liberal dilution, was necessary to conciliate the interests in the valley of the DesPlaines and Illinois River, which would otherwise be adversely affected. *It can hardly be doubted that the canal will eventually form a part of an improved waterway between the Great Lakes and the Mississippi River*, though its full depth will probably not be required for that purpose. Congress has not adopted any scheme for this improvement, but by its direction a survey was made, and plans with estimates for a waterway 14 feet deep were submitted, by a board of engineers in a report dated August 26, 1905. The board found that for a distance of about 100 miles from Chicago the improvement must be with locks and dams, and as the quantity of water required would be merely that needed for the service of locks and other incidentals, the extent of the improvement of depth which could be obtained in that part of the route was without limit so far as it depended upon the amount of water available. *For the remaining distance, about 223 miles, the improvement would be an enlargement of the open channel and the degree to which it was practicable was entirely dependent upon the quantity of water flowing. The board assumed that the Chicago Drainage Canal would eventually be permitted to take 10,000 cubic feet per second from Lake Michigan, and it expressed the opinion that with that volume added to the natural low-water discharge of the Illinois River a depth of 14 feet in the open channel could be maintained;* also that if a much greater depth was to be secured a much larger volume of water *must be taken* from Lake Michigan."

Further, Mr. Lyman E. Cooley, a witness for defendant, whose evidence is undisputed in the record, on the same subject, makes the following statement (Appellant's Narrative, p. 298):

"Perhaps I may add in that connection that in the later consideration of the matter by the State after 1907, it is based on a flow of 14,000 second feet; and that the Deep Water Project is not practicable without the aid of the large water supply from Lake Michigan, which has been authorized by the State law.

Outside of that, we would be limited to eight or nine feet as the best that could be done.

These depths of fourteen feet were predicated by the original act and collateral legislation in 1889, and in all subsequent legislation, were based on a flow of 10,000 feet and the report of 1907 used that depth of fourteen feet as a preliminary depth, but states that with the aid of the 14,000 feet, it will be possible to continue twenty-four feet to the City of Peoria and twenty feet more or less from thence to the mouth of the river.

And I assume from the fact that the constitutional amendment was based on that report, that is the project. It is the one that has been advocated by the Lakes to the Gulf Deep Waterways Association, and the one that was presented to Congress in the hearings of 1910, before the House Committee and before the Senate Committee, and Congress made conditional appropriation of a million dollars for the beginning of work, whenever an understanding should be reached with the State of Illinois regarding a plan of co-operation."

Recently, Col. William V. Judson, for a number of years United States engineer at Chicago, who studied late waterway projects of the State of Illinois, in a report concerning the use of the diversion of water from Lake Michigan by appellant for waterway purposes, March 23, 1921, (H. R. Document No. 2, 67th Congress, 1st Session), said:

"For a 9-foot channel with an increment of 4167 second feet, the cost, either with dams retained or removed, appears almost prohibitive, and the probability that Congress will limit the increment to 4167 second feet is, in my opinion, so remote that this hypothesis may be left out of consideration. * * * In my opinion, to most reasonably conform to the probable conditions of the future, an 8-foot project should now be adopted, based on a 7500 second feet withdrawal for purposes of estimate, and with all dams removed. *Then should Congress place the limit of the amount of water to be withdrawn from Lake Michigan at* 10,000 *second feet, which I deem probable, and under proper conditions, advisable,* that increment would of itself increase the depth to 9 feet."

Counsel refer to the case

In re Boyer, 109 U. S. 629,

which case merely holds that admiralty has jurisdiction concerning the collision of two boats navigating the Illinois and

Michigan Canal. The crossing of this canal by the Calumet Sag Channel, was authorized by the Secretary of War permit of June 30, 1910. (Appellant's Narrative, p. 82.)

In building appellant's Sanitary and Ship Canal, appellant did not excavate in the Illinois and Michigan Canal. It built a large canal to replace the old canal, providing for the new canal a connection with the Upper Basin of the Illinois and Michigan Canal in the DesPlaines River. The new canal became a navigable water of Illinois and of the United States, all of which was agreeable to Federal and State policies. *Mortell* v. *Clark*, 272 Ill. 210, (Appellant's Brief, 119).

Here (Appellee's Brief, p. 215) appellee merely rehashes arguments made elsewhere and fully answered by us. (*Infra*, p. 29.)

Appellee's counsel refer to the statement in the report of appellant's president as to any limitation of the amount of diversion. Appellant's president, however, in that report (Appellee's Brief, p. 217) said:

> "I believe that we should have the volume requested for our needs as they appear and are justified."

We ask, can any one question the good faith and fairness of such a statement? This statement was made by an official representing the public, who had no purely private concern in the matter. The reference, counsel make to this statement, only shows the extremities to which they are driven for any argument.

We have heretofore mentioned appellant's witness Wisner's conclusions as to the minimum run-off of the Chicago River Drainage Area (Infra, p. 69). That river's drainage area run-off was stated by Mr. Wisner, and it is not disputed in this record. (Appellant's Narrative, p. 189.)

> "The drainage area of the Chicago River basin is about 307 square miles. The run-off of the Chicago River basin in a dry season is practically the city water supply, and some little ground water, but at times of maximum floods it will reach as high as 10,000 cubic feet per second."

Mr. Cooley also testified that the maximum run-off of the Chicago River Drainage Area was 10,000 cubic seconds feet (Appellant's Narrative, pp. 278, 279). In fact the determination of this maximum run off was one of the first steps taken by the Drainage & Water Supply Commission in planning this work. It is hardly fair to characterize the statements as guesses. They were the findings of witnesses competent to make them. There was no evidence offered by appellee in opposition. If there had been, appellant could have cumulated its evidence in this respect.

Appellee's suggestion that the State of Illinois has not delegated its authority under the Congressional Act of March 2, 1827, to appellant, is too frivolous to require answer.

Appellee's Point V-B.

Its Brief (p. 219)

The Act of June 29, 1906, entitled

> "An Act for the control and regulation of the waters of the Niagara River, for the preservation of Niagara Falls, and for other purposes,"

at this point in its brief, is specially discussed by appellee, and some remarkable claims are made. Counsel attempt to construe the Act to prohibit diversions from any of the Great Lakes in the United States for any purpose, domestic, sanitary or navigation, except by the consent of the Secretary of War. Realizing the insufficiency of Section 10 of the 1899 Act, to support their contentions, counsel seek *by construction* of the Niagara Falls Act to make it apply to the Chicago diversion. The mere fact that to support their position a construction of the Act is necessary under the authorities cited by us in our original brief (Point IV (b), pp. 165-173), furnishes the answer, as by counsel's own admission Congress has not by those plain and unmistakable expressions required, exercised its power over these diversions.

The Act only applies, as it is stated expressly in the first section, to

> "the diversion of water from Niagara River or its tributaries in the State of New York."

The committee report quoted by counsel (their Brief, p. 221) upon this very Act, expressly recited the conditions under which diversions had and did then exist for water power purposes from the Niagara River at Niagara Falls in the State of New York; that the diversions at that time were authorized only by acts of the State of New York. The Federal Government had not prior to that time assumed any jurisdiction; and the committee believed that the Federal Government should *then* exercise its authority. As the committee report states:

> "It is thought best by the Committee that the Federal authority should *now* be exercised * * *"

In another place in the report, it is stated:

> "It is, however, very desirable, if not essential, that legislation be *now* enacted to prevent the further depletion or diversion of the waters of the river, and to furnish a basis for diplomatic action".

This is a clear and definite statement that as to *diversions* even from boundary waters for *any purpose*, Congress had not seen fit to exercise its power; that the diversions up to that time had been treated as lawful, having *only* the authority of the State of New York. So, when Congress sought to exercise its powers over the subject of diversions, it confined itself to the diversions from the Niagara River, and specifically authorized the Secretary of War to grant certain permits. Section 2 prescribes the conditions under which the Secretary of War may grant permits for power diversions. His course of action in exercising this power, delegated to him, is definitely prescribed. Up to that time no authority had been granted to the Secretary of War to fix diversions or to interfere in any manner with the State's action as to diversions; other-

wise there would have been no occasion for the passage of the Niagara Falls Act. And when Congress assumed jurisdiction over diversions, it confined its regulation to the Niagara River or its tributaries, *in the State of New York*. All other diversions were excluded, not only impliedly, *but expressly*, and, impliedly and expressly, by said Act, they were left in the same condition they were before the Niagara Falls Act was passed, namely, the authority of the State, in which the diversion was authorized, was left supreme and unhindered by Congressional Act or Federal regulation.

The proviso of Section 1 relates to the first part of the Section, namely,

> "that the diversion of water from Niagara River or its tributaries in the State of New York, is hereby prohibited, except with the consent of the Secretary of War, as hereinafter authorized in Section 2 of this Act".

The proviso applies to the whole of the first clause of Section 1, and when the words are used in the proviso,—

> "That this prohibition shall not be interpreted as forbidding the diversion of the water of the Great Lakes or of Niagara River for sanitary or domestic purposes, or for navigation,"—

Congress did expressly say that the Niagara Falls Act should not only not apply to the Great Lakes, but not even to the Niagara River, as to diversions for sanitary, domestic or navigation purposes. When the words were used following the ones last quoted of the proviso,—

> "the amount of which may be fixed from time to time by the Congress of the United States or by the Secretary of War of the United States, under its direction",—

it merely expressed the condition which existed anyway, that Congress might in the future specially exercise jurisdiction to regulate diversions for those particular purposes. It had not theretofore done so. We cited and discussed this Niagara Falls Act (our Original Brief, Point IV (C), p. 179) to show that Congress at the time it was passed, expressed itself to

the effect that it did not consider it had prior to that time assumed to regulate diversions or to authorize the Secretary of War to regulate them for domestic or sanitary purposes. We also in our original brief (p. 53, 180) referred to the debate in the Senate when that body was considering the conferees' report on the Niagara Falls Act, and to the very pertinent and illuminating statement of the late Senator Lodge—

> **"The first section of the bill protects the right of Chicago."**

Counsel refer to the case of

Cummings v. *Chicago,* 188 U. S. 410,

and assume to quote from the opinion in that case (Appellee's Brief, p. 223), which does not support their contention as to a negative pregnant. The quotation is not from the opinion of this Court in

Cummings v. *Chicago, supra,*

but is from the opinion in

Lake Shore, Michigan Southern Railroad Company v. *Ohio,* 165 U. S. 365, 368,

wherein it was claimed that Section 7 of the 1890 Act delegated to the Secretary of War exclusive authority as to the authorization for the construction of bridges over streams wholly within the state. The particular clause of Section 7 of the 1890 Act under consideration in that case, is the one in the proviso after the word "provided", in the last part of said section, as follows:

> "Provided, That this section shall not apply to any bridge, bridge-draw, bridge piers, and abutments the construction of which has been heretofore duly authorized by law, or be so construed as to authorize the construction of any bridge, draw-bridge, bridge piers, and abutments, or other works, under an act of the legislature of any state, over or in any stream, port, roadstead, haven, or harbor, or other navigable water *not wholly within the limit of such state*".

The Court merely held in *Lake Shore, Michigan Southern Railroad Company Case, supra,* that the words

"not wholly within the limit of the state",

showed that as to waters *wholly* within the limits of the State, the State's authority was not curbed; that, still, as to bridges over such waters, the State could authorize their construction.

Referring to the proviso of Section 1 of the Niagara Falls Act, it must follow that as to waters diverted for sanitary, domestic or navigation purposes from the Great Lakes or from the Niagara River, the States' authority still existed under their reserved powers.

The only limitation was that Congress might thereafter assume jurisdiction over diversions for such purposes, or direct the Secretary of War to take action regarding them.

Counsel again refer to

United States v. *Rio Grande Dam & Irrigation Company,* 174 U. S. 690,

and suggest that we reread that case. We find no reference in that case to diversions for either sanitary, domestic or navigation purposes. Furthermore, the use of the water of the Rio Grande River was not provided for under any reserved power of a state, but only under legislation of a territory — New Mexico. **Furthermore, the Denver and Rio Grande Dam & Irrigation Works had not been either under construction or in operation for upwards of a third of a century under such circumstances that Congress was not only directly advised, but because of the magnitude, must be presumed to have known of their existence, whereby it should be concluded that their construction and operation were treated by Congress as lawful and proper, at least until it should interpose itself to specifically and specially regulate it.**

Appellee's Point V–C.

(Its Brief, p. 226)

Counsel quibbles (its brief, p. 226) over our statement that that International Waterways Commission, by its January 4, 1907, report regarding the Drainage Canal, recommended that the Chicago diversion should be allowed to the extent of at least 10,000 cubic seconds feet of water; whereas appellee's counsel say the report recommended that the diversion should not exceed 10,000 cubic seconds feet, or that the Government should prohibit the diversion of more than that amount. We fail to see any real distinction in view of the fact that the amount of diversion in controversy here is 10,000 cubic seconds feet.

It was perfectly reasonable that the International Waterways Commission, upon whose recommendations the terms of the Treaty of 1909 were fixed, should treat the diversion of 10,000 cubic seconds feet as an existing diversion. The capacity of the canal was at least 10,000 cubic seconds feet. The works of appellant, including the deepening and widening of the channels of the Chicago River and its branches for 10,000 cubic seconds feet diversion, had been substantially completed. It remained only for the population to increase, as it has done, so that the legal ratio of dilution would require shortly the full 10,000 cubic seconds feet. As we pointed out in our original brief (p. 190), the International Waterways Commission, in its January 4, 1907, report, in speaking of the Chicago Drainage Canal diversion, said:

> "Nor does it wish to re-open the case of the Chicago Drainage Canal as designed and built. *It accepts that as a fixed fact, with its attendant diversion of* 10,000 *cubic feet per second through the* Chicago River". (Appellant's Narrative, p. 522.)

NOTE: The quotation in our original brief is incorrect, in that the words "in the bill" should be as above quoted—"and built".

The above report was on the subject of the Chicago Drainage Canal. Reference to earlier reports of the International Waterways Commission upon the subject of the diversion of the waters of the Niagara River, at Niagara Falls, for power purposes between the United States and Canada indicates that the United States was charged with the full 10,000 cubic seconds feet diversion at Chicago in determining the amount that should be allowed to Canada and to the United States. The Canadian section of the International Waterways Commission, April 25, 1906, made a report on this subject, a portion of which is as follows: (Appellant's Narrative, p. 103)

"If our proposal is carried out the diversion will be about as follows:

Diversion on the American Side Per Second Cubic Feet	
Niagara Falls	18,500
Chicago Drainage Canal	10,000
Total	28,500
Diversion on the Canadian Side	
Niagara Falls and on the Niagara Peninsula	36,000"

* * *

"The diversion by the Chicago drainage canal should be limited to the use of not more than 10,000 cubic feet per second. * * * This would give an apparent advantage to Canadian interests, but as the diversion is not of serious injury to the Falls and does not materially affect the interests of navigation, it is more than counter-balanced by the complete diversion of 10,000 cubic feet by way of the Chicago drainage canal to the Mississippi River."

On May 3, 1906, the International Waterways Commission made a report signed by both the Canadian and American members, in part as follows: (Appellant's Narrative, p. 104):

"The Commission has made a thorough investigation of conditions existing at Niagara Falls and the two sections have presented reports to their respective govern-

ments setting forth these conditions, to which attention is invited. The following views and recommendations are based upon a careful study of the facts and conditions set forth in these reports * * *"

* * *

"3. The Commission, therefore, recommends that such diversions, inclusive of water required for domestic use or the service of locks in navigation canals, be limited on the Canadian side to 36,000 cubic feet per second, and on the United States side to 18,500 cubic feet per second (and in addition thereto, a diversion for sanitary purposes, not to exceed 10,000 cubic feet per second, be authorized for the Chicago drainage canal), and that a treaty or legislation be had limiting these diversions to the quantities mentioned."

The report of January 4, 1907, of the International Waterways Commission, on the Chicago Drainage Canal, only related to whether the two countries should agree to a diversion in excess of 10,000 cubic seconds feet of water, which amount the previous report of the Commission, as above stated, had recommended and had treated as an existing diversion, as appears by the following statement of said report: (Appellant's Narrative, p. 514):

"20. It was not generally known until after publication in March last of the report of the American section of this commission upon Niagara Falls that an amount greater than 10,000 cubic feet per second would be asked for. In that report, subsequently concurred in by the Canadian section, it was recommended that the diversion of 10,000 cubic feet be allowed. The preservation of Niagara Falls alone was considered, and that in the light of the tacit agreement above described. It was supposed at the time that this was all that Chicago needed, but the recommendation gave offense to the officials of the sanitary district, and the further demand then came out in the form of appeals to the committees of Congress and to the Secretary of State. It is necessary now to take up the question anew, and, after considering it in all its bearings, to reach some conclusion as to whether there should be a limit to the amount of water to be diverted at Chicago, and, if so, as to what that limit is."

Again the Commission stated, in its report (Appellant's Narrative, p. 522), as follows:

> "The extension of the system (diversion) to the Calumet River, alone, is in question".

Further, the said report stated (Appellant's Narative, p. 528):

> "The preservation of the levels of the Great Lakes is imperative. The interest of navigation in these waters is paramount, subject only to the right of use for domestic purposes in which term is included necessary sanitary purposes. In our report of November 15, 1906, upon the application of the Minnesota Canal & Power Co. to divert certain water in Minnesota, we recommended, among other things 'that any treaty which may be entered into should define the uses to which international waters may be put by either country without the necessity of adjustment in each instance, and would respectfully suggest that such uses should be declared to be (*a*) uses for necessary domestic and sanitary purposes; (*b*) service of locks for navigation purposes; (*c*) the right to navigate.' It is our opinion that so far as international action is concerned a treaty provision of that kind is all that is required in this case. We accordingly renew our recommendation of November 15, 1906, just quoted."

It is apparent from the foregoing quotations from the International Waterways Commission reports, which formed the basis of the treaty, that both of the high contracting parties agreed to the diversion of 10,000 cubic seconds feet of water from Lake Michigan at Chicago, and that it was treated as an existing diversion. **The right to divert that amount from Lake Michigan, was not, at the time the treaty was made, in dispute.** The only dispute was as to the right to withdraw an additional 4,000 cubic seconds feet through the Calumet River and the Calumet Sag Channel. Therefore, Article 2 of the Treaty, providing for suits to be instituted by citizens for damages, and the right of either one of the high contracting parties to object in case of injury to navigation, could

only apply, so far as the Chicago diversion was concerned, to any diversion in excess of the 10,000 cubic seconds feet. Article 2 expressly, as pointed out by us in our original brief, reserved the right to the United States and to the respective state governments, to deal as they should see fit with non-boundary waters like Lake Michigan (as to uses of water thus in dispute) subject only to the said limitations as to suit and objection for injury to navigation. 10,000 cubic seconds feet diversion was not in dispute.

Article 3 of the Treaty expressly provides that it should not interfere with the uses of boundary waters for domestic and sanitary purposes. Article 8, states the order of precedence, and makes the use for domestic and sanitary purposes paramount or first. Our object in referring to those clauses in our original brief, as is obvious, was to show that even as to boundary waters, diversions for domestic and sanitary purposes should not be disturbed; and also, to give further support to the express words of Article II, reserving full rights in the United States and respective state governments, as to diversions from non-boundary waters.

It will be observed in the quotations from the International Waterways Commission report of May 3, 1906 (infra, p. 84), and the report of January 4, 1907, (infra, p. 84), that they treated the Chicago diversion as being one for ordinary sanitary purposes. Counsel suggests that other cities about the Great Lakes might do the same thing, thus, as they say, entirely draining the lakes, and that Chicago is the only city which diverts water for this purpose and therefore it cannot be treated as a diversion for ordinary sanitary purposes. On the other hand, it is obvious that it is an ordinary diversion, because it was the only way Chicago could protect its water supply. The other cities about the Great Lakes are not so situated that they, or any of them, could take advantage of this best way of providing pure drinking water.

Mr. Lyman E. Cooley, in his testimony on the subject of the Chicago diversion, which evidence is undisputed in this record, stated (Appellant's Narrative, p. 311):

"Chicago is the only city situated about the Great Lakes in which sewage disposal can be made through the back lots, and in which even storm waters for long distances along the lake shore may be absolutely excluded from the lake itself, the source of water supply. The pass that we have to cut down to divert our waters to the southwestward is only 7 to 8 feet as measured by the rock floor at Lemont above the low water of 1847; and only 2 to 3 feet above the high water of 1838, so that a channel can be cut in that direction at a minimum cost.

On the other hand, the lowest divide to the east between the waters of the lakes and the Ohio River is the Wabash-Maumee Divide at Ft. Wayne, which is about 190 feet above Lake Erie. And on the north is the Fox-Wisconsin Divide at Portage, Wisconsin, between the Fox River that empties into Green Bay and the Wisconsin River which empties into the Mississippi River, and this divide is 210 feet above the lake. So it is not possible at any other point about the Great Lakes to make a solution at all similar to that which has been provided at Chicago.

It is one of the endowments of our site, and it is the reason we are here, and it is the reason that the city is here; and from my point of view we are entitled to avail ourselves of it like any other bounty of nature, and to utilize the lakes in that connection.

From a conservation standpoint we utilize the lakes in that connection for all the utilities that can be worked out of it. It is perhaps the highest conservation to which waters have ever been put in the world."

APPELLEE'S POINT VI.

(Its Brief, p. 236.)

Appellee, under Point VI discusses the effect of the various permits. We concede, only for the sake of argument, the proposition suggested in the first paragraph of appellee's brief under this point (Appellee's Brief, p. 236).

Appellee's Point VI-A.

(Its Brief, p. 236.)

We fail to see the purpose of the quotation from Major Marshall's report of June 24, 1896 (Appellee's Brief, p. 237). Major Marshall suggested there were certain questions to come up later—among them, whether the diversion would be allowed by the United States and Great Britain. The treaty of January 11, 1909, reserved to the State of Illinois the right to divert water from Lake Michigan for sanitary purposes. Congress has treated the diversion as lawful, in that it has not seen fit to regulate diversions for these purposes. The right to divert the amount claimed by appellant has been authorized not only by the permits of July 11, 1900, but by the one of May 8, 1899.

Appellee's Point VI-B.

(Its Brief, p. 238.)

We pointed out in our original brief that the recital (May 8, 1899 permit),—that the Chicago River had been improved at the time the permit was granted for a withdrawal through it of 300,000 cubic feet per minute—, did not limit the granting clause of the permit, which *granting clause* contained no words of limitation. We cited *Corrigan Transit Co. et al.* v. *Sanitary District of Chicago,* 137 Fed. 851, which held that

the recital and the preambles of the permit in no way modify the granting clause.

Counsel say (Appellee's Brief, p. 241) that the December 5, 1901, order was accepted by appellant "in lieu of previous permits" and referred to the condition of said order stating that the permit was "subject to such modification as the public interest may from time to time require." How this December 5, 1901, order could be in lieu of the May 8, 1899, permit, it is difficult to conceive. The order was made under Condition 2 of the 1899 permit, which related solely and only to modification in the event a current should prove unreasonably obstructive to navigation on the Chicago River. The Secretary of War could not enlarge that condition by using words in a conditional clause in the order, which order was made expressly, and could only spring from Condition 2 of the original permit.

Appellee's Point VI-C.

(Its Brief, p. 241.)

July 11, 1900, permits.—Here again counsel fail to take into consideration the long expressed purpose of appellant in enlarging the channels of the Chicago River and its branches. The ordinance of April 21, 1891, of appellant's Board of Trustees expressed its purpose concerning these river channels. The applications for the July 11, 1900 permits recited the plan of widening of the river channels to 200 feet and their corresponding deepening. Such excavations of the river channels were designed to, and the result would, enlarge the cross sections of the river channels for a flow of 10,000 cubic seconds feet through them limited to a current of less than a mile and a quarter an hour prescribed by the Secretary of War. It was part of the plan adopted by the Board of Trustees under the ordinance of April 21, 1891, to make these river channels the supply channels for the Sanitary and Ship Canal, with its capacity of 10,000 cubic seconds feet of water. This

plan was expressed by said ordinance (April 21, 1891—appellant's original brief, p. 34). The first application for permit to carry out this program was made June 16, 1896, in which it was stated (Appellant's original brief, p. 36):

> "The work of the Sanitary District has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport in Will County, twenty-eight miles distant.
>
> Our connection with Lake Michigan must be through the Chicago River, with the West Fork and the South Branch of which we make a junction at Robey Street."

The excavation under these July 11, 1900, permits was in furtherance of the original plan. This work accomplished the purpose of appellant for its required diversion. General Bixby so found in his report of 1906 on the Chicago Drainage Canal (infra, p. 61). Secretary of War Stimson in his January 8, 1913, statement did not find that a current was or would be created in the Chicago River, obstructive to navigation, with a diversion of 10,000 cubic seconds feet through the enlarged channel of the Chicago River and its branches. The permits of July 11, 1900, were subject to the same conditions as the May 8, 1899, permit. After the work under the July 11, 1900 permits was done the Secretary of War has never found, or objected to the diversion of 10,000 cubic seconds feet through the channels of the Chicago River and its branches to the Sanitary and Ship Canal on the ground, that a current was, or would be, created injurious to navigation on said river.

Appellee's Point VI-D.

(Its Brief, p. 243.)

The effect of the September 11, 1907, permit as to the North Shore Channel, and the June 30, 1910, permit as to the Calumet Sag Channel, has been discussed by us elsewhere (infra, pp. 64. 65).

Appellee's Point VI–E.

(Its Brief, p. 243.)

Counsel cites *Southern Pacific* v. *Olympian Dredging Co.*, 260 U. S. 205, which has been discussed by us elsewhere (infra, p. 49).

APPELLEE'S POINT VII.

(Its Brief, p. 244.)

Counsel curiously quote a part of a sentence from our brief (p. 152), as indicating that we concede that Congress may occupy the field so far as diversions by states for sanitary and domestic purposes are concerned, to the exclusion of any exercise of power by the state. Our position is that that question is not now before this Court, as is indicated by the sentence immediately following the one partly quoted by appellee. The states' acts are lawful until Congress occupies the field, which it may do at any time. It cannot be deemed to have occupied the field unless it has clearly expressed such intention.

Appellee's Point VII-A.

(Its Brief, p. 247.)

Counsel cite *Henderson* v. *Mayor of New York*, 92 U. S. 183, but do not state the true facts of that case. In *Miln* v. *City of New York*, 11 Peters 103, this Court held valid Section 1 of the Statute of New York, providing that the Master, within twenty-four hours after arrival, should report to the Mayor the name, place of birth, last legal residence, age and occupation of every person brought as a passenger. In the *Passenger cases*, 7 Howard 283, the Court held a Statute of New York placing a tax of a certain amount upon each passenger coming into the port to be invalid as a direct tax or burden upon interstate commerce

In

Henderson v. *Mayor of New York, supra,*

the statute of New York in question required the Master to give a bond of a certain amount for each passenger, and upon failure to give bond, to pay a certain amount for each

passenger coming into port on his vessel. Failure to give bond or make payment incurred a penalty of $500 for each default, which was made a lien upon the vessel. The Court held that the real purpose of the statute was to collect the $1.50 per passenger and that it was, therefore, void, as a direct tax or burden upon interstate commerce. *Miln* v. *New York, supra,* was merely distinguished. It was not overruled.

Kansas City S. R. Co. v. *Kaw Valley Drainage,* 233 U. S. 75,

held invalid an order of the state court directing the absolute removal of a bridge over which interstate commerce was carried. These cases have no application to the propositions here.

Appellee's Point VII-B.

(Its Brief, p. 249.)

Counsel quote from *Morgan* v. *Louisiana Board of Health,* 118 U. S. 455. We paraphrase part of their quotation to suit the facts in this case as follows:

> "But it may be conceded that whenever Congress shall undertake to provide for the commercial cities of the United States a general system *prescribing the use and diversion of navigable waters of the United States for public health (of quarantine)*, or shall confide the execution of the details of such a system to a national board of health, or to local boards, as may be found expedient, all state laws on the subject would be abrogated, at least so far as the two are inconsistent."

NOTE: We replace the words in parentheses by the words in italics in paraphrasing the quotation to emphasize its application to this case.

Counsel neglected to add the very pertinent last sentence of the paragraph quoted, as follows:

> **"But until this is done, the laws of the State on the subject are valid."**

The second reason given by this Court, for its said holding, is stated as follows (p. 465):

> "But, aside from this, quarantine laws belong to that class of state legislation which, whether passed with in-

tent to regulate commerce or not, must be admitted to have that effect, and which are valid until displaced or contravened by some legislation of Congress.

The matter is one in which the rules that should govern it may in many respects be different in different localities, and for that reason be better understood and more wisely established by the local authorities. The practice which should control a quarantine station on the Mississippi River, a hundred miles from the sea, may be widely and wisely different from that which is best for the Harbor of New York. In this respect the case falls within the principle which governed the cases of *Wilson* v. *Blackbird Creek Marsh Co.*, 2 Pet. 245 * * *." (Many more like cases were cited)

So, here the question of the proper way to provide a pure water supply for Chicago and thereby protect the public health may be best handled by the local authorities. The use of the navigable waters of the United States for that purpose, in the way most suitable for the interests of the locality, should be determined by the local authorities. The proper solution of the problem in one locality may be entirely different and may require entirely different application of principles to the solution in another locality. We have in the United States cities located where the temperatures are extreme. In other parts, there is practically no change. In some localities the people are engaged entirely in industrial pursuits—such as manufacturing; in others, agriculture or the raising of fruits are the principal activities. The ideals and desires of the people of different localities are not alike. The people of some localities demand that greater care should be taken in the protection of health and in the removal of odors or things offensive to the eye. The people or their representatives in local self-government in each of these localities can best determine how their purely local affairs in the interest of public health shall be administered. It is the purpose of Congress to permit the activities of the local governments to continue as exercised by them under the police power for public welfare, but always with the reservation

that Congress may, when it finds the occasion necessary, intervene. Until it does, the local regulations are valid. An excellent example is the Congressional Act for the preservation of Niagara Falls of June 29, 1906, under which Congress stepped in to regulate diversions from the Niagara River. These diversions, based solely upon the laws of the State of New York, **even for power purposes from an international stream, injuring navigation not only on the Niagara River but on Lake Erie, outside of the State of New York, were considered lawful and valid.** And these diversions for power purposes from this international stream were created and continued during the pendency not only of the Act of September 19, 1890, but also that of March 3, 1899. Yet, no action was taken by the Attorney General or appellee to enjoin those diversions. These corporations diverting water to make electricity to sell for profit were treated as law-abiding citizens. On the other hand, appellant, a public municipal corporation, sustained by public taxation, is considered and called a culprit, acting beyond the pale of the law.

Appellant's justification, not only under the direct Act of Congress of March 2, 1827, but further under the permits of the Secretary of War, acting under Section 7 of the 1890 Act and Section 10 of the 1899 Act, and under the law of overruling necessity, Congress not having regulated the subject, is called baseless, and likened to the apology of a child.

The case of

Mobile County, etc. v. *Kimball*, 102 U. S. 691,

related to an improvement by the state of the River, Bay and Harbor of Mobile under an act of the legislature of Alabama, and the language of the case is applicable only to that situation.

We have heretofore pointed out the necessity of the diversion of 10,000 cubic seconds feet for navigation purposes as well as for the protection of Chicago's drinking water supply (infra, p. 72). Counsel assert that no one of our cases

cited under Point IV.-B is in point (Appellee's brief, p. 252). In support of this statement they say:

> "*New York* v. *Miln*, 11 Peters 102, was overruled in *Henderson* v. *Mayor of New York*, 92 U. S. 183; 23 Law Ed. 543."

New York v. *Miln, supra*, on the contrary, was reaffirmed in *Henderson* v. *Mayor of New York, supra*, and the latter case was distinguished from the *Miln case*, as we have pointed out (infra, p. 92) because the purpose of the section of the statute under consideration in *Henderson* v. *Mayor of New York* was a direct tax upon the passengers or the boat carrying the passengers of so much per passenger. It was held to be a direct tax or burden upon interstate commerce. The requirement of the statute under consideration in *New York* v. *Miln*—that the master should give the names and other information as to each passenger on his boat—was held to be a proper regulation under the police power of the state.

Our Point IV.-B (Appellant's original brief, p. 163) is that Congress did not intend that the Secretary of War could regulate the diversion of water from Lake Michigan and thus frustrate acts of the state pursuant to police power. In order that the act should be so construed, it was necessary that such Congressional intention should appear plainly and in unmistakable terms.

Under Point IV.-C of our original brief (p. 176), we showed that, as to this particular diversion, Congress, by other acts, had indicated that it was not its intention that the Chicago diversion for sanitary purposes should be limited.

We do not quarrel with the quotation from *Wilkerson* v. *Rahrer*, 140 U. S. 545, as appellant's diversion "does not belong to commerce." (Appellee's Brief, p. 253.)

In

Wisconsin v. *Duluth*, 96 U. S. 375,

the Court had under consideration acts of Congress specially relating to the Duluth Harbor and the canal across the Saint Louis River to Superior Bay in Wisconsin.

APPELLANT'S POINT VIII.

(Its Brief, p. 255.)

Appellee asserts various facts, some sixteen in number, to establish no acquiescence or estoppel on the part of appellee. We will take them up in order.

(1) Appellant's work was instituted prior to September 19, 1890. (Infra, p. 27.)

(2) Appellee's officers co-operated with appellant in building its canal and in providing for the diversion to the amount of water claimed by appellant it has a right to withdraw from Lake Michigan. (Appellant's Statement of the Case, its brief, pp. 18 to 29, 34 to 41, *Infra*, pp. 104 to 110.)

There was no suggestion that congressional action was required, but merely that Congress might exercise its power under the commerce clause of the Constitution to regulate the diversion. Until that was done, under the law, appellant's acts were lawful and legal. There was no pretense that executive officers might attempt or had the power to hinder or limit appellant in the operation of its diversion works as proposed.

(3) This point is answered under (2), *supra.*

(4) The engineer's report of August 16, 1895, referred to by appellee, related to the subject of lake levels. When the permits were later given, not only for the enlargement of the Chicago River to physically make possible the diversion, but also for the channels opening, under the permit of May 8, 1899, they did not contain any condition as to the effect of the diversion upon surface elevations of the lakes. If there was any injury to lake levels, it was waived.

(5) By the Treaty of 1909, Great Britain has consented to the 10,000 cubic seconds feet diversion. In any event, it can not object.

Congress has not acted to modify the diversion, which is one of the conditions of the permits. The action here is only by executive officers to limit the diversion.

(6) The permits only recited as a condition the paramount authority of Congress, not "of the Federal Government" acting through executive officers.

(7) The Act of 1899 was not retroactive. It was only prospective. Structures built, lawful under previous conditions, were not made illegal.

(8) Again, it was the paramount authority of Congress that was recognized under the application for the permit of May 8, 1899, and in the permit itself; not that of the Federal Government, stirred into action by executive officers.

(9) The May 8, 1899, permit was attempted to be modified by the Secretary of War, acting solely under Condition 2 of the permit relating to current in the Chicago River. Obviously, when appellant had created the cross sections of the Chicago River and its branches to remove any necessity for limitation of flow, as there was no current affecting navigation, the orders limiting the withdrawal ceased to have effect, or the Secretary had no power in the matter.

(10) The effect of the September 11, 1907, permit and the condition thereof, has been fully discussed by us elsewhere. (Infra, p. 64.)

(11) Appellee's counsel are quite free in their interpretation of the prayer of the bill of the Calumet River suit. They say (Appellee's brief, p. 259):

> "The prayer of the bill was for an injunction restraining appellant from reversing the flow of the river and from withdrawing from Lake Michigan any water except as authorized by the Department of War (the amount of water thus authorized being then 4,167 cubic seconds feet)."

The bill in that case relates only to the withdrawal through the Calumet River and Calumet Sag Channel. The prayer

likewise covers that and nothing else. Note the following express words of the prayer which eliminated the Chicago River (Rec., Vol. VIII, p. 6):

> "and from doing or attempting anything in any way to reverse the flow of the said Calumet Rivers, and from doing or attempting anything in any way to divert or abstract any waters from Lake Michigan in any channel *other than the Chicago River as already authorized by said Secretary of War,* unless *prior to beginning any of said work* or doing or attempting to do any of such things, *the Chief of Engineers of the United States shall have recommended, and the Secretary of War of the United States shall have authorized, the doing of such work.* * * *"

At the time this bill was filed, March 23, 1908, the permits of July 11, 1900, were in existence, valid, had never been revoked. The work recommended by the Chief of Engineers and authorized by the Secretary of War had been commenced, was then proceeding, and appellant was expending vast sums in performing it. The prayer of the bill itself expressly eliminated from any question the diversion through the Chicago River and its channels resultant from *work recommended by the Chief of Engineers and authorized by the Secretary of War.* And this bill was filed by the Attorney General under the same authority, Section 12 of the 1899 Act, that the bill in the main channel suit instituted October 6, 1913, is sought to be sustained. A plainer recognition of appellant's right to divert the 10,000 cubic seconds feet through the channels of the Chicago River and its branches to the Sanitary and Ship Canal, and of our position in respect to it, it would be difficult for appellant itself to make to order.

(12) Appellee has set forth here the average yearly flow of water through the Sanitary and Ship Canal, beginning in the year 1900, and ending with the year 1913. Some point is attempted to be made of a passing remark in the report of the International Waterways Commission of January 8, 1910, to the effect that it had asked for the records of withdrawal,

and had been refused by appellant. We know of no issue raised in this record that appellant had refused to give information to appellee as to the amount of its withdrawal. Such refusal to this one commission might have been made by some clerk or officer of the appellant and without the sanction of its board of trustees or its president. There is no place in the record where there is an assertion made by appellee that it did not know of the amount of the average yearly diversion during all this period. Immediately preceding the very statement made by the International Waterways Commission as to the refusal of appellant to furnish it the records, is the further observation that it was not material to the matters under consideration by the Commission, and that the Commission believed the diversion to be greater than 4,167 cubic feet per second. The report stated (Rec., Vol. VII, p. 253):

> "The flow through the canal since June, 1904, has been assumed to be 4,167 cubic feet per second, the quantity authorized in the permit of the Secretary of War. It is believed to have been greater, but the difference is not sufficient to vitiate the results sought for here."

Had the Commission considered appellant's records material for its investigation, an application to the President of appellant's Board of Trustees, or to the Board itself, would undoubtedly have obtained the desired records of flow. They were public officers, not personally interested.

Furthermore, Mr. Isham Randolph, the chief engineer of appellant from the time of the opening of its Sanitary and Ship Canal to 1907, and Mr. George M. Wisner, appellant's chief engineer from that time until about the year 1920, both testified as to the volume of flow through the Chicago River, and the Sanitary and Ship Canal, and the circumstances thereof. No question was asked of them by appellee as to whether the records of flow had ever been refused appellee, or any one else.

(13) The effect of the Calumet Sag permit of June 30, 1910, has been elsewhere considered. (Infra, p. 65.)

(14) The effect of the application of Secretary of War Stimson's refusal of May 8, 1910, to remove the limitation of December 5, 1901, and formally authorize the diversion of 10,000 cubic seconds feet, has been fully considered by us under Point VIII of our argument. (Our original brief, p. 205.)

(15) The works for the diversion of 10,000 cubic seconds feet through the Chicago River and its branches to the Sanitary and Ship Canal, had been substantially completed when the application of February 5, 1912, and the refusal of January 8, 1913, by Secretary of War Stimson, were made, and the Main Channel suit—October 6, 1913—was commenced.

(16) The record does not disclose any delays caused by appellant in the final disposition of this case, and *there were none.*

Appellee again cites the *Wheeling Bridge case,* 13 Howard 553, which has been fully discussed and distinguished by us. (Infra, p. 54.)

In

Monongahela Navigation Co. v. *United States,* 148 U. S. 312,

this Court held that the United States should pay the Navigation Company compensation for the destruction of the canal built by it pursuant to legislation of the State of Pennsylvania and the invitation of the United States. In summing up the facts, this Court said (p. 334):

> "But in this case there was not only the full authority of the state of Pennsylvania, but also so far as respects this particular lock and dam they were constructed at the *instance* and *implied invitation* of *Congress.* The Act of March 3, 1881, making an appropriation for the improvement of the rivers, in terms provided that no such improvement should be made until the Navigation Com-

pany had in good faith started upon the building of this lock and dam. *This lock and dam connected* the *lower* improvements *already* made by the Navigation Company with the *upper improvements proposed* to be made by Congress, and the appropriation by the latter was conditioned on the company's undertaking their construction. This is something more than the mere recognition of an existing fact; it is an *invitation* to the company to *do* the *work;* and *when* in *pursuance* of that *invitation*, and under *authority* given by the state of *Pennsylvania*, the company has *constructed* the lock and dam, it does *not lie* in the power of the state or the *United States* to *say* that *such* lock and dam are an *obstruction* and *wrongfully* there, or that the right to compensation for the use of this improvement by the public does not belong to its owner, the Navigation Company."

What were the Acts of Congress and of the officers of the United States that constituted the invitation to the Monongahela Navigation Co.? On March 3, 1881, Congress, by an act, appropriated $25,000 for improving the Monongahela River in West Virginia and Pennsylvania, provided that (p. 315):

"* * * this sum shall not be expended until the Monongahela Navigation Company shall have undertaken in good faith the building of lock and dam number seven at Jacob's creek, and until said company shall, in manner satisfactory to the Secretary of War, give assurance of their ability and purpose to complete the same."

Thereafter, on March 24, 1881, the United States engineer officer in that district wrote the Navigation Company reciting the Congressional Act mentioned, asking that the Navigation Company proceed in good faith to build the lock and dam.

We have heretofore shown (*infra*, pp. 104 to 110) Appellant's Statement, Original Brief, pp. 18-22, 48-59) the invitation extended by various acts of Congress in making surveys and requiring reports, and by the reports themselves, to construct the link in this waterway from Lake Michigan across the continental divide to the Desplaines River.

In addition, by Congressional Acts in providing for the improvement of the Chicago River, Congress invited the co-operation of appellant in deepening and widening the channels of the South Branch and the West Fork to conform to the Government's plan and project for the improvement of navigation on the Chicago River and its branches. It is admitted by the pleadings (Appellant's Narrative, pp. 18, 39) that $4,216,066.36 was expended by the United States in the improvement of the Chicago River and Harbor, and that $1,626,539.20 of said amount was expended on the Chicago River proper. This latter amount was expended from 1896 to 1913. The facts, which are undisputed in this record, as to the Government's work on the Chicago River and the South branch covering the period from 1896 to 1913, are stated by the witness George M. Wisner (Appellant's Narrative, pp. 184-186):

"The Government did not expend any money in connection with the improvement of the Chicago River until 1896.

Since 1896 the United States expended, up to say June 30, 1913, in the improvement of the Chicago River itself approximately $1,626,000.

It was expended for dredging the North and the South Branches to a depth of 17 feet on the first project, and later the deepening of the North Branch as far north as Belmont avenue, I think, to a depth of 20 feet.

The Government also bought some land on both branches of the river for the purpose of constructing what is known as turning basins. These are basins that are large enough so that vessels can turn around and come back down the river bow first. The one on the North Branch is at Diversey boulevard, and the one on the South Branch is at the junction of the West Fork and the South Branch, just east of Ashland Avenue. Part of this money on the original project was expended for widening the Chicago River at some of the narrowest and most dangerous places. Part of this money was expended deepening the main branch of the river to a depth of 20 feet from the mouth to the junction of the

two branches. Generally this covers the money that was expended by the Government for the improvement of the river.

The City of Chicago has expended in the improvement of the Chicago River approximately $6,275,000.

From about 1861 to the present time, approximately to this time it was expended for dredging of the Chicago River, both the main river and on all its branches, building of bridges and docks, and general improvements.

These improvements in the Chicago River were done by the United States Government during the time that the Sanitary District was completing its works—particularly the South Branch. The deepening of the North Branch has been done in quite recent years; that is deepening the North Branch to 20 feet.

Since the 17 foot project of the United States Government it has done no work on the South Branch, although it has deepened the North Branch to 20 feet. *The Sanitary District took up its work and did this dredging.* When the Sanitary District started on this project, the Government had not quite completed the dredging to 17 feet. It was widening the river at certain places where it was narrow, that is the South Branch. *Some of this work of the Government and the Sanitary District was carried on simultaneously. The widening done by the Government however was at a few places, and did not amount to very much.*

The Sanitary District commenced its work on the improvement of the Chicago River along about 1896."

Let us now examine the Congressional Acts concerning the Chicago River improvement in cooperation with and inviting the appellant to deepen and widen the South Branch of the Chicago River and the West Fork of the South Branch.

The first item looking to the improvement of the Chicago River appears in the Rivers and Harbors Bill of July 13, 1892, (Vol. 1, Laws, Improvement of Rivers and Harbors, p. 611; United States Stat. at L. Vol. 27, p. 88,) as follows (619):

"Improving harbor at Chicago, Illinois: Completing improvement, seventy-two thousand dollars; and the en-

gineer in charge of the harbor is directed, in his next report, to submit what, if any, improvement should be made by the Government in Chicago River, and the cost of same."

The Rivers and Harbors Act of August 18, 1894, (Vol. 1, Laws, Improvement of Rivers and Harbors, p. 677; United States Stat. at L. Vol. 28, p. 338,) contains the following item (685):

> "Improving harbor at Chicago, Illinois: Completing improvement, eighty thousand dollars; and the Secretary of War may, in his discretion, use twenty-five thousand dollars of this sum in the improvement of Chicago River up to the forks of said river."

The Rivers and Harbors Act of June 3, 1896, (Vol. 1, Laws Improvement of Rivers and Harbors, p. 743; United States Stat. at L. Vol. 29, p. 202), contained the following (781):

> "For improving the Chicago River, in Illinois, from its mouth to the stock yards on the South Branch and to Belmont Avenue on the North Branch, as far as may be permitted by existing docks and wharves, to be dredged to admit passage by vessels drawing sixteen feet of water, according to the recommendation of Captain W. L. Marshall, of the Corps of Engineers of the United States Army, in his report under date of August ninth, eighteen hundred and ninety-three."

It is important now to examine the report of Captain Marshall of August 9, 1893, especially mentioned in said Act. This report mentioned the Sanitary and Ship Canal then under construction, as follows (Appellant's Narrative, p. 457):

> "To remedy the, at times, insupportable and disgusting condition of the river and its branches; to purify the river and to preserve the city water, relief is now sought under state laws by constructing a drainage canal from the south branch of Chicago River to the Desplaines River above Joliet, capable of discharging into the Illinois River Valley from three hundred thousand to six hundred thousand cubic feet of water per minute.
>
> * * *

This channel has been located from the south branch of the Chicago River to Lockport, and is under construction, but no provision has yet been made for channels of supply from Lake Michigan. Whatever the outcome or plans of the local officials having this work in charge may be, it can be said that the Chicago River and its branches cannot in their present condition, supply materially more than from one-third to one-half of the minimum requirements of the law, without producing currents that will be prohibitory to navigation at some of the bridges and obstructions now existing.

It is certainly evident, granting the proposition that effective channels for the purpose will be constructed, that if this method of solving the drainage problem is to be carried to conclusion, there must be a complete remodeling of Chicago River throughout both its branches, and there must be also artificial channels of large capacity to furnish even approximately effective outfalls to the sewerage systems of a great city founded on low lands extending some twenty-two miles long, and for miles back from the lake, as well as other large feeders connecting the lake with such channels."

The importance of some time improving these rivers to provide a depth of twenty to twenty-one feet was mentioned; also the removal of the docks and bends in widening the river. The tunnels under the river necessary to be removed were mentioned (Appellant's Narrative, pp. 458-460). The report also stated that it would be necessary to rebuild bridges over the river and to consider the extension of navigation from the Illinois River to Lake Michigan (Appellant's Narrative, pp. 460, 461). The report recommended that immediately the Chicago River from its mouth to the stock yards on the South Branch and to Belmont Avenue on the North Branch should be improved and dredged to admit passage by vessels drawing sixteen feet of water, and that encroachments by persons building docks into the river and that obstructive bridges should be limited. This recommendation only covered the immediate necessities. The greater development for twenty and twenty-one feet by the removal of tunnels

and the dredging and widening of the Chicago River and its branches was definitely contemplated and *suggested* by the report.

The Rivers and Harbors Act of February 26, 1897, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 807; United States Stat. at L. Vol. 29, p. 597), contained the following item (813):

> "Improving Chicago River, Illinois: For continuing improvement from its mouth to the stock yards on the South Branch and to Belmont Avenue on the North Branch, one hundred and thirteen thousand dollars, in pursuance of the provisions of 'An Act making appropriations for the construction, repair, and improvement of certain public works on rivers and harbors, and for other purposes,' approved June third, eighteen hundred and ninety-six; and it is hereby declared to be the true intent and meaning of the said provisions of said Act relating to the improvement of said Chicago River that all of the work in the improvement of said river which *was recommended or suggested* to be done in the interest of commerce by Captain William L. Marshall, of the Corps of Engineers of the United States Army, in his report of August ninth, eighteen hundred and ninety-three, may be done."

The Rivers and Harbors Act of July 1, 1898, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 827; United States Stat. at L. Vol. 30, p. 597), contained the following (830):

> "Improving Chicago River, Illinois: For continuing improvement from its mouth to the stock yards on the South Branch, and to Belmont Avenue on the North Branch, four hundred thousand dollars."

The Rivers and Harbors Act of March 3, 1899, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 843; United States Stat. at L. Vol. 30, p. 1121), contained the following item (895):

> "Improving Chicago River, in Illinois: Survey and estimate of cost *for a channel twenty-one feet deep* from its mouth to the *stock yards on the South Branch*, and to Belmont Avenue, on the North Branch, so far as may be

permitted by existing docks and wharves, exclusive of cost of removing or constructing bridges or piers or lowering tunnels; and the aforesaid *depth of twenty-one feet is hereby adopted as the project depth for the improvement in lieu of that fixed by the Act of June third, eighteen hundred and ninety-six:* Provided That all the work of removing and reconstructing bridges and piers and lowering tunnels necessary to permit a practicable channel with said depth to be obtained shall be done, or caused to be done, by the City of Chicago without expense to the United States."

It will be recalled that this very item of said Rivers and Harbors Act was under consideration by this Court in

Chicago Street Ry. Co. v. *Chicago,* 201 U. S. 505,

wherein the Court held that Congress itself had given assent to the removal of the tunnels and the Secretary of War's authority was unnecessary. This included the reconstruction of bridges therein mentioned. It would apply, also, necessarily to the work of appellant of deepening and widening the South Branch and the West Fork of the South Branch of the Chicago River to conform to the project adopted by Congress. However, the consent of the Secretary of War for this work was in every respect obtained.

The Rivers and Harbors Act of June 6, 1900, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 926; United States Stat. at L. Vol. 31, p. 588), contained the following item (927):

"Improving Chicago River, Illinois: For continuing improvement from its mouth to the stock yards on the South Branch, and to Belmont Avenue on the North Branch, sixty-two thousand dollars."

The Rivers and Harbors Act of June 13, 1902, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 949; United States Stat. at L. Vol. 32, p. 331), contained the following item (994):

"Improving the Chicago River, Illinois: Continuing improvement, three hundred and six thousand four hundred and fifty-seven dollars."

The Rivers and Harbors Act of March 3, 1905, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 1080; United States Stat. at L. Vol. 33, p. 1117), as to a survey, contained the following item (1127):

> "West Fork of the South Branch of the Chicago River, with a view to securing a twenty-one foot channel."

The Rivers and Harbors Act of March 2, 1907, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 1220; United States Stat. at L. Vol. 34, p. 1073), contained the following item (1259):

> "Improving Chicago River, Illinois: Continuing improvement and for maintenance, three hundred thousand dollars."

The Rivers and Harbors Act of June 25, 1910, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 1381; United States Stat. at L. Vol. 36, p. 630), contained the following item (1417):

> "Improving Chicago River, Illinois: Continuing improvement and for maintenance, one hundred and seventy-five thousand dollars."

The Rivers and Harbors Act of February 27, 1911, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 1460; United States Stat. at L. Vol. 36, p. 933), contained the following item (1479):

> "Improving Chicago River, Illinois: For maintenance, thirty-four thousand dollars."

The Rivers and Harbors Act of July 25, 1912, (Vol. 2, Laws, Improvement of Rivers and Harbors, p. 1521; United States Stat. at L. Vol. 37, p. 201), contained the following item (1567):

> "Improving Chicago River, Illinois: For continuing improvement, $28,000."

The Rivers and Harbors Act of March 4, 1913, Vol. 2, Laws, Improvement of Rivers and Harbors, p. 1574; United States Stat. at L. Vol. 37, p. 739, contained the following item (1596):

"Improving Chicago River, Illinois: For maintenance, $10,000."

The Rivers and Harbors Acts of August 1, 1914, (U. S. Stat. at L. Vol. 38, p. 636), July 27, 1916, (U. S. Stat. at L. Vol. 39, p. 401), August 8, 1917, (U. S. Stat. at L. Vol. 40, p. 258), and March 2, 1919, (U S. Stat. at L. Vol. 40, p. 1283), all contained small items making appropriations for the maintenance of the Chicago River.

It will be noted that after the year 1912, no appropriation was made for the further enlargement of the Chicago River, its North Branch, South Branch and West Fork, as at that time the 1920 and 1921 foot project had been completed. **The United States had done its work as provided by the project of Congress in the Chicago River proper and in the North Branch. Appellant had enlarged the South Branch and the West Fork according to the same project of Congress, which enlargement of said South Branch and West Fork was connected with and was a part of appellee's improvement of the Chicago River proper and of the North Branch. The appropriations thereafter were for maintenance only.**

The foregoing demonstrates not only an invitation to appellant to make the improvements in the South Branch and West Fork of the Chicago River to carry out the project of Congress for the improvement of those rivers to 20 and 21 foot depth, removal of tunnels, reconstruction of bridges, but also the actual cooperation of appellee through Congress with appellant, as appellant was doing its work of enlarging the channels of these rivers. The work done by appellant in deepening and widening the South Branch and West Fork, according to the project adopted by Congress, connected with, and was a part of, the work done by appellee in deepening

and widening the Chicago River proper and the North Branch. The invitation of appellee to appellant to carry out the work necessary for the diversion of 10,000 cubic seconds feet of water from Lake Michigan, is much stronger than that mentioned in

Monongahela Navigation Company v. *United States, supra.*

Appellee's Point VIII-A.

(Its Brief, p. 263.)

The authorities cited here do not apply, for appellant did not induce, by act or representation, appellee to acquiesce in the construction of the works for the diversion.

Appellee's Point VIII-B.

(Its Brief, p. 267.)

In

Union Bridge Company v. *United States,* 204 U. S. 364,

cited by appellee, there was express authority given the Secretary of War under Section 18 of the Rivers and Harbors Act of 1899 to require the alteration of bridges theretofore constructed.

Here again appellee fails to observe that there has been no congressional action revoking the rights of appellant as existed in the case of

United States v. *Chandler Dunbar Company,* 229 U. S. 51.

Appellee knew at all times that appellant was proposing to divert at least 10,000 cubic seconds feet of water through the channels of the Chicago River and its branches to the Sanitary and Ship Canal; that it was constructing its works

for that purpose, and was deepening and widening the river channels in order that its purpose might be physically accomplished.

Appellee's Point VIII–C.

(Its Brief, p. 270.)

Counsel bases its argument upon a false premise, namely, that there has been a revocation. Congress has done nothing. The United States is moved here solely by the action of executive officers. The Secretary of War has, not even, attempted any revocation of appellant's rights.

Appellee was not misled. Appellee knew for what purpose appellant was enlarging the channels of the Chicago River and its branches. It knew that one of the purposes of the construction by appellant of its works with the attendant diversion of water from Lake Michigan, was the disposal of sewage and drainage so that it would not reach Chicago's water supply. The Secretary of War granted the permits, with the understanding, which is the law, that Congress might thereafter regulate the entire situation, at which time only would the appellant's diversion works be subject to Federal regulation.

Counsel say, (Appellee's Brief, p. 282) that the fixing of the reference plane for the improvement of the channels of the Great Lakes six inches lower is unimportant. We called attention to this to show that Congress itself, in fixing this reference plane for the improvement of these channels, accepted the Chicago diversion and sought to offset for any effect upon the lakes' surfaces that it was claimed would take place. We are unable to see how the action of executive officers can set at naught this plain congressional acquiescence.

APPELLEE'S POINT IX.

(Its Brief, p. 283.)

Appellee's counsel having now consumed 282 printed pages in, as they believe, establishing their right in this court for an affirmance of the decree below, without, however, meeting categorically a single argument of appellant, and believing that it is now the time to deliver the last and fatal solar plexus blow, and deprive appellant of its last heart throb, assert that the injunction should be *effective immediately* and *without condition;* and that appellant be at once forever *restrained, without condition,* from diverting more than 4,167 cubic seconds feet from Lake Michigan.

This position is sought to be maintained in face of the admitted facts in this record, that the immediate limitation of the diversion as prescribed by the injunction, would cause pollution of Chicago's drinking water supply, resulting in the rage of typhoid fever and other water born diseases, public nuisances in the Chicago River, Sanitary and Ship Canal, Des Plaines and Illinois Rivers, creation of diseases along those rivers, destruction of fish life in the Illinois River and generally havoc in this community. A guess, as to the extent of the damage to result from the limitation of the diversion as stated, is beyond the power of a human being to hazard.

Appellee's Point IX-A.

(Its Brief, p. 284.)

Counsel for appellee discuss the right of the Attorney General to institute suit for an injunction, and thus the jurisdiction of the court. The question of jurisdiction of a Federal court, may be at any time raised, and the court will do so of its own motion.

Osborn v. *Bank of U. S.*, 9 Wheaton 738.

Wayman v. *Southard*, 10 Wheaton 1.
United States v. *Moore*, 3 Cranch 159.
Wilson v. *Mason*, 1 Cranch 45.
Mansfield C. & L. M. R. Co. v. *Swan*, 111 U. S. 379.
Bors v. *Preston*, 111 U. S. 252.
Morris v. *Gilmer*, 129 U. S. 315.
Pepper v. *Fordyce*, 119 U. S. 468.
Union Iron Bridge & Mfg. Co. v. *Otoe County*, 120 U. S. 225.
Mississippi & Run River Boom Co. v. *Patterson*, 98 U. S. 403.

Jurisdiction cannot be conferred by consent of the parties. There is no consent here.

The Secretary of War, in the June 30, 1910, permit as to the Calumet Sag Channel, may have called the Calumet River suit filed March 23, 1908, a friendly suit. We have not discovered a condition of this kind at any point in this litigation. Furthermore, the Calumet River suit has ceased to be of any particular concern to anyone, in view of the later Main Channel suit of October 6, 1913, involving all diversions through the channels of the Chicago River and its branches to the Sanitary & Ship Canal, and, also, through the Calumet River and the Calumet Sag Channel.

The statement by counsel of the facts and holding of this court in

Economy Light & Power Company, 256 U. S. 113, (Appellee's Brief, p. 285),

furnishes its distinction. There the suit was to remove a part of a structure, which is expressly provided for under Section 12 of the Act of 1899. Necessarily, if the court had obtained jurisdiction by proper action to remove a structure or a part of a structure, as specifically provided by the said section of said act, then the decree could be made effective

by enjoining the defendant from thereafter constructing the same or a like structure.

U. S. v. *Rio Grande Dam & Irrigation Company, supra,*

is not an authority in support of appellee's contention for in that case the action was brought under the express provision of Section 10 of the 1890 Act authorizing the Secretary of War to institute a suit for injunction to enjoin the **creation** of an **obstruction.** That case had been instituted prior to the passage of the Act of March 3, 1899. In fact it was first argued in this court in November, 1898, and decided May 22, 1899. In withdrawing from the Attorney General the broad powers which entitled the Attorney General to institute the Rio Grande Dam & Irrigation Company suit, Congress expressed an intention that the Attorney General should not thereafter exercise such broad powers. Thus it restricted the Attorney General's powers under the new act of 1899, and, evidently, expected the penal clauses of the statute to be a sufficient safeguard.

We do not believe that the statement by appellee's counsel (Appellee's Brief, p. 290), that the provisions of Section 12 of the 1899 Act did not supersede and repeal similar provisions of Section 10 of the 1890 Act, is seriously presented.

Counsel again cite the

Wheeling Bridge case, 13 Howard 553, (Appellee's Brief, p. 292).

How that case can be treated as having any application on the question whether the Attorney General has authority to institute this suit cannot be determined by us. That suit was instituted by the sovereign State of Pennsylvania, under the express provision of the Constitution giving this court jurisdiction as to controversies between the states.

In re Debs, 158 U. S. 564,

cited and quoted at length by appellee (Appellee's Brief, p. 293-297) related to the protection of the property of the

United States and the carrying of the mails. Furthermore, there were no statutory provisions prescribing what the Attorney General might do, as there is here.

Appellee's Point IX-B.

(Its Brief, p. 297.)

Comparative Injury.

It must be borne in mind that the sole legal proposition asserted in this case by appellee, is that, appellant, having been found here, without the affirmative authorization of the Secretary of War for a diversion of 10,000 cubic seconds feet of water from Lake Michigan, the injunction must issue as a matter of course. In what manner this authorization failed, is entirely immaterial, on appellee's theory. Of course, as we have pointed out extensively in our original brief herein and in this reply brief, that authorization was obtained. Appellee's counsel assert that it is unnecessary for appellee to show or even allege, material alteration or modification of the navigable waters of the United States or material injury to navigation; that all that is required, is that there is an alteration or modification of such navigable waters. To what extent, is beside the question. The case relied upon so much by them (*United States* v. *Rio Grande Dam & Irrigation Company*, 174 U. S. p. 690), does not uphold their contention, for there this court sent the case back for further evidence to determine whether the injury to navigation by the construction and operation of the dam, would be unreasonable.

Counsel fail, we believe, to appreciate that the powers exercised by the State of Illinois for the construction and operation of appellant's works, are just as necessary for the maintenance and preservation of the union, as those powers exercised by Congress under the commerce laws of the Constitution. This Court will reconcile the actions of the two sovereignties.

As has been so admirably stated by The Solicitor General in his valuable work entitled "The Constitution of the United States," recently published, this court is in the nature of a continuation of the constitutional convention. It is a tribunal where the great questions, involving the interpretation of the Constitution in its application to the states, may be individually settled. In many instances the exercise by the state of its police power in some manner and to some extent affects the exercise of Federal power. A very excellent example is the construction of bridges over navigable streams. It is necessary for the welfare of the state that these navigable waters shall be bridged. Yet they do obstruct navigation.

In the case of

Escanaba Transportation Company v. *Chicago*, 107 U. S. 678,

an ordinance of Chicago, closing bridges certain hours of the day, was upheld; yet interstate commerce was affected. The comparative injury that would result to the commerce of the United States and the injury to the City of Chicago and State of Illinois by not closing the bridges at those hours, was necessarily an important question to be considered in that case. And Congress has not in any way sought to regulate diversions of or the use of navigable waters for sanitary purposes and in the interest of public health.

Counsel are asking this court to uphold the mere fiat of a bureau of the Federal Government, which bureau has as its head the Chief of Engineers of the United States Army, because the Chief of Engineers failed to recommend in 1912 the removal of the limitation of the diversion of December 5, 1901, and thereupon the authorization of a diversion of at least 10,000 cubic seconds feet of water through the channels of the Chicago River and its branches to the Sanitary and Ship Canal. And this request of appellee's counsel is in the face of the admitted facts—colossal damage to appellant.

Appellee's Point IX-C.

(Its Brief, p. 302.)

Appellant, by making the offer contained in its motion of July 12, 1920, in connection with the settlement of the decree, was merely seeking to compose a controversy. It is not going to carry its corporate entity to the St. Clair or Niagara or St. Lawrence Rivers and build compensating or regulating works there, but proposes merely to pay a sum of money which shall equal the cost of constructing and maintaining such works, in order to compromise a lawsuit. What we ask the court to do, is to say to appellee:

> "You cannot have your injunction to the full extent you ask, when appellant offers to do a thing which will, in every way under the admitted facts in this case, make you entirely whole."

And it must also be remembered that Congress may, thereafter, interpose itself in this matter, if the solution proposed is not to its liking.

Counsel (Appellee's Brief, p. 304) discuss the Treaty of January 11, 1909, and assert that the remedial works cannot be constructed without the consent of the Joint Commission, and quote Article 4 of the Treaty. The very clause of that article quoted, provides that neither government shall construct remedial works on its own side of the boundary which shall have the effect of raising the *natural* levels of the water on the other side. If appellee's contention is correct, that this diversion reduces the levels below their natural levels, and the only purpose of the remedial works is to place the levels in the same condition as if the diversion did not exist, then there would be no raising of

> "the natural levels of waters on the other side of the boundary."

But whether it is necessary to obtain the consent of the Joint Commission or anyone else, is immaterial for the ad-

mitted facts in this case are that the effect of the Chicago diversion may be entirely compensated for by the construction of these remedial works. Therefore, if consent is refused, it would be for no good or valid reason, and appellant should not be, in that event, unnecessarily injured by the absence of such consent.

Counsel say (Appellee's Brief, p. 305) that the decree which appellant proposes could not be enforced. We apprehend no difficulty in the settlement of a decree which would make it a condition that appellant pay to the United States such an amount as the Secretary of War or some officer or tribunal of the United States, should determine the cost of the remedial works to be when they were properly authorized by Congress, or by such other authority as would be necessary. The diversion of the full 10,000 cubic seconds feet would be subject to those conditions.

Appellee's Point IX-D.

(Its Brief, p. 310.)

Again, notwithstanding the matter stated by appellee, in its conclusion to its brief (p. 316), it requests that the injunction be immediately made effective. Counsel again refer to a motion to strike certain portions of appellant's answer. The record does not disclose that any such motion was ever presented to the lower court. Notice that a motion would be entered was given February 28, 1914, (Rec. Vol. 8, p. 126), but no motion was ever filed and no order was ever entered passing upon any such motion.

The facts in support of our contention in this respect, as to the postponement of the time the injunction should be made effective, are undisputed in this record.

There is no suggestion by us that this court in any manner by sustaining appellant's position would take anything from

Congress, as counsel asserts (Appellee's Brief, p. 313). Congress still has the right, if it chooses, as it has had the right for over a third of a century since these works have been under construction or in operation, to regulate them and the amount of diversion, if appellant's action is not in keeping with its wishes.

APPELLEE'S CONCLUSION.

(Its Brief p. 316.)

The conclusion of appellee's brief makes a most remarkable suggestion; namely, that the Court, notwithstanding the admitted equities of this case in appellant's favor, confirm the lower court's decree as it now exists without prejudice to the Chief of Engineer's recommending, and the Secretary of War's granting authority for, the diversion from Lake Michigan required by appellant, until Congress may at either this coming session of the present Congress, or at the next Congress, exercise its power to regulate the Chicago diversion under the Commerce Clause of the Constitution. Counsel suggest that this Court disregard the fundamental principle of constitutional law,—that until Congress acts, the state's exercise of its reserved power is lawful. Appellee's counsel thus would make the rule,—that the state's exercise of the reserved power is lawful, *only for a limited time,* namely, the end of the next Congress. What would happen if Congress did not act within the time mentioned, counsel do not disclose. We presume, according to counsel's suggestion, the decree would then be effective without *any condition.*

This concession of the law officers of the United States is no more than the concession which the Secretary of War and the Chief of Engineers were prepared to make, when Judge Landis gave his opinion herein, at which time a memorandum from the Chief of Engineers, approved by the Secretary of War, was submitted to the Trustees of The Sanitary District, dated July 21, 1920. This appears from the letter of Col. Wm. V. Judson, of May 24, 1921, to the Chief of Engineers (Appellant's Narrative, p. 351):

> "14. In regard to the contention of the Sanitary District that it is necessary to divert more than 4,167 cubic feet per second in order to avoid contamination of

the City water supply and consequent epidemics, I was empowered in a memorandum of the Secretary of War for the Chief Engineers dated July 21, 1920, to say **'that if Judge Landis' decree is accepted as final, the War Department will issue no permit, since it is without legal power to do so, but will ask no further orders from the Court to enforce the limitation so long as the City of Chicago proceeds with dispatch to prepare plans and put them into process of execution for its sewage system. If the City of Chicago then prepares plans and consents to the War Department having current knowledge of its activity, either by reports to the courts or otherwise, the situation will be under the control of Judge Landis until the whole problem is disposed of. If, however, the City of Chicago proposes to appeal the case and takes no steps pending the appeal to cure the trouble, Colonel Judson should be instructed to make no concessions or promises of any kind.'** This memorandum of the Secretary of War was obtained through the Chief of Engineers at my solicitation for use whenever Judge Landis decides to finish the hearing on Attorney Adcock's arguments for allowing a total diversion of 10,000 second feet. In this connection Mr. Adcock was making the argument that the War Department would be arbitrary in acting on the findings of the court, and a statement was desired which would show that the Secretary of War would not be arbitrary in the matter. * * *

A second conference was held on February 7, 1921, at which the United States Attorney was represented by his assistant, Mr. J. B. Boddie. The proposal of the Secretary of War as embraced in the last paragraph of his memorandum of July 21, 1920 (E. D. 98093/657), was discussed and the Sanitary Trustees stated that they were unable to accept the proposition that Judge Landis' decree be accepted as final. On the other hand they stated that they would proceed diligently in the preparation and execution of plans for the treatment of sewage within the Sanitary District."

Obviously, the corporate officers of appellant could not, in the manner suggested, give away, through this proposed bargain, the fundamental rights of the people of this community.

We respectfully submit that the willingness to make these concessions demonstrates that the real basis for this litigation is not the injury alleged to result from appellant's diversion, but rather the desire to place in the hands of the Chief of Engineers of the U. S. A., this extraordinary power claimed for his in Appellee's Brief.

Undoubtedly counsel was moved to make this suggestion as to affirmance of the decree without prejudice to the Chief of Engineer's and Secretary of War's action, because of lack of faith in their position taken under Point IX (that the decree should be effective *immediately* and *without condition*). They are forced to admit that this Court could not, in justice and in keeping with its precedents, fail to do that justice to appellant which the facts warrant; that the enforcement of the lower court's decree without granting the necessary reasonable time to appellant and other municipalities within its territory, to readjust themselves to the condition of the limitation of diversion to 4,167 seconds feet, would be unjust, inhuman and not in accordance with equitable principles; that the time stated by appellant and the other municipalities that would be required to make changes, (*uncontradicted by the record*), is reasonable and proper. But notwithstanding their institution of these suits and their selection of the forum, appellee's counsel suggest that in some other place than this court, sitting as a court of equity, that justice, to which appellant is entitled, may be obtained.

In order that this great community may be relieved of an intolerable situation pending Congressional action, the Chief of Engineers would first be required to recommend the granting of authority by the Secretary of War, and thereafter the Secretary of War, on such recommendation, would be required to authorize the diversion. The Chief of Engineers may or may not recommend, and after his recommendation, the Secretary of War may or may not authorize the diversion. There are no prescribed rules or regulations under

which the Chief of Engineers or the Secretary of War shall act. These officers may refuse to act for any reason or reasons that to them seem justifiable, whether the reasons are sound, or are without any foundation.

In this connection we call attention to the very pertinent language in

Willamette Iron Bridge Co. v. *Hatch*, 125 U. S. 1, 16,

referring to this Court's decree in the *Wheeling Bridge case*, 13 Howard 518, permitting time in which to change the bridge, and, in speaking of the claim of Virginia, that it could do with the Ohio River as it chose within its boundary, this Court said (page 16):

> "This plea, therefore, presented not only a great question of international law, but whether rights secured to the people of the United States by compact made before the Constitution, were held at the mercy or caprice of every or any of the States to which the river was a boundary. The decision of the court denied this right. The plea being insufficient as a defense, of course the complainant was entitled to a decree prostrating the bridge, which had been erected *pendente lite*. But to mitigate the apparent hardship of such a decree, if executed unconditionally, the court, in the exercise of a merciful discretion, granted a stay of execution on condition that the bridge should be raised to a certain height, or have a draw put in it which would permit boats to pass at all stages of the navigation."

Appellee attempts to distinguish the action of the Court in the *Wheeling Bridge case* from appellant's suggestion that time be permitted for readjustment, by stating that, in the *Wheeling Bridge case*, Pennsylvania was suing only as a private litigant and there was no question of enforcement of paramount authority. Our examination of the facts of the *Wheeling Bridge case* does not disclose grounds for the distinction sought, as the *Wheeling Bridge case* turned principally upon the compact between Virginia and Kentucky, confirmed by Congress. This compact was treated as con-

gressional legislation defining the character of the Ohio River as a navigable stream, and of the bridge, violating this Act of Congress, Pennsylvania could complain. Counsel further fail to give consideration to the cases cited by us in our original brief (page 185),—*that the United States cannot expect the courts of its own creation to give in its behalf more favorable consideration than they would show to other litigants.*

Counsel in their brief (page 320) assert that it was not necessary to call upon a court of equity to enforce the supposed limitation of the Secretary of War of December 5, 1901, and counsel do not state, but we presume they mean, the army might have been called upon to proceed to the site of this diversion and take possession of appellant's works, and take such action as would be necessary to limit that diversion to 4,167 seconds feet. We doubt whether counsel are serious in this statement, in view of the provisions of Section 12 of the Rivers and Harbors Act of March 3, 1899, specifying what may be done in the event structures are placed in navigable waters without the authority of the Secretary of War. There are two remedies—namely, (1) as to structures—a suit for an injunction; and (2) as to structures and obstructions—penal action. No other remedies are provided, and there are none. How the army could be called into action counsel do not enlighten us. We know of no Act of Congress authorizing any officer of the United States to take such action.

CONCLUSION.

Counsel's claims for the affirmance of the decree below are based upon the contention that the appellant is without the authority of the Secretary of War for this diversion; that it is a condition precedent to the appellant's right to divert this water that it have this authorization. They have not met our argument that the Rivers and Harbors Act of March 3, 1899, does not in those plain and unmistakable terms required indicate the intention of Congress to exercise jurisdiction over diversions of water at Chicago, or the use and diversion of water for sanitary purposes. Our argument remains unassailed, that, assuming the Act of March 3, 1899, delegates to the Secretary of War authority to regulate diversions, he has not, in the clear manner required, limited the diversion to the amount fixed by the District Court's decree, because of the conflict between the December 5, 1901, supposed limitation and the permits of July 11, 1900, for the enlargement of the Chicago River. In referring to this diversion, this Court, in

Missouri v. *Illinois*, 200 U. S. 496, 519,

said:

> "In the case at bar, whether Congress could act or not, **there is no suggestion that it has forbidden the action of Illinois.**"

The supposed limitation of the diversion by the order of December 5, 1901, the basis of the Attorney General's suit here, is a mere shadow. This court will not give force and effect to such action of an administrative officer, as it stated in

Interstate Commerce Commission v. *Illinois Central R. R. Co.*, 215 U. S. 452, 470—

> "Beyond controversy, in determining whether an order of the Commission shall be suspended or set aside,

> we must consider * * * and (c) a proposition which we state independently, although in its essence it may be contained in the previous one, viz., whether, even although the order be in form within the delegated power, nevertheless it must be treated as not embraced therein, because the exertion of authority which is questioned has been manifested in such an unreasonable manner as to cause it, in truth, to be within the elementary rule that the substance, and not the shadow, determines the validity of the exercise of the power."

Appellant's diversion required by state law is authorized under the March 2, 1827 Act. The Secretary of War has actually granted the permission (May 8, 1899) which appellee's counsel claim was required. The conditions of this permit have been entirely fulfilled by appellant; appellee cannot base any right upon the limitation of the Secretary of War's order of December 5, 1901, made almost a quarter of a century ago, in view of congressional action and appellant's enlargement of the Chicago River as authorized by the Secretary of War.

Counsel refer to delays in this litigation and attempt to lay the blame therefor upon appellant, the fallacy of which we have heretofore shown, and they state (Appellee's Brief, p. 320):

> "and the patience with which it has accepted the inordinate and inexcusable delays in this litigation show the keen desire of the Government that no possible injustice should be done to the people of Chicago."

For upwards of a third of a century, during the construction and operation of this Canal, Congress, (advised and notified by its own officers of the initiation of the project, of the progress of the work, its purposes, probable effects upon the Great Lakes and claimed injuries to navigation), to whom power to regulate commerce was delegated and who could have acted, not only did not act adversely, but, on the contrary, passed acts recognizing the diversion. The

delay mentioned by counsel shows the lack of any real basis for appellee's claim to an injunction, and demonstrates that the person really concerned is the Chief of Engineers of the United States Army who seeks sanction for the assertion of arbitrary and unlimited power and control over navigable waters, because, a condition precedent to the Secretary of War's acting, in each instance, is the Chief of Engineer's recommendation. If such power be conceded to him, this one officer of the United States Army can frustrate the efforts of a sovereign state in the interest of public health.

Respectfully submitted,

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SUPREME COURT

No. 161

IN THE

Supreme Court of the United States

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO, *Appellant.*

vs.

THE UNITED STATES OF AMERICA, *Appellee.*

Appeal from the District Court of the United States for the Northern District of Illinois Eastern Division.

PETITION FOR REHEARING ON BEHALF OF APPELLANT.

HECTOR A. BROUILLET,
CLYDE L. DAY,
GEORGE F. BARRETT,
LOUIS J. BEHAN,
EDMUND D. ADCOCK,
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IN THE

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO, *Appellant*, vs. THE UNITED STATES OF AMERICA, *Appellee.*	Appeal from the District Court of the United States, for the Northern District of Illinois Eastern Division.

PETITION FOR REHEARING ON BEHALF OF APPELLANT.

Now comes The Sanitary District of Chicago, appellant, and respectfully petitions this Honorable Court to vacate the order of affirmance entered herein on the 5th day of January, 1925, and to grant a rehearing in the above entitled cause.

To refresh the Court's recollection of the oral argument, the appellant submits herewith as an appendix to this petition for rehearing, a printed transcript of the oral argument of all counsel.

In support of this petition for rehearing, appellant submits suggestions hereto attached and made a part hereof.

Respectfully submitted,

THE SANITARY DISTRICT OF CHICAGO,

By HECTOR A. BROUILLET,
CLYDE L. DAY,
GEORGE F. BARRETT,
LOUIS J. BEHAN,
EDMUND D. ADCOCK,

SUGGESTIONS IN SUPPORT OF FOREGOING PETITION FOR REHEARING.

(1) The Court's construction of the treaty of January 11, 1909, between the United States and Great Britain, concerning Canadian boundary waters, is erroneous.

The opinion of the Court as to this treaty is as follows (Printed Opinion, p. 3):

> "It (the United States) has a standing in this suit not only to remove obstructions to interstate and foreign commerce * * * but *also to carry out treaty obligations to a foreign power* bordering upon some of the lakes concerned * * * With regard to the second ground, the treaty of January 11, 1909, with Great Britain, expressly provides against uses *'affecting the natural level or flow of boundary waters'* without the authority of the United States or *the Dominion of Canada within their respective jurisdictions and the approval of the International Joint Commission agreed upon therein* * * * a withdrawal of water on the scale directed by the Statute of Illinois * * * cannot be done without the consent of the United States, *even were there no international covenant in the case.*"

The clause of the treaty quoted by the court above, is contained in Article 3 of the Treaty, which relates only to uses, obstructions or diversions of boundary waters as shown by the following, which includes the language quoted by the Court (Treaty, Article 3, Appellant's Narrative 532):

> "It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter provided for by special agreement between the Parties hereto, no further or other uses or ob-

structions or diversions, whether temporary or permanent, OF BOUNDARY WATERS *on* either side of the *line, affecting the natural level or flow of boundary waters* on the other side of the line, shall be made except by authority of the United States or the Dominion of Canada within their respective jurisdiction and with the approval, as hereinafter provided, of a Joint Commission, to be known as the International Joint Commission."

Boundary waters are defined to be waters from main shore to main shore of the lakes and rivers or the portions thereof along which the international boundary passes, as shown by the preliminary article of the Treaty. (Appellant's Narrative 530.)

"For the purposes of this Treaty boundary waters are defined as the waters *from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes,* including all bays, arms, and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers and waterways, or waters flowing from such lakes, rivers and waterways, or the waters of rivers flowing across the boundary."

The International boundary does not pass along or through Lake Michigan, it is not a boundary water, and it is excluded by the treaty from all regulations covering boundary waters.

That the provisions of the treaty as to boundary waters do not apply, is further demonstrated by Article 1 of the Treaty. The first paragraph of Article 1 provides that navigation of

"all navigable boundary waters"

shall forever continue free and open for the purposes of commerce to the inhabitants and citizens of each country. But in order to give this right of navigation in the

waters of Lake Michigan, the second paragraph of the Article 1 expressly provides

> "that so long as this treaty shall remain in force this same right of navigation shall extend to the waters of Lake Michigan * * *."

In other words, Lake Michigan is not of the class of boundary waters. (Appellant's Narrative 531.)

The powers of the International Joint Commission are fixed and determined by the following language of Article 8 of the Treaty (Appellant's Narrative 535):

> "The International Joint Commission shall have jurisdiction over and shall pass upon all cases involving the use or obstruction or diversion of the waters with respect to which under articles 3 and 4 of this treaty the approval of this commission is required."

Article 4 has no bearing upon the matters in issue and relates principally to the construction of remedial works in boundary waters.

Lake Michigan is not within the provisions of Articles 3 or 4, is not under the jurisdiction of the International Joint Commission and there are no "treaty obligations to a foreign power" (Printed Opinion, p. 3) as to diversions from Lake Michigan to be carried out by the United States.

The United States reserved complete and exclusive control over all diversions from Lake Michigan by Article 2 of this Treaty (Appellant's Narrative, p. 531):

> "Each of the High Contracting Parties reserves to itself, or to the several State Governments on the one side and the Dominion or Provincial Governments on the other, as the case may be, subject to any Treaty provisions now existing with respect thereto, the exclusive jurisdiction and control over the use and diversion, whether temporary or permanent, of all waters on its own side of the line

which in their natural channels would flow across the boundary or into boundary waters; but it is agreed that any interference with or diversion from their natural channel of such waters on either side of the boundary resulting in any injury on the other side of the boundary, shall give rise to the same rights and entitle the injured parties to the same legal remedies as if such injury took place in the country where such diversion or interference occurs; *but this provision shall not apply to cases already existing or to cases expressly covered by special agreement between the parties hereto.*

It is understood, however, that neither of the High Contracting Parties intends by the foregoing provision to surrender any rights which it may have to object to any interference with or diversions of waters on the other side of the boundary the effect of which would be productive of material injury to the navigation interests on its own side of the boundary."

Full jurisdiction of the United States over diversions from Lake Michigan was reserved by Article 2, subject only to the two conditions mentioned, viz.:

(1) The right of injured parties of Canada to sue; and

(2) The right of Canada to object on account of material injury to its navigation interests.

With neither one of those conditions can this Court be concerned. In any event, the conditions do not apply, because, (*first*) the Chicago diversion to the full amount was then existing; and (*second*), the Chicago diversion to the amount of 10,000 cubic seconds feet was settled and agreed upon between the two countries at the time the treaty was made; and Canada could not object as the Treaty was designed to settle all questions then (Appellant's Narrative 530):

> *"pending between the United States and the Dominion of Canada involving the rights, obligations or interests of either in relation to the other or to the inhabitants of the other along their common frontier,"*

The only pending, unsettled and disputed question was the one involving the right of appellant to divert 4,000 cubic seconds feet through and by way of the Calumet River and the Calumet Sag Channel, in addition to the 10,000 cubic seconds feet then diverted through and by way of the Chicago River, for the International Waterways Commission established under joint legislation of Canada and the United States, had settled the right of Illinois and appellant to divert up to 10,000 cubic seconds feet through the Chicago River, and the Commission found that there was no dispute as to this amount. This is shown particularly by the report of the International Waterways Commission of January 4, 1907, on the Chicago Drainage Canal. (Appellant's Narrative 505, *et seq.*)

In speaking of the diversion through the Chicago River, the Commission by said report, stated that (Appellant's Narrative 522):

> "It has satisfied itself upon that point nor does it wish to re-open the case of the Chicago Drainage Canal as designed and built. It accepts that as a fixed fact, with its attendant diversion of 10,000 cubic feet per second through the Chicago River. *The extension of the system to the Calumet River alone is in question,* * * *."

This report was signed by all of the Canadian and American members of the International Waterways Commission.

The plain terms of the treaty preclude any construction that Lake Michigan is under the jurisdiction of the International Joint Commission or that the United States

is obligated to any foreign power as to diversion of water from Lake Michigan. However, reference to the reports of the International Waterways Commission whose duties required them to study and make recommendations concerning all questions between Canada and the United States as to the terms and basis of a treaty then in contemplation and the negotiations leading up to the making of the treaty, and its ratification by the United States Senate, leave no doubt as to our position. When the question of ratification was before the Foreign Relations Committee of the United States Senate, Chandler Anderson of the State Department, at the request of said committee, gave it a memorandum explaining the provisions of the treaty. Among other things, this memorandum stated (Proceedings of Foreign Relations Committee, 57-62d Congresses):

"It is important to have in mind certain general features of the treaty which may be briefly stated as follows:

(1) The distinction which is drawn in the preliminary article between the boundary waters and waters which are tributary to boundary waters and waters of rivers flowing across the boundary is carefully observed in Articles II and III of the treaty.

(2) Article II applies only to waters which in their natural channels would flow across the boundary or into boundary waters, that is before they have passed the boundary or become part of boundary waters; and it cannot by any construction of its provisions apply to the use or obstruction or diversion of boundary waters.

(3) Article III by its express provisions applies only to uses, obstructions or diversions of boundary waters, and cannot by any construction of its provisions have any application to the use, obstruction or diversion of tributary waters or waters of rivers flowing across the boundary.

(4) Article IV, exclusive of the paragraph thereof relating to the pollution of waters, applies only to waters flowing from boundary waters or to the waters of rivers flowing across the boundary *after they have passed the boundary* and can have no application to waters tributary to boundary waters or to waters of rivers flowing across the boundary before they have passed the boundary.

(5) The jurisdiction of the International Commission is strictly limited by Article III to cases arising under Articles III and IV; and it will be observed that under Article IV the Commission is given no jurisdiction over cases arising under the pollution clause of that Article; it is evident, therefore, that the International Commission can have no jurisdiction over cases arising under Article II.

* * *

The waters of Lake Michigan do not come within the definition of boundary waters, as defined in the preliminary article of the treaty, and it will be noted that in Article 1 of the treaty the waters of this lake are not included among the boundary waters of the Great Lakes system but are covered by special provision in the second paragraph of that article.

The question has arisen as to the effect upon Lake Michigan of the provisions of Article II which deals with tributary waters or rather with all waters which in their natural channels flow across the boundary or into boundary waters, and the objection is made that if the provisions of this Article apply to Lake Michigan, the right to recover damages for injuries resulting on the other side of the line on account of the diversion of tributary waters might interfere with the diversion of the waters of Lake Michigan for the purposes of the Chicago Canal.

In response to this objection, *attention is called to the express provision in this Article that it shall not apply to cases already existing which would seem to cover, and was certainly intended to cover, the Canal system at Chicago.*

But in any case, an examination of the provisions of the article will show that, as pointed out in paragraph numbered (6) above, the right of action for

damages applies to private or individual interests in distinction from public or governmental interests, and such interests are given only the same rights which similar interests on the American side of the line would have in the absence of this treaty.

In effect, this provision brings the Canadian interests within the jurisdiction of the United States for this purpose.

The treaty, therefore, recognizes that the settlement of the question of the use of waters of Lake Michigan is purely a domestic question and leaves undisputed the governmental rights of the United States with respect to it.

But this is the view of Great Britain and Canada as shown by the last paragraph of the article which reserves to each of the High Contracting Parties any right which it may now have to object to any interference with or diversion of waters on the other side of the boundary, the effect of which would be productive of material injury to the navigation interests on its own side of the boundary. This provision relates to public interests in distinction from private interests, and would be wholly unnecessary if under the preceding provisions of the article any right was given to recover damages for injuries to public interests on the other side of the line."

Hon. Elihu Root, Secretary of State, was before the Foreign Relations Committee of the Senate at the time that it was considering the ratification and at the time the memorandum of the said Chandler Anderson was before the Committee, and in explaining the terms of the treaty, said (Proceedings of Foreign Relations Committee, 57-62d Congresses, pp. 271-2):

"The great bulk of the water goes on the Canadian side and the Waterways Commission that was appointed some time ago to deal with the question of the lake levels reports, I think, that 36,000 feet can be taken out on the Canadian side and 18,500 feet on the American side without injury to the Falls. I thought it wise to follow the report of the Commission and put in 1,500 feet in addition to get round

numbers, so our limit is higher than we want but their limit would not be cut down below what it is because there are three companies on the Canadian side who have works there. Then there is this further fact why we could not object to this 36,000 cubic feet on the Candian side: We are now taking 10,000 cubic feet per second out of Lake Michigan at Chicago, and I refused to permit them to say anything in the treaty about it. I would not permit them to say anything about Lake Michigan. I would not have anything in the treaty about it, and under the circumstances, I thought it better not to kick about this 36,000. They consented to leave out of this treaty any reference to the Drainage Canal and we are now taking 10,000 cubic feet per second for the Drainage Canal, which really comes out of this lake system."

(International Waterways Commission Report, Canadian Section, April 25, 1906, Appellant's Narrative 103; Report of Entire Commission, May 3, 1906, Appellant's Narrative 104.) Article 5, which fixes the amount of the diversions of the two countries at Niagara Falls, as do the other articles of the treaty contain substantially the recommendations of the International Waterways Commission.

Appellee agrees with us as to the rights of the United States over Lake Michigan under this Treaty (Its Brief, p. 234):

> "*Article 2 expressly reserves to the United States exclusive control over diversions from Lake Michigan* so long as there is no material injury to Canadian navigation interests."

Obviously, the words, "so long as there is no material injury to Canadian navigation interests", do not state the legal effect of the second paragraph of Article 2 of the Treaty to which they are intended to refer, because that merely gives the right to Canada to object and objection could only be made through diplomatic channels

(not important here). Canada is precluded from making objection as the Chicago diversion to the amount of 10,000 seconds feet was settled and agreed upon prior to the making of the Treaty.

(2) The permits of May 8, 1899 and of July 11, 1900, and others of similar import, are not revocable at the will of the Secretary of War, or for any reason except those reserved by the permits themselves. There is no provision of statute by which the Secretary of War may revoke.

In fact, there is no provision of statute by which the Secretary of War may revoke permits for causes reserved in the permit, but we assume that the general power to grant contains impliedly the right to make reservations in the permit entitling him to modify it, if permittee does not comply with the conditions. Section 18 of the Rivers and Harbors Act of March 3, 1899, is the only section empowering the Secretary of War to cause the modification of an obstruction once approved by him and that covers a bridge which had previously been approved, when such bridge has become unreasonably obstructive to navigation, and then only after hearing with the right of the owner of the bridge to be heard. Appellant had acted upon these permits and had expended large sums of money in reliance upon them. Appellee has never made the contention and the point was never argued which is stated by the Court's opinion in this case (Printed Opinion 6) as follows:

> "After this statute was passed, the Secretary of War granted various permits which are relied upon by the appellant, *although in their nature they all were revocable licenses*".

The Secretary of War cannot revoke at will for the very good reason that he has not been delegated that authority. This position does not go to the extent of saying,

however, that Congress might not by itself by some act revoke the permits or direct the Secretary of War to do so. This construction of the power of the Secretary of War to revoke a permit acted upon, was placed upon the similar act of September 19, 1890, by Attorney General Richard Olney, in an opinion to the Secretary of War rendered June 25, 1894; (21 Opinions of Attorneys General, 41, 45).

> "The remaining, question, whether the permit granted February 13, 1894, can, under the existing circumstances of this case, be revoked, is more easily answered. It does not involve the issue whether the power to rescind a permit is a necessarily implied element of the power to grant it, or whether, all the circumstances remaining the same, the Secretary of War, after granting a permit, might cancel it because of a change of mind as to the wisdom or propriety of his original action. Upon the facts appearing in the papers submitted the circumstances are not unchanged, but on the faith of the permit the Altamonte Water Company has gone forward and made contracts, spent large sums of money, and otherwise materially altered its situation. *Under such circumstances,* I am of the opinion that the Secretary of War *is not now at liberty to revoke the permit.*"

Many times this Court has held that the Secretary of the Interior could not erase from the approved rolls the names of citizens of Indian tribes or revoke the approval of an allotment of land, because there was no such power granted by statute.

Garfield v. *U. S., ex rel., John E. Goldsby,* 211 U. S. 249.

Same case, 30 App. Cases, Dist. of Col. 177;

nor could the Secretary of the Interior revoke without express statutory authority approval of an easement for a railroad over public lands.

Noble v. *Union River Logging & R. R. Co.,* 147 U. S. 162.

See, also,

U. S. v. *Schurz*, 102 U. S. 378.
Moore v. *Robbins*, 86 U. S. 530.
Mosgrove v. *Harper*, 33 Ore. Repts., 252.

That permits granted by the Secretary of War are not in their nature revocable at the will of the Secretary, is shown by the provision for the granting of permits by the Secretary of War for the diversion of waters at Niagara Falls, as contained in Section 2 of the Act for the Preservation of Niagara Falls, known as the Burton Act, June 29, 1906. (34 U. S. Stat. at Large, 626.) In the first part of said Section 2 of said Act, the Secretary of War was authorized "to grant permits for the diversion of water in the United States from said Niagara River or its tributaries for the creation of power to individuals, companies or corporations," etc. There is no provision for revocation and the power is general, similar to the power granted under Section 10 of the Rivers and Harbors Act of March 3, 1899. Under a later provision of said Section 2 the Secretary is authorized "to grant revocable permits from time to time" to another class of persons, indicating that Congress construed general authority to grant permits not specifically designated to be revocable as not implying authority to revoke at will.

The court may have assumed that the permits of the Secretary of War granted under the Rivers and Harbors Act of March 3, 1899, or the similar section of the Rivers and Harbors Act of September 19, 1890, had been construed to be revocable at will or in their nature revocable, by this court in *United States* v. *Chandler-Dunbar Water Power Company*, 229 U. S., 51, 57 Law Edition, 1063, 1077. However, an examination of the record in that case, discloses that the permits of January

12th and April 2, 1888, August 13, 1892, July 6, 1893, March 14, 1899, June 9, 1902, December 12, 1902, March 10, 1903, May 8, 1905, June 15, 1906, April 14, 1909 issued in the Chandler-Dunbar Water Power Company case, which were expressly revoked by the act of Congress of 1909, were by express terms revocable at will. In other words, the Secretary of War by the permit itself reserved the right to revoke for any cause.

The condition as to revocation in said permits in the *Chandler-Dunbar case,* is as follows:

> "That at any time, whenever in the opinion of the Secretary of War it may for any reason be expedient that this license should be revoked, the Secretary of War shall and may cause notice to that effect to be given. * * *"

It is significant that during the period that the Secretary of War was issuing permits to the appellant in which he reserved the right only to modify or revoke for certain reasons stated in the permit, he was at the same time issuing permits to another corporation by which he reserved the right to revoke at will or for any cause. He recognized that he might issue two kinds of permits, one revocable at will, the other not revocable, or only revocable or to be modified for a cause stated in the permit, and permits of the latter character he chose to issue to appellant.

(3) The Court has erroneously construed the language and effect of the permits of May 8, 1899, July 11, 1900, July 23, 1901, December 5, 1901 and September 11, 1907, and the statement of January 8, 1913, of Secretary Stimson, mentioned on pages 6 and 7 of the Court's opinion.

The opinion of the Court states (Printed Opinion, p. 6):

> "On May 8, 1899, the Secretary, on application of the appellant, granted permission to open the channel, assumed in the recitals *to have a flowage capacity of* 300,000 *cubic feet per minute* with a velocity of one and one-quarter miles an hour, on the conditions that the permit should be subject to the action of Congress (which was superfluous except as a warning); that if at any time the current created proved to be *unreasonably obstructive to navigation or injurious to property he reserved the right to close or modify the discharge;* * * *."

The statement in the foregoing quotation does not correctly interpret the recital of said permit as to the 300,000 cubic feet per minute. The court has also erroneously stated the effect of condition 2 of the May 8, 1899, permit, in that the right to revoke is limited to unreasonable obstructions to navigation or injury to property by current *in the Chicago River*, instead of to navigation or property wherever located, as the opinion of the court seems to indicate.

The recital states merely that appellant

> "has been heretofore granted permission by the Secretary of War to make certain improvements in the Chicago River for the purpose of correcting and regulating the cross section of the river so as to secure a flowage capacity of 300,000 cubic feet per minute, with a velocity of 1¼ miles per hour," (Appellant's Narrative, p. 481.)

That recital does not state the capacity of appellant's Sanitary and Ship Canal to be only 300,000 cubic feet per minute. It merely mentions the improvement of the Chicago river channels under Secretary of War permits. The capacity of that channel was fixed by state law, and it was so constructed to have a capacity of 10,000 cubic seconds feet. The only reference to the channel is in that

portion of the preamble preceding that just above quoted—

> "whereas the Sanitary District of Chicago, a municipal corporation organized under the laws of the State of Illinois, has constructed an artificial channel from Robey Street, Chicago, to Lockport,"

The capacity of the channel as fixed by state law, as planned and as actually constructed, was within the knowledge of the Chief of Engineers and the Secretary of War at the time the permit was granted, as expressly advised by War Department Engineers in the discharge of their duties.

If the Court by reference to said 300,000 cubic feet per minute as stated in the preamble to said permit, intends thereby to treat said permit as only authorizing a diversion of that amount, subject to the express conditions of the permit, or if the Court for any other reason has construed the said permit of May 8, 1899, as not authorizing a diversion in excess of 300,000 cubic feet per minute, subject to the conditions of said permit, then a reference to certain pertinent facts surrounding the issuance of said permit will clearly demonstrate this misapprehension.

Beginning with the passage of appellant's act of May 29, 1889, the Chief of Engineers and the Secretary of War were given copies of the act, which act fixed the capacity of appellant's main channel at not less than 10,000 cubic seconds feet of water, the plans of appellant's main channel made under the requirements of said act, and information as to progress of construction of the channel. These facts came to them from the Division Engineer at Chicago. (Appellant's Narrative, pp. 451-454-455.)

August 16, 1895, the Chief of Engineers and Secretary of War received a report from a Special Engineer Com-

mission, consisting of Col. Poe, Major Rufiner and Major Marshall. (Appellant's Narrative, p. 465.) This Board of Engineers was to report upon

> "the probable effect of the operation of the Chicago Drainage Canal upon the lake and harbor levels and upon the navigation of the Great Lakes and their connecting waterways."

In that report they state the capacity of appellant's Main Channel to be 600,000 cubic feet per minute, as follows: (Appellant's Narrative, p. 467.)

> *"Throughout the rock sections and those sections in which there is a preponderance of hard material or where rock may appear, the section adopted is designed according to law for a flow of 600,000 cubic feet of water per minute, which means provision for a population of three million people."*

Major Marshall, United States Engineer at Chicago, under the direction of the Rivers & Harbors Act of June 3, 1896, made a report to the Chief of Engineers which was submitted to Congress by the Secretary of War (H. R. Document 353, 54th Congress, 2d Session) and in connection with the capacity of Appellant's main channel, stated (Appellant's Narrative 487):

> "To comply with the law of the State of Illinois under which this drainage canal is constructed—it has been constructed of a capacity to discharge 600,000 cubic feet per minute through the section excavated in rock and 300,000 cubic feet per minute throughout the earth section—the law requires a discharge of 20,000 cubic feet per minute for each 100,000 inhabitants of the drainage district, which at present requires more than 300,000 cubic feet and in a few years will require the full 600,000 cubic feet discharge through the canal."

The report of Major Marshall, dated April 24, 1899, to the Chief of Engineers, in regard to the application of Appellant to open its canal, which was granted by the

permit of May 8, 1899, in referring to the capacity and amount of withdrawal, stated (Appellant's Narrative 479):

> "20,000 cubic feet per minute must be taken from Lake Michigan for each 100,000 population of the District; already nearly 400,000 cubic feet must be taken, * * *."

The capacity of the artificial channel mentioned in the permit of May 8, 1899, as having been then constructed—being 600,000 cubic feet per minute, or 10,000 cubic feet per second—authorized to be opened, was clearly made known to the Chief of Engineers and the Secretary of War through United States engineer officers in the performance of their duty.

There are other attendant facts that are important. April 21, 1891, as soon as Appellant's main channel was surveyed and its capacity determined upon, the Board of Trustees of Appellant adopted a project for the improvement of the Chicago River to make the artificial channel under construction available (Appellant's Narrative 454)—

> "Resolution of April 21, 1891, of the Board of Trustees of the Sanitary District of Chicago.
>
> * * *
>
> Resolved, That this Board hereby ordains that The Sanitary District of Chicago do forthwith enter upon, use, widen, deepen and improve the Chicago River from its mouth at Lake Michigan to the South Branch thereof, and also the South Branch thereof, together with the South and West Forks thereof so as to make the same a proper and sufficient supply channel for the main channel heretofore surveyed from the Chicago River to Joliet; and further, that the Acting Chief Engineer be, and he is hereby, directed immediately to investigate and report upon the capacity of said River and its said South Branch and Forks for that purpose, and also as to any changes that should be made therein, and that a copy of this resolution,

certified by the clerk, be forthwith transmitted to the Mayor and Common Council of the City of Chicago, and the Secretary of War of the United States."

The Chicago River, its South Branch and West Fork thereof, was then narrow, shallow and tortuous. To permit taking through the river channels the amount of water represented by the capacity of Appellant's main channel required their enlargement. To permit the taking through the channels of those rivers the water *immediately* necessary at the time of the opening of the main channel, comparatively small improvement was necessary. The excavation and work under the permits of June 3, 1896, October 28, 1897, November 30, 1898, March 10, 1899, May 12, 1899 and June 13, 1899, corrected the river channels for this latter purpose (Appellant's Narrative 473 to 478). This was the improvement referred to in the preamble of the May 8, 1899, permit. The application for the first permit for the temporary improvement of these river channels is significant (Appellant's Narrative 88)—

"The work of The Sanitary District of Chicago has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport in Will County, Twenty-eight miles distant.

Our connection with Lake Michigan must be through the Chicago river with the West Fork of the South Branch of which we make a junction at Robey Street. We send herewith a map showing in a general way our plans for improving the Chicago River by widening and deepening at the points indicated thereon by red hatchings and by figures which refer to explanation, given in the legend on the map. It is desired to so correct and regularize the cross section of the river as to secure a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles per hour."

July 3, 1896, permit was granted as to this first improvement of the Chicago River to make the cross section so as to secure a flowage of 300,000 cubic feet per minute and contained the condition that a current should not be introduced in the Chicago River. The other permits for similar improvements contained like conditions.

Therefore, after this work was done, the flowage capacity of the Chicago River channels had been so corrected that 300,000 cubic feet per minute could be taken through without creating an objectionable current, and Appellant was thus authorized by these various permits to take that amount of water through. The main channel, however, was constructed with the capacity to take twice that much water—which larger amount of water would be required in a few years—and appellant desired approval of the entire plan by the Secretary of War. It, therefore, made the application for the May 8, 1899, permit, which permit was granted to:

> "open the channel constructed and cause the waters of Chicago River to flow into the same, subject to the following conditions: * * *
>
> 2. That if, at any time, it become apparent that the *current* created by such drainage works in the south and main branches of the Chicago river, be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago river and its South Branch. * * * (Appellant's Narrative 482.)

According to said permit the only condition of taking from Lake Michigan the amount of water which represented the maximum capacity of Appellant's channel—10,000 cubic second feet—was the reservation that the Secretary of War might determine the manner in which

the water should be taken through the Chicago River, such manner and such determination to be based upon the enlargement of the river so that a *current* in said river should not exist unreasonably obstructive to navigation. And the immediate provision for the very material enlargement of the Chicago River Channels to take through them an amount of water equal to the capacity of appellant's Main Channel and consented to by the July 11, 1900, permits about now to be mentioned, leaves no question as to the intention of the Secretary of War under condition 2 of said May 8, 1899, permit.

The permit approved all modifications of the navigable capacity of the Great Lakes and reserved merely the right of the Secretary of War to approve the manner of taking the full amount of water required for Appellant's canal through the Chicago River channels.

On July 11, 1900, two permits were issued pursuant to the application of The Sanitary District, authorizing the enlargement of the Chicago River, its South Fork and West Fork, by deepening it from seventeen to twenty-six feet and widening it at all points to two hundred feet. This improvement cost almost $11,000,000 and no objection has ever been made by appellee to the current in the River created after the improvement was completed with the diversion of 10,000 cubic seconds feet. The permits themselves refer to the May 8, 1899, permit and the conditions thereof. The application for the permits and the permits were granted under the reserved condition 2 of the permit of May 8, 1899,—the Secretary of War should determine the manner in which the full amount of water should be taken through the Chicago River channels, so that a current would not be created unreasonably obstructive to navigation. This Court, however, in its opinion, with reference to said permits, stated (Printed Opinion, p. 6):

"On July 11, 1900, improvements of the Chicago River were permitted with the statement that the permission did not affect the right of the Secretary to revoke the permit of May 8, 1899."

The above language carries the inference that the Court assumed that the condition of the July 11, 1900, permits allowed the Secretary of War to revoke the permit of May 8, 1899, at will, and that modification of the May 8, 1899, permit was not confined to the causes or conditions expressly reserved in said permit. The July 11, 1900, permits reiterate the conditions of the May 8, 1899, permit. That the Court's construction of the July 11, 1900, permits is erroneous, is shown by a mere reading of it. We quote from the first one as they are alike, (Appellant's Narrative 92):

"Sir: I have the honor to acknowledge the receipt of your letter of April 26th last, requesting, in behalf of the Sanitary District of Chicago, permission to change, alter and improve the Chicago River, from Lake Street to Ashland Avenue, in Chicago, as shown on maps which accompanied your said letter.

Replying thereto I beg to inform you that there is no objection on the part of the War Department to the prosecution of work of improvement of Chicago River, specified in the above mentioned letter and delineated on the maps which accompanied the same, it being understood that this statement as to the attitude of the War Department shall not be understood as involving the general government in any way with the expense incident to the carrying out of the project, and does not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago River and cause them to flow into the artificial channel, *such permission* being subject to the following conditions, viz.:

* * *"

The balance of the July 11, 1900, permit is a quotation from the May 8, 1899, permit of all the conditions of same—being three in number. The words:

> "such permission being subject to the following conditions"

—refer to the May 8, 1899, permit and modify the words

> "to regulate or revoke the permit granted under date of May 8, 1899"

and confine regulation and revocation to the conditions of the May 8, 1899, permit. These permits show that the Secretary of War then considered that the permit of May 8, 1899, authorized the diversion, subject to the conditions, to the maximum capacity of the main channel, for the work to be done under the July 11, 1900, permits would double the flowage capacity of the Chicago River channels so that the 10,000 seconds feet could be taken through without creating a current injurious to navigation.

The orders of the Secretary of War of July 23, 1901, and December 5, 1901, were made expressly under condition 2 of the May 8, 1899, permit, under which the Secretary of War was to regulate the manner by which the Appellant should withdraw water through the Chicago River channels, and that only. The conditions of those two permits of July 23, 1901, and December 5, 1901, refer to condition 2 of said permit of May 8, 1899, for that condition is quoted in the permit of December 5, 1901. The subject matter of the two permits was the regulation under said condition 2. Condition 2 of December 5, 1901, permit, and the similar condition of the permit of July 23, 1901 (Appellant's Narrative 25):

> "That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require"

cannot be construed as revoking, or attempting to revoke, the consent given by the Secretary of War as to the modification of the navigable waters of the United States other than the Chicago River. That condition must be confined to condition 2 of the May 8, 1899, permit as to the method of taking through the Chicago River channels the amount of water required by Appellant for the operation of its main channel to its full capacity, for in issuing the said orders or permits of July 23 and December 5, 1901, the Secretary was attempting and assuming only to act under the reservation contained in condition 2 of the May 8, 1899, permit as to regulating the withdrawal through the Chicago River.

Condition 2 of the permit of September 11, 1907, as to the North Shore Channel, which was merely to allow making connection with Lake Michigan at Wilmette, Illinois, and was not to increase the diversion through the Chicago River and merely a part of the Chicago river diversion (Appellant's Narrative 82):

> "That the total diversion of water from Lake Michigan through the Chicago River into the Illinois River shall be no greater than already authorized by past War Department permits"

—referred only to past permits, which were that the Secretary of War had approved the diversion to the capacity of the main channel—10,000 cubic feet per second—and had consented to the modification of all navigable waters of the United States resulting from such diversion subject only to regulating the enlargement of the Chicago River channels to take through them the amount required by appellant.

The permit of June 30, 1910, as to the Calumet Sag Channel was issued for convenience and necessity and was not intended to in any manner affect the rights of

either party, and, as the Court states, was not to be used in the litigation to test rights. No revocation of authority given by the Secretary of War under previous permits was intended nor can Appellant be considered in any respect to have waived rights already granted.

The statement of the Secretary of War of January 8, 1913, was merely the refusal of an application to remove the limitation theretofore made by the Secretary of War under condition 2 of the permit of May 8, 1899, the reason for which limitation had been then removed, as the Chicago River channels had been enlarged to take the amount of water fixed by the capacity of Appellant's main channel—10,000 cubic seconds feet. There was no attempt at that time by the Secretary of War to revoke any permit given, even if he considered he had the power.

(4) The Attorney General did not attempt under the bill of complaint in this proceeding, to exercise any authority other than that alleged to have been given him by Section 12 of the Rivers and Harbors Act of March 3, 1899.

This Court, in its opinion said (Printed Opinion, p. 1):

> "The prohibition of such alterations and obstructions in the Act of March 3, 1899, c. 425, Sec. 10; 30 Stat., 1121, 1151, is set out at length and relied upon but the frame of the bill does not exclude a reliance upon more general principles if they were needed in order to maintain it."

Outside of the general priciple that the pleading of a party shall be taken most strongly against him, there is nothing in the bill of complaint here which indicates that the Attorney General sought to exercise power under any other Act of Congress than the Act of March 3, 1899, or that he attempted to act under general authority. On the contrary, it was admitted by counsel for appellee on

oral argument in reply to questions put by Mr. Justice McReynolds, that the basis of the bill of complaint was the Act of March 3, 1899. (See pages 132 and 133, Printed Transcript of Oral Argument appendix hereto.)

The March 3, 1899, Act does not authorize the Attorney General to institute suits to enjoin the creation or continuance of an obstruction. It merely authorizes him by injunction to remove a structure.

Respectfully submitted,

HECTOR A. BROUILLET,
CLYDE L. DAY,
GEORGE F. BARRETT,
LOUIS J. BEHAN,
EDMUND D. ADCOCK,

I hereby certify that this petition for rehearing in this case is filed in good faith, the contents thereof and the suggestions attached are believed to be true, and the same is not interposed for delay.

Respectfully submitted,

EDMUND D. ADCOCK,
Of Counsel for Appellant.

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IN THE

SUPREME COURT OF THE UNITED STATES

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO, *Appellant*, vs. THE UNITED STATES OF AMERICA, *Appellee*.	Appeal from the District Court of the United States, for the Northern District of Illinois, Eastern Division.

TRANSCRIPT OF ORAL ARGUMENT.

Washington, D. C.,
Monday, Dec. 8, 1924.

The above-entitled cause came on, for oral argument, before the full court, at 1:40 o'clock P. M.

Appearances:

For the appellant:

Edmund D. Adcock, Esq.; George F. Barrett, Esq.; Louis J. Behan, Esq.; and Clyde L. Day, Esq.

For the appellee:

Hon. James M. Beck, Solicitor General of the United States.

Joseph B. Fleming, Esq., Special Assistant to the Attorney General.

Amicus curiae, in favor of appellant:

Daniel N. Kirby, Esq.

Amici curiae, in favor of appellee:

Hon. Andrew B. Dougherty, Attorney General of Michigan;

Harvey D. Goulder, Esq., for Lake Carriers' Association;

Hon. Herman L. Ekern, Attorney General of Wisconsin;

Hon. U. S. Lesh, Attorney General of Indiana;

Hon. C. S. Ferris, Deputy Attorney General of New York.

The Chief Justice: This is the case in which I have had some conversation with counsel with reference to the time to be taken?

Mr. Beck: Yes, sir. In this case, if the Court please, which is one of exceptional magnitude, in addition to the counsel for the Government and the counsel for the Sanitary District of Chicago, there appear as *amici curiae*, on behalf of appellant, the attorneys-general of the States of Illinois, Missouri, Louisiana and Tennessee, and on behalf of the United States there appear as *amici curiae*, the attorneys-general of Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin.

The Chief Justice referred to the informal negotiations, or, at least, to a discussion with respect to the—

The Chief Justice: Well, you might say "negotiations." (Laughter.)

Mr. Beck: With respect to the time; and as I understand it will be your Honors' pleasure to give the appellant three hours and the counsel for the Government two hours and a half.

The Chief Justice: That will make five and a half hours.

Mr. Beck: That will make five and a half hours, yes.

The Chief Justice: Yes, I think that is fair, on account of the number of counsel engaged and the importance of the case, as well as the number of facts that the record would indicate that require discussion.

But there is one question that I would like to suggest: This case has been long in dispute, or the controversy has been long in dispute. It goes back as far as the time when I was Secretary of War. And I do not remember what happened then; but I remember that a number of counsel came before me with reference to the matter—perhaps it was a permit; I have forgotten just what it was.

Mr. Adcock: It only related, your Honor, to one adjunct of the main channel—one phase of it.

The Chief Justice: Well, I do not know enough about it to know whether it should disqualify me or not. Counsel ought to have advised themselves with respect to that; but if there is the slightest objection, or if there is any doubt about it, of course I will withdraw.

Mr. Adcock: There is no objection, so far as we are concerned. I might state in this connection also that it was when Mr. Justice McReynolds was attorney general that the suits were instituted; but that is no objection to his sitting in the case, so far as we are concerned.

Mr. Justice McReynolds: Did I bring the suit when I was attorney general?

Mr. Adcock: Yes, sir, under Section 12 of the Act of March 3, 1899.

Mr. Justice McReynolds: Well, do you not think that I had better excuse myself?

Mr. Adcock: Not so far as we are concerned.

Mr. Justice McReynolds: Well, how about this record? Is this record just dumped in on us, like it was dumped in on the District Court, without any modification?

Mr. Adcock: I think you will find that there is filed with the appellant's brief, as an appendix, a condensation of the record.

Mr. Justice McReynolds: Well, but has the record been made up in accordance with the rule, or is it sent up as originally taken?

Mr. Adcock: It is sent up as originally taken.

Mr. Justice McReynolds: Well, you know we have talked about that rather severely. How many pages of this record are there?

Mr. Adcock: About 5,000.

Mr. Justice McReynolds: Well, do you expect anybody to read that?

Mr. Adcock: The condensation complies, I think, with the rule, so far as that is concerned—the condensation that we have prepared and printed and furnished, in connection with the galley proofs, etc., that have been given to counsel; that embraces practically everything that is material.

Mr. Justice McReynolds: I know; but why was not the record made to comply with the rule?

Mr. Adcock: Well, at that time we thought that it would probably be impossible to condense the record; and there was an order entered by the lower court, which I think complies with the rules, directing it to be taken up as the record was printed in the lower court.

Mr. Justice McReynolds: I do not think that that record ought to be imposed on us.

Mr. Adcock: I do not believe that there is any imposition on the Court here as the record now stands, with the condensation. I do not believe there are any disputed questions of fact here that are very material.

Mr. Justice McReynolds: Well, is it a question of fact involved in this case, or a question of law?

Mr. Adcock: I do not believe there is any material question of fact, no; practically all the facts that are material are admitted.

Mr. Justice McReynolds: Well, I was wondering what all this record was about, if there was no question of fact?

Mr. Adcock: Well, there was a great deal of testimony taken in regard to the hydraulics of the Great Lakes; there were a great many documents that were put in evidence that were necessary to show what had been done, running over, probably, a century, since the Act of March 2, 1827.

May I proceed?

The Chief Justice: You may.

Mr. Adcock: The Chief Justice was making a statement—

Mr. Beck (Interposing): Before you proceed, let me say that the Government concurs in the suggestion of Mr. Adcock that it will be agreeable to both counsel, if your Honor, the Chief Justice, and your Honor, Mr. Justice McReynolds, should sit in this case.

The Chief Justice: That is understood, then. I do not think that either side is making any great concession (laughter). But those of us that are affected by it, I am sure, appreciate the courtesy.

Mr. Adcock: Well, the only thing the Chief Justice did was to find that, as Secretary of War, he had no right to do anything, as the Chief of Engineers had not recommended anything. (Laughter.) And I think Mr. Justice McReynolds, as Attorney General, merely signed the bill as one of his ordinary duties, and probably never read it.

The Chief Justice: Well, you may proceed, Mr. Adcock.

I suggest this to counsel: If you will give me a list of the assignment, or the allocation of the time—

Mr. Adcock: I was just going to suggest that.

The Chief Justice (Continuing): I will keep the time as against your own colleagues, and of course, as against yourselves and the other side, in the same way.

Mr. Adcock: Well, in addition to the *amici curiae* as mentioned by the Solicitor General, in support of the appellant, there is the City of Chicago; the Association of Commerce of Chicago; some commercial organizations of St. Louis; the Mississippi Valley Association; and similar organizations of Memphis; and similar organizations of New Orleans.

As I understood the suggestions which were made to the Chief Justice in regard to the time, and as indicated when the *amici curiae* were permitted to file briefs, and when they asked permission to participate in the argument, there was to be one counsel representing the *amici curiae* to be heard.

Mr. Daniel N. Kirby, of St. Louis, will use half an hour of our time; and he will be the only counsel representing the *amici curiae* to argue on the appellant's side.

Mr. Beck: May I just say that I did not understand that there was to be only one *amici curiae* to argue; and the arrangement of the appellee was that Mr. Goulder, of Cleveland, should speak for twenty minutes for the Lake Carriers' Association; and Attorney General Dougherty, of Michigan, should speak for the seven Attorneys-General who are freindly to the Government.

The Chief Justice: Well, you can arrange it as you please among yourselves; but I think it will help you if you can give me an assignment of time, so that I can keep a record of it.

Mr. Adcock: Yes, sir.

I have been selected to present the case for appellant; and I know of no reason for that, except that I have been with the case since the beginning of the year 1913, and most of the evidence was presented by me in behalf of the Sanitary District. Otherwise, I would not have the assurance to accept that duty of attempting to present a matter of this kind.

And I expect to be able to present the case—or we intend to on our side to present all of our contentions in our opening statement; and on behalf of the appellant directly and on be-

half of the *amici curiae*, I desire, of the two hours and a half which we have, to present the matter in the opening in two hours, reserving only half an hour for closing. And I will endeavor to make it shorter, if it can be done; but on account of the circumstances that must be called to the attention of the Court, I fear that I will be unable to do that.

The Chief Justice: Very well; you may proceed, Mr. Adcock.

Oral argument of Edmund D. Adcock, Esq., on behalf of appellant, The Sanitary District of Chicago.

Mr. Adcock: This comes here from the District Court at Chicago, and is a direct appeal.

The decree in that court which is questioned here, enjoins the Sanitary District of Chicago, the appellant, which is a municipal corporation organized under the laws of that State, from diverting or abstracting from Lake Michigan any waters in excess of 4,167 cubic seconds feet, or 250,000 cubic minutes feet. Now, when you speak of seconds feet or minutes feet, it means the number of cubic feet of water that will pass a given point in a minute, or in a second.

Mr. Justice Holmes: Just give me that number again: How many second feet?

Mr. Adcock: 4,167 cubic seconds feet of water.

Mr. Justice VanDevanter: That means cubic feet per second?

Mr. Adcock: Cubic feet per second; and we speak of it shortly as "seconds feet"; and that corresponds to 250,000 cubic feet per minute.

The decree of the lower court held that Section 20 and Section 23 of the Sanitary District Act, that is, the act under which appellant was organized, were void and unconstitu-

tional, in that they limited the quantity of water that that act provided should be diverted from Lake Michigan—

Mr. Justice Sutherland (Interposing): That is, an act of the State of Illinois?

Mr. Adcock: That is an act of the State of Illinois. The act was passed on May 29, 1889, a little over a third of a century ago; and construction was commenced almost immediately, and occupied a period of approximately ten years.

Section 20 of that act provides that there shall be caused to flow or drain from Lake Michigan through the channel —that is the sanitary and ship canal, which is the main diversion channel of the appellant, and Des Plaines and Illinois Rivers, not less than 20,000 cubic feet of water per minute for every 100,000 population. The population at the time the decree was entered being approximately 3,000,000 people, the required withdrawal, which was mandatory, was 10,000 cubic seconds feet of water, or 600,000 cubic feet per minute.

The application of the Commerce Clause of the Constitution is involved in the case; and I think the jurisdiction of this Court was decided in the case of *Cummings* v. *Chicago*, in 188 U. S.

There is also, perhaps, involved, the interpretation of the treaty between the United States and Great Britain as to boundary waters. The Government would give a certain construction to that treaty; and we give a certain construction; and there is some dispute about that.

The case involves the construction of section 10 of the Rivers and Harbors Act of March 3, 1899. That will be found at page 108 of our brief; and beginning at page 106, you will find set out in juxtaposition the acts of 1890 and 1899, which were similar; that is, sections 7 and 10 of the 1890 act were similar to sections 9, 10 and 12 of the 1899 act.

Mr. Justice Holmes: Which is the act we are called upon to deal with?

Mr. Adcock: The 1899 act, which appears in the second column.

Mr. Justice Holmes: Yes, I see it.

Mr. Adcock: The case involves, primarily, the whole plan and program that the State of Illinois adopted in 1889, for the protection of the water supply of Chicago and its environs; to provide for that city a pure drinking water; and to keep Lake Michigan, the only water supply, unpolluted.

It also involves—which was one of the features of this act—the program of the State of Illinois as to making provision for a deep waterway from Lake Michigan to the Gulf of Mexico. There were two objects of that act.

The decree in this case, your Honors, if made effective immediately and without condition—the Court suspended the operation of the decree during the appeal here—would absolutely prostrate all the works that have been built by the appellant, at a cost of something like $100,000,000.

It would create a condition, which is admitted, I think, in the record in this case; there is no testimony to the contrary; and I think the Government in its brief so admits—it would create an intolerable condition, which would cause conditions of nuisance in the Chicago River; the Sanitary and Ship Canal, the main channel; and the Des Plaines and Illinois Rivers. If the amount of water were limited as contended for by our opponents, the Chicago River, with its pollution of sewage and drainage at numerous times during the year would go into Lake Michigan, carrying with it that pollution, polluting the water supply; and the result would be the raging of typhoid fever and other water-borne diseases—perhaps causing the condition which existed prior to the construction of the canal, when the rate would run up to 170 deaths per 100,000 inhabitants; whereas now the typhoid death rate is less than 8 per 100,000.

Mr. Justice VanDevanter: The United States brought this suit, did it?

Mr. Adcock: The United States brought the suit.

Mr. Justice VanDevanter: Now, it was decided on what ground? What was the ground of the lower court's decision?

Mr. Adcock: I am coming to that. The United States instituted the suit; and there was a question of jurisdiction in the lower court. That is, the suit was brought at the instance of the Attorney General, under section 12 of this Rivers and Harbors Act of 1899, appearing at page 108 of our brief. There is a question as to whether the Attorney General under that section had the authority to institute the suit; and therefore, there was a question of jurisdiction. The act provides that he may institute a suit for injunction to cause the removal of a structure or part of a structure. This suit is not for that purpose.

Mr. Justice McReynolds: Read the act and let us see what it says.

Mr. Adcock (Reading):

> "And further, the removal of any structures or parts of structures"—

Mr. Justice McKenna: What are you reading from?

Mr. Adcock: Page 109 of my brief.

> "And further, the removal of any structures or parts of structures erected in violation of the provisions of the said sections may be enforced by the injunction of any circuit court exercising jurisdiction in any district in which such structures may exist, and proper proceedings to this end may be instituted under the direction of the Attorney General of the United States."

Mr. Justice McReynolds: Is that the only thing he is authorized to do under the act?

Mr. Adcock: That is the only thing.

Mr. Justice McReynolds: And what did he ask in this case?

Mr. Adcock: He asked that the appellant be enjoined from diverting from Lake Michigan any waters in excess of 4,167 feet.

Mr. Justice McReynolds: Well, was that an attack on structures, or what was it?

Mr. Adcock: He attacked our right to take that quantity of water—in excess of that quantity.

Mr. Justice VanDevanter: Well, the bill was framed with the idea that you did have the right to take some water, was it?

Mr. Adcock: It was framed with the idea that we had the right to take 4,167 seconds feet.

Mr. Justice VanDevanter: He assailed the right to take anything in excess of that?

Mr. Adcock: Yes, sir.

Mr. Justice VanDevanter: On what ground did the bill proceed?

Mr. Adcock: The bill proceeded on this ground—perhaps I should state that there were two suits here; and I was just about to state the issues which are involved—

Mr. Justice VanDevanter (Interposing): Were they brought at the same time?

Mr. Adcock: No. The first suit was brought March 23, 1908; and the second one was brought October 6, 1913. The first one was consolidated with the second one. I do not believe, so far as the Court is concerned, it is necessary to give much attention to the first suit; because it only involved an adjunct to the main diversion channel; and the second suit was instituted to enjoin the diversion from any and all sources in excess of a certain amount.

And that second bill of complaint set up the organization of appellant under this act of May 29, 1889; and the construction of the works; and alleged that it was withdrawing from Lake Michigan an amount of water in excess of 4,167 seconds

feet, which was the limitation that it was claimed by the bill that the Secretary of War had placed upon the amount of the withdrawal.

It also set up the issuance of various permits. The first permit was issued May 8, 1899, and was unlimited in amount.

The Chief Justice: We will suspend at this point.

Thereupon, at 2:00 o'clock p. m., the Court took a recess until 2:30 o'clock p. m.

AFTER RECESS.

Oral argument of Edmund D. Adcock, Esq.,—Resumed.

The Chief Justice: Mr. Adcock, you may proceed.

Mr. Adcock: I had started to answer a question at the time of the recess.

Mr. Justice VanDevanter: With regard to that permit that you spoke of: To what extent had permits been issued before this suit was begun, and what, if any, restrictions were there in those permits?

Mr. Adcock: The first permit, for the opening of the main channel, provided that it should cause the water to flow through the channel, subject simply to three conditions. That is known as the permit of May 8, 1899.

One condition was, that if Congress should act to modify or control the amount of the diversion, then the permit should be of no further force or effect. Of course, I take it that that is the law anyway.

The second condition was that if the withdrawal of this water from Lake Michigan through the channels of the Chicago River and its branches to the Sanitary and Ship Canal, should create a current unduly destructive to navigation, or

unreasonably destructive to navigation on that river, then the Secretary of War might close said discharge, or modify it.

There was just one other condition, a third condition, which I do not think is material here, and that is that the Sanitary District should be responsible for damages; and that was held in the *Corrigan* case, to apply only so far as the United States was concerned.

Mr. Justice VanDevanter: Now, is it true that in the beginning the Chicago River flowed into Lake Michigan?

Mr. Adcock: Yes, sir, in its natural condition.

Mr. Justice VanDevanter: And that the natural flow of the rivers and lakes beyond the Chicago River to the west go through to the Mississippi River?

Mr. Adcock: Yes, sir.

Mr. Justice VanDevanter: And that you opened the channel through, and thereby you reversed the natural flow of the Chicago River?

Mr. Adcock: Yes, sir.

Mr. Justice VanDevanter: So that you carry the water away from Lake Michigan?

Mr. Adcock: Yes; a certain quantity of water is diverted by our channel—

Mr. Justice VanDevanter (Interposing): Now, certain permits were issued by the Secretary of War?

Mr. Adcock: Yes, sir.

Mr. Justice VanDevanter: Were they permits directly to divert, or were they permits authorizing or extending to the construction of these improvements, which had as their object this diversion of waters?

Mr. Adcock: The first permit provided that the channel—that is, the channel that had then been constructed—might be opened through the Chicago River to flow through the Chicago

River to that channel, subject to the conditions which I have mentioned.

Now, the Chicago River and its branches—perhaps I can show you better on this map which we have set up—

Mr. Justice VanDevanter (Interposing): Before you get to that, where did your limit of 4,167 feet come in? Where does that come in?

Mr. Adcock: There was a later limitation, or an order made by the Secretary of War limiting the amount of that diversion to 4,167 feet.

Mr. Justice VanDevanter: When was that made?

Mr. Adcock: That was on December 5, 1901; and it was made solely because of the current in the Chicago River, and made because of objections by navigation interests at that time.

Now, right there is the very important proposition in this case: At the time that this limitation was made, the channels of the Chicago River and its branches were like this—Here (indicating on map) we have a map showing the Sanitary District works; and the limits of the Sanitary District (indicating); and also the Continental Divide, which you, Mr. Justice VanDevanter, spoke about, through which this channel is cut (indicating), which is a very small elevation of land, about seven or eight miles from Lake Michigan; and only seven or eight feet above the mean level of Lake Michigan.

The Chicago River—the main river—is shown on this map in blue (indicating); and it extends from Lake Michigan out about a mile west. Then we have the south branch of the Chicago River, running in a southerly and southwesterly direction (indicating); and then we have the West Fork of the south branch (indicating), which connects with it; and the main Sanitary and Ship Canal (indicating), the northern terminus of which is on the West Fork of the south branch, at Robey Street, in Chicago (indicating); and the main channel

extends from that point (indicating), Robey Street; and the West Fork of the south branch, twenty-eight miles, to a point just above Joliet, in Will County, and extends through Cook County—

The Chief Justice (Interposing): Is there not another river, the Calumet River, there?

Mr. Adcock: Yes, sir; that is the one that your Honor had to do with; that is an adjunct of the main channel.

The Chief Justice: Well, that runs into Lake Michigan, naturally, does it not?

Mr. Adcock: The Sag channel? The Calumet River runs into Lake Michigan naturally; and the Sag channel, or the "Calumet Sag channel," as it is called, runs from the Little Calumet River at this point (indicating), at Blue Island, westerly to the main channel at Sag, Illinois, and is merely an adjunct of the main channel. And it was designed to take care of the drainage south of the earlier limits of the Sanitary District.

Mr. Justice Sanford: Does that reverse the flow of the Calumet River?

Mr. Adcock: Yes, sir, that reverses the flow of Calumet River.

Mr. Justice McReynolds: Now, you came and asked the Secretary of War for a permit to divert this water upstream?

Mr. Adcock: Yes, sir, and to open the channel.

Mr. Justice McReynolds: And he gave you the permit?

Mr. Adcock: He gave us the permit.

Mr. Justice McReynolds: Under certain conditions?

Mr. Adcock: Yes, sir, under certain conditions.

Mr. Justice McReynolds: Well, how did this suit arise? Was it because you had violated those conditions, or what was it?

Mr. Adcock: The Secretary on December 5, 1901, limited—

Mr. Justice McReynolds (Interposing): Did what?

Mr. Adcock: Limited the amount of the diversion, and specified that it should not be over 4,167 seconds feet.

Mr. Justice McReynolds: He had authority to do that, did he?

Mr. Adcock: There is a question as to whether he had any power to regulate. I think he did have the power to limit the diversion because of the current in the Chicago River; but for no other reason. I think the power did not exist in him to limit or control the quantity of the water, so far as any other conditions were concerned. His one duty as an administrative officer was with reference to our works as they affected the Chicago River.

Now, coming to this proposition: The Chicago River at the time that limitation was made was very shallow. It was only 16 or 17 feet deep, and as narrow as 80 or 90 feet at places; and at that time the Secretary of War limited the diversion because of that condition.

The Sanitary District, however, in cooperation, as we will show later, with the Government, and appreciating that it was necessary to enlarge the channels of the Chicago River and its branches, in order to take the amount of water required through them, without creating a current unduly obstructive to navigation in the river, applied to the Secretary of War for permission to so enlarge those rivers that the larger diversion could be taken through without creating this current.

And accordingly, applications were made very shortly after the channel was open, which was January 17, 1900. I mention that fact, because it is one of the guide posts of the litigation: It applied to the Secretary of War to permit it to deepen the South Branch and the West Fork of the South Branch, from the northern terminus of the channel that had been constructed

through the Chicago River, to twenty-six feet, and widen it at all points to 200 feet.

Now, that entailed the complete enlargement of that river, the raising of bridges, the replacement of old center pier bridges with modern bascules; and the expense that the Sanitary District was put to in that improvement was upwards of $10,500,000. The Secretary of War on July 11, 1900, pursuant to applications, authorized the work to be done; that is, the work of enlarging these rivers, and the work was completed about the year 1912.

The limitation that is spoken of—the December 5, 1901, limitation—which was made when the river was in the shallow and narrow condition, is the basis of this lawsuit. That is the sole ground upon which the Government brought its injunction.

Mr. Justice VanDevanter: That limitation was not revoked when the last permit for enlargement was granted?

Mr. Adcock: It happens that the December 5, 1901, limitation, the basis of the lawsuit, was made after the permits of July 11, 1900, but before the work under those July 11, 1900, permits had been completed.

Mr. Justice McReynolds: What were the conditions of the permit of 1901?

Mr. Adcock: The conditions of the permit? The limitation was made under condition 2 of the original permit, and the limitations were, as we conceive them, the same as the limitations of the original permit.

Mr. Justice McReynolds: What were they? Please tell me that.

Mr. Adcock: I will read that permit, if I may. In order to get at that permit, it is necessary to read the first limitation; there was a limitation made on the 9th of April, 1901,

which appears at page 23 of our narrative statement, and which reads as follows:

> "Whereas, under date of May 8th, 1899, the Secretary of War granted permission unto The Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, upon the following condition, *inter alia*:"

And then it quotes the condition 2 of the original permit:

> "'(2) That if, at any time, it becomes apparent that the current created by such drainage works in the south and main branches of Chicago River be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its south branch.'
>
> "And whereas, It is alleged by various commercial and navigation interests that the present discharge from the river into the Drainage Canal sometimes exceeds three hundred thousand (300,000) cubic feet per minute, causing a velocity of nearly three (3) miles per hour, which greatly endangers navigation, in the present condition of the river.
>
> "Now, therefore, This is to certify that the Secretary of War, upon the recommendation of the Chief of Engineers, hereby directs said Sanitary District to regulate the discharge from the river into the Drainage Canal so that the maximum flow through the Chicago River and its south branch shall not exceed two hundred thousand (200,000) cubic feet per minute."

Then on July 23, 1901, that permit was again changed as to amount, by simply permitting the Sanitary District to take through the river 300,000 cubic feet per minute, between the hours of 4:00 p. m. and 12:00 o'clock midnight; that is the time when there was not much navigation on the river.

We have the permit of December 5, 1901, which is at page 24 of appellant's narrative, and which reads as follows—and this is the one upon which this suit is based.

Mr. Justice Brandeis: And the last one that was issued?

Mr. Adcock: Not the last one. I will come to that later. The other one was only a temporary matter. This permit of December 5, 1901, reads as follows:

"Whereas, Under date of May 8th, 1899, the Secretary of War granted permission unto the Sanitary District of Chicago to open the artificial channel from Robey Street, Chicago, to Lockport, and cause the waters of Chicago River to flow into the same, upon the following conditions, *inter alia*."

And after again quoting condition 2, it continues:

"And whereas, the Secretary of War subsequently directed said Sanitary District of Chicago, to regulate the discharge of water into the Chicago Drainage Canal so that the maximum flow through the Chicago River shall not exceed 200,000 cubic feet per minute from midnight to 4 p. m., nor 300,000 cubic feet per minute from 4 p. m. to midnight;

"And whereas, Said Sanitary District of Chicago has applied to the Secretary of War for permission to increase the flow between midnight and 4 p. m., daily, to 250,000 cubic feet per minute; and the Chief of Engineers has recommended that the increase applied for be granted, but that the rate of flow from 4 p. m. to midnight be reduced to 250,000 cubic feet per minute, so that the flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day.

"Now, therefore, This is to certify that, in accordance with the recommendation of the Chief of Engineers, the Secretary of War hereby gives unto the Said Sanitary District of Chicago permission to regulate said discharge so that the maximum flow through the Chicago River shall not exceed 250,000 cubic feet per minute throughout the 24 hours of the day, upon the following conditions:

"(1) That this permission shall be in lieu of the present authorized rates of flow as stated above.

"(2) That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

"(3) That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized."

Then on January 17, 1903—and all these limitations were before the work of the improvement, the enlargement of the Chicago River, under the July 11, 1900, permits was completed—. On January 17, 1903, a permit was issued allowing the Sanitary District to increase the withdrawal or discharge through the Chicago River to 350,000 cubic feet per minute, during the winter months.

Mr. Justice McReynolds: Well, all of that is just detail leading up to your final conclusion, is it not?

Mr. Adcock: Yes, sir.

Mr. Justice McReynolds: Well, what is the final thing that you are contending for?

Mr. Adcock: Well, our proposition is simply this: That so far as these permits are concerned, we have complied with every condition made by the Secretary of War as to the current in the Chicago River, which was the only condition that he placed upon our withdrawal of the waters—

Mr. Justice McReynolds (Interposing): And therefore you claim you have the right to take out an unlimited quantity of water : Is that your conclusion?

Mr. Adcock: No. We have the right to take the amount fixed by our Illinois act, and the amount which we have provided by our works to take, which is approximately 10,000 seconds feet of water.

Mr. Justice McReynolds: And the Secretary of War has nothing to do with it?

Mr. Adcock: The Secretary of War has nothing to do with the quantity that we might take from Lake Michigan, except in so far as the taking of that water through the channels

of the Chicago River and its branches might effect those river channels or navigation thereon.

Mr. Justice McReynolds: Wholly without regard to the Secretary of War's opinion in regard to the navigability of the Lakes as affected by that diversion?

Mr. Adcock: Yes.

Mr. Justice McReynolds: Is that the issue in this case?

Mr. Adcock: That is one of the issues, your Honor.

Mr. Justice McKenna: What is the other issue?

Mr. Adcock: Another situation is this: That under the act of March 2, 1827, we were authorized—that is, the State of Illinois was authorized, to build a canal from Lake Michigan to the Illinois River, uniting the waters of Lake Michigan with those of the Illinois River.

Mr. Justice Holmes: What was the date of that act?

Mr. Adcock: March 2, 1827.

Mr. Justice McReynolds: Was anything said about the size of the canal in the act?

Mr. Adcock: No. The State was to exercise its discretion in that respect. There was no limitation as to the size of the canal.

Mr. Justice McReynolds: And nothing was done until 1900?

Mr. Adcock: A canal was built in 1848 by the State.

Now, that is the situation, so far as the permits are concerned.

And it is also to be said, as to the act of March 2, 1827—there is a whole lot more to that proposition, as to the authority of Congress, or the authority given by Congress to the State of Illinois than merely the act of March 2, 1827; there are many circumstances that must be taken into consideration before that proposition can be left.

Mr. Justice Brandeis: Is there any contested question of fact to which we must address our attention?

Mr. Adcock: There is this question of fact: It is claimed by the Government that the withdrawal of the water in excess of 4,167 seconds feet will lower the levels of the Great Lakes and the connecting canals, and thereby injure navigation.

Mr. Justice Sutherland: On the Lakes?

Mr. Adcock: On the Lakes. There is also the allegation as to the Chicago River. There may be a question, some small question, of fact as to the current of the Chicago River.

On that proposition we merely say this: That no evidence was introduced by the Government as to the current in the Chicago River until after all of our evidence was put in. It was merely rebuttal, and I believe an afterthought. The only testimony was the testimony of certain Lake captains as to what they thought the current was there in the Chicago River and its branches when their boats met other boats, or were abreast of other boats.

On the other hand, we had the testimony of our chief engineer, Mr. Isham Randolph, who laid out the works, and who testified that there could be taken through the river, and that he planned the works so as to take the 10,000 cubic feet per second through the channels of those rivers and there would not be a current of over a mile and a quarter an hour —that is, under the enlarged improvement. And Mr. Wisner also testified to that; he was chief engineer of the Sanitary District for a time. The report of General Bixby, who was one of the chief of engineers of the United States Army, in 1906, with reference to the conditions of current in the Chicago River, stated that the current would not exceed 1.2 miles per hour. That is all set forth in the brief.

So that Secretary of War Stimson in 1913, when he refused the application to remove this limitation and for express authority for 10,000 seconds feet diversion, made no

objection to any current in the Chicago River; and so far as we know, the Government has never found—there is no Government engineer who ever found that the improved or enlarged cross section of those rivers would create a current —or that a current would be created in those rivers with the 10,000 seconds feet taken through—

Mr. Justice McReynolds (Interposing): Now, you have the permission of the War Department to take out 300,000 cubic feet per minute, have you?

Mr. Adcock: We have permission, it is our contention, to take out through the Chicago River the amount of water that would result from the deepening and widening of the Chicago River and its branches under the July 11, 1900, permits.

Mr. Justice Brandeis: Even if that would affect the navigation of the Great Lakes?

Mr. Adcock: Yes, sir.

The Chief Justice: Was there not a reservation as to navigability?

Mr. Adcock: There was not a reservation, no, not in the permit. The only reservation was with reference to the current in the Chicago River. Our contention is this: That so far as the acts of Congress are concerned—and the only two acts that I know of are the act of September 19, 1890, and the act of March 3, 1899—there are no express words showing that Congress has intended to occupy the field as to diversions of water, or to regulate the diversions; and that it has not delegated to the Secretary of War any authority to fix or regulate the amount of diversion, but only the administrative duty with reference to the conditions that might exist in the Chicago River.

Now, that is under a general proposition of law that I think has been upheld by this Court in numerous cases; and Mr. Justice Holmes, in the case of *Missouri* v. *Illinois*, stated

that, so far as the United States is concerned, it had done nothing to forbid this diversion. That was a suit that involved this very diversion.

Mr. Justice Brandeis: Will you just pardon me if I interrupt you with a question?

Mr. Adcock: Yes, sir; certainly.

Mr. Justice Brandeis: Will you state what your position is in regard to the contention which, I understand, the Government has made, that this diversion does injuriously affect the navigation on the Great Lakes?

Mr. Adcock: Our position is merely this on that question: No witness was ever presented in this case to testify as to observing any lowering of the levels of the Lakes, or as to any injury to navigation. Nobody testified that they were unable to load a boat as heavy because of this diversion.

Mr. Justice Brandeis: Well, do you deny that navigation upon the Lakes is affected?

Mr. Adcock: Yes, sir.

Mr. Justice Brandeis (Continuing): By the diversion? You deny that, do you?

Mr. Adcock: We take this position, your Honor: That there is no evidence in the record from which it can be determined that any injury did exist to navigation by reason of the claimed lowering of the surface elevations of the Lake —that is, Lake Michigan—some five inches, as claimed here, and Lakes Erie and Ontario certain smaller amounts.

Mr. Justice Brandeis: And is it also your contention that, if the Government, through the Chief of Engineers, has reached the conclusion that the diversion would injuriously affect navigation, that is an immaterial fact?

Mr. Adcock: It is an immaterial fact; because the Chief of Engineers—and the Secretary of War can only act upon the recommendation of the Chief of Engineers—has not been delegated that authority.

And then our further proposition is that, by other acts of Congress, some fifteen or so in number, Congress has recognized this diversion; has sought to provide for its continuance, and has not only not forbidden it, but has done things which would indicate an intention that it should exist.

Mr. Justice Brandeis: And you mean by recognizing the diversion that it recognized the amount of the diversion, and not merely the fact that there was some diversion?

Mr. Adcock: Yes, sir.

The Chief Justice: Mr. Adcock, the permit that you refer to is that signed by W. Cary Sanger, Assistant Secretary of War, dated December 5, 1901?

Mr. Adcock: Yes, your Honor.

The Chief Justice: Now, that provides that "the Secretary of War reserves the right to close said discharge through such channel, or to modify it to such extent as may be demanded by navigation?"

Mr. Adcock: Yes.

The Chief Justice (Continuing): "demanded by navigation and property interests along said Chicago River and its south branch?"

Mr. Adcock: Yes, sir.

The Chief Justice: Now, you claim, do you, that that navigation mentioned there is limited only to the navigation on the Chicago River?

Mr. Adcock: Yes, sir, because the original permit was limited only to that. That was the condition to the original permit, and the Secretary of War was acting only under Condition 2 in limiting it to that amount.

The Chief Justice: And then a further condition, No. 2, is:

> "That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require."

Mr. Adcock: Yes, sir.

The Chief Justice; Now, do you say that—

Mr. Adcock (Interposing): Yes, sir, we say that that does not enlarge Condition 2 of the original permit, because the limitation was made by virtue of Condition 2 of the original permit.

Mr. Justice McReynolds: What did the court below hold on these issues?

Mr. Adcock: The court held that the Secretary of War had the authority to limit this discharge; that is, that because the Sanitary District found itself in this lawsuit without an express authorization by the Secretary of War as to the amount, the injunction must follow; that it did not make any difference how it happened that the express authorization did not exist. It is our position that that December 5, 1901, permit—

Mr. Justice McReynolds (Interposing): If you will tell me what the court decided, I will be much obliged to you.

Mr. Adcock: That is what the court decided.

Mr. Justice McReynolds: The court decided that the Secretary of War had power to control this situation?

Mr. Adcock: Yes, sir.

Mr. Justice McReynolds: And that he issued an order limiting you to so much water?

Mr. Adcock: Yes, sir.

Mr. Justice McReynolds: And that you must not exceed it; is that right?

Mr. Adcock: That is right. And that it did not make any difference whether the cause of that limitation had been removed or not. It is our position that, when the limitation of 4,167 seconds feet was made there was a reason for it, because of the restricted condition of the river, but that

when we removed that reason, then necessarily the limitation itself would have no further force or effect.

Mr. Justice McReynolds: Did the Secretary of War decide that you had removed that limitation?

Mr. Adcock: That we had removed the limitation? There is no statement by the Secretary of War as to any current in the Chicago River unreasonably obstructive to navigation, but there was only a current therein of a mile and a quarter an hour, which was the amount that the Secretary of War indicated would be satisfactory.

The Chief Justice: Did the district judge rule, in effect, that these reservations by the Secretary of War gave him complete control?

Mr. Adcock: No. He simply held that, because we did not have an express authority as to an amount—that is, because the Secretary of War had not removed that limitation, it did not make any difference why he failed to remove the limitation; that for that reason, the injunction should follow.

Mr. Justice VanDevanter: In other words, the court recognized that there might be other reasons why that limitation should be preserved, and that even though one reason was removed, the others might still subsist?

Mr. Adcock: Yes, sir—that he might not like the color of the applicant's eyes.

Mr. Justice Brandeis: And did the court make any finding of fact in the matters which you say are in issue?

Mr. Adcock: No. There was simply a short decree.

Mr. Justice VanDevanter: Was it shown or admitted that the level of the Lakes was a good deal lowered?

Mr. Adcock: No; we do not admit that.

Mr. Justice VanDevanter: Well, was it shown in the evidence?

Mr. Adcock: There were many expert witnesses put on the stand who testified as to the determination of increment of these various outlet rivers, and that from that, theoretically, Lakes Michigan and Huron would be five inches less in depth because of this diversion, and that the surface elevation would be that much lower than it would have been.

Mr. Justice VanDevanter: Well, did they state that they had measured the water and found that there was that much difference in the level of the lakes?

Mr. Adcock: No; they made no measurement showing that. They made a great number of measurements of the discharge of these outlet rivers; and they took from the records the stage of the controlling lake at that time; and from those discharge measurements they attempted to obtain the increment of the outlet rivers. Now, an increment is the increase or decrease in the flow of the outlet river, due to the rise or fall of the controlling lake stage of one foot. And having determined the increment, they then divided the amount of the diversion—say 10,000 seconds feet—by the amount of the increment; and the fraction that was obtained represented the fraction of a foot that it was claimed the lakes were lowered.

Now, there were a great many things that had to be done, and done accurately, in order to make a discharge measurement, or a number of discharge measurements of these outlet rivers. The actual elevations—the mean elevations—of the lakes for the ten years immediately preceding the opening of this channel were lower than they were for the ten years subsequently thereto. There are a great many things that enter into the determination of the levels of the lakes. They fluctuate from time to time. Perhaps I could just show you that here on this map (indicating).

The lake levels were higher after the opening of the channel than they were before.

Mr. Justice VanDevanter: Habitually, or only for a time?

Mr. Adcock: Ten years; the ten-year mean elevation.

Mr. Justice VanDevanter: Then what happened?

Mr. Adcock: Well, the testimony in this case was practically closed in 1914; and that ten-year period is the only comparison that was made. I think I have here (indicating) the map which shows that. That (indicating) is a hydrograph of the Great Lakes, and shows the fluctuations from year to year, from 1860, to the end of 1914 in the lake surfaces. Lake Superior is not claimed to be affected in any way.

Mr. Justice Brandeis: What is that dip that you have there on the map?

Mr. Adcock: This dip here (indicating)?

Mr. Justice Brandeis: No; further up; a little further along.

Mr. Adcock: That condition is due to the fact that at this time, or about this time, I think Lake Superior was regulated. That is, movable dams were put in the St. Mary's River to regulate the level of Lake Superior, and so as to keep it within smaller limits than the others. And that was done for the benefit of the water power there.

Mr. Justice VanDevanter: Since then there has been less fluctuation?

Mr. Adcock: So far as Lake Superior is concerned. I think it has been kept within probably a foot and a half. You see, before that—here (indicating on map) is the figure for 1900. There were fluctuations, just the same as existed afterwards; and that is due to the supply which comes from rain on the surface of the lakes, and also on the drainage areas.

Mr. Justice VanDevanter: Near your right hand on the map is Lake Superior; what is that lowest figure shown there?

Mr. Adcock: That (indicating) is 1911. That was the low water time.

Now, in connection with that proposition, we show that in 1903, practically all of these critical points of navigation were improved by the United States. That reference plane of the improvement was placed approximately six inches lower, as the engineer testified, as the claimed effect on Lake Michigan. And the testimony also shows that the only vessels there claimed to be affected by this diversion are the ore-carrying vessels.

We have in this record a table which shows the ports between which the ore-carrying vessels ply, which shows that there have at all times been depths of water greater than the project depths as fixed by Congress, and that all these harbors—all these critical points of navigation—were improved under appropriations by Congress, and what navigation there is now has been entirely provided for by appropriations of Congress—that is, in supplying greater depths, etc.; and the depths are greater than the natural channels provided before there was any improvement. And that therefore, Congress, presumably, has taken care of this diversion.

Mr. Justice Butler: Is there any testimony in the record as to conditions since 1914? Or is there anything to show what volume of water per second has been taken from Lake Michigan since that time?

Mr. Adcock: By the Sanitary District?

Mr. Justice Butler: Yes.

Mr. Adcock: There was testimony put in in 1923, just before this decree was entered, which showed the population of the Sanitary District at that time. The population was shown in 1914, and the increase was at the rate of about 72,000 a year. And the statute expressly provided how much water should be taken.

Mr. Justice Butler: How much was taken?

Mr. Adcock: 10,000 seconds feet.

Mr. Justice Butler: 10,000 seconds feet?

Mr. Adcock: Yes, sir; they had 3,000,000 inhabitants, and that was the amount that was required according to the statute.

Mr. Justice Butler: How long has that amount been taken? I am trying to get at the situation which has developed since the taking of the testimony or the making of the records.

Mr. Adcock: That has developed progressively since 1900, when the population was about a million and a half. And I think in 1913 the population was about 2,500,000, and the increase is about half a million between that time and 1923—perhaps a little more.

Mr. Justice VanDevanter: And the lake levels you have not brought down to 1923?

Mr. Adcock: That has not been done. All that hydraulic testimony was put in by 1914. The later testimony that was put in, 1923, was more in relation to the settlement of the decree.

Mr. Justice Brandeis: How much have you increased the draft in the ten years from the year 1914 to date?

Mr. Adcock: How much have we increased the draft?

Mr. Justice Brandeis: Yes.

Mr. Adcock: The draft of vessels?

Mr. Justice Brandeis: No, the water—the drawing off of water by you?

Mr. Adcock: Oh. There has been an increase of about 2,500 seconds feet in the amount of water drawn; I think about that. That has been according to the population. I think it was about 7,500 seconds feet in 1914.

Mr. Justice Brandeis: You have increased it about 2,500 seconds feet?

Mr. Adcock: Yes, sir.

The Chief Justice: Mr. Adcock, before you go on, you referred to section 12 and section 10 of the act of 1899.

Mr. Adcock: Yes, sir.

The Chief Justice: I understood you to say that there was no authority, in your judgment, to get an injunction against what was here enjoined?

Mr. Adcock: Yes, sir.

The Chief Justice: Because the act referred only to an injunction against the removal of any structures or parts of structures?

Mr. Adcock: Yes, sir.

The Chief Justice (Continuing): erected in violation of the previous section. Have you not got to refer back to section 10 in order to find out what that means? Does not section 10 provide "that it shall not be lawful to excavate and fill, or in any manner, alter, or modify the course, location, condition, or capacity—"

Mr. Adcock (Interposing): Yes, sir.

The Chief Justice (Continuing): "of any port, roadstead, haven, harbor, canal, lake," and so on, or the channel of any navigable water of the United States. Is that not incorporated into section 12?

Mr. Adcock: But it expressly provides for the removal of a structure or part of a structure. Now, if you will notice section 10—

The Chief Justice (Interposing): Well, you have put in a good deal of the structure, have you not?

Mr. Adcock: The purpose here—what is sought in this suit is merely an injunction against the operation, or the continuance, as they claim, of an obstruction.

Now, if you will notice, section 10 of the act of 1890, which is printed on page 109 of my brief opposite the act of 1899, provides that:

"The creating or continuing of any unlawful obstruction in this act mentioned may be prevented and such obstruction may be caused to be removed by the injunction of any circuit court exercising jurisdiction in any district in which such obstruction may be threatened or may exist; and proper proceedings in equity to this end may be instituted under the direction of the Attorney General of the United States."

In other words, the old act properly provided for the institution of a suit of this kind for the relief here sought; whereas the new act does not provide for that; and it must have been the intention of Congress that the Attorney General should not have that power; otherwise, why the change?

The Chief Justice: Do you mean that Congress deliberately left out the remedy by injunction where what was done would alter or modify the "course, condition, location, or capacity of any port" etc.?

Mr. Adcock: It only related to the removal of a structure, and that was what the Secretary of War had to do with. That is, all of the things that are named in sections 9 and 10 that he may authorize are structures; that is, something built in navigable waters; something that occupies some position in those waters. And there is no provision for an injunction to remove an obstruction.

Now, this channel that was constructed here (indicating on map) is the main Sanitary and Ship Canal, as I pointed out. The lower end of that canal (indicating) is 36 miles from Lake Michigan. It is 26 feet deep and 165 feet wide in the rock section, and 225 in the earth section.

Section 23 of the act provided that, if a canal were cut through the rocky divide, or the Continental Divide, it should have a capacity of not less than 600,000 cubic feet per minute, or 10,000 cubic feet per second.

You will notice here (indicating on map) a blue line, here towards the bottom. That is the old Illinois and Michigan

canal. And that has been entirely abandoned, replaced and supplanted by the new canal, as held by the Supreme Court of Illinois.

Now, in regard to this March 2, 1827 act, I want to simply refer to some of the things that transpired prior to the time that act was passed and after its passage, and while the State of Illinois was exercising its power under that act.

Mr. Justice Sutherland: Before you come to that, may I ask you this question about section 12?

Mr. Adcock: Yes, sir.

Mr. Justice Sutherland: Is it your contention that, unless the suit can be maintained under the provisions of section 12 it cannot be maintained at all?

Mr. Adcock: Yes, sir: That Congress provided the method for the removal of structures that had been put in navigable waters contrary to the provisions of sections 9 and 10 and other sections of that act.

Mr. Justice Sutherland: Well, could not the United States maintain a suit to prevent obstructions to navigation independently of that law?

Mr. Adcock: I do believe that with that act—I believe that it is shown by the passage of these acts that it was intended by Congress that this method should be followed. There may be a question as to that. I simply want to make the point, your Honor.

Mr. Justice VanDevanter: Well, suppose you did not have this provision that you have referred to, in the latter part of section 12; suppose it was not there: Would you say that no suit could be brought?

Mr. Adcock: No.

Mr. Justice VanDevanter (Continuing): To remove obstructions?

Mr. Adcock: No.

Mr. Justice VanDevanter: You think that is necessary in order to remove obstructions?

Mr. Adcock: I think they simply put it there in order to—

Mr. Justice VanDevanter (Interposing): You think they could not have brought a suit without that section?

Mr. Adcock: I believe they could have, under their general power—

Mr. Justice VanDevanter (Interposing): Now, they have not taken away the power to bring a suit against other things that are in violation of the act. Why do you say that this power does not exist?

Mr. Adcock: Well, merely this: That Congress under these acts has provided a plan by which these structures may be removed. For instance, under section 18 of the act which relates to the changing of bridges, there is no provision for an injunction. The only provision there is for a fine. And the Secretary of War must follow a certain procedure. He has got to have a hearing, and provide that the bridge shall be altered or modified—

Mr. Justice VanDevanter (Interposing): You are familiar with the *Elephant Butte* case, are you not?

Mr. Adcock: What is the name of it?

Mr. Justice VanDevanter: The *Elephant Butte* case?

Mr. Adcock: I do not recall it just now.

Mr. Justice VanDevanter: Well, it involved a dam in New Mexico and Colorado; and it was there found that one of the affluents of the Rio Grande River was being tapped and the water was being taken out.

Mr. Adcock: Do you mean the *Rio Grande Dam & Irrigation Co.* case?

Mr. Justice VanDevanter: Yes.

Mr. Adcock: I know that case, of course.

Mr. Justice VanDevanter: And the United States brought a suit to prevent that obstruction, on the ground that it was impairing the navigability of the river below, and that it affected also the ability of the United States to comply with its treaty stipulations with Mexico.

Mr. Adcock: Yes; I know that case; that is in the 174 U. S. reports.

Mr. Justice VanDevanter: They did not have any difficulty there about the right to bring such a suit, did they?

Mr. Adcock: That suit was brought under the act of 1890, the language of which is entirely different. It provided for the institution of a suit of that kind. And besides, that was as to a dam being constructed—which, as the court stressed in that case, was especially mentioned in the act of 1890.

Mr. Justice VanDevanter: Do you think the *Economy Light & Power Co.* case is consistent with your view?

Mr. Adcock: That was a dam across the water; and the only question there was whether it was a navigable water of the United States or not; that was a structure; the dam had been started; they had started to build it; and of course, if they could remove a part of the structure, certainly the court could enter an injunction which would prevent them going ahead and building the structure that had been started.

Yes, those cases were cited by counsel for the Government.

Now, I would like for just a few minutes to proceed in the consideration of this act of March 2, 1827. And that has a great deal to do with the early history of this country.

We have here (indicating) a map which shows the navigation of the Mississippi waterway system. This water route (indicating) extending from Chicago here, down across the Continental Divide, which was a very small divide (indicating), the Des Plaines and Illinois Rivers (indicating) and so on to the Gulf of Mexico (indicating)—is a very old plan.

And in the laying out of the Northwest Territory, under the cession of Virginia in 1783, and the Ordinance of 1787, the question of the development of this water route was under consideration; and originally the northern boundary of the lower three States in the Northwest Territory—that is, the territory that afterwards became those States—was a line drawn through the very southern end of Lake Michigan. When the Illinois enabling act was passed, the day it was passed it was amended to provide for the new state, the port here at Chicago (indicating on map) and a certain amount of territory back of it, in order to support that, and in order that the water route should be entirely within Illinois. And as it was stated in the resolution presented by Mr. Pope for the amendment of the enabling act in order to cover this additional territory, the fact that the water route was all within Illinois, would draw the attention of the State of Illinois to the development of the waterway.

Then in 1822, Congress passed the act of March 30, 1822, which was the first act of Congress with reference to the development of this waterway, which provided; the title of the act was as follows:

> "An act to authorize the State of Illinois to open a canal through the public lands to connect the Illinois River with Lake Michigan."

A portion of said act reads as follows:

> "That the State of Illinois be, and is hereby authorized to survey and mark through the public lands of the United States, the route of the canal connecting the Illinois River with the southern bend of Lake Michigan; and ninety feet of land on each side of that canal shall be forever reserved from any sale to be made by the United States."

Now, that act ceased to have any force and effect because there were certain things that Illinois was to do within a period of years, that it did not do. And in 1826 the Gen-

eral Assembly of Illinois memorialized Congress with reference to the construction of a canal and the importance of it.

On March 2, 1827, Congress passed another act, which had substantially the same title, and which provided:

> "That there be and hereby is granted to the State of Illinois, for the purpose of aiding the said State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each side of said canal, and reserving each alternate section to the United States, to be selected by the Commissioner of the Land Office, under the direction of the President of the United States, from one end of the said canal to the other; and the said land shall be subject to the disposal of the Legislature of the said State, for the purpose aforesaid, and no other; provided, that the said canal when completed shall be and forever remain a public highway for the use of the Government of the United States, free from any toll, or other charge, whatever, for any property of the United States, or persons in their service passing through same."

Now, in 1822 and 1824, the government of Great Britain refused to the citizens of the United States the free navigation of the St. Lawrence River, and that question was not settled until the treaty of 1854.

I am referring to these facts with reference to the enabling act of Illinois, and the actions of Great Britain, to show the intention to construct a canal of a certain size, and to create and enlarge this waterway to the dimensions that the Government had in mind at that time.

On January 9, 1836, the State of Illinois passed an act under which the Illinois and Michigan Canal—the one I pointed out on the map, which extends down to Utica, on the Illinois River, about 100 miles—under which act that was built. Section 16 of that act provided that the canal should be of a certain width and should be supplied with water from Lake Michigan, and from such other sources as the canal commissioners might provide.

And in fact, Lake Michigan was the only place from which they could get water for the operation of the canal; and it was the only place for the upper section of the canal which could cross through the Continental Divide. And it also provided that there should be reserved on each side of the canal 90 feet, for the purpose of enlargement. And you will recall that the act of March 30, 1822—that is, the act of Congress, had a similar provision, that there should be reserved a certain amount for enlargement.

So we have the width of the original canal, which would be 45 feet—that is, the canal itself—and the amount reserved, 90 feet on each side, for enlargements, which would make a canal 225 feet in width.

The canal was completed in 1848; and at that time the diversion of water from Lake Michigan commenced. It was not completed, however, on the original plan, because of lack of funds, so far as the upper stretch was concerned. It was completed on what was called the "shallow cut plan."

In 1861, the General Assembly of Illinois authorized and empowered the canal commissioners to make a survey for the improvement of this canal—an improvement of the waterway. It was not only the enlargement of the canal, but also for the purpose of providing water so that the Illinois River would be made deeper and they would have depths there for navigation purposes—

Mr. Beck (Interposing): Mr. Adcock, would you mind explaining to the Court that this is not the canal that is in suit?

Mr. Adcock: I will come to that.

Mr. Beck: I do not want the Court to think that you are talking about the canal in controversy.

Mr. Adcock: No, I will come to that.

Mr. McReynolds: Is this canal in operation now?

Mr. Adcock: No.

Mr. Justice McReynolds: When was it abandoned?

Mr. Adcock: The canal is in operation from Joliet, this point (indicating on map) south to Utica. It is not in operation from Joliet north, because it has been supplanted by the Sanitary and Ship Canal that is here in controversy; and it has been entirely abandoned, and that has taken its place; and instead of maintaining the old canal, they build a new one right alongside it, which took the place of it, and was under the provisions of the 1827 act.

In fact, our organic act provided that we might occupy the site of that canal, if it were necessary; that is, if we desired to do it. But we did not do it, because it was cheaper to dig the canal alongside of the old canal than to build one on the site of the old canal.

Mr. Justice Sutherland: Well, did the act of 1827 fix the width of 45 feet, or did it make this additional grant of 90 feet on each side for the canal?

Mr. Adcock: No, it did not.

Mr. Justice Sutherland: What did it provide?

Mr. Adcock: It merely provided that a certain amount of land was granted to the State of Illinois, to construct a canal to unite Lake Michigan with the Illinois River. But the act of March 30, 1822, did provide that there should be reserved 90 feet on each side of the canal; and this act of 1827 was a reenactment of the old act of 1822.

Mr. Justice Sutherland: Did either act say anything about the diversion of water or the size of the canal?

Mr. Adcock: No. That was left, as we conceive, to the discretion of the State, to build a canal that it considered suitable for commerce, to be operated in such a way as it considered reasonable.

Mr. Justice Sutherland: Well, do you mean to say that that canal was 45 feet wide at that time?

Mr. Adcock: The act under which the canal was built, that is, the act of Illinois, provided that it should be not less than 45 feet wide, and that there should be reserved on each side 90 feet for enlargement of the canal.

Mr. Justice Sutherland: Was there anything provided about the depth?

Mr. Adcock: Yes, the Illinois act contained a provision as to the depth. I think it provided that it should be not less than six feet deep.

Mr. Justice Sutherland: Six feet deep?

Mr. Adcock: Yes, sir.

Mr. Justice Sutherland: And the present canal is of what depth?

Mr. Adcock: It is 26 feet deep. The idea there, I assume, is this: That if the canal is widened, it necessarily would carry a depth corresponding to the width, as commerce might require—

The Chief Justice (Interposing): Well, Mr. Adcock, in order to help us understand this as you go along, is it your contention that the United States is in a situation now where it may not deny nor prevent the taking of water from Lake Michigan for the purpose of building a canal?

Mr. Adcock: Our position is this: That the United States directly authorized us to build a canal; that there was no limitation as to how it should be built, the amount of water that should be taken—or, to put it another way, they invited Illinois to exercise its authority.

The Chief Justice: Well, you did build a canal?

Mr. Adcock: Yes, sir.

The Chief Jusice: Under that authority?

Mr. Adcock: Under that authority.

The Chief Justice: And now you are seeking to enlarge that authority by the fact of the original grant?

Mr. Adcock: No; we are simply acting under the authority, which we consider as a continuing authority, not only to build a canal which suited the demands of navigation at that time, but to maintain a canal across there which would suit the demands of navigation as they might afterwards appear. That is our proposition.

Mr. Justice Holmes: Which act are you referring to? Who do you say gave you that authority?

Mr. Adcock: Congress.

Mr. Justice Holmes: Did you say which act of Congress it was?

Mr. Adcock: The act of March 2, 1827.

And also, putting it another way, that under the act of 1827, Congress invited Illinois to exercise the authority which was reserved to it under the Constitution—that is, the police power to develop these waterways and use the canal for a waterway or for any other legitimate purpose.

Mr. Justice Brandeis: And your contention is that this grant is a preferential grant over the rights, whatever they may be, of other States, for navigation and other uses of water on the Great Lakes?

Mr. Adcock: Yes. That is, that it was granted in the interests of navigation.

Mr. Justice Brandeis: Well, I mean it was a preferential grant for navigation, so that it took precedence over any other uses that Congress might want to make of that water—or the States bordering on the Great Lakes?

Mr. Adcock: I do not think that we are in the position here, your Honor, where we take the position—or that it is necessary to determine the proposition as to what would happen if Congress should now occupy the field or exercise its power in regulating the amount of diversion for navigation purposes.

Mr. Justice Brandeis: That is, you could gradually, with the increasing demands of navigation and the size and draft of vessels—you could continue, at least until Congress otherwise provided, to increase your draft from time to time, regardless of its effect on the Great Lakes?

Mr. Adcock: So long as the acts of Illinois were reasonable and reasonably necessary for the purpose.

Mr. Justice Brandeis: Well, I mean for navigation through the canal down to the Mississippi?

Mr. Adcock: Yes, sir, so long as Congress permitted that.

Mr. Justice Sanford: Is it your contention that this increased taking of water is necessary for navigation purposes?

Mr. Adcock: It is our position, your Honor, that when the canal was provided for, that is, under the act of May 29, 1889, they had two propositions in mind—providing a canal for navigation purposes, as well as to take care of the sewage and protect the water supply. That at that time there was a demand for a deep waterway to the Gulf of Mexico, of 14 feet, and that the waterway could not be created without the diversion of water.

And I would like to refer, as I have just about come to that point, to what the United States Government did with reference to the size of a canal, with reference to a deep waterway and the idea of a diversion of water from Lake Michigan for the deep waterway; because it was necessary not only to build a canal of certain size for the increased demands of navigation, as they conceived it then, but also to provide water for the Illinois River. That is a never-failing water supply because at time of low water the flow of the Illinois River was practically nothing—from one to five hundred cubic feet per second—and this increase would give very great depth in the Illinois River, for the purposes of navigation; and this is what Illinois did in 1861—

Mr. Justice Sanford (Interposing): Was anything said in those later acts of Congress in reference to drainage, or was it merely a matter of allocation?

Mr. Adcock: No; this Court, speaking through Mr. Justice Holmes, in *Missouri* v. *Illinois*—and I think I might just as well read that here—said:

> "Some stress was laid on the proposition that Chicago is not on the natural watershed of the Mississippi because of the rise of a few feet between the DesPlaines and the Chicago River. We perceive no reason for a distinction on this ground. The natural features relied upon are of the smallest, and if under any circumstances they could effect the case, it is enough to say that Illinois brought Chicago into the Mississippi watershed, in pursuance not only of its own statutes, but also of the acts of Congress of March 30, 1822, and March 2, 1827."

And on that proposition our Supreme Court said, in the 272 Illinois, speaking through Mr. Justice Carter of that court—and that was a suit brought by a taxpayer to enjoin the construction of the Sag Channel, which is an adjunct of the main channel, and is located down here (indicating on map); and the court said:

> "Said act of 1903"—

That was an act that specially related to the Calumet Sag channel, and is not the act of May 29, 1889, which related to the main Sanitary and Ship Canal:

> "Said act of 1903 permits the crossing of the Illinois and Michigan canal near Sag bridge and provides for the abandoning of certain portions of said canal. Counsel for appellant argue that this is in violation of the Federal grant of 1822, under which the Illinois and Michigan canal was constructed, which provides, among other things: 'If said ground shall ever cease to be occupied by and used for a canal suitable for navigation, the reservation and grant hereby made shall be void and of none effect.' The canal was built under the authority of Congress of March 2, 1827, the act of 1822 having been mutually abandoned by the State and Federal governments. This Federal act did not provide

just where the canal should enter Lake Michigan, simply stating that the land was granted for the purpose of opening 'a canal to unite the waters of the Illinois River with those of Lake Michigan.'"

That is the one we call the "Sanitary and Ship Canal."

"The Sanitary District's main channel as now constructed practically complies with this act and furnishes a canal more suitable for navigation than the Illinois and Michigan canal. Furthermore, the Sag channel or cut-off is required to be navigable by said act of 1903, and the proof shows that the Calumet River is navigable to the point where it is intersected by the Sag channel. This cut-off would therefore also practically comply with both of said Federal acts as to furnishing part of the canal for connection of the Illinois River with Lake Michigan."

In 1861—referring to the resolution of the Illinois General Assembly with reference to the enlargement of this canal and enlargement of the waterway—it provided for a survey—

"of the different methods proposed or desirable for improving the navigation of the Illinois River, by dredging or excavation of the channel and wing dams, or by supplying water from Lake Michigan, through the enlargement and deepening of the Illinois and Michigan Canal, or otherwise, or by opening a channel from Lake Michigan by way of the South Branch of the Chicago River and Mud Lake to the DesPlaines River and down said Canal to a point that would secure a free, flowing, ample and never-failing supply of water, sufficient for navigation of the Illinois River at all seasons and times, * * * and to include also an estimate for the channel hereinbefore mentioned, of sufficient size to admit of full and free steamboat navigation from the Illinois River to Chicago and Lake Michigan, as well as a size sufficient for supplying water for all the deficiencies of navigation in the Illinois River, at all seasons."

The Chief Justice: What was the enacting body?

Mr. Adcock: Illinois.

The Chief Justice: The Illinois Legislature?

Mr. Adcock: Yes, the Illinois Legislature.

And President Lincoln, in his second message to Congress, in 1862—I think it was on December 1, 1862—recommended that this matter be considered, the matter of the enlargement of this waterway. So that they had in mind, not only the size of the canal, but a diversion of a quantity of water from Lake Michigan.

Now, following those—and we must have in mind also President Lincoln's message—in 1866, Congress provided for a survey of this waterway, with the idea of improving it. And General Wilson, who made the report in 1867, stated:

> "The Illinois River seems to have been especially designed by nature as the link by which the waters of Lake Michigan are to be connected with those of the Mississippi. * * * the data herein contained, together with the existence of a canal of limited capacity already in operation, demonstrate beyond a doubt that the waters of the Lake may be carried into the Illinois River through a navigable channel of any required dimensions, and at a cost which cannot be regarded as excessive when the objects to be obtained are duly considered. * * * The summit will be inexhaustible, and this cannot be said of any other practicable line of water communication between Lake Michigan and the Mississippi River."

In 1871, the Illinois and Michigan Canal was completed on the deep cut plan, by which water was taken from Lake Michigan by gravity—a greater amount than had been theretofore withdrawn.

And following that, a report was made by another engineer officer, in which he stated:

> "The improvement of the eastern portion of the Illinois and Michigan Canal involves the further cutting down of the summit level and enlarging the waterway so as to afford an unfailing supply of water from Lake Michigan for the improved Illinois River."

Mr. Justice Sutherland: What are you reading from now?

Mr. Adcock: That is in one of the reports. I am reading a quotation from my brief.

Now, there were a number of reports made by engineers pursuant to acts of Congress up until the very time that this act of May 29, 1889, was passed—all recommending that a large canal should be built across this divide to take water from Lake Michigan for the operation of the canal, and to supply water for the Illinois River.

On May 28, 1889, which is just one day before appellant's organic act was passed, the General Assembly of Illinois stated its waterway policy; that is, it was to provide a waterway of the greatest dimensions and to take water from Lake Michigan for its operation, in order to provide these needs.

Now, while all of this was going on and the canal was being enlarged for waterway purposes, the City of Chicago, which had a very rapidly growing population, used that canal in order to dispose of its sewage; that is, to partially dispose of it.

Of course, it did not divert from Lake Michigan all the drainage and sewage; but part of it was diverted. And Chicago cut down the summit level, so as to complete the canal on the deep cut plan, in order to cleanse the Chicago River.

And further, in 1883, the General Assembly of Illinois directed that Chicago should put in pumps at the northern end of this canal, in order to take more water in order to cleanse the river. The population was increasing, reaching almost a million people—with the sewage partially going into Lake Michigan. Typhoid fever was raging. In other words, we had 40 years ago, by reason of our population, the problem which Cleveland and Milwaukee only have today. Because of this aggregation of population, our water supply was polluted by virtue of the Chicago River flowing into Lake Michigan.

Consequently, the city council of Chicago appointed—or, under the authority of the city council of Chicago there was

appointed, a drainage and water supply commission, in 1886, to study the whole question of sewage disposal; and the protection of the water supply and the navigation features also.

That commission was to report not later than the next General Assembly, which was in 1887. They made their report on January 30, 1887, in which they recommended the construction of the diversion works which I have described to you here; that is, the very works which the Sanitary District has built in order to divert at all times the drainage and sewage from Lake Michigan.

The act was passed after very deliberate study; that is, our Sanitary District act. It was passed pursuant to this report of the commission. And it was pursuant to a study by the committee of the legislature which was to sit *ad interim*. The legal adviser of that committee was the late John P. Wilson, of Chicago; and Chicago went about to provide for this waterway—that is, the State of Illinois did in its legislation—and to provide at the same time for the disposition of the sewage and the protection of the water supply.

The day before this act was passed, Major Marshall, who was the engineer at Chicago, made a report, which is contained in the reports of the Chief of Engineers—and this will give you some idea as to how the United States considered this proposition, and the agitation that was then in existence as to a deep waterway from Chicago to the Gulf of Mexico. He stated:

> "Whenever the large channel contemplated by the City of Chicago for drainage is actually determined upon, in view of the fact that the channel for navigation and the channel for drainage across the Chicago divide must necessarily occupy the same field, it is evident that, to avoid duplication of expense, the channel, at least, in the expensive rock section, should be constructed based on the immediate requirements of navigation, while at the same time giving a sufficient flowage capacity to carry off the drainage of the Sanitary District."

And the act under which these works were constructed provided for these navigation features. It provided that when the canal was constructed it should be a navigable waterway of the United States, and that it should be of certain depth and velocity, etc., and not over three miles per hour, all of which was necessary for navigation.

Now, following immediately upon the passage of this act, the Sanitary District of Chicago was organized; and it was a special act; although general in scope, it was really in substance a special act. They immediately commenced the survey of this canal.

The reports of the Chief of Engineers for 1890 contained verbatim copies of our act. And each year thereafter those reports contain reports of General Marshall as to the progress of the work, the purposes of the canal, what we proposed to do, not only as to its size but the diversion of water and the amount which was fixed by the act specifically; that is, that in the rock section it should be not less than 600,000 cubic feet per minute.

On April 21, 1891, very shortly after the appellant's board was organized, it passed an ordinance which stated that they would enter upon, use, widen, deepen and improve the Chicago River and the South Branch and the West Fork, in order to make that river large enough to serve as a supply channel by which the waters of Lake Michigan should be taken through the rivers to the Sanitary and Ship Canal.

That resolution or ordinance was sent to the Secretary of War, and very shortly after that, in 1892, Congress passed the first act relating to the improvement of the Chicago River; and it is our contention in this respect that, as soon as Chicago started upon its plan of deepening and widening the South Branch and West Fork of the Chicago River, Congress then proceeded to make appropriations for the improvement of the Chicago River itself.

And in this connection, there was no work done by the United States in the improvement in the channels of those rivers, except in the Chicago River itself; the work in the South Branch and West Fork was done by the Sanitary District; the work went along together; and the work done by the Sanitary District connected with that done by the United States in the Chicago River.

I want to refer just a minute to the act of March 3, 1899, which contains a provision with reference to the improvement of the Chicago River and the cooperation going on between the United States and the Sanitary District, the appellant, in that improvement.

Mr. Kirby: Do you mean the act of Congress?

Mr. Adcock: That is the act of Congress, yes, of March 3, 1899. And this act, under which the *Tunnel cases* the *West Chicago Street Ry. Co.* v. *Chicago,* in the 201 U. S. reports, opinion by Mr. Justice Harlan, if I remember correctly. There is a provision in that act reading as follows:

> "Improving Chicago River, Ill.: For continuing improvement from its mouth to the stockyards on the South Branch and to Belmont Ave. on the North Branch, $113,000, in pursuance of the provisions of an act"—

No; this was the act of February 26, 1897, which I wanted to read first, which adopted the project reported by Major Marshall in his letter of August 9, 1893, which described the Sanitary District works, the diversion, and suggested the 21-foot improvement. Then the act of March 3, 1899, came right along following that, as follows:

> "Improving Chicago River, in Illionis: Survey and estimate of cost for a channel 21 feet deep from its mouth to the stockyards"—

that is, the Chicago River—

> "To the stockyards on the South Branch, and to Belmont Ave., on the North Branch, so far as may be permitted by existing docks and wharves, exclusive of cost

of removing or constructing bridges or piers or lowering tunnels; and the aforesaid depth of twenty-one feet is hereby adopted as the project depth for the improvement in lieu of that fixed by the Act of June third, eighteen hundred and ninety-six: Provided That all the work of removing and reconstructing bridges and piers and lowering tunnels necessary to permit a practicable channel with said depth to be obtained shall be done, or caused to be done, by the City of Chicago without expense to the United States."

Mr. Justice Holmes: What page is that?

Mr. Adcock: This is page 107 of our reply brief.

Now, it was held in the *West Chicago Street Ry.* case that I have just mentioned, where the suit was brought by the people to remove the tunnels, that the consent of the Secretary of War to the removal of the tunnels was unnecessary, because Congress had meant to give its assent by this act.

Now, the proviso refers to tunnels, or one of the things referred to is tunnels. It was also necessary, as stated in the proviso, to reconstruct bridges; necessary to excavate about 21 feet, and to widen the rivers, in order to make the channel correspond to the greater depth.

And when the work was done, that is our work, in the South Branch (indicating on map) and in the West Fork (indicating), where we deepened the river to twenty-six feet and widened it and changed the bridges—it was all under the authority—or, at least, not necessarily express authority, but certainly with the cooperation of the Federal Government; because they had laid out the project for that depth; we did the work and spent the money, over $10,000,000, and connected that work with their improvement in the Chicago River. They made no expenditures, or made no improvements in the South Branch or the West Fork. The only improvement made by the Government, which was done as we excavated in the South Branch of the West Fork, was in the main river itself, and in the North branch. So that the im-

provements by the Sanitary District of Chicago connected up; and they connected up with the Government work, forming a through connection through the South Branch, the West Fork, and the main channel down to Joliet, and on the old Illinois and Michigan Canal, through the Illinois River, to the Gulf of Mexico.

So that our channels and the work that we did was certainly under those circumstances invited by the Federal Government.

And that was the very act—this item that I have read was contained in the Rivers and Harbors Appropriation Bill which contains this section 10 that we speak of.

Now, is it not reasonable to assume that this great work having been completed at that time, and that act passed, that if it had been intended that the amount of water that Chicago should divert for these purposes should be curbed, then some express words would have been used?

Now, going on, there have been some acts which provide for surveys of this water route. And in one of them, that of June 6, 1900, we find this language, which I think is very important, that a board of engineers should be appointed to make a survey of a waterway and report the estimate of cost for a channel ten feet deep, and for a channel twelve feet deep, and for a channel fourteen feet deep, "through said proposed route, and that the said estimates cover and include a proper connection at Lockport with the Sanitary and Ship Canal which has been constructed by the Sanitary District of Chicago."

In other words, with the idea of connecting right up with that.

Now, there are many other acts, which are set forth in our briefs, passed almost every year, providing for these surveys, providing for reports as to the construction of compensating works in the various river outlets of the Great Lakes, in order to offset for any claimed damage to commerce, or offset for

the lowering of the levels of the Lakes. All of those were provided for.

And we come further to the act of June 29, 1906, for the preservation of Niagara Falls; and I would like just for a few moments to draw your attention to that, because I think it is important. That act provided—it is found at page 51 of my brief:

> "That the diversion of water from Niagara River or its tributaries, in the State of New York, is hereby prohibited, except with the consent of the Secretary of War as hereinafter authorized in section two of this Act: Provided, that this prohibition shall not be interpreted as forbidding the diversion of the waters of the Great Lakes or of Niagara River for sanitary or domestic purposes, or for navigation, the amount of which may be fixed from time to time by the Congress of the United States or by the Secretary of War of the United States under its direction."

In other words, we have there an act of Congress which expressly, it seems to me, states that Congress had not then authorized the Secretary of War to regulate diversions. If it had, there would have been no occasion for the passage of that act, because the Secretary of War could have stopped the diversions, as Congress intended that he should under that act at Niagara Falls. And up to that time the diversions at Niagara Falls for water power purposes, for the making of electricity, existed solely and only under the authority of the State of New York. They were in no different position than the diversion here for sanitary and waterway purposes at Chicago. They existed under the police power of the State, and under that alone.

And in the conference report, when there was an amendment that had been introduced, the late Senator Lodge, in discussing an amendment that Senator Hopkins of Illinois had offered, said:

> "The first section of the bill protects the rights of Chicago. No treaty would be made by our commissions which would impair or infringe those rights."

In other words, even in an act which only related to the Niagara River in New York, Congress was so careful that that should not by any possibility be construed to cover diversions for sanitary and domestic purposes, that it put in the provision that the act did not give the Secretary of War any authority, but those things might be taken care of by Congress later.

I wonder just how much time I have left, if your Honor please?

The Chief Justice: You have, I should say, about ten minutes left of your two hours.

Mr. Adcock: Yes. The importance of these acts that I have just mentioned, running over this period of years, shows that there was an intention on the part of Congress to provide means by which this diversion would exist.

Under the act of June 25, 1910, a board of engineers was appointed to report upon a waterway from the Great Lakes to the Gulf—

The Chief Justice (Interposing): Yes; that is just what you have consumed now, an hour and fifty minutes.

Mr. Adcock: Yes, thank you. (Continuing): To report upon compensating works to offset for the diversions for water power purposes and for other purposes.

That is, they were to make a report on the waterway from Lockport to Utica; and they were also to report upon the means by which the levels of the Lake, or the lowering of the lake levels, could be offset by the construction of compensating works in these outlets, not only for waterway purposes, but for other purposes. And they made their report. And they found in that report that, by building contracting works in the St. Clair River and the Niagara River, the channels of these rivers could be so contracted that the lake levels could be restored to the conditions in which they would be if the diversions did not exist.

On June 30, 1917, Congress by joint resolution again provided for a survey as to means of taking care of all diversions. This is not the only diversion from the Great Lakes. There are some 112,000 cubic feet per second of diversion for water power purposes. There are only 2,300 cubic feet for navigation purposes. The Niagara diversions are for power purposes. There are diversions through the Welland Canal of 3,500 seconds feet, 2,400 seconds feet for power and only 1,100 feet for navigation. Through the Barge Canal there are diversions for power and navigation purposes. And at St. Mary's River, practically the entire flow of that river is used for water power.

Mr. Justice Sutherland: The water is all returned to the stream, is it not?

Mr. Adcock: Yes; but at Niagara Falls there is an effect upon Lake Erie; and also by virtue of the Welland Canal diversion, and as I understand it, the diversion by means of the Barge Canal—

Mr. Justice McReynolds (Interposing): What is the Barge Canal?

Mr. Adcock: It extends from Buffalo across to Albany; it is the New York Barge Canal, as I understand it.

Mr. Justice McReynolds: Oh.

Mr. Adcock: Does that place it in your mind?

Mr. Justice McReynolds: You mean the Erie Canal?

Mr. Adcock: Well, it is the old Erie Canal, yes, sir. It has just been constructed.

Mention has been made of the navigation features of the Sanitary District. These works that have been constructed will provide a waterway to the Gulf of Mexico with a depth of nine feet. They will provide water in the Illinois River, so that there will be a greater depth. We have a water communication twenty-six feet deep—the United States has, from Lake Michigan, clear to Joliet, across the most expensive cut.

And from a sanitary standpoint, the diversion of this water has accomplished a great deal. The death rate from typhoid fever prior to the opening of the canal has sometimes been as high as 170 per 100,000 of population. That has been entirely cut down. There are no epidemics now; and for the ten years since the building of the canal the mean average per year has been in the neighborhood of 7.6 per 100,000 of population. That has been reduced so that in 1923 it was about one per 100,000 of population—a decrease greater than for any other city similar situated. Of course, it is not assumed that the entire result was due to this drainage canal.

Mr. Justice McReynolds: Suppose all of that is true, what good does that do us?

Mr. Adcock: It just shows the necessity for this diversion.

Mr. Justice McReynolds: Well, you might show the same thing about inoculation; and I was just wondering how that would help us in deciding this case.

Mr. Adcock: Now, the propositions which I sought to show here, but which I am not even able to cover in the oral argument, but which I think are covered in our briefs, are these:

This diversion of water has been authorized by the act of March 2, 1827, so that it is affirmatively authorized by law; Congress. And it has been affirmatively authorized by law; because section 10 of the 1890 act, instead of containing the words "affirmatively authorized by Congress," contains the words "affirmatively authorized by law"; and in the case of *Bellingham Bay Boom Co.*, it was held that that meant a State act.

Mr. Justice Holmes: What was that last act that you cited?

Mr. Adcock: That was the act of September 19, 1890.

Now, assuming that section 10 authorizes the Secretary of War to act with reference to this diversion—we will concede it does, so far as the diversion affects the Chicago River:

We contend that we have fulfilled every condition of the permits that have been given by the Secretary of War. That is, we have so reconstructed river so that there is no injury to navigation. There is no current. The Government has never complained in that respect.

That under the July 11, 1900, permits, for the excavation of those rivers, which permits were given for that purpose, the only purpose of excavating was to provide this larger diversion, so that we could take the amount of water required by our act through the rivers; and we contend that necessarily, when the Secretary of War, upon the recommendation of the Chief of Engineers, authorized the doing of that work, he gave authority for the altering or modifying of the navigable waters of the United States, not only in the Chicago River, but wherever located, and strictly in accordance with the provisions of section 10 of that act; that is, laying aside all questions as to the provisions of the act of March 2, 1827, as to the limitations of our law, and as to the authority under the reserved power of the States, the Congress of the United States has invited the construction of these works.

And there is no evidence in the record,—as stated by Mr. Justice Holmes in the case of *Missouri* v. *Illinois*, all the evidence of the Government in this case for an injunction is based upon an inference of the unseen; there is no evidence that the levels of the lakes have been affected or lowered, or that there has been an injury or damage to commerce.

Now, it does not make any difference what legal right the Government has here, there cannot be an injunction which will take effect immediately and without condition. Because it would create an intolerable situation at Chicago. The people, the appellant, the municipalities within appellant's district, that is, the City of Chicago and all the other municipalities taking water from Lake Michigan depending upon these

diversion works for their pure water supply, must have time in which to readjust themselves.

The Chief Justice: What is the exact order?

Mr. Adcock: That the appellant be enjoined from diverting or abstracting from Lake Michigan any water in excess of 4,167 cubic seconds feet.

The Chief Justice: And how much are you taking now?

Mr. Adcock: Ten thousand seconds feet. It is perfectly obvious that if it was cut down to 4,167 second feet there would be no water for the oxidation of sewage. The drainage run-off the Chicago River is 10,000 cubic seconds feet. That is the maximum run-off of the Chicago drainage area, being that amount, would cause the Chicago River to go into Lake Michigan a number of times a year, and carry with it the drainage and sewage, if this diversion were kept within that amount.

The Chief Justice: Well, you concede, then, that you have no express authority from the Secretary of War beyond the 4,167 feet?

Mr. Adcock: No. We claim that we had express authority. If you want to look, the authority exists under the July 11, 1900 permits—well, I want to say that perhaps I did not quite understand the Chief Justice's question. That is, we have not any express authority stating 10,000 seconds feet, or any amount over 4,167 seconds feet. The only authority we have is the authority under the original permit—that is, so far as permits go—from the Secretary of War. And we have fulfilled all the conditions of those permits. That is, the only condition that he placed in the permit was the current in the Chicago River. And we have done the things in the channel of the Chicago River that were necessary to remove any current that would exist by virtue of taking 10,000 cubic seconds feet through those channels. So that, so far as that permit is concerned, we have complied with it.

We have done the work in the deepening and widening of the rivers under the permits of July 11, 1900. And that was the only work that was necessary in order to take our water through there. We had to do it; and unless we did that work we could not get the water through. And it was the purpose of the work; and having given us authority to do the work, he necessarily gave us the authority to do those things which would result from the work.

Mr. Justice Butler: How many intakes are there?

Mr. Adcock: There is a channel here (indicating on map) at the northern end, north of Chicago, at Wilmette, which connects with the North Branch of the Chicago River. Then there is the Chicago River itself. And there is a conduit at 39th Street, which picks up, by intercepting the sewage along the shore 2,000 feet; and then there is this Calumet Sag Channel (indicating).

Mr. Justice Butler: That is four, is it?

Mr. Adcock: No, that is 6,500 coming through the main river—

Mr. Justice Butler (Interposing): No; I mean four intakes?

Mr. Adcock: There are five.

Mr. Justice Butler: And one under construction further north?

Mr. Adcock: No; there are none under construction now.

Mr. Justice Butler: You have completed all of them?

Mr. Adcock: We have completed our diversion works.

Now, we have a plan or provision made for taking care of the sewage that will not be oxidized by this 10,000 seconds feet. But the basis of the whole thing, of the whole proposition, is the diversion from Lake Michigan of 10,000 seconds feet, in order to keep the Chicago River and all its branches supplied with sufficient water for those purposes.

Mr. Justice Brandeis: What other means have you adopted to take care of the sewage?

Mr. Adcock: We have put in sewage purification works to supplement that diversion; but they are only supplemental.

Mr. Justice Brandeis: Where are they?

Mr. Adcock: Those are the various projects that are laid out (indicating on map); and it is shown in the testimony—

Mr. Justice Brandeis (Interposing): What proportion of the present sewage of the city will be taken care of by those works?

Mr. Adcock: Those works will be installed by 1945, under an ordinance adopted August 7, 1919; and that ordinance was passed in cooperation with the United States Engineer at Chicago, and it is to take care of the increase of the population in that period.

Mr. Justice Brandeis: In the next twenty-one years?

Mr. Adcock: In the next twenty-one years; and also the waste, etc., that now overloads the channel.

Mr. Justice Brandeis: Is there at present an overload?

Mr. Adcock: Yes, sir.

Mr. Justice Brandeis: How much is the overload, in comparison with the capacity of the channel?

Mr. Adcock: Well, it creates a condition in the Illinois River that is bad. It is due principally to trade wastes that have to be taken care of.

Mr. Justice Brandeis: How large is that overload, estimated in percentage?

Mr. Adcock: About fifty per cent. It represents all the sewage of about a million and a half people.

Mr. Justice Brandeis: And is it the impossibility of producing these supplemental works before the end of twenty-one years that leads to their being deferred until 1945?

Mr. Adcock: No. In order to work out this project—the art of sewage disposal, if you can call it an art, has been in a state of flux or change for a great many years; and one method would be adopted, only to be thrown away for some other method; and it has required—

The Chief Justice (Interposing): In the meantime, you have opened the exit from Lake Michigan?

Mr. Adcock: Yes; but the studies of these methods have been going on all the time, and it has been assumed—

The Chief Justice (Interposing): It has been done on the theory that you needed the water?

Mr. Adcock: On the theory that we had to have the water, and that it is absolutely necessary for the disposal of the sewage.

(Thereupon, at 4:30 o'clock p. m., the Court adjourned until Tuesday, December 9, 1924, at 12:00 o'clock noon.)

SECOND DAY.

Washington, D. C.,
Tuesday, Dec. 9, 1924.

The above-entitled cause came on, for further oral argument, before the full Court, at 12:00 o'clock noon.

Appearances as heretofore noted.

Oral argument of Daniel N. Kirby, Esq., amicus curia, in favor of appellant.

Mr. Kirby: May it please the Court: On behalf of my associate, Mr. Lynde of Chicago and myself, I desire to express our appreciation of the courtesy of the Court in permitting us to participate, and of the courtesy of the parties to the record in consenting.

We are here representing the States of Illinois, Missouri, Tennessee and Louisiana; also various chambers of commerce and boards of trade in the cities of Chicago, St. Louis, Memphis and New Orleans. We also represent the Mississippi Valley Association, an organization whose membership includes shippers, persons interested in navigation, extending from St. Paul to New Orleans, and who therefore, in their interests, represent the whole of the Mississippi Valley. So it may fairly be said that we represent the people and commerce of the Mississippi Valley.

The Mississippi Valley is interested in this decree and in its effect, from two points of view, and for two reasons: *First*, in respect of navigation in the Mississippi Valley; and *second*, the question of sanitation as affecting the State of Missouri, particularly, and the State of Illinois directly.

As to navigation, the primary interest of all of the Mississippi Valley is, of course, for the improvement and the direct use of the Mississippi River and of this historic highway from the Lakes to the Gulf, for the purposes of navigation and commerce.

This decree, we submit, will prejudice the navigability of the Mississippi River itself, if it should be put into effect. The extent to which the navigability of the Mississippi River is prejudiced will appear from the fact that the low water flow of the Mississippi River at St. Louis—and low water time is the critical period of navigation of the Mississippi River—the total flow is only 33,000 cubic feet per second, including this 10,000 cubic feet which is obtained from Lake Michigan.

Now, if this decree goes into effect and more than half of that added water taken from Lake Michigan should be taken out of the Mississippi River, the effect upon navigation between St. Louis and Cairo, Illinois, which is the critical part of the river, will be seriously impaired.

The navigability of the Mississippi River and the supply of water for navigation in that stream has become lessened through the effect of the drainage of swamps in the sources of the tributaries of the river in the far north; so that the critical time in the navigation of the river is becoming more and more a problem of difficulty to the engineering department of the United States.

The secondary interest that these Mississippi Valley States have in this question of navigation is due to the fact that, because of the revived interest in navigability of the Mississippi River due to the Government's cooperation since the war in creating and operating a barge line from St. Louis to New Orleans, which carries vast quantities of freight now between those two points; a single barge load of grain carrying as much grain from St. Paul to the Gulf as a whole trainload of freight cars. It has revived interest of the whole Mississippi Valley in the navigability of the inland waters and in the promotion and further carrying out of the project, which has been under contemplation and consideration by the Government for many decades, and that is the project for a deep waterway from the lakes to the Gulf.

Now, the existence of an available, an actual, route by water, not only from the cities and towns immediately upon the Mississippi River and its tributaries that are navigable, but available for part rail and part water routes, extends the influence of this decision not only to the immediate Mississippi Valley and to its navigable tributaries, but all over the West, so far as the rail lines reach, over which, in conjunction with this water route, there are available combination rail and water rates, and the existence of this available water route from St. Louis, or from a point higher on the Mississippi, to the Gulf at this time has the effect of a leveling and lowering influence upon the rail rates to the Coast from all of these shipping points in this vast territory that may be called the "Mississippi Valley freight territory,"

and the trade territory tributary to the Mississippi Valley itself.

So that, in respect of navigation, these States and people are vitally interested in the question whether the navigability of the Mississippi River and of this proposed waterway and of this historic waterway between the Lakes and the Gulf, is going to be seriously impaired by the effect of this decree.

Next, the State of Illinois, in respect of sanitation, is directly interested, because this record shows that, if the flow, taking into consideration the increased population of Chicago and the increase in its surface waters and sewage—because of the increase in population and industrial consumption and use of water, which tends to poison it—if that flow of 10,000 cubic feet per second be cut down more than one-half, as this decree would do, why, then, the record shows that a condition of very grave menace to the health of the people of Chicago, and all the communities along the canal, the DesPlaines and Illinois Rivers, will be seriously threatened.

Of course, we in Missouri, and in St. Louis particularly, under the decision of this Court in *Missouri* v. *Illinois*—if we must fall heir to the sewage of Chicago in our drinking water, we are vitally interested in the question of sanitation, to the extent that the water that comes from Lake Michigan shall be adequate to safely dilute that sewage so that it will not be a menace to the health of the people of St. Louis.

The States lower on the Mississippi River are not immediately interested in that question of sanitation, because, by processes of nature, the water probably becomes purified.

With these interests and these peoples, and this vast extent of territory to be prejudiced by this decree if enforced, we have examined this record, and we respectfully submit that it presents a very narrow issue, as a matter of law. This

is not a suit by the Government to abate a public nuisance. It is not a suit by the Lake States, or any of them, complaining that the State of Illinois, as part owner of the waters of Lake Michigan, is making an unfair, unjust or inequitable use of those waters, to the prejudice of the Lake States.

Nor is it a suit by the Government of the United States, based on the general ground that the State of Illinois is making an undue or unreasonable use of navigable waters within its own borders.

The sole basis of these bills, your Honor, is that they rest upon the charge and the legal theory that any diversion of waters from Lake Michigan by the State of Illinois is unlawful, unless it be authorized by the Federal consents prescribed by section 10 of the Rivers and Harbors Act of 1899.

Now, that obviously brings before this Court, as the first question for legal consideration, the very important question of the sovereign power of the United States, and of Illinois, in respect of what Illinois has done in relation to navigable waters within her borders. Because it should be remembered that even Lake Michigan is wholly within the United States. No part of Canada borders on Lake Michigan; that all of the work that Illinois did, either directly through its own State expenditures of money, or through this subordinate agent of Illinois, has been done upon the navigable waters of the United States, wholly within the borders of the State of Illinois. That is, the work directly affecting waters of the United States within the borders of the State of Illinois.

Now, if the Court please, Mr. Adcock did not have time yesterday to state *seriatim* to the Court the legal propositions on which the Sanitary District and the State of Illinois, and this side of this great controversy, rest in this case. And they have asked me if I would read to the Court, or state to the Court, *seriatim*, what those propositions are, so that before the Government counsel make their arguments, the Court will have before it, in a connected and complete form

what these legal questions are, and what the contentions are; and to the extent that my time permits, I shall endeavor to deal with one or two of what I regard as the more important of these questions.

> "Proposition 1: The action of Illinois in providing for the diversion of water for navigation and sanitary purposes was valid, in the absence of any Congressional action."

In other words, our contention is that this case falls within the class of cases designated by this Court in many of its decisions as of the concurrent jurisdiction class, rather than within the class of cases wherein the legislative jurisdiction is exclusively vested in Congress.

In other words, until Congress acts, under the decisions of this Court in the concurrent jurisdiction class of cases, we understand the law to be firmly established that the State is free to exercise its sovereign power to use navigable waters within its borders, by bridging them; by building dams in them; by appropriating and diverting those waters for the public benefit of the people of the State; unless and until Congress shall step in with its superior power and interfere or regulate what the State has thus attempted to do, in the absence of Congressional action.

> "Proposition 2: Upon the entrance of Illinois into the Union, Congress recognized Illinois' authority to divert the waters and invited it to divert the waters."

Mr. Justice Sutherland: Will you not read that again, Mr. Kirby?

Mr. Kirby: Yes, your Honor:

> "Upon the entrance of Illinois into the Union, Congress recognized the authority of Illinois—"

Meaning its State sovereign authority—

> "to divert the waters of Lake Michigan into the Mississippi watershed, and it invited Illinois to do so."

This contention is based, *first,* upon what Mr. Adcock read to your Honors yesterday as to what happened in Congress when Illinois was admitted.

The resolution in its original form for the admission of Illinois into the Union did not contemplate including within the borders of Illinois any of Lake Michigan. But upon the floor of Congress an amendment was offered on the same day that the act of admission was passed; the effect of that amendment being, so far as this case is concerned, that in order to invite the attention of this new State just being admitted into the Union to the desirability of opening a waterway to connect the water of Lake Michigan with those of the Illinois River, it would be well to give Illinois as a part of her territory some of Lake Michigan; and that was done; the amendment became a part of the act of admission.

So that when Congress took the State into the Union, there was that invitation to look into this matter of the waterway; an invitation to the State to exercise its sovereign power in that regard.

Again, in 1822—Mr. Adcock read to your Honors the act by which at that time Congress more definitely expressed the same desire; because then it made a grant of land to the State of Illinois for the purpose of assisting the State in opening this very canal, the stated purpose of which was to unite the water of Lake Michigan with those of the Illinois River.

And again, the act of 1822 having become void because Illinois could not carry it out, the act of 1827 was passed, expressly in terms for the purpose of aiding the State of Illinois to unite the waters of Lake Michigan with those of the Illinois River.

And what did that mean, your Honors? What was necessarily implied in that? It was the recognition by Congress, we submit, of the fact that Illinois had sovereign authority as a sovereign State to act in respect of navigable waters

within its own borders, unless and until Congress should interfere. And in aid of that State power, Congress said in this act of 1827:

> "We will give you land that you can sell for the purpose of enabling you to carry out this State work and this State plan, which we invite you to engage upon involving these waters."

What would a Union of those two bodies be? Necessarily, it meant a diversion of water from Lake Michigan into the Gulf of Mexico, because the Gulf was lower in level than Lake Michigan.

The Chief Justice: Do you think Congress would have the power to delegate or give away its control of navigation, by legislation which should bind Congress not to restrict the taking of water which might interfere with navigation?

Mr. Kirby: No, your Honor, I do not think Congress could give away the power granted it by the Constitution under the Commerce Clause.

The Chief Justice: And if not, then the arguments here are only arguments with reference to its purpose, and therefore, there is nothing to prevent Congress from restricting it. Now, Congress has restricted it, has it not, in section 10 and section 12 of the act?

Mr. Kirby: We think not your Honor. We do not think that section 10 or section 12 of this act intended at all to delegate from Congress to the Secretary of War, especially when the Secretary of War could act only on the recommendation of the Chief of Engineers, the broad power to say that a diversion of Lake Michigan might be made into some other watershed. Congress never intended to delegate any such power. We think there are powers delegated there, and that they are powers appropriate to be delegated, and that they have delegated them in a constitutional manner. But we think that if the act is sought to be interpreted as making a wide delegation of power on questions of public policy, as

the question of your Honor intimates, such a delegation would have been unconstitutional, because Congress did not attempt to prescribe any general principles, or any rules subject to which the Secretary of War should determine the questions—the very questions affecting the public policy and the international controversies that might follow from the delegation and the exercise by a delegated administrative officer of such broad legislative powers as those involved. We think that section 10 has a very useful and a very wide scope. And I shall not have time to discuss it more, because I would like, if the Court will permit me, to cover these points in this statement.

The Chief Justice: Go right ahead.

Mr. Kirby: But that is our attitude about section 10 of the act.

The next proposition is—

> "That Congress has continually cooperated with Illinois over the long period of years since the 1827 act was passed; and it has never yet indicated its disapproval of this diversion, and has never yet attempted to either stop this diversion or to regulate it."

The next proposition is—

> "The Congress, by its attitude and action, has approved what Illinois has done in opening this canal and conducting this diversion of water from Lake Michigan, by repeatedly appropriating and expending money to help complete the work in the Chicago River and connect with appellant's channels."

In the decision of this Court in *Chicago Street Ry. Co.* v. *People*, in 201 U. S., it was held that the work thus provided for could have been completed and carried out without the permit. And that was the ruling of this Court.

In other words, there exists in this case a direct assent or consent of Congress itself, this Court held in that *Street Railway* case in Chicago, the subject of which was the lower-

ing of some tunnels that ran under the Chicago River and were used for street railway purposes; and in that case the permit of the Secretary of War had not been obtained for the doing of the work—this Court held that it was not necessary, because the consent of the Congress had been directly given for the doing of that work, and all that was reasonably to be implied from that consent went with the consent.

Mr. Justice Holmes: I remember a case of that kind, but I do not know the citation.

Mr. Kirby: That is in 201 U. S.

Mr. Justice McKenna: You did not give the page?

Mr. Kirby: No, I did not. I have not the page here.

My next contention is:

> "That section 10 of the Rivers and Harbors act of 1899, which is the act on which these bills are founded, cannot be construed to delegate to the Chief of Engineers and the Secretary of War authority to fix the quantity of water that may be diverted."

In other words, if the Sanitary District now went to the Secretary of War and the Chief of Engineers with a new proposal to divert from Lake Michigan through a small river into the Mississippi Valley, the contention is that the Secretary of War was not intended by Congress to have the power to determine whether a diversion could or could not be made, his power being limited to certain administrative features relating to the method in which the work could be done; and that that construction of the act appears more strongly from the fact that the approval of the thing through the Secretary of War must originate with the Chief of Engineers; that what Congress had in mind was that any work proposed to be done which would affect the navigable capacity of the waters of the United States should be so done, as to its manner of construction and the laying out of the work, and all of the engineering features affecting the method of doing that work,

as would be in harmony with the policy and plans of the engineering department in respect of the navigable waters of the United States and their improvement and whether the proposed work would prejudice their navigability. In other words, that the proper construction, and the only lawful construction, the only constitutional construction that may be given to section 10 of the act is that it is administrative in nature and narrow in scope, for the purpose of protecting the engineering features of work which is to be done.

Mr. Justice Sanford: Would you say that they could not provide for the limiting of the amount of water taken, in so far as it affected the navigability of the river by the Secretary of War?

Mr. Kirby: Certainly; but not to determine the broad question.

Mr. Justice Sanford: And that these permits were strictly in exercising that power?

Mr. Kirby: Certainly, that is it; that is a matter affecting the engineering features.

Mr. Justice Brandeis: Why is not the navigability of the lake and of the harbors at the lake ports also an administrative question?

Mr. Kirby: I think it would be, your Honor, so far as the channels into the lake are concerned.

Mr. Justice Brandeis: Well, according to the testimony, the depth of the harbors was affected by this diversion?

Mr. Kirby: But the United States itself did the work of the deepening of those harbors, so as to cooperate with this diversion of waters.

Mr. Justice Brandeis: Well, then, why should not the amount of the deepening necessary to preserve navigation be a matter which the Secretary of War could determine?

Mr. Kirby: I think the matter of the deepening of the channel itself would be a matter that would properly fall under the jurisdiction of the Secretary of War and the Chief of Engineers. But the fundamental question whether Illinois is to be allowed to divert or not is a different question—

Mr. Justice Brandeis (Interposing): No,—how much; not whether it can take, but how much is proposed to be taken?

Mr. Kirby: Yes. But in the act of 1827, in which there was no limit of the amount of water that was to be diverted in order to accomplish this union of the waters of Lake Michigan with those of the Illinois River—what is the reasonable construction that the parties themselves have put upon the depths and the effect of the development of navigability of those waterways? The diversion by the State of Illinois actually began in 1848. There was diversion then, but it was under gravity flow, and gravity flow could not accomplish the purpose, because there was no cut through the divide; the cut was not deep enough.

In 1871, they cut the channel deeper, from 1871 on, with never a protest from Congress, with never an objection from Congress to the continuation of such diversion, Illinois has continued, either directly or through this Sanitary District, to divert water—what quantity? Such quantity as Illinois, under its own statutes, declared to be reasonable and necessary. For what purposes? For two purposes: *First*, for sanitation, which was an entirely proper subject for Illinois to use these waters for—for protecting the health of its own people.

And *second*, for navigation. And navigation was not a mere incidental, because what money that Illinois spent and the work it did was in harmony with the very plans and projects of the engineering department for the development of this deep waterway proposed to be built between Chicago and the Mississippi River.

Mr. Justice Brandeis: What was the largest diversion up to the time when this 4,000 feet was authorized?

Mr. Kirby: 60,000 cubic feet per minute. That is all that the old Illinois and Michigan canal would take, as I understand it. The cut through the divide would only permit that much. That quantity—while that began in 1871, when the deep cut was first made, it diminished, through the gradual decrease of the water supply and the lowering of the level of the Lakes that occurred about that time; there is no charge that it was due to this diversion.

But this whole present diversion we claim is a lawful diversion, and a continuation of the diversion of the old Illinois and Michigan canal, and not, as the Government claims, a new diversion beginning with the present ship canal. This entire diversion began in a small way. Chicago was small. The needs of navigation were small. As the States grew and as the needs grew, they had to increase it for both purposes; there is no doubt about that. It might be conceded that sanitation was the primary purpose, but it was a lawful purpose.

The Chief Justice: Do you mean it was the primary purpose of the act of 1827?

Mr. Kirby: Oh, no, your Honor.

The Chief Justice: Well, is there anything in that act that indicates that sanitation was any purpose?

Mr. Kirby: No, your Honor; we suppose that Congress would have no power to grant for sanitation purposes to the State.

The Chief Justice: Well, but it has power to give permission for changing the level of the Lake?

Mr. Kirby: Yes, sir.

The Chief Justice: And if that was for sanitation, then I should say that the power to restrict would follow, in the interest of navigation?

Mr. Kirby: Obviously, the act of 1827 could deal only with such power as Congress had under the Commerce Clause, and that related to navigation.

The Chief Justice: Well, it has control over navigation; and the right to control navigation can be exercised by restricting the use for sanitation, or granting the use for sanitation?

Mr. Kirby: If the use for sanitation prejudices navigability, yes, your Honor. There is no charge of that kind in this case. This case rests entirely on the proposition that in lowering the Lake levels—that any diversion of water from Lake Michigan will necessarily lower the lake levels.

The Chief Justice: Well, it may.

Mr. Kirby: Yes; it will, appreciably.

The Chief Justice: Well, even though it affects sanitation, it affects navigation, and brings it within the power of Congress, does it not?

Mr. Kirby: Yes; but our contention is that Congress has expressly assented to that use of the waters of Lake Michigan.

The Chief Justice: In what way?

Mr. Kirby: By this act of 1827, for the purposes of navigation it has permitted the diversion. It wanted to unite those two bodies of water—to divert enough water from Lake Michigan to create a waterway available to meet the needs of the growing communities that might call upon it for use as the country develops. And Congress has never interfered with that, unless this Court shall construe this section 10 of the act of 1899 as intended to be an interference.

Mr. Justice Sanford: Do you mean to say that you are only removing so much as is necessary for navigation, and not for other purposes?

Mr. Kirby: Well, I will not say that, your Honor.

Mr. Justice Sanford: Then that consent will only extend to that which you are authorized to do, and for the purpose for which you are authorized to do it?

Mr. Kirby: Very true.

Mr. Justice Sanford: Now, if there is more than that done, how does it come under the consent?

Mr. Kirby: It does not come under the consent, except to this extent: That Congress knew perfectly well, and it is indisputable from the evidence in this case that it knew perfectly well, that Illinois, in its own sovereign power, was proposing to use it for the other purpose as well; and it has never interfered; but that on the contrary Congress was, in the act of 1827, and by a consistent course of conduct ever since, cooperating with the State of Illinois, by making repeated appropriations, the effect of which contemplated the continuance of this diversion of water by Illinois.

The Chief Justice: Although the consent had been refused, so far as the Executive was concerned?

Mr. Kirby: Yes, sir; but we had authority direct from Congress to make a diversion adequate to meet the needs of commerce, for the purposes of that canal.

When the act of 1899 was passed by Congress, may it please your Honors, Congress knew full well the full details of this project. They had before them the report of the Chief of Engineers showing exactly the quantity of water proposed to be diverted through this channel, 10,000 cubic feet of water per second. They knew the provisions of the Illinois act regulating the amount that Illinois was directing its subordinate to take out of Lake Michigan for the purposes of sanitation and navigation. And Congress has never acted since then to say that Illinois was prejudicing navigation—unless such action can be found in section 10 of this act.

Now, we think it important to keep in mind this distinction: That until Congress acted, Illinois had a right as a sovereign

to use those waters for sanitation; and all that it needed for sanitation, subject always to the superior power of Congress to interfere if it prejudiced the navigability.

In other words, while we are in a perfect position to say that the act of 1827 gave this consent of Congress, we are also in a position to say, under the doctrines of this Court in the concurrent jurisdiction class of cases, that, without the consent of Congress, or until Congress interfered to prevent, the State of Illinois, under its sovereign power could take as much water as it reasonably needed for such purposes as the State deems necessary. And the fact that these waters were partly within the borders of other States, and that to some extent this diversion might affect a foreign government, did not affect the right of the State—Congress' power being dormant—to deal with these waters as it pleased —subject always to the right of Congress to step in and say, "No."

The Chief Justice: You are now using extra time. You have consumed about thirty-seven minutes.

Mr. Kirby: My time was thirty minutes. I beg the Court's pardon.

The Chief Justice: Before you go, have you stated all of the legal propositions that you were reading?

Mr. Kirby: No, your Honor, I have not. But that is our misfortune.

Mr. Adcock: Go ahead and read them.

Mr. Justice Holmes: Will you tell me before you finish this: Is there somewhere in the briefs where those propositions are summed up that you can refer us to?

Mr. Kirby: I am afraid they are not summed up in this way in any of the briefs. It is a work that was done last night, for the purpose of condensing them.

The Chief Justice: Your associate says you can go ahead. Your side has the time.

Mr. Kirby: Thank your Honor. I will then read them without attempting to expound them.

Mr. Justice Holmes: I believe you had got through the fifth proposition.

Mr. Kirby: I think so, your Honor.

I am asked to say, in connection with what I have stated to the Court, that as late as 1904, after the act of 1899 had gone into effect, and after this present Sanitary and Ship Canal had been operating for four years, Congress, in one of the Rivers and Harbors Acts, granted consent to the State of Illinois to remove some of the obstructions in the Illinois River, the purpose of that grant being to stimulate and enlarge the flow of the Illinois River so as to exclude this diversion from Lake Michigan which was then being made.

And Mr. Adcock's brief in this case contains numerous instances in which Congress took action—not action indicating a hostile attitude towards the continuance of this diversion, but on the contrary, spending money and doing things which indicated a cooperative attitude by Congress with this continued diversion that Illinois was making, and with full knowledge on the part of Congress that Illinois was doing it for the purpose of sanitation, as well as for the purpose of navigation.

And now, I shall read the rest of the propositions:

"Proposition 5. Congress, by numerous acts providing for surveys and reports as to compensating works and means to offset for theoretical lowering of the level of the lake, has recognized the authority to divert; and if anything was to be done to offset for the effects upon navigation, Congress proposed to provide the works, instead of stopping the diversion.

If Congress had not recognized the authority and the right to diversion, it could easily, by special act, have stopped the diversion, instead of appropriating money to find means to make good what it was permitting us to continue to do.

Proposition 6: Congress has, in the improvements provided for in the Rivers and Harbors acts since appellant's channel has been opened, expressly taken care of any theoretical effect upon navigation.

The actual depths of harbors, are not less than the project depths fixed by Congress; so that actual navigability with respect to the harbors has not been prejudiced.

Proposition 7: The appellee must allege and prove substantial, unreasonable damage to navigation and to commerce. It has not sustained this proposition by proof, either with respect to the lakes, or with respect to the Chicago River.

Proposition 8: By virtue of the preceding acts of Congress, the Secretary of War, under section 10, had nothing to do with the quantity of diversion; and he so construed the situation in his original permit, and did not alter that position until 1913, after the district had made large expenditures carrying out the work contemplated by the original permit.

The jurisdiction of the Secretary was confined to issuing permits upon the recommendation of the Chief of Engineers, with reference to the manner of the construction of works in the Chicago River.

All the conditions of these permits have been complied with.

Either the Secretary of War has no jurisdiction over the quantity of the diversion, as we contend, or he has some jurisdiction. If he has jurisdiction, then in authorizing the construction of work at an expense of over $10,000,000, he exercised that authority and authorized the result of the work.

Proposition 9: The question before the Court is not whether there is a permit to flow 10,000 cubic seconds feet, but whether an existing work, through which flows that quantity, unreasonably interferes with the navigation of the river.

The proof is conclusive that there is no current in the Chicago River unreasonably obstructive to navigation; and as an instrumentality of commerce, it is one thousand fold superior to the river before appellant's expenditures began.

Proposition 10: For the sake of argument, forget all about permits and acts of Congress authorizing the diversion: The question, boiled down, is, Does the existing work protecting the health of Chicago substantially interfere with interstate commerce? If it does not, the works of Illinois being reasonable, any action on the part of the United States or even by Congress, destroying the same would be unreasonable.

Proposition 11: The equitable conscience of this Court cannot destroy $100,000,000 worth of property, and endanger the lives of 3,000,000 people, unless the law of the United States clearly and unmistakably so requires."

To which should be added that the act of 1910 did not intend to stop, regulate or interfere with diversions existing at that ime. It was prospective in its effect and intent, and not retrospective.

Mr. Adcock: You mean the act of 1899.

Mr. Kirby: I mean the act of 1899, under which the suits were brought.

The reference to the *Chicago Street Railway* case, Mr. Justice Holmes, is 201 U. S., 505, at 507.

Mr. Justice Sanford: I would like to ask you one question: In view of these arguments and propositions of law, would you allow that the suit could be maintained if the proofs showed that the diversion created a substantial impairment of commerce in the lakes?

Mr. Kirby: I would not, if a proper suit was brought for that purpose. But that is not this case.

Mr. Justice Sanford: Then you come back to the form of the suit?

Mr. Kirby: Yes, your Honor.

The Chief Justice: If you have not those points shown in your brief, you might make copies of those and hand them to the clerk.

Mr. Kirby: I thank your Honor.

Oral Argument of Hon. James M. Beck, Solicitor General of the United States, on behalf of the appellee, the United States of America.

The Chief Justice: Mr. Beck.

Mr. Beck: If the Court please: I have followed with great interest the first part of my learned brother Kirby's argument, and with great attention also; because in my judgment, its tendency is to sustain the contention of the Government, for the reason that it shows that, while the right of the Government to avail itself of an injunction to vindicate its paramount authority over the navigability of the Great Lakes is a justiciable question; yet the comparative benefits to the Mississippi Valley, or to the Great Lakes region, from the unlawful diversion of water from Lake Michigan is not a justiciable question, but is a political question, and that the forum to determine what shall be done, under a very trying situation, is for Congress and not for this Court.

For it is quite obvious, that this Court not only lacks the power, but lacks the means, to balance what have been called in the appellant's brief the equities of the case between Illinois and the Mississippi Valley and between the Great Lakes regions who, through their spokesmen, will shortly be heard.

Now, this case, notwithstanding a ponderous record and many briefs and the magnitude of the interests involved, seems to me a very simple one. It is like a watermelon, large in bulk but very slight in substance.

The contention upon which my friend based his last remark to the Court was that the form of this action was not to prevent an unlawful impairment of navigation of the Great Lakes, but simply to remove an obstruction in the matter of the Calumet River, and later, of the Chicago River. I shall presently show that that is a gross misconception of the language of the Government's bill.

Mr. Justice Sutherland: Mr. Solicitor General, before you get fairly under way, I would like to ask you this question: Does this narrative statement that has been furnished us by counsel on the other side from your point of view state the case correctly?

Mr. Beck: I think it is substantially correct. In our reply brief we have called attention to some inaccuracies; but we have no objection to the Court assuming its substantial accuracy, except where we have ventured to show that it was in error; and that has not occurred in many places. I have no doubt the narrative statement was prepared in good faith, and is a fair review of the 5,000 pages of testimony.

Now, before I come to the form of the action, I want to explain to the Court a little more in detail the history of these permits. I want to show, by chronological statement of the facts in the case, how far, as intimated by Mr. Kirby, the Government engineers and the officials in Washington have cooperated with the Sanitary District in changing the currents of two rivers and in diverting the waters of Lake Michigan to an amount which, if you estimated it, not in seconds, but in hours, staggers the imagination. I think that, if the Court will patiently follow me in this chronological statement of the official acts done between the United States and the Sanitary District, it will be in very little doubt, if any, with respect to the merits of the contention.

It begins before the Republic began, on July 13, 1787, when the Confederation passed the Northwest Ordinance, in which it was provided that:

> "The navigable waters leading into the Mississippi and the St. Lawrence, and the carrying places between the same, shall be common highways and forever free, as well to the inhabitants of this territory as to the citizens of the United States and those of any other States that may be admitted into the Confederacy, without any tax, impost or duty therefor."

When the Constitution took from the various States the power over interstate commerce, through conflicting regulations and imposed it in the Government they created, and when the first Congress of the United States came to meet, they reenacted this part of the Northwest Ordinance. So that, when the Territory of Illinois was constituted a State, it had, as this Court decided as recently as in the *Economy Light & Power Co. case,* reported in 256 U. S.—it decided that, while the Ordinance of 1787 making these Great Lakes and also the Mississippi River open highways for the benefit of the entire people of the United States—that while those provisions of the Ordinance did not act as limitations upon State authority, as contrasted with the powers which the Original Thirteen States had, yet, they did survive in full force as regulations of interstate commerce and as declarations of the National will with respect thereto.

Now, the next point to be remembered—and I shall refer to it hereafter; and I only refer to it now as indicating what should have been in the minds of the Sanitary District of Chicago when they embarked upon this hazardous experiment—is that, just a century ago, in this Court, in the case of *Gibbons* v. *Ogden,* the plenary power of the United States in respect to interstate commerce was vindicated; and thereafter it became perfectly clear, in a succession of decisions, that while, as to navigable rivers wholly within a State there were still reserved some rights with respect to local facilities and purely police regulations, whose validity would be assumed until Congress declared to the contrary, yet, with respect to interstate navigable rivers or highways, the State had no reserved power with respect to those, and that even if Congress had not acted with respect to interstate highways, yet its very silence and inaction was a declaration that those water highways should flow unvexed to the destination Nature had ordained for them.

Of course, the whole point in *Gibbons* v. *Ogden* was that, although the Hudson River was wholly within the State of New York, nevertheless it was not competent for the State of New York to determine the conditions of its navigability.

Now, that being so, we come to the point—and I shall dismiss it very briefly—we come to the two acts of Congress, of 1822 and 1827. Of the first it is unnecessary to say more than that, Congress having made a donation of land for the construction of a canal upon certain conditions, the conditions were never complied with and the canal was never built under that act.

When, however, Congress in 1827, acting upon a memorial of the people of Illinois, granted certain lands for the purpose of constructing a canal, the dimensions of the canal can be measured by the fact that the memorial which was addressed to Congress and upon which it acted contemplated an expense of $700,000. At all events, that canal is not this canal. And I venture to say that at the time that act was passed by Congress, Chicago was not even in existence, unless it was a trading post, with, possibly, a few houses; but at all events, as a municipality it was not in existence.

And I venture to say that no more untenable proposition has been advanced to this Court—and that is saying a great deal—than the suggestion that an act of Congress granting land in aid of the construction of a canal in 1827, for navigation purposes, before Chicago had any political existence—that that should be regarded, for all future time, as an authority to a city that thereafter came into existence to construct a canal the cost of which they say, with its attendant works, now amounts to $100,000,000—not for the purpose of navigation, but primarily as a common sewer. To say that the construction of a little canal nearly a century ago, for one purpose, is an implied authority for the construction of another canal for an entirely different purpose, is a proposi-

tion that I shall not take the time of the Court to further discuss.

In 1889, the State of Illinois embarked upon this hazardous, and as I fear it may prove, fateful experiment. They created, having had through various commissions examinations made into the subject of what should be done with the sewage of Chicago, which at that time was a city of about a million and a half people—they passed the act which created the Sanitary District, and which made it mandatory for all time for the Sanitary District to take from the waters of Lake Michigan an amount of water proportionate to each 100,000 people of that city. And that in face of the fact that, of course, Chicago was already growing by leaps and bounds.

Now, at that time, it is well to remember, three other great cities had, in the same decade, considered the same problem. London, which has twice the population of Chicago, and Berlin and Paris, which have approximately the same population as Chicago. And every one of them, without in any way diverting the waters of the waterways upon which those cities are located, found a way to dispose of sewage by eliminating the solids from the liquids, then treating the solids chemically, and in that way disposing of it in a way that still maintained the purity of the drinking water and at the same time the health of the people. And to this day the great city of London and the great cities of Paris and Berlin have solved this problem without any such unlawful appropriation of other people's waters as marked the action of the Sanitary District in this case.

However, there was this temptation to the State of Illinois to adopt the method that they were going to adopt, namely: That it was not only a great deal cheaper—because, as Secretary Stimson, I think it was, so well said when he came to dispose of the questions in one of the applications made to him, it was not merely a question of comparative methods of sanitation; it was a question of cost; and it was a great

deal more economical for Chicago to utilize the waters of Lake Michigan to flush a canal that was thenceforth, primarily, at least, a great sewer, than to dispose of its sewage in the approved, modern chemical methods such as were adopted by London, Paris and Berlin.

Moreover, Chicago determined to further reduce the expense of the improvement by constructing great hydroelectric works at Joliet, was it not?

Mr. Fleming: Lockport.

(Mr. Beck (Continuing): Great hydroelectric works at Lockport, to utilize the current thus created by the diversion of waters of Lake Michigan through the canal. And thereby it has maintained a very large electrical producing company, which has furnished the parks and the public buildings of Chicago with light, and has given a great advantage to Chicago by utilizing such power.

It is quite obvious that such power could never have been created had they not forced into this drainage canal this current of 10,000 cubic feet per second. Because, so far as the navigation is concerned, the reports of the engineers are that the diversion of 1,000 cubic feet per second is all that the canal needs for navigation; but that for the purpose of creating a current that would run three miles an hour, it was necessary to divert a much larger volume of water, and thereby create the hydroelectric works which would enable the cheap generation of electricity.

Thereupon the State by legislative act created, as I said, this Sanitary District of Chicago, which is the appellant in the case.

Now, before they had asked for a bid; before a spade had been driven into the ground; before there had been any expense incurred whatever by the City of Chicago, Congress, which up to that time had remained silent on the subject, passed a law which was a plain assumption of full authority

by Congress over the navigable waters and lakes of the country, and likewise included a specific prohibition of the very thing that the Sanitary District was planning. For under the act of September 19, 1890, passed shortly after the Illinois act which created the appellant, it was provided—

> "That the creation of any obstruction, not affirmatively authorized by law, to the navigable capacity of any waters, in respect to which the United States has jurisdiction, is hereby prohibited."

And it is further made unlawful for any one—listen to these words—

> "in any manner to alter or modify the course, location, condition or capacity of the channel of said navigable waters of the United States, unless approved and authorized by the Secretary of War."

Therefore, in 1890, before they had expended one penny upon this great improvement, they had fair notice that, if they thereby desired to impair or alter the course, location, condition or capacity of the channel of any navigable waters of the United States, they must first get the consent of the Secretary of War.

Now, let us see how they tried to get that consent, and what happened:

In 1892, the United States became aware of the fact that Chicago was planning a very extensive water scheme, which might threaten the navigability of the Lakes. A board of engineers was then appointed to consider and report upon "the probable effect of the operation of the Chicago Drainage Canal upon the lake and harbor levels and upon the navigation of the Great Lakes and their connecting waterways."

Now, please remember, therefore, that the War Department appointed a board of engineers before even the bids had been invited for the construction of any part of this work.

On March 22, 1895, the United States Engineer at Chicago wrote to the Sanitary District to ask for information to aid

the board of engineers, as to what conclusions the Sanitary District had arrived at as to the effect of its plans—I am now quoting—

> "upon the levels of the Great Lakes by the operation of your canal."

On August 16, 1895, the board of engineers reported—now listen to this:

> "The abstraction of 10,000 cubic feet of water per second from Lake Michigan will lower the levels of all the lakes of the system, except Lake Superior, and reduce the navigable capacities of all the harbors."

That would not seem to require any extensive engineering genius, to know that; because I would simply like to indicate to the Court what 10,000 cubic feet per second means in one single calendar day: It is 864 millions of cubic feet of water every day of the year that Chicago is now diverting, and has steadily diverted during the sixteen years that the United States, in its own courts, has sought by peaceful methods to stop it.

So I say that on August 16, 1895, the board of engineers of the War Department had already found the fact that the abstraction of 10,000 cubic feet of water per second would have that effect.

On June 16, 1896, the Sanitary District wrote to the Secretary of War, and after referring to the fact that the canal was under construction, asked his permission to proceed with the work upon the lines indicated, and so far as is consistent with propriety, the cooperation of the United States engineering department.

On July 3, 1896, the Secretary of War, having under consideration the question whether the abstraction of even 5,000 cubic feet of water per second would affect the navigability of the Chicago River and of the Great Lakes, permitted the change of the current of the Chicago River, with this proviso:

> "That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago

to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.

That it will not cover obstructions to navigation by reason of this work while in progress, or when completed."

So they had expressly said that, while the permit was given to extract 5,000 cubic feet per second from Lake Michigan, it was not to be interpreted as approval of the plans of the Sanitary District.

Now, on October 28, 1897, the Secretary of War, having under consideration an application of appellant to widen the Chicago River, gave the same authority, but with the same condition above quoted.

On November 30, 1898, the Secretary of War, having again under consideration an application—and when I say "an application," I mean always by the appellant—to build a coffer dam on the Chicago River, called the attention of the Sanitary District to the act of 1890—that is the act which I just read, which made it unlawful to alter in any way the channel of navigable waters.

On December 16, 1898, the Secretary of War, having under consideration appellant's application to remove certain bridges on the Chicago River, again granted leave; and again with a like recital of the paramount authority of the Federal Government.

On March 3, 1899, Congress strengthened the act of 1890.

And let me say how that came to be strengthened; because it has not yet been suggested to the Court: The act of 1890 made the creation of any obstruction not affirmatively authorized by law to the navigable capacity of any water in respect to which the United States had jurisdiction unlawful.

Now, this Court in the *Bellingham Bay Boom* case, held that the words "authorized by law" included the law of a State, as well as a law of Congress.

And thereupon, in 1899—and by that time the Sanitary District works were nearing completion but had not yet been completed—in 1899 Congress, presumably in view of the decision of this Court, that an obstruction might be authorized under a State law without offending the provision of that act, strengthened it in the following way; it provided:

> "That the creation of any obstruction not affirmatively authorized by Congress to the navigable capacity of the waters of the United States is hereby prohibited."

And then it again added:

> "That it shall not be lawful in any manner to alter or modify the course, location, or condition or capacity of any port, canal, lake, or the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to the beginning of the same."

Now, on March 10, 1899, another permit was granted to erect another bridge over the Chicago River, with a like condition.

On April 22, 1899, appellant again applied for permission to open the channel constructed by it as soon as it was completed. That is interesting, as showing that when Congress strengthened the act of 1890 by the act of 1899, as a matter of fact their works were still under construction and had not been completed. The application recited the necessity under the act of 1890 of obtaining the authority of the War Department; that is, the appellant's own application recited the necessity of getting the consent.

Thereupon, it was referred by the War Department to the local engineer of the United States in Chicago. And I want to read a part of his report to his superior. He says:

> "It is a strange fact that this city has expended, or will expend, over $30,000,000 with the intention of diverting an apparently unlimited amount of water from the Great Lakes to the Mississippi drainage area for

sanitary purposes, without finding out whether such diversion would be allowed by the great interests of the United States and the Colonies of Great Britain along the chain of Great Lakes in the navigation of the rivers and harbors of the Great Lakes. Now they ask the authority of an executive officer of the United States to open a channel that will, to some unknown extent, lower the levels of all the Great Lakes below Lake Superior and of their outlets, introduce a current, also unknown, and not to be ascertained otherwise than by actual experiment, in Chicago River, the most important navigable river of its length on the glode, but which is already obstructed by bridges, masses of masonry and bends, and of difficult navigation at best."

On May 8, 1899, the Secretary of War authorized the opening of the channel upon the following conditions:

"The Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the water of Chicago River to flow into the same, subject to the following conditions:

"(1) That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

"(2) That if at any time it becomes apparent that the current created by such drainage works to the South and main branches of the Chicago River be unreasonably obstructive to navigation"—

Note that:

"Be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close the discharge to said channel, or to modify it to such extent as may be demanded by navigation and property interests along said Chicago River and its South branch."

Then appears a third provision, that the Sanitary District must assume responsibility for all damage done to navigation by the change of the current of the river.

On July 11, 1900, the War Department, responsive again to applications of the Sanitary District, gave permission to make certain changes in the Chicago River, with the proviso that they were to be subject to the conditions that I have already read.

On April 9, 1901, the Secretary of War restricted the flow of the Chicago River to 200,000 cubic feet per minute.

On July 23, 1901, the Secretary of War again, on application of the appellant, modified the order, so as to permit 300,000 cubic feet per minute between certain hours.

Mr. Justice Holmes: What date was that?

Mr. Beck: July 23, 1901.

On December 5, 1901, upon a further application of appellant, a permit was granted it to divert 4,167 cubic feet of water per second, upon the following conditions—

Now, while our case does not rest upon this permit, yet it is well to remind the Court that the question before the Court is, not whether Chicago Sanitary District was planning these vast works; it is not whether the Sanitary District shall stop the appropriation of the waters of Lake Michigan. It is purely a question whether the Sanitary District shall be entitled to take more than 4,167 cubic feet per second from Lake Michigan, for its municipal purposes. And again, translating that into a day, it means, each day, 432 million cubic feet.

Now, in 1901, the Secretary of War granted permission to take 4,167 cubic feet of water per second; and these were the conditions upon which he gave the permit:

> "That this permission shall be in lieu of the present authorized rates of flow as stated above."

That referred to the 300,000 cubic feet per minute between certain hours of the day, for a certain time.

> "(2) That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require."

So it was not merely a question of the navigability of the Chicago River, as to which there was a contention that this vast forced current was affecting its navigability. The Secretary of War said that, whatever the public interests might hereafter require, the permission must be regarded as subject to that.

Then follows the third provision, as to the responsibility of appellant for damages to navigation.

On December 29, 1902, the Secretary of War issued a permit authorizing the Sanitary District to divert for a certain 350,000 cubic feet per minute. That is, of course, a great deal more in a day; and in issuing the permit it was stated:

> "We recognize your responsibility as guardian of the interests of navigation."

On January 17, 1903, a permit was granted of the additional flow of 350,000 cubic feet per minute until March 31, 1903, when it expired.

On March 14, 1903, the Illinois Legislature increased the corporate limits of the City of Chicago, which, of course, very much changed the nature of the problem; and although it is not necessary for my case to say that what was done when Chicago was a small city is not necessarily binding upon the Government in reference to the larger city, yet it is well to remember, when you consider the acts of the Washington Government in this matter, that the situation was changed with the growth of Chicago, and with this special act, which very much increased it.

On March 14, 1907, the Secretary again having under consideration an application to reverse the flow of the Calumet River—and now we come to where the fight begins. They thereupon, having obtained the permission of the Secretary of War to change the current of the Chicago River so that, instead of flowing into Lake Michigan, it would thence flow through various rivers into the Mississippi, and thence to the Gulf—

Mr. Justice Holmes: (Interposing) Was that in 1907, did you say?

Mr. Beck: 1907, yes, this last date; March 14, 1907. They thereupon asked for a like provision to reverse the flow of the Calumet River, so that it would flow southward, instead of eastward.

Mr. Justice Sutherland: That is further north, is it?

Mr. Beck: It is further south.

Mr. Justice Sutherland: Yes, I see—it is southwest.

Mr. Beck: The Secretary of War, after reciting the report made by the Chief of Engineers on this application, which stated that:

> "In my opinion, this abstraction will undoubtedly lower the levels of all the waters of the Great Lakes, except those of Lake Superior, and thus diminish the nagivable capacity and depth of the various channels and harbors which have been deepened and improved under authority of Congress."

After reciting that, the Secretary of War declined the permit, stating that it was one that required submission of this great question of capital and National importance to the Congress of the United States.

On September 11, 1907, the Secretary of War again, upon an application to connect Lake Michigan with the North

Branch of the Chicago River, gave the permission, with the express proviso:

> "That the total diversion of water from Lake Michigan through the Chicago River into the Illinois River shall be no greater than already authorized by past War Department permits."

Now comes the act as to which Mr. Adcock was prudently very silent.

Up to that time the Sanitary District had recognized the paramount authority of the Federal Government over these extra territorial waters—I mean Lake Michigan. It had at all times recognized that all it could obtain of waters that were beyond its territorial boundaries was that which the Federal Government would permit. It also recognized that it could not reverse the course of two rivers that, for centuries had flowed into Lake Michigan, without the consent of the Federal Government.

But the moment that the Secretary of War declined to reverse the course of the Calumet River, as he had authorized the reversal of the course of the Chicago River, the Sanitary District thereupon passed this resolution:

> "Whereas, This board is advised that it has the right and that it is its duty under the laws of the State of Illinois to construct its said channel and reverse the flow of said Calumet River, notwithstanding the refusal of the Secretary of War to issue a permit authorizing the same, for the purpose of furnishing the proper sanitary methods of disposing of the sewage of the territory and inhabitants contiguous to the said proposed channel and within the corporate limits of the Sanitary District of Chicago, and unless restrained by a court having jurisdiction of the subject matter at the instance of the United States Government."

In other words, it simply flouted the Federal authority over the question and insisted that it was going to take what Chicago needed for its sanitary purposes, the War

Department to the contrary notwithsanding, unless a court should declare otherwise.

Mr. Justice Butler. What was the date of the resolution?

Mr. Beck: The resolution, sir, is September 18, 1907.

On March 23, 1908, on what was an implied invitation to us to begin an action if we wanted to vindicate Federal authority, we brought this action.

It has been intimated to this Court—or, at least, perhaps I misunderstood my learned brother—that all that this action contemplated was an action to restrain obstructions in the Calumet River. Now, let me read, so that you may know the nature of this suit that we brought after the challenge to our authority.

Without taking too much time to read it, the third and fourth paragraphs at great length—I am reading from volume 8 of the transcript of record—paragraphs three and four at great length describe the impairment to the levels of the Great Lakes by the proposed construction; and then coming down to the final averments of the bill, which will show its true nature, it says:

> "*Eleventh.* Your orator further represents, upon information and belief, that the defendant desires, proposes and intends to divert the waters of Lake Michigan as aforesaid, through the said Calumet rivers and the Calumet-Sag Channel as aforesaid, for sanitary purposes and for the development of valuable water power which it proposes to sell; that the Congress of the United States has not fixed any amount of such waters for such proposed diversion, and has not provided for the diversion of any of such waters through the said Calumet rivers and the said Calumet-Sag Channel, and that the Secretary of War of the United States, under the direction of Congress, or in any other way, has not fixed any amount of such waters for such proposed diversion, but, on the contrary, has refused so to do, and has refused to authorize the diversion of any of such waters through said rivers and said channel.

"*Twelfth.* Your orator further represents that the defendant cannot lawfully construct or maintain the said proposed Calumet-Sag Channel as above described, cannot lawfully reverse the flow of the said Calumet rivers as it plans and proposes to do as aforesaid, and cannot lawfully divert and abstract the waters of Lake Michigan as it plans and proposes to do as aforesaid.

"*Thirteenth.* That the defendant on the sixteenth day of October, 1907, actually began the excavation of the said proposed Calumet-Sag Channel, at the westerly end of the same, with a force of men under the supervision of one William M. McCartney, its assistant engineer, and your orator is informed and believes, and so charges the facts to be, that the defendant intends to, and will, continue and complete the construction of said channel," etc.

Well, perhaps I ought to read it:

"And will, continue and complete the construction of said channel, reverse the flow of the said Little Calumet and the said Calumet rivers as aforesaid, and divert and abstract the waters of Lake Michigan as aforesaid, and maintain said channel as aforesaid, to the manifest and irreparable injury of your orator and its interstate navigation and commerce, unless restrained by the injunction of this honorable court."

It is an amazing fact that we are now in the concluding chapter of that litigation, that has been pending for 16 years. And if this Court will read the bill and answer, you will see that, notwithstanding a great deal of disingenous pleading—I mean averments in the answer—there was no reason whatever why the case should not have been disposed of upon bill and answer. And yet 5,000 pages of testimony were taken upon issues that, while appropriate before a committee of Congress, were wholly inappropriate in a judicial proceeding. And six years were consumed in that way.

On June 27, 1910, notwithstanding the pendency of this suit, they again applied to the Government for permission to open this channel, with the understanding, as they con-

cede, that the total quantity of water to be withdrawn from Lake Michigan was not to exceed that already authorized by the Secretary of War.

The Secretary, on June 30, 1910, granted the permit, upon the following conditions, among others:

> "(*a*) That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.
>
> "(*d*) That the amount of water withdrawn from Lake Michigan, through the Chicago and Calumet rivers together, shall not exceed the total amount of 250,000 cubic feet per minute (4,167 cubic feet per second) already authorized to be withdrawn through the Chicago River alone."

And, therefore, our Government, acting with the very greatest consideration for the interests of the City of Chicago, having first refused permission to reverse the flow of the Calumet River, now granted it; and it was accepted, and the current was reversed by the Sanitary District of Chicago, upon the faith of what the Secretary of War had provided, that it would not take from the waters of Lake Michigan more than 4,167 feet.

February 5, 1912, appellant asked the Secretary of War for permission to withdraw from Lake Michigan not to exceed 10,000 cubic feet per second, such permission to be revocable. By this time it was quite clear that it was not merely a national question; it was international. The British Empire had intervened and protested against what, to them was a great wrong. The Dominion of Canada had its representatives make representation that they were being affected, as far as the St. Lawrence River, by this diversion, because at that time they were using far in excess of the amount that they were permitted to take—on this diversion of 864 million cubic feet of water per day.

On January 8, 1913, the Secretary of War rendered his opinion. Now, I will not take time to read that, although it would be the most effective thing I could do in argument. But that was by Mr. Stimson, as Secretary of War. On this application of theirs to divert 10,000 cubic feet of water per second, the Secretary held it under consideration for 11 months; and in those 11 months the most patient and exhaustive hearings were held. At those hearings were not only all the great interests involved in this controversy represented by counsel, but the Dominion of Canada likewise.

In those hearings, it was shown that the levels of the Great Lakes had been reduced, anywhere from four to six inches; and that it had an effect upon navigation which, in its most moderate estimate, was not less than $1,000,000 per year to private owners; that its effect was felt as far as Niagara Falls, and as far as the water power projects on the St. Lawrence River.

And let me add that the chief engineer for the Sanitary District disclaimed any intention to question the calculations of the engineers. There were various boards of engineers who, upon a patient and exhaustive examination, had found that the Great Lakes were slowly falling and that, in many of the important harbors, there were already very practical and serious consequences due to the act of the City of Chicago.

Secretary Stimson thereupon refused to grant the permission. He rendered an opinion, which the Court will find in the record, and he made certain findings of fact. And the ultimate findings are these:

> "*First.* That the diversion of 10,000 cubic feet per second from Lake Michigan, as applied for in this petition, would substantially interefere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.
>
> "*Second.* That that being so, it would not be appropriate for me, without express congressional sanction, to permit such a diversion however clearly demanded by the local interests of the sanitation of Chicago.

"*Third.* That on the facts here presented no such case of local permanent necessity is made evident.

"*Fourth.* That the provisions of the Canadian treaty for settlement by joint commission of 'questions or matters of difference' between the United States and Canada offer a further reason why no administrative officer should authorize a further diversion of water manifestly so injurious to Canada against Canadian protest."

And thereupon he declined to grant the petition.

On February 24, 1913, following that, the United States Engineer at Chicago, becoming aware that Chicago was using a great deal more water than the permit had given authority to use, wrote to the appellant and asked what it intended to do to keep future operations within the limits of existing War Department permits.

To that letter there never was a reply.

On March 15, 1913, the United States Engineer at Chicago again wrote to the Sanitary District of Chicago, for a reply.

On March 22, 1913, the attorney for the Sanitary District wrote a letter to the engineer, in which he suggested that it would be well for the Government to bring another suit, in which he said that if we brought another suit that would cover all phases of the litigation, that he would speedily—I quote his words:

> "The Sanitary District will cooperate to speedily make up and try the issues"

of the case.

Now, there never was a disputable issue of fact that a court could consider, and very few disputable questions of law that need any real discussion; because all pertinent questions of law were decided by this Court just a century ago in *Gibbons* v. *Ogden*.

And yet this cooperation that is "to speedily make up an issue" and get a decision upon the merits of the second suit

(which we thereupon brought) has been so manifest that today, eleven years later, we find ourselves in the Supreme Court, still vainly asking for an injunction that we had asked sixteen years ago to prevent this impairment.

On October 6, 1913, the Government commenced its second suit.

And again I say to the Court, before you read any of the testimony in this case, only read the pleadings. They are voluminous; they are prolix; they contain a great deal of irrelevant matter; but if you read the pleadings, you will marvel that the case was not passed upon by the court on bill and answer.

Now, we come to what happened to the legal proceedings. And here is a chapter that it is difficult to dwell upon with self-restraint:

For six long years the Government of the United States was held back by testimony, nearly all of which had no legal relevancy whatever. It was on the ground of Chicago's sanitation needs; and whether we had acquiesced by estoppel, and various other issues that you will see in the record; but none of them of sufficient merit to have had any serious discussion by opposing counsel.

At the end of six years, it was at length submitted to Judge Landis. Judge Landis held the case for six years more; and at the end of six years, the Government protesting against the delay, he sent for counsel and thereupon told them that he had found the facts in favor of the Government; that he had reached the conclusion upon the testimony that the navigability of the Great Lakes was affected. He sustained the legal contentions of the Government. He sustained our contention, made from the beginning, that these affirmative defenses which had taken all this time were irrelevant in law. We had filed exceptions from the beginning, protesting against the prolongation of legal proceedings, by all manner

of irrelevant defenses; and our exceptions had been overruled. And now, at length, after the horse was stolen, the barn door was closed, by saying that we were entirely right, that these affirmative defenses were valueless.

Mr. Justice Brandeis: What was the date of that?

Mr. Beck: The decisions of Judge Landis?

Mr. Justice Brandeis: Yes.

Mr. Beck: It was on June 19, 1920. Now, Judge Landis felt that he owed some explanation to the Government of which he was an administrator of justice, and to the parties; and he said that his delay was in part due to the fact that the Great War was in progress—although it would occur to some of us that the very existence of the Great War made the navigability of the Great Lakes of even greater concern.

Secondly, he said that he had the understanding that there was a possibility of a composition of differences here, that would enable the questions to be permanently adjusted; and then at the end of his oral opinion, which directed a decree in favor of the Government, he gave what was evidently, and what he himself says was, his real reason: He said that he did not want the injunction that he directed to issue to us for 30 days; and he added:

> "Make that 60 days, and you may put in it, if it does not destroy the appealability of the order, you may put in a provision retaining me in control. The thing that the Government wants, at least the court wants, being a citizen of Chicago, the thing I want is water without microbes. That is why I have held your lawsuit."

Thereupon the counsel, still "speedily cooperating" with us for a speedy decision of the case, sought leave to open the case *de novo*, in order that the decree could be modified —with this extraordinary suggestion: That if we, having for six years litigated this question, and having now established that we were entitled to the injunction to restrain them from using more than 4,167 cubic feet of water per second—

they now came in and said, "If you will allow us to take 10,000 cubic feet a second, and will give us 25 years, at the end of 25 years we hope to take care of the sewage of Chicago in excess of that, for which the 10,000 cubic feet is now adequate."

In other words, they wanted us, at the end of the litigation, to surrender every contention we had made, accept their diversion of 10,000 cubic feet a second, and trust to them that, as Chicago went forth with the stride of a giant, at the end of 25 years they might do something to stop the further diversion of water from Lake Michigan.

Now, Judge Landis having given this oral opinion and directed the decree, thereupon, for two years more, he refused to enter that decree. The Government protested; it protested again and again. Judge Landis would not enter the decree. They could not appeal.

I became Solicitor General. The archives of our Department were full of letters from the Secretary of War asking whether something could not be done. He, in turn, was subjected to pressure from the great States that were being seriously affected. And finally I determined—and I say it without hesitation—to address a communication to the Judiciary Committee of the House of Representatives calling attention to the fact that, although we had obtained a recognition of our rights to an injunction, the formal order and decree we could not get the court to enter.

Mr. Justice McReynolds: Mr. Beck, is there anything to hinder the United States from asking for a mandamus to overcome a situation like that?

Mr. Beck: I think there is no reason—

Mr. Justice McReynolds (Interposing): I have considered it myself in the past; and I wish you would try it the next time this thing happens.

Mr. Beck: I am greatly obliged for your Honor's suggestion; and I certainly will take the liberty of submitting it to the Attorney General.

But if every city in this country were to adopt what I say, with reluctance, was the selfish policy of the Sanitary District of Chicago, the only way that the Federal Government could vindicate its authority would be, not to go into its courts at all, but to do exactly what was done at the time of the Pullman strike—to stop by force such forcible appropriation of something that does not belong to the City of Chicago.

Well, Judge Landis, I say, for two long years refused to enter that order; and just as I was about to make it the subject of a communication to the Judiciary Committee of the House of Representatives, he was translated into the higher realms of baseball jurisprudence; and thenceforth the Government started with a new deal.

Nevertheless, it was another year before we finally got the decree—I do not say this with respect to Judge Carpenter as being any criticism of him; because when the case was finally assigned to him, after Judge Landis had resigned, Judge Carpenter was ill for a time; and it took time to do it; and there is not the slightest imputation on my part of any delay on the part of Judge Carpenter.

But at all events, it was June 18, 1923, before we finally got a decree, in a case that we had instituted fifteen long years before in the courts of this country, to vindicate the authority of the United States.

Now, those are the skeleton bones of this controversy.

Can this Court recall, in all the litigation of this character, anything comparable to this? There have been many controversies before this Court between the United States and either private interests or public interests, with respect to obstructions wholly within a State, and concerning nav-

igable waters that were wholly within a State. But can this Court recall a single instance where, in the case of a great interstate water highway connecting the heart of the continent with the Atlantic ocean, dedicated by the Ordinance of 1787 forever as a public highway; authority over which, plenary in character, was assumed by the Constitution of the United States—where a suit having been brought under that Constitution, namely, to stop just such unlawful and conflicting action of the States with respect to interstate commerce, there has been anything comparable to this. Can you imagine a waterway so vast in extent and so purely national and international in character that could be impaired and the interests of every one having rights upon that great highway be sacrificed for sixteen years by a city, however great? And no one admires the greatness of Chicago more that I do. As the Chief Justice said yesterday to the learned counsel for the Sanitary District—he said: "Well, you needed the water; is that not the fact, that you needed the water?" And he assented. The only defense that can be suggested is that they needed it, and they took it. And they are taking it to this day; and they are going to take it just as long as the strong arm of the Government fails to stop them.

And the great problem that is going to confront this Court, I venture to say, is not going to be so much the problem of the legal merits of the case, but what to do with the conditon which has been created by the unwillingness of the Sanitary District of Chicago to respect Federal authority, and which, unfortunately, may affect millions of men and women.

Of course, it will be understood that the Government does not concede for one moment that the utilization of 4,167 cubic feet per second will not answer the sanitary needs of Chicago. It may not answer the hydroelectric needs at the works at Lockport. That is a different proposition. But if it had ever been necessary for the Government to take up the question as to how far the health of Chicago could be preserved

by the utilization of this vast quantity of water which we permit, why we would have had some testimony to offer on that subject.

The attitude of the Sanitary District of Chicago in this matter recalls to my mind language used by this Court in a case which, if any other opinion than that of *Gibbons* v. *Ogden* was necessary, would be very pertinent authority. I mean the *Wheeling Bridge* case. In the *Wheeling Bridge* case, the State of Virgina authorized, as the Court will remember, a bridge across the Ohio River. The bridge was wholly within the State of Virginia. Pennsylvania brought a bill to restrain the maintenance of that bridge.

Now, let us see what this Court said with respect to what was fairly due to a court of equity—and if that is due to a court of equity in litigation between one State and another, how much more is it due to a court of equity where the United States in its soverign capacity is the litigant? This Court said in the *Wheeling Bridge* case:

> "The Bridge Company had legal notice of the institution of the suit, and of the application for an injunction to stay their proceedings, before their cables were thrown across the river. This should have induced them to suspend, for a time, their great work, alike creditable to the enterprise of their citizens, and the genius and science of the engineer who planned the bridge and superintended its construction. It is a matter of regret that, by the prosecution and completion of the bridge, they have incurred a high responsibility.
>
> For the reasons and facts stated, we think that the bridge obstructs the navigation of the Ohio, and that the State of Pennsylvania has been, and will be, injured in her public works in such manner as not only to authorize the bringing of this suit but to entitle her to the relief prayed."

Now, if only the administration of the Sanitary District had read those words in 1890, before they had ever incurred so much as a dollar of expense; before the work of construc-

tion had begun; if they had then said, "In view of the position of the United States Government and this act of Congress which forbids us to in any way alter, modify or affect the navigable capacity of any river or lake"—if they had said, "We will not proceed in the thing until we first see whether we can get the approval of Congress", the very serious and difficult situation that confronts this Court—and that will confront, I venture to predict, the Congress—would all have been spared.

Because at that time it might well have been that Congress would have said to the State of Illinois, "If you can purify your sewage by the methods adopted by London, Berlin and Paris, and without impairment of the waters of Lake Michigan, we cannot give you the consent and you must use other methods known to science"; or the Government might have said, "We will cooperate with you to the extent of allowing a certain amount of water—always provided that the amount of water that you divert does not substantially affect the navigation of the Lakes.

And they might then, long since, instead of now; instead of now, at this late day asking for 25 years in which to prepare to respect the rights of others—they might well have said, "Give us the 4,167 cubic feet per second and we will start now, in 1900, the construction of a sewage disposal plant according to enlightened and scientific methods. We have no desire to injure other interests on the Great Lakes; the Great Lakes are the pride of Chicago, as well as of Duluth, Cleveland or any other city they are on. It is our highway as well as theirs; and therefore we will not in any way impair the navigable capacity."

But instead of doing that, with the full knowledge of the position of the Federal Government, they proceeded to spend hundreds of millions of dollars, upon a plan that is destructive of all—I will not say "comity", because it is not a question of comity; it is a question of power. It is violative of

the power of the Federal Government as the great trustee of the interstate navigable waters, and is certainly destructive of the great interests of millions and millions of other people who live along the Great Lakes.

And if it were permitted, of course it would simply mean that, if Chicago could utilize at pleasure the waters of Lake Michigan, Cleveland can do it; Duluth can do it; Buffalo can do it; and we would be back exactly where we were before the Constitution of the United States was adopted, namely, a mass of conflicting regulations of commerce, with States and Cities grabbing everything in sight, without reference to the common weal; and with a state of affairs which, had the Constitution of the United States not been adopted, might conceivably have ended in war.

Because, as a matter of fact, nothing is more significant in the proceedings of the Constitutional Convention, than the very grave apprehension that Washington felt, and Franklin felt and others felt, that if that convention failed method of adjustment between the constituent States would be one of the sword and the gun, and not the peaceful methods of the political charter.

Now, I think I can complete before the Court takes a recess all that I care to say. I had intended—but it seems so useless—to make an argument upon the legal propositions; I cannot think that they can be in any doubt.

The Chief Justice: Mr. Beck, there was an issue made as to the proof, or the weight of the proof—as to whether this diversion reduced in any way substantially the depth of water in the ports and the harbors along the Great Lakes?

Mr. Beck: Well, yes; but our answer to that would be that the finding of the Secretary of War at the time that first suit was started was conclusive of the question as to the effect; and that therefore it was not any longer open to judicial controversy.

But if you eliminate the effect to be given to his findings—and he was the person to whom Congress had delegated the authority; because he was not speaking as Secretary of War; he was speaking as the authorized arbiter of Congress; and when Congress said, "If the Secretary of War finds that an obstruction exists," I take it that that, as any political act of Congress, would be binding upon the judiciary, unless there was, of course, a gross abuse of discretion in the matter.

Well, I was about to say that I will not pretend to discuss the authorities; because our friends attempted two gigantic tasks: The first task was the phenomenal one of diverting some of the waters of the Great Lakes from their natural destination in the Atlantic Ocean to the Gulf of Mexico—and that was an undertaking grandiose enough to be worthy of Chicago.

The second was equally remarkable—to divert the decisions of this Court for a hundred years, from their course and where their destination now is—and from their immediate origin a century ago, when Mr. Webster in the case of *Gibbons* v. *Ogden*, established the exclusive power of Congress with respect to the interstate waterways of the country. And I think that, as the engineers found in difficult to reverse the current of the rivers and of the lakes, their very great legal talent will find it very difficult—in fact, if we may judge by my friend Mr. Adcock's opening remarks he has found it very difficult—to change the current that has flowed for 100 years of legal authority.

If more than the case of *Gibbons* v. *Ogden*, were needed, I need only remind the Court of the year 1851, when three cases were decided that were conclusive. One case was the *Wheeling Bridge* case, to which I have already referred, in which it was held that, although a bridge was wholly within a State and authorized by that State, yet if it were over a navigable river of an interstate character, the State was without any authority to grant the permission.

The second, of course, was the case of *Cooley* v. *Board of Wardens,* where, although the particular local regulation was recognized, yet it was expressly on the ground that, while, with respect to waters wholly within a State and regulations of a purely local character, they would be recognized in the absence of Congressional action, yet, where it was not of that nature, and where the effect was to regulate or obstruct interstate commerce with respect to matters as to which a uniform rule was required, there the power of the Federal Government was exclusive, without regard to Congressional action.

The third case was that of the *Genesse Chief,* decided in that great term of the Court, where this Court held that the Federal Government had an admiralty jurisdiction over these Great Lakes, which it denominated as "great inland seas."

Now, the law as thus defined at that time has never been expressly questioned. And it, possibly, has had a very recent and a very careful defintion in the *Minnesota Rate* case, where Mr. Justice Hughes, in speaking for this Court, said:

> "The grant in the Constitution of its own force, that is, without action by Congress established the essential immunity of interstate commercial intercourse from the direct control of the states with respect to those subjects embraced within the grant which are of such a nature as to demand that, if regulated at all, their regulation should be prescribed by a single authority. It has repeatedly been declared by this Court that as to those subjects which require a general system or uniformity of regulation, the power of Congress is exclusive. In other matters, admitting of diversity of treatment according to the special requirements of local conditions, the states may act within their respective jurisdictions, until Congress sees fit to act; and, when Congress does act, the exercise of its authority overrides all conflicting state legislation."

This Court will remember that in the *Newport and Cincinnati Bridge Co.* case, decided some years after the *Wheel-*

ing Bridge case, not only Kentucky and Ohio had legalized the bridge, but the United States legalized it, and thereafter it became apparent that the obstruction, either by the growth of population or the changes in commerce, or otherwise, while originally not a nuisance, had become a nuisance. And Congress withdrew its consent. Thereupon it was said—and it is so apt to the argument which has been made here today, that Congress, by some species of estoppel, or acquiescence, or waiver, has permitted Chicago to construct this great canal and is therefore estopped from any action with respect to it.

It is fair to remember that, in the *Covington Bridge* case, Congress having withdrawn its assent, this Court said that Congress had full power to withdraw what it had once given; for the very reason that, of course, as the trustee of interstate commerce, it cannot bargain away its mighty trust; it cannot sell or barter away forever its police power. It certainly has the right at any time when, in the changing conditions of commerce it becomes necessary for a new rule or regulation with respect to that commerce to be adopted, to prescribe a new plan, even though it conflicts with some regulation that it has previously made.

(Thereupon, at 2:00 o'clock p. m., the Court took a recess until 2:30 o'clock p. m.).

AFTER RECESS.

Oral Argument of Hon. James M. Beck, Solicitor General of the United States—Resumed.

The Chief Justice: You may proceed, Mr. Beck.

Mr. Beck: If the Court please: I had almost completed my argument at the time the Court adjourned.

But there is one practical consideration that I want to bring to the attention of the Court before I conclude:

Throughout this litigation—and I think the Court will agree with this when it comes to examine the matter—the Government has not been unmindful of the welfare of the people of Chicago. Now, the United States represents, in all matters within its reserved powers, the people of the City of Chicago, not the Sanitary District. And the Government is still very mindful of the welfare of the people of Chicago. It would not have allowed this litigation to drift for sixteen years, if it had not been sensible to what is a hard situation, due to the fact that Chicago is committed to an experiment from which it cannot in a day extract itself.

And therefore, at the end of my brief—somewhat over italicized—I venture to make a suggestion to the Court, if it should reach the conclusion that the Government's contention is right. I will briefly read the substantial part of it; and with that I will close my argument:

> "It is a condition and not a legal theory that confronts the Government. The question is not judicial, and this Court will presume that the Legislative and Executive branches of the Government will not be unmindful of all the equities of the situation.
>
> "As this serious problem will require time for its careful consideration, the Government cannot object, if the Secretary of War, acting on the recommendation of the Chief of Engineers, sees fit, pending the action of Con-

gress, and as a *modus vivendi* to modify the existing permit and temporarily permit a greater diversion of waters."—If he sees fit.

"If there be any doubt as to his power under the authority already delegated to him, the Government has no objection to a proviso in any decree that this Court may enter which will provide that the decree and the injunction, while immediately effective, shall be without prejudice to any temporary permit that the Secretary of War, acting upon the recommendation of the Chief of Engineers, may see fit to grant in the nature of a *modus vivendi*, pending the action of Congress in the premises.

"This would set at rest the authority to make some temporary arrangement in the event the present Congress could not dispose of the question before it adjourns *sine die* on March 4, and especially in the event that Congress might not be again in session until the first Monday of December next.

"It should, however, be made clear that the recognition and enforcement of the just rights of the United States Government are not to depend on or to await the conclusion of any argument between the Sanitary District and the Government. It should not be a question of what the Sanitary District should now concede, but what the Government of the United States should now allow.

"If Congress, (or the Executive, to the extent of its delegated power), voluntarily and in consideration of the inherent difficulty of the situation and the welfare of the people of Chicago gives some temporary permit until the whole problem can be finally solved by Congress, there should be no further opportunity for the Sanitary District to begin the litigation afresh and prolong it for another sixteen years under the plea that the decree of this Court was entered upon the faith that the Sanitary District and the United States Government should make some contract in the matter.

"The question is not one of contract, but of governmental power. The United States has the right to stop the unlawful diversion of the Sanitary District of the waters of Lake Michigan for the uses of the City of Chicago.

"In exercising this power, it need not bargain or contract with the Sanitary District.

"Its power is not that of a coequal, as the learned counsel for the Sanitary District seem to intimate, but the power of a sovereign."

Mr. Justice McReynolds: What relief have the United States asked in this matter?

Mr. Beck: We have asked that they be enjoined from diverting any waters of Lake Michigan in excess of 4,167 cubic feet per second.

Mr. Justice McReynolds: Well, what authority have we to go into that?

Mr. Beck: What authority? I do not think this Court has any authority to go into that. But I think this Court, in entering a decree, could eliminate any doubt on the subject, by making it clear that the Secretary of War, acting on the recommendation of the Chief of Engineers, that being the authority to which the Congress has delegated it, can, if he sees fit, grant a temporary permit, in the nature of a *modus vivendi*, for the excess—

Mr. Justice McKenna (Interposing): And go over this whole investigation again? Do you mean to go over the whole investigation again?

Mr. Beck: No, sir. That is why I was so insistent that, if this Court should follow that suggestion, it be made perfectly clear that it is not a question of any negotiations or contracts with the Sanitary District; but it is wholly a question of what the Government now, proceeding in its own way, will allow, if anything, beyond what it has already granted.

Mr. Justice Holmes. You mean merely to make it plain that the injunction will not prohibit allowing the use of the water to such extent as the Secretary of War for the time being, working under the act of Congress, may permit?

Mr. Beck: Yes, sir, that is the thought of the Government.

Argument of Hon. Andrew B. Dougherty, Attorney General of Michigan, amicus curiae, in favor of appellee.

Mr. Dougherty: May it please the Court: I am here as the representative of the Attorneys General of seven great States bordering on the Lakes—all of those States except the State of Illinois.

We have a vital interest in this suit. We all believe that we have property rights in the waters of the Great Lakes. We have on those lakes and connecting rivers 2,900 and some-odd miles of coast line. The State of Michigan, where I live, has 1,624 miles of coast line. All of it, except that part bordering on Lake Superior, is affected disastrously by any diversion of water. Lake Superior, being above the falls of the St. Mary's River, of course, is not affected. But every drop of water taken by the State of Illinois, or its agents, must necessarily substract a drop from the waters of Lake Michigan, from the waters of Lake Ontario, from the waters of Lake Huron, and a smaller proportion from the waters of Lake Erie.

Mr. Justice McReynolds: Are you asserting any right of your own here under this bill?

Mr. Dougherty. I am not a party to the bill.

Mr. Justice McReynolds. I am trying to see what your claim is: Are you representing the Government, or what?

Mr. Dougherty: I am with the Government.

The Chief Justice: He is the Attorney General of Michigan.

Mr. Dougherty: I am the Attorney General of Michigan.

Mr. Justice McReynolds: Well, do you stand on the rights of the United States, or on your own, or what?

Mr. Dougherty: We stand on the rights of the United States.

Mr. Justice Holmes. While asserting that, I presume your position is that, if you see fit to bring a bill, you would have a *locus standi* to bring suit?

Mr. Dougherty: Yes, we would have. Wisconsin brought an original bill in 1922. That bill has been answered, and the case is now in abeyance and will be brought to trial and orders for proofs taken, I presume.

The Chief Justice: And we permitted you to argue here because you were directly interested in the question whether the United States had power to bring this bill and enforce it?

Mr. Dougherty: Yes, your Honor. We are interested, in Michigan, Wisconsin and Minnestota, and in other States in a lesser degree, in these lakes, because they are the great natural highway of the interior of the country.

We produce in those three States a large proportion of the iron ores. They must all go to market. They have to go to market in the East. They have to go over the Lake course—at a cost of one-tenth of the railroad freight. Those things have to be brought down from day to day and from year to year, to keep pace with the economic advance.

Now, Mr. Goulder will follow me for a few minutes; and I have but a few minutes to speak. But let me say that the commerce of the Great Lakes has increased some 4,000 times since the St. Mary's canal was built. All the ores goes through that way, except a few that go out of Escanaba and go to Chicago.

And the gentlemen said that it was only the large interests that were complaining. If your Honors please, every man who owns a fishing boat and keeps it in the mouth of a creek or cove; every man who owns a pleasure boat, has suffered from this.

Now, I am not going to take any time to go into the argument of whether these lakes have been lowered or not; but I want to state one fact:

The three largest tributaries of Lake Michigan, the St. Joseph and Grand Rivers of Michigan and the Fox River in Wisconsin, bring to Lake Michigan 11,500 cubic feet of water per second. The Chicago Sanitary District has created a channel that takes away almost the equal of the flow of those rivers, 10,000 feet a second. It is not necessary to demonstrate, by figures or in any other way, that there is a lowering of the lakes. That fact is patent from that statement. I use the Government engineers' reports.

The State of Illinois owns to the boundary line in the center of Lake Michigan; along a shore line of some 60-odd miles, about 30 miles out, is the boundary line as prescribed by the enabling acts of Congress. There is an area of about 2,000 miles. The State of Michigan has an area, according to the figures furnished by the International Waterways Commission, of some 22,000 miles of those waters. Illinois, with an ownership of ten per cent, practically, of those waters, presumes to own all of them.

I do not believe that is the law. I believe, as this Court enunciated in the *Port of Seattle* case against the Oregon-Washington Railroad Co., that Michigan owns every foot of water within her boundaries, subject only to the right of the Federal Government to use those waters for navigation.

And I do believe that, when the Federal Government takes the waters, or uses the waters, for navigation, it should, in its wisdom, use those waters to improve the navigable system in which they are found, rather than to transport them to another navigation system, which is watered by the great Father of Waters.

We do not envy Chicago her growth and prosperity. We claim, however, that Chicago should respect our rights. We do claim that there is an ample way to take care of this sewage without a diversion of our property, if the Court please.

I do not think, in view of the shortness of the time, that I will take the time allotted to me, but will leave it to the Government counsel. But I do want this Court to understand that all the people of Michigan, and the people of the other States, have been for years vastly interested in this subject; and that they deem this an invasion of their rights.

Thank you.

Argument of Harvey D. Goulder, Esq., counsel for The Lake Carriers' Association, amicus curiae, in favor of appellee.

The Chief Justice: Mr. Goulder.

Mr. Goulder: May it please your Honors: My time is limited, and I will not take more than ten minutes in stating some of the points that the Solicitor General has asked me to make.

I filed as *amicus curiae* a short brief, which I trusted, from its very brevity, might take the interest of the Court sufficiently for them to read it. And in that brief are citations, I think, of testimony and the principal legal authorities that are of moment in this case.

Of course, with the Solicitor General, I share the feeling of doubt as to what is the position of the other side. But I take it from their answer, which denies that they ever recognized the authority or the right of the United States Government to interfere in any manner, either with the construction, or with the quantity of water to be taken from Lake Michigan; and the fact that their statute of Illinois creating the district said that, if a channel were erected which connected the DesPlaines River, it should be a navigable channel, and that the United States in that case would be authorized to have control over it for navigation purposes, but not to interfere with its use for sanitation and drainage purposes—I take it that that is their position.

Now, counsel on page 94 of the reply brief says that they have a right to use the navigable waters of the United States for the local interests as determinined by the local authorities.

The President of the Sanitary District stated—and he is quoted in Secretary Stimson's report and decision—that it was pernicious to suppose that 10,000 cubic feet should be the limit, and that they were entitled to all the water that they might want or take, as their interests and their necessities for sanitation purposes required. On which the Secretary commented, as stated in my brief.

> "It is therefore quite conceivable that compliance with their sanitary needs according to this method of sanitation may eventually materially change this great national water course now existing through the Lakes."

I shall content myself with trying to picture very briefly what this commerce is that we are talking about.

Here (indicating on map) are the Great Lakes. Here is Duluth (indicating); here is Chicago (indicating); here are the Straits of Mackinac (indicating); here is the "Soo" canal (indicating), where there is a fall of 19 feet from Lake Superior.

There we have created that enormous commerce, so that through that canal there passes, during the eight months of the season of navigation, more than double the tonnage passing through the Panama and the Suez Canal.

Down here (indicating) we reach the foot of Lake Erie: and here (indicating) is Niagara Falls. Now, for our big ships, which are the great bulk of the trade, or nearly all of the trade, we are stopped at the foot of Lake Erie (indicating).

The records show (and the testimony in this case bears it out) that the large ship of the Great Lakes is 600 feet

or a little more in length, about 55 feet beam, and about 32 feet of molded depth—

The Chief Justic. 32 feet of what?

Mr. Goulder: Molded depth; that is the depth from the top to the bottom of the ship. These ships would draw 22 or 24 feet of water with perfect safety.

And in the evolution of the Great Lakes, and in this enormous business, the ship that does not carry more than 10,000 tons is either obsolete or rapidly becoming obsolete. It is also the subject of testimony in the case, and in the official reports transmitted by the Secretary of War—and I made references to those in my brief—that these ships, all of them, load to 20 feet, or can load to 22 feet or more. They say—just let me read it; it will be quicker than paraphrasing it:

> "The Great Lakes system forms one of the world's greatest highways for water-borne transportation. The Great Lakes fleet moves more than 100 million tons of freight each season. These vessels are from 280 to 265 feet in length"—

Nearly all of them in this trade now are 500 feet or more in length—

> "and have a carrying capacity of from 3,000 to 15,000 short tons. Most of them can be loaded to a draft of about 22 feet. They are the most economical carriers in the world, their rates usually being less than one-tenth of a cent per ton-mile, and sometimes only a third of that amount. Rail rates are several times as much, often being at least ten times the water rates. The annual saving over the cost of moving this same freight by rail exceeds a quarter of a billion dollars."

A quarter of a billion dollars saved to the public each year. I would estimate that at nearer half a billion.

Now, some more facts about this: We have some maps here showing the movement of iron ore. Our industrial supremacy is largely based on iron and steel. Eighty-six

per cent of all the iron and steel made in the United States is from the ore that comes down this waterway;—and an English committee reported years ago that we never could rival England in that respect, because, while we had the raw material, the cost of transportation would always be prohibitive. The cost of transportation is now about one-fifth what it was at that time; and that has built up this entire industry, which with all of these millions of men employed and billions of dollars invested, is dependent upon this waterway.

I may illustrate further: In the statistical book of the War Department—which they started issuing since your Honor the Chief Justice was there—they get their statistics from the different districts and put them all together, combining them—showing all the foreign, domestic and internal commerce; and they show that, of all of the water-borne commerce of the United States on all of the coasts and all the internal waterways, 27 per cent is carried over the Great Lakes. It is more than the total of the foreign commerce in and out of the United States, on both coasts. It is about 45 per cent of all the foreign and coastwise trade of the Pacific, the Gulf and the Atlantic coast.

That is the story,—I wish I had time to dwell on it—of what this great water route is which they threaten, and which the Government is trying to conserve.

The Chief Justice: Can you tell us, Mr. Goulder, or have you figured upon it, how much loss would be entailed to this navigation in any way by the lowering of the level of the Lakes six inches?

Mr. Goulder: Yes, your Honor, my two points succeeding this, which are the only ones I want to bring out—and I will do so as briefly as I can—will indicate what the injury is and what the loss is due to that lowering of the level.

Now, the effect of taking a large body of water out from Lake Michigan in reducing levels it is not necessary to prove.

I should say that the proof is ample and all one way, and I cited it on page 25 of my brief. It is uncontradicted and indisputable evidence. It is shown by the records of the War Department, and by the testimony of various witnesses who were called in the case.

In particular, there was a witness named Shenahan, who had a great deal to do with the Coast Service; and he said that the taking of 10,000 cubic feet of water per second from the lake would reduce the level of the lake 5½ inches. Now, up in the Lake Region, we all call it a half a foot—six inches—that is, in Lake Michigan and Lake Huron, which really, as you will see from the map (indicating) are one body of water. There is just the Straits of Mackinac separating them; and the effect would be the same on Lake Erie; below that, it has a greater effect; and on the Lower St. Lawrence River—where they are talking about a "Lakes to the Atlantic waterway"—the diminution is probably a foot.

Now, the appellants recognize this. They deny that there is any diminution. But they recognize it in the proposal for works of some time to compensate for the lowering.

I cannot conceive that question of compensation to be involved in this case. But they recognize the diminution. And the court below held as to this, that the carrying capacity of these 22-foot ships is affected in the result, seriously affected, even by the excess over 4,167 feet that the Sanitary District is using.

I cannot take further time in the discussion of that, but must come to this point: That everything shows this: The testimony is clear and it is unequivocal in this regard, and is confirmed by every report of the Government that can be cited: That one inch of water means from 75 to 100 tons of cargo capacity loss.

So that six inches diminution of water would represent from 450 to 600 tons of freight on every loaded trip on every

one of the ships that have been engaged in this enormous business. I am speaking now about the bulk business—I mean ore flux, stone, grain, of which we carry 500 million bushels in a season, and coal, which is about 30 millions.

And the ship that is not so affected by every inch of reduction of water is either, as I have said, obselete or nearly so.

And may I illustrate: The effect of that reduction of level is just as if the Sanitary District were to go out and spread a floor over the bottom of all that system, five or six inches deep. There is absolutely no difference between raising that in all these critical places—all these channels where the Government has spent $100,000,000 in improvements; it has spent $20,000,000 at the "Soo," which has this enormous tonnage going through it—and lowering the level of the Lakes.

And the lake system is shown by all these reports, and is world-known, as furnishing free, open, unrestricted, competitive transportation—the deepest and most efficient in the history of the world. The Detroit River, according to the reports and the testimony, is the most used water course in all the world. Now, that is what the testimony shows. And aside from my statement here, it is shown by Government reports which are cited in the Government brief and in my brief; it is shown beyond peradventure; and there is not anything in the evidence to the contrary. It is indisputable that that is the effect.

Now, what is the result?

We lose 100 tons—no, I am wrong: On sixty out of some 400 ships engaged, we lose 100 tons an inch, or 600 tons for six inches of lowering of level. On the ships coming next to those, we lose between 500 and 600 tons with six inches lowering.

Now, as to what that loss consists of. I say there are two losses: The direct loss to the ship in freights; and the loss to the general public.

On the question of loss, the Solicitor General said that the lowest estimate ever heard, or ever appearing in any report that was ever mentioned—not appearing in any report, but ever suggested by anybody, was $1,000,000 a year from this diminution. And the Government report says it is at least a million and a half.

Now, aside from the other testimony, which is collated and cited under that head in my brief, there is this—and it is uncontradicted by any syllable of testimony in this case:

Mr. Livingston, the president of the Lake Carrier's Association, was asked to go into it thoroughly and compute the annual loss; and he gives the figures and the reference to volume 1 where his testimony is contained, is in the brief—he gives the figures, and the result at a low estimate he gives as $500,000 per inch. That would be $3,000,000 a year in direct loss of freights through this reduction of the lake levels.

Now, I assert that that testimony of Mr. Livingston, was gotten up with care, and that low figures were taken; he was very careful; he gave his figures, and they show a difference of $500,000 per inch. Now, there is a typographical error in the brief which makes my statement a little garbled; but it was all progressive, with the increasing traffic and size of the ship; and I make the estimate in my brief that, by now, that loss cannot fairly be considered to be less than $4,000,000 a year.

Now, the loss to the general public has been spoken of. There are all the mines, the docks, the elevators, the shipbuilding plants, etc.; then, down below us are all the furnaces; and there is everything involving any ramification of the iron business, or anything made of iron or steel.

There are millions of people spread all over this country; and they are all interested in—what? That we may be able to continue to give the answer to the British committee that we

have heretofore given by our performance—that we can and we do carry this iron ore down at the phenomenally low rates which I have stated, and of which the reports are full, and that that does enable this country to take its preeminent position where we make more steel and iron than Great Britain, France and Germany combined; and 80 per cent of it is made out of this ore, because of this cheap transportation route, without which that could not be accomplished.

And so it is as to all the grain of the Northwest: I spoke about 500 million bushels of grain coming down at these low prices. And there is the coal going up at these low prices, always away below the rail rates; the rail rates for carrying such freight always being more than five times as much, and as the Government report shows, often being ten times as much as the rate by this water route.

May I in closing say this further? That, taking the commerce of the Great Lakes, the Government computations are all based on an average haul of these bulky freights, or bulk cargoes of a little over 100 miles. The total length of the haul from the head of Lake Superior to Lake Erie is approximately a thousand miles. The ton-mile performance of this transportation route equals 25 per cent of the ton-mile service of all the railroads in the United States and it is nearly one-half as great as that of all of the railroads east of the Mississippi and north of the Ohio River.

Now, I submit that when counsel come in on the question of the action of the Government—and I am frank to say that I question the right of Congress to shake off the trust which it has. I question the right of Congress—I do not know that this is involved in this case—or of any authority in the world, with that trust fastened upon those waters, and fastened upon the other hand upon the general government of the United States for navigation and commerce—I question whether there exists anywhere authority to permit the diversion of those waters for sewage purposes or sanitary purposes, or

anything else than navigation purposes. And in that connection there are in the record reports showing that 1,000 cubic feet per second of water is ample for any channel that they could have that would comport with the general Mississippi transportation. They recommended a depth of eight feet for the channel, which might be increased to nine feet; and it is shown conclusively that 1,000 cubic feet per second is enough water for that.

And we have a right, our ships and our people—and I speak not only for ships, but for the cognate interests connected with the transportation part of it—the carriage of all this ore, grain, coal, and everything of that kind—we have a right to come in and say that Chicago may not say, with regard to these interstate and international navigable waters, put in charge of the United States: "We do not recognize the authority of the United States at all in the matter, in any shape or manner. They have no right to say anything, and no authority to say anything about how we do it or how much water we take. If we make a navigable channel, why, we will let the United States come in and regulate the navigation end of it; but they must not interfere with its use for these non-navigation purposes."

And to further say, in the face of the fact, as acknowledged by their own action as stated here by counsel, and as shown in volume 8 of this record, that they are making purification plants. They can do it; and the testimony shows that they took care of 800,000 population; and the highest authority in this country says that urban sanitation, or urban sewage, may be cared for to any desired limit by these shore scientific modern methods. Because we had sanitary engineers, and members of the American Society of Civil Engineers testify, and their testimony dissipated any old idea that this is in any experimental stage and cannot be done.

I refer to Harrison B. Eddy, of Boston, one of the leading sanitation authorities in this country.

And I went further to say as to the local interests that they talk about,—that is that the State or local interests may regulate the water to the exclusion of the United States or anybody else, that there are two things to be thought of: In the first place, they are manufacturing power as the result of this diversion. Their engineer testifies—and I have cited the page in my brief, that they can manufacture power with that flow of water to the value of $2,750,000; and they do manufacture power; and that that power is used in the reduction of expenses, or sold in the reduction of expenses.

Now, a local interest, then, is using this antiquated, discarded, open sewer plan, because it is cheaper than other methods, and they can still further cheapen it by the manufacture of power if they can get plenty of water.

And there is one other consideration: That during all the time of this controversy, the Chicago packers, and a certain foreign products plant, have been pouring the filth of a most unsanitary character (because it has so much of solids) into this sewer, to the extent which they themselves admit—and you have heard the counsel say it—would represent the ordinary sewage of a million and a half inhabitants.

Argument of Joseph B. Fleming, Esq., on behalf of appellee.

Mr. Fleming: Just a few words, if your Honors please, in conclusion of our side of the case; and I shall supplement very briefly the admirable presentation of Mr. Beck on behalf of the Government.

The bill in this case charges, briefly, that this diversion at Chicago did create an obstruction not affirmatively authorized by Congress to the navigable capacity of certain waters of the United States.

The bill charges also, after a recital of the facts, that they sought to alter and modify the course, the condition and

capacity of the two rivers, without work having been recommended by the Chief of Engineers and authorized by the Secretary of War.

Your Honors asked yesterday as to the findings of the trial court. Very briefly, they are these—and the findings are in the record: That this diversion at Chicago did result in a lowering of the levels of the Great Lakes and their connecting waters. That this diversion would constitute and did constitute an obstruction to the navigable capacity of the Great Lakes. That the defense of sanitation was untenable, and those portions of the answer setting forth the defense of sanitation should be stricken out and an injunction should issue.

Judge Carpenter rendered an opinion, which is also incorporated in this record, in which he says, "I have read this entire and I am in complete accord with what Judge Landis found."

Now, we get back in this case to Section 10; and counsel for the Sanitary District has sought to find an affirmative authorization by Congress.

They have told your Honors that there is no statute covering the Chicago diversion; that is stated by both counsel who have addressed the Court thus far.

And they have called the attention of your Honors to the Niagara Falls Act of 1906, a piece of legislation directed primarily to the necessity of the preservation of scenic grandeur, and to protect against further depletion of the Falls. They call attention to that act and tell your Honors that Congress indicated by that enactment of that law an intention to legislate specifically, and that the general legislation of March 3, 1899, is not effective.

Now, in that connection, I want to call attention very briefly to the *Rio Grande* case, for this reason: It sets forth the definition of what constitutes an obstruction within the purview of this act.

The court, after calling attention to section 10 of the act of 1890—and by the way, that is identical with this act, so far as the particular section is concerned, except that it says, "authorization by Congress" in the act of 1899; and an "authorization of law" is required by the act of 1890.

Referring to section 10 the court said:

> "As this is a later declaration of Congress, so far as it modifies any privileges or rights conferred by prior statutes, it must be held controlling, at least as to any rights attempted to be created since its passage; and all the proceedings of the appellees in this case were subsequent to this act. This act declares that 'the creation of any obstruction, not affirmatively authorized by law, to the navigable capacity of any waters in respect to which the United States has jurisdiction, is hereby prohibited.'
>
> "The language is general, and must be given full scope. It is not a prohibition of any obstruction to the navigation, but any obstruction to the navigable capacity; and anything, wherever done or however done, within the limits of the jurisdiction of the United States, which tends to destroy the navigable capacity of one of the navigable waters of the United States, is within the terms of the prohibition."

I will read just one sentence from the *Economy Light & Power Co.* case.

Mr. Justice Holmes: Do you mean that case in 256 U. S.?

Mr. Fleming: Yes, sir.

> "But as recognized in the *Gilman* case, 3 Wall. 713, Congress may exercise its authority through general as well as through special laws, the power in either case being supreme. The act of 1899—"

The act under consideration—

> "Is a due assertion of the authority of Congress over all of the navigable waters within its jurisdiction, and it must be accorded full weight."

We cited other cases in our brief upon the same subject.

They seek to tie themselves to the two old acts of Congress, the act of 1822 and the act of 1827, and invoke those statutes as a justification for their proceedings here—for the construction of the canal and the diversion at Chicago. Just a word or two, if your Honors please, with respect to that:

The act of 1827 provided that the canal should be commenced within five years and completed within twenty years. Three years later, if your Honors please, as showing the purpose of Congress, the Congress passed an act authorizing the State of Illinois to construct a railroad between the points in question, showing conclusively the purpose Congress had in mind.

This matter was before Secretary Stimson and he covered the situation in his opinion of January 8, 1913, finding that the only purpose was the purpose of navigation and that sanitation was not considered.

One thing more: That act, if your Honors please, provides for the creation of a particular canal the location of which was to be determined by law, and was subsequently determined. It is not claimed here by appellants that the canal they constructed is within the ninty-foot zone reserved on either side of the old forty-five-foot canal. This canal is a distinct, separate proposition. An authorization from Congress to construct a bridge across the Ohio River at a certain point is not an authorization to construct two bridges a mile apart.

They told your Honors yesterday and they told your Honors again this morning, that the old Illinois and Michigan Canal has been abandoned and replaced by the new one. They say "We have built another canal alonside the old one."

Now, what are the facts? If your Honors please, on July 1, 1919, the State of Illinois passed this act, which I am going to quote briefly. This act became effective on July 1, 1919; and section 3 of the act—and by the way, the Sanitary

District of Chicago has its own board of trustees elected by the people. They have jurisdiction over their canal—the Sanitary and Ship Canal; the other canal is under the control and direction of a State board.

Section 3 of this act of 1919 reads as follows:

> "The Department of Public Works and Buildings of this State is authorized and directed to protect against and prevent encroachments upon said Illinois and Michigan Canal, throughout its entire course as originally constructed, and to preserve its navigable capacity throughout the entire course. And it may, when the permission of the Federal Government is obtained, change and improve said canal and provide terminal facilities. No permission heretofore or hereafter granted which results in the obstruction to navigable capacity of any portion of said canal, or interferes with its use for any of the purposes herein named, shall operate in any way to deprive the State of Illinois of its rights."

The only right, if your Honors please, that the Sanitary District has in that canal is to cross it at certain portions, the portions specified. Their contention in this respect was disposed of likewise in the *Rio Grande* case. They raised a similar contention there, if your Honors please; and the Court answered that contention there.

One thing more: That canal was for the purpose of navigation, and not sanitation. And the record shows, if your Honors please, that 1,000 cubic feet per second is adequate for all transportation or navigation purposes. That is the finding, too, of Secretary Stimson.

There is nothing, if your Honors please, in this record, showing that the Sanitary District has any right under the act of 1827. The State of Illinois has not conferred any right upon them. The Illinois Legislature, in the enactment of the law to which I called attention, effective July 1, 1919, negatives any such delegation.

Mr. Kirby told your Honors this morning that the works constructed by the State of Illinois affected only waters within the State of Illinois, if I understood him rightly.

The fact is that the Chicago diversion is equal to the contribution of all the tributaries of Lake Erie; it is five per cent of the volume of water which passes over Niagara. It is five per cent of the total contribution of Lakes Michigan, Superior, Huron and Erie. Is not that fact, in and of itself, sufficient to show a "modification of the condition, course, and capacity of the navigable waters of the United States?" Now, if your Honors please, the evidence in this case is replete as to the effect upon the Lake levels; the reports of governmental committees and official bureaus have been presented in evidence; there are the reports of the International Waterways Commission; there are two reports—

Mr. Justice McReynolds (Interposing): Mr. Counsel, how far have we got to look into that question of fact? What is your case really bottomed upon here? Is it not bottomed upon the right of the Secretary of War to control this situation?

Mr. Fleming: Yes, your Honor.

Mr. Justice McReynolds: Now, could the Sanitary District go behind his decision?

Mr. Fleming: No. That is our contention. We contend that in our brief as well.

Mr. Justice McReynolds: I am trying to see, then, what we have got to do with the question of fact as to whether the water in the Lake is lowered or whether it is not; that is the thing I would like to have you enlighten me upon.

Mr. Fleming: Well, I do not know; but in the light of the inquiries propounded by your Honors this morning, I thought I had better discuss that question.

Mr. Justice McReynolds: Well, I want to know what we have to do with that question? Well, is it not your conten-

tion that the Secretary of War prohibited this thing, and had a right to prohibit this thing?

Mr. Fleming: Yes.

Mr. Justice McReynolds: And suppose the Secretary of War had taken no action at all: Would that make any difference?

Mr. Fleming: Yes. Independently of that statute, your Honor, the Government had a right to protect the navigable waters of the United States.

Mr. Justice McReynolds: Without any statute?

Mr. Fleming: Independently of any statute.

Mr. Justice McReynolds: But does the United States set up that right here in this suit?

Mr. Fleming: Oh, no; this proceeding here is predicated upon section 10 of the act of 1899.

Mr. Justice McReynolds: Well, is not that your whole case?

Mr. Fleming: We have a bill here which covers the situation independently of the statute, in my judgment.

Mr. Justice McReynolds: What do you mean by "a bill here"?

Mr. Fleming: We set forth the impairment of the navigability of the Great Lakes, by withdrawal of the water at Chicago—a situation which would warrant relief to the Government, independently of the statute—no, answering your inquiry further—

Mr. Justice McReynolds (Interposing): Is that the ground upon which the United States is proceeding here?

Mr. Fleming: No; we are proceeding, if your Honor please, on the theory that there is an obstruction to the navigable capacity of the Great Lakes, "without affirmative authorization of Congress"; that the "course, and condition" of cer-

tain navigable waters of the United States have been altered and modified—

Mr. Justice McReynolds (Interposing): Yes; but we have to decide this case upon the issues that you have raised.

Mr. Fleming: Those are the issues.

Mr. Justice McReynolds: And I was trying to see whether you have asserted the broad power of the United States irrespective of any statute?

Mr. Fleming: No, we do not. We argue that in our brief, but we have not put that in the pleadings. Our bill is predicated upon section 10 of the act of March 3, 1899.

The Chief Justice: As I understand your argument, it goes to the point that, even if the objection of the act of 1899 does not apply in giving a remedy by injunction, you still have that remedy growing out of the relations between the parties?

Mr. Fleming: Yes; and this Court has so held in the *Wheeling Bridge* case, to which the Solicitor General has referred; and we cite numerous other cases in support of that proposition. Independently of that statute, we have that right.

Well, I will not present any further reports or proofs or excerpts from the records in connection with the elevation of the lake levels, nor in connection with the injury to navigation, unless your Honors will so indicate. I have here excerpts from reports showing injuries to navigation, as testified by witnesses and found by commissions; but unless your Honors so indicate, I will not refer to them further.

Mr. Justice Holmes: You have cited them in your brief, have you not?

Mr. Fleming: We have cited them in our brief.

One word, then, with reference to the current, the excess current in the Chicago River: Counsel have told your Honors that no evidence was presented in regard to the current

in the Chicago River until after the evidence was in; that it was plainly an afterthought. Mr. Kirby told your Honors this morning that the proof was conclusive that there was no current in the Chicago River injurious to navigation.

Now, what are the facts? The bill involving the Chicago River was filed on October 6, 1913; and the bill in the Calumet River suit was filed on March 23, 1908. And this testimony showing the excess current in the Chicago River was presented on April 8, 1914. And that testimony, if your Honors please, is unanswered in this record. The testimony with respect to the excess current in the Chicago River was that of ship captains and navigators, men who traversed the Lakes and the Chicago River for years. Their testimony was that the current was from two to six or seven miles per hour—something away beyond what has ever received the semblance of permission of the Secretary of War.

They all testified to the prejudcial effect upon navigation; that it was exceedingly difficult and dangerous, in view of that excess current, to navigate the Chicago River. We set forth the details of that testimony on page 115 of our brief —commencing there.

They call your Honors attention to governmental reports and surveys. They call attention to the fact that fifteen different acts of Congress have recognized this canal; that appropriations have been made for investigation. And each and every one of those contentions have been answered in the *Wheeling* case—and by the way, the *Wheeling* case is a complete answer to each and every contention raised in this case. We do not need to go further than the citation of that case.

The testimony shows, if your Honors please, in the first branch of the case, namely, the obstruction, that there has been a lowering of the levels of the Great Lakes; that that reduction amounts to five or six inches. Secretary Stimson found six and nine-tenths inches, if I am not mistaken. But

there has been a lowering of the levels of the Great Lakes, due to the increase of current in the Chicago River.

Those two propositions constitute an obstruction to the navigable capacity of the waters involved. We do not need to show an obstruction under this statute. The language is comprehensive. All we need to show is a modification. And we have shown, as the record shows, the creation of a large navigable stream flowing away from Lake Michigan and discharging its waters into another watershed.

The record shows a change in the condition of the Illinois River and the DesPlaines River—plainly a change in the condition of these navigable waters of the United States. The case is determinable, as Mr. Beck said, on the pleadings, without reference to the proof.

Congress enacted in 1890, and again in 1899, these acts; and the ultimate question is, have the acts of appellant been permitted, or have they been done pursuant to Federal laws? The record establishes conclusively, if your Honors please, that they have not.

In *Missouri* v. *Illinois,* to which counsel alluded yesterday, this Court said:

> "It is a question of the first magnitude whether the destination of the great rivers of the United States is to be the sewers of the cities along their banks. Obviously, of far greater magnitude, is the question whether the waters of the Great Lakes are to be subject to the unrestricted depletion by the States and cities, without regard to navigation purposes, and whether the once paramount right of Congress over navigation is to be made subordinate to the claims of the States."

Now, in view of the record in this case, if your Honors please,—and there is not any controversy about the lowering of the level, but the only controversy is about the extent of the lowering; the only thing as to which there is any dispute in the evidence, is as to the extent—we submit that we are entitled to an affirmance of the decree.

Closing argument of Edmund D. Adcock, Esq., on behalf of appellant.

Mr. Adcock: If the Court please: In the time left at my disposal, it will be impossible for me to take up every point that has been argued here in opposition.

The Chief Justice: You only have about ten minutes left.

Mr. Adcock: Yes. I submit that our reply brief takes up, I think, in consecutive order, the arguments made in the brief of the Government.

There are one or two things to which I would like to call the Court's attention.

It seems to me that the fundamental proposition here is the question of the State's power, in the absence of any act of Congress occupying the same field. That is the whole question. And that until Congress acts, then this power, which is in the interest of public health and under the police power, remains. And we are not denying the right of Congress specifically to legislate upon that subject.

Mr. Justice McReynolds: Well, before you finish, I wish you would tell me, if you do not mind, what kind of decree you would like to go down to the court below, if this judgment is affirmed?

Mr. Adcock: If I may have the opportunity to do so.

Mr. Justice McReynolds: Yes, I just suggest that to you.

Mr. Adcock: We stand upon our fundamental rights that the action of the State of Illinois here providing for the protection of the Health of its citizens, is absolutely valid until Congress has acted. And when it does act, it must act in those plain and unmistakable terms—

The Chief Justice (Interposing): Then your contention is that the enlargement of the diversion to 10,000 cubic feet a second was lawful?

Mr. Adcock: Absolutely lawful.

The Chief Justice: And is still lawful?

Mr. Adcock: And is still lawful. And that section 10 of the act of 1899 does not in those terms forbid it—in the terms that are required in order to forbid the action of the State—

Mr. Justice Holmes (Interposing): Your contention might involve this: Do you not think that if the State of Illinois has the power to enlarge it, some other State would have the power to take water in the same way?

Mr. Adcock: If the Court please. That is not the issue in this case.

Mr. Justice Holmes: I am quite aware that that is not the issue; but I was speaking of the breadth of your statement.

Mr. Adcock: Our contention is that, so far as the United States is concerned, so long as the State of Illinois is acting reasonably in the interest of its public health, then that action remains lawful, unless Congress has clearly and unmistakably stated its intention otherwise.

Mr. Justice Sutherland: No matter how much it interfers with navigation?

Mr. Adcock: So long as it is reasonable. In the case of *Hennington* v. *Georgia,* the court sustained the action of the State against the operation of trains on Sunday, both interstate as well as others. The *Covington Bridge* case, to which counsel refers, involved the fixing of tolls over a bridge directly operating upon interstate commerce.

We are not acting in defiance of the United States so far as commerce is concerned. We are acting within the sphere of our powers; and until Congress under the commerce clause forbids us, our action is lawful.

And not only has it not forbidden us, if your Honors please; but it has taken action which clearly recognizes this diversion; it has taken such action from the very time that this act was passed; and when the Sanitary District expressed its purpose to occupy the Chicago River for this supply channel,

Congress immediately provided for the improvement of the Chicago River in connection with appellant's improvement of the South Branch and the West Fork. On April 1st—

Mr. Justice VanDevanter: Well, there would not have been any objection to your doing that anyway?

Mr. Adcock: It was what we were working for.

Mr. Justice VanDevanter: But there would not have been any objection to your doing that?

Mr. Adcock: The only corporate purpose that we had in doing that was in order to make that channel—in order to take that water through there; we had no other corporate power. And it was done right along.

And the very act, if your Honors please, which contains this section 10 contains in another section an item with reference to the Chicago River under which *Tunnel Cases* were decided, making a project depth of twenty-one feet, on condition that the local authorities should reconstruct the bridges and lower the tunnels at their own expense; and this court said that they meant in that case to give the congressional assent. The tunnels were removed, and it was held that the consent of the Secretary of War was unnecessary. We reconstructed the bridges that were expressly provided for in that act. We did also the excavation to deepen the channels, and to widen the channels.

And this court said, in *Missouri* v. *Illinois*, where this very diversion was involved, and where the question was the effect upon the Mississippi River:

> "In the case at bar, whether Congress could act or not, there is no suggestion that it has forbidden the action of Illinois."

And I refer you also to a case involving this very proposition, which I have mentioned before—this very permit—an opinion by Mr. Justice Baker, in our Circuit Court in the case of *Corrigan Transit Company* v. *Sanitary District*, 137

Federal Reporter; and I respectfully call the Court's attention to the Niagara Falls act, to the Burton act; and I do not believe that there is a possibility of reading that act without coming to the conclusion that what they intended to say there was that they had not given the Secretary of War authority to fix the quantity of diversions from the Great Lakes, and that they were not going to do so, but that that was something that might be taken up in the future. And there was no occasion to pass that act with reference to Niagara Falls, if the Secretary of War had the authority.

Counsel has referred to water power. There is not a syllable upon this record upon which it can be stated that this great work was done for the purpose of obtaining water power. It was not until 1903 that an act was passed specially containing the provisions with reference to the development of this power which would be incidentally created; and it would have been perfectly criminal for us to have gone ahead and used the water for sanitation purposes that was absolutely necessary, without using the power that had been going to waste and would go to waste unless we harnessed it up.

Now, Counsel has had much to say about the suit that was filed March, 1908, and I want to submit to your Honors, in that connection, that the contention in that respect is exactly the opposite of what counsel for the Government claims; and the necessary result or construction of what happened is exactly the opposite of what counsel claims. For in that case the Attorney General when he brought the suit only asked for an injunction against doing or attempting anything in any way "to reverse the flow of the said Calumet Rivers, and from doing or attempting anything in any way to divert or abstract any waters from Lake Michigan in any channel other than the Chicago River as already authorized by the Secretary of War, unless prior to beginning any of said work".

Now, what was the situation with reference to permits at that time? The Secretary of War and the Chief of Engineers, in construing this whole proposition, assumed that the only thing they had to do with was the question of the current in the Chicago River and how we would get this water from Lake Michigan to our channel. That was the engineering proposition.

So that the only condition that they ever placed upon us was with reference to the current in the Chicago River.

Now, what did we do? We have complied with the conditions of the May 8, 1899 permit—

The Chief Justice (Interposing): I do not understand you.

Mr. Adcock (Continuing): By improving the river so that there is no current in the Chicago River obstructive to navigation—

The Chief Justice (Interposing): Well, did the permit refuse you permission to use the Calumet River?

Mr. Adcock: The Calumet River is not involved, your Honor.

The Chief Justice: I know; but it is there, is not in the suit of 1908? Is it not referred to there?

Mr. Adcock: Yes. If I may, I will just continue and carry that point through:

At that time, we had a War Department permit of July 11, 1900, to improve and enlarge the Chicago River so as to get a greater quantity through. That is, the work of deepening the river from seventeen to twenty-six feet and widening it, etc., was then authorized by the Secretary of War. The work was under way. The *Tunnel Case* was not decided until 1906. The work of deepening and widening the river was not completed until 1912.

Now, on September 11, 1907, when we got a permit for the North shore channel, there was a condition that the taking

of water should not exceed what was given by other War Department permits. It was necessarily assumed that when we had completed that improvement of the Chicago River, the permit or the right—the thing that would follow from that, namely, taking the water through, would be completely authorized.

So that, when the June 30, 1910, permit was issued, there was a condition that it should not exceed 4,167 cubic feet a second; and the purpose of that limitation was that, if they gave us that permit, we would not have any more than we had right to take through the Chicago River, because that proposition was in litigation.

And there was also in the permit a condition that it should not be used in litigation. In other words, it was a case of having a *modus vivendi*—due to a feeling that the channel had to be constructed. And there was a suggestion in General Bixby's report that that additional amount should be taken through there in order to relieve the Chicago River, so as not to get too much through that river. So that that was one of the reasons.

So that after that permit was given under those conditions, the only question was as to the legality of the taking of the 10,000 cubic feet a second through the Chicago River. And it was not, I submit, until Secretary of War Stimson's opinion of 1913 that we had any idea or information—and the record shows that—that that amount would not be allowed through the Chicago River.

So that there was no delay. Judge Landis stated that the testimony on that proposition had occupied some time; and after 1910, the only thing involved was the right under the suit instituted in 1913; and the testimony, after we found that question was raised, was taken in 1913 and 1914; and the record does not disclose a single action taken by the Sanitary District to delay any of the litigation.

Now, as to the treaty proposition—have I over-stepped my time, your Honor?

The Chief Justice: Yes, you have.

Mr. Adcock: I beg the Court's pardon. Unless you will give me just a little more time—

The Chief Justice (Interposing): I cannot give you any more.

Mr. Adcock: Well, I am sorry to have done that. But I just submit that our reply brief does cover these different points consecutively.

(Thereupon, at 3:50 o'clock p. m., the Court proceeded to the consideration of other business.)

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WM. R. STANSB
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IN THE

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OCTOBER TERM, 1924.

No. 161

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Appellant,

vs.

UNITED STATES OF AMERICA,
Appellee.

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INTRODUCTION.

This case involves a conflict between the sovereign power of Illinois and that of the United States, the decision of which is vital to the inhabitants of Chicago, and of vast importance to the people and commerce of the Mississippi Valley. It does not involve any issue between states, nor between any state and appellant.

The above named amici curiae are interested in the issues in the above-entitled cause, and are prejudiced by the decree below, in respect of navigation and of sanitation.

Navigation: All of these states and commercial bodies are interested in the preservation and development of the navigable channel that has long constituted a public highway or water route between Lake Michigan and the Gulf of Mexico,—consisting of the Chicago River that opens into Lake Michigan, the Sanitary and Ship Canal of Appellant linking the Chicago River with the Des Plaines and Illinois Rivers, and the Mississippi River.

For the adequate maintenance and operation of this water route, a diversion from Lake Michigan of at least ten thousand cubic feet of water per second is necessary, particularly in aid of that part of the route lying within the State of Illinois, and of that part of the route in the Mississippi Valley extending from the mouth of the Illinois River (about twenty-two miles above the City of St. Louis), to Cairo, Illinois.

The effect of the decree limiting the diversion to 4,167 cubic feet per second, would seriously impair and lessen the navigability of this existing water route.

The Mississippi Valley needs this water route first, for direct use at the low freight rates offered by all water or part water routes, and second, to furnish an available all water or part water route in competition with all rail routes, so as to reduce the competitive freight rates of the latter.

Sanitation: The effect of the decree, if enforced, would be to create a dangerous and intolerable public nuisance along this water route within the State of Illinois, because of the consequent inadequate dilution of Chicago sewage passing through this water way (Appts. Narr. St. pp. 190, 199, 200, 209, 377).

While the State of Illinois and its commercial interests,

are immediately and vitally interested in this feature of the case, the State of Missouri, particularly the inhabitants of St. Louis and of other Missouri communities along the Mississippi River, are also deeply concerned, and would be seriously prejudiced by the decree.

The danger that St. Louis and the State of Missouri expected from the Chicago sewage when Missouri sued Illinois in January, 1900 (about the time the present Sanitary and Ship Canal was being opened), 180 U. S. 208, 200 U. S. 496;—was prevented only because the quantity of water that has been diverted from Lake Michigan through the canal to dilute this sewage, proved to be adequate in quantity to dilute and purify the sewage. An insufficient dilution of this sewage, which would result from an enforcement of this degree, would inevitably create a public nuisance and spread disease, not only along this waterway within the State of Illinois, but also to the City of St. Louis and other Missouri cities and towns along the Mississippi River.

The States of Tennessee and Louisiana, while not materially interested in the question of sanitation as such, are interested in having this waterway throughout its entire length, maintained in sanitary condition for safe use, free from risk of disease, to those who use it in transporting freight and passengers.

STATEMENT OF FACTS.

To avoid unnecessary repetition, we adopt the statement of facts contained in the brief filed on behalf of appellant, and shall endeavor to state in this brief only such facts as seem essential to disclose the interests of these states and commercial bodies, and to support the contentions herein submitted on their behalf.

The "Continental Divide," or elevation of land separating the watershed of the St. Lawrence River from that of the Mississippi River, lies in the northeastern portion of Illinois, within the limits of appellant, a few miles from Lake Michigan. At its lowest part the Divide is only a few feet above the normal level of Lake Michigan.

Since the earliest time covered by local history, there was a natural navigable water route from Lake Michigan, across this Divide, into the Des Plaines and Illinois Rivers, and thence by the Mississippi River to the Gulf of Mexico (Appellant's Narrative Stat. 400, 403). In early days explorers followed this ancient waterway, and fur traders used the same route. There are records that during high water, a natural water connection existed between the Des Plaines River and the Chicago River within what is now the City of Chicago (Appellant's Narrative Stat. 407).

The existence of this water route led in 1818, to the inclusion within the new State of Illinois of what is now the northern portion of Illinois, together with a part of Lake Michigan. The object of this inclusion as stated in Congress was to gain a coast on Lake Michigan and thereby to connect Illinois, through the Lakes, with the States of Indiana, Ohio, Pennsylvania and New York; and it was also stated that:

> "The facility of opening a canal between Lake Michigan and the Illinois River, is acknowledged by every one who has visited the place. Giving to the proposed state the port of Chicago (embraced in the proposed lim-

its) will draw its attention **to the opening of the communication between the Illinois River and that place**, and the improvement of that harbor'' (App. Narr. St. 405).

The existence of this water route led to the beginning of the settlement at the mouth of the Chicago River, which was organized later as the Village of Chicago, in 1833, with an estimated population of three hundred and fifty (App. Narr. St. 265). This village grew into the present City of Chicago, and this growth was possible because favorable transportation facilities existed from the beginning, viz: the water route by the Great Lakes furnished easy access to other lake ports and to New York state; and the Des Plaines-Illinois River route furnished access to the growing State of Illinois and to the entire Mississippi Valley.

The existence of these water routes and the growth of the port of Chicago at their junction, led still later to the construction of many important railroads into Chicago, and made Chicago an important center of transportation by both rail and water.

In the early days of Illinois, transportation flourished on this water route, as it did on the Missouri and Mississippi.

But later, the rapid development of the Middle West and the resulting marvelous increase in its natural and manufactured products, stimulated the construction of a vast network of railroads that competed with each other, and paralleled and competed with these inland water routes. This extensive and intense rail competition, maintained under highly economic operating conditions, gradually overcame and lessened the water transportation, and discouraged the adequate maintenance of inland waterways, so that transportation over this particular waterway and throughout the Mississippi Valley, became reduced to a relatively small volume.

Then the World War threw its enormous burden of traffic upon the railroad transportation systems of the country,

which broke down under it, and in the light of their proved inadequacy, and of the large increase in freight rates that resulted from war and post-war increased operating costs, shippers again turned to the waterways for relief. Through this experience, the shipping world has come to see the folly of handling by rail heavy low-grade commodities, like grain, coal, lumber, ore, iron, etc., as to which quick delivery is not essential, and for which there may be available an all-water or part-water route with its substantially lower freight rates. So the value and need of our inland waterways has again become and is, a subject of live importance to the business world and to the Government.

During the War Congress recognized this need of inland waterways to supplement our existing railroad systems.

In the "Federal Control Act" ("An Act to Provide for the Operation of Transportation Systems while under Federal Control, for the just compensation of their owners, and other purposes," 40 Stat. L. 451), the President was specifically authorized (Sec. 6) to spend such amounts as he deemed necessary for the **utilization of waterways** and **the creation of water transportation agencies.**

In the "Transportation Act" of 1920, (41 Stat. L. 499), in Section 500, Congress declared it to be its policy: **"To permit, encourage and develop water transportation service and facilities** in connection with the commerce of the United States, and to foster and preserve in full vigor, **both rail and water transportation."**

And in the same Section it was made the duty of the Secretary of War, in aid of this policy of Congress, to investigate extensively and to report to Congress concerning all matters that might assist in the development of inland waterways.

And by Section 201, of the same Act, upon the termination of Federal control, all boats, barges, etc., **on inland waters,**

acquired by the United States pursuant to the Federal Control Act, were transferred to the Secretary of War" • • • who shall operate or cause to be operated such transportation facilities, so that the lines of inland water transportation used by or through the President during Federal control shall be continued, and assume and carry out all contracts and agreements in relation thereto, entered into by or through the President in pursuance of such paragraph, prior to the time above fixed for such transfer."

It was further made the duty of the Secretary of War under one of the specific provisions of this Section, to operate or provide facilities for water carriage on the Mississippi River above St. Louis.

Under these Acts of Congress, the Government created and is successfully operating a barge line freight service on the Mississipi and Black Warrior Rivers, known as the "Mississippi-Warrier Barge Line."

To further the development of this carrier, and to place it on a more stable basis, Congress passed the Act entitled, "An Act to Create the Inland Waterways Corporation, for the purpose of carrying out the mandate and purpose of Congress as expressed in sections 201 and 500 of the Transportation Act, and for other purposes," (Approved June 3, 1924.)

A corporation was formed to take over and continue this freight service and to "as soon as there is an improved channel **sufficient to permit the same**, initiate the water carriage heretofore authorized by law upon the Mississippi River above St. Louis." This corporation is controlled by the Secretary of War, who, under Section 3 (b) of the Act, shall not discontinue present facilities nor develop new lines without Congressional authorization therefor, though he may report recommendations concerning them.

That this Government owned large barge line has been and

is being successfully operated between St. Louis and New Orleans, is a matter of common knowledge.

By the creation and operation of this line the Government has provided a through freight service between St. Louis and New Orleans, and has demonstrated that such a service is practicable as a matter of navigation, and in competition with parallel rail lines. It has also proved to the farmers and producers of other natural products, and to the manufacturers and merchants, throughout the Mississippi Valley freight territories, that this ancient route to the seas, giving access to the markets of the world at water or part water freight rates, is sill available, practicable and economic. Its value and importance to the Mississippi Valley now and in the future, are limited only by the extent to which the Government is willing to maintain and make available these inland waterways.

In addition to these developments resulting from the proved inadequacy of rail transportation during the War, a further development has emphasized the importance to shippers in the Middle West, of improving water transportation on the Mississippi River and from the River to the Lakes.

The construction and operation by the Government of the Panama Canal and of Government owned sea-going freight vessels, opened the markets of South and Central America to the products of the Mississippi Valley, and also had a marked effect on the rail freight rates between the Middle West and points on the Atlantic and Pacific coasts. Until these developments, such limited water competition as existed, although important, had not had its full effect upon rail rates from coast to coast, and between coast points and the Middle West. But these developments caused a large volume of coast to coast traffic and of Middle West to coast traffic, to move wholly or partly by water routes and thus to be diverted from the rail lines. Coast to coast rail rates had always tended to

be lower than the combination rail rates to and from Middle West points, and this fact caused a constant conflict between the desire of the coasts for low transcontinental rail rates and the desire of the Middle West to obtain combination rail rates no higher than the coast to coast rail rates. This conflict resulted in much litigation regarding such rates, also in frequent amendments of the Long and Short Haul clause (Sec. 4) of the Act to Regulate Commerce; and another effect was to make the rail rates more inflexible and less capable of adjustment to meet changing commercial conditions.

Since the existence of an available water route to the Gulf constitutes today the only effective regulator of long haul rail rates, this Mississippi Valley waterway, having a connection (via Appellant's canal) with Lake Michigan, and an outlet via the Missouri River for the products of the vast territory traversed by the Missouri, and having large additional territories tributary to the upper Mississippi, the Ohio River and each of the navigable rivers that empty into the Mississippi south of Cairo, Illinois, is today a vital factor in the transportation facilities of the United States.

The shippers and receivers of freight throughout this important part of the United States, whose businesses developed on a practical equality of transportation cost with their seaboard competitors, are now suffering serious disadvantages in competing with other parts of this country and in foreign trade, because of adverse rail rates to the sea. The recent improvement by the Government of water transportation facilities in the Mississippi Valley and its declared purpose to improve inland waterways generally, alone promises relief.

It has also opened wide the door of reasonable hope and expectation, that this historic route from the Lake to the Gulf, and the Mississippi River itself, will not be made less

navigable than at present, but will be improved and enlarged in navigable capacity, so as to forever and effectively "unite the waters of Lake Michigan with those of the Illinois River," for the use of deep draft barges and other freight bearing vessels, suitable for modern navigation, and for the transportation of large volumes of freight in competition with modern freight trains.

The volume of water (10,000 cubic feet per second) that has been and is now being diverted through appellant's canal into the Mississippi River, constitutes a substantial portion of the river between St. Louis and Cairo during low water seasons.

By Act of Congress, March 2, 1907, (34 Stat. L., p. 1073) a special Board of Engineers was created, who made a survey of the Mississippi River from St. Louis to the Gulf. This Board reported to the Secretary of War, June 7, 1909, and their report is Document No. 50, Sixty-first Congress, First Session. This report shows that at low water stage, the Mississippi River from St. Louis to Cairo has a flow of only 33,000 cubic feet per second, including the water diverted from Lake Michigan, and that this addition of 10,000 cubic feet per second adds one and one-half feet to the depth of this part of the river during the low water months. At high water, the maximum flow at St. Louis was 1,146,000 cubic feet per second.

It is a matter of common knowledge that this part of the Mississippi River is difficult to navigate at low water because of numerous shifting sand bars and a shallow, shifting channel; and the above facts from the Engineers' Report show how substantial a part of the river during low water months is the water diverted from Lake Michigan, and how necessary it is to the maintenance and operation of this waterway.

Various depths (twenty-four, fourteen and nine feet) for this Lakes to the Gulf deep waterway, have been considered by the Government, by the State of Illinois and by others

interested. The public demand for a twenty-four foot channel and its desirability, were so potent that the improvement of the Chicago River and the construction of the main channel of the canal for a distance of thirty-six miles from Lake Michigan, to within a mile or two of Joliet, Illinois, were completed with a depth of twenty-four feet; (Appts. Narr. St., p. 296).

This provided a much greater navigable capacity than would have resulted had the canal been built merely for adequate sanitation purposes. For merely sanitation purposes it could have been built **"for only a fraction** of the cost that was necessitated in building a channel of the present dimensions, in order to fit it for navigation." (Appts. Narr. St., p. 391.)

Below Joliet (beyond the jurisdiction of the Sanitary District) the State of Illinois is constructing improvements and has asked the Government to co-operate to create a preliminary depth of fourteen feet to the Mississippi (230 miles), to be further deepened progressively as the need of navigation may require (Appts. Narr. St., p. 297), and the waterway now actually under construction is required by the Illinois Act to be of a depth of not less than 14 feet over mitre sills.

To maintain such a fourteen-foot channel through the State of Illinois, a diversion of 10,000 cubic feet per second is essential. (Appts. Narr. St., p. 298.) The Illinois Act of 1889, creating the Sanitary District, contemplated a depth of at least fourteen feet with a diversion of 10,000 cubic feet per second. (Appts. Narr. St., p. 298.) This plan was advocated by the Lake to the Gulf Deep Waterways Association, and Congress made a conditional appropriation to begin the work whenever an understanding should be reached with Illinois regarding a plan of co-operation. (Appts. Narr. St., 299.)

The Report of the International Waterway Commission

upon the Chicago Drainage Canal, Jan. 4, 1907, (App. Nar. pp. 505 to 529), states (p. 512):

> "It can hardly be doubted that the canal will eventually form a part of an improved waterway between the Great Lakes and the Mississippi River, though its full depth will probably not be required for that purpose. Congress has not adopted any scheme for this improvement, but by its direction a survey was made, and plans with estimates for a waterway fourteen feet deep were submitted, by a Board of Engineers in a report dated Aug. 26, 1905. The Board found that for a distance of about 100 miles from Chicago the improvement must be with locks and dams and as the quantity of water required would be merely that needed for the service of locks and other incidentals, the extent of the improvement of depth which would be obtained in that part of the route was without limit so far as it depended upon the amount of water available. For the remaining distance, about 223 miles, the improvement would be an enlargement of the open channel and the degree to which it was practicable was entirely dependent upon the quantity of water flowing. The Board assumed that the Chicago Drainage Canal would eventually be permitted to take 10,000 cubic feet per second from Lake Michigan, and it expressed the opinion that with that volume added to the natural low water discharge of the Illinois River, a depth of fourteen feet in the open channel could be maintained; also that if a much greater depth was to be secured, a much larger volume of water must be taken from Lake Michigan."

That improvement of navigation in the Illinois River depends on the volume of flow from Lake Michigan, is further shown by the following references to Appellant's Narrative and the documents there quoted: Letter of Division Engineer of Chicago (May 24, 1921; App. Narr, p. 50; Report of Col. Macond, Jan. 25, 1875; App. Nar. pp. 419-420; Report of Capt. Marshall, U. S. Division Engineer of Chicago, 1895 Appr. Narr. 463.

While the plan for a fourteen-foot channel seems to be the one generally accepted and favored as desirable to be accomplished,—the actual work being done by the Government

as shown by Rivers and Harbors Appropriation Acts, has been for the present maintenance of channel depths of: nine feet from the mouth of the Mississippi to the mouth of the Ohio; eight feet from the mouth of the Ohio to the mouth of the Missouri, and six feet from there to Minneapolis.

Since the low water flow between St. Louis and Cairo is only 33,000 cubic feet per second (as stated above), it appears that the 10,000-foot diversion from Lake Michigan constitutes at such critical times almost one-third of the Mississippi River between these points.

From the beginning, Illinois has assisted Chicago to utilize the peculiar advantages of its natural location in protecting its water supply and taking care of sewage, by diverting water from Lake Michigan.

The original plan for the construction of the Illinois-Michigan canal contemplated a flow by gravity from Lake Michigan. Owing to lack of funds this plan was not carried out but from the beginning water for the canal was obtained from Lake Michigan by pumping works. In the report made pursuant to provisions of the Rivers and Harbors Act of 1902 (App. Narr., p. 498), the history of this matter is summarized as follows:

> "Besides being a highway of commerce, the Illinois and Michigan Canal has from the beginning served to carry off the sewage of Chicago. The Chicago River has always been the main receptacle of the sewage of the City, and as the volume of the sewage has increased with the growth of the City, additional facilities for discharging it into the Canal have become necessary. When the Canal was opened in 1848, a pumping plant was established at Bridgeport, where it joins the Chicago River. In 1860, the capacity of this plant was nearly doubled, being increased to about 400 cubic feet per second. Later on the summit level of the Canal was cut down so as to provide a continuous gravity flow from the Chicago River and Lake Michigan. That work was completed in 1871 and the pumping plant abandoned. In 1883, a new pumping plant was brought into use, having a nominal

> capacity of 750 cubic feet per second, but it soon became evident that the discharging capacity of the old canal was quite inadequate to carrying the volume of water required to dilute the sewage, and that a new and greatly enlarged channel must be provided."

Cooley testified that when the Illinois and Michigan Canal was opened to gravity flow it had an estimated capacity of 40,000 cubic feet per minute, which declined due to a decline in lake levels to 20,000 feet per minute. Pursuant to a resolution of the Legislature in 1881, the City of Chicago erected pumping works with the capacity of not less than 60,000 feet per minute. (App. Narr., pp. 272-273.)

Chicago, from the beginning, properly availed itself of the advantages of its natural location. The present canal, therefore, is merely the final development of an historic plan.

In view of the Lake States' claim of damage to their navigation interests, the evidence which disproves the existence of any such damage should be noted.

The testimony on this point is uncontroverted. Joseph Ripley, one of the United States engineers, described in detail the basis upon which navigation improvements in the Great Lakes are made. (App. Narr., p. 154.) In the Acts of Congress making appropriations for navigation improvements, navigable depths are fixed in relation to what is known as a "reference plane," *i. e.*, a plane (or level) fixed by the Engineers at a certain definite number of feet and inches above sea level. Navigable depths are fixed by the Acts of Congress at so many feet below the reference plane. The testimony shows plainly that reference planes for navigation improvements in the Great Lakes were, in 1901 and 1903, reduced from six feet to a foot or more in order to allow for the lowering of the levels of the Great Lakes anticipated by the engineers to result from the Chicago and other diversions. This testimony demonstrates that the depths provided by Congress in improving navigation in the Great

Lakes were in fact produced to the full extent contemplated. For instance, in spite of the claimed lowering of the Lakes, where a 21-foot project was desired by Congress, dredging took place to such an extent that 21 feet was obtained after the lowering of lake levels had occurred.

THE ACTUAL ISSUES BEFORE THIS COURT.

In view of the extensive scope of the claims made in the brief for the Lake States, and of the numerous points presented in the briefs of the parties to this record, it is particularly important to keep in mind the **exact nature** and **very limited scope** of the issues presented in this appeal.

In this case the Appellant is enjoined by the decree "from diverting or abstracting any water from Lake Michigan * * * **in excess** of 250,000 cubic feet per minute," *i. e.*, 4,167 cubic feet per second. (Appts. Narr. St., p. 117.)

The bills rest the entire case for the Government on the theory that Section 10, of the Rivers and Harbors Act of March 3, 1899, renders unlawful the Appellant's works and the resulting diversion, because:

(a) The diversion of water from Lake Michigan creates "an obstruction to the navigable capacity" of the Great Lakes; and

(b) Under Section 10, of the Rivers and Harbors Act of March 3, 1899, no obstruction of any kind or degree can be created without the consent of Congress and the permission of the Secretary of War;

(c) Congress has not authorized this diversion, and the Secretary of War has permitted Appellant to thus divert **only** 4,167 cubic feet per second; and that therefore

(d) **All diversion in excess of said quantity is unlawful.**

It thus appears that this entire case rests upon Section 10 of the Act of 1899, and that the decree must fall unless it can be justified under this Act.

The above statements accurately summarize the averments of the bills on the points involved.

This is not a suit in equity to abate an alleged nuisance. It is not an original proceeding before this Court by the Lake States against Illinois to determine whether Illinois, as part owner of Lake Michigan, is making an inequitable or unreasonable use of lake waters, thereby causing substantial injury to the navigation interests of the other Lake States. It is not even a suit by the Government to abate this diversion at Chicago on the ground that it constitutes a substantial injury to navigability. Nor does the Government sue as a trustee for the benefit of the Lake States or the people.

The above analysis of the bills and decree shows that the single issue upon this appeal is **whether Section 10, of the Rivers and Harbors Act of March 3, 1899, renders unlawful any diversion in excess of 4,167 cubic second feet.**

This brief is filed by leave of court on behalf of these *Amici Curiae* because of the facts above set forth, to show that the decree below should be reversed.

BRIEF OF POINTS AND AUTHORITIES.

I.

INTRODUCTORY: THE QUESTION OF SOVEREIGN POWER AS BETWEEN THE UNITED STATES AND THE STATE OF ILLINOIS.

Missouri v. *Illinois*, 200 U. S. 518;
Columbus v. *Merc. Trust Co.*, 218 U. S. 645;
Covington Bridge Co. v. *Kentucky*, 154 U. S. 204, 209;
Montgomery v. *Portland*, 190 U. S. 89, 105;
Lake Shore R. R. Co. v. *Ohio*, 173 U. S. 285, 292;
U. S. v. *Rio Grande Dam Co.*, 174 U. S. 690, 702, 703;
Guttierres v. *Albuquerque L. & I. Co.*, 188 U. S. 545, 553, 554;
Boquillas L. & I. Co. v. *Curtis*, 213 U. S. 339, 344, 345;
Willamette Iron Bridge Co. v. *Hatch*, 125 U. S. 1, 8;
Escanaba Trans. Co. v. *Chicago*, 107 U. S. 678, 683;
Cummings v. *Chicago*, 188 U. S. 410, 430.

II.

BEFORE CONGRESS HAD ACTED AT ALL ON THE SUBJECT OF OBSTRUCTING NAVIGABILITY, ILLINOIS WAS FREE TO AND DID EXERCISE ITS SOVEREIGN POWER OVER THESE NAVIGABLE WATERS WITHIN ITS OWN BOUNDARIES, BY BUILDING A CANAL TO "UNITE THE WATERS OF LAKE MICHIGAN WITH THOSE OF THE ILLINOIS RIVER," AND IN THE OPERATION OF THIS CANAL, FOR THE DUAL PURPOSE OF NAVIGATION AND SANITATION, ILLINOIS SINCE 1848 HAS CONTINUOUSLY AND LAWFULLY DIVERTED WATER FROM LAKE MICHIGAN.

Covington Bridge Co. v. *Kentucky*, 154 U. S. 204, 209;
U. S. v. *Rio Grande Dam Co.*, 174 U. S. 690, 703;

Illinois Session Laws 1836, page 145;
Corrigan Trans. Co. v. *Sanitary District*, 137 Fed. 851, 857.

III.

THIS EXERCISE OF SOVEREIGN POWER BY ILLINOIS, IN CONSTRUCTING AND OPERATING A CANAL THAT UNITED THE WATERS OF LAKE MICHIGAN WITH THOSE OF THE ILLINOIS RIVER, AND THAT DIVERTED WATER FROM LAKE MICHIGAN INTO THE MISSISSIPPI VALLEY, HAD THE SANCTION AND APPROVAL OF CONGRESS LONG BEFORE THE ORIGINAL CANAL WAS BUILT.

32 Annals of Congress, 15th Congress, 1st Session, 1677;
Act of March 30, 1822, 3 Stats. at L. 659;
Act of March 2, 1827, 4 Stats. at L. 234.

IV.

NEITHER THE BILLS, NOR THE DECREE, ARE BASED ON ANY CONTENTION OR SHOWING THAT ILLINOIS HAS UNNECESSARILY OR UNREASONABLY OR SUBSTANTIALLY INTERFERED WITH INTERSTATE COMMERCE. ON THE CONTRARY, THEY REST ENTIRELY ON THE THEORY THAT ILLINOIS CANNOT DIVERT ANY WATER FROM LAKE MICHIGAN FOR USE IN THE CANAL, WITHOUT THE FEDERAL CONSENTS PRESCRIBED IN SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899. IT IS THE THEORY OF THE BILLS THAT BOTH THE AFFIRMATIVE CONSENT OF CONGRESS AND THE PERMISSION OF THE SECRETARY OF WAR, AND THE RECOMMENDATION OF THE CHIEF OF ENGINEERS, MUST BE OBTAINED AS CONDITIONS PRECEDENT TO ANY DIVERSION WHATEVER. ON THIS THEORY NEITHER THE BILLS NOR THE DECREE CAN STAND, FOR THE REASONS TO BE STATED IN THE FOLLOWING POINTS.

U. S. v. *Rio Grande Dam Co.*, 174 U. S. 690, 703;
Escanaba Transit Co. v. *Chicago*, 107 U. S. 678, 683;
Cummings v. *Chicago*, 188 U. S. 410, 430.

V.

SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, WAS NOT INTENDED TO BE RETROACTIVE IN EFFECT. IT DOES NOT APPLY TO THIS ALREADY EXISTING DIVERSION WHICH HAD BEEN VALIDLY AUTHORIZED BY ILLINOIS. IT LOOKS TO THE FUTURE NOT TO THE PAST.

U. S. v. *Bellingham Bay Boom Co.*, 176 U. S. 211, 214;

U. S. v. *Rio Grande Dam Co.*, 174 U. S. 690, 703.

VI.

CONGRESS DID NOT INTEND BY SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, TO DECLARE THAT THIS PARTICULAR DIVERSION IS IN FACT, EITHER AN OBSTRUCTION TO NAVIGABILITY OR AN UNREASONABLE OR UNNECESSARY OR SUBSTANTIAL OBSTRUCTION. NOR DID CONGRESS INTEND, BY SUCH ACT, TO TAKE SUCH GENERAL OR EXCLUSIVE POSSESSION OF THE SUBJECT OF OBSTRUCTIONS TO NAVIGABILITY, AS TO RENDER UNLAWFUL ALL OBSTRUCTIONS NOT SPECIFICALLY AUTHORIZED BY FEDERAL CONSENTS, AS PRESCRIBED IN THE ACT.

Cummings v. *Chicago*, 188 U. S. 410, 430.

VII.

THE FACT THAT CONGRESS BY THE "NIAGARA FALLS ACT" OF 1906, EXPRESSLY GAVE TO THE SECRETARY OF WAR AUTHORITY TO CONSENT TO DIVERSIONS OF WATER FROM THE NIAGARA RIVER, SHOWS CLEARLY THAT CONGRESS HAD NOT THERETOFORE INTENDED TO COVER THE SAME FIELD BY SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, WHEREBY IT WAS DECLARED UNLAWFUL "TO ALTER * * * THE * * * CAPACITY OF ANY * * * CANAL, LAKE * * * OR OF THE CHANNEL OF ANY NAVIGABLE WATER OF THE UNITED STATES, UNLESS THE WORK HAS BEEN RECOMMENDED BY THE CHIEF OF ENGINEERS AND AUTHORIZED BY THE SECRETARY OF WAR PRIOR TO BEGINNING THE SAME."

Act of June 29, 1906, 34 Stats. at L. 626;
59th Congress, 1st Session, Report #4694;
Congressional Record June 2, 1906.

VIII.

TO SUSTAIN THE DECREE, IT IS NECESSARY TO CONSTRUE SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, AS A GRANT TO THE SECRETARY OF WAR OF UNLIMITED POWER TO PERMIT OR REFUSE THE CREATION OF OBSTRUCTIONS TO NAVIGATION. THE ACT DOES NOT ADMIT OF SUCH A CONSTRUCTION.

1. The power, conferred by the Act upon the Secretary of War, was intended to be administrative in effect and narrow in scope. It could not have been intended to authorize him to act, in place of Congress, in deciding broad questions of sovereign right or public policy, such as the judicial question whether Illinois had the sovereign power to divert water from Lake Michigan, or the legislative questions whether Illinois should be allowed to divert water, and what quantity, and for what purpose.

2. In attempting by his order of December 5, 1901, to fix and limit the quantity of water that appellant might divert from Lake Michigan, the Secretary of War necessarily assumed that he had power:

(a) To supersede and make inoperative the statute of Illinois theretofore enacted, pursuant to its reserved police power, by which Illinois had authorized appellant to use navigable waters within the state for the health and welfare of its people.

(b) To deny to the Illinois and Mississippi River Valleys the diversion of the quantity of water needed for effective waterway navigation, and to decide that the interests of the Great Lakes were of higher public value than those of the Mississippi Valley.

(c) To substantially reduce the low water flow of these two rivers, and thereby greatly increase the cost to the Government of maintaining a reasonable channel from the Lakes to the Gulf.

(d) To decide the question of public policy involved, in permitting a diversion of 4,167 c. f. s., thereby, to this extent, lowering lake levels and reducing water power at Niagara, and so deciding rights claimed by the citizens of Canada, while at the same time denying the right of appellant to a larger diversion.

IX.

(1) IF CONGRESS HAD INTENDED BY ITS ACTS TO DELEGATE TO THE SECRETARY OF WAR THE POWER TO DECIDE SUCH QUESTIONS, THIS ATTEMPTED DELEGATION WOULD HAVE BEEN UNCONSTITUTIONAL AND VOID, BECAUSE CONGRESS FAILED TO FURNISH ANY GUIDE, PRINCIPLE OR RULE, PURSUANT TO WHICH THE SECRETARY SHALL EXERCISE THE POWER IN QUESTION.

Wichita R. R. Co. v. *Public Utilities Commission,* 260 U. S. 48, 58.

(2) AND EVEN IF SUCH POWER HAD BEEN VALIDLY DELEGATED, THE MANNER OF ITS EXERCISE IN THE CASE AT BAR CANNOT BE SUSTAINED UNDER THE "DUE PROCESS" CLAUSE—BECAUSE MANY INTERESTS DIRECTLY AND ADVERSELY AFFECTED BY THE DECISION OF THE SECRETARY, INCLUDING THESE AMICI CURIAE, WERE GIVEN NO NOTICE OR OPPORTUNITY TO BE HEARD, AND THE ACT REQUIRED NO SUCH NOTICE OR HEARING.

Union Bridge Co. v. *U. S.* 204 U. S. 364, 385;
Monongahela Bridge Co. v. *U. S.* 216 U. S. 177, 192.

X.

ASSUMING FOR ARGUMENT ONLY, THAT SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, AND THE AUTHORITY OF THE SECRETARY OF WAR THEREUNDER, DID APPLY TO APPELLANT'S DIVERSION, NEVERTHELESS THE REQUIREMENTS OF SAID ACT WERE MET, IN THAT ILLINOIS HAD OBTAINED THE PRIOR "AFFIRMATIVE AUTHORITY OF CONGRESS," AND THE PARTICULAR WORKS WERE "AUTHORIZED BY THE SECRETARY OF WAR" AND "RECOMMENDATION BY THE CHIEF OF ENGINEERS."

(1) The State of Illinois built its Sanitary and Ship Canal, pursuant not only to the sovereign power of the State, but also under the "affirmative authority" of Congress.

Mortell v. *Clark,* 272 Ill. 201, 213.

(2) The particular "works" which resulted in this diversion by appellant were also "authorized by the Secretary of War," and "recommended by the Chief of Engineers."

XI.

THE CONTENTIONS MADE IN THE BRIEF FILED ON BEHALF OF THE LAKE STATES, APPEARING AS AMICI CURIÆ, ARE EITHER OUTSIDE THE ISSUES OF THIS CASE, OR WITHOUT MERIT.

Illinois Central R. R. v. *Illinois*, 146 U. S. 387, 435;
U. S. v. *Rio Grande Dam Co.*, 174 U. S. 697;
Kansas v. *Colorado*, 206 U. S. 46;
Guttierres v. *Albuquerque L. & I. Co.*, 188 U. S. 545, 553, 554;
Boquillas L. & I. Co. v. *Curtis*, 213 U. S. 339, 344, 345;
Leovy v. *U. S.*, 177 U. S. 621, 636;
Missouri v. *Illinois*, 200 U. S. 496, 526.

XII.

WITHOUT REGARD TO QUESTIONS OF LEGAL POWER, THE RELATIVE EQUITIES IN THE INSTANT CASE REQUIRE A REVERSAL OF THE DECREE.

BRIEF OF THE ARGUMENT.

I.

INTRODUCTORY: THE QUESTION OF SOVEREIGN POWER AS BETWEEN THE UNITED STATES AND THE STATE OF ILLINOIS.

We understand, and shall assume in this brief, that the courtesy extended by the Court to these *amici curiae* permits them merely to make such suggestions as they think may aid the Court in its consideration of the issues presented by the record. Therefore, in presenting the contentions herein submitted on behalf of these *amici curiae*, and also in endeavoring to answer the contentions made in the briefs for the Lake States and for the Lake Carriers Association, we shall endeavor to confine this brief to the points that we think are thus in issue.

In the case at bar, two sovereigns, Illinois and the United States, have each attempted to exercise sovereign power concerning certain navigable waters of the United States located within the State of Illinois. Each sovereign claims that its own action was valid and effective, and that the other's action was, in certain respects, illegal and ineffective. So, before a conclusion can be reached, it is necessary, first, to have clearly in mind the exact subject matter involved, and the nature and extent of the power of each sovereign over this subject matter.

The subject matter consists of the navigable waterway between Lake Michigan and the mouth of the Illinois River, **all of which** (including a part of Lake Michigan) **lies within the State of Illinois**, and part of which (the southwest part of the Lake) is the **property** of Illinois.

By work done wholly within its own borders, *i. e.*, by deepening and widening the Chicago River, and by building and

operating a canal to be used for navigation and sanitation, Illinois has reversed the flow of the Chicago River, and with water thereby extracted by gravity flow from Lake Michigan, has greatly improved the navigability of this waterway, has purified Chicago's water supply, has abated the unsanitary condition of the Chicago and Illinois Rivers, and has disposed of Chicago sewage by diluting it and causing it to flow away from the Lake and down this waterway, instead of into the Lake. Illinois claims that all of these acts were within its sovereign powers.

But the Government claims that this diversion of water has to some extent lowered the level of the Lakes, has thereby caused "an obstruction" to their "navigable capacity," and is unlawful solely because Illinois did not obtain the several Federal consents required by Section 10, of the Rivers and Harbors Act of 1899.

The State of Illinois has all the powers of a sovereign except those expressly granted to the National Government by the Constitution of the United States. There exists no superior law which controls Illinois in the exercise of its reserved sovereign powers, unless it be found in the language of the Constitution, or in a law of the United States, properly founded upon the Constitution.

Missouri v. *Illinois*, 200 U. S. 518, at .....

Even though an exercise of State sovereignty may result in remediable injury to another state or its citizens, there exists no superior law which because of such injury renders unlawful such exercise of sovereignty. The Constitution provides a remedy for such situations, but in no sense contains any prohibition against such acts. The injured state may, by original suit before the Supreme Court redress such injuries, and in a proper case the Supreme Court may assert the power of the nation to prevent such acts, and of course declare them unlawful, but in advance of such a decision by the

Supreme Court, there exists no power to declare such acts unlawful, nor is there any law applicable thereto. Up to the present, no decision of this Court in a proper case, has declared the acts of Illinois here in question, to be unlawful.

To protect the health of its people by providing proper supplies of drinking water and adequate sanitary disposals of sewage is peculiarly within the sovereign powers of Illinois; (*Columbus* v. *Mercantile Trust Co.*, 218 U. S. 645, at 648).

In respect of local subjects that concern its public policy, a state **may** (as shown by cases cited herein), **exercise its sovereign powers** over **navigable waters within its borders.**

While the power to construct **a canal** within a state, as in the case at bar, is cited by this court as an instance in the class of cases in which the power of the state is exclusive of Congressional control under the Commerce Clause, (*Covington Bridge Co.* v. *Kentucky*, 154 U. S. 204, at 209), the power **to improve navigable channels within a state**, as in the case at bar, is within the class of cases described by this court in the same case (page 211) as of "**concurrent jurisdiction,**" *i. e.*, the failure of Congress to take complete legislative control of the subject **leaves the states free to act**; (*Montgomery* v. *Portland*, 190 U. S. 89, at 105); and when the state's sovereign powers are exercised in reference to matters more or less connected with interstate commerce, such powers are not restricted to mere regulations pertaining to the health, morals or physical well being of the public, but may also include actions designed to promote the public convenience or prosperity, like bridging navigable rivers within the state, etc.; (*Lake Shore R. R. Co.* v. *Ohio*, 173 U. S. 285, at 292).

When Congress, by failing to take complete legislative control of the subject, leaves the states free to act in respect of subjects of "concurrent jurisdiction," a state may act, even though it thereby causes incidental obstruction to navigability.

In the exercise of such power **a State may permit the appropriation and diversion of water from a navigable stream,** subject, however, as in the case of other concurrent powers, to a proper exercise of the jurisdiction of Congress to preserve navigability.

In *U. S.* v. *Rio Grande Dam Co.*, 174 U. S. 690, at 702-703, there was a diversion of water from the Rio Grande River (flowing between the United States and Mexico), and a claim by the United States, that such diversion of water from the Rio Grande River should be abated as a substantial obstruction to navigability.

Concerning the power of a state to change the common law rule against the appropriation of the waters of a river, this court said, at page 702-3, (heavy face type ours):

> "* * *, it is also true that as to every stream within its dominion **a state may change this common law rule** and **permit the appropriation of the flowing waters for such purposes as it deems wise** * * *.
>
> Although this power of changing the common law rule as to streams within its dominion undoubtedly belongs to each state, yet two limitations must be recognized: * * * That **it (the state) is limited by the superior power of** the general government **to secure the uninterrupted navigability** of all navigable streams within the limits of the United States. In other words, the jurisdiction of the general government over interstate commerce and its natural highways vests in that government the right to take all needed measures **to preserve the navigability** of the navigable water courses of the country even against any state action. **It is true there have been frequent decisions recognizing the power of the state, in the absence of congressional legislation, to assume control of even navigable waters within its limits to the extent of creating dams,** booms, bridges **and other matters which operate as obstructions to navigability. The power of the state to thus legislate for the interests of its own citizens is conceded,** and **until** in some way **Congress asserts its superior power,** and the necessity of preserving the general interest of the people of all the states, **it is assumed that state action, although in-**

volving temporarily an obstruction to the free navigability of a stream, is not subject to challenge. A long list of cases to this effect can be found in the reports of this court. See among others, the following: *Wilson* v. *Black Bird Creek Marsh Co.* 2 Pet. 245; *Gilman* v. *Philadelphia,* 3 Wall. 713; *Escanaba Co.* v. *Chicago,* 107 U. S. 678; *Willamette Iron Bridge Co.* v. *Hatch,* 125 U. S. 1."

All this proceeds upon the theory that non-action by Congress implies its assent to the action taken by the state.

For other cases in which there were diversions or appropriations of water and in which the power of the states was recognized, see: *Guttierres* v. *Albuquerque Land & Irr. Co.* 188 U. S. 545, at 553-554; *Boquillas Land and Irr. Co.* v. *Curtis,* 213 U. S. 339, at 344-345.

The power of the United States, is limited to the constitutional grant of power to **"regulate"** through the action of Congress, interstate and foreign commerce, which includes power to protect the navigability of the navigable waters of the United States: (*Willamette Iron Bridge Co.* v. *Hatch,* 125 U. S. 1, at 8; *U. S.* v. *Rio Grande Dam Co.* 174 U. S. 690, at 703.)

But this grant of power does not *per se* exclude all exercise by the states of their sovereign power over navigable waters within their own borders.

The power of Congress **must be exercised,** in order to become effective as a restraint upon state action. And its exercise does not necessarily or in all cases exclude or invalidate state action.

This Court has, in a number of cases, treated the powers of a state to improve navigable waters within its borders as pertaining to the "concurrent jurisdiction," *i. e.,* to the class of cases in which a failure by Congress to take complete legislative control of the subject leaves the states free to act upon such portion of said subject as Congress has not

completely occupied; *Montgomery* v. *Portland,* 190 U. S. 89, at 105; *Escanaba Transp. Co.* v. *Chicago,* 107 U. S. 678, at 683.

In the last named case this court held—in respect of bridges built by the City of Chicago across the Chicago River, (a part of the same navigable water involved in the case at bar), which bridges were complained of as obstructions to the navigability of the river,—that such local subjects are of the "concurrent jurisdiction" class, *i. e.,* **within the power** of the state (page 683), **"until Congress interferes and supersedes it."** And speaking of the state's exercise of such power, and the superior control of Congress over the same, the Court said, at page 683 (heavy type ours):

> "When its power is exercised **so as to unnecessarily obstruct** the navigation of the river or its branches, Congress may interfere and remove the obstruction. * * *
>
> But **until Congress acts** on the subject the **power of the state over bridges across its navigable streams is plenary."**

But in order thus to interfere, Congress must in fact exercise its constitutional power to regulate commerce, and it can do this **only by legislation** which **clearly evidences its intent to interfere with what the state has theretofore done** in the exercise of the latter's sovereign power.

As this Court said in *Cummings* v. *Chicago,* 188 U. S. 410, at 430, in construing Section 10, of the Rivers and Harbors Act of March 3, 1899, and in deciding that by said Section 10, Congress did not assume even such exclusive jurisdiction as to override the necessity of complying with the requirements of a mere ordinance of the City of Chicago, which called for the prior approval of a city officer:

> "If it had intended by the Act of 1899 * * * **to supersede entirely,** the authority which the states, in the absence of action by Congress, have in such matters, such a radical departure from the previous policy of the Government **would have been manifested by clear and**

explicit language. In the absence of such language, it should not be assumed that any such departure was intended."

Therefore, unless it be held that Section 10, of the Act of 1899, does contain a clearly expressed intent of Congress to interfere with and abate this diversion of water from Lake Michigan, which Illinois had theretofore validly authorized, and to which Congress itself had theretofore expressly given its approval by the Act of March 2, 1827, **the authority and action of the State must stand.**

II.

BEFORE CONGRESS HAD ACTED AT ALL ON THE SUBJECT OF OBSTRUCTING NAVIGABILITY, ILLINOIS WAS FREE TO AND DID EXERCISE ITS SOVEREIGN POWER OVER THESE NAVIGABLE WATERS WITHIN ITS OWN BORDERS, BY BUILDING A CANAL TO "UNITE THE WATERS OF LAKE MICHIGAN WITH THOSE OF THE ILLINOIS RIVER," AND IN THE OPERATION OF THIS CANAL, FOR THE DUAL PURPOSES OF NAVIGATION AND SANITATION, ILLINOIS SINCE 1848 HAS CONTINUOUSLY AND LAWFULLY DIVERTED WATER FROM LAKE MICHIGAN.

Each of these purposes, as shown by above cases, was within the sovereign powers of Illinois. Independently of any consent by Congress, it had the power to authorize the construction of a navigable canal, within its borders. (*Covington Bridge Co.* v. *Kentucky,* 154 U. S. 204 at 209.) And that this power was exercised for the purpose of preserving the health of its people,—a matter over which Congress had no jurisdiction—certainly did not weaken the legal effectiveness of the state's exercise of its sovereign power.

Moreover, as held in *U. S.* v. *Rio Grande Dam Co.,* 174 U. S. 690 at 703 (see above), the State also had concurrent power to change the common law rule in reference to flowing waters, and to authorize a diversion of water from Lake Michigan, for use in the canal, and (Congress not having

acted adversely) the State had this power even without the consent of Congress.

The State of Illinois, by its General Assembly, passed an Act, January 9, 1836, (Illinois Sessions Laws, 1836, p. 145; Appts. Narr. St. pp. 412, 413), under which the "Illinois and Michigan" canal was constructed.

By this Act the width of the canal was fixed and additional space for its future enlargement was provided. The depth was to be suitable for ordinary "canal navigation."

That a diversion of water from Lake Michigan through said canal was contemplated, is shown by the provision in Section 16, of said statute, that the canal was **"to be supplied with water from Lake Michigan** and such other sources as the canal commissioners may think proper."

Work on this canal was started by Illinois on July 4, 1836, and the canal was put in operation in 1848. Because adequate funds were lacking to construct a "deep cut" canal through the Divide, the original canal was constructed on the "shallow cut plan" with a summit level eight feet above Lake Michigan (Appts. Narr. St. 416.) But water was supplied by pumps from the Chicago River at Bridgeport (where the canal and river met) and thus from Lake Michigan. To the extent that the canal was fed from the Calumet and Chicago rivers, both of which emptied into Lake Michigan, **there was a diversion.**

Such diversion continued until 1871, when the "Deep Cut Plan" had been adopted and carried out (Appts. Narr. St. p. 419) for the dual purposes of providing greater depth in the canal, and of relieving unsanitary conditions in the Chicago River. Water from Lake Michigan was thereafter supplied to the canal by gravity flow, (Appts. Narr. St. 420-421). And because later this flow was reduced by a natural lowering of the level of Lake Michigan the flow was, in 1883, materially

increased by pumping. (Appts. Narr., Cooley's testimony, p. 272.) This increased diversion continued until Appellant's "Sanitary and Ship Canal" was constructed and opened in place of the Illinois and Michigan canal, for the dual purposes of navigation and sanitation, pursuant to Act of the General Assembly of Illinois, May 29, 1889, (Session Laws of Illinois 1889, p. 126), which created Appellant, authorized the construction and operation of the present canal, and directed a diversion of water from Lake Michigan. (Appts. Narr. St. p. 449.)

All this had been done by Illinois before Congress passed the Act of March 3, 1899, on which these bills rely.

As was said by the Circuit Court of Appeals, 7th C. in *Corrigan Transit Company* v. *The Sanitary District of Chicago*, 137 Fed. 851, at 857:

> "With the commerce clause in abeyance, Illinois, as to every being in the world except future congresses was absolute sovereign in the premises."

III.

THIS EXERCISE OF SOVEREIGN POWER BY ILLINOIS, IN CONSTRUCTING AND OPERATING A CANAL THAT UNITED THE WATERS OF LAKE MICHIGAN WITH THOSE OF THE ILLINOIS RIVER, AND THAT DIVERTED WATER FROM LAKE MICHIGAN INTO THE MISSISSIPPI VALLEY, HAD THE SANCTION AND APPROVAL OF CONGRESS LONG BEFORE THE ORIGINAL CANAL WAS BUILT.

This claim of Illinois, that it had the power, as a sovereign state, to build and operate a canal that would divert waters from Lake Michigan into the Mississippi Valley, has been recognized by Congress ever since Illinois became a state, in 1818.

When Congress, in 1818, fixed the boundaries of Illinois, prior to admitting the state, Congress, by an amendment to

the original act, included within the new state what is now the northern part of Illinois, including the southwestern part of Lake Michigan. The purpose of this inclusion, as then stated in Congress, was to gain a coast on Lake Michigan and thereby to connect Illinois through the lakes with the states of Indiana, Ohio, Pennsylvania, and New York; and it was also stated (32 Annals of Congress, 15th Congress, First Session, p. 1677); that:

> "The facility of opening a canal **between Lake Michigan and the Illinois River is acknowledged** by everyone who has visited the place. **Giving to the proposed state** the Port of Chicago (embraced in the proposed limits), will **draw its attention to the opening of the communication between the Illinois River and that place, and the improvement of that harbor.**" (App. Narr., page 405.)

By thus "**drawing the attention**" of Illinois "**to the opening of the communication between the Illinois River and the Port of Chicago,**" it is clear that Congress expected and practically invited the new state to exercise its sovereign power by opening such a "communication," leaving, of course, to the state, liberty of action under its sovereign power to determine the size and character of the canal, thus suggested as desirable to be opened between the two water sheds.

The well known fact that the water level of the Port of Chicago, opening into Lake Michigan, was much higher than the Gulf of Mexico, necessarily involved and assumed a diversion of water from the Lake into the Illinois River and the Mississippi Valley, when such a "communication" should be "opened." This expectation of Congress, that Illinois would construct and operate a canal to connect Lake Michigan and the Illinois River, was given more definite expression by the Act of Congress of March 30, 1822, (3 U. S. St. at L., page 659; App. Narr. Statement, 410). From this Act we quote:

> "**An Act to Authorize the State of Illinois to Open a**

Canal Through the Public Lands to Connect the Illinois River with Lake Michigan.

SECTION 1. Be it enacted * * * that the State of Illinois be, and is hereby authorized to survey and mark, through the public lands of the United States, the route of the canal connecting the Illinois River with the southern bend of Lake Michigan; * * * and the use thereof forever shall be, and the same is hereby vested in the said state, for a canal, and for no other purpose whatever; * * * provided, also, and it is hereby further enacted and declared, that the said canal when completed shall be and forever remain a public highway, etc. * * *"

Concerning the above language it should be noted:

(a) The title indicates that in 1822, Congress was still expecting Illinois "to open a canal to connect the Illinois River with Lake Michigan," as the "communication" between the Illinois River and the Port of Chicago that Illinois had been invited to open when it was admitted as a state.

The title also clearly recognizes that Illinois had sovereign power to open such a canal, because the authority expressed in the title has relation only to opening a canal through the public lands, for which the consent of Congress was necessary, but is not predicated on the theory that Congress could authorize the opening of a canal through any other lands.

(b) Section 1, of the Act, emphasizes the idea that the authority intended to be granted, had relation to a permit to cross the public lands rather than a permit to build a canal. This appears from the words:

> "Illinois * * * is hereby authorized to survey and mark through the public lands of the United States the route of the canal connecting the Illinois River with the Southern bend of Lake Michigan."

By the words "the canal," Congress evidently had in mind some previously discussed plan for a canal, rather than by this Act to originate a new project.

This Act also contained a provision, that if Illinois did not

make a survey and furnish a complete copy thereof to the Treasury Department within three years, then the grant of land made by the Act, would become void; and the failure of Illinois to comply with this condition, did in fact void the Act.

The project for such a canal, however, did not die. In 1826, the legislature of Illinois petitioned Congress for an additional Act to aid Illinois in the construction of the canal.

In this memorial of Illinois, (App. Narr., page 411), it is stated:

> "That **the construction of a canal, uniting the waters of Lake Michigan with the Illinois River,** will form an important addition to the great connecting links in the chain of internal navigation, etc."

In 1827, Congress granted this petition of Illinois, by the Act of March 2, 1827, (4 U. S. Stat. at L. page 234), entitled and providing:

An Act To Grant a quantity of land to the State of Illinois, for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan.

> "Section 1. Be it enacted * * * that there be and hereby is granted to the State of Illinois, for the purpose of aiding the said State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width on each side of said canal * * *; provided, THAT the said canal when completed shall be and forever remain a public highway for the use of the Government of the United States free from any toll or other charge whatever for any property of the United States or persons in their service passing through the same; * * *
>
> (2) And be it further enacted, That, so soon as the route of said canal shall be located and agreed on by the said State, it shall be the duty of the Governor thereof, or such other person or persons as may have been, or shall hereafter be, authorized to superintend the construction of said canal, to examine and ascertain the particular sections to which said State will be entitled

under the provisions of this Act, and report the same to the Secretary of the Treasury of the United States."

(a) Here again, the attitude and action of Congress show, that in 1827, it was still expecting Illinois to open the water communication between the Illinois River and the Port of Chicago, to which, as above stated, reference had been made in Congress as one of the purposes of including a part of Lake Michigan within said state.

The language of the Act, constitutes an express recognition by Congress, that Illinois had sovereign power to build a canal to connect the waters of the Illinois River with those of Lake Michigan, because the grant made by Congress was not of permission **to construct** such a canal but was of land, and was expressly made, for the purpose "of aiding" Illinois, in the exercise by the latter of its sovereign power to open such a canal.

(c) A canal that would, as stated in Section 1, of the Act, unite the waters of the Illinois River with those of Lake Michigan, necessarily meant a diversion from the St. Lawrence water shed to the Mississippi Valley, of whatever quantity of water Illinois might in its sole discretion decide to thus divert; and this quantity was necessarily subject to such additions from time to time as Illinois might deem necessary, for the purpose of meeting the changing conditions of its advancing civilization.

(d) While this grant was of land, and was not expressed to be a grant of Congressional permission or authority to build a canal, (thus evidencing the Congressional concept that Illinois, under its sovereign power, could build such a canal without the prior authority of Congress), it is nevertheless, **by necessary implication,** a clear expression by Congress of its consent and approval to the construction by Illinois of a canal that would unite the waters of the Illinois River with those of Lake Michigan.

We therefore respectfully submit, that it is clear from the attitude and actions of Congress, above set out: That Congress understood and assumed, that the exercise of sovereign power by Illinois, in constructing and operating such a canal **did not require the prior consent of Congress**; and that the historic project for the union of said navigable waters had not only the sanction and approval of Congress before the original canal was built, but it also had the affirmative aid of Congress to the extent that Congress deemed its aid necessary to authorize the resulting diversion of Lake waters, by a grant of lands which could be sold by Illinois and the proceeds used in the construction of the canal.

IV.

NEITHER THE BILLS, NOR THE DECREE, ARE BASED ON ANY CONTENTION OR SHOWING THAT ILLINOIS HAS UNNECESSARILY OR UNREASONABLY OR SUBSTANTIALLY INTERFERED WITH INTERSTATE COMMERCE. ON THE CONTRARY, THEY REST ENTIRELY ON THE THEORY THAT ILLINOIS CANNOT DIVERT ANY WATER FROM LAKE MICHIGAN FOR USE IN THE CANAL, WITHOUT THE FEDERAL CONSENTS PRESCRIBED IN SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899. IT IS THE THEORY OF THE BILLS THAT BOTH THE AFFIRMATIVE CONSENT OF CONGRESS AND THE PERMISSION OF THE SECRETARY OF WAR, AND THE RECOMMENDATION OF THE CHIEF OF ENGINEERS, MUST BE OBTAINED AS CONDITIONS PRECEDENT TO ANY DIVERSION WHATEVER. ON THIS THEORY NEITHER THE BILLS NOR DECREE CAN STAND, FOR THE REASONS TO BE STATED IN THE FOLLOWING POINTS.

The State of Illinois having validly authorized the diversion of water from Lake Michigan pursuant to the State's plenary though "concurrent jurisdiction," it follows that thereafter Congress could take action to prevent such diversion only **if the diversion constituted an unreasonable or substantial interference with interstate commerce, by materially obstructing navigability.**

We respectfully submit that this conclusion necessarily follows from the fact that the sovereign power, when thus exercised by Illinois, was validly exercised, and therefore the State's permission to divert water from the Lake was a valid permission, even though such action "caused incidental obstruction to navigability," (*U. S.* v. *Rio Grande Dam Co.*, 174 U. S. 690 at 703).

As this Court said in *Escanaba Transp. Co.* v. *Chicago*, 107 U. S. 678 at 683, referring to the State's exercise of its said power by building bridges across the navigable Chicago River:

> "When its power is exercised **so as to unnecessarily obstruct** the navigation of the river or its branches, **Congress may interfere and remove the obstruction.**"

But Congress **must act** in order to thus "interfere" with the State's action. And it cannot be possible that Congress may interfere with and abate what the State has validly done, unless the State has in fact caused an unreasonable or substantial obstruction to navigability.

If a state has in fact caused an unreasonable or substantial obstruction to navigalibity, which Congress thereafter seeks under its dominant power, to abate, Congress may do so only by a statute appropriate to effectuate such purpose. Such a statute must, in clear and explicit language, express the intent of Congress to interfere with what the State has already done. This, it may do either by expressly referring to the particular obstruction intended to be abated, or by defining some general class of obstructions intended to be abated, within which class the particularly obstruction will fall. And no pre-existing obstruction will be presumed to come under condemnation by Congress, unless the intent of Congress to abate it has been clearly and explicitly expressed in one or the other of the above methods.

No Act of Congress directed toward the abatement of ob-

structions to be created in the future, will be construed to also condemn existing obstructions that had theretofore been validly authorized by a State, unless this retroactive intent is also expressed in clear and explicit language.

Under this established doctrine, we respectfully submit that the decree below is erroneous and should be reversed with dismissal of the bills, because:

(a) The fact does not seem open to dispute, that Illinois had exercised its sovereign power, and had validly authorized a diversion of water from Lake Michigan, and such diversion had commenced—all with the express sanction of Congress—long before Congress enacted any general law purporting to deal with obstructions to navigability.

(b) An examination of Sec. 10 of the Act of 1899, discloses that:

First: This Section is prospective in effect. It was not intended to apply to existing structures. A comparison with Sec. 18 of this Act, which is clearly intended to apply to such existing structures as come within its terms, demonstrates the correctness of this conclusion as to Section 10.

Second: No distinction is drawn in Sec. 10, between obstructions to navigability authorized and created by due exercise of State sovereignty, and structures otherwise originated.

Third: The Section does not evidence or declare such an exclusive taking over of its subject matter by Congress as to supersede all State authority. This Court has so construed it in *Cummings* v. *Chicago,* 188 U. S. at p. 430.

Fourth: The conclusion is inevitable, in view of the above quoted declarations of this Court concerning the method in which Congress must act in order to effectively assert its superior power over obstructions to navigability theretofore validly authorized by a State, that no intent to interfere with or abate this diversion can be found in Section 10, because

such intent must be "manifested by clear and explicit language," and Section 10 contains no language that clearly or explicitly shows such intent.

Fifth: The language of this Section clearly shows it was not an attempt by Congress to enunciate the rule of the Escanaba Case, *supra*, that is, to *generally* forbid unnecessary, unreasonable or material obstructions to navigation authorized by the States. And the Government in this case has not so interpreted the statute, because,

(c) There is no allegation in the bills, that the State of Illinois has unreasonably, unnecessarily, or substantially obstructed navigation by this diversion. There is not a single allegation designed to define or describe the extent or character of the claimed obstruction to navigation.

On the contrary, the case made by the bills, is that all of Appellant's acts are unlawful to the extent that they were not previously authorized by the several Federal consents required (according to the theory of the bills) in every case of any obstruction to navigation, however, authorized, or however slight.

V.

SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, WAS NOT INTENDED TO BE RETROACTIVE IN EFFECT. IT DOES NOT APPLY TO THIS ALREADY EXISTING DIVERSION WHICH HAD BEEN VALIDLY AUTHORIZED BY ILLINOIS. IT LOOKS TO THE FUTURE NOT TO THE PAST.

(1) The language of Section 10 itself is prospective, not retrospective. Thus,

> "Section 10. **That the creation of any obstruction** not affirmatively authorized by Congress to the navigable capacity of any of the waters of the United States **is hereby prohibited;** * * * and **it shall not be lawful** * * * in any manner **to alter or modify** * * * **the capacity** of any * * * canal, lake, etc.; or of the channel of any

navigable water of the United States unless the work **has been recommended** by the Chief of Engineers and **authorized** by the Secretary of War **prior to beginning** the same."

This contention finds added support in the fact that Section 18, of this same Act, does expressly evidence the intent to apply the provisions of Section 18, to already existing bridges, as well as to those thereafter to be constructed. Thus, the opening portion of the Section reads:

> "SEC. 18. That whenever the Secretary of War shall have good reason to believe that any railroad or other bridge **now constructed**, or which **may hereafter be constructed** over any of the navigable waterways of the United States is an unreasonable obstruction to the free navigation of such waters, etc. * * *, it shall be the duty, etc."

In other words, it is evident by a comparison of this above quoted language of Section 18, with the above quoted language of Section 10, that Congress had in mind distinguishing between obstructions to navigability that already existed and those still to be created, in expressing its intent concerning each of said classes of obstructions; and that as to bridges, both those already in existence and those still to be constructed, Congress expressed its intent to make Section 18 retroactive, by the use of "clear and explicit language" to evidence said intent. On the other hand, in Section 10, having no intent to make said Section retroactive, Congress omitted all such language, and on the contrary employed language that distinctly looks to the future, not to the past,—that is distinctly prospective, not retrospective in effect.

(2) In *U. S.* v. *Bellingham Bay Boom Co.*, 176 U. S. 211, this Court construed Section 10 of the Rivers and Harbors Act of 1890 as not retroactive.

The first sentence of Section 10 of said Act of 1890 reads:

> "That the creation of any obstruction, not affirmatively authorized by law, to the navigable capacity of any wa-

ters in respect of which the United States has jurisdiction, is hereby prohibited. * * *"

Concerning this Section the Court said (176 U. S. 211 at 214):

> "It is evident that the first sentence of the 10th Section of the Federal Act refers to an obstruction created **after the passage of the Act.**"

And in *U. S.* v. *Rio Grande Dam Co.*, 174 U. S. 690, speaking of the same Section 10 of the Act of 1890, the Court said, page 708:

> "Whatever may be said in reference to obstructions existing at the time of the passage of the Act, under the authority of state statutes, it is obvious that Congress meant **thereafter,** no state should interfere with the navigability of a stream without the condition of national assent."

It may safely be said, that if either of said Acts of 1890, or 1899, contained expressions looking to the past, it was the Act of 1890, rather than the Act of 1899. Therefore, the fact that Section 10, of the Act of 1890, was held not to be retroactive argues the more strongly for a similar conclusion in respect to Section 10, of the Act of 1899.

VI.

CONGRESS DID NOT INTEND BY SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, TO DECLARE THAT THIS PARTICULAR DIVERSION IS IN FACT, EITHER AN OBSTRUCTION TO NAVIGABILITY OR AN UNREASONABLE OR UNNECESSARY OR SUBSTANTIAL OBSTRUCTION. NOR DID CONGRESS INTEND, BY SAID ACT, TO TAKE SUCH GENERAL OR EXCLUSIVE POSSESSION OF THE SUBJECT OF OBSTRUCTIONS TO NAVIGABILITY, AS TO RENDER UNLAWFUL ALL OBSTRUCTIONS NOT SPECIFICALLY AUTHORIZED BY FEDERAL CONSENTS, AS PRESCRIBED IN THE ACT.

It is only necessary to read Section 10, of the Act of 1899, to show that Congress did not by this Act refer specifically

to this diversion of water at Chicago, or declare it to be either an obstruction to navigability, or an unreasonable or unnecessary or substantial obstruction to navigability. If Congress had intended to interfere with or to abate this already existing Chicago diversion, the cases above cited show that it would have been necessary for Congress to do so by language clearly expressing such intent.

And assuming that it was open to Congress to express such intent, either by specific reference to this particular diversion, or by taking such general or exclusive possession of the subject of obstructions to navigability as would render unlawful, not only this particular obstruction, but all other existing obstructions that had not received the express authorization by Federal authorities as prescribed in the Act,—it is also plain that by Section 10, Congress did not intend to take such general or exclusive possession of this subject as to render this diversion unlawful.

This was clearly the basis of the reasoning of the Court in the decision of *Cummings* v. *Chicago* (188 U. S. 410) as above quoted.

When it is remembered, that by the Act of 1827, as shown above, Congress had expressly recognized the validity of this exercise of the sovereign power of Illinois, and had approved the project for such a canal, it should be still more necessary, to find unmistakable evidence in the words of this general statute expressing such intent, in order to bring within its condemnation this previously approved canal.

We therefor respectfully submit, that the conclusion is inevitable upon the authorities above quoted, that the bills and decree cannot stand because Section 10, of the Act of 1899, on which alone this entire case rests, did not make unlawful this diversion of water at Chicago which had theretofore been validly authorized by the State of Illinois.

VII.

THE FACT THAT CONGRESS BY THE "NIAGARA FALLS ACT" OF 1906, EXPRESSLY GAVE TO THE SECRETARY OF WAR AUTHORITY TO CONSENT TO DIVERSIONS OF WATER FROM THE NIAGARA RIVER, SHOWS CLEARLY THAT CONGRESS HAD NOT THERETOFORE INTENDED TO COVER THE SAME FIELD BY SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, WHEREBY IT WAS DECLARED UNLAWFUL "TO ALTER * * THE * * * CAPACITY OF ANY * * * CANAL, LAKE * * * OR OF THE CHANNEL OF ANY NAVIGABLE WATER OF THE UNITED STATES, UNLESS THE WORK HAS BEEN RECOMMENDED BY THE CHIEF OF ENGINEERS AND AUTHORIZED BY THE SECRETARY OF WAR PRIOR TO BEGINNING THE SAME."

On June 29, 1906 Congress passed the Act for the preservation of Niagara Falls, and for the control and regulation of waters of the Niagara River. (34 Stat. at L. 626.) In the report (59th Cong. 1st Sess. Report No. 4654, Cong. Rec. June 2, 1906) submitted by the Rivers and Harbors Committee of the House accompanying this bill, the Committee states:

> "The Committee regarded the jurisdiction of the United States over Niagara River as unquestionable, because it is a navigable stream in the greater part of its length, and although the waters in some portions are not navigable by reason of falls and rapids, the control of such portions is essential to its adequate maintenance for purposes of navigation. * * * At the beginning of the development of water power at Niagara Falls, no account seems to have been taken of the possible danger to the cataract. The diversion of water was commended as an industrial endeavor of material benefit to the country. While there are, no doubt, many who regret that this diversion was ever commenced, it is impossible to ignore entirely the development which has occurred without injustice to those who have undertaken it. At the same time, it is the opinion of this Committee that these rights should be construed with strictness; that no permit should be issued by the Federal Government for the diversion of water, either for that now in use or which may hereafter be used, except with the right of revocation."

The report also states (heavy face type ours):

"It appears that numerous franchises have been granted by the State of New York for the diversion of water and the creation of power. Of this, however, only two of any considerable importance have been acted upon. * * * The total diversion of water for these two companies which is authorized by the State of New York amounts to 17,200 and 9,500 cubic feet respectively; in all 26,700 cubic feet to be taken from the American side. The total amount at present utilized is about 12,600 cubic feet." * * *

It is a matter of some surprise that the companies which have proceeded to divert the waters of the river under the authority of the State of New York, have never appealed to Congress or to the Federal Government to confirm the authority granted by that state. It is thought best by the Committee that the Federal Authority should now be exerted not merely for the preservation of the scenic grandeur of Niagara Falls, but for the maintenance of navigation and the proper control of the river as a boundary stream."

The first Section of this Act reads as follows:

"That the diversion of water from Niagara River or its tributaries, in the State of New York, is hereby prohibited, except with the consent of the Secretary of War as hereinafter authorized in Section 2 of this Act; but, Provided, That this prohibition shall not be interpreted as forbidding the diversion of the waters of the Great Lakes or of Niagara River for sanitary or domestic purposes, or for navigation, the amount of which may be fixed from time to time by the Congress of the United States or by the Secretary of War of the United States under its direction."

As stated above, the bills in this case rest exclusively on the theory that Section 10, of the Act of 1899, forbids any obstruction to navigation not authorized by the Federal consents specified in the Section and that by this diversion at Chicago an obstruction to navigation as defined in Section 10, has occurred. If this were a proper interpretation of the meaning of Section 10, clearly the diversions from the Niag-

ara River, a navigable stream, had already been forbidden by Section 10, of the Act of 1899.

It must be assumed that in passing the Niagara Falls Act, particularly in view of the prohibitions contained in its first section, Congress did not intend to do an idle or unnecessary thing, nor to do over again anything that it considered had been accomplished by its previous legislation,—therefore, we respectfully submit, that by passing the Niagara Falls Act, Congress itself has thereby construed Section 10, of the Act of 1899, **as not forbidding diversions.**

As stated in the report above, until the passage of the Niagara Falls Act, the sole authority for diversions in the Niagara River were the statutes of the State of New York. No Federal supervision of this matter had occurred.

It may be well to point out, concerning the Niagara Falls Act, that the proviso relating to diversions of the waters of the Great Lakes or of the Niagara River, for sanitary or domestic purposes, is prospective in its nature, and does not apply to diversions existing at the time of the enactment. The reasons for this interpretation of the proviso are clearly stated in the brief filed on behalf of the appellant, point IV (c) of argument, page 179-181.

VIII.

TO SUSTAIN THE DECREE, IT IS NECESSARY TO CONSTRUE SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, AS A GRANT TO THE SECRETARY OF WAR OF UNLIMITED POWER TO PERMIT OR REFUSE THE CREATION OF OBSTRUCTIONS TO NAVIGABILITY. THE ACT DOES NOT ADMIT OF SUCH A CONSTRUCTION.

(1) The power conferred by the Act upon the Secretary of War was intended to be administrative in nature and narrow in scope. It could not have been intended to authorize him to act, in place of Congress, in deciding broad questions

of sovereign right or of public policy, such as the judicial question whether Illinois had the sovereign power to divert water from Lake Michigan, or the legislative questions whether Illinois should be allowed to divert water, and what quantity, and for what purposes.

An examination of Section 10, shows at once that Congress in the enactment of this statute did not, as it has done in other matters, for instance the regulation of railroad interstate rates, lay down a broad general principle, and delegate to the Secretary of War authority to determine in particular instances whether facts justified or required the application of the principle.

Section 10, entirely fails to define under what circumstances the Secretary of War shall grant a permit. Congress, of course, cannot be presumed to have delegated to the Secretary of War its own legislative power. To avoid any such interpretation, which would invalidate the section, the power of the Secretary must be strictly construed, and to be of an administrative nature. The propriety of construing his authority as narrow in scope is strengthened by the fact, that under Section 10, the Secretary of War has power to grant the permit specified in the Act, only when the work has been first recommended by the Chief of Engineers.

As disclosed by the record in this case, Secretary of War Taft so construed the statute, when he refused a permit requested by appellant, on the ground that the work in that particular instance, had not been recommended by the Chief of Engineers (Rec., Vol. VIII, 113, 114).

Aside from the first sentence of Section 10, it is submitted that the language there used applies only to construction or engineering works. The Section declares it to be unlawful "to **build**" or "commence the **building**" of certain specified structures. It then declares it to be unlawful "to **excavate**, or **fill**, or in any manner to alter or modify the course, loca-

tion, condition or capacity of" navigable waters, "unless the **work** has been recommended by the **Chief** of **Engineers** and authorized by the Secretary of War prior to **beginning** the same." The words emphasized above refer, we submit, to matters of engineering work, as distinguished from the results of such work or its uses or effects when completed. They serve merely to point out the manner in which proposed *methods* of engineering work, such as excavation, filling, etc., may receive the approval of the Government.

Of course, when Congress passed the Act, it knew that for many years it had been appropriating money and directing its use for harbor, river, and channel improvement, and had been carrying out such improvements through the War Department under the supervision of the Chief of Engineers. Is it not a reasonable interpretation of the Congressional intent to conclude that requiring permits for "works" was insisted upon in order that constructions in the navigable waters of the United States undertaken by persons other than the War Department should be harmonious and not inconsistent, with the plans of harbor development and improvement which the Department was or would at any time be carrying out, pursuant to Congressional requirement? This seems to us a reasonable interpretation of this Section, and if this be its interpretation, clearly the authority of the Secretary and of the Chief of Engineers is, as stated above, administrative in nature and not broad, arbitrary or unlimited.

(2) **In attempting by his order of December 5, 1901, to fix and limit the quantity of water that appellant might divert from Lake Michigan, the Secretary of War necessarily assumed that he had power:**

> **(a) To supersede and make inoperative the Statute of Illinois theretofore enacted pursuant to its reserved police power, by which Illinois had authorized appellant to use navigable waters within the State for the health and welfare of its people.**

We shall now endeavor to show,—by examining the nature and effect of the order of the Secretary of War of December 5, 1901, by which in substance, he decided that Illinois may divert 4,167 cubic feet of water per second, but may not divert any water in excess of said amount fixed by him,—that Section 10 of the Act of 1899 should not be construed as is claimed in these bills, because such construction presupposes the existence of authority in the Secretary of War far different in nature and greater in scope than could have been contemplated by Congress, or even validly delegated to him by Congress.

The authorities heretofore discussed show that the power of Congress to interfere with and abate a previously State-authorized obstruction to navigability, is a legislative power. Therefore, since its exercise must be predicated upon the judgment of Congress itself, either concerning a particular obstruction, that it is substantial and should be interfered with and abated—or concerning a general class of definitely described obstructions within which a particular obstruction might fall—it is obvious that if the Secretary of War were to decide such questions and within his undirected discretion to issue or refuse a permit, he would thereby exercise a legislative power that Congress is incapable of delegating.

We have endeavored to show earlier herein, that the language of Section 10, of the Act of 1899, is not open to the construction that it does either outlaw this particular diversion or lay down any general retroactive rule under which this obstruction would become outlawed. It is obvious that by deciding in his order of December 5, 1901, that appellant should not be permitted to divert from Lake Michigan more than a limited quantity of water fixed by him, the Secretary of War attempted to exercise the power of Congress to interfere with a prior Act of Illinois, valid when enacted and only to be superseded by the exercise of Congressional power to take exclusive possession of the field.

It is manifestly the theory of the bills, that if the Secretary of War had permitted a diversion of 10,000 cubic feet per second, these suits would not have been brought, because under said theory the diversion of 10,000 cubic feet per second would have been lawful. In other words, the Government's charge of illegality rests entirely on the theory that because the Secretary of War has not permitted this diversion it is unlawful, and, therefore, the Government claims that power was delegated to the Secretary of War to grant or permit diversions to any extent whatsoever, if recommended by the Chief of Engineers.

Certainly Congress could not have intended so completely to delegate its own legislative power.

(b) **To deny to the Illinois and Mississippi River Valleys the diversion of the quantity of water needed for effective waterway navigation, and to decide that the interests of the Great Lakes were of higher public value than those of the Mississippi Valley.**

The decision of the Secretary of War not only involved the important question of delegated authority discussed above in subdivision (a), but also required him to decide the broad question of public policy whether, as between the Illinois and Mississippi Valleys on the one hand, and the Great Lakes on the other, any diversion should be permitted and the extent and quantity thereof.

Certainly Congress did not intend to delegate to an executive or administrative officer any such comprehensive power. The broad nature of the power actually exercised by the Secretary of War is shown by the facts in this record. The Government claims a lowering of lake levels of about 5½ inches. Our statement of facts shows that the water diverted by Appellant when turned into the Mississippi River at Grafton serves to increase depths in the Mississippi between Grafton and the mouth of the Ohio about a foot and one-half. The

Court will note that all that Congress is attempting to maintain in this part of the Mississippi River is a navigable depth of six feet. Can it be claimed that Congress intended to delegate to the Secretary of War the power to decide as between the navigation interests of the Mississippi Valley and those of the Great Lakes which should be preferred? This seems to us inconceivable.

(c) **To substantially reduce the low water flow of these two rivers, and thereby greatly increase the cost to the Government of maintaining a reasonable channel from the Lakes to the Gulf.**

The necessary effect of the decision by the Secretary of War that Appellant, instead of diverting 10,000 cubic feet per second, should be compelled to reduce its diversion to less than one-half of said amount, is to substantially diminish the flow of the Illinois and Mississippi Rivers. And this in turn necessarily increases the cost to the Government of the work of dredging and otherwise keeping open and protecting a reasonably usable channel on the Illinois and Mississippi Rivers. It is peculiarly within the province of Congress alone to determine how much money shall be spent for this particular purpose and where it shall be spent. Certainly Congress did not intend by Section 10, of the Act of 1899, to delegate to the Secretary of War any such broad power; and yet this is in effect the Government's claim.

(d) **To decide the question of public policy involved in permitting a diversion of 4,167 cubic second feet, thereby, to this extent, lowering lake levels and reducing water powers at Niagara, and so deciding alleged rights claimed by citizens of Canada, while at the same time denying the right of appellant to a larger diversion.**

The record shows that the contest or conflict between water power interests at Niagara on the one hand, and the interests of Chicago and the Mississippi Valley which need this 10,000

cubic feet of water on the other hand, constitutes an aggressively active dispute. This dispute involves to some extent the claims made by Canadian interests of the right to divert water at Niagara. Also the extent to which Canadian interests may be damaged by this Chicago diversion. If, as the record indicates, a diversion of 10,000 cubic feet per second has caused a lowering of lake levels to the extent of 5½ inches, each other diversion, as well as any contemplated decrease or increase of this diversion, would also have its effect upon lake levels. Therefore, it is clear that if Section 10, of the Act of 1899, be construed to authorize the Secretary of War at his discretion, upon recommendation of the Chief of Engineers, to determine the quantity of diversions that may be made at Chicago, or elsewhere, such decisions would not only involve international relations and claims, but would also delegate to him power to decide questions of broad public policy that Congress alone may validly decide.

IX.

(1) IF CONGRESS HAD INTENDED BY THESE ACTS TO DELEGATE TO THE SECRETARY OF WAR THE POWER TO DECIDE SUCH QUESTIONS, SUCH AN ATTEMPTED DELEGATION WOULD HAVE BEEN UNCONSTITUTIONAL AND VOID, BECAUSE CONGRESS FAILED TO FURNISH ANY GUIDE, PRINCIPLE OR RULE, PURSUANT TO WHICH THE SECRETARY SHALL EXERCISE THE POWER IN QUESTION.

In *Wichita Railroad* v. *Public Utility Commission*, 260 U. S. 48, at page 58, this Court, in dealing with the constitutionality, under a state statute, of an order entered by an administrative body, held the order invalid because not entered in compliance with the general rules laid down in the statute. The Court said, at page 58:

> "This conclusion accords with the construction put upon similar statutes in other states. * * * Moreover, it accords with general principles of constitutional government. The maxim that a legislature may not dele-

gate legislative power has some qualifications, as in the creation of municipalities, and also in the creation of administrative boards to apply to the varying details of rate schedules the regulatory police power of the state. The later qualification is made necessary in order that the legislative power may be effectively exercised. In creating such an administrative agency the legislature, to prevent this being a pure delegation of legislative power, must enjoin upon it a certain course of procedure and certain rules of decision in the performance of its function. * * * It is a wholesome and necessary principle that such an agency must pursue the procedure and rules enjoined and show a substantial compliance therewith, to give validity to its action."

We submit that it is not possible to find any expression in Section 10, of the Act of 1899, which prescribed any procedure the Secretary of War must follow, in granting or refusing the permits therein specified, nor any rules by which he shall be guided in determining whether a particular obstruction shall or shall not be permitted. So far as the language is concerned, the power of the Secretary to grant or refuse a permit is not restricted, confined or guided by any expression whatever to be found in the Section.

The only way in which the power of the Secretary to grant or refuse a permit under this Section can be constitutionally sustained, is to read into the Section by construction the intention of Congress that this power is a narrow one, to be exercised as above suggested merely for the purpose of keeping engineering and other structures in the navigable waters of the United States harmonious and consistent with the work of harbor and channel improvement conducted by the Secretary of War.

It must be assumed that Congress knew of the above "constitutional maxim" concerning the delegation of power by Congress, and that therefore, not having by Section 10 prescribed any course of procedure or rules of decision to control the Secretary of War in granting or issuing permits, it

is clear that Congress did not intend to delegate to the Secretary of War the broad powers claimed by these bills.

(2) AND EVEN IF SUCH POWER HAD BEEN VALIDLY DELEGATED, THE MANNER OF ITS EXERCISE IN THE CASE AT BAR CANNOT BE SUSTAINED UNDER THE "DUE PROCESS" CLAUSE—BECAUSE MANY INTERESTS DIRECTLY AND ADVERSELY AFFECTED BY THE DECISION OF THE SECRETARY, INCLUDING THESE AMICI CURIAE, WERE GIVEN NO NOTICE OR OPPORTUNITY TO BE HEARD, AND THE ACT REQUIRED NO SUCH NOTICE OR HEARING.

That the interests of these *amici curiae* are adversely affected by the Secretary of War's action is, we assume, not open to question.

In the case of *Union Bridge Co.* v. *United States,* 204 U. S. 364, this Court was called upon to construe another Section (18) of the Act of 1899. The following provisions of this Section should be carefully noted:

> "SEC. 18: Whenever the Secretary of War shall have good reason to believe that any railroad or other bridge now constructed or which may hereafter be constructed, over any of the navigable waterways of the United States, is an unreasonable obstruction to the free navigation of such waters, on account of insufficient height, width of span, or otherwise, or where there is difficulty in passing the draw opening or the draw span of such bridge by rafts, steamboats or other water craft, it shall be the duty of the said Secretary, first giving the parties reasonable opportunity to be heard, to give notice to the persons or corporations owning or controlling such bridge, so to alter same as to render navigation through or under it reasonably free, easy and unobstructed; and in giving such notice, he shall specify the changes recommended by the Chief of Engineers that are required to be made, and shall prescribe in each case a reasonable time in which to make them. * * *"

The rights of those whose interests are to be affected by the action of the Secretary of War are here fully protected. Notice must be given. A hearing must be allowed. The

changes required must be specified. A reasonable time within which to make the changes must be permitted. Furthermore, the power of the Secretary can only be exercised when there is an "**unreasonable**" interference with navigation.

Contrast these provisions with the provisions of Section 10.

The opinion in the *Union Bridge Case, supra,* discloses the requirements which Section 10 must meet before it can be held constitutional. The Court said (204 U. S., p. 385):

> "It would seem too clear to admit of serious doubt that the statute under which the Secretary of War proceeded is in entire harmony with the principles announced in former cases. In no substantial, just sense does it confer upon that officer, as a head of an executive department, powers strictly legislative or judicial in their nature, or which must be exclusively exercised by Congress or by the Courts. It has long been the policy of the Government to remove such unreasonable obstructions to the free navigation of the waterways of the United States as were caused by bridges maintained over them. That such an object was of common interest and within the competency of Congress, under its power to regulate commerce, everyone must admit; for commerce comprehends navigation; and therefore to free navigation from unreasonable obstructions is a legitimate exercise of that power. *Gibbons* v. *Ogden,* 9 Wheaton, 1, 189, 190. As appropriate to the object to be accomplished, as a means to an end within the power of the national government, Congress, in execution of a declared policy, committed to the Secretary of War the duty of ascertaining all the facts essential in any inquiry where the particular bridges over the waters of the United States, were unreasonable obstructions to free navigation. Beyond question, if it had so elected, Congress, in some effective mode and without previous investigation through executive officers, could have determined for itself primarily, the fact whether the bridge here in question was an unreasonable obstruction to navigation, and if it was found to be of that character, could by direct legislation have required the defendant to make such alterations of its bridge as were requisite for the protection of navigation and commerce over the waterway in question. * * *

By the statute in question, Congress declared in effect that navigation should be free from unreasonable obstructions arising from bridges of insufficient height and width of span or other defects. It stopped, however, with this declaration of a general rule and imposed upon the Secretary of War the duty of ascertaining what particular cases came within the rule prescribed by Congress, as well as the duty of enforcing the rule in such cases. In performing that duty, the Secretary of War will only execute the clearly expressed will of Congress, and will not, in any true sense exert legislative or judicial power. * * * To this may be added the consideration that Congress, by the Act of 1899, did not invest the Secretary of War with any power in these matters that could reasonably be characterized as arbitrary. He cannot act with reference to any bridge alleged to be an unreasonable obstruction to free navigation without first giving the parties an opportunity to be heard. He cannot require any bridge of that character to be altered even for the purpose of rendering navigation through or under it reasonably free, easy and unobstructed, without giving previous notice to the persons or corporations owning or controlling the bridge specifying the changes recommended by the Chief of Engineers, and allowing a reasonable time in which to make them. * * * In the present case, all the provisions of the statute were complied with. The parties concerned were duly notified and were fully heard. Nor is there any reason to say that the Secretary of War was not entirely justified, if not compelled, by the evidence in finding that the bridge in question was an unreasonable obstruction to commerce and navigation as now conducted.

We are of the opinion that the Act in question is not unconstitutional as conferring upon the Secretary of War powers of such nature that they should not be delegated to him by Congress."

The reasoning thus employed by the Court in construing Section 18, of the Act of 1899, is, in and of itself, sufficient to demonstrate the unconstitutionality of any such delegation of powers as the bills in this case claim.

The *Union Bridge Case, supra,* was followed by the deci-

sion in *Monongahela Bridge* v. *United States*, 216 U. S. 177. Again a question arose under Section 18, of the Act of 1899. The Court was urged to reconsider its ruling in the Union Bridge case, and in the opinion stated the law as follows (p. 192):

> "This Court has heretofore held, upon consideration and after an examination of the adjudged cases:
>
> (1) That 18th Section of the river and harbor Act of March 3, 1899, 30 Statutes 1151, could not reasonably be taken as a delegation of legislative and judicial power to an executive department of the government; that the statute did not in any real, constitutional sense delegate to the Secretary of War any power that must, under our system of government, be exclusively exercised either by the legislative or judicial branch of the government; that under its paramount power to regulate commerce on and over the navigable waters of the United States, Congress could require that such waters be free from unreasonable obstructions to navigation; that the statute in effect prescribed the general rule, applicable to all navigable waters, that free navigation should not be hampered by unreasonable obstructions arising from bridges of insufficient height, width of span, or other defects; that instead of exerting its power by direct legislation in each case of a bridge alleged to constitute an unreasonable obstruction to navigation, Congress charged the Secretary of War with the duty of ascertaining, in each case, upon notice to the parties concerned, whether the particular bridge came within the general rule prescribed;
>
> * * *
>
> (2) That the Act of 1899 did not invest the Secretary of War with arbitrary power in the premises, since in reference to any bridge alleged to constitute an unreasonable obstruction to navigation, he was bound, before making any decision or taking final action, to notify the parties interested of any proposed investigation by him, give them an opportunity to be heard, and allow a reasonable time to make such alterations as he found to be necessary to free navigation."

The Court also said, page 195:

> "It is for Congress, under the Constitution, to regulate the right of navigation by all appropriate means, to

declare what is necessary to be done in order to free navigation from obstruction, and to prescribe the way in which the question of obstruction shall be determined. Its action in the premises cannot be revised or ignored by the Courts or by juries, except that when it provides for an investigation of the facts, upon notice and after a hearing before final action is taken, the Courts can see to it that executive officers conform their action to the mode prescribed by Congress."

We represent here substantial interests that are adversely and materially affected by the decision of the Secretary of War limiting the amount of appellant's diversion. In reaching this decision, there was in fact no hearing of any kind, nor any notice to these *amici curiae*, and they had no opportunity to be heard. So far as they are concerned, there was an entire absence of all those requirements of due process, which alone, under the two above decisions, could render constitutional Section 10.

X.

ASSUMING FOR ARGUMENT ONLY, THAT SECTION 10, OF THE RIVERS AND HARBORS ACT OF 1899, AND THE AUTHORITY OF THE SECRETARY OF WAR THEREUNDER, DO APPLY TO APPELLANT'S DIVERSION, NEVERTHELESS THE REQUIREMENTS OF SAID ACT WERE MET, IN THAT ILLINOIS HAD OBTAINED THE PRIOR "AFFIRMATIVE AUTHORITY OF CONGRESS," AND THE PARTICULAR WORKS WERE "AUTHORIZED BY THE SECRETARY OF WAR" AND "RECOMMENDED BY THE CHIEF OF ENGINEERS."

(1) The State of Illinois built its Sanitary and Ship Canal, pursuant not only to the sovereign power of the state, but also under the "affirmative authority" of Congress.

As we have endeavored to show above (Point III of this brief), the Act of March 2, 1827 (4 U. S. Stat. at L, p. 234), evidenced the expressed purpose of Congress to "aid" Illinois "in opening a canal to unite the waters of the Illinois River with those of Lake Michigan."

While the grant was of *land*, the fact that it was for the expressed purpose of *aiding* Illinois in the opening of such a canal, necessarily implied and carried with it, the affirmative sanction of Congress, to the opening of such a canal; and the grant of this sanction effectively disposes of any contention that under the Commerce Clause, the right to build such a canal was exclusively vested in Congress.

As we have also endeavored to show, under Point III of this brief, it was clearly the view of Congress concerning its powers and those of Illinois respectively, that Illinois had the sovereign power to build such a canal without the consent of Congress, and the land grant made by Congress in aid of this exercise of state sovereignty, constituted not only a recognition by Congress that Illinois had such power, but it also "affirmatively" expressed the sanction and approval of Congress to the carrying out of this project for a canal.

The purpose of Congress in making this grant was undoubtedly in aid of navigation and commerce; and the jurisdiction of Congress attached solely under the Commerce clause. But the sovereign power of Illinois to build and use the Canal for sanitation as well as commerce cannot be denied.

Because of the well known physical facts, that the waters of the Illinois River flow (via the Mississippi) into the Gulf of Mexico, and that the level of the water of Lake Michigan is much higher than that of the Gulf, this grant necessarily included and contemplated the consent of Congress to the diversion of water from Lake Michigan through said canal and into the Mississippi River.

This consent of Congress was given without condition or limitation upon the size of the canal or the quantity of water that might thus be diverted. That the navigable waterway thus contemplated was intended to forever exist, be maintained and operated, as a public waterway, was expressly stated in the Act.

Therefore it does not seem open to question, that so far as the United States is concerned, Illinois had and has the "affirmative authority" of Congress, and the right and power, to forever maintain and operate a navigable ship canal "uniting the waters of the Illinois River with those of Lake Michigan"; that this canal may be of capacity and size reasonably adequate to care for the needs of navigation and commerce as they may develop; and that the quantity of water that may be diverted from Lake Michigan for this purpose, may be increased from time to time to meet the reasonable needs of Illinois for its public purposes;—all without the need of further or additional consent of the United States.

The record shows that pursuant to this Act, and also under its own sovereign power as hereinabove stated, Illinois in 1836 passed a statute under which the "Illinois and Michigan Canal" was constructed and operated.

We have already shown that when this Illinois and Michigan Canal was improved by a deep cut across the Divide in 1871, water flowed by gravity from Lake Michigan through the Chicago River into the canal, and has continued to do so ever since, thus uniting the waters of the Illinois River with those of Lake Michigan.

We have also shown that Appellant's present Sanitary and Ship canal took the place of this earlier canal.

The Supreme Court of Illinois, in *Mortell* v. *Clark*, 272 Ill. 201 at 213,—referring to Appellant's present canal, said:

> "**The canal was built under the authority of the Act of Congress of March 2, 1827,** the Act of 1822 having been mutually abandoned by the state and Federal Government. * * * This Federal Act did not provide just where the canal should enter Lake Michigan, simply stating that the land was granted for the purpose of opening 'a canal to unite the waters of the Illinois River with those of Lake Michigan,' etc. **The Sanitary District's main channel as now constructed complies with this Act and furnishes a canal more suitable for navigation than**

the Illinois and Michigan Canal. Furthermore, the Sag channel or cut off is required to be navigable by the said Act of 1903, and the proof shows that the Calumet River is navigable to the point where it is intersected by the sag channel. This cut off would, therefore, also **practically comply** with both of said Federal Acts as to furnishing part of the canal for connection of the Illinois River with Lake Michigan."

This decision by the Supreme Court of Illinois, is conclusive upon the fact that Appellant's present canal was constructed pursuant to a grant expressed in the Act of March 2, 1827; that it was intended to take the place under said Act, of the Illinois and Michigan canal; and that it is in fact and law a substitute under said Act for the Illinois and Michigan canal, as the canal "to unite the waters of the Illinois River with those of Lake Michigan."

We shall not attempt in this brief, to state or discuss the numerous facts appearing of record and discussed in the brief of Appellant, showing the attitude of the United States toward the Illinois and Michigan canal, during its construction and long service or toward the construction, opening and use of Appellant's present Sanitary and Ship canal, up to the time when the Secretary of War attempted in 1901 to limit the amount of diversion from Lake Michigan.

We deem it sufficient for the purpose of this brief, to respectfully submit on this feature of the case, that said Act of Congress of 1827, constitutes the legally effective "affirmative authority" of Congress, for any reasonable method that Illinois might adopt, for the purpose of uniting the waters of the Illinois River with those of Lake Michigan,—and for periodically increasing the capacity of its canal, and the consequent diversion of water in order to keep the canal reasonably adequate to meet the growing needs of the communities served by it. As to the propriety of the method used by Illinois in carrying out this power,—and the improved health of its people due to these acts is fully described in this

record,—it is sufficient to say that this case on the record, presents only a question as to what power exists but no question as to the reasonableness of its exercise.

Neither of these bills seeks to attack Appellant's diversion on the ground that Illinois has abused or made unreasonable use of, the affirmative authority of Congress thus granted to Illinois by the Act of 1827.

(2) **The particular "works" which resulted in this diversion by appellant were also "authorized by the Secretary of War," and "recommended by the Chief of Engineers."**

The permit of May 8, 1899, in its granting power, states:

> "The Chief of Engineers having consented thereto, this is to certify that the Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the water of Chicago River to flow into the same, subject to the following conditions:"
> (the substance of which was):
> (1) That it is the intention of the Secretary of War to submit the questions connected with this work to Congress, for consideration, the permit to be subject to such action as may be taken by Congress.
> (2) The Secretary of War reserved the right to close or modify it in order to prevent a current unreasonably obstructive to navigation, in the Chicago River.
> (3) The Sanitary District to assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in the Chicago River.

The opening of Appellant's canal, the reversal of the current of the Chicago River, and the consequent diversion of water from Lake Michigan were therefore authorized by the Secretary of War. So far as this case is concerned, there are no conditions upon this permit, because: Many secretaries of war have submitted the matter of this diversion to Congress, but no action has been taken by it; and there is no contention now that a current exists in the Chicago River unreasonably obstructive to navigation.

The Government, as well as Appellant, and the City of Chicago, spent large amounts of money in widening and deepening the channel of the Chicago River, and as the result of such work, 10,000 cubic feet of water per second may be diverted from Lake Michigan through the River and canal, without introducing an unreasonable current into the Chicago River.

We shall not present in detail, the several permits issued by the Secretary of War from time to time to the City of Chicago, or to the Sanitary District, permitting the various steps in the work above referred to, which resulted in the widening and deepening of the Chicago River. These are fully described in Appellant's brief.

We respectfully submit, however, that a consideration of these permits, particularly of the fundamental permit of May 8, 1899, above quoted, conclusively shows that each item of engineering work and construction, directly or indirectly causing a diversion from Lake Michigan of 10,000 cubic feet per second, has been specifically recommended by the Chief of Engineers and permitted by the Secretary of War.

Only after all of these permits had been issued, did the Secretary of War in 1901, by what purports to be a permit, attempt to regulate or limit the amount of water which flowed by gravity from Lake Michigan, as a necessary result of the engineering works theretofore authorized. When the work contemplated in 1901, had been completed, there was no longer any reason for a regulation of the amount of the diversion as affecting the current in the Chicago River. Moreover, the permit of 1901, was not in legal effect, a permit, but was an attempt to regulate the conduct of Appellant's works, and to qualify the unqualified permit that had previously been granted. No such power was given by Sec. 10.

XI.

THE CONTENTIONS MADE IN THE BRIEFS ON BEHALF OF THE LAKE STATES APPEARING AS AMICI CURIAE, ARE EITHER OUTSIDE THE ISSUES OF THIS CASE OR WITHOUT MERIT.

The contentions presented in points I, II, and III, of the brief for the Lake States, (page 12 to 29 of Argument), are a unit, and should be considered together.

Their substance is:

(a) That the Lake States are **absolute owners** of **all the waters** of the Lakes that were within their respective boundary lines when **admitted to statehood**, with the right **to have the said fixed quantity of water, plus all natural additions thereto, maintained as against any and all unnatural diversion or abstraction** (Lake States brief page 18);

(b) But since the "lower riparian owner on a stream may claim, as against the upper riparian owner, the right to a continued uninterrupted flow of the stream passing his lands," it follows, that a "lower state" on these lakes has a similar right "as against the upper states";

(c) While a riparian owner on a navigable stream can claim the right **to the use** of the water," the states' claim in this instance is to the full proprietary ownership of these waters";—therefore, the state's right thus being greater than that of a riparian owner—**the quantity** of the water under state ownership * * * was fixed and the State entitled to assert its sovereignty and ownership over such quantity and all natural additions thereto," (Brief page 17 to 18), consequently these Lake States can in this action, assert their said alleged rights as against this diversion at Chicago; and

(d) That Illinois, although a joint owner, was without right to authorize a diversion of the waters of the Great Lakes into another watershed, and thereby to provide for

"the extraordinary uses" of these waters by an agency of the state.

Concerning the above contentions we respectfully submit that:

(1) They are wholly irrelevant to the issues in the case at bar.

This is not a suit in equity to abate an alleged nuisance. It is not an original suit by the Lake States against Illinois to determine whether Illinois, as part owner of Lake Michigan, is making an unfair, inequitable, or unreasonable use of Lake waters. It is not even a suit by the Government to abate this diversion at Chicago, on the ground that it constitutes a substantial injury to navigability. This case is confined to the single issue, whether under Section 10, of the Act of 1899, Appellant's diversion of 10,000 cubic feet of water, is unlawful.

Upon this issue, the fact that these Lake States claim to own certain fixed proportions of the waters of the Great Lakes, is obviously of no consequence whatever.

(2) These contentions of the Lake States are based on a palpable misunderstanding of the established doctrines of this court, concerning the sovereign power of a state over navigable waters within its borders.

So far as concerns the issues in the case at bar, there is nothing peculiar to the Great Lakes or their waters, that distinguishes them from tide waters within a state, or waters of navigable rivers within a state or along its borders. There is no issue here concerning the title to lands bordering on or extending under any part of these Lakes, or concerning land between low water and high water marks, or concerning title upon such lands. All kinds of waters, tide, lake, and river—within a state, if in fact navigable for interstate commerce, would constitute part "of the navigable waters of the United

States" to which the Commerce Clause of the Constitution applies.

Concerning the sovereign rights and power of a state over navigable waters, including those of the Great Lakes, this court said, in *Ill. Cent. R. Co.* v. *Illinois*, 146 U. S. 387, at 435, (Heavy type ours):

> "It is settled law of this country that the ownership of, and dominion and sovereignty over, lands covered by tide waters, within the limits of the several states, **belong to the respective states within which they are found with the consequent right to use and dispose of any portion thereof, when that can be done without substantial impairment of the interest of the public in the waters, and subject always to the permanent right of Congress to control their navigation as far as may be necessary for the regulation of commerce with foreign nations and among the states.** * * *
>
> The same doctrine, in this court held to be applicable by lands covered by fresh waters in the Great Lakes, over which is conducted and extended commerce with different states and foreign nations."

But a state's ownership of such lands and its sovereignty over such waters, is not that of a private ownership; it is rather that of a sovereign trustee for the benefit of its public and for such reasonable uses as accord with the public welfare.

See *Ill. Cent. R. Co.* v. *Illinois*, 146 U. S. 387, at 457-8, where the court said:

> "Many other cases might be cited where it has been decided that the bed or soil of navigable waters is held by the people of the state in their character as sovereign in trust for public uses to which they are adapted, (citing cases)."

And at page 459 the court said:

> "The soil under navigable waters is held by the people of the state in trust for the common use and as a portion of their inheritant sovereignty. Any act of legislation concerning their use has to consider the public welfare. It is, therefore, appropriately within the exercise of the police power of the state."

We respectfully submit that a fundamental error of the above contentions for the Lake States, lies in their assumption that a state cannot change the common law rule regarding the right of a lower riparian owner to have the flow of a river continued.

The decisions of this Court have firmly established the doctrine, that a state may, out of its sovereign control and power over navigable waters within its borders, change this rule of the common law, and permit such reasonable uses, diversions and consumptions of its public waters, "for such purposes as it deems wise." (*U. S.* v. *Rio Grande Dam Co.*, 174 U. S. 690, at 702.)

In *Kansas* v. *Colorado,* (a diversion case), 206 U. S. 46, the court said, (heavy type ours) at page 93:

> "It is enough for the purpose of this case that each state has full jurisdiction over the lands within its borders, including the bottoms of streams and other navigable waters (Citing many cases).

And at page 94:

> **"It may determine for itself whether the common-law rule in respect to riparian rights or that doctrine which obtains in the arid regions of the West of the appropriation of waters for the purposes of irrigation shall control. Congress cannot enforce either rule upon any state** * * * At page 95—"But when the states of Kansas and Colorado were admitted into the Union they were admitted with the full powers of local sovereignty which belonged to other states (citing cases), and Colorado, by its legislation, has recognized the right of appropriating the flowing waters to the purposes of irrigation. Now the question arises between two states, one recognizing generally the common-law rule of riparian rights and the other prescribing the doctrine of the public ownership of flowing water. Neither state can legislate for, or impose its own policy upon the other. A stream flows through the two and a controversy is presented as to the flow of that stream. It does not follow, however, that because Congress cannot determine the rule which shall control between the two states, or be-

cause neither state can enforce its own policy upon the other, that the controversy ceases to be one of a justifiable nature, or that there is no power which can take cognizance of the controversy and determine the relative rights of the two states."

Thereupon the Court held that there was jurisdiction under the constitution to determine as between the two states, whether Colorado was unreasonably using its own property so as to inflict damage upon the neighboring state.

And in this case the court's decree did not disturb the existing diversions.

For additional cases in which this court has recognized the power of a state to change said common-law rule, see *Guittieres* v. *Albuquerque Land and Irr. Co.* 188 U. S. 545, at 533-554; *Boquillas* v. *Curtis,* 213 U. S. 339, at 344-345.

In *Leovy* v. *United States,* 177 U. S. 621, at 636, this Court held, that the act of a state in draining swamps for the purpose of protecting the health of its public, was a proper exercise of sovereign power even though such draining had the effect of partially impairing the navigability of neighboring waters.

In the case at bar, the state of Illinois, by appropriate legislation, has exercised its sovereign power over these waters within its borders, and has expressly authorized this division, thereby changing the common-law rule upon which are based the above contentions of the Lake States.

We therefore respectfully submit that under the above decisions of this court, said contentions are wholly without merit, and also have no place in a consideration of the issues here involved.

We do not contend that there are no limitations upon this sovereign power of Illinois. Its power is, of course, subject to the superior commerce power of Congress, if, and when Congress has properly acted. And an abuse of this power

by Illinois, may subject it to accountability for, or restraint upon, its action, in an appropriate original proceeding in this Court for said purpose. But the case at bar involves no such issues, and the fact that they are sought to be injected into this case by the Lake States cannot broaden the issues presented by this record.

(3) A further complete answer to the above contentions of the Lake States exists in the decision of this Court in *Missouri* v. *Illinois*, 200 U. S. 496, at 526, where the Court said:

> "Some stress was laid on the proposition that **Chicago is not on the natural watershed of the Mississippi**, because of a rise of a few feet between the Desplaines and the Chicago rivers. **We perceive no reason for distinction on this ground.** The natural features relied upon are of the smallest. And if, under any circumstances, they could affect the case, **it is enough to say that Illinois brought Chicago into the Mississippi watershed in pursuance, not only of its own statutes, but also of the acts of Congress of March 30, 1922** (*chap.* 14, 3 *Stat. at L.* 659), **and March 2, 1827** (*chap.* 51, 4 *Stat. at L.* 234), **the validity of which is not disputed.** *Wisconsin* v. *Duluth*, 96 *U. S.* 379, 24 *L. ed.* 668.)

(4) It is perhaps well, that the brief for the Lake States so frankly discloses their real and only substantial reason for objecting to this diversion at Chicago.

The unsubstantial nature of the claim of injury to the navigation interests of the Great Lakes has already been pointed out in the "statement" of this brief and is discussed at length in the brief for Appellant. But on pages 24 and 29 of the brief for the Lake States, many statements (most of which are not supported by any evidence in this record), are made concerning the interests of New York, Pennsylvania, Ohio, and Michigan, in the development of hydro-electric power at Niagara. It is at least a reasonable inference that the desire for greater profits from the sale of power, constitutes a much more urgent inducement for their opposition to this diver-

sion, than any fear that injury to navigation may result from such a slight (and easily compensated) lowering of Lake levels as this case presents.

We have already referred to the report appearing in the Congressional Record of the Rivers and Harbors Committee concerning the Niagara Falls Act of June 29, 1906, from which it appears that the Niagara River is a navigable stream in the greater part of its length, and that the State of New York, without at all seeking in any way the authority or approval of Congress, repeatedly authorized diversions from this River prior to 1906 **amounting in all to 26,700 cubic feet per second.** The Committee in its Report says:

> "It is a matter of some surprise that the companies which have proceeded to divert the waters of the River under the authority of the state of New York, have never appealed to Congress or to the Federal Government to confirm the authority granted by that State. It is thought best by the Committee that the Federal authority should now be exerted, not merely for the preservation of the scenic grandeur of Niagara Falls but for the maintenance of navigation and the proper control of the River as a boundary stream." (59 Congress, First Session, Report No. 4654, Congressional Record, June 2, 1906.)

In respect of this diversion at Niagara, much greater in amount than any diversion through the canal of Appellant, it would seem that the State of New York had no doubt as to its own sovereign power in the matter. Certainly New York is in no position to contend that Illinois could not exercise the same kind of sovereign power that New York itself thus exercised.

The facts, stated in the brief for the Lake States, concerning the present development of power at Niagara on the American side, show that the so-called "improved development" is under a main head of 215 feet. If the development were carried out to its full extent, the head would be in excess of 300 feet.

It therefore appears, that at the present time, approximately one-third of the available horse power at Niagara from the present authorized diversions, is wasted. Until this power is fully developed and this waste stopped, New York and its neighboring states, can hardly claim any very substantial injury from the diversion at Chicago. If the water now flowing into Appellant's canal were all to take its original course through the Niagara River, New York and its neighboring states, would not be obtaining any more power, because of New York's failure to properly develop their own authorized diversion.

The other contentions for the Lake States, and those made in the brief for the Lake Carriers Association, are already answered in this brief.

XII.

WITHOUT REGARD TO QUESTIONS OF LEGAL POWER, THE RELATIVE EQUITIES IN THE INSTANT CASE REQUIRE A REVERSAL OF THE DECREE.

Without regard to questions of power, the following considerations present equities which this Court should weigh:

a. If the decree be immediately enforced the health of all the inhabitants of Chicago and its surrounding communities—more than three million residents—will be endangered.

b. The importance of this consideration alone far outweighs all reasonable claim that there has been any discernible injury to navigation on the Lakes.

c. Any actual injury is more than offset by appellant's offer to do equity, by paying for the construction of compensating and regulating works which will restore and maintain lake levels.

d. In view of the practicability of restoring and maintain-

ing lake levels at relatively trifling cost, no decree should be permitted to defeat or hamper, or render prohibitive in cost, the established policy of the government to open and maintain a deep waterway from the Lakes to the Gulf.

e. In view of the feasibility of restoring and maintaining lake levels at relatively trifling cost without reducing the diversion at Chicago, no decree should subject the communities along the Illinois River and the Mississippi River, including the inhabitants of St. Louis, to the grave perils bound to follow an inadequate dilution of Chicago sewage.

f. In weighing the equities in respect of navigation alone, can there be any doubt that the importance of preserving and improving the navigability of the Lakes to the Gulf waterway for the benefit of these *amici curiae* and those they represent, far outweighs any equity for relief against a mere engineer's theory that injury to navigation on the Lakes has resulted from this diversion, although no Lake Captain has ever been found, able to perceive it?

(g) In weighing all the equities of this case, if the Court shall undertake to do so, can there be any doubt that the importance of protecting the health of the people of Chicago, St. Louis and other endangered communities, plus the importance of improving the navigability of the Lakes to the Gulf waterway in accord with the established public policy of Congress, far outweigh the importance of increasing the hydroelectric power at Niagara, the existence of which has stimulated these Lakes States into active opposition to Appellant's diversion?

We shall not attempt to elaborate the foregoing suggestions, believing that enough has already been said in the appellant's brief and this brief to bring to the court's attention the pertinent facts.

For the reasons herein stated, and upon the equities of the

case, we respectfully submit that the decree below should be reversed.

Respectfully submitted,

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IN THE

Supreme Court of the United States.

OCTOBER TERM, A. D. 1924.

No. 161

THE SANITARY DISTRICT OF CHICAGO,
Appellant,

vs.

THE UNITED STATES OF AMERICA,
Appellee.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES, FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION.

BRIEF AND ARGUMENT FOR THE STATES OF INDIANA, MICHIGAN, MINNESOTA, NEW YORK, OHIO, PENNSYLVANIA AND WISCONSIN AS AMICI CURIAE.

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IN THE

Supreme Court of the United States.

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO,
Appellant,

vs.

THE UNITED STATES OF AMERICA,
Appellee.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES,
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EASTERN DIVISION.

BRIEF AND ARGUMENT FILED BY THE STATES OF INDIANA, MICHIGAN, MINNESOTA, NEW YORK, OHIO, PENNSYLVANIA AND WISCONSIN BY PERMISSION OF THIS COURT AS *AMICI CURIAE.*

STATEMENT OF THE CASE.

MAY IT PLEASE THE COURT:

The States of Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania and Wisconsin, joining in this brief, have together with the State of Illinois extensive shore lines on the Great Lakes and all have a large volume of commerce on the Great Lakes, the waters of which

are being abstracted by the appellant. The State of Michigan alone has 1,624 miles of shore line. The Great Lakes with their connecting channels, constitute the most important system of inland navigation in the world. The traffic which passed through Detroit River, its busiest link, in 1910, amounted to 73,526,602 tons valued at about $771,000,000. About 80 per cent of this traffic is carried in large freight carriers, which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the lakes; but could be loaded much deeper if the depth of water permitted. Some of the larger of the vessels carry an additional load of 85 tons for each inch of additional draft. Every inch added to the navigable depth of water would therefore be of material benefit to commerce.

The Great Lakes constitute a series of enormous natural reservoirs, each of which serves to regulate the flow in the river constituting its outlet and to maintain the lake below. They are interdependent. The study of one, to be complete, must include the study of all. The total area drained by the Great Lakes is about 287,688 square miles. Of this total about one-third is occupied by the lakes themselves; that is, devoted to reservoir purposes. The result is a uniformity of level and a uniformity of flow which are truly wonderful—a perfection of regulation which no work of man ever did or ever will approach. (Rec., Vol. 4, p. 3435.)

The division of the waters between the Great Lakes Basin and the Mississippi River Basin is known as the Continental Divide, an elevation of land in the State of Illinois within a few miles of Chicago. The Calumet and Chicago Rivers by their natural flow are properly within the Great Lakes Basin and drain into the waters of Lake Michigan. The natural flow of the waters of Lake Mich-

igan is northerly. The natural flow of the Des Plaines and Illinois River is into the Mississippi River Basin. The boundaries of the various states bordering on the Great Lakes are so extended as to include the lands under and the waters of the Great Lakes within the limits of the boundaries of the federal government. While permission to file briefs as *amici curiae* was but recently granted, to these states, citizens and municipalities of these respective states have been active for years in their opposition to the abstraction of these waters. This is apparent by reference to the record (Vol. 6, Exhibit of proceedings before the Secretary of War in connection with application of the Sanitary District for permission to divert 10,000 cubic feet of water—1912).

> "There is owned at this port several freighters of the largest class of freighting ships in the world. They combine and carry in one cargo more than one and one-half million tons from Lake Superior to the lower lakes. The depth of the connecting rivers are affected by the levels of Lakes Huron and Michigan.—The lowering of these rivers seriously affects the carrying capacity of these large steamers and we earnestly protest against—any diversion."
>
> Duluth Commercial Club, Minnesota—Rec., Vol. 6, page 3737.

> "Milwaukee Harbor Commission now engaged in the task of devising means of improving present harbor conditions and formulating plans for the city harbor * * * regards with solicitude the apparent increasing * * * lower water levels in the Great Lakes, which, if continued, must result in added expense for river and harbor maintenance and great depreciation in carrying capacity of lake tonnage."
>
> Secretary, Milwaukee Harbor Commission, Rec., Vol. 6, p. 3739.
>
> Resolutions, Merchants & Manufacturers' Association of Milwaukee, Rec., Vol. 6, p. 3739.
>
> Governor of Wisconsin, Rec., Vol. 6, p. 3740.

"Every inch of the present depth in Manitowoc River is of great value to this city and to thousands of shippers both east and west of this port."

Mayor of Manitowoc, Rec., Vol. 6, p. 3740.

To same effect:

Mayor of Marinette, Rec., Vol. 6, p. 3740.

Marinette Chamber of Commerce, Rec., Vol. 6, p. 3742.

Mayor and Common Council of Sheboygan, Wis., Rec., Vol. 6, p. 3742.

Mayor and Common Council of DePere, Wis., Rec., Vol. 6, p. 3742.

Mayor and Common Council of Green Bay, Wis., Rec., Vol. 6, p. 3743.

"Every port in Michigan will be injured; every fruit farm in Western Michigan jeopardized and the future development of the State hindered."

House of Representatives, Michigan, Vol. 6, p. 3744.

State Senate of Michigan, Vol. 6, p. 3743.

See also:

Letter of J. C. McLoughlin, Member of Congress, Rec., Vol. 6, p. 3744.

Mayor and Chamber of Commerce, Charlevoix, Mich., Rec., Vol. 6, p. 3745.

Mayor and City Council of Escanaba, Mich., Rec., Vol. 6, p. 3745.

Mayor of City of Petoskey, Mich., Rec., Vol. 6, p. 3746.

Mayor of City of Muskegon, Mich., Rec., Vol. 6, p. 3746.

(Diversion) "Would be fraught with detrimental results to the harbor of the City of Toledo."

Ohio, Toledo Commerce Club, Rec., Vol. 6, p. 3747.

Cleveland Chamber of Commerce, Rec., Vol. 6, p. 3748.

Board of Control of Sandusky, Ohio, Rec., Vol. 6, p. 3749.

Sandusky (Ohio) Business Men's Association, Rec., Vol. 6, p. 3749.

"Government records show that up to June 30, 1911, federal authorities had spent at Buffalo and Black Rock in waterway improvements * * * $7,932,380.68; and during the same period the citizens of Buffalo expended in the improvements of its harbor, $4,880,149.20 * * *. The level of Lake Erie was one foot five inches lower in 1911 than in 1908, attributed not only to natural causes, but to the diversion of water from Lake Michigan under the present permit. This condition in the past few years has resulted in the lowering of the loading capacity of vessels, which has been reflected in the rates charged, causing loss not only to the shipping interests but to the commercial interests as well, and as the tendency is to build larger and larger boats in order to reduce the transportation cost to a minimum, any action that will interfere with the operation of the large boats should be viewed as a public calamity."

Harbor and River Committee, Buffalo Chamber of Commerce, Rec., Vol. 6, pp. 3749-50.

Shipmasters' Association, Buffalo, Rec., Vol. 6, p. 3751.

Shipmasters' Association, Ogdensburg, N. Y., Rec., Vol. 6. p. 3751.

Lockport (N. Y.) Board of Trade, Rec., Vol. 6, p. 3752.

"The present current makes navigation (in Chicago River) difficult and any increase would seriously impair movement of vessels if not make impos-

sible handling of goods to and from industries located on river."

Signer, Association of Lake Lines, Rec., Vol. p. p. 3753.

Niagara Falls Power Co. (N. Y.), Rec., Vol. 6, p. 3754.

"During the year 1911, the critical points in the lake routes were six inches lower than the average level for the last fifty years. There is invested in lake shipping some $200,000,000.00—carrying capacity of vessels during the year 1911, was reduced over ten per cent, due to the lowering of lake levels by natural causes which must have been aggravated by the new outlet at Chicago."

Shenango Furnace Co., Pittsburgh, Pa., Rec., Vol. 6, p. 3754.

A reading of the record presented in this case shows clearly that the abstraction of the waters from Lake Michigan reduces materially the levels of all the Great Lakes and connecting waters, with the exception of Lake Superior. However, navigation of Lake Superior is materially affected by any lowering of the levels of the lower lakes and connecting waters; these determining the depths to which a boat could load in navigating to or from points, in Lake Superior and the other Great Lakes.

"The shoalest spot is the one that governs." (Appellant's narrative statement, page 147.)

The lowering of the lake levels was proceeded with by the appellant upon the theory that it was, in any event, entitled to use so much of the waters of Lake Michigan as it needed for its corporate use, and at least that the United States had authorized the consequent obstruction to navigation occasioned by such abstraction of waters. All of these contentions the states deny, the states tak-

ing the position that the waters in the Great Lakes belong to the states; held by them in trust for the use of their citizens, and that no one state or state agency may abstract these waters to the injury of the rights of the other states therein without the explicit assent of these other states; that under no circumstances can any one state, or a state agency or municipal corporation of any state, divert the waters naturally belonging to the Great Lakes Basin, so that these waters are forever lost to this basin; that the United States has not a proprietary right to these waters and is limited in the use thereof to the right of Congress to regulate the commerce carried on by means of these waters between states or between states and foreign nations.

Within the short time (Appellant's Narrative and Statement of the Pleadings, etc., together with Brief, were received by us October 22, 1924) given to the states, it was deemed inadvisable to attempt the preparation of a statement of the case independently from that statement prepared and presented in the brief of the government filed herein, and for the purposes of the presentation of the states' brief herein it is respectfully urged and prayed that we may adopt as our statement of the case, in so far as it meets the positions taken by us, the government's statement.

BRIEF.

Points and Authorities.

I.

THE STATES BORDERING ON THE GREAT LAKES, UPON BEING ADMITTED TO FULL RIGHTS OF STATEHOOD, RESPECTIVELY ACQUIRED A PROPRIETARY OWNERSHIP IN ALL THE WATERS IN THE GREAT LAKES WITHIN THE BOUNDARY LINES, AS THEN ESTABLISHED, OF THE STATES.

Martin v. *Wadell*, 16 Pet. 367, 10 U. S. (L. Ed.) 997.

Pollard v. *Hagan*, 44 U. S., 3 How. 212 (11:565).

Manchester v. *Massachusetts*, 139 U. S. 240.

Illinois Central R. Co. v. *Illinois*, 146 U. S. 387.

Kansas v. *Colorado*, 206 U. S. 46.

Port of Seattle v. *Oregon & Wash. R. Co.* 255 U. S. 56.

Barney v. *Keokuk*, 94 U. S. 324, 24 L. Ed. 224.

II.

AS OWNERS OF THE WATERS IN THE GREAT LAKES WITHIN THE BOUNDARIES OF THE RESPECTIVE STATES, THE STATES ARE ENTITLED AT ALL TIMES TO HAVE ALL THE WATERS COMING NATURALLY TO THEM, YIELDING ONLY, IF AT ALL, TO THE DEMAND OF PUBLIC COMMERCIAL NECESSITY AS ASSERTED BY APPROPRIATE CONGRESSIONAL ACTION.

Kansas v. *Colorado*, 206 U. S. 46.

Hodge v. *Eaton*, 135 Fed. 411-414.

Hudson County Water Co. v. *McCarter*, 209 U. S. 349.

Farnham on Waters (1904), Vol. I, p. 29-602.
Holyoke Water Power Co. v. *Conn. River Co.* 20 Fed. 71.
Pine v. *New York*, 112 Fed. 98.
U. S. v. *Rio Grande*, 174 U. S. 690.
Missouri v. *Illinois*, 180 U. S. 208.

III.

THE STATE OF ILLINOIS WAS WITHOUT RIGHT AS A STATE TO AUTHORIZE THE ABSTRACTION OF THE WATERS OF THE GREAT LAKES AND CONNECTING WATERS SO AS TO PERMANENTLY DIVERT THESE WATERS INTO ANOTHER WATERSHED; AND PROVIDE FOR THE EXTRAORDINARY USES OF THESE WATERS BY A STATE AGENCY OR MUNICIPAL CORPORATION OF THE STATE.

Economy Light & Power Co. v. *U. S.* 256 U. S. 113, 65 L. Ed. 847.
New York City v. *Pine*, 185 U. S. 93, 46 L. Ed. 820.
Sands v. *Manistee River Imp. Co.* 123 U. S. 288, 31 L. Ed. 149.
Farnham on Waters, Vol I, p. 59.
Withers v. *Buckley*, 20 How. 84, 15 L. Ed. 816.
Mobile County v. *Kimball*, 102 U. S. 691, 26 L. Ed. 238.
Hyde on International Law (1922), Vol. I, pp. 315-316.
Holyoke Water Power Co. v. *Conn. River Co.* 20 Fed. 71.
Ferguson v. *Arthur*, 117 U. S. 482.
Huse v. *Glover*, 119 U. S. 544, 30 L. Ed. 488.

IV.

CONGRESS HAS NOT AUTHORIZED ANY ABSTRACTION OF THE WATERS OF LAKE MICHIGAN AS IS CLAIMED BY APPELLANT.

(a) The Act of Congress of March 2, 1827, cannot be construed as authorizing any diversion or abstraction of waters from Lake Michigan.

(b) The Secretary of War was without power to authorize any abstraction of such waters.

Hubbard v. *Fort*, 188 Fed. 987.

Act of Congress, March 2, 1827 (4 Stats. at L., p. 234).

Act of Congress, March 2, 1833 (4 Stats. at L., U. S., p. 662).

Burke v. *Snively*, 208 Ill. 328.

Chicago v. *Green*, 238 Ill. 258.

People v. *Nelson*, 133 Ill. 565.

Separate Section 3, Constitution of Illinois, 1870.

U. S. v. *Rio Grande Dam & I. Co.* 174 U. S. 706.

V.

CONGRESSIONAL AUTHORITY FOR ABSTRACTION OF WATERS OF LAKE MICHIGAN MUST BE BASED SOLELY UPON COMMERCIAL IMPROVEMENT OF THE WATERS OF LAKE MICHIGAN OR IMPROVEMENT OF COMMERCE.

(a) Congress has no authority to authorize diversion except as exercised under its constitutional power to regulate commerce.

(b) The only right in and to the waters of Lake Michigan on the part of Congress is the right to use these

waters as an avenue of commerce or commercial regulation.

Farnham on Waters, Vol. I, p. 59.
Withers v. *Buckley,* 20 How. 84, 15 L. Ed. 816.
Mobile County v. *Kimball,* 102 U. S. 691.
Depew v. *Wabash & E. Canal,* 5 Ind. 8.
Port of Seattle v. *Oregon & Wash. Ry. Co.* 255 U. S. 56, 65 L. Ed. 500.

ARGUMENT.

I.

THE STATES BORDERING ON THE GREAT LAKES, UPON BEING ADMITTED TO FULL RIGHTS OF STATEHOOD, RESPECTIVELY ACQUIRED A PROPRIETARY OWNERSHIP IN ALL THE WATERS IN THE GREAT LAKES WITHIN THE BOUNDARY LINES, AS THEN ESTABLISHED, OF THE STATES.

In the case of

The Port of Seattle v. *Oregon & Washington Ry. Co.* 255 U. S. 56, 65 L. Ed. 500,

on the question as to whether or not the Oregon & Wash. Ry. Co. acquired, as owner of lands adjoining sea waterway in The Port of Seattle, the right to build in the waterway piers, wharves and other structures over which it could secure access from its land to the navigable channel, Mr. Justice Brandeis, in delivering the opinion of the court, said:

> "The right of the United States in the navigable waters within the several states is limited to the control thereof for purposes of navigation. Subject to that right Washington became, upon its organization as a state, the owner of the navigable waters within its boundaries and of the land under the same. (*Weber* v. *State Harbor Com.* 18 Wall. 57, 21 L. Ed. 798.) By section one of article 17 of its Constitution, the state asserted its ownership in the bed and shore 'up to and including the line of ordinary high tide, in waters where the tide ebbs and flows.' The extent of the state's ownership of the land is more accurately defined by the decision of the highest court, as being the land below high-water mark, or the meander line, whichever of these lines is the lower. The character of the state's ownership in the land and in the waters is the full proprietary

right. The state, being the absolute owner of the tide lands and of the waters over them" * * *

In

Barney v. *Keokuk*, 94 U. S. 324, 24 L. Ed. 224,

the court said:

"and since this court, in the case of *The Genesee Chief* v. *Fitzhugh*, 12 How. 443, 13 L. Ed. 1058, has declared that the Great Lakes and other navigable waters of the country, above as well as below the flow of the tide, are, in the strictest sense, entitled to the denomination of navigable waters, and amenable to the admiralty jurisdiction, there seems to be no sound reasons for adhering to the old rule as to the proprietorship of the beds and shores of such waters. It properly belongs to the states by their inherent sovereignty, and the United States has wisely abstained from extending (if it could extend) its survey grounds beyond the limits of high water."

Above citation was quoted with approval by Mr. Justice Brewer in *Kansas* v. *Colorado*, 206 U. S. 46.

Touching upon this matter, in the case of

Martin v. *Wadell*, 16 Pet. 367, 10 U. S. L. Ed. 997,

the court held:

"That when the American Revolution was concluded, the people of each state became themselves sovereign, and in that character held the absolute right to all their navigable waters and the soils under them for their own common use, subject only to the rights since surrendered by the Constitution to the general government."

See also,

Pollard v. *Hagan*, 44 U. S., 3 How. 212 (11:565).
Manchester v. *Massachusetts*, 139 U. S. 240.
Illinois Central R. Co. v. *Illinois*, 146 U. S. 387.

II.

AS OWNERS OF THE WATERS IN THE GREAT LAKES WITHIN THE BOUNDARIES OF THE RESPECTIVE STATES, THE STATES ARE ENTITLED AT ALL TIMES TO HAVE ALL THE WATERS COMING NATURALLY TO THEM, YIELDING ONLY, IF AT ALL, TO THE DEMAND OF PUBLIC COMMERCIAL NECESSITY AS ASSERTED BY APPROPRIATE CONGRESSIONAL ACTION.

"A river which flows through the territory of several states or nations is their common property. Each is entitled to its navigation throughout its whole extent, so far as it can be exercised without injury to the rights of others. It is a great natural highway conferring, besides the facilities of navigation, certain incidental advantages, such as, fishery and the right to use the water for power. Neither nation can do any act which will deprive the other of the benefits of those rights and advantages. The inherent right of a nation to protect itself and its territory would justify the one lower down the stream in preventing by force the one further up from turning the river out of its course or in consuming so much of the water for purposes of its own as to deprive the former of its benefit. * * * Courts, having a supervisory jurisdiction over the acts of the political department of government, will prevent acts by that department which will injure the rights of the neighboring states. The gifts of nature are for the benefit of mankind, and no aggregation of men can assert and exercise such rights and ownership of them as will deprive others having equal rights, and means of enjoying them, of such enjoyment. The acts of nations must be governed by principles of right and justice. The days of force and self-aggrandizement at the expense of neighboring nations are passed, and the common right to enjoy the bountiful provisions of Providence must be preserved."

Farnham on Waters (1904), Vol. I, p. 29.

Hudson County Water Co. v. *McCarter*, 209 U. S. 349.

This is a case in which the defendant under a contract with the City of Bayonne, in New Jersey, first laid mains in that city for the purpose of carrying waters to Staten Island in the State of New York. By their contracts it is to get the water from the Passaic River at Little Falls, where the East Jersey Water Co. has a large plant by which the water is withdrawn. The State of New Jersey enacted legislation making it unlawful for any person or corporation to transport or carry the waters of any lake or pond or stream in the state into another state for use therein. In the opinion, delivered for the court by Mr. Justice Holmes, it was said:

> "We are of the opinion further that the constitutional power of the state to insist that its natural advantages shall remain unimpaired by its citizens is not dependent upon any nice estimate of the extent of present use or speculation as to future needs. * * * It finds itself in possession of what all admit to be a great public good, and what it has it may keep and give no one a reason for its will."

In discussing this case in the lower court, 70 New Jersey Equity 695, Justice Pitney said:

> "It will, of course, be observed that the case before us is not at all parallel to the case that would be presented were the state of New Jersey or citizens thereof setting up a right to interfere with the flow of water that otherwise would, in its natural course, reach the territory of a neighboring state. Such a case was presented in *New York City* v. *Pine*, 185 U. S. 93, 22 U. S. Sup. Ct. Rep. 592. There the City of New York constructed a dam on the west branch of Byram River, within the state of New York, this being a non-navigable stream of fresh water arising in New York, flowing thence through the state of Connecticut, and emptying into Long Island Sound. The plaintiffs were riparian owners of land in the state of Connecticut, and brought action in federal Circuit Court for an injunction to restrain the city from diverting the waters of the west branch from their natural flow through the

plaintiff's lands. *The Supreme Court assumed, without deciding, that although the west branch above the dam and all the sources of the supply of water to that branch are within the limits of the state of New York, that state has no power to appropriate such water or prevent its natural flow through through its customary channel into the state of Connecticut.* The injunction was denied, however, and the right of the plaintiffs to pecuniary compensation established in its stead, on the ground of their acquiescence in the construction of the works by means of which the diversion was to be effected.

In the great case of *Kansas* v. *Colo.* 185 U. S. 125, 22 U. S. Sup. Ct. Rep. 592 (decided on demurrer, but not yet determined on final hearing), the state of Kansas, partly on the basis of its ownership of riparian land upon the Arkansas River and partly in the right of its citizens who are riparian owners thereon, is seeking to enjoin the state of Colorado from withdrawing from the river for irrigation of the arid lands of Colorado so much of the waters of the river as to materially injure the riparian lands in Kansas. A demurrer to the bill was overruled on the ground that in a case of so great importance a determination of the questions involved ought to be left until the facts were established by proofs. *Impliedly the right to prevent an undue interference with the natural flow of the river was recognized.*"

In the *Hodge* v. *Eaton*, 135 Fed. 411, in a suit by settlers in Wyoming, on a stream which arises in Colorado, to restrain the diversion of water from such stream in Colorado, the court stated the following to be a general principle:

> "*The idea of an exclusive right in the people of a state to divert its running waters to the injury of riparian owners in another state must be equally unattainable. Indeed, the doctrine of riparian ownership and use of running water is not subject to political boundaries. Between hostile states the doctrine must be recognized, but any such repudiation would be simply vis major. Between states dwelling in peace and concord, as are the states of our Union, the equal rights of the inhabitants of*

each state to the waters of intersecting streams must always be recognized.''

One state cannot authorize changes in the river which will injure property in another state.

Holyoke Waterpower Co. v. *Connecticut River Co.* 52 Conn. 570; 22 Blatchf. 131, 20 Fed. 71,

and the upper state cannot divert the water to the injury of property or the destruction of navigation lower down, and attempts to do so will be restrained by courts having jurisdiction of the parties.

Pine v. *New York,* 50 C. C. A. 145, 112 Fed. 98.
Kansas v. *Colo.* 185 U. S. 125, 46 L. Ed. 838, 22 Sup. Ct. Rep. 552.
U. S. v. *Rio Grande,* 174 U. S. 690, 43 L. Ed. 1136.

Nor has the upper state a right to pollute the water in such a way as to render it unfit for domestic use in the lower one.

Missouri v. *Illinois,* 180 U. S. 208, 45 L. Ed. 497, 21 Sup. Ct. Rep. 331.

In support of the contentions herein urged, reference is made to the case of

Kansas v. *Colorado,* 206 U. S. 46.

The waters of the Great Lakes are owned by the respective states in a proprietary sense. The holding is in trust for all its citizens for uses of navigation, fishing, etc. The holding by the state is not in the strict sense that of a riparian owner, that right to the use of waters arising from being the owner of the banks along a stream, but is rather in the capacity of a conservator, standing ever as the guardian of the people's right to use these waters for navigation and other lawful uses, seeing that these uses are in no way ever curtailed or destroyed. As

to these Great Lakes, the duty of each state to the other is to so use these waters as not to abridge to any extent the rights of the other states. If the lower riparian owner on a stream may claim, as against the upper riparian owner, the right to a continued, uninterrupted flow of the stream passing his lands, why may not the lower state then claim, as against the upper state, the same right as one of its citizens could claim against a citizen of another state? While a riparian owner on a navigable stream can claim but the right to the use of the water, the states' claim in this instance is to the full proprietary ownership of these waters. True, that the waters themselves being of a wandering, transient nature, the precise waters which were within the boundaries of the particular border state when admitted to the Union did not continue to remain in the state, and when these waters passed out in a natural manner the state lost its property in them, but at the same time gained a property to those waters naturally coming in to replace those naturally leaving. But, at the time of its admission into the Union, the quantity of the waters under state ownership and sovereignty was fixed and the state was entitled to assert its sovereignty and ownership over such quantity and all natural additions thereto as against any and all unnatural diversion or abstraction.

III.

THE STATE OF ILLINOIS WAS WITHOUT RIGHT AS A STATE TO AUTHORIZE THE ABSTRACTION OF THE WATERS OF THE GREAT LAKES AND CONNECTING WATERS SO AS TO PERMANENTLY DIVERT THESE WATERS INTO ANOTHER WATERSHED AND PROVIDE FOR THE EXTRAORDINARY USES OF THESE WATERS BY A STATE AGENCY OR MUNICIPAL CORPORATION OF THE STATE.

Appellant attempts to justify its right to abstract these waters from Lake Michigan, and indeed any amount of water which the State of Illinois may determine as proper, by reason of the powers conferred upon it under the Illinois Act of May 29, 1889 (Appellant's Brief and Argument, p. 155) asserting that the State of Illinois has reserved to it the police power to take the amount of water reasonably required for the purposes designed—namely, the protection of the water supply of Chicago and its environs.

The states herein recognize the principle that Illinois, under its police powers, should take all necessary steps to protect the water supply of the state, but it is respectfully submitted that in the exercise of this police power the State of Illinois was not justified in authorizing any unreasonable use and abstraction of the waters of the Great Lakes to the injury of the navigability of the Great Lakes and connecting waters, and the rights of the respective border states to their respective rights to the use of these same waters for navigation, development of water power and other lawful uses.

That the use of these waters being made by appellant is an extraordinary use; that is, extraordinary as to the

purpose for which the water is taken as well as the amount of water used, needs no argument.

It is undisputed in the record that the abstraction of 10,000 cubic second feet of water by appellant reduces the levels of the Great Lakes and connecting waters at various places of from four and five-tenths inches to six and nine-tenths inches, and that any reduction of the levels of these waters necessarily tends to nullify costly improvements heretofore made throughout the Great Lakes, both by the states and the federal government, and that a withdrawal of 10,000 cubic feet per second would nullify the expenditures made throughout the Great Lakes under authority of Congress to the amount of many millions of dollars, as well as inflicting a great loss on the navigation interests using these waters, and a loss to the states using these waters for power purposes. (See Rec., Vol. 8, pp. 52, 53, 54.)

In

Economy Light & Power Co. v. *U. S.* 256, pp. 113, 65 L. Ed. 847,

suit was brought by the United States to restrain defendants from constructing a dam in the Des Plaines River at a point in Grundy County, Ill., without the consent of Congress or authority of the legislature of the state:

> "The public interest in navigable streams of this character in Illinois and neighboring states, and the Federal authority over such as are capable of serving commerce among the states, do not arise from custom or implication, but have a very different origin. By article 4 of the compact in the Ordinance of July 13, 1787, for the government of the territory northwest of the River Ohio, it was declared: 'The navigable waters leading into the Mississippi and St. Lawrence, and the carrying places between the same, shall be common highways, and forever

free, as well to the inhabitants of the said territory, as to the citizens of the United States, and those of any other states that may be admitted into the Confederacy, without any tax, impost or duty therefor.'" * * * "To the extent that it pertained to internal affairs, the Ordinance of 1787—notwithstanding its contract form—was no more than a regulation of territory belonging to the United States, and was superseded by the admission of the state of Illinois into the Union 'on an equal footing with the original states in all respects whatever.' *But so far as it established public rights of highway in navigable waters capable of bearing commerce from state to state, it did not regulate internal affairs alone, and was no more capable of repeal by one of the states than any other regulation of interstate commerce enacted by the Congress.*"

In construing the provisions of the fourth section of the ordinance for the government of the northwest territory (Ordinance of 1787), Mr. Justice Fields said:

> "The provision of the clause that the navigable streams should be highways without any tax, impost or duty *has reference to their navigation in their natural state. It did not contemplate that such navigation might not be improved by artificial means, by the removal of obstructions or by the making of dams for deepening the waters, or by turning into the rivers waters from other streams to increase their depth.*"
>
> *Huse* v. *Glover*, 119 U. S. 544, 30 L. Ed. 488.

It does then appear that the provisions of the ordinance of 1787, for the government of the northwest territory, in so far as these provisions establish the public rights of interstate navigation in the Great Lakes still remain as binding upon all the states in their relation to each other and to the federal government. The right of navigation is the first great right to which these

waters are dedicated, and any other use of these waters affecting their navigable capacity is prohibited.

> "Any duty imposed upon a riparian state, either by international law or by contract to maintain the navigability of an international river, implies an obligation also to check within places subject to the control of such state the commission of any acts which, unless restricted would prove injurious to navigation.
>
> This obligation would seem to render improper the tolerance of any diversion productive of such an effect even though it should occur at a point where the river ceased to be navigable and lay wholly within the domain of the acquiescent territorial sovereign."
>
> Hyde International Law, 1922, Vol. 1, 315-316.

In

New York v. *Pine*, 185 U. S. 93, 46 L. Ed. 821,

Mr. Justice Brewer, delivering the opinion of the court, said:

> "Without deciding, *we assume that*, although the west branch above the dam and all the sources of supply of water to that branch are within the limits of the state of New York, it has no power to appropriate such water or prevent its natural flow through its accustomed channel into the state of Connecticut; that the complainants have a legal right to the natural flow of the water through their farms in the state of Connecticut and cannot be deprived of that right by and for the benefit of the City of New York or by any legal proceedings either in Connecticut or New York."

In

County of Mobile v. *Kimball*, 102 U. S. 691, 26 L. Ed. 238,

> "The improvement of harbors and bays and navigable rivers *within the states* may be regulated by state authority, *if it does not impair their free navigation as permitted under the laws of the United*

States, nor defeat any system for the improvement of their navigation provided by the general government."

In

Holyoke Water Power Co. v. *Connecticut River Co.* 20 Fed. p. 71,

"The improvement of the navigation of navigable rivers within a state is a part of the state's governmental duties * * * and * * * the riparian proprietor within the state is subject to the just exercise of this (governmental) power. The land is under the jurisdiction of the state and the state derives the power to inflict remote and consequential injuries upon it by virtue of such jurisdiction. Jurisdiction confers the power and the right to inflict consequential injury, but where no jurisdiction exists, the right ceases to exist. It is a recognized principle that the statute of one state in regard to real estate cannot act extraterritorially. As Connecticut has no direct jurisdiction or control over real estate situate in another state, it cannot indirectly, by virtue of its attempted improvement of its own navigable waters, control or subject to injury foreign real estate."

If as proprietors of these waters the states cannot object when one of the states insists upon taking these waters and forever destroying them by abstraction so that these states are denied any future use of these waters, it would seem absurd for the courts to say that the states' right to these waters is a "full proprietary one."

"'Proprietary' as defined by the Imperial Dictionary, means belonging to; ownership, as proprietary rights. By Webster, as belonging or pertaining to a proprietor; 'proprietor' being defined as one who has the legal right or exclusive title to anything whether in possession or not; an owner."

Ferguson v. *Arthur*, 117 U. S. 482, 29 L. Ed. 979.

Here one state desires to take away from each of these states of from three to five inches level of the Great Lakes' waters. Should Illinois authorize a municipal corporation of that state to dump solid matter on the bottom of all the lakes to an extent of three-inch thickness, there would be no question about the right of the other states to prevent this, and certainly such offending municipal corporation could not justify its act on the grounds of permission derived from an Illinois state statute. When the Illinois statute attempted to give to the appellant the right to abstract waters from Lake Michigan for the extraordinary purpose of washing sewage away from the City of Chicago and its environs, and in the extraordinary amounts indicated in the statute, it was in effect granting to the appellant the right to take property belonging to all of these states and this, obviously, it could not do.

The withdrawal from Lake Michigan through the Drainage Canal of 10,000 c. f. s. obviously means so much less flowing through the Niagara and St. Lawrence Rivers. The aggregate fall or head on the Niagara and that part of the St. Lawrence forming the international boundary line, is approximately 400 feet. This amount of water if allowed to flow in its natural course is capable of developing on the St. Lawrence and Niagara Rivers 400,000 constant horsepower of electrical energy—the equivalent of from three to four millions tons of coal—annually.

The State of New York is more directly interested in the question of hydro-electric power development, than the other states in whose behalf this brief is presented, but the States of Pennsylvania, Ohio and Michigan, on account of their proximity to the Niagara and St. Lawrence Rivers, are deeply interested in this question.

Hyro-electric power developed on the St. Lawrence and Niagara Rivers may very easily be made available for use in the three states last mentioned. It is a fact that there is now being constructed by the New York, Lockport & Ontario Power Company, a transmission company in the western part of New York state, a transmission line from Niagara Falls to Warren, Pa., to connect with the transmission lines of the Pennsylvania Electric Corporation, which last named company has transmission lines extending across the State of Pennsylvania into the State of Maryland.

The development and distribution of 400,00 hydro-electric horsepower among the industries of these four states means a tremendous saving in the coal resources of the country, and as a broad proposition is of sufficient importance to the public to require the Sanitary District, within a reasonable time, to replace the present unscientific system for sewage disposal with some other more scientific and standardized system.

In presenting this point and the above statement, we have not overlooked the testimony of Mr. Isham Randolph, consulting engineer for the Sanitary District, found in the record, Vol. VI, at pages 3598, 3599. Mr. Randolph has undertaken to state the value to the Sanitary District of the power capable of development from the 10,000 c. f. s. diverted through the drainage canal. His statement that 30,000 horsepower can be developed at Lockport is substantially correct. His further statement of the amount of power capable of development from 14,000 c. f. s. is also substantially correct, but the significance of the statement of the amount of power capable of development from 14,000 c. f. s. is that it is the intention of the Sanitary District to ultimately withdraw 14,000 c. f. s. rather than to be limited to the withdrawal of even 10,000 c. f. s.

The amount of power capable of development from 10,000 c. f. s. and 14,000 c. f. s. respectively, on the Des Plaines and Illinois Rivers below Lockport, is not a material fact in the determination of the question before this court. If any weight is to be given to the fact that the withdrawal of 10,000 c. f. s. or 14,000 c. f. s. from Lake Michigan, through the Des Plaines and Illinois Rivers by way of the drainage canal, increased the volume of water flowing through these rivers and thereby makes possible a development of any amount of power, the question resolves itself into one of water power or hydro-electric power development, and we are getting away from the proposition that the real and avowed purpose of the Sanitary District in withdrawing water from Lake Michigan, under the Illinois statute, is to provide a system of sewage disposal for the people of Chicago and adjacent territory.

Mr. Randolph has further undertaken to state the amount of power that 10,000 c. f. s. will develop at Niagara Falls on the Niagara River, and also he has undertaken to state the price at which power sells at Niagar Falls, to wit, $9.50 per horsepower. He has not qualified or shown that he has any knowledge of the price at which power is sold at Niagara Falls. His statement that 10,000 c. f. s. developed by the *Shellcock* Company (Schoellkopf Company), under a head of 200 feet, and 80 per cent efficiency, will produce 181,000 horsepower, is erroneous. It is a fact well known to the War Department, and other departments of the government, that the development of the Schoellkopf Company is under a mean head of 215 feet; that its efficiency is above 90 per cent; and, that the amount of power which it is actually producing from the use of 19,500 c. f. s. is over 400,000 horsepower.

The above is a statement of present conditions. Mr. Randolph, in his testimony, referred to conditions in the year 1914 which were somewhat different from the present conditions. His statement that power sells at Niagara Falls for $9.50 per horsepower is obviously erroneous. It is a fact well known and understood among engineers and in the hydro-electric world generally, that on the Canadian side, at Niagara Falls, at an early date, a contract was made by one company for the sale of hydro-electric power at that price. No hydro-electric power has ever been sold at that price on the American side. We are assured by the Niagara Falls Power Company (the successor of the Schoellkopf Company and other companies), the only company developing hydro-electric power on the American side of the Niagara River, that the average price of hydro-electric power developed on the American side of the Niagara River, for several years before the year 1914, was not less than $16 per horsepower, and that the price for which such power has sold from that time to the present time is $20 per horsepower.

The Sixty-fifth Congress, by Public Resolution No. 8, authorized the Secretary of War, among other things,—

> "To make a comprehensive and thorough investigation, including all necessary surveys and maps, of of the entire subject of water diversion from the Great Lakes and the Niagara river, including navigation, sanitary and power purposes, and the preservation of the scenic beauty of Niagara Falls and the rapids of Niagara river, and to report to Congress thereon at the earliest practicable date."

The work provided for by the above resolution was entrusted by Major General Beach, chief of engineers of the army, to Col. J. G. Warren, corps of engineers, division engineer, Lake Division. The work entrusted to Colonel Warren was undertaken by him and his as-

sistants, and performed with great thoroughness. The work was completed by him in 1919, and on August 30th of that year he made his report to the chief of engineers of the United States Army. On November 19, 1920, the chief of engineers transmitted this report to the Secretary of War. On the 7th of December, 1920, the Secretary of War transmitted the same to the Congress. This report is commonly known as "The Colonel Warren Report," and is the best authority extant on the subjects therein treated.

This subject is quite fully discussed in Colonel Warren's report at pages 93, 94, 398, 399, 400. On pages 93 and 399, there are statements showing the comparative cost of producing steam electric power and hydro-electric power at Niagara Falls, and the estimated price at which such power might be sold in large blocks to the public. The estimated price of steam electric power to the public, in large blocks, is $50.70 per horsepower, while the estimated price of hydro-electric power to the public, in large blocks, is $19.50 per horsepower.

The purpose of referring to Mr. Randolph's testimony is to point out to the court that certain statements made by him are erroneous; that the average price of electrical power to the public, in large blocks, on the American side previous to 1914 was not less than $16 per horsepower; that the average price at the present time is $20 per horsepower; that the cost of producing hydro-electric power on the Niagara River, and the price for which the same can be furnshed to the public are in any event much less than on the DesPlaines or Illinois Rivers, and that so far as the question of hydro-electric power development is related to the withdrawal of water from Lake Michigan by the Sanitary District, the development and sale of power from that volume of water is much more

beneficial to the general public if developed on the Niagara and St. Lawrence Rivers, and means a very large economic saving.

Mr. Randolph, in his testimony, made no reference to the re-use of water on the St. Lawrence River and the amount of power capable of development at that point from the water withdrawn from Lake Michigan through the Sanitary Canal. 10,000 c. f. s. on that part of the St. Lawrence River forming the international boundary line is capable of developing approximately 100,000 horsepower at a cost which will permit its sale to the public, in large blocks, at about the same price as power developed at Niagara Falls on the American side.

The conditions at Niagara Falls are recognized and commented up by the Federal Power Commission in its First Annual Report, at pages 8-10. We quote the following from page 9:

> "The Niagara plants, among the first to be constructed in this country, developed only 10.6 horsepower per second-foot of water. Modern design will permit of 19 horsepower."

The improved development which has been made by the Niagara Falls Power Company actually develops over 20 horsepower per second-foot of water. This improved development is under a mean head of 215 feet. If the development were under the full head of upwards of 300 feet possible on the Niagara River between Niagara Falls and Lake Ontario, there would be obtainable 30 horsepower for each second-foot of water.

IV.

CONGRESS HAS NOT AUTHORIZED ANY ABSTRACTION OF THE WATERS OF LAKE MICHIGAN AS IS CLAIMED BY APPELLANT.

The Act of Congress of March 2, 1827, cannot be construed as authorizing any diversion or abstraction of waters from Lake Michigan.

Appellant, by a most interesting, if not convincing, argument attempts to connect its right to the abstraction of waters from Lake Michigan with the provisions of the Act of Congress of March 2, 1827. (Appellant's Brief, p. 115.)

The State of Illinois had in 1827 authority to construct canals. Congress, to aid the state to construct a canal to connect the waters of the Illinois River with those of Lake Michigan, made, under the said Act of 1827, a grant of lands, the revenue from the sale of which lands so granted could be used to aid in the contemplated canal construction. To take advantage of the grant, the construction of the canal was to be commenced within five years and completed within twenty years. The canal contemplated by this Act of 1827 was to be a navigable public highway for the transportation of persons and property, and such a one as would suit the needs of commerce. This is emphasized when we read the Amendment to this Act of March 2, 1827, made by the Act of March 2, 1833, (4 Statutes at Large, page 662), under the terms of which the lands granted under the Act of March 2, 1827, could be "used and disposed of by said state, for the purpose of making a railroad instead of a canal as in said act contemplated; and that the time for commencing and completing said canal or railroad, whichever the State of Illinois may choose to make, be and is extended five years:"

Illinois chose to build a canal instead of a railroad. The title of the Act of March 2, 1827, uses the words "connect the waters," while Section one of the act the words "unite the waters" are used. Neither "a connection" or "a uniting" of the waters contemplated, inferred nor authorized an abstraction or diversion or any of these waters. The canal actually constructed by the state, "had a summit of eight feet above Lake Michigan, and it was fed in ordinary seasons from the Des Plaines River and by a feeder through the Sag Valley and the Calumet River at Blue Island." (Rec., Vol. 3, p, 1716—Appellant's Narrative Statement, p. 269.)

That the state understood that the Act of March 2, 1827, did not contemplate any abstraction of the waters of Lake Michigan is best illustrated by the method in which the state acted under its authority to construct this canal.

That there can be no possible connection between the navigation canal authorized by the Act of March 2, 1827, and the Sanitary Canal built by the appellant is plain.

Since the adoption of its Constitution of 1870, the State of Illinois is without authority to loan its credit or make appropriations in aid of canals. The constitutional provision referred to reads as follows:

> "The Illinois and Michigan canal shall never be sold or leased until the specific proposition for the sale or lease thereof shall first have been submitted to a vote of the people of the State at a general election, and have been approved by a majority of all the votes polled at such election. The General Assembly shall never loan the credit of the State, or make appropriations from the treasury thereof, in aid of railroads or canals: Provided, that any surplus earnings of any canal may be appropriated for

its enlargement or extension." (Const. 1870, separate sec. 3; Starr & Cur. Stat. 1896, p. 206.)

In the case of

Burke v. *Snively*, 208 Ill. 328-348,

Mr. Justice Boggs, delivering the opinion of the court, in construing the above cited section of the Illinois Constitution of 1870, held that this section prohibited an appropriation by the legislature in aid of the Illinois and Michigan Canal, which is the canal constructed by the State of Illinois with the aid of the money derived from the sale of the lands granted to the State of Illinois under the provisions of the aforesaid Act of Congress of March 2, 1827. In his opinion, Justice Boggs said, among other things:

> "Though it does not aid to the determination of the question of the power of the legislature to make the appropriation in question, it is not inappropriate to remark that the fears entertained by members of the constitutional convention that more modern and more speedy means of transporting passengers and commodities would soon supplant the canal and divert traffic from it, and the canal would become practically of no use as a waterway or highway of traffic and commerce and would cease to produce an income sufficient to pay the expenses connected with its management, and would, unless restrained by the constitution, become a regular applicant at the door of the State treasury for appropriations of money of the tax-payers of the State, *have been verified*. In 1876 the tolls received for the use of the canal aggregated $113,293, but since that year there has been a marked and substantially gradual decrease in such receipts. In 1900 so little demand was there for the canal as a highway or waterway for transportation of persons or property that but $13,867 were paid as tolls. In 1901 the use of the canal for the purpose of trade or commerce was so little availed of that but $8120 were collected from tolls. The gross receipts were much larger in all

the years than the sums stated, but the excess arose from sales of ice privileges and sales of water power. But in addition to all receipts, of every character, during these years, heavy appropriations from the treasury of the State, amounting to something more than one-half a million dollars, have been asked and obtained from the public treasury to meet the deficiencies arising from the management and operation of the canal. The canal has practically fallen into disuse for any of the purposes of transportation of either persons or property, and has been perverted to mere commercial purposes of supplying water power to those along its banks and selling privileges to cut ice from its pools. It is no longer a highway of commerce." (The opinion was filed Feb. 17, 1904.)

The appellant was created as a "Sanitary District" under the provisions of the Act of Illinois of May 29, 1889, "An Act to create Sanitary Districts, etc." (Rec., Vol. 8, p. 90.)

It was said in *Chicago* v. *Green*, 238 Ill. 258, "The purpose of the Act of 1889 was to furnish a common outlet for the sewage of the incorporated municipalities within the limits of the district," and in *People* v. *Nelson*, 133 Ill. 565, "A Sanitary District is a municipal corporation organized to secure, preserve and promote the public health." Within the limits of the title and the body of the act under which appellant exists and operates, while navigation might be the result, it could not be the object of the construction of any drain or canal by this appellant. A sanitary canal built by the appellant may result in being used, in part, as a navigation canal, but the Sanitary District, the appellant, would have to justify the existence of any of its canals upon the ground that such canal was built solely to meet the needs of sanitation.

While the construction of a navigation canal was en-

tirely foreign to the act under which appellant derives its powers, nevertheless the record shows that more than $15,000,000 of the expenditures actually made upon the Chicago Drainage Canal by this appellant was distinctly for the benefit of navigation. (Rec., Vol. 3, pp. 1176-1177.)

Obviously there can be no connection between the navigation canal mentioned in the Act of Congress of March 2, 1827, and appellant's Sanitary Canal.

The Secretary of War Was Without Power to Authorize Any Abstraction of Such Waters.

The permit issued by the Secretary of War on the 8th day of May, 1899, was based upon the provisions of Section 10 of the Rivers and Harbors Act of March 3, 1899. This permit authorized the diversion of 300,000 cubic feet per minute of the waters of Chicago River so as to cause them to flow into the artificial channel constructed by the appellant. So far as we have searched the record we are unable to find any instance where the work of an abstraction of the waters of the Great Lakes, at least beyond 4,167 cubic second feet, has ever been recommended by the chief of engineers U. S. Army. It is apparent that in all proceedings before the Secretaries of War, that the Secretaries were persuaded by such reports as were given to them by the chief of engineers that the particular "work" of abstraction of Lake Michigan waters would be "an obstruction to the navigable capacity" of the Great Lakes. Secretary of War, Hon. Henry L. Stimson, emphasized this, when in denying the application of the appellant to abstract 10,000 cubic second feet, he said:

> "It is clear that even under the conditions heretofore manifested on these applications, the propo-

sition to divert the waters of Lake Michigan into another watershed has not been entertained without hesitation and careful restriction by my predecessors. The propriety of obtaining congressional sanction for the project has been pointed out from the beginning; and the form in which the permit has been granted, even for the moderate amount of diversion permitted, has been so phrased as to indicate that the permission was predicated upon the absence of any substantial injury to commerce. The sanitary canal has never received the direct sanction of Congress."

It also seems clear that the Secretaries of War construed the Rivers and Harbors Acts of 1890 and 1899 to mean and provide that the Secretary of War, under these acts, could not legally authorize any work of "altering or modifying the course, condition and capacity" of the Great Lakes, or other navigable waters of the United States when it was apparent that such work would obstruct the navigable capacity of the waters, unless and before Congress, by affirmative congressional action, authorized the particular work of obstruction. The conclusions reached by the Secretary of War upon denying the aforesaid application for the abstraction of 10,000 cubic second feet, indicate the construction placed upon the Rivers and Harbor Act of 1899. The conclusions are as follows:

"*First.* That the diversion of 10,000 cubic feet per second from Lake Michigan, as applied for in this petition, would substantially interfere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.

Second. That that being so, it would not be appropriate for me, without express congressional sanction, to permit such a diversion, however clearly demanded by the local interests of the sanitation of Chicago.

Third. That on the facts here presented no such case of local permanent necessity is made evident." (Rec., Vol. 8, page 58.)

It is also clear that at the time of the original authorization by the Secretary of War, May 8, 1899 (Rec., Vol. 8, pages 44-45), that the only contemplated "obstruction to the navigable capacity of the waters of the United States" was as to the waters of the Chicago River. As the exact effect upon the Great Lakes and connecting waters of abstracting a given amount of water therefrom could only be ascertained after prolonged observations (Appellant's Narrative Statement, page 514), it is evident that it was apparent at the time this permit for the abstraction of 4167 cubic second feet was given that an obstruction to the navigable capacity of the Great Lakes and connecting waters was not contemplated. The reduction in the amount authorized, made by Secretary of War, Hon. Elihu Root (April, 1901), was directed at obstructions to the navigability of the Chicago River. (Rec., Vol. 8, page 46.) So, too, were the official authorizations of the War Department secretaries, *until* the application of the Sanitary District for an increased abstraction of these waters was considered by Secretary of War, Hon. Henry L. Stimson, during the time from February 5, 1912, to January 8, 1913. (Rec., Vol. 8, pages 48, 49, 50.)

It seems clear, from an examination of the provisions of Sections 9 and 10 of the Rivers and Harbors Act of March 3, 1899 (U. S. Stat. at L., Vol. 30, page 1121), that affirmative congressional action must be taken with regard to any construction or work which will obstruct the navigable capacity of any of the waters of the United States, and for authorization to construct any bridge, dam, dike or causeway over or in any port * * * canal * * * or other navigable water of the United States, except when the bridge, etc., is across rivers and other waterways, the navigable portions of which lie

wholly within the limits of a single state and such structures are being erected under authority of the legislature of that state. Wharves, piers, etc., built under the provisions of Section 10 may be constructed if they do not obstruct the navigable capacity of any of the waters of the United States when the plans for such construction have been recommended by the chief of engineers and authorized by the Secretary of War. So, too, under the provisions of Section 10, the work of excavating, filling, altering or modifying the course, etc., of any port * * * canal * * * or the channel of any navigable water of the United States may be undertaken when recommended by the chief engineer and authorized by the Secretary of War, and the work so undertaken does not obstruct the navigable capacity of any of the waters of the United States.

A construction of the aforesaid Rivers and Harbors Act of Congress, of March 3, 1899, was made by the court in the case of

Hubbard v. *Fort*, 188 Fed. 992.

It was there said:

> "Upon the only ground of demurrer considered, the question is thus reduced: Is this authority from the Secretary of War plenary or merely permissive? So far as applicable to the present question, such section may be summarized thus: *First*, the creation of any obstruction to the navigable capacity of any waters of the United States is prohibited unless affirmatively authorized by Congress; *second*, it shall not be lawful to build any structure in a navigable river or water of the United States, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and, *third*, it shall not be lawful to excavate or fill the channel of any navigable water of the United States unless such work is recommended by said Secretary of War prior to beginning the same.

This section was construed in *Cobb* v. *Lincoln Park*, 202 Ill. 427, 67 N. E. 5, 63 L. R. A. 264, 95 Am. St. Rep. 258, and *Wilson* v. *Hudson County Water Co.*, 76 Atl. 560. In both of these it was held that the Secretary of War's authorization was a mere license to do the work and not a grant of power to do it. In the latter case V. C. Walker, adopting the view of the Illinois court, said: 'The doctrine of *Cobb* v. *Lincoln Park* as applicable to the case under consideration may be paraphrased as follows: The provisions of Section 10 of the Rivers and Harbors Act of March 3, 1899, were designed to protect the navigable waters of the United States from encroachment and from obstructions to navigation, and to commit the duty of their protection to an officer of the general "government without whose permission no such obstructions can be made; that the act is a mere regulation for the benefit of commerce and navigation, and that the license or permission of the Secretary of War is only a finding and declaration that a proposed structure or excavation would not interfere with or be detrimental to navigation, *and is not equivalent to a positive declaration by the authority of Congress that the licensee may make such obstruction or excavation without first obtaining the consent of the owner of the submerged land;* that the act is not a declaration touching the rights of the owner of the submerged lands in question, and, assuming that the permission of the general government to the excavation and laying of the proposed pipe line is necessary, such permission is not given to override the rights of the owner of the submerged lands, namely, the state of New Jersey, and it is, as said, the declaration by the guardian of the interests of the public at large that the proposed work will not interfere with navigation, and is strictly permissive, and not an authorization by paramount authority to do the work proposed. * * *

It is perfectly apparent that nowhere in the tenth section of the Rivers and Harbors Act of 1899 *is there any intention, expressed or implied, to grant to any person or corporation the right to lay a pipe line under navigable waters in lands belonging to a*

state or individual for the purpose of transporting any merchantable commodity whatever. The only intention discovered is, as already said, the authorization of such a work if it may be lawfully done, and the intention is to authorize it to be done only in such a way as to prevent its being any obstruction to navigation. * * *

In this connection, it may be observed that the tenth section of the Rivers and Harbors Act does not provide that it shall be lawful for the Secretary of War to authorize the excavation of land in the channel of any navigable waters of the United States, but only that it shall not be lawful to do the work without the authorization of the Secretary, before beginning the work. *The section as worded clearly contemplates that the consent of the Secretary shall merely be permissive of the doing of work for which authority already exists.*

In view of the context, the word 'affirmatively' was legitimately used to distinguish the two kinds of authority referred to, and to make it plain that the initial authorization to create an obstruction was not to rest on implied, but express—affirmative—congressional authority. * * *

Among the changes effected by the Act of 1899 was to require the affirmative authorization of Congress to create any obstruction to the navigable waters of the United States, except that bridges, dams, dikes, and causeways in or across the navigable portions of which lie wholly within the limits of a single state was permitted if authorized by state legislation and the location and plans of such structure were approved by the Chief of Engineers and of the Secretary of War." * * *

The provisions of the Rivers and Harbors Act of Sept. 19, 1890 (26 Stats. at L. 426), were before this Supreme Court for construction in the case of *U. S.* v. *Rio Grande Dam & I. Co.* (174 U. S. 706), wherein it was said:

"Whatever may be said in reference to obstructions existing at the time of the passage of the act, under the authority of state statutes, it is obvious that Congress meant that thereafter no state should

interfere with the navigability of a stream without the condition of national assent. It did not, of course, disturb any of the provisions of prior statutes in respect to the mere appropriation of water of non-navigable streams in disregard of the old common-law rule of continuous flow, and its only purpose, as is obvious, was to affirm that as to navigable waters nothing should be done to obstruct their navigability without the assent of the national government. * * *

The language is general, and must be given full scope. *It is not a prohibition of any obstruction to the navigation, but any obstruction* to the navigable capacity, and anything wherever done or however done, within the limits of the jurisdiction of the United States which tends to destroy the navigable capacity of one of the navigable waters of the United States, is within the terms of the prohibition. *Evidently Congress, perceiving that the time had come when the growing interests of commerce required that the navigable waters of the United States should be subjected to the direct control of the national government, and that nothing should be done by any state tending to destroy that navigability without the explicit assent of the national government, enacted the statute in question.*"

V.

CONGRESSIONAL AUTHORITY FOR ABSTRACTION OF WATERS OF LAKE MICHIGAN MUST BE BASED SOLELY UPON COMMERCIAL IMPROVEMENT OF THE WATERS OF LAKE MICHIGAN OR IMPROVEMENT OF COMMERCE.

Report of a special board of engineers, which is signed by General W. H. Bixby, chief of engineers, U. S. Army, dated January 23, 1911, pages 8-9, says:

"For purposes of navigation, a diversion from Lake Michigan of less than 1,000 second feet of water is all that will be necessary. For purposes of sanitation the works of the Sanitary District of Chicago were designed to allow the diversion of 10,000

second feet and now contemplate a total of 14,000 second feet, the additional 4,000 second feet to be obtained by a diversion of water through the Calumet River and a connecting canal following the Sag route. The War Department, while awaiting the definite action of Congress, has so far permitted the diversion of 4,167 second feet, and the Sanitary District is understood to be using 7,000 second feet. As the water which is at present being diverted from the lake appears to have already seriously affected the navigation of its harbors and connecting waterways, prompt congressional action is recommended to limit the diversion." (Rec., Vol. 6, p. 3633-3634.)

The report referred to in the above is included in the record, in Volumn 4, pages 2397-D and 2397-E, but the references in the report to the foregoing quotation is not included in the transcript of the record.

"The right of the United States in the navigable waters within the several States is limited to the control thereof for the purposes of navigation. Subject to that right Washington became upon its organization as a State the owners of the navigable waters within its boundaries."

Port of Seattle v. *Oregon & Washington Ry. Co.*, 255 U. S. 56.

The right in and to the navigable waters belonging to the states surrendered by the states to the general government was that right given to the general government under the provisions of Subsection 3 of Section 8, Article 1, of the Constitution of the United States, under the terms of which:

"the Congress shall have power * * * to regulate commerce with foreign nations and among the several states."

"The jurisdiction of the general government over interstate commerce and its natural highways, vest in that government the right to take all needed measures to *preserve the navigability of the navigable water courses of the country, even against any*

state action, and nothing should be done by any state tending to destroy such navigability without explicit assent of the National Government."

United States v. *Rio Grande Dam & I. Co.,* 174 U. S. 690.

In regard to these waters, as highways upon which the commerce of the states and nations move, Congress is given a power to control their use in the interest of that commerce. This authority is given to Congress for the purpose of aiding, and not destroying, navigation and commerce, so that, although the authority over navigable waters is absolute in execution of the trust imposed in it, whatever obstructions Congress authorizes must be for the purpose of improving the navigation of the streams, or of facilitating commerce.

Farnham on Waters, Vol. 1, page 60.

See,

Depew & Wabash and E. Canal, 5 Ind., p. 8.

If the federal government was undertaking the construction of a canal connecting the Great Lakes with the Illinois River, the government would have to base its authority for such action upon the exercise of its power to regulate commerce. The Government could not undertake the work of providing a water course for washing away sewage of a municipal corporation of the State of Illinois.

Obviously, that which Congress itself could not do, the Secretary of War could not do under any claimed congressional authorization or assumed delegation of congressional power.

The states, therefore, respectfully submit, that, in view of the fact that the abstraction of any of the waters of the Great Lakes would tend to affect and obstruct the navigation thereon, no more waters thereof should, or could, be used by the Government than was necessary in the general improvement of commerce, and that the

use of the Sanitary District of these waters, in excess of the amount of waters necessary to provide a commercial highway; which clearly seems to be an amount of less than 1,000 cubic second feet, must be considered as an obstruction of navigation and a hindrance to commerce.

All of which is respectfully submitted.

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No. 161.

IN THE

Supreme Court of the United States

OCTOBER TERM, A. D. 1924.

THE SANITARY DISTRICT OF CHICAGO,
Appellant,
vs.
THE UNITED STATES OF AMERICA,
Appellee.

BRIEF OF THE CITY OF CHICAGO, APPEARING AS AMICUS CURIAE.

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BARNARD & MILLER PRINT, CHICAGO

IN THE

Supreme Court of the United States

OCTOBER TERM, A. D. 1924.

No. 29839.

THE SANITARY DISTRICT OF CHICAGO,
Appellant,
vs.
THE UNITED STATES OF AMERICA,
Appellee.

BRIEF OF THE CITY OF CHICAGO, APPEARING AS AMICUS CURIAE.

MAY IT PLEASE THE COURT:

This case has pursued its way through many years of litigation without taking into account the interests of the City of Chicago as a municipality. The people of the city, along with the people of the numerous other towns, villages and cities of the Sanitary District of Chicago, have had their interests presented by the attorneys for the District. But as a municipal corporation the City of Chicago has not even had the benefit of sharing representation with the many other municipal and quasi-municipal corporations whose property interests are affected by this litigation.

When it is considered that there are a large number of these corporations, so large a number in fact that the list of villages, towns and cities on pages 4 and 5 of the Petition of the City of Chicago contains only a portion of them, it becomes apparent at once that even if an

attempt had been made to present the property interests of these municipalities, the very important interests of the City of Chicago could not have been adequately handled merely as a unit in a list of municipalities aggregating considerably more than fifty and perhaps numbering one hundred. The property interests of all of these outside of the City of Chicago are comparatively small, and arguments could be used against them which would not apply in the case of the large city. To be sure, the necessity for pure water exists in the small community as well as in the large community, and the principle involved in being deprived of a hearing is the same in both cases, but otherwise the matter presents itself in an entirely different aspect when a city of great size seeks to adjust itself to conditions which may be readily overcome by a corporation of small size. Since neither the City of Chicago nor any of these other corporations have had a hearing, however, it is idle to discuss what kind of presentation should have been made for this city as distinguished from the others.

The City of Chicago had a waterworks system and an enormous investment of capital therein long before The Sanitary District of Chicago was created. The creation of this District did not take this plant away from the City. It retained this property and made such immense additions thereto that the enormous investment we speak of becomes small by comparison. All these investments, the original investment and the additions, have been put into a water plant built so that the whole system adapts itself to the conditions that exist which The Sanitary District is striving to maintain in this suit. The plant belongs to the City of Chicago in its corporate capacity. At least half of this tremendous plant would be rendered useless or nearly so if the decree entered in the court below were to stand, while the corporation which owns it

has not had its day in court. This would amount to a deprivation of property without due process of law on a scale that is staggering.

To anyone who is not familiar with the situation, the holding of this property and its management by one municipal corporation and the control and responsibility for the supply of water to the plant by another municipal corporation seems an anomalous condition. It has been explained to a certain extent, but not entirely, in the briefs presented in this case. We will attempt a further elucidation, confining ourselves to those points which we think have not been fully explained.

Like all rapidly growing communities, the City of Chicago, from the time of its incorporation, was confronted by a debt limitation. Likewise, as is the case with most growing communities, it was confronted with the danger of pollution of its water supply.

The debt limitation fixed by the Constitution of the State of Illinois was five per cent of the total value of the property of the City as ascertained for purposes of taxation at the last preceding assessment. Section 12 of Article IX of the said Constitution reads as follows:

> "Section 12. No county, city, township, school district, or other municipal corporation, shall be allowed to become indebted in any manner or for any purpose, to an amount, including existing indebtedness, in the aggregate exceeding five per centum on the value of the taxable property therein, to be ascertained by the last assessment for State and county taxes, previous to the incurring of such indebtedness. Any county, city, school district, or other municipal corporation incurring any indebtedness as aforesaid, shall before, or at the time of doing so, provide for the collection of a direct annual tax sufficient to pay the interest on such debt as it falls due, and also to pay and discharge the principal thereof within twenty years from the time of contracting the same. This section shall not be

construed to prevent any county, city, township, school district, or other municipal corporation, from issuing their bonds in compliance with any vote of the people which may have been had prior to the adoption of this Constitution in pursuance of any law providing therefor."

When it became certain that the supply of water was contaminated and would ultimately be so polluted that the danger to health would be great, the City undertook to find means to overcome this. The manner in which the danger was avoided by the construction of the canal was fully described in the record and is told in the brief of appellant. But there is one reason for the creation of The Sanitary District of Chicago that has been very lightly touched upon. That is the fact that the City of Chicago was prevented by its debt limitation from itself undertaking the construction of a sanitary canal, and that its people had to resort to the subterfuge of creating a new municipal corporation superimposed on its territory in order to get around this limitation. It was the only way in which it was possible to finance an improvement which would obviously cost a great deal of money, and which in fact has cost a sum approaching a hundred million dollars.

This was one of the principal reasons why The Sanitary District of Chicago was created. The function of digging supply tunnels, building intakes and pumping and supplying water was not turned over to the Sanitary District. It performed and is now performing the function of purifying the water supply. All the rest of the work of supplying water to the City, to its inhabitants, to other municipalities within the district, and to their inhabitants, continues to be the function of the City of Chicago, which has many other functions to perform, requiring revenue.

Necessarily the plant comprising the water system of so great a city would have been costly under any circumstances. But it was rendered more costly by reason of certain provisions of the Sanitary District Act which imposed additional obligations and expense on the City of Chicago.

Section 26 of this Act reads as follows:

"Section 26. Whenever in any such sanitary district there shall be a city, incorporated town or village which owns a system of water-works and supplies water from a lake or other source which will be saved and preserved from sewage pollution by the construction of the main channel, drain, ditch or outlet herein provided for, and the turning of the sewage of such city and district therein, and there shall be in such sanitary district any territory bordering on any such city, incorporated town or village, within the limits of another city, incorporated town or village, which does not own any system of water-works at the time of the creation of such sanitary district, then upon application by the corporate authorities of such latter named city, incorporated town or village, the corporate authorities of such city, incorporated town or village, having such system of water-works shall furnish water at the boundary line between such municipalities by means of its water works to the corporate authorities asking for the same in such quantities as may be required to supply consumers within said territory, at no greater price or charge than it charges and collects of consumers within its limits for water furnished through meters in like large quantities:

Provided, however, that where any such latter named city, incorporated town or village has no territory bordering upon such city, incorporated town or village so owning a system of water-works and supplying water as aforesaid, such latter named city, incorporated town or village may receive water in the same manner and under the same conditions as though it had territory bordering upon such municipality owning a system of water-works and supplying water as aforesaid; *provided,* such latter named

city, incorporated town or village builds or causes to be built suitable and sufficient water mains to the limits of such city, incorporated town or village so owning a system of water-works and supplying water as aforesaid to connect with the water mains and receive the water from such city, incorporated town or village so owning a system of water-works and supplying water as aforesaid."

The above provision requires the City of Chicago to serve, in addition to its own population of 3,000,000, communities surrounding it having a population of 300,000. This would entail in the first instance a plant enlarged ten percent above the needs of the City, but obviously of much greater capacity, since the tendency towards a proportionately larger population beyond its borders grows greater as its business area expands.

Consequently, the City of Chicago has on its hands a costly plant, immensely valuable at present, a large part of which would be rendered useless if deprived of an unpolluted supply of water, and the balance serviceable only in cast it constructs an enormously expensive filtration plant. In addition to this it would have constructed a portion of a plant of no value whatever because it was constructed for outside communities that would have to be cut off and compelled to find their own pure water supply. The alternative to this latter proposition is the building of a filtration plant designed to furnish pure water beyond its borders as well as to its own inhabitants.

With such tremendous interests at stake, can it be said that the City of Chicago has had its day in court? Much has been said about the great cost of the sanitary and ship canal of the appellant, and it is shown that its cost was somewhere near $100,000,000, and that the loss to the people of Chicago and the surrounding communities would be enormous.

Nothing has been said about the cost of the water distributing plant of the City of Chicago, however, which may easily have cost two or three times as much, and the total loss to the people of this district may run into figures comparable to those for financing a great war.

Adding together the cost of the canal, the cost of the City's water system, the cost of the water systems of other municipalities in the district, and estimating the total loss, there is no doubt that the Court has not been fully advised regarding these tremendous property interests. Nor can it fully understand the insignificance, as compared to such interests, of other interests that conflict therewith from the standpoint of navigability of waters. There is no method by which the court can arrive at a just comprehension of the situation in the present state of the record.

It is true, of course, that the necessity for pure water is the paramount need of the people of Chicago and deserves the first consideration. If there was opposed to this the possibility of contamination of water supplies of other communities and danger to the health of people in other places, there might be some reason for saying that the interests of the people of the City of Chicago cannot be so taken care of that other interests must suffer. But that is not the case.

The use of this water by the City of Chicago and surrounding territory does not operate to deprive other communities of pure water or to endanger the health of people elsewhere. It is not pretended that the suit has anything to do with the preservation of health in other districts and communities besides those in or near The Sanitary District of Chicago. The only things that are solicitously to be looked after are the navigation interests of cities and towns located on the great lakes.

When a comparison is made between the property interests of the City of Chicago that are placed in jeopardy by the decree in this case and the interests of the lake towns and cities that would theoretically be damaged in the lessened navigability of their harbors, the balance of convenience is so largely on the side of Chicago that the comparison becomes ludicrous. It is like a pop gun beside a cannon.

We are not disposed to concede that it has been established by the evidence that the lake level would be lowered by the withdrawal of 10,000 cubic feet of water per second. We believe that it would take twenty years of careful measurement and sounding to make any thing like a safe estimate or prediction on this point. The water rises and falls over a period of years under no known or fixed rule. It may vary one way or another and seemingly confirm conclusions drawn from observations made for three or four years, and then without apparent cause (or at least without cause that can be ascertained immediately) shift the other way.

Under these conditions it becomes more especially and peculiarly within the province of the court to take into consideration the balance of convenience of which we speak. The City of Chicago could afford to make good many times over the loss sustained by any and all Federal, State and municipal agencies that have to do with navigation on the Great Lakes (if any) and still be very much better off with the right to withdraw 10,000 cubic seconds feet of water, Add to this the fact that no such loss or damage has been established, and it at once becomes plain that there is the greatest danger of doing injustice beyond measure to one municipality and its people where no real or substantial good can be accomplished for any other.

Turning now to the possibility of helping itself out of its unhappy predicament if the flow of water should be reduced as proposed, what chance has the present generation for a pure water supply? It is not to be conceived that this court would sanction any program or enter any decree which would result in the possible raising of the typhoid rate to even the lowest that obtained prior to the opening of the canal. That was 27 deaths per year for each 100,000 inhabitants. It is now one for each 100,000 inhabitants. Therefore, such an increase among 3,300,000 people would amount to 858 additional deaths per year.

It might be said that this sort of figuring is merely conjectural—that the means of fighting typhoid have improved, and that there is no danger of such a result. Be that as it may, the fact remains that there will be an increased death rate under such conditions. The rich will find means of circumventing it by the purchase of spring water (although even that is often impossible and subject to fraud on the part of the purveyor), but the poor will drink the contaminated water and suffer for it.

The only possible solution at present is a filtration plant. Large areas of land would have to be cleared near the shores of Lake Michigan, great reservoirs would have to be constructed, and other things would have to be done, involving an outlay of approximately $100,000,000. The present generation would have neither the means to finance nor the time to build such a plant.

The land would have to be secured either by converting the City's beautiful lake front parks into reservoirs for purposes of purification, or land of great value would have to be condemned to secure the necessary area.

There is no other way of supplying the needs of the people of Chicago and the surrounding territory except

from the waters of Lake Michigan. The water at the present time is supplied for drinking purposes and for domestic purposes from the same pipes as carry water for manufacturing plants and other uses. There never was any occasion for dividing the supply. The division could not be made now. Hence, the filtration of all the water pumped, amounting to over 800,000,000 gallons per day, would be necessary.

The financing of such a filtration plant by any of the ordinary methods which a municipality can legitimately employ is out of the question. We have already shown that it was necessary to create a new municipal corporation in order to make possible the construction of the canal. It would be necessary to create another municipal corporation to raise such an amount of money as would be required for a filtration plant. The mere statement of such an idea is sufficient to provoke a smile. It took thirty years of agitation to create The Sanitary District of Chicago. It would take longer to create another municipal corporation for the sole purpose of building a filtration plant.

The ordinary methods for financing such an improvement are either by issuing bonds or by direct taxation. To this may be added, in this case, the collection of water rates.

The impossibility of floating bonds for this purpose is manifest when the constitutional limitation already quoted is taken into account. As was stated in the Petition of the City of Chicago, heretofore filed herein, the debt limitation under the Constitution is now $89,433,-268.95. There have already been authorized bonds to such an extent that, with other indebtedness that must be figured, the total debt would be $89,891,700 if all authorized bonds were issued. That is the comptroller's estimate as of November 20, 1924.

All water certificates and bonds or certificates for a filtration plant would have to be included in the limitation. (See *Stone* v. *City of Chicago*, 207 Ill. 492; *Lobdell* v. *City of Chicago*, 227 Ill. 218.) Hence, if all other improvements were allowed to remain at a stand-still and no new public improvements were undertaken, the possibility of issuing the necessary bonds would be so remote as to be unthinkable.

It might occur to someone to say in reply to this argument that the debt limitation of five per cent in the Constitution is not such a thing as need stand in the way of the people of a great state forever—that if it was a matter of life and death for three millions of its people a change could be made in this provision of the Constitution. In truth, however, the obstacle is insuperable. It is extremely difficult to amend the Constitution of Illinois when there is no objection to the proposed amendment. When there is opposition of a substantial nature it is impossible. The provision for amendment (Art. XIV, Sec. 2) is as follows:

> "Section 2. Amendments to this Constitution may be proposed in either House of the General Assembly, and if the same shall be voted for by two-thirds of all the members elected to each of the two Houses, such proposed amendments, together with the yeas and nays of each House thereon, shall be entered in full on their respective journals; and said amendments shall be submitted to the electors of this State for adoption or rejection, at the next election of members of the General Assembly, in such manner as may be prescribed by law. The proposed amendments shall be published in full at least three months preceding the election, and if a majority of the electors voting at said election shall vote for the proposed amendments, they shall become a part of this Constitution. But the General Assembly shall have no power to propose amendments to more than one article of this Constitution at the same session, nor to the same article oftener than once in four years."

Even so salutory an amendment as the one just voted upon, whereby the number of amendments that could be proposed at one time was raised to two, which was known as the "Gateway Amendment," and against which there appeared no pronounced opposition, seems to be defeated. The same thing happened to the revenue amendment offered several years ago, which was the last preceding amendment and was apparently acceptable as a means for making needed revenue changes. When it is considered that there would be pronounced opposition to any amendment of the Constitution which would call for largely increased taxation, or which affects The Sanitary District of Chicago in any way, whether adversely to the interests of the people "down-state" or not, the utter hopelessness of turning to this supposed means of relief is manifest.

Hence, there is no chance whatever of raising the necessary revenue either by means of a bond issue or by any subterfuge for evading the established debt limitation.

So far as raising the necessary money for an improvement of such magnitude by direct taxation is concerned, that is also out of the question. A comparison between the rates of taxation, whether taken on a *per capita* basis or on a property basis, or by any other means, would show the rate of taxation in Chicago for local purposes at least up to the average. The Department of Commerce issues statistics of the Bureau of the Census which clearly demonstrate this, although it is extremely difficult to make a comparison which is even approximately correct. (See Table 14, pp. 266 to 307, Financial Statistics of Cities Having a Population of Over 30,000; Published by Department of Commerce in 1924.)

Since it must be conceded that there is necessity for local expenses which will take up such average tax rate,

there is no occasion for reciting at length the financial worries of the City of Chicago as a municipality. It has these to quite as full an extent as other municipalities. They would effectually prevent the diversion of any considerable sum out of the annual revenues from the fund for general corporate purposes to the water fund.

Finally there remains the possibility of raising water rates sufficiently to finance such an improvement as the installation of a filtration plant. While this may be conceded to be the most promising of the methods suggested, it has its limitations. The appropriations for the current year for the Bureau of Water are less than $15,000,000. (See Journal of the Proceedings of the City Council of the City of Chicago, March 28, 1924, page 2365.) The income from water rates at present is far below this, the system showing a loss of considerable size from year to year.

To raise water rates sufficiently to take care of present deficiencies and at the same time build a filtration plant would mean such an increase as would at least double the rates—perhaps treble them. The taking on of such a burden would be equivalent to an increase in the taxation, and in any event it would amount to a great loss to the owners of property in the City.

Another feature of the situation with respect to the installation of a filtration plant must not be lost sight of. That is the time it would take to prepare and to build such a plant. This has been estimated as twenty years. It may be conceded that this subject is more or less problematical, but that a large amount of time would be necessary is certain.

Water now comes through tunnels extending underneath the lake for distances of from two to four miles. Whether these would be rendered useless or whether they can be

so converted that they will form parts of the proposed filtration plant belongs to those engineering problems which we are not called upon to go into. But whatever is done with them, the cost manifestly would be great, and the time necessary to convert them would be a matter of many years. On the other hand, if the court should decide to affirm the decree, it would depend entirely on the indulgence of the court whether it would go into effect immediately or not.

In this connection it might be well to consider that the entry and the enforcement of the decree in the court below have been put off for a number of years, and the danger of which complaint is made in the bill does not seem to have become greater or more imminent.

In presenting the view of the situation which this brief sets forth we have to some slight extent traveled beyond the record, although we have, in such matters as do not appear in the record, endeavored to confine ourselves to things that are matters of common knowledge.

The principal contention that we make, having in mind that arguments on both the sanitary and ship canal features of the controversy have been presented by others, is that the decree, if affirmed, would be the means of wiping out large property values of the City of Chicago, that this would be done without a hearing and without taking testimony concerning the comparative value of the property rights affected. We are late in presenting this phase of the controversy, but on the whole we believe it is better to present it now and in this case than to wait until this case is ended and then attempt to set up our rights in an independent proceeding.

While we have stressed the property interests of the City of Chicago in this brief, lest it be understood as

trying to give greater prominence to these than to the health and sanitary features of the case, we repeat that the question of the health of the people is of much greater importance than anything else in the case. To turn back the foul waters which the people of this district have been at such pains to divert would create havoc in the community. It would mean the destruction of a record of constant improvement in the matter of public health that has been unbroken for 30 years. It would turn back the wheels of progress and open the floodgates of disease upon an unprotected public. The consequences would be appalling if a single typhoid epidemic were to result, and with the sewage returning to the lake it would be impossible to avoid that.

We join with the appellant in praying for a reversal of the decree, in order that when the case is reopened the City of Chicago may have an opportunity to intervene and present the phase of the case we have outlined above.

Respectfully submitted,

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.....

Corporation Counsel of the City of Chicago.

Leon Hornstein

.....

Assistant Corporation Counsel of the City of Chicago.
Solicitors for the City of Chicago.

(8)

IN THE

Supreme Court of the United States.

OCTOBER TERM, A. D. 1925.

No. 161

THE SANITARY DISTRICT OF CHICAGO,
Appellant,

vs.

UNITED STATES OF AMERICA,
Appellee.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION.

PETITION FOR REHEARING ON BEHALF OF AMICI CURIAE ALLOWED BY ORDER OF COURT TO APPEAR AND OPPOSE THE AFFIRMANCE BY THIS COURT OF THE DECREE BELOW.

GUNTHORP-WARREN PRINTING COMPANY, CHICAGO.

IN THE

Supreme Court of the United States.

OCTOBER TERM, A. D. 1925.

THE SANITARY DISTRICT OF CHICAGO,
Appellant,

vs.

UNITED STATES OF AMERICA,
Appellee.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION.

PETITION FOR REHEARING ON BEHALF OF AMICI CURIAE ALLOWED BY ORDER OF COURT TO APPEAR AND OPPOSE THE AFFIRMANCE BY THIS COURT OF THE DECREE BELOW.

Now come the states of Illinois, Missouri, Louisiana, and Tennessee and the Chamber of Commerce of St. Louis, Memphis Chamber of Commerce, New Orleans Board of Trade, New Orleans Association of Commerce, Mississippi Valley Association, and the Chicago Association, as *amici curiae* appearing by leave of court first had and obtained, and respectfully petition this Honorable Court to vacate the order of affirmance en-

tered herein on the 5th day of January, A. D. 1925, and to grant a rehearing in the above entitled cause.

In support of this petition for rehearing the above mentioned *amici curiae* submit suggestions hereto attached and made a part hereof.

EDWARD J. BRUNDAGE,
Attorney General of Illinois.

JESSE W. BARRETT,
Attorney General of Missouri.

J. FRANK THOMPSON,
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DANIEL N. KIRBY,
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APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION.

SUGGESTIONS IN SUPPORT OF THE FOREGOING PETITION FOR REHEARING.

In order that we may present the points relied upon to justify this application as concisely as possible, we must first outline briefly the opinion of the court.

The opinion begins by describing the bill. It states that obstructions to navigation in violation of Section 10 of the Act of March 3, 1899, are specifically pleaded, but says:

> "The form of the bill does not preclude a reliance upon more general principles if they were needed in order to maintain it."

The works of the appellant were then described, and the answer is summarized.

The discussion of the law begins by resting the jurisdiction upon the sovereign power of the United States

to regulate commerce and control navigable waters. It is stated that the Attorney General, by virtue of his office, might bring this proceeding without statutory authority.

The court then lays down the rule that the power of the United States is superior to that of the states, and in matters where the national importance is imminent and direct, even when Congress has been silent, the states must not act at all.

The court then takes up the defense urged by appellant that the United States had given its assent to appellant's acts, and construes the Act of March 2, 1827, so much referred to in the argument. The court then quotes the material portions of Section 10 of the Act of March 3, 1899, and states:

> "This statute repeatedly has been held to be constitutional in respect of the power given to the Secretary of War. *Louisville Bridge Co.* v. *U. S.*, 242 U. S., 409, 424; 61 L. ed. 395, 403; 37 Sup. Ct. Rep. 158."

The court says this statute is a broad expression of public policy forbidding obstructions to navigable capacity, "not authorized by law," referring we assume, in the last phrase, to the power given the Secretary of War to issue permits for such alterations of navigable capacity.

The court says:

> "There is neither reason nor opportunity for a construction that would not cover the present case."

The court concludes its analysis of the question with the following expression:

> "This withdrawal is prohibited by Congress, except so far as it may be authorized by the Secretary of War."

The court then enters into a detailed discussion of

the several permits issued, and finds that no defense can be founded upon these permits. Referring to these *amici curiae*, the court says:

> "States bordering on the Mississippi allowed to file briefs as *amici curiae*, suggest that they were not heard, and that rights have not been represented before the Secretary of War. * * * The interest that the river states have in increasing the artificial flow from Lake Michigan is not a right, but merely a consideration that they may address to Congress, if they see fit, to induce a modification of the law that now forbids that increase unless approved as prescribed. * * * It is doubtful, at least, whether the Secretary was authorized to consider the remote interests of the Mississippi states or the sanitary needs of Chicago. All interests seem in fact to have been copiously represented, but he certainly was not bound to give them a hearing on the application upon which he was requested to pass."

The court then reviews the history of the litigation and the delay in reaching a decision, and concludes by affirming the injunction below.

I.

IN HOLDING THAT THE STATES DO NOT HAVE AUTHORITY TO AUTHORIZE DIVERSIONS FROM NAVIGABLE WATERS IN THE ABSENCE OF CONGRESSIONAL ACTION, IN THE FIRST PLACE, NO SUCH ISSUE IS TENDERED BY THE BILL OF COMPLAINT, AND IN THE SECOND PLACE, THE CONCLUSION OF THE COURT, OBITER WE SUBMIT, IS CONTRARY TO A LONG LINE OF PRIOR DECISIONS BY THIS COURT.

(a) We assume that this court applies the fundamental rule of equity that relief is limited to the allegations of the bill and does not go beyond the scope of the prayer. The bill of complaint in this case is founded solely upon the allegation that appellant failed to ob-

tain a permit in accordance with the requirements of Section 10 of the Act of March 3, 1899, authorizing diversions in excess of 250,000 c. f. a minute. The prayer of the bill (Vol. 8, Trans. of Rec., 44) prays for an injunction enjoining appellant from diverting waters in excess of 250,000 c. f. per minute as already authorized by the Secretary of War, and this was the injunction issued by the court below.

A fair consideration of the bill will demonstrate that there are no allegations alleging that the Attorney General is proceeding for the purpose of enforcing the sovereign power of the United States in a matter over which, even in the absence of Congressional action, the states can have no jurisdiction, by reason of any alleged exclusive effect of the Commerce Clause of the Constitution. The language of the opinion, therefore, in reference to this is clearly a misconstruction of the record. The case of the Government must stand or fall upon the validity and effect of Section 10 of the Act of March 3, 1899.

(b) Without referring to the authorities, this court has construed the Commerce Clause of the Constitution in many matters in such a way as to leave to the state concurrent jurisdiction over much of the realm of interstate commerce, which jurisdiction may be lawfully exercised until Congress has taken possession of the field by apt legislation.

This court has said as to a few matters, that they are such as to be within the exclusive jurisdiction of Congress because by their nature they require a uniform system or plan of regulation.

The opinion in this case does not claim any such basis for its conclusion that diversions from navigable streams require only one plan of regulation applicable to all

parts of the United States, and to all attempted diversions of water, whether for purposes of aiding mining, irrigation, reclamation projects, drainage of swamps, or as in the instant case, the improvement of waterways, and the incidental facilitation of sanitary projects. It is clear that in the nature of the subject matter, one uniform system of regulation would not operate for the public benefit.

In the *Rio Grande Dam Case,* 174 U. S. 690, this court dealt with diversions from navigable waters on the theory that these were within the concurrent jurisdiction of the states.

The following cases reflect this view: *County of Mobile* v. *Kimball,* 102 U. S. 691; *Lindsay* v. *Phillips,* 176 U. S. 126; also: *U. S.* v. *Crest,* 243 U. S. 316, and the *Bellingham Bay Boom Case,* 176 U. S. 223. Perhaps the leading authority on this subject is the case of *Cooley* v. *Board of Wardens,* 12 Howard, 289.

We respectfully submit that this court has, therefore, laid down a rule inconsistent with a long line of prior decisions.

II.

IN CONCLUDING AS THE COURT DOES THAT SECTION 10 OF THE ACT OF MARCH 3, 1899, IS CONSTITUTIONAL, THE COURT CITES AN AUTHORITY WHICH DOES NOT SUSTAIN ITS CONCLUSION IN ANY WAY WHATSOEVER, AND OVERLOOKS THE FACT THAT ON SETTLED PRINCIPLES OF CONSTITUTIONAL LAW WHICH ARE NOT CONSIDERED BY THE COURT IN ANY DECREE WHATSOEVER IN THIS DECISION, THE POWERS EXERCISED BY THE SECRETARY OF WAR IN THE INSTANT CASE ARE UNCONSTITUTIONALLY DELEGATED, IF THIS SECTION BE CONSTRUED TO CONFER SUCH AUTHORITY.

The court says in the opinion:

> "This statute has repeatedly been held to be constitutional in respect of the power given to the Secretary of War. *Louisville Bridge Co.* v. *United States,* 242 U. S. 409, 424; 61 L. ed. 395, 403; 37 Sup. Ct. Rep. 158."

Immediately prior to this sentence the court quotes the applicable portions of Section 10 of the Act of March 3, 1899. The *Louisville Bridge case,* cited to support this conclusion, does not concern itself in any degree whatsoever with Section 10, but did involve the exercise by the Secretary of War of the power conferred upon him by Section 18 of the Act of March 3, 1899, to regulate bridges, which unreasonably obstruct navigation. There is no other case which we have been able to find which squarely holds that the power conferred by Section 10 of the Act of 1899 is a constitutional grant of authority, and none is cited in the opinion except the erroneous citation just pointed out.

In a number of cases the court has had occasion to construe and pass upon the authority of the Secretary

of War under Section 18 of the Act of 1899, particularly *Union Bridge Co.* v. *United States,* 204 U. S. 364, and *Monongahela Bridge Co.* v. *United States,* 216 U. S. 177. The court summarizes the state of the law in the latter decision, particularly as to the extent to which Congress could delegate its authority to the Secretary of War, and the manner in which such delegation must be constitutionally exercised, in the following expressions:

> "This Court has heretofore held, upon consideration and after an examination of the adjudged cases:
>
> (1) That 18th Section of the river and harbor Act of March 3, 1899, 30 Statutes 1151, could not reasonably be taken as a delegation of legislative and judicial power to an executive department of the government; that the statute did not in any real, constitutional sense delegate to the Secretary of War any power that must, under our system of government, be exclusively exercised either by the legislative or judicial branch of the government; that under its paramount power to regulate commerce on and over the navigable waters of the United States, Congress could require that such waters be free from unreasonable obstructions to navigation; that the statute in effect prescribed the general rule, applicable to all navigable waters, that free navigation should not be hampered by unreasonable obstructions arising from bridges of insufficient height, width of span or other defects; that instead of exerting its power by direct legislation in each case of a bridge alleged to constitute an unreasonable obstruction to navigation, Congress charged the Secretary of War with the duty of ascertaining, in each case, upon notice to the parties concerned, whether the particular bridge came within the general rule prescribed; * * *
>
> (2) That the Act of 1899 did not invest the Secretary of War with arbitrary power in the premises, since in reference to any bridge alleged to constitute an unreasonable obstruction to navigation, he was bound, before making any decision or tak-

> ing final action, to notify the parties interested of any proposed investigation by him, give them an opportunity to be heard, and allow a reasonable time to make such alterations as he found to be necessary to free navigation."

SECTION 10 in its construction and effect is entirely different. It lays down a broad prohibition of any obstruction of the navigable capacity of any waters of the United States, "not affirmatively authorized by Congress." And then provides that it shall not be lawful to do certain varieties of obstructions, nor to alter the capacity of any navigable water, "unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same."

Each of the acts mentioned in the concluding portion of the section which may be so authorized by the Secretary of War and Chief of Engineers, would, clearly, without such authorization, fall within the purview of the general prohibition in the first sentence of the statute. There is no test nor rule of any kind whatsoever specified in the statute by which the administrative officers are to be guided in determining whether or not their authority shall be granted. None of the requirements of due process providing for a hearing or notice to interested parties are found in this section. The language just quoted from the prior decisions of the court indicate clearly, we submit, that the exercise of authority conferred by Section 18 was held in these cases to be constitutional, simply and solely because the requirements of due process were, by the language of Section 18, carefully safeguarded and preserved. Based on the reasoning of these decisions Section 10 must be construed to be unconstitutional and void. This point was fully presented to the court in the brief filed

on behalf of *amici curiae,* pages 45 to 57, inclusive. It was only touched upon in the argument, due to the way in which the case was presented. Yet, nevertheless this court must assume that its decision will serve as authority for the granting by Congress of broad, unlimited and practically arbitrary power to administrative officers, a conclusion, not in the public interest, inconsistent with all prior decisions, and, we believe, not intended by the court in this case.

That the writer of the opinion of the court was unconsciously concerned with the requirements of due process as embodied in the exercise of the power conferred upon the Secretary of War by Section 10 of the Act of 1899 is clearly illustrated by the expressions in the opinion concerning the intervention of these *amici curiae.*

The court said:

> "States bordering on the Mississippi, allowed to file briefs as *amici curiae* suggests that they were not heard and that rights have not been represented before the Secretary of War. * * * It is doubtful, at least, whether the Secretary was authorized to consider the remote interests of the Mississippi States or the sanitary needs of Chicago. All interests seem in fact to have been copiously represented, but he certainly was not bound to give them a hearing upon the application upon which he was requested to pass."

In stating that these *amici curiae* were represented before the Secretary of War, the court has fallen into error. There is nothing in the record to support this statement.

As shown in the petition upon which the court granted us leave to appear, the interest of these *amici curiae* is primarily a navigation interest. Therefore, primarily a matter concerning which the Secretary of War is di-

rectly empowered and authorized to act. It is difficult to understand the doubt expressed in the above statement as to the right of the Secretary to consider the interests of the Mississippi states.

We do not believe that a fair consideration of the facts justify calling these interests remote. The water transportation from Chicago to the Gulf of Mexico by way of appellant's canal to the Illinois River and the Mississippi River, affords one continuous water route. The geographical distance of the State of Louisiana for instance, from the port of Chicago, does not, we submit, affect the question. Consideration of a single unit of water transportation was necessarily involved. That these rights and this interest should have been heard and duly considered if any broad, statesmanlike handling of this problem is to be reached, cannot be disputed.

The very fact that the court expressed doubt as to the authority of the Secretary of War to give consideration to these matters demonstrates, we believe, that any proper construction of Section 10 cannot be held to confer the type of authority exercised by the Secretary of War in this case.

Conclusion.

In conclusion we would respectfully urge that the court glance at the index to the printed transcript of the oral argument, filed as an appendix to the petition for rehearing of appellant in this case, which shows the questions asked by the court during the oral argument. In the three hours or 180 minutes of time allotted to counsel for appellant and these *amici curiae*, there were 219 questions asked from the bench. Any fair consideration of this transcript of the oral argument will show,

we submit, that the case could not have been adequately presented in the time allowed. And furthermore it is clear that counsel for the United States made several statements in their argument obviously prejudicial to our side of the question, not supported by the record, to which appellant had no opportunity whatever to reply.

The importance of this case and the broad departure from principles heretofore accepted as settled, alone would justify this petition.

We respectfully urge, therefore, that further opportunity to more fully present the important questions, many of which have obviously not been adequately spread before the court should be allowed.

Respectfully submitted,

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In the Supreme Court of the United States

OCTOBER TERM, 1924

THE SANITARY DISTRICT OF CHICAGO, appellant *v.* THE UNITED STATES OF AMERICA, appellee	No. 161

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

BRIEF FOR APPELLEE

ARGUMENT ON THE FACTS

(Pages 1—122.)

INTRODUCTORY STATEMENT

This case, which was subjected to the unprecedented delay of over *fifteen* years in the court below, involves the right of the appellant, Sanitary District of Chicago, to divert from Lake Michigan an indefinite and increasingly large amount of water, in defiance of legislation by Congress and of rulings by the Department of War. The appellant has a

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permit from the War Department to divert 4,167 cubic feet per second (hereinafter abbreviated as "c. s. f."); it is actually diverting at least 10,000 c. s. f.

The Sanitary District of Chicago is a municipal corporation created in 1889 under a statute enacted by the Illinois Legislature in that year. As such corporation it is entirely separate from and independent of the city of Chicago; the area of the district served by appellant includes not only Chicago but suburbs to the north and to the west and southwest. Chicago is, therefore, in the unique position of having its water supply and sewage disposal problem handled by *two* municipal corporations. As the result of appellant's diversion works, the city has profited by an exceptionally cheap water supply in comparison with that of other cities situated on the Great Lakes.

The total area of appellant's district is 437.39 square miles and it had a population in 1922 of 3,142,000. In addition to disposition of the sewage of the population, it has the duty of disposing of industrial wastes which are equivalent to the sewage of an additional population of 1,500,000. It is estimated that by 1960 the population and industrial equivalent of appellant's district will total 8,160,000. (Appellant's Narrative, pp. 361–362.) Appellant's organic act requires it to divert through its canal 20,000 cubic feet of water per minute for each 100,000 of population (333 c. s. f.).

The diversion complained of by appellee is accomplished by turning from the Great Lakes and into

the Mississippi Valley a large navigable river, equivalent in flow to the sum of the three principal tributaries of Lake Michigan. This is done through appellant's canal, referred to in its brief as the "Sanitary and Ship Canal." The canal is about 28 miles long and extends from a tributary of the Chicago River southwest across the divide to just north of Joliet, Illinois, where it empties into the Des Plaines River. The location of this canal, and its relation to the Chicago River, is explained by the map to be found in Appellant's Narrative (opposite page 92). Chicago River proper is very short and flows east into Lake Michigan (it is shown in yellow on the map and enters Lake Michigan at a point just north of the notation "Chicago Harbor" on the lake). It is formed by two branches meeting at about a mile inland (also shown in yellow on the map), and known as the North and South Branches of the Chicago River. About three miles south of the juncture of these two branches the South Branch is formed by two forks, the West Fork and the South Fork.

Appellant's canal connects with the West Fork of the South Branch of the Chicago River. The old Illinois and Michigan Canal connects with the South Fork from which for many years before 1900 the city diverted a small amount of water by means of a pumping station. Appellant's diversion of water from Lake Michigan is distributed as follows:

(1) Through the Main Channel of the Chicago River, 6250 c. s. f.

(2) Through the North Branch of the Chicago River (which is connected with Lake Michigan by a canal north to Wilmette, Illinois, and by a conduit at Lawrence Avenue—both marked yellow on the map), 1750 c. s. f.

(3) Through the 39th Street conduit(which empties into an arm of the South Fork of the South Branch and thence flows into the West Fork), 2,000 c. s. f.

This is a total of 10,000 c. s. f. (See Appellant's Brief, pp. 13–14.)

There is a further diversion of 2,000 c. s. f. by appellant by means of another canal which runs from the Little Calumet River to the appellant's main canal at Sag, Illinois. It is shown in red on the map. The Calumet River, to which the Little Calumet is tributary, enters into Lake Michigan at a point several miles south of the mouth of the Chicago River.

Appellant's main canal has a constructed capacity of 14,000 c. s. f., at least in the rock section. Excavation began in 1893. It was connected with the West Fork of the South Branch on January 17, 1900. The Wilmette Canal was completed in 1910 and the Calumet-Sag Canal in 1922.

By reason of the large diversion of water and its potential power, appellant was able to install a large hydro-electric plant in 1907, just north of Joliet. The power energy is converted into electricity and is sold to the profit of appellant to municipalities, parks, and districts.

The appellant's brief and narrative statement gives a misleading impression of the issues involved on this appeal. It's statements that "there is no question of pleading involved" and that with certain exceptions "there is no dispute as to any facts in the record" (Appellant's Brief, p. 4) are contradicted by the record. So also is the heading "Undisputed Evidence" with which appellant has inaccurately entitled a large portion of its narrative statement (pp. 163–344).

When the decree was entered by the court below, there was pending a motion by the appellee made on the filing of the answers, to strike certain portions of the appellant's answer in the Main Channel Suit. These portions set up the affirmative defenses upon which the appellant then and now places its chief reliance. The so-called "undisputed evidence" consists of evidence, offered and received by the commissioner over the objection of the appellee, in support of these portions of appellant's answer. It was not necessary for appellee to offer evidence in rebuttal on these issues, as it relied upon its motion which was to strike out untenable defenses, which motion was based on the theory that the averments of the answer did not set up any admissible defense. It was understood throughout the entire litigation that if any of these averments should be held to constitute an admissible defense, the appellee should have the right to offer testimony upon the issue thus raised, and the court reserved this right to the appellee.

Judge Landis, in his oral opinion rendered June 19, 1920 (Rec. Vol. VIII, p. 151), held that none of the matters, set up in these portions of appellant's answer, constituted a defense, and said he would enter an order sustaining the appellee's exceptions thereto. Judge Carpenter came to the same conclusions, as will be seen by reference to his opinion filed June 18, 1923. (Rec. Vol. VIII, p. 127.) While no order striking this portion of the answer was ever actually entered, the final decree was understood by both parties as necessarily accomplishing the same result. Consequently, if this Court should be of the opinion that these portions of the answer *do* allege a sufficient defense, the appellee will be entitled to an opportunity to rebut the so-called "undisputed evidence."

There *is* therefore a very serious dispute, as a matter of fact, as to the correctness of the conclusions advanced by appellant's witnesses. The fact that other cities on the Great Lakes and elsewhere, some of which are nearly as great in size as Chicago was when the appellant's canal was built, have been able satisfactorily to solve their sewage and drinking water problems without recourse to the extreme method employed by appellant, and without suffering from typhoid or other epidemics, is sufficient to indicate that the appellant's witnesses have not said the last word upon the subject. Equally suggestive are certain inadvertent admissions to be found here and there both in the testimony and in appellant's brief.

I

The issues involved in the two suits and a brief history of the proceedings in the trial court

The issues presented by this appeal can not be thoroughly understood without a brief analysis of the pleadings in the two suits, which, although consolidated, do not present altogether identical questions. For convenience, these two suits will be referred to as (1) The Calumet River Suit and (2) The Main Channel Suit. Before undertaking this analysis we take this occasion to call the Court's attention to the fact that it is now *sixteen* years since the institution of the first suit. Six years (1908–1914) were consumed in the taking of testimony; for six years more (1914–1920) the case was held under advisement by Judge Landis; for three years more the case was pending on appellant's motion for a modification of the terms of the decree for an injunction which Judge Landis indicated he would enter, but never did. Against this delay the Government continuously protested. This Court will form its own judgment as to the sufficiency of Judge Landis's reasons for denying the Government a formal decree, to which he had recognized it was justly entitled. If the Government refrains from further comment on this matter, its reticence should not be regarded as an implied recognition of the sufficiency of Judge Landis's reasons.

For convenience we here set forth Section 10 of the River and Harbor Appropriation Act of

March 3, 1899 (30 St. at L., p. 1151, Ch. 425), for it is on this statute that the rights of the appellee are to a large extent based:

> That *the creation of any obstruction not affirmatively authorized by Congress*, to the navigable capacity of any of the waters of the United States *is hereby prohibited;* and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and *it shall not be lawful* to excavate or fill, or *in any manner to alter or modify the course, location, condition, or capacity of*, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or enclosure within the limits of any breakwater, or of the channel of *any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same.*

In our summary of the pleadings we refer to the appellee and appellant as complainant and defendant respectively.

A. Calumet River suit

The bill in this case was filed March 23, 1908. It sought to prevent the defendant from doing two

things: (1) reversing the direction in which the Calumet River flowed, clearly a "modification" of the condition of a navigable river within any definition of that term, and (2) the withdrawal of water from Lake Michigan in a different way and in a larger amount than was authorized by the Secretary of War. The answer of the defendant was filed March 23, 1908. The issues presented by these pleadings may be summarized as follows:

The bill averred that the Calumet River is one of the navigable waters of the United States. The answer admitted that the Calumet River is navigable for part of its course, but denied the navigability of its upper portion and certain branches. No point, however, has ever been made on this question for the obvious reason that it is admitted that what was proposed to be done by the defendant would affect the navigable portion of the river if it affected the river at all. The bill averred and the answer admitted the expenditure by the United States of money in the improvement of the Calumet River.

The bill averred and the answer admitted that on November 28, 1906, application was made by the defendant to the Secretary of War for a permit to reverse the flow of the Calumet River and to divert water through it from Lake Michigan; *that this application was refused by the Secretary of War on March 14, 1907;* that on September 18, 1907, the Board of Trustees of the defendant passed an order declaring that it intended to reverse the flow of the

Calumet River and to withdraw water from Lake Michigan through it for use in its channel *without the authorization of the Secretary of War*, unless the defendant was prevented by injunction from so doing. The bill alleged that it was the defendant's intention to divert 4,000 c. s. f. from Lake Michigan through the Calumet River and the answer admitted an intention to divert an amount from 2,000 to 4,000 c. s. f. (The diversion through this river having since been accomplished, we may now state that it at present amounts to 2,000 c. s. f. and that the channel is so constructed as to permit of an easy enlargement to 4,000 c. s. f.)

The bill alleged and the answer denied that the effect of this diversion would be to lower the level of Lake Michigan and its connecting rivers, channels, and harbors and to modify the condition and obstruct the navigable capacity of the said navigable waters of the United States. The bill alleged that there was neither an Act of Congress nor an authorization of the Secretary of War for the withdrawal of the water. *The answer denied that Section 10 of the Act of March 3, 1899, was of any binding force on the defendant and challenged the power of the Federal government to interfere with the proposed diversion.*

The answer thereupon proceeded to assert three affirmative defenses, which as will readily be seen, are the defenses upon which it places its chief reliance on this appeal:

(1) Congress, by the Acts of March 30, 1822 (3 St. at L. 659), and March 2, 1827 (4 St. at L. 234),

relating to a grant of land to aid the state of Illinois in the construction of the Illinois and Michigan Canal, conferred upon the state of Illinois an authority broad enough to include the diversion of water from Lake Michigan for the purposes of the Sanitary & Ship Canal. (It may be noted that these Acts were passed before the City of Chicago even existed.)

(2) That the water to be withdrawn from Lake Michigan was to be used for sanitary purposes, including the prevention of the pollution of the drinking water of Chicago; that the withdrawal was part of a general plan of sanitation of which the central feature was the Main Channel of the Sanitary District Canal with which the Calumet Channel was to be connected, and in view of the proposed use for the purposes of sanitation the withdrawal of the water was beyond the control of the Federal government, being comprised within the police power of the state.

(3) That the proposed work was in the interest of navigation; that the canal might be used as a part of a system of waterways connecting Lake Michigan with the Mississippi River and was therefore in harmony with the policy of both Federal and State governments to provide a navigable waterway between the Great Lakes and the Mississippi River.

On June 25, 1908, the complainant filed exceptions to the answer presenting the point that the three affirmative defenses were not admissible in this litigation. These exceptions were overruled on June 26, 1908, and, issue being joined by replication filed

on that day, the complainant proceeded to take evidence before a commissioner appointed by the court for that purpose.

The evidence of the complainant, which was directed to the questions of the effect of the diversion of the water upon the navigable capacity of the lakes and their connecting waters and the resulting injury to the interests of navigation, was concluded July 8, 1909. (Rec. Vol. I, pp. 428–445.) The defendant, instead of immediately attempting to meet the testimony of the United States on those points, again opened negotiations with the Department of War, and on June 27, 1910 (Rec. Vol. VII, p. 27), made application to the Secretary of War to open a channel from the Calumet River to its existing Main Channel so as to substitute two routes instead of one between Lake Michigan and its canal. On June 30, 1910, the Secretary of War granted a permit (see *infra*, p. 58) which in substance provided that, *subject to the control of the Secretary of War and his right to revoke the permit at will*, the Sanitary District might withdraw from Lake Michigan through the Chicago and Calumet Rivers together the same total quantity of water which it was then authorized to withdraw from the Chicago River, namely, 4167, c. s. f. It was further expressly provided that this permission by the Government should not affect in any way the friendly suit to determine the right of the Sanitary District to divert from Lake Michigan for sanitary purposes water in excess of the amount authorized by the

Secretary of War. This stipulation as to the pending litigation was observed by the defendant *and no amendment of the pleadings in the Calumet River suit has been made.* The issues upon the record are precisely as they were prior to the permit of June 30, 1910, and the case stands exactly as if the permit had not been granted. Nevertheless, in the face of the conditions of this permit, the defendant thereafter continued to maintain the position that it might reverse the flow of the Calumet River as a matter of right against the prohibition of the Secretary of War, and that it is entitled to withdraw water in an unlimited quantity from Lake Michigan so long as it is required for purposes of sanitation.

As is apparent from the appellant's brief (p. 11) work in this canal, which was stopped when the bill of complaint in the Calumet River suit was filed in 1908, was resumed after June 30, 1910. Its construction was completed in 1922 and its capacity as now constructed is approximately 2,000 c. s. f. It reverses at practically all times the flow of the Calumet and Little Calumet Rivers. It is designed for further widening to provide a maximum capacity of 4,000 c. s. f. (Appellant's Brief pp. 11–12, 13.)

The defendant, having made this temporary arrangement with the Secretary of War (which by express agreement was not to affect the litigation then pending) proceeded to take the evidence of witnesses to establish the desirability of using the water for sanitary purposes and to show that while there were other efficient methods for the disposition

of the sewage of the Calumet District, the dilution method, which required the diversion of water from the lake, was the cheapest. The last of these witnesses was examined on June 1, 1911 (Rec. Vol. 1, p. 482). The defendant did not then attempt to produce evidence contradicting the complainant's case as to the effect of the diversion of the water upon the condition and navigable capacity of the lakes. Instead, on February 5, 1912 (Rec. Vol. VII, p. 6) the defendant applied to the Secretary of War for permission to withdraw from Lake Michigan through the Chicago and Calumet Rivers not to exceed 10,000 c. s. f., such permission to be revocable at any time by the Secretary of War, and subject to such action as Congress might take in the premises. This application was heard extensively by the Secretary of War *and on January 8, 1913, was denied*. (Rec. Vol. VII, p. 7.) During the month of January, 1913, the War Department learned that appellant was diverting more than 4,167 c. s. f. in defiance of the order of the Secretary of War. Appellant's attention was called to its acts by communications from the United States Engineer at Chicago, and appellant, through its attorney, Mr. Adcock, requested that its rights be determined by suit for an injunction. (Rec., Vol. VI, pp. 3968–3973.) On March 18, 1913, the defendant renewed the taking of its evidence. The hearings before the Commissioner, at which were examined witnesses for the defense, and those in rebuttal for the government, proceeded until June 10, 1914. By agreement, the evidence taken in the

Calumet River suit was to be used also in the Main Channel suit involving the withdrawal of water from Lake Michigan through the Chicago River in excess of the amount authorized by the Secretary of War.

B. Main Channel suit

The bill in this case was filed October 6, 1913 and grew out of the refusal of the defendant to comply with the decision of the Secretary of War with respect to the amount of water to be withdrawn from Lake Michigan. The defendant, having refused to comply with the ruling of the Secretary of War, and persisting in diverting an amount of water in excess of 4,167 c. s. f., the United States filed this suit to enforce obedience to the order. The bill sought, therefore, to prevent the defendant from withdrawing water from Lake Michigan in excess of 4,167 c. s. f. The answer of the defendant was filed on January 16, 1914. The issues presented by these pleadings may be summarized as follows:

The bill charges and the answer admits that the Chicago River is a navigable water of the United States and that the United States has spent large sums of money in improving it; that on May 8, 1889, the defendant applied to the Secretary of War for authority to divert water from the Chicago River into its canal, and that the making of the applications and the granting of permits had taken place from that time on, as was charged in the bill. (These applications, permits, etc. will not be set forth here, as they are discussed at length below, *infra*.

pp. 37–67). They included, of course, the defendant's application of February 5, 1912 to increase the amount withdrawn through the Chicago and Calumet Rivers to 600,000 cubic feet per minute (10,000 c. s. f.) and the denial of this application on January 8, 1913. The bill alleged and the answer denied that the defendant had been withdrawing water from Lake Michigan in excess of 250,000 cubic feet per minute (4,167 c. s. f.) and that the effect of the withdrawal of an amount in excess of that authorized by the Secretary of War would be to modify the condition and obstruct the navigable capacity of the Great Lakes and their connecting channels and to modify the condition and capacity of the channel of the Chicago River and to inflict injury on the navigable interests of the United States.

In the remaining portion of the answer the defendant stated at length certain facts with reference to the history of its organization and the construction of the canal and reasserted the three affirmative defenses which it had set up in its answer in the Calumet River suit and on which it is now relying in this Court. These matters were, however, set up with considerable more detail. For example, the answer averred that unless the defendant was permitted to withdraw more than 4,167 c. s. f., it would be necessary for the city of Chicago to reconstruct its system of sewers at a cost of more than $100,000,000 and to maintain it at an expense which when capitalized would represent in the aggregate an investment of $240,000,000; that the sum of

$82,000,000 already spent by the defendant would be practically wasted. The answer also contained allegations of details to the effect that Congress had at various times appropriated money for the improvement of the Illinois River and for the purpose of investigating waterway projects connecting Lake Michigan with the Mississippi River, and from those acts of Congress the defendant suggested as a defense an implied authority to withdraw water from Lake Michigan without the express authorization of Congress and in defiance of the decision of the Secretary of War. Out of these allegations and others as to government projects for improving navigation between Lake Michigan and the Mississippi River (never authorized by Congress or approved by the Department of War) the defendant attempted to create a claim of laches, acquiescence, and implied approval on the part of the United States with respect to the construction of the canal. There were also allegations claiming an estoppel by reason of the institution of the suit by the government to compel the removal of the dam of the Economy Light & Power Company in the Desplaines River at Dresden Heights, Illinois, but this seems to have been abandoned, at least on this appeal, as an element of estoppel.

On February 28, 1914, the complainant filed its motion to strike all of the answer setting up these three affirmative defenses on the ground that none of the matters thus set forth constitute admissible de-

fenses in this case. As has already been stated, this motion was pending throughout the proceedings until the entry of the final decree by Judge Carpenter on June 18, 1923, and this decree was intended to be, and was understood by the parties to sustain the complainant's motion. By agreement, the evidence which had been taken in the Calumet River suit was to be used in this, the Main Channel suit, so far as applicable, with the same effect as if the commissioner had been designated and had taken testimony in the latter case. Further testimony was taken up to the month of December, 1914. Shortly thereafter, the case was submitted to Judge Landis on the record as made (including Volumes I to VII of the record now before this Court which have been rebound for the purpose of this appeal) and on the motion of the complainant.

C. Decision of Trial Court

The efforts of the Government to bring the case to an early conclusion and a final decree establishing its rights are partially revealed by the record. (Rec., Vol. II, pp. 3878–3880.)

Judge Landis kept the case under advisement for over six years, his reasons for the delay being set forth in the oral opinion which he finally rendered on June 19, 1920. (Rec. Vol. VIII, p. 149.) The pendency of the war, his understanding that there was a possibility of a compromise, and his indisposition as a citizen of Chicago to have microbes in his drinking water, were his assigned reasons. Judge Landis in effect found:

(1) That there was a substantial lowering of the surface of the Great Lakes by reason of the unauthorized diversion of water, together with a changing of the current of the Chicago River;

(2) That this lowering of the level constituted a creation of an obstruction to the navigable capacity of the Great Lakes, particularly with respect to the proof showing the depth of the harbors of the Great Lakes;

(3) That the power of Congress with respect to navigable waters having been exercised was paramount, and therefore the affirmative defenses relied on by the defendant were not admissible;

(4) That there should be an order striking those portions of the defendant's answer setting up the affirmative defenses;

(5) That an injunction should issue, its operation to be suspended for thirty days after the beginning of the next session of the Supreme Court of the United States.

On July 12, 1920, the defendant made a peculiar motion—that the court "reconsider its oral opinion and oral direction heretofore announced concerning the form of decree to be entered in said causes." In effect the motion asked that the decree enjoin the defendant only from diverting from Lake Michigan *more than 10,000 c. s. f.* on condition that if Congress or other competent governmental authority should provide for the construction in the St. Clair, Niagara, or St. Lawrence Rivers of works to compensate for any diminishing levels of the Great Lakes due to the

defendant's diversion, then the defendant should defray the expense and pay the cost of construction and maintenance of any such works upon request therefor by the United States. In connection with the motion the defendant offered and agreed to defray the expense, or to pay to the United States upon demand the cost of the construction and maintenance of such works in accordance with an ordinance which the defendant had passed on July 8, 1920. Certain portions of the record and testimony previously taken in the cause were cited in support of the motion.

The motion was later amended by averments to the effect that the defendant had passed an ordinance providing for supplementing the works already constructed by a program for the construction and operation of works for the purification of sewage so that within a period of twenty-five years such purification works should be constructed and in operation and that the amount of sewage and waste so passing into the Desplaines River should be at least 50 per cent less than that passing at the time of the motion. The amendment also averred the passage of a statute by the legislature of Illinois authorising the defendant to construct the works and carry out the program for sewage purification, as set forth in the ordinance.

Judge Landis resigned his position as judge on March 1, 1922, without entering any final order or decree. Thereafter the case was assigned to Judge Carpenter. On April 25, 1923, further testimony

was taken in behalf of the defendant before a commissioner. (Rec. Vol. VIII, pp. 175-223.) It was all received subject to the objection of the complainant and had to do with matters within the scope of the second affirmative defense of the defendant. It purported to show the cost of other methods of disposition of sewage and the time it would take to accommodate the works then constructed and any new system to the needs of the probable population of Chicago. There was also testimony to the effect that under the law of the State of Illinois the revenue that would be received by the defendant would not meet the probable expenses until the year 1945.

On June 18, 1923, Judge Carpenter entered an order denying the defendant's motion and refusing its offer. On the same day, Judge Carpenter entered a final decree enjoining the defendant from diverting or abstracting any waters from Lake Michigan in excess of 250,000 cubic feet per minute. The opinion of Judge Carpenter (Rec. Vol. VIII, p. 127) in substance adopts the opinion of Judge Landis as to the points in issue.

II

A review of the efforts of the appellant to obtain permission from the Federal Government to withdraw water from Lake Michigan, showing that there is no foundation in fact for the claim of invitation, acquiescence, and laches made by the appellant

We do not believe that appellant's Statement of the Case affords to this Court a sufficiently clear account of what transpired between the appellant

and the Federal authorities in connection with the unauthorized diversion of water from Lake Michigan. Throughout appellant's brief counsel for appellants have seen fit to substitute their own (and we believe unjustified) interpretation of official documents for the actual language of the documents. They have also ascribed purposes and intentions, particularly to the Secretary of War, for which there is no basis in the documents or elsewhere in the record. Inasmuch as these instruments speak for themselves, we shall now discuss them in chronological order:

A. The enabling act of the Illinois legislature, passed May 29, 1889

The statute under which the appellant was organized and which, together with certain amendments, is the source of its powers and duties, was enacted by the Illinois legislature on May 29, 1889, and is entitled, "An Act to create sanitary districts and to remove obstructions in the Desplaines and Illinois rivers." The Act is general in its terms and provides a method for the incorporation of municipal corporations in Illinois with authority to make provision for the drainage of the incorporated territory. We need not dwell on those portions of the statute having to do with the general powers of such corporations (see Rec. Vol. IV, p. 2327). The portions of the statute which are of chief interest to this case are found in Sections 20 and 23. These sections by explicit language contemplate the construction of a canal diverting water from Lake Michigan into the Desplaines or

Illinois River and require that it be constructed of sufficient size and capacity to maintain a continuous flow of not less than 300,000 cubic feet per minute (5,000 c. s. f.). They further require that if the population of the district draining into such channel should at any time exceed 1,500,000, the channel should be made and kept of such size that it will produce and maintain at all times an additional flow of not less than 20,000 cubic feet of water per minute for each 100,000 of the population of the district. It is manifest, therefore, that this statute requires the appellant not merely to take 10,000 c. s. f. (600,000 cubic feet per minute) but requires the appellant to take a considerable amount in excess of that for each 100,000 of population over Chicago's present population of 3,000,000. The purpose indicated by the statute, therefore, and confirmed by the acts of the appellant, as well as by its contentions that it is justified by consideration of the police power, is evidently to take an *unlimited* amount of water in defiance of any acts of Congress or rulings of the Secretary of War. As the population of the district increases nearly 70,000 a year, it thus asserts the right to augment annually its present unauthorized diversion of water to the extent of approximately 15,000 cubic feet per minute. Even were the appellant limited to 10,000 c. s. f., it would on its own admissions be violating the requirements of Sections 20 and 23 of the statute from which it derives its existence and power, and those sections would be at least partially invalid.

B. Condition of Federal law as to control of navigable waters at the time of the passage of the Illinois enabling act of May 29, 1889

At this time (1889) there was no general Federal statute with respect to the control of navigable waters. As is shown under our Point II (*infra*, p. 136) this Court had held that, as to modifications and improvements the effect of which was entirely within the boundaries of a state on navigable waters wholly therein, Congress had left the states free to act, their action being subject to what Congress might do when it saw fit to assume control. As to acts which were national or international in their scope or effect—and the navigability of the Great Lakes is of this character—the failure of Congress to legislate was, under the well established principle, an expression of its will that the subject should be free from restrictions or impositions by the state.

The diversion of such a large quantity of water from Lake Michigan with its consequent effect on the levels of the Great Lakes was a subject both national and international in its scope, and the silence of Congress did not give to the state of Illinois the right to create what was in fact a large navigable river flowing away from Lake Michigan and a very appreciable obstacle to the navigable capacity of Lake Michigan and the other Great Lakes.

C. The Federal Act of September 19, 1890

During the year following that in which the Sanitary District enabling act was passed, Congress

enacted a general law for the protection of the navigable waters of the United States. By Section 10 of the River and Harbor Appropriation Act of September 19, 1890, Ch. 907, 26 Stat. 454, it was provided—

> that the creation of any obstruction, not affirmatively authorized by law, to the navigable capacity of any waters, in respect to which the United States has jurisdiction, is hereby prohibited.

By Section 7 of the same Act it was made unlawful—

> to excavate or fill, or *in any manner to alter or modify the course, location, condition, or capacity* * * * of the channel *of said navigable water of the United States, unless approved and authorized by the Secretary of War.*

Thus it was made necessary, before modifying the condition or capacity of the navigable waters of the United States, to obtain the authorization of the Secretary of War.

As to the preliminary authority of law required in the case of an obstruction of a navigable water *wholly within the boundaries of a state*, this Court decided in the year 1899 in the case of *United States v. Bellingham Bay Boom Company*, 176 U. S. 211, that such authority might be conferred either by a law of Congress or by a law of the state passed before Congress had itself legislated upon the subject.

D. Organization of Sanitary District and preliminary work on the canal

The incorporation of the appellant was completed by a vote of the people in November, 1889 and its first Board of Trustees was elected in December, 1889. Nothing, however, was done with respect to the construction of a canal prior to the passage of the Act of Congress of September 19, 1890. Several years thereafter were spent in consideration of routes for the canal and estimates of the cost of construction. Plans for the canal were finally agreed upon and bids upon certain propositions were received on June 8, 1892. (Rec. Vol. IV, p. 2363.) The actual construction was not undertaken until 1893. Therefore, all work was done after Congress had provided that such work must have the affirmative approval of the Secretary of War.

E. Suggestions of Federal aid in construction of canal

From the very beginning, the relation of the proposed canal to the Federal government was the subject of consideration by both the state and federal authorities. The government engineers had been at work for many years upon plans for the improvement of the navigable waters connecting Lake Michigan with the Mississippi River, and when the Sanitary District Canal was first projected there were suggestions by those connected with the Sanitary District and by the office of the Chief of Engineers, that, in the construction of the canal, there should be cooperation on the part of the local

and federal authorities, and that the United States should contribute something toward the expense of building the canal. (See Rec. Vol. IV, p. 2362–3; 2172–4.) Nothing came of such proposals, however, and Congress granted no aid whatever for the construction of the canal.

F. Early assertion of Federal control with respect to obstructions to navigation

So far, however, as the construction of the canal involved any modification of the capacity or condition of any navigable waters of the United States, the federal authorities were prompt in asserting their paramount authority. For example, as early as August 24, 1892, before any actual work of construction had been undertaken, Capt. W. L. Marshall, United States Engineer at Chicago, sent to appellant's Board of Trustees a communication containing the following:

> The matter of Federal cooperation with you must necessarily soon come up, but I can readily see that you may prefer to bring it up as a distinct proposition. (Rec. Vol. IV, p. 2377.)

On May 23, 1893, Capt. Marshall sent a communication to the president of appellant's Board of Trustees which contained the following:

> As far as the obstructions to navigation in Chicago River are concerned, we will deal with them under United States laws, but in case these laws are silent, or where questions arise where under these laws things may be

done that may not be done under state and local laws, the custom of this office has always been to respectfully suggest to the Secretary of War that no action be taken until the local authorities expressed their assent, and that in no case should a permit be granted by the War Department until it be shown that the authorities of the State of Illinois expressed their concurrence in such action. (Rec. Vol. IV, p. 2378.)

In Capt. Marshall's report dated August 9, 1893 (contained in the report of the Chief of Engineers, 1893), there appears the following:

> Without criticizing in any way the local measures taken for local relief, it may be said that the state laws, if effectively executed for the purposes specified, seemingly require changes in the capacity of Chicago River and its branches that may increase, may diminish, or may even entirely destroy their value for commercial purposes. In any case under existing laws, no alteration in the capacity of Chicago River can be made without the consent of the Secretary of War, or without full examination by agencies established by Congress, and the execution of the state laws are therefore limited by superior authority. (Rec. Vol. IV, p. 2368.)

On March 22, 1895, Col. Poe, United States Engineer at Chicago, sent to the appellant's Board of Trustees a communication which was as follows:

> The Board of Engineers appointed by direction of the Secretary of War to consider and report upon "the probable effect of the opera-

tion of the Chicago Drainage Canal upon the lake and harbor levels and upon the navigation of the Great Lakes and their connecting waterways" would be pleased to receive from your Honorable Board of Trustees any information or data bearing upon the subject submitted to us, and especially the following:

First. *The conclusions arrived at from investigations* made by your authority or by others *as to the effects upon the levels of the great lakes by the operation of your Canal*, including any mathematical analyses and discussions of the question from which these conclusions have been arrived at.

* * * * *

Third. Whether any part of the inner harbor of Chicago, which includes Chicago River and its branches, will be utilized as part of the proposed Canal, and if so what amount of water you propose to take through these river channels.

* * * * *

In making these inquiries, the Board of Engineers consider that your Honorable Body is much interested in the solution of the questions submitted to us, and therefore desirous to aid as far as practicable in arriving at correct conclusions. (Rec. Vol. IV, p. 2380–1.)

The appointment of the Board of Engineers referred to in the foregoing letter followed the observations published in the Chief of Engineer's report for 1893 which indicated a lowering of the surface levels

of Lake Erie of approximately 5¼" for a diversion of 10,000 c. s. f. at Chicago.

The Chief of Engineer's report for 1893 contains a statement to the effect that the city of Chicago expects to turn into the channel of the Illinois River at some future time 5,000 c. s. f. of Lake Michigan water and at some more remote period 10,000 c. s. f., but not probably within a generation. (Rec. Vol. IV, p. 2373.)

The Board of Engineers mentioned in Col. Poe's letter of May 22, 1895, made its report on August 16th of that year. In this report we find the following:

> It is true there is nothing showing that the consent of Congress had been asked for this enterprise. Certain that the subject had not been treated as an Inter-State affair; to say nothing of its being an International affair.
>
> * * * * *
>
> But it is sufficient to say that all that is now changed. The adopted policy is to defend, as well as improve all water courses, now navigable, or probably navigable in the reasonably close future. Waterways are under the charge of the United States, and there is no likelihood of their being abandoned for some time to come. * * *
>
> *The abstraction of 10,000 cubic feet* of water per second from Lake Michigan *will lower the levels of all the lakes of the system except Lake Superior and reduce the navigable capacities of all harbors* and shallows throughout the system to an extent that may be determined,

> if at all, by actual measurements only. Under the laws of the United States *these changes in capacity can not be made without Federal authority*, and to enable the executive officers of the United States to act advisedly in the matter it is necessary in the opinion of the Board not only that these measurements be taken, but that the money cost of restoring the navigable depths in channels and harbors be carefully estimated. (Rec. Vol. VI, p. 3936–39.)

At the very outset, therefore, we find that the United States asserted its paramount control with respect to the creation of obstructions to navigable waters. Indeed, shortly after the actual work of construction was begun, the Department of War put squarely up to the appellant the effect of the operation of this canal upon lake and harbor levels and upon the navigation of the Great Lakes and their connecting rivers.

G. Permit of July 3, 1896, and proceedings with reference thereto

If there were any doubt that the question of the effect of the diversion of water upon lake levels was under consideration by both parties from the very beginning and that the paramount control of the United States was asserted on its part and conceded by the local authorities, an end is put to that doubt by correspondence relating to the permit of July 3, 1896, to make certain changes in the capacity of the channel of the Chicago River.

On June 16, 1896, the president of appellant's Board of Trustees wrote to the Secretary of War, from which we quote the following:

> The work of the Sanitary District of Chicago has progressed so far that it is now necessary for us to enter upon that which must be done in the Chicago River to make available the artificial channel which we have under construction from Robey Street, Chicago, to Lockport in Will County, twenty-eight miles distant.
>
> Our connection with Lake Michigan must be through the Chicago River with the West Fork of the South Branch of which we make a junction at Robey Street. We send herewith a map showing in a general way our plans for improving the Chicago River by widening and deepening at the points indicated thereon by red hatchings and by figures which refer to explanations given in the legend on the map.
>
> * * * * *
>
> *We ask your permission to proceed with the work upon the lines indicated and so far as is consistent with propriety the cooperation of the United States Engineering Department.* (Rec. Vol. VI, pp. 3572–3.)

On June 24, 1896, Major Marshall of the Corps of Engineers at Chicago, wrote to the Chief of Engineers at Washington, saying among other things:

> As far as the work itself is concerned there can be no objection to it, as in every case the

navigable channel of Chicago River will be improved, and at this stage I am unable to do otherwise than to recommend the granting of the authority sought.

The question that must come up later for the action of the War Department, to wit: Whether the improved channel of Chicago River will be sufficient to carry 300,000 cubic feet of water per minute without lessening or destroying the navigability of Chicago River, or whether the City of Chicago will be allowed by the United States and Great Britain to take any water at all from the Great Lakes, with the inevitable result of lowering their levels is not now under investigation, and is one that will not probably be settled or decided by executive officers. It is or may rather be considered an international question. (Rec. Vol. VI, p. 3573.)

Major Marshall went on to recommend that the necessary authority be granted under five conditions, the second and third of which were as follows:

(2) That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submitted for consideration.

(3) That it will not cover obstructions to navigation by reason of this work while in progress, or when completed. (Rec. Vol. VI, p. 3574.)

On July 3, 1896, Acting Secretary of War Doe granted a permit to make the requested changes on

the conditions recommended by Major Marshall including the following:

> (2) That the authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.
>
> (3) That it will not cover obstructions to navigation by reason of this work while in progress or when completed. (Rec. Vol. VI, p. 3574.)

On October 28, 1897, the appellant applied for a permit to widen the Chicago River between Quincy and Harrison Streets. (Rec. Vol. VI, p. 3575.) In response to this application, the Secretary of War issued a permit which was subject to exactly the same conditions as the permit of July 3, 1896, and included the following:

> (2) That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.
>
> (3) That it will not cover obstructions to navigation by reason of this work while in progress, or when completed. (Rec. Vol. VI, p. 3576.)

On November 12, 1898, the appellant applied for a permit to build a cofferdam around the east side of the center pier of the Adams street bridge, on the Chicago River. This permit was granted on November 30, 1898. It recited, as did also the permit to

widen the Chicago River between Quincy and Harrison Streets, the Act of Congress making it unlawful to build structures of this kind or modify the condition of the navigable waters of the United States without the authority of the Secretary of War. (Rec. Vol. VI, pp. 3579–3581.)

On December 16, 1898, the appellant applied for a permit to remove bridges at the Taylor Street crossing and replace them with bridges of a different type. This permit was granted on January 13, 1899, and like its predecessors recited the paramount authority of the federal government in the premises. (Rec. Vol. VI, p. 3579–81.) A similar application was made by the appellant on February 27, 1899, and a similar permit issued by the Secretary of War on March 10, 1899, with respect to another bridge at Taylor Street. (Rec. Vol. VI, pp. 3584–5.) Similar application was made on April 26, 1899, for the construction of a cofferdam along the west side of the Chicago River, and on May 12, 1899, a permit was issued by the Secretary of War similar in form to the preceding ones, expressly reciting the authority of the War Department in the premises. (Rec. Vol. VI, pp. 3582–3583.)

H. The Federal Act of March 3, 1899

Before the completion of its channel by appellant and before any application had been made for the diversion of water from Lake Michigan, Congress changed the law relating to the control of navigable waters of the United States in certain important

respects. Obstruction of navigable waters wholly within the boundaries of the state authorized by the state legislature had been held to be "affirmatively authorized by law" (within the meaning of that phrase as it appeared in Section 10 of the Act of Congress of 1890) in the case of *United States* v. *Bellingham Bay Boom Company*, 176 U. S. 211. Among the changes made by the new Act of 1890 was the substitution of the words "affirmatively authorized by *Congress*" with the result that the new Act prohibited the creation of any obstructions without the authorization of Congress. Section 10, with which the present suits are vitally concerned, has already been set forth (supra, p. 8) and is analyzed elsewhere (infra, p. 174). We may state here, however, that both analysis of the statute and the history of the legislation leads inevitably to the conclusion that it was the purpose of Congress, as expressed in the most sweeping language, not only to prohibit obstructions but also to forbid that there should be, after the passage of the Act of March 3, 1899, any alteration or modification of the course, location, condition or capacity of navigable waters of the United States without authority of the Department of War; that it was not necessary that such proposed alteration or modification should amount to an obstruction of the navigable capacity of the waters, but permission was required in all cases even though the proposed alteration or modification might amount to an *increase*, rather than a decrease, of the navigable capacity of the waters

To invoke the statute it became necessary thereafter only to show that the proposed work does in fact amount to an alteration or modification of the course, location, condition or capacity of such navigable waters.

1. Application and permit for formal permission to open channel of the sanitary district to connect it with the Chicago River

It has already been noted that in the permits already issued by the Secretary of War the express reservation had been made—

> That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.

There was the further reservation and condition—

> That it (the permit) will not cover obstructions to navigation by reason of this work while in progress or when completed.

In the light of these conditions it is difficult to understand appellant's contention that these early permits, which were limited specifically to authority to make certain improvements in the channel of the Chicago River, are to be construed as any authority whatsoever to introduce a current into that river or to create any obstruction either in that river or elsewhere. That the appellant did not at that time so construe these permits is apparent from its application to the Secretary of War on April 22, 1899, *for permission to open the channel constructed by it as*

soon as it was completed. In connection with this application the appellant submitted to the Secretary of War a draft of permit which it requested be issued. This draft, after various recitals of work done by the appellant, contained further recitals specifically mentioning the permits of July 3, 1896 (in connection with which it recited "said approval being subject to limitations therein set forth"), and the other permits of November 16, 1897, November 30, 1898, January 18, 1899, and March 10, 1899. The draft also contained the following very significant admission:

> Whereas, it is necessary, under the Act of Congress of September 19, 1890, that authority shall issue from the War Department under which the said Sanitary District may cause the waters of the Chicago river to flow to the west into the main channel of the said District. (Rec. Vol. VI. p. 3849.)

This application was referred to Major Marshall, United States Engineer in charge at Chicago. On April 24, 1899, Major Marshall reported to the Chief of Engineers (a portion of his report being quoted in appellant's brief, p. 39). Other portions of the report which appellant omitted to quote are the following:

> It is a strange fact that this city has expended, or will expend, over $30,000,000 *with the intention of diverting an apparently unlimited amount of water from the Great Lakes* to the Mississippi drainage area for

sanitary purposes, *without finding out whether such diversion would be allowed by the great interests of the United States* and the Colonies of Great Britain along the chain of Great Lakes in the navigation of the rivers and harbors of the Great Lakes. *Now they ask the authority of an executive officer of the United States to open a channel that will, to some unknown extent, lower the levels of all the Great Lakes below Lake Superior and of their outlets,* introduce a current, also unknown, and not to be ascertained otherwise than by actual experiment, in Chicago river, the most important navigable river of its length on the Globe, but which is already obstructed by bridges, masses of masonry and bends, and of difficult navigation at best.

The possible effects of this diversion are not known further than that to some unknown degree they will be injurious. Whether the amount of this injury will be so small as to be accepted by the interests affected, in view of the manifest advantages to and apparent necessities of their neighbors, cannot be determined by other than the interests themselves.

It is clear to me that I am not competent to make a recommendation as to what should ultimately and definitely be done. (Rec., Vol. VI, p. 3586.)

Major Marshall's report then discusses the probable effect of the opening of the channels on the levels of the Great Lakes and expresses his opinion that the abstraction of from 300,000 to 600,000 cubic feet per minute (5,000 c. s. f. to 10,000 c. s. f.) would permanently lower Lakes Michigan, Huron, and Erie

from three to eight inches, corresponding to an extreme reduction of from 160 to 466 tons in the carrying capacity of the large vessels of the lakes. Major Marshall further says:

> But the State law is unlimited in its requirements. 20,000 cubic feet per minute must be taken from Lake Michigan for each 100,000 population of the district; already nearly 400,000 cubic feet must be taken, and at the same ratio of increase for a few decades, in a very short time there must be taken 1,000,000 cubic feet per minute under this indefinite law. *The amount should be limited and the injurious effect stopped somewhere.*

His report then discusses the uncertain results and dangers to navigation in the Chicago River by reason of the current to be introduced, suggests that the entire subject be referred to Congress for final solution, and that only a conditional permit or authority be granted to appellant upon the same conditions which the Secretary of War ultimately inserted in the permit which was granted. (Rec. Vol. VI, p. 3586; Appellant's Narrative, pp. 478–481.)

On May 8, 1899, the Secretary of War granted a permit to open the channel. After reciting portions of Section 10 of the Act of Congress of March 3, 1899, and the intention of the appellant to introduce a current into this canal of 300,000 cubic feet per minute, the permit certifies that—

> the Secretary of War hereby gives permission to the said Sanitary District of Chicago to open the channel constructed and cause the water

of Chicago River to flow into the same, subject to the following conditions:

1. That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of the Sanitary District of Chicago to Congress for consideration and final action, and that this permit shall be subject to such action as may be taken by Congress.

2. That if, at any time, it become apparent that the current created by such drainage works in the south and main branches of Chicago river be unreasonably obstructive to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago river and its south branch.

3. That the Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago river. (Rec. Vol. VII, pp. 1–2.)

J. Permits of July 11, 1900

On July 11, 1900, in response to appellant's applications of April 26, 1900, and June 7, 1900, the Secretary of War granted permits to the appellant to make changes in the Chicago river near Lake Street, 12th Street, and Ashland Avenue. In view of the extreme assertions made in appellant's brief (without foundation in the record) as to the purpose and intent of these permits, we call specific attention to

the language of the permits which recite among other things that they do—

> not in any way invalidate, waive or affect the right of the Secretary of War to regulate or revoke the permit granted under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago river and cause them to flow into the artificial channel. (Rec. Vol. VII, p. 43.)

These permits of July 11, 1900, then recited the conditions upon which the permit of May 8, 1899, was granted. There is nothing in the record to support appellant's frequent assertions that the Secretary of War gave any promise, or made any statement, or obligated the United States in any way, to increase the authorized diversion of water when the work under these permits of July 11, 1900, should be completed. The express recitals of the permits negative the inferences which appellant repeatedly states as matters of fact.

K. Modifications of permit of May 8, 1899

On April 9, 1901, the permit of May 8, 1899, was modified by the Secretary of War by directing the appellant to regulate the diversion from the river into the canal so that the maximum flow through the Chicago River and its south branch should not exceed 200,000 cubic feet per minute. The permit recited the second condition contained in the permit of May 8, 1899, and further recited that—

> it is alleged by various commercial and navigation interests that the present discharge from

> the river into the Drainage Canal sometimes exceeds three hundred thousand (300,000) cubic feet per minute, causing a velocity of nearly three (3) miles per hour, which greatly endangers navigation, in the present condition of the river. (Rec. Vol. VII, pp. 2–3.)

The appellant never questioned the authority of of the Secretary of War to make this modification, and, indeed, it could not, for it was clearly an exercise of the right expressly reserved in the original permit.

On July 23, 1901, the Secretary of War, in response to an application of appellant, made a further modification permitting a flow of 300,000 cubic feet per minute (5,000 c. s. f.) between the hours of 4 P. M. and 12 o'clock midnight—

> which approval will be subject to revocation by the department in case the increase shall prove to be dangerous to navigation. (Rec. Vol. VII, p. 3.)

On December 5, 1901, in response to a further application of the appellant, the permit was again modified to permit the appellant to divert not exceeding 250,000 cubic feet per minute (4167 c. s. f.) throughout the twenty-four hours of the day upon the following conditions:

> 1. That this permission shall be in lieu of the present authorized rates of flow as stated above.
>
> 2. *That the permission herein given shall be subject to such modification as in the opinion of*

the Secretary of War the public interests may from time to time require.

8. That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized. (Rec. Vol. VII, pp. 4–5.)

This permit of December 5, 1901, again expressly recited the second condition contained in the original permit of May 8, 1899, and was clearly an exercise of the right of the Secretary of War reserved in that permit and the others which had followed it. The appellant never questioned the right of the Secretary of War to make the modification as, indeed, it could not.

On December 29, 1902, the appellant applied for a further modification so as to permit it to increase the flow to 350,000 cubic feet per minute during the closed season of navigation. The application stated, among other things:

We recognize your responsibility as the guardian of the interests of navigation. (Rec., Vol. VI, p. 3862.)

On January 17, 1903, an amended permit was issued by the Secretary of War giving the appellant permission to increase the flow from 250,000 to 350,000 cubic feet per minute until March 31, 1903—

after which date it shall be reduced to 250,000 cubic feet per minute, as now authorized, upon the following conditions:

1. That the permission herein given shall be subject to such modification as in the opinion

of the Secretary of War the public interests may from time to time require.

2. That said Sanitary District of Chicago shall be responsible for all damages inflicted upon navigation interests by reason of the increase in flow herein authorized. (Rec., Vol. VII, pp. 5–6.)

This permit contained recitals calling attention to the original permit of May 8, 1899, and the permit of December 5, 1901, and particularly the condition contained in the latter permit—

> *that the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.* (Rec. Vol. VII, p. 5.)

So far as the Main Channel is concerned, this permit was the last one granted and it is by its terms and by the terms of the permit of December 5, 1901, that the right of the appellant to divert water from Lake Michigan must be determined.

L. Amendment of May 14, 1903, by Illinois Legislature to enabling act of May 29, 1889

On May 14, 1903, the Illinois legislature passed a law enlarging the corporate limits of appellant so as to include what are known as the Calumet and North Shore Districts. The Act provided for the navigation of the channels created by the appellant and gave authority to construct dams, water wheels, *and other works necessary to develop and render available the power arising from the water passing through its channels.*

Section 27 of the Act provided for the building of the Calumet Canal, giving the appellant authority to construct a channel *across* the Illinois and Michigan Canal. Section 27 further required appellant to—

> maintain the same proportion of dilution of sewage * * * as is now required by the Act creating said Sanitary District—

namely, 20,000 cubic feet per minute for each 100,000 inhabitants of a district. Section 27 further made provision for preventing any interference with the navigation of the Illinois and Michigan Canal by connecting the Main Channel of the Sanitary District with the upper basin of the Illinois and Michigan Canal at Joliet by a channel of specified dimensions equipped with the necessary locks. Sections 5 and 6 gave specific authority for the developing of water power and the conversion of such power into electrical energy and the sale and disposition of such energy to private persons or corporations. Section 8 of the Act provided:

> The said Sanitary District shall, at the expense of said District, in all respects comply with the provisions of the acts of Congress of March 30, 1822, and March 2, 1827, as construed by the courts of last resort of the State of Illinois and of the United States, in relation to the Illinois and Michigan Canal, so far as it affects that portion of the Illinois and Michigan Canal vacated or abandoned by the terms of this Act.

M. Findings of U. S. Lake Survey and International Waterways Commission

After the granting of the initial permit to the appellant to open its channel on May 8, 1899, the investigations for the purpose of determining the effect of the diversion upon the lake levels were continued by the United States Lake Survey.

On June 13, 1902 (32 Stat. 373), Congress passed a law providing for the formation of the International Waterways Commission, to be composed of three members from the United States and three from Canada. The duties of this commission were to investigate and report upon the conditions and uses of the waters adjacent to the boundary lines between the United States and Canada, including all of the waters of the lakes and rivers whose natural outlet is by the River St. Lawrence to the Atlantic Ocean; also upon the maintenance and regulation of suitable levels, and also upon the effect upon the shores of those waters and the structures thereon, and upon the interests of navigation, by reason of the diversion of these waters from or change in their natural flow; and further to report upon the necessary measures to regulate such diversion, and to make such recommendation for improvements and regulations as should best subserve the interests of navigation in those waters.

The report of the International Waterways Commission on January 4, 1907, is discussed elsewhere and its findings set forth (*infra*, p. 74). The findings of the commission as to the lowering of levels by a

diversion of 10,000 c. s. f. at Chicago were substantially the same as were established by the evidence in this case. The report of the commission concluded with certain recommendations, among which was the following:

> The preservation of the levels of the Great Lakes is imperative. The interests of navigation in these waters is paramount, subject only to the right of use for domestic purposes, in which term is included necessary sanitary purposes.
>
> * * * * *
>
> A careful consideration of all the circumstances leads us to the conclusion that the diversion of 10,000 cubic feet per second through the Chicago river will, with proper treatment of the sewage from areas now sparsely occupied, provide for all the population which will ever be tributary to that river, and that the amount named will therefore suffice for the sanitary purposes of the city for all time. Incidentally it will provide for the largest navigable waterway from Lake Michigan to the Mississippi river which has been considered by Congress.
>
> We therefore recommend that the Government of the United States prohibit the diversion of more than 10,000 cubic feet per second for the Chicago Drainage Canal. (Rec. Vol. IV, pp. 2432–3.)

N. Decision of Secretary of War on application of Sanitary District to withdraw water through Calumet River

On November 28, 1906, the appellant applied to the Secretary of War for a permit to reverse the flow of

the Calumet River and to divert water from Lake Michigan through that river into a channel which it was to construct and which was to connect with its Main Channel. After the report of the International Waterways Commission on January 4, 1907, above mentioned, the Secretary of War on March 14, 1907, made his ruling, which was transmitted to the appellant. His communication recited Section 10 of the Act of Congress of March 3, 1899. It further recited that the question of whether the Chief of Engineers had power to recommend, or the Secretary of War to permit, such a change in the flow of a river had been submitted to the Judge Advocate General, who held that the case was one in which they had such power. The ruling further recited the recommendation of the Chief of Engineers which contained the following:

> 3. In my opinion, this abstraction will undoubtedly lower the levels of all the waters of the Great Lakes, except those of Lake Superior, and thus diminish the navigable capacity and depth of the various channels and harbors which have been deepened and improved under authority of Congress.
>
> 4. Leaving out Lake Superior, there are more than 100 works of river and harbor improvements on the Great Lakes and their connecting waters for which appropriations aggregating more than $80,000,000.00 have been made. The application of this vast sum has resulted in securing and maintaining specified depths and widths of channel, which Congress

has decided to be required for the accommodation of the traffic using those waters.

5. To diminish these depths, even to a slight extent, would not only prove a serious injury to the traffic, but would practically undo the work which has been accomplished by Congressional direction, and necessitate the expenditure of further large sums of money for restoration. Any project that tends, in a measure, to annul or reverse the orders of Congress, as expressed in the various river and harbor acts appropriating funds for improving the harbors and channels connecting with the Great Lakes, should meet the disfavor of the Department, unless it has been sanctioned by that body. In my judgment such a project is the one under consideration, and for this reason I am unwilling to recommend favorable action thereon, assuming that the Department is empowered to take such action, as is held by the Judge Advocate General.

The communication of the Secretary of War then proceeded to state:

The decision of the Chief of Engineers and its final character has made it unnecessary for me to consider the merits of the question, but I may say this much, that the application for a change in the Calumet River is to be made the basis for the withdrawal of a large amount of water from Lake Michigan and that all interested in the enormous lake traffic view the settlement of the question with grave apprehension. Added to this, is the international complication which is likely to arise in the

threatened lowering of the lake level in the ports and harbors and canals of Canada. On the other hand, it is maintained with great emphasis and elaboration of detail that the change in the Calumet River is essential to the healthful sanitation of Chicago, and that the threatened injury to navigation is so small as to be negligible.

Between two such great interests, the decision must be affected more or less by large public policy and expediency, and while I agree in the construction of the Judge Advocate General that the issue is left by statutes to the recommendation of the Chief of Engineers, and the concurrent decision of the Secretary of War, it may be fortunate that circumstances now require submission of this question of capital and national importance to the Congress of the United States. (Rec. Vol. VII, pp. 23–25.)

O. Wilmette permit

On September 11, 1907, the Secretary of War, in response to application of the appellant on September 2, 1907, issued a permit authorizing appellant to connect Lake Michigan at Wilmette, Illinois, with the North branch of the Chicago River. This permit contained the following condition, among others:

> That the total diversion of water from Lake Michigan through the Chicago river into the Illinois river shall be no greater than already authorized by past War Department permits. (Rec. Vol. VII, p. 26.)

P. The ordinance of the appellant asserting its independence of Federal control

As soon as it had obtained its permit for the construction of the Wilmette channel, subject to the limitation as to total diversion of water already mentioned, and while it was accepting the benefits of that permit and acting thereunder, the appellant proceeded on September 18, 1907, to pass an order declaring its intention to reverse the flow of the Calumet River and to divert water from Lake Michigan without the authority of the Secretary of War unless restrained by a court proceeding at the instance of the United States government. (Rec. Vol. VIII, p. 7.) The sole justification for its defiance of federal authority is to be found in the following recital contained in said order:

> Whereas, This board is advised that it has the right and that it is its duty under the laws of the State of Illinois to construct its said channel and reverse the flow of said Calumet river, *notwithstanding the refusal of the Secretary of War to issue a permit authorizing the same*, for the purpose of furnishing the proper sanitary method of disposing of the sewage of the territory and inhabitants contiguous to the said proposed channel and within the corporate limits of the Sanitary District of Chicago, and *unless restrained by a court having jurisdiction of the subject matter at the instance of the United States Government*.

It should be noted that neither in this order nor at any time prior thereto was any claim made

that appellant had authority under the Acts of Congress of 1822 and 1827 relating to the Illinois and Michigan Canal. This idea was clearly an afterthought.

Q. The Calumet permit of June 30, 1910

Following the passage of appellant's order of September 18, 1907, the appellee filed the Calumet River suit on March 23, 1908, to enjoin the reversal of the flow of the Calumet River and the diversion of water through that river from Lake Michigan. After the complainant (appellee) had concluded the taking of its evidence showing the effect on the lake levels of the proposed diversion, the appellant on June 27, 1910, made another application to the Secretary of War for permission to open the channel through the Calumet River so as to substitute two routes instead of one between Lake Michigan and the Main Canal, *it being understood that the total quantity of water to be withdrawn from Lake Michigan was not to exceed that already authorized by the Secretary of War*. On June 30, 1910, the Secretary of War, acting upon this application, granted such a permit—

> subject to all pertinent conditions of the existing permissions and to other express conditions as follows:
>
> (*a*) That it be distinctly understood that it is the intention of the Secretary of War to submit the questions connected with the work of The Sanitary District of Chicago to Congress for consideration and final action, and that

this permit shall be subject to such action as may be taken by Congress.

(*b*) That if, at any time, it become apparent that the current created by such drainage work in the Calumet, as well as Chicago rivers, be unreasonably obstructive to navigation, or injurious to property, the Secretary of War reserves the right to close the discharge through said channel or rivers, or to modify it to such an extent as may be demanded by navigation and property interests along said rivers.

(*c*) That The Sanitary District of Chicago must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in the Calumet as well as Chicago river.

(*d*) That the amount of water withdrawn from Lake Michigan, through the Chicago and Calumet rivers together, shall not exceed the total amount of 250,000 cubic feet per minute (4,167 cubic feet per second) already authorized to be withdrawn through the Chicago river alone.

(*e*) That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

(*f*) That this permission shall in nowise affect or in any manner be used in the friendly suit now pending in the Circuit Court of the United States for the Northern District of Illinois brought by the United States of America against the Sanitary District of Chicago, to determine the right of the said

Sanitary District to divert from Lake Michigan for sanitary purposes an amount of water in excess of that now being diverted, without having first obtained a permit from the Secretary of War.

(*g*) That the War Department shall have free access at all times to the water-flow records of the Sanitary District of Chicago and free access also to the regulating works and all other parts of its canals for the purpose of checking records or making water-flow measurements.

(*h*) That the plans for the proposed work shall be submitted to and approved by the Chief of Engineers and the Secretary of War.

(*i*) That the work shall be subject to the supervision and approval of the Engineers Officer of the United States Army in charge of the locality. (Rec. Vol. VII, pp. 27–29.)

The recitals of the permit leave no doubt as to the reasons of the Secretary of War for his action. They show that—

> So long as the water flow remains unchanged there seems to be no special objections to its extension to both rivers instead of confining it to a single one, especially since if the new (Calumet) route be developed later to a navigable state the double route will be advantageous to navigation interests.

B. Application of February 5, 1912

The appellant then proceeded to introduce certain evidence in the Calumet River suit as to the alleged necessity for using the water for sanitary purposes

(Rec. Vol. I, pp. 445–564), but no evidence as to the effect of the diversion upon lake levels was produced. On February 5, 1912, the appellant applied to the Secretary of War "for an enlargement" of the terms of the permit of May 8, 1899, as modified by the permits of December 5, 1901, and June 30, 1910. The application was for permission—

> to withdraw from Lake Michigan through the Chicago river and Calumet river not to exceed 10,000 cubic feet of water per second; such permission to be revocable at any time by the Secretary of War, and subject to such action as the Congress of the United States may see fit to take in the premises. (Rec. Vol. VII, p. 7.)

There were extended hearings before the Secretary of War upon this application. (Rec. Vol. VI, pp. 3601–3845). It was stipulated in these cases that the proceedings before the Secretary of War are to be considered in evidence with like effect as if witnesses were called and original exhibits produced and identified herein. (Rec. Vol. VI, p. 3601.)

There was opposition to the granting of the permit on the part of members of Congress and other persons representing towns and cities in Minnesota, Michigan, Wisconsin, Ohio, and New York. The granting of the permit was also opposed by the representatives of various navigation interests of Chicago and property owners and residents throughout the entire Illinois valley. The opposition of the Chicago interests centered upon the effect of the increased flow in producing a current in the Chicago river which would

be extremely detrimental to navigation. (Rec. Vol. VI, p. 3616.)

Statements that the local situation was extremely critical; that even under the present flow navigation in the river was carried on at great hazard; and that any increase in the velocity of the current would mean disasters were made by the vessel owners and representatives of the Association of Lake Lines.

There was opposition to the granting of the permit on the part of representatives of the Canadian government as well as representatives of Canadian navigation interests. Briefs on behalf of the Canadian government were submitted in opposition to the application. (Rec. Vol. VI, pp. 3630–3631; 3711–3732.) The grounds urged in the briefs included the diminishing of the capacity of navigable waters of the United States and Canada and infliction of injury upon the navigation interests of Canada; also the terms of the Boundary Waters Treaty of January 11, 1909.

As to the effect of the withdrawal of the water on lake levels, the statement of the appellant, submitted by its attorney and its Chief Engineer, substantially admitted the correctness of the calculations as to the probable lowering of levels. (Rec. Vol. VI, pp. 3701–2.) See also the opinion of Lieut. Col. Zinn, Engineer in charge at Chicago. (Rec. Vol. VI, pp. 3732–3737.)

8. Decision of Secretary of War on January 8, 1913, denying appellant's application for increased diversion

After ample opportunity had been given to the appellant to be heard, the Secretary of War announced his finding on January 8, 1913. The document incorporating his findings is of some length and may be found set forth in full in the record. (Rec. Vol. VII, pp. 7–17.) We quote, however, portions of that document as follows:

> It is clear that even under the conditions heretofore manifested on these applications the proposition to divert the waters of Lake Michigan into another watershed has not been entertained without hesitation and careful restriction by my predecessors. The propriety of obtaining congressional sanction for the project has been pointed out from the beginning; and the form in which the permit has been granted, even for the moderate amount of diversion permitted, has been so phrased as to indicate that the permission was predicated upon the absence of any substantial injury to commerce.
>
> * * * * *
>
> In the argument before me it was urged that the present canal represented the growth and development of a national policy expressed in two acts of Congress, 1822 and 1827, which authorized the construction of a canal "to connect the Illinois river with Lake Michigan," thus connecting the two watersheds. (Acts of Mar. 30, 1822, and Mar. 2, 1827.) But these statutes authorized a canal for the purpose of navigation and not sanitation. (*Mis-*

souri v. *Illinois*, 200 U. S. 526.) The Illinois and Michigan canal, actually constructed under their authority, derived its water for navigation purposes from the Calumet, Desplaines, and Chicago rivers, and not from the lakes. And although in the latter part of its existence, it was used to a very slight extent to help purify the waters of the Chicago river and thus sanitate the city of Chicago, such a purpose could not have been dreamed of at the time its construction was authorized by Congress, 90 years ago. I can not see that its authorization and construction offer the slightest congressional sanction for the great canal now under discussion, which was not even contemplated until much more than half a century later. Even at the time when the present canal was constructed and opened it is very evident that its ultimate possible effect upon the navigation of the Great Lakes was not clearly realized by those interested in that navigation.

The Secretary of War then states his conclusion—

that the withdrawal of 10,000 cubic feet per second would substantially interfere with the navigable capacity of the Great Lakes and their connecting rivers,

and sets forth the amount of the reductions (infra, p. 72). Every argument now made by the appellant by way of affirmative defense was presented to and passed upon by the Secretary of War. He reached the conclusion that there would be substantial injury to the improvements effected by the United States and Canada in harbors and rivers on the Great Lakes

and *that the proposed further diversion would be a violation of the Canadian Boundary Waters Treaty.* He estimates the lowest careful estimate of "injury to American vessels alone at $1,000,000 per year." He disposes of the argument that owing to the fact that the levels of the lakes vary on account of winds and change of barometric pressure by amounts even greater than the reduction, therefore the proposed reduction would be of no consequence. He calls attention to the fact that the demand for this diversion is based solely upon Chicago's needs for sanitation, there being involved in the case no issue of conflicting claims of navigation. According to the Chief of Engineers' report, so far as the needs of a deep waterway from the Great Lakes to the Mississippi are concerned:

> *The maximum amount of water to be diverted from Lake Michigan need actually be not over 1,000 feet per second,*

a conclusion supported by other evidence cited by the Secretary of War. He points out the fact that "from the standpoint of navigation alone in such a waterway too great a diversion of water would be a distinct injury rather than a benefit." He expresses grave doubts as to whether under Sections 9 and 10 of the Act of Congress of 1899 the Secretary of War has any authority or discretion

> to grant a permit which would inflict a substantial injury upon commerce in order to benefit sanitation.

He expresses the opinion that "no further diversion of water should be permitted at Chicago without the direct sanction of the Congress of the United States," saying:

> I do not for one moment minimize the importance of preserving the health of the great City of Chicago; but when a method of doing this is proposed which will materially injure a most important class of the commerce of the Nation and which will also seriously affect the interests of a foreign power, it should not be done without the deliberate consideration and authority of the representatives of the entire Nation. The growth of Chicago is phenomenal and its representatives are quite unwilling to put any final limit to the demand which may be made upon the waters of Lake Michigan for its sanitation under the system now in use. I have before me the report of 1911 of the president of the sanitary district, in which he says:
>
> "I am of the opinion that the presumption that our water supply is to be limited to 10,000 cubic feet per second, or 600,000 cubic feet per minute, is gratuitous and mischievous and should not be voiced by the officials of this district. I believe that we should have the volume requisite to our needs as they appear and are justified."
>
> It is therefore quite conceivable that compliance with their sanitary needs according to this method of sanitation may eventually materially change this great natural watercourse now existing through the lakes.

The considerations involved in the application the Secretary finds to be "broad questions of national policy." He then takes up the question of the sanitary needs of Chicago and expresses an opinion that the amount of water applied for is not necessary to a proper sanitation; at bottom the issue comes down to the question of cost; that there are other adequate systems of sewage disposal which are in use throughout the world including all the other cities on the Great Lakes. He says:

> The evidence before me satisfies me that it would be possible in one of the several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition.
>
> * * * * *
>
> It is manifest that so long as the city is permitted to increase the amount of water which it may take from the lakes, there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage. *This is particularly true in view of the fact that by so doing it may still further diminish its expenses by utilizing the water diverted from the lakes for water power at Lockport.* But it must be remembered that for every unit of horsepower realized by this water at Lockport four units of similar horsepower would be produced at Niagara, where the natural conditions are so much more favorable.

The matter of restoration of the lake levels by compensated works is considered by the Secretary. He points out that—

> such compensating works can only be constructed by the authority of Congress and at very considerable cost. It is not a matter which is in the hands of the Secretary of War. * * * Furthermore, in most cases such compensating works could only be constructed with the joint consent of our neighbor Canada,

and consequently disposes of all arguments based upon the Boundary Waters Treaty, considerations of which lead him to the conclusion "that the question is not merely national but international." He states in this regard—

> The establishment by formal treaty between the two countries of a tribunal with jurisdiction to decide just such questions seems to me to afford an additional reason against the assumption of jurisdiction to decide the question by an administrative officer of one of those countries.

In conclusion the Secretary of War sets forth his conclusions as follows:

> First. That the diversion of 10,000 cubic feet per second from Lake Michigan, as applied for in this petition, would substantially interfere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.
>
> Second. That that being so, it would not be appropriate for me, without express congressional sanction, to permit such a diversion,

however clearly demanded by the local interests of the sanitation of Chicago.

Third. That on the facts here presented no such case of local permanent necessity is made evident.

Fourth. That the provisions of the Canadian treaty for settlement by joint commission of "questions or matters of difference" between the United States and Canada offer a further reason why no administrative officer should authorize a further diversion of water manifestly so injurious to Canada against Canadian protest.

The prayer of the petition is therefore denied. (Rec. Vol. VII, p. 7–17.)

After this decision of the Secretary of War, which involves and passes upon substantially every contention now made by the appellant, it came to the attention of the War Department that appellant was diverting from Lake Michigan more water than was authorized by the permits then in force.

On February 24, 1913, acting under instructions from the War Department, the United States Engineer at Chicago wrote to appellant a letter which contained the following:

> I am directed by the War Department to notify you that measurements made by the Engineer Department during January indicate that since the Secretary of War's decision of January 8, 1913, you have been diverting from Lake Michigan more water than the 4,167 second-feet authorized by the existing War Department permits.

Your attention is invited to Section 10 of the Act of March 3, 1899, which is being violated by such diversion, also to the provisions of Sections 12 and 17 of the same act, a marked copy of which is inclosed.

Kindly advise this office what steps, if any, you propose to take to keep future diversions within the limits of the existing War Department permits and how soon such reduction of diversion may be expected.

I have also to inform you that a continuation of the excess diversion may require action by the United States District Attorney. (Rec., Vol. VI, p. 3968.)

On February 27, 1913, the president of the appellant replied to the foregoing letter without complying with its request for information and stating merely that the letter would be taken up at the next meeting of appellant's board of trustees. (Rec., Vol. VI, p. 3969.)

On March 15, 1913, the United States Engineer at Chicago, again acting under instructions from the War Department, wrote a second letter, of the same tenor as the one above quoted. (Rec., Vol. VI, pp. 3969–70.)

Finally, on March 22, 1913, Mr. Adcock, attorney for the appellant (the same who is now appellant's attorney of record on this appeal), wrote at some length to the United States Engineer at Chicago in an attempt to justify appellant's action. In his letter he mentioned the pendency of the Calumet River suit and the defense of appellant that it was acting

under the reserved police power of the State for the preservation of the lives and health of its citizens. He further states:

> You are no doubt aware that the International Waterways Commission by its report of 1907 recommended that no question be raised as to the right of the Sanitary District to flow through its channels for sanitary purposes *at least* 10,000 cubic feet of water per second. (Rec., Vol. VI, p. 3971.)

The inaccuracy of this statement is pointed out elsewhere (*infra*, p. 226), for counsel for appellant make the same misstatement in appellant's brief.

Mr. Adcock's letter proceeded as follows:

> The Board of Trustees of the Sanitary District appreciate their responsibility in the matter. *It is their desire that the rights of the Sanitary District be finally determined.* With this in view, and inasmuch as the suit now pending relating to the Sag Channel involves issues which are somewhat similar to the questions now involved in the interrogatories propounded in your two letters, I respectfully suggest that the bill of complaint in the case of the *United States* v. *Sanitary District* now pending be amended or a supplemental bill filed so that all the issues above referred to may be settled and promptly adjudicated. A great deal of testimony has been already taken, all of which will apply to the issues that would be raised by the proposed amended proceedings. A great deal of time, work, and trouble would be saved by pursuing

> the method I suggest and the Sanitary District will cooperate to speedily make up and try the issues upon the issues which may be presented by the amended or supplemental bill proposed, and will also stipulate that all testimony thus far taken be treated as having been taken in the amended proceeding. (Rec., Vol. VI, pp. 3972–73.)

In spite of this letter, appellant has seen fit to make the contention before this court that the appellee should not have proceeded by bill for injunction and that it was restricted to criminal proceedings against appellant and its officers. *It was by appellant's own request that suit for an injunction was instituted instead of criminal proceedings.*

As a result of the decision of the Secretary of War and of appellant's defiance of it, the Second or Main Channel suit was instituted.

Under our Point VIII (*infra*, p. 255), we shall deal further with the appellant's contention that the United States by acquiescence, laches, or implied authority has estopped itself from asserting its paramount control over navigation in the case of appellant.

III

Evidence as to the quantity of water now being withdrawn by the appellant from Lake Michigan and as to the amount it intends to withdraw in the future if its contentions are upheld

There is no dispute that the appellant is diverting at least 10,000 c. s. f. from Lake Michigan through its various channels. Owing to the fact that the

hearing of testimony on this subject was concluded in 1913, the record does not reveal the exact amount withdrawn since then. That it is at least 10,000 c. s. f., however, is apparent both from the allegations contained in the appellant's motion of July 12, 1920 (Rec. Vol. VIII, p. 152), from the assumed facts taken as the basis for the testimony taken in behalf of the appellant on April 25, 1923, and from admissions in the appellant's brief. This conclusion is supported by the fact that in 1923 the population of appellant's drainage district exceeded 3,142,000 (Rec. Vol. VIII, p. 217), which population would (under Sections 20 and 23 of the Illinois Act of 1889) require a diversion of about 10,500 c. s. f.

In fact, we are warranted in assuming that the appellant is regularly diverting 12,000 c. s. f. The Calumet Sag Canal was not completed until 1922 and from that time on had and has a capacity of 2,000 c. s. f. (to be increased later to 4,000 c. s. f.). According to appellant's admissions in its brief (pp. 13–14) it is at present withdrawing 6,250 c. s. f. through the main channel of the Chicago River, 1,750 c. s. f. through the North Branch of the Chicago River (1,000 at Wilmette and 750 through the Lawrence Avenue conduit), and 2,000 c. s. f. through the 39th Street conduit—a total of 10,000 c. s. f. (Appellant's Narrative, p. 191). That this is the actual truth is confirmed by appellant's frequent reiterations that 10,000 c. s. f. is the amount of the maximum or flood run-off of the Chicago *River* Basin (not the "Chicago River *Drainage* Area" as

appellant states, Appellant's Brief, p. 6—see Appellant's Narrative, p. 189). Incidentally, appellant does not explain how it was able to manage with a diversion of considerably *less* than 10,000 c. s. f. up to and including 1913, nor how it avoids the supposed bad effect of a maximum run-off in the Calumet River Basin, where it amounts to over 15,700 c. s. f. (Appellant's Narrative, p. 520), nor what it does with the trade wastes (from the stockyards and tanneries) entering its canal from the sewers of Chicago, which "require as much water to dilute it as would be necessary to take care of the sewage of a million and a half people" (Appellant's Brief, pp. 78–79).

The average amount of water which was withdrawn by appellant from the opening of the canal until 1913, was, according to appellant's chief engineer, as follows:

	Cubic second feet
1900	4314
1901	4437
1902	4569
1903	5144
1904	5271
1905	5381
1906	6292
1907	6444
1908	6596
1909	6970
1910	7132
1911	7295
1912	7458
1913	7619

(Rec. Vol. III, p. 1618.)

The report of the International Waterways Commission of January 8, 1910, shows that prior to that

time appellant refused to give that Commission information as to the amount of water it was diverting. (Rec. Vol. VII, p. 253.)

As evidence of the amount of water which appellant proposes to divert in the future, we cite the testimony of appellant's witnesses as to the probable future population of Chicago, keeping in mind the Illinois statutory requirement of amount of diversion per 100,000 of population:

	Human	Industrial equivalent	Total	Diversion in c. s. f.
1930	3,710,000	1,700,000	5,410,000	18,083
1940	4,425,000	1,900,000	6,325,000	21,083
1950	5,140,000	2,100,000	7,240,000	24,133
1960	5,800,000	2,300,000	8,100,000	27,300

(Rec. Vol. VIII, 217, Appellant's Narrative, p. 362.)

The magnitude of the proposed withdrawal can be appreciated when compared to the present flow of rivers tributary to the Great Lakes, and of connecting waters between the Great Lakes, as shown under our next subheading.

IV

The effect of the withdrawal of water from Lake Michigan upon the levels of the Great Lakes

(A) Comparison with other waters

For the purpose of convenient comparison we cite from the record evidence as to the mean annual flow of the following streams tributary to Lake Michigan:

	Cubic second-feet
Grand River	4,620
St. Joseph River	3,575
Fox River	3,370

(Rec. Vol. VII, pp. 462–3, 471–2.)

and of the following connecting waters between the Great Lakes:

	Cubic second-feet
St. Marys River	82, 000
Detroit River	204, 200
Niagara River	212, 000
St. Lawrence River (at its head)	254, 400

(Rec. Vol. VII, p. 344.)

The appellant's diversion is, therefore, substantially equivalent to the combined flow of the three principal tributaries to Lake Michigan, and to five per cent of all the water contributed by the Superior, Michigan, Huron and Erie basins.

Even in the absence of testimony directly bearing on the effect of this diversion on the lake levels, this would seem sufficient to constitute such a modification of the condition of navigable waters of the United States as to require the recommendation of the Chief of Engineers and the authorization of the Secretary of War. Likewise, the great increase of waters emptied into the Desplaines and Illinois Rivers constitutes such a modification. *The appellant has created a large navigable river flowing away from the Great Lakes.*

(B) Decision of the Secretary of War on January 8, 1913

On January 8, 1913 the Secretary of War, in rendering his decision denying appellant's application for a permit to divert 10,000 c. s. f., found that the withdrawal of 10,000 c. s. f.—

> would substantially interfere with the navigable capacity of the Great Lakes and their connecting waters. (See supra, p. 58.)

And that such a withdrawal would reduce levels as follows:

	Inches
Lakes Huron and Michigan	6.9
Lake St. Clair	6.0
Lake Erie	5.4
Lake Ontario	4.5
St. Lawrence River and Rapids Plat	4.8+

The Secretary of War further found:

> This reduction would create substantial injury in all of the American harbors of the Great Lakes and in the St. Mary's, St. Clair, and Detroit rivers. It would produce equal injury in Canadian harbors on the Great Lakes, and a still greater injury on the lower St. Lawrence, the Canadian officials claiming a probable lowering effect of 12 inches at Montreal at low water. (Rec. Vol. VII, p. 10–11.)

This finding is entitled to great weight in this case; in fact, we maintain that the appellant will not be heard to contradict it. It was made in a proceeding which the appellant invited by its application for a permit to withdraw 10,000 cubic feet of water per second from Lake Michigan. The Government of Canada was represented at the hearing, and submitted its evidence. The Secretary of War had before him the reports of the Lake Survey and the International Waterways Commission, as well as the conclusions of the Chief of Engineers, whose statutory authority in passing upon the application was, as stated in the finding, concurrent with and independent of that of the Secretary of War. The principal expert witness for the appellant, Gardner S. Williams, upon whose

criticisms of the work of the government engineers the appellant is relying in this case, had commenced his work in the case more than three years prior to the hearing before the Secretary of War. None of his criticisms or conclusions were submitted to the Secretary of War. On the contrary, the Chief Engineer for the Sanitary District (Rec. Vol. VI, p. 3701) expressly stated that he did not wish "*to question the accuracy of the figures or the fairness of the calculations.*" Here was a controversy which involved the relations between this nation and Canada; a controversy in which a finding was to be made as to the right of a foreign government. The appellant presented its case, and upon this vital question of the effect of the diversion of the water on the lake levels it produced no evidence to contradict the conclusions of the government engineers. Having invited the hearing, it permitted the Secretary of War to make a finding upon the assumption that it accepted the correctness of the methods used by the United States engineers.

We submit, therefore, that in this proceeding the appellant will not be heard "to question the accuracy of the figures or the fairness of the calculations" of the Government engineers as to the effect of the withdrawal of water from Lake Michigan upon the levels of the lakes.

The conclusions of the Secretary of War in his report and the contentions of the United States in this case, however, are sustained by the overwhelming weight of the evidence in this record.

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(C) Official reports as to effect of diversion upon lake levels

Investigations begun in 1895 by a board of engineers appointed by the Secretary of War, carried on in 1898 by the Deep Waterways Commission, and then transferred to the United States Lake Survey in 1899 resulted in extensive observations on the St. Clair, Detroit, Niagara, and St. Lawrence Rivers (Rec. Vol. IV, pp. 2454–2493, 2380; Vol. VII, 253). The result of the work is summarized in the report of the International Waterways Commission, dated January 4, 1907, as follows:

* * * The amounts by which the mean level, as derived from observations of the last 46 years of the various waters will be lowered by a discharge of 10,000 and also by 14,000 cubic feet per second are given in the following table:

Location	Water level lowered by diversion at Chicago of—	
	10,000 cubic feet per second	14,000 cubic feet per second
	Feet	*Feet*
Lake Huron and Michigan	0.52	0.70
Lake St. Clair	.45	.64
Lake Erie	.45	.64
Lake Ontario	.35	.49
St. Lawrence River at Rapids Plat	.40	.57

The length of time required to produce this effect is about 5 years; about half of it will be produced at the end of 18 months. The above figures give the effect at average level; they are much more considerable during low-water periods. (Rec. Vol. IV, p. 2418–19.)

This report is signed (Rec. Vol. IV, p. 2433) by the three representatives from the United States and the three representatives from Canada.

General Ernst and Haskell, the two engineers who represented the United States on the Commission, and Wilson, Secretary of the American Section, testified as witnesses for the appellee in this case.

Subsequent to the report of the International Waterways Commission additional observations with reference to the Niagara river were made in 1907 and 1908. (Rec. Vol. II, p. 848.) Those observations check almost exactly with the measurements which had been made in 1899. (Rec. Vol. I, p. 254.) Additional observations were made for the St. Clair river in 1909. (Rec. Vol. I, p. 291.) On January 8, 1910, the International Waterways Commission made another report, in which were set forth its findings as to discharge *increments* of the river outlets of the Great Lakes System. (See Rec. Vol. VII, p. 294–5.)

According to this table (the increment being the difference in discharge corresponding to a difference in lake level of 1 foot) the withdrawal of 10,000 cubic feet of water per second from the lake produces a lowering of the level of Lakes Michigan and Huron of from *5.8 to 7.4 inches;* of Lake St. Clair of from 5.9 to 6.5 inches; of Lake Erie of from 4.8 to 6.1 inches; and of Lake Ontario of from 4 to 4.5 inches. The lowering effect of the withdrawal changes with the elevation of the lakes; a given withdrawal produces a larger effect at times of low water than at times of high water. A consideration of this fact explains the

difference in the increments which have been deduced from different series of observations.

There is, also, in the record the statement of the Canadian representatives as to the effect of the withdrawal upon the levels of the Canadian waters. This statement sets forth their conclusions with respect to levels as follows:

Lake	Actual diversion	Loss of level, assumed diversion of—	
		10,000 c. s. f.	14,000 c. s. f.
	Inches	*Inches*	*Inches*
Michigan-Huron	3.07	7.4	10.3
Erie	2.6	6.1	8.6
Ontario	1.9	4.5	6.3
Rapids Plat	2.8	6.8	9.8
Cornwall Canal	2.1	5.0	6.9
Coteau	2.2	5.4	7.6
Montreal	4.3	10.25	14.4
Lanoraie	2.2	5.4	7.6
Sorel	2.5	6.0	8.4

(Rec. Vol. VI, pp. 3639-3640.)

The facts with reference to this diversion are established by evidence as strong as can be produced in support of any engineering proposition.

This conclusion as to the effect of the diversion of water from Lake Michigan upon the lake levels has been so generally accepted by engineers that it has not been looked upon as a matter which was open to debate. While the statement as to the result has changed slightly as new observations and computations have been made, the range is a very narrow one, and the latest figures agree substantially with the earlier computations of the Government engineers. An excellent statement of the principle involved is

found in the report of Maj. Keller, dated August 13, 1903 (Rec. Vol. IV, p. 2603), as follows:

> It seems hardly necessary to prove that if unaccompanied by works which will diminish the flow in the natural outlet, an artificial diversion caused by creating a new outlet for any body of water must lower its level below that which would have existed in the absence of the artificial outlet and diversion and that the amount of such lowering will depend upon the size of the new outlet and the volume thus diverted. Certainly the asserted lowering would hardly be questioned were the diversion at Chicago of volume, for instance, equal to that of the natural discharge at Port Huron. Familiar examples in proof of this might readily be multiplied, but one will suffice: Consider the case of a trough or fountain basin which receives a constant supply of water and from which the waste flows through a rectangular notch or cut in the rim, the maximum discharge capacity of the notch being slightly greater than the constant volume of water flowing into the trough or basin. As a result of the excess discharge capacity of the notch, the basin will never fill flush to the rim, but will reach and maintain some level of equilibrium slightly below the top, and the waste will then equal the constant supply. If now the size or cross section of the outlet is increased either by widening the first notch or by adding another one elsewhere in the rim, the volume of water outflowing will at once be increased and will then temporarily exceed the supply. The surface level

> of the basin will therefore fall until it is so low as once more to bring supply and waste into equilibrium. It is plain that the difference between the new level of the basin and its former elevation is due to the additional notch and is dependent on its size or cross section. The same effects will follow even if the supply is variable, but it will, of course, be more difficult to demonstrate them directly.

See also the report of the Board of Engineers for Rivers and Harbors, of December 16, 1913. (Rec. Vol. IV, p. 2581.)

(D) Evidence sustaining the official reports

The official reports of the United States are sustained in this case by evidence of the highest order.

The expert witnesses for the United States, so far as the testimony deals with matters of an engineering nature, were men of recognized distinction in the engineering profession, or men who, by reason of specialized training in river hydraulics and hydrography were uniquely qualified adequately to solve the questions involved in this case.

We shall not take the time of this Court to set forth the qualifications and experience of these witnesses. An unsatisfactory and incomplete summary is contained in Appellant's Narrative (pp. 126–131), while the qualifications of appellant's witnesses are treated very elaborately. A full account will be found in the portions of the record there referred to.

That the diversion of water at Chicago in the Drainage Canal lowers the Great Lakes system from the foot of the rapids in St. Marys River to some point in the lower St. Lawrence River was not questioned by the engineering experts produced on behalf of the appellant, and there appears no serious questioning of this fact by the appellant in any of the evidence. The controversy is as to the measure of this lowering for a specific volume of diversion. The difference in the conclusions as to the measure of the lowering in the four Great Lakes concerned is as follows:

	Secretary of War, Jan. 8, 1913	Best evidence of appellee	Williams, appellant's witness principal
Lakes Michigan and Huron:	*Inches*	*Inches*	*Inches*
10,000 c. s. f.	6.9	6.0	4.1
14,000 c. s. f.	9.6	8.4	5.7
Lake Erie:			
10,000 c. s. f.	5.4	5.5	3.5
14,000 c. s. f.	7.6	7.7	4.9
Lake Ontario:			
10,000 c. s. f.	4.5	5.0	4.0
14,000 c. s. f.	6.3	7.0	5.6

It appears from these figures that for a diversion of 10,000 c. s. f., Mr. Williams' conclusions were that the lowerings would be substantially *two* inches less for Lakes Michigan-Huron and Erie and *one* inch less for Lake Ontario than the determination of the lowering by the United States Engineers. The controversy, then, is as to the correctness of the conclusions of the Secretary of War and the Government Engineers on the one hand, and those of the only witness for the appellant, who made an analysis of the data of the Government Engineers and reached conclusions

of his own. It should be added that Mr. Williams, in his conclusions, has the partial endorsement of appellant's witnesses, Frederic P. Stearns and John R. Freeman, and of vague generalizations by Lyman E. Cooley. In the analysis of the testimony, however, it will appear that the corroboration of these two engineers, well known in the profession, is of a superficial character, without adequate study of the data.

Appellant's expert testimony in the hydraulic phase of the case is mainly that of a single engineer.

The qualifications of this one engineer to criticize the many expert witnesses of the appellee will not bear close scrutiny. His conclusions were of a partisan character, determined for no other purpose than to contribute to the defense in this case. His failures on previous occasions in attempting to measure the flow of the American channel of the Detroit River, and to conduct discharge measurements on the St. Mary's River do not indicate either experience or expert knowledge. (Rec. Vol. II, pp. 769-780.)

An interesting sidelight is thrown upon Mr. Williams' testimony by the fact that he was a witness for the State of Missouri in the suit brought in this Court against the State of Illinois and appellant to restrain the drainage of sewage into the Illinois and Mississippi Rivers by appellant (200 U. S. 496). In that case Mr. Williams testified to the appalling effects which appellant's diversion and discharge of sewage at Chicago would have on the citizens of

Missouri. Mr. Williams testified, among other things, to the following:

> The danger impending over the citizens of Missouri as the result of the discharge of the sewage of Chicago through the Drainage Canal into the waters of the Illinois River is a most fearful menace to the life and welfare, not only of the citizens of Missouri but of the citizens of other cities below the mouth of the Illinois River, leaving entirely out of consideration the question of typhoid fever. (Rec., Vol. II, p. 763.)

Mr. Williams was of the opinion that—

> there would be great danger of the occurrence of an epidemic of anthrax, not only among the human inhabitants of the State of Missouri but also among the lower animals using the water. (Rec., Vol. II, p. 763.)

and that glanders and other vicious diseases would probably attack the inhabitants of the plaintiff State. Mr. Williams was so positive of his conclusions that he stated that it was—

> almost a certainty that the germs of the disease would be communicated or transmitted to the water supply of the City of St. Louis and the consumers thereof (Rec., Vol. II, p. 765).

And that—

> it would undoubtedly lead to an outbreak of Asiatic cholera in the City of St. Louis. (Rec., Vol. II, p. 765.)

See also further portions of his testimony. (Rec., Vol. II, pp. 766–768.)

Mr. Williams' information on the condition of the Niagara River at the International Bridge Section was the result of observations made from the car window while passing across the bridge on a railroad train. (Rec., Vol. II, p. 915.) His experience was almost exclusively with the measurement of very small streams. (Rec., Vol. II, pp. 781–782.)

Mr. Williams also served as an expert witness against the United States in the case in which the United States sought the condemnation of the water power at Sault Ste. Marie, the case of *United States* v. *Chandler-Dunbar Water Power Company*, 229 U. S. 53. It appears further that when Mr. Williams needed to have some discharge measurements made in the St. Lawrence River in connection with a water-power project he employed a Mr. Blanchard, who was assistant to Mr. Sabin on the St. Clair River, and who was in charge of the discharge measurements of the Detroit River, both under the United States Lake Survey.

The object of the hydraulic measurements on the Great Lakes, begun in 1898, had no bearing whatever on any controversy that might arise regarding the depletion of the Great Lakes system by reason of the diversions at Chicago.

An appreciation of the care in which the appellee's observations were made, of the effort and expense devoted to ascertaining the truth, and of the improbability of any material error can be appreciated only by a review of technical evidence to an extent that would be out of place in this brief. Little idea

of the processes of river measurement and of the inapplicability and shallowness of the appellant's criticisms of the methods employed by appellee's experts can be gained without an elaborate study of their testimony. (See particularly the testimony of Mr. Shenehon.)

Appellant, in criticizing the conclusions reached by appellee's witnesses, lays particular stress upon its claim that appellee's witnesses erred in assuming that a certain stage (or level) of the Lake at an estimated number of minutes before the time the discharge measurement was made was the stage that controlled the particular discharge at the time the measurement was made. (Appellant's brief, pp. 65–66.) In advancing this criticism, appellant's witness (and counsel for appellant) assumed that all ascending stages of the Lake were high stages and that all descending stages were low stages. The increment resulting from a low stage of the Lake was found to be less than the increment from a high stage; translated in terms of effect on the lake levels, a diversion of 10,000 c. s. f. results in a greater lowering when the lake is at a low stage than when it is at a high stage.

Appellant's assumption is without basis in the record or in fact. There are as many ascending stages of the lake at low elevations as there are descending stages; the same is true as to high elevations. For instance, if measurements happened to be taken when the elevation of the lake is rising

even though it be approaching its highest point, and if, as appellant claims, appellee's witnesses were in error as to the time taken for the effect of the elevation to reach the measuring section, the discharge measurements would be too low. On the other hand, after the climax is reached and the elevation is going down, the discharge measurements at high elevations would, according to appellant, be too high. There were several hundred discharge measurements made. Just as many were made during descending stages as ascending stages, and any possible error pointed out by appellant is compensated by the opposite error at other times.

Appellant's brief (p. 66) also contains a very confusing and misleading statement as to assumptions made by appellee's witnesses with respect to the time in which the flow in appellant's canal would be changed throughout from 4,167 c. s. f. to 10,000 c. s. f. Two of the appellee's experts (Ray and Moore) made estimates as to this length of time. Appellant attempted to refute their testimony by tests made; and these tests permitted certain definite conclusions. One of these is that the appellant was attempting to create a flow of 10,000 c. s. f. through the full length of the canal by discharging 9,000 c. s. f., or a little more, at Lockport. Under these circumstances, it is not surprising that a long period of time was required to establish a flow of 10,000 c. s. f. (Rec., Vol. VI, pp. 3447–48, 3505; Rec., Vol. VII, pp. 789, 92.)

The inapplicability of appellant's canal test to the rivers of the Great Lakes may be seen at a glance from the following comparison:

First, the change in flow in the Niagara River, for example, is caused by relatively small change in the lake at the *head* of the river. A hundred or more measurements were made when the water did not rise or fall more than two inches in an hour, and this meant a change of only about two per cent in the flow (Rec. Vol. II, pp. 848–51; Vol. VII, pp. 149–53.)

Second, the change of flow in appellant's canal was caused by sudden opening of gates at *the foot of the canal*, and the almost instantaneous change was from 4,000 to 9,000 c. s. f. or more. This was a change more than sixty times greater than the change in the river flow.

Mr. Shenehon's discussion of reservoir effect in the Niagara River indicates that the appellant's experts were fully cognizant of the hydraulic principles involved in variations of flow. (Rec. Vol. V, pp. 3172–76.)

In fact, these experiments made by appellant in its canal do not in any way disprove the determinations of the appellee's engineers. When the gates at appellant's power house at Lockport were open to the capacity of 9,000 to 10,000 c. s. f., it had to draw off a quantity of water from the storage in the forebay of the power house and canal. If the amount of the storage is taken into consideration, it will be found that the change of flow at various places along the canal up the canal from the power house travels

approximately at the rate determined by the Government engineers. Appellant's stress is laid upon the fact that it takes a much longer time to secure a uniform flowage throughout the entire canal of the full amount of water for which an opening is made at the power house. We must, however, take into consideration the source of supply of the water.

In Lake Erie, for example, at the mouth of the Niagara River, if there is an increment in the elevation it immediately moves down the Niagara River to the International Bridge and the flow is increased correspondingly directly to the elevation. In the case of appellant's canal, however, the effect of the opening (the lag, as it is called in this case) must travel back through the canal over thirty miles to Lake Michigan and then the water from Lake Michigan must travel down the canal again in order to secure a uniform flow of the increased amount. The Chicago River is filled with slips between its various docks. The storage in these slips must be drawn down in order to increase the slope from the river to Lake Michigan. In the meantime Lake Michigan itself may have fallen, and this would tend to retard the flow from Lake Michigan through the Chicago River and canal. In the Niagara River, on the other hand, there is but one factor involved—that is, the elevation of Lake Erie at Buffalo. The change in volume corresponds directly to that change in elevation.

(E) The effect of the appellant's diversion of water from Lake Michigan is a substantial interference with the navigable capacity of the Great Lakes

In addition to the finding of the Secretary of War in his decision of January 8, 1913, in which the Chief of Engineers concurred (Rec. Vol. VII, p. 10), there is considerable evidence of the important results of each variation of an inch in the lake levels. For example, in the report of the International Waterways Commission, dated January 8, 1910, it is stated:

> The traffic which passed through the Detroit River, its busiest link, in 1907, amounted to 71,226,895 tons, valued at about $700,000,000. About 70 per cent of this traffic is carried in large freight carriers which are loaded down to the greatest draft that can be carried into the harbors or through the channels between the lakes. With the depth now available they are usually loaded to a draft of about 19 feet, but careful watch is kept upon the stage of the waterways and advantage is taken of any temporary increase of stage to load the vessels deeper. The number of deep-draft vessels, as well as their size, and the share of lake traffic which they carry is increasing each year, while the lake traffic itself is increasing with great rapidity. Vessels which would carry an additional load of 85 tons for each inch of additional draft have recently been added to the fleet. Every inch added to the available depth of water would, therefore, be of material benefit to commerce. (Rec., Vol. VII, pp. 248–9.)

In the proceedings before the Secretary of War the representatives of the Canadian Government made clear the substantial nature of the effect produced by the diversion of this amount of water as follows:

> That these seemingly small changes are important and divert traffic may be seen from the fact that in 1905, when the water in Lake Huron reached a minimum of 580.66 during the season of navigation and had a mean level for the year 580.95, there passed east through the American canals at the Soo 32,632,268 net tons and through the Canadian canal only 4,146,740 net tons. Practically all the large carriers with grain, iron ore, flour, and wheat passed through the United States canals.
>
> In 1910 when the water in Lake Huron reached a minimum of 579.51 during the season of navigation and had a mean level of only 580.15 the Canadian canal with its three inches more water carried the bulk of the heavy freight east and passed nearly all the large carriers, the figures being Canadian canal, 31,531,036 tons, and United States canals, 15,602,673 tons.
>
> That is to say, that, with plenty water (19.89 feet to 20.78 feet in the Poe lock), the Canadian lock passed only 11.3 per cent of the freight, but, with low water (18.08 to 18.73 feet in the same lock), the extra three inches in the Canadian lock increased these figures to 67 per cent. (Rec. Vol. VI, p. 3643.)

The importance of one inch of depth at the critical points of navigation is shown by the large amounts which have been expended by the Government in increasing those depths a few feet. In Vol. I of the report of the Chief of Engineers for 1893, p. 533, there is a résumé of the projects for improving the depths of the channels at the critical points prior to that time; and in the record in this case there appears (Vol. VI, p. 3624–3625) a summary showing that almost $100,000,000 had been spent prior to June 30, 1911, in improving the harbors and channels of the Great Lakes.

The principal points at which each inch of lowering produces a substantial effect are given by Mr. Shenehon (Rec., Vol. I, p. 320) as follows:

> The floor of the Poe lock is one of the critical points at the present time. The north end of Lake Michigan is an intricate place for navigation, with a good many shoals. And when a shoal is two inches nearer the surface by the lowering of the lake level, it becomes more of a menace. The vessels, in thick weather sometimes get astray, and loss of draught on a shoal may mean a very serious thing to a vessel. The Manitou Passage in Lake Michigan is a place of the same kind; Gray's reef passage, Sturgeon Bay canal, is a critical point, and the entrance to Green Bay is a place where a vessel is likely to get into trouble. The foot of Lake Huron approaching the St. Clair river is another place; also Lake St. Clair; the foot of the Detroit River and Bar Point, which is just beyond the Detroit

> River, and the west end of Lake Erie; and more particularly that part of Lake Erie leading toward Toledo. The west end of Lake Erie is shallow. When the new lock is built at the Sault, giving greater drafts, the Poe lock will cease to be a critical point; and when the Livingston channel is built in the main Detroit River that will cease to be a critical point. But these others remain; these are fixed and that is what I mean by saying that the points that are critical at the present time, after improvements have been made permitting deeper navigation, those that are safely passed over now, two inches of lowering will reduce their efficiency. (Rec. Vol. I, p. 320–321.)

The appellant, however, asserts that this lowering is not to be regarded as a substantial one for the reasons: (1) That the lake levels vary from other causes more than from the effect of the proposed diversion; (2) because lake levels subsequent to the opening of the Drainage Canal were actually higher than they were prior to 1900; (3) because the United States itself has, by improvements in the Detroit and St. Clair Rivers, increased their discharging capacity, and therefore lowered the levels of Lakes Michigan and Huron by from 6 inches to 1 foot.

The first of these contentions is amply disposed of by the Secretary of War's decision and the report of the International Waterways Commission of January 4, 1907:

> The oscillations will remain the same as before, but low water will fall lower and high

> water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works. (Rec. Vol. IV, p. 2420).

See also the testimony of Major Keller (Rec. Vol. IV, p. 2608) and the statement of the representatives of the Canadian Government in the hearing before the Secretary of War (Rec. VI, p. 3640).

Appellant's second argument, that the lake levels were higher after the opening of the canal than they were before, is effectively answered by its own witness, Mr. Williams (Rec. Vol. II, p. 755):

> Q. What inference, as an engineer, is it your intention that the court at the hearing of this case shall draw from your table number LXV so far as it throws light upon the question of fact which is involved in this case?
>
> A. That the lakes are actually higher now than they were before the diversion. That is all.
>
> Q. *In your opinion does it throw any light at all upon the question of fact as to the effect of diversion?*
>
> A. *None whatever.*

As a matter of fact, however, appellant's statement is misleading. The lake levels, averaged over a period from 1861 to 1900, were higher *by six inches* than the average for the period from 1900 to 1910. (Rec. Vol. VII, p. 759.) Reference to the charts on the subject in appellant's narrative (opposite p. 220) will show a considerable lowering after 1910. Fur-

thermore, appellant was not withdrawing 10,000 c. s. f. during this period; the amount increased gradually from 4,314 c. s. f. in 1900 to 7,619 c. s. f. in 1913.

As to third of appellant's arguments, namely, that by the improvements in the Detroit and St. Clair Rivers their discharging capacity had been increased and therefore the level of Lakes Michigan and Huron had been lowered, the evidence of the appellee's engineers showed that the deposit of material in one part of the river had compensated for dredging in other parts. (Rec. Vol. V, p. 3005, 3334, 2844.)

This dredging, however, even if it had all the effect which is claimed for it by the appellant, was done by the United States in the improvement of navigation. It was part of a general project, and may have been deemed wise in the long run, even if there were some lowering of lake levels. Certainly, in the face of the express statements of the government engineers, it furnishes no argument that a lowering such as that which will be produced by the diversion of the water at Chicago is not to be looked upon as a substantial one.

An example of the inaccuracy with which counsel for appellant has prepared this portion of their case for presentation to this Court is found in such statements as the following (Appellant's Brief, p. 67):

> The unimportance of a few inches is shown by the failure of the appellee to remove a platform over the floor of the Poe Lock,

> which reduced the available depth of the Poe Lock approximately 0.33 of a foot, or about 4 inches. This condition existed from the time it was available for navigation in 1898 to 1913, when Mr. Ripley testified as to such condition. (Appellant's Narrative, p. 154.)

Both the above statement and the summary of Ripley's testimony in Appellant's Narrative seek to give the impression that Ripley was testifying from personal knowledge. As a matter of fact, Ripley was testifying from a *plan* of the lock.

Whatever the plan may have been, the platform was *not* built four inches or any other amount above the lock. This is clear from the testimony of appellee's witness De Young and the survey to which he testified. (Rec. Vol. VI, pp. 3977–78.) Curiously, not only is there no mention of De Young's name in Appellant's Narrative, index or otherwise, but his name is not even included in appellant's elaborate index of the record. (Vol. A.) There is no excuse for counsel's misstatement.

Another example is the following statement (appellant's Brief, pp. 67–68):

> The reference plane for the navigation improvement project of 1903, of the critical points of navigation between Lake Superior and Erie ports provided for by Congress, was fixed by the Engineer Corps *six inches lower* because of the diversion of 10,000 second-feet at Chicago. (Appellant's Narrative, p. 155.) In other words, these critical points of naviga-

> tion were dredged and deepened six inches lower than they would have been had the Chicago diversion not existed, and navigation was thus protected from the claimed effects of the Chicago diversion.

Reference to the record discloses that in the 1903 project the improvements were referenced to an assumed water surface of 4.0 lower in one case and 2.7 in the other. (Rec. Vol. III, p. 1298.)

V

The injury to navigation resulting from the lowering of the Lakes

We have already called attention to the findings of the Secretary of War on January 8, 1913, in this regard.

> The lowest careful estimate of injury to American vessels alone is reported by the Chief of Engineers at $1,000,000 per year. (Rec. Vol. VII p. 11.)

This finding of the Secretary of War is supported by the report of the International Waterways Commission of December 1, 1907 (Rec. Vol. IV, p. 2420–2421), and by the evidence of the witnesses for the United States in this case.

In fact, the extent of the injury to commerce which will be inflicted by this lowering of lake levels has never been seriously questioned. In the final report by the Board of Engineers on Waterways from Lockport, Illinois, to the mouth of the Illinois River, dated August 15, 1913, the members of that Board unite in the following statement:

> The largest lake freighters recently built carry over 80 short tons of freight for each inch of loaded draft, and an uncompensated Chicago diversion of 10,000 second-feet would cause a loss to each vessel of at least 446 tons in carrying capacity for each down trip through the channels connecting with Lakes Michigan and Huron. This, based upon 25 trips per season, with vessels returning light, means a loss of at least 11,150 tons per year, and at a freight rate of 55 cents per ton represents a monetary loss of at least $6,000 per large vessel per year. During the season of 1912 there passed through the locks at Sault Ste. Marie over 72,000,000 tons of freight, the greater part of which was carried in vessels of such size as to be affected by any loss of depth caused by a Chicago diversion. The tonnage of 1913 bids fair to exceed the tonnage of 1912. The lowest estimate of the loss to American vessels alone that has been brought to the attention of the Board is over $1,000,000 per annum, and the loss will increase with the increase in the number and size of vessels. (Rec. Vol. IV, p. 2587.)

In this connection should also be considered the statement of the representatives of the Canadian Government in the hearing before the Secretary of War. (Rec. Vol. VI, pp. 3644–3645.) The figures presented by them show with respect to Canadian vessels—

> a total loss per annum of $281,628 to the lake freighters in freight charges alone

in addition to the loss resulting from the building of boats designed for certain depths in reliance upon a maintenance of those depths. They state further:

> The damage accomplished by the lowering of the lakes and St. Lawrence levels can not be computed and shown simply by the loss of carrying capacity in tonnage for vessels. There is more to consider; the loss to the public at large in delaying cheaper rates; the loss to the country in rendering all harbour and channel improvements more costly and retarding their completion. (Rec. Vol. VI, pp. 3644–3645.)

The Shipping Federation of Canada, in its statement before the Secretary of War, reached substantially the same conclusions, finding a loss to Canadian vessels of $273,093 in freight per season. It states also that at least one-half of the trans-Atlantic steamers, etc., would be affected in trading at Montreal, to the extent of ten inches in draught, as would also be affected the deep-draught colliers of the Dominion Coal Co., and, as a result, there would be an additional loss of $322,675 per season. It calls attention to the

> fact that a very large number of steamers at present using the St. Lawrence route have been especially designed and built for that trade, relying on the minimum depth of the present channel which is availed of by shipowners to the last inch. (Rec. Vol. VI, pp. 3678.)

Analysis of evidence as to effect of lowering on navigation

(1) In speaking of the lowering of the surface levels of the Great Lakes and the connecting waterways, or loss of depth in these, it is understood that this lowering is referred to the surface levels which would exist in the absence of the diversion in the Chicago Drainage Canal which causes these lowerings. A lake, as Michigan, for instance, may be actually higher for a series of years following the opening of the Drainage Canal. The variation in the rainfall, the run-off, and the evaporation from these basins is such that the surface levels change from season to season and from year to year. We have periods of high water and periods of low water, and a period of ample supply with its tendency to higher levels may mask for a time the lowering effect caused by the diversion. See testimony of Wheeler (Rec. Vol. I, p. 91) and Shenehon (Rec. Vol. I, p. 286).

(2) Assuming for illustrative purposes a lowering of five inches for a diversion of 10,000 cubic second-feet in the Drainage Canal, the loss in load for draught of 19 feet 7 inches instead of 20 feet, of one of the big lake freighters is, for each inch, from 80 to 88 tons of 2,000 pounds, or 400 to 444 tons for 5 inches loss of draught. The loss in tonnage for losses in draught as computed by appellee's witness, Dr. Sadler (Vol. III, p. 1245), gives substantially the same result. See also the testimony on this question of Noble, Ernst, Townsend, Wheeler, Sabin, Livingstone, Kel-

ler, Shenehon, and Coulby. (Rec. Vol. I, pp. 15–16, 64, 77, 118, 180, 203, 246, 320, and 430.)

(3) For the large type of lake freighters whose loss of carrying capacity is 400 tons for a loss of 5 inches in draught, the annual loss depends on the number of loads carried during the season. Taking twenty round trips as a basis, and considering the upbound trips as light or partial loads, but the down bound trips as loaded to the limit of navigable depths, the loss of freight for the year for such a vessel is 8,000 tons. Some considerable range in the actual number of trips made appears from the testimony; see testimony of Livingstone, Coulby, Sabin, Wheeler and Adams. (Rec. Vol. I, pp. 203–205, 430–440, 443, 181, 118, and Vol. III, pp. 1372–3.) The testimony leads inevitably, we believe, to the conclusion that twenty round trips is a conservative number as a basis for computing the measure of damage to commerce. The inclusion of small craft in Professor Adams' figures accounts or his low estimate of the number of trips (11.6).

(4) The measure of annual damage based on an assumed loss of draught varied from the figures testified to by appellant's witness, Dr. Sadler (Appellant's Narrative, p. 159; Appellant's Brief, p. 68) to considerably higher figures established by the testimony of the appellee's witnesses, Wheeler, Livingstone and Coulby. (Rec. Vol. I, pp. 118, 207, 481.) Wheeler estimated the annual loss at $227,230 for each inch of draught loss; Livingstone, $500,000 and Coulby

(testifying merely to the loss of his fleet of 61 vessels), $48,800.

While the maximum losses of carrying capacity are borne by the biggest vessels, mention at least should be made of the damage to a great fleet of smaller steamers and sailing vessels trading in the shallower ports.

(5) The above estimates of damage are based on the conditions for one of the years 1907, 1912 and 1913. In 1907, the commerce passing through the Soo Locks was 58,217,214 tons, and in 1913, it was 79,718,344 tons. an increase of 37 per cent in six years. In ten years, 1903 to 1913, the commerce increased from 34,674,437 to 79,718,344 tons, an increase of 117 per cent. In the 20-year period, 1893 to 1913, the commerce increased 638 per cent, so that the commerce of the latter year is more than seven-fold that of the former year. (Statistical report of commerce 1913, p. 11, Rec. Vol. VI, p. 3600.)

The record does not reveal the increase from 1913 to 1924.

(6) The abstraction of a great volume of water from the Great Lakes system by the diversion at Chicago entails great losses in the water power capacity of the Niagara and St. Lawrence rivers. At Niagara Falls alone, 10,000 cubic second feet is equivalent when developed with the highest efficiency to 280,000 horse power. (Rec. Vol. 1, p. 314.) On the St. Lawrence River, in the Long Sault Rapids alone the loss is 45,000 horse power. (Rec. Vol. I,

pp. 314–15–33.) The losses to the Canadians in the depletion of the volume of flow of the Cedar, Cascade, Split Rock, Coteau and Lachine Rapids has not been estimated, but is a very considerable figure. Assuming a gross annual rental of $10 per horse power on on the turbine shaft at Niagara Falls, the annual aggregate rental amounts to $2,800,000, and half this amount capitalized at ten per cent, is $14,000,000. The annual rental value of an electrical horse power at Niagara Falls is stated by appellee's witness F. G. Ray, at $18 per year. (Rec. Vol. V, p. 2814, 2849–50.)

While it is recognized that the water diverted in the Chicago Drainage Canal will augment the water powers at Lockport, and on the Des Plaines and Illinois rivers, these powers are insignificant and petty in comparison with the great developments in the Niagara River.

(7) The lowering of the surface levels of the waters of the Great Lakes from the ship docks at Sault Ste. Marie to the Gulf of St. Lawrence does entail a loss of draught in that class of lake vessels carrying the greater percentage of freight. The draughts to which these vessels are loaded crowds the limit of draught in the navigable channels. In support of this statement we cite the testimony of appellee's witnesses, Noble, Ernst, Townsend, Sabin, Livingstone, Keller, and Ray, and appellant's witness, Ripley. (Rec. Vol. I, pp. 15, 26, 63, 76–77, 179, 180, 185, 201, 246–7, 248, 280; Vol. III, 1318, 1343–44.)

(8) While the damage to commerce due to lower surface levels caused by the diversion at Chicago is already great, this damage will be aggravated when the present through routes of vessel travel are developed for larger, deeper draught vessels; or the cost of this development will be greatly increased by the extra five or six inches of earth or rock excavation required to secure the same draught with lowered lake and river surface levels.

As illustrative of the measure of this increased cost, assume an artificial channel 300 feet wide at bottom and a mile in length. For six inches extra depth, the increase in excavation is 29,333 cubic yards. Estimating the cost of this excavation at $2 per yard (Rec. Vol. III, p. 1319) the cost is $58,666 per mile.

The cost of excavation for six inches required by lower surface levels for navigation on draughts of 25 feet or 30 feet because of the larger areas involved will be much in excess of the cost of excavation to make 20 and 21 foot navigation available, assuming the same lowered lake surface levels.

Deep draught navigation on the Great Lakes is not speculative, but certain. See testimony of appellee's witnesses, Ray and Noble (Rec. Vol. V, p. 2809; Vol. I, p. 3), and of appellant's witnesses, Cooley and Ripley (Rec. Vol. III, pp. 1706–7, 1818–19).

The first passage through the Soo locks of a vessel over 500 feet in length was in 1904. In

1913, 170 vessels ranging in length from 510 to 617 feet passed the Soo locks, and these vessels carried 52 per cent of the freight through these locks, or 41,400,000 tons. Statistical Report of Commerce, 1913. See also testimony of Dr. Sadler. (Vol. III, pp. 1253 et seq.) As an illustration of the growth and the present needs of draught for ocean traffic, the depth of the Panama Canal's depth recommended was 40–40½ feet. (Rec. Vol. III, p. 1317.) Appellant's witness, Sadler, assuming that business on the lakes should increase at the same rate during the next 24 years that it had during the preceding 24 years, estimated the damage done by the loss of three inches draught at $30,000,000.

(9) Not only have the lengths of vessels increased, but the larger types have been built for, or are capable of loading to, draughts of from 21 to 25 feet. See testimony of appellee's witnesses, Wheeler, Sabin, Livingstone, and Coulby (Rec. Vol. I, pp. 118–119, 179, 207–208, 209, 431, 436) and appellant's witness Sadler (Rec. Vol. III, pp. 1251–52).

(10) The surfaces of the lakes are subject to certain fluctuations due to seasonal changes, and certain oscillation due to barometric inequalities and wind. Some testimony on the part of the appellant purported to show that a lowering of a few inches due to the lake diversion will, for this reason, be insignificant and cause no substantial injury to commerce. (Rec. Vol. III, p. 1776.) The fallacy of this suggestion, which appears obvious, was clearly estab-

lished by the testimony. We quote from the testimony of appellee's witness Shenehon:

> Whatever the water level is, if it had been lowered, say two inches, by a diversion, you would still be short your two inches where you needed it, in the critical places. The natural fluctuations due to winds and to seasonal conditions are independent of the Drainage Canal, and the loss in draft is always measured by the amount of the lowering; you are always two inches closer to the bottom in such a case, whether the lake is raised or whether the lake is tilted up or not; you are always two inches closer to the bottom than you would be otherwise; and when you are running over critical areas two inches may count. Perhaps I should say: When you are attempting to run over critical areas. (Rec., Vol. I, p. 320.)

See also the testimony of appellee's witnesses Ernst, Wheeler, and Coulby. (Rec. Vol. I, pp. 64, 70, 71, 116, 180, 444–445.) See also the portions of the report of the International Waterways Commission, quoted by General Ernst:

> The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works.
>
> A permanent average lowering of six inches in the lake's level therefore is not easily observable, and will probably not be noticed by navigators.

(11) It is good practice to improve channels and waterways so as to allow some clearance below the keel of the vessel. In rivers or protected channels where waves are not large in times of storm, this clearance is needed in order to allow for the squat or settling of a vessel when running at high speeds. If this clearance is not available, a loss of speed to the vessel is the result. In waterways exposed to wave action an additional clearance is needed to care for the surging of the vessel in a sea. Whatever clearance in these waterways is desirable, it is obvious that the lowering of the surface levels by the diversion at Chicago lessens the effective value of this clearance, and that channels and waterways of this character are damaged to this extent. Assuming a lowering of six inches due to the diversion at Chicago, it becomes apparent that where under the condition of no diversion a foot existed between the keels of vessels, but half a foot remains after the effects of the diversion have been accomplished. Considerable testimony along this line has been incorporated by the appellant, which purports to show that since this clearance is desirable, the effect of the lowering is of small moment. No controversy exists as to this clearance being good practice. It does not follow, however, that any large clearance of this kind is desirable or necessary on the floor of a ship lock such as that at Sault Ste. Marie, and the evidence is conclusive that no such clearance has existed in the critical improved channels in the lower Detroit River. The absence of

this clearance in the Detroit River has compelled vessels to run at slow speed.

(12) The lessened depth due to the lowering of the surface levels of the waters of the Great Lakes system by reason of the diversion at Chicago creates an obstruction to navigation wherever the mean depths are at present 20 feet or less, and having in mind future navigation, wherever the depths are 30 feet or less, and this obstruction exists in every bay, harbor, and inlet of these lakes including the terminal chambers at the entrance to ship locks. It creates an obstruction to navigation also in the St. Marys river from the ship locks, and including the ship locks; in the St. Clair, Detroit, Niagara, and St. Lawrence Rivers wherever the depths are within the limitation stated above. Places where the depths are close to the present limits of navigation, 19 to 20 feet, have been particularly spoken of in the testimony as critical areas. As the effect of this surface lowering is to limit the navigable areas of the Great Lakes and to change the sailing courses of the through freighters and make them longer, the lowering is an obstruction to navigation and a damage to the commerce of the Great Lakes. The limitation of the available sailing courses for the vessels of the Great Lakes caused by this lowering constitutes an obstruction to navigation. It is impracticable to limit the navigation of the Great Lakes only to avenues laid down as sailing courses.

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In times of storm and fog many vessels diverge widely from the avenue traversed in times of clear air and fair weather. Any shoal or shallow area which has less depth by reason of the diversion at Chicago is an increased menace to vessels under these conditions, and is therefore an obstruction to navigation. While the limitations of loading will for a large percentage of the tonnage be fixed by the critical places in the main avenues of commerce, such as the Soo Locks, the Middle or West Neebish in the St. Marys River, Lake St. Clair, the lower Detroit River, the West end of Lake Erie, the approach to the particular harbor as Milwaukee, Chicago, Gary, Indiana Harbor, Toledo, Cleveland, Buffalo, or Toronto, the vast shallows and shoals of the Great Lakes are still more of a menace with lower levels than with such levels as would exist in the absence of the diversion at Chicago. The foregoing is, we believe, conclusively established by the evidence. See particularly the testimony of appellee's witness Ray (Rec. Vol. I, pp. 29, 273–278, 281–3), Shenehon (Rec. Vol. I, pp. 320–321), and Livingstone (Rec. Vol. I, p. 222) and for further evidence (Rec. Vol. I, pp. 105, 201, 246–248, 429). Ray cites many particular instances in which a difference in draught of two inches determines whether a boat will ground or clear (see Rec. Vol. I, pp. 246–248).

VI

Evidence as to methods of compensating for loss of lake level

To offset the damage to navigation caused by the lessened drafts resulting from the diversion at Chicago, three suggestions are offered by the appellant. First, build boats of such additional length that on the lessened draught they would carry the same amount of freight as the shorter boats on the impaired draught; second, excavate the various waterways and deepen the lock chambers to regain the lost draught; third, raise the surface levels of the various lakes and rivers by regulating or compensating works, so as to secure the original draughts.

Offsetting damage by lengthening vessels

The first suggestion of lengthening the vessels appears trivial. The appellant's witness Sadler estimated the cost of additional length to offset loss of draught inches as follows:

93 vessels 500 to 600 ft. in length	$1,404,300
73 vessels 600 ft. class	$1,197,200

This method of lessening the extent of the damage to commerce is, of course, a direct tax on the vessel interests, and a tax that goes on eternally, and is worthy of small consideration as a feasible solution.

Partially restoring depths by dredging, etc.

The second suggestion of restoring navigable depths by deepening the bottom in the various waterways, including the local chambers, had already received consideration by the International Waterways Com-

mission in its report on the Chicago Drainage Canal in 1907. The findings of this Commission are as follows:

> 28. The total cost of restoring the depth in the harbors of the Great Lakes and the channels between the lakes is therefore roughly $10,000,000, and of restoring it in the Welland and St. Lawrence Canals is $2,500,000 additional, or $12,500,000 in all.
>
> 29. The shores of the Great Lakes are very far from being fully developed, and it is highly probable that many harbors not now in existence remain to be created, or if in existence remain to be improved. The lowering of the lakes' surface increase the difficulty and cost of such improvements. This consideration is of importance, although no money value can now be given it.
>
> 30. The expenditure of the sums mentioned above will restore the depths now existing, but it will not prevent very serious annoyance to the navigation interests during the execution of the work. The time required will be several years, and in the meantime the vast commerce of the Great Lakes will be hampered not only by deficient depth but also by the occupation of the channels, already crowded with commerce, by the excavating machines. (Rec. Vol. 4, p. 2422.)

The highly superficial character of the estimates made by the appellant's witness Ripley is revealed by his testimony. (Rec. Vol. III, pp. 1306–7, 1347–9, 1350–1, 1353.)

This testimony indicates very clearly that the method of excavation and deepening alone will not restore the navigable depths when the surface levels are lowered four inches or six inches, and that the cleaning-up processes will not restore the advantageous condition of the channel as it would exist in the absence of the lowering caused by the diversion at Chicago. The extra depths excavated by prior contracts are an asset to present navigation by allowing some partial clearance, at least, below the keels of vessels for more facile navigation; and in view of the greater navigable depths which the testimony in this case indicates are certain to prevail on the Great Lakes, the work of excavation already done is an asset towards the future deepening which the appellant in this case may not impair. In the end, Mr. Ripley's estimate is of so approximate a character and has omitted so many important channel ways, and has failed to take into account great lake areas where vessels may seek refuge in time of storm, that the cost indicated by Mr. Ripley, great as it is, is entirely inadequate to restore the navigable depths of the Great Lakes system and remove the obstructions to navigation created by the diversion at Chicago.

Regulating or Compensating Works

This method of restoration appears in some cases to represent sound engineering practice. The Board of Engineers on Deep Waterways in its report of June

30th, 1900, recommends regulating works to be placed at the head of the Niagara river. These works were to consist in part of submerged dams or weirs, and in part of movable gates operated from overhead platforms resting on masonry piers. The estimated cost at this time was $796,923. The raising of the level of Lake Erie contemplated by these works was much in excess of the lowering caused by the diversion of 10,000 cubic second feet at Chicago, and was probably enough to more than compensate in Lake St. Clair and nearly compensate Lakes Michigan and Huron and the St. Marys river. Appellee's witness, Alfred Noble, was a member of this board. Mr. Noble testified (Rec. Vol. I, page 29) that since 1900 the cost of engineering works in general has increased. The presumption is that these regulating works would cost more at the present time than in 1900. The maintenance and operation of regulating works of this character should be taken into consideration in estimating the full outlay.

The International Waterways Commission in a report dated June 20, 1913, recommends compensating works to be built in the Niagara river just above Chippewa, within a few miles of the rapids above the cataract at Niagara Falls. These compensating works consist of a series of submerged concrete weirs stretching across the river. The estimated cost of these works is $3,500,000. The cost of annual maintenance and operation is not stated. These compensating works are estimated to

raise the level of the Niagara river in the vicinity of the works about three feet, and to raise the mean level of Lake Erie 4¼ inches, the mean level of Lake St. Clair about 2¾ inches, and the mean level of Lakes Huron and Michigan about 1⅛ inches. Notwithstanding the great expense of these works, it appears that for the mean lake level compensation is not such as to fully offset a lowering of 5½ inches of Lake Erie caused by the diversion of 10,000 cubic second feet at Chicago. In times of low water, however, the estimated compensating effect is about 6⅛ inches, which more than compensates the lowering by the diversion above mentioned. It is interesting to note in connection with the project of the International Waterways Commission the criticisms which this commission makes in its preliminary report upon the earlier project of June 30th, 1900, of the Board of Engineers on Deep Waterways. As indicative of the extreme differences of opinion as to the feasibility, expense, best method, and probable results of such regulating or compensating works as the appellant proposes, we need only refer to the testimony in which the subject is discussed. (Rec. Vol. IV, pp. 2616–2621, 2621–2627; Vol. V, p. 3348; Vol. IV, pp. 2614–2615, 2588–89; Vol. III, p. 1172, 1173–1175; Vol. II, pp. 742–3; Vol. III, pp. 1336–1339; Vol. I, p. 328.)

The International Waterways Commission regards the project of the Board of Engineers on Deep Waterways as impracticable. The Board of Engineers on Lakes to Gulf Waterway criticizes as unwise the

scheme of regulation proposed by Dean Shenehon. Appellant's witness Ripley appears to regard movable regulating works as desirable to maintain the full section of waterway in times of high water, which the scheme of the Lakes to Gulf Board violates in its method of submerged weirs. The project of submerged weirs of the above Board places the crest of these weirs 24 to 25 feet below the surface level of the St. Clair River, and the effect of these weirs is to increase the current wherever the weirs are located. In view of future navigable depths of 30 feet on the Great Lakes as indicated by the works of the Canadian government in the Welland Canal, these submerged weirs will become an obstruction to navigation. It is a question whether this system of submerged weirs on the St. Clair River would not augment the formation of ice blockades, and therefore tend to unduly raise the levels of Michigan-Huron and deplete during the winter season the elevations for Lakes Erie and Ontario, so that the Great Lakes system is thrown out of coordination.

We can not believe, however, that this Court will regard any of this evidence as material to the issues of this case.

To put into operation any scheme of compensation or regulation may require under the existing treaty with Great Britain the favorable action of the Joint High Commission.

Article IV of the treaty with Great Britain concerning the boundary waters between the United

States and Canada, proclaimed May 13, 1910, provides:

> The high contracting parties agree that, except in cases provided for by special agreement between them, they will not permit the construction or maintenance on their respective sides of the boundary of any remedial or protective works or any dams or other obstructions in waters flowing from boundary waters or in waters at a lower level than the boundary in rivers flowing across the boundary, the effect of which is to raise the natural level of waters on the other side of the boundary, unless the construction or maintenance thereof is approved by the aforesaid International Joint Commission. (Rec. Vol. IV, p. 2564.)

The evidence submitted by the appellant as to the cost of deepening channels and the expense of constructing compensating works only emphasizes the fact that this diversion of water at Chicago is part of one problem affecting both this nation and Canada, the solution of which, so far as this nation is concerned, must be in the hands of the Federal Government. It is the contention of the appellee that this is precisely where it has been placed by Congress; and that the withdrawal of the water, as well as the deepening of channels and the building of compensating works, must be authorized by Congress and approved by the War Department.

VII

Injury to navigation due to current caused by excess flow through Chicago River

The current in the Chicago River in excess of the current authorized by the Secretary of War is extremely dangerous to navigation. This matter becomes particularly important in this case not only because it is a material interference with navigation but because it is in direct violation both of the Act of Congress of March 3, 1899, and the permits of the Secretary of War.

It appears in the record that the flow through the Chicago River varies throughout the day. It is increased in late afternoon and evening, which is the time when the greatest demand is being made upon the power house at Lockport.

It is true that the cross section of the Chicago River has been increased since 1901, and that a larger volume of flow can be accommodated without increasing the current. The testimony of the Chief Engineer of the appellant (Rec., Vol. III, p. 1598) on direct examination is as follows:

> The river has been widened to a width of at least 200 feet and it has been deepened so that at the dock lines there is a depth of water of 16 feet, gradually deepening to a point 50 feet out from the docks where it is 26 feet deep for the middle 100 feet of the river.

This testimony is somewhat misleading. This does not apply to openings at bridges, and there are

many bridges in the Chicago river. Upon cross-examination of this witness (Rec. Vol. VI, pp. 3482–3488) it appeared that at the bridge openings the total width in some cases is as low as 140 feet, and at the St. Charles Air Line Bridge the width of the two draws are 55½ and 59½ feet. The width of the river is less than 175 feet at nearly every bridge between Halsted Street and the lake; at Van Buren Street the total width, including a by-pass, is 156 feet; at Taylor Street the width is 140 feet, with two by-passes of 137 square feet each.

Of course, the situation at the narrowest points is the one to be considered. These are the critical, the dangerous, points.

The testimony shows that the current in the Chicago river is greatly in excess of a mile and a quarter per hour and that it is detrimental and dangerous to navigation. The appellee called as witnesses a number of ship captains and navigators who have spent their lives in navigation and who have had experience in navigating ships on the Chicago river from two to thirty years.

The testimony of these men was that the current in the river is from two to ten miles per hour; that the safe draught was not over eighteen and a half feet; and that it was very dangerous to navigate the Chicago river because of the excessive current. (Rec. Vol. V, pp. 3020–3021, 3022–3023, 3023–3026, 3028, 3029, 3031–3033, 3033–3034, 3043, 3044, 3054.)

The largest boats do not navigate the Chicago river; they can not come in. A boat, however, of

50 feet beam loaded to 20 feet would occupy a cross section of approximately 900 square feet. Two such boats would occupy about one-half of the entire cross section of the river at many places, leaving that part of the river nearest the docks, the sides and bottom where there is normally a slow current for the passage of water. In this way the mean velocity is necessarily doubled and the maximum velocity would be correspondingly increased. While the testimony that there is a current of ten miles an hour may be somewhat exaggerated, yet from this evidence it is obvious that there must be a very great current and of course many times in excess of a mile and a quarter per hour rate.

Most of the witnesses were not cross-examined. What cross-examination there was by appellant was largely to show that the Chicago river is now deeper and wider than it was before the Sanitary District canal was opened, and that much of this work had been done by the Sanitary District. Of course, this is perfectly true, and as far as cross section is concerned, the navigability of the Chicago river is now greatly improved. On the other hand, during the last fifteen years, as is pointed out elsewhere in this brief, the size of boats has greatly increased and channels and harbors have had to be deepened and widened accordingly. Also, it should be kept in mind that the improvements in the Chicago river have been made with the consent of the Secretary of War and the Chief of Engineers.

The current and the navigability generally of the Chicago river was before Secretary of War Stimson upon the application of the Sanitary District of February 5, 1912. (Rec. Vol. VI, pp. 3616, 3618.)

As the condition exists to-day in the Chicago river there is a current far in excess of any current that has received any semblance of approbation by the Secretary of War, and a current which is detrimental and in fact dangerous to the navigation of the river. This is caused by the fact that the appellant is flowing through that river more water than is authorized by the Secretary of War. It amounts to a modification of the condition and capacity of the channel of a navigable water of the United States, and aside from all other elements of the case is sufficient to justify an injunction by this court in the case involving the diversion through the Chicago river.

VIII

There are no acts of Congress and no investigations or surveys of United States officers which amount even remotely to an invitation to build this canal, or to authority for its construction

Appellant's contention that authority for its unauthorized acts is to be found in the Act of Congress of 1827 relating to the Illinois and Michigan Canal, is discussed at length under our Point V, A (*infra*, p. 203).

Similar contentions with respect to the Niagara Falls Act of 1906 and the Canadian Boundary

Waters Treaty of 1910, are dealt with under subdivisions B and C of Point V (*infra*, pp. 219 and 226).

The attempt to work out some sort of estoppel from the reports of Government engineers with respect to the improvement of navigation between Lake Michigan and the Mississippi river, is discussed in our Point VIII (*infra*, p. 255).

IX

The evidence as to the cost of building sewers, purifying works, etc., in case the unauthorized diversion is enjoined

Appellant's brief (pp. 73–74) presents certain extraordinary conclusions as to the effect of forcing it and the City of Chicago to adopt methods such as are successfully being employed by practically all the large cities on the Great Lakes. In view of the appellee's motion to strike those portions of appellant's answer setting up such matters on the ground of their immateriality, no attempt was made by the appellee to rebut the testimony on which the conclusions are based. Reference to the record will disclose that the testimony is largely by interested witnesses and that it is not invulnerable. Inasmuch as the appellant predicates its contentions on the theory that such testimony is "undisputed evidence," it will not be inappropriate to direct the attention of this Court to certain significant facts.

The water supply and sewage disposal of a great city are usually parts of a problem which is handled by *one* municipality. In the case of Chicago we have

two municipal corporations dealing with this problem—the City of Chicago and the Sanitary District. The city has control of the water supply and the sewers. The Sanitary District undertakes to dispose of the sewage. The water supply is taken from Lake Michigan, and the expense to the city, therefore, for water supply is very much less than other cities are obliged to incur for that purpose.

Even if the City of Chicago were obliged to rebuild its system of sewers and to construct purifying works in order to take care of its sewage with the quantity of water now authorized by the Secretary of War, the expense to which it would be put on account of water supply and sewage disposal would not be greater, in proportion to its population, than that to which other cities have been put and which other cities must incur in the near future. Mr. Fuller, one of the witnesses for the appellant, stated (Rec. Vol. III, p. 1468) that the cost to the City of Washington for water supply and sewage disposal works was $104 per capita, and presented figures showing that for a part of its water supply works the City of New York has already expended more than $200,000,000. In the light of these figures it can not be said that appellant's highest estimate of expense is more than some other cities are paying for a pure water supply.

It will not do to say that there is no other way of disposing of the sewage of Chicago, because many other cities are obliged to dispose of their sewage, and are disposing of it, in other ways.

It should be remembered that except for a brief hearing in April, 1923, the bulk of the testimony on this question was heard prior to December, 1914. At that there is a statement in the record of the hearing before the Secretary of War as to other successful methods of sewage disposition in London, Manchester, and Birmingham, England; Emscher District, Germany; Columbus, Ohio; Baltimore, Md.; and Toronto, Canada. In all these cases, according to the statement—

> the quantity of water for diluting the final affluents is quite insignificant.

The statement says further that—

> the subject of purification of sewage is far beyond the experimental state. * * *
>
> It is to be noted also that the experience of other cities, notably the experience of Manchester with the Manchester Ship Canal, shows conclusively that the natural discharge of the Chicago river plus, say, 1,000 second-feet drawn from Lake Michigan for navigation purposes, would be amply sufficient to carry away through the drainage canal the purified effluents of Chicago and the whole Sanitary District. (Rec. Vol. VI, pp. 3648–3649–3650–3651–3652.)

The appellant itself has recognized that it is only a matter of time when it must adopt another method of sewage disposal. (See statement of appellant; Chief Engineer at the hearing before the Secretary of War, Rec. Vol. VI, pp. 3691–3692.)

The reports of Engineers Hering and Fuller (Rec. Vol. I, pp. 496–548), and of Mr. Wisner, Chief Engineer of the appellant, show clearly that there are other feasible methods of sewage disposal which may be used by Chicago, and that, really, the only question involved is one of expense. The Secretary of War dealt with this contention of the appellant as follows:

> I have carefully examined, however, the evidence which both sides have introduced bearing upon the sanitary needs of the City of Chicago, and my conclusion is in no way shaken. I am not persuaded that the amount of water applied for is necessary to a proper sanitation of the City of Chicago. The evidence indicates that at bottom the issue comes down to the question of cost. Other adequate systems of sewage disposal are possible and are in use throughout the world. The problem that confronts Chicago is not different in kind but simply larger and more pressing than that which confronts all of the other cities on the Great Lakes, in which nearly 3,000,000 people of this country are living. The urban population of those cities, like that of Chicago, is rapidly increasing, and a method of disposition of their sewage, which will not injure the potable character of the water of the lakes, must sooner or later be found for them all. The evidence before me satisfies me that it would be possible in one of several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition. A recent report of the

> engineer of the sanitary commission (Oct. 12, 1911) proposes eventually to use some such method, but proposes to postpone its installation for a number of years to come, relying upon the present more wasteful method in the meanwhile. It is manifest that so long as the city is permitted to increase the amount of water which it may take from the lakes there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage. (Rec. Vol. VII, pp. 14–15.)

This feature of the case need not, we believe, be further discussed for, after all, under the theory of appellee, these considerations urged by the appellant can not be given effect over the paramount rights of Federal control of Navigation.

ARGUMENT ON THE LAW

(Pages 123-326)

I

All the waters here involved are "navigable waters of the United States" as that term is used in the various acts of Congress

As is already apparent from our Statement of the Case, the waters involved in this litigation are the following:

1. The Great Lakes except Lake Superior, the various connecting waters between the Great Lakes and the St. Lawrence River.

2. The Chicago River, including its branches, and the Calumet River, including its branches.

3. The Desplaines, Illinois, and Mississippi Rivers.

There is substantially no dispute as to the navigable character of these waters (except possibly as to the upper portion of the Little Calumet River), nor is it disputed that these waters are embraced within the term "navigable waters of the United States" both as employed in the Acts of Congress and as defined by this Court in discussing the scope of the power of Congress with reference to interstate commerce. We shall, however, take this occasion to refer to decisions of this Court which determine the matter conclusively.

The definition of "navigable waters of the United States" is originally to be found in the case *The Daniel Ball* v. *United States*, 1871, 10 Wall. 557,

although it was necessarily involved in the prior decision of this Court in the case of *The Propeller Genesee Chief et al.* v. *Fitzhugh et al.*, 1851, 12 How. 443, and was recognized by the Congress of the Confederation over sixty years prior thereto in the Ordinance of 1787 (see *Economy Light & Power Co.* v. *United States*, 256 U. S. 113). The definition as stated in the case of *The Daniel Ball* is as follows:

> Those rivers must be regarded as public navigable rivers in law which are navigable in fact. And they are navigable in fact when they are used, or are susceptible of being used, in their ordinary condition, as highways for commerce, over which trade and travel are or may be conducted in the customary modes of trade and travel on water. And they constitute navigable waters of the United States within the meaning of the Acts of Congress, in contradistinction from the navigable waters of the States, when they form in their ordinary condition by themselves, or by uniting with other waters, a continued highway over which commerce is or may be carried on with other States or foreign countries in the customary modes in which such commerce is conducted by water. (10 Wall. 563.)

The principles thus stated have been recognized and applied by this Court in a great many cases among which we mention *United States* v. *The Steamer Montello*, 1870, 11 Wall. 411; same case, 1874, 20 Wall. 430; *Oklahoma* v. *Texas*, 1921, 258 U. S. 574; *Brewer-Elliott Oil & Gas Co.* v. *United States*, 1922, 260 U. S. 77.

The character of the Chicago River, its branches and forks as navigable waters of the United States is specifically recognized in *Escanaba and Lake Michigan Transportation Co.* v. *City of Chicago*, 1883, 107 U. S. 683. The same is true of the Calumet River in *Cummings* v. *Chicago*, 1902, 188 U. S. 410, and of the Desplaines and Illinois Rivers in *Economy Light & Power Co.* v. *United States*, 256 U. S. 113.

The Great Lakes, their connecting waters, and the St. Lawrence River, in addition to being navigable waters of the United States (*The Propeller Genesee Chief*, 12 How. 443; *United States* v. *Rodgers*, 150 U. S. 249; *Illinois Central R. R. Co.* v. *Illinois*, 146 U. S. 387) are "international waters, being dedicated in perpetuity to the common navigation of all the inhabitants" of the countries on both sides of the boundary (Moore, International Law Digest, Vol. 1, p. 675; Hyde, International Law, 1922, Vol. 1, pp. 320–321).

The international character of these waters has been recognized by this court in *The Propeller Genesee Chief, supra* (pp. 453–454):

> These lakes are in truth inland seas. Different states border on them on one side, and a foreign nation on the other. A great and growing commerce is carried on upon them between different states and a foreign nation, which is subject to all the incidents and hazards that attend commerce on the ocean. Hostile fleets have encountered on them, and prizes been made; and every reason which existed for the grant of admiralty jurisdiction

> to the general government on the Atlantic seas, applies with equal force to the lakes. There is an equal necessity for the instance and for the prize power of the Admiralty Court to administer international law, and if the one cannot be established, neither can the other.
>
> Again. The Union is formed upon the basis of equal rights among all the States.
>
> * * * * *
>
> That equality does not exist, if the commerce on the lakes and on the navigable waters of the West are denied the benefits of the same courts and the same jurisdiction for its protection which the Constitution secures to the States bordering on the Atlantic.

In *Moore* v. *American Transportation Co.*, 24 How. 1, 37–38, this Court, in holding that navigation of the Great Lakes did not fall within the statutory phrase "inland navigation," said:

> But the business upon the great lakes lying upon our northern frontiers, carried on between the states, and with the foreign nation with which they are connected (and this is the only business which Congress can regulate, or with which we are dealing), is of a very different character. They form a boundary between this foreign country and the United States for a distance of some twelve hundred miles, and are of an average width of at least one hundred miles; and this, without including Lake Michigan, of itself three hundred and fifty miles in length and ninety in breadth, which lies wholly within the United States.

> The aggregate length of these lakes is over fifteen hundred miles, and the area covered by their waters is said to be some ninety thousand square miles. The commerce upon them corresponds with their magnitude. * * *
>
> This commerce, from its magnitude, and the well known perils incident to the lake navigation, deserves to be placed on the footing of commerce on the ocean; and we think, in view of it, Congress could not have classed it with the business upon rivers, or inland navigation, in the sense in which we understand these terms.
>
> These lakes are usually designated by public men and jurists, when speaking of them, as great inland waters, inland seas, or great lakes.

In *United States* v. *Rodgers*, 150 U. S. 249, 258, the Great Lakes were held to be "high seas" within the meaning of an Act of Congress. See also *United States* v. *Chandler-Dunbar Water Power Co.*, 229 U. S. 53, in which this Court said that the matter of the levels of the Great Lakes (p. 67)—

> was a matter of international consideration, for Canada, as well as the United States, was interested in the control and regulation of the lake water levels.

The international character of the Great Lakes and their connecting waters is confirmed by the Boundary Waters Treaty of January 11, 1909. Inasmuch as this treaty is discussed more at length elsewhere we shall pause here only to note that to a limited extent Lake Michigan is likewise given an international

character by the covenant in Article I that the free and open navigation provided for with respect to the boundary waters "shall extend to the waters of Lake Michigan."

II

The level of the Great Lakes and the diversion of water from the St. Lawrence River basin to the Mississippi River basin are both subjects of interstate commerce national (and also international) in character and are of such a nature as to require exclusive control by Congress. Independently, therefore, of any assertion of control by Congress, the Illinois Enabling Act of 1889, in so far as it authorized and directed the appellant to do the acts here complained of without authorization of Congress, was void.

We propose under this heading to demonstrate that independently of the Acts of Congress of September 19, 1890, and March 3, 1899, the State of Illinois (acting through its creation, the Sanitary District of Chicago) had no right or power to do the acts here complained of. Particularly it had no right to do any act, whether within or without its territorial limits, that would lower the level of the Great Lakes, their connecting waters, and the St. Lawrence river, or to create a large navigable river debouching into another river basin, without the authority of Congress. The subject of the level of these waters is, we believe, national (and, indeed, international) in character; it is, therefore, of a sort as to which the non-action of Congress is to be taken as a declaration that it shalll be free from interference by the several States. The conclusion to which we are led is that Sections 20

and 23 of the Enabling Act of the Illinois legislature of 1889, in so far as they purported to require the appellant to withdraw certain amounts of water from Lake Michigan (20,000 cubic feet for each 10,000 inhabitants of the district) irrespective of the authorization of Congress, were unconstitutional and void because of their inevitable conflict with the exclusive power of Congress over such subjects of interstate commerce.

In view of the fact that Congress has beyond question asserted its paramount control over these subjects by the Act of March 3, 1899 (Section 10 of which specifically prohibits these acts of the appellant), our contentions under the present heading may be thought unnecessary. We are led to include them in this brief by the misleading assertions by appellant as to the state of the law prior to March 3, 1899, from which appellant attempts to work out some sort of authority or justification for its defiance of the law after that date.

In the first place, appellant's brief reiterates frequently that an apparently unlimited diversion of water by it was lawful under the law as it existed prior to the assertion of Federal control by Congress in the Act of September 19, 1890. We do not understand the significance of this assertion, for admittedly the Act of Congress of September 19, 1890, was passed two years before any contracts had been let or work begun on the excavation of the channel for the canal. The basis for this contention, whatever may be its

significance, is apparently in the line of decisions beginning with *Willson* v. *Black Bird Creek Marsh Co.*, 2 Pet. 245, which hold that, in the absence of legislation by Congress, a state may lawfully authorize an obstruction of navigable waters *entirely within its boundaries*. As is manifest from our analysis of these cases (infra. p. 136) this doctrine was never extended to navigable waters which, like the Ohio River or the Great Lakes, are not wholly within the boundaries of a single state; in fact, its application to these waters was negatived in such cases as the *Wheeling Bridge Case*, 13 How. 558. The extent of lawful state action in such waters was restricted to matters purely local in character, such as the regulation of pilotage (*Cooley* v. *Port Wardens*, 12 How. 299) or the improvement of harbors (*Mobile County* v. *Kimball*, 102 U. S. 691). The authorization of Congress was and always has been a necessary prerequisite to the creation of obstructions or modifications of the navigable capacity of such waters.

In the second place, appellant's brief reiterates no less frequently that its acts were "affirmatively authorized by law" within the meaning of that phrase as it appears in Section 10 of the Act of Congress of September 19, 1890. We cannot conceive what bearing this contention has on any questions involved in this case for the Act of Congress of March 3, 1899, was enacted into law nearly a year before the appellant (under the permit of May 8, 1899) accomplished a connection between its channel and the Chicago

River and thereby diverted water from Lake Michigan. The basis for this contention, however, is a misapplication of the decision of this Court in *United States* v. *Bellingham Bay Boom Co.*, 176 U. S. 211, which held that in the case of an obstruction of a navigable stream confined *wholly within the boundaries of a State*, the words "affirmatively authorized by law" in the Act of 1890 included lawful authorization by an act of the state legislature (see infra, p. 201). Manifestly, an obstruction of a navigable water like Lake Michigan or the Ohio and Mississippi Rivers could not *lawfully* be authorized by legislation of a single state *either* before or after the enactment of the Act of 1890.

The international character of the subject of the levels of the Great Lakes was noted by this Court in *United States* v. *Chandler Dunbar Water Power Co.*, 229 U. S. 53, at pp. 66–67:

> That outflow [i. e., from Lake Superior] has great influence both upon the water level of Lake Superior and also upon the level of the great system of lakes below which receive that outflow. A difference of a foot in the level of Lake Superior may influence adversely access to the harbors on that lake. The same fall in the water level of the lower lakes will perceptibly affect access to their ports. This was a matter of international consideration, for Canada, as well as the United States, was interested in the control and regulation of the lake water levels.

If we are correct in our contention that this subject of lake levels is *national* in character and is therefore exclusively under the control of Congress, then it makes no difference whether interference with that control proceeds from a state statute or from the acts of individuals. As was said in *Kansas City Street R. Co.* v. *Kaw Valley Drainage Dist.*, 233 U. S. 75, at p. 78:

> The freedom from interference on the part of the states is not confined to a simple prohibition of laws impairing it, but extends to interference by any ultimate organ.

We shall now proceed to a brief citation of cases involving the distinction between subjects *local* and subjects *national* in character with respect to interstate commerce, and particularly with respect to obstructions and modifications of the navigable capacity and condition of navigable waters of the United States.

A

Those subjects of interstate commerce which require a general system or uniformity of regulation are national in character, and as to such subjects the power of Congress is exclusive; those subjects of interstate commerce admitting of diversity of treatment according to the special requirements of local condition are local in character, and as to such subjects the States may act within their respective jurisdictions until Congress sees fit to act

Cases involving the principle set forth in the foregoing subheading have been reviewed so recently and so thoroughly in the *Minnesota Rate Cases*, 230 U. S. 352, that we shall not attempt to do more than observe more particularly the application of

the principle to obstructions of navigation and of the navigable capacity of navigable waters of the United States. We quote, however, the following pertinent portions of the opinion in that case (pp. 399–400):

> There is no room in our scheme of government for the assertion of state power in hostility to the authorized exercise of Federal power. The authority of Congress extends to every part of interstate commerce and to every instrumentality or agency by which it is carried on, and the full control by Congress of the subjects committed to its regulation is not to be denied or thwarted by the commingling of interstate and intrastate operations. This is not to say that the nation may deal with the internal concerns of the state, as such, but that the execution by Congress of its constitutional power to regulate interstate commerce is not limited by the fact that intrastate transactions may have become so interwoven therewith that the effective government of the former incidentally controls the latter. This conclusion necessarily results from the supremacy of the national power within its appointed sphere.
>
> * * * * *
>
> The grant in the Constitution of its own force, that is, without action by Congress, established the essential immunity of interstate commercial intercourse from the direct control of the states with respect to those subjects embraced within the grant which are of

such a nature as to demand that, if regulated at all, their regulation should be prescribed by a single authority. It has repeatedly been declared by this court that as to those subjects which require a general system or uniformity of regulation, the power of Congress is exclusive. In other matters, admitting of diversity of treatment according to the special requirements of local conditions, the states may act within their respective jurisdictions until Congress sees fit to act; and, when Congress does act, the exercise of its authority overrides all conflicting state legislation.

* * * * *

The principle which determines this classification underlies the doctrine that the states can not, under any guise, impose direct burdens upon interstate commerce. For this is but to hold that the states are not permitted directly to regulate or restrain that which, from its nature, should be under the control of the one authority, and be free from restriction, save as it is governed in the manner that the national legislature constitutionally ordains.

In *Covington & Cincinnati Bridge Co.* v. *Kentucky*, 154 U. S. 204, will be found a summary of cases applying the principle to questions of navigation, and a later summary is contained in the briefs of counsel in *Wilmington Transportation Co.* v. *R. R. Commission of California*, 236 U. S. 151.

The cases are not hard to classify for they fall naturally into two groups: (1) Those involving waters, the navigable portions of which, like the

Chicago and Calumet Rivers, are wholly within the bounds of a single state, and which for convenience will be referred to as *State* navigable waters, and (2) those involving waters the navigable portions of which, like Ohio River and Lake Michigan, are in two or more states, or like the other Great Lakes form boundaries between this and other countries, and which for convenience will be referred to as *interstate* navigable waters.

B

Until Congress asserted its paramount control the subject of obstructions to the navigable capacity of State navigable waters, not affecting navigable waters without the State, was deemed to be local in character and was held to be subject to the authority of the State

We have no doubt whatever but that prior to the assertion of Federal control over the matter the State of Illinois might lawfully have authorized the construction of bridges in the Chicago and Calumet Rivers. Bridges, prohibitive as they might be of navigation in those rivers, could have no effect on navigation elsewhere. So, too, the State might have authorized dams in those rivers so long as the water was ultimately permitted to flow into Lake Michigan and the dam was for some legitimate purpose within the power of the State. Such obstructions, however, differ greatly from an obstruction of an interstate water, whether by a bridge whose span is too low or by decreased water levels which limit the draught of boats. Such cases will be discussed under our next subheading.

(1) *Cases involving dams across state navigable waters* are *Willson* v. *Black Bird Creek Marsh Co.*, 2 Pet. 245;

Pound v. *Turck*, 95 U. S. 459; *Huse* v. *Glover*, 119 U. S. 543; and *Monongahela Navigation Co.* v. *United States*, 148 U. S. 312.

(2) *Cases involving bridges across state navigable waters* are *Gilman* v. *Philadelphia*, 3 Wall. 713; *Escanaba and Lake Michigan Transportation Co.* v. *Chicago*, 107 U. S. 683; *Cardwell* v. *American Bridge Co.*, 113 U. S. 205; *Hamilton* v. *Vicksburg, Shreveport and Pacific R. R. Co.*, 119 U. S. 280; *Willamette Iron Bridge Co.* v. *Hatch*, 125 U. S. 1, and *Lake Shore & Michigan Southern R. Co.* v. *Ohio*, 165 U. S. 365.

(3) *Cases involving improvement of state navigable waters* are *Withers* v. *Buckley*, 61 U. S. 84, *Sands* v. *Manistee River Improvement Co.*, 123 U. S. 288. In this connection may also be considered cases like *Huse* v. *Glover*, 119 U. S. 459, where by means of locks and dams the navigation of a state navigable water has been facilitated.

In every one of these cases the navigable water was, like the Black Bird Creek, the Chippewa River, and the Schuylkill River, wholly within the State which authorized the obstruction. In none of them did the obstruction affect or injure the navigable capacity of an *interstate* navigable water.

C.

With respect to interstate navigable waters, the subject of obstructions to their navigable capacity has always been deemed national in character, and subject to the exclusive control of Congress.

The obstruction resulting from a bridge the span of which is too low, and the obstruction resulting

from a lowering of water level, are manifestly of the same character. In the one case a boat can not clear because its mast or chimney will strike the bridge; in the other case, a boat can not clear because its keel will strike the river or lake bed. There is no distinction in principle, therefore, between the two types of obstruction, and the action of appellant in the present case is exactly the same in nature and effect as if it had thrown a bridge across Lake Michigan, or any of the Great Lakes or their connecting waters, the span of which was six inches too low for the passage of the larger vessels. That a State may not lawfully create such an obstruction, even in the absence of any affirmative assertion of control by Congress, is, we believe, conclusively established by such cases as the *Wheeling bridge case*, 13 How. 553, and *Covington & Cincinnati Bridge Co.* v. *Kentucky*, 154 U. S. 204. It was impliedly held in all the cases discussed in our preceding subheading, having to do with obstructions of *state* navigable waters.

We shall first, however, by a brief review of the cases, point out the limits to which this Court has heretofore gone in upholding state action with reference to *interstate* navigable waters.

1. *The power of the States with respect to interstate navigable waters has at all times been limited to matters purely local in character, incidental to and aiding commerce, and not affecting navigation elsewhere*

It would serve no useful purpose to undertake an analysis of all the cases which might properly be

grouped under this subheading. They are important only in so far as they illustrate the application to state restrictions on navigation of interstate waters, of the distinction between subjects of interstate commerce local and national in character. In the cases which have already been referred to (*supra*, p. 134) are cited what we believe to be representative cases on this question, and we need not repeat the citations or review the facts of each case. It will be noticed, however, that the cases fall into four fairly well-defined classes. Other, and perhaps better, classifications might possibly suggest themselves, but would not, we believe, add anything to the solution of our present query.

(*a*) *The regulation of pilotage.*—The case which originally dealt with this subject, and which may be regarded as the leading case is *Cooley* v. *Port Wardens*, 12 How. 299.

(*b*) *Protection of coasts and improvement of harbors, bays, and streams.*—The leading case dealing with this subject is *Mobile County* v. *Kimball*, 102 U. S. 691.

(*c*) *Quarantine and inspections laws and the policing of harbors.*—A typical case dealing with this subject is *Morgan's, etc., Co.* v. *Louisiana Board of Health*, 118 U. S. 455. This and similar cases are important in our consideration of appellant's claim of justification under the state's police power.

(*d*) *Regulation of wharfs, piers, and docks.*—A typical case dealing with this subject is *Parkersburg, etc., Trans. Co.* v. *Parkersburg*, 107 U. S. 691.

It will be noticed that there are seemingly no cases involving the right of the state, in the absence of legislation by Congress, to divert water from an interstate navigable water for purposes of sewage disposition or drinking water. The principles applied in the foregoing cases suggest, however, the correct application of the principle distinguishing between subjects of interstate commerce local and national in character. The ordinary diversion, which might properly be regarded as local in character, is that which returns the water thus used to the same navigable body of water. Such a use has no effect on the level or the navigability of that water, and is the method employed by nearly every city, so far as we know, except Chicago.

It will further be noticed that in all the foregoing cases, even those involving public health, such as quarantine and inspection laws, the paramount control of Congress over the various subjects is explicitly recognized, to be asserted when and where it sees fit.

2. Obstructions to the navigable capacity of interstate waters without authority from Congress have always been held unlawful, being national in character and subject to the exclusive control of Congress

We submit that the case of *Pennsylvania* v. *Wheeling and Belmont Bridge Co.* (usually referred to as the *Wheeling Bridge Case*), 13 How. 518, conclusively establishes that, even in the absence of any assertion of its paramount control by Congress, obstructions to the navigable capacity of interstate

waters are unlawful. In that case the state of Pennsylvania, by original bill filed in this court, sought to restrain the Bridge Company from proceeding with the construction of a bridge across the Ohio River at Wheeling. The facts of the case resemble the instant case to a striking extent.

At the point when the bridge was being constructed the Ohio River was wholly within the boundaries of Virginia, but was, of course, an interstate navigable water because of its serving as a highway of commerce for the states both above and below Wheeling. In this respect, therefore, it more than covers the instant case where we are dealing with a situation exactly as if a bridge were thrown across any of the Great Lakes or their connecting waters. The Bridge Company justified its act by authority conferred upon it by an act of the Virginia Legislature, just as appellant does under the Illinois Enabling Act of 1889. During the pendency of the suit the Bridge Company proceeded with the construction of the bridge so that it was completed at the time the decision of this Court was rendered, holding it an unlawful obstruction; just as in the instant case appellant has proceeded with its program of construction of canals, diverting water through the Calumet River, and taking an unauthorized amount of water from Lake Michigan in the face of the institution of the Calumet River Suit in 1908 and the Main Channel Suit in 1913, and the limitations contained in the prior permits.

The contentions of the Bridge Company in regard to the *extent* of the obstruction were substantially the same as appellant's, as is shown by the following:

> But it is said, the bridge constitutes no serious obstruction to the navigation of the Ohio; that only seven steamboats of two hundred and thirty which ply upon the river as high as Pittsburgh are obstructed, and that arises from the height of their chimneys, which might be lowered at a small expense in passing under the bridge; that by the introduction of blowers the chimneys might be shortened without lessening the speed of the boats; that the goods and passengers which are conveyed on the public lines of communication, between Pittsburgh and Philadelphia, could be as well conveyed on boats of lower chimneys, and consequently the State, as proprietor of those lines, if at all injured, is injured so inconsiderably as not to lay the foundation of this procedure; that none of the packets or the other boats on the river are owned by the State of Pennsylvania (p. 568).

The same argument was made, too, that the theory of such cases as *Willson* v. *Black Bird Creek Marsh Company*, 2 Pet. 245, having to do with obstructions of *state* navigable waters should be applied, and that there was "no act of Congress prohibiting obstructions on the Ohio River." As a matter of fact the only Act of Congress was the sanctioning of a compact made by Virginia and Kentucky, at the time of the latter's admission into the Union, which compact was the same as that contained in Article IV of the Ordinance of 1787, the provisions of which were accepted and agreed to by the State of Illinois.

Other contentions of the appellant in the *Wheeling Bridge case*, which are echoed by appellant in this case, are summarized in the opinion as follows:

> That the bridge is a connecting link of a great public highway, as important as the navigation of the Ohio River; that Pennsylvania had set the example of authorizing bridges across the Ohio; that certain engineers of the United States had recommended a wire suspension bridge at Wheeling, and gave as their opinion that "by an elevation of ninety feet, every imaginable danger of obstructing the navigation would be avoided;" that certain reports of committees in Congress recognized the necessity of a bridge at Wheeling, and recommended an appropriation for that purpose; that the headway for steamers left by the bridge is amply sufficient, forty-seven feet above the water, for all useful purposes; and if sufficient draught can not be had at that height, blowers might be added; that chimneys might have hinges on them; so as to be lowered without much inconvenience; that the bridge will not be an appreciable inconvenience to the average class of boats; that the bridge will not diminish or destroy trade between Pittsburgh and other ports, or do irreparable injury to the citizens of Pennsylvania (p. 558).

This Court, in holding the *Wheeling Bridge* to be an unlawful obstruction, and in granting the injunctive relief prayed by the State of Pennsylvania, ruled against substantially every contention made by

the appellant in the present case. We quote portions of the opinion as follows:

> And this injury is of a character for which an action at law could afford no adequate redress. It is of daily occurrence, and would require numerous, if not daily prosecutions, for the wrong done; and from the nature of that wrong, the compensation could not be measured or ascertained with any degree of precision. The effect would be, if not to reduce the tolls on these lines of transportation, to prevent their increase with the increasing business of the country.
>
> If the obstruction complained of be an injury, it would be difficult to state a stronger case for the extraordinary interposition of a court of chancery. In no case could a remedy be more hopeless by an action at common law. The structure complained of is permanent, and so are the public works sought to be protected. The injury, if there be one, is as permanent as the work from which it proceeds and as are the works affected by it. And whatever injury there may now be, will become greater in proportion to the increase of population and the commercial developments of the country. And in a country like this, where there would seem to be no limit to its progress, the injury complained of would be far greater in its effects than under less prosperous circumstances (p. 562).
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> * * * * *
>
> It is objected that there is no act of Congress prohibiting obstructions on the Ohio River, and

that until there shall be such a regulation, a state, in the construction of bridges, has a right to exercise its own discretion on the subject.

* * * * *

The case of *Wilson* v. *The Black Bird Creek Marsh Company*, 2 Pet. 250, is different in principle from the case before us. A dam was built over a creek to drain a marsh, required by the unhealthiness it produced. It was a small creek, made navigable by the flowing of the tide. The Chief Justice said it was a matter of doubt, whether the small creeks, which the tide makes navigable a short distance, are within the general commercial regulation; and that in such cases of doubt, it would be better for the court to follow the lead of Congress. Congress have led in regulating commerce on the Ohio, which brings the case within the rule above laid down. The facts of the two cases, therefore, instead of being alike, are altogether different.

No state law can hinder or obstruct the free use of a license granted under an Act of Congress. Nor can any state violate the compact, sanctioned as it has been by obstructing the navigation of the river. More than this is not necessary to give a civil remedy for an injury done by an obstruction (p. 566).

* * * * *

The fact that the bridge constitutes a nuisance is ascertained by measurement. The height of the bridge, of the water, and of the chimneys of steamboats, are the principal facts to be ascertained. If the obstruction

exists, it is a nuisance. To ascertain this a jury is not necessary. It is shown in the report, by a mathematical demonstration. And the other matters, connected with the case, as to the benefit of high chimneys, lowering of them in passing under the bridge, and shortening chimneys, are matters of science and experience, better ascertained by a report than by a verdict. And the same may be said of the statistics which are in the case (p. 568).

* * * * *

The Bridge Company had legal notice of the institution of the suit, and of the application for an injunction to stay their proceedings, before their cables were thrown across the river. This should have induced them to suspend, for a time, their great work, alike creditable to the enterprise of their citizens, and the genius and science of the engineer who planned the bridge and superintended its construction. It is a matter of regret that, by the prosecution and completion of the bridge, they have incurred a high responsibility.

For the reasons and facts stated, we think that the bridge obstructs the navigation of the Ohio, and that the State of Pennsylvania has been, and will be, injured in her public works in such manner as not only to authorize the bringing of this suit but to entitle her to the relief prayed (p. 578).

In view of the relief granted to the State of Pennsylvania in the *Wheeling Bridge case*, where the liti-

gants were in the situation of private individuals before this court, how much stronger is the right of the United States, relying upon its *paramount* and *exclusive* right of control of such subjects of interstate commerce as are national in character?

After the decision in the *Wheeling Bridge case*, "Congress in the exercise of its constitutional authority to regulate commerce, legalized the structure, by a legislative enactment" (*The Wheeling Bridge*, 18 How. 421). This Court, in holding that by reason of the act of Congress its previous decree could not be enforced, said (p. 430):

> So far, therefore, as this bridge created an obstruction to the free navigation of the river, in view of the previous acts of Congress, they are to be regarded and modified by this subsequent legislation; and although it still may be an obstruction in fact, is not so in the contemplation of law.

In *Newport and Cincinnati Bridge Co.* v. *United States*, 105 U. S. 470, a bridge across the Ohio River between Newport and Cincinnati had been authorized, both by an act of Congress and by acts of the Ohio and Kentucky Legislatures, which required the bridge company to comply with the regulations of Congress. Congress later withdrew its assent. The right of Congress to do this was upheld. This Court said:

> It can not be denied that but for the act of 1871 [16 Stat. at L., 573], a bridge built according to the original plan would have

> been a lawful structure which the Company could have maintained until Congress withdrew its assent, or required alterations to be made. The paramount power of regulating bridges that affect the navigation of the navigable waters of the United States is in Congress. It comes from the power to regulate commerce with foreign Nations and among the States.
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> * * * * *
>
> That the Ohio is one of the navigable rivers of the United States must be conceded. It forms a boundary of six States and the commerce upon its waters is very large.
>
> No question can arise in this case upon what the States have done, for both Ohio and Kentucky required the Company to comply with the regulations of Congress.
>
> * * * * *
>
> We conclude that the withdrawal by Congress of its assent to the maintenance of the bridge, when properly made, is, for all the purposes of this case, equivalent to a positive enactment that from the time of such withdrawal the further maintenance of the bridge shall be unlawful, notwithstanding the legislation of the several States, upon the subject. If modifications are directed, assent is, in legal effect, withdrawn, unless the required changes are made. (Pp. 475–6, 479.)

In *Miller* v. *Mayor of New York*, 109 U. S. 385, was involved the lawfulness of the Brooklyn Bridge. In that case the facts showed that not only the authority of the New York Legislature but also of

Congress had been obtained. Because of its connection with Long Island Sound, the East River may be regarded as an interstate water.

In *Covington & Cincinnati Bridge Co.* v. *Kentucky*, 154 U. S. 204, this Court held that Kentucky had no power "to regulate tolls upon a bridge connecting it with another state, without the assent of Congress."

> The authority of the state, so frequently recognized by this court, to fix tolls for the use of wharves, piers, elevators, and improved channels of navigation, has always been limited to such as were exclusively within the territory of a single state, thus affecting interstate commerce but incidentally, and cannot be extended to structures connecting two states without involving a liability of controversies of a serious nature (p. 221).

In *Kansas City, S. R. Co.* v. *Kaw Valley Drainage Dist.*, 233 U. S. 75, the Kansas court, on petition of the Drainage District, had ordered the railroad company to remove its bridges across the Kansas River. It appeared that in 1903 the river had overflowed its banks, flooded a large part of Kansas City, Kansas, and caused great loss, and that the railroad company's bridges on account of their elevation had caused the river to overflow. Referring to the judgment of the Kansas court, this Court said (p. 78):

> They are out-and-out orders to remove bridges that are a necessary part of lines of commerce by rail among the states. But that subject matter is under the exclusive control of Congress and is not one that it has

> left to the states until there shall be further action on its part. The freedom from interference on the part of the states is not confined to a simple prohibition of laws impairing it, but extends to interference by any ultimate organ.

Further citation and analysis of cases bearing on this question would be superfluous. Fundamentally we are dealing with the same question which arose in *Gibbons* v. *Ogden*, 9 Wheat. 190, where it was held once and for all time that a state might not interfere with a subject of interstate navigation national in character, even by an act taking place within its own borders. Other familiar authorities to the same effect are *Brown* v. *Maryland*, 12 Wheat. 419; *Henderson* v. *Mayor of New York*, 92 U. S. 259; *Hall* v. *DeCuir*, 95 U. S. 485; *Lord* v. *Goodall, etc., Steamship Co.*, 102 U. S. 541; *Gloucester Ferry Co.* v. *Pennsylvania*, 114 U. S. 196; *Philadelphia & S. Mail S. S. Co.* v. *Pennsylvania*, 122 U. S. 326; and *Sault Ste. Marie* v. *International Transit Co.*, 234 U. S. 333.

Appellant, by diverting the equivalent of a large navigable river from a fork of the Chicago River, is creating a result which is national in scope. It is just as surely regulating what boats may navigate the St. Clair River and the other critical points of Great Lake Navigation and what boats may enter the various harbors and trade at the various docks as if it were enforcing a law forbidding boats of a certain draft from trading on the Great Lakes. While pretending to concede the power of Congress

to regulate, it nullifies the power by abstracting the thing to be regulated.

Returning, in conclusion, to the fundamental distinction which has been made by this Court between matters local and matters national in character, we submit that the subject of the levels of the Great Lakes does not *permit* of diversity of treatment according to the local requirements of cities on their shores. What Chicago can do so can Milwaukee, Toledo, and Cleveland. As was stated by this Court in the case of *Pennsylvania* v. *West Virginia*, 262 U. S. 553 (p. 596):

> The question is an important one; for what one state may do others may, and there are ten states from which natural gas is exported for consumption in other states.

That the subject will admit "only of one uniform system or plan of regulation" must be apparent from the fact that the depths of harbors, locks, and other improvements which have been and will be undertaken at great expense in the Great Lakes—whether by the United States, the state, or private individuals—necessarily depend on trustworthy calculations as to the depths of the lakes and on confidence that the levels will be maintained by a paramount authority. The matter can not be left to the conflicting requirements of local conditions.

D

Under the compact contained in article 4 of the ordinance of 1787, Illinois may not interfere with or decrease the navigable capacity of Lake Michigan or any of the other Great Lakes

To quote from the opinion of this Court in *Economy Light & Power Co.* v. *United States*, 256 U.S. 113, 118:

> The public interest in navigable streams of this character in Illinois and neighboring states, and the Federal authority over such as are capable of serving commerce among the states, does not arise from custom or implication, but has a very definite origin. By article 4 of the compact in the Ordinance of July 13, 1787, for the government of the territory northwest of the river Ohio, it was declared: "The navigable waters leading into the Mississippi and Saint Lawrence, and the carrying places between the same, shall be common highways, and forever free, as well to the inhabitants of the said territory as to the citizens of the United States, and those of any other states that may be admitted into the Confederacy, without any tax, impost, or duty therefor." (1 Stat. at L. 51, 52, note; U. S. Rev. Stat. 1878, ed. pp. 13, 16.)

The effect of this compact was held to be as follows:

> To the extent that it pertained to *internal affairs*, the Ordinance of 1787—notwithstanding its contractual form—was no more than a regulation of territory belonging to the United States, and was superseded by the admission of the state of Illinois into the

Union "on an equal footing with the original states in all respects whatever" (p. 120).

* * * * *

But, so far as it established public rights of highway in navigable waters capable of bearing commerce from state to state, it did not regulate internal affairs alone, and was no more capable of repeal by one of the states than any other regulation of interstate commerce enacted by the Congress, being analogous in this respect to legislation enacted under the exclusive power of Congress to regulate commerce with the Indian tribes. (p. 120).

In the *Wheeling Bridge Case*, 13 How. 518, 565–6 this Court gave the same interpretation to a similar compact between Virginia and Kentucky.

Congress have not declared in terms that a state, by the construction of bridges, or otherwise, shall not obstruct the navigation of the Ohio, but they have regulated navigation upon it, as before remarked, by licensing vessels, establishing ports of entry, imposing duties upon masters and other officers of boats, and inflicting severe penalties for neglect of those duties, by which damage to life or property has resulted. And they have expressly sanctioned the compact made by Virginia with Kentucky, at the time of its admission into the Union, "that the use and navigation of the River Ohio, so far as the territory of the proposed State, or the territory that shall remain within the limits of this Commonwealth lies thereon, shall be free and common to the citi-

> zens of the United States." Now, an obstructed navigation can not be said to be free.
>
> * * * * *
>
> This compact, by the sanction of Congress, has become a law of the Union. What further legislation can be desired for judicial action?

On the other hand, in such cases as *Escanaba & Lake Michigan Transportation Co.*, 107 U. S. 678; *Cardwell* v. *American River Bridge Co.*, 113 U. S. 205; *Huse* v. *Glover*, 119 U. S. 543; *Hamilton* v. *Vicksburg, Shreveport and Pacific R. R. Co.*, 119 U. S. 280; *Sands* v. *Manistee River Improvement Co.*, 123 U. S. 288; and *Willamette Iron Bridge Co.* v. *Hatch*, 125 U. S. 1, this court held the compact inapplicable to obstructions over navigable waters entirely within the boundaries of a single state.

We submit that the principle to be extracted from these cases is that where the obstruction or restriction of navigability is of a *state* navigable water, the compact does not apply; where it is of an *interstate* navigable water such as the Ohio River or the Great Lakes, the compact is, and has always been in force. It is true that the Economy Light & Power Co. case involved an obstruction to what was before 1890 a *state* navigable water (i. e., the Desplaines River); yet Congress had by its Acts of 1890 and 1899 extended its paramount control to such waters, and they had therefore become to that extent *interstate* navigable waters.

E

The subject of the levels of and diversion of waters from the Great Lakes is necessarily national because international in character and therefore subject to the exclusive control of Congress

Under our Point I we call attention to the decisions of this Court relating to the *international* character of those of the Great Lakes which are boundary waters. (Supra, pp. 125–128.) They have been held subject to admiralty jurisdiction (*The Propeller Genesee Chief*, 12 How. 443); they have been held to be "high seas" (*United States* v. *Rodgers*, 150 U. S. 249) and navigation on them was held not to constitute "inland navigation" (*Moore* v. *American Transportation Co.*, 24 How. 1). The matter of their levels has been held to be "of international consideration." (*United States* v. *Chandler-Dunbar Water Power Co.*, 229 U. S. 53.)

> These lakes are in truth inland seas. Different states border on them on one side, and a foreign nation on the other. A great and growing commerce is carried on upon them between different states and a foreign nation, which is subject to all the incidents and hazards that attend commerce on the ocean. (*The Propeller Genesee Chief*, 12 How. 443, 453.)

As was said by this Court in *Lord* v. *Goodall, etc., Steamship Co.*, 102 U. S. 541, (p. 544).

> Navigation on the high seas is necessarily national in its character. Such navigation is clearly a matter of "external concern" affecting the nation as a nation in its external affairs. It must therefore be subject to the national government.

In *Henderson* v. *Mayor of New York*, 92 U. S. 259, this Court held invalid a statute imposing onerous conditions upon the master of every vessel arriving in the Port of New York from foreign ports or other states. We quote from the opinion (p. 273):

> A regulation which imposes onerous, perhaps impossible, conditions on those engaged in active commerce with foreign nations must of necessity be national in its character. It is more than this; for it may properly be called "international." It belongs to that class of laws which concern the exterior relation of this whole nation with other nations and governments. If our government should make the restrictions of these burdens on commerce the subject of a treaty, there could be no doubt that such a treaty would fall within the power conferred on the President and the Senate by the Constitution. It is, in fact, in an eminent degree, a subject which concerns our international relations, in regard to which foreign nations ought to be considered and their rights respected, whether the rule be established by treaty or by legislation.
>
> It is equally clear that the matter of these statutes may be and ought to be the subject of a uniform system or plan.

In this connection we call attention to the following discussion of the specific subject under consideration (i. e., diversions of international waters) in the recent work of Charles Cheney Hyde on International Law:

> The diversion of the waters of an international stream for any purposes, such as those

of sanitation, navigation, power or irrigation, tends to interfere with the fullest use of the river by all riparian proprietors. There may be said to be an essential conflict between the interest of the stream as a whole, and that of the particular State diverting its waters. Where a river traverses or serves as the boundary of the territories of several States, the existence of the river interest, as such, becomes the more apparent, because of the common concern of all in its welfare.

* * * * *

In the case of a navigable river a special element projects itself which at once opposes any unrestricted taking of water serving to diminish the depth of channels of navigation and thus to impair their value. Any duty imposed upon a riparian State, either by international law or by contract, to maintain the navigability of an international river, implies an obligation also to check within places subject to the control of such State the commission of any acts which, unless restricted, would prove injurious to navigation generally. This obligation would seem to render improper the tolerance of any diversion productive of such an effect even though it should occur at a point where the river ceased to be navigable and lay wholly within the domain of the acquiescent territorial sovereign. (Vol. I, pp. 313–316.)

The international character of the appellant's proposed diversion of water has been understood and emphasized frequently by the officers of the United

States familiar with the matter. (See Appellant's Narrative, 469–471.) It was emphasized in the Report of the Board of Engineers on August 16, 1895. (Rec. Vol. VI, pp. 3931–3940.) It was mentioned by Major Marshall in his report to the Chief of Engineers on April 24, 1899 (Rec. Vol. VI, p. 3586), before the appellant was given its first permit to divert water. In the ruling of the Secretary of War on March 14, 1907, in which he refused appellant's application for a permit to reverse the flow of the Calumet River and divert water from Lake Michigan through it, the Secretary of War stated:

> Added to this, is the international complication which is likely to arise in the threatened lowering of the lake level in the ports and harbors and canals of Canada * * * It may be fortunate that circumstances now require submission of this question of capital and national importance to the Congress of the United States. (Rec. Vol. VII, p. 25.)

In the decision of the Secretary of War of January 8, 1913, denying appellant's application for an increased diversion, he stated:

> The question therefore becomes not merely national but international. (Rec. Vol. VII, pp. 7–17; Appellant's Narrative, p. 36.)

This view of the Secretary of War had an ample basis in the hearing which had taken place before him, for representatives of a foreign government and of foreign interests were strenuously opposing the appellant's application and made an imposing showing of serious injury to their interests.

Finally and, we submit, conclusively, the President of the United States and Congress have recognized the question as having an international character, affecting the United States in its external relations, by participating in the creation, organization, investigations and reports of the International Waterway Commission, and by negotiating and entering into the Canadian Boundary Waters Treaty of January 11, 1909. We discuss the provisions of this treaty elsewhere (infra, pp. 226, 305) and shall not dwell on them here. That treaty, we believe, just as certainly and effectively as a positive act of Congress, forbids the unauthorized diversion of waters by the appellant, and even permits the Canadian Government to complain of the authorized diversion of 4167 c. s. f. if it should prove injurious to navigation on the Canadian side of the boundary waters. The treaty, also, by its prohibition of the placing of submerged weirs and dams as compensating works without the approval of the International Joint Commission, an international tribunal, manifests the absurdity of appellant's contention that it should receive a *permit* from the Federal *judiciary* to take 10,000 c. s. f. on condition that it pay for the construction and maintenance of such weirs.

III

Whatever may have been the case prior to 1890, Congress assumed control of the subject of obstructions to the navigable capacity, and modifications of the course, condition, and capacity, of all navigable waters of the United States by its act of September 19, 1890, and even more extensively by its act of March 3, 1899.

Whether or not, in the absence of an assertion of its paramount control by Congress, the appellant might lawfully have obstructed the navigable capacity of the Great Lakes, such an assertion of control *was* made in unmistakable terms by the Acts of Congress of September 19, 1890 (26 St. at L. 454), and of March 3, 1899 (30 St. at L. 1151). Inasmuch as the provisions of the Act of 1890, though partially repealed by the Act of 1899, throw some light on the meaning and scope of the later statute, we shall first set forth the applicable portions of the Act of 1890.

Section 7 of the Act of 1890 provided in part:

> It shall not be lawful hereafter * * * to excavate or fill, or in any manner to alter or modify the course, location, condition or capacity of the channel of said navigable water of the United States, unless approved and authorized by the Secretary of War.

Section 10 of the Act of 1890 provided in part:

> That the creation of any obstruction, not affirmatively authorized *by law*, to the navigable capacity of any waters, in respect of which the United States has jurisdiction, is hereby prohibited.

The Ninth Circuit Court of Appeals in *United States* v. *Bellingham Bay Boom Co.*, 81 Fed. 658 (affirming same case, 72 Fed. 585, and later affirmed by this Court; 176 U. S. 211), held that the words "affirmatively authorized by law" in Section 10 of the Act of 1890 included authorization by a state legislature where the navigable water was wholly within the boundaries of the state. Thereupon the Act of 1899 was passed, Section 10 of which replaced the above-quoted portions of Sections 7 and 10 of the Act of 1890, as follows:

> That the creation of any obstruction not affirmatively authorized *by Congress*, to the navigable capacity of any of the waters of the United States is hereby prohibited; and * * * it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or enclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same.

It would seem that a mere reading of the above-quoted statutory provisions is all that is necessary to demonstrate that the appellant's acts were in violation of the Act of 1899 and would have been in violation of the Act of 1890 if that act were in force. In this connection, it should be remembered that prior to the enactment on March 3 of the Act of 1899 appel-

lant had done nothing affecting in the slightest any navigable waters of the United States except the accomplishing of certain improvements in the Chicago River. These improvements were made under permits of the Secretary of War expressly reciting:

> That this authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must hereafter be submitted for consideration. (Appellant's Narrative, p. 474; Rec. Vol. VIII, p. 122.)

The mere excavation of a ditch in the interior of a state is of no concern to the Federal Government. The diversion of water by appellant, so far as it was lawful, was under the permit of May 8, 1899, and was not accomplished until January 17, 1900. Until January 17, 1900, therefore, the appellant did nothing affecting either the navigable capacity, the location, the condition, or the course of any navigable water of the United States. Its acts must be judged under the provisions of the Act of 1899.

Can there be any doubt that *since* the enactment of the Act of 1899—

(1) The appellant has created an obstruction to the navigable capacity of navigable waters of the United States—

(*a*) By lowering the levels of the Great Lakes, their connecting waters, and the St. Lawrence River.

(*b*) By introducing into the Chicago River an unduly rapid current, dangerous to navigation.

(2) The appellant has modified the course, location, condition, and capacity of navigable waters of the United States—

(*a*) By lowering the levels of the Great Lakes, their connecting waters, and the St. Lawrence River, whether or not the lowering be sufficient to obstruct.

(*b*) By introducing into the Chicago River an increased current, whether or not it be dangerous to navigation.

(*c*) By diverting into the Mississippi Basin waters which would naturally flow into the St. Lawrence basin.

(*d*) By increasing the amount of water flowing down the Desplaines, Illinois, and Mississippi Rivers.

(*e*) By reversing the course of the Calumet River.

Even if this Court should be of the opinion that the lowering of the Great Lakes by several inches and the increased current in the Chicago River do not constitute *obstructions* within the meaning of the first clause of Section 10, they, and the other acts above listed under (2), constitute violations of the last clause of that section.

Nor, as a matter of fact, is there room for doubt that if the applicable provisions of the Act of 1890 were in force, the appellant would be violating those provisions. (1) Appellant would be violating Section 10 of that Act forbidding obstructions. The construction given by this Court to the words "affirmatively authorized by law" does not assist appellant, for a state legislature never had the power or right to authorise obstructions to waters like Lake Michigan, not wholly within the state's boundaries.

(2) Appellant would be violating Section 7 of that Act forbidding modifications of the condition, etc., of navigable waters. No exception was made in Section 7 for acts authorized by state legislatures; in *every* case the approval and authorization of the Secretary of War was required.

Although the statutes themselves seem to us to answer every contention made by appellant, we shall nevertheless review the decisions bearing on the interpretation and application of these statutes. We shall reserve for separate consideration in our Point IV certain particular points made by appellant as to whether the acts of appellant created an *obstruction* or a *modification;* in our Points V and VI we shall meet the claim of appellant that its acts *have* been authorized by Congress and the Secretary of War.

A

In all decisions on the subject prior to these acts of Congress, even where the State's act was upheld as a legitimate exercise of its police power, this court has expressly recognized that when Congress should see fit to act the authority of the State came to an end

Under subheadings B and C of our Point II (supra, pp. 35 to 136) we have discussed in another connection the long line of cases beginning with *Willson* v. *Black Bird Creek Marsh Company*, 2 Pet. 245, which, in the absence of legislation by Congress, upheld the power of the State to create certain obstructions to the navigable capacity of navigable waters entirely within their boundaries and to regulate purely local matters in their ports on interstate navigable waters. The purposes for which the States might formerly exercise this limited power were varied

but in a general way they all came within the scope of the police power. In some cases it was for the protection of public health (*Willson* v. *Black Bird Creek Marsh Company*, 2 Pet. 245; *Morgan's, etc., Co.* v. *Louisiana Board of Health*, 118 U. S. 455); in some cases it was for furthering of commerce in saw-logs, etc. (*Pound* v. *Turck*, 95 U. S. 459); in some cases it was for improvement of rivers or harbors (*Mobile County* v. *Kimball*, 102 U. S. 691; *Sands* v. *Manistee River Improvement Co.*, 123 U. S. 288); in some cases it was for public convenience and commerce crossing a bridge (*Gilman* v. *Philadelphia*, 3 Wall. 724; *Escanaba & Lake Michigan Transportation Co.* v. *Chicago*, 107 U. S. 683). We know of no case in which the object of the State's act, if held lawful, was not referable to its police power.

In *every* such case, in *express* language, a reservation was made: when Congress saw fit to legislate on the subject the authority of the State ceased, and any act, by legislation or by any ultimate organ, in conflict with the assertion of control by Congress, would be void and unlawful.

B

By its acts of 1890 and 1899 Congress made an effectual assertion of its paramount control over all navigable waters of the United States and assumed jurisdiction of the subjects mentioned in the above heading

In *United States* v. *Rio Grande Dam & Irrigation Co. et al.*, 174 U. S. 690 (reversing 51 Pac. 674), this court, speaking through Mr. Justice Brewer, said (p. 703):

> It is true there have been frequent decisions recognizing the power of the state in the ab-

sence of congressional legislation to assume control of even navigable waters within its limits to the extent of creating dams, booms, bridges, and other matters which operate as obstructions to navigability. The power of the state to thus legislate for the interests of its own citizens is conceded, and until in some way Congress asserts its superior power and the necessity of preserving the general interests of the people of all the states, it is assumed that state action, although involving temporarily an obstruction to the free navigability of a stream, is not subject to challenge. A long list of cases to this effect can be found in the reports of this court. See, among others, the following: *Wilson* v. *Black Bird Creek Marsh Co.*, 2 Pet. 245; *Gilman* v. *Philadelphia*, 3 Wall. 713; *Escanaba Co.* v. *Chicago*, 107 U. S. 678; *Willamette Iron Bridge Co.* v. *Hatch*, 125 U. S. 1.

After discussing certain Acts of Congress (14 St. at L. 253, Chap. 262 and 26 St. at L. 1101), the court said (p. 707):

> But whatever may be said as to the true intent and scope of these various statutes, we have before us the legislation of 1890. On September 19, 1890, an act was passed containing this provision (26 Stat. at L. 454, sec. 10).

The court then quotes Sec. 10 and proceeds (pp. 707-708):

> As this is a later declaration of Congress, so far as it modifies any privileges or rights conferred by prior statutes, it must be held controlling, at least as to any rights attempted to be created since its passage; and all the pro-

ceedings of the appellees in this case were subsequent to this act. This act declares that "the creation of any obstruction, not affirmatively authorized by law, to the navigable capacity of any waters in respect to which the United States has jurisdiction, is hereby prohibited." Whatever may be said in reference to obstructions existing at the time of the passage of the act, under the authority of state statutes, it is obvious that Congress meant that thereafter no state should interfere with the navigability of a stream without the condition of national assent. It did not, of course, disturb any of the provisions of prior statutes in respect to the mere appropriation of water of non-navigable streams in disregard of the old common-law rule of continuous flow, and its only purpose, as is obvious, was to affirm that as to navigable waters nothing should be done to obstruct their navigability without the assent of the national government. It was an exercise by Congress of the power, oftentimes declared by this court to belong to it, of national control over navigable streams, and various sections of this statute, as well as in the act of July 13, 1892 (27 Stat. at L. 88, 110), provide for the mode of asserting that control. It is urged that the true construction of this act limits its applicability to obstructions in the navigable portion of a navigable stream, and that as it appears that although the Rio Grande may be navigable for a certain distance above its mouth, it is not navigable in the territory of New Mexico, this statute has no applicability. The lan-

guage is general, and must be given full scope. It is not a prohibition of any obstruction to the navigation, but any obstruction to the navigable capacity; and anything, wherever done or however done, within the limits of the jurisdiction of the United States, which tends to destroy the navigable capacity of one of the navigable waters of the United States, is within the terms of the prohibition. Evidently Congress perceiving that the time had come when the growing interests of commerce required that the navigable waters of the United States should be subjected to the direct control of the national government, and that nothing should be done by any State tending to destroy that navigability without the explicit assent of the national government, enacted the statute in question. And it would be to improperly ignore the scope of this language to limit it to the acts done within the very limits of navigation of a navigable stream.

See also *Lake Shore & Michigan Southern Ry. Co.* v. *Ohio*, 165 U. S. 365; *United States* v. *Bellingham Bay Boom Co.*, 176 U. S. 211; *Cummings* v. *Chicago*, 188 U. S. 410; *Union Bridge Co.* v. *United States*, 204 U. S. 364; *Philadelphia Co.* v. *Stimson, Secretary of War*, 223 U. S. 605; *United States* v. *Chandler-Dunbar Water Power Co.*, 229 U. S. 53.

In *Economy Light & Power Co.* v. *United States*, 256 U. S. 113 (affirming 256 Fed. 792), this court said:

> But, as was recognized in the *Gilman case* [*Gilman* v. *Philadelphia*, 3 Wall. 731], Congress may exercise its authority through general as well as through special laws, its power

> in either case being supreme. The Act of 1899 * * * is a due assertion of the authority of Congress over all navigable waters within its jurisdiction; and it must be accorded due weight as such (p. 121).

In *Southern Pacific Company et al.* v. *Olympian Dredging Company*, 260 U. S. 205, 207–208 this court said:

> By the Act of September 19, 1890 (26 Stat. at L. 453, 454, chap. 907), Congress inaugurated a new policy of general, direct control over the navigable waters of the United States.
>
> * * * * *
>
> By this legislation Congress assumed jurisdiction of the subject of obstructions to navigation, and committed to the Secretary of War administrative power in so far as administration was necessary.

No point is made by appellant as to the constitutionality of these Acts of Congress. Any possible contention that there has been an undue delegation of power to the Secretary of War is effectively met by the decisions of this Court in such cases as *Union Bridge Co.* v. *United States*, 204 U. S. 364; *Philadelphia Co.* v. *Stimson, Secretary of War*, 223 U. S. 605.

C

The effect of Section 10 of the Act of 1899 is to make the creation of such obstructions or modifications dependent "upon the concurrent or joint assent of both the national Government and the State government"

We have already pointed out the interpretation given by this Court to the words "affirmatively authorized by law" as they appear in Section 10 of the Act of 1890 in *United States* v. *Bellingham Bay Boom Co.*, 176 U. S. 211 (supra, p. 193). The same

interpretation was given the words as they appeared in another section of the Act of 1890 in *Lake Shore & Michigan Southern R. Co.* v. *Ohio*, 165 U. S. 365. Incidentally, it may be noted that in the *Bellingham Bay Boom Co. case*, this Court held the obstruction unlawful, for the evidence showed that it was not even authorized by the Act of the Oregon Legislature. That the words "affirmatively authorized by law" did not cover obstructions caused within the state but affecting navigable capacity of waters outside the state is clear from the opinion of this Court in *United States* v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 698. In that case, which arose under Section 10 of the Act of 1890, the unlawful act consisted of diverting the water of a *nonnavigable* river in the Territory of New Mexico with a harmful result to the navigable capacity of that river in its navigable portion *outside* the Territory. The fact that New Mexico was not a state is immaterial; the act of its legislature was just as lawful or unlawful as authorization for the dam.

There is, therefore, no doubt as to the meaning and intent of the words "affirmatively authorized by Congress" as they appear in Section 10, of the Act of 1899. An act of the state legislature can not authorize an obstruction to the navigable capacity of a navigable water of the United States whether within or without the boundaries of the state. There must be Federal authority. That it must be an *Act* of Congress in the case of an obstruction, and not

merely the authorization of the Secretary of War, is shown under our next subheading.

The question then arose in *Cummings* v. *Chicago*, 188 U. S. 410, as to whether the words "affirmatively authorized by Congress" in Section 10 of the Act of 1899 were intended (p. 428)—

> to supersede, for every purpose, the authority of Illinois over the erection of structures in navigable waters wholly within its limits? Did it intend to declare * * * that the assent of the Secretary of War, proceeding under the above acts of Congress, was alone sufficient to authorize such structures?

In that case Cummings, having obtained the recommendation of the Chief of Engineers and a permit from the Secretary of War, proceeded to construct a dock in the Calumet River. An ordinance of the City of Chicago, enacted under power duly delegated it by the Illinois Legislature, required the permission of its department of public works as a condition precedent to the construction of any dock within the limits of the city. This Court, in holding that the state's authority had not been superseded to that extent, said (pp. 430–31):

> But we will not at this time make any declaration of opinion * * * as to the extent to which Congress may go in the matter of the erection or authorizing the erection of docks and like structures in navigable waters that are entirely within the territorial limits of the several states. Whether Congress may, against or without the expressed will of a state, give

affirmative authority to private parties to erect structures in such waters, it is not necessary in this case to decide. It is only necessary to say that the act of 1899 does not manifest the purpose of Congress to go to that extent under the power to regulate foreign and interstate commerce and thereby to supersede the original authority of the states. *The effect, of that Act, reasonably interpreted, is to make the erection of a structure in a navigable river, within the limits of a state, depend upon the concurrent or joint assent of both the national government and the state government.* The Secretary of War, acting under the authority conferred by Congress, may assent to the erection by private parties of such a structure. Without such assent the structure can not be erected by them. But under existing legislation they must, before proceeding under such an authority, obtain also the assent of the state acting by its constituted agencies.

Montgomery v. *Portland*, 190 U. S. 89, involved an identical situation with regard to the Willamette River in Oregon, and, in the words of the opinion, "this case can not be distinguished in principle from *Cummings* v. *Chicago*." A third case applying the same principles is *North Shore Boom & Driving Company* v. *Nicomen Boom Company*, 212 U. S. 406, involving the lawfulness of a boom in the North River, a river wholly within the boundary of the state of Washington. The boom was in violation of the laws of Washington; it did not appear whether or not the Boom Company had complied with the Federal stat-

ute. This Court, after quoting the first portion of Section 10 of the Act of 1899, said (p. 413):

> It leaves out the words "not affirmatively authorized by law," and substitutes "not affirmatively authorized by Congress." There is, therefore, no reference to state action or state law. Obstruction not affirmatively authorized by Congress is prohibited, but the case of the state assent remains with the state for its sole adjudication.
>
> The construction of the boom of defendant in this case, the state court has decided, was not authorized by the state. Whether it was or not is not a Federal question.

A further application of the same principle is found in *Port of Seattle* v. *Oregon & Washington R. Co.*, 255 U. S. 56, in which this Court said (pp. 69–70):

> So far as the pierhead lines are concerned, the railroad concedes that their establishment by the United States did not create, as against the state, a right to wharf out. They merely fixed the line beyond which piers might not extend. * * * And the power of the United States in this respect was not exhausted by its first exercise. [Citing *Philadelphia Co.* v. *Stimson*, 223 U. S. 605.] The lines so fixed, although acted upon by the erection of piers, could be changed by the United States at any time. [Citing *Greenleaf Johnson Lumber Co.* v. *Garrison*, 237 U. S. 251.]

The case of *International Bridge Co.* v. *New York*, 254 U. S. 126, involves a very different situation. The bridge was erected in 1874, under authority of an

Act of Congress, between Squaw Island in the Niagara River and the mainland of New York State. The state of New York brought suit against the Bridge Company to recover penalties for failure to place upon the bridge a roadway for vehicles and a pathway for pedestrians. This Court said (p. 132):

> The part of the structure with which we are concerned is within the territorial jurisdiction of the state of New York. There was no exercise of the power of eminent domain by the United States. The state was the source of every title to that land, and, apart from the special purposes to which it might be destined, of every right to use it. Any structure upon it, considered merely as a structure, is erected by the authority of New York.

The case had nothing to do with the bridge as an obstruction of the navigable capacity of the Niagara River.

What encouragement appellant can extract from any of these cases is beyond our comprehension. *None* of them holds that state authority alone is sufficient for the creation of an obstruction or a modification of the condition of a navigable water of the United States. All of them have expressly held that Federal assent, either by Act of Congress or authorization from the Secretary of War (depending on the character of the proposed act) is a necessary condition precedent. Why cases such as *Cummings* v. *Chicago* should have been cited to any other effect we are unable to understand.

D

Under Section 10 of the act of 1899 an act of Congress is necessary to authorize the creation of an obstruction to the navigable capacity of a navigable water of the United States; for a modification of the condition, etc., of such navigable water, not amounting to an obstruction, the recommendation of the Chief of Engineers and the authorization of the Secretary of War is necessary

Apparently counsel for appellant contend that, in the face of the seemingly explicit language of Section 10 of the Act of 1899, an act of Congress is not necessary to authorize the creation of an obstruction to the navigable capacity of a navigable water of the United States; that power has been delegated to the Secretary of War to authorize any and all manner of obstructions, and that all that is necessary to legalize an obstruction is a permit from him following a recommendation by the Chief of Engineers. (See Appellant's Brief, Point II, particularly pp. 131–139.)

What advantage this surprising contention, even if tenable, would bring to appellant is hard to understand, for appellant has never had either the recommendation of the Chief of Engineers or a permit from the Secretary of War to divert more than a limited amount of water, which, since March 31, 1903, has been a maximum of 4,167 c. s. f. Appellant is, of course, arguing that certain permits granted it for the making of improvements in the Chicago River are permits to take 10,000 c. s. f. and, indeed, an unlimited amount of water. This is in spite of express recitals in those permits negativing any such interpretation. This we shall discuss in our Point VI, however. (Infra, pp. 241–242.)

We submit that, without doing shocking violence both to the English language and to fundamental rules of grammar and syntax, the applicable portions of Section 10 can be read to mean only the following:

> (1) The creation of any obstruction to the navigable capacity of a navigable water of the United States must be affirmatively authorized by Congress; e. g., there must be an act of Congress, general or special, authorizing the obstruction.
>
> (2) A modification of the course, location, condition, or capacity of any navigable water of the United States, when *not* amounting to an obstruction, must, to be lawful, be recommended by the Chief of Engineers and authorized by the Secretary of War.

A bridge or any other structure may or may not be an obstruction. An example of this is the *Wheeling Bridge case*, 13 How. 518. With its span at ninety feet the bridge was held to be an obstruction; the Bridge Company was directed by decree of this Court to elevate it to one hundred and eleven feet, a height at which it would not be an obstruction. There can be no doubt, however, but that Federal assent would be necessary to construct such a bridge, no matter how high, under existing legislation.

So with a modification of the condition or capacity of a navigable water. A lowering of the lake levels of five inches may, and under the evidence in this case does, amount to an obstruction. A lesser lowering such as would be caused by the authorized diversion of 4,167 c. s. f. might not be enough to constitute

an obstruction. Both situations are covered by Section 10, the one requiring an act of Congress and the other requiring *at least* the recommendation of the Chief of Engineers and the authorization of the Secretary of War. As a matter of fact, Congress has power to declare all modifications to be obstructions. (See cases cited under our next subheading, pp. 214 to 217.) Whether or not it has done so by Section 10, however, it is unnecessary to decide.

The interpretation we have placed upon the statute was given expression in *Hubbard* v. *Fort*, 188 Fed. 987, in which the Circuit Court in the District of New Jersey said (pp. 992–993):

> So far as applicable to the present question, such section (10) may be summarized thus: First, the creation of any *obstruction* to the navigable capacity of any waters of the United States is prohibited unless affirmatively authorized by Congress; second, it shall not be lawful to build any *structure* in a navigable river or water of the United States, except on *plans recommended* by the Chief of Engineers and *authorized* by the Secretary of War; and, third, it shall not be lawful to excavate or fill the channel of any navigable water of the United States unless such work is recommended by said Secretary of War prior to beginning the same. [If literally exact, the last clause should have read "recommended by the Chief of Engineers and authorized by the Secretary."]

The case of *West Chicago Street Ry. Co.* v. *Illinois, etc.*, 201 U. S. 506, declared a specific permit from the Secretary unnecessary only because the act (30 Stat. 1153) provided that a specific improvement of the Chicago River, involved in that case, should be at the expense of the city, and this provision of the statute was held an implied permit by Congress for this specific work, dispensing with the necessity of further authority from the Secretary under Section 10 of the act (p. 527).

The construction we contend for is supported by considerations drawn from other sections of the Act of 1899 and by the interpretation given by this Court to the Act of 1890. We do not pretend to understand just what message is intended to be conveyed by appellant's elaborate dissection of the two statutes. (Appellant's Brief, pp. 133–136.) It does not require much discernment, however, to discover that counsel for appellant have taken desperate liberties with the facts of the instant case in an endeavor to bring them within the views apparently held by the Supreme Court of Maine in *Maine Water Company* v. *Knickerbocker Steam Towage Company*, 99 Me. 473, 59 Atl. 953. For example, counsel say (Appellant's Brief, pp. 131–2):

> Excavating and filling in the channels of the Chicago River and its branches was the *only* work appellant was required to do in navigable waters of the United States to accomplish and bring about the diversion. The reversal of the current and flow of the

> Chicago River and its branches was a *necessary* result. * * * That includes, of course, the diversion of water *to the amount required by state authority*.

We hardly know whether to take such statements seriously or not. Are we to understand that the Chicago River simply flowed into the Sanitary & Ship Canal without the assistance of the appellant, as the necessary result of improvements made by it in the Chicago River under permits that expressly stated that they did not confer authority to divert water? Or that later permits to widen and otherwise improve the river automatically sent a current into the canal at the rate of 20,000 cubic feet per minute per 100,000 population in the district ("the amount required by state authority")? Has appellant, then, no control over the amount it is diverting? The absurdity of such a contention is self-evident.

We take the liberty of quoting further from the well-reasoned opinion in the case of *Hubbard* v. *Fort*, *supra*, in the absence of any decision of this Court having to do with the interpretation of Section 10 in this regard:

> And how can it be said that the structures or the works subsequently referred to in this section may not amount to an obstruction to such navigable capacity? It is to be noted that "excavate or fill" is associated with "alter or modify the course, location, condition, or capacity of any" navigable water, all of which

may be so performed as to become serious obstructions to navigation. That such obstructions may be but slight, and that some will be of only temporary duration, would not make them any less obstructions and within the prohibition. Any less comprehensive interpretation of the first part of section 10 would do violence to its language and, as already said, be meaningless. If Congress intended that as to all other obstructions not prohibited by section 9 no affirmative action by Congress should be necessary, but that they might be constructed upon obtaining the permission of the Secretary of War it used singularly inapt and ambiguous language in expressing such intention.

* * * * *

As the law stood immediately before the act of 1899 was passed, the initial authorization of the Congress to create obstructions to the navigable capacity of an intrastate water was not necessary if state legislative authority for such construction had been obtained, and the building of wharves and other structures mentioned in the first part of section 7 of the act of 1890, in any United States navigable water, was only prohibited without the permission of the Secretary of War, if they obstructed or impaired navigation, commerce, or anchorage. The erection of bridges and their appurtenances over intrastate waters was permitted without the need of the approval of the Secretary of War, if authorized by law before the passage of said act. The excavating, filling, altering, etc., the channel

of navigable waters was permitted if approved and authorized by the Secretary of War.

Among the changes effected by the act of 1899 was to require the affirmative authorization by Congress to create any obstruction to the navigable waters of the United States, except that bridges, dams, dikes, and causeways in or across waters the navigable portions of which lie wholly within the limits of a single state were permitted if authorized by state legislation and the location and plans of such structure were approved by the chief of engineers and by the Secretary of War. Perhaps without the change from "authorized by law" to "authorized by Congress" no obstruction to the navigable capacity of interstate waters without affirmative congressional enactment would have been lawful, but a present reading of the law in the light of the history of its enactment clearly evinces to my mind a legislative purpose to require affirmative action on the part of Congress before such a crossing of interstate streams as contemplated by complainants in this suit shall be permitted, and that only when such congressional action shall have been taken can the powers delegated to the Secretary of War be put into operation. (188 Fed. 996–7, 998–9.)

The fallacy of the reasoning of the Supreme Court of Maine lies in its omission to consider that in the Act of September 19, 1890, the effect of the combined provisions of sections 7 and 10 gave the same result that it thought could not have been intended in the

later statute. The structures covered by section 7 of the earlier act could be authorized by the Secretary of War *if* they did not constitute obstructions. If they did, they were forbidden by Section 10 unless "affirmatively authorized by law." The conclusion of the Maine court disregards the word "affirmatively" and renders it meaningless; indeed, the result is the substitution of the word "impliedly."

E

Whether the entire navigable capacity, and whether the unmodified condition of a navigable water should be conserved for the use and safety of navigation, are questions legislative in character, and the determination of these questions by Congress is conclusive

By Section 10 of the Act of 1899 (as well as by the corresponding provisions in Sections 7 and 10 of the Act of 1890), Congress has made unlawful, not only the creation of *obstructions* to navigable capacity, but also any modification of "the course, location, condition, or capacity of any * * * navigable water of the United States." The latter may or may not actually amount to *obstructions*. That Congress has power to exercise its paramount control to this extent, and that its determination as to the extent of the exercise is conclusive, is, we submit, not open to question.

In *United States* v. *Chandler-Dunbar Water Power Co.*, 229 U. S. 53, this Court, speaking of the power of Congress over interstate commerce, said (p. 62):

> It includes navigation and subjects every navigable river to the control of Congress. All means having some positive relation to

the end in view which are not forbidden by some other provision of the Constitution are admissible.

This Court further said (pp. 64, 65, 70):

> So unfettered is this control of Congress over the navigable streams of the country that its judgment as to whether a construction in or over such a river is or is not an obstacle and a hindrance to navigation is conclusive. Such judgment and determination is the exercise of legislative power in respect of a subject wholly within its control.
>
> * * * * *
>
> *The conclusion to be drawn is, that the question of* * * * *whether the whole flow of the stream should be conserved for the use and safety of navigation, are questions legislative in character,* and when Congress determined, as it did by the act of March 3, 1909, that the whole river between the American bank and the international line * * * was "necessary for the purposes of navigation of said waters and the waters connected therewith," *that determination was conclusive.*
>
> * * * * *
>
> It is for Congress to decide what is and what is not an obstruction to navigation.

In *Southern Pacific Company et al.* v. *Olympian Dredging Company*, 260 U. S. 205, this Court speaking of the Acts of 1890 and 1899, quoted with approval language from the opinion in *Monongahela Bridge Co.* v. *United States*, 216 U. S. 177 (see *infra*, p. 189) to the same effect.

In *Philadelphia Co.* v. *Stimson*, 223 U. S. 605, this Court said (pp. 635, 638):

> When the state of Pennsylvania established harbor lines and thus undertook to regulate the rights of navigation, its action, however effective as between the state and the riparian proprietors, was necessarily subject to the paramount power of Congress. The state lines can be conceded no permanent force, as against the will of Congress, without substituting for its constitutional authority the supremacy of the state with respect to navigable waters.
>
> It is for Congress to decide what shall or shall not be deemed in judgment of law an obstruction of navigation. *Pennsylvania* v. *Wheeling & B. Bridge Co.*, 18 How. 421. And in its regulation of commerce it may establish harbor lines or limits beyond which deposits shall not be made or structures built in the navigable waters. The principles applicable to this case have been repeatedly stated in recent decisions of this court.
>
> * * * * *
>
> It must be concluded, therefore, that it was competent for Congress to provide for the establishment of the harbor lines in question for the protection of the harbor of Pittsburgh. It acted within its constitutional power in authorizing the Secretary of War to fix the lines.

See also *Wheeling Bridge case* (second case), 18 How. 421; *Union Bridge Co.* v. *United States*, 204 U. S. 364; *Gibson* v. *United States*, 166 U. S. 269; *Scranton* v. *Wheeler*, 179 U. S. 141; *Chicago, B. &*

Q. R. Co. v. *Illinois*, 200 U. S. 561; *West Chicago Street R. Co.* v. *Illinois*, 201 U. S. 506; *Hannibal Bridge Co.* v. *United States*, 221 U. S. 194.

The vice of appellant's contention is that it attempts to place upon the already overburdened court a heavy burden which is not justiciable but political in nature. It asks the court to usurp the political function of Congress to determine the legislative policies of the Government.

F

Congress has committed to the Secretary of War and the Chief of Engineers the administrative duty of determining whether a modification of the condition, etc., of navigable waters is such that they can approve or whether it amounts to an obstruction requiring affirmative authorization from Congress; the determination of those questions by the Secretary of War and the Chief of Engineers is conclusive

It will be recalled that at the very outset, in granting the permit of May 8, 1899, the Secretary of War entertained grave doubt as to his power to authorize the diversion of water by appellant. This was the reason for the incorporation of the first condition in that permit, namely, that it should "be subject to such action as may be taken by Congress." The report of Major Marshall, United States Engineer at Chicago, to the Chief of Engineers of the United States, on April 24, 1899 (Rec. Vol. VI, p. 3586), confirms this and shows that the basis for the doubt was the effect of the diversion on the levels of the Great Lakes. The Chief of Engineers and the Secretary of War came to the conclusion that since the lowering from a diversion of 300,000 cubic feet per minute would not exceed three inches, they might

hazard a consent *subject* to the action of Congress. At that time there had not been any considerable investigation of the effect on the lake levels.

In 1907, however, when the subject of a further diversion by opening a new outlet through the Calumet came up, the subject of the effect on lake levels had been elaborately investigated by the United States Lake Survey and the Secretary of War and the Chief of Engineers had before them its reports and also the conclusions of the International Waterways Commission in its report of January 4, 1907. The Chief of Engineers reached the conclusion that the proposed further abstraction would—

> undoubtedly lower the levels of all the waters of the Great Lakes, except those of Lake Superior, and thus diminish the navigable capacity and depth of the various channels and harbors which have been deepened and improved under authority of Congress—

and came to the conclusion that the War Department should deny the application, it being a matter for the sanction of Congress. (Rec. Vol. VII, pp. 23–25.) The Secretary of War followed the recommendation of the Chief of Engineers, as the statute required him to, and denied the application. Both the Wilmette Permit of September 11, 1907, and the Calumet Permit of June 30, 1910, were expressly conditioned on a limitation of the total withdrawal to 4167 c. s. f.

On February 5, 1912, appellant applied for permission to divert 10,000 c. s. f. There was an ex-

tended hearing. The report of Lt. Col. Zinn, Engineer in charge at Chicago (Rec. Vol. VI, pp. 3732–3737), shows the reasons for the recommendation of the Chief of Engineers against allowing the application; the reasons were substantially the same as those expressed by the Secretary of War. In his decision on January 8, 1913, denying the application, the Secretary of War came to the following conclusions (among others):

> First. That the diversion of 10,000 cubic feet per second from Lake Michigan, as applied for in this petition, would substantially interfere with the navigable capacity of the navigable waters in the Great Lakes and their connecting rivers.
>
> Second. That that being so, it would not be appropriate for me, without express congressional sanction, to permit such a diversion, however clearly demanded by the local interests of the sanitation of Chicago.

With regard to the prior permits, he said:

> The propriety of obtaining congressional sanction for the project has been pointed out from the beginning; and the form in which the permit has been granted, even for the moderate amount of diversion permitted, has been so phrased as to indicate that the permission was predicated upon the absence of any substantial injury to commerce. (Rec. Vol. VII, pp. 7–17.)

The Chief of Engineers and the Secretary of War have, therefore, made a decision, after a hearing in

which there has never been a suggestion of unfairness or fraud or arbitrary action, that a diversion of more than 4,167 c. s. f. would be an obstruction to the navigable capacity of navigable waters of the United States and that, therefore, the increased diversion was one which only Congress could authorize. Certain it is that the Chief of Engineers and the Secretary of War refused to authorize it. The appellant, however, proceeded in defiance of the decision to divert an increased amount of water until it now exceeds 10,000 c. s. f.

We submit that the necessary effect of Section 10 of the Act of Congress of March 3, 1899, is to make the decision of the Chief of Engineers and the Secretary of War final. The decision of such a question by Congress is, as we have already pointed out in the preceding subheading, final as a determination of a legislative question. By Section 10 it has necessarily committed the determination of certain facts to these officers of the United States. They can recommend and authorize a modification of the condition of navigable waters if and when, after investigation by the Chief of Engineers, they find that the modification will not amount to an *obstruction*. If they find that it *will* amount to an obstruction, then the modification must await the action of Congress. Furthermore, even if there were no showing that the modification would actually amount to an obstruction, there is no duty on the part of the Chief of Engineers to recommend, or the Secretary of War to authorize, it. They may and should

be guided by what seems to be for the best interest of the United States in the preservation of the navigability of its waters.

The appellant is now asking this Court to disregard, as appellant has done, what is in effect the decision of Congress on a legislative matter. While the decision comes from the Chief of Engineers and the Secretary of War, it must be regarded as having the same force and effect as that of Congress which might unquestionably have determined the matter itself. The decisions of this Court do not, we believe, leave the matter open to doubt. In *Southern Pacific Co. et al.* v. *Olympian Dredging Co.*, 260 U. S. 205, this Court said (pp. 208–210):

> That the Secretary of War was authorized to impose the condition heretofore quoted does not admit of doubt. The power to approve implies the power to disapprove, and the power to disapprove necessarily includes the lesser power to condition an approval. In the light of this general assumption by Congress of control over the subject and of the large powers delegated to the Secretary, the condition imposed by that officer can not be considered otherwise than as an authoritative determination of what was reasonably necessary to be done to insure free and safe navigation so far as the obstruction in question was concerned.
>
> * * * * * *
>
> It was not for the petitioners, however, to question either his reasons or his conclusions. They were justified in proceeding upon the assumption that what the Secretary, in the

exercise of his lawful powers, declared to be no obstruction to navigation, was in fact no obstruction. The language which this court employed in *Monongahela Bridge Co.* v. *United States*, 216 U. S. 177, 195, is pertinent. "* * * Congress intended by its legislation to give the same force and effect to the decision of the Secretary of War that would have been accorded to direct action by it on the subject. It is for Congress, under the Constitution, to regulate the right of navigation by all appropriate means, to declare what is necessary to be done in order to free navigation from obstruction, and to prescribe the way in which the question of obstruction shall be determined. Its action in the premises can not be revised or ignored by the courts or by juries, except that when it provides for an investigation of the facts, upon notice and after hearing, before final action is taken, the courts can see to it that executive officers conform their action to the mode prescribed by Congress."

See also the cases cited under the preceding subheading. These cases meet every contention made by appellant both in its Point VIII and its Point III (c).

IV

Appellant has created and is maintaining an obstruction to the navigable capacity of navigable waters of the United States in violation of section 10 of the act of Congress of March 3, 1899

That appellant has violated and is continuing to violate the last clause of Section 10 of the Act of

1899, forbidding modification of the condition, etc. of navigable waters, hardly seems open to question. The creation of a large navigable river flowing away from Lake Michigan into the Mississippi River Basin, equal in volume to the combined flow of the Grand, Fox, and St. Joseph Rivers and substantially five per cent of the flow over Niagara Falls; the lowering of the lake levels; the increased current in the Chicago River, and other incidents—show such a violation conclusively. We shall, therefore, take no time to demonstrate what is self-evident, by discussion of the evidence in this connection.

That appellant is likewise violating the first clause of Section 10 forbidding the creation of obstructions to navigable capacity can hardly be doubted, under the evidence in this case and the decisions of this Court. In our Statement of the Case (pp. 74 to 78) we have pointed out the conclusions reached, after careful investigation and painstaking observations over a period of years, by the Chief of Engineers, the United States Lake Survey, and the International Waterways Commission as to the amount of the lowering of levels. The question was raised in the Calumet River Suit instituted in 1908 and the appellant made no effort to rebut the testimony of appellee's witnesses on this subject, all men of experience and standing. In the hearing before the Secretary of War on appellant's application for an increased diversion, which led to the Secretary's decision of January 8, 1913, and his findings as to the

effect of the diversion, the Chief Engineer for appellant said he did not wish "to question the accuracy of the figures or the fairness of the calculations." It was only after the application had been refused and the Main Channel Suit was instituted that appellant sought to discredit the figures and calculations. It sought to do so largely through the testimony of one man who was employed by appellant in connection with the litigation and therefore was not a disinterested witness, a man whose expert qualifications will not bear close scrutiny. On the basis of the data furnished by *appellee's* witnesses, this individual assumed to criticize the methods, observations, and deductions of the United States Lake Survey, the International Waterways Commission, and the testimony of a host of competent expert engineers. The superficiality of his criticisms is amply demonstrated by the evidence, and we do not feel called upon to enter upon a detailed discussion of its technical features. Even this witness, however, conceded a lowering in the lake levels of approximately two inches less than those of the appellee's most trustworthy witnesses. In the case of Lake Michigan appellant's witness conceded a lowering of 4.1 inches for a diversion of 10,000 c. s. f. (See Statement of the Case, p. 79.)

The material and substantial injury to navigation caused by each inch of lowering is, we believe, incontrovertibly established by the evidence. (See Statement of the Case, p. 94.) That we are dealing,

not with a fanciful or theoretical effect, but a concrete obstruction is perfectly apparent from the narrow margin which the larger boats have even now over critical points in the Great Lakes. It will not do to say that there should be a clearance of two feet anyway as a margin of safety. The same result follows: the draught of the boat must still be so many inches less. The same applies to the oscillations due to barometric conditions, etc.

Finally, the injury to navigation by the increased and dangerous current in the Chicago River must be considered; the Secretary of War has repeatedly indicated his view that a current of a mile and a quarter an hour is all that is consistent with safe navigation of the river. We do not believe that appellant will gainsay that it has created and is maintaining a current of a greater rapidity.

That the unauthorized acts of appellant have created an obstruction in violation of the prohibition of Section 10 of the Act of 1899 is clear from a consideration of the cases interpreting the meaning and scope of the clause in question.

A

"Anything wherever done or however done, within the limits of the jurisdiction of the United States, which tends to destroy the navigable capacity of one of the navigable waters of the United States, is within the terms of the prohibition"

The language quoted in this subheading is from the opinion of this Court in *United States* v. *Rio Grande Dam & Irrigation Company*, 174 U. S. 690. In that case the Irrigation Company was proceeding to construct a dam across the Rio Grande River in the

territory of New Mexico and to appropriate the waters of that stream for the purposes of irrigation. The Rio Grande River was not navigable within the limits of New Mexico, but became a navigable river at a point considerably lower down in its course. Under the issues raised by the pleadings, the facts were assumed to be that most of the flow of the river had already been appropriated by other parties and the defendant proposed to take the balance. This, according to the averment of the defendant, "would be very largely only so acquired from the excess storm and flood waters now unappropriated, useless, and going to waste." This Court said (p. 708):

> It is urged that the true construction of this act limits its applicability to obstructions in the navigable portion of a navigable stream, and that as it appears that although the Rio Grande may be navigable for a certain distance above its mouth, it is not navigable in the territory of New Mexico, this statute has no applicability. The language is general, and must be given full scope. It is not a prohibition of any obstruction to the navigation, but any obstruction to the navigable capacity, and anything, wherever done or however done, within the limits of the jurisdiction of the United States which tends to destroy the navigable capacity of one of the navigable waters of the United States, is within the terms of the prohibition. Evidently Congress, perceiving that the time had come when the growing interests of commerce required that the navigable waters of the United States

> should be subjected to the direct control of the national government, and that nothing should be done by any state tending to destroy that navigability without the explicit assent of the national government, enacted the statute in question. And it would be to improperly ignore the scope of this language to limit it to the acts done within the very limits of navigation of a navigable stream.

This language is, in itself, sufficient answer to the untenable position taken by appellant throughout its brief that, having widened and improved the channel of the Chicago River under its permits of July 11, 1900, so as to accommodate an increased flow, appellant was thereafter helpless to control the amount of water flowing into its canal, and was not responsible if 10,000 c. s. f. happened to go through its gates at Lockport. The words "anything wherever done or however done" seem broad enough to cover the failure and refusal of appellant to close its gates far enough to limit the flow to 4,167 c. s. f., especially in view of its acceptance of the various permits up to and including the Wilmette Permit of September 11, 1907 and the Calumet Permit of June 30, 1910, in both of which appeared the express condition that the total diversion of water from Lake Michigan should not exceed the 4,167 c. s. f. already authorized. Appellant received privileges in these permits on what must be construed to be an additional agreement on its part to observe the limitation on the diversion.

B

To constitute an obstruction neither material injury and damage to commerce nor unreasonable obstruction to navigation are necessary

Under its Point VI (b), appellant contends that the injury and damage to commerce must be *material* and the obstruction to navigation must be *unreasonable*. Both requirements are, as a matter of fact, met in the instant case. (See Statement of the Case, *supra*, pp. 70 to 106.) That appellant's contention is not the law, however, is clear from consideration of this Court's decisions in *United States* v. *Rio Grande Dam & Irrigation Company*, 174 U. S. 690, and *Economy Light & Power Co.* v. *United States*, 256 U. S. 113.

In the Rio Grande case this Court passed adversely on such a contention in saying of the language in Section 10 (p. 708):

> It is not a prohibition of any obstruction to the *navigation*, but any obstruction to the navigable *capacity*.

The case was remanded, directing—

> an inquiry into the question whether the intended acts of the defendants * * * will substantially diminish the *navigability* of that stream within the limits of present navigability, and if so, to enter a decree restraining those acts to the extent that they will so diminish. (p. 710.)

That the evidence in the instant case meets this requirement is shown in our Statement of the Case. We do not belive that the word "substantially" as

used by this Court in the excerpt just quoted was intended to mean more than *appreciably*, that is, in a manner in which it would have to be taken account of in estimating the navigable capacity of a water. If it be true, as appellant asserts, that harbors and other improvements built in the Great Lakes since the diversion have been calculated so as to allow for the several inches loss in level, further proof would be unnecessary. The importance of every inch in critical points in these waters is, however, proved by the practice of navigators in taking careful note of the levels in connection with loading their vessels; every loss of an inch means a loss in tonnage of some eighty tons. A matter of five or six inches is very substantial in places where, like the Poe Lock, there is a depth of only 18 to 20 feet. (Rec. Vol. VI, p. 3643.)

Appellee was under no obligation to prove material injury and damage to commerce, but, nevertheless, did so. (Statement of the Case, *supra*, pp. 94 to 106.) That this was not a necessary element in its case is clear, not only from the Rio Grande case, but also *Economy Light & Power Co.* v. *United States*, 256 U. S. 113. In that case the United States sought by injunction to restrain the Power Company from constructing a dam in the Desplaines River in Illinois.

> The district court found that there was no evidence of actual navigation within the memory of living men, and that there would be no present interference with navigation by the building of the proposed dam. The

> circuit court of appeals did not disturb this finding [168 C. C. A. 138, 256 Fed. 792, 798]. But both courts found that in its natural state the river was navigable in fact (p. 117).
>
> * * * * *
>
> We concur in the opinion of the circuit court of appeals that a river having actual navigable capacity in its natural state, and capable of carrying commerce among the states, is within the power of Congress to preserve for purposes of future transportation, even though it be not at present used for such commerce, and be incapable of such use according to present methods, either by reason of changed conditions or because of artificial obstructions (p. 123).

That a small variation of lake levels is *substantial* and may constitute an obstruction is confirmed by the language we have elsewhere quoted from *United States* v. *Chandler-Dunbar Water Power Co.*, 229 U. S. 53, (*supra*, p. 131).

Another case which may be considered in this connection is the first *Wheeling Bridge case*, 13 How. 553. As has already been pointed out, practically all the contentions here made by appellant were urged and overruled (*supra*, p. 139). See, too, the excerpt elsewhere quoted from *Hubbard* v. *Fort*, 188 Fed. 992 (*supra*, p. 178).

Appellant cites *Union Bridge Co.* v. *United States*, 204 U. S. 364. That case, however, involved a proceeding in the nature of a criminal information under Section 18 of the Act of 1899 making it the duty of the

Secretary of War to institute certain proceedings whenever he—

> shall have good reason to believe that any railroad or other bridge now constructed, or which may hereafter be constructed, over any of the navigable waterways of the United States, is an *unreasonable* obstruction to the free navigation of such waters.

The insertion of the word "unreasonable" was naturally due to the conflicting interests of commerce over the bridge and under the bridge. The fact that the word was specifically employed in the case of bridges confirms our contention that it is not to be read into Section 10.

We do not comprehend in what respect the other cases cited by appellant on this subject can possibly be deemed in point.

Appellant's Point VI, (c), is substantially a paraphrasing of the point just discussed, with the additional claim that the obstruction must "*clearly exist.*" The cases chiefly relied on, *New York* v. *New Jersey & Passaic Valley Sewage Commissioners*, 256 U. S. 296, and *Kansas* v. *Colorado*, 206 U. S. 46, are readily distinguished from the instant case. The principle governing controversies between states, as expressed by this Court in the former case, as is follows (p. 309):

> Before this court can be moved to exercise its extraordinary power under the Constitution to control the conduct of one state at the suit of another, the threatened invasion of rights must be of serious magnitude, and it must be

established by clear and convincing evidence. *Missouri* v. *Illinois*, 200 U. S. 496.

The reasons for this principle are clearly set forth in *Kansas* v. *Colorado* (pp. 97–98).

> As Congress can not make compacts between the states, as it can not, in respect to certain matters, by legislation compel their separate action, disputes between them must be settled either by force or else by appeal to tribunals empowered to determine the right and wrong thereof. Force, under our system of government, is eliminated. The clear language of the Constitution vests in this court the power to settle those disputes. We have exercised that power in a variety of instances, determining in the several instances the justice of the dispute. Nor is our jurisdiction ousted, even if, because Kansas and Colorado are states sovereign and independent in local matters, the relations between them depend in any respect upon principles of international law. International law is no alien in this tribunal.
>
> * * * * * *
>
> One cardinal rule, underlying all the relations of the states to each other, is that of equality of right. Each state stands on the same level with all the rest. It can impose its own legislation on no one of the others, and is bound to yield its own views to none. Yet, whenever, as in the case of *Missouri* v. *Illinois*, 180 U. S. 208, the action of one state reaches through the agency of natural laws, into the territory of another state, the question of the extent

> and the limitations of the rights of the two states becomes a matter of justiciable dispute between them, and this court is called upon to settle that dispute in such a way as will recognize the equal rights of both and at the same time establish justice between them. In other words, through these successive disputes and decisions this court is practically building up what may not improperly be called interstate common law.

This principle of equality has no application to a case which presents a conflict between a paramount sovereign power of Congress and an assertion of power by a state.

> There is no room in our scheme of government for the assertion of state power in hostility to the authorized exercise of Federal power. (*Minnesota Rate Cases*, 230 U. S. 352, 399)

The case of *Mississippi R. R. Co.* v. *Ward*, 2 Black 485 (cited and quoted in Appellant's Brief, p. 199) was simply a suit between private individuals.

In the instant case, however, the obstruction was *clearly* proved unless the conjectures and superficial criticisms of one person, whose interest and qualifications are open to question, can be deemed to cast any serious doubt on the conclusions of the United States Lake Survey, the International Waterways Commission, the Chief of Engineers of the United States, the Secretary of War, and a host of expert engineers of high standing.

C

Appellant's criticism of appellee's use of expert evidence in this case is unfounded

In its Point VI (a) appellant takes occasion to criticize appellee's use of expert testimony to prove the lowering of the levels of the Great Lakes and the injury to navigation and commerce, and complains that "no one testified to observing any lowering effect" or "to observing a loss in the amount the boats actually carried." (Appellant's Brief, p. 194). Does one need to see very much more than the physical phenomenon of a large navigable river carrying 10,000 c. s. f. into the Mississippi Valley? Appellant will not assert that the evidence of the total discharge of the Niagara River was a mere matter of expert testimony, and that it is taking practically five per cent of that discharge. It will not deny that it is abstracting from Lake Michigan substantially as much as is contributed by the combined flow of the Grand, St. Joseph, and Fox Rivers.

Such a contention was made and answered in the first *Wheeling Bridge Case*, 13 How. 518, 568:

> The fact that the bridge constitutes a nuisance is ascertained by measurement. The height of the bridge, of the water, and of the chimneys of steamboats are the principal facts to be ascertained. If the obstruction exists, it is a nuisance. To ascertain this a jury is not necessary. It is shown in the report, by a mathematical demonstration. And the other matters connected with the case as to the benefit of high chimneys, lowering of them in pass-

> ing under the bridge, and shortening chimneys, are matters of science and experience, better ascertained by a report than by a verdict. And the same may be said of the statistics which are in the case.

Appellant cites *Missouri* v. *Illinois*, 200 U. S. 496, and *North Dakota* v. *Minnesota* 263 U. S. 365. We have already pointed out the distinction between controversies among states, which come into this Court on a basis of equality, and the present controversy, in which the Federal Government is asserting its paramount right. *Salvin* v. *North Brancepeth Coal Co.*, L. R. 9 Ch. App. 705, also cited by appellant, was a controversy between private parties, and can be of no assistance in a case of this kind.

V

The obstructions created by appellant have never been affirmatively authorized by Congress as required by section 10 of the act of March 3, 1899

Under its Point I appellant claims to find Congressional authority for an apparently unlimited diversion of water in the Act of Congress of March 2, 1827, relating to the Illinois and Michigan Canal, and even goes so far as to assert that—

> The Secretary of War construed the Congressional Act of March 2, 1827, and the laws of Illinois, as affirmatively authorizing the diversion. (Appellant's Brief, p. 90.)

This is the only express claim of appellant to Congressional authority but elsewhere in its brief we find substantially the same contention made with

regard to the Niagara Falls Act of 1906 and the Canadian Boundary Waters Treaty of January 11, 1910 (Appellant's Brief, pp. 188–192). We shall treat of all three claims of authority under the same heading.

We discuss them only under protest. Section 10 of the Act of Congress of March 3, 1899, demands that the particular obstruction be "*affirmatively* authorized," and the word "affirmatively" forbids any *implication* of authority. The statutory requirement can not be met by anything short of *express* authority.

A

The Act of Congress of March 2, 1827, relating to the Illinois and Michigan Canal did not constitute such authorization.

Fully to appreciate appellant's ingenuity in resurrecting this ancient Act of 1827 (4 St. at L. 234) it is necessary only to read its provisions and to know how much, or how little, was done under the authority of that statute. We need not pause to discuss the prior Act of March 30, 1822 (3 St. at L. 659) as, by its terms, it was abandoned by failure of Illinois to comply with its conditions. The pertinent portions of the Act of 1827 are as follows:

> An act to grant a quantity of land to the State of Illinois for the purpose of aiding in opening a canal to connect the waters of the Illinois River with those of Lake Michigan. [Approved and in force March 2, 1827.]
>
> SECTION 1. *Be it enacted by the Senate and House of Representatives of the United States of America in Congress Assembled*, That there be

and hereby is granted to the State of Illinois, for the purpose of aiding the said State in opening a canal to unite the waters of the Illinois River with those of Lake Michigan, a quantity of land equal to one-half of five sections in width, on each side of said canal, and reserving each alternate section to the United States, to be selected by the Commissioner of the Land Office, under the direction of the President of the United States, from one end of the said canal to the other; and the said land shall be subject to the disposal of the Legislature of the said State, for the purpose aforesaid, and no other: *Provided*, That the said canal when completed, shall be and forever remain a public highway for the use of the Government of the United States, free from any toll, or other charge, whatever, for any property of the United States, or persons in their service passing through the same: *Provided*, That said canal shall be commenced within five years and completed in twenty years, or the State shall be bound to pay to the United States the amount of any lands previously sold, and that the title to purchasers under the State shall be valid.

SEC. 2. And be it further enacted, That so soon as the route of the said canal shall be located and agreed on by the said State, it shall be the duty of the Governor thereof, or such other person or persons as may have been, or shall hereafter be, authorized to superintend the construction of said canal, to examine and ascertain the particular sections to which said State will be entitled, under the provisions of

this act, and report the same to the Secretary of the Treasury of the United States.

SEC. 3. And be it further enacted, That the said State under the authority of the Legislature thereof, after the selection shall have been so made, shall have power to sell and convey the whole or any part of the said land, and to give a title in fee simple therefor, to whomsoever shall purchase the whole or any part thereof. (Rec. Vol. VIII, Rec. 68–69.)

This land grant amounted to 200,000 acres. (Rec. Vol. IV, p. 2228.)

By an act passed January 9, 1836, the State Legislature of Illinois provided for the construction of the Illinois and Michigan Canal (Rec. Vol. IV, pp. 2295–2304):

SEC. 16. (Description—Proviso). The said canal shall not be less than forty-five feet wide at the surface, thirty feet at the base, and of sufficient depth to insure a navigation of at least four feet, to be suitable for ordinary canal-boat navigation, to be supplied with water from Lake Michigan and such other sources as the canal commissioners may think proper, and to be constructed in the manner best calculated to promote the permanent interest of the country; reserving ninety feet on each side of said canal to enlarge its capacity, whenever in the opinion of the board of canal commissioners the public good shall require it.

The canal as originally projected and worked on from 1836 to 1841 had a declivity of an inch per mile, or 2.9 feet between Bridgeport (on the fork of the

south branch of the Chicago River) and Lockport. Lack of funds prevented its completion on this plan. When work was resumed in 1843 a temporary expedient was adopted, of a temporary level eight feet above the Chicago datum. (Rec. Vol. III, 1718.) The canal was opened in 1848. It was fed in ordinary seasons from the Desplaines River and by a feeder through the Sag Valley and the Calumet River at Blue Island. A dam was built across the Calumet River at an elevation eleven feet above the Chicago datum. This was not sufficient in the dry seasons, and a Dutch Wheel or Lift Wheel was erected at Bridgeport for the purpose of supplementing the feed water of the canal. (Rec. Vol. III, p. 1716.) In time of drought—about 45 days in the year—the canal received water by pumping from the Chicago River. (Rec. Vol. VI, p. 3723.)

In 1865, an enabling act was procured from the Illinois Legislature which authorized the City of Chicago, by arrangement with the Canal Trustees, to deepen this canal on the original plan for sanitary purposes. (Rec. Vol. VIII, pp. 70–71.) This plan was completed in 1871. When opened to gravity the canal is estimated by appellant's witness Cooley to have carried out 40,000 cubic feet per minute. The lake was then high and in later years, when it fell, the capacity shrunk to 15 to 20,000 cubic feet per minute, which was scarcely more than the dry weather flow. In 1881 the Illinois Legislature by resolution authorized Chicago to install pumps at the north terminus of the canal (i. e., Bridgeport) whereby at least

60,000 cubic feet per minute should be pumped from the Chicago River into the canal. These pumps were installed in 1883, but were not taken over by the city until 1886. (Rec. Vol. III, 1718–1719.)

According to appellant's own witness, Cooley, after 1883 the Illinois and Michigan Canal was operated—

> up to a limit of 60,000 feet of water per minute or a thousand feet per second, which was little in excess of the ordinary flow of the sewers coming from the water supply and the ground waters. (Rec. Vol. III, p. 1736.)

In testimony given several years later, after the hearing before the Secretary of War, appellant's Chief Engineer Wisner, stated that the capacity of the canal after 1871 was 24,000 cubic feet per minute, and that after the installation of the pumping works at Bridgeport, a total of 50,000 to 60,000 cubic feet per minute was caused to flow into the canal from the Chicago River. The witness then made what was on its face a *guess*, unsupported by observation, measurements, or facts, that the diversion of this amount—

> had the practical effect of reversing the Chicago River * * * when there was a dry weather flow (i. e., a minimum run-off). (Rec. Vol. VI, p. 8433.)

If the dry-weather flow of the Chicago River is as little as 60,000 cubic feet per minute, it is hard to understand why appellant's witnesses elsewhere were so bold as to state its maximum run-off as 10,000

c. s. f. If any water was ever diverted from *Lake Michigan* before the opening of the appellant's canal in 1900, it was an insignificant amount in a limited portion of the year, and that there ever was a reversal of current prior to 1900 may well be doubted.

Now, having briefly reviewed the history of this canal, we may appropriately repeat the comment made by representatives of the Canadian Government in a brief filed with the Secretary of War in reply to appellant's contention:

> To argue that the operation of a small pumping plant for 45 days in the year raising an insignificant amount of water for navigation purposes for locks 110 feet long, 18 feet wide and 6 feet deep, justifies the diversion of 10,000 cubic feet of water per second, is a somewhat unusual expansion of terminology. (Rec. Vol. VI, p. 3724.)

The decision of the Secretary of War on January 8, 1913, contained the following:

> In the argument before me it was urged that the present canal represented the growth and development of a national policy expressed in two acts of Congress, 1822 and 1827, which authorized the construction of a canal "to connect the Illinois River with Lake Michigan," thus connecting the two watersheds. (Acts of March 30, 1822, and March 2, 1827.) But these statutes authorized a canal for the purpose of navigation and not sanitation. (*Missouri* v. *Illinois*, 200 U. S. 526.) The Illinois and Michigan Canal, actually con-

> structed under their authority, derived its water for navigation purposes from the Calumet, Des Plaines, and Chicago Rivers, and not from the Lakes. And although in the latter part of its existence it was used to a very slight extent to help purify the waters of the Chicago River and thus sanitate the City of Chicago, such a purpose could not have been dreamed of at the time its construction was authorized by Congress, 90 years ago. I can not see that its authorization and construction offer the slightest congressional sanction for the great canal now under discussion, which was not even contemplated until much more than half a century later. (Appellant's Narrative, pp. 29–30.)

The reasoning of the Secretary of War would seem unanswerable. Since counsel, however, press the point so urgently, we shall pursue it further.

1. *The authority in both the act of March 30, 1822, and the act of March 2, 1827, was for the construction of a particular canal, the location of which was to be determined by law.*

The act of the Illinois Legislature of January 9, 1836, reserved ninety feet on each side of the proposed canal "to enlarge its capacity" and the canal was constructed under the authority of that act. It is not claimed that the appellant's canal is within this ninety foot zone; it could not be, for the new canal is 160 to 200 feet wide. The land granted to Illinois by the Federal government was sold to individuals.

The Act of Congress authorizes *a* canal, not two canals or a dozen. Would appellant claim that Congressional authority to build one bridge over the Ohio River includes authority to build another a mile away?

The Illinois and Michigan Canal exists to-day. In fact, it was the subject of legislation by the General Assembly of Illinois as late as July 1, 1919, Section 3 of which is exceedingly interesting in view of appellant's assertion that its canal *replaces* the old one:

> SEC. 3. The Department of Public Works and Buildings is authorized and directed to protect against and prevent encroachments upon said Illinois and Michigan Canal *throughout its entire course as originally constructed, and to preserve its navigable condition throughout said entire course*, and it may, when the permission of the Federal government is obtained, change and improve said canal to provide terminal and harbor facilities for interchange of freight or for any other use in connection with transportation which said department may deem advantageous to the State. No permission heretofore or hereafter granted, which results in obstruction to the navigable condition or capacity of any portion of said canal or interferes with its use for any of the purposes herein named shall operate in any way whatever to deprive the State of any of its rights in said canal or canal lands, and all obstructions or structures heretofore or hereafter erected or placed in said canal shall be subject

> to removal upon the order of said Department of Public Works and Buildings: *Provided, however*, The use of the Sag Channel of the Sanitary District of Chicago shall not be prevented nor shall it be considered an obstruction within the meaning of this section, but the State may require, in the development of its waterways and the use of said Illinois & Michigan canal such changes in the crossing of the Illinois and Michigan canal by said Sag channel as may be necessary for the use of said Illinois and Michigan canal by the State.

Note, too, that the Illinois Legislature does not regard itself as immune from Federal control with respect to the old canal. It regards it as necessary to obtain the permission of the Federal government to change or improve the canal. And yet appellant is in substance saying that the Illinois Legislature bestowed upon appellant in 1889 all its rights in connection with the old canal and that these rights included authority to build a new one many times its size. When counsel state (Appellant's Brief, p. 123) that—

> Illinois fixed the amount of the diversion by appellant's organic act, which action was also pursuant to the Act of Congress of March 2, 1827;

they are ascribing an intention to the Illinois Legislature which it did not have and which was specifically negatived no longer ago than 1919. *Appellant has nothing whatsoever to do with the canal constructed under the Act of Congress of 1827*, and has no rights

with respect to it further than permission to cross it with the Sag channel. Even this permission is subject to such modification "as may be necessary for the use of said Illinois and Michigan Canal by the State."

2. *The authority in the act of March 2, 1827, was for a canal for the purpose of navigation and not sanitation*

Neither Congress nor the State of Illinois contemplated the use of the proposed canal for any purpose but navigation. It is extremely doubtful whether Congress has any power to authorize a diversion of navigable waters for the mere purpose of sanitation; at any rate, it did not intend to do so. From 1871 to 1900 it was as a matter of fact used by the city of Chicago to some extent for sewage disposal. The authority of Congress to do this was not asked nor given. The amount of water taken was insignificant and it is doubtful whether at its maximum Chicago withdrew a perceptible quantity from Lake Michigan. In *Missouri* v. *Illinois*, 200 U. S. 496, this Court, referring to the early Acts of Congress, said (p. 526):

> Of course these acts do not grant the right to discharge sewage.

There is evidence in this case that 1,000 c. s. f. is sufficient for navigation purposes. (Rec. Vol. VI, pp. 3633–4.) The fact that a canal is big enough to accommodate 10,000 or 14,000 c. s. f. does not mean that appellant *has* to take that much. In fact a slower current would be better for purposes of navi-

gation. The fact that the maximum run-off of the Chicago River is 10,000 c. s. f. is immaterial. So far as navigation is concerned, it makes little difference whether the current flows one direction or the other. Furthermore, the maximum run-off of the Calumet River is over 15,000 c. s. f. Does that mean that eventually appellant will be forced to take over 25,000 c. s. f. under the Act of 1827?

When counsel for appellant state (Appellant's Brief, p. 122) that—

> To provide a "never-failing supply of water for navigation of the Illinois River at all times," it was likewise necessary to have a volume of water from Lake Michigan for navigation purposes of that amount (e. g. 10,000 c. s. f.)—

they are making a statement without foundation in the record or in fact.

In this connection the following may be quoted from *Ex parte Boyer*, 109 U. S. 629, 631:

> The Illinois and Michigan Canal is an artificial navigable waterway, connecting Lake Michigan and the Chicago river with the Illinois river and the Mississippi river. By the Act of Congress of March 30th, 1822 (ch. 14, 3 Stat. at L. 659), the use of certain public lands of the United States was vested in the State of Illinois forever, for a canal to connect the Illinois river with the southern bend of Lake Michigan. The Act declared "That the said canal, when completed, shall be and forever remain a public highway, for the use of the Government of the United States, free from any toll or other charge whatever, for

> any property of the United States, or persons in their service, passing through the same." This declaration was repeated in the Act of March 2, 1827 (ch. 51, 4 Stat. at L. p. 234), granting more land to the State of Illinois to aid it in opening the canal. We take judicial notice of the historical fact that the canal, 96 miles long, was completed in 1848, and is 60 feet wide and 6 feet deep, and is capable of being navigated by vessels which a canal of such size will accommodate and which can thus pass from the Mississippi river to Lake Michigan and carry on interstate commerce, although the canal is wholly within the territorial bounds of the State of Illinois. By the Act of 1822, if the land granted thereby shall cease to be used for a canal suitable for navigation, the grant is to be void.

If, as this case seems to imply, the Illinois and Michigan Canal became a navigable water of the United States, then there could have been no modification of its course, condition, *location*, or capacity after September 19, 1890, without the approval of the Secretary of War. Nor could it have been excavated or filled in without such approval. The Act of Congress of that date, in Section 7, forbade it. A declaration of its navigability was made by the Illinois Legislature.

Appellant's assertion that in constructing the new canal it was merely *replacing* the original canal becomes merely the admission that it was from the outset engaged in an unlawful act.

3. *Sections 7 and 10 of the Act of Congress of September 19, 1890, and section 10 of its Act of March 3, 1899, made unlawful any greater diversion than was already being effected in 1890*

The largest amount of water ever forced into the Illinois and Michigan Canal at the Bridgeport Pumping Station was 60,000 cubic feet per minute, and even that amount was not maintained at all times. Let us assume, however, that that much was being withdrawn when the Act of 1890 became effective. Thenceforth any increase in the diversion was *at least* a modification of the condition, etc., of a navigable water of the United States, namely, the Chicago River, and, if on occasions of dry weather flow the current was reversed from Lake Michigan, there was not only a modification of the *course* of the Chicago River but also a modification of the condition of Lake Michigan. If the diversion became great enough appreciably to affect the level of Lake Michigan or to cause a dangerous current in the Chicago River, then there was an *obstruction*. By its legislation Congress said in effect, that the navigable waters of the United States should be left in *statu quo*.

Whatever authority the State may have had under the Act of 1827, the Act of 1890 put an end to any *further* or *increased* exercise of it.

Somewhat the same contention was made in *United States* v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 690. The Irrigation Company sought

to justify its obstruction of the Rio Grande River by certain acts of Congress (14 St. at L. 253, Chap. 262 and 26 St. at L. 1101), of which this Court said (p. 706):

> Obviously by these acts, so far as they extended, Congress recognized and assented, to the appropriation of water in contravention of the common-law rule as to continuous flow. To infer therefrom that Congress intended to release its control over the navigable streams of the country and to grant in aid of mining industries and the reclamation of arid lands the right to appropriate the waters on the sources of navigable streams to such an extent as to destroy their navigability, is to carry those statutes beyond what their fair import permits.
>
> * * * * *
>
> To hold that Congress, by these acts, meant to confer upon any state the right to appropriate all the waters of the tributary streams which unite into a navigable watercourse, and so destroy the navigability of that watercourse in derogation of the interests of all the people of the United States, is a construction which can not be tolerated. It ignores the spirit of the legislation and carries the statute to the verge of the letter and far beyond what under the circumstances of the case must be held to have been the intent of Congress.

Similarly in the instant case, however, appellant may attempt to disguise its claim, it is really claiming the "right to appropriate all the waters of the tributary streams which unite into a navigable watercourse and so destroy the navigability of that

watercourse." If the Act of Congress of 1827 is still in force and authorizes a diversion of 10,000 c. s. f. in defiance of the Secretary of War, then there is no limit to the diversion appellant may lawfully make. That, in fact, this has in the past been appellant's position is indicated by the report in 1911 of appellant's president in which he says:

> I am of the opinion that the presumption that our water supply is to be limited to 10,000 cubic feet per second, or 600,000 cubic feet per minute, is gratuitous and mischievous and should not be voiced by the officials of this district. I believe that we should have the volume requisite to our needs as they appear and are justified. (Appellant's Narrative, p. 34.)

Grants by Congress of authority to create obstructions to navigable waters must be strictly construed. *Newport and Cincinnati Bridge Co.* v. *United States*, 105 U. S. 470.

4. *The diversion through the Illinois and Michigan Canal affected only an intrastate water, i. e., the Chicago River; it did not affect interstate waters, such as the Great Lakes.*

Except for the guess of appellant's witness Wisner, its Chief Engineer, there is no evidence that even the maximum amount of water diverted through the Illinois and Michigan Canal effected a reversal of current in the Chicago River and caused water to flow in from Lake Michigan. Even the reversal testified to by Wisner took place only in the dry-weather

flow. At no time was an *appreciable* amount of water abstracted from the lake, and at that it had to be pumped out—gravity was not sufficient.

The only navigable water affected was therefore the Chicago River, and that, being an intrastate water, was subject to the State's authority prior to September 19, 1890. The limited diversion of 1,000 c. s. f. might therefore be deemed to have been "affirmatively authorized by law" within the requirement of Section 10 of the Act of that date. This could furnish no justification for interference with an *interstate* navigable water such as Lake Michigan by diverting an amount sufficient appreciably to affect it.

Other considerations may suggest themselves further in answer to appellant's claim that its acts are authorized by the Act of Congress of 1827. We believe that the foregoing sufficiently dispose of appellant's strange claim; and that it is unnecessary to point out the constantly reiterated inaccuracies contained in its brief as to the intentions and purposes of the Secretary of War, the State and the appellant. None of them dreamed of invoking the authority of the Act of 1827 until the exigencies of this litigation made it necessary for appellant to hunt desperately for authority.

We recur, however, to a rather pertinent inquiry: by what right, title or interest is *appellant* asserting any authority under the Act of 1827? None has been delegated to it by the Illinois Legislature, and the State of Illinois is not a party to this litigation.

B

The Niagara Falls Act of 1906 did not constitute such authorization; if anything, it forbade the unauthorized diversion

We are not certain as to whether or not appellant means to place any reliance on this statute. (See Appellant's Brief, pp. 51–54, pp. 179–180.) We submit, however, that not only do its provisions not support appellant's interpretation of it but they may fairly be interpreted to forbid appellant's unauthorized diversion of water.

This statute was effective from 1906 to 1908, inclusive (when the Calumet project was born, its permit applied for and refused, and the Calumet River Suit begun). It required that the amount of *any* diversion of lake water for domestic, sanitary, or navigation purposes be fixed from time to time either by Congress or the Secretary.

Section 1, so far as material, reads (34 Stat. 626, ch. 3621):

> SEC. 1. That the diversion of water from Niagara River or its tributaries, in the State of New York, is hereby prohibited, except with the *consent* of the Secretary of War as hereinafter authorized in section two of this act: *Provided*, That this prohibition shall not be interpreted as forbidding the *diversion* of the *waters of the Great Lakes* or of Niagara River for *sanitary* or *domestic purposes*, or for *navigation*, the amount of which may be fixed from time to time by the Congress of the United States or by the Secretary of War of the United States under its direction.

Section 2 authorizes the Secretary to "grant permits" and "revoke permits" for diversion, and

requires him to make "regulations preventing and limiting the diversion."

Section 3 punishes diversion contrary to the act and provides that—

> the removal of * * * any construction *incidental to or used for such diversion* * * * as well as any diversion of water * * * in violation hereof, may be enforced or enjoined at the suit of the United States * * * instituted under the direction of the Attorney General.

We submit that this act reaches diversion from Lake Michigan at Chicago.

(1) Its prime purpose was to prevent further depletion of the flow at Niagara Falls. Lake Michigan, through Lakes Huron and Erie, was a chief source of supply. The title of the act is "For the construction and regulation of the waters of Niagara River, *for the preservation of Niagara Falls*, and for other purposes." The side notes in 34 Stat. 626, opposite section 1 read: "Niagara Falls; Preservation of. Post, p. 824. Proviso: Diversion of waters." And the reference (34 Stat. 824) is to a resolution of the same Congress passed March 15, 1906, requiring the international commission to report as to—

> what action is * * * necessary and desirable to *prevent the further depletion of the water flow over Niagara Falls.*

And in the committee report submitting the measure, which, with minor amendments, became the present act, and as a substitute for a bill pre-

viously introduced (3 House Rep., 59th Cong. 1st sess., Rep. No. 4654) its object was explained as follows:

> Should Congress decide that in those portions * * * where navigation exists *the water should flow in its present condition, without depletion or diversion*, it would *seem that no judicial or other authority could review its action in the premises.* It is a matter of some surprise that the companies which have proceeded to divert the waters of the river under the authority of the State of New York have never appealed to Congress or to the Federal Government to confirm the authority granted by that State. It is thought best by the committee that the Federal authority should now be exerted, not merely for the preservation of the scenic grandeur of Niagara Falls, but *for the maintenance of navigation* and the proper control of the river as a boundary stream. * * *
>
> It is, however, very desirable, if not essential, that legislation *be now enacted to prevent the further depletion or diversion of the waters of the river* and to furnish a basis for diplomatic action.
>
> In the bill presented a very large responsibility is imposed upon the Secretary of War. This course has been maturely considered and has seemed desirable, because the question of impairment of the scenic beauty of the cataract and of the *interference with navigability* or the integrity of Niagara River as a boundary stream is largely one of hydraulic engineering. *It can not now be determined*

> what quantity of water can be withdrawn without the impairment of the scenic grandeur of Niagara Falls, *nor can it be determined to what extent* such *diversion will interfere with navigability or the integrity of the stream as stated. It is expected that this authority will be exercised by the Secretary of War with strictness.*

This being its general purpose, we must apply the principle of construction that as between two possible readings that must be adopted which will tend to effectuate rather than that which will tend to defeat the purpose of the act. *Virginia* v. *Tennessee*, 148 U. S. 519; *United States* v. *Freeman*, 3 How. 565; *Jones* v. *Guaranty Co.*, 101 U. S. 626.)

(2) Against the application of the act to the Chicago diversion it will be urged that the words in the opening clause of section 1, "that the diversion of water from Niagara River, or its tributaries, *in the State of New York*," limit the scope of the *whole* act to diversions *made somewhere in that State*. Thus read, it would leave the act inoperative as to the chief sources of supply and insufficient to accomplish its purpose. It is not at all necessary so to read it. The words "in the State of New York" may be either treated as *descriptio* as to the river (to distinguish it from any other possible river of like name elsewhere) or they may be made to modify the river alone (whether as description or locally) by merely bracketing the words "or its tributaries" or by transposing them to read "from Niagara River, in the State of

New York or (from) its tributaries." Such reading accomplishes the full purpose of the act.

Indeed, this not only may be, but must be done upon the principle "*noscitur a sociis*"—concerning which in *Virginia* v. *Tennessee*, *supra*, the court (p. 519) says:

> *Noscitur a sociis* is a rule of construction applicable to all written instruments. Where any particular word is obscure or of doubtful meaning, taken by itself, its obscurity or doubt may be removed by reference to associated words.

The proviso of the very same section (1) reading—

> That this prohibition shall not be interpreted as *forbidding the diversion of the waters of the Great Lakes*, or of Niagara River for sanitary or domestic purposes, or for navigation, etc.,

in *its* negative *pregnant* is an implied declaration that it must be interpreted as *forbidding diversion from the Great Lakes for any other purpose.*

In *Cummings* v. *Chicago*, 188 U. S. 410, this court, quoting from *Lake Shore, etc., R. Co.* v. *Ohio*, 165 U. S. 365, said (pp. 429–30):

> The construction claimed for the statute is that its purpose was to deprive the States of all power as to every stream, even those wholly within their borders; whilst the very words of the statute, saying that its terms *should not be construed as conferring* on the States power to give authority to build bridges on streams not wholly within their limits, *by a negative pregnant* with an affirma-

tive, *demonstrate that the object of the act was* not to deprive the several States of the authority to consent to the erection of bridges over navigable waters wholly within their territory.

Turning to the succeeding sections of the act:

The first clause in section 2 authorizes the Secretary to "grant permits for the diversion of water in the United States from said Niagara River, or its tributaries." It may be said that because Niagara River lies between New York State and Canada that the words "in the United States" take the place of the words "in the State of New York" in the earlier section. (We think that their real purpose was to keep the legislation within the jurisdiction of Congress. But if we read it as "from said Niagara River in the United States" equally must we read it as "from its tributaries *in the United States.*) This may not be said, however, of the opening clause of section 3, reading "diverting water from said Niagara River, *or its tributaries,*" since it has no reference either to the State or to the United States, while the language in section 4 providing for negotiations between the United States and Great Britain "for such regulation and control of the waters of the Niagara River and *its tributaries* as will preserve the scenic grandeur of Niagara Falls and of the rapids of said river" would seem to make clear that the tributaries referred to are those wherever located which contribute to the flow of water over the Falls. The act, then, *does* reach diversion of water from Lake Michigan at Chicago.

It remains but to consider what the act commands; and in this case the material mandate is found in the proviso of section 1, *supra*. Applying to its reading the rule laid down in the *Cummings case, supra*, we find that it forbids diversion from the Great Lakes save for three purposes, viz, sanitary, domestic, and navigation, and as to these provides—

> The amount of which [diversion] may be fixed from time to time by the Congress of the United States, *or by the Secretary of War* of the United States under its direction.

Only by compliance with this proviso can a lawful diversion be made from the waters of the Great Lakes. There is no room for misconstruction as to what it demands. The amount of the diversion must be fixed either (1) by Congress or (2) by the Secretary under its direction. Any diversion, or threatened diversion, without such prior fixing of amount, or in excess of an amount so previously fixed, is unlawful and may be enjoined.

The words "under its direction," as applied to the Secretary, mean the direction given to him either in the succeeding section 2 of this act, or like direction given by any other act (such as 1890 or 1899).

In this statute Congress has left no room for the contention that it has deliberately or otherwise relegated to the courts its own function to determine whether an obstruction will or will not be created.

Neither this act nor its proviso contains any reference to obstruction to navigable capacity. And so (under *United States* v. *Chandler-Dunbar Co.*, 229

U. S. 53, 64, supra) the judgment and determination either of the Congress or of the Secretary of War, as its agent, is conclusive as to whether a particular proposed diversion "is or is not an obstruction and a hindrance to navigation;" and the court must enjoin either upon a showing that no application has been made to the Congress or to the Secretary or that if made it has been denied by either. In no other way can the exclusive control of Congress over the subject be preserved.

This act of 1906 operates upon all diversions or work in aid thereof not accomplished prior to its passage.

In reply to appellant's hypercritical construction of the act as meaning that the Secretary of War might *thereafter* limit the diversion and that he did not already have the power, we suggest that counsel read again the case of *United States* v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 698. In that case there was a *diversion* of water at a point on the Rio Grande River far above its navigable portion; this was held to be not merely a *modification* but an *obstruction*.

C

The Canadian Boundary Waters Treaty of January 11, 1909, did not constitute such authorization; instead, it forbade any diversion over 4,167 c. s. f.

It is difficult to treat patiently with assertions such as are made by counsel for appellant with regard to the intent and effect of the Treaty. The International Waterways did *not* recommend that there should be allowed a diversion of "at *least* 10,000 cubic second

feet of water." (Appellant's Brief, p. 188.) In the report of May 3, 1906, it recommended that the diversion be "not to *exceed* 10,000 cubic feet per second." (Appellant's Narrative, p. 105.) In its report of January 4, 1907, it recommended that "the government * * * *prohibit* the diversion of more than 10,000 cubic feet per second." (Appellant's Narrative, p. 105.)

The International Waterways Commission did *not* find "the Chicago diversion to the amount of 10,000 second feet * * * to be an existing diversion." (Appellant's Brief, p. 190.) This is apparent from the following portions of thier report of January 4, 1907:

> The Chicago Drainage Canal was then constructed, water being turned into it for the first time in January, 1900. It was not then, and has not since been, completed to its full capacity as designed. In some places where the excavation was in rock the full dimensions of the prism were taken out, but in earth a considerable volume was left to be removed by the easy method of dredging hereafter. When fully completed it was designed to have a capacity of 600,000 cubic feet per minute, or 10,000 cubic feet per second, flowing at a velocity of 1.25 miles per hour in earth and 1.9 miles per hour in rock. (Appellant's Narrative, p. 509.)
>
> 10. The channel of the Chicago River is not large enough to transmit that volume from the lake to the canal except at velocities which are an obstruction to navigation. The amount

which the Secretary of War has thus far permitted the sanitary district to pass through the river is 4,167 cubic feet per second. In order to obtain authority for a larger amount the trustees have undertaken to enlarge the channel of the river and have accomplished a large amount of work in that direction. (Appellant's Narrative, p. 510.)

The board assumed that the Chicago Drainage Canal would *eventually* be permitted to take 10,000 cubic feet per second from Lake Michigan. (Appellant's Narrative, p. 512.)

18. The diversion of large bodies of water from Lake Michigan for supplying the drainage canal has not been authorized by Congress. The plans of the sanitary district, except those for the enlargement of the Chicago River, have not been submitted to any Federal authority for approval. It was only after the opening of the canal that application was made to the Secretary of War for permission to divert the quantity of water required by The State law. The secretary granted permission for such quantity as would pass through Chicago River without detriment to navigation, a quantity considerably less than that required by the State law. After experimenting with various amounts it was fixed at 250,000 cubic feet per minute, or 4,167 cubic feet per second, and that is the amount now authorized. It is "subject to such modification as, in the opinion of the Secretary of War, the public interests may from time to time require." Copies of all the permits granted by the Secretary of War in this connection will be found in Appendix I. (Appellant's Narrative, p. 513.)

> There appears to be a tacit general agreement that Chicago needs or *will need* about 10,000 cubic feet of water per second for sanitary purposes and that the city should have it without further question. (Appellant's Narrative, p. 514.)

That 10,000 c. s. f. was not an "existing diversion" is apparent from the testimony as to the actual diversion by appellant from 1900 to 1913. (See Statement of the Case, p. 69.) In 1907 appellant was withdrawing 6,444 c. s. f.; in 1910, 7,132 c. s. f. As a matter of fact, as late as 1909 the appellant *refused* to inform the International Waterways Commission what it was withdrawing. In the report of the Commission of January 8, 1910, it is stated:

> In 1900 the Chicago Drainage Canal began diverting water from Lake Michigan. The amount diverted between January, 1900, and June, 1904, inclusive, was computed from data furnished by the U. S. Engineer Office at Chicago. *The flow through the canal since June, 1904, has been assumed to be 4,167 cubic feet per second, the quantity authorized in the permit of the Secretary of War.* It is believed to have been greater, but the difference is not sufficient to vitiate the results sought for here. An application by the Commission to the Sanitary District of Chicago for a copy of their record met with a refusal to furnish it. (Rec. Vol. VII, p. 253.)

Let us now examine the provisions of the Treaty. Article 2, quoted in Appellant's Brief (p. 189),

preserved the right of citizens of one country to sue in the courts of the other country for damages as to any injury caused by a diversion with the proviso—

> but this provision shall not apply to cases already existing or to cases expressly covered by special agreement between the parties hereto.

Let us assume that this provision prevented any individuals in Canada from suing for an injury caused by an *existing* diversion. The appellant's diversion of 10,000 c. s. f. was *not* an existing diversion. It actually was diverting 6,970 c. s. f. which it was concealing from the knowledge of the International Waterways Commission. Its *authorized* diversion was 4,167 c. s. f. which that Commission assumed to be the *then* flow through the canal. In interpreting the word "existing" as it appeared in the Treaty, were not the negotiators of it justified in assuming that the appellant was obeying the law? The question of an increased diversion had not theretofore been raised directly except by the appellant's application for a permit to divert 4,000 c. s. f. through the Calumet River. This had been denied. Of course, it was known that some day the appellant might ask for 10,000 c. s. f. but it was more than doubtful that the Secretary of War, having refused the Calumet application because of its effect on the lake levels, would ever grant permission to divert this amount.

Furthermore, the right of individuals to sue is a very different matter from the right of their respec-

tive governments in international law. This is apparent from the second paragraph of Article 2 of the Treaty, which is as follows:

> It is understood, however, that neither of the High Contracting Parties intends by the foregoing provision to surrender any right which it may have to object to any interference with or diversions of waters on the other side of the boundary the effect of which would be productive of material injury to the navigation interests on its own side of the boundary. (Appellant's Narrative, p. 532.)

Appellant takes the strange position that this paragraph applies only to *further* diversions, when it plainly states that it applies to *any* diversion and that neither party to the Treaty surrenders the right by anything stated in the first paragraph.

Article 3 of the Treaty reads:

> It is agreed that, in addition to the uses, obstructions, and diversions heretofore permitted or hereafter provided for by special agreement between the Parties hereto, no further or other uses or obstructions or diversions, whether temporary or permanent, of boundary waters on either side of the line, affecting the natural level or flow of boundary waters on the other side of the line, shall be made except by authority of the United States or the Dominion of Canada within their respective jurisdiction and with the approval, as hereinafter provided, of a Joint Commission, to be known as the International Joint Commission.

> The foregoing provisions are not intended to limit or interfere with the existing rights of the Government of the United States on the one side and the Government of the Dominion of Canada on the other, to undertake and carry on governmental works in boundary waters for the deepening of channels, the construction of breakwaters, the improvement of harbors, and other governmental works for the benefit of commerce and navigation, provided that such works are wholly on its own side of the line and do not materially affect the level of flow of the boundary waters on the other, nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes. (Appellant's Narrative, p. 532.)

Appellant after stating that—

> the treaty expressly eliminates from its terms by the preliminary article, Lake Michigan. * * * Obviously, Lake Michigan is not a boundary water, as defined by the Treaty (Appellant's Brief, pp. 188–9)—

later employs the truncated quotation from article 3—

> nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes (Appellant's Brief, p. 189).

Manifestly, if the last sentence applies to Lake Michigan, so also does the first paragraph of article 3, which prohibits any further diversions except with

the approval of the International Joint Commission, a tribunal created by Article 7 of the Treaty.

The Chicago diversion is not "the ordinary use of such waters for domestic and sanitary purposes." The ordinary use consists in such use as causes the water to return eventually to the same channel so that there is no appreciable effect on the level of the water. Chicago is the only city in the world diverting a large-sized river into another watershed. What is so unusual that only one city in the world has done it can hardly be deemed an *ordinary* use. Under appellant's construction of the word, Cleveland may divert Lake Erie into the Ohio River, and each other city on the Great Lakes may do likewise, with the result that these waters become unnavigable because of "ordinary" uses.

Appellant's organic law requires a diversion of 20,000 cu. ft. per minute for each 100,000 of population. If 10,000 c. s. f. is an "ordinary" use, then 25,000 c. s. f. will be an "ordinary" use in 1950.

Counsel for appellant again distorts the provisions of the Treaty by stating:

> Article VIII expressly provides that the uses for domestic and sanitary purposes shall be paramount. (Appellant's Brief, p. 189.)

As a matter of fact, Article 8 provides that—

> The International Joint Commission shall have jurisdiction over and shall pass upon *all* cases involving the use or obstruction or diversion of the waters with respect to which

> under Articles 3 and 4 of this Treaty the approval of this Commission is required. (Appellant's Narrative, p. 535.)

According to appellant, Articles 3 and 4 apply only to *boundary* waters, not Lake Michigan. Article 8 further provides that the Commission shall be governed in *such* cases "by the following rules and principles," included in which is an order of precedence as to uses "for *these* waters." First in the order of precedence is "uses for domestic and sanitary purposes." (Appellant's Narrative, p. 535.)

Where does the Treaty *authorize* or "protect" the Chicago diversion. Article 2 expressly reserves to the United States exclusive control over diversions from Lake Michigan, so long as there is no material injury to Canadian navigation interests. The United States, by entering into the Treaty, did not contract to maintain either the existing diversion of 4,167 c. s. f. or a future diversion of 10,000 c. s. f.

It is useless to cite cases for the elemental proposition that a treaty, under the Federal Constitution, is a law of the land as an act of Congress is. This is only true when the provisions of the treaty prescribe a rule by which the rights of a person may be determined and when such rights are of a nature to be enforced in a court of justice. In *Foster* v. *Neilson*, 2 Pet. 253, this court said (p. 314):

> A treaty is in its nature a contract between two nations, not a legislative act. It does not

> generally effect, of itself, the object to be accomplished; especially so far as its operation is intraterritorial; but is carried into execution by the sovereign power of the respective parties to the instrument. In the United States a different principle is established. Our Constitution declares a treaty to be the law of the land. It is consequently to be regarded in courts of justice as equivalent to an act of the legislature, whenever it operates of itself without the aid of any legislative provision. *But when the terms of the stipulation import a contract—when either of the parties engages to perform a particular act, the treaty addresses itself to the political, not the judicial, department; and the legislature must execute the contract before it can become a rule for the court.*

It is elemental also that there must be *a clear case* of *conflict* between a treaty and a statute.

> Repeals by implication are never favored, and a later treaty will not be regarded as repealing an earlier statute by implication, unless the two are absolutely incompatible and the statute can not be enforced without antagonizing the treaty. (*Johnson* v. *Browne*, 205 U. S. 309, 321.)

There is certainly no "clear case of conflict" between a statute forbidding obstructions to navigable capacity of waters in the United States without authorization from the Secretary of War and the above-quoted provisions of the Treaty.

VI

Appellant's diversion in excess of 4167 c. s. f. has not been recommended by the Chief of Engineers nor authorized by the Secretary of War, as required by section 10 of the act of Congress of March 3, 1899.

Assuming, but not conceding, that the acts of the Appellant are not such as to require affirmative authorization by Congress, there can be no question but that they must be recommended by the Chief of Engineers and authorized by the Secretary of War. They are at least modifications of the course, condition and capacity of navigable waters of the United States. Appellant apparently concedes this.

A mere reading of the various applications of appellant and of the permits granted by the Secretary of War would seem amply sufficient to show how absurd is appellant's contention that it *has* authority from the Secretary of War. It is impossible, however, to point out all the misstatements contained in appellant's brief as to the language, effect, and purpose of these permits. They furnish their own answer to these misstatements.

A

The permits for improvements in the Chicago River prior to May 8, 1899, not only did not include authorization for any diversion of water but expressly withheld it

The permit of July 3, 1896 (the first granted to appellant) authorized appellant to make certain changes in the capacity of the channel of the Chicago River. The permit of November 16, 1897, authorized appellant to widen the Chicago River between

Quincy and Harrison Streets. Both permits contained the following express conditions:

> (2) That the authority shall not be interpreted as approval of the plans of the Sanitary District of Chicago to introduce a current into Chicago River. This latter proposition must be hereafter submitted for consideration.
>
> (3) *That it will not cover obstructions to navigation, by reason of this work while in progress or when completed.* (Rec. Vol. VI, pp. 3574, 3575.)

The second permit recited the provisions of Section 7 of the Act of Congress of 1890 and was expressly granted under that Act (not under the Act of 1827).

The reason for the conditions is apparent not only from the report of the Board of Engineers of August 16, 1895 (see Statement of the Case, p. 30), but also by the report of Major Marshall submitted to the Chief of Engineers of the United States on June 24, 1896 (see Statement of the Case, p. 32), in connection with appellant's application for the first permit. These reports, in no uncertain language, express alarm as to the effect of the diversion even of 300,000 cu. ft. per minute upon the levels of the Great Lakes, and as to whether the United States could do this without the consent of Great Britain. These considerations, as well as the current of the Chicago River, were the reasons for imposing the conditions in the permits. As Major Marshall said:

> *The question that must come up later for the action of the War Department, to wit. Whether*

the improved channel of Chicago River will be sufficient to carry 300,000 cubic feet of water per minute without lessening or destroying the navigability of Chicago River, or whether the City of Chicago will be allowed by the United States and Great Britain to take any water at all from the great lakes, with the inevitable result of lowering their levels is not now under investigation, and is one that will not probably be settled or decided by executive officers. It is or may rather be considered an international question. (Rec., Vol. VI, p. 3573.)

Of course, there was no objection to improving the navigability of the Chicago River as long as no other question was involved. Appellant had full notice then and there that whether it would *ever* be allowed to divert any water, and if so, how much, was uncertain.

B

The permit of May 8, 1899, did not constitute such authorization

1. On April 22, 1899, the appellant applied for permission to open the channel. Its application (Rec. Vol. VI, p. 3848) and the report of Major Marshall which accompanied it (Rec. Vol. VII, pp. 1–2) show that a diversion of 300,000 cu. ft. per minute with a diversion of 1¼ miles an hour was all that was contemplated at the time. Major Marshall was of the opinion, however, that a discharge of 300,000 cu. ft. per minute would lower Lakes Michigan and Huron in an amount which would "not probably much exceed three inches" and that *this much* would not be as serious an injury to navigation as the effect of

the current on the Chicago River. The express recitals in the permit of May 8, 1899 show this. (Rec. Vol. VII, pp. 1–2.) The permit also expressly purports to be issued under Section 10 of the Act of Congress of March 3, 1899 (*not* under the Act of 1827). And it was expressly subject to conditions, one of which was:

> 2. That if, at any time, it become apparent that the current created by such drainage works in the south and main branches of Chicago river, be *unreasonably obstructive* to navigation or injurious to property, the Secretary of War reserves the right to close said discharge through said channel or to modify it to such extent as may be demanded by navigation and property interests along said Chicago river and its south branch.

2. The above quoted condition was not fulfilled. It was represented to the Secretary of War and not denied by appellant, that the discharge sometimes exceeded 300,000 cu. ft. per minute "causing a velocity of nearly three (3) miles per hour, which greatly endangers navigation." The Secretary of War thereupon, by instrument dated April 9, 1901, after reciting the violation of the condition, directed the appellant to limit its discharge to 200,000 cu. ft. per minute. A minor variation was made by order of July 3, 1901, permitting a flow of 300,000 cu. ft. per minute between 4. p. m. and 12 o'clock midnight. On December 5, 1901, acting on another application of Appellant, the Secretary of War granted

what may be regarded as a new permit to divert 250,000 cu. ft. per minute throughout the day, upon the express conditions:

> 1. That this permission shall be in lieu of the present authorized rates of flow as stated above.
>
> 2. That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require. (Rec. Vol. VII, pp. 4–5.)

On January 17, 1903, an amended permit was granted by the Secretary of War reciting the conditions in the permit of December 5, 1901, and granting authority to divert 350,000 cu. ft. per minute from its date to March 31, 1903, "after which date it shall be reduced to 250,000 cubic feet per minute as now authorized." This permit contained the following condition:

> 1. That the permission herein given shall be subject to such modification as in the opinion of the Secretary of War the public interests may from time to time require.

The Wilmette permit of September 11, 1907, and the Calumet permit of June 30, 1910, both contained express conditions that the total diversion of water by appellant from Lake Michigan into the Illinois River should not exceed the 250,000 cu. ft. per minute already authorized by previous permits. (Rec. Vol. VII, pp. 26, 27–29.)

The permit of May 8, 1899, in its unmodified condition, *is not in force* and has not been in force except during the short period from May 8, 1899, to December 5, 1901 (and then only as modified). The permit of December 5, 1901, was accepted by appellant *in lieu* of the previous permits. Whether or not the permit of May 8, 1899, limited the diversion or not is palpably immaterial.

C

The permits of July 11, 1900, relating solely to improvements in the Chicago River, did not constitute such authorization

On July 11, 1900, the Secretary of War gave permission to appellant to make certain changes in the Chicago River at Lake Street, 12th Street, and Ashland Avenue. Appellant had previously applied for permission to make these changes representing that

> the modification and alteration of said river as above indicated will greatly benefit navigation in said river (Rec. Vol. VII, p. 39)

and saying nothing whatsoever as to its plans to divert an increased amount of water into the canal or connecting the applications in any way with the canal. In fact, the applications merely recited that appellant was a municipal corporation authorized by the State of Illinois

> to enter upon, widen, deepen, and otherwise improve any navigable stream, river, or other waterway.

The permit, however, expressly recited the following:

> It being understood that this statement * * * *does not in any way invalidate, waive, or affect* the right of the Secretary of War to regulate or revoke the permit granted under date of May 8, 1899, to the Sanitary District of Chicago, to divert the waters of the Chicago river and cause them to flow into the artificial channel.

In other words, appellant was granted no more permission or authority than it already had under the permit of May 8, 1899. How, then, can counsel for appellant, in seeming seriousness, make such statements as the following:

> Excavating and filling in the channels of the Chicago River and its branches was the only work appellant was required to do in navigable waters of the United States to accomplish and bring about the diversion. The reversal of the current and flow of the Chicago River and its branches was a *necessary* result. Anyway, this was consented to specifically by the permit of May 8, 1899, for the opening of the canal. The work of improving these channels was done for the purpose only of providing for the abstraction of the water through them in a proper manner. * * *
>
> That includes, of course, the diversion of water to the amount required by State authority (10,000 cubic feet per second). (Appellant's Brief, pp. 131–2.)

D

Appellant, having applied for and accepted the various permits up to and including the Wilmette permit of September 11, 1907, and the Calumet permit of June 30, 1910, and having thus agreed to the conditions on which those permits were issued, is estopped to assert any claim that it is entitled to divert more than 4,167 c. s. f.

It is most astounding that the appellant should seek to invoke principles of estoppel against appellee. (See our Point VIII, infra, p. 270.) It is the *appellant* that is clearly estopped. Appellant has applied for, and has accepted, valuable privileges and authority from the Secretary of War on express conditions. It accepted the privileges and now asserts that it is not bound by the conditions to which it assented!

The permission to connect the North Branch of the Chicago River with Lake Michigan by the Wilmette Canal, and to construct a pile crib in Lake Michigan and to deposit filling within the limits of that crib were only upon condition that the total diversion be limited to 4,167 c. s. f. The permission to connect the Calumet River with appellant's canal and to divert water through it were contingent on the same condition, as well as nine other conditions. May appellant now be heard to contend that it has authority from the Secretary of War or any Federal authority to divert 10,000 c. s. f. or more?

E

The Secretary of War may impose conditions on permits granted by him under Section 10 of the Act of March 3, 1899, and may revoke or modify such permits on nonfulfillment of these conditions

Under its Point III (c) appellant contends that the Secretary of War is only authorized to grant or refuse

a permit; that he has no authority to modify. This contention has recently been disposed of in *Southern Pacific Company et al.* v. *Olympian Dredging Company*, 260 U. S. 205. In speaking of Section 7 of the Act of 1890 this Court said (p. 208):

> That the Secretary of War was authorized to impose the condition heretofore quoted does not admit of doubt. The power to approve implies the power to disapprove, and the power to disapprove necessarily includes the lesser power to condition an approval. In the light of this general assumption by Congress of control over the subject and of the large powers delegated to the Secretary, the condition imposed by that officer can not be considered otherwise than as an authoritative determination of what was reasonably necessary to be done to insure free and safe navigation so far as the obstruction in question was concerned.

See also cases cited under Point III, E and F.

VII

Appellant's unauthorized diversion of more than 4167 c. s. f., with its consequent effect on the level of the Great Lakes and on the condition of the Chicago, Calumet, and Des Plaines Rivers, can not be justified as an exercise of the police power reserved to the State.

In its Point IV appellant seeks to avoid the effect of Section 10 of the Act of Congress of 1899 "by simply invoking the convenient apologetics of the police power." (*Kansas City S. R. Co.* v. *Kaw Valley Drainage Dist.*, 233 U. S. 75.) Curiously, however, appellant concedes at the outset that Congress *may* "occupy the entire field concerning

the regulation of navigable waters of the United States" (Appellant's Brief, p. 152). Apparently, therefore, appellant's contention is that the cases which hold that by its Acts of 1890 and 1899 Congress *has* asserted its paramount control and "meant that thereafter no state should interfere with the navigability of a stream without the condition of national consent" (*United States* v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 698) are *wrong* and should be overruled with respect to the obstruction created by appellant. To express the contention in another way, appellant may create an obstruction, no matter how great, if it does so for the supposed interest of public health. An equal obstruction, caused by anyone else in the exercise of some other object of the police power of the state, such as the improvement of its interior navigation, would be unlawful.

No such distinction is made by Congress. The object of its legislation was the preservation of the navigable capacity of navigable waters of the United States. "The language is general and must be given full scope." (*United States* v. *Rio Grande Dam & Irrigation Co., supra.*) *All* obstructions and *all* modifications are unlawful. Whatever the individual states might have done with respect to obstructing navigable waters wholly within their boundaries, in the exercise of their police powers, that power could not thereafter be exercised without national assent. Congress did not intend to make an exception of one object of police power as against any others.

The unqualified use of the word "obstruction" leaves no room for the exercise of any police power to create an obstruction without national assent. It may be conceded that the word "modification" does not cover the ordinary use of a navigable water such as might have been made by an upper riparian owner in a state where riparian rights are recognized (as distinguished from the rule of prior appropriation which obtains in certain western states). The ordinary use is such as preserves the full flow of the river, without any appreciable modification. We are not interested in the present case in determining the right of an upper riparian owner or city to discharge sewage into the river to the detriment of a lower riparian owner or city. That is a matter concerning individuals or cities. The United States *is* interested in preserving the full, unmodified navigable capacity of its navigable waters. The ordinary use which a riparian owner or city would make of such waters does not involve any appreciable effect on their navigable capacity; in the ordinary case the land on which the riparian owner or city is located *drains* into the same navigable water, and while it may not be as pure, its availability for navigation is unaffected.

The appellant is not making an *ordinary* use of the navigable waters along which the City of Chicago is located. An *ordinary* use is such as Milwaukee, Detroit, Cleveland, and other cities on the Great Lakes are making. Appellant is diverting the equivalent of *three* navigable rivers of the United States,

into another watershed, and now pleads the police power of the state as sanctioning the injury it is inflicting on navigation affecting the entire nation as well as a foreign nation. The fact that Chicago is the *only* city in the entire world which has adopted this method certainly answers appellant's assertion that this is an exercise of a supposed police power to make ordinary or reasonable use of the water.

When appellant asserts that its Enabling Act of 1889 rests upon the police power of Illinois never delegated to the Federal Government, and that its objects were "*first*, the protection of public health; *second*, the improvement of the state's waterways" (Appellant's Brief, p. 155) it is disregarding such elemental and well-established principles that it seems unnecessary to discuss them in detail. The cases cited and quoted by us under our Points II and III are an effective answer to these assertions. We shall, therefore, limit ourselves to a brief mention of the principles and leading cases which are conclusive of the matter.

A

On a subject of interstate commerce national in character and requiring exclusive control by Congress, there is not, and never has been, any reserved police power in the State to invade that control even for the protection of public health

In *Henderson* v. *Mayor of New York*, 92 U. S. 259, this Court held invalid a statute of New York which was for the purpose of preventing the immigration of diseased paupers. We quote from the opinion:

> But assuming that, in the formation of our government, certain powers necessary to the

administration of their internal affairs are reserved to the States, and that among these powers are those for the preservation of good order, of the health and comfort of the citizens, and their protection against pauperism and against contagious and infectious diseases, and other matters of legislation of like character, they insist that the power here exercised falls within this class, and belongs rightfully to the States.

This power, frequently referred to in the decisions of this court, has been in general terms, somewhat loosely called the police power. It is not necessary for the course of this discussion to attempt to define it more accurately than it has been defined already. It is not necessary, because whatever may be the nature and extent of that power, where not otherwise restricted, *no definition of it and no urgency for its use can authorize a State to exercise it in regard to a subject-matter which has been confided exclusively to the discretion of Congress by the Constitution.*

Nothing is gained in the argument by calling it the police power. Very many statutes, when the authority on which their enactments rest is examined, may be referred to different sources of power, and supported equally well under any of them. A statute may, at the same time, be an exercise of the taxing power and of the power of eminent domain. A statute punishing counterfeiting may be for the protection of the private citizen against fraud, and a measure for the protection of the

currency and for the safety of the government which issues it. It must occur very often that the shading which marks the line between one class of legislation and another is very nice, and not easily distinguishable.

But, however difficult this may be, it is clear from the nature of our complex form of government, that, whenever the statute of a State invades the domain of legislation which belongs exclusively to the Congress of the United States, it is void, no matter under what class of powers it may fall, or how closely allied to powers conceded to belong to the States (pp. 271–272).

See also *Kansas City S. R. Co.* v. *Kaw Valley Drainage Dist.*, 233 U. S. 75.

B

On all other subjects of interstate commerce, when Congress has asserted its paramount control, there is no police power reserved in the State to invade that control

Appellant in effect asserts that the State of Illinois has not surrendered to the Federal Government control over, or power to interfere with, interstate commerce or the navigable capacity of navigable waters, with respect to the protection of public health and the improvement of the state's waterways.

(1) THE PROTECTION OF PUBLIC HEALTH

In *Morgan, etc., Co.* v. *Louisiana Board of Health*, 118 U. S. 455, 464, this Court said:

We do not think it necessary to enter into the inquiry whether, notwithstanding this, it is to be classed among those police powers which were retained by the States as ex-

clusively their own, and, therefore, not ceded to Congress. For, while it may be a police power in the sense that all provisions for the health, comfort, and security of the citizens are police regulations, and an exercise of the police power, it has been said more than once in this court that, even where such powers are so exercised as to come within the domain of federal authority as defined by the Constitution, the latter must prevail. *Gibbons* v. *Ogden*, 9 Wheat. 210; *Henderson* v. *Mayor*, 92 U. S. 272; *New Orleans Gas Co.* v. *Louisiana Light Co.* 115 U. S. 661.

But it may be conceded that whenever Congress shall undertake to provide for the commercial cities of the United States a general system of quarantine, or shall confide the execution of the details of such a system to a national board of health, or to local boards, as may be found expedient, all state laws on the subject will be abrogated, at least so far as the two are inconsistent.

See also *Compagnie Francaise* v. *Louisiana Board of Health*, 186 U. S. 380, and *Louisiana* v. *Texas*, 176 U. S. 1, 19, in which this Court said:

> vindication of the freedom of interstate commerce is not committed to the state of Louisiana.

(3) FOR THE IMPROVEMENT OF THE STATE'S WATERWAYS

We assume that in speaking of the "State's Waterways" counsel for appellant have reference to rivers such as the Chicago, Calumet, and Desplaines Rivers which, while wholly within the boundaries of

the state, are yet navigable waters of the United States. We concede that waters having no interstate communication, such as an interior lake in Illinois having no navigable outlet, is subject to the state's power. That counsel, in the face of the Acts of Congress of 1890 and 1899, should contend that the State still has the right to improve navigable waters of the United States within its limits, without national assent, seems incredible in the light of the sort of "improvement" we are discussing. This particular question was, however, settled in *Mobile County* v. *Kimball*, 102 U. S. 691, 697–699:

> Of the class of subjects local in their nature, or intended as mere aids to commerce, which are best provided for by special regulations, may be mentioned harbor pilotage, buoys and beacons to guide mariners to the proper channel in which to direct their vessels.
>
> * * * * *
>
> That power which every State possesses, sometimes termed its police power, by which it legislates for the protection of the lives, health, and property of its people, would justify measures of this kind.
>
> * * * * *
>
> Where, from the nature of the subject or the sphere of its operation, the case is local and limited, special regulations adapted to the immediate locality could only have been contemplated. State action upon such subjects can constitute no interference with the commercial power of Congress, for when that acts the State authority is superseded. Inaction of Congress

> upon these subjects of a local nature or operation, unlike its inaction upon matters affecting all the States and requiring uniformity of regulation, is not to be taken as a declaration that nothing shall be done with respect to them but is rather to be deemed a declaration that for the time being, and until it sees fit to act, they may be regulated by state authority.

See also *Wisconsin* v. *Duluth*, 96 U. S. 379.

Incidentally, appellant persists in confusing the amount of diversion necessary for sewage disposal with the amount necessary to provide for a navigable canal. According to appellant's witnesses the former requires 10,000 c. s. f. According to the record, the latter requires 1,000 c. s. f. (Appellant's Narrative, p. 33; also see Rec. Vol. VI, pp. 3633–34; Vol. VII, p. 54.)

As authority for its contentions under this heading counsel cite *Cummings* v. *Chicago*, 188 U. S. 410; *Montgomery* v. *Portland*, 190 U. S. 89; and other cases which do not even remotely sustain its contention. They are discussed elsewhere (*supra*, p. 170).

It hardly seems necessary to distinguish the cases cited by appellant under its Point IV (b). Not one of them is in point. *New York* v. *Miln*, 11 Pet. 102, was overruled in *Henderson* v. *Mayor of New York*, 92 U. S. 259. None of the cases has to do with an attempted exercise of state authority in conflict with an assertion of paramount control by Congress.

Under its Point IV (c) appellant contends that "Congress has otherwise by legislation indicated that

it was not its intention to prohibit the operation of appellant's diversion works" (Appellant's Brief, p. 176). This question is not appropriate to a discussion of the state's supposed police power and we are treating it elsewhere. The supposed acquiescence of Congress is treated under our Point VIII (infra, p. 267).

The effect of the Niagara Falls Act is treated under our Point V, B. (supra, p. 219). The reports of the International Waterways Commission and the Canadian Boundary Water Treaty are discussed under our Point V, C (supra, p. 226). We pause only to call attention to the recurrent misstatement that—

> This Commission [the International Waterways Commission] found the diversion of 10,000 second feet to be an existing fact. (Appellant's Brief, p. 178.)

That this is not true, see page 227 *supra*.

Appellant's interpretation of "the only purpose" of the resolution of Congress of April 21, 1904 (Appellant's Brief, p. 178), is, of course, without foundation in the record.

In conclusion we may appropriately call attention to remarks that this Court has made in other cases, in respect to appellant's contention. In *Wilkerson v. Rahrer*, 140 U. S. 545, this Court said (p. 557):

> That which does not belong to commerce is within the jurisdiction of the police power of the State; and that which does belong to commerce is within the jurisdiction of the United States.

In *Wisconsin* v. *Duluth*, 96 U. S. 379, 386–387, this Court said:

> We do not feel called upon to make an argument to prove that these statutes of the Congress of the United States, and these Acts of the Executive Department in carrying those statutes into effect, constitute an adoption of the canal and harbor improvement started by the City of Duluth, and a taking exclusive charge and control of it; that they amount to the declaration of the Federal Government, that we here interpose and assert our power; we take upon ourselves the burden of this improvement, which properly belongs to us, and that hereafter this work for the public good is in our hands and subject to our control.
>
> If the merest recital of these Acts of Congress, and of the War Department under them, do not establish that proposition, we can have little hope of making it plain by elaborate argument.
>
> Nor can there be any doubt that such action is within the constitutional power of Congress. It is a power which has been exercised ever since the government was organized under the Constitution. The only question ever raised has been, how far and under what circumstances the exercise of the power is exclusive of its exercise by the States. And while this court has maintained, in many cases, the right of the States to authorize structures in and over the navigable waters of the States, which may either impede or improve their navigation, in the absence of any action of the General Government in the same matter, the doctrine

> has been laid down with unvarying uniformity, that when Congress has, by any expression of its will, occupied the field, that action was conclusive of any right to the contrary asserted under state authority. The adjudged cases in this court on this point are numerous.

In *United States* v. *Chandler-Dunbar Water Power Co.*, 229 U. S. 53, this Court said (p. 62):

> All means having some positive relation to the end in view which are not forbidden by some other provision of the Constitution are admissible.

In *Wabash St. L. & P. Ry. Co.* v. *Illinois*, 118 U. S. 557, this Court said (p. 577):

> And if it be a regulation of commerce * * * it must be of that national character, and the regulation can only appropriately exist by general rules and principles, which demand that it should be done by the Congress.

VIII

The right of Appellee to an injunction is not barred by laches, acquiescence, or estoppel

That appellee should be called upon to meet any such contention as is made in Point V of appellant's brief, is not without its humorous side. If ever a party to litigation were estopped from setting up a claim, it is appellant—by reason of its acceptance of the benefits and the conditions of the various permits and particularly the Wilmette and Calumet permits.

We shall not again set forth the facts (to which we have already been forced to make too frequent ref-

erence) bearing on appellant's charge of acquiescence, etc. They are reviewed in our Statement of the Case (*supra*, p. 21), and may be summarized as follows:

(1) No work in the building of the Canal was done until after the passage of the Act of September 19, 1890, which required the authorization of the Secretary of War for the modification of the condition of the navigable waters of the United States.

(2) The necessity for federal cooperation was stated to the appellant by the Government Engineering Department in 1892, prior to the commencement of work on the canal.

(3) The paramount control of the Government with respect to navigation was again asserted by the Government Engineering Department in 1893, immediately following the commencement of work on the canal.

(4) The question of the effect upon lake levels and the navigable capacity of the lakes and their connecting rivers was raised specifically by the Government Engineering Department in 1895, and notice with reference thereto was given to the appellant. This was during the early stages of the work, and long before the completion of the main channel of the canal. The Board made a report, in which the effect of the withdrawal was stated, and the control of the United States asserted.

(5) In 1896, when the appellant sought a permit to make changes in the Chicago River, it was stated in the official records that the question of whether

the District would be allowed by the United States and Great Britain to take any water at all from the Great Lakes, was one which must come up later for the action of the War Department, and in the permit, which was granted, it was expressly stated that it was not to cover obstructions to navigation by reason of the work while in progress or when it was completed. Of the grand total of over seventy-five million dollars which the appellant claims to have expended upon this work, less than twelve million dollars had been expended at this time. Of course, in drawing any comparison between the extent of the injury to navigation and the injury to the appellant in case it is not permitted to withdraw the water, the appellant, in any view of the situation, is limited to the amount it had expended at the time this permit was accepted and acted upon.

(6) From 1896 until the completion of the channel the appellant accepted and acted upon permits which, in express terms, recited the paramount authority of the Federal Government over modifications of the condition of navigable waters, and which provided that they were not to cover obstructions to navigation when the canal was completed.

(7) The Act of 1899, strengthening the authority of the United States officers and making the authorization of Congress itself necessary to the creation of an obstruction to navigable capacity, was passed prior to the completion of the main channel and before application was made for a permit to connect the canal with the Chicago River, and therefore prior

to the time when the question of the effect of the withdrawal of the water was presented in a way which called for a ruling.

(8) In the draft of permit which the appellant submitted on April 22, 1899, and which it requested the Government to issue, it is expressly recited that it is necessary, under the existing law, that authority should issue from the War Department under which the appellant might cause the waters of the Chicago River to flow to the west into the main channel of the canal. In the permit of May 8, 1899, the paramount authority of the Government is distinctly asserted, and the appellant accepted the benefit of this permit.

(9) The permit of May 8, 1899, was modified from time to time by the United States, sometimes upon its own motion and sometimes at the request of the appellant. These modifications, which in every case asserted the paramount authority of the Federal Government, were accepted by the appellant, and the benefits thereunder were enjoyed by the appellant.

(10) After the application to reverse the flow of the Calumet River was denied, in 1907, the appellant applied for and obtained a permit to withdraw water from Lake Michigan through the Wilmette branch of its canal. This permit expressly recited that the total amount to be withdrawn from the lake should not exceed the amount then authorized. The appellant accepted this permit with this condition, and then, on September 18, 1907, passed the order in

which it denied the authority of the United States to withhold the water which was required for the purposes of sanitation.

(11) The Calumet River suit was instituted on March 23, 1908, following appellee's defiance of authority by proceeding to construct the Calumet-Sag Canal. The bill of complaint alleged the intention of appellant to divert 4,000 c. s. f. through that canal; that the effect would be to lower the level of Lake Michigan, etc., and to modify the condition and obstruct the capacity of navigable waters of the United States. The prayer of the bill was for an injunction restraining appellant from reversing the flow of the river and from withdrawing from Lake Michigan any water except as authorized by the Department of War (amount of water thus authorized being then 4,167 c. s. f.).

(12) The actual diversion by appellant from 1900 to 1913, according to appellant's chief engineer, was as follows:

Year	Cubic second-feet
1900	4,314
1901	4,437
1902	4,569
1903	5,144
1904	5,271
1905	5,381
1906	6,292
1907	6,444
1908	6,596
1909	6,970
1910	7,132
1911	7,295
1912	7,458
1913	7,619

(Rec. Vol. III, p. 1318.)

The above shows that in 1900 the appellant did not take as much as 300,000 cubic feet per minute, and that for several years thereafter it was not diverting enough more than 250,000 to be apparent to the eye. As late as 1909, the appellant refused to give to the International Waterways Commission access to its records or information as to the amount of its withdrawal. The report of the International Waterways Commission of January 8, 1910 (Rec. Vol. VII, p. 253) indicates that the U. S. Engineer Office at Chicago had figures showing the diversion from January, 1900, to June, 1904, but that beyond that date figures were unobtainable. The Commission assumed "that the flow through the canal since June, 1904, * * * to be 4,167 cubic feet per second, the quantity authorized in the permit of the Secretary of War."

(13) The permit to reverse the flow of the Calumet River was obtained in 1910 upon the express understanding that it should not be used in any way to affect the pending litigation with respect to the withdrawal of water through the Calumet River, and contained a similar restriction on the total diversion.

(14) In 1912 the appellant made application to the Secretary of War for a permit to withdraw 10,000 cubic feet per second from Lake Michigan through its various channels. There was a formal hearing upon this application at which the Canadian Government was represented. The claims of the Canadian Government were presented, and the appellant replied to those claims. There was a finding by the

Secretary of War upon the claims of Canada as to injury to its navigable waters.

(15) The decision of the Secretary of War was rendered January 8, 1913. On October 6, 1913, the Main Channel suit was instituted.

(16) None of the delays in the prosecution of either the Calumet River suit or the Main Channel suit are due to appellee. They are due (1) to delays caused by appellant, and (2) the unwillingness of Judge Landis to render an immediate decision. (Rec. Vol. VIII, p. 149.)

It is submitted that these facts do not show any authority from the United States for the diversion of this water, or any acquiescence in the act of the appellant; on the contrary, they show a recognition by the appellant of the paramount right of control on the part of the United States which is asserted in this case.

Appellant also seeks to construct some sort of invitation from the United States by citing extracts from reports of Government engineers. It may be conceded that for nearly fifty years the question of the improvement of navigation between Lake Michigan and the Mississippi river has been under consideration. There have been many surveys; many projects have been discussed; tentative plans have been stated, but there has never been any specific plan adopted by the Engineer Department or authorized by Congress. An examination of the Government surveys and reports shows that they are utterly different in their nature from the appellant's

project, and they cannot be interpreted as an invitation to divert from Lake Michigan ten times the quantity of water required for purposes of navigation under any project that has received consideration. (See Rec. Vol. IV, p. 2240, 2248, 2249, 2252, 2254, 2259–61, 2165–66, 2371–2372, 2183, 2204, 2579–80, 2582–2603.)

It is significant that the Bridge Company in the *Wheeling Bridge Case*, 13 How. 553, made exactly the same contentions (p. 558):

> * * * that the bridge is a connecting link of a great public highway, as important as the navigation of the Ohio River; that Pennsylvania had set the example of authorizing bridges across the Ohio; that certain engineers of the United States had recommended a wire suspension bridge at Wheeling, and gave as their opinion that "by an elevation of ninety feet, every imaginable danger of obstructing the navigation would be avoided"; that certain reports of committees in Congress recognized the necessity of a bridge at Wheeling, and recommended an appropriation for that purpose; that the headway for steamers left by the bridge is amply sufficient, forty-seven feet above the water, for all useful purposes; and if sufficient draught can not be had at that height, blowers might be added; that chimneys might have hinges on them; so as to be lowered without much inconvenience; that the bridge will not be an appreciable inconvenience to the average class of boats; that the bridge will not diminish or destroy trade between

> Pittsburgh and other ports, or do irreparable injury to the citizens of Pennsylvania.

In view of the fact that these contentions were all passed upon unfavorably by this Court in that case, there seems little room for appellant's present claims in this regard.

We now call attention to sell-settled principles which are, we submit, conclusive against all claims of estoppel, etc., on the part of appellant.

A

Any contention that appellee's right to an injunction is barred by laches is untenable

1. Even as between private persons where delay is induced by act or representation of one person, the doctrine of laches is never applied in his favor against the other. In *Loring* v. *Palmer*, 118 U. S. 321, 345–6, the Court said:

> His delay in bringing the suit is to be construed in connection with the uncertainty that existed as to the true situation of his accounts. Loring must have known that Palmer relied on him to keep the accounts, and having himself been guilty of such glaring errors in his statements and in his claims, Palmer is not to be charged alone with the fault of delay. * * * It is clear that, if Palmer had known the actual condition of the accounts at the time, he would promptly have claimed his rights, and that, to say the least, Loring was as much responsible for this uncertainty as Palmer.

In *Townsend* v. *Vanderwerker*, 160 U. S. 171, 186, this Court said:

> The question of laches does not depend, as does the statute of limitation, upon the fact that a certain definite time has elapsed since the cause of action accrued, but whether, under all the circumstances of the particular case, plaintiff is chargeable with a want of due diligence in failing to institute proceedings before he did. In this case we think the delay is fully explained.

In *Gunton* v. *Carroll*, 101 U. S. 426, 429:

> The delay in making it [a partition which was prerequisite to suit for specific performance] was that of Carroll and of his devisees. For this the complainants were in no manner chargeable with laches and should receive no detriment. (Citing cases.)

2. Laches, however long continued, is not imputable against the United States to bar it of its sovereign rights. In *United States* v. *Kirkpatrick*, 9 Wheat. 720, 735, this Court said:

> The general principle is that laches is not imputable to the Government; and this maxim is founded, not in the notion of extraordinary prerogative, but upon a great public policy. The Government can transact its business only through its agents; and its fiscal operations are so various and its agencies so numerous and scattered, that the utmost vigilance would not save the public from the most serious losses, if the doctrine of laches can be applied to its transactions.

In the case of *United States* v. *Beebe*, 180 U. S. 343, 354, this Court said:

> Generally speaking, the laches of officers of the Government can not be set up as a defense to a claim made by the Government. (Citing cases.)

In *Armstrong* v. *Morrill*, 14 Wall. 120, 144–5, this Court said:

> But the court held that the limitation (a restrictive condition) could not be extinguished by any inattention or neglect in compelling the owner to comply with it, for no laches is to be imputed to the Government and against it no time runs so as to bar the public rights, which is no more nor less than another form of words for expressing the ancient rule of the common law that time does not run against the State.

See also *United States* v. *Dalles*, M. R., 140 U. S. 632; *United States* v. *Insley*, 130 U. S. 263; *Metropolitan Ry. Co.* v. *District of Columbia*, 132 U. S. 11; *United States* v. *Michigan*, 190 U. S. 405; *Redfield* v. *Parks*, 132 U. S. 243–4. In the last case it was held that State legislation could not operate to change this rule, the Court saying (pp. 243–4):

> The foundation of this rule is the proposition that time does not run against the Government, that no statute of limitation affects the rights of the Government, unless there is an express provision to that effect in the statute, and even then it can not be conceded that State legislation can in this manner imperil

> the rights of the United States or overcome the general principle that it is not amenable to the statute of limitations or the doctrine of laches.

In the case of *United States* v. *Michigan*, *supra*, a case very like the case at bar, involving a grant in aid of a canal, and authorizing statutes of the State of Michigan, the existence of those statutes did not prevent the application of the rule here contended for. The case of *Missouri* v. *Illinois* and *Sanitary district*, 180 U. S. 208, involved the very State legislation and district powers that are involved in this case. It was urged against the right of Missouri to complain of the flow of sewage that it was barred by reason of laches and the action taken and expenditures made under the State legislation. It was contended on behalf of the defendants—

> if the bill was not prematurely filed, then it was filed too late; that by standing by for so long a period the complainant was guilty of such laches that a court of equity will not grant relief.

Of this claim the court said (p. 245):

> The inconsistency between these contentions is manifest, and on consideration we are of opinion that the suggestion that the complainant's remedy has been lost by delay, is not founded in fact or reason.

(See also same case, 200 U. S. 496, 520.)

B

Any contention that appellee's right to an injunction is barred by acquiescence is untenable

1. This feature so far as it involves alleged non-action during the period the appellant was operating under the State statutes and later making expenditures on the original project is disposed of by *Union Bridge Co.* v. *United States*, 204 U. S. 364, 400, as follows:

> There are no circumstances connected with the original construction of the bridge, or with its maintenance since, which so tie the hands of the Government that it can not exert its full power to protect the freedom of navigation against obstructions. Although the bridge, when erected under the authority of a Pennsylvania charter may have been a lawful structure, and although it may not have been an unreasonable obstruction to commerce and navigation as then carried on, it must be taken under the cases cited, and upon principle, not only that the company when exerting the power conferred upon it by the State, did so with knowledge of the paramount authority of Congress to regulate commerce among the States, but that it erected the bridge subject to the possibility that Congress might, at some future time, when the public interest demanded, exert its power by appropriate legislation to protect navigation against unreasonable obstructions. Even if the bridge, in its original form, was an unreasonable obstruction to navigation, the mere failure of the United States, at the

> time, to intervene by its officers or by legislation and prevent its erection, could not create an obligation on the part of the Government, etc. * * * Its mere silence or inaction when individuals or corporations, under the authority of the State, place unreasonable obstructions in the waterways of the United States, can not have the effect to cast upon the Government an obligation not to exert its constitutional power to regulate interstate commerce.

In *Rundle* v. *Canal Co.*, 14 How. (U. S.) 92, the court quotes the Supreme Court of Pensylvania, as follows:

> And, in this respect, a grant by a public agent of limited *powers, and bound not to throw away the interests confided to it,* is different from a grant by an individual who is master of the subject. To revoke the latter after an expenditure in the prosecution of it, would be a fraud. *But he who accepts* a license from the legislature, knowing that he is dealing with an agent bound by duty not to impair public rights, does so at his risk; and a voluntary expenditure on the foot [faith] of it gives him no claim to compensation.

So far as it involves action or omission by officers or Congress, the matter will be treated under "Estoppel" *infra*, p. 270.

2. Acquiescence in work or expenditures while there was no suggestion of *use of more than permitted* quantities of water is no estoppel to object to a *later plan calling for greater* quantities of water. Nor does acquiescence, as to the Chicago River, estop to object

to a later plan to change the channel or current of the *Calumet*, any more than acquiescence in a Chicago project would estop to object to a Milwaukee project.

In *Los Angeles W. Co.* v. *City*, 88 Fed. 720, 745–6, the court said:

> Defendants further contend that complainants have so acquiesced in the action of the council in the fixing of water rates as to estop them * * * and also have been guilty of such laches * * * as is fatal. * * * This contention, in my opinion, is not well taken. * * * But, even if the complainants had not protested, *their acquiescence in ordinances establishing rates prior* to the year 1896 *would not be acquiescence in the ordinance* of that year, for the obvious reason that the last-named ordinance *made a greater reduction of rates than any previous* ordinance.

3. Moreover, having itself induced the appellee's delay by its methods and representation, the appellant is estopped from urging either delay or acquiescence.

Bridge Co. v. *United States*, 105 U. S. 482.
Branch v. *Jesup*, 106 U. S. 468.
International Contracting Co. v. *Lamont*, 155 U. S. 309–10.
Moran v. *Comm.*, 2 Black 732.
Wallace v. *Loomis*, 97 U. S. 163.
County v. *Barnes*, 94 U. S. 70, 73.
and cases cited *supra* under sub-heading A (1), supra, p. 263.

4. Finally, while you may balance equities through expenditures, as between two *otherwise equal* rights or powers, to determine superiority, this may *never*

be done between a *superior and inferior power or right*, because the superior power must always be superior, and there is nothing to be determined. (In re *Rahrer*, 140 U. S. 555, 556, 557; *Houston & Texas Ry.* v. *United States*, 234 U. S. 350, 351, 352.)

C

Any contention that appellee's right to an injunction is barred by estoppel is untenable

There can be no estoppel against the Government in this case, because (1) the acts complained of constitute a public nuisance; (2) a revocable license can never support an estoppel; (3) officers whose acts are relied on have no power to grant the privilege; (4) mere appropriations to *investigate* are immaterial; (5) cooperation in improving Chicago River was merely for betterment of navigation; (6) toleration of other diversion or diversions by Government is immaterial; (7) there was not a dollar spent on later Calumet project on the faith of any congressional action.

We have dealt elsewhere (Point V, supra, p. 203) with the contention that the Act of Congress of 1827 relating to the Illinois and Michigan Canal, the Boundary Waters Treaty, and the Niagara Falls Act can be construed as authority for appellant's unlawful acts.

(1) ESTOPPEL CAN NEVER BE URGED IN FAVOR OF A PUBLIC NUISANCE

Any unlawful interference with navigation is a public nuisance *per se*.

The author, Joyce, on Nuisances, defining the terms, says, A nuisance consists in unlawfully doing any act which (3) unlawfully interferes with or obstructs, or tends to obstruct, any navigable lake, reservoir, etc. (sec. 4, pp. 8–9), and such anuisance (per se) is an obstruction to a navigable stream. (Sec. 12, p. 20.)

In *Phalen* v. *Virginia*, 8 How. (U. S.) 163, this court said (p. 168):

> It is a principle of the common law, that *the king can not sanction a nuisance.*

In *People* v. *Gold Run D. & M. Co.*, 66 Cal. 152, this court said:

> As to the claim of right derived from prescription and the statute of limitations, it is sufficient to say that a right to continue a public nuisance can not be acquired by prescription. (Citing cases.) Nor can it be legalized by lapse of time * * *. Against it, however long continued, the State is bound to protect the people. * * * (Noting *People* v. *Booth*, 32 N. Y. 397.) "For all the people of the State are interested in the question, and have the right to use all bays and navigable rivers within the State."

In *Missouri* v. *Illinois and Sanitary District*, 180 U. S. 242–3, this court said:

> In the first place, it is urged that the drawing, by artificial means, of the sewage of the city of Chicago into the Mississippi River may or may not become a nuisance * * *.

The court then cites *Attorney General* v. *Jamaica Pond Aq. Corp.*, 133 Mass. 361, which action was to enjoin defendants from lowering the waters in one of the public ponds of Massachusetts, and it quotes from the opinion in that case, as follows, p. 363:

> The cases are numerous in which it has been held that the attorney general may maintain an information in equity to restrain a corporation exercising the right of eminent domain *under a power delegated to it by the legislature*, from any abuse or perversion of the powers which may create a public nuisance or injuriously affect or endanger the public interests.

The closing language in the court's opinion (p. 248) in the main case (Sanitary District case) is not apposite here because (1) Missouri had no power superior to that of Illinois; (2) any substantial interference with a superior power warrants and demands injunctive protection.

(2) ESTOPPEL IS NEVER APPLIED WHERE, HAD A PRIVILEGE BEEN GRANTED, IT MUST HAVE BEEN REVOCABLE ONLY

In *Rundle* v. *Canal Co.*, 14 How. (U. S.) 92–3, involving a legislative grant to build a mill dam in a navigable river, which dam was rendered useless by a later authorized canal, this court quotes from the Supreme Court of Pennsylvania in a like case, as follows:

> "He was bound to know that the State had power to revoke its license whenever the

> paramount interests of the public should require it. * * * But he who accepts a license from the legislature knowing that he is dealing with an agent bound by duty not to impair public rights, does so at his risk * * *." [The court itself then continues:] Nor can the plaintiff claim by prescription against the public for more than the act confers on him, which is at best impunity for a nuisance.

In *Doyle* v. *Continental Insurance Co.*, 94 U. S. 535, 540–2, this court said:

> The correlative power to revoke or recall a permission is a necessary consequence of the main power * * * [citing cases] This is justifiable because the complainant has no constitutional right to do business in that State. * * * This is the whole point of the case, and, without reference to the injustice, the prejudice, or the wrong that is alleged to exist, must determine the question. No right of the complainant * * * is infringed, etc.

In *Morris* v. *United States*, 174 U. S. 196, 282, this court said:

> Here we may pause to observe that the only power given to the commissioners was to grant *licenses*, from time to time, and *until* Congress should assume and exercise its jurisdiction within the territory, and it was declared that any wharf built in the waters of the Potomac without such license or in disregard of its provisions, was declared to be a common nuisance.

> The licenses contemplated therefore were temporary, and liable to be withdrawn by Congress on assuming jurisdiction. Such legislation certainly can not be relied on as either conferring or recognizing rights to erect and maintain permanent wharves within the waters of the Potomac and the Eastern Branch.

The appellant was bound to know when it turned toward these navigable waters that though it gained permits they could never pass more than a revocable license. Unless it was willing to take that hazard, it was bound to seek out and develop some other system. Here there was not only *express* refusal to permit any of the acts here complained of, but such permits as were given were accompanied by such conditions as amply justified the later refusals.

In *Lowndes* v. *Huntington*, 153 U. S. 32, involving a claim of right to use a navigable bay for oyster cultivation, this court said:

> In other words, all he claims is that he had an implied license from the State; but such license (if one existed) was subject to revocation and was revoked, etc.

In *St. Anthony Falls W. P. Co.* v. *St. Paul W. Comm.*, 168 U. S. 349, 372–3, wherein the power company *claimed property rights* under State charter in navigable waters, this court said:

> These grants were in legal effect subject at all times to the paramount right of the State as trustee for the public to divert a portion of the waters for public uses, and they were also

> subject to the rights in regard to navigation and commerce existing in the General Government under the Constitution of the United States. [Citing cases.]
>
> * * * This construction * * * assumes the power of a * * * legislature to bind future legislatures in dealing with these public rights * * * (which, under the decision of this court in *Illinois Central Railroad* v. *Illinois*, 146 U. S. 387, is at least doubtful), etc.

The court then cites and approves *Rundle* v. *Canal Company*, supra.

(3) ACTS OF OFFICERS

Reports of engineering officers, communications of International Waterways Commission, action of the Attorney General, establishment of plans by engineers, etc., can not foreclose sovereign rights in respect to which the officers have no power to act for the United States (in granting privileges). See excerpt from the Wheeling Bridge Case (supra, p. 267).

In *Pine River Logging Co.* v. *United States*, 186 U. S. 279, 291, this court said:

> No authority had been given them to extend the contracts either as to the quantity or quality of timber to be cut. * * * They, as well as the parties thereto, were equally bound by its provisions. * * * No conduct of theirs can estop the Government from asserting its rights to recover for timber cut beyond the quantity and quality specified in the contract. [Citing cases.] We are there-

fore of opinion that the defendants can not take refuge under the consent or acquiescence of the Government agent in the disregard of these contracts.

In *Whiteside et al.* v. *United States*, 93 U. S. 247, 257, this court said:

> The rule as to the effect of the like act of a public agent is otherwise, for the reason that it is better that an individual should occasionally suffer from the mistakes of public officers or agents, than to adopt a rule which, through improper combinations or collusion, might be turned to the detriment and injury of the public * * * And it is clear that if the cotton was abandoned or captured property, within the meaning of the act of Congress, under which it was collected, transported, and stored, the acts of the officer were unauthorized and unlawful.

In this case it was held that a release of the cotton by officers was not binding on the United States.

In *Morris* v. *United States*, 174 U. S. 196, 288, this court said:

> It was the opinion of the court below that under the legislation * * * jurisdiction with respect to private wharves had been conferred upon the authorities of the city, and that hence the Chief Engineer is without any lawful authority to issue such licenses. * * * We see no reason to doubt the soundness of this conclusion, though for the reasons already given, even if the power to grant such licenses had belonged to the Chief of Engineers, they would not have vested any rights in fee, etc.

The appellant not only knew that the Secretary was claiming jurisdiction as the agent of Congress, but at least until 1907, conceded the Secretary's jurisdiction.

In *Williams* v. *Wadsworth*, 51 Conn. 277, 310, the court said:

> The defendant having knowledge that the plaintiff disputed his right to divert the water in the manner contemplated and would endeavor to prevent it by legal proceedings, notified him that he intended to take the water to his dwelling house, and requested him to institute legal proceedings by way of prevention before expense should be incurred. The plaintiff disregarded the request, and the defendant insists that he should not now be heard by way of objection. * * * Thenceforth the defendant assumed the risk attendant upon his action.

The foregoing completely answers any suggestion that the recital in the petition of November 28, 1906, of a desire to have the Government consent before incurring expense as to the Little Calumet, could limit the rights of the Government or enlarge those of the district.

In *State, etc.*, v. *Brewer*, 64 Ala. 298, the court said:

> Estoppels against the State can not be favored. They may arise from its express grants; but can not arise from the laches of its officers. * * * It was not within the *scope* of the *powers of the auditor* to allow the credit, etc.

In note to *State of Michigan* v. *Jackson, etc., Co.* C. C. A. 345, 354, it was said:

> But, on the other hand, the State can not be bound, either on the ground of estoppel, acquiescence, or implied ratification, by any acts of its officers which are byond the scope of their authority, or which are illegal, fraudulent, or negligent, or by defaults or omissions of such officers possessing the same characteristics. [Citing cases, among others *Hunter* v. *United States*, 5 Pet. 173 and *People* v. *Brown*, 67 Ill. 435.]

See also *Floyd Acceptances*, 7 Wall. 666; *Lee* v. *Munroe*, 7 Cranch 366, 3 L. ed. 373; *State* v. *Chilton*, 49 W. Va. 453; *Pulaski* v. *State*, 42 Ark. 118.

In *City of Mobile* v. *Sullivan Timber Co.*, 129 Fed. 302–3, the court said:

> Surely it will take something more than proof of the quiescence of a commission like that [Mobile River Commission] to estop the municipality which holds the title for the public benefit from proceeding with its duty to protect the public interest. Estoppels are not favored by the law, and this would seem especially true when by such estoppel it is attempted, by the omission or indifference of officials, to finally conclude the rights of the public to a public use.

The court quotes from *Mayor of Jersey City* v. *American Dock, etc., Co.*, 23 Atl. 682, 684, as follows:

> The title is vested in the city in trust for the public, and is therefore inalienable and

indeposable, except by legislative action. The composition of the so-called title of the defendant, it will be observed, consists of the acquiescence and neglect of the trustee of a public use and the deed of a board having no power over the subject. Such a claim seems to me singularly futile.

(4) CONGRESSIONAL APPROPRIATION TO INVESTIGATE IMPROVEMENT OF NAVIGATION IN ILLINOIS AND DES PLAINES RIVERS CAN NOT CONSTITUTE ESTOPPEL

No doubt Congress, ever since the Act of 1822 (providing for Illinois and Michigan Canal), has steadily had in mind connecting the Lakes with the Mississippi River for purposes of navigation. It would have eagerly invited the construction not of one but of many connecting channels, all with an eye single to interior navigation, and it often has investigated many suggested projects; but an appropriation to investigate methods of improving navigability of the Illinois and Des Plaines Rivers can not be warped into a permit to convert the Calumet River into a sewer, or a permit to withdraw 10,000 cubic second-feet of water from Lake Michigan. Nor, indeed, could an appropriation directly to investigate the propriety of suffering such a withdrawal be twisted into a permit so to do. One may send an agent to investigate the proposed purchase of a cattle ranch, but it will not constitute an agreement on his part to purchase, nor authorize the owner to urge estoppel by reason of assumption that he would purchase.

One may incur expense in determining whether he ought to consent to a railroad right of way across his farm, but this does not estop him from disputing the railroad's right to cross.

In the pleading, and throughout this case, the appellant has subtly sought to obscure the plain distinction between navigation and sewage. The latter demands many times the volume of flow needed for the former. Furnishing the flow necessary for the former would not at all injure navigation, but furnishing the added flow now said to be needed for sewage, does. The appellant, and before its creation, the city of Chicago, began by arrangement with the State as early as 1858, to try to connect itself with navigation channels, and particularly the Illinois and Michigan Canal; and in the several petitions to the Secretary of War it kept prominently to the front the suggestion the *benefit of navigation*, and sedulously screened the underlying motive of sewage. The Government properly consented to straightening and enlarging the Chicago River channel, always with the condition of a withdrawal limit which finally became 4,167 cubic second-feet; and not until 1912 did the appellant make application for any more. It did most of its work on the representation that that amount would meet their needs. And if the project would admit of no larger withdrawal, and it were not threatening to withdraw more, this suit would not be pending. Until the threat to injure the public right of navigation there

was no occasion to appeal to the courts, just as until the sewage deposits threatened became objectionable to the State of Missouri, there was no occasion for it to appeal to the courts. (*Missouri* v. *Sanitary District*, 180 U. S. 208, 243–5–6–7.)

(5) COOPERATION IN IMPROVEMENT OF CHICAGO RIVER

This was for the sole purpose of bettering navigation. All that has been said under the heading last above applies here. The Government would have no objection to-day to widening or deepening of channels so long as the lake withdrawals were limited to the maximum of its permit. And the appellant induced the Government's belief that it would not require more than the permitted amount.

(6) SUFFERING OTHERS, INCLUDING CANADA, TO LOWER, AND LOWERING BY ITS OWN WORKS, CANNOT CONSTITUTE ESTOPPEL

The Government was entirely within its rights had this been done, for the whole subject is in the exclusive control of Congress and no outsider can complain of its permits or undertake to regulate or apportion them for Congress. The City of Milwaukee could not urge the 4,167 cubic second-feet authorized at Chicago as a justification for diverting whatever added amount it desired from the lake without a permit.

Per contra: The appellant can not urge other diversions, whether permitted or merely suffered, as a justification for its diverting without a permit.

Indeed, it was to avoid just such controversy that Congress required *national assent* to *any diversion whatever*.

(7) GOVERNMENT WORK OF DEEPENING CHANNELS OF GREAT LAKES CAN NOT CONSTITUTE ESTOPPEL

It is said this will overcome the effect of the appellant's proposed withdrawal of water. History shows a steady artificial deepening of the harbors and channels of the lakes and connecting rivers by the Government at enormous cost. Confessedly the appellant's acts will somewhat shoal them. Some boat that could have just passed over a bar before would be caught now. The tendency is to diminish and to interfere with navigable capacity. It will not do to say that the shoaling will be less than the Government has allowed for, or that compensating works proposed in order to raise the water a foot on Lake Erie would more than cover the lowering caused by the district. The Government, if it planned compensating works, did so to get deeper water because deeper water was demanded—not to hold the water constant against the unlawful diversion of the appellant or of others similarly situated. If it used a lower plane, it did so for precautionary purposes. "No person can found a right on his own wrong," nor on the effort by another to guard against the consequences of that wrong. If appellant could urge these features, so could every other city or person diverting. Every foot of deepening accomplished by the Government would be made an excuse

for lowering by others of a like amount, until the Government's increase of depth would spell disaster instead of benefit to navigation. This principle applied to the very great deepening accomplished in the past would have to-day resulted in leaving the lakes with a net depth for navigation purposes no greater than when Federal improvement of lake waters began.

IX

Appellee is entitled to an injunction, effective immediately, restraining appellant from diverting more than 4,167 c. s. f.

Appellant makes five contentions which for convenience we are treating under one heading:

A. That the Attorney General has no authority to institute suit for an injunction restraining the maintenance of an obstruction. (Appellant's Point III (b).)

B. That the doctrine of comparative injury applies and therefore a court of equity should deny relief. (Appellant's Point VII.)

C. That appellant's motion of July 12, 1920, should have been allowed, and a modified injunction allowed conditional on the construction and maintenance of compensating works in the Great Lakes. (Appellant's Point IX (a).)

D. That the operation of the injunction should be suspended for a period of years. (Appellant's Point IX (b).)

E. That the decree of injunction should provide that it should be subject to any further action that

the Secretary of War might take. (Appellant's Point IX (c).)

These will be discussed in the same order as above noted.

A

The Attorney General has authority to institute suit for an injunction in aid of the performance of the Government's duty to preserve the navigability of navigable waters of the United States

Under its Point III, subheading (b), appellant contends that the Attorney General, under the Act of March 3, 1899, is only authorized to institute suits in equity for the *removal* of *structures*, and that the District Court was without jurisdiction to entertain this suit or enter the decree. A search of the record discloses that nowhere either in the pleadings or by motion or in the evidence or during the hearing was the jurisdiction of the District Court as a court of equity questioned and that both parties treated the case as a proper case for equity jurisdiction. Judge Carpenter stated, in his opinion (Rec. Vol. VIII, p. 129) "The jurisdiction of the court has not and could not be challenged." *Proceedings for bill for injunction rather than by indictment were at the request of the appellant itself.* (See Statement of the case, p. 66). Inasmuch, however, as the point is made, we make reply to it.

A portion of the Calumet permit of June 30, 1910, may appropriately be quoted here:

> That this permission shall in nowise affect or in any manner be used in the friendly suit now pending in the Circuit Court of the United States for the Northern District of Illinois

> brought by the United States of America against the Sanitary District of Chicago, to determine the right of the said Sanitary District to divert from Lake Michigan for sanitary purposes an amount of water in excess of that now being diverted, without having first obtained a permit from the Secretary of War. (Rec. Vol. VII, p. 28.)

The appellant therefore has been perfectly content to have its right determined by a court of equity on a bill for an injunction, both in the Calumet River suit and in the Main Channel suit.

(1) SECTION 12 OF THE ACT OF MARCH 3, 1899 IS SUFFICIENT AUTHORITY FOR THE INSTANT SUIT

Section 12 of the Act of March 3, 1899 provides that—

> the removal of any structures or parts of structures erected in violation if the provisions of the said sections may be enforced by the injunction of any circuit court exercising jurisdiction in any district in which such structures may exist and proper proceedings to this end may be instituted under the direction of the Attorney General of the United States.

Appellant contends that because of this provision the Attorney General can sue only to *remove* structures or parts of structures erected in violation of Section 10, and that in the present case he is not suing to *remove* any *structures*. A sufficient answer to this contention would seem to be the recent decision of this Court in *Economy Light & Power Co.*,

256 U. S. 113. In that case the defendant had commenced the construction of a dam across the Des Plaines River in Illinois. The decree not only ordered the removal of the portion already constructed but perpetually enjoined the defendant from placing any further obstruction in the river and from doing any other act or performing any other work in connection with the construction of the dam. (See *Economy Light & Power Co.* v. *United States*, C. C. A., 7th Circuit, 256 Fed. 792, 793.) The decree was affirmed in the Circuit Court of Appeals for the Seventh Circuit and by this Court in *Economy Light & Power Co.* v. *United States*, 256 U. S. 113. It is apparent from the opinion of this Court that the suit was regarded merely as one to enjoin the construction of a *proposed* dam; for example, it is stated (p. 115):

> This was a suit brought by the United States against appellant in the district court for the northern district of Illinois, eastern division, for an injunction to restrain defendant from constructing a dam in the Des Plaines river at a point in Grundy county, Illinois, without the consent of Congress or authority of the legislature of the state, and without approval of the location and plans by the Chief of Engineers and the Secretary of War of the United States. Relief was prayed upon two grounds: (1) That the river bed where the dam was being constructed was the property of the United States; (2) that the Des Plaines river was a navigable waterway of the United States, and the *proposed* construction of a dam therein

was in violation of the Act of Congress of March 3, 1899 (chap. 425, § 9, 30 Stat. at L. 1121, 1151; Comp. Stat., § 9971, 9 Fed. Stat. Anno.; 2d ed., p. 81).

Throughout the opinion the obstruction is referred to as the "proposed dam."

If appellant's construction of Section 12 be correct, then the United States is powerless to prevent an obstruction to the navigable capacity of its navigable waters until the obstruction is at least partially accomplished. The Attorney General can sue only to *remove* structures or parts of structures, erected in violation of the Act of 1899. But such a construction leads to absurd results that could never have been intended by Congress. The very first act in building a dam or a bridge may be the throwing of a cable or a girder across a stream. Once even this much is accomplished, the most injurious results may be effected by the blocking of the stream to all navigation and yet the injured parties must await, according to appellant, until a court has ordered the *removal* of the cable or girder; they may not, knowing the plans of a defendant to do such an act, *restrain* its accomplishment before the harm is done. Suppose that a defendant, intending to throw a bridge across a river, first builds the approaches and supports on land belonging to him on both sides of the river. These structures in themselves are not in violation of any law. Must the United States wait until he throws a cable across? Or a person may be planning to sink a vessel in a stream for the purpose of blocking

traffic or for some purpose of his own. Must everyone, including the United States, wait until this is accomplished and the arduous task of removing the wreck is ordered by a court?

But, says appellant, we concede that an injunction may issue in such a case, but it must be against a *structure*, and a diversion is not a structure. Having conceded that the word *remove* must receive a liberal interpretation in the light of the undoubted intent of Congress, appellant must, we believe, concede that the word *structure* should receive a similarly liberal interpretation. There are several considerations, however, which lend confirmation to this:

(1) The word *structure* was intended to be at least coordinate with the *obstructions* covered by the preceding sections 9, 10, and 11. The cognate derivation of the two words indicates that much. It is usually some sort of *structure* which causes the *obstruction*. For example, in *United States* v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 690, the *obstruction* was a lowering of the level of the navigable portion of the Rio Grande River, by reason of a diversion of water in its nonnavigable portion; the offending *structure* was a dam in the nonnavigable portion. In the instant case, the *obstruction* is the lowering of the level of the Great Lakes, by reason of a diversion of water in the West Fork of the South Branch of the Chicago River; the offending *structure* is the works of appellant which divert, under the operation of appell-

ant's agents, an unauthorized amount of water. In either case, the purpose of the statute is to remove the obstruction by removing its cause. The word *structure* means anything which causes an *obstruction*.

(2) Congress intended by the Act of March 3, 1899, to *extend*, not to *limit*, the scope of Federal control over obstructions and modifications of the navigable capacity of navigable waters. This is clear from other provisions in the Act, as well as the considerations which led to its enactment.

(3) An act such as the Act of March 3, 1899, must be liberally construed in favor of the paramount right of which it purports to be an exercise. "The language * * * must be given full scope." (*United States* v. *Rio Grande Dam & Irrigation Co.*, *supra*.)

(4) Congress could never have intended to leave to the hazard of a jury a question such as is presented in the instant case. The delay incident to criminal proceedings would make it fatal to the object sought to be accomplished, i. e., the preservation of the navigable capacity of navigable waters of the United States. A judgment on an indictment would not remove the obstruction. Finally, it would be impossible to persuade a jury to convict in a community receiving the benefits of the appellant's unlawful acts.

(5) In the Act of 1890, Section 10 provided that injunction proceedings might be instituted to enjoin *obstructions*. Section 12 of the Act of 1899 was

intended to have a broader scope and to cover *all* structures in violation of Sections 9, 10, and 11, whether the structures amounted to, or caused, obstructions, or were merely unlawful modifications of the condition of a navigable water, not amounting to obstructions.

In *Virginia* v. *Tennessee*, 148 U. S. 519, this Court said:

> And the meaning of a term may be enlarged or restrained by reference to the *object* of the whole clause in which it is used.

See also *United States* v. *Freeman*, 3 How. 565 and *Jones* v. *Guaranty Co.*, 101 U. S. 626.

We submit that the maxim "*noscitur a sociis*" is aptly applied in interpreting the word "*structure*". The associated words are to be found in what is prohibited in Sections 9, 10, and 11. (*Virginia* v. *Tennessee*, supra, p. 519.)

(2) INDEPENDENTLY OF SECTION 12, THERE IS SUFFICIENT AUTHORITY FOR THE INSTANT SUIT

Let us assume that Section 12 of the Act of 1899 does not apply to the present case. Appellant contends that if this is so there is an implied *denial* of authority from Congress for the institution of the instant suit. The basis for this contention rests chiefly on the provision contained in Section 10 of the Act of 1890 authorizing the removal of obstructions by suit for injunction. This, according to appellant, has been repealed and is an indication that no such

authority was longer to be given the Attorney-General of the United States.

It is by no means certain that this portion of a Section 10 of the Act of 1890 was repealed. Section 20 of the Act of 1899 (30 Stat. 1155) provided in part

> that all laws or parts of laws inconsistent with the foregoing Sections 10 to 20, inclusive, of this Act are hereby repealed.

Whether the injunction clause in Section 10 of the Act of 1890 was thus repealed depends upon whether it is inconsistent with any portion of the later Act, and this has never been decided.

Assuming, however, that all of Section 10 of the Act of 1890 was repealed, this could not have been intended to operate as a denial of the right to sue for an injunction in such cases as the present, for the following reasons:

(1) In 1895 this Court rendered its decision in Re Debs, 158 U. S. 564, and upheld for the first time the broad power of the United States to protect interstate commerce from interference without either a showing of pecuniary interest or specific statutory authority from Congress. The question had been one of extreme doubt before that time. Congress must be assumed to have known of that decision and to have regarded it unnecessary thereafter to insert specific statutory authority for injunction suits in such matters, and to have taken it for granted that the United States had such power anyway.

(2) The reason for the insertion of the clause in Section 12 of the Act of 1899, providing for the

removal of structures must then be taken to insure that the United States could *remove* the structures as well as prevent their construction, a power not always incident to suits for injunctions and resembling rather the *abatement* of a nuisance.

(3) Another reason for the insertion of the clause in Section 12 of the Act of 1899 may well be that not all structures erected in violation of Sections 9, 10, and 11 of that Act amounted to *obstructions*, and Congress wanted to insure power to remove them also.

(4) The considerations numbered (2), (3), and (4) above mentioned in the preceding heading with regard to the interpretation of the word *structure* are also persuasive that Congress did not, by Section 12, intend to deny to the United States rights which it had independently of statute.

In the *Wheeling Bridge case*, 13 How. 518, this Court decreed an injunction in favor of the State of Pennsylvania, enjoining the maintenance of an obstruction, although there was no statutory authority for an injunction in such cases. It was held that a *prima facie* case for the exercise of equity jurisdiction had been made out and—

> Such a proceeding is as common and as free from difficulty as an ordinary injunction bill.

In that case, however, the State of Pennsylvania alleged and, it was held, had sufficiently shown a property interest to be protected. That the United States need have neither a property interest nor statutory authority to protect interstate commerce

from interference was made clear In re Debs, 158 U. S. 564. We quote at length from the opinion (pp. 581–591):

> If all the inhabitants of a state, or even a great body of them, should combine to obstruct interstate commerce or the transportation of the mails, prosecutions for such offenses had in such a community would be doomed in advance to failure. And if the certainty of such failure was known, and the national government had no other way to enforce the freedom of interstate commerce and the transportation of the mails than by prosecution and punishment for interference therewith, the whole interests of the nation in these respects would be at the absolute mercy of a portion of the inhabitants of that single state.
>
> But there is no such impotency in the national government. *The entire strength of the nation may be used to enforce in any part of the land the full and free exercise of all national powers and the security of all rights entrusted by the Constitution to its care.* The strong arm of the national government may be put forth to brush away all obstructions to the freedom of interstate commerce or the transportation of the mails. If the emergency arises, the army of the nation, and all its militia, are at the service of the nation to compel obedience to its laws.
>
> But passing to the second question, is there no other alternative than the use of force on the part of the executive authorities whenever obstructions arise to the freedom of interstate commerce or the transportation of the mails?

Is the army the only instrument by which rights of the public can be enforced and the peace of the nation preserved? Grant that any public nuisance may be forcibly abated either at the instance of the authorities, or by any individual suffering private damage therefrom, the existence of this right of forcible abatement is not inconsistent with nor does it destroy the right of appeal in an orderly way to the courts for a judicial determination and an exercise of their powers by writ of injunction and otherwise to accomplish the same result. * * *

So, in the case before us, the right to use force does not exclude the right of appeal to the courts for a judicial determination and for the exercise of all their powers of prevention. *Indeed, it is more to the praise than to the blame of the government that,* instead of determining for itself questions of right and wrong on the part of these petitioners and their associates and enforcing that determination by the club of the policeman and the bayonet of the soldier, *it submitted all those questions to the peaceful determination of judicial tribunals,* and invoked their consideration and judgment as to the measure of its rights and powers and the correlative obligations of those against whom it made complaint. And it is equally to the credit of the latter that the judgment of those tribunals was by the great body of them respected and the troubles which threatened so much disaster terminated.

* * * * * *

> *Every government, entrusted by the very terms of its being with powers and duties to be exercised and discharged for the general welfare, has a right to apply to its own courts for any proper assistance in the exercise of the one and the discharge of the other*, and it is no sufficient answer to its appeal to one of those courts that it has no pecuniary interest in the matter. The obligations which it is under to promote the interest of all and to prevent the wrong-doing of one resulting in injury to the general welfare is often of itself sufficient to give it a standing in court. This proposition in some of its relations has heretofore received the sanction of this court.

The Court then calls attention to the holdings in *United States* v. *San Jacinto Tin Co.*, 125 U. S. 273, 31 L. ed. 747, and *U. S.* v. *American Bell Teleph. Co.*, 128 U. S. 315, 32 L. ed. 450, and continues:

> It is obvious from these decisions that while it is not the province of the government to interfere in any mere matter of private controversy between individuals, or to use its great powers to enforce the rights of one against another, yet, whenever the wrongs complained of are such as affect the public at large, and are in respect of matters which by the Constitution are entrusted to the care of the nation, and concerning which the nation owes the duty to all the citizens of securing to them their common rights, then the mere fact that the government has no pecuniary interest in the controversy is not sufficient to exclude it from the courts, or prevent it from taking

measures therein to fully discharge those constitutional duties.

The national government, given by the Constitution power to regulate interstate commerce, has by express statute assumed jurisdiction over such commerce when carried upon railroads. It is charged, therefore, with the duty of keeping those highways of interstate commerce free from obstruction, for *it has always been recognized as one of the powers and duties of a government to remove obstructions from the highways under its control.*

* * * * *

Indeed, the obstruction of a highway is a public nuisance (4 Blackstone, 167) and a public nuisance has always been held subject to abatement at the instance of the government. *Atty. Gen.* v. *Tudor Ice Co.* 104 Mass. 239, 244; 6 Am. Rep. 227; *Atty. Gen.* v. *Jamaica Pond Aqueduct Corp.* 133 Mass. 361; *Pine City* v. *Munch*, 42 Minn. 342, 6 L. R. A. 763; *State* v. *Goodnight*, 70 Tex. 682.

After discussion and approval of other cases, including *Gilman* v. *Philadelphia*, 70 U. S. 713, 18 L. ed. 96 and the *Wheeling Bridge case*, 13 How. 518, this Court said:

It is said that seldom have the courts assumed jurisdiction to restrain by injunction in suits brought by the government, either state or national, obstructions to highways, either artificial or natural. This is undoubtedly true, but the reason is that the necessity for such interference has only been occasional.

The Debs case has been quoted with approval in connection with questions pertinent to the present case in *Louisiana* v. *Texas*, 176 U. S. 1, 19; *United States* v. *Trans-Missouri Freight Association*, 166 U. S. 290, 343; *Missouri* v. *Illinois*, 180 U. S. 208, 236; *Northern Securities Company* v. *United States*, 193 U. S. 197, 356.

B

The doctrine of comparative injury has no application to a suit by the United States to protect its sovereign power over interstate commerce

In *Ruppert* v. *Caffey*, 251 U. S. 264, this Court said (p. 301):

> While this is a government of enumerated powers, it has full attributes of sovereignty within the limits of those powers.

As was stated in *Re Debs*, 158 U. S. 564, 582:

> The entire strength of the nation may be used to enforce in any part of the land the full and free exercise of all national powers and the security of all rights intrusted by the Constitution to its care. The strong arm of the national government may be put forth to brush away all obstructions to the freedom of interstate commerce or the transportation of the mails. If the emergency arises, the army of the nation, and all its militia, are at the service of the nation to compel obedience to its laws.

Must the United States, because it chose rather to submit this case "to the peaceful determination of judicial tribunals" have its sovereign rights made a delusion by a "comparison of equities?"

> There is no room in our scheme of government for the assertion of state power in hostility to the authorized exercise of Federal power. (*Minnesota Rate Cases*, 230 U. S. 352, 399.)

There *would* be such room if allowance were made for a "comparison of equities" when the United States has not only asserted its paramount control but has proved an interference with that control by a state agency such as appellant. See the exhaustive note with respect to the doctrine of comparative injury in enjoining nuisances in 31 L. R. A. (N. S.) 881.

There *can* be no equities in a case such as this. Either the United States has proved a violation of Section 10 of the Act of March 3, 1899 or it has not. If it has, there is an unlawful assertion of State power in hostility to the sovereign power of the Nation, and no excuse or justification can be recognized. The hostility must cease, and it is the State which must withdraw from the controversy.

What *are* the equities that appellant desires that this Court consider?

(1) Is it the fact that the appellant, at the end of 1892 or the early part of 1893, commenced to excavate in the State of Illinois? It did so in the face of the Act of Congress of 1890 and of the suggestions on every hand that Federal cooperation would be necessary.

(2) Or the fact that appellant continued to spend money after 1896? It did so in the face of an express

warning from the Board of Engineers in 1895 and a notice from the Secretary of War in 1896 that no authority was yet given it to divert water from the Chicago River.

(3) Or the fact that it continued to spend money after 1899? This was in the face of warnings too numerous to mention, in the reports of the Engineer in Charge at Chicago and in the conditions of the permits and in the provisions of the Act of 1899, which were constantly brought to its attention?

(4) Or the fact that it continued to spend money after the Calumet River Suit was instituted? or the Main Channel Suit?

Thus we might go on, but it is unnecessary. Yes, the appellant has expended over $75,000,000 of the money of taxpayers, not in reliance upon, or because of putting faith in any misleading assertion or act of appellee's officers or agents, but on a *gamble* that the United States would not put an end to it. The effect of the execution of its projects upon the navigable waters of the United States was put up to it squarely at every stage of its negotiations with the Government. The appellant seemed to ignore that its canal was in the United States, and subject, always, to Federal control.

The *equities* that appellant now asserts are nothing more than the results of *defiance* of unquestionable Federal authority. Were the advantages of unlawful acts ever deemed to create *equities* in the law breaker?

And have equities *ever* been asserted against a sovereign right? The principle for which appellant contends is the same principle to which this Court, in *Union Bridge Co.* v. *United States*, 204 U. S. 401, referred as one which "would seriously impair the exercise of the beneficent power of the government to secure the free and unobstructed navigation of the waterways of the United States." (See *supra*, p. 267.)

Appellant asserts that the injury to appellee is comparatively slight and may be easily compensated. That is for the appellee, not appellant, to judge, and Congress and the Secretary of War have passed upon the question. Their determination is conclusive The same contentions were made in the *Wheeling Bridge Case*, 13 How. 518, 568:

> But, it is said, the bridge constitutes no serious obstruction to the navigation of the Ohio; that only seven steamboats, of two hundred and thirty which ply upon the river as high as Pittsburg, are obstructed; and that arises from the height of their chimneys, which might be lowered at a small expense, in passing under the bridge; that, by the introduction of blowers, the chimneys might be shortened without lessening the speed of the boats; that the goods and passengers which are conveyed on the public lines of communication, between Pittsburg and Philadelphia, could be as well conveyed on boats of lower chimneys, and consequently the State, as proprietor of those lines, if at all injured,

> is injured so inconsiderably as not to lay the foundation of this procedure; that none of the packets or the other boats on the river are owned by the State of Pennsylvania.

This Court said further (p. 578):

> The Bridge Company had legal notice of the institution of the suit, and of the application for an injunction to stay their proceedings, before their cables were thrown across the river. This should have induced them to suspend, for a time, their great work, alike creditable to the enterprise of their citizens, and the genius and science of the engineer who planned the bridge and superintended its construction. It is a matter of regret that, by the prosecution and completion of the bridge, they have incurred a high responsibility.

See also *Miller* v. *Mayor of New York*, 109 U. S. 385.

Under the pleadings in this case, the appellee offered no evidence to meet that introduced by appellant in support of its affirmative defenses, as there was a motion to strike pending. We do not, of course, concede the correctness of any of appellant's exaggerated figures either as to the amount of diversion really necessary to take care of all practical danger from a maximum run-off in the Chicago River or as to the cost of installing purification works such as other cities on the Great Lakes and elsewhere have done. We merely state, that conceding them to be true, they are immaterial and constitute no defense. We have

noted, however, that in spite of the supposed fatal effects of the run-off of 10,000 c. s. f. in the Chicago River, the appellant was able to manage with a great deal less from 1900 to after 1913 and even now claims to ask only 8,000 c. s. f. so far as the Chicago River is concerned (the other 2,000 c. s. f. to be diverted through the Calumet River). Of this 8,000 c. s. f. a large part, probably over 1,000 c. s. f., is from drinking water, etc. The maximum run-off of the Calumet River is 15,700 c. s. f. and yet appellant has never planned on more than 4,000 c. s. f. diversion through that river.

The power of appellant to raise money by taxation or otherwise is a matter for the State of Illinois. The appellant assumes to justify its acts under State authority: presumably it can obtain the necessary authority to raise money.

The equities involved in this case, using the word in a broad and not a legal sense, are not with the appellant.

In asking this Court to balance "equities," appellant is in effect asking it to disregard the decision of Congress and the Secretary of War, and to grant appellant a *permit* to continue its defiance of Federal authority. If there *are* equities, the proper forum in which to present them is Congress.

C

The lower court did not err in denying appellant's motion of July 12, 1920

The appellee sought by suit instituted in the proper forum to restrain appellant from diverting more than

4,167 c. s. f., the limitation placed upon it by the Secretary of War. By its motion of July 12, 1920, appellant in effect asked permission from the *court* to divert not exceeding 10,000 c. s. f. on the strength of an offer which it then made to pay the expense of constructing such regulating and compensating works as the United States might determine to build to offset for the lowering of the lake levels and connecting channels, due to a diversion of 10,000 c. s. f. The works were to be built in such places as the St. Clair and Niagara Rivers. We need not dwell on the feasibility or probable expense of such works (as to which questions there was extreme difference of opinion—see Statement of the Case, p. 107), or whether the appellant can ever constitutionally spend money of Illinois taxpayers on submerged weirs on the international boundary. The fundamental legal obstacles to any such decree are sufficient without consideration of questions of fact.

(1) APPELLANT MAY NOT BE UPHELD IN ITS UNLAWFUL DIVERSION BY ITS OFFER TO GIVE APPELLEE SOMETHING ELSE OF ALLEGED EQUAL VALUE

In *Kansas* v. *Colorado*, 206 U. S. 46, this Court said p. 100:

> Colorado could not be upheld in appropriating the entire flow of the Arkansas river, on the ground that it is willing to give, and does give, to Kansas something else which may be considered of equal value. That would be equivalent to this court's making a contract between the two states, and that it is not authorized to do.

This principle applies with even greater force to a suit by the United States to enforce a sovereign right.

(2) THE POWER OF GRANTING OR REFUSING AUTHORIZATION LIES IN CONGRESS, AND, SO FAR AS IT HAS BEEN DELEGATED, IN THE CHIEF OF ENGINEERS AND THE SECRETARY OF WAR

In the case of *Wilson* v. *Shaw*, 204 U. S. 2432, this court said:

> We have no supervising control over the political branch of the Government in its action within the limits of the Constitution. *Jones* v. *United States*, 137 U. S. 202, and cases cited in the opinion; *Re Cooper*, 143 U. S. 472, 499, 503.

(3) UNDER THE TERMS OF THE CANADIAN BOUNDARY WATERS TREATY OF JANUARY 11, 1909, THE CONSTRUCTION OF SUCH WORKS AS THE APPELLANT PROPOSES CAN NOT BE UNDERTAKEN WITHOUT THE APPROVAL OF THE INTERNATIONAL JOINT COMMISSION

Article 4 of the Treaty reads as follows:

> The High Contracting Parties agree that, except in cases provided for by special agreement between them, they will not permit the construction or maintenance on their respective sides of the boundary of any remedial or protective works or any dams or other obstructions in waters flowing from boundary waters or in waters at a lower level than the boundary in rivers flowing across the boundary, the effect of which is to raise the natural level of waters on the other side of the boundary

unless the construction or maintenance thereof is approved by the aforesaid International Joint Commission.

Article 8 of the Treaty provides:

> This International Joint Commission shall have jurisdiction over and shall pass upon all cases involving the use or obstruction or diversion of the waters with respect to which under Articles 3 and 4 of this Treaty the approval of this Commission is required.
>
> * * * * *
>
> The Commission in its discretion may make its approval in any case conditional upon the construction of remedial or protective works to compensate so far as possible for the particular use or diversion proposed, and in such cases may require that suitable and adequate provision, approved by the Commission, be made for the protection and indemnity against injury of any interests on either side of the boundary.
>
> In cases involving the elevation of the natural level of waters on either side of the line as a result of the construction or maintenance on the other side of remedial or protective works or dams or other obstructions in boundary waters or in waters flowing therefrom or in waters below the boundary in rivers flowing across the boundary, the Commission shall require, as a condition of its approval thereof, that suitable and adequate provision, approved by it, be made for the protection and indemnity of all interests on the other side of the line which may be injured thereby.

> The majority of the Commissioners shall have power to render a decision. In case the Commission is evenly divided upon any question or matter presented to it for decision, separate reports shall be made by the Commissioners on each side to their own Government. The High Contracting Parties shall thereupon endeavor to agree upon an adjustment of the question or matter of difference, and if an agreement is reached between them, it shall be reduced to writing in the form of a Protocol, and shall be communicated to the Commissioners, who shall take such further proceedings as may be necessary to carry out such agreement. (Rec., Vol. IV, pp. 2564–2567.)

If this Court were, to permit by its decree a diversion of 10,000 c. s. f. it would be invading not only the field of political questions committed to Congress, but also the field of international questions committed to an international tribunal.

(4) THE DECREE WHICH APPELLANT PROPOSES WOULD BE VOID AND INOPERATIVE, IN THAT IT WOULD CONTAIN A CONDITION WHICH THE COURT WOULD BE POWERLESS TO ENFORCE

The construction of submerged weirs in the Niagara and St. Clair Rivers may never be authorized by Congress. Even if authorized by Congress they may never be permitted by the International Joint Commission. If they *are* authorized, they may cost many times what the appellant has in mind or is able to pay. The appellant will feel free to say that the works are not such as it had in mind when it made

the offer. There will be no way of determining the meaning of such a decree or the proper manner of enforcing it. In the meantime appellant will be diverting 10,000 c. s. f. and, to judge by its past performances, considerably more.

In *Kansas City S. R. Co.* v. *Kaw Valley Drainage District*, 233 U. S. 75, it was recognized that such a decree could not be entered. We quote from the opinion as follows (pp. 77-78):

> The supreme court [of Kansas] recognized that it could not order the bridges to be raised to the required height without the authority of the Secretary of War.
>
> * * * * *
>
> But the court went on, on the assumption that it would lead to the elevation of the bridges, and seemingly for the purpose of accomplishing indirectly what it admitted that it could not do directly, to make an unqualified absolute order, as we have said, that the defendants should clear the channel of all obstructions on their lines up to the specified heights—in other words, to remove the bridges as they stand.
>
> These judgments must be taken as they read upon their face. They are not conditional orders to raise the bridge if the defendants can obtain the consent of parties not before the court, and of one authority at least not subject to its control. They can not be qualified by speculation as to what is likely to happen in fact. They are out-and-out orders to remove bridges that are

> a necessary part of lines of commerce by rail among the states. But that subject matter is under the exclusive control of Congress and is not one that it has left to the states until there shall be further action on its part.

In Corpus Juris, Vol. 21, p. 658, we find the following:

> A decree should ascertain and fix with definiteness and certainty the rights and liabilities of the respective parties to the cause. If it is uncertain and indefinite in these particulars it is at least erroneous and may be void.

and on pp. 645–6, the following:

> A final decree whose validity and force depend upon the performance of some condition by one of the parties is void.

See also 14 Ruling Case Law, 321; 25 L. R. A. (N. S.) 271, note; *American School Furniture Co.* v. *Sauder Co.*, 106 Fed. 781; *Hawley* v. *State Bank*, 134 Ill. App. 96; *Bank of Commerce* v. *Goolsby*, 129 Ark. 416, 196 S. W. 803; *Simmons* v. *Jones*, 118 N. Car. 472, 24 S. E. 114; *Pennsylvania Co.* v. *Bond*, 99 Ill. App. 535 (affirmed in 202 Ill. 95, 66 N. E. 941).

In the case of *Pennsylvania Co.* v. *Bond*, *supra*, the Appellate Court said, on p. 542:

> This portion of the decree is doubtless open to objection. By its terms it becomes effective only if it shall appear that these things have been done. How it is to be determined whether they have been done, the decree does not state. Why counsel should have submitted to the chancellor a decree containing

such a condition, especially when the evidence showed that the condition had been already fulfilled, we are at a loss to discover. This part of the decree is by its terms inoperative.

In the case of *Bank of Commerce* v. *Goolsby*, 129 Ark. 416, 446 the Supreme Court of Arkansas said:

> The decree in favor of J. H. Frost, E. B. Russum, A. N. Cole, R. O. Herbert, Alta Blaylock, J. O. Gunter, C. L. Pyle, W. H. Cole, R. T. Powell, Lawrence Wright, R. P. Reynolds, E. D. Vann, and J. O. Johnson, against the directors were upon the contingency or condition that each of these parties should pay the decrees rendered against them respectively in favor of the bank. These decrees were not only anomalous, but they were without authority of law and void.
>
> That a judgment *in praesenti* can not be rendered and grounded upon a future condition or contingency, see *Battell & Collins* v. *Lowery et al.*, 46 Iowa 49. In the course of the opinion in that case the court said:
>
> "If there was a present judgment, it was at most a judgment that there should be a judgment. But we cannot sanction such an anomalous proceeding."

The cases cited by appellant to the effect that a court of equity may impose conditions on relief granted to a complainant asking an injunction are so plainly inapplicable to the case at bar that discussion of the proposition seems a work of supererogation. The appellant does not seek to impose a condition on the appellee, for the court admittedly can not

require Congress or the Secretary of War to authorize the building of the compensating works. The appellant instead is seeking by indirection to obtain from the court a permit to do something forbidden by valid legislation, and as a consideration for the dispensation offers to submit to a condition which can never be enforced against it. It asks that its illegal acts be legalized.

Cases having to do with the rights of a court of equity to require security in the form of a bond from a complainant or to require that a complainant recognize an equitable right of the defendant are not in point. The maxim that he must do equity who asks it has no application to the facts now before the court.

D

The decree for an injunction should be effective immediately

Under its Point IX (b) appellant argues that the operation of a decree for an injunction should be postponed until "appellant and the cities, villages, and towns within its limits can readjust their works of sewage disposal or of purifying the water supply." (Appellant's Brief, p. 218.) Apparently appellant is really asking a postponement until at least 1945. Appellant plans, between now and 1945, to construct artificial purification works *only* to take care of sewage *in excess of that disposed of by 10,000 c. s. f.* After that it plans to install works to purify the sewage now taken care of by the unlawful diversion. Having in mind the time already wasted this proposal simply

postpones the vindication of the rights of the United States to the Greek Kalends. Substantially the only reason suggested by appellant for the long delay is that *state* limitations on appellant's power to raise revenue by taxation and bonds will not permit an earlier accomplishment of these objects. The United States need not await the pleasure of the Legislature of Illinois to enforce the rights of the former.

If this Court should deem these matters material, appellee should have an opportunity to controvert the testimony.

Appellant's argument under this heading is but a reiteration of what it has elsewhere urged under the heading of "comparison of equities" and also in connection with its motion of July 12, 1920. The answer, too, is the same.

In the first place, to enter a decree, such as appellant asks, is but to recognize that appellant *has* equities or a partial *defense* against the claim of the United States. The paramount power of the United States over interstate commerce becomes subject to conditions not to be found in the Constitution and arising solely from the unlawful and reckless acts of appellant.

As was stated in the Debs case, 158 U. S. 564, the United States need not have appealed to its Courts for the peaceful determination of the questions arising from a defiance of its sovereign power:

> The strong arm of the national government may be put forth to brush away all obstructions to the freedom of interstate

> commerce or the transportation of the mails. If the emergency arises, the army of the nation, and all its militia, are at the service of the nation to compel obedience to its laws.

Appellant's obstruction might have been forcibly abated. The right of the United States is absolute and immediate. Is it to be qualified because the *state* has placed a limitation on appellant's power to raise revenue?

In the second place, and this is really another aspect of the same question, to delay the operation of the injunction is, in effect, to give appellant a *permit* to divert 10,000 c. s. f. for the period of the delay. This, however, is a *legislative* power, to be exercised only by Congress and, to a limited extent, by the Chief of Engineers and the Secretary of War. Their determination is *conclusive* (see our Point III, E and F, supra, pp. 181 to 184).

The proper forum, then, for the presentation of appellant's equities is in Congress, the Secretary of War having determined the unauthorized diversion to be an obstruction. If time is needed for the adaptation of appellant's works to the decree, there is no reason to doubt that Congress will give that time by a temporary permit. It cannot be assumed that Congress will act arbitrarily or unjustly. Congress has already declared the diversion to be unlawful by its prohibition of obstructions in Section 10 of the Act of 1899. It is for Congress to give it a temporary legitimization if that is necessary.

In its Point IX (d), appellant concedes that "this matter should be settled by Congress." (Appellant's Brief, p. 226.) With this we thoroughly agree. It *has* been settled by Congress by its enactment of the Section 10 of the Act of 1899 and the present unauthorized diversion is prohibited and unlawful. If it is to be made lawful, either temporarily or permanently, that *too* must be settled by Congress, not by appellant.

Appellant has recognized, also, that Congress is the proper forum for relief for, as is stated in its brief (p. 226), bills in its behalf have been and *are* pending in Congress.

> The hearings on these bills were not concluded when the last session of this Congress ended, and the Committee adjourned to take up the matter at the next session of this Congress. The said bills are still pending, undisposed of by said Committee on Rivers and Harbors of the House, no action has been taken thereon, and they have not yet been reported. (Appellant's Brief, p. 226.)

Presumably, Congress, in the exercise of its sovereign power, will accomplish a just solution of the problem. Whether the solution pleases appellant or not, it will be conclusive. It may find that appellant should be permitted to take 10,000 c. s. f. It may find that that is too much, and that appellant's arguments and conclusions based on the supposed maximum run-off of the Chicago River are not accurate or well founded. Is this Court to take from Congress its freedom and power to deter-

mine the matter conclusively and effectively for the best interests of the Nation as a whole? It would, if it suspended the operation of the injunction for any considerable period of time. This would enable the appellant again and for another period of many years to stake the lives and health of a great city on a *hazard* that by the end of that time it would have persuaded the United States to legalize its diversion. In this connection we quote from the opinion of the Secretary of War in his decision rendered January 8, 1913:

> A recent report of the engineers of the sanitary commission (Oct. 12, 1911) proposes eventually to use some such method, but proposes to postpone its installation for a number of years to come, relying upon the present more wasteful method in the meanwhile. It is manifest that so long as the city is permitted to increase the amount of water which it may take from the Lakes, there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage. This is particularly true in view of the fact that by so doing it may still further diminish its expenses by utilizing the water diverted from the Lakes for water power at Lockport. (Appellant's Narrative, pp. 35–36.)

It is now over sixteen years since the Calumet River suit was instituted; it is over eleven years since the Secretary of War rendered his decision denying appellant's application for an increased diversion; it is over twenty-eight years since appellant had its

first official warning (in the permit of July 3, 1896) that permission to divert water, and how much, were matters of uncertainty. Now it wants not only until 1945 but an indefinite period beyond that.

Appellant may, however, direct the attention of this Court to the decree in the first Wheeling Bridge Case, 13 How. 553. In that case the decree provided that the Bridge Company should have until the following February 1st to make the changes in its bridge necessary to remove the obstruction. The State of Pennsylvania, however, was suing in its proprietary right and the parties appeared before this Court in the character of private individuals. There was no occasion for a question of the assertion of the paramount and exclusive jurisdiction of Congress. When Congress later exercised that jurisdiction this Court held itself bound by it. (18 How. 421.)

This grave question, so long unsolved, will never be solved by the only department of the government that can solve it (namely, Congress) until this litigation is ended by this Court by a decree that is *definitive and obligatory*. Such a decree, declaring the just rights of the United States and requiring prompt respect by the Sanitary District for the rights of the Government, need not be inconsistent with any existing power of the Secretary of War, acting upon the recommendation of the Chief of Engineers, to grant a temporary permit pending the action of Congress.

CONCLUSION

The length of this brief, as well as the dimensions of the record in this case and the time consumed in bringing it to a conclusion, are out of all proportion to the difficulty of the legal issues. There never has been any serious question either of law or of fact since the institution of the Calumet River suit in 1908. While counsel for appellant have devoted an imposing brief to an attempt to justify appellant's conduct, their claims, on examination, prove to be mere challenges of elementary and well-settled principles of law, or arguments based on facts which are not present in this case.

In our review of the cases and the principles established by them, we have, therefore, been forced to make constant reference to "propositions which may have been thought axioms." We offer in excuse the considerations to which Mr. Chief Justice Marshall gave expression near the close of his opinion in *Gibbons* v. *Ogden*, 9 Wheat. 1, 222:

> The conclusion to which we have come depends on a chain of principles which it was necessary to preserve unbroken; and, although some of them were thought nearly self-evident, the magnitude of the question, the weight of character belonging to those from whose judgment we dissent, and the argument at the bar demanded that we should assume nothing.

The instant case is unique in that while its far-reaching consequences affect vitally the interests of a whole nation and are of a magnitude not easily

exaggerated, its *justiciable* issues are comparatively insignificant. Appellant's brief argues little if anything that was not determined against appellant by Chief Justice Marshall in *Gibbons* v. *Ogden*, reaffirmed again and again by this court. It is a matter of regret that both appellant and appellee should have been caused the expenditure of time, money, and effort by this protracted and unnecessary litigation.

In insisting upon its paramount and exclusive control over the subject-matter of this litigation, the Government of the United States is performing an unpleasant and yet unavoidable duty. It is trustee of the navigable waters of the United States for the use, benefit and enjoyment of the whole Nation and it would betray that trust if it suffered appellant's defiant challenge to pass unnoticed, particularly when other States of the Nation and a foreign government are complaining. The appellee is entrusted, too, with exclusive control of the Nation's relations with foreign countries and it can not permit either a state or a municipal corporation to deal with its international problems.

Yet the Government's position must not be misunderstood. Nothing that has been urged before this court is intended to belittle or ignore the welfare of the great and progressive community growing within appellant's district. Whether the emergency is as great as certain of appellant's witnesses have intimated, or not, Chicago's problem in this matter is a serious and perplexing one, in which the entire Nation should take a sympathetic interest and to the

solution of which the Nation by its duly constituted authorities should address itself without delay.

In solving this question, however, the Nation must, under its Constitution, act through its Congress and not through its courts. Once this Court has made a declaration of appellee's sovereign right and has pronounced unlawful appellant's invasion of that right, the way will be cleared for the presentation of Chicago's case to the only forum which can render a valid decision on its merits. The issues will then be unobscured and uncomplicated by frivolous defenses, which, although advanced by appellant for many years, require little time of this or any court for their decision.

Throughout this litigation the Government of the United States and its legal representatives have not been unmindful of the welfare of the people of Chicago. Within the scope of its delegated power, the Federal Government (and not the Sanitary District) represents the people of Chicago; and, so representing them—whose truest welfare must be that of the whole people of the United States—the Federal Government has endeavored to act in this matter for the common welfare. Certainly it has not been lacking either in consideration or patience in this litigation. But in its deep concern for the welfare of Chicago, the Government must also have regard for the rights and interests of the great States and populous cities which have equal rights in the waters of Lake Michigan.

It is a condition and not a legal theory that confronts the Government. The question is not judicial, and this

Court will presume that the Legislative and Executive branches of the Government will not be unmindful of all the equities of the situation.

As this serious problem will require time for its careful consideration, the Government can not object, if the Secretary of War, acting on the recommendation of the Chief of Engineers, sees fit, pending the action of Congress, and as a modus vivendi to modify the existing permit and temporarily permit a greater diversion of waters.

If there be any doubt as to his power under the authority already delegated to him, the Government has no objection to a proviso in any decree that this Court may enter which will provide that the decree and the injunction, while immediately effective, shall be without prejudice to any temporary permit that the Secretary of War, acting upon the recommendation of the Chief of Engineers, may see fit to grant in the nature of a modus vivendi, pending the action of Congress in the premises.

This would set at rest the authority to make some temporary arrangement in the event the present Congress could not dispose of the question before it adjourns sine die on March 4, and especially in the event that Congress might not be again in session until the first Monday of December next.

It should, however, be made clear that the recognition and enforcement of the just rights of the United States Government are not to depend on or to await the conclusion of any agreement between the Sanitary District and the Government. It should not be a question of what

the Sanitary District should now concede, but what the Government of the United States should now allow.

If Congress, (or the Executive, to the extent of its delegated power,) voluntarily and in consideration of the inherent difficulty of the situation and the welfare of the people of Chicago gives some temporary permit until the whole problem can be finally solved by Congress, there should be no further opportunity for the Sanitary District to begin the litigation afresh and prolong it for another sixteen years under the plea that the decree of this Court was entered upon the faith that the Sanitary District and the United States Government should make some contract in the matter.

The question is not one of contract, but of governmental power. The United States has the right to stop the unlawful diversion by the Sanitary District of the waters of Lake Michigan for the uses of the City of Chicago.

In exercising this power, it need not bargain or contract with the Sanitary District.

Its power is not that of a coequal, as the learned counsel for the Sanitary District seem to intimate, but the power of a sovereign.

It was not necessary for the Government to go into the United States courts to assert rights which were so clear or to discharge duties which were so imperative. Nothing more clearly marks its consideration for the people of Chicago than that it consented, before enforcing its undeniable rights, to go into its courts, and the patience with which it has accepted the inordinate and

inexcusable delays in this litigation show the keen desire of the Government that no possible injustice should be done to the people of Chicago.

Is it not time to consider the welfare of other cities and great States? The interests of all the people, for whom in this matter the United States stands in a great trust relation, imperatively require that the power and authority of the United States should now be vindicated so clearly and emphatically that the Sanitary District may have no further excuse to persist in its unlawful diversion of lake waters by treating the decree of this Court as a pretext for fresh litigation. Assuredly the Sanitary District has had its day in court and the time has come when it should obey the laws of a country, of which it is but a part.

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NOVEMBER, 1924.

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No. 161.

In the Supreme Court of the United States

OCTOBER TERM, 1924.

THE SANITARY DISTRICT OF CHICAGO, *Appellant*,
vs.
THE UNITED STATES OF AMERICA, *Appellee*.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION.

THE CASE.

The injunction is (Rec. Vol. VIII, p. 131) that the Sanitary District be "enjoined from diverting or abstracting any waters from Lake Michigan over and above or in excess of 250,000 cubic feet per minute"—or 4167 feet per second.

The statement of defendant in answer and exhibits (Vol. VIII, pp. 9 and 58) is that on permit from Secretaries of War to take 250,000 feet per minute (4167 feet per second) defendant is abstracting 480,000 feet per minute, and the proof indicates even more, for purely local benefit and economy in sewage and trade waste disposal, cheapened by the manufacture of electric power on a large scale.

It cannot be denied and the court below finds, that on the evidence it cannot be controverted that this results in lowering lake levels, and the abstraction of the excess over 250,000 feet per minute impairs seriously the navigability of the Great Lakes water route—the great-

est and cheapest in the world. (The conceded total reduction of the lake levels is 5½ inches and even greater in the St. Lawrence River.) The Court finds that this inflicts a direct loss to those dependent on the water navigation route.

In the report of the International Waterways Commission, 1907, (Vol. IV, p. 2421), the direct yearly loss to vessels alone in freight earnings is conservatively placed at a million and a half, but this is put on good authority of President Livingstone, of the Lake Carriers' Association, on figures produced (Vol. I, pp. 205-6-7) at easily a half million dollars per inch of reduced draft, which would amount to some four million dollars annually for six inches—and that was in 1909. His testimony goes fully into the subject and see Coulby (Vol. I, p. 428). It must be taken into account that the traffic is rapidly increasing and has been since this testimony was given in 1909, the iron ore alone in 1920 amounting to 64,512,000 tons (Vol. VIII, p. 220).

But there is also the vast loss and damage to some 106 improved harbors in the States fronting the Great Lakes and over 50 on the Canadian side—and to the country at large and its industrial business dependent on the Great Lakes route for the annual movement of more than a hundred million tons of raw materials and other commodities wherein the saving in freight rates, compared with the cost of rail transportation, easily reaches or exceeds a quarter of a billion dollars every year.

The object and being and purpose of the defendant Sanitary District are avowedly for local sewage treatment only, to which has been added manufacture of electric power to reduce the expense. Mention is here

and there made in the Record of a navigation channel to connect the Mississippi system of river navigation with Chicago by joint action of the United States and Illinois; but that is still in the future. Examinations and surveys by the United States show, however, that the requirements of such a channel would not exceed 1,000 cubic feet per second (Vol. VIII, p. 54); and in the instant case the injunction is against the sanitary canal exceeding 4,167 cubic feet per second.

Defendant-appellant, confessing in answer the abstraction of a great excess of water over 4,167 feet per second and that the entire diversion and abstraction is used for non-navigation purposes referred to, a convenient, and with the power production, the cheaper method—claims the right under a general state statute of 1889, authorizing the formation of sanitary districts to care for local sewage, with some details applicable to such a District if one should be set up at Chicago, and in that case to take from the Lake and use whatever might be necessary to its purposes, and, under a supplemental act of 1903 specifically authorizing such District to erect works to develop power, raising the necessary money by local taxation.

The answer also avers, as will be later shown, that the Sanitary District has never recognized and denies any right or authority of the United States to interfere, although (see finding of District Court Vol. VIII, p. 151) from the very beginning it has applied to succeeding Secretaries of War not alone for the original permit, but repeatedly for increases thereof—which have been denied—and the thousands of pages of Record are replete with applications to the Secretary of War for permits or increase, official reports of government engineers, etc.

In fine, the right and authority of the general government are now unqualifiedly denied by defendant-appellant.

The injunction was granted by the District Court at Chicago. The facts and the law were passed upon and decision and opinion rendered (orally) by Judge Landis (Vol. VIII, p. 149), and again, after his retirement, on motion to modify, by Judge Carpenter (Vol. VIII, p. 127). And there appears also in the Record (Vol. VII, p. 7 and also Vol. VIII, p. 50) the well considered decision and opinion of Secretary of War Stimson (Jan. 8, 1913) in which he reviews the facts on the record made before him, and the law.

All three are challenged in their findings of fact and of law—which were to the effect that there was serious impairment and damage to the navigability of the Great Lakes water route from the unwarranted abstraction of water,—that the right of navigation was paramount and the United States did have authority and right to interfere, and, furthermore, that even for sewage disposal there was no justification or necessity for such lavish use and waste of water.

Statements of facts will have been presented in briefs of counsel for the parties. For our own part we deem the admissions of facts in the answer and exhibits of appellant herein to be sufficient to call for affirmance of the decree below by the two District Judges in Chicago, each of whom was frank to state a personal sympathy toward another result; and sufficient to support the conclusion and decision of so good a lawyer as Secretary Stimson, whose opinion is incorporated in the Record (Vol. VII, p. 7; also Vol. VIII, p. 50). The findings of all these the appellant specifically challenges.

CONNECTION OF THE LAKE CARRIERS' ASSOCIATION WITH THE SUBJECT.

The interest of the Lake Carriers' Association, which prompts the application for and leave to file this brief, should not be misunderstood. It is a business league composed of members who own and operate ships on the Great Lakes, not itself owning or operating or financially interested in any respect soever in any ship. But, through its membership, it has been alive to and at all times attentive to everything tending to the improvement of or threatening the navigable capacity and usefulness of this great water transportation route, which, to common knowledge, has grown to such enormous proportions as that it furnishes the country at large the cheapest and most efficient transportation known to history of such raw materials as grain, iron ore, coal, stone and other commodities, therein performing a ton-mile service exceeding 25 per cent of ton-mile service by all railroads in the United States, and being substantially one-half that of the railroads east of the Mississippi and north of the Ohio River in the general region in which the Great Lakes lie; and this at a cost, over and by means of this great, open, free, competitive national and international highway, which compared with similar service by railroads, if that were possible, is one-fifth or less. It is common knowledge also, that in the procession of business events this spread grows larger.

The haul from the head of Lake Superior or of Lake Michigan to the foot of Lake Erie is approximately a thousand miles. The rate of iron ore (by the long ton) for this distance, is not more than for a rail haul of 125 to 150 miles. Enough wheat to make a barrel of

flour is commonly carried a thousand miles for about 10 cents,—a ton of coal for less than the cost of shoveling it into the basement of one's home. These and other similar statistics appear fully in the Record, and, indeed, being of common knowledge, are neither in dispute nor disputable.

DIRECT LOSS TO SHIPPING.

The members of the Association, as private ship owners, have personal interest in averting the calamity of heavy direct loss, which will be later referred to, from the impairment of the navigable capacity of the Great Lakes, such as has been already occasioned by the abstraction of unprecedented quantities of water by the Sanitary District at Chicago, which, we may remind here in passing, is taken for purely local benefit for sewage purposes by, what the Record shows to be, a more convenient method, as against not only possible but other reasonable and well known methods in world wide use, which do not require any such extravagant waste.

THE PUBLIC INTEREST.

It is also fitting that such an Association present argument here on a broader question than personal loss to its members, since in the evolution of business in this country the farming interests of the northwest and the iron and steel industry depend upon the cheap transportation by this waterway, and as well the distribution of coal to the northwest. In the evolution billions of dollars have been invested and many millions of our population have come to be employed on the farms, in the mines of iron ore and coal, the quarries of stone, the docks and other terminals, furnaces, ships, shipbuilding plants and every conceivable thing that goes into the

cosmos of the gigantic industry and the social enterprises of the whole country.

Recognizing the necessity of taking advantage of this cheap water route and for its development and fullest utilization, the whole country being directly interested, our Government, and the same is true of the Canadian Government, has been keenly alive and satisfactorily active in its improvement and against any impairment for local benefit, throughout the whole route; improving it in respect to dangerous shoals and narrow and restricted channels connecting the different lakes. Even by 1911, (Vol. VI, p. 3624) our own Government had expended $100,000,000. This has included the construction of great locks and appurtenant canal at Sault Ste. Marie to overcome the fall of nearly twenty feet between Lake Superior and the lower lakes; large improvement of channels at the foot of Lake Superior and throughout much of St. Mary's River, both above and below the locks at the Soo, down to Lake Huron, including an artificial cut of several miles to shorten the distance and avoid dangerous conditions in the navigation of the river, marking the channel with ranges and lights so the great steamers can run the river at night, and nearly all of this is under Government regulation in the navigation of ships. Not to particularize too far, again at the foot of Lake Huron and the head of St. Clair River, large improvements have been made, in enlarging, deepening and taking out obstructions to navigation, and again at the foot of St. Clair River, where it debouches into Lake St. Clair; then all of the 25 miles across Lake St. Clair, and, in the Detroit River, where, in its lower end, our Government has established, additional to previous channels, the greatest channel improvement in the world in the Livingstone Channel; and

so on below that and at the head of Lake Erie are miles of dredged improved channels, and at Buffalo a six million dollar improvement in the Black Rock Canal and lock, and Government assistance has been freely given in aid of terminal harbor improvements. Besides, many millions have been expended for lighthouses, fog signals and coast guard service.

Over all of this the Government exercises its supervision for the preservation and maintenance of the water route, and there is a system of lake surveys, a hydrographic service, and all of the adjuncts necessary to preserving and improving and making for greater usefulness to the nation all this as an open and competitive free waterway, without a dollar of tolls and over which, according to public statistics, 121,000,000 tons of cargoes are already carried in a single season of navigation.

From the Record in this case and from public and general Government statistics, and of general knowledge, the saving by this route to the people of the United States is in every year more than the total that the appellant claims to have been able to spend and would be required to spend to care for its sewage.

In considering a question of admiralty and maritime jurisdiction, Chief Justice Taney said of the Great Lakes in 1851, (*The Genessee Chief*, 12 Howard, at 453):

> "If the meaning of these terms was now for the first time brought before this Court for consideration, there could, we think, be no hesitation in saying that the lakes and their connecting waters were embraced in them. These lakes are in truth inland seas. Different States border on them on one side, and a foreign nation on the other. A great and growing commerce is carried on upon them between different States and a foreign nation, which is sub-

ject to all the incidents and hazards that attend commerce on the ocean. Hostile fleets have encountered on them, and prizes been made; and every reason which existed for the grant of admiralty jurisdiction to the general government on the Atlantic seas, applies with equal force to the lakes. There is an equal necessity for the instance and for the prize power of the admiralty court to administer international law, and if the one cannot be established neither can the other."

Nine years later (1860) the court, by Nelson, J. said, (24 How. 38):

"According to the best official statistics, the value of the property annually, the subject of this commerce, exceeds $600,000,000, employing more than sixteen hundred vessels, with an aggregate tonnage exceeding 400,000 tons. These vessels are duly licensed for the foreign trade, as well as for that carried on coastwise. This commerce, from its magnitude, and the well known perils incident to the lake navigation, deserves to be placed on the footing of commerce on the ocean; and, we think, in view of it, Congress could not have classed it with the business upon rivers, or inland navigation, in the sense in which we understand these terms.

These Lakes are usually designated by public men and jurists, when speaking of them, as great inland waters, inland seas, or great lakes; * * *."

The Record (Vol. IV. p. 2420) shows this tonnage by 1907 to have reached approximately two million tons Custom House measurement, which is approximately one-half the cargo carrying capacity, the numbers of the vessels being less because of their very great increase in size from year to year.

Later, in 1892, this Court, speaking through Field, J., said of the Great Lakes (146 U. S. 436):

"The Great Lakes are not in any appreciable respect affected by the tide, and yet on their waters, as said above, a large commerce is carried on, exceeding in many instances the entire commerce of States on the borders of the sea."

In report on "Diversion of Water from the Great Lakes and Niagara River," by the United States Board of Engineers for Rivers and Harbors, August 30, 1919, transmitted by the Secretary of War, December 7, 1920, to the Speaker of the House of Representatives, at page 91, we find:

"The Great Lakes system forms one of the world's greatest highways for water-borne transportation. The Great Lakes fleet moves more than 100,000,000 tons of freight each season. • • • These vessels are from 280 to 625 feet in length and have a carrying capacity of from 3,000 to 15,000 short tons. Most of them can be loaded to a draft of about 22 feet. They are the most economical carriers in the world, their rates usually being less than one tenth of a cent per ton-mile, and sometimes only a third of that amount. Rail rates are several times as much, often being at least 10 times the water rates. The annual saving over the cost of moving this same freight by rail exceeds a quarter of a billion dollars."

In reference to the waters of the Great Lakes, some general principles laid down by the International Waterways Commission may well be accepted:

1. In all navigable waters the use for navigation purposes is of primary and paramount right. The Great Lakes system, on the boundary between the United States and Canada, and finding its outlet by the St. Lawrence to the sea, should be maintained in its integrity.

2. Permanent or complete diversions of navigable waters or their tributary streams should only be permitted for domestic purposes and for the use of locks in navigation canals.

3. Diversions can be permitted of a temporary character, where the water is taken and returned, and when such diversion cannot interfere in any way with the interests of navigation.

As to the foregoing matters, we assume that apt reference to the record will be made in the main briefs, but all these matters are beyond dispute and of such public record and common knowledge that we believe the Court will not fail to take judicial notice.

We then have, according to published reports and the testimony in the case not to be disputed, that the direct loss to the individual ship owners by a diminution of 6 or even 5½ inches, the conceded impairment here, would, according to testimony which should be accepted (Lake Carriers' President Vol. I, p. 205), amount to some four million dollars a year, assuming an average rate of 50 cents per ton as in 1916, which capitalized, at 5% would be eighty million dollars. And the testimony is that vessel owners keep close track of the stage of water and take advantage of every period of high stage to load their boats to greater draft. During the time when low stage prevails, they are correspondingly handicapped and the carrying capacity of the fleet is materially reduced.

The effect of abstracting 10,000 cubic feet per second at Chicago lowers the lake levels by at least 5½ inches; that is, all of the lakes below Superior, which is some 20 feet above the waters below, requiring the locks at Sault Ste. Marie; and this effect is more serious as we go down the system through the St. Lawrence to the sea.

GREAT LAKES-MISSISSIPPI WATERWAY.

To dispose of the shibboleth of navigable canal or channel to connect with the Mississippi Valley improvement of our great interior rivers, surely we need go no further in this case where the decree prohibits and enjoins the use of more than 4167 cubic feet per second, than to say that the Record shows, according to Government report, that a depth of not over 10 feet is all that could be utilized for such a waterway, ample to comport with the channels of the Mississippi, existing or proposed, and sufficient to accommodate an annual commerce of one hundred million tons; and that less than 1,000 cubic feet per second from Lake Michigan would amply supply the needs and the use of such channel (Vol. VIII, p. 54). This is the utmost that the vision of this generation can see for the future.

The United States Statute of 1827 is referred to by defendant as in some sort justifying the granting of unlimited authority to take water from the Lakes for these unnecessary non-navigation purposes of dilution of sewage and manufacture of power for Chicago and its environs and all increase of population.

That act was in terms confined to a navigation canal to connect the Mississippi with the south end of Lake Michigan, not specifying Chicago or any particular point. It granted certain lands in aid of building such a canal. There was no right expressly conferred to take any water from the Lakes by that Act. But a canal, the Illinois and Michigan, was built and operated for years, without taking any appreciable quantity from the Lake, and that canal has apparently fallen into desuetude.

It is idle to argue this as supporting the claims of the Sanitary District (formed expressly for non-naviga-

tion purposes) to extract for that purpose many times the admitted requirements of a navigation channel.

The Illinois act of 1889, on the other hand, is a general statute authorizing formation of Sanitary Districts anywhere in the State—and providing only that if one is made to connect with certain rivers, the United States shall be authorized to operate said channel for navigation—"*but not to interfere with its control for sanitary or drainage purposes.*" See Sec. 24, Act 1889 (Exhibit A—Vol. VIII, p. 105).

DEFENDANT CLAIMS RIGHT TO UNLIMITED ABSTRACTION FOR SANITARY AND DRAINAGE PURPOSES.

The answer of the defendant in the main channel case (paragraph 26), in which the injunction was granted, avers that the Sanitary District was authorized by the State to construct a channel of sufficient size to take care of not only the sewage and drainage of the City of Chicago and its environs, but also the sewage and drainage as the increase of population might require.

In the Record, Vol. VII, p. 13 and VIII, p. 55, the published report of the President of the Drainage Canal, as was submitted at a hearing before Secretary Stimson, is quoted as saying:

> "I am of the opinion that the presumption that our water supply is to be limited to 10,000 cubic feet per second, or 600,000 cubic feet per minute, is gratuitous and mischievous and should not be voiced by the officials of this district. I believe that we should have the volume requisite to our needs as they appear and are justified;"

on which the Secretary comments:

> "It is therefore quite conceivable that compliance with their Sanitary needs according to this method of sanitation may eventually materially change this great national water course now existing through the Lakes."

In the answer, paragraph 40, (Vol. VIII, p. 87), it is further averred:

> "Defendant has never recognized the right of the United States in any manner to interfere with the construction, operation or use of the Main Channel of the Sanitary District or any of its adjuncts or additions; that it has never recognized the right of the United States in any manner to determine or direct how the said Main Channel or its adjuncts or additions, as hereinbefore mentioned, should be operated or used, or the amount of water that should be abstracted from Lake Michigan through its various channels or adjuncts or additions thereto to carry out the provisions of said Act of May 29, 1889."

And in Paragrap' 26 of the same answer, (Vol. VIII, p. 77), that, it was f rther provided by said Act, under which the Sanitary District was organized, that the channel, when completed, should be a navigable channel of the United States and that the United States should

> "have authority to take over and operate said channel, for navigation purposes, but not for sanitary or drainage purposes."

The language of the statute, however, is "not to *interfere* with its control for sanitary or drainage purposes."

THERE ARE OTHER AVAILABLE METHODS OF SEWAGE DISPOSAL.

The answer admits that there are other methods of sewage disposal although claiming, in Paragraph 43, that the only method by which defendant can *efficiently* take care of and remove the sewage and drainage from its limits and protect the water supply of the inhabitants of Chicago and its environs is the one laid out under the Act of May 29, 1889, and acts amendatory and supplementary thereto. One of these subsequent acts was that of May 14, 1903, referred to in Paragraph 32 of the answer, (Vol. VIII, p. 81). It was:

> "To enlarge the corporate limits of said District and to provide for the navigation of the channels created by said District, and to construct dams, water wheels and other works necessary to develop and render valuable power arising from the water passing through its channels, and levying taxes therefor."

The answer then proceeds to say (Paragraph 32) that by about 1907 the defendant had then completed works at a cost of "approximately" $5,000,000, producing power worth "approximately" $900,000 per year net; which revenue "is used toward defraying the other expenses of defendant."

Other testimony would tend to show a greater revenue, which would increase with increase of flow. The testimony of defendant's engineer, Randolph (Vol. VI, p. 3599) is that a flow of 10,000 cubic feet per second would develop Horse Power to the annual value of $2,750,000—computed at the low rate of $25.00 per H. P.,—at the net yearly value stated in the answer of $30.00, it would be over three and a quarter millions.

It is to such uses that defendant puts the water abstracted from a great water navigation route, never to be returned, claiming good right to further increase the quantity according to its own view of its necessity for such use, and which it may well be said might go on until it would materially change this great natural water course existing through the Lakes.

We submit that it appears throughout the Record that Chicago can, by modern, approved, scientific methods well known and adopted by many other large communities, dispose of its sewage. It appears (Record, Vol. VIII, p. 192), that Chicago is itself erecting such works on a large scale. In the decision referred to of the Secretary of War in 1913 (Record, Vol. VII, p. 14 and VIII, p. 55), it was said that the evidence:

> "satisfies me that it would be possible in one of several ways to at least so purify the sewage of Chicago as to require very much less water for its dilution than is now required by it in its unpurified condition. A recent report of the engineer of the sanitary commission (Oct. 12, 1911), proposes eventually to use some such method, but proposes to postpone its installation for a number of years to come, relying upon the present more wasteful method in the meanwhile. It is manifest that so long as the city is permitted to increase the amount of water which it may take from the Lakes, there will be a very strong temptation placed upon it to postpone a more scientific and possibly more expensive method of disposing of its sewage. This is particularly true in view of the fact that by so doing it may still further diminish its expenses by utilizing the water diverted from the Lakes for water power at Lockport."

THERE IS NO ESTOPPEL AND NO ACQUIESCENCE IN THE EXCESS DIVERSION.

In paragraph 37 of the Answer (Vol. VIII, p. 84), endeavor is made by averments to attach some action of Congress through the permit of Secretary of War Alger and the action of Secretary Root in 1903, which limited the quantity to 250,000 feet per minute, and reports of the Waterways Commission, appropriations for surveys of tentative or possible channels for navigation, reports of engineers, and so on, with the effect in some indefinite way to estop the Government of the United States or deprive the Government from the exercise of its authority to safeguard the rights of the people of the United States against the impairment of the navigability of a great public, national and international water course. This is answered by the finding of the court below (Vol. VIII, p. 151)—that the Federal Government has been recognized from before the beginning of the diversion and that the constant attitude of the defendant was a recognition of the control of the Federal Government over this whole question.

The annual report for 1916 of Secretary of War Baker, at page 64, says this:

> "A conditional permit was granted in 1901, authorizing the diversion of 4,167 cubic feet seconds, and this amount has continued to be the legal limit. The drawing of water from the Chicago River into the canal affects the general navigation interests of the country on account of the tendency of such diversion to lower the level of the waters of the Great Lakes. From the beginning the operations of the Sanitary District have been looked upon with disfavor by navigation interests, and the Secretary of War has not only declined to increase the

diversion temporarily authorized, but has adhered to the decision that the permit granted was of a temporary character and that no permanent diversion of the waters of Lake Michigan could be made without express authority from Congress. Nevertheless the Sanitary District has for many years been withdrawing a much larger amount of water than is authorized by this permit. Upon two different occasions the Sanitary District has refused to conform to decisions of the Secretary of War declining to grant authority for larger diversions and has declared its intention to continue excess diversions unless prevented by injunction. Accordingly, in 1908 and again in 1913, bills in equity were filed at the instance of the War Department by the Attorney General seeking to enjoin excess diversion. The two suits were consolidated and tried in the United States District Court for the Northern District of Illinois, but remain undecided.

It seems quite clear that with the growth of population in Chicago the authorites of the Sanitary District contemplate still larger diversions than those already made, perhaps, to the extent of 10,000 cubic feet seconds. This, it is estimated by the United States Lake Survey, would lower the waters of Lake Michigan and Lake Huron nearly 7 inches, Lake Erie about 5½ inches, and Lake Ontario about 4½ inches, mean lake levels, the reduction being much greater at low-water periods. The effect of such a lowering of lake levels would obviously be enormous losses to navigation interests and would necessitate large expenditures by the General Government for the restoration and reorganization of river and harbor improvements on the Great Lakes and their connecting waters, for which already appropriations aggregating more than $90,000,000 have been made."

And see opinions of Judges Landis and Carpenter (Vol. VIII, p. 149, and p. 127).

LOCAL AS AGAINST GENERAL NATIONAL INTERESTS.

The case really is admitted to be on the facts a simple question of local convenience, advantage and gain, in defiance of the paramount right of navigation for which all this navigable water is held in trust for the public, and the authority and responsibility for the conservation of which is in the United States, as to waters of the United States and in a foreign nation as to its part of the navigable waters; and against the interest of all the rest of the people of the United States and, for that matter, of Canada, and all of the investments in and of other states and cities fronting the Great Lakes and the docks, ships, farms, mines, furnaces and all other ramifications involving investments of billions of dollars and the industrial and domestic interests of the millions of people, whose cause appeals to the Governments on both sides of the waterway through a length of many thousands of miles.

Grant, that Illinois may own the fee of the bed of the Lake. This is a qualified fee, burdened with the public trust for navigation. Illinois, in the general provisions of the Act of 1889, or in any special provision of that Act or in the subsequent Acts, has not pretended to grant to the Sanitary District the State's qualified title to the submerged lands of its Lake front (Record Vol. VIII, p. 103, Sec. 22, Act 1889). But if it had attempted this, it could not, by possibility, shake off the trust which qualifies its fee, much less may it be claimed that Illinois with about 60 miles of lake frontage could, if it would, impair the navigability of all the waters in and in front of the seven other states fronting the Lakes or any of the other thousands of miles of lake and river

frontage because over all the paramount public right of navigation and authority and responsibility are vested in the United States by reason of the complexity of state, individual and other right of control over their interstate commercial waters and their care and control, and the responsibility of supervising and protecting all these against private or local encroachment or impairment for local advantage and authority to protect all against any breach of the great trust.

SUGGESTION OF COMPENSATING WORKS AND TREATY.

As has been suggested it is not the purpose to argue *in extenso* all of the various facts that have been put forward by the appellant. In justification we may speak briefly of the appellant's suggestion about compensating works.

The Record shows that anything in the nature of works to effect a compensation for the lowering caused by the excess withdrawal of water at Chicago would involve some system of works throughout the whole Great Lakes and St. Lawrence waterway. This, as stated by Secretary Stimson (Vol. VIII, p. 65) would involve some joint arrangement with Canada. This is inescapable. The Record, while it speaks on the subject of such works, is silent as to any definite plan. There is no precedent—there are various suggestions.

It appears that as far back as 1900 there was a partial plan by a dam at the head of the Niagara River which was abandoned. Whether such works could be established, appears, as far as the record is concerned, to be a matter of conjecture and opinion. In other words, there is nothing tangible about the character of

the works, which would have to be some general character.

This suggestion was not accepted by the lower court and motion to suspend the entering of a decree for injunction was denied (Vol. VIII, p. 130). At the same reference appears the statement of the District Court that,

> "It is doubtful whether the State of Illinois could authorize expenditures to be made in foreign states and foreign countries to restore the water levels."

We submit that in view of the claim of defendant that its finances and means of raising of funds will not enable it to complete the works for the scientific, modern method of sewage disposal and purification of water before 1945, it is a doubtful proposition to pay whatever may be the cost of such compensating works throughout the Lakes as might be decided necessary by the two governments, and we suggest that there can be little doubt of the right of a taxpayer in Illinois, or in the Sanitary District, to enjoin the imposition of taxes for the purpose of expending money in works in other states or in a foreign country, or both.

So far as the Treaty, itself, is concerned, as a recognition: It is clear in its terms and there is absolutely no recognition of the Chicago Drainage Canal District. That, as said by Secretary Stimson, seems to have been carefully excluded. There is no indication in the Treaty of the quantity of water being diverted and the published report of the Sanitary Board is not shown, and for all the record shows, they may have been representing a use not exceeding the 250,000 cubic feet before 1909, when the Treaty was negotiated; and indeed reference to any

well authenticated statistics will show that prior to 1910, the average withdrawal was about 4,000 feet; since the treaty, the amount has been greatly increased so as to reach not less than 8,000 feet, probably as much as 10,000. In the "Warren Report," of August 30, 1919, "Diversion of Water from the Great Lakes and Niagara River," page 176, these figures are given, on the authority of the Engineer of the Sanitary District:

1908—4421 feet
1909—2766 feet
1910—3458 feet
1913—7191 feet
1914—7105 feet
1915—6971 feet
1916—7325 feet
1917—7786 feet.

CURRENT IN CHICAGO RIVER.

There is some engineering testimony descriptive of the Chicago River and improvements alleged to have been made by the Sanitary District of the City of Chicago or by the Government. But a dangerous current has been created and operates as a serious detriment of even that local port and to the navigation interests by the interference of the Sanitary District, as shown by the testimony of Livingstone (Vol. I. p. 419); Emersen (Vol. V, p. 3021); Jaenke (Vol. V, p. 3022); Minskey (Vol. V, p. 3023); Green (Vol. V, p. 3029); Hamilton (Vol. V, p. 3031) and Simons (Vol. V, p. 3033), whose cross examinations follow beginning Volume V, p. 3034. This is well summed up by Mr. Sullivan, set out in Volume VI, p. 3616, as follows:

> "I would like to add a word as a vessel owner and a man operating steamers in the City of Chi-

cago. The local situation there is something extremely critical. Under the present flow of 4,000 cubic feet,—we presume it is 4,000 feet a second—navigation in the River is carried on at great hazard. The center pier structures and the swift current make it extremely dangerous and we have suffered loss of property and loss of life in consequence of these hazardous conditions. So far as any increase of the current goes, I should say it would mean disaster, and I am sure that so far as our ships are concerned we would not be able to operate them in the Chicago River. I do not want to appear as antagonistic to the Sanitary District, only in respect of the increasing of the flow so that it will make it impossible for us to navigate our boats. * * *

The current in the river in the Chicago River at present is extremely detrimental to the safe handling of boats, and any increase in the velocity of the current would mean disaster. It would simply close Chicago as a port against any of the so called modern ships, and to a large number of the vessels of an extremely smaller size."

This is based on conditions when the Sanitary District used, as Mr. Sullivan says, a flow of 4,000 feet, or practically the limit imposed by the Secretary of War in his conditional permit, since which time it is found and conceded that the flow is double or more; always the average is spoken of, but it is not a steady flow of the exact number of feet per second.

SUMMARY.

It is not our office and it is not our intention to go with any fullness into the questions, particularly the legal ones, necessarily to be argued by other counsel in the case, or do more than call to the attention of the

Court some of the points and some of the leading cases supporting, all which will be fully presented and argued by the other counsel in briefs and before the Court.

I.

The Great Lakes (Including Lake Michigan) and Connecting Rivers, Constitute a Great National and International Navigable Waterway.

The character and extent of the commerce carried on the Great Lakes is fully shown in the Record, both from the testimony of witnesses and also from Government reports. Mention might be made of the testimony of Ernst (Vol. 1, p. 62), Livingstone, (Vol. I, pp. 200, 398), Coulby, (Vol. I, p. 428), not to name many others. Then by way of official reports and documents, there are many (See Vol. IV, pp. 2406, 2420; Vol. VIII, p. 53); all of these show the enormous volume of the traffic which in a single season of navigation (8 months) has exceeded one hundred million tons. The port of Duluth-Superior, in point of water traffic handled, is the greatest in the world, and the Detroit River the most used navigable channel in the world. This Court has repeatedly taken notice of the amount and character of commerce on these inland seas. Three cases have already been mentioned:

The Genessee Chief, 12 How. 443, at 453;

Moore vs. American Transportation Co., 24 How. 1, at 38;

Illinois Central Railroad Co. vs. Illinois, 146 U. S. 387, at 436.

II.

The Abstraction of Water at Chicago Lowers Lake Levels.

While proof of this self evident fact is not necessary, such proof fully appears throughout the record; as for example, in the testimony of Noble, (Vol. I, p. 9), Haskell, (Vol. I, p. 35), Wilson, (Vol. I, p. 50).

The two District Judges found from the testimony that the abstraction of water did lower lake levels (Vol. VIII, pp. 129, 150). This was also the finding of Secretary of War Stimson after the full hearing before him, (Vol. VIII, p. 52), and it also appears from reports of the various Engineers, e. g., tabulated statement (Vol. IV, p. 2419). It may be taken as established that the abstraction of 10,000 cubic feet lowers the water of Lakes Michigan, Huron and Erie, as well as the rivers between Lakes Huron and Erie, where every inch is greatly needed, between 5 and 6 inches, and that the effect in the St. Lawrence River is even greater.

III.

The Lowering of Water Reduces Size of Cargoes.

It is shown by the testimony, particularly that of Haskell, (Vol. I, p. 30), Livingstone (Vol. I, pp. 200, 398) and Coulby (Vol. I, p. 428), that the large boats load to the limit allowed by the depth of the channels, particularly the shallow channels between Lakes Huron and Erie, and that one inch of water means from 75 to 100 tons of cargo, and this is confirmed by Reports of the Engineers. This lowering of navigable waters surely constitutes an interference with commerce and navigation.

IV.

The Right of Navigation is Paramount.

Many cases might be cited on this; see *United States vs. Chandler-Dunbar Company,* 229 U. S. 53, where in the syllabus this language is used:

> "Every structure in the water of a navigable river is subordinate to the right of navigation, and must be removed, even if the owner sustain a loss thereby, if Congress, in assertion of its power over navigation, so determines."

Cummings vs. Chicago, 188 U. S. 410, 427;
Greenleaf Johnson Lumber Co. vs. Garrison, Secretary of War, 237 U. S. 251;
Willink vs. United States, 240 U. S. 572.

V.

The Authority of the National Government Overrides That of the States in Respect to Navigable Waters.

It is sufficient to quote from *United States vs. Rio Grande Irrigation Company,* 174 U. S. 690, at page 703, where Mr. Justice Brewer uses this language:

> "Jurisdiction of the general Government over Interstate commerce and its natural highways vests in that Government the right to take all needed measures to preserve the navigability of the navigable water courses of the country, even against any state action."

In *Cummings vs. Chicago,* 188 U. S., 410, at page 428, this is said to control of navigation:

> "If the power of the state and that of the Federal Government come in conflict, the latter must control and the former yield."

VI.

The Rivers and Harbors Acts of September 19, 1890, and of March 3, 1899, are Valid and Effective.

Whatever might have been argued when the Sanitary District commenced operations under the enabling act of the State of Illinois of May 29, 1889, since the decision by this Court in *Union Bridge Company vs. United States,* 204 U. S. 364, February, 1907, it must be considered settled that the Federal Government has supreme control of navigable waters and that Congress may delegate to the Secretary of War the power and authority to grant or to refuse applications of States, corporations or individuals, either to create obstructions such as bridges or piers, or "to alter or modify the course, location, condition or capacity of any port, roadstead, haven, harbor, canal, lake, harbor of refuge," etc.

Union Bridge Company vs. United States has been uniformly followed in subsequent decisions of this Court, such as *Greenleaf Johnson Lumber Company vs. Garrison, Secretary of War,* 237 U. S., 251, where in the syllabus there are the following very pertinent paragraphs:

> "The power of the sovereign State or Nation is perpetual—not exhausted by one exercise—and all privileges granted in public waters are subject to that power; the exercise of which is not a taking of private property for public use but the lawful exercise of a governmental power for the common good.
>
> When one acting under state authority erects anything in navigable waters he does so with full knowledge of the paramount authority of Congress to regulate commerce among the States and subject to the exercise of such authority at some future time by Congress.

The power of the States over navigable waters is subordinate to that of Congress and the State can grant no right to the soil of the bed of navigable waters which is not subject to Federal regulation."

VII.

Estoppel, Even if there Were Facts to Warrant Such as to a Private Individual, Cannot Operate Against the Government.

The most the Sanitary District ever secured from the United States was a revocable, conditional permit, limited to 250,000 feet per second, and the Record shows unequivocally that the various Secretaries of War (including Taft, Stimson and Baker) have persistently refused to enlarge the grant or to acquiesce in larger withdrawal.

Morris vs. United States, 174 U. S. 196, 282;
Union Bridge Company vs. United States, 204 U. S. 364.

VIII.

The Action Was Properly Brought in the Court Below.

While in the court below it appears that no question was raised as to the jurisdiction of that court, Judge Carpenter saying in his opinion (Vol. VIII, p. 129):

"The jurisdiction of the court has not and could not be challenged,"

some claim is now being made that the action was improperly brought, and that the court had no jurisdiction to entertain the complaint of the United States. The

language of the Rivers and Harbors Acts is sufficient grant of authority for the Attorney General to institute the action; but if that were not so, the United States, without any such statute, would have full power to invoke the aid of the courts in stopping irreparable damage to commerce and navigation.

Cotton vs. United States, 11 How. 229;
United States vs. Cook, 19 Wall. 594;
United States vs. Rio Grande Dam and Irrigation Company, 174 U. S. 690.

IX.

As Concededly the Sanitary District Is Withdrawing Water Greatly in Excess of the Permit, the Injunction Should Be Affirmed.

The Sanitary District applied for and received a permit from the United States Government to take from Lake Michigan water not exceeding in volume 4,167 cubic feet per second. It has made repeated applications to have the amount increased, but has met with refusal from every succeeding Secretary of War. Without the necessary permits, the Sanitary District has gone forward and defiantly taken all the water that it has thought it needed, up to 10,000 cubic feet per second, and now boldly takes the position that as a matter of right it is entitled to take all that it desires, without authority from the Federal Government and without any permit; and in pleadings as well as in testimony and in argument, denies the authority of the United States to regulate or stop the abstraction of water from Lake Michigan and the Great Lakes system. If the constitutionality and effectiveness of the Rivers and Harbors Acts are con-

ceded, as they must be in view of the repeated decisions by this Court, and the jurisdiction of the Court is established, there can be but one decision, and that is the affirmance of the judgment of the District Court.

Respectfully submitted,

HARVEY D. GOULDER,
Counsel for Lake Carriers' Association,
as *Amicus Curiae.*

November 5, 1924.

Kirby 11

Concurrent Jurisdiction Case.
Does not Congress take
Jurisdict of the Great
Lakes?

1822
1827 Congress invited Ill to
to Connect Waters of
Lakes with the Mississippi
Illinois
Land granted

Offered if Congress
would delegate or give
up the power - Sabine
R Joint Resolution 10 -
12 did not regulate
the use of the Water.

Congress has to operate
with Illinois - Does
not have to stop any

into the diversion
=
No permit necessary
because Congress
gave it — Current
Case St Ry Case
201 U.S.

The acts — cannot
delegate to Brig power
to pass on the di-
version — See section
10 — Limited to Navigat-
of Rivers & Harbors
Lake navigat

Practical Construction of the Powers to be exercised thereby may be taken. (Act of 1827 does not relate to Canals taken)

Note: May the powers of Congress upon Navigable Rivers be exercised on account of the demands for Canals Works carried on under State Laws?

The Act of 1899 to 1904
gave the consent to removal
obstructions in the River.

Congress has recog-
nized the authority
& right to divert
the waters.

Actual depth of
harbor not less
than record

they had nothing
to do with grants

Question is whether
the Current of
Chyo R

2. Does the work
of Sanitation, and
Mutually interfere
with &c
The Engineers and
the Ch will not

Dec-9

1

M. Rees

Question is political not justiciable.

#

Chronology

July 13, 1787

N.W. Ordinance - water common highways &c.

27 Land grant. Not specific

27. Congress acting on Memorial of people of Ill. Land grant to his majesty. (This no authority for $10,000,000 for swamps)

9- Ill contended on this enhancement. Created the Sanitary Dist. Made it mandatory to take quantities diverting with potalak

40 - Sept 19. Act provided that obstructions are forbidden - also to regulate the Comm. Navigability except as authorized by the Secy of War.

2 - Bd of Engrs appointed by War Dept to pass upon effect

Mch Engrs ordered on improvements to take

5. Report against the Project. ~~Would~~ that Lower would lower the Lakes &c—

6- July 3. Secy Lowndes 5000 ft Lbs. Authority—shall not be authority to make a current.

97 - Oct. Authority to Warden River

20 leave & remove wrecks

1. Act strengthening
act of 1890 — by
adding - Creation of
any Obstruction not
affirmatively authorized by Congress.
&c &c

19 — Bridge Permit
Referred to Local
U.S. Atty &
Recommends
14 Issuance of Permit
to Chicago

0. July 11- Permission to make certain changes- 20 000 cu ft per minute- Then 30 000

01. Portion + $250 000 Cu ft per Minute.

02. Order asked 350 000

3. Ill Merchandise Mart of Chicago.

07 Application to change floor of Calumet Expy reported that this would lower the grant Cubs may decline

97. Permit to N Br Chg R

Held quash the
the same -

7/1907 Result of Hearing
Dist to reverse
Calumet River
Notwithstanding re-
fused -

28 March.

This action has commenced.

~~Vol. II. III. IV.~~

Case showed have been disposed of by [illegible] on both answer

12. &c. granted. permit. amount to be withdrawn from Lake Mich by boats Rivers - 25000 -

13 see Attorneys Opinion Reported 1899 Ca ft an ground of the Navi of Great Lakes

SANITARY DISTRICT OF CHICAGO *v.* UNITED STATES.

APPEAL FROM THE DISTRICT COURT OF THE UNITED STATES FOR THE NORTHERN DISTRICT OF ILLINOIS.

No. 161. Argued December 8, 9, 1924.—Decided January 5, 1925.

1. A suit to enjoin an agency of the State of Illinois from continuing diversions of water from Lake Michigan which lower that lake and threaten the like effect upon other lakes and connecting waters of the Great Lake System, including the St. Lawrence, is maintainable by the United States not only to remove obstruction to interstate and foreign commerce, but also to carry out treaty obligations to a foreign power. (Treaty of January 11, 1909, with Great Britain, 36 Stat. 2448.) P. 425.
2. *Semble* that such a suit might also stand upon an ultimate sovereign interest in the Lakes. *Id.*
3. The suit may be brought by the Attorney General, in virtue of his office, and it need not be authorized by a statute. P. 426.
4. The power of the United States to remove obstructions to interstate and foreign commerce is superior to that of the States to provide for the welfare or necessities of their inhabitants. *Id.*
5. Touching interstate and foreign commerce, in so far as the States may act Congress can override what they have done; but, in matters of imminent and direct national importance, they may not act at all, even where Congress has been silent. *Id.*

6. Irrespective of any international compact, a State cannot authorize diversions of water from the Great Lakes which will affect their level, without the consent of Congress. P. 426.
7. Even if it were possible for the United States to estop itself by grant or contract from exercising its power in matters of national and international concern, its act must be strictly construed against such a result. P. 427.
8. The Act of March 2, 1827, granting land to Illinois to open a canal uniting the waters of the Illinois River with those of Lake Michigan vested no irrevocable discretion in the State with regard to the amount of water to be withdrawn from the Lake. *Id.*
9. The withdrawal of water in this case, except in so far as it may be authorized by the Secretary of War, is prohibited by the Act of March 3, 1899, c. 425, § 10, 30 Stat 1151, as involving a change in the condition of the Lakes and the Chicago River (admitted to be navigable) and an obstruction to their navigable capacity. P. 428.
10. Revocable licenses granted by the Secretary of War under the above Act of 1899, concerning the appellant's canal and the quantity of water to be taken from Lake Michigan,—considered and *held* no justification for the excessive diversions here complained of by the Government. P. 429.
11. Refusal of the Secretary of War to license greater withdrawals of water from Lake Michigan by the appellant through its canal, for the sanitation of Chicago, did not infringe any rights of that City arising from its investment in the canal property, or of States bordering on the Mississippi based on their interest in increasing the artificial flow; nor were those states or the city, entitled to be heard before the license was refused. P. 431.

Affirmed.

APPEAL from a decree of the District Court enjoining the appellant from diverting water from Lake Michigan in excess of 250,000 cubic feet per minute, the amount authorized by the Secretary of War.

Mr. Edmund D. Adcock, with whom *Mr. Clyde L. Day*, *Mr. George F. Barrett* and *Mr. Louis J. Behan* were on the briefs, for appellant.

I. Appellant was organized under an act of Illinois passed in the exercise of the State's police power. This

act fixed appellant's powers and duties, and specified the required diversion of water from Lake Michigan. *Wilson* v. *Board of Trustees*, 133 Ill. 443, 465; *People* v. *Nelson*, 133 Ill. 565, 580, 582, 592, 594; *Beidler* v. *Sanitary District*, 211 Ill. 628, 638; *Pittsburg, etc. Ry. Co.* v. *Sanitary District*, 218 Ill. 286, 287, 295; *United States* v. *Bellingham Bay Co.*, 176 U. S. 211.

The diversion of water to operate the Canal has been authorized by the Act of Congress of March 2, 1827. *Missouri* v. *Illinois*, 200 U. S. 496, 519, 526; *Mortell* v. *Clark*, 272 Ill. 201, 213; Messages and Papers of the Presidents, vol. 5, p. 3334.

Appellee, through its engineer officers and the Secretary of War, observed the action of the State of Illinois and appellant pursuant to its authority in planning and constructing the diversion works. The Secretary consented to the work necessary to accomplish the diversion and authorized the opening of the main channel of the district. He construed the Act of March 2, 1827, *supra*, and the laws of Illinois, as affirmatively authorizing the diversion.

The Secretary, charged with the duty of enforcing the Rivers and Harbors Acts of 1890 and 1899, has thus construed a diversion to the capacity of appellant's canal, to have been "affirmatively authorized by law" and "affirmatively authorized by Congress." These acts of the Secretary should have the force of judicial interpretation.

II. The permits of the Secretary of July 11, 1900, authorizing the work of deepening and widening the channels of the Chicago River to provide for the diversion or abstraction from Lake Michigan through them of the amount of water required by the state law according to the population of appellant, constituted all the authority required by appellant from appellee, to divert said waters. *Maine Water Co.* v. *Knickerbocker Co.*, 99 Me. 473;

Rivers and Harbors Act of 1890, §§ 7 and 10; Rivers and Harbors Act of 1899, §§ 9, 10 and 12.

The altering or modifying of the navigable capacity of the waters affected was thus authorized and is lawful. *Cummings* v. *Chicago*, 188 U. S. 410; *Hubbard* v. *Fort*, 188 Fed. 987; *Maine Water Co.* v. *Knickerbocker Co.*, *supra*; *Hudson County Water Co.* v. *McCarter*, 209 U. S. 349.

III. The Secretary of War has authorized the opening of the canal, its operation and attendant diversion of water, by the permit of May 8, 1899, every condition of which has been fulfilled, assuming such conditions to be valid. See *Monongahela Bridge Co.* v. *United States*, 216 U. S. 177, 195; *Philadelphia Co.* v. *Stimson*, 223 U. S. 605; *Kwock Jan Fat* v. *White*, 253 U. S. 454, 464.

The Attorney General, under the Act of March 3, 1899, is only authorized to institute suits for the removal of structures. The District Court was without jurisdiction to entertain this suit. Act of March 3, 1899, § 12; *Ogden City* v. *Boreman*, 20 Utah, 98; Endlich, Interp. of Stats., § 51; Sutherland Stat. Constr., § 140; *United States* v. *Rio Grande Co.*, 174 U. S. 690.

The Secretary of War is only authorized to grant or refuse a permit. He has no power to regulate the diversion.

IV. The Illinois Act of May 29, 1889, was sufficient legislative authority for appellant's diversion works and for the diversion of water required by them. *Cummings* v. *Chicago*, 188 U. S. 410, 427, 428, 430; *Montgomery* v. *Portland*, 190 U. S. 89, 107; *Corrigan Transit Co.* v. *Sanitary District*, 137 Fed. 851, 856; *Canada Atlantic Transit Co.* v. *Chicago*, 210 Fed. 7, 10, 11; *Laurel Hill Cemetery* v. *San Francisco*, 216 U. S. 358; *Escanaba Co.* v. *Chicago*, 107 U. S. 678; *Lake Shore, etc. Ry. Co.* v. *Ohio*, 165 U. S. 365; *Cardwell* v. *American Bridge Co.*, 113 U. S. 205; *Huse* v. *Glover*, 119 U. S. 543; *Willamette Bridge Co.* v. *Hatch*, 125 U. S. 1.

The creation of appellant's canal and its other diversion works, was "authorized by law" under the Rivers and Harbors Act of 1890. *United States* v. *Bellingham Bay Co.*, 176 U. S. 211.

The diversion is lawful under the police power without the express consent of the Secretary of War. Any other construction of the Act of March 3, 1899, would tend to nullify appellant's acts in the interest of public health, which cannot be where the congressional intention is not expressed in plain and unmistakable terms. *Columbus* v. *Mercantile Trust Co.*, 218 U. S. 645, 658; *Missouri* v. *Kansas Gas Co.*, 265 U. S. 298; *Public Utilities Comm.* v. *Landon*, 249 U. S. 236; *Pennsylvania Gas Co.* v. *Public Serv. Comm.*, 252 U. S. 23; *Texas* v. *White*, 7 Wall. 700, 725; *New York* v. *Miln*, 11 Pet. 102, 139; *Minnesota Rate Cases*, 230 U. S. 352, 402; *Lake Shore, etc. Ry. Co.* v. *Ohio*, 173 U. S. 285; *Hennington* v. *Georgia*, 163 U. S. 299, 317; *Crossman* v. *Lurman*, 192 U. S. 189; *Plumley* v. *Massachusetts*, 155 U. S. 461; *In re Rahrer*, 140 U. S. 545, 554; *Mutual Loan Co.* v. *Martell*, 222 U. S. 225, 233; *Cummings* v. *Chicago*, 188 U. S. 410, 430; *Savage* v. *Jones*, 225 U. S. 501; *Missouri Kans. & Tex. Ry. Co.* v. *Haber*, 169 U. S. 613, 623; *Reid* v. *Colorado*, 187 U. S. 137, 148; *Sinnot* v. *Davenport*, 22 How. 227, 243; *Missouri Pac. Ry. Co.* v. *Larabee Flour Mills Co.*, 211 U. S. 612, 623; *Missouri Kans. & Tex. Ry. Co.* v. *Harris*, 234 U. S. 412, 418; *Carey* v. *South Dakota*, 250 U. S. 118, 122; *Houston, etc. Ry. Co.* v. *United States*, 234 U. S. 342; *Illinois Cent. R. R. Co.* v. *Public Utilities Comm.*, 245 U. S. 493, 510; *Sligh* v. *Kirkwood*, 237 U. S. 52, 60; *Hammer* v. *Dagenhart*, 247 U. S. 251, 273, 275, 276; *Child Labor Tax Case*, 259 U. S. 20, 37.

Congress has otherwise by legislation indicated that it was not its intention to prohibit the operation of appellant's diversion works, or that any act of any of its officers should have that effect. *United States* v.

Chandler-Dunbar Co., 229 U. S. 53; *International Bridge Co.* v. *New York*, 254 U. S. 126, 131; *West Chicago Street R. R. Co.* v. *Chicago*, 201 U. S. 506, 527.

V. Appellee has invited and acquiesced in the construction of the canal to divert the water.

It is estopped now to deny the right. *Missouri* v. *Illinois*, 200 U. S. 496, 526; *United States* v. *Pennsylvania Dock Co.*, 272 Fed. 839, 848; *United States* v. *Osage County*, 254 Fed. 570, 573; *United States* v. *Debell*, 227 Fed. 775, 779; *United States* v. *Midway Oil Co.*, 232 Fed. 619, 631; *United States* v. *Chandler-Dunbar Co.*, 152 Fed. 41, 81; *Monongahela Nav. Co.* v. *United States*, 148 U. S. 312, 334; *Hemmer* v. *United States*, 204 Fed. 898, 901; *Iowa* v. *Carr*, 191 Fed. 257, 266.

As for the treaty between the United States and Great Britain of January 11, 1909, relating to Canadian boundary waters,—when the treaty was made, the right to divert this water by appellant and the State of Illinois was recognized. That right was not in any respect curbed. The treaty expressly eliminates from its terms by the preliminary article, Lake Michigan. Lake Michigan is not a boundary water, as defined by the treaty.

Article II of the treaty reserves to each of the parties, or to the state governments, or provincial governments, as the case may be, all rights over these nonboundary waters. And again, in Art. III, it is stated: ". . . . nor are such provisions intended to interfere with the ordinary use of such waters for domestic and sanitary purposes." Article VIII expressly provides that the uses for domestic and sanitary purposes shall be paramount.

The treaty thus completely protects the diversion at Chicago. There was no dispute between the United States and the Dominion of Canada as to the right to divert 10,000 cubic seconds feet of water from Lake Michigan at Chicago. The International Waterways Commission, which was composed of representatives of the two

governments, settled that. Its two reports of May 3, 1906, and January 4, 1907, were signed by all the members of the Commission—three from the United States and three from Canada. As to the diversion at Chicago, the only question remaining unsettled was whether there should be diverted more than 10,000 cubic seconds feet of water.

Article II thus left unhampered the power of the sovereign over the waters that were not boundary waters within the sovereign's territory, subject only—(1) to the right of the citizens of one country to sue in the courts of the other country for damages caused by a diversion not then existing; (2) to the right merely of either party to object to further diversions than those which existed, to the injury of navigation. The Chicago diversion to the amount of 10,000 seconds feet was found by the International Waterways Commission to be an existing diversion. The right of the sovereign having jurisdiction over Lake Michigan, a nonboundary water, subject to the conditions mentioned, was thus reserved. As to those waters, the sovereign could do anything with them it chose. *The Exchange*, 7 Cr. 116, 136. See also opinion of Judson Harmon on right of United States in the Rio Grande, 21 Ops. Atty. Gen. 274, 280.

The waters which are diverted from Lake Michigan at Chicago are wholly within the limits of the State of Illinois.

The treaty is the law of the land, and may properly be said to have been made, so far as the Chicago diversion is concerned, for the benefit of the State of Illinois and the appellant. The State or the appellant may compel the recognition of such contract right. The treaty reserved the right of the sovereign—and the State is a complete sovereign except as to those things delegated to the Federal Government—over these waters. At least the United States, by making the treaty, must be

construed to have acquiesced and consented to the diversions as they existed at the time, unless some definite action were taken by Congress indicating a different intention.

VI. No witness was produced by appellee to testify that lowering of the lake surfaces, or damage to commerce, was ever actually observed. Appellee's case depends entirely upon an inference of the unseen and the subtle analyses of expert witnesses, which cannot form the basis of an injunctional decree. *Missouri* v. *Illinois*, 200 U. S. 496, 523; Joyce on Nuisances, 1906, ed., §§ 299 420; *Salvin* v. *North Brancepeth Coal Co.* L. R. 9, Ch. App. 705, 709; *North Dakota* v. *Minnesota*, 263 U. S. 365.

The injunction should not have been entered unless the injury and damage to commerce was material and the obstruction to navigation was unreasonable. *United States* v. *Rio Grande Co.*, 174 U. S. 690, 709; *Corrigan Transit Co.* v. *Sanitary District*, 137 Fed. 851, 857; *Lake Shore etc. Ry. Co.* v. *Ohio*, 173 U. S. 285, 294; *Cummings* v. *Chicago*, 188 U. S. 410, 428; *Union Bridge Co.* v. *United States*, 204 U. S. 364, 365, 385, 400.

It must appear, in a case of this character, that an unreasonable obstruction and damage to commerce clearly exist. *New York* v. *New Jersey*, 256 U. S. 296, 309; *Kansas* v. *Colorado*, 206 U. S. 46, 117; *Attorney General* v. *Mayor*, 13 Weekly Reporter, 1863–1865, 888; *Mississippi, etc. R. R. Co.* v. *Ward*, 2 Black, 485, 495; 2 Story, Com. on Eq., 203, 204.

VII. If it appear that the granting of an injunction would cause comparatively greater injury to the defendant than benefit to the complainant, a court of equity will not hesitate to deny the relief. 1 Joyce on Injunctions, § § 20, 25; *Kansas* v. *Colorado*, 206 U. S. 46, 117; *Georgia* v. *Tennessee Copper Co.*, 206 U. S. 230, 237; *Dun* v. *Lumbermen's Credit Assn.*, 209 U. S. 20;

McCarthy v. *Bunker Hill Co.*, 164 Fed. 927; *New York* v. *Pine*, 185 U. S. 93.

VIII. The statute does not authorize the Secretary to make any findings or conclusions. If it did, they would be subject to review. *Philadelphia Co.* v. *Stimson*, 223 U. S. 605, 620; *Hardin* v. *Jordan*, 140 U. S. 371; *Rosenberger* v. *Harris*, 136 Fed. 1001, 1002; *United States* v. *United Verde Copper Co.*, 196 U. S. 207, 215; *School of Magnetic Healing* v. *McAnnulty*, 187 U. S. 94, 110.

In any event, Secretary Stimson's findings and conclusions were erroneous. *Corrigan Transit Co.* v. *Sanitary District*, 137 Fed. 851, 855; *Mortell* v. *Clark*, 272 Ill. 201; *United States* v. *Rio Grande Co.*, 174 U. S. 690.

IX. The lower court should have granted the motion that the appellant be enjoined from taking in excess of 10,000 cubic seconds feet of water from Lake Michigan on condition that appellant pay the cost of constructing such compensating or regulating works as the United States should provide to be built to offset for the claimed lowering of the lake surfaces and their connecting channels due to 10,000 seconds feet diversion at Chicago. Admitting, for the sake of argument, only, all contentions of appellee to be true, appellant cannot be enjoined from taking an amount of water materially less than 10,000 cubic seconds feet, until appellant and cities and towns within its limits can, if at all, readjust their works of sewage disposal and of purification of water supply to suit the changed conditions.

The decree absolutely enjoined appellant from withdrawing from Lake Michigan in excess of 4,167 seconds feet. The Secretary of War would be powerless under it to authorize any further diversion.

This matter should be settled by Congress. *New York* v. *New Jersey*, 256 U. S. 296, 313; *Virginia* v. *West Virginia*, 246 U. S. 565; Amer. Bar Assn. Journal, February, 1922.

Mr. Daniel N. Kirby, with whom *Mr. Edward J. Brundage*, Attorney General of Illinois, *Mr. Jesse W. Barrett*, Attorney General of Missouri, *Mr. J. Frank Thompson*, Attorney General of Tennessee, *Mr. Percy Saint*, Attorney General of Louisiana, and *Mr. Cornelius Lynde* were on the brief, for the States of Illinois, Missouri, Tennessee and Louisiana, the Chamber of Commerce of St. Louis, the Memphis Chamber of Commerce, the New Orleans Board of Trade, the New Orleans Association of Commerce, the Mississippi Valley Association, and the Chicago Association of Commerce, as *amici curiae*, by special leave of Court.

Mr. Solicitor General Beck and *Mr. Joseph B. Fleming*, Special Assistant to the Attorney General, with whom *Mr. Attorney General Stone* and *Mr. Louis B. Caldwell*, Special Assistant to the Attorney General, were on the brief, for the United States.

I. The Great Lakes, their connecting waters, and the St. Lawrence River, are navigable waters of the United States (*The Genesee Chief*, 12 How. 443; *United States* v. *Rodgers*, 150 U. S. 249; *Illinois Cent. R. R. Co.* v. *Illinois*, 146 U. S. 387,) and also "international waters, being dedicated in perpetuity to the common navigation of all the inhabitants" of the countries on both sides of the boundary, I Moore, Int. Law Dig., p. 675; I Hyde, Int. Law, 1922, pp. 320, 321; *The Genesee Chief*, 12 How. 443; *Moore* v. *American Transp. Co.*, 24 How. 1, 37, 38; *United States* v. *Rodgers*, 150 U. S. 249, 258; *United States* v. *Chandler-Dunbar Co.*, 229 U. S. 53.

Their international character is confirmed by the Boundary Waters Treaty of January 11, 1909. Lake Michigan is likewise given an international character by the covenant in Art. I, that the free and open navigation provided for with respect to the boundary waters "shall extend to the waters of Lake Michigan."

II. The level of the Great Lakes and the diversion of water from the St. Lawrence River basin to the Mississippi basin are both subjects of commerce regulation, national (and also international) in character, such as to require exclusive control by Congress. Independently, therefore, of any assertion of control by Congress, the Illinois Act of 1889, in so far as it authorized and directed the appellant to do the acts here complained of without authorization of Congress, was void.

Appellant reiterates that its acts were "affirmatively authorized by law" within the meaning of § 10 of the Act of September 19, 1890; but the Act of March 3, 1899, was enacted nearly a year before the appellant (under the permit of May 8, 1899) accomplished a connection between its channel and the Chicago River and thereby diverted water from Lake Michigan. The basis for this contention, however, is a misapplication of the decision in *United States* v. *Bellingham Bay Co.*, 176 U. S. 211,—which held that in the case of an obstruction of a navigable stream confined wholly within the boundaries of a State, the words "affirmatively authorized by law" in the Act of 1890 included lawful authorization by an act of the state legislature. Manifestly, an obstruction of a navigable water like Lake Michigan or the Ohio and Mississippi Rivers could not lawfully be authorized by legislation of a single State either before or after the enactment of the Act of 1890.

It makes no difference whether interference with that control proceeds from a state statute or from the acts of individuals. *Kansas City So. Ry. Co.* v. *Kaw Valley District*, 233 U. S. 75, 78.

Those subjects of interstate commerce which require a general system or uniformity of regulation are national in character, and as to such the power of Congress is exclusive; those admitting of diversity of treatment according to local conditions are local in character, and as to

such the States may act within their respective jurisdictions until Congress sees fit to act. *Minnesota Rate Cases*, 230 U. S. 352; *Covington Bridge Co.* v. *Kentucky*, 154 U. S. 204; *Wilmington Transp. Co.* v. *Railroad Commission*, 236 U. S. 151.

Until Congress asserted its paramount control, the subject of obstructions to the navigable capacity of state navigable waters, not affecting navigable waters without the State, was deemed to be local in character and subject to the authority of the State. See, (1), cases involving dams across state navigable waters; *Willson* v. *Black-bird Creek Co.*, 2 Pet. 245; *Pound* v. *Turck*, 95 U. S. 459; *Huse* v. *Glover*, 119 U. S. 543; and *Monongahela Nav. Co.* v. *United States*, 148 U. S. 312; (2), cases involving bridges across state navigable waters; *Gilman* v. *Philadelphia*, 3 Wall. 713; *Escanaba Co.* v. *Chicago*, 107 U. S. 683; *Cardwell* v. *American Bridge Co.*, 113 U. S. 205; *Hamilton* v. *Vicksburg, etc. R. R.*, 119 U. S. 280; *Willamette Bridge Co.* v. *Hatch*, 125 U. S. 1; and *Lake Shore, etc. Ry. Co.* v. *Ohio*, 165 U. S. 365; (3), cases involving improvement of state navigable waters; *Withers* v. *Buckley*, 20 How. 84; *Sands* v. *Manistee Co.*, 123 U. S. 288. See *Huse* v. *Glover*, 119 U. S. 543.

The power of the States with respect to interstate navigable waters has at all times been limited to matters purely local in character, incidental to and aiding commerce, and not affecting navigation elsewhere. The cases fall into four fairly well-defined classes: (1), the regulation of pilotage, *Cooley* v. *Board of Wardens*, 12 How. 299; (2), protection of coasts and improvement of harbors, bays, and streams, *Mobile County* v. *Kimball*, 102 U. S. 691; (3), quarantine and inspection laws and the policing of harbors, *Morgan's S. S. Co.* v. *Louisiana Board of Health*, 118 U. S. 455; (4), regulation of wharves, piers, and docks, *Transportation Co.* v. *Parkersburg*, 107 U. S. 691.

Obstructions to the navigable capacity of interstate waters without authority from Congress have always been held unlawful, *Pennsylvania* v. *Wheeling Bridge Co.*, 13 How. 518; *Bridge Co.* v. *United States*, 105 U. S. 470; *Miller* v. *Mayor of New York*, 109 U. S. 385; *Covington Bridge Co.* v. *Kentucky*, 154 U. S. 204; *Kansas City So. Ry. Co.* v. *Kaw Valley District*, 233 U. S. 75; *Gibbons* v. *Ogden*, 9 Wheat. 190; *Brown* v. *Maryland*, 12 Wheat. 419; *Henderson* v. *Mayor of New York*, 92 U. S. 259; *Hall* v. *DeCuir*, 95 U. S. 485; *Lord* v. *Steamship Co.*, 102 U. S. 541; *Gloucester Ferry Co.* v. *Pennsylvania*, 114 U. S. 196; *Philadelphia Co.* v. *Pennsylvania*, 122 U. S. 326; *Sault Ste. Marie* v. *International Transit Co.*, 234 U. S. 333.

The subject of the levels of the Great Lakes does not permit of diversity of treatment according to the local requirements of cities on their shores. What Chicago can do, so can Milwaukee, Toledo, and Cleveland. *Pennsylvania* v. *West Virginia*, 262 U. S. 553, 596.

Under the compact contained in Art. IV of the Ordinance of 1787, Illinois may not interfere with or decrease the navigable capacity of Lake Michigan or any of the other Great Lakes. *Economy Light Co.* v. *United States*, 256 U. S. 113, 118; *Pennsylvania* v. *Wheeling Bridge Co.*, 13 How. 518.

On the other hand, in such cases as *Escanaba Co.* v. *Chicago*, 107 U. S. 678; *Cardwell* v. *American Bridge Co.*, 113 U. S. 205; *Huse* v. *Glover*, 119 U. S. 543; *Hamilton* v. *Vicksburg, etc. R. R.*, 119 U. S. 280; *Sands* v. *Manistee Co.*, 123 U. S. 288; and *Willamette Bridge Co.* v. *Hatch*, 125 U. S. 1, this Court held the compact inapplicable to obstructions over navigable waters entirely within the boundaries of a single State.

The principle to be extracted from these cases is that where the obstruction or restriction of navigability is that of a state navigable water, the compact does not

apply; where it is of an interstate navigable water such as the Ohio River or the Great Lakes, the compact is, and has always been in force.

The subject of the levels of and diversion of waters from the Great Lakes is necessarily national because international in character, and therefore for the exclusive control of Congress. *United States* v. *Chandler-Dunbar Co.*, 229 U. S. 53; *Lord* v. *Steamship Co.*, 102 U. S. 541, 544; *Henderson* v. *Mayor of New York*, 92 U. S. 259; I Hyde, Int. Law, pp. 313–316.

III. The purposes for which the States might formerly exercise their limited power all came within the scope of the police power. In some cases it was for the protection of public health, *Willson* v. *Black-bird Creek Marsh Co.*, 2 Pet. 245; *Morgan's S. S. Co.* v. *Louisiana Board of Health*, 118 U. S. 455; in some for furthering of commerce, *Pound* v. *Turck*, 95 U. S. 459; in some for improvement of rivers or harbors, *Mobile County* v. *Kimball*, 102 U. S. 691; *Sands* v. *Manistee Co.*, 123 U. S. 288; in some for public convenience and commerce, as a bridge, *Gilman* v. *Philadelphia*, 3 Wall. 724; *Escanaba Co.* v. *Chicago*, 107 U. S. 683.

By the Acts of 1890 and 1899 Congress made an effectual assertion of its paramount control over all navigable waters of the United States and assumed jurisdiction of the subjects mentioned above. *United States* v. *Rio Grande Co.*, 174 U. S. 690. See also *Lake Shore, etc. Ry. Co.* v. *Ohio*, 165 U. S. 365; *United States* v. *Bellingham Bay Co.*, 176 U. S. 211; *Cummings* v. *Chicago*, 188 U. S. 410; *Union Bridge Co.* v. *United States*, 204 U. S. 364; *Philadelphia Co.* v. *Stimson*, 223 U. S. 605; *United States* v. *Chandler-Dunbar Co.*, 229 U. S. 53; *Economy Light Co.* v. *United States*, 256 U. S. 113; *Southern Pac. Co.* v. *Olympian Co.*, 260 U. S. 205.

There has been no undue delegation of power to the Secretary of War. *Union Bridge Co.* v. *United States*,

204 U. S. 364; *Philadelphia Co.* v. *Stimson*, 223 U. S. 635.

The effect of § 10 of the Act of 1899 is to make the creation of such obstructions or modifications dependent "upon the concurrent or joint assent of both the national government and the state government." *Cummings* v. *Chicago*, 188 U. S. 410; *Montgomery* v. *Portland*, 190 U. S. 89; *North Shore Boom Co.* v. *Nicomen Boom Co.*, 212 U. S. 406; *Port of Seattle* v. *Oregon & Washington R. R. Co.*, 255 U. S. 56; *International Bridge Co.* v. *New York*, 254 U. S. 126.

Under § 10 of the Act of 1899, an act of Congress is necessary to authorize the creation of an obstruction to the navigable capacity of a navigable water of the United States; for a modification of the condition, etc., of such navigable water, not amounting to an obstruction, the recommendation of the Chief of Engineers and the authorization of the Secretary of War are necessary. *Hubbard* v. *Fort*, 188 Fed. 987; *West Chicago Street R. R. Co.* v. *Chicago*, 201 U. S. 506. Distinguishing *Maine Water Co.* v. *Knickerbocker Co.*, 99 Me. 473.

Whether the entire navigable capacity, and whether the unmodified condition of a navigable water, should be conserved for the use and safety of navigation, are questions legislative in character, and their determination by Congress is conclusive. *United States* v. *Chandler-Dunbar Co.*, 229 U. S. 53, 62; *Southern Pac. Co.* v. *Olympian Co.*, 260 U. S. 205; *Monongahela Bridge Co.* v. *United States*, 216 U. S. 177; *Philadelphia Co.* v. *Stimson*, 223 U. S. 605, 635, 638. See also *Pennsylvania* v. *Wheeling Bridge Co.*, 18 How. 421; *Union Bridge Co.* v. *United States*, 204 U. S. 364; *Gibson* v. *United States*, 166 U. S. 269; *Scranton* v. *Wheeler*, 179 U. S. 141; *Chicago, B. & Q. Ry. Co.* v. *Drainage Commrs.*, 200 U. S. 561; *West Chicago Street R. R. Co.* v. *Chicago*, 201 U. S. 506; *Hannibal Bridge Co.* v. *United States*, 221 U. S. 194.

IV. Appellant has created and is maintaining an obstruction to the navigable capacity of navigable waters of the United States in violation of § 10 of the Act of Congress of March 3, 1899.

To constitute an obstruction, neither material injury and damage to commerce nor unreasonable obstruction to navigation are necessary. *Economy Light Co.* v. *United States*, 256 U. S. 113; *United States* v. *Chandler-Dunbar Co.*, 229 U. S. 53; *Pennsylvania* v. *Wheeling Bridge Co.*, 13 How. 553; *Hubbard* v. *Fort*, 188 Fed. 992. Distinguishing, *Union Bridge Co.* v. *United States*, 204 U. S. 364; *New York* v. *New Jersey*, 256 U. S. 296; *Kansas* v. *Colorado*, 206 U. S. 46; *Mississippi, etc. R. R. Co.* v. *Ward*, 2 Black, 485.

V. The obstructions have never been affirmatively authorized by Congress, as required by § 10 of the Act of March 3, 1899.

The authority in the Acts of March 30, 1822, and March 2, 1827, was for the construction of a particular canal, the location of which was to be determined by law, and for the purpose of navigation, not sanitation.

Sections 7 and 10 of the Act of September 19, 1890, and § 10 of the Act of March 3, 1899, made unlawful any greater diversion than was practiced in 1890. *United States* v. *Rio Grande Co.*, 174 U. S. 690.

The Niagara Falls Act of 1906 did not constitute such authorization; if anything, it forbade the unauthorized diversion.

The Canadian Boundary Waters Treaty of January 11, 1909, did not constitute such authorization; instead, it forbade any diversion over 4,167 cubic seconds feet.

VI. Appellant's diversion in excess of 4,167 cubic seconds feet has not been recommended by the Chief of Engineers nor authorized by the Secretary of War, as required by § 10 of the Act of March 3, 1899.

Appellant, having applied for and accepted the various permits, is estopped.

The Secretary of War may impose conditions on permits granted by him under § 10 of the Act of March 3, 1899, and may revoke or modify such permits on nonfulfillment of these conditions. *Southern Pac. Co.* v. *Olympian Co.*, 260 U. S. 205.

VII. Appellant's unauthorized diversion cannot be justified as an exercise of the police power.

On a subject of interstate commerce national in character and requiring exclusive control by Congress, there can be no reserved police power in the State to invade that control even for the protection of public health. *Henderson* v. *Mayor of New York*, 92 U. S. 259; *Kansas City So. Ry. Co.* v. *Kaw Valley District*, 233 U. S. 75.

On all other subjects of interstate commerce, when Congress has asserted its paramount control, there is no police power reserved in the State to invade it. *Morgan's S. S. Co.* v. *Louisiana Board of Health*, 118 U. S. 455, 464. See also *Compagnie Francaise* v. *Louisiana Board of Health*, 186 U. S. 380; *Louisiana* v. *Texas*, 176 U. S. 1, 19; *Mobile County* v. *Kimball*, 102 U. S. 691, 697–699; *Wisconsin* v. *Duluth*, 96 U. S. 379.

VIII. The right of appellee to an injunction is not barred by laches, acquiescence, or estoppel.

Section 12 of the Act of March 3, 1899, is sufficient authority for this suit. *Economy Light Co.* v. *United States*, 256 Fed. 792, 793; s. c. 256 U. S. 113.

Congress intended by the Act of March 3, 1899, to extend, not to limit, the scope of federal control over obstructions and modifications of the navigable capacity of navigable waters.

In the Act of 1890, § 10 provided that injunction proceedings might be instituted to enjoin obstructions. Section 12 of the Act of 1899 was intended to have a broader scope and to cover all structures in violation of §§ 9, 10, 11, whether the structures amounted to, or caused, obstructions, or were merely unlawful modifications of the

condition of a navigable water, not amounting to obstructions.

Independently of § 12, there is sufficient authority for the instant suit. *In re Debs*, 158 U. S. 564; *Pennsylvania* v. *Wheeling Bridge Co.*, 13 How. 518; *United States* v. *San Jacinto Tin Co.*, 125 U. S. 273; *United States* v. *American Bell Tel. Co.*, 128 U. S. 315; *Gilman* v. *Philadelphia*, 3 Wall. 713; *Louisiana* v. *Texas*, 176 U. S. 1, 19; *United States* v. *Trans-Missouri Freight Assn.*, 166 U. S. 290; *Missouri* v. *Illinois*, 180 U. S. 208, 236; *Northern Securities Co.* v. *United States*, 193 U. S. 197, 356.

The doctrine of comparative injury has no application. *Ruppert* v. *Caffey*, 251 U. S. 264; *In re Debs*, 158 U. S. 564, 582; 31 L. R. A. (N. S.) 881; *Union Bridge Co.* v. *United States*, 204 U. S. 401.

Under the terms of the Treaty of January 11, 1909, the construction of such compensating works as the appellant proposes cannot be undertaken without the approval of the International Joint Commission.

The decree which appellant proposes would be void and inoperative, in that it would contain a condition which the Court would be powerless to enforce. The construction of submerged weirs in the Niagara and St. Clair Rivers may never be authorized by Congress. Even if so authorized, they may never be permitted by the International Joint Commission. If authorized, they may cost many times what the appellant has in mind or is able to pay. *Kansas City So. Ry. Co.* v. *Kaw Valley District*, 233 U. S. 75, 77–78.

Mr. Andrew B. Dougherty, Attorney General of Michigan, for the States of Michigan, Indiana, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin, as *amici curiae*, by special leave of Court. *Messrs. U. S. Lesh*, Attorney General of Indiana; *Henry S. Sweeny*, Assistant

Attorney General of Michigan; *Clifford L. Hilton*, Attorney General of Minnesota; *Carl Sherman*, Attorney General, and *Edward G. Griffin* and *C. S. Ferris*, Deputy Attorneys General, of New York; *C. C. Crabbe*, Attorney General of Ohio; *Geo. W. Woodruff*, Attorney General, and *Phillip Wells*, Deputy Attorney General, of Pennsylvania; and *Herman L. Ekern*, Attorney General of Wisconsin, were also on the brief.

Mr. Harvey D. Goulder for the Lake Carriers' Association as *amicus curiae*, by special leave of Court.

Mr. Francis X. Busch and *Mr. Leon Hornstein*, by leave of Court, filed a brief on behalf of the City of Chicago, as *amicus curiae*.

MR. JUSTICE HOLMES delivered the opinion of the Court.

This is a bill in equity brought by the United States to enjoin the Sanitary District of Chicago, a corporation of Illinois, from diverting water from Lake Michigan in excess of 250,000 cubic feet per minute; the withdrawal of that amount having been authorized by the Secretary of War. It is alleged that the withdrawal of more, viz., from 400,000 to 600,000 cubic feet per minute, has lowered and will lower the level of the water of Lake Michigan, Lake Huron, Lake St. Clair, Lake Erie, Lake Ontario, Sault Ste. Marie, St. Mary's River, St. Clair River, Detroit River, Niagara River, St. Lawrence River, and all the harbors, &c., connected therewith, all of which are alleged to be navigable waters of the United States, and will thus create an obstruction to the navigable capacity of said waters; and that it will alter and modify the condition and capacity of the above named and their ports, &c., connected with them. The prohibition of such alterations and obstructions in the Act of March 3,

1899, c. 425, § 10; 30 Stat. 1121, 1151, is set out at length and relied upon but the frame of the bill does not exclude a reliance upon more general principles if they were needed in order to maintain it.

The withdrawal practised and threatened is through an artificial channel that takes the place of the Chicago River, formerly a little stream flowing into Lake Michigan, and of a part of its branches. The channel instead of adding water to the Lake has been given an opposite incline, takes its waters from the Lake, flows into the Desplaines River, which empties into the Illinois River, which in its turn empties into the Mississippi. The channel is at least twenty-five feet deep and at least one hundred and sixty-two feet wide; and while its interest to the defendant is primarily as a means to dispose of the sewage of Chicago, *Missouri* v. *Illinois*, 200 U. S. 496, it has been an object of attention to the United States as opening water communication between the Great Lakes and the Mississippi and the Gulf.

The answer shows that the defendant is proceeding under a state act of May 29, 1889, by which it was provided that a channel should be made of size sufficient to take care of the sewage and drainage of Chicago as the increase of population might require, with a capacity to maintain an ultimate flow of not less than 600,000 cubic feet of water per minute, and a continuous flow of not less than 20,000 cubic feet for each 100,000 of the population within the sanitary district. It denies that the defendant has abstracted from 400,000 to 600,000 feet per minute, but as it alleges the great evils that would ensue if the flow were limited to the amount fixed by the Secretary of War or to any amount materially less than that required by the state act of May 29, 1889, and as it admits present conditions to be good, the denial cannot be taken very seriously. The act sufficiently indicates what the State threatens and intends to do unless

stopped. The answer also denies that the abstraction of water substantially in excess of 250,000 cubic feet per minute will lower the levels of the Lakes and Rivers concerned or create an obstruction to the navigable capacity of those waters. It goes into the details of the construction of the channel; the expenses incurred; and the importance of it to the health of the inhabitants of Chicago, both for the removal of their sewage and avoiding the infection of their source of drinking water in Lake Michigan which had been a serious evil before. It shows the value of the channel for the great scheme of navigation that we have mentioned; recites acts of Congress and of officers of the United States alleged to authorize what has been done, and to estop the United States from its present course, and finally takes the bull by the horns and denies the right of the United States to determine the amount of water that should flow through the channel or the manner of the flow.

This brief summary of the pleadings is enough to show the gravity and importance of the case. It concerns the expenditure of great sums and the welfare of millions of men. But cost and importance, while they add to the solemnity of our duty, do not increase the difficulty of decision except as they induce argument upon matters that with less mighty interests no one would venture to dispute. The law is clear, and when it is known the material facts are few.

This is not a controversy between equals. The United States is asserting its sovereign power to regulate commerce and to control the navigable waters within its jurisdiction. It has a standing in this suit not only to remove obstruction to interstate and foreign commerce, the main ground, which we will deal with last, but also to carry out treaty obligations to a foreign power bordering upon some of the Lakes concerned, and, it may be, also on the footing of an ultimate sovereign interest in the Lakes.

The Attorney General by virtue of his office may bring this proceeding and no statute is necessary to authorize the suit. *United States* v. *San Jacinto Tin Co.*, 125 U. S. 273. With regard to the second ground, the Treaty of January 11, 1909, with Great Britain, expressly provides against uses 'affecting the natural level or flow of boundary waters' without the authority of the United States or the Dominion of Canada within their respective jurisdictions and the approval of the International Joint Commission agreed upon therein. As to its ultimate interest in the Lakes the reasons seem to be stronger than those that have established a similar standing for a State, as the interests of the nation are more important than those of any State. *In re Debs*, 158 U. S. 564, 584, 585, 599. *Georgia* v. *Tennessee Copper Co.*, 206 U. S. 230. *Hudson County Water Co.* v. *McCarter*, 209 U. S. 349, 355. *Marshall Dental Manufacturing Co.* v. *Iowa*, 226 U. S. 460, 462.

The main ground is the authority of the United States to remove obstructions to interstate and foreign commerce. There is no question that this power is superior to that of the States to provide for the welfare or necessities of their inhabitants. In matters where the States may act the action of Congress overrides what they have done. *Monongahela Bridge Co.* v. *United States*, 216 U. S. 177. *Second Employers' Liability Cases*, 223 U. S. 1, 53. But in matters where the national importance is imminent and direct even where Congress has been silent the States may not act at all. *Kansas City Southern Ry. Co.* v. *Kaw Valley Drainage District*, 233 U. S. 75, 79. Evidence is sufficient, if evidence is necessary, to show that a withdrawal of water on the scale directed by the statute of Illinois threatens and will affect the level of the Lakes, and that is a matter which cannot be done without the consent of the United States, even were there no international covenant in the case.

But the defendant says that the United States has given its assent to all that has been done and that it is estopped to take the position that it now takes. A State cannot estop itself by grant or contract from the exercise of the police power. *Texas & New Orleans R. R. Co.* v. *Miller*, 221 U. S. 408, 414. *Atlantic Coast Line R. R. Co.* v. *Goldsboro*, 232 U. S. 548, 558. *Denver & Rio Grande R. R. Co.* v. *Denver*, 250 U. S. 241, 244. It would seem a strong thing to say that the United States is subject to narrower restrictions in matters of national and international concern. At least it is true that no such result would be reached if a strict construction of the Government's act would avoid it. This statement was made and illustrated in a case where it was held that an order of the Secretary of War under the Act of March 3, 1899, c. 425, the same act in question here, directing an alteration in a bridge must be obeyed, and obeyed without compensation, although the bridge had been built in strict accord with an act of Congress declaring that if so built it should be a lawful structure. *Louisville Bridge Co.* v. *United States*, 242 U. S. 409, 417. *Greenleaf Johnson Lumber Co.* v. *Garrison*, 237 U. S. 251. It only remains to consider what the United States has done. And it will be as well to bear in mind when considering it that this suit is not for the purpose of doing away with the channel, which the United States, we have no doubt, would be most unwilling to see closed, but solely for the purpose of limiting the amount of water to be taken through it from Lake Michigan.

The defendant in the first place refers to two acts of Congress: one of March 30, 1822, 3 Stat. 659, which became ineffectual because its conditions were not complied with, and another of March 2, 1827, c. 51, 4 Stat. 234, referred to, whether hastily or not, in *Missouri* v. *Illinois*, 200 U. S. 496, 526, as an act in pursuance of which Illinois brought Chicago into the Mississippi watershed. The

act granted land to Illinois in aid of a canal to be opened by the State for the purpose of uniting the waters of the Illinois River with those of Lake Michigan, but if it has any bearing on the present case it certainly vested no irrevocable discretion in the State with regard to the amount of water to be withdrawn from the Lake. It said nothing on that subject. We repeat that we assume that the United States desires to see the canal maintained and therefore pass by as immaterial all evidence of its having fostered the work. Even if it had approved the very size and shape of the channel by act of Congress it would not have compromised its right to control the amount of water to be drawn from Lake Michigan. It seems that a less amount than now passes through the canal would suffice for the connection which the United States has wished to establish and maintain.

In an appropriation Act of March 3, 1899, c. 425, § 10; 30 Stat. 1121, 1151; Congress provided "That the creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; . . . and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or inclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same." By § 12 violation of the law is made a misdemeanor and punished, and the removal of prohibited structures may be enforced by injunction of the proper Court of the United States in a suit under the direction of the Attorney General. This statute repeatedly has been held to be constitutional in respect of the power given to the Secretary of War. *Louisville Bridge Co.* v. *United States*, 242 U. S.

409, 424. It is a broad expression of policy in unmistakable terms, advancing upon an earlier Act of September 19, 1890, c. 907, § 10; 26 Stat. 426, 454, which forbade obstruction to navigable capacity "not affirmatively authorized by law," and which had been held satisfied with regard to a boom across a river by authority from a State. *United States* v. *Bellingham Bay Boom Co.*, 176 U. S. 211. There is neither reason nor opportunity for a construction that would not cover the present case. As now applied it concerns a change in the condition of the Lakes and the Chicago River, admitted to be navigable, and, if that be necessary, an obstruction to their navigable capacity, *United States* v. *Rio Grande Dam & Irrigation Co.*, 174 U. S. 690, without regard to remote questions of policy. It is applied prospectively to the water henceforth to be withdrawn. This withdrawal is prohibited by Congress, except so far as it may be authorized by the Secretary of War.

After this statute was passed the Secretary of War granted various permits, which are relied on by the appellant although in their nature they all were revocable licenses. On May 8, 1899, the Secretary, on application of the appellant, granted permission to open the channel, assumed in the recitals to have a flowage capacity of 300,000 cubic feet per minute with a velocity of one and one-quarter miles an hour, on the conditions that the permit should be subject to the action of Congress (which was superfluous except as a warning); that if at any time the current created proved to be unreasonably obstructive to navigation or injurious to property he reserved the right to close or modify the discharge; and that the Sanitary District must assume all responsibility for damages to property and navigation interests by reason of the introduction of a current in Chicago River. On July 11, 1900, improvements of the Chicago River were permitted with the statement that the permission did not affect the

right of the Secretary to revoke the permit of May 8, 1899. On April 9, 1901, the Secretary, Mr. Root, directed the Sanitary District to cut down the discharge to 200,000 cubic feet per minute. On July 23, 1901, at the appellant's request, he amended the order to permit a flow of 300,000 feet between 4 p. m. and twelve, midnight, subject to revocation. On December 5, 1901, again on the application of the appellant, leave was given to discharge not exceeding 250,000 feet per minute during the whole twenty-four hours, but subject to such modification as the Secretary might think that the public interests required. On January 17, 1903, the allowance was increased to 350,000 feet until March 31, 1903, after which date it was to be reduced again to 250,000 feet all subject to modification as before. On September 11, 1907, and on June 30, 1910, permissions were granted to make another connection with Lake Michigan and to open a channel through Calumet River (this last refused by Mr. Secretary Taft on March 14, 1907) on the understanding that the total quantity of water withdrawn from the Lake should not exceed that already authorized by the Secretary of War. Finally on February 5, 1912, the appellant, setting forth that the population of the Sanitary District exceeded 2,500,000 and was increasing rapidly, and that the only method then available for disposing of the sewage of this population was by diluting it with water flowing from Lake Michigan through the canal, asked permission to withdraw not exceeding 10,000 cubic feet per second, subject to such restrictions and supervision as might seem proper to the Secretary and to revocation by him. On January 8, 1913, Mr. Secretary Stimson carefully reviewed the situation, including the obvious fact that so large a withdrawal would lower the levels of the Lakes and the overwhelming evidence that it would affect navigation, and held that he was not warranted in excepting the appellant from the prohibition of

Congress on the ground of even pressing sanitary needs. It appears to us that the attempt to found a defence upon the foregoing licenses is too futile to need reply.

States bordering on the Mississippi allowed to file briefs as *amici curiae* suggest that they were not heard and that rights have not been represented before the Secretary of War. The City of Chicago makes a similar complaint and argues that it is threatened with the loss of a hundred million dollars. The interest that the River States have in increasing the artificial flow from Lake Michigan is not a right, but merely a consideration that they may address to Congress, if they see fit, to induce a modification of the law that now forbids that increase unless approved as prescribed. The investment of property in the canal and the accompanying works took the risk that Congress might render it valueless by the exercise of paramount powers. It took the risk without even taking the precaution of making it as sure as possible what Congress might do. But we repeat that the Secretary by his action took no rights of any kind. He simply refused an application of the Sanitary Board to remove a prohibition that Congress imposed. It is doubtful at least whether the Secretary was authorized to consider the remote interests of the Mississippi States or the sanitary needs of Chicago. All interests seem in fact to have been copiously represented but he certainly was not bound to give them a hearing upon the application upon which he was requested to pass.

After the refusal, in January, 1913, to allow an increase of flow, the appellant was notified by direction of the War Department that it was drawing more water than was allowed and was violating § 10 of the Act of March 3, 1899. In reply it intimated that it was bound by the state law to which we have referred and in obedience to it had been flowing 20,000 cubic feet per minute for each

100,000 of population and could not reduce that flow. It suggested that its rights should be determined by a suit, and accordingly this bill was filed on October 6, 1913. An earlier suit had been brought on March 23, 1908, to prevent the construction of a second channel from Lake Michigan through the Calumet River to the appellant's main channel, leave to do which had been refused as we have seen by Mr. Secretary Taft. (The permit subsequently granted on June 30, 1910, was with the understanding that it should not affect or be used in the 'friendly suit' then pending to determine rights.) The earlier suit was consolidated with the later present one, and it was agreed that the evidence taken in that should be used in this, so far as applicable. There was some delay in concluding the case, which the defendant naturally would desire, but after it was submitted to the Judge according to his own statement he kept it about six years before delivering an oral opinion in favor of the Government on June 19, 1920. No valid excuse was offered for the delay. There was a motion for reconsideration, but the Judge took no further action of any kind until he resigned in 1922. On June 18, 1923, another Judge entered a decree for an injunction as prayed, with a stay of six months to enable the defendant to present the record to this Court.

The parties have come to this Court for the law, and we have no doubt that as the law stands the injunction prayed for must be granted. As we have indicated, a large part of the evidence is irrelevant and immaterial to the issues that we have to decide. Probably the dangers to which the City of Chicago will be subjected if the decree is carried out are exaggerated, but in any event we are not at liberty to consider them here as against the edict of a paramount power. The decree for an injunction as prayed is affirmed, to go into effect in sixty days—without prejudice to any permit that may be issued by the Secretary of War according to law.

Affirmed.